WRECK POND BROOK WATERSHED
REGIONAL STORMWATER MANAGEMENT PLAN

BOOK 1: Watershed Characterization

Prepared by
Wreck Pond Brook Watershed Technical Advisory Committee

Under the Authority of
Wreck Pond Brook Watershed
Regional Stormwater Management Plan Committee

Lead Planning Agency: Monmouth County Planning Board

Monmouth County Planning Board
Hall of Records Annex
1 East Main Street
Freehold NJ 07728

SEPTEMBER 2008

WRECK POND BROOK WATERSHED
REGIONAL STORMWATER MANAGEMENT PLAN

BOOK 1: Watershed Characterization

Prepared by
Wreck Pond Brook Watershed Technical Advisory Committee

Under the Authority of
Wreck Pond Brook Watershed
Regional Stormwater Management Plan Committee

Lead Planning Agency: Monmouth County Planning Board

PRINCIPAL STUDY PARTICIPANTS

Monmouth County Office of Geographic Information Systems

Monmouth County Planning Board

New Jersey Department of Environmental Protection, Division of Watershed Management

New Jersey Department of Agriculture

Najarian Associates

Rutgers Cooperative Research and Extension

Freehold Soil Conservation District

Monmouth University

Monmouth County Planning Board
Hall of Records Annex
1 East Main Street
Freehold NJ 07728

SEPTEMBER 2008

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

The Wreck Pond Brook Regional Stormwater Management Plan (WPBRSWMP) has been developed to address stormwater quantity and quality concerns within the watershed. The Plan has been developed in accordance with Subchapter 3 (Regional Stormwater Management Planning) of the New Jersey Department of Environmental Protection (NJDEP) Stormwater Management regulations (NJAC 7:8). The regional stormwater planning process is designed to address stormwater issues that are best managed on a regional, not a state or local basis.

The Plan provides a detailed description of existing watershed conditions including the results of several monitoring efforts and field investigations, modeling studies, identification of problems and proposed solutions. This document is Book 1 of the RSWMP and provides data on the characterization of the watershed and environmental concerns. Book 2 provides the Management Plan.

Wreck Pond Brook extends from its headwaters in Wall Township near Allaire Airport and flows east-southeast to discharge into Wreck Pond. Wreck Pond is located on the boundary between the boroughs of Spring Lake and Sea Girt in Monmouth County, New Jersey. Wreck Pond is approximately 73 acres in size and a portion of it is tidally influenced. The eastern end of the Pond contains an outfall structure that exchanges water with the Atlantic Ocean. The watershed to the Pond extends to the northwest as shown on Figure 1.

The Wreck Pond watershed was identified as a watershed of concern by the NJDEP. Outflow from Wreck Pond to the Ocean during storm events has been identified as the cause of swimming beach closings in Spring Lake and Sea Girt. The Monmouth County Health Department (MCHD) regularly monitors bacteria levels at Ocean swimming beaches. Using those data, MCHD found that bacteria levels exceeded the Ocean bathing beach standards at Ocean beaches in the vicinity of the outfall following storm events. In 2002, the Health Department instituted a 24-hour swimming ban that would be implemented whenever rainfall exceeds 0.1 inch or when a plume from the outfall was visible and a 48-hour ban when rainfall exceeds 2.8 inches in 24 hours. This ban applies to the recreational bathing waters at the Brown and York Avenue beaches in Spring Lake and The Terrace and Beacon beaches in Sea Girt. Due to this provisional ban, the outfall from Wreck Pond has been the source of most of the swimming bans at the New Jersey Ocean beaches over the last several years.

In addition, the overall water quality of waters in the watershed, including Wreck Pond is of concern. Algal blooms, nutrient loads, and sedimentation are noted issues. Further, flooding has been noted in many parts of the watershed. The storm of October 2005 caused significant flooding, particularly in the lower portions of the watershed.

The local municipalities, Monmouth County and NJDEP identified certain initial goals for development of the RSWMP. These include reduction of beach closings, improvement of the overall quality of Wreck Pond and other waters, and reduction of flooding.

In response to concerns about beach closings caused by Wreck Pond outflow, NJDEP developed a plan for Wreck Pond Restoration in 2004 to eliminate or reduce those closings. The plan identified four basic restoration measures including dredging, stormwater management measures, extension of the outfall to move the mixing zone farther from the swimming beaches and wildlife management measures to reduce bacteria levels.

Several elements of NJDEP's plan were implemented. The Wreck Pond outfall was extended about 300 feet further from shore and a portion of the Pond closest to the outfall was dredged. This work was completed in 2006. Further dredging of the Pond is not currently planned. NJDEP also provided funds for goose management efforts.

NJDEP also provided financing for the County of Monmouth and NJ Department of Agriculture (NJDA) to prepare a Regional Stormwater Management Plan for the Wreck Pond Brook Watershed. Stormwater management throughout the watershed to reduce sediment loading was required prior to any funding to dredge the entire pond to ensure that dredging would provide a long-term solution. .

NJDEP then requested that the Monmouth County Planning Board (MCPB) act as a Lead Planning Agency to complete and move to adoption a Wreck Pond Brook RSWMP. NJDEP offered a $350,000 grant to aid in the planning process. The MCPB and its staff agreed and work commenced immediately to develop a Scope of Work and Budget for review and approval by the Department.

MCPB staff determined that the Wreck Pond Brook RSWMP project could provide the framework for all RSWMPs that might be initiated in the County of Monmouth in the future. Therefore, a primary objective of the project was to institutionalize the planning process as much as possible. Additionally, it was recognized that a substantive amount of technical work would need to be done in order to accumulate a body of hydrographic, hydraulic, topographic, geographic, water quality, land use planning and character assessment data that could be used in the planning process. In order to meet the institutional and data management objectives of the project, Planning Board staff polled; the Chief Engineer for the New Jersey Department of Agriculture's (NJDA) Soil Conservation Committee, the Freehold Soil Conservation District, the Monmouth County Engineering Department, the Monmouth County Planning Board's Engineering Section, the Monmouth County Office of Geographic Information Systems (GIS) Management and the Monmouth County Health Department and asked if they would serve as a Technical Advisory Committee (TAC) for the project. All agreed to serve on the TAC and to contribute as much of their staff time to the project as they could.

MCPB staff then developed a Scope of Work and an operating budget for the project. NJDEP approved the Scope of Work in April 2004 and asked that the project be completed in two years. The MCPB agreed to the project time frame. Two meetings between MCPB staff and the municipalities in the watershed were held in May and June of 2004 and an initial meeting of a proposed RSWMP Committee was held in August 2004.

The initial Scope of Work focused almost entirely on reducing sediment loadings to the Pond in support of dredging. However, as the planning process proceeded the Scope of Work for the Regional Stormwater Management Plan expanded to include load reductions for bacteria, nutrients and other water quality parameters. The scope further expanded to encompass flooding concerns, particularly after the October 2005 storm. The timeframe for project completion was expanded accordingly.

1.1 Lead Planning Agency and Authority

The RSWMP Committee initiated its work as set out in the approved Scope of Work in August of 2004. The Monmouth County Planning Board was selected by the RSWMP Committee to act as the Lead Planning Agency for the project at their regular meeting of June 2005 and the Monmouth County Planning Board agreed by Resolution to serve as Lead Planning Agency on June, 20, 2005. The RSWMP Committee's authority to select a lead planning agency was granted to it by the State of New Jersey under N.J.A.C. 7:8-3.2 et seq. A request to recognize the Wreck Pond Brook RSWMP Committee was mailed to NJDEP on June 24, 2005 and subsequently approved.

1.2 Purpose and Goals

This Wreck Pond Brook RSWMP is designed to meet the requirements for a regional stormwater plan in accordance with under NJAC 7:8-3. According to that regulation "A Regional Stormwater Management Plan shall address stormwater-related water quality, ground water recharge and/or water quantity impacts of new and existing land uses in a Regional Stormwater Management Planning Area."

The overall goal of this management plan is to improve the water quality of the ponds and streams within the watershed, to reduce watershed loadings of pollutants associated with current and future land uses, to reduce flooding, and to eliminate or greatly reduce beach closings from the discharge from Wreck Pond to the Atlantic Ocean. The Plan is to develop workable solutions that can be implemented by the municipalities and standards that may be employed in review of new projects. The Plan also will be reviewed and updated as needed to ensure it continues to be responsive to changing watershed conditions.

At the start of this process, the NJDEP and Monmouth County Planning Board staff had identified the following issues of concern

- Erosion in the watershed.

- Sediment loads and deposition at Wreck Pond and other watershed ponds.
- Bacteria, nitrate and phosphorus loads discharged to Wreck Pond.
- Beach closings near the Ocean discharge of Wreck Pond.
- Stream base flow to maintain/improve dilution factors.
- Stream peak flow and the connection to stream bank erosion and sediment transport.
- Stream passing flow and potential as a future surface water supply.
- Existing impoundments as stormwater management, scenic and recreation features.
- Municipal stormwater management planning efforts.

The initial planning process expanded the scope to include flooding, algal blooms and sediment in other watershed ponds. The need for improvements in flood control was further highlighted by the storms of October 2005.

During development of the plan, additional issues related to stormwater in the watershed were identified by the County, NJDEP, other agencies, municipalities, and local residents. In addition to flooding and beach closings, Wreck Pond also has reportedly become very shallow with mucky sediments and other signs of water quality impairment. The tidal fluctuation within the Pond is reportedly reduced. The impounded portion of Black Creek is noted to be very shallow and mucky and subject to algal blooms. Algal blooms and mucky bottoms are also reported for the upstream ponds, along with other signs of diminished water quality.

The streams within the watershed also are of concern for water quality and flow issues. Both major tributaries to the Pond have been found by NJDEP to be in non-attainment status for certain designated uses, including Aquatic Life and/or Recreation.

1.3 Partners and Committees

Monmouth County Planning Board has been the lead agency for this project under the leadership of Tom Kellers and then Turner Shell. The planning process and development of this plan has primarily been conducted by the Wreck Pond Watershed Technical Advisory Committee, along with input from the RSWMP Committee. As noted, the RSWMP Committee has been meeting regularly, with over sixty members including those on the TAC, municipal officials and staff, as well as other interested parties, including local residents.

Agencies, institutions and firms represented on the TAC or the Stormwater Committee include Monmouth County Office of GIS, Monmouth County Engineering, NJDEP, Division of Watershed Management, NJ Department of Agriculture, Rutgers Cooperative Extension, Freehold Soil Conservation District, Monmouth University, Najarian Associates, US Fish and Wildlife Service, Monmouth County Health Department, NJDEP Marine Water Monitoring, and the Municipalities.

1.4 Scope

The project scope is to provide a Regional Stormwater Management Plan that characterizes the watershed, identifies stormwater related problems, proposes solutions to those problems, conforms to regulatory requirements and provides guidance to regional and local stakeholders. The Plan includes overall watershed characterization, stream assessments, agricultural land analysis, water quality data collection and analysis, watershed land use review, build-out land use analysis, hydrologic and hydraulic modeling, watershed water quality modeling and a bacteria source tracking study. The results of these studies have been synthesized to focus areas of concern and to develop management measures and restoration options within the watershed.

NJDEP provided ongoing guidance in the Plan development process. The Plan includes several elements undertaken by the County and the study partners. These elements are discussed in detail within the body of this report.

- Monmouth County Planning Board: Overall study coordination, identification of areas of concern, proposed mitigation measures

- Monmouth County staff, in particular the GIS Office, assessed the preliminary data and support with the County GIS system. The GIS data was then used to develop GIS thematic layers unique to the Wreck Pond Brook Watershed. The GIS data were used by the other partners in preparing their studies and to identify management and restoration options for the watershed.

- Monmouth County Staff: Collection of weekly water quality data

- NJ Department of Agriculture, State Soil Conservation Committee: Measured stream flow and analyzed stream and watershed runoff characteristics in order to develop stream flow models and comprehensive watershed runoff models. These models were designed to assess they hydrologic condition of the watershed and assist in the development of management recommendations for land and water resources.

- Freehold Soil Conservation District: Conducted stream assessments along the streams and tributaries within the watershed.

- Monmouth University: Microbial Source Tracking Study: Employed the Multiple Antibiotic Resistance technique to attempt to identify the sources of bacteria in samples taken from Wreck Pond and other watershed waters along with collection of water quality data.

- Rutgers Cooperative Extension: Surveyed agricultural and recreational lands within the watershed for pollutant generation sources. Conducted water quality and soils monitoring, analyzed current management techniques and proposed management recommendations.

- Najarian Associates: The County contracted with Najarian Associates (NA) to coordinate the plan document, including detailed analysis of the County water quality data, development of the watershed characterization portion of the Plan and writing of the report based on technical studies, field investigations and data from the County and other study partners. The watershed characterization included the synthesis and mapping of GIS data from the MC Office of GIS and NJDEP as well as other watershed information. NA also participated in watershed modeling and conducted surveying of stream sections.

Other agencies that assisted or provided data include Monmouth County Health Department who collects weekly beach bacteria data and the Southern Monmouth Regional Sewerage Authority who provided laboratory services for bacteria analyses for County Monitoring Data.

The study partners, other members of the TAC, and the RSWMP Committee used the data and results of the detailed watershed studies, monitoring, field studies, and modeling analyses to develop the Management Plan, including the stormwater specific mitigation projects, design and performance standards and the implementation strategy. These elements are provided in Book 2 of the WPBRSWMP.

1.5 Introduction to Book 1

This volume is Book 1 of the Regional Stormwater Management Plan. It presents the General Watershed Characterization as well as results from various technical studies conducted for the watershed. These include Stream Assessments, Microbial Source Tracking, Water Quality Monitoring, Hydrologic and Hydraulic Modeling and Watershed Hydrologic and Water Quality Modeling.

2 WATERSHED CHARACTERIZATION

The Wreck Pond Brook watershed includes about 8,174 acres (±12.74 sq. miles) in southern Monmouth County New Jersey as shown on Figure 1. The western boundary of the watershed is in Wall Township and extends east-southeast to Wreck Pond on the border of Spring Lake and Sea Girt. The Pond discharges through an outlet structure into the Atlantic Ocean. The watershed also includes lands in Spring Lake Heights. The major tributaries are Hannabrand Brook, Wreck Pond Brook and Black Creek. Numerous ponds are found within the watershed.

The watershed characterization is based primarily on existing data. Much of the data was provided by the MCOOGIS office as data layers from the GIS mapping. Additional data was taken from the NJDEP GIS data layers. Other available local data was used including NJDEP, USGS, Freehold Soils, EPA, County and other reports.

The characterization also includes technical studies done for this project. These are discussed in separate sections, below.

2.1 Location and Jurisdictional Boundaries

The watershed is located entirely within Monmouth County and NJDEP Watershed Management Area No. 12. Four municipalities are included in the watershed, as noted on Figure 1. Wall Township comprises about 84% of the watershed, or ±6890 acres. Table 1 summarizes the acreage within each municipality.

Table 1: Jurisdictional Boundaries

Municipality	Area (Acres)	Percent of Watershed
Wall Township	6890	84%
Spring Lake Borough	407	5%
Spring Lake Heights Borough	736	9%
Sea Girt Borough	139	2%
TOTAL	8172	

2.2 Topography

The watershed varies from essentially flat around Wreck Pond, to gently rolling to the west. Figure 2 shows the general topography of the watershed. Elevations vary from about 155 feet in the northwestern portion, to just above sea level at Wreck Pond. Slopes are generally mild, but are steeper in the upper watershed, particularly along the

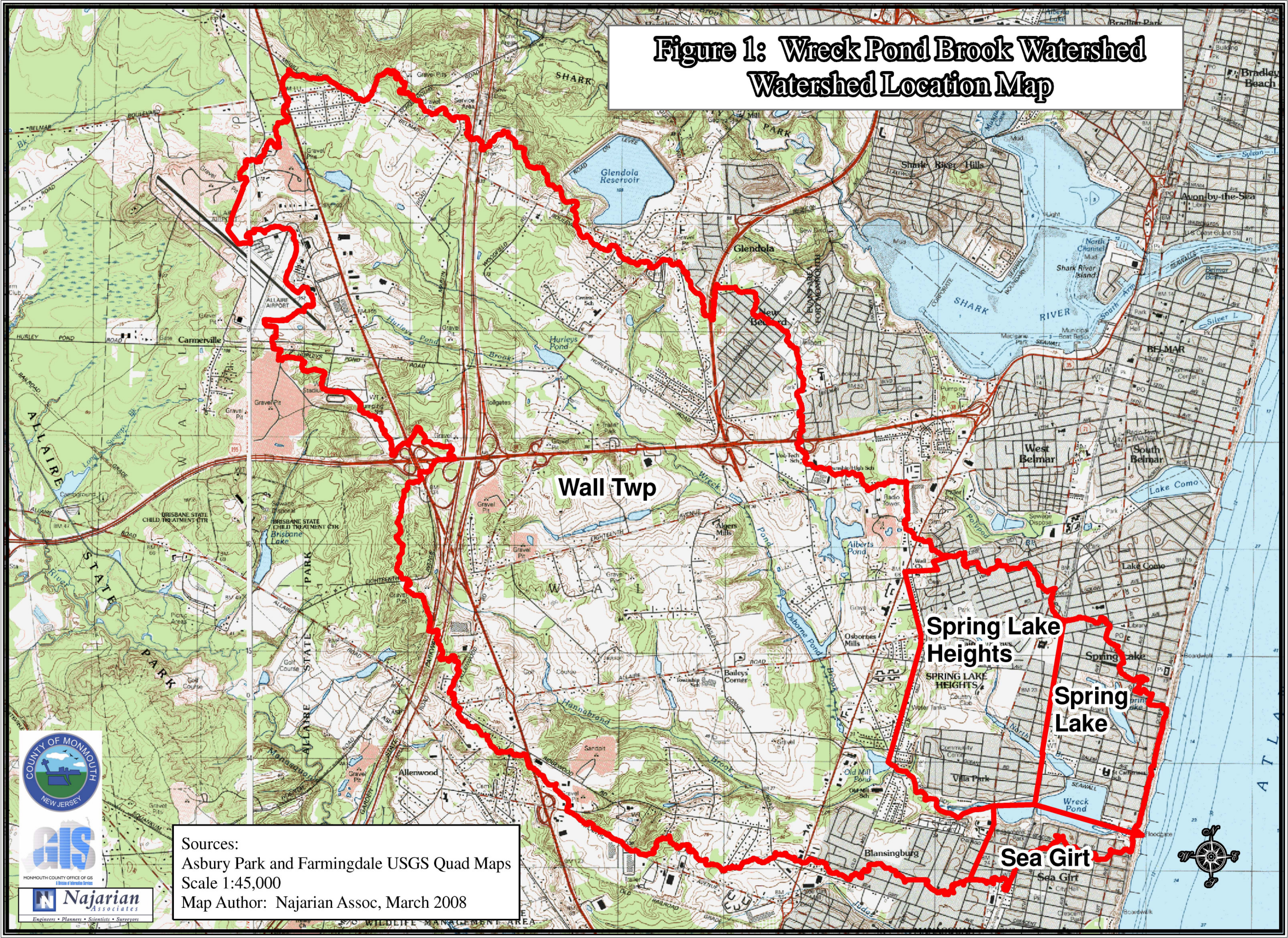


Figure 1: Wreck Pond Brook Watershed
Watershed Location Map
Wall Twp
Spring Lake Heights
Spring Lake
Sea Girt
Sources:
Asbury Park and Farmingdale USGS Quad Maps
Scale 1:45,000
Map Author: Najarian Assoc, March 2008
COUNTY OF MONMOUTH
NEW JERSEY
Najarian Associates

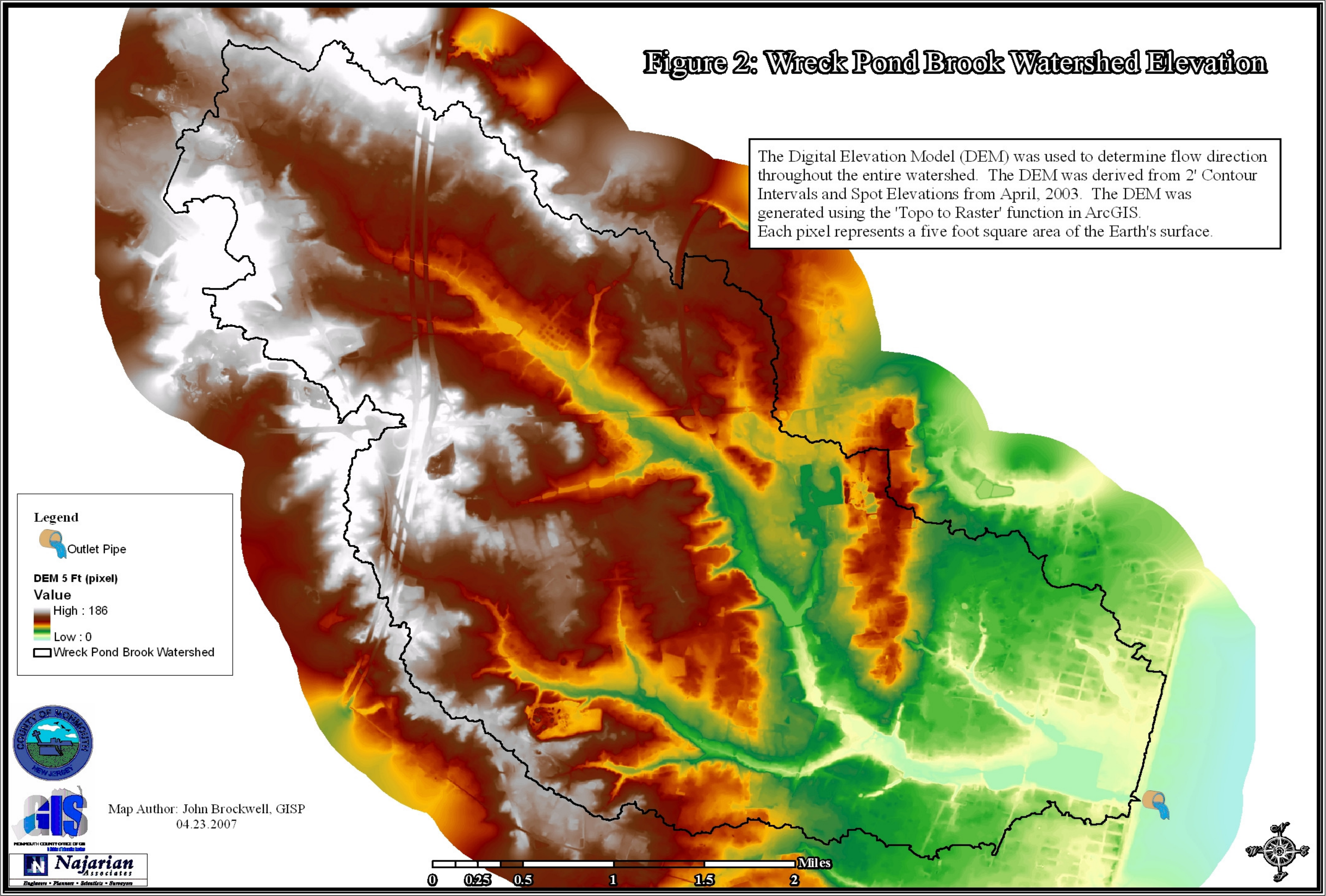


Figure 2: Wreck Pond Brook Watershed Elevation
The Digital Elevation Model (DEM) was used to determine flow direction throughout the entire watershed. The DEM was derived from 2' Contour Intervals and Spot Elevations from April, 2003. The DEM was generated using the 'Topo to Raster' function in ArcGIS.
Each pixel represents a five foot square area of the Earth's surface.
Legend
Outlet Pipe
DEM 5 Ft (pixel)
Value
High : 186
Low : 0
Wreck Pond Brook Watershed
Map Author: John Brockwell, GISP
04.23.2007
Najarian Associates
0
0.25
0.5
1
1.5
2
Miles

stream corridors. Manmade steeper slopes are located in the remnant sand and gravel mines in Wall Township. However, the watershed generally contains slopes less than 15%.

2.3 Geology and Hydrogeology

The Wreck Pond watershed is located within the New Jersey Coastal Plain physiographic province. The Coastal Plain consists of unconsolidated sand and gravel formations inter-layered with clayey materials. The sand and gravel layers generally are good water-bearing zones or aquifers. According to the NJ Geologic Survey mapping, the site is underlain by the Cohansey formation and the lower member of the Kirkwood Formation (see Figure 3).

The Cohansey sand is a medium to coarse grained quartz sand with “minor amounts of pebbly sand, fine- to coarse-grained sand, silty and clayey sand and inter-bedded clay (USGS, 1989). Locally, there can be relatively thick clay beds. The Kirkwood formation is variable, with thick clay beds along the coast and inter-bedded gravels and sands. Together, these two formations form the Kirkwood-Cohansey aquifer. This aquifer is predominately a water-table aquifer.

Ground water aquifers are also present at depth in the watershed. The Upper Aquifer of the Potomac-Raritan-Magothy formation is about 1000 feet below sea level in the vicinity of Spring Lake Heights. Overlying this aquifer are the Englishtown Aquifer and the relatively thin Mount Laurel-Wenonah Aquifer. These aquifers are under confined conditions, with various confining beds present.

The deeper aquifers provide water supply within the watershed. Figure 4 provides locations of the public water supply wells within the watershed as provided by NJDEP GIS data. Table 2 summarizes the information on these wells.

According to the GIS layer, most of these wells are within the Englishtown aquifer. The average depth of these wells is about 706 feet. One well is listed as finished in the Mount Laurel-Wenonah Aquifer and is about 564 feet deep. The wells in the Mobile Home park are shallower, at about 75 feet deep, and are in the Kirkwood-Cohansey aquifer. The average pumping rate of the wells are 464 gpm for the Englishtown wells and 12.5 gm for the Kirkwood-Cohansey wells, while the pumping rate for the well in the Mt. Laurel-Wenonah well is 200 gpm.

Each public supply well has a calculated wellhead protection area. Currently, NJDEP regulates certain development within wellhead protection areas. Other wells may be present in the watershed that do not supply public community water.

Figure 3: Wreck Pond Brook Watershed Geology

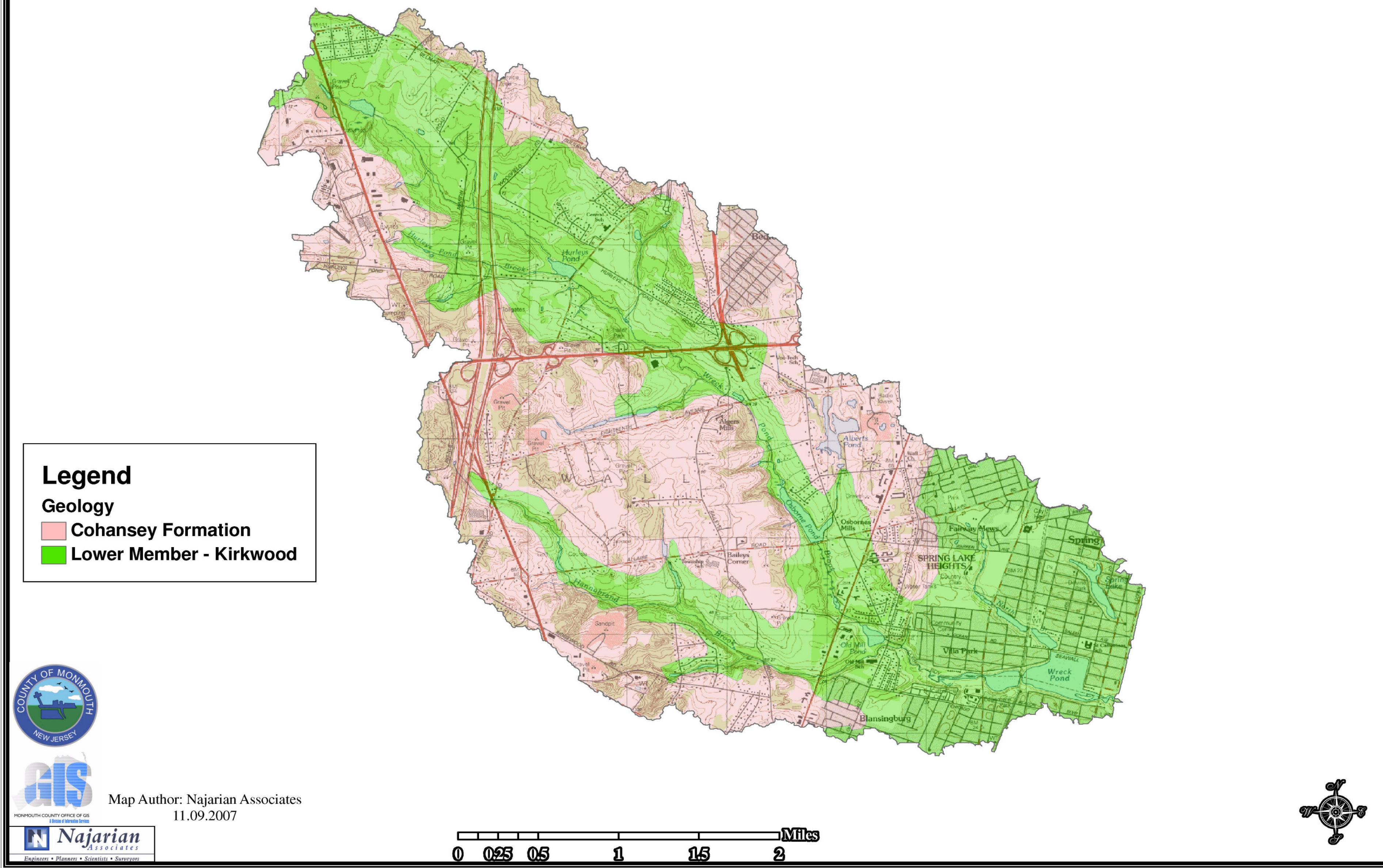
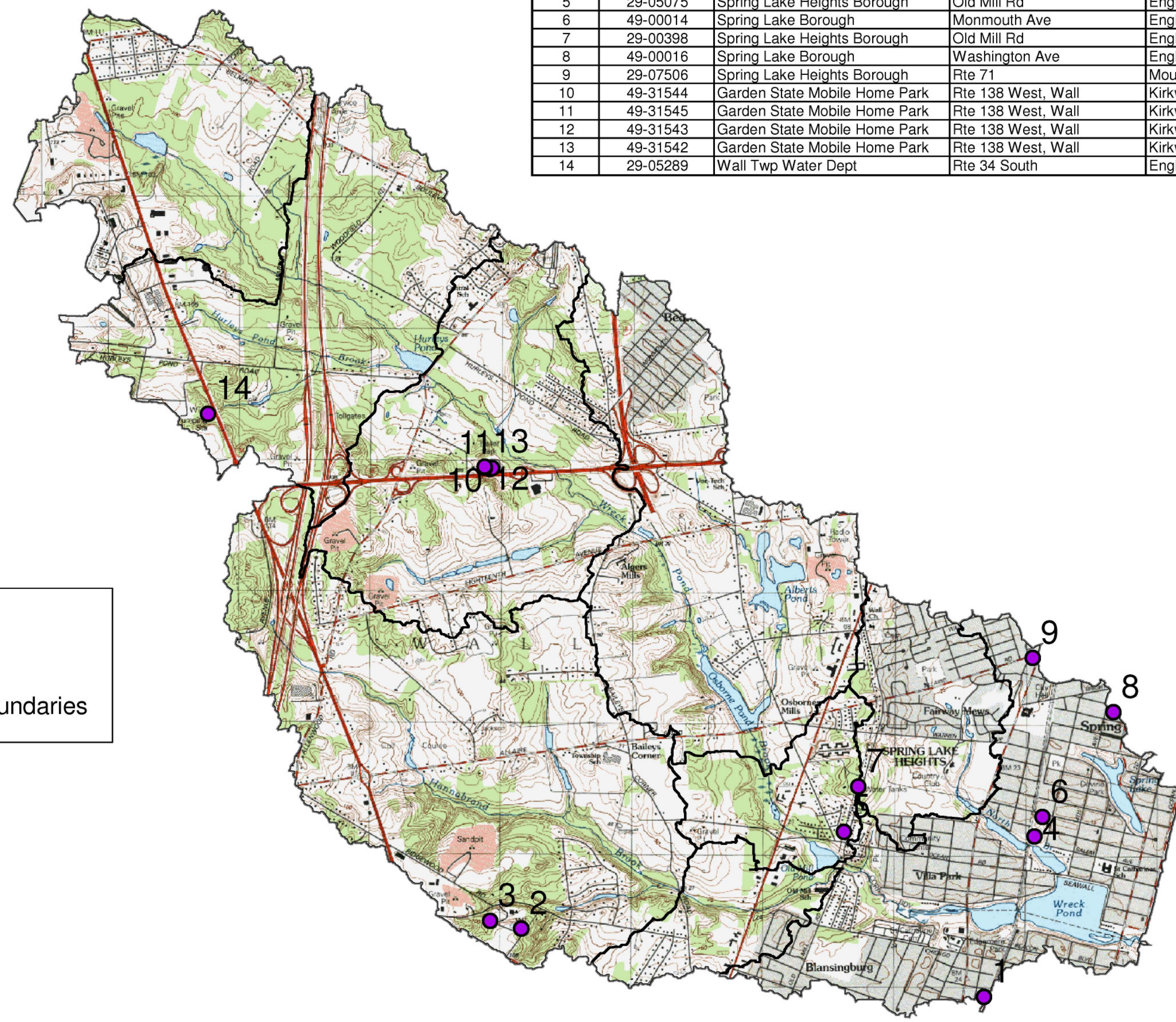


Table 2: PUBLIC WELL INFORMATION						
Well #	**Well Permit**	**OWNER - Municipality**	**Address**	**Depth**	**Pumping Rate**	**Aquifer**
1	29-04102	Sea Girt Water Dept	Philadelphia & Bell Pl	715	420	Englishtown aquifer
2	29-02869	Wall Twp Water Dept	Atlantic Ave	757.42	400	Englishtown aquifer
3	29-02870	Wall Twp Water Dept	Tilton Corner Rd	728	400	Englishtown aquifer
4	49-00015	Spring Lake Borough	Monmouth Ave	707	500	Englishtown aquifer
5	29-05075	Spring Lake Hts Borough	Old Mill Rd	685	450	Englishtown aquifer
6	49-00014	Spring Lake Borough	Monmouth Ave	698	550	Englishtown aquifer
7	29-00398	Spring Lake Hts Borough	Old Mill Rd	713.5	510	Englishtown aquifer
8	49-00016	Spring Lake Borough	Washington Ave	705	500	Englishtown aquifer
9	29-07506	Spring Lake Hts Borough	Rte 71	564	200	Mt Laurel-Wenonah aquifer
10	49-31544	Garden State Mobile Home Park	Rte 138 West, Wall	75	12.5	Kirkwood-Cohansey aquifer
11	49-31545	Garden State Mobile Home Park	Rte 138 West, Wall	75	12.5	Kirkwood-Cohansey aquifer
12	49-31543	Garden State Mobile Home Park	Rte 138 West, Wall	75	12.5	Kirkwood-Cohansey aquifer
13	49-31542	Garden State Mobile Home Park	Rte 138 West, Wall	75	12.5	Kirkwood-Cohansey aquifer
14	29-05289	Wall Twp Water Dept	Rte 34 South	654	450	Englishtown aquifer

As part of the management of stormwater, protection of aquifer recharge and ground water quality are essential factors. In the coastal area, overuse of groundwater can cause intrusion of saline water into the near-shore aquifers.

Figure 4: Public Water Supply Wells

PUBLIC WELL INFORMATION				
Well #	Well Permit	OWNER - Municipality	Address	Aquifer
1	29-04102	Sea Girt Water Dept	Phildelphia & Bell Place	Englishtown aquifer system
2	29-02869	Wall Twp Water Dept	Atlantic Ave	Englishtown aquifer system
3	29-02870	Wall Twp Water Dept	Tilton Corner Rd	Englishtown aquifer system
4	49-00015	Spring Lake Borough	Monmouth Ave	Englishtown aquifer system
5	29-05075	Spring Lake Heights Borough	Old Mill Rd	Englishtown aquifer system
6	49-00014	Spring Lake Borough	Monmouth Ave	Englishtown aquifer system
7	29-00398	Spring Lake Heights Borough	Old Mill Rd	Englishtown aquifer system
8	49-00016	Spring Lake Borough	Washington Ave	Englishtown aquifer system
9	29-07506	Spring Lake Heights Borough	Rte 71	Mount Laurel-Wenonah aquifer
10	49-31544	Garden State Mobile Home Park	Rte 138 West, Wall	Kirkwood-Cohansey water-table aquifer system
11	49-31545	Garden State Mobile Home Park	Rte 138 West, Wall	Kirkwood-Cohansey water-table aquifer system
12	49-31543	Garden State Mobile Home Park	Rte 138 West, Wall	Kirkwood-Cohansey water-table aquifer system
13	49-31542	Garden State Mobile Home Park	Rte 138 West, Wall	Kirkwood-Cohansey water-table aquifer system
14	29-05289	Wall Twp Water Dept	Rte 34 South	Englishtown aquifer system



Legend

- Public Wells
- Sub-Watershed Boundaries

Map Author: Najarian Assoc.
11.09.2007

0 0.25 0.5 1 1.5 2 Miles

2.4 Soils

Soils are classified as to hydrologic groups and type. Figure 5 provides a map by hydrologic soil group and Figure 6 provides a soil map for the watershed. A variety of soils are present. Table 3 provides a summary of the soil types in the Watershed.

Hydrologic soils group classifies soils as to runoff potential. The properties of a soil that influence infiltration of precipitation control the hydrologic soil group. Soils are grouped from A (low runoff potential) to D (high runoff potential). This property is important in modeling runoff from a watershed.

Table 3: Summary of Soils

Soil Name	Approx. Area (Acres)	Hydrologic Soil Group	Hydric?
ATSION	219	C/D	Y
DOWNER	3268	B	N
EVESBORO	647	A	N
FALLSINGTON	198	B/D	Y
FREEHOLD	104	B	N
HAMMONTON	181	B	N
HOLMDEL	24	C	N
HOOKSAN	9	A	N
HUMAQUEPTS	491	D	Y
KLEJ	204	B/D	Y
LAKEHURST	61	A	N
LAKEWOOD	220	A	N
PITS	443	A	N
SASSAFRAS	1482	B	N
SULFAQUENTS	6	D	Y
UDORTHENTS	299	Varies	
WATER	166	N/A	
WOODSTOWN	151	C	N

2.5 Climate

The watershed is located within the New Jersey Coastal Zone. Climate in New Jersey varies by location, but some general observations about Stat climate can be made. The following information is taken from the New Jersey Climate Overview (Office of NJ Climatologist, 2007). Average precipitation along the southeast coast is about: 40 inches, with about 25 thunderstorms. Snow may fall from around November 15 to April 15.

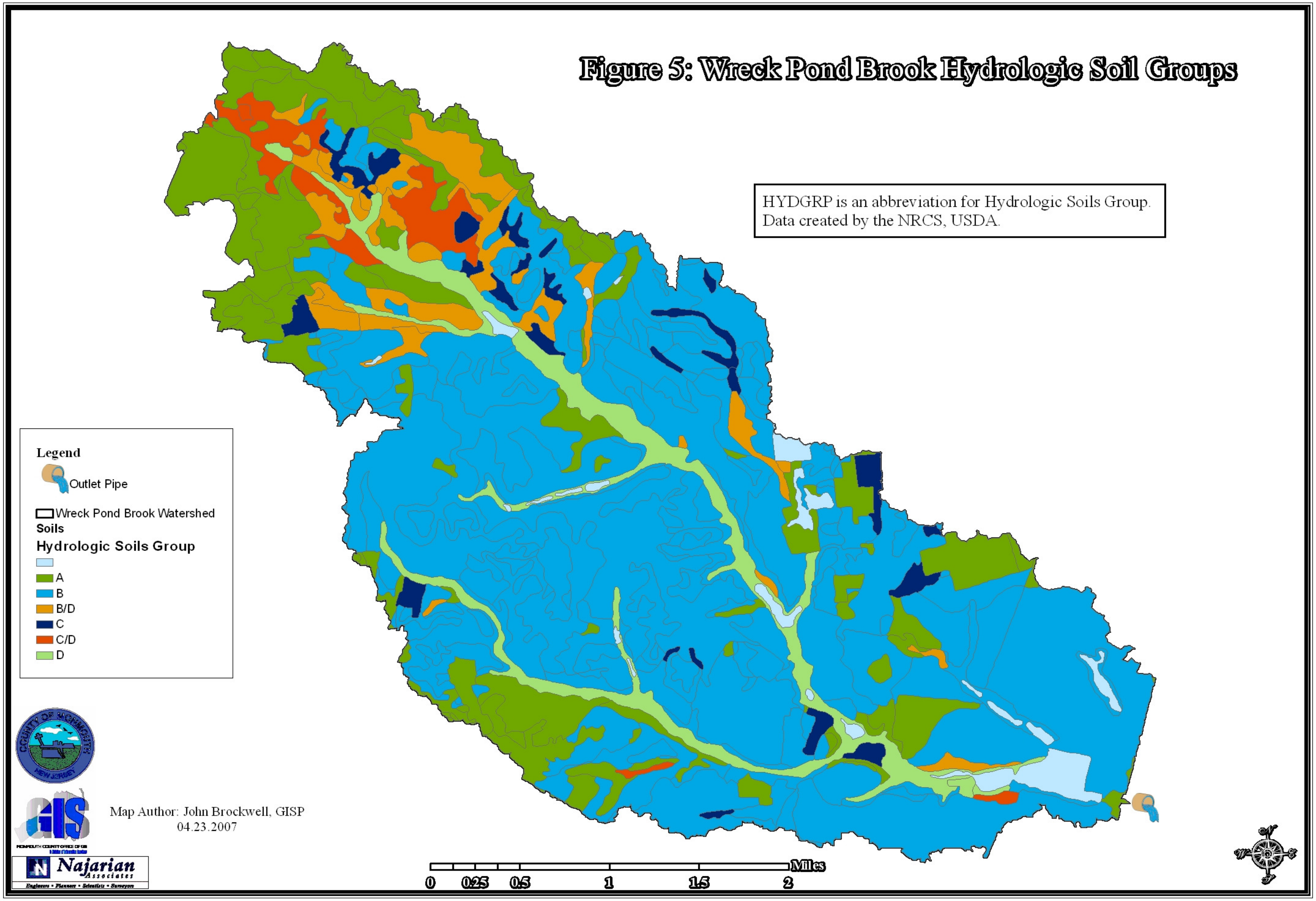


Figure 5: Wreck Pond Brook Hydrologic Soil Groups
HYDGRP is an abbreviation for Hydrologic Soils Group.
Data created by the NRCS, USDA.
Legend
Outlet Pipe
Wreck Pond Brook Watershed
Soils
Hydrologic Soils Group
A
B
B/D
C
C/D
D
Map Author: John Brockwell, GISP
04.23.2007
Najarian Associates
Miles
0
0.25
0.5
1
1.5
2

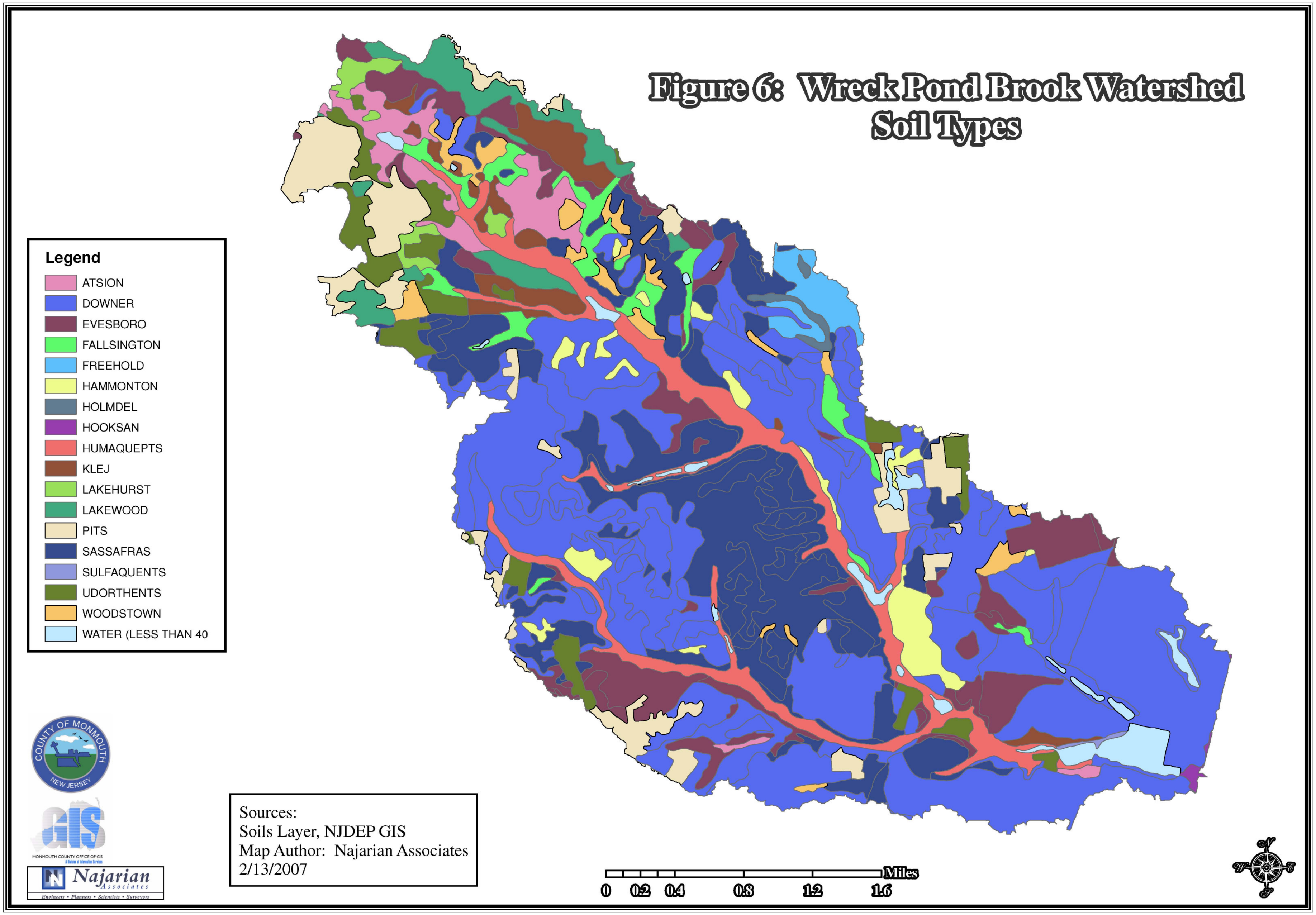


Figure 6: Wreck Pond Brook Watershed
Soil Types
Legend
ATSION
DOWNER
EVESBORO
FALLSINGTON
FREEHOLD
HAMMONTON
HOLMDEL
HOOKSAN
HUMAQUEPTS
KLEJ
LAKEHURST
LAKEWOOD
PITS
SASSAFRAS
SULFAQUENTS
UDORTHENTS
WOODSTOWN
WATER (LESS THAN 40
Sources:
Soils Layer, NJDEP GIS
Map Author: Najarian Associates
2/13/2007
0
0.2
0.4
0.8
1.2
1.6
Miles

In the Coastal areas, the climate is influenced by the interaction of oceanic and continental influences. The Ocean tends to keep temperature fluctuations less extreme than in the interior and seasonal changes are more gradual.

In the fall and early winter, the ocean is warmer than the land meaning the coastal zone is typically warmer than the interior areas. However, in the spring the ocean winds keep temperatures cooler along the Coast.

Sea breezes strongly influence the coastal climate. As noted in the State climate summary:

> When the land is warmed by the sun, heated air rises, allowing cooler air at the ocean surface to spread inland. Sea breezes often penetrate 5-10 miles inland, but under more favorable conditions, can affect locations 25-40 miles inland. They are most common in spring and summer.

Coastal storms, often called as nor'easters, occur commonly from October to April. These storms bring strong winds and heavy rains and at least one such event occurs each winter and some years can bring five to ten. Tropical storms and hurricanes are potential concerns for coastal areas. These storms can bring substantial rain as well as severe high tides and coastal erosion. Flooding and other damage can occur in the coastal zone due to such storms.

2.6 Hydrology

The Wreck Pond Brook watershed includes several major streams. These streams drain to Wreck Pond, which has tidal exchange with the Atlantic Ocean. Wreck Pond Brook is the major stream within the watershed. Numerous ponds and small lakes are also found in the watershed. Figure 7 shows the major hydrologic features within the watershed and the subwatershed boundaries. Table 4 provides data on the subwatershed areas.

All of the streams within the watershed are classified as FW2-NT (FW2 Non-trout) in the New Jersey Surface Water Quality Standards. None of the streams are Category 1 (C1). None of the ponds or lakes are specifically listed in the Standards. Thus, these are also classified as FW2-NT. Non-trout waters are not considered suitable for trout because of their physical, chemical, or biological characteristics, but are suitable for a wide variety of other fish species.

In all FW2 waters the designated uses are:

1. Maintenance, migration and propagation of the natural and established biota;
2. Primary and secondary contact recreation;
3. Industrial and agricultural water supply;

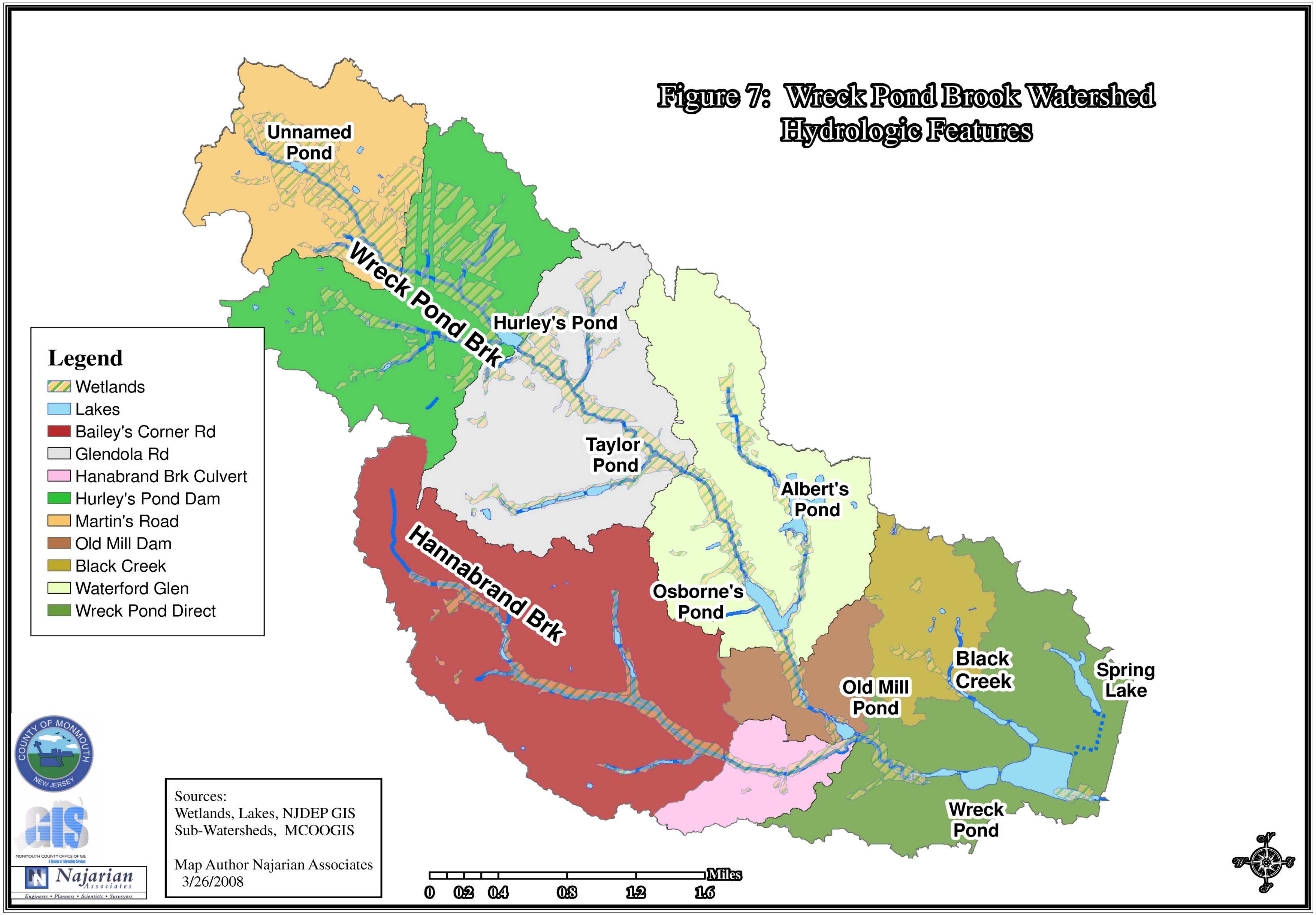


Figure 7: Wreck Pond Brook Watershed Hydrologic Features

4. Public potable water supply after conventional filtration treatment and disinfection; and
5. Any other reasonable uses.

Table 4: Subwatershed Areas		
Stream	**Subwatershed**	**Area (acres)**
Black Creek	Spring Lake Golf Course	416.40
Total		**416.40**
Wreck Pond Brook	Martin's Road	821.23
	Hurley's Pond Dam	1164.00
	Glendola Rd @ Wreck Brook	1121.17
	Waterford Glen	1231.78
	Old Mill Dam Culvert	303.06
Total		**4641.24**
Hannabrand Brook	Bailey's Corner Rd	1716.75
	Hannabrand Brook Culvert	259.71
Total		**1976.46**
Wreck Pond Direct	Wreck Pond	**1137.96**

Wreck Pond Brook drains the central portion of the watershed, originating just north of Allaire Airport in Wall Township and flowing to the southeast. The drainage area is about 4,640 acres. The main stem of the stream is about 7.6 miles long. Depending on the time of year, average base flows can range from 2.5 cfs to 7.5 cfs in the upstream portion of the stream and from 7.5 cfs to 18 cfs in the downstream portions. The Wreck Pond Brook subwatershed includes the largest watershed area at about 4,641 acres, which is more than half of the watershed area.

The Wreck Pond Brook headwaters are at the Route 34 divide and drainage from the upland flows to a wetland complex associated with the Brook and an unnamed pond with a timber dam. The area was previously a sand and gravel mining facility and the pond was likely a source for wash water for the production of washed sand and gravel. The operation was active from the late 19th century through the 1950s. The timber dam and berm have been breached and the impoundment drained (WMAC, 1996).

The Brook flows through Hurley's Pond. This Pond also receives drainage from an unnamed tributary and directly from developed areas in the Glendola section of Wall Township. The Pond is contained by a dam and Hurley's Pond Road is located on top of the dam. Downstream of this Pond, several tributaries join the Brook which then flows into Taylor's Pond where another tributary joins the Brook. Further downstream, Wreck Pond Brook flows into Osborn's Pond (sometimes called Trimmers Pond) which is controlled by a dam under Allaire Road.

A major tributary discharges to the northern leg of Osborn's Pond. This drains a sub-watershed that includes a pond and wetland complex associated with a historic sand and gravel mining and washing operation that was located just south of Eighteenth Avenue. A large pond complex known as Albert's Pond is still present in this area. Reportedly, this Pond is up to 60 feet deep.

Downstream of Osborn's Pond, the Brook flows into the Old Mill Pond. Hannabrand Brook (discussed below) joins Wreck Pond Brook just downstream of Old Mill Road. The Brook then discharges into Wreck Pond.

Hannabrand Brook flows through the southern portion of the watershed. It is about 4 miles long and has a drainage area of about 1,976 acres. Average base flows along the stream can range from 2 cfs to 4 cfs, depending on the time of year.

Black Creek, also known as the North Branch of Wreck Pond Brook, drains the northern portion of the watershed and is the shortest tributary at about 1.2 miles. The lower portion of this Creek is impounded and controlled by the weir structure at Ocean and Shore Roads in Spring Lake. The impounded area covers about 11 acres and is subdivided by railroad tracks. Average base flows along the stream can range from 2 cfs to 3.5 cfs, depending on the time of year.

The other hydrologic features of the watershed are numerous lakes and ponds. These are generally human made structures. Figure 7 shows the ponds within the watershed, which are summarized in Table 5. Other unnamed small ponds are also found throughout the watershed, included some impounded areas along the streams.

Table 5: Lakes and Ponds

Name	Area (ac)
Unnamed Pond	2.72
Hurley's Pond	6.46
Taylor Pond	0.71
Albert's Pond	25.75
Osborne's Pond	20.21
Old Mill Pond	6.13
Spring Lake	14.38
Wreck Pond	73.36

Wreck Pond covers about 73 acres. It was originally an estuary open to the Ocean. During the 1930s, the outlet structure was constructed. The outlet structure allows exchange with the Ocean and there is a noticeable tidal fluctuation in the eastern portion of the Pond. Recently, residents of the area have reported a noticeable decline in the degree of tidal fluctuation.

Wreck Pond can be divided into several sections. The eastern portion of the Pond extends from the bridge on First Avenue to the outfall structure and is about 1.4 acre in size. This section of the pond is the most influenced by tidal exchange. According to the NJDEP, the pond bottom in this area is primarily sandy.

Moving west, the pond is relatively narrow between First and Second Avenues and the bottom is primarily sandy. Along Second Avenue, the pond opens to it widest expanse and is about 1,400 feet wide. This section of the pond extends from Second Avenue to the Railroad Bridge, a distance of about 2,000 feet, and is about 57.6 acres in size. Within this section of the Pond, both the northern shoreline (along Ocean Road) and the eastern shoreline (along Second Avenue) are either bulkheaded or rip-rapped. The northwestern shoreline, along Shore Road in Spring Lake Heights, is not bulkheaded but contains a more natural shoreline. This section of the Pond is generally shallow and the bottom is very mucky.

The western portion of the pond extends from the railroad bridge to the west. It is somewhat narrower and generally has only limited tidal exchange. This portion of the Pond is about 14.2 acres. The northern shoreline contains park right along the shore, with grassed and some treed and shrub areas. The southern shoreline contains a wooded area to the east, with homes along the remainder of the shoreline.

The end of the Pond is considered to be Route 71. However, Wreck Pond Brook west of this road is still somewhat ponded.

Spring Lake is a pond located north of Wreck Pond. Although this pond is separate from Wreck Pond, it is connected to Wreck Pond via stormwater infrastructure piping, shown as a dotted line on Figure 7. Spring Lake is also connected to the Ocean, by a control valve and piping system that was utilized during the dredging of Spring Lake in the early 1990s. The control valve is closed at all times and is maintained by the Spring Lake Department of Public Works.

Besides Wreck Pond, the largest ponds are Albert's Pond at about 26 acres and Osborne's Pond at about 20 acres. Both of these ponds are located in the Waterford Glen sub-watershed.

Further downstream is Old Mill Pond, located at the Old Mill Inn, just north of Old Mill Road. This pond has a surface area of about 6.1 acres. Further northwest is Hurley's Pond, with a surface area of ±6.5 acres. This pond is fed by the main stem of Wreck Pond Brook and a tributary from the west, along Hurley Pond Road.

2.7 Flooding

Flooding is a concern within certain parts of the watershed. Figure 8 presents the US FEMA flood hazard area map for the watershed. Within the watershed about 651 acres are within Zone AE. This zone corresponds to "the 1-percent annual chance floodplains that are determine in the Flood Insurance Study by detailed methods of analysis"

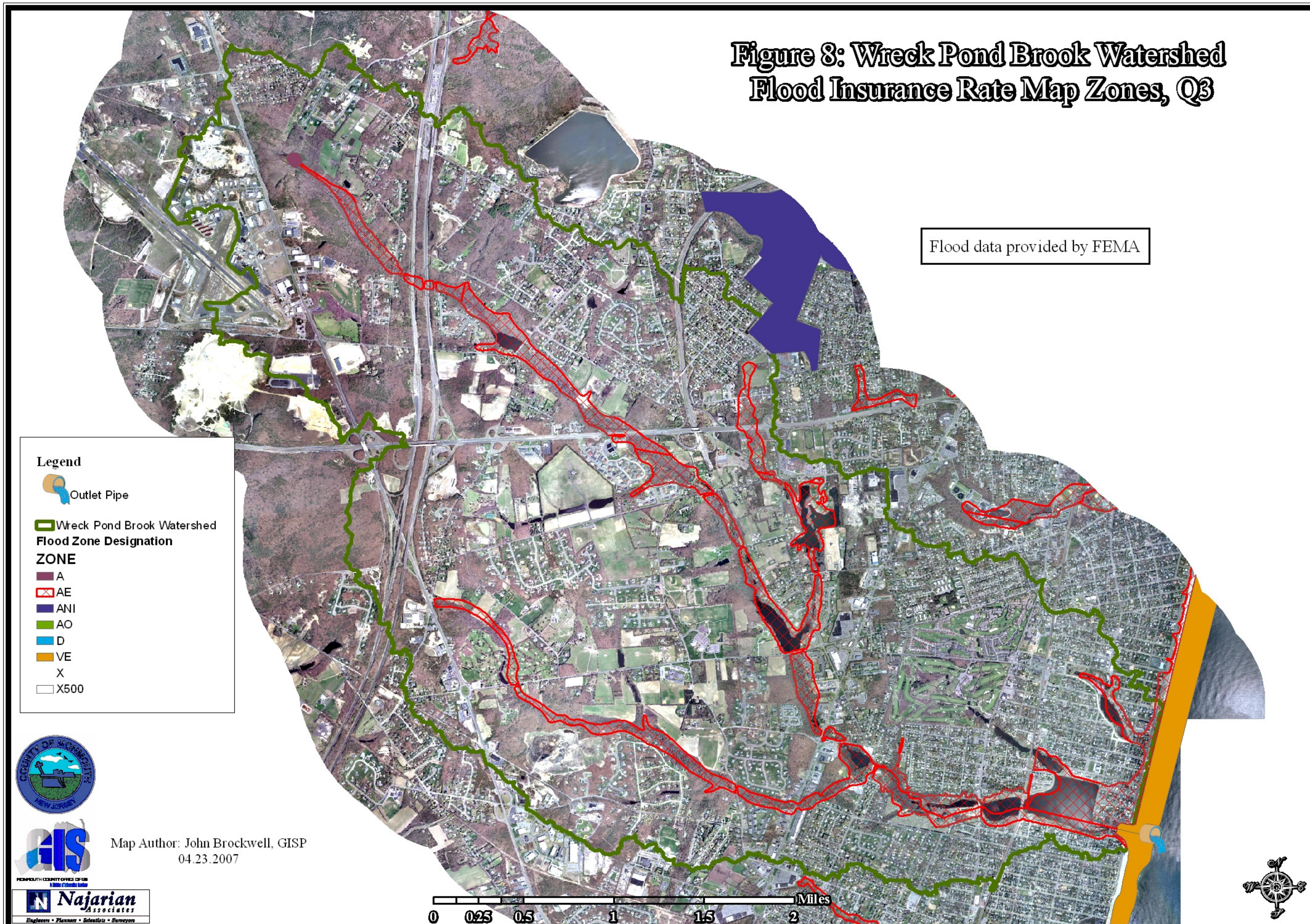


Figure 8: Wreck Pond Brook Watershed
Flood Insurance Rate Map Zones, Q3
Flood data provided by FEMA
Legend
Outlet Pipe
Wreck Pond Brook Watershed
Flood Zone Designation
ZONE
A
AE
ANI
AO
D
VE
X
X500
Map Author: John Brockwell, GISP
04.23.2007
Najarian
Associates
0
0.25
0.5
1
1.5
2
Miles

(FEMA, 2007). The 1-precent annual chance flood is commonly called the 100-year flood as it is anticipated that one such event would occur every 100 years. Another 4 acres are in the A zone, which is noted as an area in which the 1-percent annual chance flood is estimated.

About 3.5 acres are within the VE zone, at the mouth of Wreck Pond. This is the area within the "1-percent annual chance floodplain that has additional hazards associated with storm waves" (FEMA, 2007).

The lower part of the watershed experienced significant flooding in October of 2005. Within Spring Lake and Spring Lake Heights streets and homes were flooded. The flooding resulted from rain of 11.58 inches over a period of 3 days. The actual flooding occurred rapidly, during an over night period surprising residents. On the evening of October 14, 2005, a flood elevation of 10.55 (NGVD 1929 Datum) at the Wreck Pond weir structure was obtained by Najarian Associates, under work being performed for the Borough of Spring Lake. This water surface elevation was collected prior to what was suspected to be the maximum peak flood elevation, which occurred in the early morning of October 15, 2005.

2.8 Ecology

The Wreck Pond watershed includes developed and undeveloped lands. Approximately 53 percent of the watershed is currently undeveloped, including about 1,100 acres of wetlands and ±2,270 acres (28%) of woodland. Figure 7 shows the overall wetland locations.

Table 6 summarizes the wetlands types within the watershed based on analysis of the land use GIS layer.

Table 6: Summary of Wetlands

WETLAND TYPE	ACRES
Agricultural Wetlands (Modified)	24.1
Deciduous Scrub/Shrub Wetlands	79.5
Deciduous Wooded Wetlands	295.1
Disturbed Wetlands (Modified)	0.7
Freshwater Tidal Marshes	4.8
Herbaceous Wetlands	46.0
Managed Wetlands (Modified)	69.1
Mixed Forested Wetlands (Coniferous Dom.)	24.6
Mixed Forested Wetlands (Deciduous Dom.)	502.8
Mixed Scrub/Shrub Wetlands (Deciduous Dom.)	45.8
Saline Marshes	10.0
Total Wetland Area	**1102.5**

Of the approximately 1,100 acres of wetlands, about 800 acres (72%) are wooded deciduous wetlands classified as either deciduous wooded wetlands or mixed forested wetlands (deciduous dominant). Only a very small area of freshwater (±4.81 acres) or saline (±9.98 acres) tidal marsh is noted.

Endangered or threatened animal species or habitat for such species are reported only in a few small patches within the watershed. NJDEP provides mapping that ranks areas of the state as to endangered species occurrence and habitat. NJDEP describes the ranks as follows:

- **Rank 5** is assigned to patches containing one or more occurrences of at least one wildlife species listed as endangered or threatened on the Federal list of endangered and threatened species.
- **Rank 4** is assigned to patches with one or more occurrences of at least one State endangered species.
- **Rank 3** is assigned to patches containing one or more occurrences of at least one State threatened species.
- **Rank 2** is assigned to patches containing one or more occurrences of at least one non-listed State priority species.
- **Rank 1** is assigned to patches that meet habitat-specific suitability requirements such as minimum size criteria for endangered, threatened or priority wildlife species, but that do not intersect with any confirmed occurrences of such species.

Thus, only Rank 3 or higher have occurrences of threatened or endangered species.

A few endangered or threatened species are noted in the vicinity of Wreck Pond. The federally listed Least Tern nests in the dunes along the beach adjacent to the eastern portion of Wreck Pond. The Piping Plover, federally listed as threatened, nests in the dunes adjacent to the outlet. A colony of Least Terns, State listed as threatened, nest on the beach seaward of the Pond outlet structure. The plant, Seabeach Amaranth, a federally listed threatened plant has been identified along “an approximately 900’ of beach between the Spring Lake and Sea Girt boardwalks”. Another plant, the state-listed endangered awl-leaf mudwort (*Limosella subulata*) has “been known to occur along the southern shoreline of Wreck Pond” according to NJDEP.

Within the watershed, the Northern Pine Snake is listed as a species of concerns in the wooded and grassed lands in the far northwestern portion of the watershed, near Allaire Airport. Otherwise, the woodlands and emergent wetlands are generally categorized as Rank 2, which is “Priority Concern”. This indicates that no endangered species or habitat for such species have been found in, or in the vicinity of, these habitats.

2.9 Critical Habitat and Environmentally Constrained Land

The Wreck Pond Brook watershed includes some environmentally sensitive lands. Most of these lands are the wetlands and streams within the watershed. As noted in Section 2.2, the watershed does not include significant steep slope areas. There are only limited areas with habitat for threatened or endangered species, including the dunes along Wreck Pond and a small portion on the southwestern edge of the watershed near Allaire airport which is potential habitat for the Northern pine snake.

No waters in the watershed are Category 1 waters.

The ponds and streams within the watershed and the accompanying wetlands and buffers provide environmental benefits to the wildlife and people in the watershed. These may be considered environmentally sensitive lands.

2.10 Land Use

The Wreck Pond watershed, like much of Coastal Monmouth County, includes a mix of land uses, primarily residential and commercial.

The eastern portion of the watershed has been developed in residential uses for many years. The 1930 aerial from the NJDEP GIS system reveals that the watershed was extensively developed for agriculture, with a few pockets of residential development or areas with housing, for example in the area called “New Bedford”. Much of the Borough of Spring Lake was already developed. The golf course in Spring Lake Heights also is visible. Over time, the agricultural lands gave way to suburban development, with some areas reverting to woodlands. Over time, suburban development moved west within the watershed. Historically, there were a few sand and gravel mines within the watershed.

The areas surrounding Wreck Pond are generally fully developed with suburban/urban uses, primarily homes with some commercial uses. This includes the communities of Spring Lake, Spring Lake Heights and Sea Girt. Moving further upstream within the watershed are less developed lands including woodlands, agricultural lands and brush areas along with suburban land uses. Wall Township contains most of the undeveloped area in the watershed. Table 7 summarizes the land use in the watershed. This information was taken from the Monmouth County GIS system, updated to 2006. The land use categories provided in Table 7 are from the NCRS (formerly the Soil Conservation Service) and are relatively broad categories.

Table 7: Land Use		
Land Use/Land Cover	**Watershed**	
	Acres	**Percentage**
Agricultural Land	39.6	0.5
Agricultural Land (Cropland)	741.6	9.1
Brush	289.8	3.6
Landscaped Commercial/Industrial/Institutional	109.5	1.3
Landscaped Commercial/Industrial/Institutional/Mixed-use	448.1	5.5
Landscaped Open Space	359.3	4.4
Landscaped Open Space (Golf Course)	261.2	3.2
Landscaped Open Space/detention basin	1.3	0.0
Orchards/Tree Nurseries	37.3	0.5
Permanently Unvegetated/Sparsely Vegetated	311.5	3.8
Residential (17% impervious)	748.1	9.1
Residential (23% impervious)	592.3	7.2
Residential (33% impervious)	1247.1	15.3
Residential (65% impervious)	239.5	2.9
Unlandscaped Commercial/Industrial/Institutional	61.8	0.8
Unlandscaped Commercial/Industrial/Institutional/Mixed-use	199.8	2.4
Water	205.6	2.5
Water Feature (Retention Basin)	10.3	0.1
Wooded Area	2270.3	27.8
TOTAL	***8174***	***100***

The land use categories in Table 7 are one way to categorize land use. However, some of the land use categories were not optimal for this study. Thus, additional analysis of land use was conducted.

Description of land use depends on the level of detail of available information as well as decisions as to how to categorize the land use. Available land use GIS files from Monmouth County and the NJDEP use the Anderson system, which assigns a code to each land use. The Anderson system codes can be very specific or more generally applied. For example, wooded lands are subdivided in that system to categories such as “Deciduous forest (>50% crown closure)” or “Mixed forest (>50% deciduous with >50% crown closure)”. The decision as to how to categorize land use depends on both the needs of the study and the need to display the land uses in an understandable format.

For the purposes of this study, land use is of concern for generation of stormwater and impacts to water quality. In addition, for the build-out analyses discussed later herein, the land use categories must be comparable to zoning classes. For example, the forested areas are all considered similar for generation of stormwater and the potential for future development, thus there is no need to further subdivide those classes. Alternatively, the potential for water quality impacts and the development of best management practices likely will differ for institutional lands, industry or a mining operation. The broad commercial/industrial/institutional categories contained uses ranging from schools to industrial lands. This was subdivided into commercial, industrial, cemetery, and mining using the Anderson Codes for 1995 and if necessary, the aerial photographs.

Finally, the landscaped open space category included a variety of uses including athletic fields, parks, planting strips at commercial or industrial buildings, and open areas adjacent to schools or businesses. In addition, the NRCS (SCS) code classified athletic fields in some locations as landscaped open space and in others as landscaped commercial/industrial/institutional, likely depending on whether the field was associated with a school. Thus, the Anderson codes and aerial photographs were used to identify the athletic fields and parks.

Table 8 provides the revised Land Use classifications. This provides 24 different land use categories. While descriptive, these are not easy to understand on a map. Further, the data will also be used in water quality modeling and compared to future zoning for the build-out analysis. Water pollutant generation data is not available for all of these land uses. Thus, fourteen general land use categories were developed and these are summarized in Table 9 and shown on Figure 9. These categories also were used to evaluate future build-out in Book 2 of the RSWMP. Note that wetlands are not one of these categories as this was not consistently reported in the land use GIS files. As noted later, wetlands were overlain on land use using the NJDEP GIS wetland layer.

The land uses in Table 9 can be subdivided into developed and undeveloped areas. Developed areas include residential, commercial, industrial and institutional lands as well as landscaped open space. Agricultural lands, while an active land use, are considered to be available for future development. Table 10 provides a broad summary of land uses as to currently developed or future developable lands.

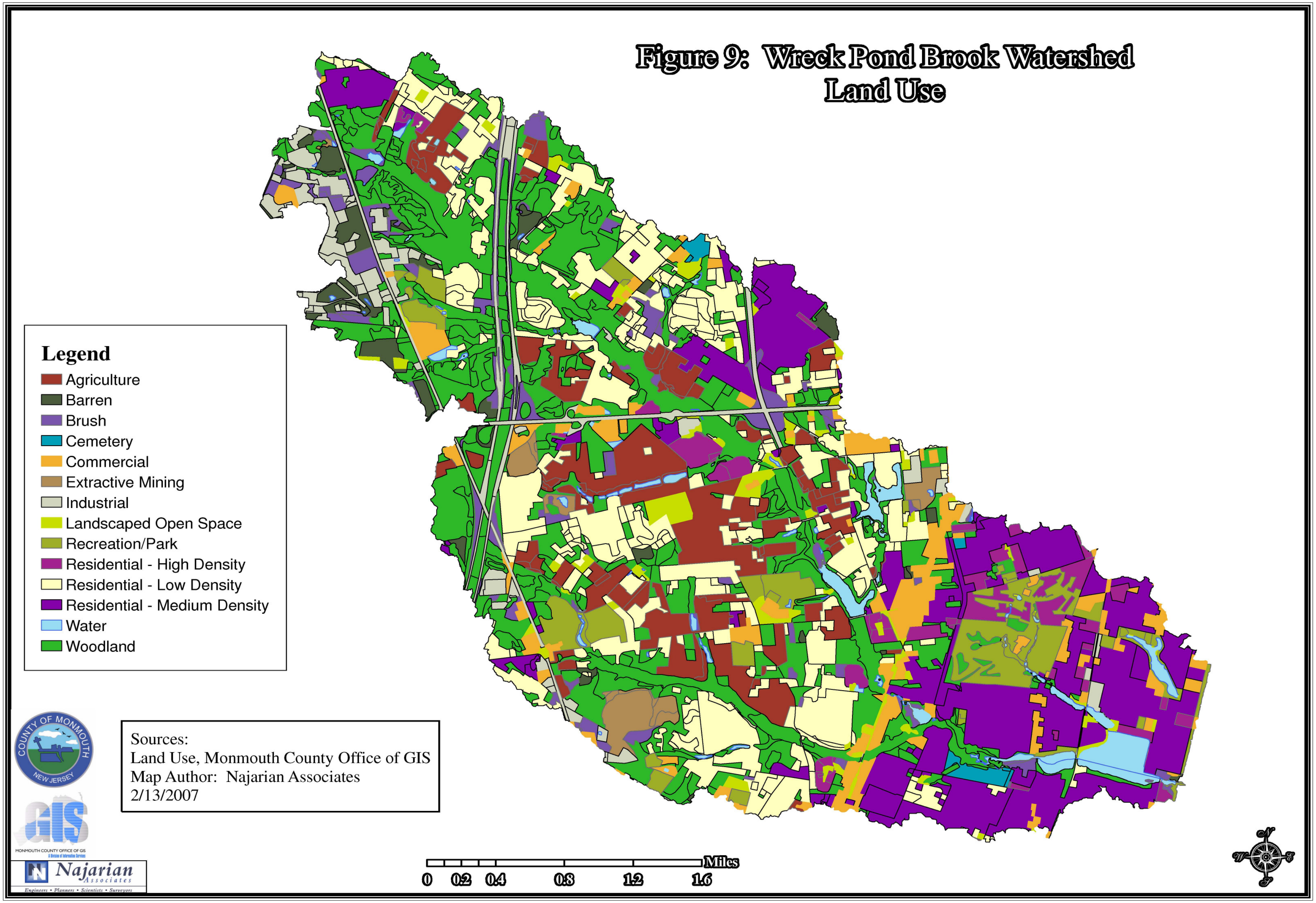


Figure 9: Wreck Pond Brook Watershed
Land Use
Legend
Agriculture
Barren
Brush
Cemetery
Commercial
Extractive Mining
Industrial
Landscaped Open Space
Recreation/Park
Residential - High Density
Residential - Low Density
Residential - Medium Density
Water
Woodland
Sources:
Land Use, Monmouth County Office of GIS
Map Author: Najarian Associates
2/13/2007
COUNTY OF MONMOUTH
NEW JERSEY
GIS
Najarian Associates
Miles
0
0.2
0.4
0.8
1.2
1.6

Table 8: Updated Land Use Summary		
Land Use Category	**Area (Acres)**	**Percent of Watershed**
Agricultural Land	41.4	0.5%
Agricultural Land (Cropland)	741.6	9.1%
Orchards/Tree Nurseries	37.3	0.5%
Permanently Unvegetated/Sparsely Vegetated	165.5	2.0%
Cemetery	38.4	0.5%
Brush	283.7	3.5%
Landscaped Commercial	302.6	3.7%
Unlandscaped Commercial	102.8	1.2%
Extractive Mining	120.9	1.5%
Landscaped Industrial	106.3	1.3%
Landscaped Transportation	160.4	2.0%
Unlandscaped Industrial	66.0	0.8%
Unlandscaped Transportation	95.3	1.2%
Landscaped Open Space	163.4	2.0%
Landscaped Open Space (Golf Course)	265.8	3.3%
Landscaped Open Space (Park)	30.9	0.4%
Recreational (Beach)	3.1	0.0%
Athletic Field	103.7	1.3%
Residential (65% impervious)	239.5	2.9%
Residential (17% impervious)	773.5	9.5%
Residential (23% impervious)	639.8	7.8%
Residential (33% impervious)	1247.1	15.3%
Water	215.9	2.6%
Wooded Area	2229.9	27.3%

Thus, of the approximately 8,174 acres in the watershed, a little less than half (about 45%) or ±3,733 acres are developed in residential, commercial, industrial or institutional lands. An additional ±442 acres (5.4%) is recreational, park or cemetery land and ±163 acres (2%) is landscaped open space. About 45% (±3,690 acres) of the watershed is agricultural, fields, barren, mining or wooded lands that may be subject to future development. Current environmental regulations, including NJDEP CAFRA, Stormwater Management and Wetland Rules will govern the nature and extent of some future development. In addition, local zoning requirements will dictate how development occurs. Book 2 of this report discusses future zoning and development.

