



CHARACTERIZATION AND ASSESSMENT OF THE HEATHCOTE BROOK WATERSHED

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Cover Photo: SBMWA bacteria sampling Site HCB7 where Heathcote Brook crosses Mapleton Road in South Brunswick Township

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INTRODUCTION

Sprawl, according to Webster's New Collegiate Dictionary, is defined as: "to creep or clamber awkwardly; to spread or develop irregularly; to cause to spread out carelessly or awkwardly." *Awkward. Irregular. Careless.* These are not words that we want to associate with the planning and development of the towns where we live, work, and play. And yet, in Central New Jersey the consequences of this careless development are clear: development is degrading our natural resources, most particularly putting the region's water quality and quantity at risk.

Across America, poor planning is allowing farmlands, forests, wetlands, and viewsheds to be devoured at an astounding rate, changing forever the character of the places we call home. Countless acres of open space have become strip malls, roads, and bare detention basins. This consumption of open space by haphazard growth is not merely aesthetically disturbing, but has severe environmental and quality of life costs.

Situated within the metropolitan corridor between New York and Philadelphia, Central New Jersey is on the front line in the battle to stop sprawl as development threatens to destroy our remaining open spaces. The consequences are clear: pollutants are elevated in many of our waterways, wildlife populations are showing signs of distress as a result of pollution, beautiful views are lost and our quality of life is diminished. Roadways and traffic congestion are eroding our sense of place and community.

Many streams in the 265-square-mile Stony Brook-Millstone Watershed (referred to from now on as the Millstone Watershed) have been designated as impaired by the New Jersey Department of Environmental Protection (NJDEP), which cites the pace of development and nonpoint source pollution as the major causes (NJDEP, 2000a). Additionally, 63% of the waterways in New Jersey are impaired for drinking, recreational, or fishing uses, and 39% of the waterways in the Nation are impaired (USEPA, 2002). According to NJDEP Land Use/Land Cover data from 1986, 1995/97, and 2002, over 21,000 acres of land were developed in the Millstone Watershed between 1986 and 2002, a rate of approximately 110 acres per month or over 110 football fields each month (one acre equals approximately one football field). During the years since 2002, this area has continued to experience extensive development, as 50 acres of land are lost to development each day in the state of New Jersey (NJDEP, 2003a).

In order to better identify the causes of declining environmental health, we need an understanding of our watershed and the changes that have occurred within its natural boundaries. The water that flows in a stream arrives there in part by flowing over the land or percolating through the soil. Thus, how we develop the land is reflected in the water quality of our streams.

Research indicates that the most effective management efforts are generally confined to subwatersheds on the order of 20-50 square miles (Center for Watershed Protection, 1998). Such a localized approach allows personal contact with the community and fosters the building of relationships and trust. Most of the successful programs changing personal behavior have also cited one-to-one relationships as the key to success. Thus, the Subwatershed Characterization and Assessment project was developed to address problems specific to a smaller subwatershed within the Millstone Watershed.

The first step in this project is to provide a characterization and assessment of a subwatershed in order to understand the causes of any problems and identify appropriate solutions or recommend steps to be taken to protect an unimpaired subwatershed. The goals of this report are to identify the current status of the environment (characterization) and compare this to community goals and adopted standards in New Jersey (assessment). Information is collected on soil types, geology, land use changes, water supply, water quality, rare and/or endangered species, critical habitats, known contaminated sites, discharges to surface and groundwater, and population changes. This information is analyzed individually in the appropriate section of the report (i.e. Landscape, Known Contaminated Sites, Soils, Water Quality) and then integrated with other data from the watershed to pinpoint the potential causes of any water quality problems, with the goal of addressing these causes and improving water quality through partnerships with NJDEP, municipalities, residents, and businesses. The last section of the report (Findings and Recommendations) summarizes the findings of the characterization and assessment and offers recommendations of steps that municipalities and planners can take to protect and improve the health of the Heathcote Brook Watershed.

Once the subwatershed is identified and evaluated, the most effective watershed management tools are selected to restore, enhance, or protect water quality. For example, if nonpoint source pollution from residential lawns or businesses is identified as a concern, the focus should be on implementing education programs for homeowners and business owners in these areas. Visual assessments of local streams can also guide management actions. Areas in need of extensive streambank restoration can be identified, as can areas with high water quality that need to be preserved. Stony Brook-Millstone Watershed Association (SBMWA), with 58 years of experience in water quality protection, has a large suite of tools that have been utilized successfully in the past to preserve our resources. These include:

- ◆ Extensive experience in education, with both adults and children;
- ◆ Streambank restoration, riparian buffer creation, and reforestation;
- ◆ One-on-one education of residents, businesses, and golf courses on best management practices for their properties in our River-Friendly Programs;
- ◆ StreamWatch, our successful, long-term water quality monitoring program;
- ◆ Work with municipalities to integrate their vision and environmental protection goals for the municipality into their zoning and ordinances; and
- ◆ Open space acquisition planning.

INTRODUCTION

Through the addition and prioritization of specific strategies and projects geared to restore, enhance, or protect water quality, SBMWA hopes to have this report serve as an NJDEP approved Watershed Management Plan. Through water quality sampling, NJDEP has identified fecal coliform pollution as a major impairment to water quality (NJDEP, 2004a and 2006c). Thus, NJDEP has made determining the sources of fecal coliform and reducing levels in streams a priority for their work.

The Heathcote Brook Watershed was the fifth subwatershed chosen to undergo scrutiny, and this Characterization and Assessment Report is the result of our investigation. The Beden Brook Watershed was the first subwatershed to be thoroughly assessed, Rocky Brook Watershed was second, Cranbury Brook was third, Royce Brook was fourth, and Duck Pond Run will be the sixth. The Heathcote Brook Watershed is located within the east-central portion of the larger Millstone Watershed, in Central New Jersey (Figure 1). This report brings together information and links data to provide an understanding of why water quality in some areas is impaired. As SBMWA has done for many years, we are working with residents, municipal officials, and businesses to understand their concerns and vision for their community, and we will work together to implement the best strategies for improving environmental quality. As an approved Watershed Management Plan, this document can help guide all entities (i.e. municipalities, NJDEP, consulting firms, and businesses) working within the Heathcote Brook Watershed to take appropriate actions to protect, enhance, or improve water quality. For this report, when discussing the entire Heathcote Brook area, it will be referred to as a watershed.

This report is intended to relay the past and present status of the Heathcote Brook Watershed and its environmental resources. The evaluation is used to set priority areas where SBMWA can utilize its effective watershed restoration tools. Goals of watershed restoration include improvement of water quality; education of local residents, businesses, and municipalities on nonpoint source pollution reduction; and a measurable reduction in nonpoint source pollution in Heathcote Brook and its tributaries.

SBMWA is not alone in our efforts. The United States Environmental Protection Agency (USEPA) has stated that nonpoint source pollution, or pollution from runoff, is currently one of the leading causes of water quality degradation (USEPA, 1996). This means that solutions, like recycling, involve everyone – our elected officials, business leaders, and all residents. This report summarizes the causes of the problems and offers recommendations on how to address them. It is up to everyone who lives, works, and plays in the Heathcote Brook Watershed to work together to provide a vision for this area and strive to protect the environment and quality of life that we value.

LANDSCAPE

A foundation for the Heathcote Brook Watershed needs to be laid in order to fully begin assessing the region. That foundation takes the form of understanding the townships that decide what happens within their borders and to the watershed, the waterways that meander through the landscape, the populations of residents that have an impact on the local environment everyday, and the flora and fauna that inhabit the area and rely on it for survival. By simply describing these basic components within the watershed, protection and preservation practices can be formed for these particular resources.