Table 9: General Land Use Categories		
GENERAL LAND USE CATEGORY	**Area (Acres)**	% of Watershed
Agriculture	820.3	10.0%
Barren	165.5	2.0%
Cemetery	38.4	0.5%
Brush	283.7	3.5%
Commercial	404.6	4.9%
Extractive Mining	120.9	1.5%
Industrial	428.1	5.2%
Landscaped Open Space	163.4	2.0%
Recreation/Park	403.4	4.9%
Residential - High Density	239.5	2.9%
Residential - Low Density	1413.4	17.3%
Residential - Medium Density	1247.1	15.3%
Water	215.9	2.6%
Woodland	2229.9	27.3%

Table 10: Land Use of Developable and Undevelopable Lands		
	Acres	**Percent**
Future Developable Lands	**3690.1**	**45.1%**
Agricultural Use	818.5	10.0%
Brush	289.8	3.3%
Unvegetated	311.5	3.8%
Woods	2270.3	27.8%
Developed or Undevelopable Lands	**4483.9**	**54.9%**
Landscaped Open Space	621.8	7.6%
Water	215.9	2.6%
Commercial/Industrial/Institutional	819.2	10.0%
Residential	2827.0	34.6%

3 WATERSHED ASSESSMENT METHODS

This section discusses tools and methods used for many of the watershed assessment studies presented later in this report. It should be noted that Section 2 also made use of the GIS tools discussed herein.

3.1 Geographic Information Systems (GIS) Methods

Much of the data for the RSWMP was taken from both State and County Geographic Information System (GIS) files. This database allows the user to create maps of the data and to calculate areas within the watershed that have mappable characteristics, such as soils or land use. The data are provided as layer files including information such as land use, geology, well locations, soils and other data. The GIS ArcView system allows the layer files to be overlain and combined to analyze geographic information. The layer files were created by digitizing mapped data such as a soils map or by analyzing other data such as using aerial photographs to determined land use.

Monmouth County's existing GIS data provided the basis for the watershed characterization. The GIS base data was derived from a series of aerial photography flights from April 2003. These were processed and developed using standard photogrammetric processes by the firm Buchart-Horn Basco Associates of York, Pa. The data has a +/- one foot horizontal and vertical accuracy and was checked for Quality Assurance/Quality Control (QA/QC) by the firm Civil Solutions, Hammonton, NJ.

The use of two-foot contour lines, spot elevations, stream centerlines and water body polygons provided the Monmouth County Office of GIS with the ability to generate high resolution digital elevation models commonly known as DEM's. Once the DEM's were processed, they could be run through a series of processes to develop vector data. The output dataset used most frequently is the sub-watershed boundary. It was subject to many changes. In August, 2005 staff from NJDA and NJDEP ground-truthed the sub-watershed boundaries and provided suggestions as to boundary adjustments based on stormwater infrastructure, which may have modified natural drainage patterns. Sub-watershed boundaries provided key functions during the course of the study, including base mapping, land use characterization and flow direction.

In 2004 Tom Kellers, then chairman of the Wreck Pond Brook Regional Stormwater Management Planning Committee, asked the Monmouth County Office of GIS to participate in the Regional Stormwater Management Plan for the Wreck Pond Brook Watershed. Around the same time, ESRI, of Redlands, California, and the University of Texas, Center for Research in Water Resources (CRWR), were collaborating on the first version of ArcHydro. ArcHydro is a data model developed to work within the ArcGIS environment. ArcHydro has an associated set of GIS tools that populate the attributes of the features in the data framework, interconnect features in different data layers and support hydrologic analysis. ArcHydro provided standardized format for collecting hydrologic data and placing it in a GIS format.

The County determined that ArcHydro would be a useful tool in development of the RSWMPs as well as for other uses within the County planning department. However, there was very little mapped data for the watersheds within the county. The staff at Monmouth County GIS began developing GIS datasets for the regional plan using the ArcHydro tools. Once acceptable datasets were developed, the ArcHydro data model was incorporated into the Regional Stormwater Management Planning process.

The Wreck Pond Brook Watershed delineation began by determining suitable locations for stream gauges. Once stream gauge locations were determined the process of defining and identifying features began. Section 3.3, following, discusses the gauge locations. The gauge locations provided the subwatershed boundaries. MCOOGIS then synthesized existing data or collected and digitized new data to provide GIS layers with data on a subwatershed basis. ArcHydro also provided the tools for the creation of a schematic of the watershed that was used to diagram the connection between each sub-watershed area and its local drainage system.

The information discussed above, along with other existing data from the MCOOGIS provided much of the data for the study. In addition, data layers from the New Jersey GIS database were included such as the landscape maps for endangered species and public well locations. Technical studies conducted as part of the RSWMP planning process also were converted to digital GIS layers. Table 11 lists many of the GIS layers used in or developed for this project.

3.2 Measurement of Rainfall

Initial development of the WPB RSWMP included the purchase and installation of a weather station. The purpose of the weather station was to provide rainfall and weather data specific to the WPB watershed for the purpose of plan and model development. As such, following a grant award from the NJDEP, Monmouth County teamed with the South Jersey Resource Conservation and Development Council, Inc. (SJRCD) to install a weather station within the watershed.

SJRCD, a non-profit organization that maintains numerous weather stations located throughout Southern New Jersey, assisted the County with installation of the weather station in Wall Township. In May, 2005, the station was installed and began collecting data. The station is sited on the grounds of the Wall Township Municipal Complex, strategically located in the central region of the watershed.

The Wall Township Weather Station is part of the SJRCD's RISE system. RISE is an acronym for "Resource Information Serving Everyone." The system was created to address the need for high quality weather data for the management of irrigation practices, and consists of twenty (20) stations in eight (8) counties.

Table 11: GIS LAYERS	
GIS File	**Data Source**
Land Use (2006)	MCGIS
Road Edges	MCGIS
Building Outlines	MCGIS
Municipal Boundaries	MCGIS
Parcels (Tax Maps)	MCGIS
Contours (2')	MCGIS
WPB Watershed Boundary	MCGIS
WPB Watershed Catchments	MCGIS
Streams	MCGIS
Lakes	MCGIS
Endangered Species	NJDEP GIS/Landscape Maps
Wetlands	NJDEP GIS Wetlands Layer
Topography	USGS Quadrangle Maps and MCOOGIS
Geology	NJDEP GIS
Well Locations	NJDEP GIS
Zoning	MCGIS and Najarian Associates
Farm and Recreation Lands	MCGIS and RCE
Sampling Locations for Pond, tributary, watershed and sediment cores	Najarian Associates, Monmouth County, Monmouth University, Rutgers Cooperative Extension

The station provides the following weather related information: temperature, wind speed, wind direction, relative humidity, solar radiation and precipitation. The precipitation information is supplied in six (6) minute intervals, as well as daily and monthly totals.

SJRCD inspects and maintains all of the Campbell Scientific CM10 weather stations including the Wall Township gauge on a regular basis. Collected data from the station is relayed back to SJRCD at regular intervals via cell phone, where the data is collected and posted to the RISE system website. Weather data can then be downloaded from the website by subscribers for their use.

3.3 Stream Gaging and County Water Quality Stations

The Wreck Pond Book watershed measures approximately 12 square miles and is bisected by several major highways. As discussed previously, the watershed includes a variety of land uses, two primary streams, a smaller tributary and numerous ponds. In order to investigate the impact of watershed characteristics on stormwater quantity and quality, the watershed was subdivided into smaller study areas. A stream gage was located at the downstream end of each subwatershed.

The gages were placed in consideration of several factors including areas with relatively homogeneous characteristics such as land use and the natural sub-watershed boundaries. "Natural" watershed break points were sought which would allow hydraulic measurements. These "control points" are typically a road crossing, culvert, bridge or dam. Once a generalized gaging location was selected, exact locations were refined based on the "measurability" of the flow at the selected locations. Stream cross sections should be fairly uniform and prismatic with well defined banks and floodplain. The stream channel upstream and downstream of the gage location ideally should be similar to the cross section at the gage location so that hydraulic modeling of the stream channel can be performed. The gage location site must also be characterized by a free-flowing water and flow should not be affected by tides or "backwater".

Lastly, safety of the investigators must be considered. Data loggers used by the investigators require manual downloading to a Palm™ type device. This necessitates safe access to the logger for extended time periods while data is retrieved Table 12 and Figure 10 summarizes the gage and sampling stations, which are described in detail in Appendix A.

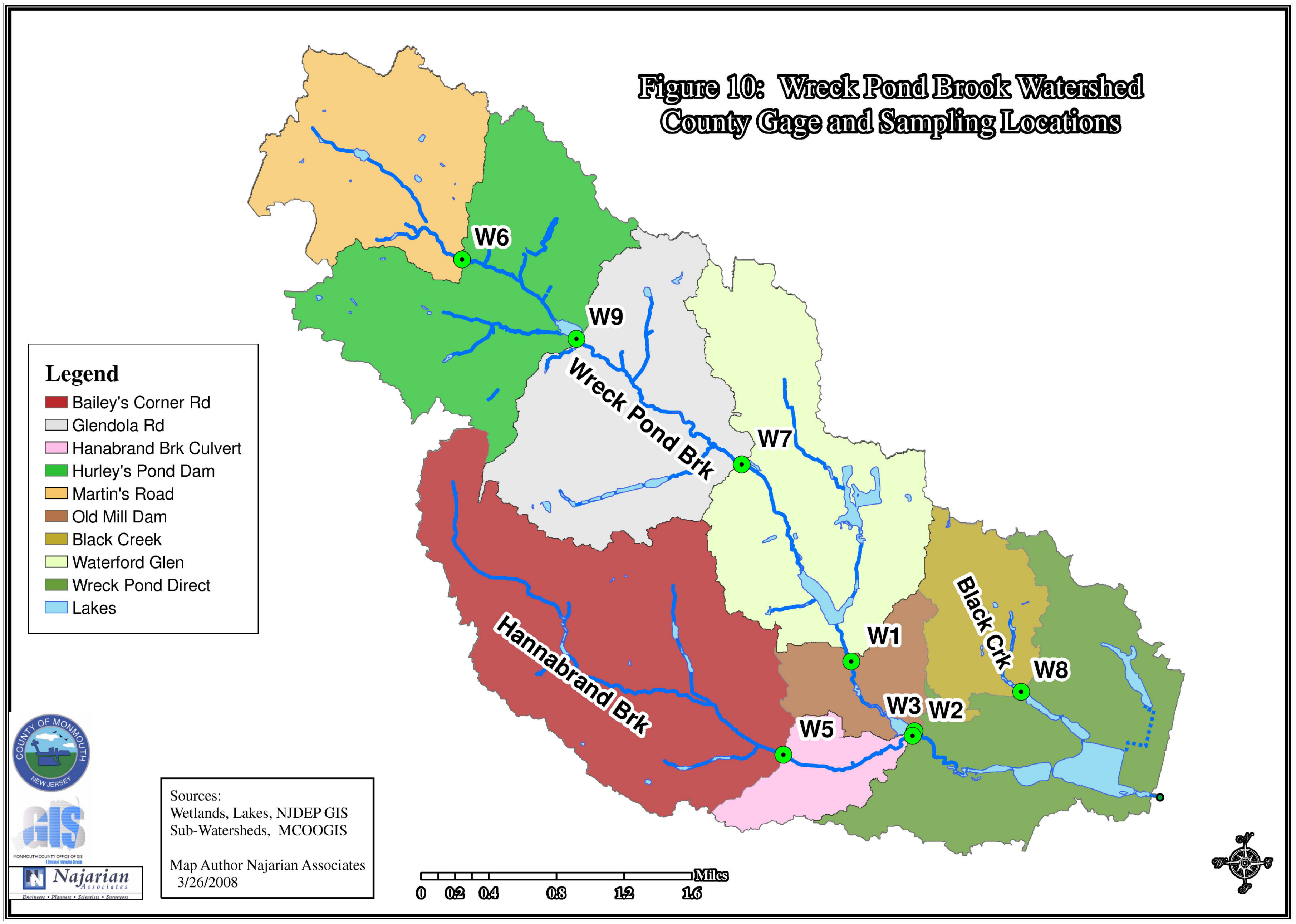


Figure 10: Wreck Pond Brook Watershed
County Gage and Sampling Locations
Legend
Bailey's Corner Rd
Glendola Rd
Hanabrand Brk Culvert
Hurley's Pond Dam
Martin's Road
Old Mill Dam
Black Creek
Waterford Glen
Wreck Pond Direct
Lakes
W6
W9
W7
W1
W3
W2
W8
W5
Wreck Pond Brk
Hannabrand Brk
Black Crk
Sources:
Wetlands, Lakes, NJDEP GIS
Sub-Watersheds, MCOOGIS
Map Author Najarian Associates
3/26/2008
Miles
0
0.2
0.4
0.8
1.2
1.6
Najarian Associates

Table 12: County Gauge and Sampling Stations		
Station #	**Subwatershed**	**Location**
Wreck Pond Brook		
W6	Martins Road	Just west of Garden State Parkway, upstream side of Martins Road culvert
W9	Hurley's Pond Dam	Downstream Side of Allenwood Road Culvert, Near Intersection of Hurley Pond Road and Allenwood Road
W7	Glendola Road	Downstream Side of Glendola Road Culvert, Adjacent to Taylor Pond
W1	Waterford Glen	Wreck Pond Brook, Stream Location Behind Waterford Glen Assisted Living Facility, Off of Route 35
W3	Old Mill Dam Culvert	Wreck Pond Brook, Downstream Side of Old Mill Road Culvert, Across Street of Old Mill Restaurant
Hannabrand Brook		
W5	Bailey's Corner Road	Hannabrand Brook, Downstream Side of Bailey's Corner Road Culvert, Just South of Pump Station
W2	Hannabrand Brook Culvert	Hannabrand Brook, Upstream Side of Old Mill Road Culvert, Adjacent to Old Mill Restaurant
Black Creek		
W8	Spring Lake Golf Club	North Branch of Wreck Pond Brook, Downstream Side of Route 71 Culvert, Southeast of Golf Course

4 STREAM ASSESSMENTS

In addition to the overall watershed assessments provided in Section 2, an in-field stream assessment was deemed necessary for the development of this Plan. All stream assessments within the watershed were performed by the Freehold Soil Conservation District (District). The assessments were performed between March 2005 and May 2006. The District utilized the United States Department of Agriculture Stream Visual Assessment Protocol methodology (SVAP) to execute the stream assessments.

4.1 Assessment Methodology

The SVAP method was developed by the Department of Agriculture as a first level assessment protocol to evaluate the aquatic ecosystems associated with streams. The SVAP method is the first step of a four-part assessment protocol to assess these ecosystems. This first level assessment provides information on basic health of the stream, specifically associated with the physical condition within the assessment area. The results of these assessments can then be used by stakeholders and planners to decide to conduct further ecological assessments, or develop design alternatives for stream restoration.

The method does not require specialized training, and can be implemented successfully with little biological, hydraulic or aquatic expertise. Essential to the method, however, are the use of reference sites. A reference site is a stream reach that has been least impacted by impairments and provides a standard for comparison during the assessment process. They represent the best condition attainable within a particular watershed or region.

The SVAP method uses a National Stream Assessment template. However, the SVAP method was designed to allow modification to the national template to better reflect conditions within a specific watershed. In this case, slight modifications to the national version included changes to the "assessment elements" and the "element scoring" by FSCD. Table 13 lists the assessment elements and their respective score ranges used during this assessment:

The information above was input into the Reach Assessment Score Sheet, which is located in Appendix B of this report. In addition to a scoring system, each element has condition categories, which include a small narrative describing what the stream reach should exhibit to warrant a specific scoring. The four condition categories include Optimal, Sub-Optimal, Marginal and Poor. For instance, in order for a reach to receive an Optimal score (score of 16 – 20) for channel flow status, the reach must exhibit the following: "Water reaches base of both lower banks, and minimal amount of channel substrate is exposed."

Table 13: Stream Assessment Scoring	
Assessment Element	**Scoring Range (Poor to Optimal)**
Pool Substrate Characterization	0 – 20
Pool Variability	0 – 20
Sediment Deposition	0 – 20
Channel Flow Status	0 – 20
Channel Alteration	0 – 20
Channel Sinuosity	0 – 20
Bank Stability – Left Bank	0 – 10
Bank Stability – Right Bank	0 – 10
Bank Vegetative Protection – Left Bank	0 – 10
Bank Vegetative Protection – Right Bank	0 – 10
Riparian Vegetative Zone Width – Left Bank	0 – 10
Riparian Vegetative Zone Width – Right Bank	0 – 10

FSCD performed all assessments by walking each stream and assessing individual reaches, recording the assessments and scores on individual Reach Assessment Score Sheets. Reaches were divided into manageable lengths, and each length received an assessment and score. In addition to the Reach Assessment Score Sheet, FSCD took photographs off all reaches assessed and recorded additional data on a Reach Assessment Data Sheet. The Data Sheet included information such as: channel width, buffer widths, bank slope descriptions, bank vegetation cover percentage, water clarity, debris, etc.

4.2 Data Collection and Management

During the assessment period, data sheets, scores, GPS coordinates of reaches and photographs were input into a controlled Microsoft Access database. Using information within the FSCD database, Najarian Associates developed a stream shapefile that can be imported into a GIS graphics program. This shapefile was then color coded according to the score ranges, and used to develop Figure 11 of this report. Figure 11 depicts each stream reach and its location within the watershed, and the color of the reach corresponds to the appropriate score range. Reaches not assessed by FSCD due to various circumstances are color coded on the figure as well.

4.3 Conclusions of Stream Assessment Study

As depicted in Figure 11, the majority of stream reaches fall under the Sub-Optimal category. These are spread throughout the watershed and exhibit no distinct pattern. The majority of Optimal reaches are located within the Waterford Glen sub-watershed. The small amount of Marginal reaches are located in the headwaters regions of the

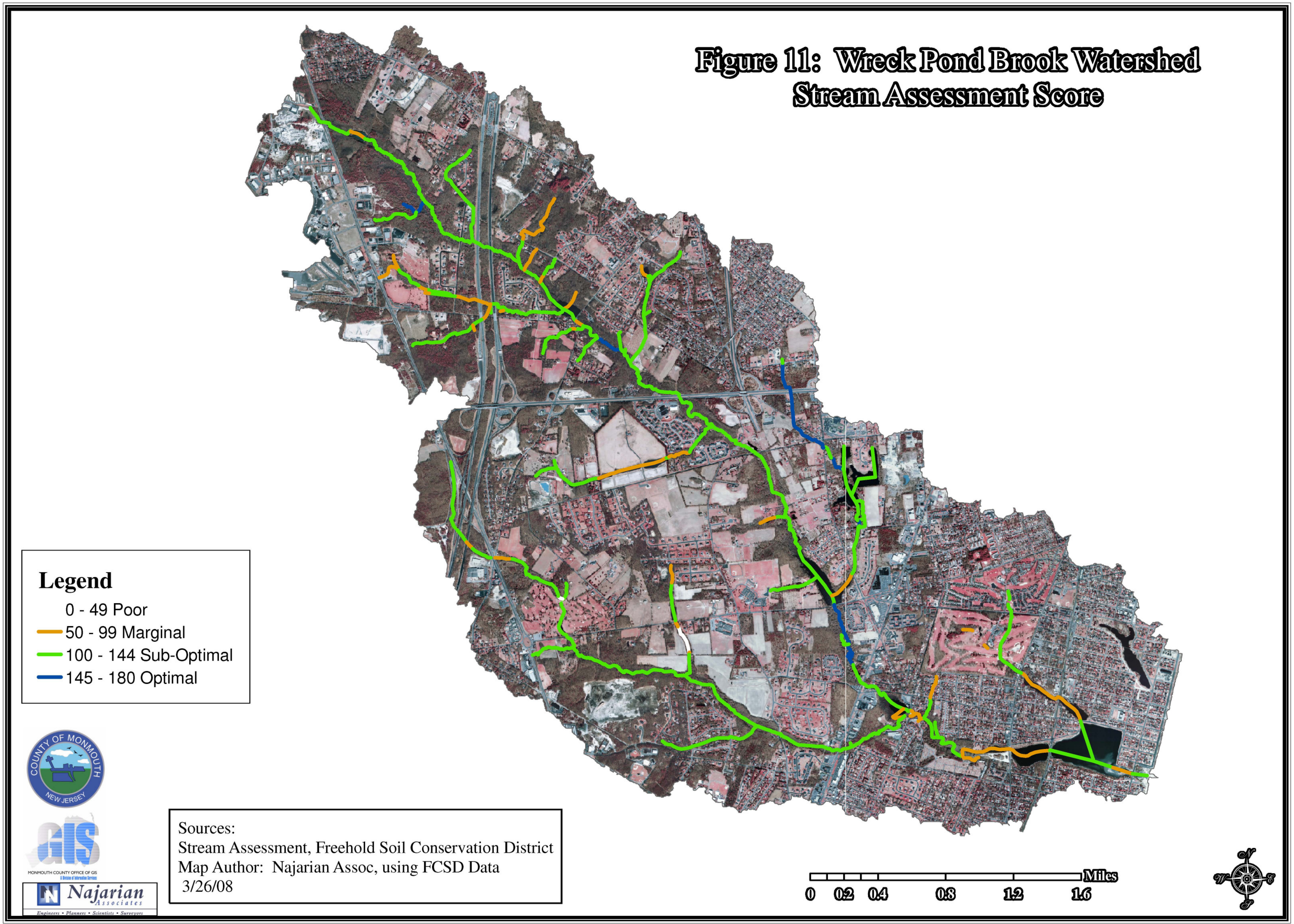


Figure 11: Wreck Pond Brook Watershed
Stream Assessment Score
Legend
0 - 49 Poor
50 - 99 Marginal
100 - 144 Sub-Optimal
145 - 180 Optimal
Sources:
Stream Assessment, Freehold Soil Conservation District
Map Author: Najarian Assoc, using FCSD Data
3/26/08
Miles
0 0.2 0.4 0.8 1.2 1.6
COUNTY OF MONMOUTH NEW JERSEY
GIS
Najarian Associates

Hannabrand Brook, by the Garden State Parkway and Route 34, and the Wreck Pond Brook, located within the Hurley's Pond sub-watershed.

Overall, the data collected by FSCD provide information to focus stream restoration and remediation efforts and BMP implementation. Additionally, specific score results within the assessments may provide evidence of other physical or biological impairments within specific parts of the watershed. For example, reaches with poor bank stability scores may be indicative of high stormwater runoff flows, causing stream bank erosion.

5 AGRICULTURAL AND RECREATION LAND SURVEY

Rutgers Cooperative Extension (RCE) has characterized the agricultural and recreational lands in the watershed, and analyzed their potential for contribution to fecal coliform and nutrient loading to Wreck Pond. Education, outreach, and recommendations for best management practices are outcomes of the characterization process. This section of the report details methodologies and provides results of the agricultural and recreational land use survey and water quality monitoring.

5.1 Identification of Farm and Recreation Parcels

Through the use of the Monmouth County GIS system, feature classes for streams, road centerlines, watershed boundaries, land use and land cover, and municipal tax records, as well as aerial photography were obtained. Examination of the tax records provided records that were labeled “3a” or “3b” with respect to farmland. These records indicate farm house and qualified farm properties. To become a qualified farm, a parcel must be actively involved in agriculture on at least five acres of the property. The Wall Township municipal Tax Atlas information used was from the year 2005, although online data from more recent years was consulted for comparison. All qualified farms found during the survey are depicted on Figure 12.

In addition, 1997 land use and land cover feature classes were analyzed to assess farm properties. The feature classes were queried under the 1997 label field and the 1997 SCS description field, and a feature class was made out of all agricultural and recreational lands in the Wreck Pond Brook watershed (Figure 12). Both sets of data were selected for land parcels within 500 feet of any water body in the Wreck Pond Brook watershed. This group was identified for potential water quality impacts. The sum of this information generated data tables with owner information for each parcel on the tax map.

Tables 14 and 15 summarize the agricultural and recreational lands in the watershed.

5.2 Agricultural Surveys

An agricultural land use survey was constructed to assess the characteristics of these parcels, and determine which were still in use as farmland. The survey was confidential, and employed the use of an identification number to make participants more comfortable answering questions. There were twenty questions on land use of the property, overall knowledge of best management practices, and willingness to let RCE tour the property and discuss management of manure and fertilizer and chemical applications with the owners. A full survey is provided in Appendix C.

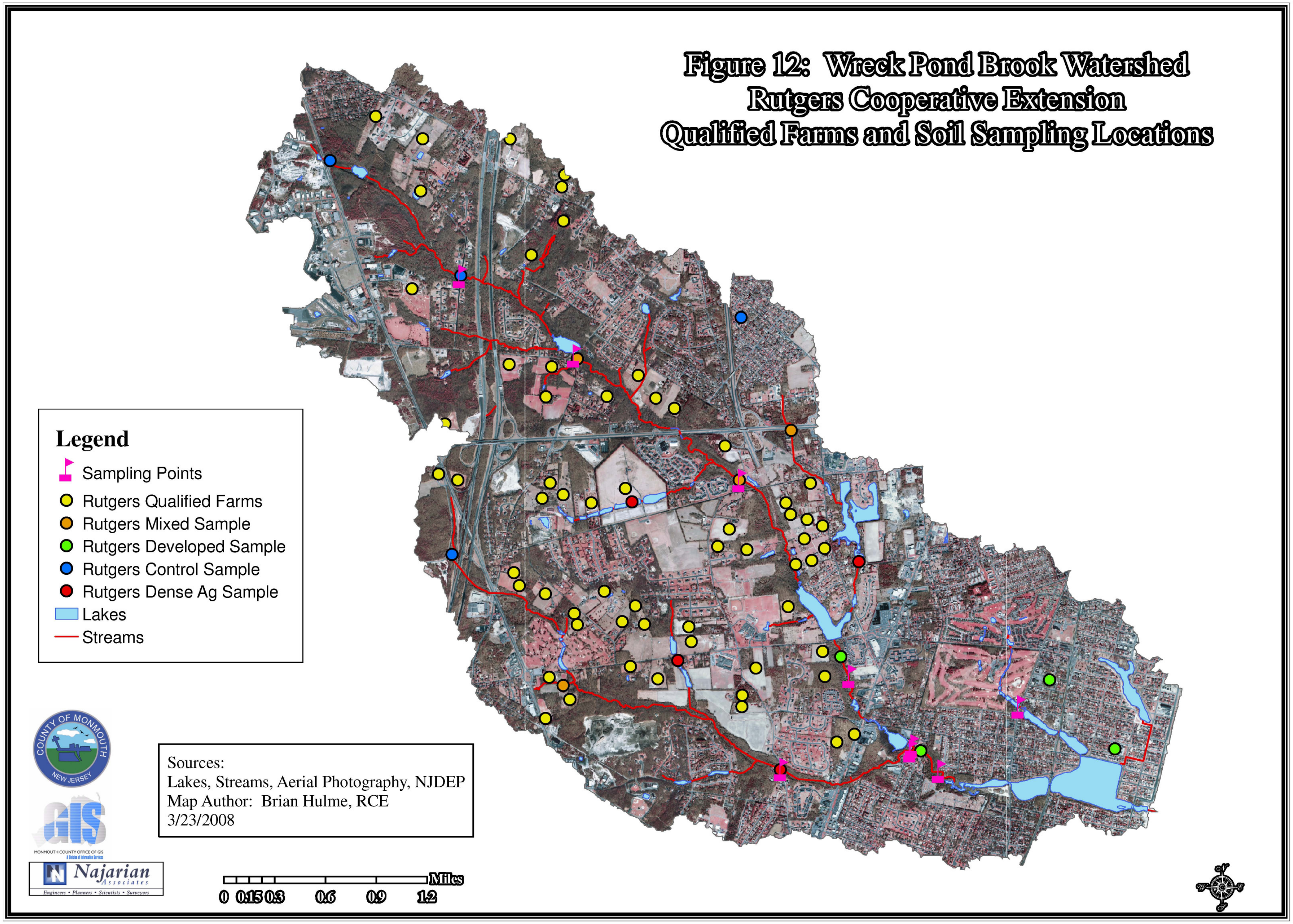


Figure 12: Wreck Pond Brook Watershed
Rutgers Cooperative Extension
Qualified Farms and Soil Sampling Locations
Legend
Sampling Points
Rutgers Qualified Farms
Rutgers Mixed Sample
Rutgers Developed Sample
Rutgers Control Sample
Rutgers Dense Ag Sample
Lakes
Streams
Sources:
Lakes, Streams, Aerial Photography, NJDEP
Map Author: Brian Hulme, RCE
3/23/2008
COUNTY OF MONMOUTH
NEW JERSEY
GIS
Najarian Associates
0 0.15 0.3 0.6 0.9 1.2
Miles

Table 14 - 2005 Wreck Pond Agriculturally Assessed Land				
LU - 2005	Assessed Size (acres)	Area Actively Farmed (acres)	Hydrologic Soil Group	Dist. To Stream (ft.)
Crop/Nursery	6.50	1.97	B, C/D	adjacent
Pasture	7.41	3.00	A, B/D	655
Crop	20.50	20.00	A, B/D	1265
Nursery	6.68	6.29	A, B/D, C/D	395
Pasture	44.60	43.63	A,B,B/D,C,C/D	220
Crop	5.58	2.54	B	680
Crop	15.76	0.00	A, B/D	adjacent
Crop	254.70	11.25	B	380
Crop	21.40	11.17	B	160
Crop	6.50	6.51	B	35
Crop	47.60	24.90	B, B/D	30
Crop	6.50	3.15	B	300
Nursery	14.53	9.09	B	adjacent
Crop	35.00	32.00	B, D	adjacent
Crop	10.00	6.23	B, B/D	240
Crop	5.40	5.24	B	540
Crop	41.58	27.47	B, A	adjacent
Crop	15.70	6.71	B	adjacent
Crop	90.00	68.38	B, A	adjacent
Crop	10.70	10.70	B, D	70
Crop	12.00	6.98	B, B/D	145
Pasture	17.20	10.79	B	520
Pasture	11.63	6.94	B	35
Pasture	6.64	3.34	A	210
Pasture	33.94	10.91	A, B	adjacent
Pasture	8.00	6.60	B	1191
Pasture	21.51	38.00	B	adjacent
Crop	22.38	7.38	B	adjacent
Pasture	5.00	2.26	B	1815
Crop	15.96	6.32	B	645
Crop	42.06	26.79	B	530
Crop	11.81		B	100
Crop	8.19		B	adjacent
Crop	9.00	2.92	B	1015
Crop	10.00	27.50	B, B/D, D	adjacent
Crop	26.44	19.94	B, B/D, C	1645
Crop	5.72	0.58	B/D	1070
Crop	5.00	5.00	B, B/D, D	adjacent
Crop	16.41	0.00	B	345
Crop	5.70		D	adjacent
Crop	5.34	8.53	B, B/D	210
Crop	10.00	5.16	B	45
Crop	12.70	10.47	B, B/D, D	adjacent
Crop	6.72	3.92	B	450
Pasture	8.24	2.71	B	380
Crop	10.44	3.24	B, B/D	adjacent
Crop	5.16	4.73	B	155
Crop	8.67	6.82	B	260
Total	***1028.50***	***528.06***		

Table 15- Wreck Pond Brook Watershed Athletic/Recreational Fields						
Code	**Name**	**LU**	**Size (acres)**	**Impervious (acres)**	**Hydro Grp**	**Dist to Stream (ft.)**
A1	Wall Stadium	Rec Land	18	5.1	Urban	1545
A2	Quail Ridge GC	Golf Course	38.1		A , B	380
A3	Wall Park	Landscap.	1.7		B	1150
A4	Wall Elem. School	Ath. Field	9.8		B/C	955
A5	Wall BOE	Rec Land	11.87		Urban	adjacent
B1	Wall Park	Rec Land	0.8		B/D	170
B2	Wall Mun. Complex	Rec Land	36.1		B	adjacent
B3	Bel-Aire GC	Golf Course	78.1		B/D	adjacent
B4	Wall BOE	Rec Land	40.82		B	335
C1	Misc. Park	Rec Land	1		B	255
C2	Wall High School	Rec Land	1.86	0.97	B	472
C3	Spring Lake Heights School	Rec Land	2.76	0.56	B/D	3520
D1	Allenwood School	Rec Land	6.7	0.6	A	730
D2	Allenwood School	Rec Land	9.42	0.12	B	845
D3	Wall Intermediate School	Ath. Field	10.25		B, B/D	610
D4	South Manor Tennis	Rec Land	0.28	0.28	B/D	420
D5	Tarpon Townhouses	Rec Land	0.78	0.18	A	470
E1	Old Mill School	Rec Land	1.82		D, A	adjacent
E2	Spring Lake Heights Park	Rec Land	1.91	0.84	A	240
E3	Fairway Mews GC	Golf Course	111	(50/50 house mix) 50	B	adjacent
E4	Spring Lake GC	Golf Course	142		B, A	adjacent
E5	Junior Junction Preschool	Ath. Field	3.87		Urban	960
E6	Spring Lake Park	Rec Land	2.7		Urban	360
E7	Misc. Park	Rec Land	0.31	0.31	Urban	adjacent
E8	St. Catherines School	Rec Land	1.42	0.42	Urban	300
Total:			***533.37***	***59.38***		

A total of 49 property owners, all in Wall Township, were identified with “qualified” agricultural properties within 500 feet of a Wreck Pond Brook tributary. The survey was sent to landowners in August 2005. Out of the 49 surveys sent, three never reached their intended recipients, indicating either a database address error or a change in land use. Nineteen of the forty-six recipients returned the mail survey. Out of the 27 remaining property owners, correct phone numbers were found for about 50% (14), with the remaining numbers unlisted or disconnected. A follow up phone survey was performed on these 14 owners, with 7 not responding to the phone call, 6 refusing to answer the questions, and one owner answering a brief phone version of the survey. This indicates that 41% of the recipients answered the survey on the first attempt to contact them, while another 28% were contacted a second time by phone. In total, 20 property owners have responded to date, yielding a 43% overall response rate.

All 20 respondents answered that their land was currently in use as agricultural property and had been for the past 5 years. There are challenges involved with interpreting the results of any survey. Some respondents accidentally skipped the questions on the back of the first page, lowering some of the response rates. One respondent answered yes and no for several questions, which, in analysis was recorded as "Not sure". An equal 44% percent of respondents indicated that there either was or was not a drainage or stream running through the property, while 11% said they didn't know. Seventy eight percent of respondents owned and farmed between 5 and 20 acres, with a few (5%) farming 0-5 acres, and the remaining 17% farming between 20 and 50 acres. No respondents farmed more than 50 acres.

Table 16 provides a summary of the uses of farmland by respondents, in percent. Respondents were allowed to choose as many answers as applied, so totals exceed 100%.

Table 16: Uses of Agricultural Land

Use	Percent of respondents
Crop/Vegetable	67%
Orchard/Vineyard	22%
Livestock/Animal	22%
Ornamental/Nursery	39%
Other	17%

Note: More than one response possible so does not add to 100%

Table 16 shows the percentage of respondents engaged in various categories of farming. Of respondents, 37% said there were domestic animals or livestock on their property, while 63% did not. Table 17 shows the breakdown of the 219 livestock identified in the survey, although one owner failed to specify the number of horses on the property. Only 21% of respondents reported using manure as a nutrient addition on their farm fields, however only 74% of respondents answered this question.

Only five respondents (29%) of the nineteen mail surveys indicated that they had manure on site. The five respondents used such manure management practices as storing manure away from water, using a flat concrete pad closed on three sides, and composting manure on site. As far as respondents performing cropland application, 33% had soil tested for proper application, and 66% only applied manure as necessary, once a year.

Table 17: Animals on Agricultural Lands		
Animal	**Total Animals**	**Number of Owners**
Chickens	70	2
Cows	12	1
Cats/Dogs	3	3
Horses*	78	2
Mini Donkeys	7	2
Pigs	4	1
Rabbits	40	1
Sheep	5	1
Total	219	13
**One respondent did supply number of horses, may be higher*		

Table 18 shows the total of all agriculturally assessed land in the Wreck Pond Watershed as of 2005. They are broken down into agricultural land use, total size and the area of those total sizes actively used for agricultural purposes.

Recreational lands were also surveyed. Table 19 is a summary of all recreational land in the Wreck Pond Watershed as of 2005. This table breaks the recreational land into land use, size and amount of impervious surfaces within each parcel. The majority of recreational and athletic fields are municipal schools or parks.

Table 18: Use of Agriculturally Assessed Land as of 2005.		
Land Use	**Size (acres)**	**Area Actively Farmed (acres)**
Pasture	164.17	128.18
Crop	836.62	382.53
Nursery	27.71	17.35
Total	***1208.5***	***528.06***

.

Table 19 Use of Recreational/Athletic Land of 2005		
Land Use	**Size (acres)**	**Impervious (acres)**
Recreational	140.25	9.38
Golf Course	369.2	50
Athletic Field	23.92	0
Total	***533.37***	***59.38***

5.3 Farm Tours

Based on the data obtained from the agricultural survey (see Appendix C) key agricultural land that may have an environmental impact on the Wreck Pond Watershed was inspected. The information gathered included the acreage of land actively farmed, the type, amount, and rate of fertilizers, herbicides and pesticides applied and the manure storage practices. The information was acquired and documented through personal interviews with the farm owners/managers. Soil samples were collected and were analyzed at the Rutgers University Soil Testing Lab and photographs.

A total of seven farms were visited and assessed. These farms were diverse in size and animals raised or crops grown. The inspections, while few in number, are believed to have given an accurate representation of typical practices at agricultural operations in the watershed. It was found through grower testimony that the quantities of fertilizers applied did not exceed what the crops can readily absorb, meaning, nutrients (Nitrogen, Phosphorous and Potassium) applied to the fields are not likely to run-off during storm events into the surrounding rivers and streams. The results from the nutrient monitoring (Appendix C) support this assumption.

However, of the four farms which raised animals, three of those farms may be impacting the watershed in a negative way in regards to manure management. It was observed that although the quantity of manure produced was relatively low, and the land was not directly adjacent to the stream, some microorganisms may reach the small tributaries of the Wreck Pond Watershed during large storm events. Table 20 describes the possible sources of contamination.

Table 20: Manure Management of Farms in Wreck Pond Watershed

Farm	Animals Raised	Appropriate Manure Management Practices?
1	18 head of steer	Yes
2	7 miniature donkeys	No
3	~ 20 chickens, 4 pigs	No
4	~ 10 sheep, ~ 20 chickens and turkeys	No

5.4 Water Quality Monitoring

Water quality measurements and a nutrient concentration study were performed. Samples were taken once a week for one year from November 2005 through November 2006 at the eight County sampling points along the upper and lower portions of the watershed on both the Wreck Pond Brook and Hannabrand Brook. Nitrate and Ammonia were collected along with conventional water quality parameters using a YSI

6600 probe, and orthophosphate data was collected with an optical calorimeter kit, initially ChemMetrics, and more recently by Hach. This differs from the collection of other water quality data discussed later in this study which was collected in the field and sent to a laboratory for analysis.

A full year, November 2005 – November 2006, of calibrated water quality measurements were made once a week at each of the eight County watershed sampling sites (Table 12 and Figure 10), with nine water quality parameters tested.

Table 21 summarizes the calibrated water quality results collected with ranges and median values. The number of observations is for all stations. The numbers vary by parameter as not every parameter had an accurate reading each week.

Table 21: RCE Water Quality Results

Parameter	Units	Range (Min & Max Observed)	# of Observations	Median Values
Temperature	ºC	2.92 - 30.34	318	16.53
Specific Conductivity	mS/cm	0.090 - 16.20	301	0.179
Dissolved Oxygen	mg/L	3.47 - 27.87[a]	214	10.39
pH	pH	5.18 - 7.48	318	6.35
Ammonia	NH_3 mg/L	0.00 - 0.040	310	0.00
Nitrate	NO_3 mg/L	0.02 - 15.79[b]	318	0.62
Turbidity	NTU	0.00 - 308.3	318	5.4
Chlorophyll	µg/L	0.0 – 16.5[c]	310	2.8
Ortho-Phosphate	PO_4^{-3} mg/L	0.05 - 1.50	223	0.27

[a]Max DO levels out of range
[b]Max nitrate levels higher than other watershed monitoring
[c]Two out-of-range values removed (48 in April and 82 in Oct)

It should be noted, that when comparing this water quality data to data collected by other partners, some readings for DO, nitrate, TSS and ortho-phosphate collected by RCE were out of acceptable ranges. This may be due to the fact that these measurements were collected via the water quality meters, while other partner data was analyzed with different methods, including laboratory analyses for nutrients and analyzed by different state certified laboratories.

pH data collected in this element is lower than those obtained by the County or by NA for the Borough study. The few very high DO readings taken by RCE were not seen in the NA monitoring or within the typical range of DO data and so are considered to be anomalous, out of range data. Similarly, comparison of nitrate data suggests that the above-standard RCE data are likely anomalies.

The table above combines all of the data for the watershed. Figures in Appendix C provide a breakdown by station. For example, as in other data collected, pH is lowest at W6.

Low pH and high turbidity were seen that did not conform to standards. Analysis of turbidity versus rainfall did not show a consistent pattern. Although nitrate was found above the drinking water standard of 10 mg/l which is a groundwater standard. It is more likely that this is a meter problem, than an accurate reading. In any event, the elevated nitrate concentrations were transient.

5.5 Macroinvertebrate Sampling

In addition to chemical and physical parameters, biological samples of macroinvertebrates were also taken at all Wreck sites once a month in June, July and August, 2006. Samples were taken using the EPA Rapid Bioassessment Protocols for Multiple Habitat Benthic Macroinvertebrate Sampling.

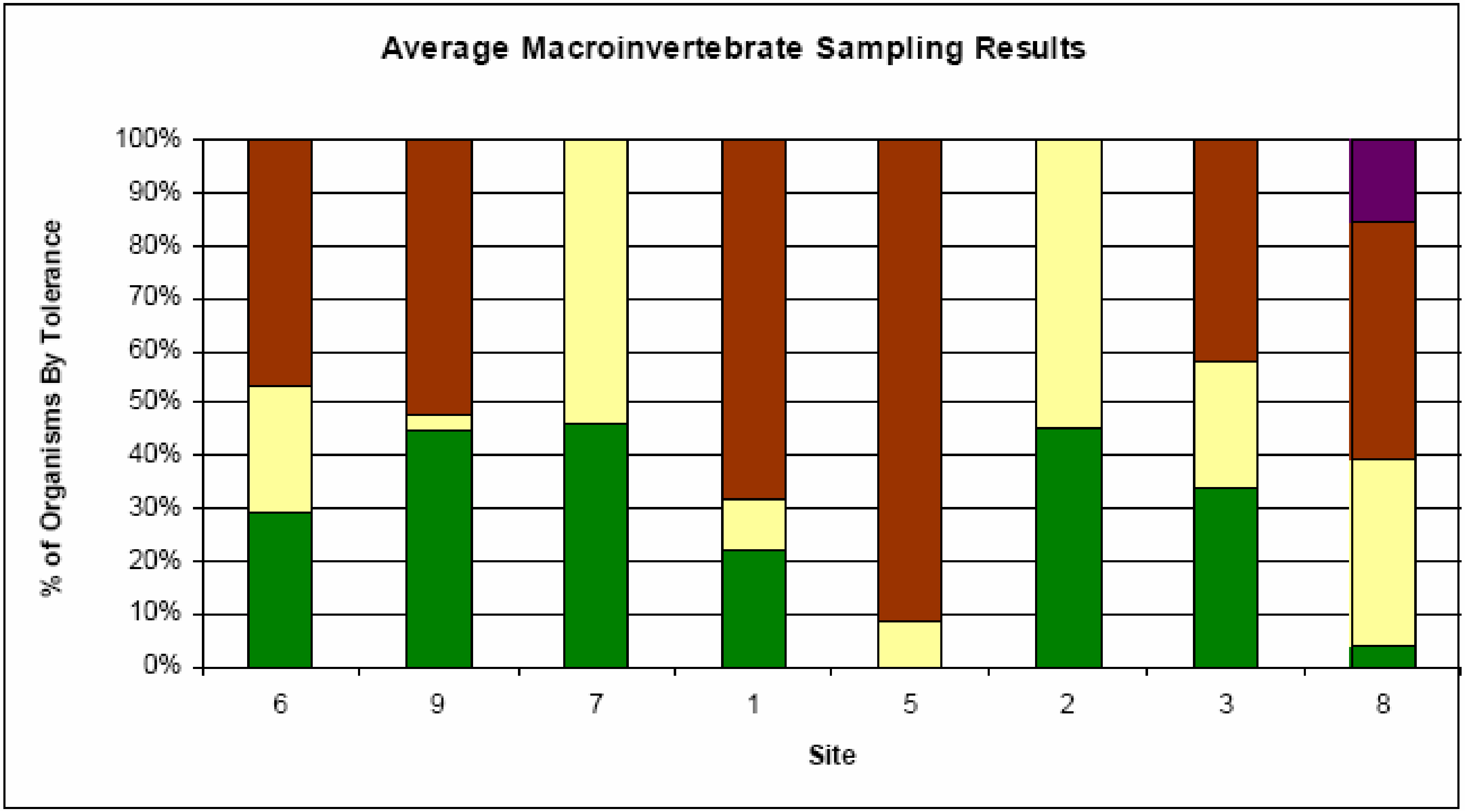
The results of the macroinvertebrate samples show a large variation between samples taken from the upper portion of the watershed and the lower portion of the watershed. Figure 13 shows the percentages of extremely intolerant organisms (purple), sensitive organisms (green), somewhat sensitive organisms (yellow) or tolerant organisms (red). In general, the sites from the upper portion of the watershed had a higher percentage of sensitive organisms. The sites from the lower portion of the watershed contained a lower percentage of sensitive organisms. Since the chemical monitoring results have shown no major nutrient loading problems, the macroinvertebrate results lead to the conclusion that the lower portion of the watershed may be experiencing higher negative effects from erosion and sedimentation.

The percentage of dominant organisms found at each site was compared to the percentage of sensitive organisms at those sites. The sites with the higher percentage of sensitive organisms also had a higher biodiversity, and the sites with a lower percentage of sensitive organisms had a lower biodiversity. Site W5 in particular should be noted as no sensitive organisms were found there.

5.6 Soil Sampling

A soils investigation also was conducted. The purpose of the soil sampling program was to determine the soil conditions existing naturally in the Wreck Pond watershed compared to the soil conditions found in representative agricultural operations as well as developed areas. The location of the soil samples was associated with the location of the stream water quality sample Wreck sites. In order to assess the general nutrient and fertility levels in the watershed, the area was first divided into four separate categories:

A. Agricultural (Ag) lands



. Legend: Purple: Extremely Intolerant;
Green: Sensitive
Yellow: Somewhat Sensitive;
Red: Tolerant

Figure 13: Wreck Pond Watershed

Average Macroinvertebrate Tolerance from RCE Sampling at Watershed Sites

B. Between Ag lands and native lands
C. Native land/control
D. Development

Agricultural lands were defined as dense agricultural areas that were farmland assessed. Native lands with indigenous vegetation areas such as forest and meadow regions with little agriculture or development served as control areas. Development areas were covered with residential housing, businesses and schools. Most stream segments included a range of these various categories within their contributing area.

Soil samples were taken in proximity to the stream water quality sample sites, and were collected either just above the stream bank, or at the farm site or home site. Samples were collected within each of the four categories. The selected soil areas in the stream site program were randomly sub-sampled ten times within a 25 foot line. The selected soil areas in the farm site program were randomly sub-sampled ten times within a one to two acre block. The selected soil areas in the home site or business program were randomly sub-sampled ten times within the half-acre of property. Sampling sites are shown on Figure 12.

Composite samples were selected and taken to the soil lab for analysis. Soil analysis consisted of levels of soil acidity as measured by pH, cation exchange capacity, macronutrient levels of phosphorus, potassium, magnesium and calcium and micronutrient levels of zinc, copper, manganese, boron and iron. Additionally, special tests were run on soil organic matter as measured by percentage of organic matter and organic carbon. Inorganic nitrogen was measured in the form of nitrate-N and ammonium-N.

The results of the stream bank soil tests revealed that all four land-use categories had macronutrient levels of phosphorus, potassium, magnesium and calcium that were either below optimum or optimum, rarely above. As for micronutrients, zinc, copper, manganese boron and iron were all either low or adequate, with the exception being iron. Iron levels were consistently high. However, these high iron readings are expected in the Wreck Pond Brook Watershed which has high levels of naturally occurring iron in soils and groundwater. The agricultural and developed stream banks showed a slightly higher level of organic matter and carbon, as well as nitrate-N and ammonium-N, than the native land control and mixed stream bank samples.

The results of the agricultural land soil tests revealed that more often than the stream bank samples, one or more macronutrients were above optimum levels, approximately 36 out of 48 samples. The micronutrients were normal, with the exception of iron, for the same reasons as described above. Organic matter, organic carbon, nitrate-N and ammonium-N had a wide range of results, depending on the field tested.

The results of the recreational and homeowner land soil tests were similar to those of the agricultural land results. The macronutrients occasionally reached above optimal levels 20 out of 32 samples, especially in phosphorus. Iron was the only high micronutrient, again for naturally occurring reasons. The organic matter, organic carbon, nitrate-N and ammonium-N showed no obvious distinction between the stream bank results or the agricultural land results.

5.7 Conclusions Agricultural and Recreational Land Survey

The study results did not find a significant impact from either the agricultural or recreational lands on the overall health of the Wreck Pond Brook Watershed. The water quality data found few instances in which water quality standards were not met. As noted, pH was most often in violation but this is likely due to naturally occurring low pH for the area. Other standard violations may be anomalies from use of water quality meters.

An area in obvious need of remediation is Site W5. Field observations make it apparent that it is being impacted by heavy soil erosion. This soil erosion is believed to be originating from a point source directly upstream. This issue is not related to agricultural or recreational lands.

The recommended action by the RCE to maintain surface water quality and further reduce what little impact agricultural or recreational lands are having on the watershed involves public education. The RCE have always recommended that prior to any planting or fertilizing that soil tests be done to first gauge the amount of nutrients already available in the land. If farmers, landscapers and homeowners follow the recommendations provided in their soil results, little nutrient run-off will take place. This policy benefits growers and landscapers in that given the high price of fertilizers, needless applications will greatly reduce costs. In addition to fertilizing practices, manure management also needs to be addressed. While it has been observed through farm tours that the majority of large, commercial Confined Animal Feeding Operations (CAFOs) appear to be complying with existing regulations in terms of manure management, smaller lands that may only have a few farm animals, do not fall into this category. These small “hobby farms” are difficult to identify and regulate.

Owner education appears to be the most effective option. To further this goal, an information packet was also handed out containing runoff and erosion BMPs from the USDA – Natural Resource Conservation Service (NRCS). The Monmouth County Agricultural Agent, William Sciarappa, Ph.D., will provide individual BMP recommendations to all those who store manure, if current storage methods appear to be inappropriate. These recommendations will help assure that those managing the farm lands are adhering to the appropriate Stormwater Management Regulations and USDA – NRCS measures, as well as preventing soil erosion and nutrient and pathogen runoff from their lands.

The RCE plans to increase their efforts in educating growers, landscapers and homeowners on the negative impacts over fertilizing has not only on their land, but the health of the entire watershed. Public informational programs are planned for any and all stakeholders to reiterate the importance of reducing stormwater runoff and erosion, as well as easily implementable low-cost Best Management Practices. On-farm demonstrations of manure management facilities and commercial practices have been conducted previously in the county and more are planned to take place in the near future to be better engage smaller operations such as seen in the Wreck Pond Watershed.

6 MICROBIAL SOURCE TRACKING

Finding the source of fecal pollution is complex because it is rare to find pollution in the Wreck Pond watershed flowing in clearly defined channels. In this watershed, fecal pollution enters the waterbody in various ways and rapidly becomes mixed. Microbial Source Tracking studies aim to deconvolute this intricate system, find the source of contamination, and then effect remediation.

A Microbial Source Tracking Study was conducted by Monmouth University in 2005 to characterize and differentiate between potential sources of bacterial contaminants contributing to the Wreck Pond watershed (Monmouth University Final Report Sept 2007) using Antibiotic Resistance Analysis (ARA) methodologies. This section summarizes that report.

ARA is a phenotypic library-based MST technique developed as a method for microbial source tracking based on the assumption that bacteria from the intestines of humans and domestic animals will have different antibiotic profiles. The antibiotic profiles should differ because hosts exposed to different antibiotics or differing amounts of the same or similar antibiotics will develop varying resistance to those antibiotics. When bacteria are grown in the presence of several different antibiotics, certain patterns of resistance are created and ARA profiles can be developed for each source. Individual profiles for bacteria present in animal species can be compiled to form a library of antibiotic resistance profiles. These profiles then can be compared with fecal pollution from unknown sources in water samples to determine the source of contamination.

Results from MST studies can be used to develop area-specific stormwater management measures to improve water quality and control the sources of pollutants that adversely affect beneficial uses of the waterbodies that comprise Wreck Pond watershed.

6.1 ARA Profile Library Creation for Known Sources

The Monmouth University MST study developed a large database of ARA profiles for potential sources of fecal pollution including farm animals, wild animals, waterfowl, humans and pets. The human source was collected from raw sewage influent to treatment plants, while known samples of the other sources were collected either directly from the animals or their droppings. Bacterial samples were grown in the presence of the various antibiotics and a library of resistance patterns was developed.

6.2 Water Sampling

Water samples were collected from 12 stations in the watershed including Wreck Pond, Old Mill Pond, Osborn Pond, Albert Pond, and the three tributary streams as shown in Table 22. Temperature, salinity, DO and pH were also measured at each station. Seven sampling events were conduced during the summer of 2005. Table 23 summarizes the ambient water quality data collected. These data show measurable salinity at stations 1, 2 and 3. DO is found below standard at several stations. In particular, the minimum DO at Station 3 within Wreck Pond as 1.7 mg/l, suggesting very low DO and highly stressed conditions. This was only noted on one occasion. DO of around 3.4-3.7 mg/l was found at several other stations, which is below standard and can impair aquatic life.

6.3 ARA Results

The overall results of the study led to the conclusion that fecal pollution in the watershed is from mixed sources. Monmouth's final report documents the fact that waterfowl, other wildlife, farm animals and humans may be sources at all of the stations. Pets were found to be of less importance throughout the watershed.

The possibility of human sources of bacteria is of concern within the watershed since a host of pathogens are associated with fecal contamination. There are no known point sources to Wreck Pond or its tributaries. In addition, there are no known septic systems within the watershed. However, there may be illicit or historic septic systems that still contribute to pollution.

Another potential source of human bacteria is cross-connection of sewer and stormwater lines or leaking sewer lines which could be a source of human contamination. The infrastructure within Spring Lake is old. However, some of the sewer mains were previously studied and areas of concern were identified and re-lined according to the Spring Lake Department of Public Works. In the time since those studies, other systems of the pipes may have been compromised. Further, connections from homes to the sewer lines may have leaks, but are not routinely impacted.

In summary, the overall conclusion of the Monmouth University report is that several sources of fecal bacteria are present in the watershed. The report suggests BMPs that may serve to reduce loadings, some of which are included in Book 2 of this Plan.

Table 22: Monmouth University Water Quality Sample Locations		
WRECK POND WATERSHED STATIONS	**STATION NAME**	**STATION LOCATION**
Station 1	Wreck Pond West of Oceanfront Floodgate	Salt pond area west of ocean floodgate south of the municipal parking lot adjacent to Brown Avenue Latitude: 40°08.317' N; Longitude: 74°01.641'W
Station 2	Wreck Pond at Second Avenue	Wreck Pond shoreline at the intersection of Second Avenue and Ocean Road Latitude: 40°08.524' N; Longitude: 74°01.782'W
Station 3	Wreck Pond	Northern shore of Wreck Pond south of Ocean Road crossing Latitude: 40°08.588' N; Longitude: 74°02.059'W
Station 4	Black Creek (N. Branch) at Ocean Road	Eastern shore of Black Creek at the intersection of Ocean Road and Fourth Avenue Latitude: 40°08.603' N; Longitude: 74°02.010'W
Station 5	Black Creek (N. Branch) East of Route 71	Stream channel of Black Creek east of Route 71 across from the Spring Lake Golf Club Latitude: 40°08.827' N; Longitude: 74°02.455'W
Station 6	Wreck Pond Brook West of Route 71	Southern shore of Wreck Pond Brook west of Route 71 adjacent to Jimmy Byrne property Latitude: 40°08.428' N; Longitude: 74°02.579'W
Station 7	Wreck Pond Brook at Old Mill Road	Northern shore of Wreck Pond Brook east of Old Mill Road at the intersection of Old Mill Road and Butternut Road Latitude: 40°08.609' N; Longitude: 74°03.189'W
Station 8	Old Mill Pond	Northeast shore of Old Mill Pond at the Old Mill Inn restaurant boat ramp Latitude: 40°08.699' N; Longitude: 74°03.261'W
Station 9	Osborn Pond	Osborn Pond at foot of Mill Pond Court Latitude: 40°09.350' N; Longitude: 74°03.572'W
Station 10	Albert Pond	Albert Pond at intersection of Oxford Lane and private road Latitude: 40°09.719' N; Longitude: 74°03.516'W
Station 11	Wreck Pond Brook at Allenwood Road	Stream channel east of Allenwood Road crossing just downstream from Hurley Pond Latitude: 40°10.652' N; Longitude: 74°05.421'W
Station 12	Hannabrand Brook At Allaire Road	Eastern stream bank of Hannabrand Brook on south side of Allaire Road across from Bel-Aire County Golf Course Latitude: 40°09.032' N; Longitude: 74°05.483'W

Table 23: Summer Water Quality Data – Monmouth University					
Date	**Time**	**Temp (^oC)**	**Salinity (ppt)**	**DO (mg/l)**	**pH**
Station 1	Minimum	17.1	12.30	4.8	7.6
	Maximum	26.8	29.60	8.8	8.5
	Mean	23.0	23.63	7.5	7.9
Station 2	Minimum	21.0	7.40	3.9	7.1
	Maximum	26.1	24.90	9.7	8.1
	Mean	24.1	17.36	7.2	7.7
Station 3	Minimum	21.4	0.00	1.7	7.1
	Maximum	28.5	22.30	11.2	8.8
	Mean	25.7	6.85	7.5	7.9
Station 4	Minimum	20.9	0.00	3.4	6.6
	Maximum	29.0	0.00	9.2	7.9
	Mean	24.9	0.00	5.7	7.3
Station 5	Minimum	20.0	0.00	3.6	6.5
	Maximum	25.5	0.00	8.8	6.9
	Mean	23.2	0.00	6.0	6.7
Station 6	Minimum	20.9	0.00	5.6	6.4
	Maximum	27.9	0.00	13.6	6.9
	Mean	23.3	0.00	8.5	6.6
Station 7	Minimum	17.7	0.00	7.7	6.3
	Maximum	20.4	0.00	10.8	6.6
	Mean	19.0	0.00	8.8	6.4
Station 8	Minimum	20.7	0.00	3.5	6.2
	Maximum	26.1	0.00	10.3	6.8
	Mean	23.3	0.00	6.8	6.5
Station 9	Minimum	18.6	0.00	5.1	6.1
	Maximum	23.5	0.00	9.0	6.9
	Mean	20.6	0.00	7.3	6.4
Station 10	Minimum	22.5	0.00	3.5	6.7
	Maximum	25.5	0.00	11.2	7.5
	Mean	24.1	0.00	5.9	7.0
Station 11	Minimum	19.3	0.00	5.0	6.2
	Maximum	25.4	0.00	7.6	9.9
	Mean	23.4	0.00	6.6	7.1
Station 12	Minimum	19.2	0.00	4.4	6.1
	Maximum	23.8	0.00	10.3	7.3
	Mean	22.6	0.00	7.7	6.5

7 HYDROLOGIC AND HYDRAULIC MODEL

The New Jersey Department of Agriculture (NJDA) conducted hydrologic and hydraulic watershed modeling as part of the RSWMP. The NJDA developed a technical report which is included by reference and is available for public review. This section provides an overview of the modeling study and summary of the results. The study and modeling effort by NJDA also provided input to much of the watershed recommendations in Book 2.

Understanding of the hydrologic cycling of water through the watershed is an essential element in developing a regional stormwater management plan. Evaluation of pollutant sources and transport, the nature and extend of flooding and the impact of land use changes depend on an accurate representation of the watershed hydrology. Watershed hydrology is typically expressed in a "model" which seeks to represent the real world processes numerically. The model output provides the numeric and location data needed by decision makers and stakeholders. For example, emergency management personnel wish to know when (time) a stream will reach its peak flow rate, and how high (elevation) the peak elevation will be, how much flow (quantity) will occur at the peak and where (spatial location) will the peak arrive. Engineers need to know how much water (cubic feet or gallons per time interval) would be expect to flow through a culvert or over a spillway given a certain amount of rainfall. Hydrologic and hydraulic models attempt to quantify the stream system to provide necessary data.

NJDA has selected two primary modeling environments to depict stream flow and stormwater runoff quantity. Both models originate from the United States Army Corps of Engineers (ACOE) Hydrologic Engineering Center (HEC) and are in the public domain. These models are well known in the engineering community and have a high degree of reliability as well as flexibility for modeling various and complex scenarios.

For stream flow modeling, the River Analysis System (HEC-RAS or RAS) was used. This model uses physical field measurements of stream and floodplain cross sections to estimate flow values (rate, velocity, energy, water surface elevation) from one section to another based on the laws of conservation of energy. The model is calibrated by adjusting parameters (channel roughness for example) until model estimates provide an acceptable match to those measured in the field. For this model, the calibration parameters were high water elevations. NJDA used physical stream flow velocity measurements made at various depths along with water surface elevation records from recording gages to develop a series of depth-flow relationships later used in runoff modeling.

For watershed runoff modeling, the ACOE Hydrologic Modeling System (HMS) model was used to represent the land areas of the watershed. The basic form of this model is the numerical representation of a parcel of land, precipitation and start and stop time for computation. Each of the subareas of the Wreck Pond Brook watershed is represented as separate but connected areas within the model. These subareas are connected by stream reaches, impoundments or junctions. Model inputs consist of subwatershed size, runoff coefficients, time parameters and stream flow hydrograph information. In addition, lakes and ponds are represented in the model by describing the storage and discharge relationships of the impoundments as stormwater runoff is "routed" through them to the next downstream sub area.

In total, NJDA has developed eight HEC-RAS models – one for each subarea gage station and approximately twelve runoff models – a calibration and verification model for sub areas and certain combinations of subareas. The result of this modeling effort is a numerical depiction of the watershed in terms of land area, runoff parameters, time parameters, impoundment hydraulics and stream reach hydraulics which can be used to analyze future build-out, zoning changes, stream erosion, flooding and numerous other land use/watershed planning issues.

7.1 Model Data Inputs

7.1.1 Stream Gage Measurements and Channel Cross-Sections

In order to develop stream flow hydrographs for use in watershed model calibration, continuously recording water depth loggers were installed at the outlet point of each subwatershed as discussed in Section 3.3. The gage locations are shown on Figure 10. The loggers were set to take measurements at approximately 15 minute intervals. This interval was selected based on results interval trials and provided the best mix of detail while avoiding excessive file size.

A "staff gage" was also installed at each station which gave an instantaneous reading of water surface depth or elevation. USGS-type steel staff gages, incremented in 0.02 foot intervals were installed approximately on the same cross section as the recording gages. Staff gages were used as a means of "double checking" the values recorded by the loggers as well as correlating stream velocity measurements to transducer recorded data.

All instrumentation placement was surveyed by Najarian Associates using a combination of high-precision GPS and traditional surveying equipment so that stream water surface level could be converted to USGS elevation, NADA 83 feet. Najarian also surveyed stream channel cross-sections, bank to bank for use in the development of rating curves, discussed below.

7.1.2 Stream Flow Velocity and Rating Curves

In order to convert simple depth logger data to volumetric flow rates, rating curves were needed at each sub-watershed station. Rating curves are equations to calculate flow from stream depth or elevation. The rating curve is used to calculate flow from the data logger depth data.

Rating curves were developed by a combination of directly relating depth to stream flow measurements and by hydraulic modeling using the United States Army Corps of Engineers (USACOE) Hydraulic Engineering Center – River Assessment System (HEC-RAS) model. The model was used to compute flow rates that were beyond the ability of the investigators to measure directly in cases were flood flows were so great that direct measurement posed a safety hazard.

For direct measurements, water depth and velocity measurements were taken in the field and used with stream cross-sections to develop rating curves. Flow versus depth was plotted and the best-fit equation calculated.

Once a particular form of equation was selected that appeared to fit the data, the equation was then used to reproduce the computed rating curve flow data points and compared to the flows as measured in the field. In this way, the equations of best-fit curves can be evaluated as to their acceptability for reproducing flow values at both the low and high end of the range of stream flow depths recorded by the gage. In some cases, such as at station W5 (Bailey's Corner Road), the dramatic change in flow regime from in-channel to overbank or floodplain could not be satisfactorily modeled by a single equation. Although a best-fit line had the appearance of faithfully representing the data points graphically, the range of flows (three to several hundred cfs) included a standard deviation that was often in excess of the lower flow values themselves. In order to overcome the accuracy problem, separate equations were used for in-channel and over bank flow conditions.

Rating curves were based on several field measurements of flow. However, field measurements were limited by time and scope. The small size of the sub-watershed mean that relatively small changes in water depth have a substantial impact on flow. As discussed later herein, additional flow measurements, particularly on Hannabrand Brook, may provide better understanding of flow.

In order to utilize the HEC-RAS model, multiple stream cross sections are needed for the model to compute and balance energy losses from one section to the next. Investigators used direct field measurements of stream flow to calibrate the HEC-RAS model for in-channel flows, but used traditional "trial and error" methods to calibrate larger, out-of-bank flows. In order to do this, surveyed cross section data, combined with Geographic Information Systems Digital Elevation Model (DEM) data and stream flow logger data was used.

NJDA, with the assistance of Monmouth County Office of GIS (MCOOGIS), developed a procedure to combine DEM data to define the floodplain portion of the stream cross section, with more highly detailed survey data of the stream channel itself to produce a hybrid cross section model used in HEC-RAS. Using a combination of add-on software packages from Environmental Systems Research Institute (ESRI, Inc) and USACOE, MCOOGIS was able to create three dimensional sections or "slices" through the floodplain and through the channel for use in HEC-RAS modeling. This method avoids extensive surveying and associated costs, but the accuracy may be limited by the DEM resolution. In this case, the available resolution of about 1 foot was adequate since much of the hydraulic and hydrologic response in the watershed is governed by small nuances in topography.

7.2 Watershed Hydrology and Modeling

In order to develop a comprehensive understanding of the hydrologic system of the Wreck Pond Watershed, the overall drainage area was sub-divided into three sub-systems for analysis. These systems are:

- Hannabrand Brook stem (Stations W5 and W2),
- Wreck Pond Brook main stem (Stations W6, W9, W7, W1 and W3),
- Black Creek (Station W8).

Within each system, there are several subwatersheds, defined by a gaging station at the downstream end. Figure 10 and Appendix A provide detailed descriptions of the monitoring locations and subwatershed areas.

Each of these subbasins was evaluated independently to simplify model development, calibration and verification. The Black Creek subwatershed is distinctly different in that the drainage outlet does not coincide with the outlets from the Hannabrand and Wreck Pond Brook. These two subareas discharge quite close to each other just below Old Mill Road in Wall Township such that hydrographs from each stem can be added together to get a complete storm hydrograph for the entire watershed.

7.2.1 Model Inputs

The NRCS method utilizes a runoff coefficient to represent the effects of soil type and land use cover complex on the generation of stormwater. The runoff curve number method is well documented in literature and widely used by consultants for designing stormwater control systems. In simplified terms, a curve number (CN) is chosen from a table of values published by NRCS using combinations of soil type and land use cover. For this investigation, GIS data for land use and soils provided a CN for each polygon which were then aggregated into a weighted CN for each subdrainage area. Curve numbers by subdrainage area are tabulated in Table 24:

In order to use NRCS procedures, a timing factor must be computed which is used to apportion runoff volume over time, creating a “hydrograph”. Thus, lag time was a key calibration parameter. Appendix D provides detail on calculation of this parameter.

Table 24: Curve Numbers		
Subwatershed	**Station#**	**CN**
WPB-Waterford Glen	W1	68.7
Hannabrand Brk - Old Mill Culvert	W2	70
WPB-Old Mill Culvert	W3	69.5
HB-Bailey's Corner Rd	W5	62
WPB-Martins Rd	W6	61
WPB-Glendola Rd	W7	66
Black Creek	W8	67
WPB-Hurley's Pond Dam	W9	65

A specific unit hydrograph was developed by the firm of Dewberry-Davis (Dewberry) under contract with NJDA. The hydrograph was formatted to be used in the modeling to convert runoff volume depth to a runoff hydrograph through use of a Peak Rate Factor (PRF). The use of local unit hydrograph provides a better estimate of actual hydrograph shape than a general hydrograph. For example, the watershed unit hydrograph uses a PRF of 230, while the standardized PRF used in the NRCS methodology is 484. The relatively flat topography in this coastal plain watershed is better represented by the lower PRF. The DELMARVA Coastal Plain unit hydrograph uses a PRF of 280, which is comparable the Dewberry results. The best results were obtained using the Dewberry Unit Hydrograph.

Precipitation data were collected as noted in Section 3.1, from the Wall Township RISE Station. When data were not available from that station, the NJ Mesonet weather data were used.

7.2.2 Peak Flow Attenuation and Other Flow Factors

The Wreck Pond Watershed contains numerous small ponds and several large lakes all of which affect storm runoff by damping peak flows. Further attenuation is provided by the riverine buffers along the main stem streams which, when inundated, act as basins themselves, storing, trapping and releasing stormwater as it moves downstream.

Impoundment Modeling: A combination of field survey and GIS measurements were used to develop reservoir rating tables when data were not otherwise available. Existing reports were available for Old Mill Pond and Hurley Pond (Monmouth County Engineering Department and Hatch-Mott McDonald for Monmouth County, respectively) which provided rating table data used for reservoir routing. Rating table data were developed for Albert's Pond, Osborne Pond, Mc Dowel Pond (18th Ave), Fairway Mews detention basins and the Spring Lake Golf Course impoundments.

Reach Routing. Investigators found that while impoundment routing was necessary for model development, impoundments alone could not account for all hydrograph peak attenuation or time lag. Therefore, several stream channel "reaches" (as defined by HMS) were modeled using the Muskingum routing method. .

Diversions: In some cases, peak flows and volumes were found to be lower downstream than upstream. This was particularly evident for some storm events within the Hannabrand stream (areas W5 and W2). Investigators conducted a detailed stream survey of the lower reaches of the Hannabrand Brook to determine if the data were erroneous or if there was a physical basis for the difference. The survey revealed numerous locations where debris dams lay across the stream, forcing higher flows into the floodplain. In some cases, the stream banks were slightly depressed which allowed flows to be diverted out of the channel. Investigators concluded that these characteristics occur randomly in time and location thus yielding variations in stream flow events.

A further examination of stream flow data during selected modeling events indicate that for this subwatershed, base flow conditions at the upper and lower gage stations were being recorded accurately indicating gages were functioning correctly. Diversion was incorporated into a calibration event for the Hannabrand Brook subwatershed. Computed results compared favorably with observed hydrographs. As noted above, however, additional rating curve data may also be needed to improve flow analysis for Hannabrand Brook.

Base Flow: Constant base flow values were set at levels determined from stream gage records which showed constant flow values before each storm event. Using this method, computed hydrographs compared very well with observed hydrographs at the receding hydrograph limb, confirming the use of the "constant monthly" method.

7.2.3 Storm Event Descriptions

Precipitation and stream gage data were examined to find appropriate storms to model. The following storms were selected for the various sub-models.

March 28, 2005. Precipitation data was procured from the New Jersey Mesonet weather station network gage located in Sea Girt as the Wall Township RISE network gage was not online at the time. There was approximately 0.34 inches of precipitation on March 23rd, 5 days prior to the modeled storm event. This storm event originally was considered "marginal" due to the time of year – at the beginning of leaf out. Vegetation would not be fully expanded and conditions may not be comparable to other events which took place later in the growing season. However the storm depth of 1.93 inches met the criteria for sufficient rainfall and there was an adequate gage response at the Hannabrand Brook gages (W5 and W2). Additionally, the gage at W2 stopped working later in the project which limited available data for use in modeling. Due to the time of year and prior rain event, it was assumed that an antecedent moisture condition above ‘average” might be present which could be modeled with higher than normal curve numbers and/or wet soils being construed as connected impervious cover to imitate quicker watershed responses.

June 24, 2006. The storm event of June 24 was characterized by heavy rains totaling about 2 inches for the 24 hour period. However, there was an initial rainfall event, followed by several hours of no precipitation, subsequently followed by the “main” storm event which constituted 1.84 inches of rain. Several attempts using the full 1.94 inches of precipitation failed to produce a good match to the gage hydrographs. Therefore, it was decided to use the 1.84 inch precipitation event as the storm event, and account for the prior rainfall as an antecedent moisture condition. The assumption was that this prior rainfall was sufficient to load vegetation, fill voids and sufficiently wet soils such that the watershed response would be more characteristic of a higher curve number and/or impervious areas that were directly connected to the stream, since soils might be saturated and would convey runoff rather than contain it.

July 6, 2006. This event was preceded by several days of precipitation totaling 1.35 inches. Typically storm events during July would be considered to be either average or below average antecedent conditions. However, there was sufficient rainfall prior to the selected event to maintain either average or above-average antecedent conditions. The July 6th event total was 1.41 inches which is somewhat smaller than desirable however the gage provided a sufficient distribution pattern and the stream gage response was adequate.

April 12, 2007. This event totaled about 2.61 inches, however the initiation of the storm was “spotty” for several hours. Therefore, the storm was modeled as a 2.55” event to account for the main body of the storm. A storm event of 1.25” occurred approximately one week prior to the modeled event. Given the time of year (early in the growing season, cooler temperatures), a slightly higher than “average’ runoff condition should exist in the watershed. Soils should be saturated and base flow in streams should be elevated.

7.3 Model Calibration and Verification

The HEC-RAS model produces a computed hydrograph and calculates runoff depth. The shape and peak flow of the hydrograph along with the computed runoff depth are compared with the actual flow hydrograph and runoff depth. The model parameters are adjusted so that the computed and actual hydrographs and runoff depth match. While peak flow can be affected by changes in curve number, lag time, unit hydrograph, drainage area and even computation interval used by HMS, runoff depth has only one primary variable (curve number).