SETTING

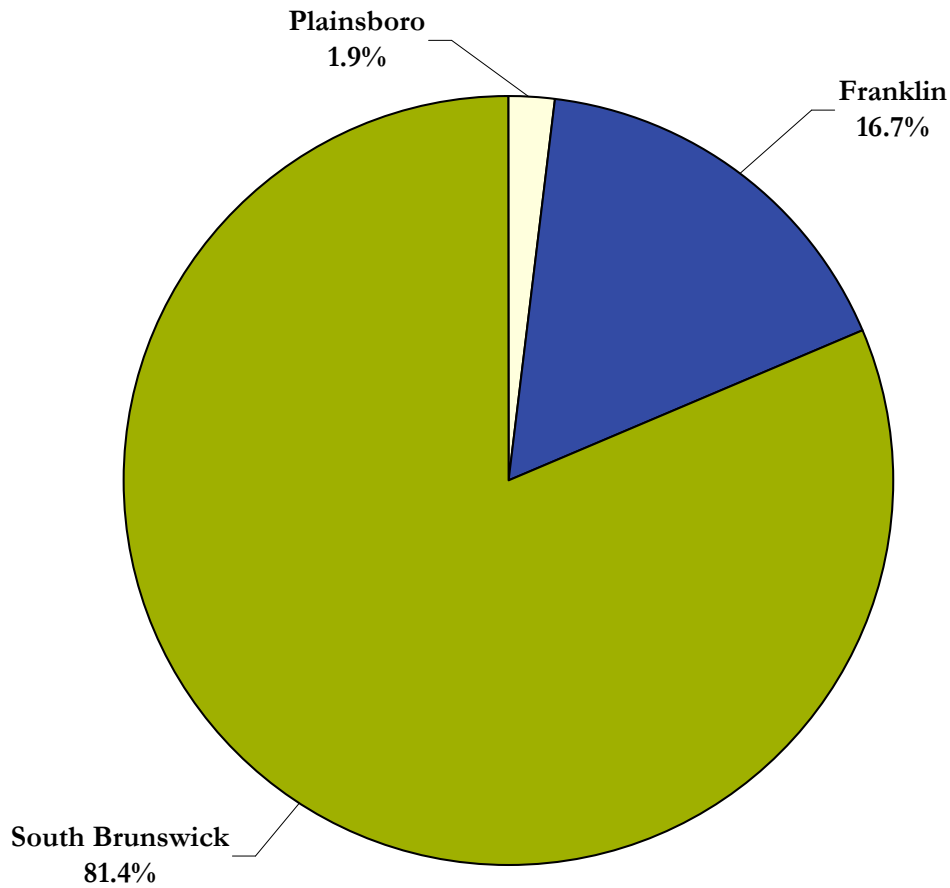
The Heathcote Brook Watershed covers about 5,855 acres (approximately 9.15 square miles) that lie in parts of Franklin Township (in Somerset County), and Plainsboro and South Brunswick Townships (both in Middlesex County). Within the watershed, the majority of the land is located in South Brunswick (4,767 acres or 81.4%). Of the remaining watershed area, 16.7% (975 acres) lies within Franklin Township, and the rest of the land (112 acres or 1.9%) is in Plainsboro Township (Figure 2, Table 1, and Graph 1).

Table 1: Municipalities within the Heathcote Brook Watershed.

Municipality	County	Acres in the Heathcote Brook Watershed	Acres in Full Municipality
South Brunswick Township	Middlesex	4,767.3	26,171.9
Franklin Township	Somerset	975.3	29,995.3
Plainsboro Township	Middlesex	112.0	8,803.4
TOTAL	---	5,854.6	64,970.6

Heathcote Brook's headwaters are in South Brunswick Township and flow approximately six miles through Franklin and Plainsboro Townships before meeting the Millstone River just southeast of Route 27 (Figure 2). Carters Brook is one of the major tributaries of Heathcote Brook, but there are also a few smaller tributaries draining into Heathcote Brook (Figure 2). When tributary lengths are included, Heathcote Brook flows a total of approximately 16 miles. Heathcote Brook flows through Reisert Pond and other smaller ponds.

Graph 1: Percentage of the Heathcote Brook Watershed area within each municipality.



HISTORY

South Brunswick Township was incorporated by an act of the State Legislature in 1798. The 18th century character of South Brunswick was that of a rural agricultural township with small clustered settlements located on major transportation routes. The early settlers took advantage of fertile soils and favorable growing conditions.

The rural nature of the Township continued throughout the 19th century, with increases in commercial and residential growth and development coinciding with the introduction of new transportation routes. The Straight Turnpike, now Route 1, was constructed in 1804.

In 1872, the Legislature first reduced the size of South Brunswick with the creation of the separate Township of Cranbury from the southern portion of South Brunswick. In 1885, it redefined and enlarged the boundaries of Cranbury, and in 1919, the size of South Brunswick was further reduced with

LANDSCAPE

the formation of Plainsboro Township. The present boundaries of South Brunswick date back to this last change.

Part of South Brunswick Township, Kingston's location on the Lenape Assunpink Trail where it crossed the Millstone River was the prime factor in its early prominence. Kingston was by far the most active and important village, being situated on both the heavily traveled King's Road and the Millstone River, combining commercial activities of both mills and taverns.

Dayton, also part of South Brunswick Township, was first known simply as The Cross Roads, where James Whitlock built a tavern on Georges Road around 1750. Early enterprises included a brick manufacturer and large nursery. In 1866, the name was changed from Cross Roads to Dayton, in honor of William L. Dayton, an attorney for the Freehold and Jamesburg Agricultural Railroad. Dayton had helped settle disputes arising from the location of a railroad right-of-way. He was later a U.S. Senator, Vice Presidential nominee, and Minister to France. The nature of Dayton's business establishments - farm implements, tow hay dealers, a general store, a nursery, and a harness maker, attests to its agricultural identity.

Dutch settlers came to the Raritan Valley circa 1650, where they met the Raritan Indians. Members of the Lenni Lenape tribe were the first inhabitants of the area. In 1664 King Charles II of England declared rule over the Dutch lands in America. He parceled out New Jersey to Lord John Berkeley and Sir Philly Carteret. Later, in 1710, a Dutch company acquired the central portion of Franklin.

During 1776 and 1777, raiding parties fighting in the Revolutionary War ravaged the Franklin area. Barns were torn down and the materials were used for construction of temporary bridges over the Raritan River. After the Battle of Princeton in early 1777, General George Washington withdrew his troops along the Millstone River and encamped overnight in Millstone. On June 14, 1777, area residents witnessed the startling scene of two divisions of General Howe's British Soldiers (about 15,000) marching along Amwell Road between Millstone and New Brunswick -- a road much traveled today. They entrenched themselves at East Millstone and Middlebush under Generals Cornwallis and DeHeister who attempted to burn every building in sight.

The British hoped to engage Washington's troops in battle, but the "Americans" were in an advantageous position at Chimney Rock, in the Watchung Mountains (Bridgewater), and refused to be drawn out. General Howe, therefore, returned his forces to Staten Island. The Griggstown section of Franklin Township produced the romantic Revolutionary War figure of John Honeyman. His home still stands at the foot of Bunker Hill Road and Canal Road. It is said that while posing as a cattle-trader sympathetic to the British, Honeyman penetrated British lines and spied on their forces. His information helped Washington plan the surprise attack that liberated Trenton.

LANDSCAPE

In 1798, the Township was incorporated into Somerset County and into the state of New Jersey, becoming legally the Township of Franklin. The area was probably named after William Franklin, last Royal Governor of New Jersey (1762 - 1776). The completion of the 22-mile portion of the Delaware and Raritan Canal through Franklin in 1834 formed a continuous water route for freight between Philadelphia and New York. During the Civil War, as much as 200,000 tons of freight were hauled each year by mule and horse drawn barges. The canal was abandoned for commercial purposes in 1932, but is still actively used for water supply, recreational canoeing, and fishing.

Historians differ as to how Plainsboro acquired its name. The oldest section of the community is the intersection of Plainsboro and Dey Roads. "Plane Tavern," constructed in the early 1700's, still stands today at this location. Some historians argue that the old bottles found by local residents give evidence that the Township was first called "Planesborough" after the tavern. Other researchers maintain that the area was first called the "Borough of the Plains" or simply "The Plains." The first U.S. Post Office designated the area as "Plainsborough." A subsequent Presidential decree in 1894 shortened the name to "Plainsboro."

The Unami, a sub-tribe of the Lenni Lenape, were the first inhabitants of the Plainsboro area. The Dutch, migrating from the original settlement of Peter Minuet (also spelled Minuit in some literature) in New Amsterdam during the mid 1600's, became the first European settlers. English settlers soon joined them. Given the region's climate, good soils, and available water, agriculture became the important economic focus. In 1897, the Walker-Gordon Laboratory Company selected Plainsboro as the site for its innovative certified dairy farm. Designed to produce clean, high quality milk and milk formulas for infant feeding at a time before pasteurization was a common practice, the farm grew to become the largest certified dairy farm in the world. The farm's "Rotary Combine Milking System," also known as the "Rotolactor," a 50-stall merry-go-round milking facility, went into operation in 1930. The farm and its Rotolactor became a novel tourist attraction. The dairy operation ceased in 1971, about the same time that the community transformed from a small farm area into a more suburban area.

POPULATION

People within a watershed have both direct and indirect impacts on water quality and therefore have opportunities to responsibly manage and improve water quality. Increasing populations within the Heathcote Brook Watershed are adding to the pressures of waste disposal and water treatment, an increased need for housing, and increased water usage. Development pressure for growing populations increases as the demand for additional infrastructure to support more residents rises.

LANDSCAPE

Population is increasing and development is expanding in the Heathcote Brook Watershed. The current trend is spreading large developed areas over the landscape, instead of clustering in hamlets, villages, or town centers. People's dependence on the automobile and the lack of reliable public transportation have encouraged this pattern of development in the area and throughout New Jersey.

The total population for the towns which fall within Heathcote Brook Watershed (not just for the portions of the Townships found within the Watershed) has increased more than eleven-fold in 70 years, from 9,815 people in 1930 to 108,852 in 2000 (Graph 2 and Table 2; New Jersey State Data Center, 2001). Total population increased at an average rate of 1,415 people per year. In comparison, the rate of increase between 1970 and 2000 was 2,092 people per year (Graph 2 and Table 3). Between 1930 and 2000, population changes for people living within the three municipalities found partially or fully within the Watershed show that growth occurred in each of the municipalities (Table 2 and Graph 2).

The South Brunswick population increased by 1,268.2% between 1930 and 2000, as it went from 2,758 residents in 1930 to a population of 37,734 in 2000 (Table 2 and Graph 2). South Brunswick contributes a large percentage of the 2000 population (34.7%) for the total population of municipalities found all or partly in the Heathcote Brook Watershed, while contributing to 81.4% of the entire watershed area (Graph 3 and Table 2). With such an increasing population in one municipality that constitutes the largest portion of the Heathcote Brook Watershed, local governance needs to thoughtfully plan out the future direction of development within South Brunswick Township.

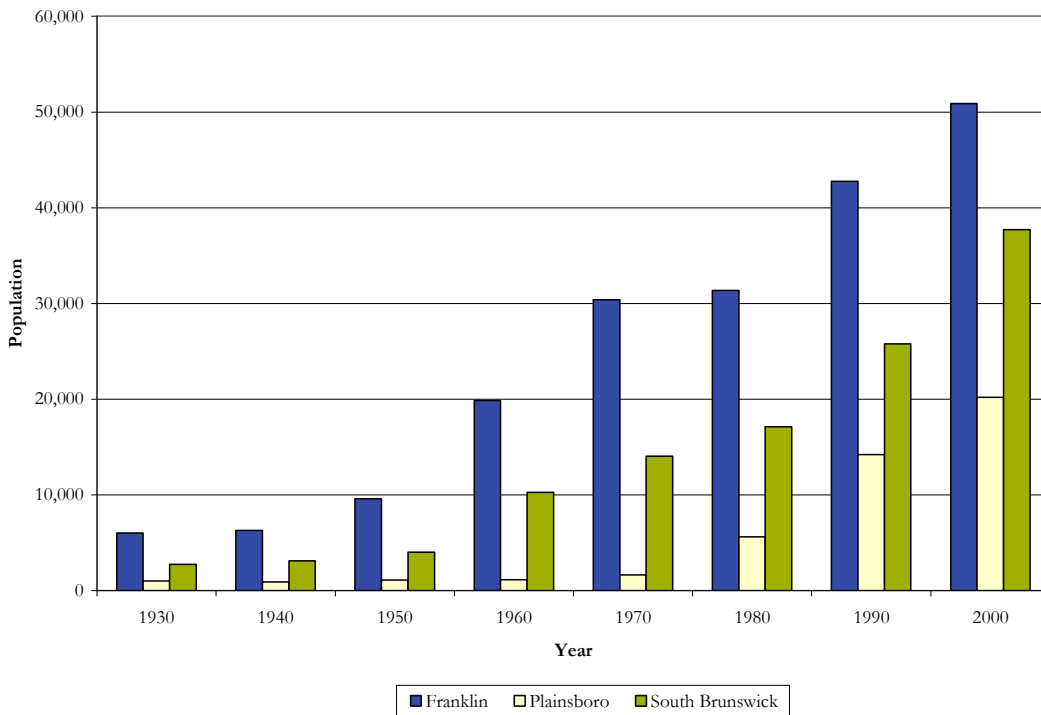
A smaller change in population was found in Franklin Township with only a 742.9% increase in population over 70 years (Table 2 and Graph 2). In fact, over the last 30 years, Franklin gained 20,514 residents while South Brunswick gained 23,676 residents in that same time period (Table 3). Franklin may contribute the largest percentage of the 2000 population for the total population of municipalities found within the Heathcote Brook Watershed, 46.8%; however, only 3.3% of Franklin lies within the Heathcote Brook Watershed. Franklin consists of only 16.7% of the entire watershed area.

The largest change in population between 1930 and 2000 occurred in Plainsboro Township with a 1,885.8% increase. However, because of its small contribution to the Heathcote Brook Watershed (1.9% of the Watershed area), Plainsboro was excluded from analyses based solely upon population impacts and is included for informational purposes only.

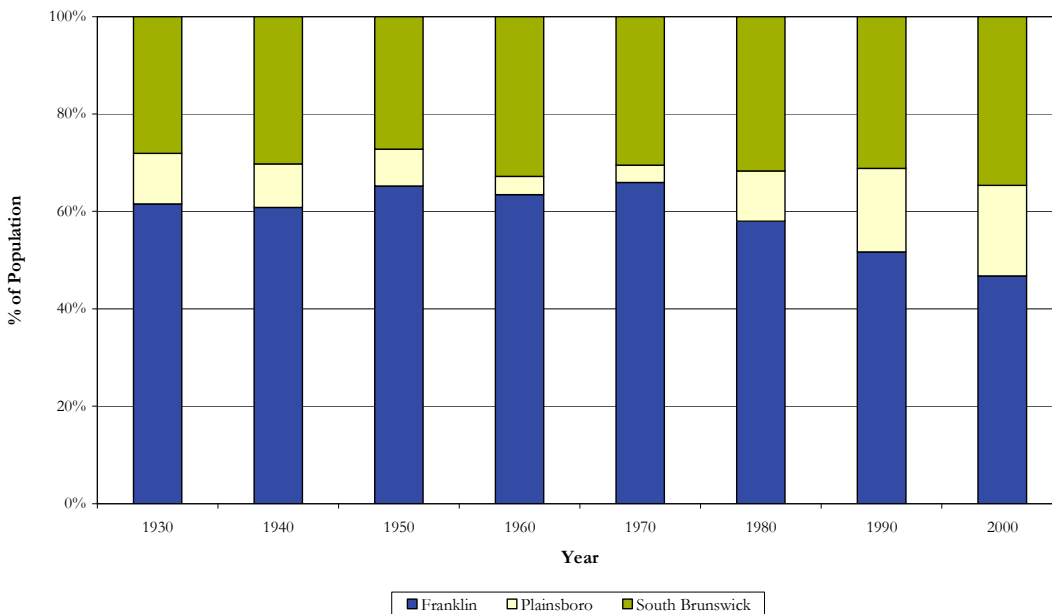
Much of the population density is distributed near major roadways like State Route 1 and State Route 27, where many businesses and direct connections to these roadways are located (Figure 3).

LANDSCAPE

Graph 2: Historical population of the municipalities within the Heathcote Brook Watershed. *



Graph 3: Percentage of total population of the municipalities within the Heathcote Brook Watershed. *



* The population figures listed are for the entire municipality and not just for the portion found in the Heathcote Brook Watershed.