Once the model parameters produced results that reasonably match the actual hydrograph in shape and peak and the runoff depth, the model is considered to be calibrated. The model is run again with a different storm and if this produces the expected result, the model is considered to be verified. If the model parameters are correct, inputting a real storm event of any type should approximate the gauged hydrograph of that event. In reality, physical conditions of the watershed are not the same for each event – antecedent soil moisture, distribution of the precipitation, physical changes in the watershed (blockages, debris, debris removal, plant growth etc.). Therefore, calibration and verification event parameters are presented as a range of values relative to computed values.

The sub-basin models were successfully calibrated and verified for two storms each. The June 2006 storm was used for both the Hannabrand and Wreck Pond Brook sub-models. Figure 14 shows the results of that calibration run.

7.4 Hydrologic Model Limitations and Results

Any modeling effort is a representation of actual natural conditions. Model limitations are typical of any modeling effort.

7.4.1 Limitations

NJDA has attempted to include as much relevant information as possible in the RAS, HMS and other computer models to obtain reasonable accuracy within given limitations of time and data. To this extent, the following limitations are identified both in model development and use.

(1) Models are planning tools, and not intended for design. Watershed conditions change, and may change rapidly. These models examine the Wreck Pond Watershed during a specific period of time and model output reflects the conditions existing at that time. The models may not be used under future conditions for the design of stormwater management structures without undergoing detailed examination and updating of model parameters. Specific numerical output should not be used to set or establish regulatory limitations such as discharge or effluent limits but as a general planning tool.

(2) Model output is an approximation of real world conditions and results should be evaluated in context with other data, such as high water marks, photographs, measurements made by other parties etc.

(3) Watershed models (HMS) are not intended to depict individual site conditions. The scope and scale of the HMS models are too larger to generally model individual land-use changes.

(4) Pond routing details were developed from GIS measurements and were not surveyed. Routing output therefore is approximate and should be verified by actual surveys of weir elevations, measurements of surface areas and elevations etc.

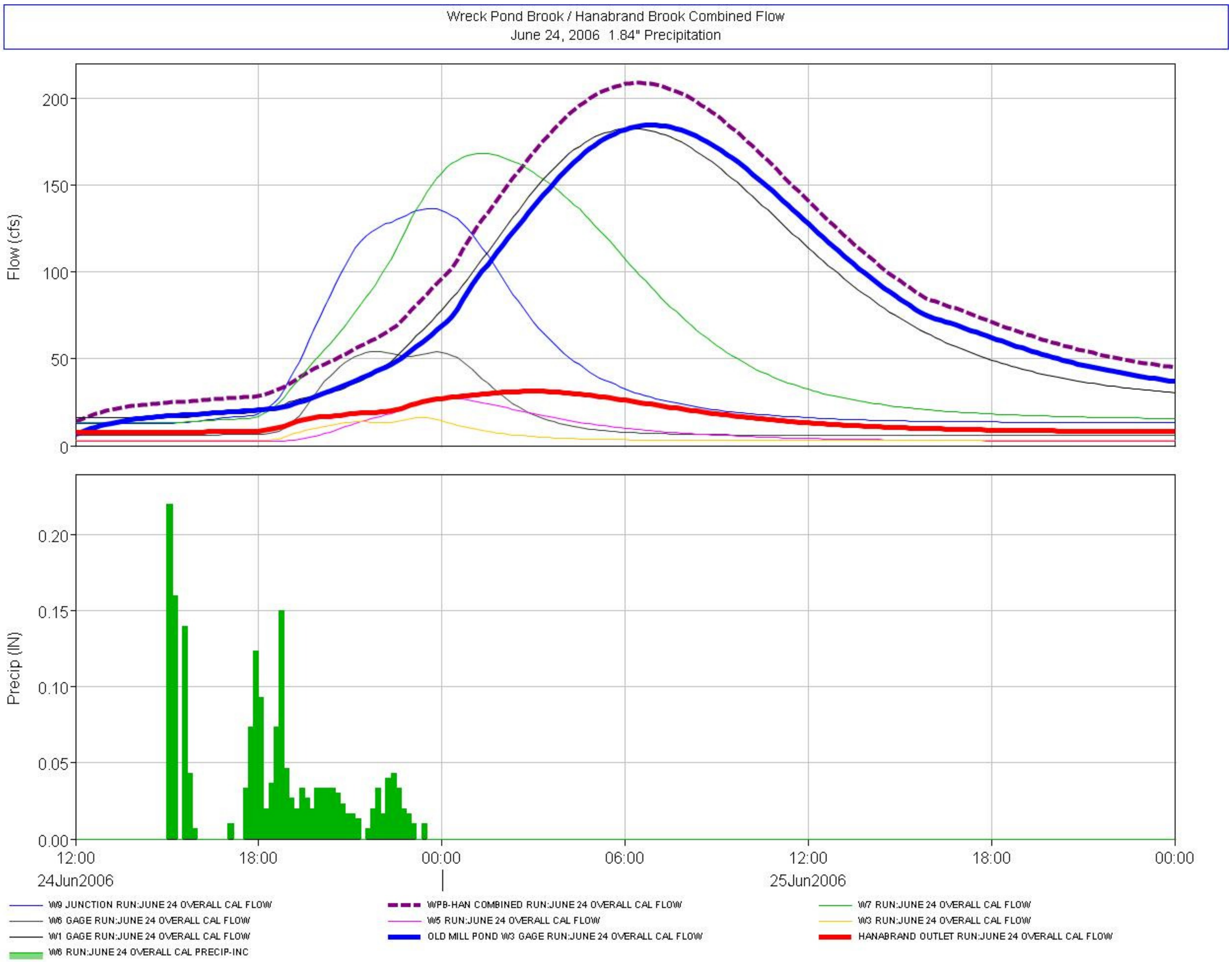


Figure 14: Wreck Pond Brook Watershed Study
NJDA Model Calibration Result – June 2006 Storm Event

(5) Rating curves for streams at gage station locations should be updated with more detailed field surveys of the channel for future hydrograph development. In addition, additional flow measurements during a variety of conditions, particularly in the Hannabrand Brook watershed, would increase the accuracy of the model. Due to the sandy/gravel soils, the cross sections were observed to have changed due to bedload movement during the study. Therefore, accuracy of the cross sections for future analysis cannot be assured.

7.4.2 Model Results

NJDA successfully developed a hydrologic/hydraulic model of the Wreck Pond Brook watershed to Old Mill Road using the USACE HEC RAS and HMS models. The following conclusions were obtained from the modeling. In addition, the results of NJDA data collection, field surveys and modeling were used to provide information for other sections of this Plan and to develop many of the recommendations in Book 2.

(1) Stream channel modeling with HEC RAS can be cost-effectively performed using a process which combines a physical survey of the channel cross section (bank to bank) with flood plain sections derived from high resolution digital terrain models (DTM) to form a composite cross section.

(2) Stream flow (HEC RAS) models indicate that overbank conditions along stream corridors contribute significantly to flood peak mitigation by storing excess runoff and slowly releasing it. Storage volume is highly dependent on seasonal variations of vegetation cover in the floodplain. The golf courses also provide significant flood storage.

(3) Hydrograph shape from gaged data reflects a fairly quick rise and fall of stream elevation for non-flood events. . This reflects the porous nature of the soils in the upper watershed (sands and gravels), which do not store incident rainfall for very long. Consequently, streams experience a fairly rapid discharge to baseflow during and immediately after the rain event.

(4) Stream floodplains appear to provide attenuation of larger storm events more so than do the many large man-made impoundments. Consequently, man-made impoundments tend to affect hydrographs of small (water quality sized) storm evens. Model output for the larger lakes, such as Hurley's Pond, Osborne's Pond and Albert's Pond show relatively little peak flow attenuation for larger events. This suggests that the major reservoirs in the watershed would require outlet modification and possibly dredging in order to increase their effectiveness with attenuation of larger storm events. Additional data, including outlet flow data, would be required to evaluate the need for and anticipated results of such modifications.

(5) The Lower Monmouth Dimensionless Unit Hydrograph was shown to be necessary for accurate reproduction of measured peak flows. The DELMARVA dimensionless hydrograph also represented gaged data fairly well. The use of the Standard (484 peak rate factor) hydrograph resulted in computed peak flows that were significantly in excess of measured gage data and could not be fit with modification of Curve Numbers or Lag time.

(6) Bankfull conditions in most streams in the watershed were achieved at rainfall depths less than 2 inches. This is less than or just equal to the NRCS one-year storm event of 2.9 inches in 24 hours for Monmouth County.

(7) Floodplain storage was randomly affected by debris jams across the channel resulting in bank overflow for small storm events. While random occurrences of debris jams made model consistency difficult at times, their occurrence prompted the recommendation contained below and elsewhere to examine select floodplain areas for possible use as regional detention facilities.

(8) The Spring Lake and Mews Golf Clubs serve as regional flood control and sediment traps for the upper Black Creek watershed due to extensive “water features” found on both sites. The combined storage at various peak basin elevations is approximately 10 acre-feet +/- and contributes to a reduction in peak discharge by about 35% at the Mews basins and a further reduction of about 10% at the Spring Lake Golf Club. Overall reduction is about 17% for small storms and about 3% for the statistical 100 year event. This indicates that their primary benefit to the Wreck Pond watershed is for the control of water quality events more than flood events. Model results also indicate that the primary source of runoff in the W8 subwatershed comes from the residential area to the north of the Mews golf and residential area. Discharge is piped via a 60” RCP under the Mews site and discharges directly into the upper reaches of the Spring Lake Golf Club water features. Time travel in the culvert and land use conditions in the upper portion of the subwatershed are the primary controllers of runoff peak and volume at the discharge point at the Rt. 71 culvert.

(14) The 100 year statistical storm event of 9.0 inches yields approximately 1900 cfs at peak discharge to Wreck Pond from the 13 square mile watershed. This peak value also may be impacted by the degree of flood plain storage available (for example, flows could be higher if not diverted upstream to the floodplain). At normal high tide elevation, a very rough estimate of the maximum discharge from the 7 foot concrete pipe is roughly 600 cfs and requires a depth in the pond (head on the pipe) of about 13 feet, effectively flooding much of the lower watershed if additional measures are not taken to empty the Pond during a storm event of that magnitude. It is essential to note that the exact conditions of the pipe lining and entrance conditions were unknown and can affect the discharge capacity of the culvert. Thus, additional flow analysis is needed at the outfall. The model does not account

for rising and falling of ocean tides, which will dynamically reduce or increase culvert capacity. Pond routing therefore assumed a static high tide condition occurring during the peak discharge into Wreck Pond.

This model will provide an ongoing tool for use in updating this model. The hydrologic model can also be extended to provide analysis of future conditions and other proposed watershed modifications.

8 WATERSHED SWMM MODEL

The County modeling efforts discussed in Section 7 provide a detailed analysis of the hydraulics and hydrology of the watershed. As part of the Borough of Spring Lake's EPA funded Wreck Pond Environmental Study, a watershed pollution budget model was developed to investigate the non-point sources of pollutants into Wreck Pond. Designed to present pollutant loading generation values for broader regions of the watershed, the model provided loadings for the upper and lower regions of the Wreck Pond Brook, the Hannabrand Brook basin, and areas in the vicinity of Wreck Pond.

The pollution budget model was expanded for the RSWMP to provide greater resolution on watershed pollutant generation. Data supplied by the MCOOGIS and NJDA allowed for enhanced model detail including analysis of the seven sub-watersheds above Old Mill Road and Black Creek. The results of this pollution budget model will complement the hydrologic and hydraulic modeling efforts of the NJDA. Additionally, the model provides flow and water quality analysis on the portion of the watershed downstream of Old Mill Road, where the NJDA model terminates, thus complementing NJDA's watershed model.

The watershed model was developed using the EPA's Stormwater Management Model (SWMM). SWMM is a comprehensive computer model designed to analyze runoff from urban watersheds. Specifically, PCSWMM was utilized, a version of SWMM developed by the Computational Hydraulics Institute, which incorporates the basic SWMM engine and includes additional interface options.

SWMM's Runoff and Transport Modules were utilized for this model. The Runoff Module uses basic rainfall and watershed data to generate the quantity and quality of stormwater flowing off the land. The Transport Module use stream channel data, along with the Runoff Module output, to route the stormwater through the watershed.

As discussed in Section 7, NJDA developed a hydrologic and hydraulic model of the upper watershed, west of Route 71. At the time the SWMM model was developed, the hydrologic model was not completed. The NJDA 's extensive in-field water level data located at each of the eight (8) sub-basins within the watershed above Old Mill Road were used to calibrate the hydraulic portion of the SWMM model. For the Wreck Pond direct watershed, watershed characteristics were used to calculate flow, along with data collected by NA for the Borough of Spring Lake's Wreck Pond Environmental Study. Because flows generated within the model drive the transport of land use generated pollutant loads, calibration of a pollution budget model to flow data is imperative.

8.1 Model Input and Flow Calibration

The GIS data for the watershed, available from Monmouth County and the NJDEP, provided much of the necessary data for model development. The data included watershed features such as sub-watershed boundaries, streams, lakes, topography, land use, and soils. Other required inputs were evaporation data, pollutant build-up wash-off rates and rainfall hyetographs. Pollutant build-up and wash-off data were taken from scientific literature and similar studies performed within the State.

Available calibration data for this model included the water level collected by the NJDA and water quality data collected by Najarian Associates (NA). Storm event water quality storm sampling was collected by NA for two storm events at Wreck Pond Brook at Old Mill (W3), Wreck Pond Brook at Glendola Road (W7) and Hannabrand Brook at Old Mill (W2). Details and results of the water quality monitoring at these stations is provided in Section 10.

The watershed model was set-up using the Runoff and Transport Modules of the SWMM program. Within the Runoff Module, each sub-watershed was input as an individual drainage basin. Flow quantities and land-use generated pollutants were then transferred to the Transport Module, where flows and water quality constituents for each sub-watershed were routed through specific stream sections. Ponds were modeled as internal storage elements within the Transport Module using available data or assumptions when data were not available.

8.1.1 Tributary Watersheds

Flows were calculated from water level data using the rating curves developed by NJDA with input from NA as discussed in Sections 3.3 and 7.1.2. Review of the flow data generated some unexpected results. Soils and land use characteristics of Wreck Pond's sub-watersheds are generally similar. Thus, it was expected that the storm-generated flow per unit area for each sub-watershed would be within a well-defined range. Further, in most cases, flow increases in a stream in the downstream direction unless the flow is interrupted by a discharge point or an impoundment. However, particularly on Hannabrand Brook, storm-generated flow as calculated from the rating curves decreased in the downstream direction. Further, significant flow volume was lost downstream on this Brook and flow per unit area was lower at the downstream station, W2 than at other stations in the study area.

To investigate this further, flow per unit area was computed for the sub-watersheds in the study as determined from the water depth data and the rating curves for the storm event of June 27, 2005. The calculated average daily flow was divided by sub-watershed area to provide an average daily flow per unit area. These unit flows were compared with the mean daily flow per unit area for that date from the USGS gaging station for the Jumping Brook in Neptune. The Jumping Brook watershed unit flow for this storm was in the range of the study sub-watershed value, although slightly lower than most. However, the flow per unit area for Hannabrand Brook at Old Mill Road (W2) and Wreck Pond Brook at Old Mill Road (W3) were significantly out of range. The Hannabrand Brook at the downstream station average daily flows was lower than expected. While the unit flow at upstream station on Hannabrand Brook, W5, was within 20-25% of the Jumping Brook flow, the flow at W2 was only 40-50% of the Jumping Brook unit flow.

On Wreck Pond Brook, the upstream Glendola Road station was within 10-20% of the Jumping Brook unit flows. However, downstream at Old Mill Road, flows were 40 to 60% higher.

The combination of higher than expected flows for Wreck Pond Brook and lower than expected flows for Hannabrand Brook at the Old Mill Road stations, suggests that some of the Hannabrand Brook flows may be diverted to Wreck Pond Brook upstream of the conjunction of these streams. As can be seen on Figure 10, these two stations are in close proximity. Thus, a further analysis was conducted that combined the flows for both streams at Old Mill Road. Using the total watershed area for both streams, the calculated unit flow is lower than for WPB alone, but it is still 15-26% higher than the unit flow for the USGS station.

Thus, the observed water depth data as converted to flow at Hannabrand Brook at Old Mill Road and Wreck Pond at Old Mill Road were not suitable for model calibration purposes for the hydraulic portion of the SWMM model. As noted, the NJDA model had not been completed when this model was developed. The NJDA modeling work later speculated that lower flows downstream on the Hannabrand Brook at W2 were due, in part, to the presence of debris dams along the stream that forced channel flows into the floodplains at flows lower than those that would typically cause flooding. In addition, NJDA noted that shifting bed load at some stations may have caused errors in the depth gage reading. These conditions are not permanent or consistent conditions within the streams. Thus, actual flows at W2 may be higher than predicted using the rating curves.

Since the SWMM model is primarily used for evaluation of generation and transport of water quality constituents herein, development of the model without consideration of redirected flow into the flood plain provides a more conservative estimate of pollutant generation within the Hannabrand Brook system. As flow in Wreck Pond Brook is still larger, the pollutant generation analysis will provide accurate estimates of the relative contributions of that watershed as well.

The flows at further upstream stations, Bailey's Corner Road (W5) and Waterford Glen (W7), respectively, were within range and used in the flow calibration process. The flows were then propagated downstream using the model. The modeled flows at Old Mill Road were compared to the data for W2 and W3 to ensure the flows were within an expected range. However, detailed flow calibration was not carried at those stations. Additional data may be needed to completely analyze the flow regime.

The flows herein compare to the NJDA modeling effort, with some exceptions noted above. As discussed in Section 7, the flow calibration process by NJDA focused primarily on storm events, while the SWMM modeling evaluated both storm and non-storm flows. The primary purpose of the SWMM model is to evaluate stormwater generated pollutant loading, which occurs at a range of flow events, while the NJDA was particularly interested in storm events related to flooding.

Further, the data loggers were not always operational, limiting available calibration periods. NJDA modeled the Hannabrand and Wreck Pond Brook systems separately and thus was able to use different storms to calibrate and verify their model for each basin. This SWMM model was developed as one model for Wreck Pond and Hannabrand Brooks. Thus, data loggers for both systems had to be operational, limiting the available flow calibration period. For these reasons, the process and results between the two models differ.

Further details of the flow calibration process, including storms selected, are provided in Appendix E. The calibration plots provided in Appendix E provide results for the summer of 2005. The flow results were validated using two other storms.

The Black Creek watershed flow was calibrated to the County station at Route 71. This subwatershed had to be calibrated separately. The data provided from the County data logger for this station (W8) was only available for 2006 while reliable data were not available at all the other stations in 2006. In addition, calibration issues arose at this station as flows peaked very quickly and connected impervious had to be increased to account for these flows. The flow per unit area appeared within range, although other information from the watershed suggests that the golf course acts to detain flow.

Flows here may have been somewhat overestimated by the direct impact of runoff from Route 71. No water quality data were available for this station.

8.1.2 Wreck Pond Direct Watershed

The eastern end of the watershed is considered the Wreck Pond direct sub-watershed. This includes the reach of Wreck Pond Brook from the station at Old Mill Road to the Pond, as well as the areas that drain directly to the Pond through stormwater outfalls. The sub-watershed was divided into three sections: Spring Lake and its contributing sub-catchments, major sub-catchments draining into Black Creek and major sub-catchments draining into the Wreck Pond Brook. Specifics regarding drainage areas, slopes and land use were input into the new model segment of the Wreck Pond SWMM Model. Flow data were not available on this portion of the stream, limiting the calibration.

8.2 Water Quality Calibration

Once the hydraulic and hydrologic portion of the model was complete, water quality calibration was conducted. The model was calibrated with the storm event water quality monitoring data collected by NA for the Borough study.

Runoff and Transport Modules of the SWMM program simulated the generation, transport and the fate of all contaminants of concern. Within the Runoff Module, pollutant build up on the watershed surface and are then washed off during storm events. The pollutant buildup occurs on a land use specific basis, i.e. pollutant generation varies by land use types. During a storm event, these pollutants are washed off the watershed surface and are then routed through the watershed streams and ponds via the Transport Module. The transported pollutants provide the calibration concentrations and loads.

The water quality calibration stations were Upper Wreck Pond Brook (at Glendola Road, W7); Lower Wreck Pond Brook (at Old Mill Road W3) and Hannabrand Brook (at Old Mill Road W2). Model parameters for the water quality calibration included land use, area, flow and pollutant buildup and washoff rates. As noted, land use was based on the Monmouth County GIS land use layer for 2006 land use and the pollutant rates were taken from scientific literature and available State studies. For the Wreck Pond direct subwatershed, wash-off coefficients developed for the outfall pipe sampling modeling of the Borough's Wreck Pond Environmental Study were used to develop area weighted averages of wash-off coefficients.

The water quality portion of the model was calibrated for total suspended solids (TSS), fecal coliform (FC), total nitrogen (TN) and total phosphorous (TP). The SWMM model generates pollutographs of water quality constituents (graphs of concentration vs. time) and estimate of total loads for the modeled period. The water quality model was calibrated for the October 17-18, 2006 storm event for which data was collected as discussed in Section 10 of this report. The calibration process compared the simulated constituent concentrations over time to the observed concentrations and the calibration parameters were adjusted until a good fit was obtained. The other storm event (September 2006) that was monitored did not provide sufficient data for validation although the available data was compared to the calibration data for consistency. Thus, the water quality component was calibrated but not verified. Further information is provided in Appendix E.

The model was generally able to match the water quality data to an acceptable level (Appendix E). However, the model over-predicted concentrations of certain parameters for lower Wreck Pond Brook (W3). Based on an assessment of the October 2006 storm sampling data, there is a significant mass loss of suspended solids and other pollutants on Wreck Pond Brook between the Glendola Road (W7) and Old Mill (W3) stations. This result is likely due to in-stream ponds located between these two stations. These ponds act to retain the flows along Wreck Pond Brook, allowing suspended sediments and associated chemical constituents to settle. This effect is also apparent in a review of the data from the September 2006 storm sampling. The peak TSS concentrations during the portion of the storm sampled for Wreck Pond Brook were 23 mg/l at Glendola Road (W7) and 2.3 mg/l at Old Mill Road (W3). Review of the annual monitoring data indicates that the base flow concentrations do not show the same pattern, suggesting this occurs at higher flows.

The model's Transport Module was not designed to simulate such extensive in-pond processes. Thus, a post-processing analysis was conducted. The observed water quality field data were coupled with the simulated SWMM flows to determine the "actual" in-stream load for the calibration storm. This provides an adjustment factor to account for settling within the watershed ponds. This comparison shows that Wreck Pond Brook loses about 40% of the TP load and 35% of its total TSS load between the Glendola Road and Old Mill Road stations.

The model is calibrated for Wreck Pond Brook and Hannabrand Brook up to Old Mill Road. Water quality data was not available for the calibration of the Black Creek sub-watershed. In addition, literature values were lacking for generation of pollutants from golf courses, which make up much of this watershed. The model was run for this sub-watershed using the calibrated model parameters. Due to the lack of sub-watershed specific data, these results must be considered a rough estimate.

The Wreck Pond-direct drainage sub-watershed consists of the reach of Wreck Pond Brook from Old Mill Road to the Pond and the watershed area directly adjacent to the Pond. No in-stream flow or water quality data were available for this sub-watershed, although the outfall pipe sampling provided flow and water quality data. Therefore, this sub-watershed is partially calibrated.

8.3 Model Predictive Runs

The watershed model was run under three scenarios for existing watershed conditions: the NJDEP 2-Year storm, a Dry Year (2001) and a Wet Year (1996). Loads generated from the land surface were calculated for all nine sub-watersheds. Calibration was done for transported loads at three stations as previously noted: W7, W3 and W2. Transported loads were also calculated for the Black Creek watershed (W8) and for Wreck Pond as a whole.

The pollution generation rate is on a per acre basis. Thus, the total load from a watershed depends on both the pollutant loading rate, the rainfall conditions, and the watershed area. As expected, the Upper Wreck Pond Brook watershed produces the largest loads for all pollutants due to its larger size. Figures 15 and 16 provide the watershed loads for TSS and total nitrogen for each model scenario for the sub-watersheds.

Watershed (runoff) loadings are conveyed downstream by the Transport Module and calculated for five sub-watersheds. Results of these model runs are depicted in Table 25 and Figures 15 and 16. The presented loadings are produced after the flows have been routed through streams and ponds, and therefore give the cumulative resultant loads at the exit point of each sub-watershed. For WPB-OM, the post-model processing (discussed above) was used to calculate the final transported loads.

These results are considered estimates as the model was not validated and the pollutant generation factors are those from the literature. The relative estimates provide valuable information about the generation of pollutants from the land surface and transport through the watershed. In particular, the result for the Black Creek and Wreck Pond direct sub-catchment are not calibrated to water quality data. The results for this

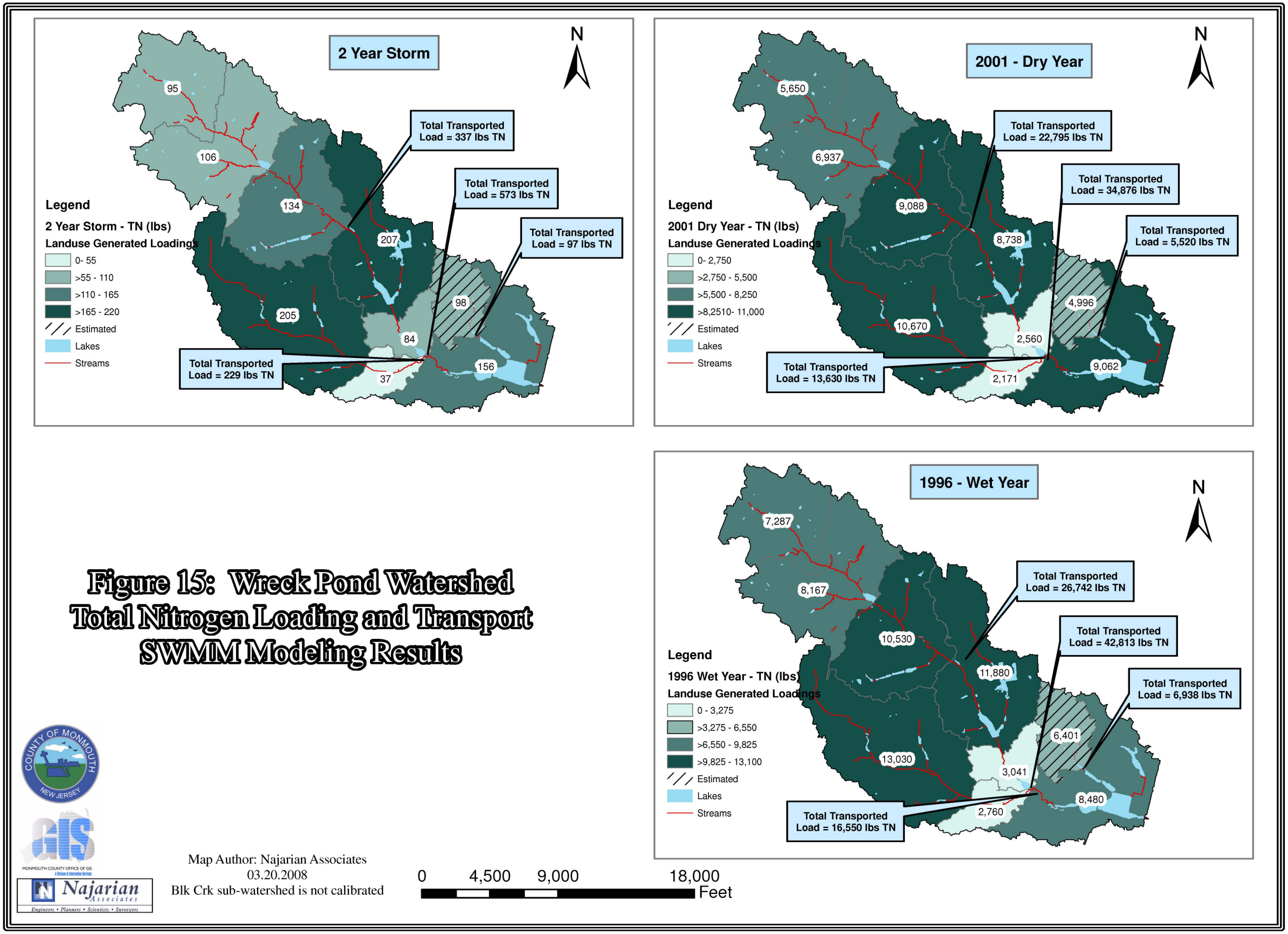
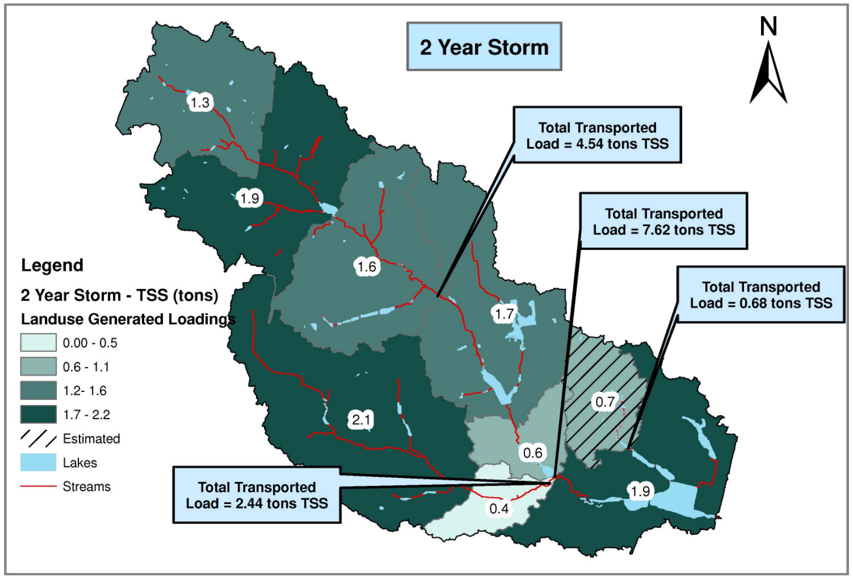
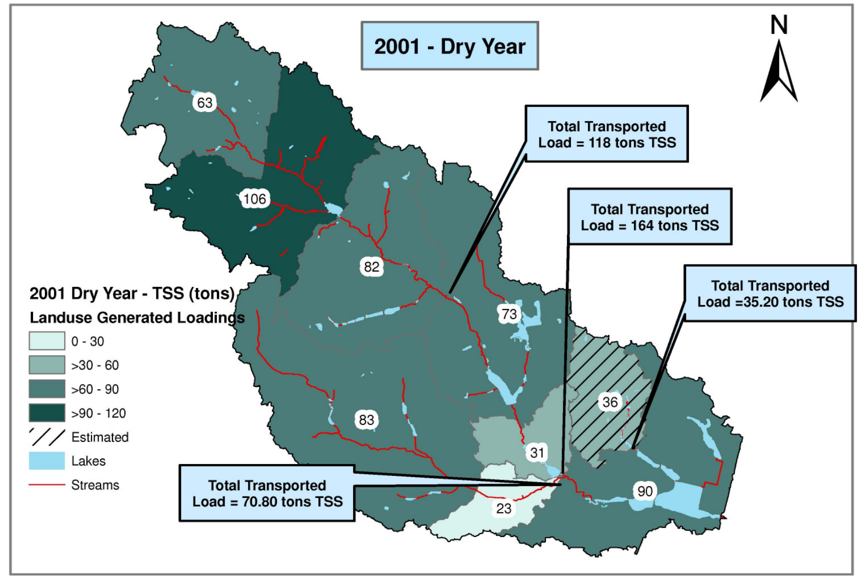


Figure 15: Wreck Pond Watershed Total Nitrogen Loading and Transport SWMM Modeling Results





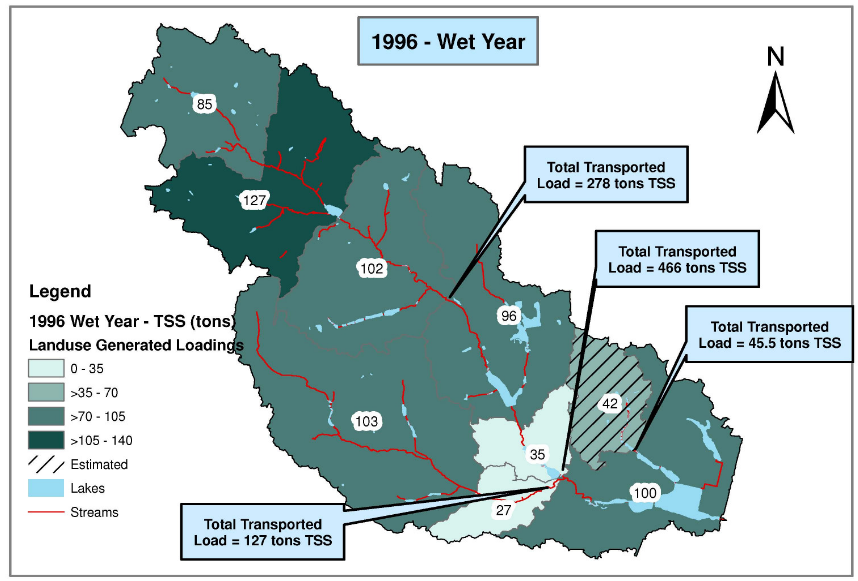


Figure 16: Wreck Pond Brook Watershed Total Suspended Solids Loading and Transport SWMM Modeling Results

Map Author: Najarian Associates
03.20.2008
Blk Crk not calibrated

0 4,350 8,700 17,400
Feet

Table 25: Model Results - Overall Pond Loadings

	FLOW ($ft^3 * 10^6$)		TN (lb)	TN (%)	TP (lb)	TP (%)	TSS (tons)	TSS (%)	FC (billions)	FC (%)
2-Year Storm										
*Upper Wreck Pond Brk**	*22.7*		*337*		*29*		*5*		*31,100*	
Wreck Pond Brook	33.7	57%	573	54%	18	30%	3	48%	38,800	43%
Hannabrand Brook	12.71	22%	229	22%	19	31%	2	32%	19,900	22%
Black Creek	3.52	6%	97	9%	8	13%	1	16%	14,900	17%
Wreck Pond Direct	8.97	15%	162	15%	15	26%	0.2	3%	15,900	18%
TOTAL	**58.9**		**1,061**		**60**		**6**		**89,500**	
1996 Wet Year										
*Upper Wreck Pond Brk**	*371.5*		*26,742*		*1,922*		*278*		*1,330,000*	
Wreck Pond Brook	529.7	55%	42,813	55%	1,236	34%	163	47%	969,000	41%
Hannabrand Brook	199.4	21%	16,550	21%	1,065	29%	127	37%	611,000	26%
Black Creek	64.0	7%	6,938	9%	529	14%	46	13%	512,000	22%
Wreck Pond Direct	177.2	18%	11076	14%	840	23%	9	3%	285000	12%
TOTAL	**970.3**		**77,377**		**3,670**		**345**		**2,377,000**	
2001 Dry Year										
*Upper Wreck Pond Brk**	*177.3*		*22,795*		*1,559*		*118.*		*480,000*	
Wreck Pond Brook	254.2	47%	34,876	55%	1,001	34%	58	35%	279,000	35%
Hannabrand Brook	116.10	21%	13,631	21%	789	26%	71	42%	236,000	29%
Black Creek	29.79	5%	5,520	9%	491	16%	35	21%	217,000	27%
Wreck Pond Direct	145.8	47%	9,559	15%	705	24%	4	2%	73,300	9%
TOTAL	**545.9**		**63,586**		**2,986**		**168**		**805,300**	

*due to settling in downstream ponds, the percentage contribution can not be properly assessed sub-catchment are hatched to illustrate this on the figures. Further, the Wreck Pond Direct results are not calibrated to a stream station. Figure 17 illustrates the relative loadings.

Wreck Pond Brook produces the highest relative flows under all scenarios due to its larger watershed area. Wreck Pond Brook produces 55-57% of the flows during the 2-year and wet-year simulations, with Hannabrand Brook providing just over 20% of the flow. During the dry year simulation, the proportion of flow from Wreck Pond Brook drops to just under 50%, while the Wreck Pond direct relative flow increases. As noted above, there is some question about under-prediction of Hannabrand Brook flows and whether there is some Hannabrand flows cross into Wreck Pond Brook upstream of Old Mill Road.

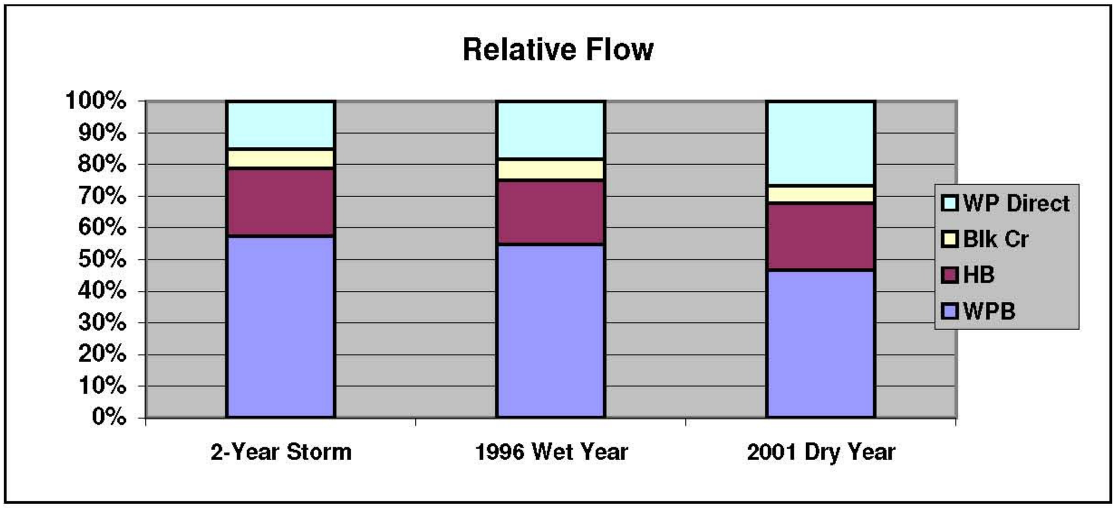
As expected, the largest watershed, Wreck Pond Brook provides most of the constituent loadings. For total N, the relative contributions mimic the flow regime. However, as shown in Figure 17, for TSS the contribution of Wreck Pond Brook is about 30% lower than expected from flow. This is due to the reduction in suspended solids seen on the lower part of the Brook. The Upper Wreck Pond Brook Watershed contributes significant loads of TSS. This watershed generates 32% of the flow in the dry-year simulation and 38% of the flow in the wet year and about 52% of the TSS load for both. Thus, without the loss of sediment in the lower Wreck Pond Brook sub-watershed, loading of TSS to Wreck Pond likely would be significantly larger.

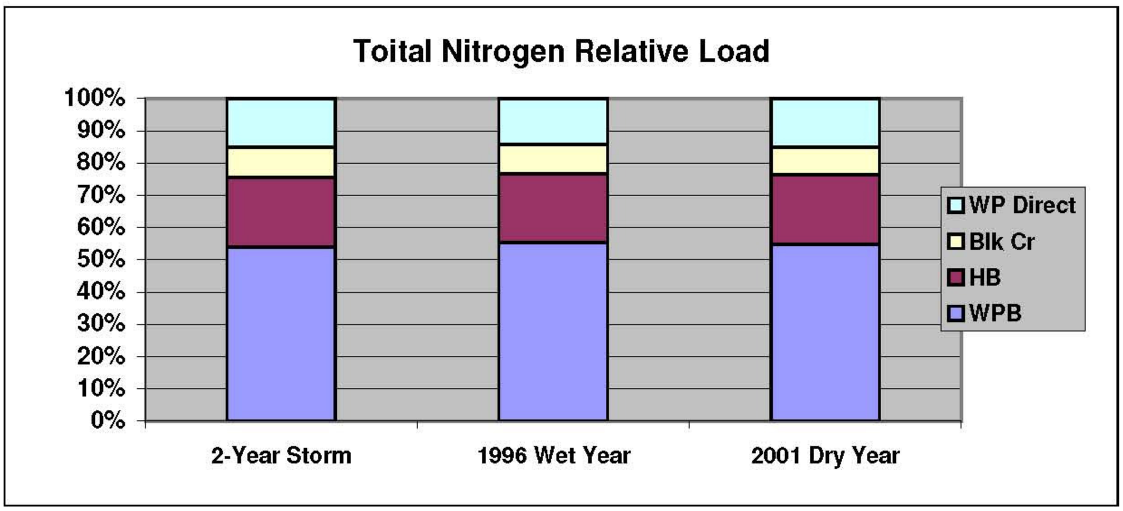
The relative Total Phosphorus (TP) loadings for Wreck Pond Brook are about 20% less than the flow contribution. In this case, the increased loads come from the more developed sub-basins in the lower watershed. Fecal coliform loadings are similar

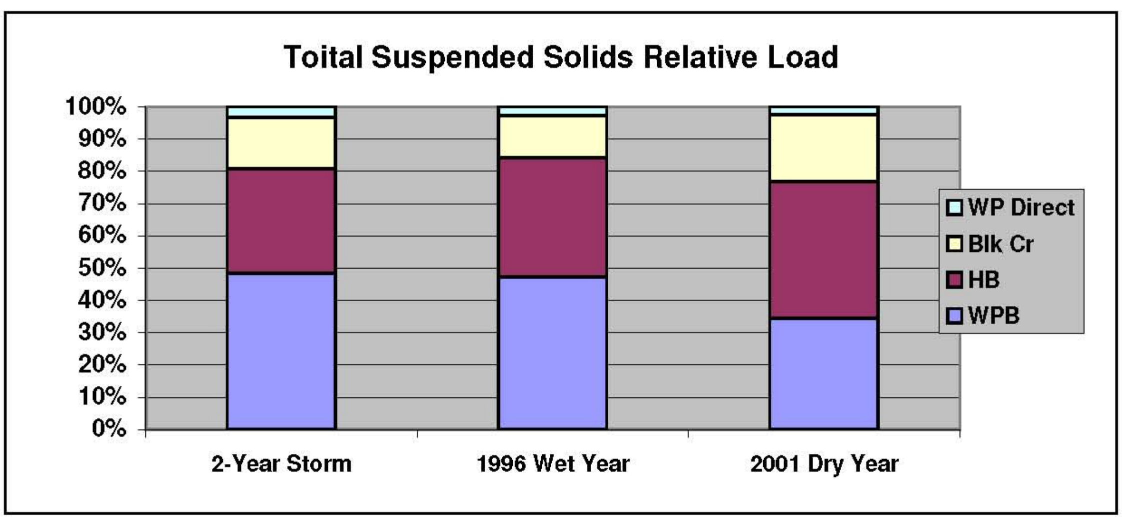
The comparison of the wet year versus the dry year show that the relative contributions of the watershed components are generally consistent. For flow, the Wreck Pond Brook watershed provides less in the dry year while Wreck Pond Direct provides more. For TSS, Hannabrand Brook provides a higher percentage of the Pond load during a dry year. Lower TSS loadings occur in the Wreck Pond direct watershed, due primarily to the extensive impervious area. However, it should be noted that sediment contributions associated with tidal inflows were not simulated by the model or reflected in these results.

In addition to looking at overall loading, loading rates were normalized by sub-watershed area to allow direct comparison of relative loadings. The normalized analysis provides a preliminary estimate of relative contribution of pollutants. These preliminary results suggest that the Black Creek, the Wreck Pond Direct and certain portions of the Wreck Pond Brook sub-watersheds provide the largest contributions of pollutant loadings on a per-acre basis for certain parameters. However, as noted above, water quality data were not available for the Black Creek sub-watershed and this is not calibrated. The NJDA modeling,

Figure 17: Relative Loading Analysis SWMM Model Results







completed after the SWMM model, has demonstrated that the Spring Lake Golf Course acts to detain stormwater flows and likely associated water quality constituents. Thus, actual water quality calibration data may show that the Black Creek watershed does not transport these loads to Wreck Pond.

8.4 Model Limitations and Conclusions

The SWMM model provides an estimate of watershed flows and pollutant loadings. The flow results were completed prior to the finalization of the NJDA hydrologic model. The limitations related to the NJDA model in Section 7, apply to this model as well. In particular, the depth gage data were inconsistent or unavailable in some cases and the rating curves were based on limited field flow measurements. Water level data may have been impacted by transient conditions, such as debris clogging the stream or shifting bed load. Additional flow and rating curve data, along with additional channel information, and the comparison of watershed flow to the USGS station at Jumping Brook, additional flow versus depth data would improve understanding and modeling of flow.

The SWMM model estimates watershed loadings of various water pollutants to Wreck Pond, demonstrating that existing land uses provide significant pollutant loads. This highlights the need to control watershed loadings to improve the quality of Wreck Pond. Although Wreck Pond Brook provides the largest contribution to the loads due in large measure to its larger flow, Hannabrand Brook provides higher unit loading rates for certain parameters.

The model also shows the important function of the Ponds on Wreck Pond Brook in controlling flow and water quality. This Brook showed a net loss of pollutant load for TSS and TP from the upper to the lower water quality station. If these Ponds cease to function to retain sediment and associated pollutants, loadings to the Pond will increase. The NJDA modeling showed a similar function for the Spring Lake golf course as a detention feature in the lower watershed.

Given the lack of control structures on Hannabrand Brook and the relatively high TSS concentrations seen here, more opportunities to improve water quality may be found in this sub-basin as reflected in the BMP suggestions in Book 2. The highly developed Wreck Pond direct sub-watershed generates roughly about 15-25% of the nutrient loadings and 9-18% of the bacteria loadings to the Pond. Implementation of stormwater BMPs in developed areas of the watershed, as discussed in Book 2, may reduce loadings of these parameters.

Future refinement of the SWMM model with additional water quality, pollutant generation, and flow data would provide additional understanding of watershed contributions of pollutants. The model demonstrates that the watershed is generating significant pollutant loads. Controlling existing watershed pollutant sources and stormwater flows will provide water quality benefits to Wreck Pond, other watershed ponds, and tributary streams.

9 RECHARGE

Recharge is degree to which precipitation infiltrates into the ground to become groundwater. Infiltration depends on geologic and soil condition, as well as land use. The more impervious surface there is in an area, the less infiltration, and thus recharge of groundwater is possible.

The NJ Geologic Survey (NJGS) has developed a method to calculate recharge rates and volumes in New Jersey. This method uses soils, land use categories, a climate factor and a recharge factor to come up with a recharge rate. This rate can be multiplied by the land area to calculate recharge volume. However, the method is useful for recharge volumes primarily for smaller sites.

In order to investigate the impact of development on recharge, an analysis was conducted using the NJGS Method. Figure 18 presents the overall recharge rates for the Wreck Pond Watershed using the existing land use, soils from the Monmouth County GIS, and the NJGS model. For simplicity, it was assumed that the location was Wall Township, since this encompasses most of the watershed.

Wreck Pond Brook is within Watershed Management Area 12. For this area, the NJGS has developed Recharge Rank Categories as follow:

A	>16 Inches per year
B	12-16 in per year
C	9-11 in per yr
D	1-8 in per yr
E	0 in per yr

Under the existing condition, recharge occurs can be calculated for about 6,325 acres of the about 8,172 acres. The analysis of ranks is as follows in Table 26 and illustrated on Figure 18. The remaining area is either water, has hydric soils (L), or has soil types for which recharge can't be calculated.

Table 26: Existing Land Use Recharge Rankings

Recharge Rank	Acreage	Percent of Watershed
A	1146.8	18%
B	3077.3	48%
C	1313.0	21%
D	584.6	9%
E	196.9	3%

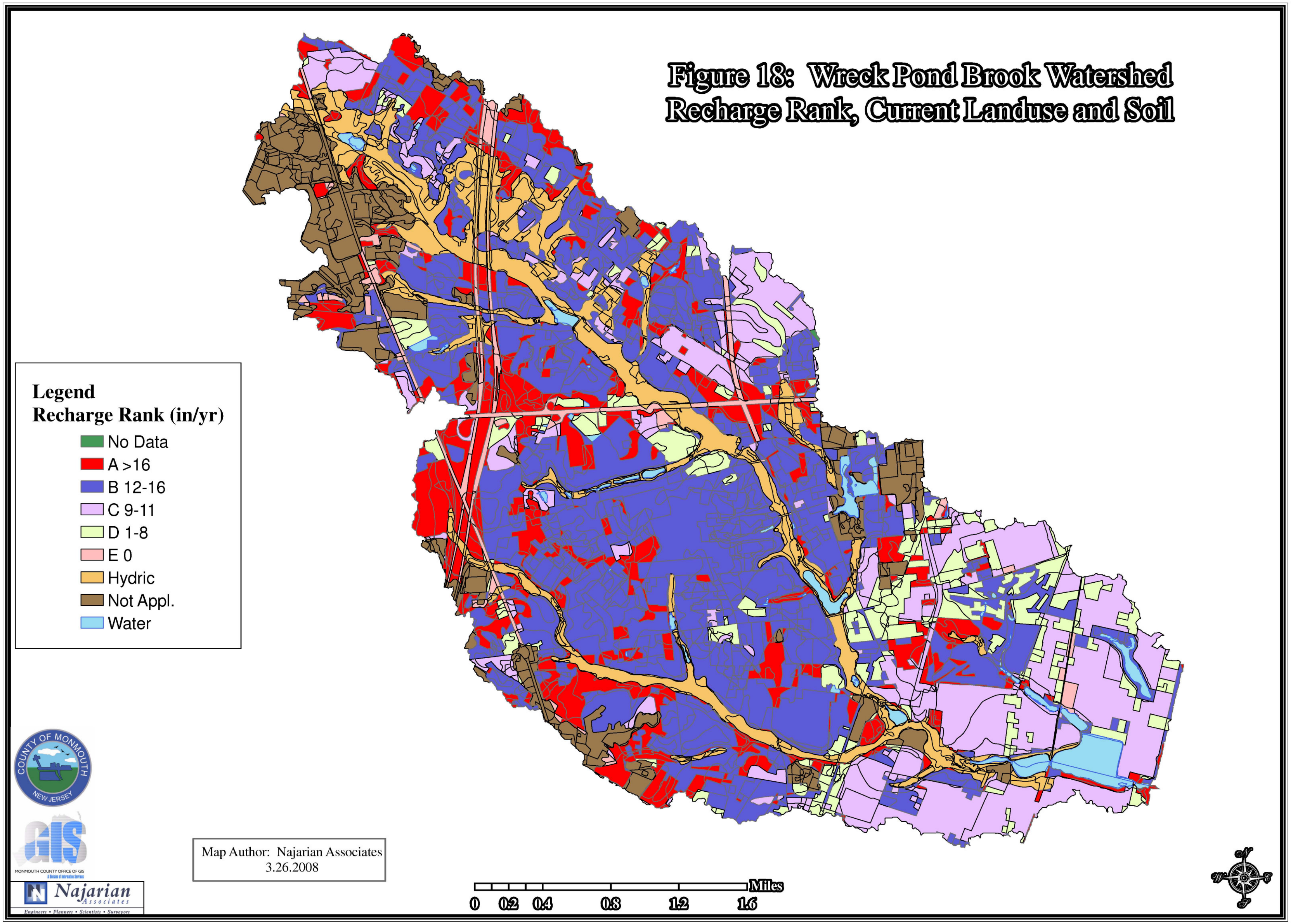


Figure 18: Wreck Pond Brook Watershed
Recharge Rank, Current Landuse and Soil
Legend
Recharge Rank (in/yr)
No Data
A >16
B 12-16
C 9-11
D 1-8
E 0
Hydric
Not Appl.
Water
Map Author: Najarian Associates
3.26.2008
0
0.2
0.4
0.8
1.2
1.6
Miles
COUNTY OF MONMOUTH
NEW JERSEY
GIS
MONMOUTH COUNTY OFFICE OF GIS
Najarian
Associates
Engineers • Planners • Scientists • Surveyors

9.1 Groundwater and Baseflow

Baseflow in streams is created by groundwater discharge. The discharge of groundwater varies depending on the elevation of the water-table. The local water table elevation varies with precipitation and with season. Typically, in New Jersey, the seasonal high water table occurs in the spring.

Baseflow in the main tributaries in the watershed were determined from flows during the SWMM and HEC modeling. Base flows ranges calculated were:

Wreck Pond Brook	2.5-7.5 cfs
Hannabrand Brook	2.0-4.0 cfs
Black Creek	2.0-3.5 cfs

Groundwater discharge to baseflow can also depend on any groundwater pumping from the local aquifers. Sections 7 and 8, above, discuss the hydrologic modeling done for this project and provides more detail on streamflow variation over time.

10 WATER QUALITY ASSESSMENT

Water quality data were collected under several study elements for this watershed management plan. Sections 5 and 6, above, summarize water quality data collected by RCE and MU in their studies. The following sections summarize the water quality sampling conducted by Monmouth County for this Plan and that done for the Spring Lake Borough Wreck Pond Environmental Study.

10.1 County Water Quality Sampling

Monmouth County collected water quality data at eight stations within the watershed for more than one year. Stations are shown on Figure 10 and listed in Table 12. Water quality data were collected for pH, temperature, TSS and two bacteria types: fecal coliform and enterococci. The data were collected weekly, generally on a Monday although sampling occasionally occurred on other weekdays. Figures 19 and 20 summarize this data.

Table 27 summarizes the data within Wreck Pond Brook from upstream to downstream for the conventional parameters while Table 28 summarizes the bacterial data. pH data shows a definite gradient moving downstream, with the lowest mean at W6 and the highest mean at W3. The maximum pH level, however, was recorded at W9.

Review of the bacterial constituents also shows the largest geometric mean at Station W9. The maximum bacterial count is difficult to determine, as some of the data were reported as “Too Numerous to Count”. W9 is the outlet from Hurley’s Pond. Thus, the data here may be affected by Pond conditions.

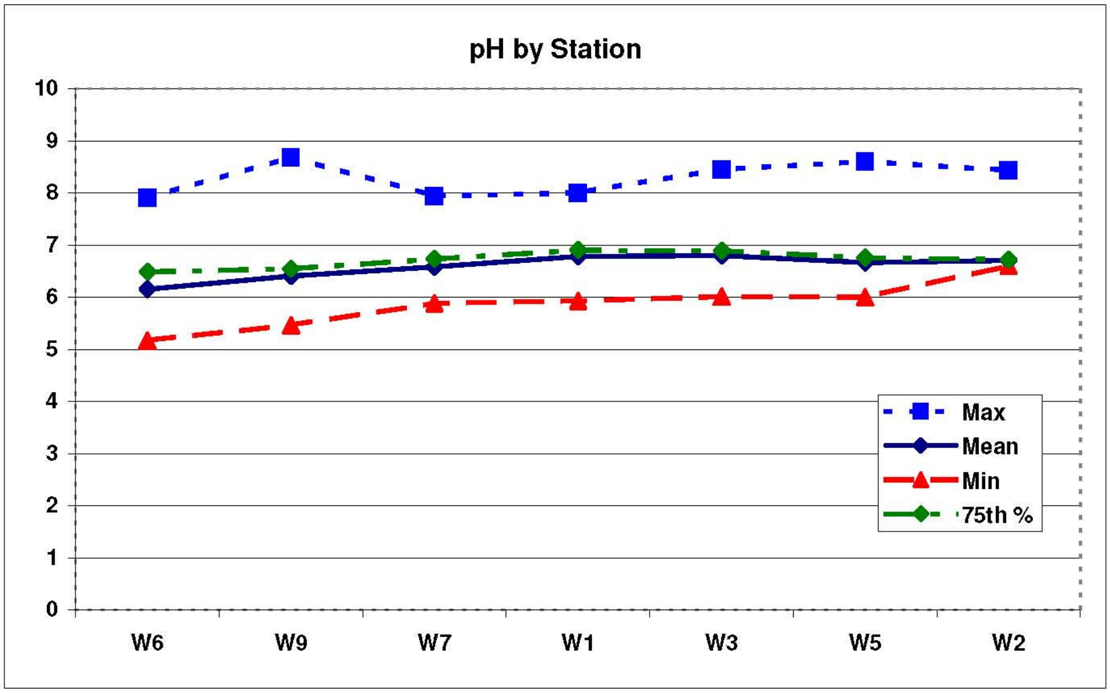
Table 29 summarizes the data for Hannabrand Brook for conventional parameters, while Table 30 summarizes the bacteria data

Bacteria levels in the two streams are similar. Neither station in Hannabrand Brook has levels as high as noted at Station W9. Elevated bacteria levels occur at both stations at certain times. The levels of fecal coliform at W2 were above the standard of 200 count/100 ml at least 24% of the time.

pH in Hannabrand Brook is similar to that found in the mid- to lower reaches of Wreck Pond Brook. The low pH levels found at W6 and W9, the upstream stations in Wreck Pond Brook, are not found. Temperature levels are similar to those in the middle sections of Wreck Pond Brook. For TSS, the mean values for Hannabrand Brook are the same as Wreck Pond Brook stations W7 and W1. The maximum TSS values in Wreck Pond Brook are substantially higher than at W7 and slightly higher than at W1. However, the peaks are not as high as at W9.

Tables 31 and 32 summarize the data for the Black Creek Station.

Figure 19: Monmouth County Weekly Sampling Summary of Results



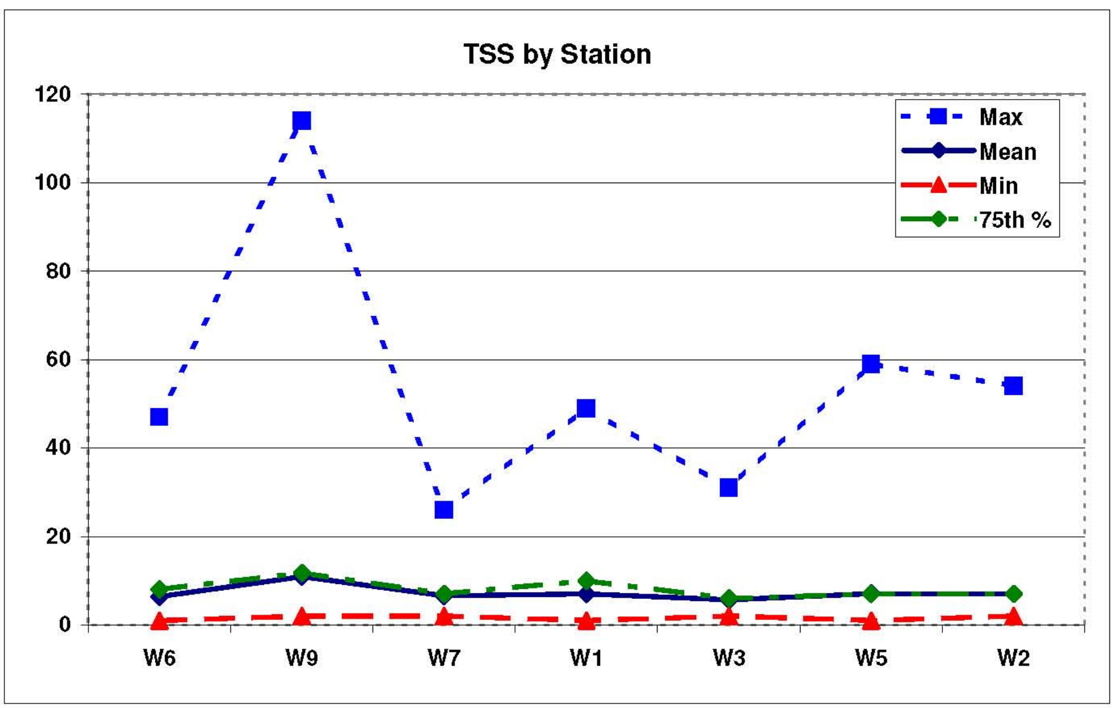
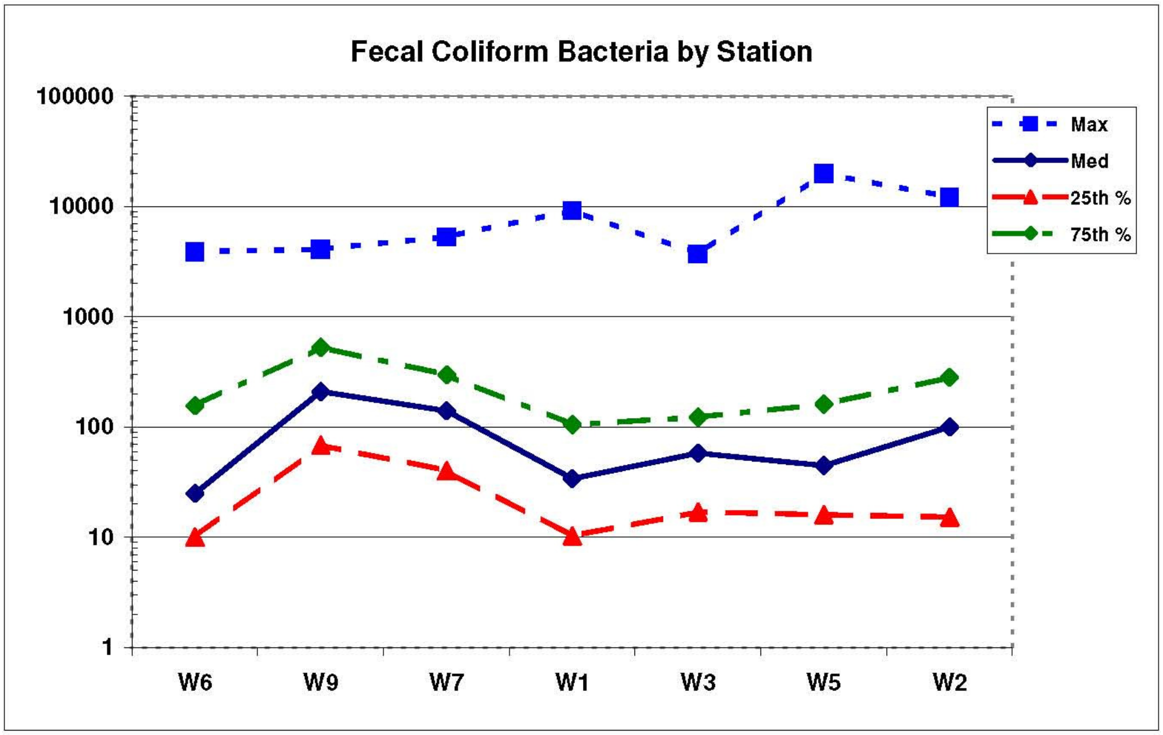


Figure 20: Monmouth County Weekly Sampling: Summary of Bacteria Results



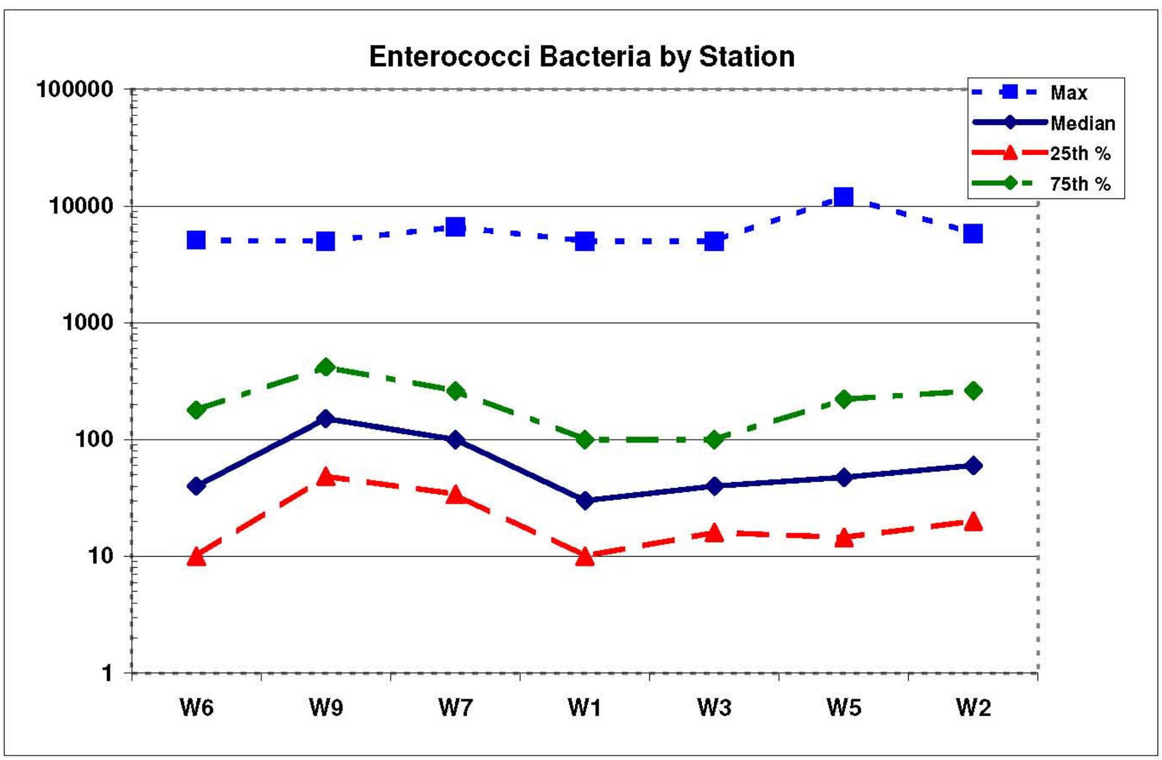


Table 27: County Water Quality Data Wreck Pond Brook - Conventional Parameters								
	N	Mean	Median	Max	Min	25th	75th	StdDev
pH								
W6	64	6.15	6.07	7.90	5.17	5.79	6.49	0.53
W9	64	6.40	6.30	8.68	5.46	6.07	6.54	0.55
W7	63	6.58	6.50	7.94	5.88	6.32	6.73	0.41
W1	64	6.78	6.73	8.00	5.93	6.63	6.90	0.40
W3	63	6.80	6.74	8.45	6.01	6.63	6.89	0.35
Temperature								
W6	62	15.0	14.8	25.8	3.3	11.8	19.1	5.2
W9	62	15.8	16.0	26.6	3.4	11.7	20.6	6.0
W7	62	16.0	15.9	26.0	3.5	11.7	20.5	5.8
W1	62	16.8	16.7	29.0	3.0	12.3	21.7	6.1
W3	62	16.4	16.2	31.2	3.0	11.2	21.1	6.7
TSS								
W6	58	6	4	47	1	3	8	7
W9	58	11	7	114	2	5	12	16
W7	58	7	4	26	2	3	7	6
W1	69	7	4	49	1	2	10	8
W3	58	6	3	31	2	3	6	5

Table 28: County Water Quality Data Wreck Pond Brook - Bacteria							
	N	GeoMean	Median	Max	Min	25th	75th
Fecal Coliform							
W6	70	40	25	3900	4	10	156
W9	70	174	209	TNTC	4	69	528
W7	70	96	140	5300	4	40	298
W1	70	41	34	9200	4	10	105
W3	70	49	58	3700	4	17	123
Enterococci Bacteria							
W6	70	45	40	5100	4	10	178
W9	70	149	150	TNTC	4	49	416
W7	70	97	100	6600	5	34	260
W1	70	36	30	TNTC	4	10	100
W3	70	46	40	TNTC	4	16	100

Table 29: County Water Quality Data Hannabrand Brook - Conventional Parameters								
	N	**Mean**	**Median**	**Max**	**Min**	**25th**	**75th**	**StdDev**
pH								
W5	63	6.66	6.55	8.60	6.00	6.47	6.76	0.40
W2	63	6.70	6.60	8.43	5.82	6.52	6.72	0.39
Temperature								
W5	62	15.9	16.2	27.0	3.9	11.5	19.8	5.7
W2	62	16.2	16.1	28.8	3.1	11.6	21.2	5.9
TSS								
W5	69	7	3	59	1	2	7	10
W2	69	7	4	54	2	3	7	8

Table 30: County Water Quality Data Hannabrand Brook - Bacteria							
	N	**GeoMean**	**Median**	**Max**	**Min**	**25th**	**75th**
Fecal Coliform							
W5	70	56	45	20000	4	16	160
W2	70	75	100	12100	4	15	283
Enterococci							
W5	70	59	48	12000	4	15	220
W2	70	75	70	5800	4	20	290

Table 31: County Water Quality Data Black Creek - Conventional Parameters								
	N	**Mean**	**Median**	**Max**	**Min**	**25th**	**75th**	**StdDev**
pH								
W8	63	6.73	6.69	8.45	5.89	6.55	6.83	0.38
Temperature								
W8	62	16.99	16.70	28.80	3.20	12.30	22.38	6.29
TSS								
W8	69	9.74	4.00	197.00	2.00	3.00	8.00	23.80

Table 32: County Water Quality Data Black Creek - Bacteria							
	N	GeoMean	Median	Max	Min	25th	75th
Fecal Coliform							
W8	70	61	90	5200	4	13	230
Enterococci							
W8	70	54	60	7300	4	13	159

Bacteria levels in the Black Creek station were similar to the other streams. There were no samples reported as too numerous to count.

10.2 Borough of Spring Lake Wreck Pond Environmental Study

The Borough of Spring Lake, under a USEPA grant, recently completed an Environmental Study of Wreck Pond conducted by NA. Several water quality monitoring programs were conduced for the Borough study. These included:

Ambient Pond and Tributary Sampling: These programs were designed to monitor the current ambient conditions within Wreck Pond and it direct tributaries. Three stations were monitored within the Pond and three within the tributaries for a period of one year with monthly samples for September, October, March and April and twice monthly samples during May through August.

Pollutant Budget Monitoring: This monitoring element was designed to monitor water quality during storm events to conduct pollutant load analyses and as input to the SWMM model discussed in Section 8. The program consisted of monitoring at three locations during two storm events.

Storm Outfall Monitoring: This element was designed to evaluate the contribution of direct stormwater discharges to the Pond. Monitoring was conducted at twelve outfall locations during one storm event.

Sediment Sampling: Sediment cores were taken from Wreck Pond and the Spring Lake. This sampling was designed to investigate bacterial levels in the Pond as well as other potential pollutants in the sediments in the Pond.

The following sections summarizes the monitoring programs and results. Additional information, including QA/QC reports, monitoring methods, and further data can be found in the Borough of Spring Lake's Wreck Pond Environmental Study. Figure 21 shows the sampling locations for the monitoring elements in this Study. Appendix F provides additional information.

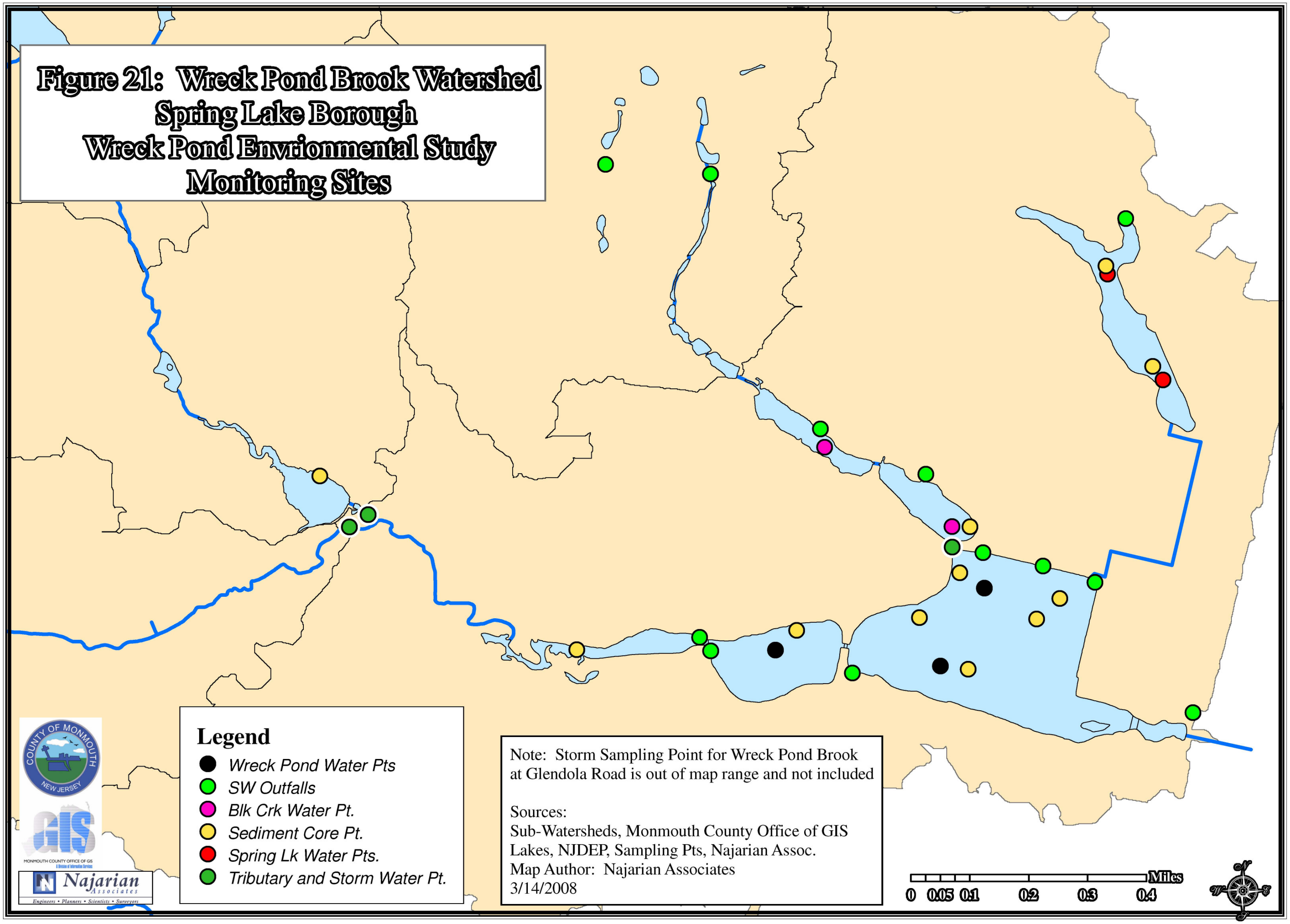


Figure 21: Wreck Pond Brook Watershed
Spring Lake Borough
Wreck Pond Envrionmental Study
Monitoring Sites
Legend
Wreck Pond Water Pts
SW Outfalls
Blk Crk Water Pt.
Sediment Core Pt.
Spring Lk Water Pts.
Tributary and Storm Water Pt.
Note: Storm Sampling Point for Wreck Pond Brook at Glendola Road is out of map range and not included
Sources:
Sub-Watersheds, Monmouth County Office of GIS
Lakes, NJDEP, Sampling Pts, Najarian Assoc.
Map Author: Najarian Associates
3/14/2008
Miles
0 0.05 0.1 0.2 0.3 0.4
COUNTY OF MONMOUTH
NEW JERSEY
GIS
Najarian
Associates

10.2.1 Pond Sampling

Three locations were sampled in the Pond as shown on Figure 21. The following field parameters were measured using a Horiba U-10 water quality meter and additional measuring instruments:

- pH
- Conductivity
- Temperature
- DO
- Turbidity
- Salinity
- Water depth (survey rod in Pond, staff gauge in streams)
- Secchi depth (only in Pond, using a secchi disk)

Grab samples were collected and sent to QC Laboratories for analysis. Samples were analyzed for the following parameters:

- Nitrate
- Nitrite
- TKN
- Ammonia
- Total Phosphorous
- Ortho-Phosphate
- CBOD
- Iron
- Manganese
- Hardness
- Alkalinity
- Chloride
- Turbidity
- TSS
- TDS
- Chlorophyll-a

In addition to chemical parameters, several bacteria groups were monitored, to evaluate the nature of bacteria in Wreck Pond. These are Fecal Coliform, Total Coliform, Fecal Streptococcus, Enterococci bacteria and Clostridium Perfringens. Algal counts were conducted and algae were identified at the genera level.