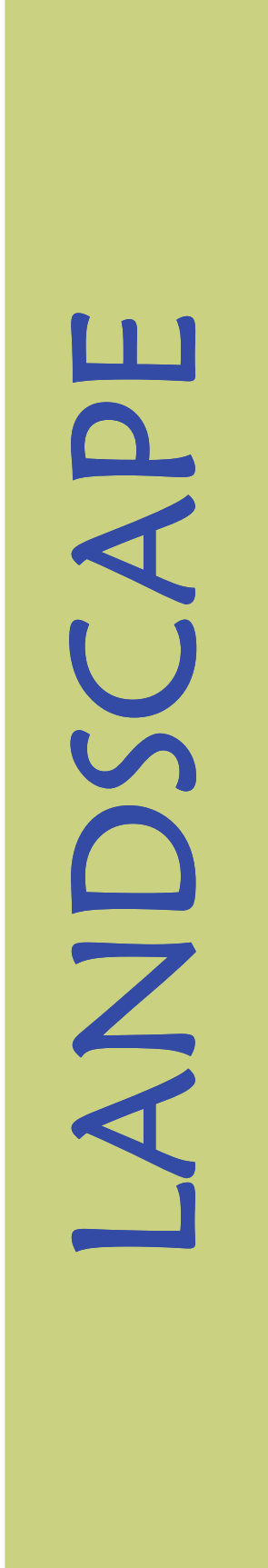


Table 2: Population changes in the municipalities that comprise the Heathcote Brook Watershed from 1930 - 2000. *

Municipality	1930 Population	2000 Population	% Population Change	% of Watershed Area	% of Municipality within Watershed
Plainsboro Township	1,018	20,215	+1,885.8%	1.9%	1.3%
Franklin Township	6,039	50,903	+742.9%	16.7%	3.3%
South Brunswick Township	2,758	37,734	+1,268.2%	81.4%	18.2%
TOTAL	9,815	108,852	+1,009.0%	100%	—

* The population figures listed are for the entire municipality and not just for the portion found in the Heathcote Brook Watershed.

Table 3: Population changes in the municipalities that comprise the Heathcote Brook Watershed from 1970 - 2000. *

Municipality	1970 Population	2000 Population	% Population Change	% of Watershed Area	% of Municipality within Watershed
Plainsboro Township	1,648	20,215	+1,126.6%	1.9%	1.3%
Franklin Township	30,389	50,903	+67.5%	16.7%	3.3%
South Brunswick Township	14,058	37,734	+168.4%	81.4%	18.2%
TOTAL	46,095	108,852	+136.2%	100%	—

* The population figures listed are for the entire municipality and not just for the portion found in the Heathcote Brook Watershed.

CRITICAL HABITATS

NJDEP's Division of Fish and Wildlife has developed The Landscape Project, a planning tool to help land managers, planners, and regulatory agencies integrate wildlife protection into their overall land use goals. The Landscape Project establishes "accurate boundaries around critical wildlife

habitats and then comparatively ranks them to offer prioritization options for varying levels of conservation and management” (Niles et. al., no date). The ranking is based upon the presence or absence of animal species of concern, state threatened and endangered species, and federally threatened and endangered species.

Due to pollution, invasive plants, development, and the loss of specific habitats many species of plants and animals are losing the basic materials they need to survive in our area (food, shelter, and clean water). Loss of animal species can be linked to loss of the resources that are necessary for survival of that species. Endangered species are those whose survival in New Jersey is in immediate danger. Threatened species are those that may become endangered if harmful conditions continue to accumulate. Species of concern are those in danger of becoming threatened.

Critical habitats cover 63.5% (3,718 acres) of the Heathcote Brook Watershed (Figure 4). Many of the critical habitats in this Watershed are areas of importance to wildlife, ranging from Suitable Habitat (suitable for fulfilling the habitat requirements of species of concern, but where no such species are documented) to areas with Priority Species (a patch of habitat where state species of special concern have been documented) (Figure 4).

Within the Heathcote Brook Watershed, critical habitats are designated for 75.8% of Franklin Township’s acreage, 95.7% of Plainsboro Township’s acreage, and 60.2% of South Brunswick Township’s acreage (Table 4).

Table 4: Percentage of Acreage in Heathcote Brook Watershed designated as critical habitats, by municipality.

Municipality	Acreage in the Heathcote Brook Watershed	Critical Habitat Acreage	% of Twp. Acreage in Watershed designated as Critical Habitats
Plainsboro	112.0	107.2	95.7
Franklin	975.3	738.9	75.8
South Brunswick	4,767.3	2,872.0	60.2

In the Heathcote Brook Watershed, there are no records of state threatened species. The counties that comprise the Heathcote Brook Watershed



support a large diversity of endangered or threatened vertebrates, invertebrates, and plants (Table 5).

Table 5: Number of endangered/threatened species in the counties that make up the Heathcote Brook Watershed, based on August 2004 data. *

County	Vertebrates	Invertebrates	Plants
Middlesex	16	5	28
Somerset	15	4	20

* NJDEP's Natural Heritage Program gives the general area where the endangered or threatened species are located. This reduces the ability to pinpoint the location of the organism's habitat, and thus reduces the impact on that particular organism.

ASSESSMENT

The pattern of population growth and subsequent sprawling development in the Heathcote Brook Watershed has a more detrimental impact on water quality than clustering development in town centers. As forested areas, lands adjacent to wetlands, and agricultural lands are developed into residences and office buildings, they create destinations that attract more development (Center for Watershed Protection, 1998). These developed areas tend to have a higher percentage of impervious cover, material that prevents water from percolating into the ground. This increase in impervious cover alters flooding patterns, increases pollutant loads to streams, raises water temperatures, and also reduces baseflow in streams during drought (Center for Watershed Protection, 1998; see Land Use section for more information). Development that sprawls over the landscape makes systematic stormwater control extremely difficult, as well as fragments forests and other habitats, thereby causing a decline in ecological health. Established centers that concentrate populations and impervious cover while maintaining surrounding open spaces allow for more effective and efficient stormwater practices and minimize habitat fragmentation. In addition, infrastructure needs and costs increase as development occurs further away from established sewer and water systems. Municipalities need to manage the additional infrastructure and development patterns so that water quality is protected. If population growth remains unchecked, additional development is sure to follow. Proactive planning needs to be performed to minimize sprawling development patterns.

There are a number of ways to reduce sprawl in New Jersey. One way is developing areas as planned unit developments. Other innovative ways to

plan developments include re-zoning (changing zoning classifications to permit less dense development), mixed-use development (integrating different land uses such as restaurants, residences, offices, and parks into projects), and conservation design (placing a development on the least environmentally restrictive portion of a property, incorporating water recycling, energy efficiency, and sustainably produced materials into building design). These alternatives need to be based on accurate scientific information about the carrying capacity of available water supplies, sewer systems, and other infrastructure, and on the goals and objectives of the municipality's Master Plan and decision-making committees. To balance development with the environment, municipalities must incorporate these alternatives into their Master Plans.

By providing alternatives to traditional development, municipalities will protect the environment, especially the sensitive habitats and the wildlife that live in them. The extensive critical habitats within Heathcote Brook Watershed are being threatened by development, and municipalities need to incorporate this information on critical habitats in order to effectively slow sprawl, improve the environment, and protect wildlife. (See Planning Future Growth and Maintaining Groundwater Resources in the Findings and Recommendations section.)

In addition to providing habitat for the conservation of rare species and protecting groundwater supplies, preserving important wildlife habitats will result in more open space for outdoor recreation. Open spaces provide places where people can escape the confines of urban and suburban living.

The headwaters for Heathcote Brook are contained in South Brunswick Township, and the headwaters for Heathcote Brook's largest tributary, Carters Brook, are in Franklin Township. Because of this, the residents in these Townships need to be especially aware of their roles in impacting and improving water quality in Heathcote Brook Watershed. (See the Protecting Water Quality's second and third findings in the Findings and Recommendations section.)

LANDSCAPE

KNOWN CONTAMINATED SITES

Contaminated sites are generally the result of spills, leaks, or careless practices with chemicals or other hazardous materials such as biological or radioactive wastes. It is important to be aware of these sites because the substances involved can be highly toxic and, therefore, can become hazards to human health as well as to the natural environment. Common contaminants found on these sites include metals, petroleum products and by-products, organic solvents, and pesticides. Several different branches of the NJDEP regulate and oversee these sites once they are discovered and evaluated.

Note that the listing of contaminated sites gives the name of the current owner of each property. The current site owner and the potentially responsible party (PRP) for the contamination are not necessarily the same. Site managers at NJDEP are currently overseeing the investigation of listed known contaminated sites. Each site has a NJDEP case manager appointed to it, and the cleanup process can run several years depending on the severity of the contamination.

There are also many residential sites that contain underground storage tanks (USTs) that have not been described or mapped. This lack of information may prove risky as the status for these USTs, whether leaking or intact, and therefore whether or not surrounding areas are being contaminated, is unknown. For privacy and cost-benefit reasons, SBMWA has not made any effort to enumerate, locate, or identify any USTs in this watershed.