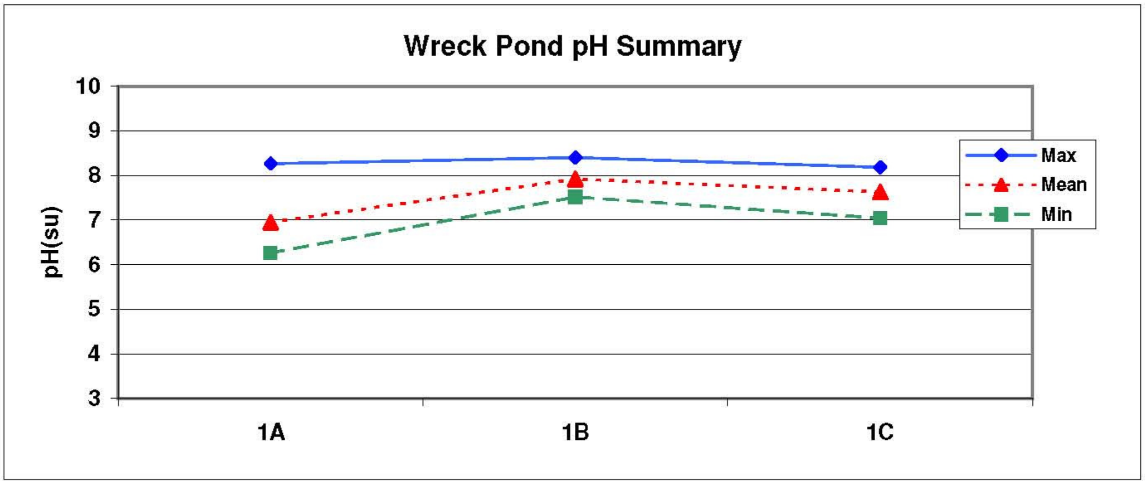
Tables 33 through 35 summarize the Pond water quality data. Figure 22 summarizes some of the Pond Monitoring data.

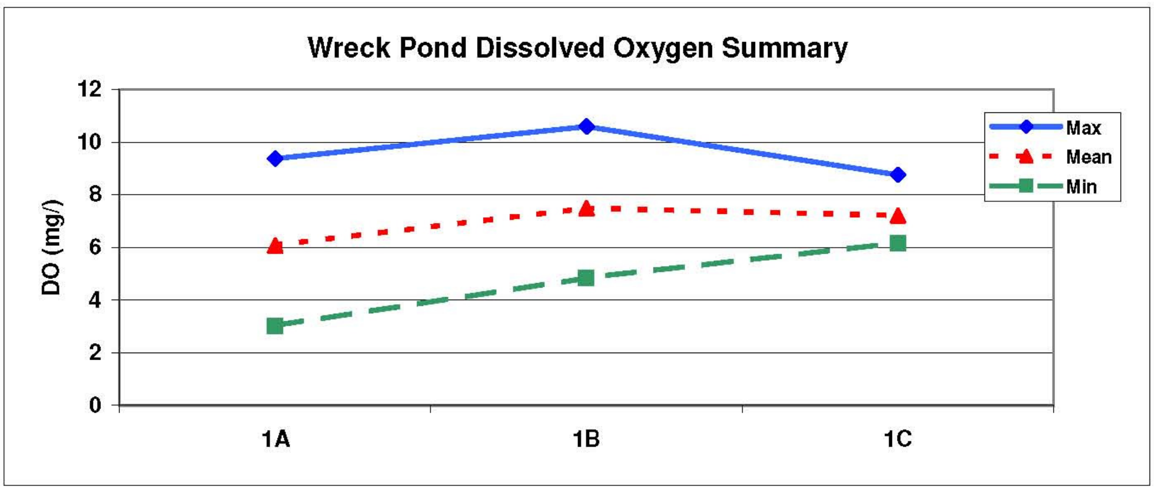
The overall quality of Wreck Pond is discussed in two separate sections: west and east of the Route 71 Bridge, as there were differences noted in the water quality conditions of the Pond in these areas.

Western Pond: The western portion of the Pond is characterized by Station WP1 and does not receive much tidal mixing, based on the limited salinity variation. This section of the Pond had earlier peaks in algal mass. DO was at a minimum in this area, dropping to just over 3 mg/l. Nitrate levels are higher in this portion of the Pond than at the other two stations. The average and minimum pH was lower in this part of the Pond. The turbidity average also was higher.

DO at Station WP1 shows a typical DO sag curve, with the minimum value in mid-summer. The minimum concentration of just over 3 mg/l is below the NJDEP standard

Figure 22: Spring Lake Wreck Pond Environmental Study
Wreck Pond Water Quality Results





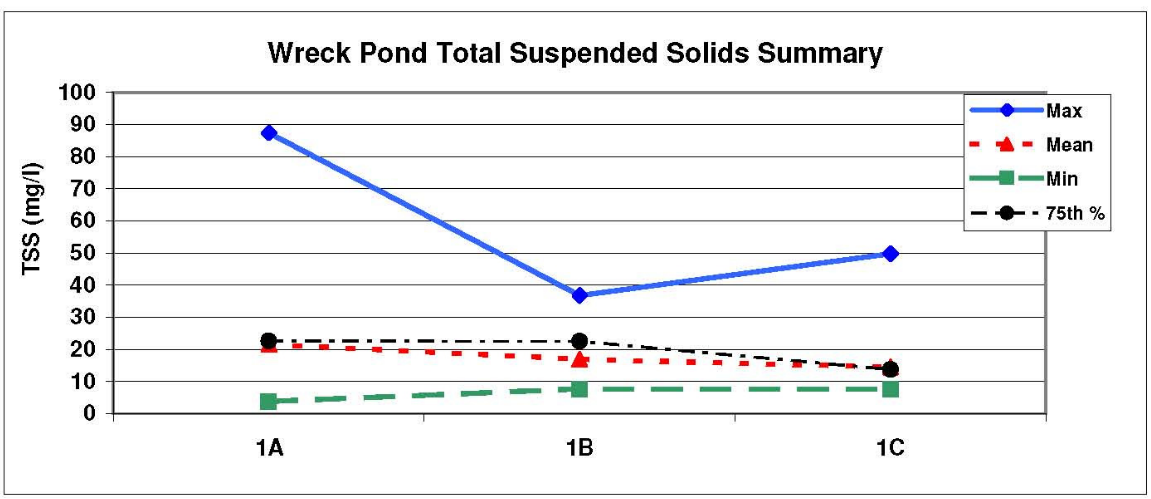
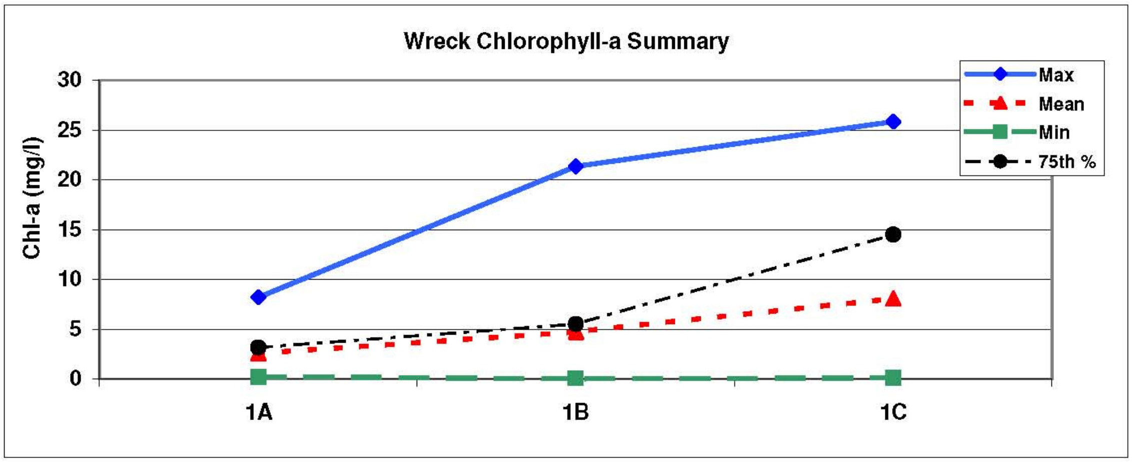
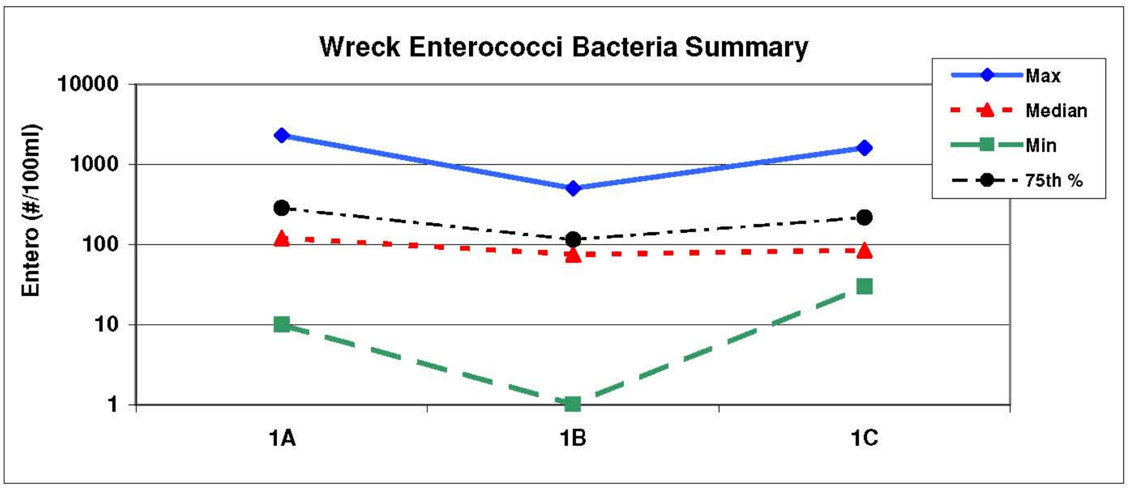


Figure 22: Spring Lake Wreck Pond Environmental Study
Wreck Pond Water Quality Results





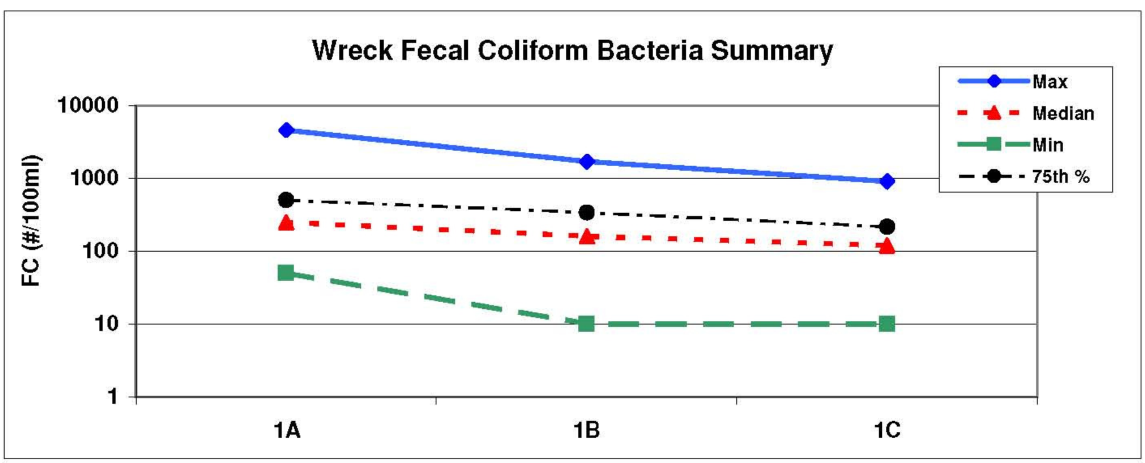


Table 33: Pond Sampling Results – WP1									
Parameter	**n**	**Units**	**Mean**	**Median**	**Max**	**Min**	**25th Percent**	**75th Percent**	**Std. Dev**
pH	12	su	6.95	6.87	8.26	6.26	6.54	7.26	0.54
Temperature	12	^{o}C	20.2	22.2	27.1	5.2	15.3	25.4	6.8
Dissolved Oxygen (DO)	12	mg/l	6.07	6.66	9.37	3.02	4.69	7.18	1.87
Spec Cond	12	mg/l	5.8	1.1	33.5	0.2	0.3	6.1	10.0
Turbidity (field)	11	ntu	21	18	70	5	9	24	19
WD Top Sed	12	ft	1.27	1.35	1.70	0.90	1.09	1.40	0.25
WD Bot Sed	8	ft	2.05	2.10	2.60	1.50	1.90	2.23	0.36
Salinity	12	%	0.33	0.07	2.13	0.00	0.01	0.26	0.63
Calcium Hardness	12	mg/l	63	35	280	18	21	51	78
Magnesium Hardn.	12	mg/l	191	72	940	12	14	155	299
Total Hardness	12	mg/l	252	105	1200	29	37	213	370
Calcium	12	mg/l	25.3	13.9	114.0	7.2	8.3	20.3	31.5
Iron	12	mg/l	1.124	1.095	1.930	0.641	0.782	1.253	0.423
Magnesium (Mg)	12	mg/l	47	17	229	3	3	39	73
Manganese (Mn)	12	mg/l	0.0668	0.0619	0.1130	0.0388	0.0494	0.0857	0.0235
Chloride	12	mg/l	1224	374	10600	42	52	596	2976
Alkalinity	12	mg/l	19.8	17.9	54.8	8.3	12.4	22.4	12.5
Tot Diss Solid (TDS)	12	mg/l	1639	458	12100	106	168	1235	3372
Tot Susp Solid (TSS)	12	mg/l	21.5	11.0	87.3	3.7	7.2	22.6	24.5
Turbidity (lab)	12	ntu	6	4	16	2	4	6	4
TKN	12	mg/l	0.628	0.695	1.290	0.300	0.300	0.820	0.324
Ammonia (NH_3-N)	12	mg/l	0.126	0.095	0.340	0.050	0.058	0.136	0.096
Nitrate (NO_3-N)	12	mg/l	0.44	0.50	0.84	0.10	0.34	0.58	0.23
OrthoPhosphate- PO_4-P	4	mg/l	0.015	0.014	0.020	0.011	0.012	0.017	0.004
Total Phosphorus	12	mg/l	0.092	0.055	0.550	0.020	0.036	0.069	0.146
Chlorophyll-a	12	mg/m^3	2.555	1.765	8.179	0.214	0.595	3.148	2.490
Carbon BOD	2[a]	mg/l	--	--	4.1	2.1	--	--	--
Clostridium Perfringens	6	/ml	--	35	120	10	15	47.5	--
Total Coliform	12	c/100ml	--	1150	4600	150	500	2250	--
Enterococci	12	c/100ml	--	120	2300	10	55	285	--
Fecal Coliform	12	c/100ml	--	250	4600	50	120	500	--
Fecal Streptococcus	12	mpn/100ml	--	950	6000	200	420	4900	--
[a]Other samples non-detect; all samples analyzed for parameter									

Table 34: Pond Sampling Results – WP2									
Parameter	**n**	**Units**	**Mean**	**Median**	**Max**	**Min**	**25th Percent**	**75th Percent**	**Std. Dev**
pH	12	su	7.92	7.81	8.40	7.52	7.72	8.20	0.32
Temperature	12	^{o}C	20.8	23.3	27.8	6.0	16.4	24.8	6.4
Dissolved Oxygen (DO)	12	mg/l	7.49	7.32	10.58	4.84	6.08	8.86	1.87
Spec Cond	12	mg/l	30.3	30.8	44.1	7.5	25.9	39.8	10.7
Turbidity (field)	11	ntu	14	10	61	3	7	15	16
WD Top Sed	12	ft	1.32	1.33	1.90	0.78	1.14	1.47	0.34
WD Bot Sed	8	ft	2.01	1.96	2.30	1.80	1.88	2.14	0.19
Salinity	12	%	1.86	1.98	2.79	0.40	1.42	2.60	0.74
Calcium Hardness	12	mg/l	416	440	750	130	305	490	183
Magnesium Hardn.	12	mg/l	2038	2100	3300	580	1475	2625	922
Total Hardness	12	mg/l	2446	2550	4000	710	1750	3125	1095
Calcium	12	mg/l	166.2	175.0	299.0	51.6	123.4	196.5	73.3
Iron	12	mg/l	0.492	0.423	0.766	0.257	0.327	0.678	0.185
Magnesium (Mg)	12	mg/l	493	509	793	141	358	635	222
Manganese (Mn)	11	mg/l	0.0398	0.0395	0.0785	0.0218	0.0286	0.0457	0.0155
Chloride	12	mg/l	9651	9230	18200	2350	7620	11250	4713
Alkalinity	12	mg/l	68.5	74.4	90.5	35.7	57.5	78.8	16.5
Tot Diss Solid (TDS)	12	mg/l	15143	16350	24300	5350	8838	19075	6370
Tot Susp Solid (TSS)	12	mg/l	16.9	11.3	36.7	7.7	8.8	22.5	10.7
Turbidity (lab)	12	ntu	3	3	6	2	3	4	1
TKN	12	mg/l	0.584	0.380	1.350	0.300	0.300	0.745	0.379
Ammonia (NH_3-N)	12	mg/l	0.106	0.060	0.370	0.050	0.050	0.106	0.100
Nitrate (NO_3-N)	12	mg/l	0.24	0.11	0.63	0.10	0.10	0.31	0.20
OrthoPhosphate- PO_4-P	3[a]	mg/l	0.030	0.014	0.061	0.014	0.014	0.038	0.027
Total PHosphorus	12	mg/l	0.043	0.045	0.079	0.010	0.027	0.058	0.022
Chlorophyll-a	12	mg/m^3	8.014	3.889	27.670	0.000	0.381	14.453	9.663
Carbon BOD	2[a]	mg/l	--	--	4	3.1	--	--	--
Clostridium Perfringens	3[a]	/ml	--	10	300	10	--	--	--
Total Coliform	11	c/100ml	--	300	4600	30	80	780	--
Enterococci	12	c/100ml	--	75	500	1	18	115	--
Fecal Coliform	12	c/100ml	--	160	1700	10	50	338	--
Fecal Streptococcus	11	mpn/100ml	--	230	1100	60	150	455	--

[a]Other samples non-detect; all samples analyzed for parameter

Table 35: Pond Sampling Results – WP3									
Parameter	**n**	**Units**	**Mean**	**Median**	**Max**	**Min**	**25th Percent**	**75th Percent**	**Std. Dev**
pH	12	su	7.63	7.64	8.18	7.04	7.44	7.79	0.31
Temperature	12	^oC	20.3	21.9	27.8	5.7	16.0	24.3	6.6
Dissolved Oxygen (DO)	12	mg/l	7.21	7.08	8.75	5.91	6.45	7.85	0.98
Spec Cond	12	mg/l	27.4	27.6	40.2	11.5	22.5	34.3	9.2
Turbidity (field)	11	ntu	10	6	22	4	5.5	14	6
WD Top Sed	12	ft	1.31	1.32	1.75	0.69	1.08	1.60	0.34
WD Bot Sed	8	ft	1.69	1.75	1.96	1.24	1.56	1.91	0.26
Salinity	12	%	1.65	1.56	2.56	0.51	1.33	2.25	0.66
Calcium Hardness	12	mg/l	394	395	810	120	268	483	204
Magnesium Hardn.	12	mg/l	1931	1900	3500	540	1250	2425	996
Total Hardness	12	mg/l	2318	2300	4200	660	1520	2875	1192
Calcium	12	mg/l	157.4	158.5	323.0	47.5	108.0	192.8	81.1
Iron	12	mg/l	0.548	0.528	1.020	0.277	0.325	0.696	0.249
Magnesium (Mg)	12	mg/l	468	461	844	131	310	585	241
Manganese (Mn)	11	mg/l	0.0431	0.0379	0.0829	0.0241	0.0315	0.0485	0.0180
Chloride	12	mg/l	9341	9670	15900	2580	7217.5	11350	4062.
Alkalinity	12	mg/l	62.9	61.7	97.4	34.9	55.8	72.2	16.9
Tot Diss Solid (TDS)	12	mg/l	13916	13300	24400	5300	10453	18875	5890
Tot Susp Solid (TSS)	12	mg/l	14.5	11.4	49.7	7.7	8.9	13.7	11.5
Turbidity (lab)	12	ntu	3	3	6	2	2	4	1
TKN	12	mg/l	0.45	0.32	0.94	0.3	0.3	0.545	0.217
Ammonia (NH_3-N)	12	mg/l	0.144	0.071	0.540	0.050	0.050	0.148	0.152
Nitrate (NO_3-N)	12	mg/l	0.17	0.11	0.45	0.10	0.10	0.18	0.11
OrthoPhosphate- PO_4-P	2	mg/l	0.012	0.012	0.012	0.011	0.011	0.012	0.001
Total PHosphorus	12	mg/l	0.047	0.039	0.110	0.010	0.026	0.057	0.031
Chlorophyll-a	12	mg/m^3	8.067	3.716	25.820	0.100	0.421	14.478	9.256
Carbon BOD	3[a]	mg/l	3.4	--	5.1	2.3	--	--	--
Clostridium Perfringens	4[a]	/ml	--	15	20	10	--	--	--
Total Coliform	12	c/100ml	--	450	3500	70	107.5	900	--
Enterococci	12	c/100ml	--	85	1600	30	65	217.5	--
Fecal Coliform	12	c/100ml	--	120	900	10	57.5	215	--
Fecal Streptococcus	12	Mpn/100ml	--	370	3700	30	200	1350	--
[a]Other samples non-detect; all samples analyzed for parameter									

of 4 mg/l and indicates possibly stressed conditions. However, by the next monitoring event two weeks later the DO had recovered and was above 4 mg/l. DO in the western section remained lower than in the Central section of the Pond throughout the summer.

Eastern (Main) Pond: Stations WP2 and WP3 characterize the main section of the Pond between Route 71 and the Railroad Bridge. This portion of the Pond is shallow and the bottom is very mucky. Movement of the boat during sampling disturbed the sediments. This portion of the Pond is influenced by tidal action.

The central part of the pond has higher DO, with the minimum at 4.8 mg/l. During the hottest part of the summer, the DO concentrations at Stations WP2 and WP3 were above the oxygen saturation level for the water temperature. Supersaturated DO can indicate that oxygen is being added to a water body through photosynthetic organisms. However, that is typically accompanied by excessive respiration at night which may drop the DO level significantly, causing DO levels below standard. As discussed further below, the period of DO super-saturation are accompanied by elevated, but not maximum, chlorophyll-a data (which indicates algal growth). DO in the central part of the Pond also is influenced by tidal action, which adds mixing to the system and increases DO.

Bacteria levels increased throughout the summer. During much of the summer, bacteria levels were above the NJDEP standard. Maximum Enterococci bacteria counts were at 1,600 #/100ml and 2,300 #/100ml at Stations WP3 and WP1, respectively at the end of August. Fecal coliform concentrations peaked at 4,600 #/100ml at WP1 and 1,700 #/100ml at WP2 in mid- to late-August.

Total phosphorus was above the NJDEP standard of 0.05 mg/l for the summer months. While common in New Jersey lakes and ponds, this indicates there is sufficient phosphorus enrichment to produce algal growth. Ortho-phosphate is generally low and is higher at Station WP1 than the other two stations.

Algal growth peaked first at Station WP1; with green algae predominate in June. In July, the green algae peaked at Station WP2, with increasing blue-green algae. Peak algal growth peaked later at Station WP3. The main section of the Pond had higher algae counts than in the western section.

The algae were dominated by green algae at the beginning of the season. The percentage of cyanobacteria, so-called blue-green algae, increased over the summer. The blue-green algae fraction increased to about 40-43% in the late summer. At Station WP3, less fluctuation was noted. At both mid-pond stations, diatom counts peaked in mid-July at 30-32%, dropping to 14-15% in the late summer.

Summer data were reviewed to determine the overall characterization of the Pond water quality. Summer chlorophyll-a averaged 11.9 ug/l, with a peak value of 27.7 ug/l. The EPA nutrient guidance document for lakes provides levels of water quality parameters that characterize trophic states in lakes. The trophic levels have overlapping ranges for these parameters, as the value of one parameter may vary in a lake considered eutrophic. The guidance document uses nutrient, chlorophyll-a, secchi depth, oxygen in the hypoliminion, and fish parameters data to classify lakes. In this case, nutrient and chlorophyll-a data are available. However, Wreck Pond is very shallow so that secchi depth is meaningless and there is no hypoliminion.

The concentrations of the available parameters fall within the eutrophic range. The peak chlorophyll–a 27.7 ug/l is below the average peak for eutrophic lakes (43) but above the average peak for mesotrophic lakes (16). Phosphorus mean is 0.045 mg/l for all of the data and 0.054 mg/l for the summer data. These values are within the eutrophic range, and also in the upper range of the mesotrophic. The average Total N is 0.72 mg/l with 0.71 mg/l in the summer. The maximum value is 1.590 mg/l. The mean N is below the mesotrophic total N mean of 0.79 mg/l, but with the exception of the minimum value, the range of Total N concentrations (0.358-1.590) fall within the eutrophic range of 0.139-1.600 mg/l.

The algal community composition is a component of eutrophication level. In the main portion of Wreck Pond, up to 43% of the algae at Station WP2 and 38% at WP3 are blue-green algae. Thus, a substantial proportion of the algae in the Pond are blue-green, often indicative of more eutrophic conditions. .

Thus, Wreck Pond is a mesotrophic/eutrophic water with nitrogen, phosphorus and chlorophyll-a values within the eutrophic range. Further nutrient enrichment will continue the eutrophication process.

Bacteria levels were somewhat higher in the western Pond, particularly for fecal coliform and fecal streptococcus. However, enterococci counts were similar in both sections. This may be due to the higher die-off of the bacteria species in saline waters or other factors.

10.2.2 Tributary Results

Three tributary stations were monitored. There are shown on Figure 21 and are:

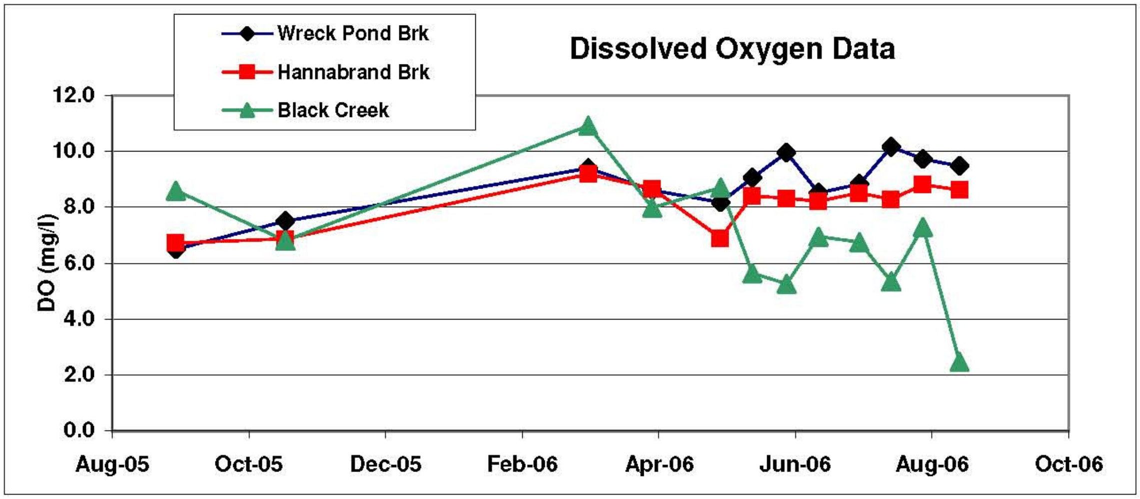
WB1: Wreck Pond Brook at Old Mill Road, downstream side of culvert
HB: Hannabrand Brook at Old Mill Road, upstream side of culvert
BC: Black Creek at Ocean Road Weir, at intersection of Ocean and Shore Roads

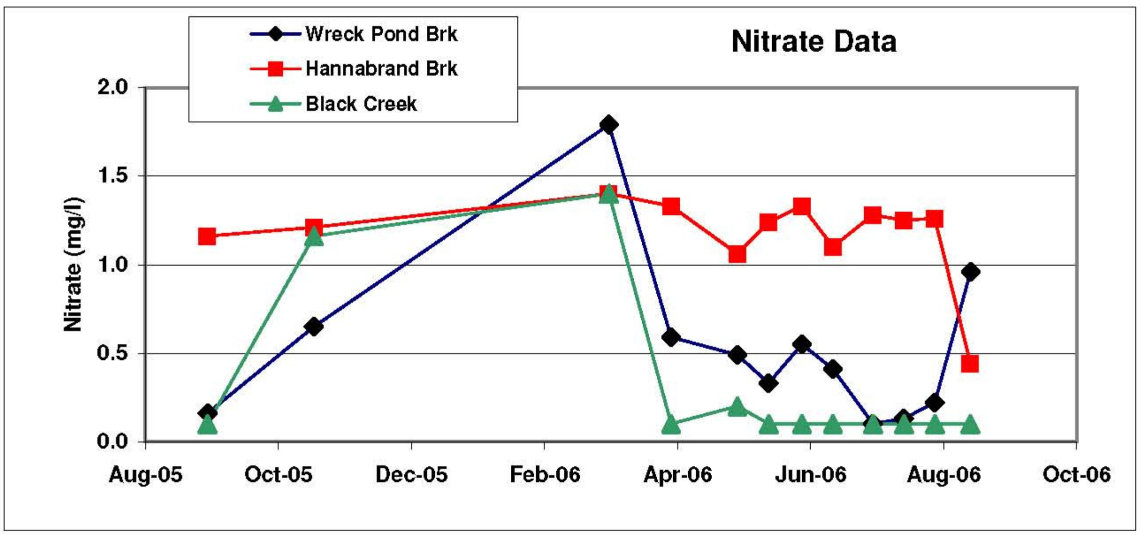
Stations WB1 and HB are located in the vicinity of County gaging stations W3 and W2, respectively. The BC station is farther downstream than County gage W8.

Table 36 through 38 summarize the tributary monitoring results. Figure 23 illustrates results for some parameters and additional information is provided in Appendix F.

Average Total Phosphorus was below standard at all three stations, although the concentrations were highest in Black Creek and exceeded the state standard of 0.1 mg/l from mid-July through the end of the summer. The peak phosphorus concentration in Black Creek was 0.273 mg/l on the last sampling day on August 30. As noted above, DO at this station was low at this time. Some of the phosphorus may be released from

Figure 23: Spring Lake Wreck Pond Environmental Study
Tributary Analyses





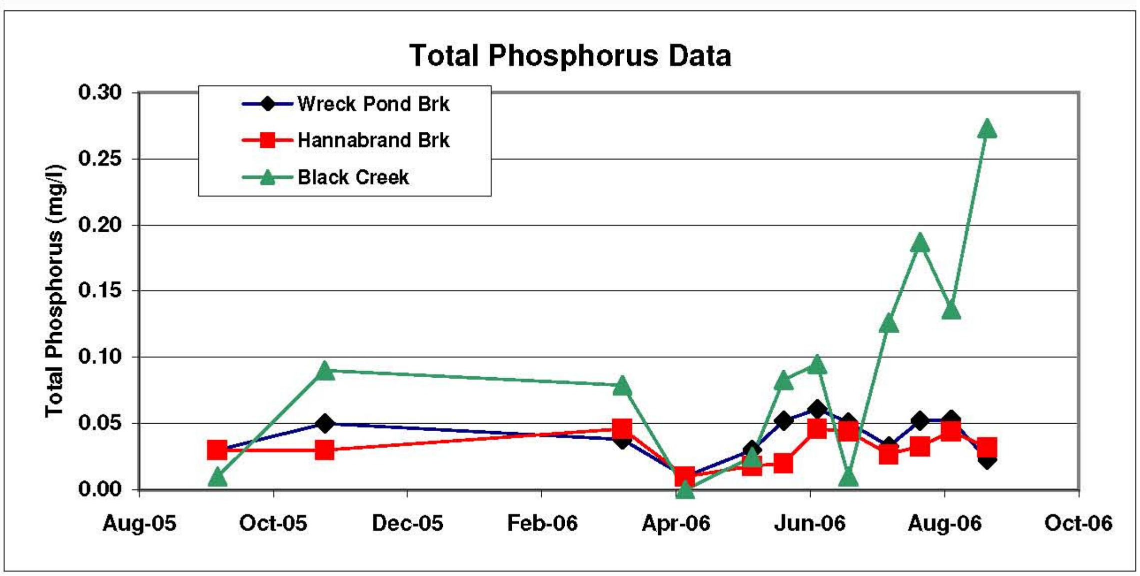
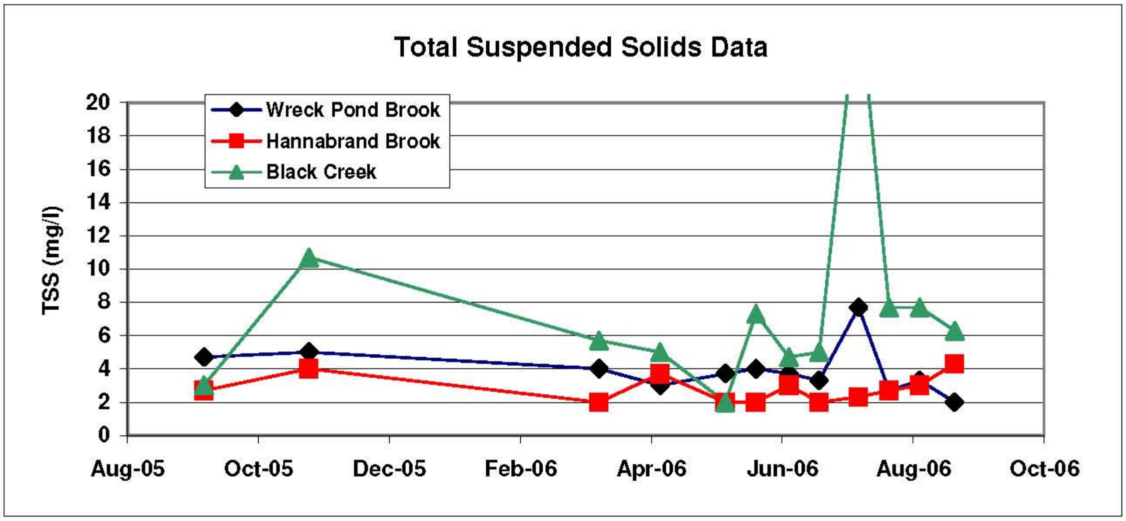
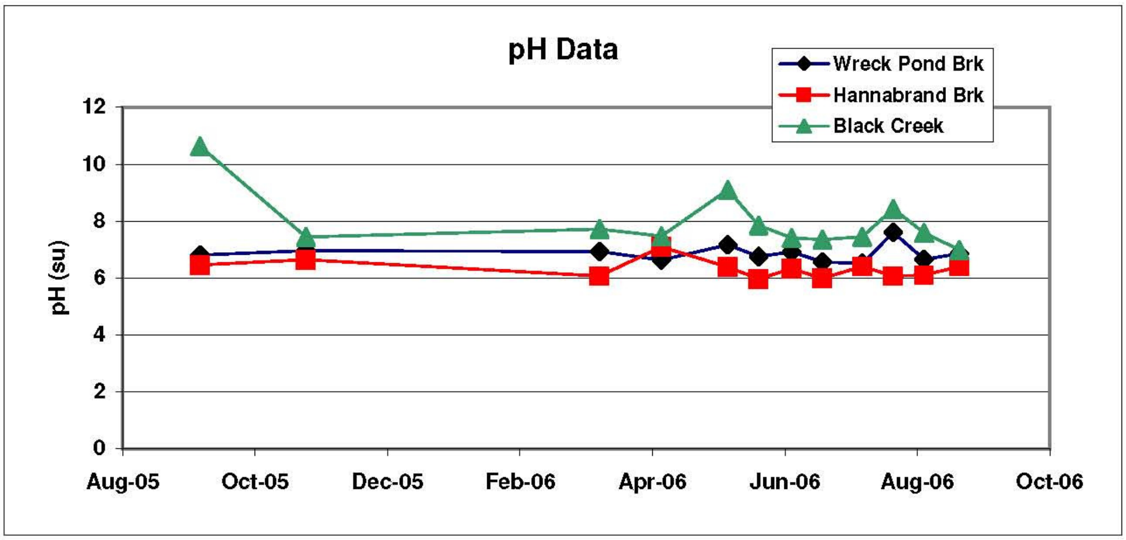


**Figure 23: Spring Lake Wreck Pond Environmental Study
Tributary Analyses**





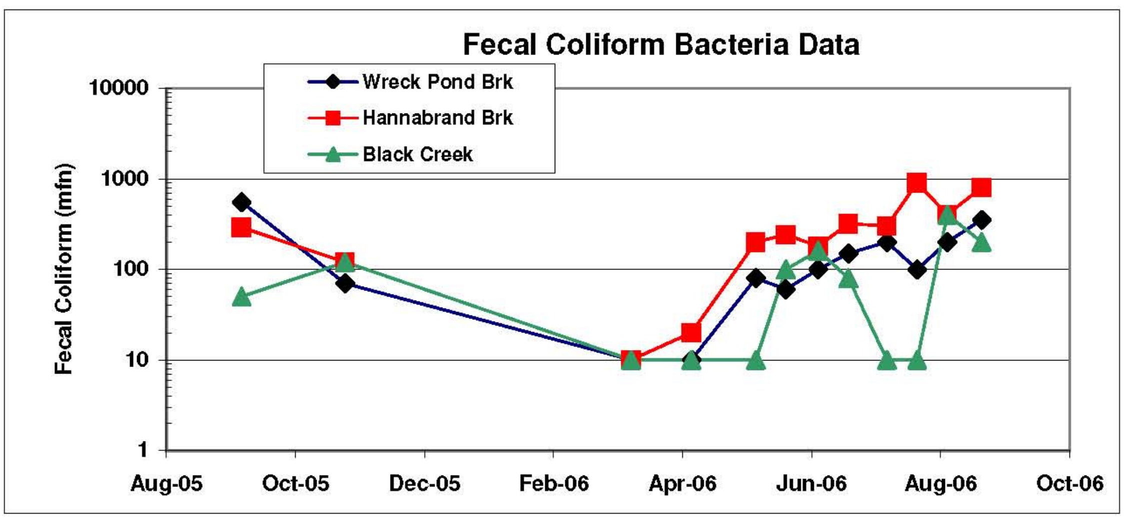


Table 36: Summary of Monitoring Data - Wreck Pond Brook									
	Units	**n**	**Mean**	**Med**	**Std Dev**	**Max**	**Min**	**75th Perc**	**25th Perc**
pH	su	12	6.86	6.83	0.30	7.60	6.51	6.94	6.65
Temperature	^{o}C	12	21.9	23.5	6.5	30.3	7.4	25.4	18.7
Dissolved Oxygen	mg/l	12	8.82	8.94	1.06	10.15	6.50	9.53	8.43
Specific Conductance	mg/l	12	0.22	0.22	0.02	0.26	0.19	0.23	0.21
Field Turbidity	ntu	12	7.50	6.50	4.19	18.00	4.00	9.00	4.00
Water Level	ft	12	0.86	0.87	0.11	1.00	0.68	0.96	0.76
Calcium Hardness	mg/l	12	20	20	3	24	14	21	19
Magnesium Hardness	mg/l	12	11	12	2	13	8	12	11
Total Hardness	mg/l	12	31	32	4	37	22	33	30
Calcium	mg/l	12	7.84	7.95	1.01	9.57	5.59	8.36	7.44
Iron	mg/l	12	1.137	1.160	0.297	1.570	0.713	1.348	0.923
Magnesium	mg/l	12	2.80	2.88	0.35	3.17	2.01	3.04	2.72
Manganese	mg/l	12	0.046	0.043	0.013	0.067	0.030	0.056	0.037
Chloride	mg/l	12	45.2	43.2	5.5	58.7	38.1	46.4	42.8
Alkalinity	mg/l	12	10.36	10.30	2.57	14.80	4.60	11.50	9.73
Total Dissolved Solids	mg/l	12	148	146	16	180	131	153	136
Total Suspended Solids	mg/l	12	3.9	3.7	1.4	7.7	2.0	4.2	3.2
Turbidity (lab)	ntu	12	3.249	3.125	1.522	7.140	0.324	3.348	2.830
TKN	mg/l	12	0.597	0.600	0.212	0.970	0.300	0.720	0.488
Ammonia (NH3-N)	mg/l	12	0.082	0.070	0.043	0.190	0.050	0.088	0.050
Nitrate (NO3-N)	mg/l	12	0.532	0.450	0.470	1.790	0.100	0.605	0.205
Total Phosphorus	mg/l	12	0.040	0.044	0.015	0.061	0.010	0.052	0.030
Total Coliform	#/100 ml	12		645		3600	30	1075	375
Enterococci	#/100 ml	12		40		700	10	60	10
Fecal Coliform	#/100 ml	12		100		550	10	200	68
Fecal Streptococcus	#/100 ml	12		415		4400	30	1450	200

Table 37: Summary of Monitoring Data – Hannabrand Brook									
	Units	**n**	**Mean**	**Med**	**Std Dev**	**Max**	**Min**	**75th Perc**	**25th Perc**
pH	su	12	6.32	6.35	0.32	7.09	5.96	6.42	6.07
Temperature	°C	12	17.4	18.4	4.3	22.5	7.6	20.2	14.8
Dissolved Oxygen	mg/l	12	8.12	8.36	0.83	9.18	6.72	8.63	7.88
Specific Conductance	mg/l	12	0.20	0.20	0.01	0.23	0.18	0.20	0.19
Field Turbidity	ntu	12	14.92	5.50	19.65	68.00	4.00	14.50	4.00
Water Level	ft	12	1.17	1.16	0.07	1.31	1.10	1.20	1.12
Calcium Hardness	mg/l	12	21	21	2	25	18	21	20
Magnesium Hardness	mg/l	12	14	15	1	16	12	15	14
Total Hardness	mg/l	12	35	36	3	41	30	36	34
Calcium	mg/l	12	8.35	8.21	0.67	9.92	7.25	8.61	8.06
Iron	mg/l	12	0.701	0.682	0.140	0.941	0.404	0.799	0.634
Magnesium	mg/l	12	3.52	3.58	0.30	3.87	2.94	3.74	3.42
Manganese	mg/l	12	0.043	0.041	0.008	0.059	0.032	0.044	0.037
Chloride	mg/l	12	35.2	33.9	4.3	45.9	30.1	36.2	32.7
Alkalinity	mg/l	10	10.71	10.70	1.16	12.40	8.84	11.20	10.13
Total Dissolved Solids	mg/l	12	1658	130	5304	18500	89	136	125
Total Suspended Solids	mg/l	12	2.8	2.7	0.8	4.3	2.0	3.2	2.0
Turbidity (lab)	mg/l	12	1.766	1.770	0.634	2.850	0.258	1.995	1.613
TKN	mg/l	12	0.503	0.500	0.168	0.860	0.300	0.583	0.398
Ammonia (NH3-N)	mg/l	12	0.112	0.100	0.050	0.250	0.056	0.120	0.090
Nitrate (NO3-N)	mg/l	12	1.172	1.245	0.250	1.400	0.440	1.293	1.145
Total Phosphorus	mg/l	12	0.032	0.031	0.012	0.046	0.010	0.044	0.025
Total Coliform	#/100 ml	12		1200		7000	90	2550	700
Enterococci	#/100 ml	12		265		600	10	405	105
Fecal Coliform	#/100 ml	12		265		900	10	340	165
Fecal Streptococcus	#/100 ml	12		750		5400	20	3525	313

Table 38: Summary of Monitoring Data – Black Creek									
	Unit	**n**	**Mean**	**Med**	**Std Dev**	**Max**	**Min**	**75th Perc**	**25th Perc**
pH	su	12	7.95	7.53	1.01	10.63	6.99	8.00	7.43
Temperature	^{o}C	12	22.1	23.9	6.6	30.1	7.3	26.0	19.0
DO	mg/l	12	6.89	6.88	2.13	10.91	2.47	8.13	5.57
Specific Conduc	mg/l	12	0.30	0.28	0.08	0.47	0.21	0.35	0.25
Field Turbidity	ntu	12	9.00	7.00	5.98	24.00	4.00	11.00	5.00
Water Level	ft	12	2.37	2.38	0.16	2.55	2.00	2.50	2.29
Calcium Hardness	mg/l	12	44	45	9	59	29	49	39
Magnesium Hardness	mg/l	12	20	20	5	30	13	22	18
Total Hardness	mg/l	12	64	65	14	90	42	69	56
Calcium	mg/l	12	17.63	17.90	3.76	23.80	11.80	19.63	15.50
Iron	mg/l	12	1.464	1.440	0.728	2.820	0.564	2.025	0.854
Magnesium	mg/l	12	4.75	4.73	1.18	7.39	3.07	5.17	4.20
Manganese	mg/l	12	0.058	0.054	0.041	0.177	0.013	0.062	0.039
Chloride	mg/l	12	49.1	44.5	16.4	82.9	28.9	58.4	38.7
Alkalinity	mg/l	12	49.34	48.85	8.97	67.20	31.50	51.73	44.45
Total Dissolved Solids	mg/l	12	193	203	47	274	134	215	148
Total Suspended Solids	mg/l	12	7.7	6.0	6.4	26.7	2.0	7.7	4.9
Turbidity (lab)	ntu	12	3.727	4.050	1.650	5.730	0.245	4.993	2.770
TKN	mg/l	12	1.065	0.775	0.781	2.720	0.300	1.275	0.595
Ammonia (NH3-N)	mg/l	12	0.235	0.080	0.296	1.000	0.050	0.323	0.054
Nitrate (NO3-N)	mg/l	12	0.305	0.100	0.459	1.400	0.100	0.125	0.100
Total Phosphorus	mg/l	12	0.094	0.087	0.080	0.273	0.010	0.129	0.021
Total Coliform	#/100 ml	12		300		2600	10	525	40
Enterococci	#/100 ml	12		35		120	10	83	10
Fecal Coliform	#/100 ml	12		65		400	10	130	10
Fecal Streptococcus	#/100 ml	12		155		2200	10	333	100
Clostridium Perf	#/100 ml	12		10		300	7	23	10

the sediments within Black Creek under the low oxygen conditions found there in late summer. Interestingly, total phosphate in the sediment core from Black Creek (see Section 2.2.3) were lower than in the cores from Wreck Pond. Also, the die-off of algae seen in the impounded section of the Creek likely added phosphorus to the system. Concentrations at the other two stations did not violate the standard.

Nitrate showed a spring peak at all three stations, with Wreck Pond Brook having the highest value of 1.79 mg/l. After the March peak, nitrate levels dropped at Stations WPB and BC to around 0.5 mg/l and to the detection limit of 0.1 mg/l, respectively. However, the nitrate concentration at Station HB remained relatively higher at about 1.1 to 1.3 mg/l. Nitrate values at this station were lower for sampling events following rainfall (5/17, 6/29 and 8/30). This was not noted in the other streams. This suggests there is higher nitrate in the base flow of Hannabrand Brook, likely from groundwater flow.

As in Wreck Pond, the bacteria concentrations in the tributary streams increased throughout the summer. The maximum fecal coliform counts per 100 ml were 550, 900 and 400 while the maximum enterococci counts (#/100ml) were 700, 600, and 120 in Wreck Pond Brook, Hannabrand Brook and Black Creek, respectively. Fecal streptococcus counts per 100 ml were 4,400, 5,400 and 2,200 at those locations.

10.2.3 Sediment Sampling

Sediment cores were taken from seven locations within Wreck Pond and four other watershed locations, including Old Mill Pond, Black Creek, and Spring Lake.

The sediment cores showed a thick layer of mucky material on the bottom of Wreck Pond and other ponds. Figures in Appendix F provide sediment grain size analysis for the cores.

Sediments were tested for several types of bacteria: Clostridium Perfringens, Total Coliform, Enterococci, Fecal Coliform and Fecal Streptococcus. It should be noted that unlike in water samples, the detection limit for bacteria in sediment is 100 #/dry grm. The tested parameters were:

Sample Depth
Grain Size
TOC
% Moisture
PP + 40
Herbicides
Fecal Coliform
Total Coliform
Fecal Streptococcus
Enterococci
Clostridium Perfringens

Nitrate
Nitrite
TKN
Ammonia
Total Phosphorous
Ortho-Phosphate
SOD

Figure 24 summarizes the bacteria results, while other data figures are located in Appendix F. Elevated phosphorus levels were found in certain cores within Wreck Pond.

Bacteria levels exhibit naturally high variability. Thus, the sediment results simply provide data at one point in time but were not extensive enough to fully describe the bacterial concentration in the Pond sediments. As discussed in Section 5 the bacteria species that are commonly measured in water quality studies are considered indicator organisms. That is, while these bacteria are present in the human intestinal tract, they are also present in the intestinal tract of animals as well as in soils. Thus, elevated levels of indicator bacteria do not necessarily mean the water is contaminated with human waste.

The highest levels of bacteria were found in the top layer of sediment, for the most part. Figure 24 shows the concentration of various types of indicator bacteria in the top layer from each core. As shown, the highest counts were of fecal streptococcus.

Further analysis of the fecal streptococcus bacteria show that the highest concentration was >600,000 #/gm found in the bottom layer in the core from Old Mill Pond (Core 3A). In Wreck Pond proper, the highest concentration was 450,000 #/gm found in the top layer in both Core 3C and Core 3G. The levels of FS are much lower in the mid-core and bottom-core samples than in the top-core samples.

10.2.4 Storm Sampling

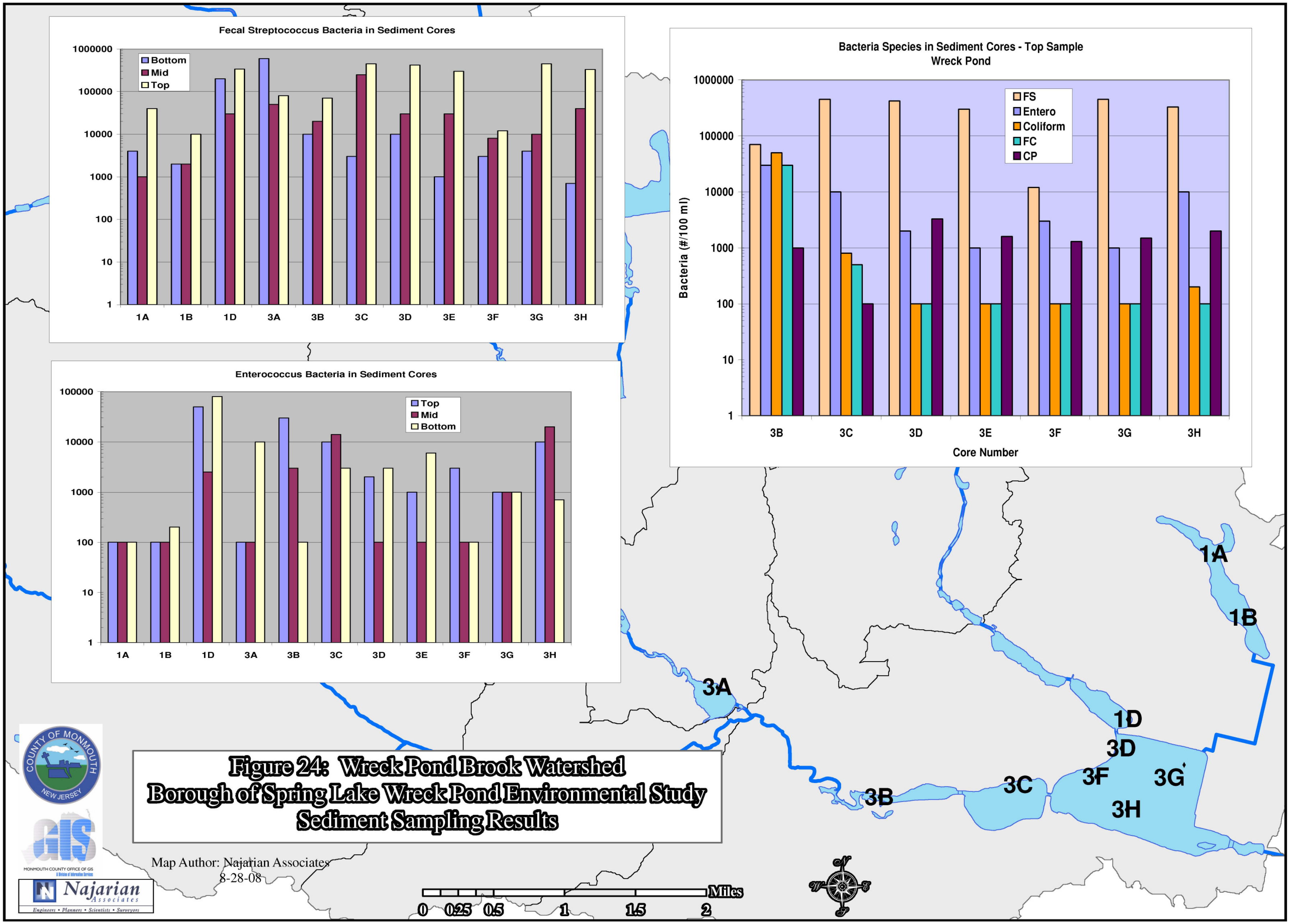
Water quality monitoring was conducted during two storm events in the watershed. The monitoring program was designed to compare pollutant loadings and to provide calibration data for the watershed model.

The sampling involved collecting surface water samples during two storm events, at three (3) sampling stations as summarized below:

WPB - OM: Wreck Pond Brook at Old Mill Road, downstream side of culvert (same location as in tributary sampling discussed above) – in vicinity of County Station W3

HB: Hannabrand Brook at Old Mill Road, upstream side of culvert (same location as in tributary sampling) – in vicinity of County Station W2

WPB-GR: Wreck Pond Brook at Glendola Road, downstream side of culvert in Wall Township- in vicinity of County Station W7



Fecal Streptococcus Bacteria in Sediment Cores
Bottom
Mid
Top
1A 1B 1D 3A 3B 3C 3D 3E 3F 3G 3H
Enterococcus Bacteria in Sediment Cores
Top
Mid
Bottom
1A 1B 1D 3A 3B 3C 3D 3E 3F 3G 3H
Bacteria Species in Sediment Cores - Top Sample
Wreck Pond
FS
Entero
Coliform
FC
CP
Bacteria (#/100 ml)
3B 3C 3D 3E 3F 3G 3H
Core Number
1A
1B
1D
3D
3F
3G
3H
3C
3B
3A
Figure 24: Wreck Pond Brook Watershed
Borough of Spring Lake Wreck Pond Environmental Study
Sediment Sampling Results
Map Author: Najarian Associates
8-28-08
COUNTY OF MONMOUTH
NEW JERSEY
Najarian Associates
0 0.25 0.5 1 1.5 2 Miles

WPB-OM and HB were selected to measure contributions from the major tributaries, Wreck Pond Brook and Hannabrand Brook, and to be located near County gage stations. The third sampling point, WPB-GR, is further upstream on Wreck Pond and provided information regarding pollutant loadings contributed from upstream parts of the watershed, which have a lower percentage of residential land uses. In addition, this station would be used to look at flow and pollutant load continuity within Wreck Pond Brook.

Storm sampling was initiated during two storm events. However, during the first storm, September 2006, precipitation did not occur as projected. Thus, sampling occurred primarily during the early part of the storm and the true rising limb and peak were not sampled. Detailed analysis was not conducted for this storm.

The storm of October 17-18 2006 was determined to be a good storm for sampling and samples were collected over the entire storm hydrograph. The total rainfall was 1.08 inches starting at about noon on October 17 and extending until about 1 am on the 18^{th}. The peak intensity was 0.16 in/hour which occur in about the middle of the storm, at about 7 pm.

The parameters selected were those expected to impact overall quality of Wreck Pond. These parameters included:

- pH
- Conductivity
- Temperature
- DO
- Turbidity
- Salinity
- Gauge height
- Nitrate
- Nitrite
- TKN
- Ammonia
- Total Phosphorous
- Ortho-Phosphate
- CBOD
- TSS
- Fecal Coliform
- Total Coliform

Further details regarding the precipitation and monitoring methods are provided in the Wreck Pond Environmental Study and data are show in Appendix E as part of the SWMM modeling effort.

The results indicate that TSS and total phosphorus concentrations were significantly higher at Hannabrand Brook than at WPB at Old Mill. The concentrations of those parameters declined on Wreck Pond Brook from Glendola Road to Old Mill Road.

The water quality data were combined with flow data from the SWMM watershed model (see Section 8) to calculate storm loadings. In addition in order to compare the loadings from the two watersheds unit loading rates (loading per acre) and Event Mean Concentration (total load divided by flow volume) were calculated for each watershed. Table 39 summarizes these results.

The load of a parameter carried by a stream would increase in a downstream direction, unless material is deposited somewhere along the way. By comparing loads on WPB at Glendola Road and Old Mill Road, the flow and loading dynamics can be examined.

As noted above, the TSS concentrations for the WPB-OM station showed little response to the storm event. This is reflected in the loading analysis. The largest TSS load is from the WPB-GR Station with the smallest load at WPB-OM. In fact, the WPB loses over 2,000 pounds of TSS between these two stations. The EMC and loads for HB are similar to those for WPB-GR.

A similar, but less pronounced pattern is noted for total phosphorus. Here, the lower Wreck Pond Brook watershed loses about half the load that is present at the WPB-GR station. For nitrate and phosphate, no such pattern is apparent and the lower watershed generates a similar amount of this parameter as the upper watershed and the HB watershed.

Ammonia and phosphate unit loading rates are very similar for all three stations. Nitrate is the almost the same for both WPB stations, but is higher at HB. This may be due in part to the higher concentration in the baseflow of HB which was noted in the pre-storm sample.

Bacteria loads are more complex as bacteria dynamics include transport and die-off. In addition, bacteria counts are notably variable. The results suggest that HB is contributing the higher load per unit acre.

The analysis demonstrates that there is some process in the lower watershed that is reducing the load of certain constituents on Wreck Pond Brook between Glendola Road and Old Mill. The Glendola Road station is about 6,500 feet downstream of the closest pond, whereas the Old Mill station is just below Old Mill Pond. In addition, Osborne's Pond, is located in the reach of WPB between these two stations. It appears that these two ponds are allowing settling of suspended solids and certain associated pollutants.

Table 39: Pollution Budget Sampling Loading Analysis				
		Hannabrand Brk (HB)	**Wreck Pond Brk at Old Mill (WPB)**	**WPB at Glendola Rd (GR)**
	Watershed Size (acres)	**1976.5**	**4643.3**	**3109.4**
TSS	EMC (mg/l)	16.4	2.3	13.2
	Load (lbs)	1771	689	2945
	Load per acre	0.896	0.148	0.947
Ammonia NH3	EMC (mg/l)	0.070	0.058	0.060
	Load (lb)	7.6	17.2	13.4
	Load per acre	0.004	0.004	0.004
Nitrate NO3- N	EMC (mg/l)	0.804	0.511	0.463
	Load (lb)	87.03	150.8	103.4
	Load per acre	0.044	0.032	0.033
Phosphate TPO4 -P	EMC (mg/l)	0.019	0.012	0.015
	Load (lb)	2.1	3.4	3.2
	Load per acre	0.001	0.001	0.001
Total Phosphorus	EMC (mg/l)	0.060	0.019	0.057
	Load (lb)	5.5	6.5	12.8
	Load per acre	0.003	0.001	0.004
Total Coliform	EMC (#/100 ml)	88916	11637	18159
	Load (billions #)	20929	15593	18389
	Load per acre	11	3	6
Fecal Coliform	EMC (#/100 ml)	5399	889	1580
	Load (billions #)	1618	1191	1600
	Load per acre	0.819	0.256	0.515

10.2.5 Storm Outfall Sampling

The final monitoring program undertaken for the Wreck Pond Environmental Study was sampling directly within stormwater outfall pipes discharging to the Pond or other waterbodies. Details regarding the process of selecting the outfalls for sampling is provided in the Wreck Pond Environmental Study. Table 40 summarizes the outfalls sampled. Figure 21 includes outfall sampling locations.

TABLE 40: Stormwater Outfall Details

Outfall Pipe #	Location/ Municipality	Pipe Size/ Type	Baseflow (inches)	DA (acres)	Notes
6b	Rt. 71, southeast of WPB Culvert, Sea Girt	21” RCP	None	51.8	
7a	End of 6th Ave., Sea Girt	24” RCP	None	18.5	
15a	Municipal Parking Lot at Ocean Ave., Spring Lake	24” RCP	None	22.5	Standing water, sand at pipe invert
18a	3rd Ave. and Passaic Ave., Spring Lake	24” RCP	1.32	75.0	
20a	End of 6th Ave., Spring Lake Heights	12”x30” RCP	1.2	72.0	
21a	5th Ave. and Salem Ave., Spring Lake	30” RCP	5.04	47.5	
22a	Ocean Rd. and Fourth Ave., Spring Lake	30” RCP	0.48	30.5	
23a	Ocean Rd. and Third Ave., Spring Lake	27” RCP	0.48	17.1	
24a	Ocean Rd. and Second Ave., Spring Lake	30” RCP	0.48	35.7	Large root 4’ up from invert, damming water
33a	Rt. 71, West side of WPB Culvert, Spring Lake Heights	18” CMP	None	13.7	
GC-1	Warren Ave. East of GC Entrance, Spring Lake Heights	54” RCP	4.8	229.9	
GC-2	Warren Ave. West of GC Entrance, Spring Lake Heights	48” RCP	0.24	50.0	

The following parameters that were monitored:

- Flow depth
- Total Nitrate/Nitrite
- TKN
- Ammonia
- Total Phosphorous
- TSS
- Fecal Coliform

Sampling was conducted for two different storm events (September and December of 2006), with six outfalls sampled during each storm.

During the storm events, the depth of flow at each outfall pipe was measured at regular time increments. Depths were converted to flow using the Manning's equation. These equations use pipe information such as slope, diameter and pipe material to convert water depth to flow volume. The flow and measured constituent concentration were used to calculate mass loadings of each pollutant at each outfall for each event. These loading values are the first flush mass loading of pollutants, and are illustrated for each storm in Tables 41-42 below: In this table the data are provided to two significant figures for loads to allow relative comparison of the loadings.

Base flow, that is flow prior to the storm event, was noted in certain pipes. During the October storm, Pipe 20a had the largest base flow. Bacteria concentrations in the base flow in this pipe were an order of magnitude higher than any other pipe in this round of sampling. Bacteria concentrations were also elevated in the post-storm baseflow in Pipe 21a for the December storm. For nitrate, the baseflow concentrations were higher in both storms. TP showed a "first flush" effect at most of the pipes for Storm 1, while TSS peaked in the second round for the most part although Pipe 6a had very high TSS concentrations in the third round. Bacteria concentrations were higher in the second storm event sampling.

10.2.6 Discussion of Storm Pipe Sampling Results

The results showed the transport of flow and water quality parameters through the pipes. Reviewing the data, certain flow or pollutant anomalies were found which are discussed briefly below.

- Outfall 15a: After the sampling began, the pipe filled very quickly to about half full. It was determined that a large quantity of sand was in the lower portion of the pipe, reducing its capacity. It is very likely that the flows at this station are biased high.

Table 41: October 27, 2006 (Storm 1) First Flush Pollutant Loads								
Outfall	**Area**	**Total Flow Volume**	**TSS**	**TKN**	**NH_3**	**NO_2/ NO_3**	**TP**	**Fecal Coliform**
	(Ac)	(L)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(billions of col)
15a*	22.4	672,765	15.3	0.61	0.39	0.51	0.14	1.82
24a[T]	35.7	66,858	1.41	0.04	0.04	0.08	0.04	0.78
23a	17.1	64,032	1.80	0.02	0.05	0.05	0.05	0.70
22a	30.5	92,747	3.06	0.09	0.10	0.09	0.10	1.97
7a	18.5	40,440	1.39	0.03	0.02	0.04	0.02	0.61
20a	72.0	278,962	7.44	0.16	0.14	0.23	0.11	34.97

*Loading larger then expected due to unexplained high field flows
[T]The Spring Lake outfall primary sub-catchment

Table 42: December 1, 2006 (Storm 2) First Flush Pollutant Loads								
Outfall	**Area**	**Total Flow Volume**	**TSS**	**TKN**	**NH_3**	**NO_2/ NO_3**	**TP**	**Fecal Coliform**
	(Ac)	(L)	(lbs)	(lbs)	(lbs)	(lbs)	(lbs)	(billions of col)
18a	75.0	191,339	23.37	0.37	0.11	0.42	0.10	88.82
GC-1	255.3	546,165	44.88	1.08	0.25	1.60	0.22	161.16
GC-2**	50.0	11,170	0.71	0.01	0.00	0.03	0.00	0.03
21a*	47.5	719,086	143.53	1.78	0.67	0.63	0.52	125.81
33a	13.7	25,115	2.06	0.12	0.02	0.02	0.01	8.32
6b	51.8	112,764	21.00	0.16	0.08	0.08	0.07	54.07

*Loading larger then expected due to unexplained high field flows
**Loading smaller then expected due to limited field flows and upstream pond storage

- Outfall 24a: The Spring Lake outfall pipe transports flows from Spring Lake as well as direct stormwater from the sub-watershed area. The flow analysis determined that during the monitoring period the first flush only included flow from the local sub-watershed, with only limited flows, if any, from increased flows out of the Spring Lake itself.

- Outfall 21a: Higher than expected flows were measured during the storm sampling at this pipe. Although not initially mapped as part of the sub-watershed to this pipe, it is possible that a large portion of the Spring Lake Borough DPW yard contributes flows to this outfall. Even with revision of the pipe sub-watershed to include this area, the flows from this sub-watershed were much larger than anticipated based on the flow per unit area for other sub-watersheds. Water quality loadings were higher than anticipated as well, based on the combination of abnormal flows and high pollutant concentrations found during sample collection. The sediment trap in the DPW yard is tied into this system, which could account for the TSS and bacteria sources, but not the large volumes of flow. This outfall should be investigated to determine flow sources as well as pollutant sources, since this is one of the primary sub-watersheds flowing to Black Creek. At this point however, the flows are so far out of range that the water quality loadings are considered inaccurate.

- Outfall GC-2: During the storm sampling, flows at this outfall were much lower than anticipated. It was discovered that the outfall is connected to an upstream pond with a control structure that detained stormwater flows. Thus, this outfall did not provide adequate flow and loadings could not be calculated.

10.3 Monmouth County Health Department

Wreck Pond is located at the mouth of the watershed. As noted previously, it is subject to tidal exchange with the Atlantic Ocean via an outfall structure. Discharge from the Pond to the Ocean has been the cause of numerous closings of ocean bathing beaches near the outfall due to high bacterial levels in the waters. One goal of the Regional Stormwater Plan is to reduce or eliminate such beach closings.

Bacteria data are collected by the Monmouth County Health Department (MCHD). Bacteria data are not collected after every storm event. Most beach closings are required due to the provisional rainfall ban, not actual monitoring data. The NJDEP extended the length of the Wreck Pond outfall to move the discharge away from the bathing zone and thus reduce the occasions when the outfall would cause bacteria levels to rise above the bathing beach standard. The actual impact of the extension of the outfall on recreational water quality in the bathing beach area has not been determined. MCHD and NJDEP are planning further monitoring in the bathing beaches near the Pond outfall.

The Monmouth County Health Department conducts monitoring of bacteria levels at beaches during the CCMP program, including Monday morning sampling. This monitoring is not designed to sample following rainfall, so there is limited data during periods of rainfall.

Review of data for the last few years does not consistently show a direct correlation between rainfall during the previous 24 hours and bacteria levels at bathing beaches near the outfall. For example, York Ave. beach in Spring Lake shows exceedances of the bacteria standard when the previous rainfall was zero as well as no exceedances when rainfall is 0.83 inches. In fact, for the sampling that occurred following the second-highest rainfall (0.83 inches, 9/5/06) only the Terrace showed any detected bacteria and, at 20 cfu, was below the standard.

Interestingly, the highest values at all of the beaches occurred when there was no antecedent rainfall for the previous week at the Wall Township station. For the July 17, 2006 sampling, elevated enterococci bacteria levels were noted at the York and Brown Avenue beaches, just north of Wreck Pond as well as the Terrace and Beacon Boulevard locations south of the Pond. The highest reading was at Beacon Blvd. at 12,400 cfu. Further south in Sea Girt the Philadelphia Ave. beach testing showed no detection and the Newark Ave was 20 cfu. Beaches to the North of York Ave also were not impacted.

MCHD discusses this event in their paper titled “Changes in Water Quality near the Extended Wreck Pond Outfall”. MCHD notes that this was an “unusual event”. The report speculates that the rapid warming of water temperatures between July 10 and 17 may have created a “downwelling” condition, in which surface water is pushed downward in the Ocean. This can interact with a secondary ocean current that flows to the South, driven by the Hudson-Raritan plume. This plume is a lighter, warmer plume of water that comes into the Ocean above Sandy Hook and flows south, and has been associated with events that have polluted the shores of Monmouth County. The MCHD notes that the relocated outfall extends 300 feet and may be into or near this southerly current driven by the Hudson-Raritan Plume. Thus, this event may not be related to water quality within Wreck Pond. By the next day all readings were at or below the detection limit of 10 cfu. Further research is required to test this theory.

The other time an exceedance occurred in the absence of rainfall was in September at the York Avenue beach. The MCHD report notes that there was very rough surf at this time that may have contributed to this transitory exceedance.

MCHD notes that overall exceedances were reduced in 2006 after extension of the outfall pipe, as compared to 2004. MCHD compared these two years as rainfall was similar. The report notes that detections and exceedances increased at bathing beaches south of the extended outfall. However, it must be noted that these results are based on the Monday morning sampling only, and thus the specific data for the two years likely represents different antecedent rainfall events.

10.4 NJDEP

The NJDEP conducted studies of Wreck Pond prior to extending the outfall and doing some initial dredging. During the summers of 2007 and 2008, NJDEP conducted monitoring under storm conditions in Wreck Pond and at stormwater outfalls. Additional monitoring is expected in the summer of 2008. Preliminary results suggest that certain stormwater outfall structures may be impacting beach bacteria levels.

10.5 Overall Evaluation of Pollutant Sources

The Wreck Pond Brook watershed has been the subject of two modeling studies and several water quality monitoring programs including the County weekly sampling and the sampling done for the Borough of Spring Lake's Wreck Pond Environmental Study. In addition, Monmouth University and Rutgers Cooperative Extension collected water quality data as part of their studies. Further, MCHD continues to conduct summer bacteria monitoring at the beaches and NJDEP is conducting bacteria studies. The results of these studies were used to evaluate possible pollutant sources.

The watershed contains a number of sources that may contribute to the loading of bacteria, nutrients and other pollutants. However, some sources are not known to be present, including:

- **Point Sources other than Stormwater:** There are no known point source discharges in the watershed.

- **Septic Systems:** There are no known septic systems within the watershed, the area is entirely sewered. It is possible that unknown historic septic systems are present.

The primary source of nonpoint sources of stormwater pollution are the land surfaces within the watershed. The various land uses generate water pollutants. Another potential non-point source is failing sewer infrastructure.

10.5.1 Assessment of Non-Point Sources

The watershed contains mixed land uses. The water quality modeling study results, described in Section 8, indicate that the Wreck Pond Brook produces most of the actual pollutant loads. As the land uses are mixed, it is not possible to use the model results to directly determine the contribution of each land use.

The modeling results, the results of the agricultural and recreational land surveys and literature information are used to assess the contribution of various land uses.

10.5.2 Land Uses

Agricultural Lands: The Rutgers survey of agricultural land, discussed in Section 5, determined that agricultural lands are not having a "significant" impact on the "overall health of the Wreck Pond Brook watershed". This finding is based on water quality data collected indicating that standards are rarely exceeded during routine sampling for pH, nutrients and other parameters using a meter. While agricultural lands are not causing contravention of water quality standards, runoff from these lands is likely adding to the overall load of bacteria, nutrients and sediment in Wreck Pond.

The Rutgers survey found that farmers reported fertilizer use within the range that would be taken up by the crops and thus excessive nutrient loading from this source was not expected. However, manure management was of concern at a few farms. These farms generally had few farm animals and thus are not likely a major source of bacteria.

Agricultural practices can impact sediment, nutrient and bacteria loading.

Park and Recreational Land: The Rutgers survey of park and recreational land also found these lands did not appear to be having a major impact on water quality.

Urban/Suburban Land: Residential land uses are dominant in the lower watershed. Construction activity is a source of sediment. Landscaping also can be a source of sediment and nutrients. Human use and pets are a source of bacteria.

10.5.3 Streams

A stream assessment and survey was conducted by the Freehold Soils Conservation District, as discussed in Section 4. The results reveal that certain stream segments are contributing sediment and possibly associated pollutants.

10.5.4 Pond Processes

The ponds in the upper watershed appear to act as retention structures that slow the flow of water and allow settling of sediment and associated pollutants. Under certain conditions, the sediments in these ponds may become re-suspended in high flows and be transported downstream.

The sediments and organic matter in the bottom of the upstream ponds and of Wreck Pond were found to contain bacteria and nutrients. Under certain environmental conditions, these pollutants may be released from the sediments back into the water column. The studies conducted thus far have not quantified these processes.

10.5.5 Water Fowl and Wildlife

Wreck Pond, Black Creek and the watershed ponds are home to a variety of water fowl including mute swans, geese and ducks. These water fowl produce fecal matter that adds bacteria directly to the ponds and is deposited along the shorelines. Other wildlife including deer may produce fecal matter that is carried to the waterways. Deer and other wildlife also use the stream corridors and the watershed in general. They impact stream and area vegetation by over-grazing sometimes stripping areas of plants. This can affect erosion. Wildlife may also be a source of bacteria.

10.5.6 Natural Conditions

The low pH in the western portions of the streams may well be due to the naturally acidic soils found in the Pineland type woodlands and soils.

10.5.7 Pollutant Source Summary

For the Wreck Pond watershed, the mixed land uses are a major source of all pollutants of interest. The results of the watershed modeling, agricultural survey, stream assessments, and bacteria source tracking did not identify one source of highest importance. For each pollutant group, identified sources are noted below.

Nutrients: Developed land uses, agricultural lands, fertilizer application

Bacteria: Developed land use, manure management in farmlands, water fowl, possible leaking infrastructure, wildlife, pets, release from Pond sediments

Sediment: Developed lands, agricultural land, un-vegetated uplands, construction sites, stream erosion, re-suspension of pond sediments

The analyses in this study did not find a particular source that was the most important component of sources for each pollutant. Thus, the sources are not ranked

Book 2 of the RSWMP provides further data and analysis of pollutant sources and the overall management plan for the watershed.

WRECK POND BROOK WATERSHED
REGIONAL STORMWATER MANAGEMENT PLAN

BOOK 2: MANAGEMENT PLAN

Prepared by
Wreck Pond Brook Watershed Technical Advisory Committee

Under the Authority of
Wreck Pond Brook Watershed
Regional Stormwater Management Plan Committee

Lead Planning Agency: Monmouth County Planning Board

PRINCIPAL STUDY PARTICIPANTS

Monmouth County Office of Geographic Information Systems

Monmouth County Planning Board

New Jersey Department of Environmental Protection, Division of Watershed Management

New Jersey Department of Agriculture

Najarian Associates

Rutgers Cooperative Research and Extension

Freehold Soil Conservation District

Monmouth University

Monmouth County Planning Board
Hall of Records Annex
1 East Main Street
Freehold NJ 07728

SEPTEMBER 2008

TABLE OF CONTENTS

PAGE

TABLE OF CONTENTS (continued)

PAGE

TABLE OF CONTENTS

PAGE

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

The Wreck Pond Brook Watershed Regional Stormwater Management Plan (WPB RSWMP) was developed to address stormwater quantity and quality concerns within the watershed. The Plan was prepared in accordance with Subchapter 3 (Regional Stormwater Management Planning) of the New Jersey Department of Environmental Protection (NJDEP) Stormwater Management regulations (NJAC 7:8). The regional stormwater planning process is designed to address stormwater issues that are best managed on a regional, not a state or local basis.

The Plan provides a detailed description of existing watershed conditions including the results of several monitoring efforts and field investigations, modeling studies, identification of problems and proposed solutions. Book 1 of the RSWMP and provides data on the characterization of the watershed and environmental concerns. Book 2 provides the Management Plan, including analysis of the potential impacts of future development on the watershed.

Book 1 provides a Characterization Report including overall watershed characteristics, details and results of the various monitoring programs conducted as part of these studies, and results to date of the modeling efforts undertaken.

Wreck Pond Brook extends from its headwaters in Wall Township near Allaire Airport east-southeast to Wreck Pond. Wreck Pond is located on the boundary between the Boroughs of Spring Lake and Sea Girt in Monmouth County, New Jersey. Wreck Pond is approximately 73 acres in size and a portion of it is tidally influenced. The eastern end of the Pond contains an outfall structure that exchanges water with the Atlantic Ocean. Figure 1 shows the location of the watershed. Figure 2 provides an aerial photograph.

The Wreck Pond Brook watershed was identified as a watershed of concern by the NJDEP. Outflow from Wreck Pond to the Ocean during storm events has been identified as the cause of swimming beach closings in Spring Lake and Sea Girt. The Monmouth County Health Department (MCHD) regularly monitors bacteria levels at Ocean swimming beaches. Using those data, MCHD found that bacteria levels exceeded the Ocean bathing beach standards at Ocean beaches in the vicinity of the outfall following storm events. In 2002, the Health Department instituted a 24-hour swimming ban that would be implemented whenever rainfall exceeds 0.1 inch or when a plume from the outfall was visible and a 48-hour ban when rainfall exceeds 2.8 inches in 24 hours. This ban applies to the recreational bathing waters at the Brown and York Avenue beaches in Spring Lake and The Terrace and Beacon beaches in Sea Girt. Due to this provisional ban, the outfall from Wreck Pond has been the presumed source of most of the swimming bans at the New Jersey Ocean beaches over the last several years.

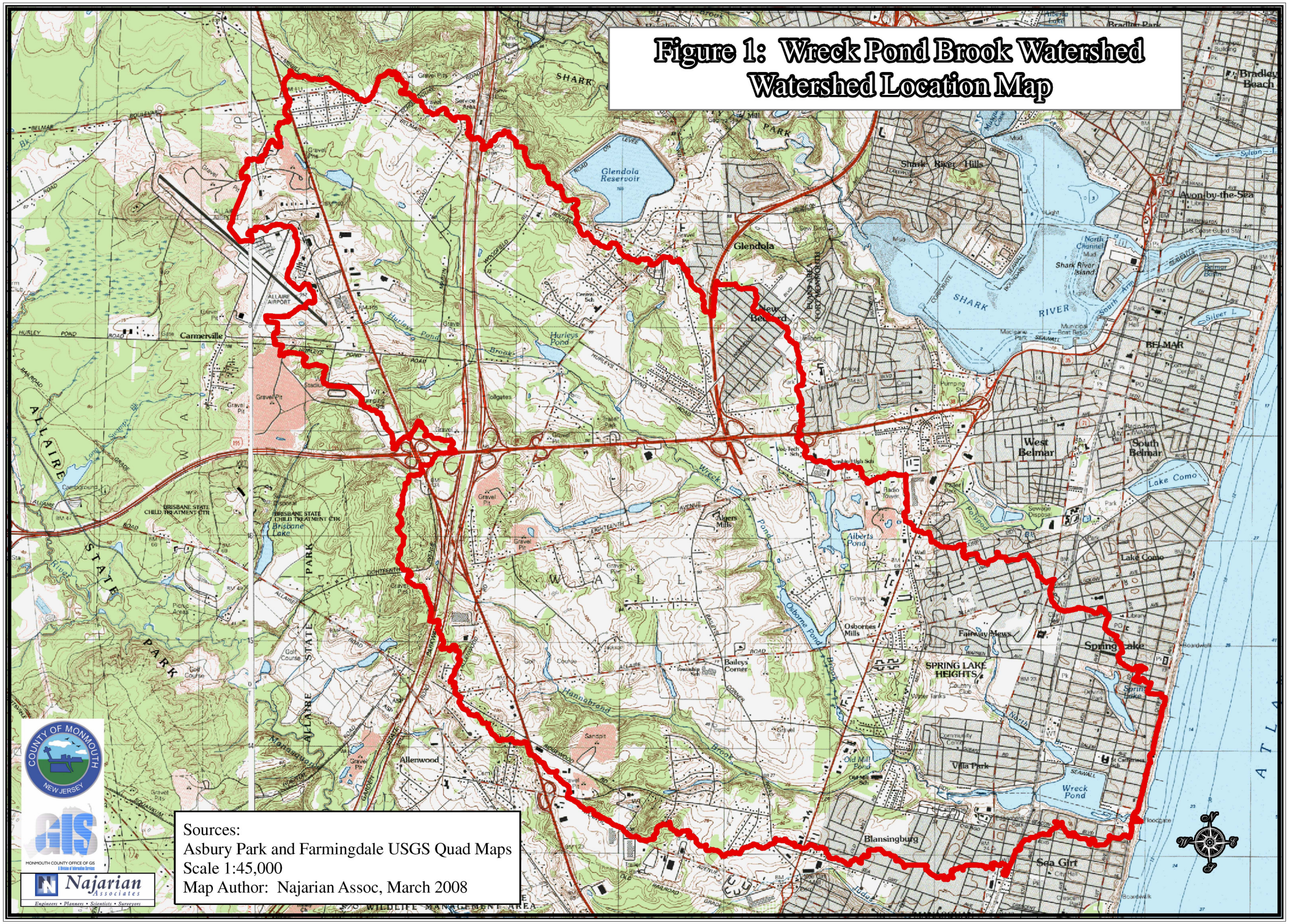


Figure 1: Wreck Pond Brook Watershed
Watershed Location Map

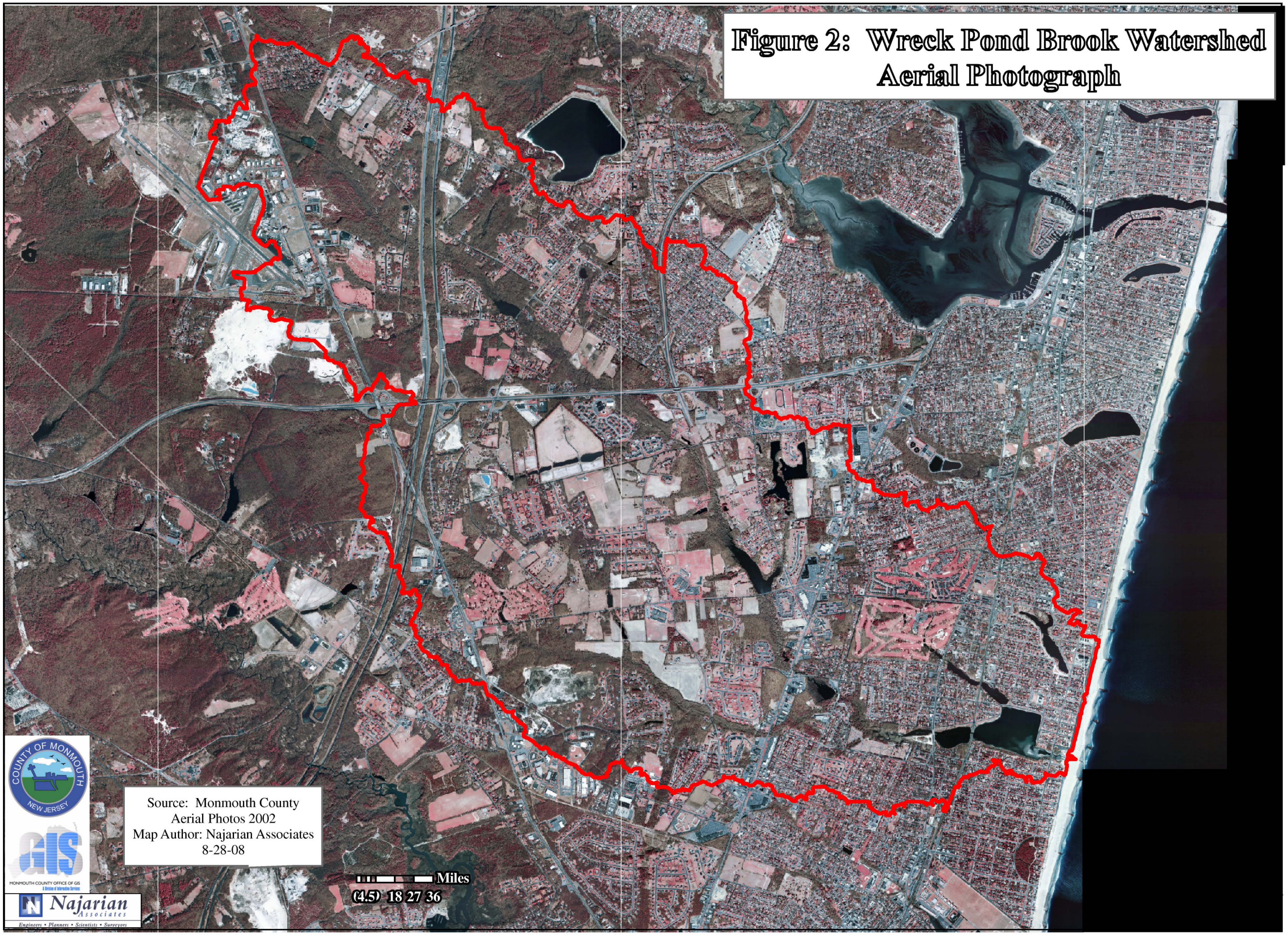


Figure 2: Wreck Pond Brook Watershed
Aerial Photograph
Source: Monmouth County
Aerial Photos 2002
Map Author: Najarian Associates
8-28-08
Miles
(4.5) 18 27 36
COUNTY OF MONMOUTH
NEW JERSEY
GIS
MONMOUTH COUNTY OFFICE OF GIS
Najarian
Associates
Engineers • Planners • Scientists • Surveyors

In addition, the overall water quality of waters in the watershed, including Wreck Pond is of concern. Algal blooms, nutrient loads, and sedimentation are noted issues. Further, flooding has been noted in many parts of the watershed. The storm of October 2005 caused significant flooding, particularly in the lower portions of the watershed.

Book 1 provides information on the stormwater related concerns identified in Wreck Pond and the overall watershed. Portions of the Introductory Sections of Book 1 are repeated or summarized herein.

1.1 Purpose and Goal

This Wreck Pond Brook RSWMP is designed to meet the requirements for a Regional Stormwater Management Plan in accordance with NJDEP regulations at NJAC 7:8-3. According to that regulation "A Regional Stormwater Management Plan shall address stormwater-related water quality, ground water recharge and/or water quantity impacts of new and existing land uses in a Regional Stormwater Management Planning Area."

The overall goal of this management plan is to outline measures that may be adopted to improve the water quality of the ponds and streams within the watershed, to reduce watershed loadings of pollutants associated with current and future land uses, to reduce flooding, and to eliminate or greatly reduce beach closings from the discharge from Wreck Pond to the Atlantic Ocean. The Plan is to develop workable solutions that can be implemented by the municipalities and standards that may be employed in review of new projects. The Plan also will be reviewed and updated as needed to ensure it continues to be responsive to changing watershed conditions.

As discussed in Book 1, the Wreck Pond Brook Regional Stormwater Management Plan Committee selected Monmouth County Planning Board as the lead agency for development of the Regional Stormwater Management Plan (RSWMP). In addition, a Technical Advisory Committee (TAC) was developed to provide technical studies and other technical support for development of the Plan. The RSWMP Committee has been meeting regularly, with over sixty members including those on the TAC, municipal officials and staff, as well as other interested parties, including local residents.

Agencies, institutions and firms represented on the TAC or the Stormwater Committee include Monmouth County Office of GIS, Monmouth County Engineering, NJDEP, Division of Watershed Management, NJ Department of Agriculture, Rutgers Cooperative Extension, Freehold Soil Conservation District, Monmouth University, Najarian Associates, US Fish and Wildlife Service, Monmouth County Health Department, NJDEP Marine Water Monitoring, and the Municipalities.

At the start of this process, the NJDEP and Monmouth County Planning Board staff had identified the following issues of concern

- Erosion in the watershed.

- Sediment loads and deposition at Wreck Pond and other watershed ponds.
- Bacteria, nitrate and phosphorus loads discharged to Wreck Pond.
- Swimming bans at beaches near the Ocean outfall from Wreck Pond.
- Stream base flow to maintain/improve dilution factors.
- Stream peak flow and the connection to stream bank erosion and sediment transport.
- Stream passing flow and potential as a future surface water supply.
- Existing impoundments as stormwater management, scenic and recreation features.
- Municipal stormwater management planning efforts.

The initial planning process expanded the scope to include flooding, algal blooms and sediment in other watershed ponds. The need for improvements in flood control was further highlighted by the storms of October 2005.

During development of the plan, additional issues related to stormwater in the watershed were identified by the County, NJDEP, other agencies, municipalities, and local residents. For example, Wreck Pond has reportedly become very shallow with mucky sediments and other signs of water quality impairment while tidal fluctuation is reportedly reduced. The impounded portion of Black Creek is noted to be very shallow and mucky and subject to algal blooms.

The streams within the watershed also are of concern for water quality and flow issues. Both major tributaries to the Pond have been found by NJDEP to be in non-attainment status for certain designated uses, including Aquatic Life and/or Recreation Uses.

1.2 Scope

The project scope is to provide a Regional Stormwater Management Plan that characterizes the watershed, identifies stormwater related problems, proposes solutions to those problems, conforms to regulatory requirements and provides guidance to regional and local decision makers and stakeholders. The Plan includes overall watershed characterization, stream assessments, agricultural land analysis, water quality data collection and analysis, watershed land use review, build-out land use analysis, hydrologic and hydraulic modeling, watershed water quality modeling and a bacteria source tracking study. The results of these studies have been synthesized to focus areas of concern and to develop management measures and restoration options within the watershed.

NJDEP provided ongoing guidance in the Plan development process. The Plan includes several elements undertaken by the County and the study partners. These elements are discussed in detail within Book 1 of the Plan. Primary responsibilities of TAC Study Partners are summarized as follows:

- Monmouth County Planning Board: Overall study coordination, identification of areas of concern, proposed mitigation measures

- Monmouth County staff, in particular the GIS Office, assessed the preliminary data and support with the County GIS system. The GIS data was then used to develop GIS thematic layers unique to the Wreck Pond Brook Watershed. The GIS data were used by the other partners in preparing their studies and to identify management and restoration options for the watershed.

- Monmouth County Staff: Collection of weekly water quality data

- NJ Department of Agriculture, State Soil Conservation Committee: Measured stream flow and analyzed stream and watershed runoff characteristics in order to develop stream flow models and comprehensive watershed runoff models. These models were designed to assess they hydrologic condition of the watershed and assist in the development of management recommendations for land and water resources.

- Freehold Soil Conservation District: Conducted stream assessments along the streams and tributaries within the watershed.

- Monmouth University: Microbial Source Tracking Study: Employed the Multiple Antibiotic Resistance technique to attempt to identify the sources of bacteria in samples taken from Wreck Pond and other watershed waters along with collection of water quality data.

- Rutgers Cooperative Extension: Surveyed agricultural and recreational lands within the watershed for pollutant generation sources. Conducted water quality and soils monitoring, analyzed current management techniques and proposed management recommendations.

- Najarian Associates: The County contracted with Najarian Associates (NA) to coordinate the plan document, including detailed analysis of the County water quality data, development of the watershed characterization portion of the Plan and writing of the report based on technical studies, field investigations and data from the County and other study partners. The watershed characterization included the synthesis and mapping of GIS data from the MC Office of GIS and NJDEP as well as other watershed information. NA also participated in watershed modeling and conducted surveying of stream sections.

Other agencies that assisted or provided data include Monmouth County Health Department who collects weekly beach bacteria data and the Southern Monmouth Regional Sewerage Authority who provided laboratory services for bacteria analyses for County Monitoring Data.

The study partners, other members of the TAC, and the RSWMP Committee used the data and results of the detailed watershed studies, monitoring, field studies, and modeling analyses to develop the Management Plan, including the stormwater specific mitigation projects, design and performance standards and the implementation strategy.

1.3 Introduction to Book Two

Book One of this document presents the Watershed characterization including results of the various technical studies that were undertaken.

The main body of Book 2 is synthesis of the data and other information from Book 1 to develop a comprehensive Stormwater Management Plan. This includes analysis of impacts of land development on stormwater flows and water quality. In addition, the study results were done to provide a detailed analysis of identified stormwater-related concerns within the watershed. The management plan presents BMP projects currently funded and underway in the watershed as well as future proposed projects. Measures that could be undertaken by the municipalities and other agencies are also identified. The Implementation Plan includes creation of a Wreck Pond Watershed Commission to continue the process, with input from the municipalities, the County, NJDEP and local residents.

2 WATERSHED CHARACTERIZATION

Book 1 provides data to characterize the watershed including soils, geology, topography, hydrology, ecology, wetlands and land use. Book 1 also provides discussion of the major technical studies done for this Plan including collection of data on stream characteristics and flow, water quality, assessment of agricultural and recreational lands, stream assessment, microbial source tracking, and watershed hydrologic and water quality modeling. Analysis of available water quality data also is provided.

The Wreck Pond Brook watershed includes about 8,174 acres (±12.74 sq. miles) in southern Monmouth County New Jersey. As shown on Figure 2, municipalities within the watershed are the Township of Wall, and the Boroughs of Sea Girt, Spring Lake Heights and Spring Lake. Wreck Pond Brook flows from its western boundary near Allaire Airpot to the east-southeast, discharging into Wreck Pond on the border of Spring Lake and Sea Girt. The Pond exchanges flow with the Atlantic Ocean through an outflow structure. Figure 3 shows the major watershed features.

Hannabrand Brook is the major tributary to Wreck Pond Brook, and is located in the southern portion of the watershed, joining Wreck Pond Brook just below Old Mill Road. Black Creek, also known as the North Branch of Wreck Pond Brook, is located in the northeastern part of the watershed. The lower portion of Black Creek is ponded. This stream discharges directly into Wreck Pond via a structure at Ocean Road. Numerous ponds are found within the watershed. A wetland corridor is present along most of the streams. Figure 3 provides the hydrologic features of the watershed. Further detail is provided in Book 1.

The watershed was divided into sub-watersheds for the hydrologic modeling and for water quality data collection by Monmouth County. The County established a monitoring location within each subwatershed. Table 1 summarizes these locations. Figure 3 shows the subwatershed areas and monitoring locations.

The watershed characterization is based primarily on existing data. Much of the data was provided by the MC Office of GIS office as data layers from the GIS mapping. Additional data was taken from the NJDEP GIS data layers. Other available local data was used including NJDEP, USGS, Freehold Soils, EPA, County and other reports.

As part of the characterization, several watershed technical studies were undertaken as discussed in Section 2.1. These technical studies provided needed background information on existing condition of the watershed and the potential pollution sources. The studies included collection of water quality monitoring data on the streams and in Wreck Pond. The water quality studies confirmed that the water quality of Wreck Pond is degraded and that loadings of sediment, nutrients and bacteria are of particular concern. Other water bodies, including Black Creek, are very shallow, with mucky bottoms and noticeable algal blooms.

Table 1: County Gage and Sampling Stations		
Station #	**Subwatershed**	**Location**
Wreck Pond Brook		
W6	Martins Road	Just west of Garden State Parkway, upstream side of Martins Road culvert
W9	Hurley's Pond Dam	Downstream Side of Allenwood Road Culvert, Near Intersection of Hurley Pond Road and Allenwood Road
W7	Glendola Road	Downstream Side of Glendola Road Culvert, Adjacent to Taylor Pond
W1	Waterford Glen	Wreck Pond Brook, Stream Location Behind Waterford Glen Assisted Living Facility, Off of Route 35
W3	Old Mill Dam Culvert	Wreck Pond Brook, Downstream Side of Old Mill Road Culvert, Across Street of Old Mill Restaurant
Hannabrand Brook		
W5	Bailey's Corner Road	Hannabrand Brook, Downstream Side of Bailey's Corner Road Culvert, Just South of Pump Station
W2	Hannabrand Brook Culvert	Hannabrand Brook, Upstream Side of Old Mill Road Culvert, Adjacent to Old Mill Restaurant
Black Creek		
W8	Spring Lake Golf Club	North Branch of Wreck Pond Brook, Downstream Side of Route 71 Culvert, Southeast of Golf Course

Wetlands are generally located in a corridor along the tributary streams. A few endangered or threatened species are noted in the vicinity of Wreck Pond. According to NJDEP GIS data from early 2008, the Least Tern nests in the dunes along the beach adjacent to the eastern portion of Wreck Pond. Reportedly, the Piping Plover also nests in the dunes adjacent to the outlet. A state-listed plant is reported along the southern Wreck Pond shoreline and the northern Pine Snake is reported in the northwest part of the watershed. Otherwise, the woodlands and wetlands are generally categorized as Rank 2, which is “Priority Concern” on the NJDEP GIS data through early 2008. This indicates that no endangered species or habitat for such species have been found in, or in the vicinity of, these habitats. Thus, the streams and wetlands in the watershed would generally receive buffers of 50 feet in accordance with State regulations.

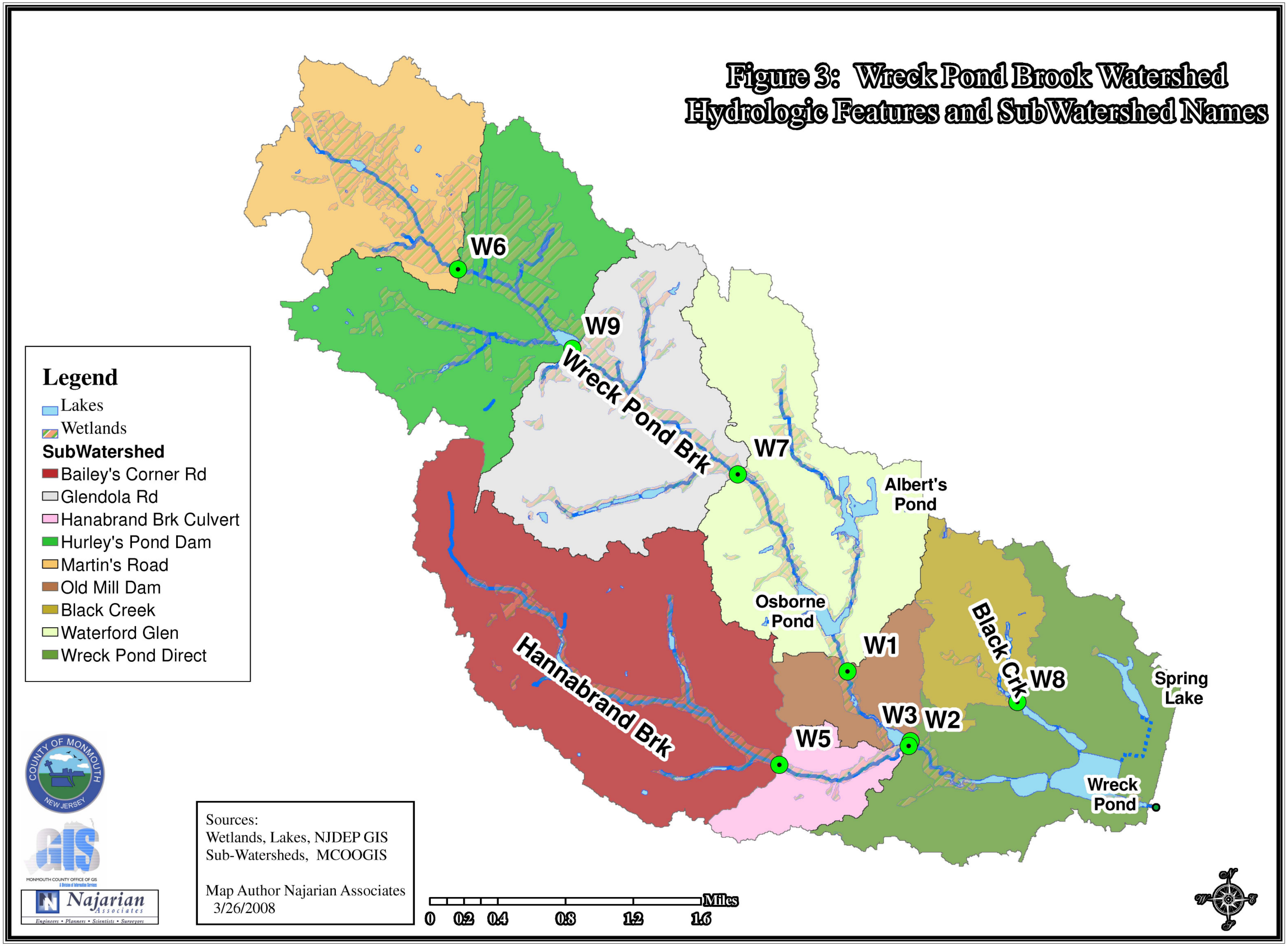


Figure 3: Wreck Pond Brook Watershed
Hydrologic Features and SubWatershed Names
Legend
Lakes
Wetlands
SubWatershed
Bailey's Corner Rd
Glendola Rd
Hanabrand Brk Culvert
Hurley's Pond Dam
Martin's Road
Old Mill Dam
Black Creek
Waterford Glen
Wreck Pond Direct
W6
W9
W7
W1
W8
W3
W2
W5
Wreck Pond Brk
Hannabrand Brk
Black Crk
Albert's Pond
Osborne Pond
Spring Lake
Wreck Pond
Sources:
Wetlands, Lakes, NJDEP GIS
Sub-Watersheds, MCOOGIS
Map Author Najarian Associates
3/26/2008
0
0.2
0.4
0.8
1.2
1.6
Miles

The Wreck Pond Brook watershed includes some environmentally sensitive lands, primarily the ponds, streams and associated wetlands. The watershed does not include significant steep slope areas and there are only very limited areas with endangered species. No waters in the watershed are Category 1 waters.

Land use within the watershed includes about 35% residential, 27% woods, and 10% commercial and industrial uses based on 2006 data.

2.1 Technical Studies

The Wreck Pond Brook watershed has been the subject of a variety of detailed technical studies. These studies included monitoring of water depth data and water quality data. The depth data was converted to flow using rating curves developed for the streams. Watershed streams were assessed by Freehold Soils Conservation District and stream segments of concern were identified. Rutgers Cooperative Extension (RCE) studied agricultural and recreational lands and found minimal potential impacts to water quality from these lands. RCE proposed modification to certain current land management practices to further reduce these minimal potential impacts. Monmouth University conducted bacteria source tracking and found a variety of sources for bacteria found in Wreck Pond and other watershed locations.

A hydrologic watershed model was developed by New Jersey Department of Agriculture and a watershed model was developed by Najarian Associates. The models investigated flow issues and pollutant loadings. Several water quality monitoring programs were conducted, including the County weekly sampling and the sampling done for the Borough of Spring Lake's Wreck Pond Environmental Study. In addition, Monmouth University and Rutgers Cooperative Extension collected water quality data as part of their studies. Further, MCHD continues to conduct summer bacteria monitoring at the beaches and NJDEP is conducting bacteria studies. The results of these studies were used to evaluate possible pollutant sources, as discussed in Section 10 of Book 1. Those results are summarized here.

2.2 Overall Evaluation of Pollutant Sources

The results of the technical studies were synthesized in Book 1, including analysis of water quality data and modeling results. These analyses were used to evaluate pollutant sources as described in the following sections.

2.2.1 Watershed Sources

The watershed contains a number of sources that may contribute to the loading of bacteria, nutrients and other pollutants. However, there are no known point source discharges in the watershed and there are no known septic systems within the watershed as the area is entirely sewered. It is possible that unknown historic septic systems are present. In addition, inter-connection of sanitary sewer and stormwater piping systems may transport sewage to watershed streams and ponds. Also, leaking sewer pipe systems may be a source of bacteria and other pollutants within the watershed. The municipalities have been surveying their piping systems and have not reported any major leaks or inter-connections. Further piping analysis will continue.

The primary non-point source of stormwater pollution is runoff from the land surfaces within the watershed. The various land uses generate water pollutants. Given the mixed land uses within each sub-watershed, the pollution budget monitoring and the watershed model loading analysis could not be used to directly determine the relative contribution of each land use. However, the mix of agricultural, suburban, commercial and industrial lands are contributing to the overall pollutant loads. In particular, some developed areas of the watershed do not have any stormwater management facilities due primarily to the age of the development.

2.2.2 Pond Processes

The ponds in the upper watershed appear to act as retention structures that slow the flow of water and allow some settling of sediment and associated pollutants, based on the NJDA modeling results and stream monitoring of storms. Under certain conditions, the sediments in these ponds may become re-suspended in high flows and be transported downstream.

The sediments and organic matter in the bottom of the upstream ponds and of Wreck Pond were found to contain bacteria and nutrients. Under certain environmental conditions, these pollutants may be released from the sediments back into the water column. The studies conducted thus far have not quantified these processes.

2.2.3 Water Fowl and Wildlife

Wreck Pond, Black Creek and the watershed ponds are home to a variety of water fowl including mute swans, geese and ducks. Water fowl produce fecal matter that adds bacteria directly to the ponds and is deposited along the shorelines. Other wildlife, including deer, may produce fecal matter that is carried to the waterways and may streams by over-grazing vegetation to increase erosion.

2.2.4 Natural Conditions

The low pH in the western portions of the streams may well be due to the naturally acidic soils found in the Pineland-type woodlands and soils.

Streams may also produce sediment from natural erosion processes, particularly during larger storms. Bacteria may be associated with soils and other watershed sediments.

2.2.5 Pollutant Source Summary

For the Wreck Pond watershed, the mixed land uses are a major source of all pollutants of interest. The results of the watershed modeling, agricultural survey, stream assessments, and bacteria source tracking did not identify one source of highest importance. For each pollutant group, identified sources are noted below.

Nutrients: Developed land uses, agricultural lands, fertilizer application

Bacteria: Developed land use, manure management in farmlands, water fowl, possible leaking infrastructure, wildlife, pets, release from Pond sediments

Sediment: Developed lands, agricultural land, un-vegetated uplands, construction sites, stream erosion, re-suspension of pond sediments

3 BUILD-OUT ANALYSIS

One of the goals of the RWSMP is to evaluate the potential impacts of future land development on stormwater within the watershed. The first step was to project future land use which was accomplished by analyzing expected watershed land use based on existing zoning.

Existing land use is analyzed in Section 2.10 of Book 1 of this Plan. Existing land use within the watershed was based on the Monmouth County GIS 2006 land use layer. Residential lands occupy 35% of watershed and woodland occupies about 27% with about 10% in commercial and industrial land use. About 55% of the watershed is already developed or is not developable, leaving about 45% of the land area available for future development. Table 9 in Book 1 summarizes existing land use and Table 2, below, (a copy of Table 10 in Book 1), presents general land use, identifying those lands available for future development.

TABLE 2: Use of Developable and Undevelopable Lands

	Acres	Percent
Future Developable Lands	**3690.1**	**45.1%**
Agricultural Use	818.5	10.0%
Brush	289.8	3.3%
Unvegetated	311.5	3.8%
Woods	2270.3	27.8%
Developed or Undevelopable Lands	**4483.9**	**54.9%**
Landscaped Open Space	621.8	7.6%
Water	215.9	2.6%
Commercial/Industrial/Institutional	819.2	10.0%
Residential	2827.0	34.6%

This existing land use information was analyzed to generate input data for the hydrologic/hydraulic and watershed water quality models as discussed in Sections 7 and 8 of Book 1 of this Plan. On a sub-watershed basis, land use percents were determined in a GIS database. The landuse categories used in the watershed SWMM model were:

- Agriculture
- Open space
- Commercial/Industrial
- Golf courses
- Residential 17% impervious
- Residential 23% impervious

- Residential 33% impervious
- Residential 65% impervious
- Woodland
- Water.

Because the generation of pollutants in the SWMM model is primarily based on land use, this information served as basic information for model development. These categories were based on review of watershed land use and were limited in the model to ten categories. Further, the availability of pollution generation data for a land use category was considered in selecting these ten categories. Impervious areas were determined using a combination of GIS data files which included roads, buildings and driveways. For the hydrologic/hydraulic model, land use was a factor in developing the CN numbers used to generate watershed flows.

The build-out scenario for the models required projection of future land use conditions, which was conducted as discussed in the following sections.

3.1 Zoning Analysis

Zoning controls future development within each municipality. The specific zoning and development regulations of each municipality control the type and density of land use that can be legally constructed at a site. Thus, analysis of zoning information is essential for evaluating the potential impacts of future development on the quantity and quality of receiving waters.

Each municipality has developed its own zoning categories according to its Municipal Master Plan. The Monmouth County GIS database includes a zoning layer for the watershed which compiles the zoning districts for each municipality into a single data layer. Categories in the zoning layer of the GIS database include zoning class ID and zoning district as defined by the municipality. Table 3 summarizes the zoning districts for the watershed, which include 38 distinct zoning districts in the four municipalities.

The GIS database does not provide detailed descriptions of each class in all cases. In addition, the zoning classes are not always directly comparable across municipalities. For example, Spring Lake has an R-1 zone which requires 15,000 sq. ft. per dwelling unit, while Wall Township designates the same zoning as R-15.

Thus, the first step in analyzing the zoning was to examine the zoning ordinance for each of the four municipalities to define the zones. The definitions in the ordinance were used to standardize the zoning districts for the watershed. Therefore, regardless of the actual zoning district designated by each municipality, a zoning classification was developed for use in this Plan.

Table 3: Zoning Districts		
Municipality	**Zone ID**	**Zoning District**
Sea Girt Boro	1E	District 1 East Single Family
	1W	District 1 West Single Family
	3	District 3 Beach
Spring Lake Boro	GC	General Commercial
	RC	Retail Commercial
	R3	Single family Residential 11,250 sq.ft per Dwelling
	R1	Single family Residential 15,000 sq.ft. per Dwelling
	R2	Single Family Residential 7,500 sq ft per Dwelling
Spring Lake Hts Boro	B-2	Commercial
	R-2	Residential
	R-3	Residential
	R-4	Residential
	R-5	Residential
Wall Twp	OR-2	Office-Research 2
	OR-5	Office-Research 5
	HD-6	
	GS_Prky	GS_Parkway
	A-I	Airport Industrial
	CR-10	Commercial Recreation/10 Acres
	CR-40	Commercial Recreation/40 Acres
	MLCC	Congregate Care/.14 DU Acre
	GI-10	General Industrial/10 Acres
	GI-2	General Industrial/10 Acres
	HD-8	High Density Multi-Family 8 DU/Acre
	HD-12	High Density Multi-Family/12 DU Acre
	HB-120	Highway Business/120,000 Sq. Ft.
	HB-200	Highway Business/200,000 Sq. Ft.
	HB-80	Highway Business/80,000 Sq. Ft
	MHP	Mobile Home Park
	MLC-9	Multi-Family 9 DU/Acre
	MLC-7	Multi-family 7DU/Acre
	ML-8A	Multi-Family 8 DU/Acre
	MCL-3	Multi-Family 3 DU Acre
	ML-3	Multi-Family 3 DU Acre
	MLC-8A	Multi-Family 8 DU Acre
	NB	Neighborhood Business/20,000 sq. Ft
	OB-120	Office Business/120,000 Sq. Ft
	OP-10	Office Park/10 Acres

Table 3: Zoning Districts (continued)		
Municipality	**Zone ID**	**Zoning District**
Wall Twp	OP-2	Office Park/2 Acres
	OR-10	Office Research/10 Acres
	OR-2	Office Research/2 Acres
	OR-5	Office Research/5 Acre
	POS	Public Office Space
	RR	Rural Residential
	RR-5	Rural Residential/5 Acres
	RR-6	Rural Residential/6 Acres
	ML-8B	Senior Citizen & Townhouse 8 DU/Acre
	R-10	Single Family Residential/10,000 Sq. Ft
	R-15	Single Family Residential/15,000 Sq. Ft
	R-20	Single Family Residential/20,000 Sq. Ft
	R-30	Single Family Residential/30.000 Sq. Ft.
	R-40	Single Family Residential/40,000 Sq. Ft
	R-60	Single Family Residential/60,000 Sq. Ft
	R-7.5	Single Family Residential/7,5000 Sq. Ft.

The zoning districts were then assigned to the appropriate general land use class developed in Section 2.10 of Book 1 which are:

- Commercial
- Industrial (includes transportation and GSP)
- Recreation/Park
- Residential-Low Density
- Residential-Medium Density
- Residential - High Density

Table 4 summarizes watershed zoning based on these classifications. Thus, the zoning data indicates that the watershed is zoned as ±67% residential, ±10% open space, ±14% office and commercial and ±9% other zones. The "other" category includes the Garden State Parkway, small industrial zones, and congregate care facilities.

Agricultural zoning is not included in the Master Plan of any of the municipalities within the watershed. However, about 10% of the watershed, approximately 820 acres, is currently in agricultural use. According to the information from the NJDA, none of these areas are currently enrolled as Farmland Preservation areas. According to the zoning, about 25% of the agricultural lands are zoned for recreation/park lands. The remaining lands currently in agricultural use are zoned primarily for residential use (71%). Almost all of the residential zoning (96%) is for low density use.

Table 4: Overall Watershed Zoning - 2006 General Categories		
Zoning District	**Approx Acreage**	**Percent**
Commercial	1366	17%
Industrial (includes transportation and GSP)	507	6%
Recreation/Park	804	10%
Residential-Low Density	3704	45%
Residential-Medium Density	1610	20%
Residential - High Density	180	2%

3.2 Build-Out Land Use

As noted above, future development will not occur on all of the lands as zoned. Thus, the next step was determination of developable lands within the watershed. Undeveloped lands were based on current land use, including lands categorized as agricultural lands, wooded lands, barren lands, extractive mining, and brush. Lands that were already considered developed for residential, commercial or industrial use were not included in this analysis. Although future redevelopment may occur on certain lands, the resulting changes in stormwater generation would not be as significant as those from the development of currently undeveloped lands.

Certain potentially developable lands could be restricted for future development. Currently, there are no farmland preservation lands within the watershed. There are, however, park and open-space lands. In addition, Wall Township includes lands zoned for open space/parks, which are expected to be unavailable for future development. It was assumed that parks, golf courses, athletic fields and municipal open space would not be further developed.

The GIS existing land use (2006) layer was used to determine potentially developable lands including woodland, barren, brush, agriculture or extractive mining uses. The GIS Zoning layer was overlain on these lands. Based on this analysis, Table 5 provides the zoning of the Potentially Developable Lands within the Watershed. The total acreage of potentially developable lands is about 3,600 acres.

These potentially developable lands may be further constrained by environmental conditions. Within the Wreck Pond Brook Watershed, wetlands and associated buffers are the major environmental constraint to development. The NJDEP Freshwater Wetlands Protection Act generally does not permit development within wetlands or fill of wetlands to create upland. Within the watershed about 1,100 acres of wetlands are mapped by NJDEP. Although this mapping is not exact, it provides a generalized picture of the wetlands within the watershed. Buffers of 50 feet are expected to the watershed wetlands as habitat for endangered or threatened species was not identified within the watershed stream corridors using Version 2 of the Landscape GIS data.

Table 5: Zoning of Potentially Developable Lands							
Zoning	**Existing Land Use**					**Future Zoning**	**% Future Land Use**
	Agriculture	**Barren**	**Brush**	**Mining**	**Woodland**	**TOTAL**	
Commercial	35.6	50.6	84.9	10.8	585.6	767.5	21.3%
Industrial	0.2	67.5	86.0	1.8	128.0	283.6	7.9%
Recreation/Park	202.8	9.0	18.8	1.1	270.9	502.7	13.9%
Residential (17% impervious)	556.0	16.1	51.6	106.8	864.7	1595.2	44.2%
Residential (23% impervious)	24.8	3.6	17.9	0.4	234.4	281.2	7.8%
Residential (33% impervious)	0.2	14.5	14.6	0.0	93.2	122.5	3.4%
Residential (65% impervious)	0.0	0.3	2.1	0.0	53.0	55.5	1.5%
Other							
	819.6	**161.8**	**275.9**	**120.9**	**2229.9**	**3608.1**	

The wetlands and a 50-foot buffer were overlain on the potentially developable lands within the watershed to determine the zoning of the wetlands and buffers. About 890 acres of wetlands, including the fifty-foot buffer, are within the potentially developable lands. Table 6 summarizes the zoning of the wetland/buffer areas within the potentially developable lands.

Table 6: Zoning of Wetlands and Buffers	
Zone	**Area (acres)**
Commercial	224.4
Industrial	15.2
Recreation/Park	0.4
Residential (17% impervious)	457.2
Residential (23% impervious)	98.8
Residential (33% impervious)	50.6
Residential (65% impervious)	43.4

It should be noted that this must be considered a rough approximation of the wetland acreage. For example, this analysis indicates that about 100 acres of the areas identified as wetlands by NJDEP mapping are mapped as a developed land use within the GIS system. Another approximately 80 acres are zoned as Public Open Space and thus is not developable land in the build-out analyses.

To determine the final developable zoning, the acreage of wetlands within each zoning category was subtracted from the acreage of Potentially Developable Land within that zone. Table 7 summarizes this result. Figure 4 shows the wetlands overlain on the developable zoning.

It should be further noted that the Recreation/Park use may include wooded lands and agricultural lands in addition to those listed. The ±503 acres zoned for recreation and park include about 200 acres of agricultural lands and about 270 acres of woodlands. However, since recreation/park land can be simply open space preserve or athletic fields, it is not known how much of these lands will be preserved as agricultural land or woodland and how much may become fields, parking lots or other park features.

Table 7: Developable Lands Zoning

	Zoned	Wetlands	Developable Zoning
Commercial	767.5	224.4	543.0
Industrial (include GSP)	283.6	15.2	268.3
Recreation/Park	502.7	0.4	502.3
Residential (17% impervious)	1595.2	457.2	1138.1
Residential (23% impervious)	281.2	98.8	182.4
Residential (33% impervious)	122.5	50.6	71.9
Residential (65% impervious)	55.5	43.4	12.0
TOTAL	**3608.1**	**890.1**	**2718.0**

The build-out analysis herein does not consider redevelopment of existing land uses in accordance with the zoning. In many cases, current land uses have uncontrolled stormwater and proposed development would be required to conform to current, more stringent stormwater management requirements. Further, more detailed information would be required as to which uses were non-conforming.

3.3 Build-out Timeframe

Review of past development rate may assist in determining an appropriate build-out horizon. Past rates of development may not predict the future as development may accelerate or slow depending on market condition and available lands. However, in order to investigate the past development rate in the watershed, land use data from 1986 and 2006 were compared.

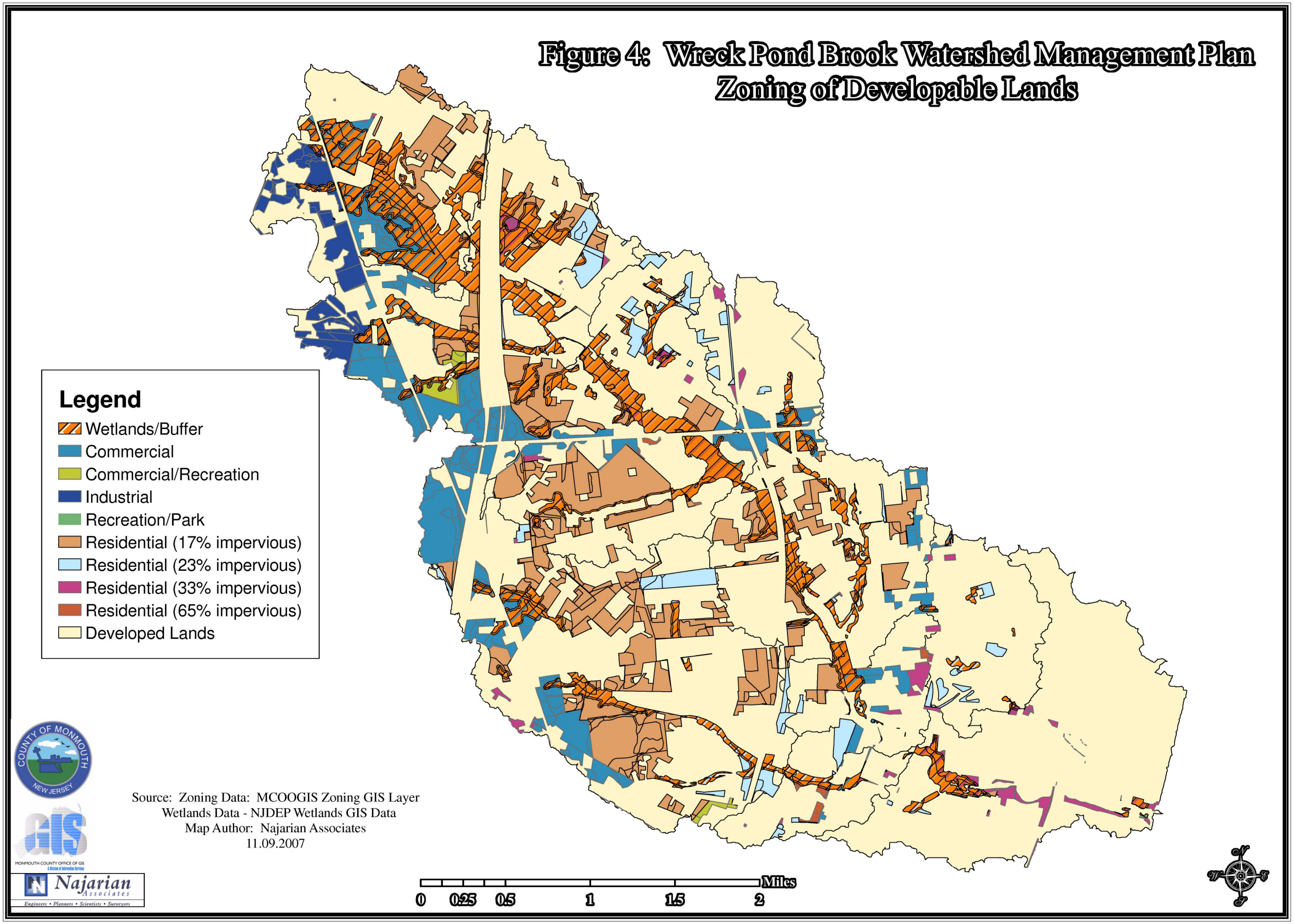


Figure 4: Wreck Pond Brook Watershed Management Plan
Zoning of Developable Lands
Legend
Wetlands/Buffer
Commercial
Commercial/Recreation
Industrial
Recreation/Park
Residential (17% impervious)
Residential (23% impervious)
Residential (33% impervious)
Residential (65% impervious)
Developed Lands
Source: Zoning Data: MCOOGIS Zoning GIS Layer
Wetlands Data - NJDEP Wetlands GIS Data
Map Author: Najarian Associates
11.09.2007
0 0.25 0.5 1 1.5 2 Miles
COUNTY OF MONMOUTH NEW JERSEY
GIS
MONMOUTH COUNTY OFFICE OF GIS
Najarian Associates
Engineers • Planners • Scientists • Surveyors

The NJDEP has a Land Use/Land Cover layer from 1986 which is summarized in Table 8. This can be compared to Table 4 for existing development as of 2006.

Table 8: 1986 Land Use		
Land Use Category	**Acres**	**Pct of Watershed**
Agriculture	1100	13.5%
Barren	213	2.6%
Forest	1693	20.7%
Urban	3996	48.9%
Water	104	1.3%
Wetlands	1066	13.0%

Several factors must be considered when comparing the 1986 and 2006 land use data. First, in 1986 wetlands were categorized as a separate category while in 2006 wetlands were included with the overlying land type, primarily woodland. Second, the land uses were reviewed and some land uses were re-categorized in 1996 and later by Monmouth County and other agencies. For example, the acreage of unvegetated land, also known as barren land, is greater in 2006 at about 311 acres than in 1986, at about 213 acres. A review of a GIS layer that combines these two land use files indicates that areas that are called unvegetated in 2006 included lands that in 1986 were classified in uses including agricultural, urban and water. Thus, the 1986 land use classes may not be directly comparable to the 2006 data and may have more inaccuracies. The later data may be more accurate due, in part, to improved mapping tools. In addition, the land use classifications schemes may differ between the two time periods.

In analyzing the 1986 Land Use data, the wetlands category was split so that the area classified as water was the same in 1986 as in 2006. The remainder of the wetlands were assigned to the woodland category.

With these caveats in mind, the available information shows a transformation of about 5% of the watershed in the period from 1986 to 2006 from agriculture or forested use to urban or barren lands. This represents a decline of about 25% of the lands devoted to agricultural use, with a 5% reduction in forested lands. Given that about 950 acres (38%) of the forest area is wetlands, about 9% of the non-wetland wooded lands were developed. The overall increase in urban land is about 4% of the total watershed area.

Although this analysis does not show a rapid increase in development of the past 20 years, development rates can accelerate if infrastructure becomes available or an owner of a large land area decides to sell. The presence of one development can change the economic viability of development of surrounding parcels. Thus, past rate of development is not a predictor for the future. Therefore, the full build-out scenario is presented herein.

3.4 Hydrologic and Water Quality Impacts of Full Build-out

The main purpose of the build-out analysis was to provide input to model scenarios under build-out land use to predict hydrologic and water quality changes in the watershed. The analysis was conducted using the watershed SWMM model developed by NA. The analysis was conducted based on full build-out conditions outlined in Section 3.2, as a conservative condition. Model input required analysis of the change from one land use to another. Table 9 summarizes this for the watershed. The actual analysis was conducted on the basis of the sub-watersheds used in the modeling.

The SWMM watershed model is discussed in Book 1, Section 8. The calibrated model was run using the full build-out land use, which assumes that all developable lands within the watershed would be converted to developed lands in accordance with zoning. This did not include existing open space areas or wetlands. Thus, the flow and loading information provided is a worst-case scenario for the watershed and Wreck Pond, while realistically excluding wetlands and buffers on which development is prohibited by State regulation.

Table 9: Land Use Changes under Build-out (acres)

	Existing	Change	Buildout
Agriculture	820.3	-794.0	26.3 (wetland/buffer)
Barren	165.5	-149.7	15.8 (wetland/buffer)
Brush	283.7	-251.3	32.4 (wetland/buffer)
Cemetery	38.4	0.1	38.5
Commercial	404.6	544.4	949.0
Extractive Mining	120.9	-119.8	1.1
Industrial	428.1	269.3	697.4
Landscaped Open Space	163.4	0.2	163.6
Recreation/Park	403.4	503.7	907.1
Residential - High Density	239.5	12.4	251.9
Residential - Low Density	1413.4	1141.9	2555.3
Residential - Medium Density	1247.1	256.3	1503.4
Water	215.9	0.3	216.2
Woodland	2229.9	-1414.1	815.8 (wetland/buffer)

Revised land use percentages and percent impervious values were input into the model for each sub-basin and the model was run for the 2-year, wet and dry year simulations. For this analysis the subwatershed areas were:

1. Upper Wreck Pond Brook (west of Route 18)
2. Lower Wreck Pond Brook (east of Route 18)
3. Hannabrand Brook
4. Wreck Pond (below Old Mill Road)
5. Black Creek

Tables 10 through 12, below, provide percent increase information for flow and pollutant loadings for the three simulations. Figure 5 shows these results graphically.

Table 10: Build Out Loading Simulation from SWMM Model
Two-year Storm at Full Build Out – Percent Increase in Load

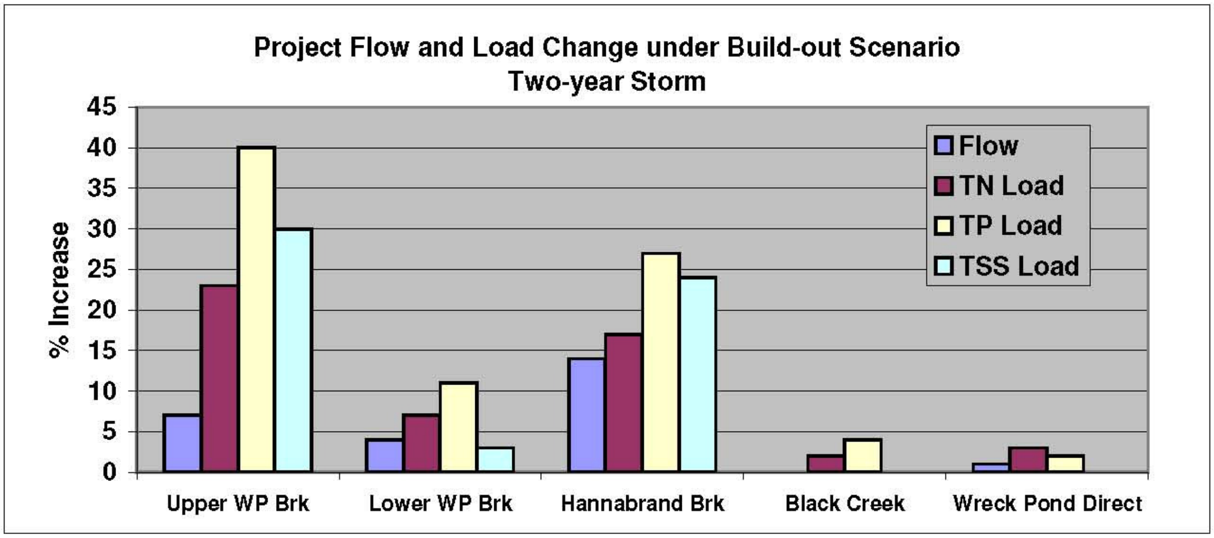
Sub-Basin	Flow Increase (%)	TN Load Increase (%)	TP Load Increase (%)	TSS Load Increase (%)	FC Load Increase (%)
Upper WP Brk	7	23	40	30	87
Lower WP Brk	4	7	11	3	41
Hannabrand Brk	14	17	27	24	107
Black Creek	0	2	4	0	6
Wreck Pond	1	3	2	0	3

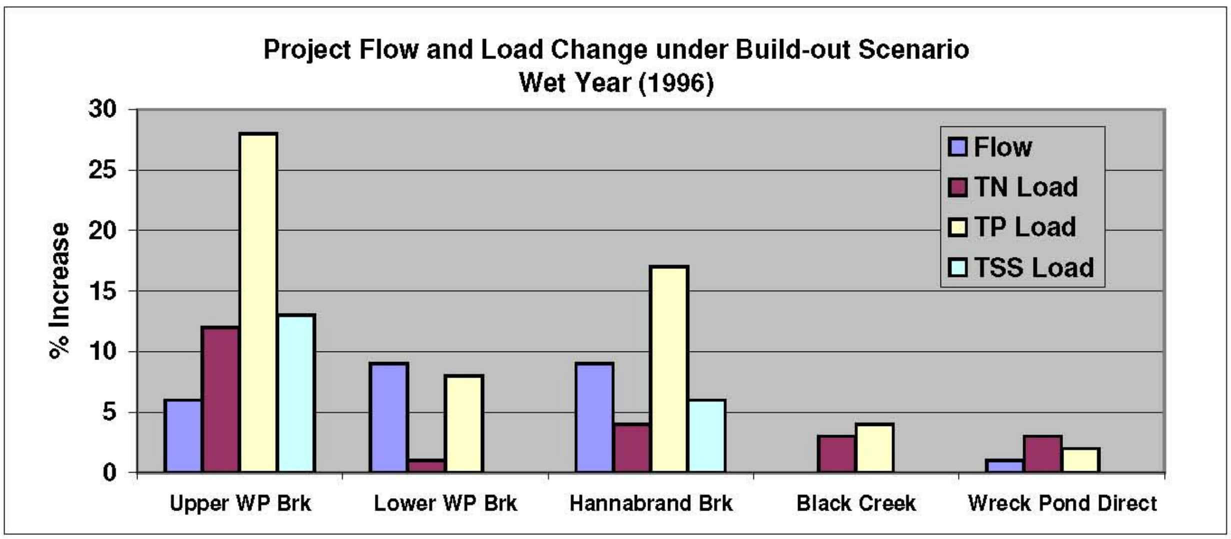
Table 11: Build Out Loading Simulation from SWMM Model
1996 Wet Year Simulation at Full Build Out – Percent Increase in Load

Sub-Basin	Flow Increase (%)	TN Load Increase (%)	TP Load Increase (%)	TSS Load Increase (%)	FC Load Increase (%)
Upper WP Brk	6	12	28	13	81
Lower WP Brk	9	1	8	0	70
Hannabrand Brk	9	4	17	6	108
Black Creek	0	3	4	0	9
Wreck Pond	1	3	2	0	4

Wreck Pond Brook Regional Stormwater Managment Plan

Figure 5: SWMM Model Results - Build-out Analysis





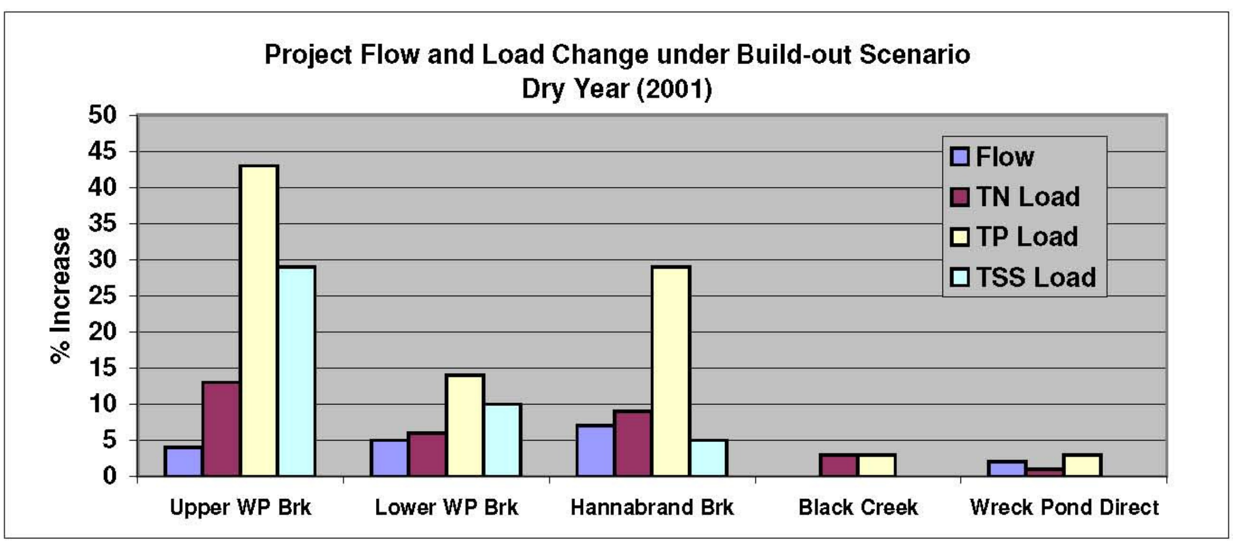


Table 12: Build Out Loading Simulation from SWMM Model 2001 Dry Year Simulation at Full Build Out – Percent Increase in Load					
Sub-Basin	**Flow Increase (%)**	**TN Load Increase (%)**	**TP Load Increase (%)**	**TSS Load Increase (%)**	**FC Load Increase (%)**
Upper WP Brk	4	13	43	29	187
Lower WP Brk	5	6	14	10	117
Hannabrand Brk	7	9	29	5	141
Black Creek	0	3	3	0	17
Wreck Pond	2	1	3	0	3

It should be noted that the bacteria analyses should be considered very preliminary as loading data for bacteria are limited.

These results indicate that the upper portions of the Wreck Pond Brook show the largest percent increases in nutrients and TSS, while lands developed along the Hannabrand Brook produce the highest percent increase in flow and bacteria. These trends can be attributed to the fact that both of these sub-basins contain the highest percentages of developable land. Thus, build-out will increase impervious area to a greater extent here than in other parts of the watershed.

The Black Creek and the Wreck Pond direct drainage sub-basins show the smallest percent increases in all categories for all simulations. This is consistent with the fact that these sub-basins are currently very close to full build out and limited increases in developed land are anticipated. However, redevelopment, including enlargement of existing homes or businesses, is not evaluated in the build-out analysis.

The model used for this build out analysis does not take into account any stormwater management measures that future developments may be required to implement under NJDEP regulations. Current NJDEP regulations require strict control of stormwater runoff from new development including maintenance of existing recharge and control of peak outflow and stormwater quality. Further, this analysis does not take into account development of areas now in open space, such as the golf courses or parks in the watershed.

These worst-case scenario build-out estimates can be used by the Borough and the County as a planning tool with respect to future development, specifically within the upper portions of the watershed. Because Wreck Pond will ultimately receive increased flows and pollutant loadings from development upstream, it is important for future development to consider potential downstream impacts and appropriate management techniques.

Originally it was planned to include the build-out scenario in the NJDA hydrologic and hydraulic model developed for this study as described in Book 1, Section 7. However, this was beyond the scope of the NJDA modeling effort for the RSWMP. Thus, the analyses herein must be considered estimates and future analysis, particularly related to flooding, with the NJDA model would provide additional information on build-out scenarios.

3.5 Recharge Impacts of Full Build-Out

Section 9 of Book 1 provides an analysis of Recharge Rank based on NJGS methodology using existing land use. This analysis was also conducted using the full build-out land use scenario described above for the developable lands. Figure 6 shows the future recharge rank while Table 13 compares the existing and future recharge.

Within the watershed, about 2,700 acres are available for future development. This excludes already developed lands, wetlands, wetlands buffers, waters, and lands zoned for future open space. Of these, recharge could be calculated for about 1,840 acres. The other acres had soil types that could not be calculated. About half of this is due to soils labeled as hydric in the NJGS methodology, although these are not identified as wetlands on the NJDEP Wetland maps. This is likely due to both areas with wetland that have not yet been identified as well inaccuracies in the soils mapping.

As discussed in Book 1, Wreck Pond Brook is within Watershed Management Area 12. For this area, the NJGS has developed Recharge Rank Categories as follow:

A	>16 Inches per year
B	12-16 in per year
C	9-11 in per yr
D	1-8 in per yr
E	0 in per yr

Clearly, the most recharge occurs in the Rank A areas and the least in Rank E.

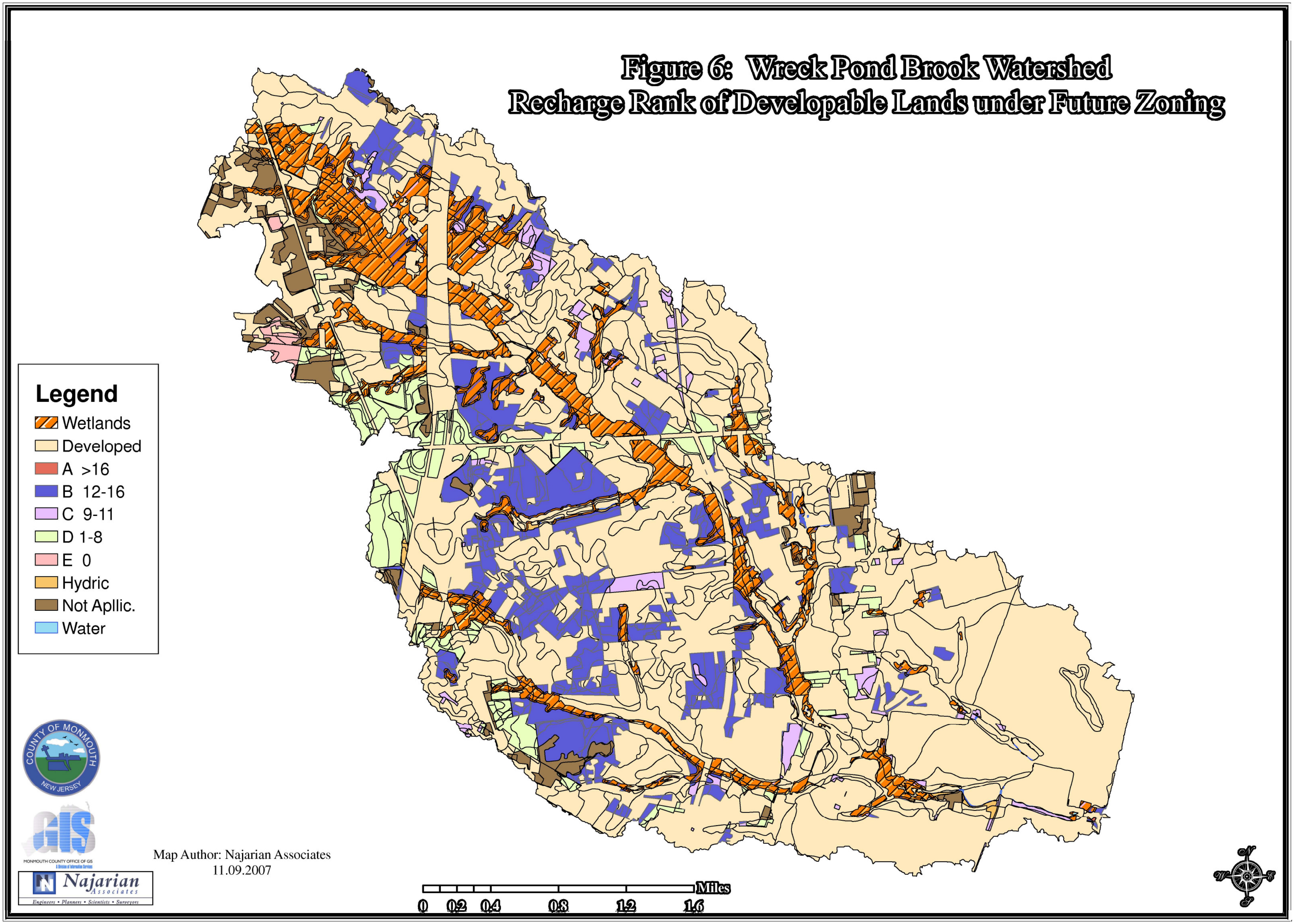


Figure 6: Wreck Pond Brook Watershed
Recharge Rank of Developable Lands under Future Zoning
Legend
Wetlands
Developed
A >16
B 12-16
C 9-11
D 1-8
E 0
Hydric
Not Apllic.
Water
Map Author: Najarian Associates
11.09.2007
Miles
0
0.2
0.4
0.8
1.2
1.6

Table 13: Recharge Rankings of Developable Lands Under Future Zoning				
	Existing Developable		Zoned	
	Area (ac)	Percent	Area (ac)	Percent
A	998	54%	0	0%
B	845	46%	1129	61%
C			195	11%
D			487	26%
E			30	2%

As expected, currently undeveloped lands have relatively high recharge rank. After development, the majority of the area will still provide recharge in Rank B, however no Rank A areas will remain. Only limited area will allow no recharge.

Using volumes, the developable area under current conditions represents about 37% of overall watershed recharge. For future, full build-out conditions, without any consideration of mitigation, a 40% reduction in recharge volume is projected. The volume of recharge lost under that scenario is about 14% of the current total calculated recharge volume. That is, with full build-out and no consideration of required stormwater mitigation measures, approximately 86% of the existing recharge will be maintained.

The current NJDEP Stormwater Management Regulations require maintenance of existing recharge rates. These regulations apply to most development projects adding 0.25 acre of impervious area. As most development would fall under those regulations, the required stormwater management techniques would maintain recharge. Thus, this analysis represents a worst-case condition considering full development under existing development and the actual impact is expected to be reduced with implementation of the NJDEP recharge requirements.

4 WATER QUALITY STANDARDS AND OBJECTIVES

Book 1 of this document provides a description of the watershed conditions and describes the numerous investigations conducted to develop this Plan. This section uses the data and results of those studies, along with NJDEP regulations, to develop the Water Quality Standards and Objections. Book 1 provides details on the monitoring that was done, including sampling locations and results.

4.1 Water Quality Management Units

The water quality planning units are shown as Figure 7 and Table 14 are described as follows:

1. Upper Wreck Pond Brook (west of Route 18)
2. Lower Wreck Pond Brook (east of Route 18)
3. Hannabrand Brook
4. Black Creek
5. Wreck Pond Direct

Table 14: Watershed Management Units

Unit	Subwatershed (Station) and County Station	Area (acres)
Upper Wreck Pond Brook		***3106.4***
	Martin's Road (W6)	821.23
	Hurley's Pond Dam (W9)	1164
	Glendola Rd (W7)	1121.17
Lower Wreck Pond Brook		***1534.84***
	Waterford Glen (W1)	1231.78
	Old Mill Dam Culvert (W3)	303.06
Hannabrand Brook		***1976.46***
	Bailey's Corner Rd (W5)	1716.75
	Hannabrand Brook Culvert (W2)	259.71
Black Creek	Black Creek (W8)	***416.4***
Wreck Pond Direct	Wreck Pond Direct	***1137.96***

Upper Wreck Pond Brook includes the Marin’s Road, Hurley’s Pond and Glendola Road subbasins. The management unit occupies about 3,100 acres and includes some of the least developed areas within the watershed. The Lower Wreck Pond Brook unit

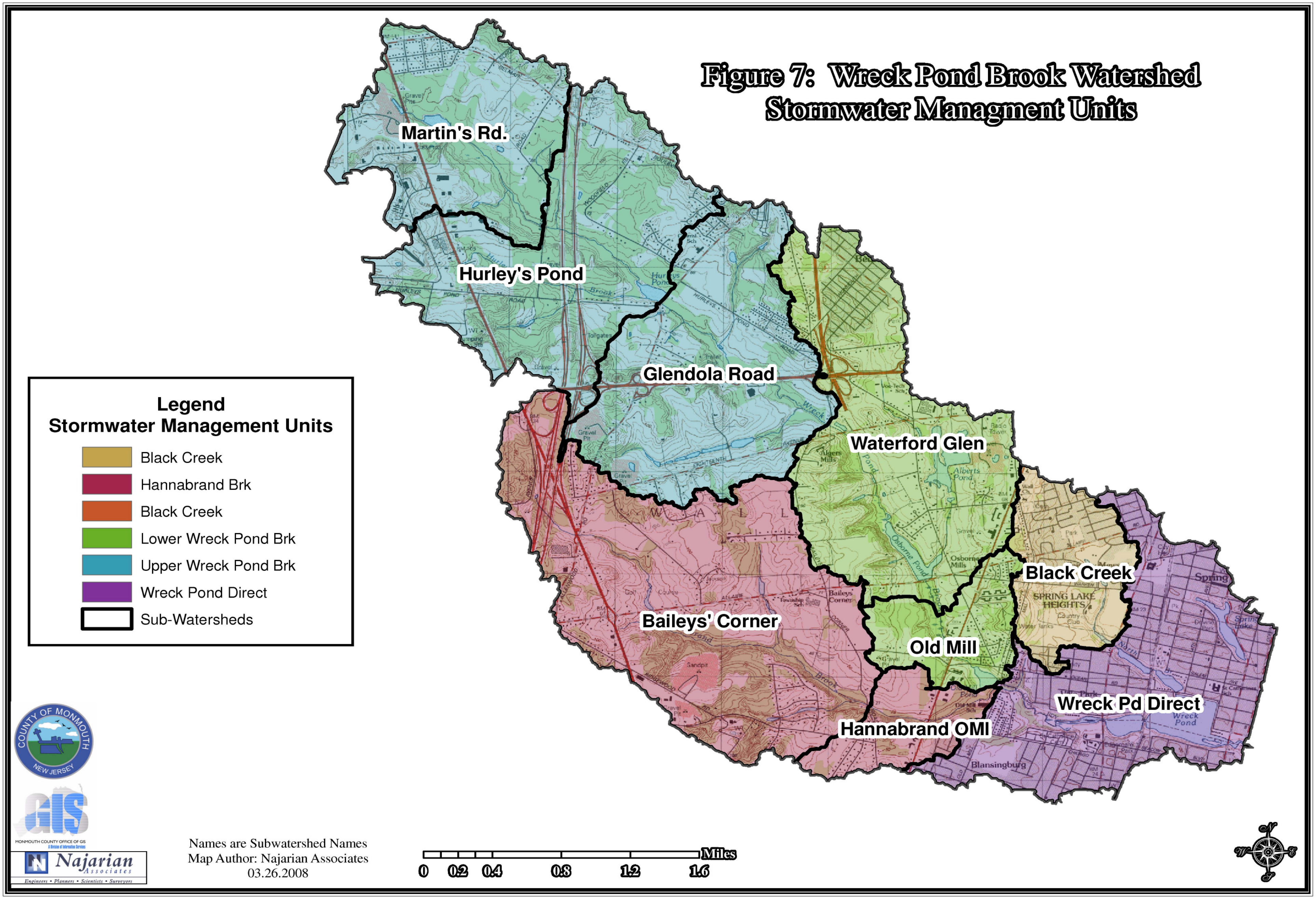


Figure 7: Wreck Pond Brook Watershed
Stormwater Managment Units
Martin's Rd.
Hurley's Pond
Glendola Road
Waterford Glen
Black Creek
Baileys' Corner
Old Mill
Wreck Pd Direct
Hannabrand OMI
Legend
Stormwater Management Units
Black Creek
Hannabrand Brk
Black Creek
Lower Wreck Pond Brk
Upper Wreck Pond Brk
Wreck Pond Direct
Sub-Watersheds
Names are Subwatershed Names
Map Author: Najarian Associates
03.26.2008
Miles
0 0.2 0.4 0.8 1.2 1.6

extends from Glendola Road to the Old Mill dam culvert and includes the Waterford Glen and Old Mill subwatershed areas and about 1535 acres. Most of the flows within the watershed are generated in these two management units.

The Hannabrand Brook unit includes the Bailey's Corner Road and Hannabrand Brook at Old Mill Road sub-watersheds. This unit has mixed land uses and some of the studies for this Plan identified areas in need of remediation. The Black Creek unit includes the Spring Lake Golf Course and the ponded section of that water which is the subject of concern to area residents. Finally, the Wreck Pond Direct unit includes Wreck Pond Brook downstream of Station W3 and Wreck Pond itself and is primarily developed. Flows enter the Pond through stormwater pipes in much of this unit.

4.2 Existing Stormwater Related Concerns

The initial RSWMP Committee focused primarily on sediment and bacteria concerns related to possible dredging of Wreck Pond and the bathing beach closures. Development of the plan, including the studies and analyses conducted as part of the RSWMP and the valuable input of the RSWMP Committee members, have identified a number of concerns related to stormwater in the watershed. This section identifies those concerns, starting with water quality impairments identified by NJDEP.

4.2.1 Water Quality Impaired Uses

Waters in NJ are classified and each classification includes designated uses in accordance with the Federal Clean Water Act and NJDEP regulations. As discussed in Section 2 in Book 1, the waters within the Wreck Pond Brook watershed are classified as FW2-NT and designated uses include maintenance of aquatic life and primary and secondary contract recreation. These uses are sometimes referred to as "fishable and swimmable". NJDEP has developed Surface Water Quality Standards (SWQS) designed to ensure that if the waters meet the applicable standards, the designated uses are attained. Current water quality standards (adopted October 2006) relevant to this Management Plan are listed in Table 15.

It should be noted that the previous water quality standards included fecal coliform instead of E. Coli limits for bacteria levels in freshwaters. Those standards were 200/100 ml with no more than 10 percent of samples in any 30-day period exceeding 400 per 100 ml. The water quality monitoring done for this RSWMP was done prior to the adoption of the current standards in October of 2006; thus fecal coliform was measured and the results are compared to the former standard.

Table 15: Relevant Surface Water Quality Standards		
Parameter	**Standard**	**Classification**
Bacteria: Primary Contact Recreation	Enterococci levels shall not exceed a geometric mean of 35/100 ml, or a single sample maximum of 104/100 ml.	SC Waters (Atlantic Ocean)
	E. Coli levels shall not exceed a geometric mean of 126/100 ml or a single sample maximum of 235/100 ml.	FW2 Waters
Dissolved Oxygen (DO)	24 hour average not less than 5.0, but not less than 4.0 at any time	FW2 Waters
Phosphorus	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	FW2 Lakes
	Except as necessary to satisfy the more stringent Lake phosphorus as total P shall not exceed 0.1 in any stream	FW2 Streams
pH	6.5-8.5	FW2
Total Dissolved Solids (TDS)	i. No increase in background which may adversely affect the survival, growth or propagation of the aquatic biota and ii. No increase in background which would interfere with the designated or existing uses, or 500 mg/L, whichever is more stringent	FW2
Total Suspended Solids (TSS)	40 mg/l	FW2
Turbidity	Thirty-day Average of 15 ntu, allowed maximum of 50 ntu	FW2

The NJDEP has assessed most waterbodies in the state for attainment of designated uses as required by USEPA regulations. The NJDEP then lists each water on one or more sublists as to whether designated uses have been attained as determined by conformance with various water quality standards. The sublists are defined as follows:

Sublist 1 – Full Attainment: All designated uses are assessed AND all uses are attained.

Sublist 2 – Attain: The designated use is assessed and attained BUT one or more designated uses in the assessment unit are not attained and/or there is insufficient information to make a determination.
Sublist 3 Insufficient Data: Insufficient data is available to determine if the use is attained
Sublist 4A Non-Attain: The designated use is not attained or is threatened; however, development of a Total Maximum Daily Load (TMDL) is not required because a TMDL has been developed for the pollutant causing non-attainment.
Sublist 4B - Non-Attain: The designated use is not attained or is threatened; however, development of a TMDL is not required because other enforceable pollution control requirements are reasonably expected to result in conformance with the applicable water quality standard(s) in the near future and the designated use will be attained.
Sublist 4C - Non-Attain: The designated use is not attained or is threatened; however, development of a TMDL is not required because non-attainment is caused by something other than a pollutant (e.g. "pollution" such as overland flow of stormwater, stream flow alterations, and habitat degradation).
Sublist 5 – Non-Attain: The designated use is not attained or is threatened by a pollutant(s) and a TMDL is required.

NJDEP uses specific parameters to evaluate use attainment. For General Aquatic Life, NJDEP uses biological parameters and if these are not available pH, DO, temperature, total phosphorus, TDS and TSS. For Recreation, bacteria levels are used, including fecal coliform or E. Coli in freshwaters and Enterococci in saline waters. NJDEP updates these lists every other year and develops an Integrated Report on water quality in accordance with requirements of the Clean Water Act, specifically sections 303(d) and 305(b).