In cases where there is groundwater contamination, the Currently Known Extent (CKE) and Classification Exception Area (CEA) are determined. The CKE is a spatially defined area within which the groundwater resources are known to be compromised, as indicated by the violation of drinking water and groundwater quality standards for specific contaminants (NJDEP, 2003b). CKEs are used to make decisions about the appropriate treatment and/or replacement of contaminated drinking water supplies. The CEA is a geographic area within which the New Jersey Ground Water Quality Standards (NJGWQS) for contaminants have been exceeded and will not be met by remediation (NJDEP, 2003b). When a CEA is designated for an area, the designated aquifer uses are suspended for the term of the CEA. The determination of both these areas is also intended to provide information to the public about contaminated groundwater areas and where well installation should be avoided, unless precautionary measures are taken to protect potable water users.

The list of contaminated sites and their remediation level is based on information in the 7th edition of the Known Contaminated Sites in NJ (KCS-NJ) Report, Spring 2006 (NJDEP, 2006a) and supplemental GIS data available from the NJDEP's Site Remediation Program. This information and data are available for download from <http://www.nj.gov/dep/srp/kcs-nj/> and as of publication

of this report were last updated on April 6, 2006. **Note: SBMWA has done its best to ensure the accuracy of the information presented in this section by using the latest available data from the NJDEP. Any discrepancies in the information presented here should not be considered the fault of SBMWA and should be brought to the NJDEP Site Remediation Program's attention at 1-800-253-5647 for reconciliation.*

There are currently 13 known contaminated sites (KCSs) in the Heathcote Brook Watershed and two additional sites barely across the northeast watershed border (Figure 5 and Table 6). Four of the 13 KCSs are located along Route 1 and three are located near Route 27 (Figure 5 and Table 6). Twelve of the 13 KCSs are located within the portion of South Brunswick found in the Heathcote Brook Watershed (Figure 5 and Table 6). Known contaminated sites are classified by category and remedial level. All of the KCSs in the Heathcote Brook Watershed are in Category A. Category A sites are those with on-site contamination of soil and/or groundwater. This contamination has been confirmed through sampling and remedial activities are required (NJDEP, 2006a).

Three sites in Heathcote Brook Watershed are listed at remedial level D: Oxy USA, Inc., Columbian Chemical Company, and the BFI South Brunswick Landfill (Figure 5 and Table 6). KCSs at remedial level D are those sites that have highly complex contamination, usually with multiple contaminants, of soils, groundwater and possibly surface water, and potable water sources. Since groundwater replenishes surface water, sustaining flows in rivers and streams, extensive groundwater contamination can affect surface water quality as well.

Six KCSs, Aerochem Research Labs, BP Service Station, Exxon Service Station, Leo's Rural Service, South Brunswick Plaza Ltd, and South Brunswick Square Shopping Center, are listed with C2 remedial levels (Figure 5 and Table 6). Remedial level C2 is associated with more complicated contaminant discharges, multiple site spills and discharges, more than one contaminant, and impacted or threatened soil and groundwater (Table 6).

South Brunswick Plaza Limited has a defined CEA (Figure 5). This indicates that the groundwater at the site has exceeded NJGWQS.

The Higgins Farm site has a defined CKE (Figure 5). This indicates the geographical extent of known groundwater contamination where water quality exceeds drinking water and groundwater quality standards for specific contaminants. It is also the only current Superfund site in the Heathcote Brook Watershed. The BFI South Brunswick Landfill is a former Superfund site. A federal trust fund (the "Superfund") was established by Congress by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, and is authorized for particularly large, extensive or dangerous contamination events. Superfund monies are available to remediate sites on

Table 6: Known Contaminated Sites in Heathcote Brook Watershed, based on 7th edition KCS-NJ Report, Spring 2006.

Preferred ID	Site Name	Address	Municipality	Remedial Level *
G000005807	Higgins Farm (Superfund Site)	Route 518	Franklin Township	C1
G000040851	16 Spruce Lane	16 Spruce Lane	South Brunswick Township	C1
188093	793 Ridge Road	793 Ridge Road	South Brunswick Township	B
G000062589	4448 Rt 27	4448 Route 27	South Brunswick Township	C1
G000007819	Aerochem Research Labs	556 Ridge Road	South Brunswick Township	C2
002904	BP Service Station #60763	4020 Route 1 North & New Road	South Brunswick Township	C2
007299	Columbian Chemicals Company	Stouts Lane	South Brunswick Township	D
007671	Exxon R/S 3-2235	Route 1 North & New Road	South Brunswick Township	C2
006910	Leos Rural Service Inc	36 to 60 Route 27	South Brunswick Township	C2
G000001350	Oxy USA Inc.	Stouts Lane	South Brunswick Township	D
G0000006724	BFI South Brunswick Landfill, a.k.a. South Brunswick Landfill (former Superfund site)	New Road	South Brunswick Township	D
G000020196	South Brunswick Plaza Ltd.	Stouts Lane & Route 1 North	South Brunswick Township	C2
25050	South Brunswick Square Shopping Center	4095 Route 1 South	South Brunswick Township	C2
202431	10 Pierson Street	10 Pierson Street	South Brunswick Township (just outside Heathcote Brook Watershed)	C1
172181	Princeton Nurseries	630 745 Ridge Road	South Brunswick Township (just outside Heathcote Brook Watershed)	C1

* Remedial Level: Level of site complexity to remediate the contamination, as outlined in KCS-NJ Report from the NJDEP's Site Remediation Program. The intent of the remedial level is to reflect the overall degree of contamination at a site recognizing that different areas may involve varying levels of action.
A = Emergency Action - Stabilization.
B = Single phase clean up of soils only; single contaminant.
C1 = Contamination source known, potential for groundwater contamination.
C2 = Contamination source known or the release has caused groundwater contamination.
C3 = Multi-phase remedial action. Contamination source unknown or uncontrolled discharge to soil and/or groundwater.
D = Multi-phase remedial action with multiple sources/releases to multiple areas, including groundwater.
N/A = Known sites not adequately assessed to a rank.

KNOWN CONTAMINATED SITES

the National Priority List, a ranking of sites that the U.S. Environmental Protection Agency (USEPA) has determined might represent long-term threats to public health and the environment.

ASSESSMENT

There are a large number of known contaminated sites in the Heathcote Brook Watershed (13 in a 9.15 square mile watershed). The PRPs and NJDEP need to stay vigilant of these sites by monitoring and performing remediation of any contamination present. This is especially true for those sites with certain or possible groundwater contamination, where the groundwater contaminants can possibly reach drinking water supplies, and more so for the Higgins Farm, which is a Superfund site.

The Heathcote Brook Watershed has many areas with high recharge to groundwater (see Water Supply section and Figure 17 for more information). These areas not only allow for quick movement of water to groundwater supplies, but also movement of any pollutants traveling with that water. By working to contain and clean up these potential sources of groundwater contamination, the municipalities will ensure that drinking water supplies are safeguarded for their residents and neighboring municipalities.

POINT SOURCE DISCHARGERS

Point source dischargers are facilities that discharge treated waste or cooling water directly to surface or groundwater. These discharges can have powerful effects on the quality and quantity of water in a stream or aquifer. Because flow from these sources is independent of storm events, the quality of effluent in surface water discharges is crucial to water and habitat quality. The NJDEP regulates these facilities, and several federal and state laws govern their discharges. Each facility is assigned a case manager and is classified according to its type of discharge (i.e., land application, a pipe discharge to surface water, a percolation lagoon, a stormwater detention basin, etc.). Discharges may combine waters from more than one source (stormwater and cooling water combinations are common). If this is done, then the permit is classified according to the major component of the discharge. Regular monitoring of the discharge by the permittee is required for all permits.