Both the upper and lower portions of Wreck Pond Brook are listed as impaired for pH on the NJDEP's 2006 303(d) list. Both sections are on Sublist 5 as impaired for Aquatic Life (general) and the upper section is also impaired for Aquatic Life (trout). However, the trout listing appears to be an error as Wreck Pond Brook is a non-trout stream and, according to the Integrated Report, only trout waters are to be assessed for that use. Both segments are on list 4A for Primary Contact Recreation. For Secondary Contact Recreation the lower segment is on Sublist 2, while the upper is on Sublist 3. The NJDEP 305b report notes that coastal area streams near the Pinelands often have naturally low pH. However, as the standards is 6.5-8.5, streams that have pH levels that fall below that value are considered out of compliance. The County water quality data summarized in Book 1 shows that the upper watershed stations on Wreck Pond Brook have pH that is below standard. The mean pH at W6 and W9 are below 6.5 while at W7, it is just above the standard. Further downstream the pH levels conform to the Standard. At W3, the mean pH is 6.8, while the minimum is 6.01.

Hannabrand Brook was listed for fecal coliform as impaired for primary contract recreation on Sublist 5 with high priority and for pH for aquatic life with medium priority in 2004. A TMDL was developed for this stream in 2005. The TMDL report focused on ways to reduce bacteria levels in stormwater. Hannabrand Brook is not listed in the 2006 listings, but is noted as de-listed for fecal coliform but not for pH. According to the Integrated Report, this Brook should appear on List 4A for fecal coliform and should be similar to WPB for pH. Monitoring conducted for this study shows that fecal coliform is elevated on the Hannabrand Brook. From mid-July through August (three bi-weekly samples in 2006), the geometric mean was 660 col/100 ml, which exceeds the standard.

Wreck Pond is listed on Sublist 3 for Recreation (primary contact) and on Sublist 5 for both Recreation (aesthetic) and aquatic life. The Integrated Report notes that the aesthetic notation is now determined to be the result of eutrophication and assumed to represent phosphorus impairment.

For aquatic life, the western part of the Pond (WP1) was below the 6.5 mg/l range in monitoring done for this Plan. DO dropped below 4 mg/l for one measurement during the summer of 2006 and in some of the data collected by Monmouth University. Both TDS and TSS were above standard, although the TDS may be related to salinity. The 75^{th} percentile for TSS is 22.6 mg/l, which is below the standard. The lab turbidity met the standard, although the field turbidity did not. Total phosphorus exceeded the standard of 0.05 mg/l with the median value at 0.055 mg/l. TDS in the eastern part of the Pond was above the standard. However, this area is subject to tidal exchange so that the chloride levels are also higher which is related to the TDS.

The comments section for the Integrated Report notes that Wreck Pond is also on Sublist 4B for bacteria impairment of primary contact recreation. However, the Appendix List in the Integrated Report notes it as Sublist 3.

4.2.2 Bathing Beach Closures

Wreck Pond is the major presumed source of Ocean bathing beach closures in the Boroughs of Spring Lake and Sea Girt. Outflow from the Pond during certain storm events can bring a plume laden with bacteria to the bathing beaches. Monitoring of Wreck Pond for this Plan found fecal coliform bacteria at a geometric mean of 1,069 col/100ml at Station WP2 for the period from mid-July to late August and of 849 col/100 ml at Station WP3 for August. This is discussed further in Section 1 of Book 1.

4.2.3 Ecologic Concerns related to Water Quality

Phosphorus is above standard and is the range for a eutrophic pond. Chlorophyll-a is also high in the Pond, reaching over 20 ppm in the summer months. Algae are visible in numerous Ponds throughout the watershed. The DO in the western section of the Pond dropped below 4 mg/l in the summer.

Limited sampling on the ponded portion of Black Creek revealed super-saturated DO, elevated total P and low secchi depth. Chlorophyll-a was not measured here, but algal blooms are noted on Black Creek.

4.2.4 Flooding Issues

Flooding issues are of concern in certain parts of the watershed. Along Wreck Pond in Spring Lake and Spring Lake Heights, flooding from Pond overflow occurs due to fluvial flows combined with high tide conditions. Flooding also occurs routinely along 18^{th} Avenue in the vicinity of the Wall Township recreation fields due to a lack of drainage structures (basins, inlets, piping etc) and reportedly overflows onto the road and neighboring properties. Other upstream areas flood as well. Extensive flooding was noted during the storm of October 2005.

4.2.5 Habitat Loss

Habitat loss is of concern as undeveloped lands such as woodlands, fields, and agricultural lands are converted to more intensive uses such as residential lands.

The environments of highest value in the watershed include the ponds, streams, stream corridors, wetlands and associated buffers that will be protected by existing NJDEP regulations under most development schemes. This will help avoid loss of the most valuable habitat. In cases where DEP regulations do not apply, habitat loss may occur with development in these environments.

4.2.6 Stormwater Management Problem Ranking

The stormwater management issues within the watershed are inter-related. A strict ranking of problems is difficult and will vary by interested party. For example, beach closings are of great importance to officials and residents in Spring Lake and Sea Girt, while other issues may be more important in the upper watershed.

The major stormwater management problems identified are:

- Ocean swimming beach closings in the vicinity of the Wreck Pond outfall, assumed to be due to excessive bacteria loadings from the Pond

- Ongoing eutrophication and water quality degradation of watershed ponds. Conditions in Wreck Pond and Black Creek are of particular concern including observed severe shallowing and reduced tidal action in Wreck Pond

- Flooding in the lower watershed. The causes of the flooding are the limited ouflow from the Wreck Pond discharge pipe especially during high tide, stream channel blockages due to debris, loss of storage volume in some ponds due to sedimentation and the tidal nature of Wreck Pond.

The pollutants of major concern in the watershed and Wreck Pond include bacteria, phosphorus, sediment and nitrogen. The input of phosphorus and nitrogen to the streams and ultimately the Ponds, leads to enrichment that promotes algal growth. The bacteria are the source of beach closings. Sediment is leading to the shoaling of the ponds within the watershed and diminished storage for flood flows as well as decreased flow attenuation that promotes settling of sediment and associated pollutants.

4.3 Specific Water Quality and Quantity Objectives

Initially, the RWSMP focused on reducing sediment loads in support of NJDEP's plan to dredge the Pond. In addition, the plan focused on eliminating or greatly reducing Ocean bathing beach closures due to bacteria flows from the Wreck Pond outfall. As Plan development proceeded, additional objectives were identified as a result of detailed data collection and input from local citizens. Objectives were expanded to include measures to reduce flooding, improve wildlife habitat, control water fowl, improve overall water quality and aesthetics of local waters and enhance recreational opportunities.

Specific water quality objectives for this Watershed Management Plan are to reduce pollutant loading levels and remove accumulated pollutants to allow attainment of all designated uses that are not limited by natural conditions. In particular, the goals are:

- Reduce bacteria levels in Wreck Pond and tributary streams to meet standards and attain the designated uses

- Eliminate or greatly reduce beach closings due to outflow from Wreck Pond or other watershed sources

- Reduce sediment loads to Wreck Pond and other ponds from both existing sources and new development.

- Reduce phosphorus loads and concentrations to meet standards, reduce eutrophication of ponds, reduce algal blooms and attain the designated uses.

- Reduce nitrogen loads to reduce eutrophication and algal blooms

- Improve the water quality, ecological health and aesthetics of Wreck Pond, Black Creek, other Ponds and the overall watershed

- Determine natural background pH levels for tributary streams to set local standard

Water quantity objectives focus on the hydrodynamic systems of streams, ponds, groundwater flows and surface runoff from developed and natural areas. In particular, objectives include:

- Improve understanding of the relationships between stream hydraulics and surface/groundwater flows and their relationship to land use management

- Identify key areas within the watershed that have a beneficial or negative impact on stream flow dynamics or stream processes

- Develop management measures, design guidelines and standards which will improve, enhance or maintain (where appropriate) the hydrologic and hydraulic characteristics of the watershed.

- Analyze expected land use changes in the watershed to anticipate or predict potential future flow and flooding problems.

Many of the studies conducted for this Plan have provided valuable information to meet or partially meet these goals. The ongoing implementation process will provide greater detail and understanding of the issues and solutions within the watershed. The RSWMP has identified design and performance standards as discussed in Section 5, following. Specific mitigation projects are In addition, the Plan has mitigation projects, and an implementation strategy designed to meet these goals, that are described in the following sections. Further achievement of these goals will require additional effort within the watershed.

5 DESIGN AND PERFORMANCE STANDARDS

As part of the regional stormwater management plan development process, NJDEP Rules (Subchapter 3 of NJAC 7:8) require that watershed specific design and performance (D&P) standards be developed that will address the problems identified during the study portion of the project. D&P standards augment the general best management practices already required by NJDEP for new development. Watershed-specific D&P standards must address not only new development, but existing sources of pollutants and other problems identified within the watershed.

The Design and Performance Standards must be implemented by NJDEP and local municipalities. Thus, these standards will be further refined during the implementation phase of the RSWMP. This section discusses existing State, regional and local development controls, proposes additional management measures for new and identifies methods to reduce loadings from existing developed areas and other existing pollutant sources.

5.1 Management Measures for New Development

Reduction of future loadings within the watershed depends on control of stormwater from future development including construction. NJDEP and other state agencies control development of larger projects through various regulations. However, smaller projects or redevelopment and expansion of existing structures are controlled at the municipal level. The following sections discuss existing regulations and proposed measures to control loading from future land development.

5.1.1 State Regulations

NJDEP

NJDEP has set several regulations that govern new development within the Wreck Pond watershed. These regulations will control the peak flow rate and volume of stormwater from new development. The following sections discuss these regulations.

CAFRA: The CAFRA Law governs develop within the Coastal Zone using the *Rules on Coastal Zone Management* (NJAC 7:7E). However, within the watershed the boundary is at Route 71. Thus, this regulation governs development generally in Spring Lake, Sea Grit and Spring Lake Heights, which are primarily developed. There is also a small area in the southwestern part of the watershed, between Route 34 and the Parkway subject to CAFRA. For locations more than 150 feet from the mean high water line of a tidal waterbody, only development of 24 units or more are regulated. Thus, this Regulation will have minimal impact on future development.

Freshwater Wetlands Protection Act and Regulations (NJAC 7:7A): The wetlands law governs development within wetlands or associated buffers. Only limited development is allowed in these areas under the regulations. Wetlands are shown on Figure 3, however, actual field delineation would be required prior to any development activity. As noted in Section 2, Build-Out Analysis, future development is not anticipated within the wetlands.

Stormwater Management Rules (NJAC 7:8): The stormwater management rules apply to any development that disturbs one acre or more of land or adds 0.25 acres of impervious surface. The rules govern stormwater generated by new projects. They emphasize the use of non-structural stormwater management techniques including minimizing disturbance and impervious surfaces and preserving natural drainage features. The rules also set requirements for maintenance of groundwater recharge and control of stormwater runoff quantity and quality. These regulations set Special Water Resource Protection Areas adjacent to Category One (C1) waters; however this does not apply in the watershed as no waters are C1.

The stormwater management rules require new development to maintain existing levels of groundwater recharge. In addition, the rules require control for stormwater peak flow, such that the post-construction peak runoff rates for the two, 10 and 100-year storm events are 50, 75 and 80 percent, respectively, of the pre-construction peak runoff rates.

These rules also require removal of 80% of the TSS generated from a site under post-development conditions. This is usually managed by a site using structural stormwater techniques, such as stormwater detention basins.

In addition, nonstructural stormwater management techniques must be incorporated into design of new developments. These techniques promote recharge and reduce direct runoff. The Rules seek to have new development conform to the following requirements:

1. Protect areas that provide water quality benefits or areas particularly susceptible to erosion and sediment loss.
2. Minimize impervious surfaces and break up or disconnect the flow of runoff over impervious surfaces.
3. Maximize the protection of natural drainage features and vegetation.
4. Minimize the decrease in the pre-construction “time of concentration.”
5. Minimize land disturbance including clearing and grading.
6. Minimize soil compaction.
7. Provide low maintenance landscaping that encourages retention and planting of native vegetation and minimizes the use of lawns, fertilizers, and pesticides.
8. Provide vegetated open-channel conveyance systems discharge into and through stable vegetated areas.
9. Provide preventative source controls.

The Rules require new development to include a certain level of nonstructural measures. These may include preservation of natural areas by deed restriction, use of native ground covers in place of turf grass, providing vegetative filters and minimizing land disturbance in project design. Management measures for impervious areas include using pervious paving as appropriate in driveways or parking areas, directing flow from impervious surfaces to sheet flow over pervious areas, dispersing or infiltration of roof runoff or changes to time of concentration.

Flood Hazard Area Rules (NJAC 7:13): These rules control development in flood hazard areas and limits fill of flood plains. The rules also require new development not to impact flooding on adjacent properties. The recent revised regulations require a riparian buffer around all streams, ranging in with from 50 feet to 300 feet. For this watershed, the riparian buffer will generally be 50 feet as the streams are not classified as C1. In these buffer areas, no vegetation can be removed.

Maintenance: The stormwater control measures required by NJDEP require regular maintenance to function properly. NJDEP requires maintenance plans to be submitted in permit applications.

NJDA - Soil Erosion and Sediment Control Program

The Soil Erosion and Sediment Control Act of New Jersey, N.J.S.A. 4:29-34 et. seq., requires that land disturbances of 5,000 square feet or greater which require the issuance of a construction permit, submit a plan to the local soil conservation district for review and certification of temporary and permanent controls for soil erosion resulting from new development. These controls are to be designed in accordance with the *Standards for Soil Erosion and Sediment Control in New Jersey*, 6th edition (current). The Standards include design criteria for temporary and permanent controls such as waterway conveyances, slope protection, detention basin design, rock riprap outlet protection and the use of vegetation to permanently stabilize disturbed soils. The Standards also require that the designer demonstrate that the proposed stormwater management system will not cause erosion at the point of discharge nor downstream or "off site" – beyond the immediate limits of the development project. Hydrologic and hydraulic evaluations of land slope, vegetation, soil type and downstream channel hydraulics are to be evaluated under these Standards.

5.1.2 Municipal Stormwater Management Plans and Local Ordinances

Stormwater runoff generated by large-scale, new development is well controlled by NJDEP regulations. However, small projects or redevelopment may not be subject to NJDEP regulation. Local ordinances require stormwater control as well.

Each municipality is required to adopt a Municipal Stormwater Management Plan in accordance with NJAC 7:8. The four municipalities within the watershed have adopted stormwater management plans and have adopted or are in the process of developing Stormwater Control Ordinances. As discussed further in Section 5.2, the municipalities have also adopted various ordinances to control certain non-point sources of pollution from existing development.

The municipalities should ensure that any development that does not require NJDEP review for stormwater incorporates stormwater BMPs to the maximum extent practicable. The following innovative measures should be considered by the municipalities as requirements for new development, redevelopment or home expansion projects, as feasible. In addition, homeowners should be encouraged to implement these measures, as appropriate, at existing homes.

Rain Gardens: Rain gardens are a way to increase infiltration and thus reduce direct stormwater runoff (see section 6.1.5). These are usable on individual lots and are gardens that include plants and soil conditions to enhance recharge. The County is working to develop a program to provide incentives to homeowners to plant these gardens.

Dry Wells: Roof runoff may be directed to dry wells for infiltration to the ground, rather than becoming direct stormwater runoff.

Pervious Paving: The use of porous paving or grass pavers may be appropriate for some types of development. This can enhance infiltration by reducing the amount of impervious area. Again, maintenance measures may be required to ensure proper continuing function of this type of pavement.

Stormwater management BMPs will only function properly if continually maintained. The municipalities should ensure necessary maintenance activities are conducted at all public and private stormwater facilities.

Municipalities will review and implement additional measures during the implementation phase of the Management Plan.

5.2 Management Measures for Existing Development

Much of the watershed is already developed. Thus, control of new development as discussed above will only provide some reduction in pollutant loadings and stormwater flows. In order to meet the overall Plan objectives, measures are needed to reduce loadings from existing land uses or other existing sources of pollution. These measures require implementation by the individual municipalities or the County. The implementation of these measures will be further considered during the implementation phase, including feasibility and cost issues.

Each of the four municipalities has adopted a Stormwater Management Plan and has adopted or is in the process of adopting the ordinances required by the State for municipal stormwater management. The municipalities also are required to implement a number of management plans and programs to manage stormwater and to ensure maintenance. These ordinances and programs include:

- **Pet Waste Ordinance**: Adopt and enforce an ordinance requiring owners and keepers to immediately and properly dispose of their pet's solid waste. Distribute informational brochure with pet licenses.
- **Litter Ordinance:** Adopt and enforce a litter ordinance, or enforce the existing State litter statute (N.J.S.A. 13:1E-99.3).
- **Improper Waste Disposal Ordinance:** Adopt and enforce an ordinance prohibiting spilling, dumping or disposal of any materials into storm sewers.
- **Wildlife Feeding Ordinance:** Adopt and enforce an ordinance that prohibits feeding of non-confined wildlife in any public park or property owned/operated by the municipality with some exceptions
- **Yard Waste Ordinance**: Adopt and enforce an ordinance that prohibits placing non-containerized yard waste in the street, with some exceptions or develop a yard waste collection program.
- **Illicit Connection Ordinance**: Develop, implement and enforce an ordinance, to the extent allowable under State law, to prohibit illicit connections to storm sewers.
- **Illicit Connection Elimination Program**: Develop, implement and enforce a program to detect and eliminate illicit connections into the municipality's small storm sewers.
- **Outfall Pipe Stream Scouring Remediation:** Develop and implement a stormwater outfall pipe scouring detection, remediation and maintenance program to identify and stabilize localized stream and stream bank scouring in the vicinity of outfall pipes operated by the municipality. Repairs shall be in accordance with the Standards for Soil Erosion and Sediment Control in New Jersey (N.J.A.C. 2:90-1).
- **Street Sweeping Program:** Municipalities are required to sweep certain streets and to report on the amount of material collected in these programs
- **Storm Drain Labeling:** Label storm drains as to "No Dumping" and provide means to maintain the labels.
- **Storm Facility Maintenance Program:** Ensure adequate long-term operation and maintenance of BMPs
- **Public Works Facility Requirements:** Ensure proper storage of material such as deicing substances or sand, proper vehicle fueling procedures, proper vehicle washwater management, proper vehicle maintenance, good housekeeping procedures and proper employee education.

The four municipalities are reported to be in compliance with these requirements by NJDEP for most items or are in the process of finalizing adoption. The municipalities provide data to NJDEP for compliance progress and implementation of the various programs.

The municipalities should continue to evaluate the effectiveness of the ordinances and programs and revise to improve their effectiveness, as permitted under NJDEP regulations and are expected to do so during the implementation phase.

5.2.1 Sanitary Sewer Improvements

The developed portions of the watershed are sewered. However, portions of the sewer system are up to 100 years old. The municipalities have spent time and effort investigating the condition of existing sewer main and trunk lines and improving them as possible. There is no evidence that this is a major source of bacteria to the Pond. Given the age of the sewer lines, however, there is the potential for seepage of sewage into the groundwater and then into the Pond. Data from NJDEP and Monmouth University studies identify this as a potential source of bacteria to Wreck Pond.

Municipalities have adopted Illicit Connection Elimination Programs which require continued investigation of their sewer infrastructure. Identified problems should be repaired as feasible. In response to the recent NJDEP studies, the municipalities and the County Health Department have looked further into the potential for leaking sewer infrastructure. As of this date, no major sewer leaks were found.

In addition, as in any developed area, leaks at individual homes may occur. Education of the public as to the importance of controlling such leaks should be implemented.

The municipalities have adopted Illicit Connection Ordinances that would not allow any such connections. Further review is expected during the implementation phase.

5.2.2 Pet Waste Reduction

The Municipalities have adopted Pet Waster Ordinances and provide information along with pet license materials. Municipalities should continue efforts to ensure pet owners clean up after their pets. Pet owners are generally compliant about cleaning up after pets on roads and sidewalks and residential properties, but may not be as compliant in open space areas. This is particularly important in open space areas that border Wreck Pond, and other ponds or streams in the watershed.

5.2.3 Street Sweeping, Yard Waste and Storm Drain Maintenance

The municipalities should continue street sweeping, yard waste management and drain maintenance as required by ordinance and programs. Street sweeping can remove sediment and associated bacteria and other pollutants from the streets. Sediments tracked onto paved surfaces during building or landscape renovations should be swept at the end of each day by the contractor.

Sediment and pollutants can become trapped in catch basins or storm drains. For example, during the outfall pipe sampling it was noted that at least one storm drain had a significant amount of sediment in it which impacted flow. Regular maintenance of these systems will improve the function and reduce loading. The municipalities report on maintenance activities to NJDEP as part of their requirements under their municipal stormwater management plan and are expected to continue maintenance activities.

5.2.4 Improper Disposal of Materials in Storm Sewers

Improper disposal of waste material (used oil, paint cleaners or solvents) or other substances to storm sewers may cause pollution. Residents are not always aware that disposing of such substances through the storm drain can flow directly to a local water body. In addition, connection of non-stormwater flows directly or through sump pumps to the stormwater system may add pollutants. Municipalities are required to label storm drains and should consider addition action and education of residents, if non-compliance is identified as a concern.

5.2.5 Waterfowl Management

Wreck Pond is home to a variety of water flow including non-migrant Canada geese and mute swans. The other ponds within the watershed are also used by water fowl, particularly Hurley's Pond. The large number of waterfowl in the ponds are generating bacteria through fecal matter deposited directly into the water and on the shoreline. Thus, to fully control the bacteria levels in Wreck Pond, control of waterfowl is essential. Reduction in the water fowl use of Wreck Pond and other Ponds in the watershed will improve water quality and have positive aesthetic impacts.

However, water fowl control is a difficult problem facing many municipalities and water bodies, such as the Chesapeake Bay. The Atlantic Flyway Task Force has identified the reduction of the mute swan population as a priority for the entire Atlantic Flyway. In their 2003 Mute Swan Management Plan, New Jersey was noted to have about 1600 mute swans, while the task force suggested reduction of the state swan population to about 500 individuals. Mute swans are known to cause ecological damage including damage to aquatic vegetation and generation of bacteria. However, swans also keep the resident goose population down due to competition.

The location of Wreck Pond in a suburban area means that methods to control the waterfowl may be controversial. The municipalities have adopted Waterfowl Feeding Ordinances which may discourage water fowl from remaining in the area. Other possible measures are discussed as follows.

Egg Addling: One of the least controversial methods of control is egg addling. The eggs within the nests are oiled and left in the nest. This prevents the eggs from hatching, yet because there are eggs in the nest, no further eggs are laid. The disadvantages are cost, man-power and the fact that most of the eggs in the population must be addled in order for this technique to have an impact on the overall population size.

Adult Population Management: Direct reduction in adult populations would involve relocating or euthanizing the waterfowl. Relocating may be difficult, as many areas within coastal New Jersey contain an overabundance of waterfowl. Local opposition may be expected to any plans to eliminate or euthanize waterfowl.

Repellents: Various substances are placed on shorelines to discourage water fowl use on shorelines. These repellents have varying degrees of success. Issues that have been associated with these are removal of the repellent by fast wash-off during rain events or by mowing.

Habitat Modification: Shoreline habitat can be modified to discourage geese from using these areas. This would require modifying the current grass areas using plantings. These plantings could also be used to hide low fencing that may discourage waterfowl. Local residents may be concerned about re-landscaping grassed areas to other vegetation.

The communities within the watershed should work together and with other local communities to manage geese on a regional basis. Local and county officials should continue to investigate new options to manage water fowl. Local citizens and officials must become informed about the consequences of permitting the continued growth of waterfowl populations in order to develop local support for a comprehensive management program. The implementation phase will include analysis of further measures.

5.2.6 Agricultural Practices

There is a relatively small percentage of agricultural land in the watershed and on-farm inspections and surveys suggested these lands have minor to no impacts on the region (see Book 1, Section 5). The relatively larger equine farms, those with approximately more that 5 horses, appeared to be well maintained in terms of manure management. The smaller farms were also well maintained, but there one simple measure that can further minimize impacts to the watershed is the installation of concrete-enclosed manure compost piles to prevent runoff flowing through these piles and entering streams.

Those farms with field crops or vegetable production also had well maintained facilities. Further reduction in possible impacts can be obtained by reducing nutrient application to that which is needed for the specific soil condition. In addition to nutrient management techniques, Rutgers Cooperative Extension offers soil nutrient testing services for a small fee. RCE will analyze soil samples for basic nutrient levels and advise of proper fertilizer application rates to achieve optimum crop production. Soil sample testing not only helps protect water quality but also provides an economic benefit as well.

Another simple practice is the planting of narrow (10 to 20 feet) wide grass filter strips around field edges to help trap sediments which would otherwise be conveyed off site during periods of moderate to heavy rainfall.

5.2.7 Improvement of Existing Stormwater Facilities

In highly developed areas, like the eastern part of the watershed, the opportunity to place stormwater management facilities at new development is limited as there is little new development. Existing stormwater controls may be limited in these developed areas. However, there may be opportunities to modify existing stormwater inlets or other structures to enhance stormwater quality control. Measures including infiltration systems, permeable paving, and bio-retention systems can be introduced at sites where the soil permeability and depth to the seasonal high water table are suitable. Areas for such new measures include parking lot islands, vacant land, and roadside swales. Rain gardens are areas with special landscaping to which runoff from roofs and impervious surfaces are directed. Monmouth County is planning a pilot study of these features (see Section 6.1.5).

The local and County stormwater facilities generally are subject to routine maintenance activities in accordance with the Municipal Stormwater Management Plans. In addition to careful consideration of existing conditions and localized flooding problems, the responsible agencies should be required to look for opportunities to enhance stormwater quality in any storm sewer system repairs or updates. Design of replacement inlets or culverts to provide water quality function should be considered during the implementation phase. Section 6 discusses an initial project currently being implemented by Monmouth County with funding from NJDEP. .

5.2.8 Fertilizer Application for Residential Landowners

As indicated in Section 5.2.6 above, appropriate application of fertilizers and pesticides to vegetation is environmentally and economically beneficial. Residents should be encouraged to reduce application of lawn products to that needed by the soil. Soil testing services offered by RCE are not limited to the agricultural community but are available to anyone interested in learning more about soil quality and health. In addition to testing services, Rutgers makes many articles available to landowners on various subjects such as pest control, disease identification and treatment, horticulture, turf management etc. Residents of the watershed should be made aware of this testing during implementation of the Plan.

NJDEP’s Clean Lawns initiative has partnered with fertilizer manufacturers to reduce the level of phosphorus within fertilizers to that typically needed in lawns. The use of these fertilizers is expected to reduce phosphorus loading levels.

6 RECOMMENDED STORMWATER MANAGEMENT SPECIFIC PROJECTS

In addition to the general management measures noted in Section 4, above, reductions in stormwater loadings may be gained by improvements to specific sites, by restoration of waters or streams in the watershed, by construction of new stormwater management facilities and by retro-fit of existing stormwater management facilities.

Through field study, consultation with the local municipalities and stakeholders in the watershed, and data review, the WPB TAC identified areas within the watershed that were of concern for pollution generation. In response to these concerns, the WPB TAC developed the *Early BMP Recommendations* list in 2005 that focused on controlling water quantity and improving water quality at discharges from specific sites. These projects are also designed to improve ecological conditions throughout the watershed. The list was developed through extensive field reconnaissance and site visits by the early members of the TAC, specifically, representatives from the County, NJDEP, MCOOGIS and NJDA. This *Early BMP Recommendations* list was submitted to the NJDEP in May 2005 in order to secure available NJDEP restoration funds for specific projects. An initial cost estimate was developed at that time which was revised to reflect current cost estimates as shown in Table 16.

Since the Initial BMP list was developed, funding has been provided by NJDEP for initiation and implementation of several projects. The allocated funding is shown in Table 16. Section 6.1, following, details the funded projects and 6.2 details Priority Projects that are proposed for future funding.

In addition to the *Early BMP Recommendations* list developed in May 2005, the Committee has since added projects to the final list of specific projects. These projects were added following additional reconnaissance, modeling results, public input, etc. These are identified in Section 6.3.

The prioritization of these recommendations was based on need for the project, time to implementation, potential impact, short- and long-term benefits, cost, maintenance requirements, habitat disturbance and improvement, and scale.

6.1 Funded Projects

NJDEP has recognized the importance of the improvement projects identified in the early stages of planning and has allocated funds for several best management practices which have been identified by the TAC and others. These projects are listed in Table 17 and described in detail in the following sections.

Table 16: Early Recommended BMP Cost Estimates				
BMP	**Details**	**Estimated Total Cost ($) (2005)**	**Estimated Total Cost ($) (2008)**	**Funding Allocated ($)**
Installation of Stormwater Treatment Devices	15 - 25 devices	1,290,000	1,406,100	1,200,000
Restoration of Old Gravel Pit on Ridgewood Road, Wall	Detention/WQ basin	391,000	426,190	500,000
Restoration of Spring Lake Golf Course Weir	Restoration of pond and weir	1,156,000	1,260,040	200,000
Wreck Pond Brook Headwaters Restoration	Restoration of berms, flow control, forebay, weir replacement, SWTD units	2,580,000	2,812,200	250,000?
Black Creek On-Line Sediment Basin	Installation of basin	190,500	Project removed, replaced by weir replacements at SLGC	
Create Natural Wetland at "Jimmy Burne" Site	WQ basin construction	620,000	675,800	0
Wreck Pond Shoreline Habitat Improvements	Shoreline stabilization and buffer plantings	900,000	981,000	0
Pond Dredging	Dredging of Old Mill and Hurley's pond, shoreline stabilization and buffer plantings	5,325,000	5,804,250	0
Upper Wreck Pond Restoration		675,000	735,750	0
Initial Cost Estimates by Omni Environmental for 2005, updated costs from TAC Analyses for 2008				

6.1.1 Installation of Manufactured Stormwater Treatment Devices

Manufactured treatment devices are concrete structures that are added to a storm sewer system prior to outfall to a waterbody. The devices provide removal of sediments and associated pollutants from stormwater which can be removed later by maintenance crews. Fifteen to 25 structures (final number to be determined by actual construction costs) will be installed on storm sewer systems discharging to Wreck Pond, Black Creek or Spring Lake. Funding provided includes an initial grant of $30,000 for preliminary study and $1,200,000 for Final Design and Construction (NJDEP).

Table 17: Funded Projects List				
Project Name	**Location**	**Concerns Addressed**	**Funding Amount ($)**	**Current Status**
Installation of Stormwater Treatment Devices	Vicinity of Wreck Pond	Sediments and associated pollutants, Floatables	1,200,000	County selected consultant, project will commence in Spring 2008
Restoration of Old Gravel Pit, Ridgewood Rd, Wall	Headwaters of Hannabrand Brook	Flows, sediment/ erosion, nutrients, bacteria	500,000	Operator lease will not be renewed, Wall will commence then with restoration
Restoration of Golf Course Weir	West of Route 71 at SL Golf Course	Flood Control, Sediment	200,000	Design Finalized, Work to commence …
Wreck Pond Brook Headwaters Restoration	Adjacent to Route 34	Flow, Sedimentation & Erosion		
Rain Gardens	Various Locations in Watershed	Flow and General Water Quality	$24,000	Site selection in process
Total Allocated Funds			$1,924,000	

In August 2006, a preliminary engineering analysis for the installation of such devices was initiated. The preliminary analysis included prioritization of unit placement, preliminary flow analysis, unit sizing, solicitation of unit pricing and specifications, and preparation of cost estimates. The funds are expected to allow retrofit of 15 to 25 stormwater outfalls. Studies done as part of this Plan determined the drainage area of various outfalls. A separate study for the County then looked at the existing infrastructure at each of the outfalls under consideration. In order to reduce cost, the installations were targeted for roadways or other publicly owned lands to eliminate the need for easements on private lands or land acquisition. The next step was investigation of the existing infrastructure for each potential outfall as to the difficulty of conducting the retrofit. Using these criteria, 25 outfalls were identified as possible sites for retrofits. Of these, ten are located within Spring Lake, nine in Spring Lake Heights, two in Wall and four in Sea Girt.

In March 2008, the County initiated a contract for final design and construction administration for the installation of the devices. Work to be performed under this contract includes surveying all potential unit sites, development of site plans, final design of units, preparation of construction drawings and specifications, aiding the County in the public bidding process to determine a contractor, construction administration and construction inspection. This work has been initiated and preliminary design has been developed for a number of these retrofits.

Detailed engineering will be conducted for each retrofit. Thus, it is possible that it will not be feasible or cost effective to install all of these devices. Water quality sampling is proposed following installation of the devices to determine their actual field effectiveness.

6.1.2 Restoration of the Ridgewood Road Former Gravel Pit

The site is located in the headwaters of Hannabrand Brook off Ridgewood Road in Wall Township. This site was formerly a Gravel Pit that is now owned by Wall Township and is currently used for shredding trees and stumps from land clearing operations, along with additional processing of landscaping material. The material is stockpiled and wholesaled as landscape mulch material. There are two stormwater discharge points that can be modified in order to attenuate stormwater flow, arrest sediment transport and deposition and address potential transport of contaminants from the site to the Hannabrand Brook. The old mining pit is approximately 100 or so acres in area.

A number of field visits to the site took place during the Plan development period. Site visits in 2005 and 2006 by TAC members provided information on basic site conditions and the stormwater runoff discharge points. The dimensions of the discharge channels leading from the site through the stream buffer were indicative of large flow volumes coming off the site during storm events.

Additionally, a recent January 2008 site visit by TAC members following a moderate rainfall event provided information regarding stormwater runoff quality. The southeastern discharge channel leading to the Hannabrand Brook contained moderate flow depths and discolored water. This flow path was followed by Committee members to the discharge point into the Hannabrand Brook, where a visible plume was entering the Brook. This fine suspended material clearly was coming from the site and its operations.

The site is mostly cleared and stockpiles of processed material may be the source of nutrients, bacteria and sediment. In addition, color and possibly contaminants in the water may be associated with a mulch dyeing process. Once in the channel, the dark gray color of the water persisted as it flowed towards the Brook. Thus, during the flows observed, it appears that the fine material does not settle out before discharge to the Brook.

It should also be noted that during Rutgers University’s assessment work, macroinvertebrate sampling was performed at all eight County sampling sites. The results indicate that biodiversity was lowest at the site located just downstream of the gravel pit.

Since the drafting of the Recommended Projects List, Wall Township submitted a Green Acres application and now owns the property. Wall Township is presently leasing the land to the current operator, and material processing will continue until the lease expires. Once the lease is expired and all restoration issues are addressed, Wall Township has plans to convert the property into passive recreation.

NJDEP has provided $500,000 for restoration of this site. Wall Township plans to undertake restoration once the lease is up for the current operator. In the meantime, Wall Township will work with the lease operator to reduce the discharge of contaminants to Hannabrand brook with temporary measures.

Restoration efforts may include drainage modifications to eliminate uncontrolled runoff to Hannabrand Brook, removal of debris and regarding and restabilization of poor, barren slopes. The use of clean dredge materials from watershed lake dredging projects as soil amendments should be considered as an aid to improving growing conditions at the former sand and gravel mine site.

6.1.3 Restoration of Weir at Spring Lake Golf Course

The weir structure at the outlet of the golf course pond system is responsible for controlling all the runoff from the entire Black Creek (W8) subwatershed area. The pond functions as a sediment and nutrient trap. The weir is in bad repair with numerous leaks and rotting timbers and is in danger of failure. Findings from reconnaissance and modeling efforts support the fact that this dam is vital to the preserving the ecological and flow conditions of Black Creek downstream of Route 71, as well as Wreck Pond. The dam provides significant settling potential for sediments in stream flows originating upstream of Route 71, and detains large volumes of stormwater runoff during storm events. The pond system mitigates the effects of localized flooding by backing floodwaters up into the golf course itself. Without the pond system, runoff from this drainage area would only increase flooding in the surrounding areas along Black Creek and Wreck Pond during large storm events.

In the early stages of plan development, a sediment basin was proposed to be constructed just downstream of the Rt. 71 culvert, to catch and settle particulates and sediments prior to entering the main body of Black Creek. It would require that a portion of the upper reach of Black Creek be utilized as a settlement area for this purpose. It became evident that a project of this scope would be extremely expensive and difficult to construct, and it was uncertain if permits could be obtained to do the work. The golf course had previously done significant engineering work and had already obtained permits for substantial renovation to the course's water features.

In cooperation with the TAC, it was decided that the golf course pond already provided the control that would be obtained from the sediment basin proposal. As a result, NJDEP provided funding for the weir and bulkhead to be reinforced with plastic sheet pile installed along the upstream face of the timber weir and bulkhead. Existing flow characteristics will be maintained. As a side benefit, the sheet piling will be installed deep enough to prevent seepage coming under the weir as it presently does, further controlling base flow and preserving the integrity of the structure. Additionally, the golf course will perform maintenance of the weir and pond (periodic dredging) at their cost which is a significant benefit ecologically as well as economically to the downstream communities.

NJDEP has provided $200,000 for design and implementation of a new weir. The design is completed and implementation is anticipated. Implementation costs were estimated to be about $900,000.

6.1.4 Wreck Pond Brook Headwaters Restoration

This project would provide restoration and add additional stormwater management measures for an area at the headwaters of Wreck Pond Brook. This area receives stormwater from existing commercial development and barren land opposite the New Jersey Sand and Gravel operation located on State Highway Route 34 in Wall Township. The area receives stormwater flow from about 25 acres of impervious surface (all commercial/industrial) and another 100 acres or so of barren land.

An abandoned sand wash water pond, known as Kellers Pond, is located several hundred yards downstream of Rt. 34 and receives runoff from the headwaters area as well as Rt. 34. The outlet weir or dam is “blown out” and no longer provides any significant stormwater control. Further, the pond is fairly shallow and receives significant deposits of silts and other sediments which wash off Rt. 34, drain from the NJ Sand and Gravel yards or is scoured from the man-made channel leading from the Rt. 34 storms ewer system to the Pond. The area surrounding and including the pond is owned by Wall Township which intends to manage the land for passive recreation and wildlife habitat.

The project scope is expected to include restoration of existing berms, design and construction of at least two spillways with sediment control forebays, design and construction of a new dam and weir to replace the existing system. Manufactured stormwater treatment devices (sediment removal only) also may be proposed in the stormwater system that serves the commercial complexes. An office complex is planned for a 10-acre property immediately adjacent to the proposed BMP area that will generate additional stormwater volume that may potentially discharge directly to the area. However, this project would be expected to be required to conform to NJDEP requirements for stormwater management.

The area contains a rich wildlife and wetland plant ecosystem that must be considered in design and construction of the project. The design is expected to include a new dam and weir to create a pond of perhaps 6 or so acres in size.

Since drafting of the original BMP list, the Committee solicited recommendations and quotes from the US Fish and Wildlife Service. Plans to reconstruct the outlet berm, install sediment traps along Route 34 and restore the pond to improve habitat were discussed with a US Fish and Wildlife Service representative during a number of Committee meetings.

NJDEP has provided $250,000 for further study of this option. Implementation costs are estimated at about $300,000.

6.1.5 Rain Garden Demonstration Project

Rain gardens are a recently developed best management practice which provides for the treatment and infiltration of runoff on individual properties. Roof and impervious surface runoff is directed to carefully constructed shallow depressions where the runoff is filtered and returned to ground water. Rain gardens are landscaping features and are designed with attractive, water-tolerant vegetation. They can be embellished with hardscaping materials such as stone and pavers to further enhance their aesthetic appeal while providing valuable control of small, nuisance-level, storm events. Compared to a conventional lawn, rain gardens allow 30% more water to soak into the ground. Because rain gardens are landscaped, they add beauty to a lawn and create a habitat for birds, butterflies and beneficial insects. According to estimates by Rutgers Cooperative Extension (RCE), one rain garden may recharge up to about 25,000 gallons of rainfall per year and thus reduces the amount of surface runoff and associated contaminants discharged directly to surface waters

The demonstration project provides funds to select and develop rain garden demonstration sites. The initial sites are expected to be public properties such as municipal complexes or schools. RCE will with local and regional agencies to select locations and the Master Gardeners of Monmouth County will help select appropriate plants with an emphasis on native species suitable for the particular soils. Educational materials will be included at each demonstration site. These projects will not only control runoff on these properties but will serve as locations for public outreach and education in order to encourage local residents to create their own rain gardens.

NJDEP has provided $24,000 for site selection, design and construction of 4 demonstration Rain Garden projects.

6.2 Other Priority Projects

In addition to the projects that have been at least partially funded, the TAC or other agencies identified several other projects for priority implementation. Table 18 identifies these projects and provides estimated costs, if known. Further detail is provided in the following paragraphs.

6.2.1 Dredging of Various Ponds

Water quality data and modeling efforts within the watershed demonstrate the importance of many of the ponds in regulating flows and allowing settling of sediment and associated water pollutants. Some ponds are known to contain significant quantities of sediment and are in need of dredging. Shoreline improvements and modifications, including the use of wetland plantings, would be introduced where needed in order to maintain/improve habitat, reduce goose populations and improve water quality features. The following projects were recommended by the Committee.

i) Dredge and restore Old Mill Pond in Wall Township to improve habitat and provide better stormwater management functions. Removal of sediments and outlet modification will be needed to increase stormwater flood control and enable future maintenance

ii) Dredge and restore the impounded portion of Black Creek (aka North Branch of Wreck Pond) in its entirety between Route 71 and Ocean Road in Spring Lake and in the segment just west of the Route 71 Bridge.

iii) Dredge and restore the western-most part of Wreck Pond on Wreck Pond Brook west of the Route 71 Bridge so it functions as a sediment containment and water quality management basin. This project would require construction of a weir at Route 71 and perhaps reconstruction of the pond so it would serve as a sediment trap and water quality feature. The pond should provide some habitat and recreation value when completed.

iv) Dredge and restoration of Hurley's Pond, at Hurley's Pond Road. The pond is privately owned. It would require dredging from an existing average depth of about 2.5 feet to possibly 6 feet. The outlet weir under the road may also require modification.

Table 18: Additional Priority and Other Future Projects List			
Project Name	**Location**	**Concerns Addressed**	**Estimated Cost ($)**
FUTURE PRIORITY PROJECTS			
Pond Dredging	Watershed Ponds- Old Mill, Hurley	Pond Ecology, Increase Pond storage volume, reduce sediment load, improve retention	$5.8 mill
Stream Restoration – Hannabrand Brk & Wreck Pond Brk	Headwaters of streams	Stream flow, erosion, sediment, associated pollutants	$2.8 mill for WPB only
Black Crk online Sedimentation Basin	Black Crk (No. Branch WPB)	Project removed from list, replaced by improvements to SLGC weir to serve same purpose	
Create Natural Wetland at "Jimmy Burne" Site	Directly west of Rte 71 and Wreck Pond Culvert	Sediment, bacteria, nutrients	$675,800
Wreck Pond Shoreline Habitat Improvements	Wreck Pond	Bacteria, waterfowl populations	$980,000
OTHER POTENTIAL PROJECTS			
Remedial/Restoration Projects at Public Works Yards	Spring Lake and Spring Lake Heights	Flow, Sediment, Erosions, Nutrients, Bacteria, other pollutants	
Other Stream Restoration Projects	1. Wreck Pond Brk trib at NJ Sand & Gravel, east of Rte 34 2. Wreck Pond Brk trib at St. Catherine's Cemetery to	Flow, sediment, erosion	
Hannabrand Brk Regional Stormwater Basin	Upstream segment of Hannabrand Brook	Flow control, sediment, other pollutants	

6.2.2 Stream Restoration Headwaters of Wreck Pond Brook and Hannabrand Brook

Final results from the FSCD's stream assessment indicate severe sedimentation conditions where Wreck Pond Brook passes under the north-bound lanes of the Garden State Parkway. This condition may be addressed through inclusion in a facility stormwater management plan prepared by the New Jersey Highway Authority. Work in this area should involve the Highway Authority, including potential funding sources.

RCE identified W5 (Hannabrand Brook at Bailey's Corner Rd in Wall) as a site in need of restoration in their studies. Water quality results from storm sampling at W5 indicated elevated TSS during storms. In addition, field investigations observed sediment and discolored flow in upper Hannabrand Brook. Restoration efforts would reduce sediment loads and other pollutants in the Brook.

6.2.3 Online Sediment Basin at Black Creek

This project was the installation of an on-line sediment basin at the discharge point of Black Creek to the North Branch of Wreck Pond just east of Route 71. However, it was determined that the purpose of the Basin could be served by improvements to the weir from the Spring Lake Golf Course, as discussed above. Thus, this project was removed from the BMP list.

6.2.4 Development of Natural Wetland at the Jimmy Burne Site

Development of a natural wetland, sediment trap and water quality management basin on the so called "Jimmy Burne" property that would work in concert with restoration of the western part of Wreck Pond (see Section 6.2.1). This is also a possible location for disposal of dredged material from dredging of Wreck Pond. This recommendation, however, will only be analyzed further if Wreck Pond dredging becomes feasible. In addition, the Township of Wall currently has in place for use of the property as a passive park which may limit the feasibility of this option. No funds have been provided.

6.2.5 Wreck Pond Shoreline Habitat Improvements

As discussed above, water fowl along Wreck Pond are a source of bacteria in the Pond. Shoreline vegetation can serve to discourage the use of the Pond by undesirable water fowl and encourage use by desirable bird species. However, this option would require cooperation by the local municipalities that may own the shoreline lands. Local residents may resist changes from grassed areas to other landscaping along the Pond shoreline. Further investigation into landscaping and other alternatives that may reduce water fowl use yet be aesthetically acceptable. No funds have been provided.

6.3 Other Potential Specific Stormwater Management Projects

As the Plan has been developed, additional potential projects have been identified. Funding sources need to be identified for these projects.

6.3.1 Public Works Yards Restoration

The Spring Lake Department of Public Works Yard is located along the banks of Black Creek, east of the NJ Transit railroad tracks. The majority of the sub-drainage area drains into roadways, into a stormwater collection system and into Black Creek. The lower portion of the yard discharges via overland flow to Black Creek. In recent years, the Borough constructed an earthen berm to encourage collection and infiltration of stormwater runoff from this lower portion of the yard. However, the west side of the berm is flanked during moderate storm events, and allows stormwater runoff and transport of sediments to discharge to Black Creek.

Similarly, the Spring Lake Heights Public Works Yard is located on the western side of the NJ transit tracks, along the banks of Black Creek. The yard is fairly well contained however a storm sewer discharge pipe drains into a ditch running between the yard and the tracks and empties directly into Black Creek, a few feet upstream of the culvert under the tracks. Evidence of erosion within the ditch and sediment deposition at the ditch outlet is visible.

Wreck Pond RSWMPC members met with representatives from both municipalities in February 2008 to identify locations for the installation of structures to control and mitigate runoff, nutrients and bacteria from both maintenance yards. It is anticipated that a joint application will be made to NJDEP for project funding via an extant municipal Memorandum of Understanding. A project under consideration is the construction of a bio-retention basin at each yard. If found feasible, these basins would likely be proposed separately so that either basin may begin construction without encumbrance from the other. The basins would provide for filtering of surface runoff, infiltration and controlled discharge to the creek. It is anticipated that nutrient and sediment loads delivered to the creek from these sites may be significantly reduced. Considerations include space needed to construct basins of sufficient size and the grading required to direct runoff to the basins. Other options may also be considered to manage the stormwater. No funding has been provided.

6.3.2 Additional Stream Restoration

In addition to the degraded streams found by FSCD during their assessments, Najarian Associates discovered two highly degraded stream reaches within the watershed. Restoration of these stream segments is proposed to improve flow conditions and reduce the potential for erosion which will reduce generation of sediment and of associated pollutants. The following paragraphs describe these stream segments.

- The stream reach flowing along the southern end of the New Jersey Sand and Gravel site, located on the western side of Route 34. There is a significant level of stream braiding and sedimentation within the stream, most likely from operations taking place on the site. This reach may be contributing to the degraded condition located just east of Route 34, as mentioned in the Wreck Pond Brook Headwaters Restoration Project discussed above.

- The stream reach flowing directly behind a large building located on the Saint Catherine's Cemetery property. The stream conveys stormwater runoff from an approximately 35 acre sub-drainage area in residential southern Wall Township.

The condition of the stream indicates that the stream as well as the stormwater runoff may be a contributor of sediments to the portion of Wreck Pond Brook located just west of the Route 71 and Wreck Pond culvert.

Restoration of these streams will reduce the potential for erosion and improve flow. Further investigation is needed to identify the causes of these issues, ownership, and feasible mitigation techniques. No funding has been provided.

6.3.3 Installation of a Regional Stormwater Basin on Hannabrand Brook

Following review of the pollution budget and modeling efforts associated with this project, the numerous ponds located along the Wreck Pond Brook promote settling of sediments during storm events. No major impoundments exist along the Hannabrand Brook. Thus during storm events, the Hannabrand Brook produces more total suspended solids per acre than Wreck Pond Brook.

The installation of a regional stormwater management basin along the Hannabrand Brook would provide potential for settling sediments generated from the associated sub-watersheds. Possible issues associated with this are location of land to locate such a basin, environmental constraints including wetlands and riparian buffers, costs, and design considerations. The current hydraulic and hydrologic efforts could support the design of this project. No funding has been allocated.

6.4 Additional Studies and Proposed Work Groups

The RSWMP and associated studies have provided significant data on watershed conditions and pollutant generation in the watershed. However, some areas of additional study have been identified. The following sections discuss additional sampling efforts and study groups under consideration.

6.4.1 Golf Course and Hannabrand Brook Storm Sampling

The Spring Lake Golf Course has received substantial attention from stakeholders in the watershed due to local concern that the golf course may be a major contributor to the deteriorated condition of Black Creek. Due to its proximity and regular application of fertilizers, it had been suspected that the Golf Course has been a contributor of non-point source pollutants to local waters. This suspicion is made without consideration of the stormwater Best Management Practices used by the golf course such as covering of all materials to prevent contact by stormwater, equipment wash stations and a computerized irrigation system that is integrated with an automated weather station to ensure that appropriate amounts of irrigation are provided in concert with natural precipitation. The golf course also engages in Canada goose control through the use of a trained border collie.

Further, the NJDA hydrologic modeling study found that the Spring Lake golf course and its ponds provide substantial benefits to Black Creek through control of flood flows. The Golf Course also appears to act to trap sediment and associated pollutants that would otherwise be transmitted to Black Creek. Residential neighborhoods that drain directly to Black Creek are generally older and do not include stormwater management controls.

In order to provide direct investigation of the source of pollutants to Black Creek, the Committee determined that a sampling program designed to provide estimates of non-point source pollutants flowing into and out of the Golf Course property would provide valuable information. The preliminary sampling design consisted of two storm sampling events at stations upstream and downstream of the Golf Course. The existing NJDA and NA modeling studies would be used to project storm flows. Sampling during multiple events would be required to ultimately determine whether or not the Golf Course is of primary concern in the transmission of pollutants to Black Creek.

Likewise, a similar sampling plan was proposed for the Ridgewood Road Gravel Pit along the Hannabrand Brook. Specific sampling points up and downstream of the site would be monitored during multiple storm events to determine the actual loadings of specific pollutants, and to quantify flow volumes discharged from the site. Sampling parameters could be expanded to sample for possible volatile organics associated with the suspected mulch dyeing operations being conducted on-site. This would provide data to be used in design of any mitigation plan.

6.4.2 Watershed Pond Studies

The numerous ponds within the watershed play a significant role in not only watershed hydraulics, but the fate and transport of non-point source pollutants as well. During model development, it became obvious that there was a lack of information regarding the major ponds within the watershed. Specifically, information such as pond bathymetry, geometry, inflow/outflow characteristics, and ambient water quality condition were not available for the majority of ponds. Additional Information on these ponds would support the refinement of the hydraulic, hydrologic and pollution budget models developed under this Plan. Once these models are updated, they can be used to more accurately design restoration alternatives discussed in this section of the Plan.

Additionally, collection of pond information would aid in the development of dredge plans for waterbodies within the watershed. Because these ponds provide potential for settling sediments and aid in flood control, the maintenance of these ponds is vital in maintaining the ecological heath of the watershed, as well as limiting the potential for flooding.

6.5 Recommendations for Black Creek

Land use within the headwaters of Black Creek are characterized by medium to high density residential areas and two golf courses. Impoundments on both the Fairway Mews and Spring Lake golf courses act to moderate stormwater flows and trap sediments and pollutants prior to discharge to Black Creek from the lower impoundment of Spring Lake golf course located just to the upstream (west) side of the Rt. 71 culvert. The remaining areas which drain directly to Black Creek consist of high density residential neighborhoods bounding Black Creek to the north and south.

The Creek is impounded by a small weir structure located under the bridge at Ocean Road as it empties into Wreck Pond. The Creek is bisected by the New Jersey Transit rail road line and flows from the westerly portion of the Creek pass under the rail line via a small concrete culvert.

Due to the configuration of Black Creek as an open body of water rather than as a true "creek" or channelized water, sediments, nutrients and other materials are trapped and settle out, causing gradual filling. Water depth is very shallow (approximately 18" or less) and the area is frequently subject to algal blooms. The ponded area provides habitat to freshwater snails and various wading birds and waterfowl. The depth appears to be too shallow for most game fish to thrive. Also due to the shallow nature, the water body is unsuitable for typical aquatic recreation such as swimming or boating. Limited water quality sampling revealed DO super-saturation and low DO levels in this area. Elevated nutrients and the known algal blooms suggest eutrophic conditions.

During the course of Plan development, local residents appealed to the RSWMP Committee for suggestions to restore Black Creek. Among the many concerns expressed were upstream pollutant sources and sediment deposits and suggested actions included dredging and removal of the weir at Ocean Avenue to restore tidal fluctuation and "flushing" of the water body during periods of high tide. In response to these concerns, the Committee established the Black Creek Subcommittee consisting of local residents and TAC members. The Subcommittee was tasked with gathering and compiling extant reports and studies which could form the basis of a distinct management plan for the Creek. At the time of the writing of this report, the subcommittee is still in the process of compiling the information, data and suggested projects.

6.5.1 Proposed Black Creek Projects

Several best management practices were jointly identified by the RSWMP Committee and Spring Lake Borough for immediate implementation in the Black Creek drainage area. These projects include the manufactures stormwater outfall project discussed in Section 6.1.1 and the rain gardens in Section 6.1.5. The Public Works Yards of both Spring Lake and Spring Lake Heights are located along Black Creek. Thus, the restoration measures under consideration in Section 6.3.1 will directly benefit the Creek.

6.5.2 Recommendations Further Action in Black Creek

The Black Creek subwatershed has several factors that render it somewhat distinct from the other subwatersheds. In addition, there is strong local interest by residents to focus attention on this area as an environmental and recreational resource. Significant factors include:

- previous studies (according to residents) have already been conducted
- the proximity to and influence of Black Creek on Wreck Pond is different than that of waters in the watershed
- dense urbanization surrounding Black Creek and a lack of large open tracts of land for regional stormwater management require unique practices to improve water quality.

The Black Creek subwatershed may be ideally suited for grant funding for the purpose of scientific analysis of current conditions and the subsequent development of a separate management plan for the sub region. Among issues the residents and other interested parties raised as concerns are:

- Dredging of Black Creek and dredged material disposal
- Prevention of future sediment deposition
- Removal of the weir at Ocean Avenue to open Black Creek to tidal action
- Protection of wading bird habitat
- Restoration of primary contact recreation
- Restoration of fisheries
- Impacts to Wreck Pond water quality with weir removal
- Management plans for the upper watershed and the residential portions of the watershed to the north and south of Black Creek
- Establishment of a local committee to oversee the plan development and management
- impacts on flooding in and around Wreck Pond and its surrounding neighborhoods

Suggested solutions to some of the identified issues are competing or even mutually exclusive. Other issues are being addressed or considered in the overall RSWMP or in the Wreck Pond Management plan developed for the Borough of Spring Lake. Certain suggested actions likely will have unacceptable impacts on other ecosystems or on Black Creek itself and others may be infeasible. For example, the removal of the weir alone will not restore Black Creek to an open, “deep water” resource. Elevation differences between the bottom of Black Creek and Wreck Pond would most likely result in the development of a narrow channel (a true creek) flowing through the muck on the bottom of Black Creek with subsequent erosion and deposition of the sediments into Wreck Pond. The impacts of combining dredging with weir removal would also have to be studied. For example, the tidal excursion is controlled primarily by the invert elevation of the existing control structure on Wreck Pond and the Ocean Road weir. Dredging of Black Creek may not promote tidal exchange under regular tidal conditions.

In addition, impacts on tidal exchange within Wreck Pond would have to be investigated.

Further, deepening of Black creek in any form will result in the loss of shallow water wading bird habitat. Modification of the storage volume of Black Creek by dredging, weir removal etc. will affect flooding in Wreck Pond (it could be improved or worsened).

As noted above and in Book1, Sections 7 and 10, flow and water quality data for Black Creek are limited. Additional monitoring is suggested to provide better understanding of flow dynamics and current water quality conditions.

A detailed analysis of any or all of these issues and proposed projects is beyond the present scope of this management plan. The complexity of the area, socially and environmentally, may warrant a stand-alone management plan which can be developed as an outgrowth and compliment to the Wreck Pond Brook RSWMP. The overall benefit to the public in general should be assessed in a cost-benefit analysis with public input to rank and prioritize the management options of Black Creek. This issue will be addressed further during the implementation phase.

6.6 Wreck Pond Rehabilitation

Implementation of watershed control and management measures will control future loadings to Wreck Pond. However, even with implementation of watershed management techniques, conditions in Wreck Pond require restoration to improve water quality. The following sections provide some options identified in the Spring Lake Borough Wreck Pond Environmental Study. That study is undergoing review by the Borough and further options may be identified.

6.6.1 Pond Dredging

Dredging of the remainder of Wreck Pond was identified as a restoration method in NJDEP's four-point plan. Dredging would remove the layer of muck at the bottom of the Pond, increase the Pond depth and volume and possibly impact the release of bacteria and other pollutants from the Pond sediments. Currently, the Pond is very shallow. Continued sedimentation will cause further reductions in Pond depth and certain areas may eventually fill in. Pond dredging may also have impacts on the flushing of the Pond from the Ocean waters.

The NJDEP estimated that over 500,000 cubic yards of material would have to be removed from the Pond to dredge it to a depth of 6 feet. This would have short-term benefits to the water quality of the Pond. However, control of generation of sediment within the watershed would be critical to ensuring that the Pond would not have to be dredged again in the foreseeable future. Other proposed management measures in this Plan would ensure reduced future loading of sediment.

While dredging may have many benefits, notably the removal of the thick layer of muck in the Pond and increased water volume for dilution, dredging may also impact tidal exchange. Tidal exchange is likely controlled not by the depth of the Pond, but by the invert elevation of the outfall pipe. In many coastal dredging projects a benefit is improved flushing as the inlet is also dredged. In this case, the tidal prism may not increase as the outfall invert elevation will not change. Under that scenario, the tidal water transported to the Pond will meet increased inertia from the larger volume of Pond water already present. In addition, as the volume of permanent pond water increases, the tidal volume will make up a lower percentage of the permanent pool volume, possibly decreasing flushing. Thus, both the potential benefits and possible negative impacts of dredging must be considered.

The major difficulties associated with dredging are the cost and implementation. The cost is governed in large measure by the cost of disposing of the material. In addition, the material may have to be hauled to off-site disposal areas, in which case significant truck traffic would occur on local streets.

Design alternatives may minimize the need to remove material from the Pond, such as construction of an island within the Pond to serve as habitat and to allow the remaining areas to be deeper. Removal of sediment from some portions of the Pond, but not the entire Pond, may be beneficial and require the removal of less material. However, this would require careful design and implementation to ensure the remaining material is not simply redistributed after the partial dredging.

A request has been made to the US Army Corps of Engineers for funding. The ACE would require additional analysis of the cost and benefits of the dredging project. As of the writing of this report, no such funding is available.

6.6.2 Shoreline Stabilization and Vegetation

Portions of the Wreck Pond shoreline are bulkheaded, portions contain riprap and portions are vegetated. Some areas of the Pond contain wooden bulkheads that appear to be dilapidated. Any areas of instability should be controlled to ensure sediment is not entering the water.

Currently, much of the shoreline is in grass. This provides access to the Pond for residents and is visually acceptable. However, the grass does not present a barrier to water fowl. As discussed in the section on water fowl management, re-vegetating this area could reduce the use of these areas by geese and make the area less attractive to these species. Local municipal officials and residents may raise aesthetics concerns about any re-vegetation proposals.

6.6.3 Measures to Reduce Beach Closings

The pollution prevention and reduction measures and the Pond rehabilitation measures noted in the two previous sections will improve the water quality in Wreck Pond over time. However, full implementation of these measures will be difficult and costly and are not likely to occur over the short-term. Even with signification reductions in pollutant loadings, there is likely to continue to be bacteria within the Pond.

If the bacteria sources cannot be completely eliminated, then the other option to reduce beach closings is to control the outflow from the Pond to the Ocean during storm events or control the movement of any outfall plume from the end of the pipe to the bathing beaches. Any solution has to consider numerous complicating factors including maintenance of the bathing beaches for the public, protection of the dune areas where endangered species nest, reduced or no impact on the potential for flooding, and maintenance of Pond water quality. Several alternatives were considered and presented to the Borough. The Wreck Pond Environmental Study identified design changes to the existing outfall structure that will retain stormwater from small to moderate storm events and allow slow discharge of these waters during the summer swimming season. The Pond would be open to tidal exchange during non-rainfall periods. Alternatives are under review by the Borough of Spring Lake. Any alternative would require additional environmental and engineering study.

6.6.4 Modification of Beach Closing Model

As discussed, beaches in Spring Lake and Sea Girt near the Wreck Pond outfall are currently required to close to swimmers whenever it rains more than 0.1 inches. However, the basis for this recommendation is from relatively old data. A recent study by the Monmouth County Health Department (MCHD) determined that high bacteria counts in the ocean waters offshore of the Wreck Pond outfall are not always directly related to rainfall in the watershed. In other parts of the US, the USGS and other agencies are developing more complex models to determine when beaches should be closed. Instead of focusing solely on rainfall, these models include consideration of tidal stage, wind direction, solar radiation and other factors. Also, there is some indication that water fowl and human use of the bathing waters and sand beaches may generate bacteria that can grow within the sand.

Agencies are focusing on development of predictive models that include factors in addition to rainfall. For example, the USGS has developed a “Nowcast” model for the Great Lakes. Although the model did not perform as well as hoped, the model did do better than simply using the previous day’s bacteria concentration.

The results of this study and the NJDEP summer 2008 sampling should be used in conjunction with Monmouth County Health Department information to develop a better decision process for Ocean swimming beach restrictions. New beach monitoring techniques and plans from other parts of the Country can be implemented as well.

6.6.5 Addition of a Pumping System

A recent consideration is the addition of a pumping system between Wreck Pond and the Atlantic Ocean. Such a system may allow for the rapid outflow of water to the

Ocean during flood events. In addition, if feasible, addition Ocean water could be added to the Pond to enhance tidal flushing. Local residents have reportedly noticed a distinct decline in the tidal flushing of the Pond since the outflow pipe was lengthened by NJDEP. This alternative would require further study as to feasibility, cost, and possible impacts to Pond ecology, flooding and other issues.

6.7 Education

The RSWMP Committee has been meeting monthly over the past several years as the plan has been developed. The Committee includes County and State agency staff, municipal officials and staff, local environmental commission members, engineering and environmental consultants to the County and municipalities, and interested public. Watershed residents have been regular attendees at these meetings and provided valuable information on watershed conditions.

Public meetings are planned as part of the finalization of the RSWMP. Meetings have been held with Muncipal officials and staff. Public meetings are proposed for the fall of 2008, following publication of the RSWMP.

As part of the Implementation Phase, additional public input will be essential. The Committee will continue to meet as needed. As discussed in the Implementation Strategy, following, a Wreck Pond Watershed Commission is proposed which will continue public education and involvement.

7 STRATEGY FOR PLAN IMPLEMENTATION

The WPB RSWMP requires implementation to be successful. The implementation process will be ongoing, with the local stakeholders, including the municipal governments, the County, residents and recreational users, moving the process forward. The implementation process will involve completion of identified projects, adoption of further management ordinances and programs, and identification of future projects. Plan updates will be ongoing.

Chapters 5 and 6 of this document identified numerous measures to control and improve stormwater within the watershed. However, the studies to date on this watershed, as in many other watersheds, have not identified one specific cause for watershed problems that can be easily mitigated. The causes of ongoing flooding, sedimentation and water quality concerns are varied and typically nonpoint in nature. Therefore, alleviating the problems will require coordination among Federal, State, County and municipal agencies, residents and businesses within the watershed, and other interested parties. Implementation will be impacted by cost and by the ability of local and regional governments to enact and enforce ordinances, programs and plans.

Certain potential measures identified herein require further study and large expenditures of money, such as dredging of Wreck Pond and the smaller ponds in the watershed. Currently, the prospects for accomplishing expensive projects in the near future are limited. Thus, the implementation process identified herein focuses on measures that can be undertaken in the near future to immediately assist in the improvement to water quality and flooding concerns within the watershed. However, the future management team will continue to identify and obtain future funding options.

7.1 Wreck Pond Watershed Commission

A Wreck Pond Watershed Commission is proposed to be become the lead agency for implementation of this plan. This agency is envisioned to include members from the municipalities within the Watershed, Monmouth County and other interested parties.

The Committee would take responsibility for implementing the Plan and would be charged with:

- Development of detailed implementation strategy for the items discussed further below
- Coordination with municipalities for changes to ordinances as discussed below
- Public Education items and projects
- Development of Grant Applications for priority projects
- Administration of Grants and oversight of consultant projects.
- Other as needed

Implementation Strategy
Monmouth County Planning Board, in conjunction with the TAC has developed a Request for Proposal to provide a grant to develop a strategy for creating a Wreck Pond Watershed Commission. The strategy will include recommendations for Commission Members, funding, regulatory control and other issues. The selected grant recipient will work with the municipalities, the County and other agencies to ensure the Commission will be a workable entity. This will be completed by the spring-summer of 2009. It is anticipated that the Commission will then convene and, with the assistance of the County and the TAC, become the lead agency for implementation of the Plan.

7.2 Wreck Pond Management

As discussed in Section 6, above, the Borough of Spring Lake with a grant from the USEPA has developed a Wreck Pond management plan that proposed certain measures designed to improve the quality of the Pond and others that require further study. Many of the measures to control sediment, stormwater and bacteria loading are those that will be implemented throughout the watershed. Others are specifically to control the quality or timing of the outflow from the pond. The proposed measures for further investigation include:

- Structural changes to the outlet structure to control small, nuisance storms.
- Revisions to the Beach Closing model from the MC Health Department
- Dredging of the entire Pond or portions of the Pond
- Use of a Pump for flood control or improved circulation

Implementation Strategy
Initially, the TAC and County and then the Commission will work with the Borough and other agencies and interested parties to continue to investigate and implement modifications to Wreck Pond to reduce beach closings in both the short-term and long-term. Priorities include analysis of the changes in tidal regime due to the extended outfall and the potential for full or partial dredging of the Pond.

7.3 Wreck Pond Watershed Website

A Wreck Pond Watershed website will become the depository of the stormwater plan as well as other information regarding the watershed. This will allow access by the public to detailed information on the plan and implementation steps.

Implementation Strategy
The Monmouth County Office of GIS is working to develop a website for the watershed. Responsibility for website enhancements and updates will pass to the Wreck Pond Watershed Commission once established.

7.4 Stormwater Management

The use of the Southern Monmouth Unit Hydrograph will be required for all stormwater analyses in the watershed. This will include applications for new developments that will be reviewed by NJDEP and the local governments. The use of this hydrograph is expected to decrease allowed stormwater flows by better defining the undeveloped stormwater flows at sites. Typically, this will result in lower pre-development flows which will mean that the allowed post-development flows will be smaller.

Implementation Strategy

The adoption of this plan will require use of the Southern Monmouth Hydrograph for all projects reviewed by NJDEP. Within 18 months of adoption of this Plan as feasible, municipalities will adopt use of the Southern Monmouth Hydrograph for projects requiring stormwater review.

7.5 Riparian Buffers

NJDEP recently adopted required riparian buffer policies. In the Wreck Pond Watershed, those buffers are expected to be 50 feet in most cases as the watershed does not contain habitat for endangered or threatened species or C1 waters at the time this Plan was developed. Given the flooding control and water quality concerns in the watershed, a larger buffer may be appropriate in some portions of the watershed. In other areas, however, this may not be necessary or beneficial. Further, there may be regulatory or institutional concerns for some of the watershed municipalities. Some of the municipalities are investigating riparian buffer policies.

Implementation Strategy

Within 18 months of plan implementation, the municipalities will report to the Wreck Pond Commission or the County regarding their plans for revised riparian buffers, if any, including implementation of revised buffer ordinances.

7.6 Development Ordinances

7.6.1 Soil Erosion and Sediment Control

Sedimentation within Wreck Pond and other ponds are a concern throughout the watershed. NJDEP currently reviews most large developments and sets requirements for stormwater quantity and quality control as described in Section 6. The Soil Conservation District reviews soil erosion and sediment control plans for development that disturbs over 5,000 sq. ft. However, smaller development and redevelopment projects are not subject to this review. Requiring implementation of soil erosion and sediment control plans for smaller projects would reduce sediment generation. This requirement could be implemented by the municipalities through stricter ordinances.

Implementation Strategy
Within 18 months of adoption of the draft Plan, the Wreck Pond Watershed Commission along with Monmouth County and the municipalities will review existing ordinances, including local stormwater control ordinances, regarding soil erosion control for smaller development projects and propose revisions to improve control, as needed. The proposed revisions should identify the review agencies, enforcement strategy and maintenance requirements.

7.6.2 Zoning and Stormwater

As discussed in Section 6, local ordinances control the location and nature of development in the watershed. NJDEP regulations control stormwater quantity and quality for larger developments. Local ordinances control smaller projects. Additional controls on stormwater quality and quantity may be appropriate for some projects, depending on existing ordinance requirements, site location, current condition and proposed development.

The Wreck Pond TAC recently met with local municipalities to discuss potential changes to zoning and development ordinances to encourage smart development and reduce impacts from changing uses. The municipalities are interested in making changes to improve water quality yet preserve their ability to allow appropriate development.

In addition to changing zoning or requiring additional stormwater controls, the ordinances may include ways to encourage the use of smart development techniques including more stringent stormwater controls, green development such as rain gardens, and other measures. Such measures may be adopted by new development or by existing homeowners, commercial properties, schools and other entities within the watershed.

Implementation Strategy
The County and TAC, and ultimately the Wreck Pond Watershed Commission will continue to work with the municipalities to amend development ordinances as appropriate and necessary. Ordinance review will consider the stormwater benefits, development costs, and municipal concerns for implementing and controlling these measures. The Wreck Pond Watershed Commission, and the municipalities, will then adopt appropriate control measures.

7.7 Municipal Management and Shared Services

In addition to controlling new development and redevelopment, municipalities can adopt means to improve current stormwater controls. Chapters 5 and 6 identify numerous measures, many of which have been implemented by the four municipalities to meet NJDEP Municipal Stormwater Plan requirements. However, implementation of certain measures is limited by local concerns including cost, consistency of requirements throughout the municipality, and local resident requirements.

Implementation Strategy

Implementation of the management measures identified in Sections 5 and 6, above, requires efforts and possible expenditures by local municipalities. To reduce costs and increase the possibility of implementing these measures, shared services should be investigated. The Wreck Pond TAC, Monmouth County and the Wreck Pond Watershed Commission will work with the municipalities to develop shared service agreements to the extent possible. Examples of possible shared services include:

Facility Maintenance: Maintenance is required by the municipalities for existing stormwater facilities such as catch basins and for the stormceptors currently being designed. Shared use of a shared vac truck for these purposes would reduce costs for individual towns.

Waterfowl Management: Several southern Monmouth County municipalities are working together to manage water fowl in the region. This effort should be continued.

7.8 Public Education

Public education and support is essential for some management elements including pet waste management, yard waste disposal, and water fowl management options.

Implementation Strategy

The County is planning public meetings regarding the Plan. Once the Wreck Pond Watershed Commission is in place, regular public input is anticipated. As discussed in Section 6.2 a Wreck Pond Watershed website is planned. Public education efforts are also being provided by agencies including the Rutgers Cooperative Extension who educates and trains landscape contractors on clean lawns initiatives, provides assistance to the agricultural community regarding reducing erosion and runoff of nutrients or pesticides. The Extension is also promoting rain gardens through education and development of a pilot project within the watershed through an NJDEP Grant.

7.9 Implementation of Specific BMP Projects

NJDEP has provided funding for several specific BMP projects as discussed in Section 5, above. The Monmouth County Planning Board and Engineering Department have taken on implementation of projects through awarding of contracts to engineering firms for studies and design of various projects. Other contracts have been awarded for construction activity for certain of the projects. The County will continue to provide oversight and management of these projects to ensure implementation is timely and within budget. However, grant application and administration and project oversight for future projects is expected to be conducted by the WPWC. The implementation time frame for these specific projects is discussed for each item in Section 5 when known.

Currently, funding has not been secured for several priority projects. The County Planning Board has been working with NJDEP to identify available funds for additional control and remediation projects. Once the WPWC is established, it will take over responsibility for prioritizing and obtaining funding for these priority projects. Other funding sources may include federal EPA grants or foundation grants.

Following implementation of many of the above measures, regular maintenance activities are required to ensure proper functioning. Responsibility for maintenance activities will fall to the local municipality in most cases. Therefore, prior to final design of any BMP measures, a maintenance agreement must be developed with the entity responsible for ongoing maintenance.

Implementation Strategy

The County and, once established, the WPWC will continue to implement funded projects along with other appropriate agencies. Future funding will be sought for other priority projects.

7.10 Funding Sources

As discussed above, funding has been secured for certain projects. However, implementation of others will depend on future funding. The Wreck Pond Watershed Commission, along with the municipalities, will be responsible for identifying and securing funding for future projects. Funding may be available from the State, from the USEPA and from the local municipalities and watershed residents and visitors.

8 FUTURE MONITORING AND PLAN UPDATES

8.1 Future Monitoring Studies

The RWSMP is a comprehensive document with various technical studies. The watershed monitoring done to date provides background data against which future changes can be evaluated. However, additional studies have been identified to clarify watershed conditions or evaluate proposed mitigation measures.

8.1.1 Black Creek

The modeling studies include one flow station and limited water quality data for Black Creek. The NA analyses for the Borough Study sampled at the outlet from Black Creek, but only limited sampling was done within the Creek. The Creek is known to develop algal blooms and sedimentation has been identified as a major problem. The water quality model was not calibrated for this sub-basin due to lack of data and lack of loading factors for golf courses. A short-term water quality monitoring program, including storm event sampling, of the ponded portion of Black Creek, the inflow and outflow would allow development of a pollutant budget model. This would also help evaluate impacts of the golf course. This may be part of the proposed Black Creek sub-committee that is one of the recommendations of this study.

8.1.2 Wreck Pond Hydrodynamics and Sediment Release

The watershed has been studied extensively, but the dynamics of the tidal and freshwater interchange through the discharge pipe has had only limited study by NJDEP during the studies for the outfall extension. If not done as part of the Wreck Pond Environmental Studies, the TAC could look to further investigations of the tidal exchange and its impact on water quality of the Pond.

8.1.3 Hannabrand Brook Flow Studies

The lower reaches of Hannabrand Brook currently appear to have localized conditions impacting expected flow peak rates and volumes. According to NJDA this may be due to debris in the stream, low bank elevations, or other in-field features. Flow transfer to Wreck Pond Brook above the confluence is another possible cause. However, data are not available to reliably quantify these effects under a range of flow conditions. Thus, a short-term flow study on two stations along this stream (W5 and W2) with concurrent measurements at a control station within the Wreck Pond Brook watershed and at W3 would further understanding of the flow dynamics on this stream.

8.1.4 Storm outfall Studies

In conjunction with NJDEP, additional sampling of direct stormwater outfalls, particularly those with base flows, could be undertaken to identify any area of particular concern for bacteria or other loadings.

8.2 Long-term Monitoring

As part of the implementation of each specific stormwater BMP project, review and monitoring as appropriate should be developed to determine the efficacy of each project.

If possible, watershed monitoring for general water quality parameters, nutrients, bacteria, sediment and pH should be undertaken on a regular basis. These studies could involve agencies or voluntary monitoring programs under the guidance of County or NJDEP staff. Use of water quality meters may be acceptable to reduce costs provided some laboratory analyses are conducted to ensure the accuracy of the meters. The WPWC will evaluate the need and cost of such programs. Sampling could be limited to the spring through fall season and should be conducted on a bi- or tri-annual basis to provide an ongoing review of watershed conditions.

Land use updates are undertaken on a regular basis by Monmouth County Office of GIS.

8.3 Procedure for RSWMP Evaluation and Updates

The Wreck Pond Watershed Committee (WPWC) is expected to be established during 2009. The WPWC will be the primary agency responsible for evaluation and update of the RSWMP. The WPWC will develop an appropriate process to evaluate and update the Plan.

The process will include evaluation of the specified measures implemented within the watershed and the effectiveness of those measures. In addition, progress by the municipalities toward adopting new ordinances and enforcing existing ordinances as well as implementation of any new programs will be reviewed. The results of any further studies will be reviewed.

The WPWC is expected to conduct regular meetings to accept input from area residents, municipalities, County and State agencies with regard to progress and additional concerns about the watershed. It is anticipated that local concern will continue to provide valuable input into the process.

As required by regulation, the Plan will be officially updated at least once every five years.

9 CONCLUSIONS

The Wreck Pond Brook Watershed Regional Stormwater Management Plan (WPB RSWMP) has been developed to address stormwater quantity and quality concerns within the Wreck Pond Brook watershed. The Plan has been developed in accordance with Subchapter 3 (Regional Stormwater Management Planning) of the New Jersey Department of Environmental Protection (NJDEP) Stormwater Management regulations (NJAC 7:8). The regional stormwater planning process is designed to address stormwater issues that are best managed on a regional, not a state or local basis.

The Plan provides a detailed description of existing watershed conditions including the results of several monitoring efforts and field investigations, modeling studies, identification of problems and proposed solutions. Book 1 of the RSWMP provides data on the characterization of the watershed and environmental concerns. Book 2 provides the Management Plan, including analysis of future development in the watershed.

Wreck Pond Brook extends from its headwaters in Wall Township near Allaire Airport and flows east-southeast to discharge into Wreck Pond. Wreck Pond is located on the boundary between the boroughs of Spring Lake and Sea Girt in Monmouth County, New Jersey. Wreck Pond is approximately 73 acres in size and a portion of it is tidally influenced. The eastern end of the Pond contains an outfall structure that exchanges water with the Atlantic Ocean. The watershed to the Pond extends to the northwest as shown on Figure 1.

The Wreck Pond watershed was identified as a watershed of concern by the NJDEP. Outflow from Wreck Pond to the Ocean during storm events has been identified as the cause of swimming beach closings in Spring Lake and Sea Girt. Dredging was identified by NJDEP as a possible solution to the bacteria issues and other water quality concerns in the Pond. However, a stormwater management plan was required for the watershed to control future sedimentation prior to further analysis of the feasibility of dredging. Thus, the original RSWMP scope primarily was concerned with sediment control. Over time, the scope was expanded to consider control of many stormwater-related issues.

Watershed characterization was conducted using existing studies and available data from both the NJDEP GIS data and the Monmouth County Office of GIS. Field studies were conducted including assessments of stream condition, analysis of water level and flow, and review of agricultural and recreational lands. These data were used to provide an overview of watershed conditions including hydrology, topography, soils, land use, and other features.

The WPB watershed is a mix of open woodlands, agricultural lands and developed areas. Most of the developed areas are in residential use, with some commercial and industrial uses. The eastern portion of the watershed is almost fully developed. The stream corridors include wetlands and wooded areas. Undeveloped areas are zoned primarily for residential use.

The overall goal of this management plan is to improve the water quality of the ponds and streams within the watershed, to reduce watershed loadings of pollutants associated with current and future land uses, to reduce flooding, and to eliminate or greatly reduce bathing beach closings associated with the discharge from Wreck Pond to the Atlantic Ocean.

Specific water quality objectives for this Watershed Management Plan are to reduce pollutant loading levels and remove accumulated pollutants to allow attainment of all designated uses that are not limited by natural conditions. In particular, the goals are:

- Reduce bacteria levels in Wreck Pond and tributary streams to meet standards and attain the designated uses

- Eliminate or greatly reduce beach closings due to outflow from Wreck Pond or other watershed sources

- Reduce sediment loads to Wreck Pond and other ponds from both existing sources and new development.

- Reduce phosphorus loads and concentrations to meet standards, reduce eutrophication of ponds, reduce algal blooms and attain the designated uses.

- Reduce nitrogen loads to reduce eutrophication and algal blooms

- Improve the water quality, ecological health and aesthetics of Wreck Pond, Black Creek, other Ponds and the overall watershed

The Plan has developed workable solutions that can be implemented by the municipalities and standards that may be employed in review of new projects. The Plan also will be reviewed and updated as needed to ensure it continues to be responsive to changing watershed conditions. The Plan process includes initiation of some BMP projects and the implementation phase will continue those efforts.

The Wreck Pond Brook watershed has been the subject of field investigations, two modeling studies and several water quality monitoring programs including the County weekly sampling and the sampling done for the Borough of Spring Lake’s Wreck Pond Environmental Study. In addition, Monmouth University and Rutgers Cooperative Extension collected water quality data as part of their studies. Further, MCHD continues to conduct summer bacteria monitoring at the beaches and NJDEP is conducting bacteria studies. The results of these studies and the watershed characterization were analyzed to evaluate possible pollutant sources.

For the Wreck Pond watershed, the mixed land uses are a major source of all pollutants of interest. In addition, wildlife, particularly waterfowl, are a significant source of bacteria in the ponds. No point sources are present in the watershed. Leaking infrastructure may be of concern in some areas.

The results of the watershed modeling, agricultural survey, stream assessments, and bacteria source tracking did not identify one source of highest importance. For each pollutant group, identified sources are noted below.

Nutrients: Developed land uses, agricultural lands, fertilizer application, wildlife

Bacteria: Developed land use, manure management in farmlands, waterfowl, possible leaking infrastructure, wildlife, pets, release from Pond sediments

Sediment: Developed lands, agricultural land, un-vegetated uplands, construction sites, stream erosion, re-suspension of pond sediments

In addition to NJDEP regulations regarding stormwater management, the four municipalities within the watershed have adopted ordinances and management plans to control stormwater impacts for new and existing development. These have been adopted in accordance with NJDEP regulations. This Plan has identified other methods and programs that the municipalities will consider in the implementation phase.

The TAC used information obtained through field studies, water quality data collection and modeling to develop a list of priority projects and funding was obtained to initiate some of these projects. Currently, a project is underway to place stormwater treatment devices on stormwater structures that flow directly to Wreck Pond. Funds have been allocated to initiate improvements at the former gravel pit on Ridgewood Road in Wall Township and the weir at the pond from the Spring Lake Golf Club. A demonstration project for rain gardens has been funded and will be implemented. Other priority projects have been identified for future funding.

The implementation phase includes development of a Wreck Pond Watershed Commission (WPWC) that will take on responsibility for implementation of this Plan. The Commission will include representative from each municipality, other agencies, and interested members of the public. The WPWC is expected to have the authority to apply for and administer grants for studies or implementation projects. The WPWC also will have the responsibility for ongoing plan implementation and updates.

Overall, the WPB Watershed Regional Stormwater Management Plan provides a detailed study of a watershed along the New Jersey Coast that contains developed and undeveloped area. This watershed is typical of many in which non-point sources, including developed lands, natural conditions and wildlife, are the primary sources of stormwater related concerns. The implementation of the recommendations and directives from this Plan will improve stormwater flows and water quality and will enhance environmental conditions in the watershed.

APPENDIX A

County and NJDA
Gauge and Monitoring Station Descriptions

The gauge and sampling stations for the County and NJDA sampling are described in the following paragraphs moving downstream.

WRECK POND BROOK STATIONS

W6 – "Martin's Road", Wall Township: This station is the farthest upstream, located above the outlets at Old Mill Road. W9 monitors a large upstream wooded area as well as the runoff generated by several industrial sites located along Rt. 34, and the highway itself. Just downstream of Rt. 34 is a defunct wash pond once used by a sand mining operation. The outlet to the pond has been breached, and the pond itself (this report will refer to the pond as "Kellers Pond", after K. Thomas Kellers, the originator of this study and a long time resident of Wall Township who frequented this heretofore unnamed pond as a youngster) is shallow and does maintain a constant pool. However it appears that the pond itself with a breached outlet provides very little in runoff attenuation for peak control.

The actual datalogger location is approximately 60 feet upstream from the culvert on Martin's Road. Investigators originally proposed to set the logger on the culvert, or just downstream. However, the culvert has a non-level entrance and therefore, standardized hydraulics for measuring flows might not apply to the structure. The channel around the logger itself is sinuous up and downstream of the logger and the floodplain is heavily vegetated. These characteristics made it difficult to develop a rating curve. However, several larger storm events, including the October 2005 flood, provided much needed data to calibrate rating curves at and beyond bank full flow. As with the station located at W7/Glendola Road, the strategic location of this site outweighed the less-than-ideal physical characteristics of the stream corridor.

W9 – "Hurley's Pond Dam", Hurley's Pond Road, Wall Township: The datalogger is mounted to the upstream face of the culvert/bridge at the outlet of the pond. The outlet structure functions as a weir, orifice and finally another weir during overtopping of Hurley's Pond Road. Hydraulics of these structures are well documented and dimensions are easily measured. Also, a prior study of this drainage area was available (Hatch-Mott McDonald, July 2004. Dam Evaluation Report Phase II for Monmouth County Engineering Department) which aided the investigators by providing comparative data. Vehicle parking is close by. Hurley's Pond Road does experience significant traffic, and the bridge is a narrow point on the road, making safety a priority in data collection from the logger. The outlet to the pond is a natural control point and is strategically located in the upper reaches of the Wreck Pond Brook Branch.

W7 – "Wreck Pond Brook at Glendola Road, Wall Township": This site is located on the wooden bridge crossing of Glendola Road and Wreck Pond Brook. The bridge is a natural hydraulic control point. Glendola Road is a dead end street with very little traffic. It serves a small community of horse farms and thus investigators felt that there would be little possibility of gage tampering. The gage was installed just downstream of the bridge opening, far enough to be beyond the influence of the opening itself. The channel is somewhat prismatic and the banks are covered with seasonally thick vegetation. Downstream the channel is somewhat straight but is interrupted by some vegetation. Although this location is ideal in terms of the overall subdivision of the watershed, some physical characteristics of the location were undesirable, such as thick organic deposits on the channel bottom and the interruption of the channel downstream by vegetation. This stretch of Wreck Pond Brook is somewhat sluggish and prone to deposits. Further downstream a farm pond discharges to the brook, which then runs through a large culvert under 18th Avenue. Investigators felt that the strategic location within the watershed took precedence over other factors which could be accounted for in data collection and modeling.

W1 – "Wreck Pond Brook at Waterford Glen, Rt. 35, Wall Township": W1 is just downstream of Osborne's Pond, a major hydraulic control structure on Wreck Pond Brook. Access to the site is from the Waterford Glen parking lot. The stream channel in this location is fairly prismatic with a free flowing water surface and somewhat stable bed. The channel is bounded by a large, heavily vegetated floodplain. Data collected from this station proved to be very consistent and showed an excellent "shape" in the hydrographs, primarily due to the influence of the pond directly upstream. Investigators considered locating the meter just downstream of Osborne's Pond at Allaire Road (a few hundred feet upstream from the final location). However, this is a popular location for fishermen which raised concerns about possible tampering with the gage.

HANNABRAND BROOK STATIONS

W5 – "Hannabrand Brook at Bailey's Corner Road": W5 is the most upstream gauge on Hannabrand Brook. Investigators evaluated several sites further upstream but found that flows were small and would be difficult to reproduce in a modeling environment. Initially investigators sought to install the meter on the bridge crossing of Bailey's Corner Road, a natural control point. However, the bridge is on a road bend, and experiences high traffic volume which rendered the location unsuitable due to safety concerns. The investigators located the meter approximately 100 feet downstream of the bridge. This location provided a prismatic cross section, free flowing water surface and safe access. Unfortunately, this location also experienced severe stream bed movement which, on several occasions, buried the meter in sands and gravels. The meter continued to function and recorded water depth measurements. However, these measurements required adjustment to account for increased sediment depth and artificial elevation of the water surface. Data used in modeling were taken from the records prior to bed movement.

W2 – "Hannabrand Brook at Old Mill Road" and W3 – "Wreck Pond Brook at Old Mill Road": These locations represent the most downstream gauge locations in the watershed determined to be above the influence of tide and backwater effects. Originally a single downstream location was selected to measure the entire watershed (W4 at Shore Road) but was abandoned after severe flooding and "backwater" were observed due to a 2-inch rainfall event. Each site has safe access, and somewhat uniform, prismatic cross section. Drawbacks to these sites which later proved difficult in the modeling process (see Section 6) include the location of Old Mill Pond directly upstream of W3 and the short channel between W3 and the Old Mill Road Culvert. For station W2, the gage (datalogger) was located upstream of the Old Mill Road culvert on the Hannabrand Branch due to the inability to gain permission for access on the property directly below the culvert. Upstream of W2, the channel winds and bends and lastly, the area between the Old Mill Pond spillway and the upstream portion of the Hannabrand overflow and flows co-mingle during extreme events (such as October 2005). Never the less sufficient logger data, complimented by photographic data by residents in the area allowed for successful stream modeling and subsequent development of rating curves.

BLACK CREEK STATION

W8 – Rt. 71 Culvert at headwaters of Black Creek, Spring Lake Heights: The last drainage area which contributes to Wreck Pond and appears to be uninfluenced by tides or backwater during normal storm events is that which is occupied by the Spring Lake Golf Club, the Mews Golf Club and the surrounding neighborhoods. A logger was initially attached to the weir at the water course /pond outlet at the Spring Lake Golf Club (SLGC) which would have been an ideal location strategically and hydraulically. Unfortunately, the wooden weir and associated bulkhead is in significant disrepair and consequently is leaking badly and allowing enough bypass flow which the investigators felt could not be easily accounted for. The bulkhead was patched successfully in one main location, but too many other areas were leaking. Therefore, the gage was relocated to the downstream side of the Rt. 71. The channel in this location is shallow and surrounded by steep slopes. The embankments are composed of dumped concrete debris and vegetation. The channel downstream of the logger is short before it enters the ponded area of Black Creek. Flows are easily measured in the channel, and the channel is fairly prismatic. This location allowed the investigators to observe the influence of the Rt. 71 drainage and its interaction with the drainage area upstream of the SLGC weir which would have been undetected had the logger been left installed on the SLGC weir.

APPENDIX B

Freehold Soil Conservation District Stream Assessment Information

Sheet # ____________

Reach Assessment Data Sheet
Wreck Pond Watershed

All assessments must be done looking downstream of reach assessment point

Subwatershed ID	____________	Inventoried by	____________
Reach ID	____________	Date	____________
Temperature (F)	____________	Time	____________
Precipitation Date	____________	Precipitation (in)	____________

Weather Conditions: Clear, Overcast, Rain, Snow

Channel Width (ft)	____________	Channel Depth (ft)	____________
Flow Width (ft)	____________	Flow Depth (ft)	____________
Right Buffer Width (ft)	____________		
Left Buffer Width (ft)	____________		

Right Bank Slope	Flat, Gentle, Moderate, Steep
Left Bank Slope	Flat, Gentle, Moderate, Steep
Right Bank Vegetation	less than 50%, 51-70%, 71-90%, 90%+
Left Bank Vegetation	less than 50%, 51-70%, 71-90%, 90%+
Right Bank Disturbance	Natural, Man-made
Left Bank Disturbance	Natural, Man-made
Right Bank Erosion	None, Minimal, Moderate, Severe
Left Bank Erosion	None, Minimal, Moderate, Severe
Right Bank Land Use	Forest, Orchard, Farmland, Industrial, Residential
Left bank Land Use	Forest, Orchard, Farmland, Industrial, Residential

Stream Movement	Stagnant, Sluggish, Slow, Swift
Water Clarity	Clear, Cloudy, Opaque, Eutrophic
Bed Material	Mud, Sand, Gravel, Rip-Rap
Bank Symmetry	Symmetric, Non-symmetric
Stream Shading	0-24%, 25-49%, 50-74%, 75-100%
Debris	None, Natural, Natural & Garbage, Garbage
Stream Alterations	None, Around Structures, 40-80% Channelized, >80% Channelized

Indicator Plants	Algae, Mosses, Herbaceous, None
Aquatic Plants	Purple Loosestrife, Phragmities, Cattails, Tussock Sedge, None

Upstream Pic #	____________	Misc Pic #	____________
Downstream Pic #	____________	Misc Pic #	____________
Right Land Use Pic #	____________	Misc Pic #	____________
Left Land Use Pic #	____________	Misc Pic #	____________

Notes:

revised 1-31-05

Sheet #______

Reach Assessment Score Sheet
Wreck Pond Watershed

Subwatershed ID________________ Inventoried By _____________

Reach ID______________________ Date _________________

Total Score____________________

STREAM ASSESSMENT FOR LOW GRADIENT STREAMS

	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent, root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present	All mud or clay or sand bottom; little or no root mat, no submerged vegetation	Hard-pan clay or bedrock. No root mat or vegetation
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Pool Variability	Even mix of large-shallow large-deep small-shallow, small-deep pool's Present	Majority of pools large deep; very few shallow	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% (20% for low gradient streams)of the bottom affected by sediment deposition.	Some new increases in bar formation mostly from gravel, sand or fine sediment; 5-30% (20-50% for low gradient streams) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel sand or fine sediment on old and new bars; 30-50% (50-80% for low gradient) of the bottom affected; sediment deposits is at obstructions, bends and constrictions.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Channel Flow Status	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	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Alteration	Channelization or dredging absent or minimal; stream width normal pattern.	Some channelization present, usually areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yrs) may be present, but recent channelization not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with Gabion or cement; over 80% of the stream reach channelized and disrupted. In stream habitat greatly altered or removed entirely.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
6. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than it was a straight line. (Note – channel braiding is considered normal in coastal plains and other low-laying areas. This parameter is not easily read in these areas.)	The bends in the stream increase the stream length 2 to 3 times longer than if it was a straight line.	The bends in the stream increase the stream length 2 to 1 times longer than if it was a straight line.	Channel straight; waterway has been channelized for a long time
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% bank has erosional scars.
SCORE (LB	Left bank 10 9	8 7 6	5 4 3	2 1 0
SCORE (RB	Right bank 10 9	8 7 6	5 4 3	2 1 0
8. Bank Vegetative Protection (score each bank) Note: determine left right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation; including trees, under story shrubs, or nonwoody macrophytes vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well represented Disruption evident but not affecting full plant growth potential to any great extent; more than ½ of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than ½ of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE (LB	Left bank 10 9	8 7 6	5 4 3	2 1 0
SCORE (RB	Right bank 10 9	8 7 6	5 4 3	2 1 0
9. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; Human activities (i.e.: parking lots, Roadbeds, clear-cuts, lawns, or crops) Have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal	Width of riparian zone <6 meters; little or no riparian vegetation due to human activites.
SCORE (LB	Left bank 10 9	8 7 6	5 4 3	2 1 0
SCORE (RB	Right bank 10 9	8 7 6	5 4 3	2 1 0

Score: Optimal 145-180 Sub-Optimal 100-144 Marginal 50-99 Poor <50

Revised 1-31-05

APPENDIX C

Rutgers Cooperative Extension
Agricultural and Recreational Field Study Information

NJ AGRICULTURAL EXPERIMENT STATION
RUTGERS
COOPERATIVE RESEARCH & EXTENSION

Agricultural Assessment

Please take a few moments to contribute to this research project. All submitted data will only be used to summarize information about the total amount and character of farmland in the Wreck Pond Brook Watershed. No individual response data will be singled out or provided to outside agencies for any regulatory purpose.

Assessment Section

1. Are you the owner or renter of an agricultural property in Wall Township?

YES NO Not Sure (explain)

2. Is this property currently being used for agriculture?

YES NO Not Sure (explain)

3. Has this property been used for agriculture within the last 5 years?

YES NO Not Sure (explain)

4. What is the size of this property?

0-5 Acres 5.1-20Acres 20.1-50 Acres >50 Acres

5. What is the size of the property currently in agricultural use?

0-5 Acres 5.1-20Acres 20.1-50 Acres >50 Acres

If the answers to 2 and 3 were no, and the answer to 5 is zero, you may skip questions 6-11.

6. What type of agriculture occurs on this property? Circle all that apply.

Crop/Vegetable Orchard/Vineyard Livestock/Animals Ornamentals/Nursery Other

7. Are there domestic animals or livestock on this property?

YES NO Not Sure (explain)

If there are domestic animals or livestock, please fill in the grid with the numbers of each type of livestock you are raising on this property.

Cows	Goats	Sheep	Pigs	Chickens	Horses	Rabbits	Dogs	Other(list)

8. Is manure used as a nutrient additive for land on this property?

YES NO Not Sure (explain)

9. Are there active pasture fields on this property?

YES NO Not Sure (explain)

10. Are any methods employed to manage manure on this property?

YES NO Not Sure (explain)

11. Please circle the following methods that are employed to manage manure on this property.

Manure is stored in a location that is away from water bodies and drainage areas
Roof or tarp over storage area
Manure is placed on a flat, solid pad . Pad is constructed of ? __________
Manure is stored in a bin enclosed on at least three sides
Manure is hauled away periodically. Frequency? ______
Fencing or other means of preventing/limiting livestock access to streams
Active manure composting performed on site
Have had cropland soil tested to determine appropriate fertilizer ratios
Manure application to fields only as needed. General frequency _______

Other (please explain):

12. Are there substantial wildlife populations on this property?

YES NO Not Sure (explain)

If there are substantial wildlife populations, please fill in the grid with an estimate of the numbers of wildlife that are regularly seen on your property.

Deer	Ducks	Geese	Raccoons	Other

Demographic/Need for Education Section

13. Are you familiar with the term “Best Management Practice” ?

YES NO Not Sure (explain)

14. Are you aware of agencies and organizations that can assist you with the management of manure on your property?

YES NO Not Sure (explain)

15. Please list the organizations you are aware of that provide assistance with water or environmental quality improvements on farmland to the agricultural community .

16. Would you or your staff be interested in attending free workshops that highlighted methods of manure management to better protect water quality ?

YES NO Not Sure (explain)

17. Would you be willing to let RCRE staff take a tour of your agricultural property to assess the use of manure and management practices?

YES NO Not Sure (explain)

18. Would you be willing to let RCRE staff record the locations of your manure storage areas/ application areas to help assess the agricultural input in the watershed?

YES NO Not Sure (explain)

19. If a manure management issue was identified, would you be interested in participating in a manure management best management practice demonstration project on your agricultural property?

YES NO Not Sure (explain)

20. Would you be interested in doing a demonstration project only if grant funding could be provided to cover some of the expenses?

YES NO Not Sure (explain)

21. Would you be interested in doing a demonstration project only if grant funding could be provided to cover all of the expenses?

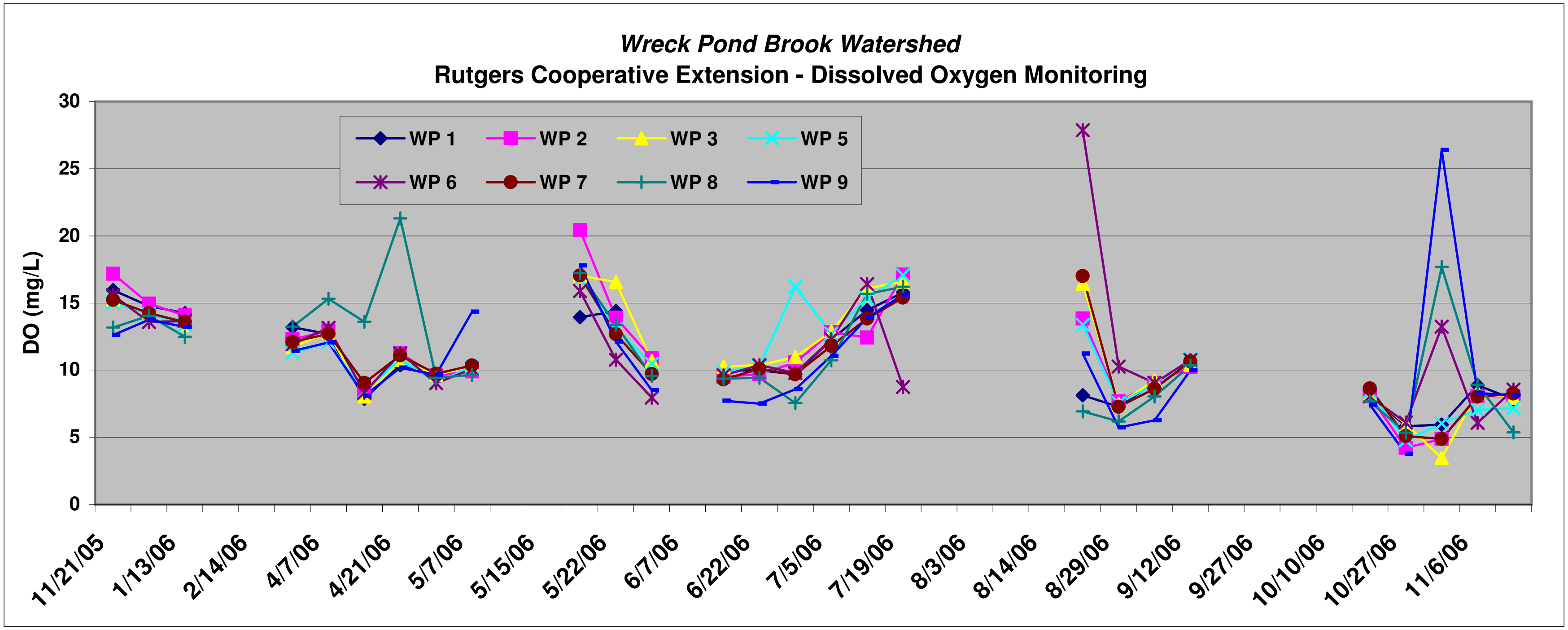
YES NO Not Sure (explain)

22. If you participated in a best management practice demonstration project, would you allow RCRE staff to monitor the effectiveness of the project in order make better recommendations for future projects?

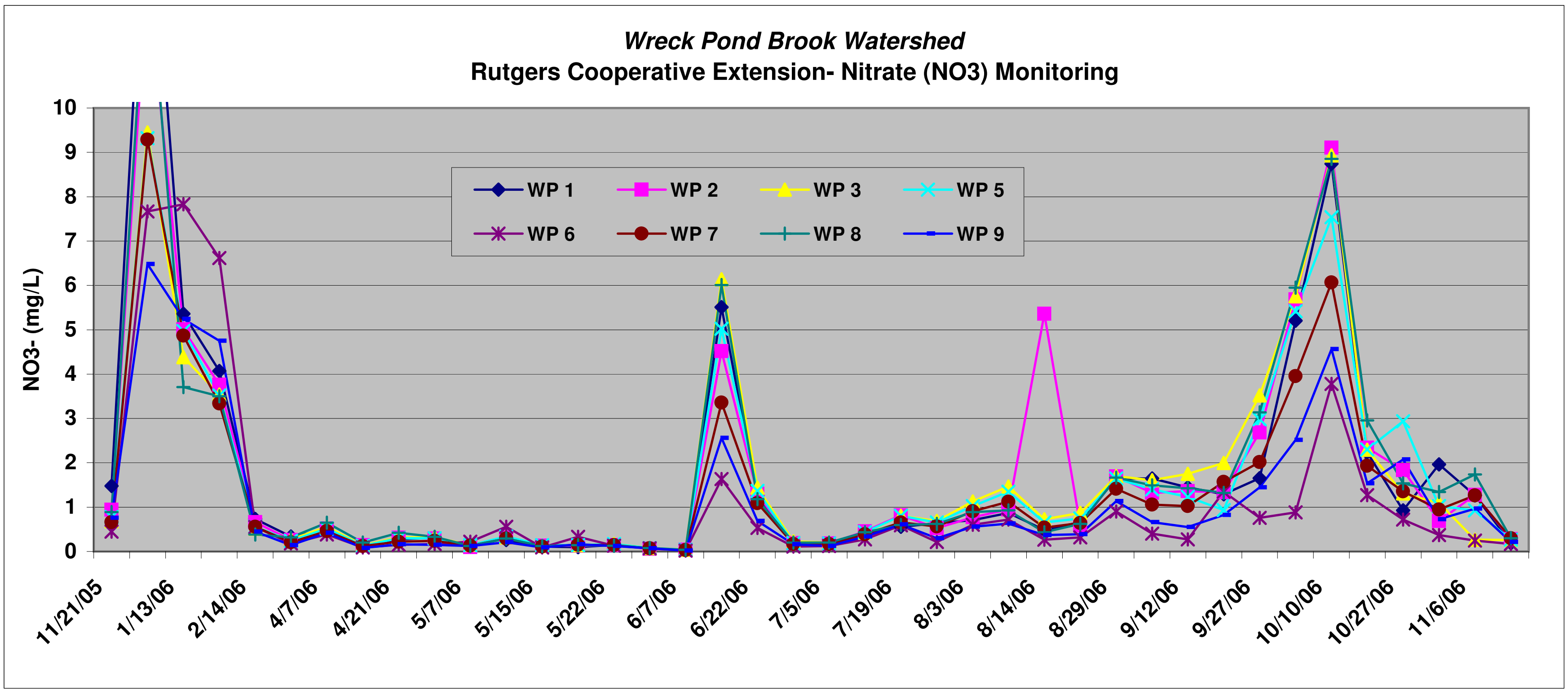
YES NO Not Sure (explain)

Thank you for cooperating with this research request, and for your time. Please send response in the enclosed envelope. If you wish to participate further in this research, please indicate on this form, or contact:

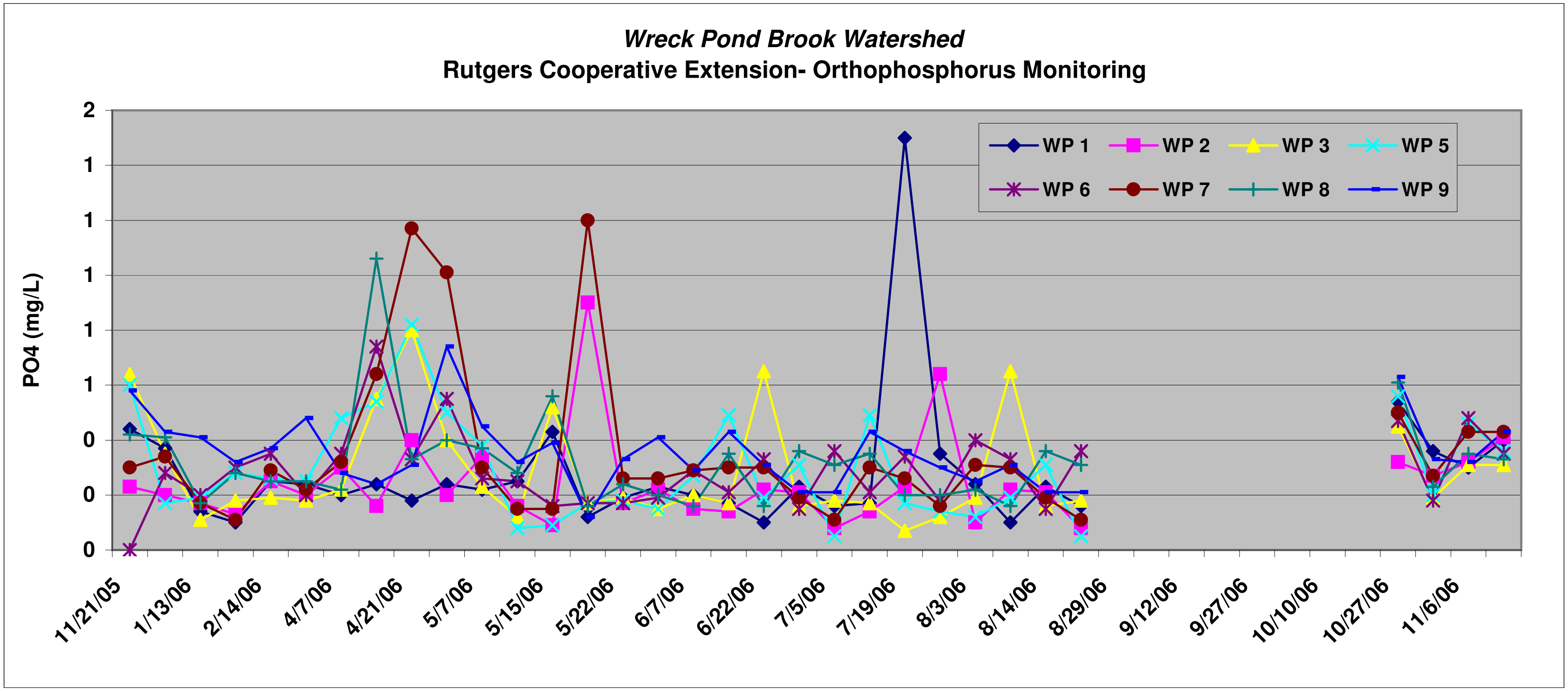
Cara Muscio
Rutgers Cooperative Research and Extension
1623 Whitesville RD
Toms River, NJ 08755
(732) 349-1210
Muscio@rcre.rutgers.edu



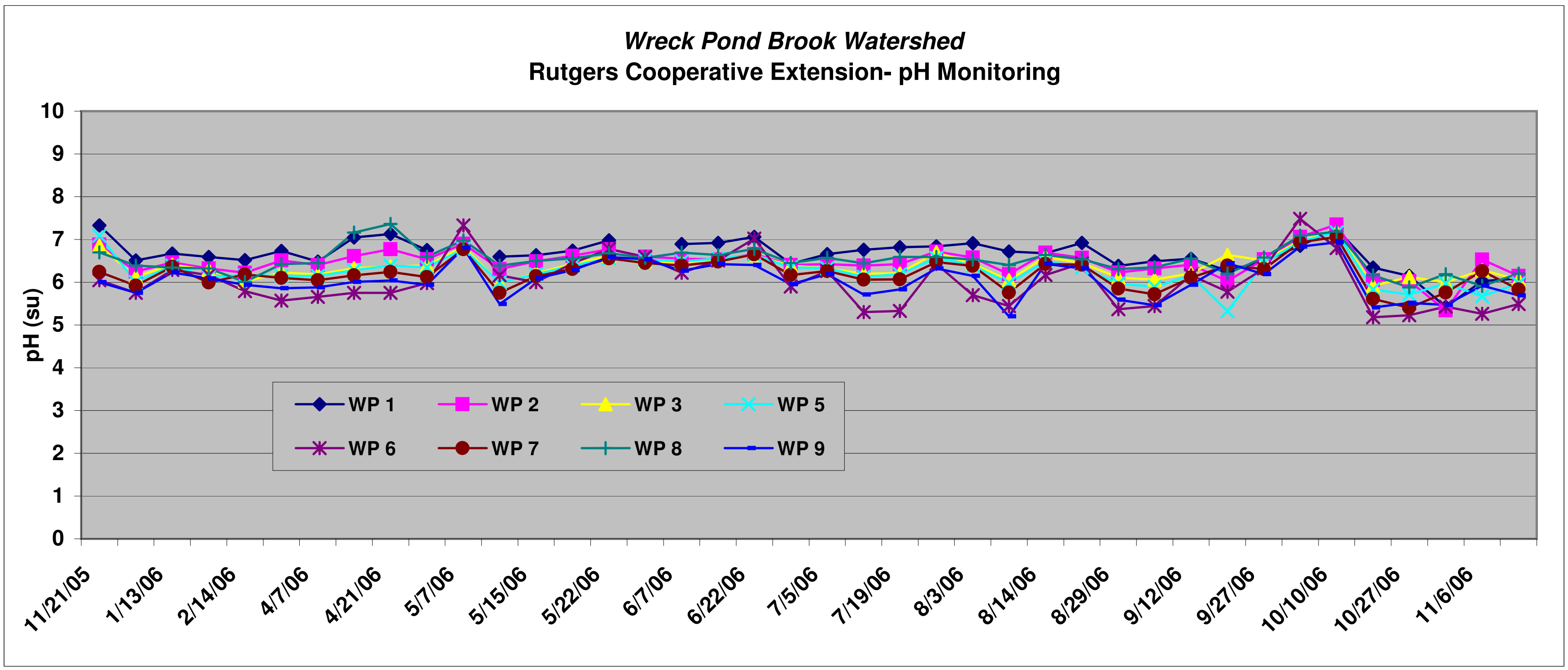
Wreck Pond Brook Watershed
Rutgers Cooperative Extension - Dissolved Oxygen Monitoring
DO (mg/L)
0
5
10
15
20
25
30
WP 1
WP 2
WP 3
WP 5
WP 6
WP 7
WP 8
WP 9
11/21/05
1/13/06
2/14/06
4/7/06
4/21/06
5/7/06
5/15/06
5/22/06
6/7/06
6/22/06
7/5/06
7/19/06
8/3/06
8/14/06
8/29/06
9/12/06
9/27/06
10/10/06
10/27/06
11/6/06



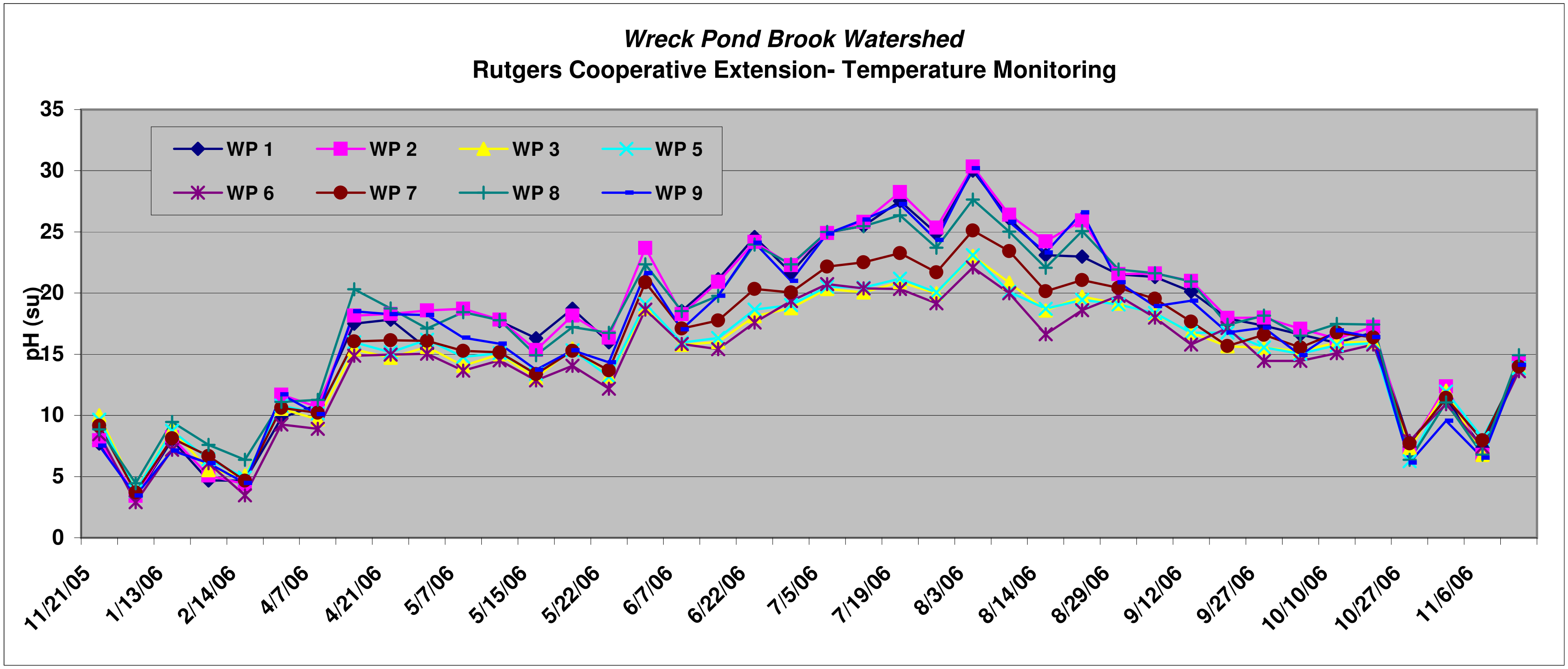
Wreck Pond Brook Watershed
Rutgers Cooperative Extension- Nitrate (NO3) Monitoring
NO3- (mg/L)
0
1
2
3
4
5
6
7
8
9
10
WP 1
WP 2
WP 3
WP 5
WP 6
WP 7
WP 8
WP 9
11/21/05
1/13/06
2/14/06
4/7/06
4/21/06
5/7/06
5/15/06
5/22/06
6/7/06
6/22/06
7/5/06
7/19/06
8/3/06
8/14/06
8/29/06
9/12/06
9/27/06
10/10/06
10/27/06
11/6/06



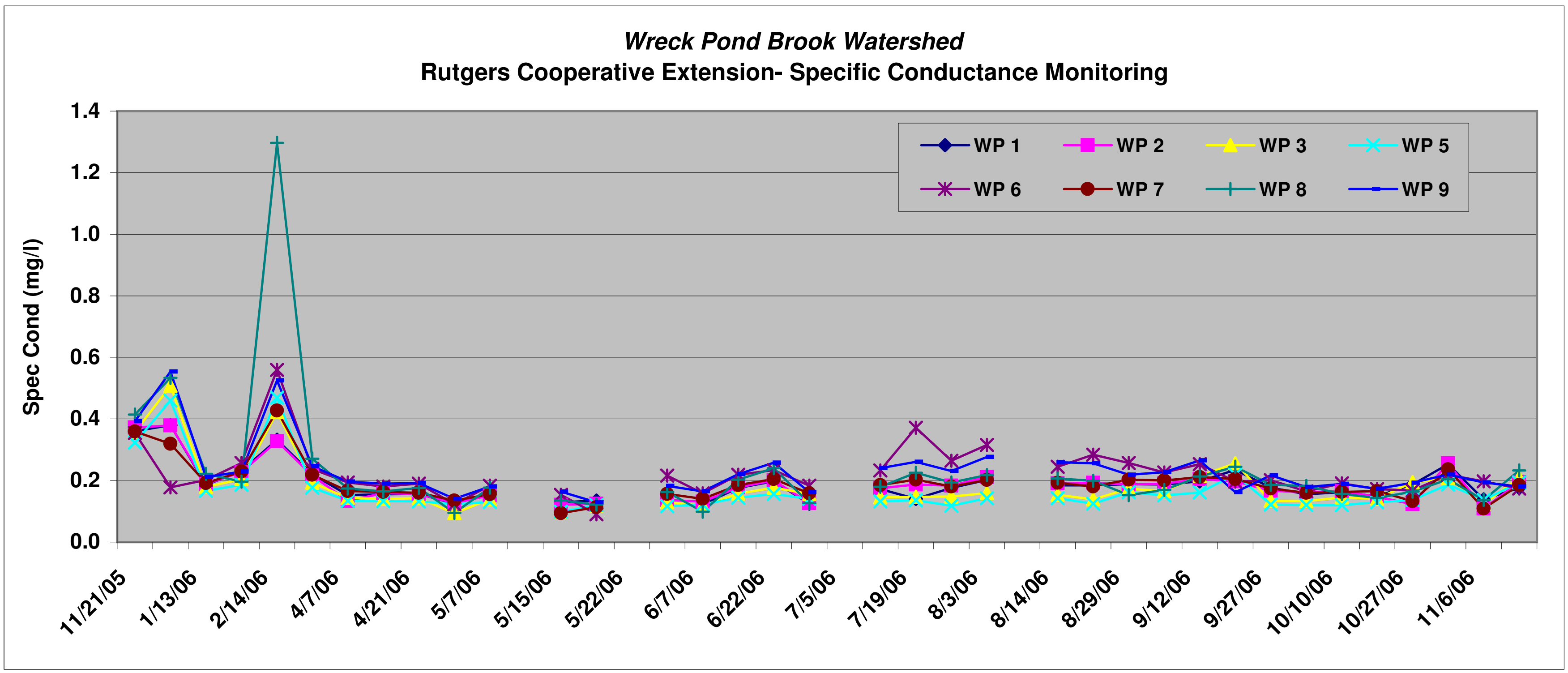
Wreck Pond Brook Watershed
Rutgers Cooperative Extension- Orthophosphorus Monitoring
PO4 (mg/L)
2
1
1
1
1
1
0
0
0
WP 1
WP 2
WP 3
WP 5
WP 6
WP 7
WP 8
WP 9
11/21/05
1/13/06
2/14/06
4/7/06
4/21/06
5/7/06
5/15/06
5/22/06
6/7/06
6/22/06
7/5/06
7/19/06
8/3/06
8/14/06
8/29/06
9/12/06
9/27/06
10/10/06
10/27/06
11/6/06



Wreck Pond Brook Watershed
Rutgers Cooperative Extension- pH Monitoring
pH (su)
10
9
8
7
6
5
4
3
2
1
0
WP 1
WP 2
WP 3
WP 5
WP 6
WP 7
WP 8
WP 9
11/21/05
1/13/06
2/14/06
4/7/06
4/21/06
5/7/06
5/15/06
5/22/06
6/7/06
6/22/06
7/5/06
7/19/06
8/3/06
8/14/06
8/29/06
9/12/06
9/27/06
10/10/06
10/27/06
11/6/06



Wreck Pond Brook Watershed
Rutgers Cooperative Extension- Temperature Monitoring
WP 1
WP 2
WP 3
WP 5
WP 6
WP 7
WP 8
WP 9
pH (su)
35
30
25
20
15
10
5
0
11/21/05
1/13/06
2/14/06
4/7/06
4/21/06
5/7/06
5/15/06
5/22/06
6/7/06
6/22/06
7/5/06
7/19/06
8/3/06
8/14/06
8/29/06
9/12/06
9/27/06
10/10/06
10/27/06
11/6/06



Wreck Pond Brook Watershed
Rutgers Cooperative Extension- Specific Conductance Monitoring
WP 1
WP 2
WP 3
WP 5
WP 6
WP 7
WP 8
WP 9
Spec Cond (mg/l)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
11/21/05
1/13/06
2/14/06
4/7/06
4/21/06
5/7/06
5/15/06
5/22/06
6/7/06
6/22/06
7/5/06
7/19/06
8/3/06
8/14/06
8/29/06
9/12/06
9/27/06
10/10/06
10/27/06
11/6/06

Table 1. Agricultural Stream Bank Soil Results

Sample ID	pH	Phosphorus (lbs./acre)	Potassium (lbs./acre)	Magnesium (lbs./acre)	Calcium (lbs./acre)	Micronutrients (ppm)	Organic Matter (%)	Organic Carbon (%)	Nitrate-N (ppm)	Ammonium-N (ppm)
A1a	4.90	40	83	160	1226	Iron - High	14.70	8.53	4	3
A1b	5.05	39	127	175	825	Iron - High	4.25	2.46	10	1
A2a	5.20	266	170	202	982	Iron - High	3.06	1.78	8	1
A2b	5.10	87	138	233	820	Iron - High	3.60	2.09	5	3
A3	5.05	117	106	192	953	Iron - High	5.14	2.98	2	2
A4	4.15	45	134	105	477	Iron - High	3.98	2.31	8	1

Table 2. Mixed Stream Bank Soil Results

Sample ID	pH	Phosphorus (lbs./acre)	Potassium (lbs./acre)	Magnesium (lbs./acre)	Calcium (lbs./acre)	Micronutrients (ppm)	Organic Matter (%)	Organic Carbon (%)	Nitrate-N (ppm)	Ammonium-N (ppm)
B1	6.25	39	116	139	1849	Iron - High	3.58	2.08	7	4
B2	4.55	39	126	101	768	Iron - High	7.52	4.36	5	7
B3	5.45	58	116	162	873	Iron - High	2.74	1.59	3	2
B4	4.50	74	64	96	688	Iron - High	10.22	5.93	9	7

Table 3. Developed Stream Bank Soil Results

Sample ID	pH	Phosphorus (lbs./acre)	Potassium (lbs./acre)	Magnesium (lbs./acre)	Calcium (lbs./acre)	Micronutrients (ppm)	Organic Matter (%)	Organic Carbon (%)	Nitrate-N (ppm)	Ammonium-N (ppm)
D1	5.65	9	69	188	1324	Iron - High	3.25	1.89	7	12
D2	5.10	95	211	137	936	Iron - High	2.49	1.44	11	7
D3	5.40	30	122	237	1092	Iron - High	4.90	2.84	13	20
D4	6.00	44	244	277	1999	Iron - High, Zinc - High	4.25	2.46	10	4

Table 4. Control Stream Bank Soil Results

Sample ID	pH	Phosphorus (lbs./acre)	Potassium (lbs./acre)	Magnesium (lbs./acre)	Calcium (lbs./acre)	Micronutrients (ppm)	Organic Matter (%)	Organic Carbon (%)	Nitrate-N (ppm)	Ammonium-N (ppm)
C1	4.65	4	131	89	329	Iron - High	4.29	2.49	2	5
C2	5.15	1	44	80	343		1.86	1.08	2	1
C3	6.60	1	51	101	731	Iron - High	1.82	1.05	2	0
C4	5.50	17	162	153	797	Iron - High	3.25	1.88	2	8

Table 5. Agricultural Land Soil Results

Description	pH	Phosphorus (lbs./acre)	Potassium (lbs./acre)	Magnesium (lbs./acre)	Calcium (lbs./acre)	Micronutrients (ppm)	Organic Matter (%)	Organic Carbon (%)	Nitrate-N (ppm)	Ammonium -N (ppm)
Hay	4.1	3	73	58	274	Iron - High	2.29	1.33	2	2
Hay	4.85	143	125	84	396	Iron - High	1.03	0.6	2	0
Hay	5.15	55	128	82	648		1.33	0.77	2	0
Hay	5	43	147	91	642	Iron - High	1.6	0.93	2	0
Hay	5.2	45	303	185	880	Iron - High	2.32	1.35	5	4
Hay	5.35	113	333	148	716	Iron - High	1.6	0.93	4	0
Hay	5.1	78	222	92	465	Iron - High	1.6	0.93	4	0
Hay	5.55	102	259	125	912	Iron - High	2.59	1.5	5	9
Hay	5.15	35	182	85	619	Iron - High	2.59	1.5	3	0
Hay	5.05	227	216	88	733	Iron - High	1.67	0.97	2	3
Hay	5.6	1037	183	91	2188	Iron - High	2.69	1.56	7	11
Mixed Vegetables	6.65	493	642	303	1874	Iron - High	3.03	1.76	4	0
Steer	7.8	113	179	224	1363	Iron - High	2.65	1.54	5	2
Steer	6.1	176	220	212	1413	Iron - High	3.03	1.76	5	3
Steer	5.9	211	290	240	1744	Iron - High	3.22	1.87	7	4
Mini Donkeys	6.15	64	69	197	1229	Iron - High				
Mini Donkeys	6.1	138	167	226	1362	Iron - High	2.58	1.5	4	3
Mini Donkeys	5.25	90	74	153	956	Iron - High	2.05	1.19	3	2
Hay	5.15	25	180	136	610	Iron - High	3.41	1.98	2	2
Mixed Vegetables	6.55	284	246	282	2321	Iron - High	4.28	2.48	6	1
Christmas Trees	5.15	275	46	57	479	Iron - High	1.56	0.91	1	0
Christmas Trees	4.75	376	47	37	203	Iron - High	1.17	0.68	1	0
Christmas Trees	4.75	344	80	42	211	Iron - High	1.01	0.59	2	1
Christmas Trees	4.85	353	82	52	305	Iron - High	1.09	0.63	1	1
Christmas Trees	5	377	83	51	371	Iron - High	1.33	0.77	1	3

Table 5. Agricultural Land Soil Results (continued)

Description	pH	Phosphorus (lbs./acre)	Potassium (lbs./acre)	Magnesium (lbs./acre)	Calcium (lbs./acre)	Micronutrients (ppm)	Organic Matter (%)	Organic Carbon (%)	Nitrate-N (ppm)	Ammonium -N (ppm)
Christmas Trees	4.95	221	47	64	560	Iron - High	1.37	0.79	2	1
Christmas Trees	4.85	370	50	45	421	Iron - High	0.94	0.54	2	1
Mixed Vegetables	6.5	587	421	129	1561	Iron - High	1.09	0.63	9	2
Mixed Vegetables	6.8	631	446	158	2127	Iron - High	1.8	1.04	3	3
Mixed Vegetables	6.7	611	488	137	1510	Iron - High	1.09	0.63	3	0
Mixed Vegetables	7.25	433	343	135	2652	Iron - High	1.52	0.88	4	0
Sweet Corn	6.8	439	340	112	1553	Iron - High	1.01	0.59	2	0
Sweet Corn	7.05	401	314	158	2282	Iron - High	1.6	0.93	4	1
Sweet Corn	6.75	373	343	154	1555	Iron - High	1.05	0.61	3	0
Sweet Corn	6.75	362	401	190	1780	Iron - High	1.56	0.91	4	1
Sweet Corn	7.2	334	453	169	2232	Iron - High	1.68	0.97	5	0
Sweet Corn	7.1	243	306	133	1488	Iron - High	1.01	0.59	3	0
Timber	4.3	143	101	62	341	Iron - High				
Timber	4.25	238	56	39	216	Iron - High				
Timber	4.15	191	103	51	355	Iron - High				
Timber	4.4	110	45	56	319	Iron - High				
Christmas Trees	5.35	221	137	108	463	Iron - High				
Christmas Trees	5.4	157	177	180	861	Iron - High				
Christmas Trees	5.6	106	64	192	817	Iron - High				
Horse Pasture	5.55	99	72	189	1041	Iron - High	2.64	1.53	7	2
Horse Pasture	5.75	141	284	224	1282	Iron - High	2.3	1.33	15	0
Mums	4.8	654	473	153	1202	Iron - High	2.41	1.4	5	0
Horse Pasture	6.3	137	282	259	1690	Iron - High	2.87	1.67	6	0
Horse Pasture	6.1	106	319	189	1183	Iron - High	1.45	0.84	5	0

Table 6. Recreational / Homeowner Land Soil Results

Description	pH	Phosphorus (lbs./acre)	Potassium (lbs./acre)	Magnesium (lbs./acre)	Calcium (lbs./acre)	Micronutrients (ppm)	Organic Matter (%)	Organic Carbon (%)	Nitrate-N (ppm)	Ammonium-N (ppm)
Soccer Field	5.35	64	184	182	1245	Iron - High	3.06	1.78	4	0
Baseball Field	5.05	97	198	170	1035	Iron - High	3.33	1.93	4	0
Soccer Field	6	122	345	336	1560	Iron - High	3.41	1.98	7	4
Soccer Field	6.45	66	244	462	1928	Iron - High	3.94	2.29	5	1
Golf Course	6	168	441	209	1517	Iron - High	4.5	2.61	4	5
Golf Course	6.4	123	284	195	1459	Iron - High	2.55	1.48	2	2
Golf Course	5.5	125	311	164	1254	Iron - High	3.54	2.05	4	2
Golf Course	5.7	117	267	179	1155	Iron - High	3.28	1.9	3	2
Golf Course	6.25	317	184	234	2494	Iron - High	3.58	2.07	1	2
Golf Course	6.2	212	174	244	1444	Iron - High	2.48	1.44	3	2
Baseball Field	6.45	43	141	219	1221	Iron - High	1.71	0.99	2	5
Soccer Field	5.95	42	89	155	834	Iron - High	1.6	0.93	2	2
Driving Range	5.95	42	127	395	2045	Iron - High	4.54	2.63	4	4
Driving Range	5.45	155	92	154	860	Iron - High	3.42	1.99	4	3
Playground	4.85	116	155	88	409	Iron - High	2.62	1.52	2	13
Soccer Field	4.95	68	117	90	384	Iron - High	2.12	1.23	2	9
Homeowner	5.45	39	94	240	1030	Iron - High				
Homeowner	5.4	50	130	245	1207	Iron - High				
Homeowner	5.8	143	69	206	1570	Iron - High, Copper - High				
Homeowner	6.95	347	417	470	4105	Iron - High				
Homeowner	5.35	135	283	259	1323	Iron - High				
Homeowner	5.55	316	287	290	1491	Iron - High				
Homeowner	6.6	32	49	126	1176	Iron - High				
Homeowner	5.35	32	133	146	1760	Iron - High				
Homeowner	4.6	137	300	161	1134	Iron - High				
Homeowner	7.15	33	201	384	2312	Iron - High				
Homeowner	6.75	30	148	252	1337	Iron - High				
Homeowner	6.5	20	130	301	1725	Iron - High				

Homeowner	7.15	170	93	573	2642	Iron - High
Homeowner	6.75	151	130	366	2889	Iron - High
Homeowner	8.1	233	202	506	13585	Iron - High
Homeowner	6.7	382	244	377	3779	Iron - High
	6.7	229	281	247	2318	Iron - High

APPENDIX D

NJ Department of Agriculture

Model Development and Calibration Figure Appendix

1. Rating Curve Development Strategy

In order to utilize the HEC-RAS model, multiple stream cross sections are needed for the model to compute and balance energy losses from one section to the next. Several different flow rates can be entered into the model, which when calibrated will give an indication of the water surface elevation corresponding to each flow rate value, which is the rating curve as described previously. Investigators used direct field measurements of stream flow to calibrate the HEC-RAS model for in-channel flows, but used traditional "trial and error" methods to calibrate larger, out-of-bank flows. In order to do this, surveyed cross section data, combined with Geographic Information Systems Digital Elevation Model (DEM) data and stream flow logger data was used.

The investigators with the assistance of Monmouth County Office of GIS (GISMO) developed a procedure to use DEM data to define the floodplain portion of the stream cross section, with more highly detailed survey data of the stream channel itself to produce a hybrid cross section model used in HEC-RAS. Survey data was "burned" into the DEM data which was then recompiled to give higher resolution in the channel portion of the DEM. Using a combination of add-on software packages from Environmental Systems Research Institute (ESRI, Inc) and USACOE, GISMO was able to create three dimensional sections or "slices" through the floodplain and through the channel for use in HEC-RAS modeling. The beauty of this system is several-fold: First, the cost for obtaining field survey data is greatly reduced since surveyors do not need to physically survey large transects through the floodplain area. Second, the cross sections are adjustable by software such that additional sections, relocated sections or repositioned sections may be easily created, exported and the RAS model updated and re-run. One significant limit of this system does exist however. The DEM data which is used to depict the floodplain areas must have sufficient resolution in elevation to make floodplain data useful. The amount of resolution needed is dependent on the terrain itself and the level of detail needed in the model.

For example, to use this method to model the Colorado River, elevation resolution of 10 or more meters would be sufficient since the terrain is highly irregular and elevation varies significantly. Error associated with DEM production would be small relative the overall changes in elevation around the Colorado. Also the flow values needed for acceptable model accuracy are high – in the order of hundreds of cubic feet per second or higher. In contrast, the Wreck Pond Brook Watershed terrain is fairly flat, and the level of precision in flow modeling is within a few CFS. These factors dictate that the DEM model have a resolution capable of resolving elevation differences of about 1 foot since much of the hydraulic and hydrologic response in the watershed is governed by small nuances in topography. The State of New Jersey produces and maintains a state-wide DEM data layer, but the maximum resolution is only 10 meters. Fortunately, Monmouth County produces and maintains its own DEM data layer with resolution of about 1 foot which provided the means to develop this hybrid method.

2. Stream Flow and Velocity Measurements.

Investigators utilized a USGS-type current meter mounted on a one-piece wading rod. The Price AA and Pygmy meters were both used to measure flow and velocity. The investigators found that the magnetic head of the Pygmy meter was prone to failure and returned it and had a wire head (cat whisker) pickup installed, which worked flawlessly. The Price AA meter utilized a magnetic head without any failure.

To measure flow at a gage station, a cross section was established using a 100 foot flexible tape reel, with the tape stretched across the section and anchored on both banks. An AquaCalc Pro computer was attached to the current meter/wading rod to record measurements. Stream cross sections were measured in one foot intervals or less to minimize error associated with the USGS method of approximating stream cross section area.

In this method, the stream flow is measured at several stations across the stream. At each station, the distance to bank and stream depth is entered into the AquaCalc Pro, the wading rod is used to adjust the height of the current meter from the stream bottom, and then a flow reading was taken. The AquaCalc Pro was set to measure velocity at a depth equal to six-tenths of the depth at that section. This is considered to be the location where a good "average" flow velocity may be found. In deeper waters, the computer can be set to take two readings, one at 2 tens and another at 8 tenths the total depth. The wading rod is calibrated to facilitate setting the depth of the current meter at 6 tenths readings.

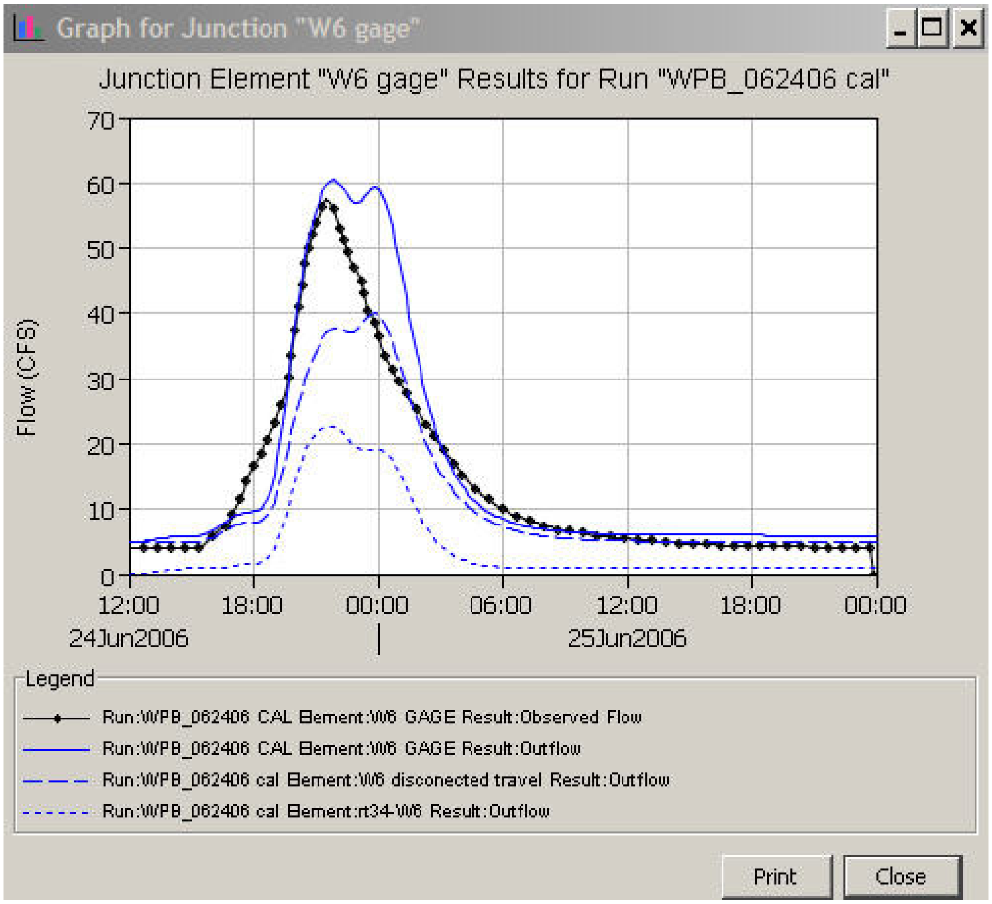
The AquaCalc Pro measures the rotation of the meter and uses internal calibration tables to convert the number of rotations into velocity. Readings are averaged over a forty second period to determine average velocity for that section. The Pro computes the sectional flow rate by averaging the width of each section, multiplied by depth to get a rectangular representation of the area through which that portion of the stream is flowing and then multiplies that flow area by velocity thus computing volume flow rate, or cubic feet per second. Adding all the section measurements across the stream results in the total volumetric flow rate, CFS, for the stream. This method essentially integrates the cross sectional area by approximating small sections of the stream with rectangles. Obviously, the smaller the rectangle (the closer the sections are to each other) the greater the accuracy the final reading will have.

The first reading (near bank) and last reading (far bank) have depth and velocity set to 0.0 which signals the beginning and end of a section measurement. The AquaCalc Pro can also store various user data, including staff and recording gage readings at the beginning and end of the measurement session. Data from the Pro is then downloaded to a PC via proprietary software and cable and is stored in Excel. A single measurement of stream flow and water surface elevation constitutes one data point on the stream rating table curve. Investigators sought to take multiple readings at each gage station, at various depths of water to create a rating curve from base flow to bank full flow. Although the AqauCalc Pro is sealed against moisture, it cannot tolerate submersion or getting soaked in a heavy rainfall. Investigators had to return the computer to the manufacturer for replacement of the mainboard after the unit was "soaked" while taking a measurement during a heavy rainfall event. A clear plastic bag was placed over the unit on subsequent readings during rain events to protect the computer without further incident.

3. Drainage Areas, Curve Numbers and Watershed Lag

Modeling parameters were developed from high resolution (1 foot) digital terrain data from the Monmouth County Office of Geographic Information Systems (MCGIS). Drainage area boundaries were field verified and changes were made to the terrain model to reflect field conditions. Curve numbers were computed by intersecting soil data and landuse data. The resultant GIS data layer was then populated with curve numbers by matching soil-landuse combinations with those shown in NRCS Technical Release 55 (TR-55), "Urban Hydrology for Small Watersheds". Curve numbers were then condensed into more general categories which had similar land use and curve numbers. CN generation was performed by Najarian Associates, of Eatontown, NJ, who was a consultant for a separate watershed study conducted by the town of Spring Lake, NJ, a member municipality in the watershed.

Curve numbers for each soil-landuse polygon were then amalgamated via the TR-55 weighting procedure to produce an overall, subwatershed Curve Number. Lastly, lag time was estimated by measuring stream channel length via GIS and assuming a flow velocity of 1 foot per second. This assumption was based on numerous field observations of velocity metering during watershed storm events. Since this estimate does not, nor could it include stream obstructions and hydraulic residence times in reservoirs, this estimate was used as a "starting point", as was the weighted curve numbers, for final model calibration and verification.



Summary Results for Junction "W6 gage"

Project : wreck Pond   Simulation Run : WPB_062406 cal   Junction: W6 gage

Start of Run :	24Jun2006, 12:00	Basin Model :	WPBstem_062406 cal
End of Run :	26Jun2006, 00:00	Meteorologic Model :	June24_2006
Compute Time :	05Jun2008, 13:25:09	Control Specifications :	june242006 _wpb stem cal

Volume Units : (•) IN ( ) AC-FT

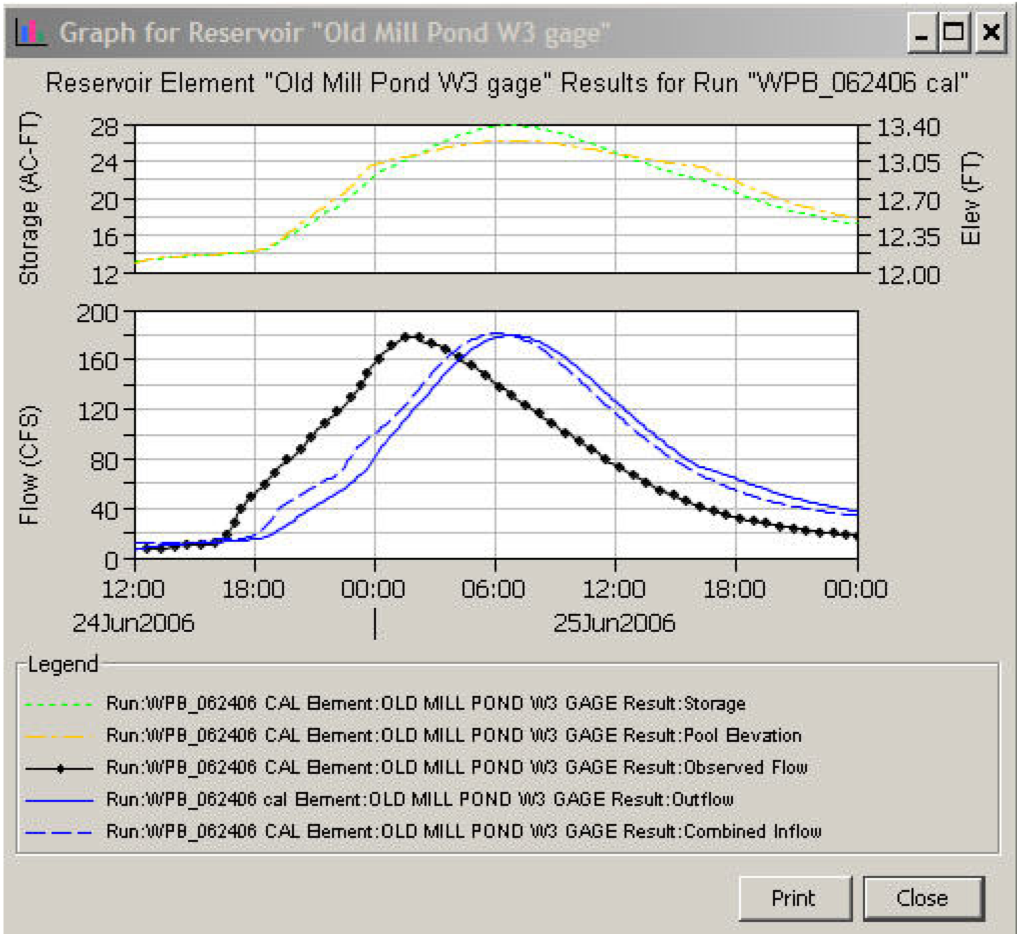
Computed Results

Peak Outflow : 60.5 (CFS)   Date/Time of Peak Outflow : 24Jun2006, 21:50
Total Outflow : 0.66 (IN)

Observed Hydrograph at Gage w6_062406

Peak Discharge :	57.60 (CFS)	Date/Time of Peak Discharge :	24Jun2006, 21:30
Avg Abs Residual :	3.25 (CFS)		
Total Residual :	0.08 (IN)	Total Obs Q :	0.58 (IN)

Print   Close



Summary Results for Reservoir "Old Mill Pond W3 gage"

Project: wreck Pond
Simulation Run: WPB_062406 cal   Reservoir: Old Mill Pond W3 gage

Start of Run:	24Jun2006, 12:00	Basin Model:	WPBstem_062406 cal
End of Run:	26Jun2006, 00:00	Meteorologic Model:	June24_2006
Compute Time:	03Jun2008, 15:52:55	Control Specifications:	june242006 _wpb stem cal

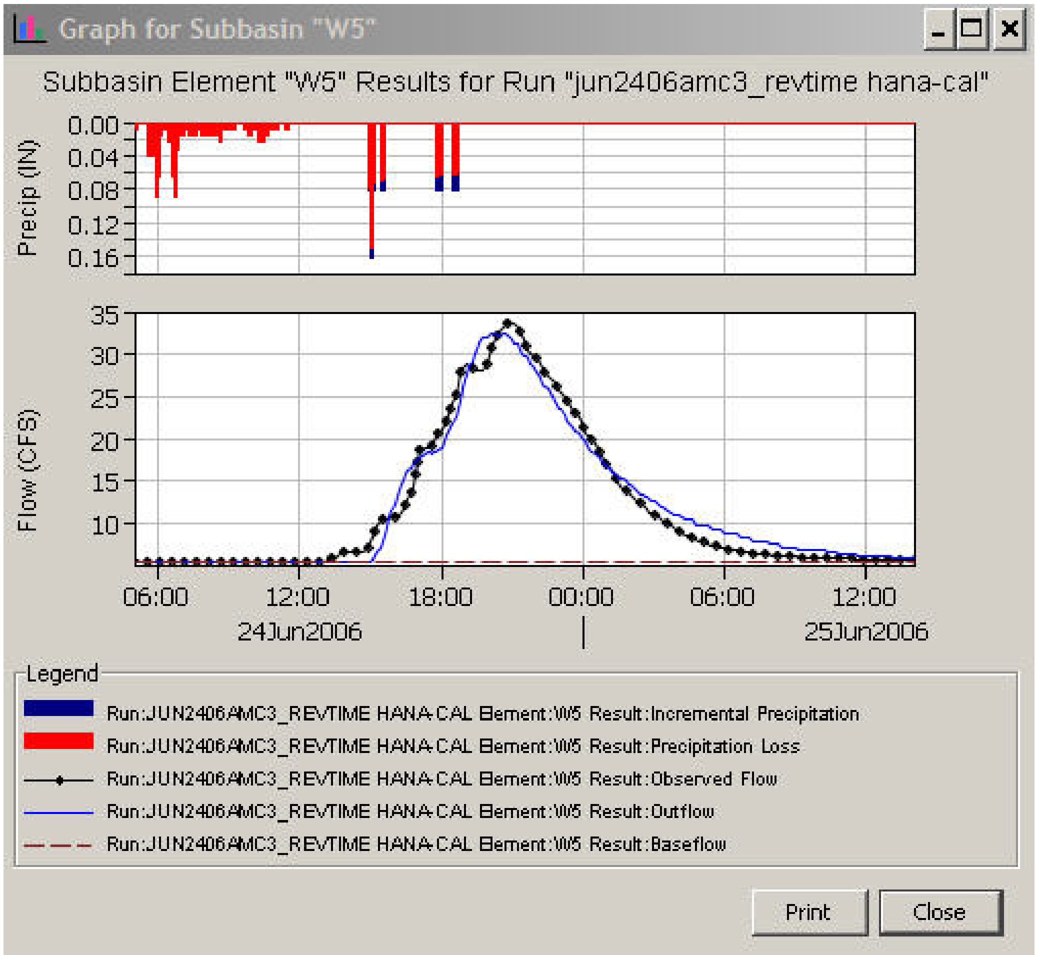
Volume Units: (•) IN ( ) AC-FT

Computed Results

Peak Inflow :	180.9 (CFS)	Date/Time of Peak Inflow :	25Jun2006, 06:10
Peak Outflow :	179.6 (CFS)	Date/Time of Peak Outflow :	25Jun2006, 06:50
Total Inflow :	0.64 (IN)	Peak Storage :	27.8 (AC-FT)
Total Outflow :	0.63 (IN)	Peak Elevation :	13.2 (FT)

Observed Hydrograph at Gage W3 62406

Peak Discharge :	177.50 (CFS)	Date/Time of Peak Discharge :	25Jun2006, 01:30
Avg Abs Residual :	37.04 (CFS)		
Total Residual :	0.03 (IN)	Total Obs Q :	0.59 (IN)



Summary Results for Subbasin "W5"

Project : WPB Hanabrand Simulation Run : jun2406amc3_revtime hana-cal Subbasin: W5

Start of Run :	24Jun2006, 05:00	Basin Model :	WPB-Hanabrand June 24 06 cal
End of Run :	25Jun2006, 14:00	Meteorologic Model :	june2406_revised time stamp
Compute Time :	12Jun2008, 10:14:51	Control Specifications :	jun242006

Volume Units : (•) IN ( ) AC-FT

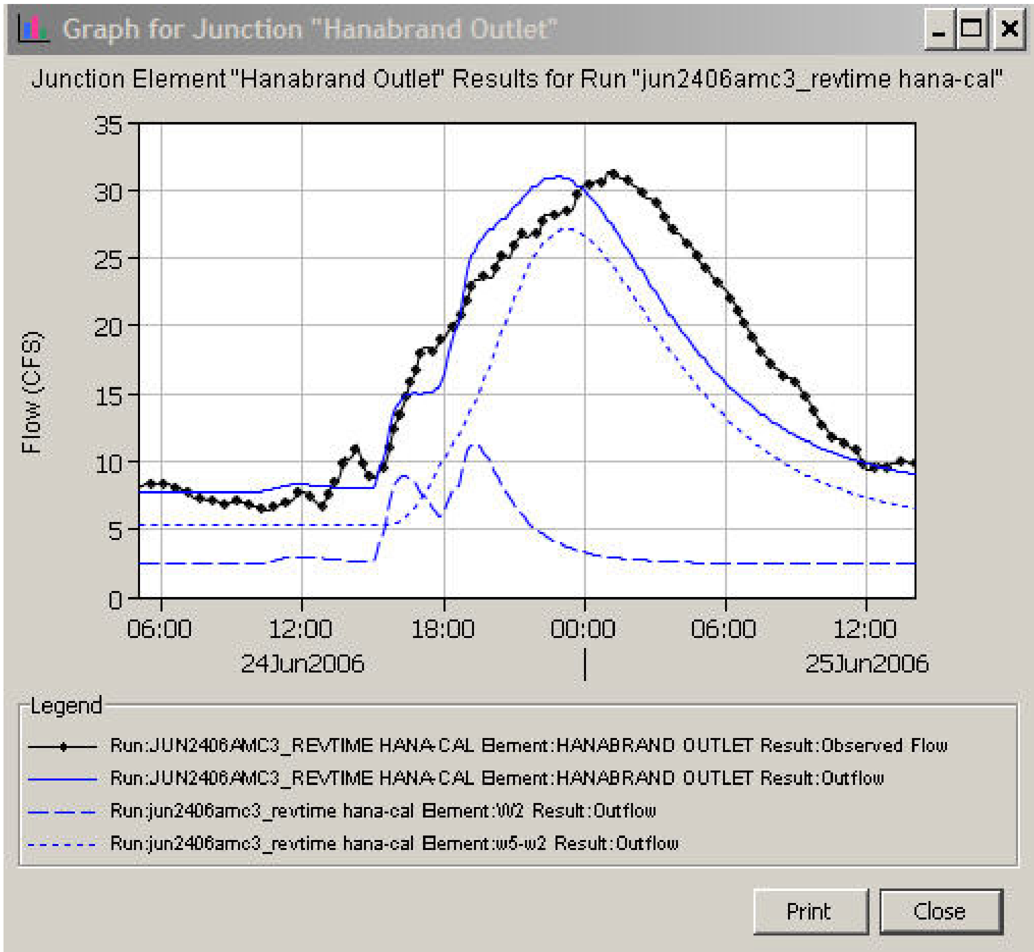
Computed Results

Peak Discharge :	32.6 (CFS)	Date/Time of Peak Discharge :	24Jun2006, 20:12
Total Precipitation :	1.84 (IN)	Total Direct Runoff :	0.13 (IN)
Total Loss :	1.71 (IN)	Total Baseflow :	0.10 (IN)
Total Excess :	0.13 (IN)	Discharge :	0.23 (IN)

Observed Hydrograph at Gage w5 june24 2006

Peak Discharge :	33.79 (CFS)	Date/Time of Peak Discharge :	24Jun2006, 20:54
Avg Abs Residual :	1.07 (CFS)		
Total Residual :	0.00 (IN)	Total Obs Q :	0.22 (IN)

Print Close



Summary Results for Junction "Hanabrand Outlet"

Project : WPB Hanabrand   Simulation Run : jun2406amc3_revtime hana-cal   Junction: Hanabrand Outlet

Start of Run :	24Jun2006, 05:00	Basin Model :	WPB-Hanabrand June 24 06 cal
End of Run :	25Jun2006, 14:00	Meteorologic Model :	june2406_revised time stamp
Compute Time :	05Jun2008, 15:31:58	Control Specifications :	jun242006

Volume Units : (•) IN ( ) AC-FT

Computed Results

Peak Outflow : 31.0 (CFS)   Date/Time of Peak Outflow : 24Jun2006, 22:54
Total Outflow : 0.26 (IN)

Observed Hydrograph at Gage w2+w5 june 24 2006

Peak Discharge : 31.39 (CFS)   Date/Time of Peak Discharge : 25Jun2006, 01:06
Avg Abs Residual : 2.48 (CFS)
Total Residual : -0.02 (IN)   Total Obs Q : 0.28 (IN)

Print   Close

APPENDIX E

SWMM MODEL CALIBRATION

1. CALIBRATION STORM SELECTION

As discussed in the main body of the report, rainfall and stream depth data were available for various periods in 2005 and 2006 to calibrate the flow portion of the models. The rainfall record and water level data availability were analyzed to determine potential target storms for calibration and verification. In order for the model to function properly over a wide range of storm conditions, calibration and verification storms were selected that featured both long duration - moderate intensity rainfall and short duration - high intensity rainfall. Storms of longer duration and lower intensity are considered pervious-dominated storms. The relatively slow and steady rainfall allows for significant infiltration, thus the model parameters related to pervious areas and infiltration like soils and initial moisture deficit have a significant influence on the model results. Conversely, storms of short duration and high intensity (e.g. thunderstorms) are considered impervious-dominated as the runoff flows quickly over the basin surfaces allowing less infiltration. Thus, the model parameters related to impervious surfaces such as percent impervious, watershed width and slope are more important.