Note that the information presented in this section was derived from the NJDEP Division of Water Quality's New Jersey Pollution Discharge Elimination System (NJPDDES) database. This database contains information of all active permitted NJPDDES dischargers that are in NJDEP's New Jersey Environmental Management System (NJEMS) database. It is available for download from <http://www.state.nj.us/dep/dwq/database.htm> and as of publication of this report was last updated on February 24, 2006. Supplemental information was obtained from the NJDEP's 2002 GIS layer for both surface water and groundwater dischargers. **Note: SBMWA has done its best to ensure the accuracy of the information presented in this section by using the latest available data from NJDEP. Any discrepancies in the information presented here should not be considered the fault of SBMWA and should be brought to the NJDEP Division of Water Quality's attention at (609) 292-4543 for reconciliation.*

PERMITTED DISCHARGERS TO SURFACE WATER

There are currently four active permitted point source dischargers in the Heathcote Brook Watershed listed in the NJEMS database (Figure 6). They are the John C. Dolph Company, a minor industrial stormwater discharger, Mohawk Labs of New Jersey, Ridge Nassau Corporation, and Dow Jones and Company, Inc (Figure 6). Mohawk Labs, Ridge Nassau Corporation, and Dow Jones and Company, Inc. are classified as stormwater dischargers. These three dischargers were identified in the 2006 NJEMS database but not included in the 2002 GIS layer; therefore, the point locations on Figure 6 refer to the facility location, not the pipe discharge location. There is also an Exxon Service Station, which is classified as a petroleum hydrocarbon remediation site, listed as a point source discharger according to NJDEP 2002 data. The Exxon Service Station is the same location as one of the known contaminated sites (Figures 5 and 6) and is located just downstream of bacteria monitoring Site HCB1 (Figure 26). The John C. Dolph Company has six discharge points (Figure 6) and is located just upstream of bacteria monitoring Site HCB2 (Figure 26). The Exxon Service Station and John C. Dolph Company are situated towards the headwaters of Heathcote Brook. Please note that the Exxon Service Station is not listed as having an active permit in the NJEMS

database as of 2006. However, since it is listed on the NJDEP 2002 GIS layer as a discharge location, it has been included in this report for completeness.

PERMITTED DISCHARGERS TO GROUNDWATER

There are no active permitted discharges to groundwater in the Heathcote Brook Watershed (Figure 6).

ASSESSMENT

Point source dischargers in the Heathcote Brook Watershed need to meet the conditions of their active permits to ensure that discharged water is properly treated to maintain the health of Heathcote Brook. South Brunswick Township and NJDEP need to be vigilant of these potential sources of pollution in this area to ensure that they do not become actual sources of pollution. Because the discharges are found towards Heathcote Brook's headwaters, it is even more important that the discharger conduct conscientious monitoring to ensure cleaner waters throughout the entire Watershed. The effluent monitoring data are submitted to NJDEP on a regular basis in the form of Discharge Monitoring Reports (DMRs) and can be accessed through the Open Public Records Act (OPRA) on NJDEP's Data Miner website:

http://datamine2.state.nj.us/DEP_OPRA/OpraMain/categories?category=NJPDES%20Permitting.

Information is also available regarding any permit violations and enforcement actions taken at http://datamine2.state.nj.us/dep/DEP_OPRA. A review of this database indicates that John C. Dolph Company, Mohawk Labs, and Dow Jones and Company, Inc. did not have any violations from the time their water quality permit was issued through December 6, 2007. Ridge Nassau Corporation had one violation in January 2005 for failure to conduct or properly document annual facility inspections. Enforcement action was taken by NJDEP and the violation status is pending.

GEOLOGY

The Heathcote Brook Watershed lies in the Piedmont Physiographic Province (Figure 7). Bedrock formations within the Piedmont are of late Triassic and early Jurassic age (230 to 190 million years old) and are part of the Newark Supergroup. Six geologic formations are present within the Heathcote Brook Watershed: the Stockton Formation, Lockatong Formation, Passaic Formation of the Brunswick Group, Passaic Formation Gray bed, Jurassic Diabase, and the Magothy Formation (Figure 8).

Following are brief descriptions of the geologic units occurring in the Heathcote Brook Watershed, listed in stratigraphic order from the lowest to the highest (from Owens, et al., 1998; Figure 8).

Stockton Formation (Upper Triassic): The Stockton Formation is a Piedmont Province formation that is unconformably overlain by Coastal Plain sediments at the margin between the Piedmont and Coastal Plain provinces, just south of Heathcote Brook Watershed. A narrow sliver of its outcrop area falls within the watershed in the southeastern section, covering only eight percent of the watershed (Figure 8, and USGS, 1995). Composition ranges from coarse-grained arkosic sandstone to mudstone, siltstone, and shale. Maximum thickness of the formation in New Jersey is 4,000 feet. The Stockton sandstone is a good building material and was a major source of the brownstone used in the construction of regional historic homes as well as urban row housing in metropolitan New York in the nineteenth century. Nassau Hall at Princeton University used local sandstone and the Joseph Stout house may also be constructed of Stockton sandstone from central New Jersey (Coastal Environmental Services Inc., 1995; Hunter and Porter, 1990).

Lockatong Formation (Upper Triassic): The Lockatong Formation is composed of dark gray and reddish-brown beds of siltstone and shale with minor amounts of fine-grained sandstone. A wedge of this outcrop, covering 27% of the watershed, lies just north of the Stockton Formation. Many of the siltstone and sandstone beds are extremely hard, chemically cemented siltstone and sandstone (argillite). Rocks of the Lockatong Formation are generally more resistant to erosion than are adjacent units and therefore form ridges, such as the face of the Sourland Mountains (Rogers, Golden, and Halpern, 1984) (Figure 2). Used less frequently than the Stockton sandstone, this argillite has been used as building stone most often in farmhouse outbuildings. Prehistoric people used this type of rock when manufacturing tools, such as arrowheads.

Passaic Formation (Late Triassic and Early Jurassic): The Passaic Formation consists of reddish brown, thin-bedded to thick-bedded shale, siltstone, and very fine-grained to coarse-grained sandstone. In addition, some zones of dark gray siltstone are present, similar to those of the underlying Lockatong Formation (USGS, 1995). The Passaic Formation is part of the Brunswick Group, which consists typically of red shale with local beds of fine-grained red sandstone; siltstone; and black, gray, or greenish shale. The Brunswick shale contains rare reptile footprints as well as

fossil remains of plants and bony fishes (Hunter and Porter, 1990; Rogers, Golden, and Halpern, 1995).

Passaic Formation Gray Bed: In some areas, contemporaneous gray lake deposits are distinct from other portions of the Passaic Formation, and therefore are mapped as a subunit of this formation as ‘gray bed’ (Figure 8). These gray lake deposits are comprised of gray to black silty mudstones, gray and greenish to purplish-gray argillaceous siltstones, black shale, and gray argillaceous fine-grained sandstones (Mulhall, 2004). Combined, the Passaic Formation and the subunit of gray lakebeds are encountered beneath approximately 1267.6 acres or nearly 22% of the Heathcote Brook Watershed.

Jurassic Diabase: The igneous diabase (trap rock) is a fine-grained to coarse-grained, dark gray to black igneous rock, which has intruded between the beds of the Newark Supergroup sediments. It is extremely hard and resistant to weathering. Forming topographic highs and ridges, the diabase is found, for example, at the top of the Sourland Mountains and is known as the Princeton Ridge (Rogers, Golden, and Halpern, 1995). In the Heathcote Brook Watershed this can be seen running east to west in the upper half (Figure 2) and covers 29% of the watershed.

Magothy Formation (Upper Cretaceous): The sediments of the Magothy are fine- to coarse-grained, locally gravelly, quartz sand, interbedded with thin layers of clay or clay-silt, mostly at the top of the Formation. Minor amounts of muscovite and feldspar occur in the sand, and large wood fragments are found in the clay layers. The Magothy occurs at the surface in the uppermost (northern) portion of the Heathcote Brook Watershed and covers 14% of that area. The sands of the Magothy Formation, together with the usually contiguous Raritan and Potomac Formations seen farther to the southeast in the Millstone watershed, serve as an extensive and regionally very important aquifer system. The Magothy Formation is one of the most vital groundwater resources within the Millstone Watershed and Central New Jersey as well as one of the most susceptible to groundwater contamination because of its widespread exposure, the high sand content, and likely thickness of 60 feet or more (Mulhall, 2004). This formation has the highest average yield from high capacity wells of greater than 500 gal/min (Figure 9).

ASSESSMENT

The geologic formations of the Heathcote Brook Watershed follow the nature of those found in the Piedmont Physiographic Province. Rock formations exert an influence on soils and therefore on vegetation and agriculture, drainage, water transportation, water supply, and types of land use. Due to the variable resistance to erosion exhibited by the sedimentary rock formations in the Watershed, stream patterns and topography are controlled by outcrop patterns and the orientation of the underlying bedrock.

GEOLOGY

Therefore, geology should be one of the tools used when making municipal policy decisions about development and related stormwater issues, water supply, etc.