Storm characteristics were reviewed for a number of storms for which the data loggers were functioning The nature of the rainfall and the flow response were evaluated. After this analysis, the June 27, 2005 storm was selected for calibration of the watershed. Two validation storms were selected July 13, 2005 and June 3, 2005. For the Black Creek sub-watershed, equipment malfunctions limited data from this period. For this sub-watershed, the May 11, 2006 storm was selected for calibration and the July 2, 2006 was selected for verification. Table E-1 provides details on the rainfall and intensity for the selected storms.

Table E-1: Details of Selected Storms

	Model Process	Date	Rainfall/Duration	Average Intensity	Storm Type
Hydrology - (except Blk Crk)	Calibration	6/27/2005	1.27 in., 18 hrs	0.07 in/hr	Pervious dominated
	Validation	7/13/2005	0.42 ins, 1 hr	0.42 in/hr	Impervious dominated
	Validation	6/3/2005	1.2 ins, 26 hrs	0.05 in/hr	Pervious dominated
Hydrology - Blk Crk Sub-Basin	Calibration	5/11/2006	1.11 ins, 6 hrs	0.19 in/hr	Pervious dominated
	Validation	7/2/2006	0.99 ins, 1 hr	0.99 in/hr	Impervious dominated
Water Quality	Calibration	10/17/2006	1.08 ins, 11.8 hrs	0.09 in/hr	Pervious dominated

2. FLOW CALIBRATION

For each storm event, rainfall data was input into the SWMM Runoff Module to generate flow and quality from each sub-watershed. The runoff results were then routed through the various streams and ponds of the watershed, using the Transport Module. For flow, calibration was an iterative process in which the flow hydrograph (a graph of flow vs. time) in which the modeled results were compared with observed flows. If necessary, the model parameters were modified and the model was re-run until the model output adequately matches the field data.

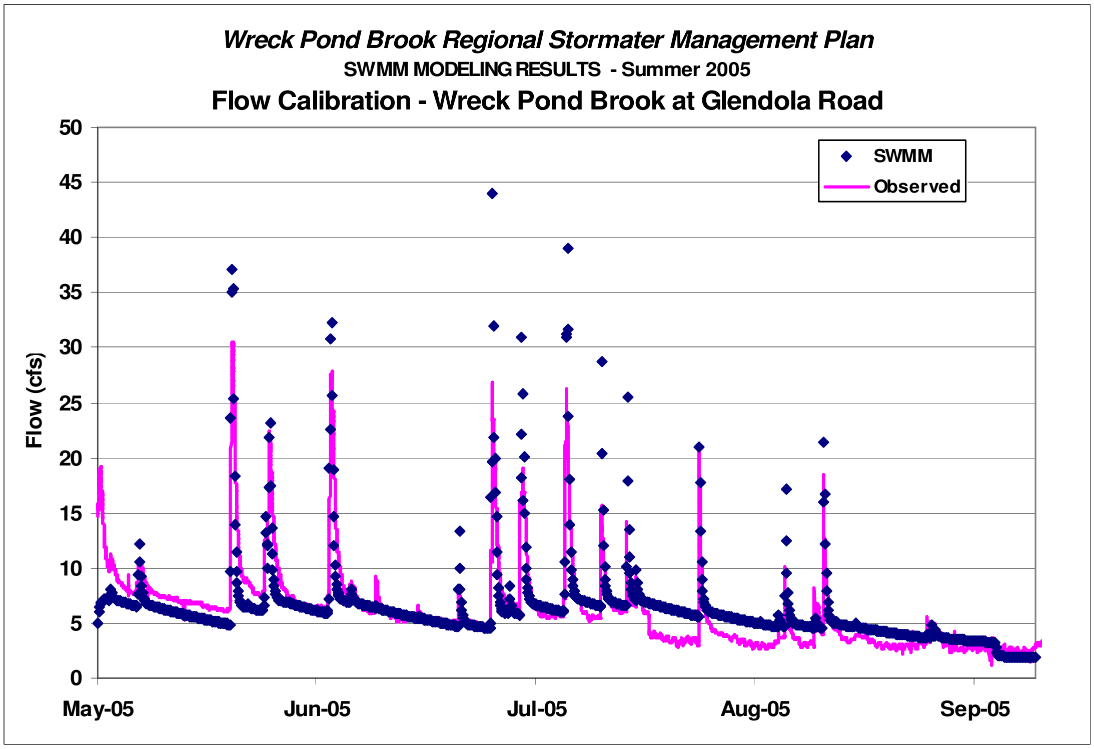
During calibration process, only a limited number of parameters were considered important for any particular sub-watershed. Overall, these parameters were: sub-basin width, connected impervious percentage, watershed slope, groundwater flow coefficient, initial upper zone moisture and stream Manning's roughness coefficient.

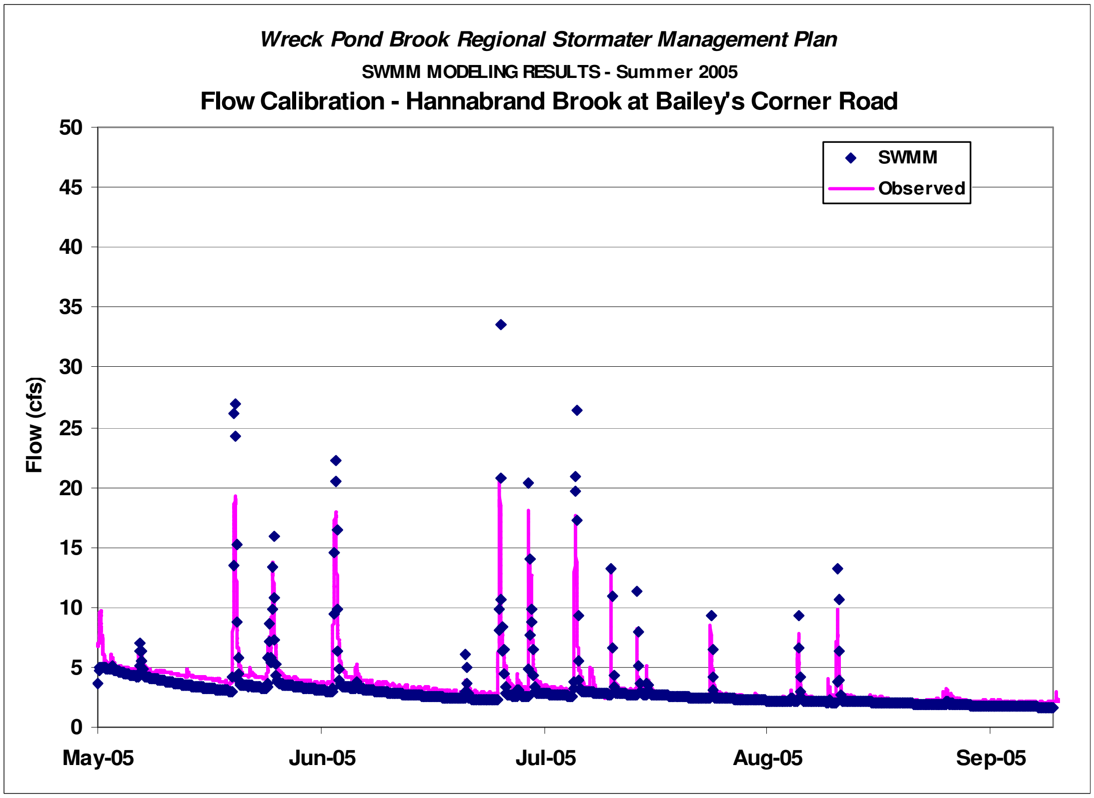
The calibration process was performed one sub-watershed at a time, for the six sub-watersheds for which flow data was deemed suitable for calibration. Calibration was complete when the flow data acceptably matched the field data flow hydrograph and volume.

Once the hydraulic and hydrologic portion of the model was calibrated, validation of the model was performed using both a pervious dominated and impervious dominated storm event. Adjustments based on both model validation runs were then made to the original calibration run, and tolerances between modeled results and in-field data for all three (3) events were checked. Overall, parameter adjustments were simultaneously made to all three (3) model simulations until acceptable tolerances for the objective functions were met for the three (3) storm events. This process was conducted for all six (6) calibrated sub-basins.

As previously stated, the calibration and verification period was the summer of 2005. The Figures below provide graphs of flow over time for that period for two calibration stations, demonstrating that the model fits the data within expected range. A similar process was followed for the Black Creek sub-watershed. However, due to the lack of flow data in 2005, two storms in 2006 were used. Flow data were not available for the other stations for 2006. The model was adapted to all sub-watersheds so that the generated flow output simulates the expected flows at the most downstream stations.

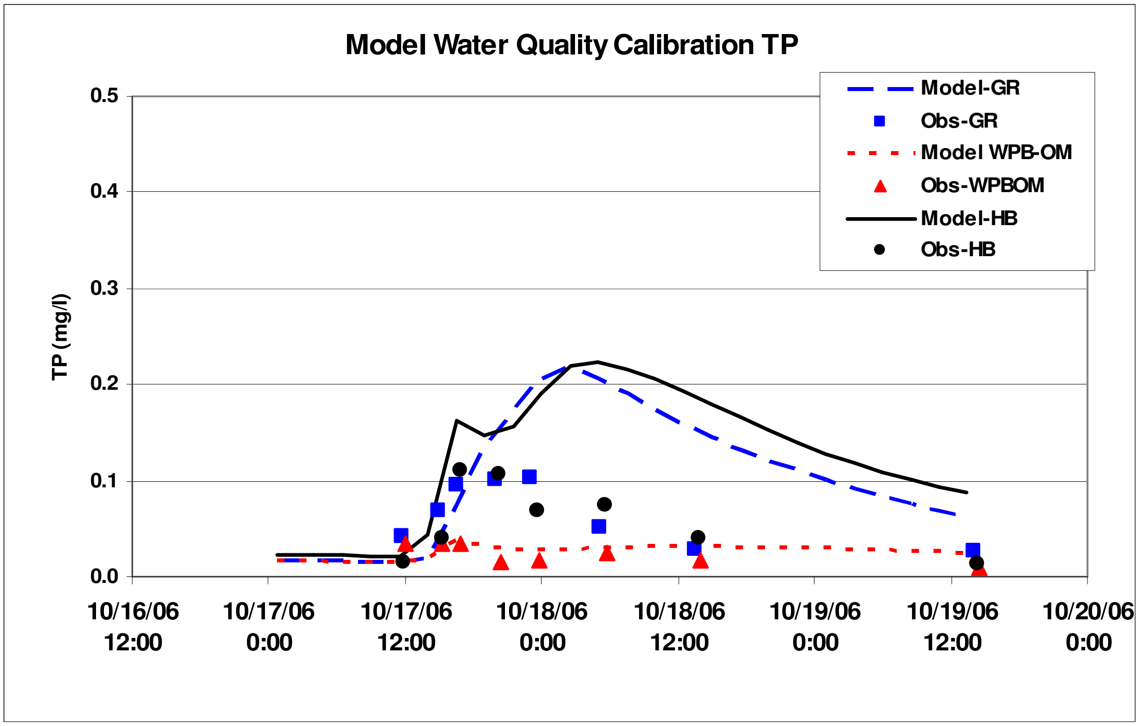
As limited data was available for the numerous ponds within the watershed, a number of assumptions were required during model development. Assumptions were made concerning: the dam discharge characteristics, general pond geometry and average pond depth. Also due to limited groundwater information throughout the watershed, some assumptions were required with regard to aquifer depth, water table elevations and stream stage elevations. It is suggested that future studies gather information regarding both of these topics.

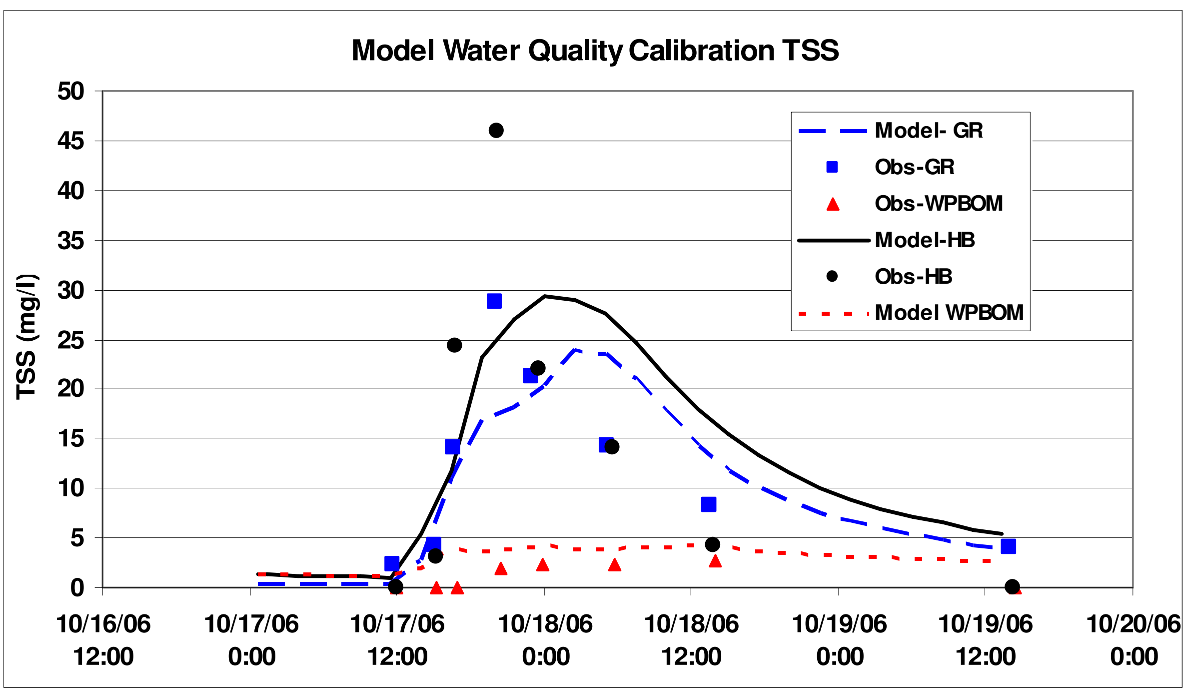

Wreck Pond Brook Regional Stormater Management Plan
SWMM MODELING RESULTS - Summer 2005
Flow Calibration - Wreck Pond Brook at Glendola Road
SWMM
Observed
Flow (cfs)
0
5
10
15
20
25
30
35
40
45
50
May-05
Jun-05
Jul-05
Aug-05
Sep-05

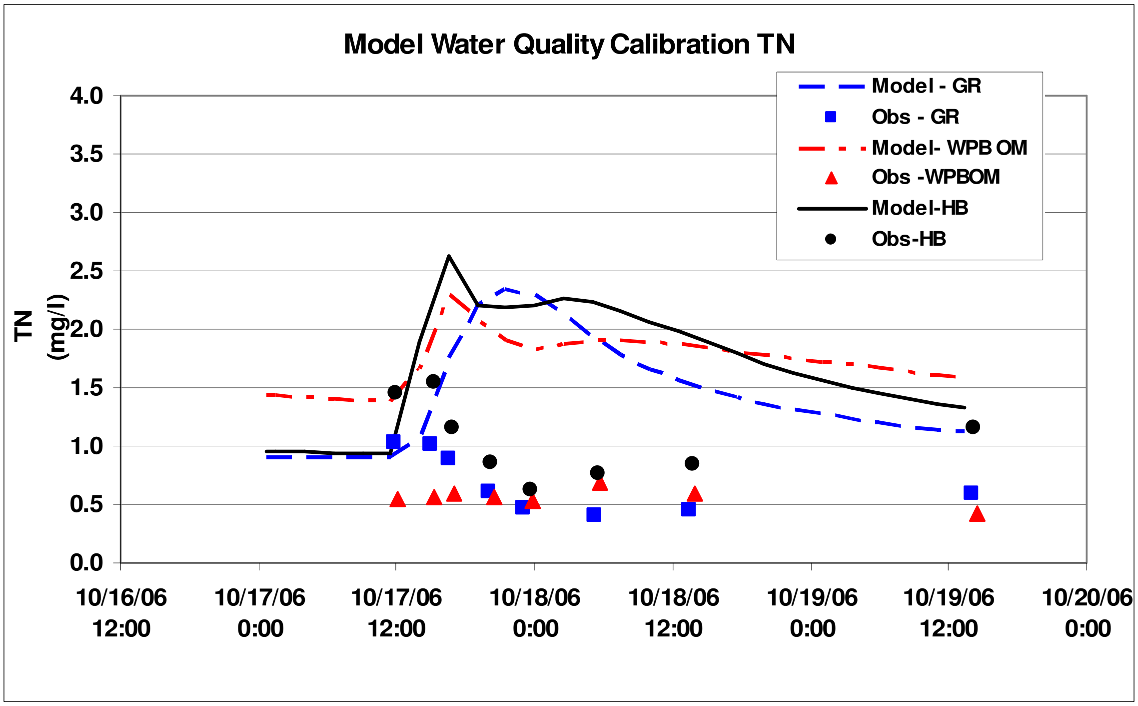

Wreck Pond Brook Regional Stormater Management Plan
SWMM MODELING RESULTS - Summer 2005
Flow Calibration - Hannabrand Brook at Bailey's Corner Road
SWMM
Observed
Flow (cfs)
0
5
10
15
20
25
30
35
40
45
50
May-05
Jun-05
Jul-05
Aug-05
Sep-05

3. WATER QUALITY CALIBRATION

The water quality calibration process was conducted for the October 16-19 2006 storm as discussed in the main body of this report. Calibration plots are as shown.






Model Water Quality Calibration TN
Model - GR
Obs - GR
Model- WPB OM
Obs -WPBOM
Model-HB
Obs-HB
TN
(mg/l)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
10/16/06 12:00
10/17/06 0:00
10/17/06 12:00
10/18/06 0:00
10/18/06 12:00
10/19/06 0:00
10/19/06 12:00
10/20/06 0:00

APPENDIX F

Supplemental Data on Results of Monitoring
Borough of Spring Lake Wreck Pond Environmental Study

1. Wreck Pond Sampling

Three stations were monitored within the Pond as show on Figure 21 in the main report. The stations were selected to reflect overall conditions in the Pond. Thus, the stations were located away from the eastern-most portion of the Pond and the outfall structure to limit the influence of ocean water on the sampling results. Two of the stations are located in the central portion of the Pond, one to the north closer to the Black Creek and Spring Lake inflows (WP2 or 1B) and one in the central portion closer to the Railroad Track Culverts separating the central and western portion of the Pond (WP3 or 1C). The third station, WP1 (or 1A), was located to provide information on the western portion of the Pond, which is not influenced by tidal exchange under most conditions. These sampling points will provide data on the variability of the quality of Wreck Pond by area, including any differences between the main portion of the pond and the narrower area upstream of the Railroad Bridge.

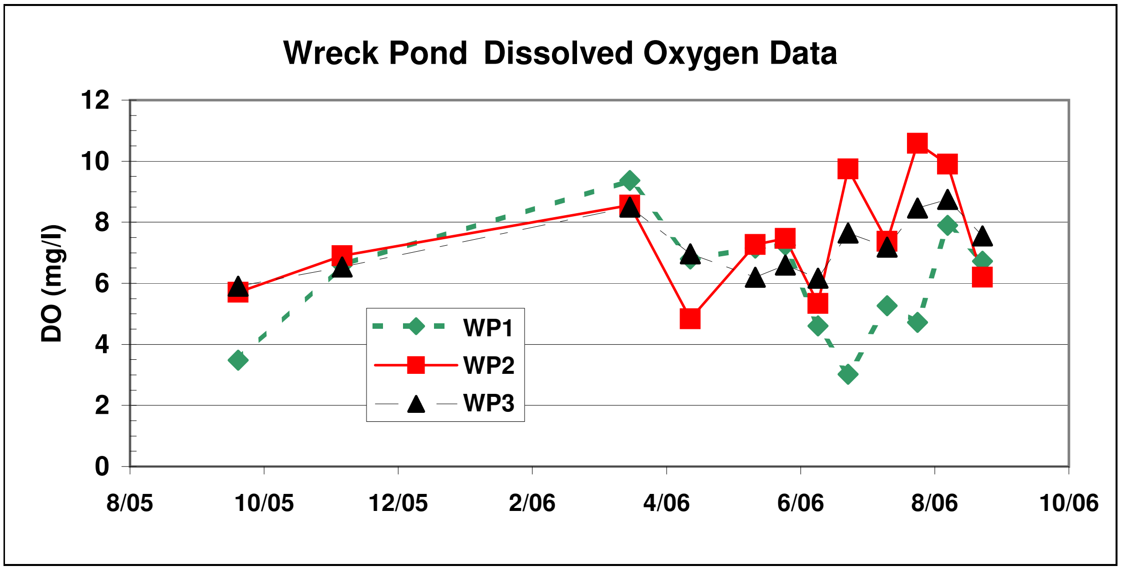
The specific sampling locations were selected by finding relatively deeper points in each respective area, according to a NJDEP hydrographic survey, performed approximately 2 years prior to initiation of sampling. During the initial sampling event, a GPS system was used to locate the sampling points and shoreline features were also recorded. Subsequent sampling events used the GPS, confirmed by the shoreline features, to ensure the same location was sampled.

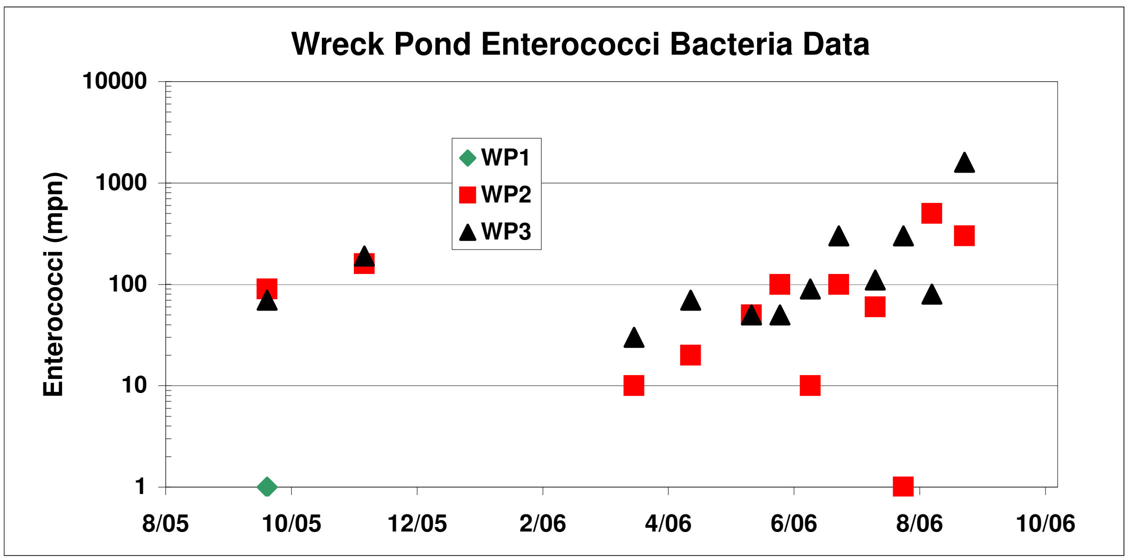
Water quality monitoring within Wreck Pond was conducted from September 2005 to August 2006. Surface water samples were collected monthly from September to November and March and April and twice a month during the summer period (May – August). The pond was not sampled during winter months to focus sampling effort during the warmer months when Pond water quality is typically of concern.

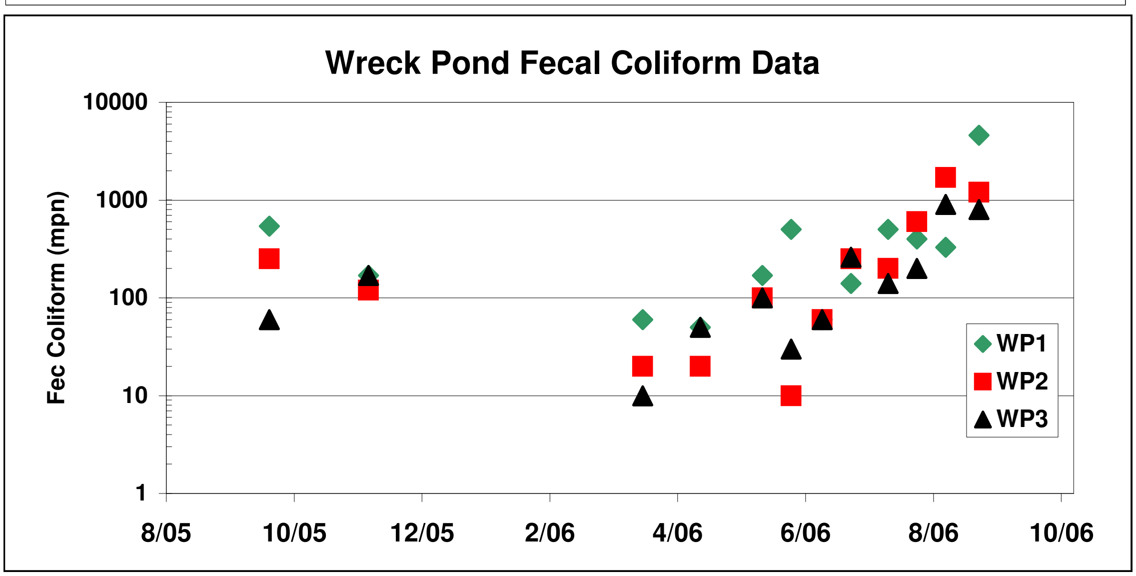
Wreck Pond exchanges tidal flow with the Atlantic Ocean. In order to sample the Pond itself, and not the incoming Ocean water, sample collections was timed to coincide with low tide to the extent possible. Thus, the predicted times of high and low tide within the Pond had to be projected. However, there is no tidal datum associated with Wreck Pond. The only tidal data available were 32 days of tidal elevations collected from December 2004 to January 2005 by Stevens Institute of Technology (Stevens), during studies for NJDEP related to the outfall pipe extension project. Stevens clearly noted tidal influence on the Pond, and determined that discharge from the Pond, as expected, would occur on average, "from just before mid-tide as the tide is falling to a point just prior to mid-tide as the tide is rising" (Stevens, 2005).

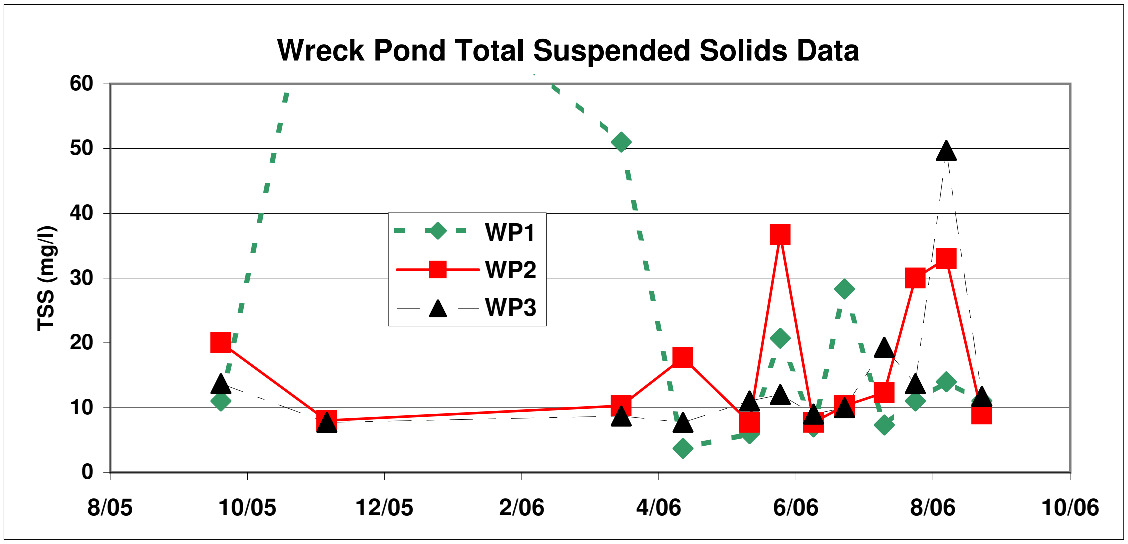
Using this information, prior to the scheduled sampling event predicted low and high tide elevations at Belmar, New Jersey were obtained. Pond sampling times were then determined to be mid-way between the Belmar low to high tide. Since the pond sampling consisted of three (3) sampling locations, during every event the schedule was adjusted such that the middle of the three (3) samples took place around the time of low tide in the Pond.

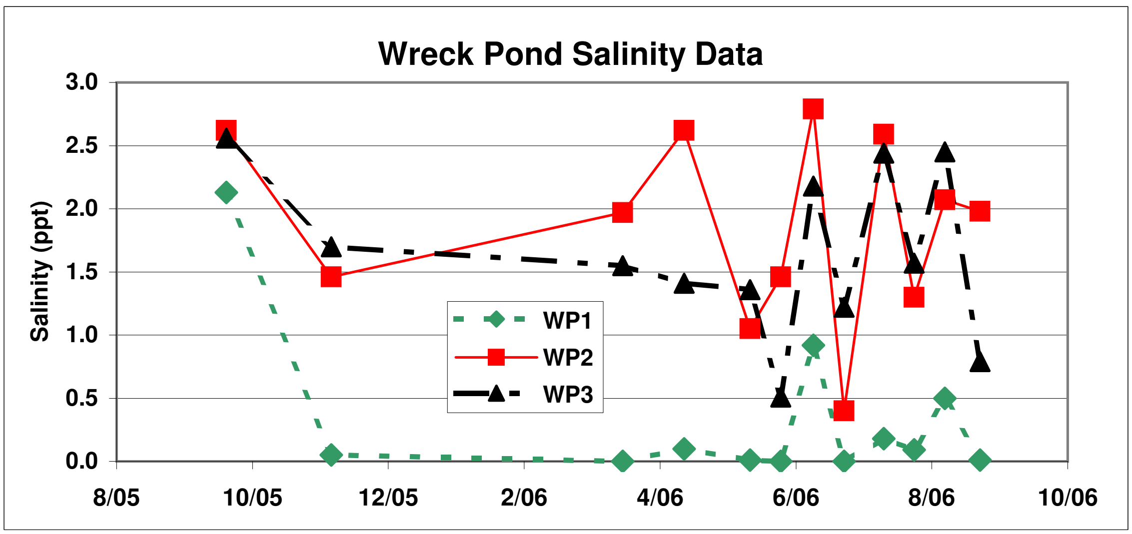
Representative Data Plots are shown in the following pages.

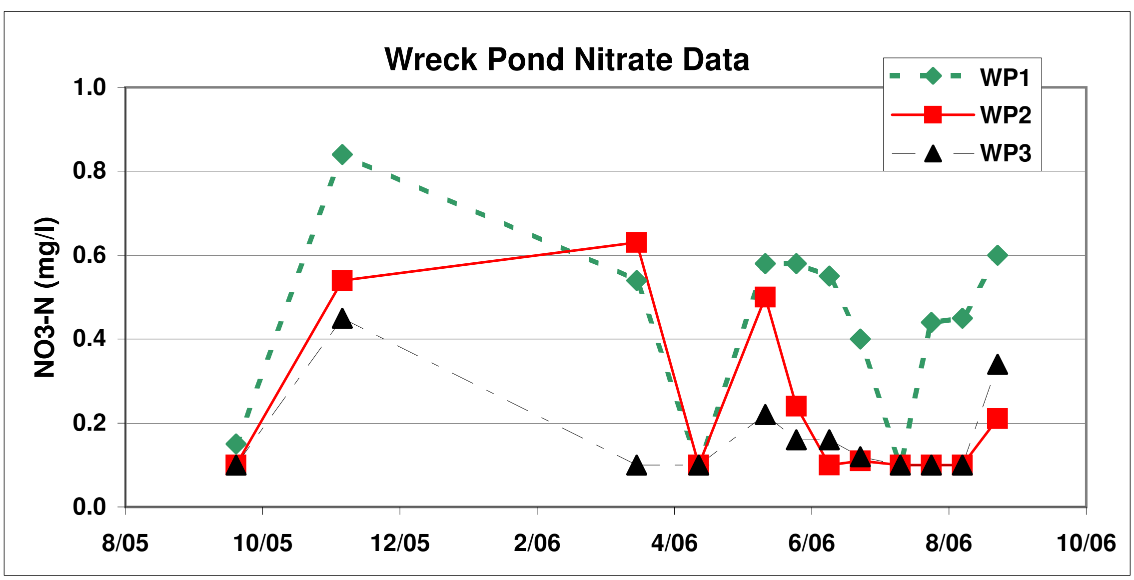

Wreck Pond Dissolved Oxygen Data
DO (mg/l)
12
10
8
6
4
2
0
8/05
10/05
12/05
2/06
4/06
6/06
8/06
10/06
WP1
WP2
WP3

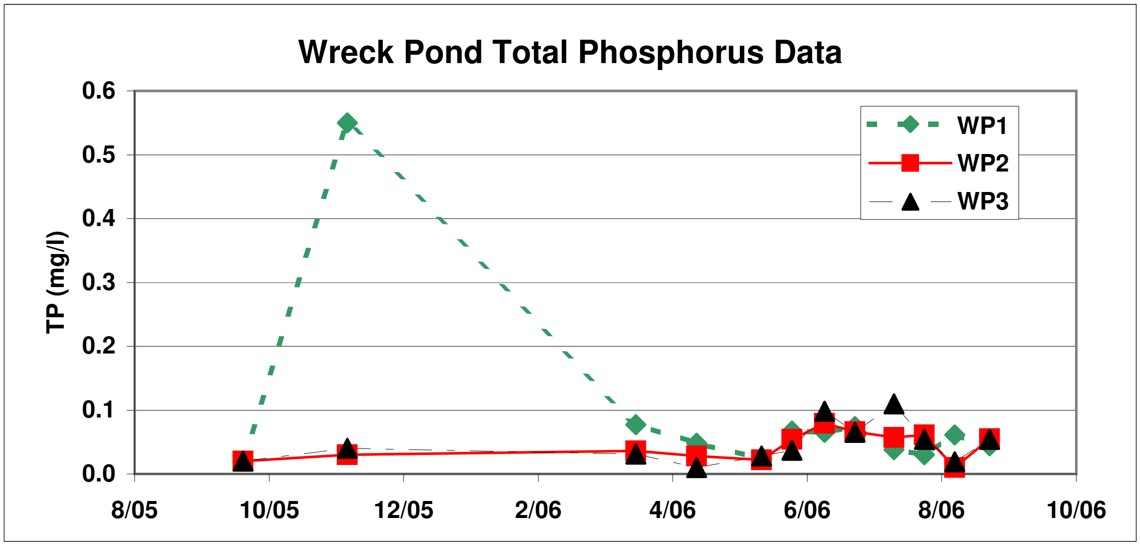

Wreck Pond Enterococci Bacteria Data
Enterococci (mpn)
10000
1000
100
10
1
8/05
10/05
12/05
2/06
4/06
6/06
8/06
10/06
WP1
WP2
WP3

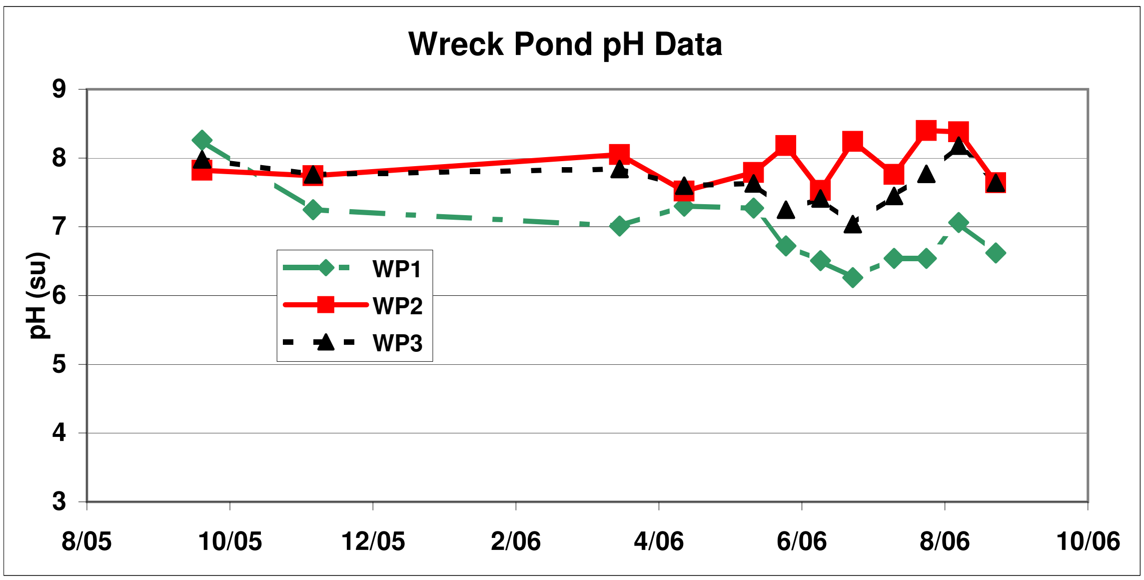

Wreck Pond Fecal Coliform Data
Fec Coliform (mpn)
10000
1000
100
10
1
8/05
10/05
12/05
2/06
4/06
6/06
8/06
10/06
WP1
WP2
WP3

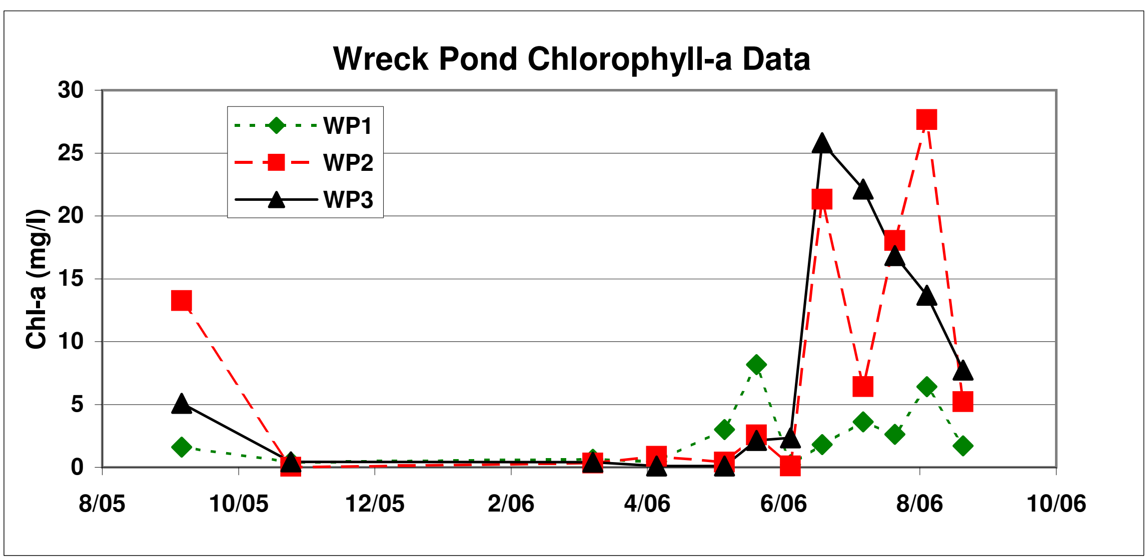

Wreck Pond Total Suspended Solids Data
TSS (mg/l)
60
50
40
30
20
10
0
8/05
10/05
12/05
2/06
4/06
6/06
8/06
10/06
WP1
WP2
WP3


Wreck Pond Salinity Data
Salinity (ppt)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
8/05
10/05
12/05
2/06
4/06
6/06
8/06
10/06
WP1
WP2
WP3


Wreck Pond Nitrate Data
NO3-N (mg/l)
1.0
0.8
0.6
0.4
0.2
0.0
8/05
10/05
12/05
2/06
4/06
6/06
8/06
10/06
WP1
WP2
WP3


Wreck Pond Total Phosphorus Data
TP (mg/l)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
8/05
10/05
12/05
2/06
4/06
6/06
8/06
10/06
WP1
WP2
WP3


Wreck Pond pH Data
pH (su)
9
8
7
6
5
4
3
8/05
10/05
12/05
2/06
4/06
6/06
8/06
10/06
WP1
WP2
WP3

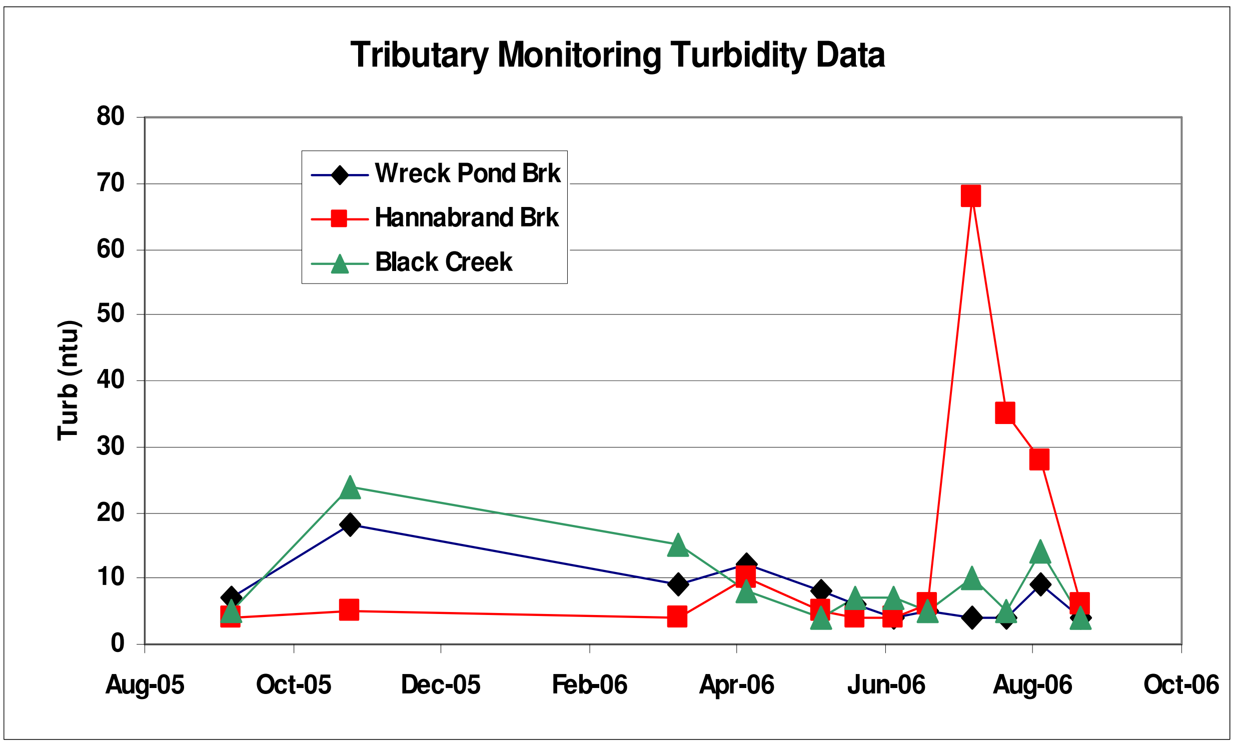

Wreck Pond Chlorophyll-a Data
Chl-a (mg/l)
30
25
20
15
10
5
0
8/05
10/05
12/05
2/06
4/06
6/06
8/06
10/06
WP1
WP2
WP3

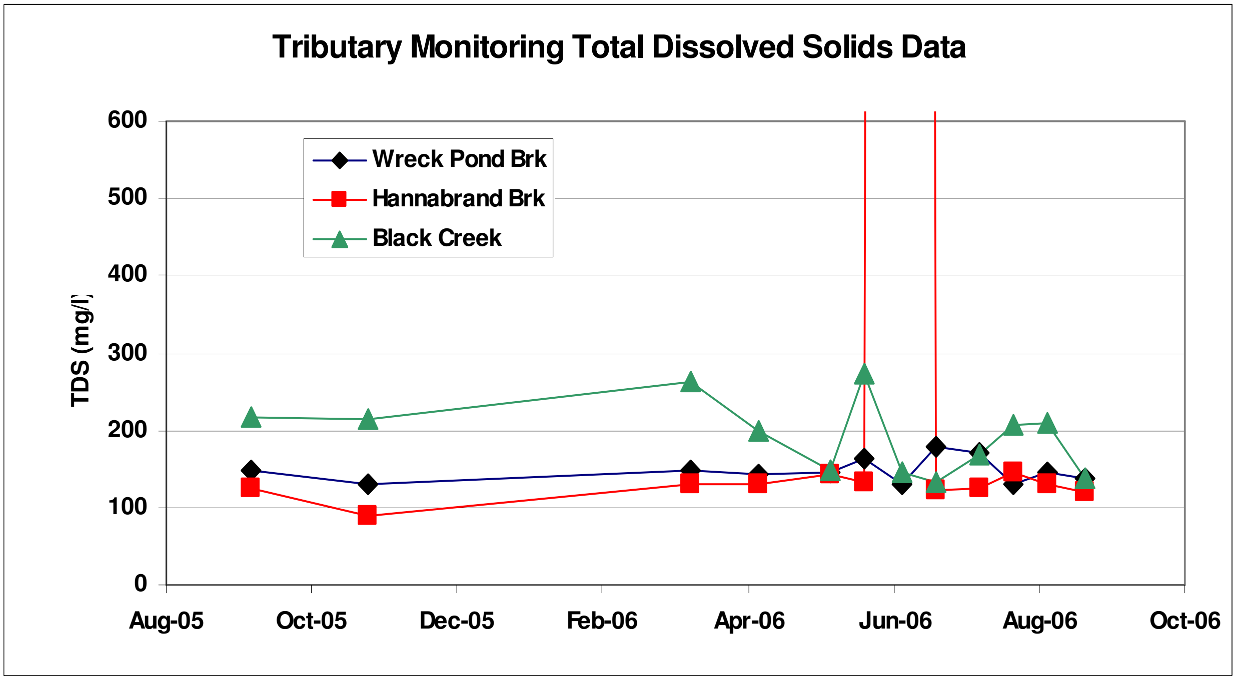
2. Tributary Sampling

Tributary station locations are shown in the main report. Sampling timing and parameters are as for the Pond sampling, although chlorophyll-a was not collected in the streams.

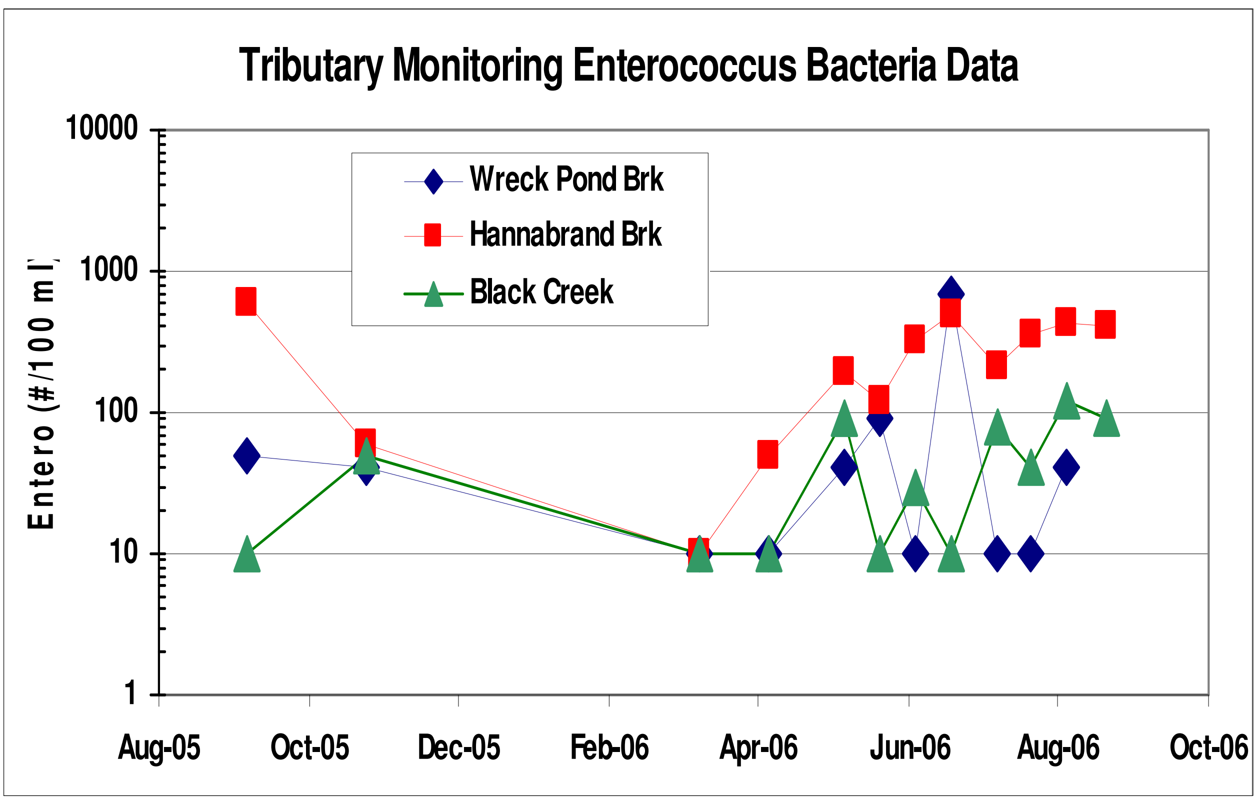
The tributary stations were accessible by foot. The staff gauges in place by Monmouth County were used to record the relative depths of water. A Gurley Precision velocity meter was used to measure the velocity of the flow at each station. In order to collect the water quality samples, a field technician in wading boots slowly waded to the collection point within the stream, walking from downstream to upstream. Once at the location, following a few seconds to allow any suspended sediments to drift downstream, sample water was collected just below the water surface.

Graphs of results are provided in the main report for some parameters. Graphs of additional parameters follow.

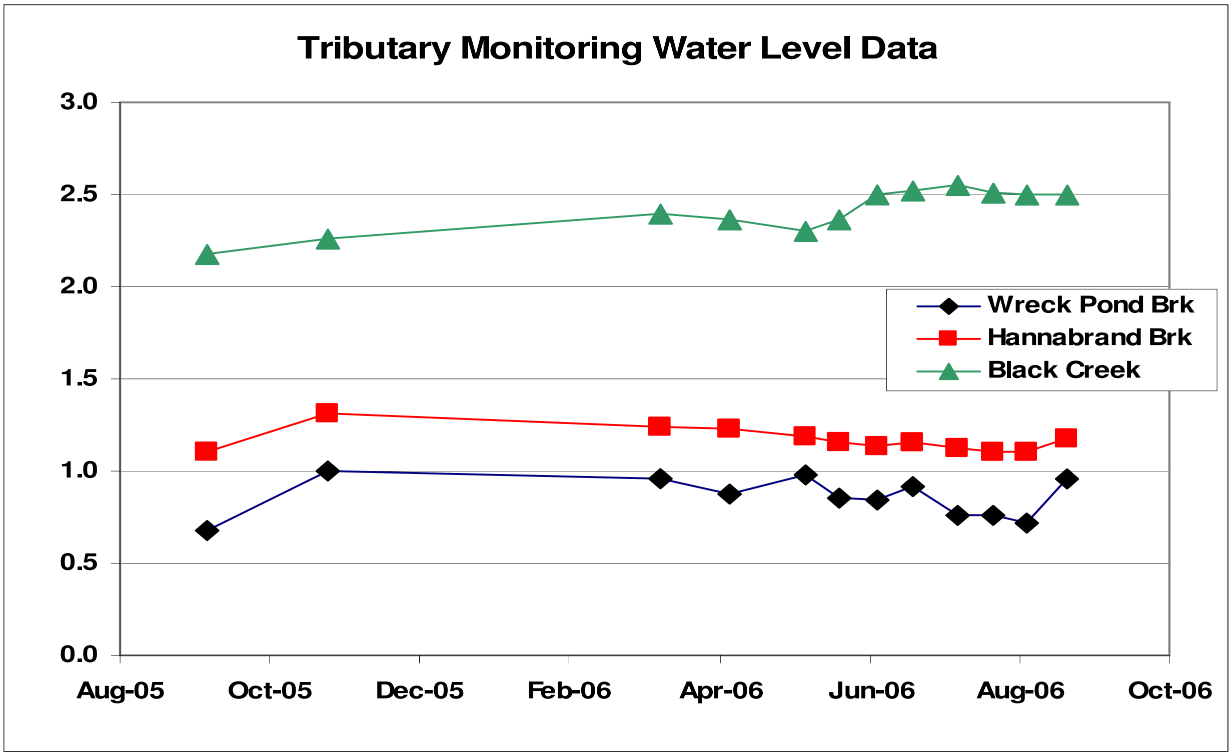


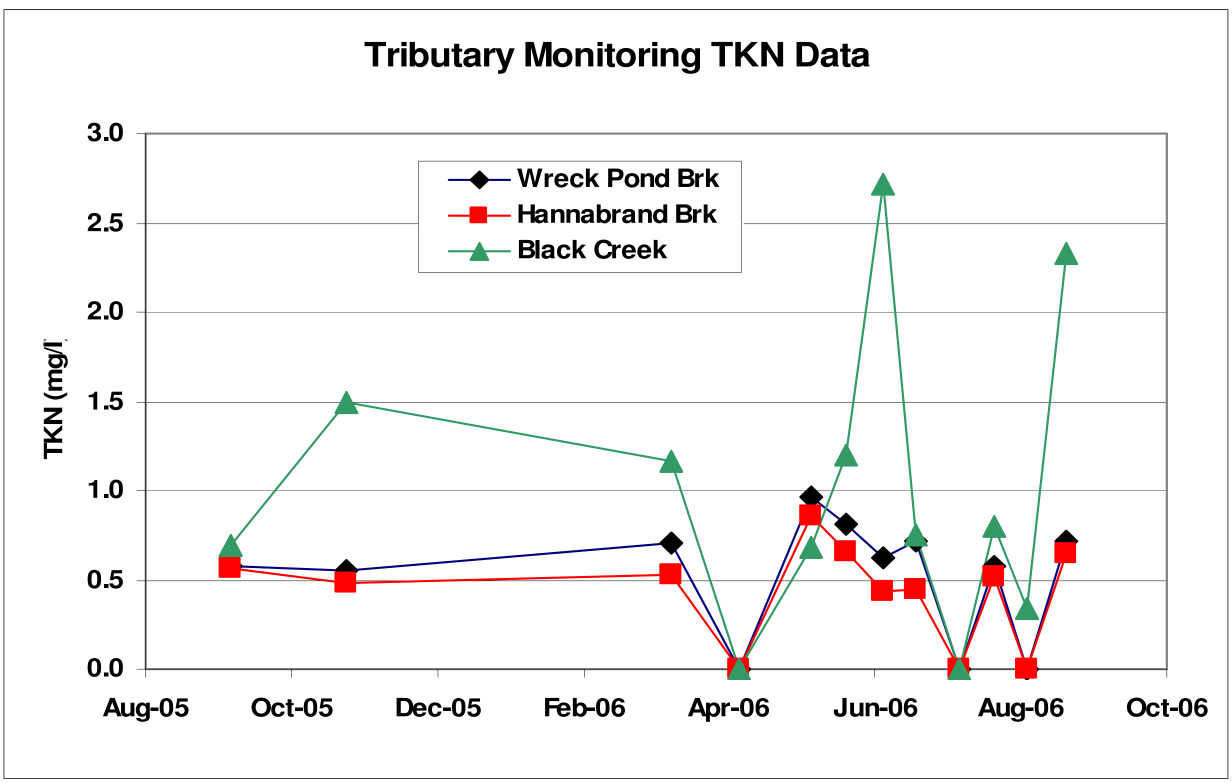


Tributary Monitoring Total Dissolved Solids Data
TDS (mg/l)
600
500
400
300
200
100
0
Wreck Pond Brk
Hannabrand Brk
Black Creek
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
Oct-06



Tributary Monitoring Enterococcus Bacteria Data
Entero (#/100 ml)
10000
1000
100
10
1
Wreck Pond Brk
Hannabrand Brk
Black Creek
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
Oct-06


Tributary Monitoring Water Level Data
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
Oct-06
Wreck Pond Brk
Hannabrand Brk
Black Creek


Tributary Monitoring TKN Data
TKN (mg/l)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Aug-05
Oct-05
Dec-05
Feb-06
Apr-06
Jun-06
Aug-06
Oct-06
Wreck Pond Brk
Hannabrand Brk
Black Creek

3. Sediment Core Sampling

Eleven (11) sediment core samples were collected within Wreck Pond and its tributaries. Seven (7) cores were taken within the Pond:

- 3B Western-most Portion of Wreck Pond
- 3C Wreck Pond, west of railroad bridge
- 3D Wreck Pond, northwestern corner
- 3E Wreck Pond, northeastern corner
- 3F Wreck Pond , western portion, near central part of shore
- 3G Wreck Pond, southwest of 3E
- 3H Wreck Pond, south central portion of pond

Four cores were taken outside of the Pond:

- 3A Old Mill Pond
- 1A Spring Lake Northwest
- 1B Spring Lake Southeast
- 1D Black Creek near weir

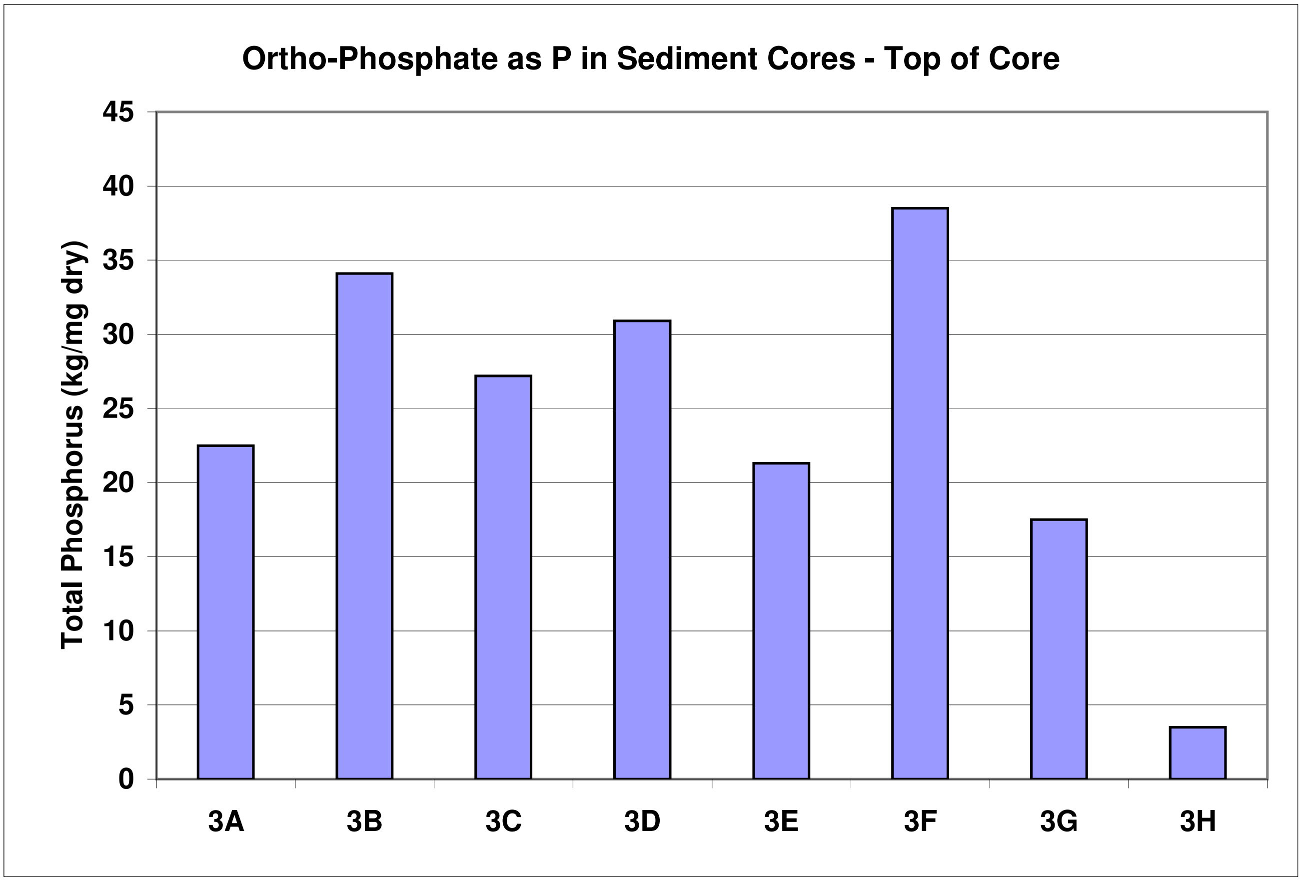
The location at which each core was taken were marked by GPS. Station 3A is designed to look at an upstream, small pond. Station 3B is in the western portion of the Pond. Stations 3C through 3H were placed within Wreck Pond in a grid formation to provide information on the ponds sediments and provide the most coverage of area. These stations were placed away from the area of the pond dredged by NJDEP in 2005. Stations 3D and 3E were located in the northeast and northwestern corners of the pond, close to the inflow points from Black Creek and the pipe from Spring Lake.

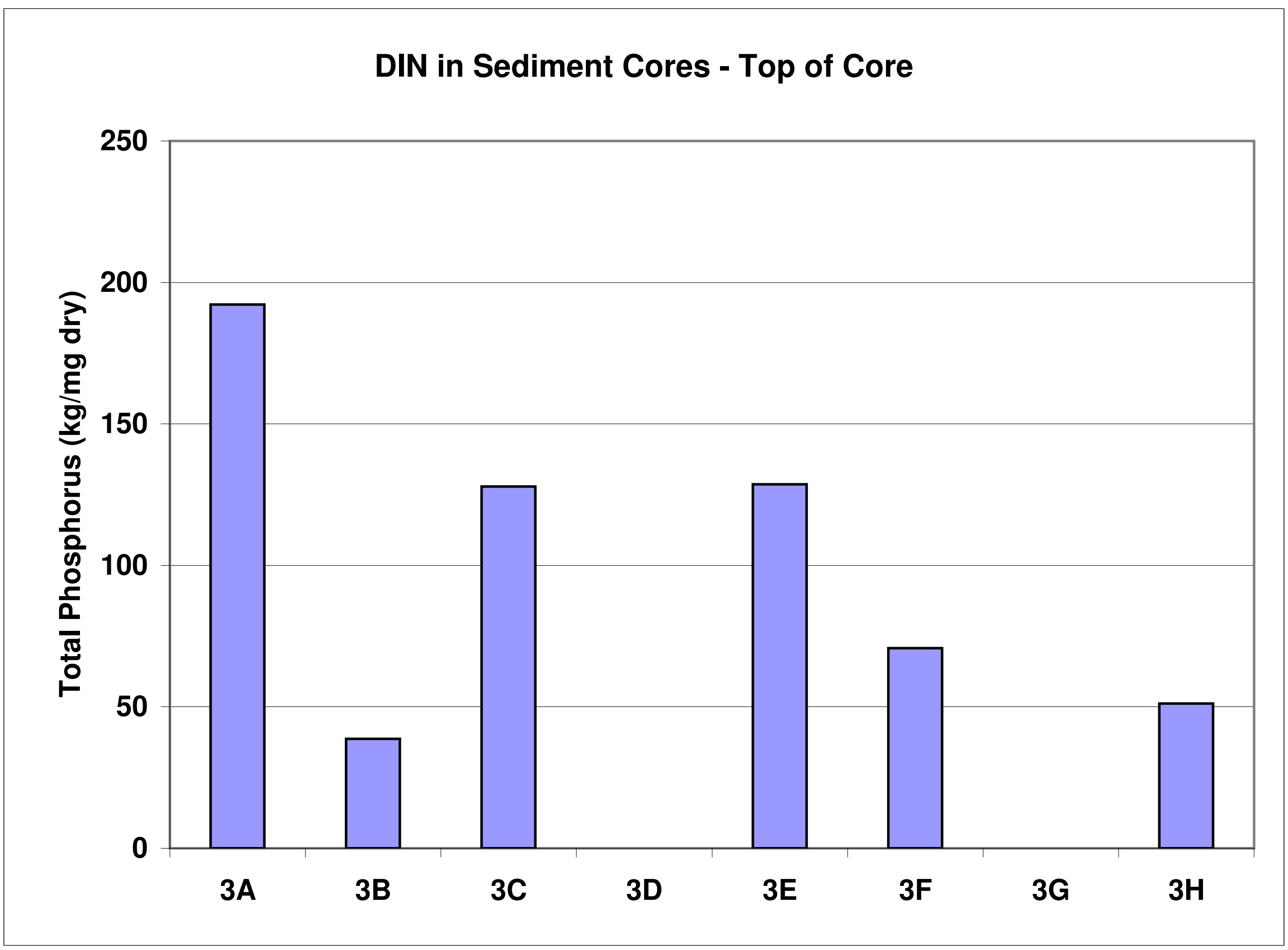
The sediment cores were collected over a four-day period by Aqua Survey, Inc. A geologist from NA logged each core.

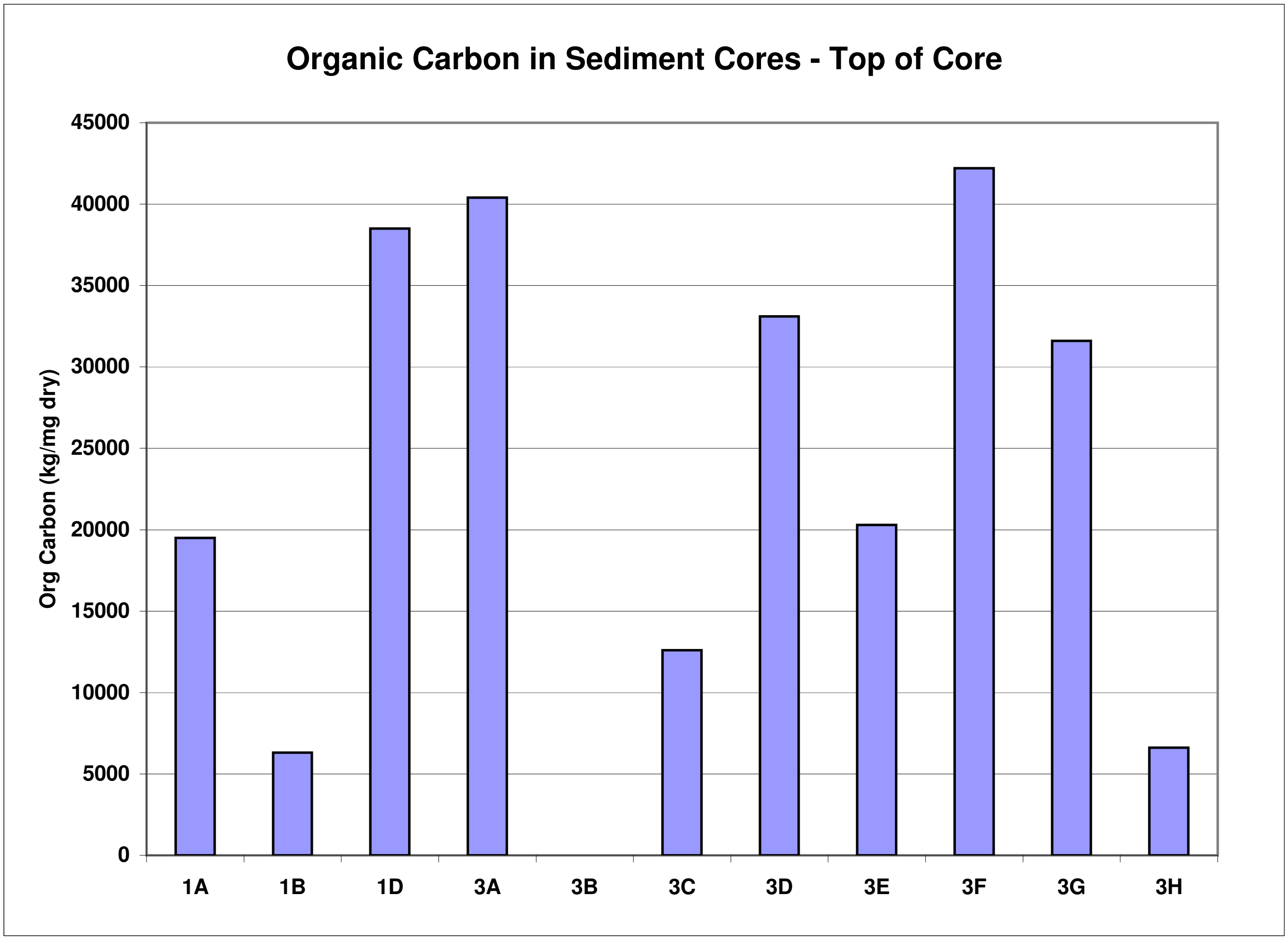
The samples were processed by NA. Samples from the top, mid and bottom of each core, as applicable, were collected and analyzed in accordance with the monitoring methods.

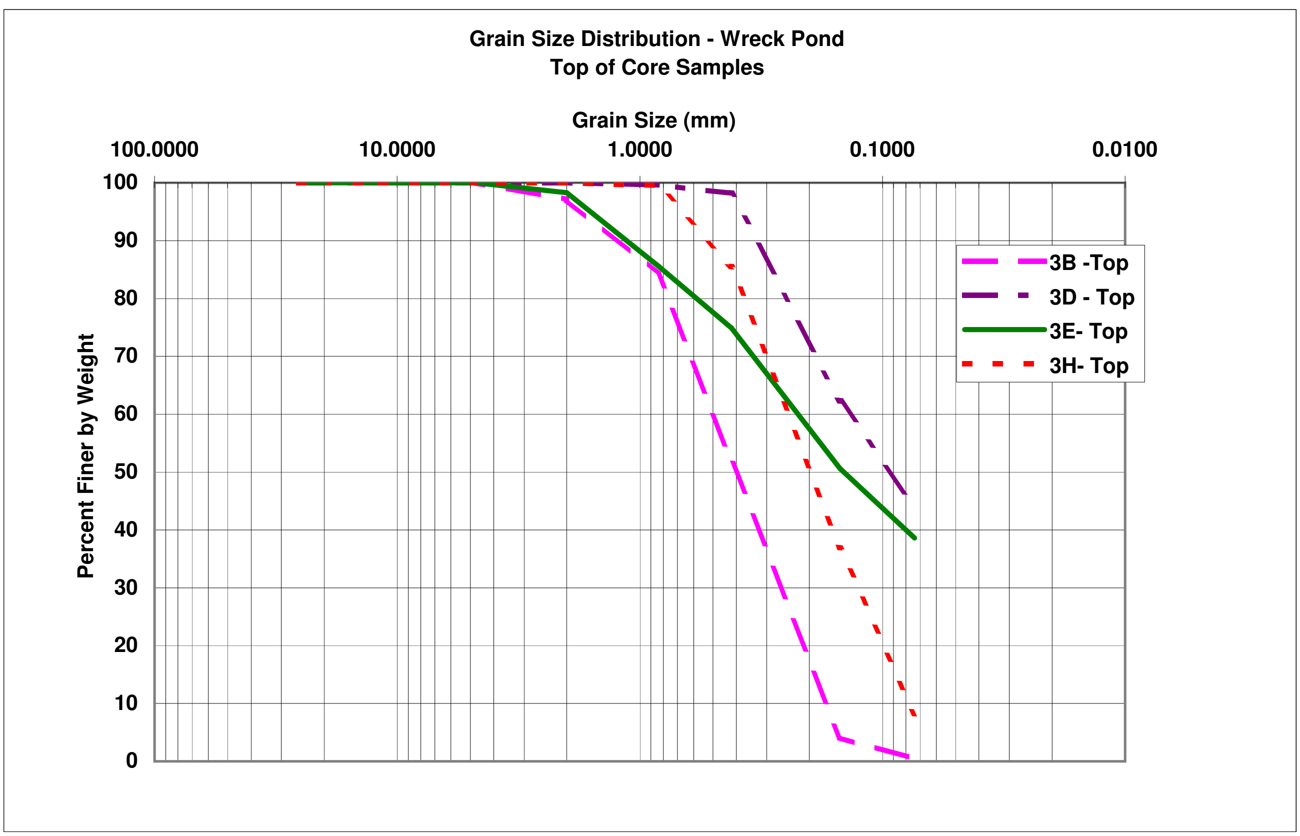
The tested parameters were:

- Sample Depth
- Grain Size
- TOC
- % Moisture
- PP + 40
- Herbicides
- Fecal Coliform
- Total Coliform
- Fecal Streptococcous
- Entercocci
- Clostridium Perfringens
- Nitrate
- Nitrite
- TKN
- Ammonia
- Total Phosphorous
- Ortho-Phosphate
- SOD


Ortho-Phosphate as P in Sediment Cores - Top of Core
Total Phosphorus (kg/mg dry)
0
5
10
15
20
25
30
35
40
45
3A
3B
3C
3D
3E
3F
3G
3H


DIN in Sediment Cores - Top of Core
Total Phosphorus (kg/mg dry)
0
50
100
150
200
250
3A
3B
3C
3D
3E
3F
3G
3H


Organic Carbon in Sediment Cores - Top of Core
Org Carbon (kg/mg dry)
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
1A
1B
1D
3A
3B
3C
3D
3E
3F
3G
3H


Grain Size Distribution - Wreck Pond
Top of Core Samples
Grain Size (mm)
100.0000
10.0000
1.0000
0.1000
0.0100
Percent Finer by Weight
100
90
80
70
60
50
40
30
20
10
0
3B -Top
3D - Top
3E- Top
3H- Top

Pond Sediment Core Analyses