The geology of Heathcote Brook Watershed is directly related to water supply and the aquifer systems (Figures 8 and 9). Heathcote Brook is within the Northwest New Jersey Sole Source Aquifer (Mulhall, 2004; see Water Supply Section for more information). NJDEP and US EPA consider groundwater to be the primary source of drinking water within designated sole source aquifers and indicate that measures should be taken to protect these critical resources. The Magothy Formation is part of the high yielding Potomac-Raritan-Magothy Aquifer system. Since this aquifer is so susceptible to groundwater contamination because of its widespread exposure and high sand content, its outcrop area should be prioritized for protection. The Passaic and Stockton Formations have a lower average yield; the Lockatong Formation's yield is even lower; and the Jurassic Diabase has the lowest yield (see Water Supply section and Figure 9).

GEOLOGY

SOILS

The soils that underlay a watershed exert an influence on the types of vegetation that grow, agriculture that can be performed, drainage patterns, water transportation, water supply, and types of suitable land use, including appropriate locations for septic systems.

Soils are classified based upon their textures, composition, and ability to drain water. Soil surveys that have been performed and mapped by the U.S. Department of Agriculture's (USDA) Natural Resource Conservation Service (NRCS) found seven soil associations that underlie the Heathcote Brook Watershed (Figure 10). The Penn-Reaville-Klinesville series underlies a small portion in the northeastern tip of the watershed; the Downer-Sassafras-Hammonton series is seen in both the northeastern part of the watershed and a small portion in the southern end. The most extensive soil series, the Hammonton-Woodstown-Mullica series, consists of a diagonal band from the northeast to the southwest. Seen just north of this in another diagonal band is the Pocomoke-Sulfaquents-Manahawkin series, the second most extensive soil series in the Heathcote Brook Watershed. The Neshaminy-Mount Lucas-Lawrenceville series exists in the northwestern tip of the watershed. The Rowland-Pope-Birdsboro series underlies the southwestern edge, while the Matapex-Matapeake-Chillum series is seen in a small portion of the southeastern edge of the watershed (New Jersey Water Supply Authority, 2000a).

HYDROLOGIC SOIL GROUPS

Based upon their various compositions, soil series have varying degrees to which they can be infiltrated by water. Their ability to drain water, especially from precipitation, is evaluated and reported as the hydrologic soil group. Much of the Heathcote Brook Watershed is classified as hydrologic soil group C, covering 3,001.4 acres out of a total of 5,854.7 acres (51.3%) in the entire watershed (Figure 11). Hydrologic soil group C represents soils with a slow infiltration rate and, therefore, a high surface-water runoff rate and is representative of the moderately fine-textured soils seen in the Piedmont Physiographic Province. This hydrologic soil group underlies much of South Brunswick and Franklin Townships in the Heathcote Brook Watershed (Figure 11).

The second most common hydrologic soil group in the Heathcote Brook Watershed is group B, representing moderate infiltration rates and moderate runoff rates (Figure 11). Approximately 28% of the watershed, or 1,655 acres, is underlain by hydrologic soil group B with moderately coarse-textured soils. Agricultural areas tend to be underlain by group B soils. The hydrologic soils in group B are found primarily along the southeast and southwest borders of the Heathcote Brook Watershed and do coincide with current or past agricultural areas (Figure 11).

Hydrologic soil group D underlies 12 % of the watershed, or 699 acres. This soil group is found primarily as streambeds and wetlands in the Heathcote Brook Watershed (Figure 11). Category D

soil groups have very slow infiltration rates and very high runoff rates since most of these soils are clayey or have an impervious layer near the surface.

Only about 56 acres, or almost 1% of the watershed, are underlain by hydrologic soil group A. This area has high infiltration and low runoff rates due to its characteristic gravelly and sandy soils. There are two small sections containing group A soils in the northeastern section of the Heathcote Brook Watershed. The majority of both of these areas has been developed and is most likely paved over (Figures 11 and 14). According to 2002 Land Use/Land Cover data, 31.5 acres, or 56.1%, of the area underlain by group A soils is urban. Of this, 7.5 acres, or 13.4%, is impervious surface.

SOIL ERODIBILITY

Soil erodibility is affected by both the susceptibility of soil to erosion and the runoff rate. It largely depends on soil structure and the amount of related vegetation or organic material. Maintaining good soil structure will help to build healthy soils and reduce the detachability of soil particles via erosion. Maintaining this structure through soil management practices is an important component to prevent soil erosion, improve water management, encourage plant growth, and improve water quality on farms and developed areas.

The erodibility is based upon the ‘K-factor,’ a measure of bare surface soil erosion. Different soils are given different K-factors based upon land use, an area’s slope, and distance to the nearest stream (Maryland Department of Natural Resources, 2001). The higher the soil’s K-factor is, the higher its erodibility. Almost all of the soils in the Heathcote Brook Watershed are classified as having medium to high erodibility (Figure 12). Highly erodible soils represent 64.8% (3,795.9 acres) of the Heathcote Brook Watershed and are found in the southeast and northwest portions, including along one of the headwater tributaries that feeds Heathcote Brook. Much of the mainstem and most of Carters Brook flow through moderately erodible soils (Figure 12).

Areas with the highest K-factor would benefit the most from riparian buffer reforestations and other best management practices geared towards anchoring the soils. The majority of agricultural areas within the Heathcote Brook Watershed are located on highly erodible soils (Figures 12 and 14). The Conservation Reserve Enhancement Program and other Natural Resource Conservation Service programs are targeted to assist farmers in implementing soil conservation practices on their farms. These highly erodible lands are also most affected by urban activities such as construction.

SEPTIC SUITABILITY

Another aspect of soils is their ability to support on-site septic systems to drain wastes: their septic suitability. Septic suitability determines whether or not septic systems are suitable for an area and which types of septic systems

are appropriate, based upon the characteristics and properties of soils in an area. Each soil type is categorized by a “suitability class” delineated by the USDA. The suitability class is calculated by combining how severely the soil type restricts a septic system’s functions with the depth where that soil type occurs (NJDEP, 1999). The septic suitability needs to be considered when determining whether or not a septic system is a viable option for new residential areas. The major limiting factors of septic suitability are based on the fact that the underlying soil may percolate too slowly or not at all, which lowers the capacity of a residential septic system to perform properly (NJDEP, 1999).

In order to function efficiently, a traditional septic system’s tank collects wastewater from bathrooms, kitchens, and laundry rooms. Water is held in the tank so that solids can separate from the liquid portion of the wastewater. The heavier solids sink to the bottom as sludge. Anaerobic (not requiring oxygen) bacteria break down the sludge and turn it into liquid waste. However, since the sludge may accumulate faster than the bacteria are capable of breaking it down, the sludge can eventually accumulate and fill up the tank, requiring a pump-out every two or three years depending on how heavily the system is used (SBMWA, 2002). The liquid waste then flows out of the tank and into a drainfield where it flows through a gravel bed. As the water slowly trickles through the soil, the processes of filtration and biological degradation by organisms in the soil remove toxic substances, bacteria, viruses, and other pollutants. The water then slowly makes its way to recharge the groundwater (SBMWA, 2002).

In the Heathcote Brook Watershed, there are many areas that are considered unsuitable for the placement of traditional septic systems due to geology and soils (Figure 13). These areas are found mainly in two major bands running northeast to southwest in the upper and central portions of the watershed. Many other areas within the Heathcote Brook Watershed are suitable for conventional or mound septic systems (Figure 13). Mound septic systems are tanks installed above ground, which are covered with fill (NJDEP, 1999).

All but a small portion of the Heathcote Brook Watershed, the northwest corner, is designated for sewer service areas (Figure 13). Sewer service areas are those portions of a municipality that are designated for the installation of sewer lines and connections to a sewage treatment plant/facility. These areas are a key determinant to the amount, location, and intensity of development. Figure 13 also shows where current sewer lines exist in South Brunswick, the largest township within the Heathcote Brook Watershed. Presumably septic systems occur in the remaining area, much of which is considered unsuitable for such systems.

Of the portion currently not designated for sewer service, almost all of Franklin Township’s portion within the Heathcote Brook Watershed, much of it is unsuitable for septic installation. According to the USDA, there are a

SOILS


few, small, scattered areas suitable for mound septic systems and a few suitable for conventional septic systems (Figure 13).

ASSESSMENT

The characteristics of the soils in the Heathcote Brook Watershed are aligned to their overall composition in the Piedmont (see Geology section for more detail). The majority of these soils is moderately fine-textured and infiltrates water into the subsurface at a slow rate. Because of this slow rate of water infiltration, much of the water that lands on the watershed enters the streams as runoff. Stormwater management in the Heathcote Brook Watershed is an extremely important tool for dealing with this runoff. Because municipalities rely on their local Soil Conservation Districts (SCDs) to enforce the sediment and soil management regulations, SCDs need to be aware of a site's soil characteristics when they review and enforce plans to control and manage soils during construction activities.

Almost all of the Heathcote Brook Watershed is categorized as having high to medium erodibility. Highly erodible soils may increase sediment loads to streams during storm or flood events. As indicated by the visual assessment data and observations during the biological assessments (see the Water Quality section for more details), this is already happening in the Heathcote Brook Watershed. Smothering of aquatic macroinvertebrate habitat and subsequent loss of biological diversity, clogging of fish gills, and reducing plant productivity by reducing sunlight availability, are impacts to streams experiencing heavy sedimentation.

The extensive sewer service areas that cover the Heathcote Brook Watershed increase the potential for development to occur if it has not occurred already. South Brunswick could prioritize the next phase of sewer line installation in those areas that are not suitable for septic and preserve the lands in acceptable septic areas. This would concentrate development in non-septic areas. Maintaining current septic areas as such would also reduce potential for development and could also help preserve critical habitats.



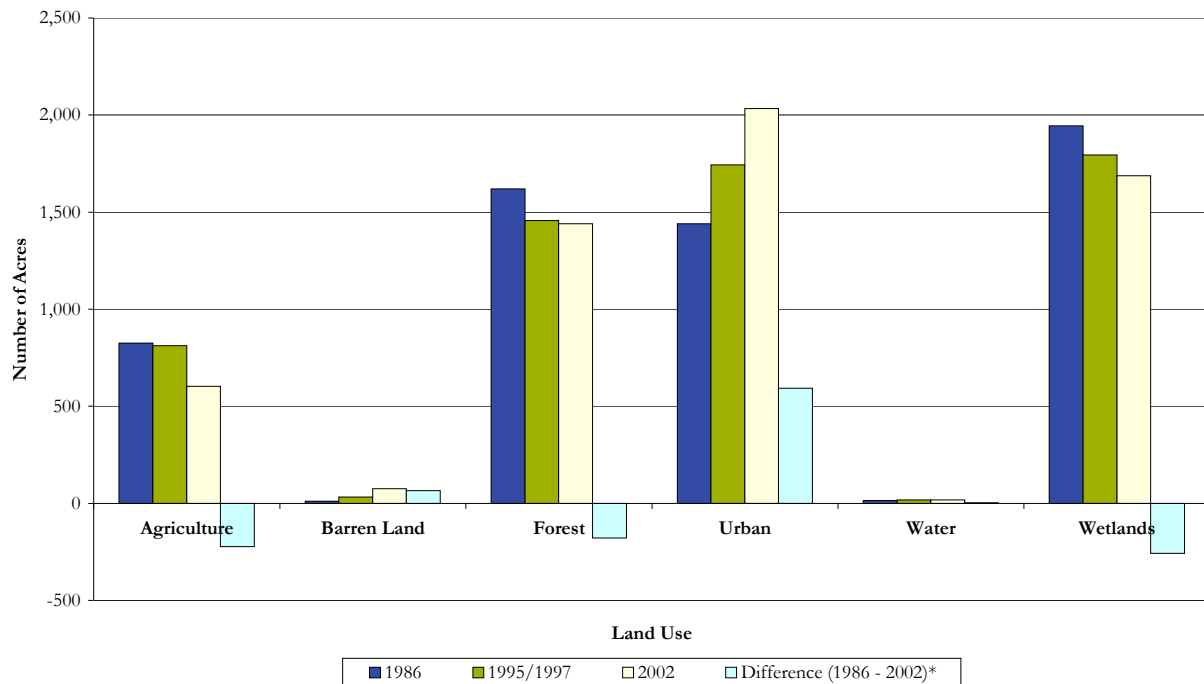
SOILS

LAND USE

Populations in the Heathcote Brook Watershed are on the rise, and corresponding residential areas and necessary infrastructure continue to be built to accommodate this increasing population. These changes are reflected in the different land use categories between 1986, 1995/97, and 2002 (Graphs 4 and 5). Land use was interpreted from photographs taken during flyovers of the State in 1986, 1995/97, and again in 2002. Heathcote Brook Watershed land use observed in the 2002 flyover is shown in Figure 14.

The information for land use comes from the NJDEP land use/land cover data from 1986, 1995/97, and 2002, but much development has occurred within the last five years. Forest, agriculture, urban/developed land, and wetlands will be discussed in more detail, as they make up the majority of land use in the Watershed. The remainder of land use in the Watershed is made up of either water (16.9 acres, or 0.23 % of Heathcote Brook Watershed) in the form of streams, lakes, ponds, reservoirs, and other water bodies; or barren lands (areas characterized by thin soil, sand, or rocks and a lack of vegetative cover in a non-urban setting; 75.1 acres or 1.3% of the Heathcote Brook Watershed) as developing land quarries and mines (Graphs 4 and 5).

Graph 4: Changes in acreage of land uses in the Heathcote Brook Watershed from 1986 to 2002.

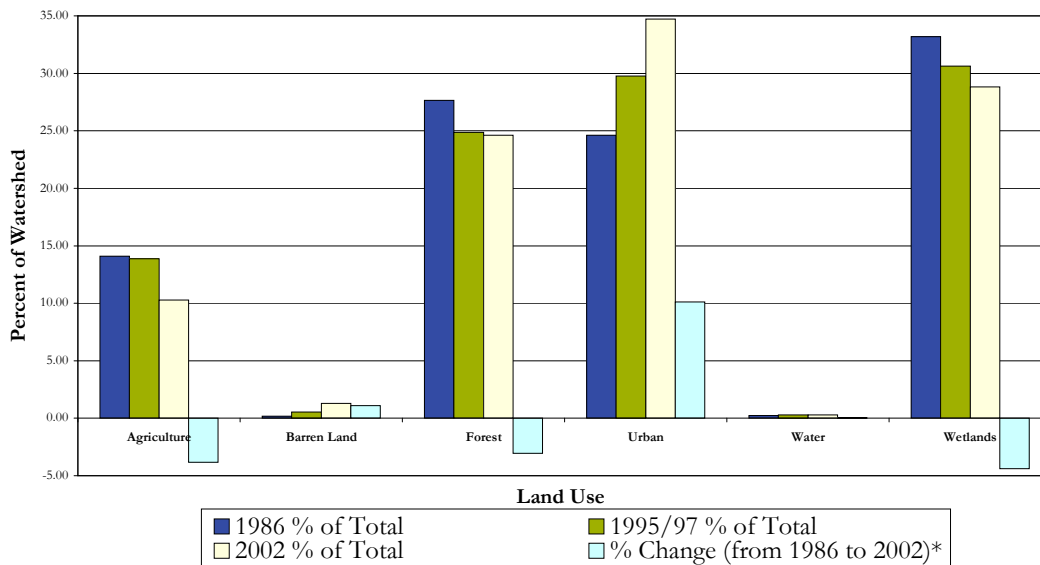


Source: NJDEP Land Use/Land Cover Data 1986, 1995, and 2002.

*Negative numbers represent a loss in acreage while positive numbers represent a gain in acreage.

In the Heathcote Brook Watershed, land use has changed substantially in the years between 1986 and 2002. There has been a gain in urban area and losses of agricultural lands, forest, and wetlands (Figure 15). Between 1986 and 2002 the landscape draining to Heathcote Brook has changed not only due to shifts in the land use, but also from increases in population and local preservation efforts. For example, Franklin Township preserved two pieces of property (the Lincoln Grove Preserve and John Flemer Preserve) during this time period with the help of the New Jersey Natural Lands Trust. To accommodate the increasing population, forests, wetlands, and agricultural lands are being developed to provide housing and services for new residents. The changes in land use were a loss of 338.2 acres for any land use between 1986 and 1995/97, with 98.9% being contributed by forests, wetlands, and agricultural lands. Between 1995/97 and 2002, 319.4 acres were developed, 90% of which had been forest, wetlands, and agricultural areas. The total loss to development between 1986 and 2002 was 657.6 acres, 94.6% previously consisting of forests, wetlands, and agricultural lands.

Graph 5: Changes in percent of total watershed area of land uses in the Heathcote Brook Watershed from 1986 to 1995 to 2002.



Source: NJDEP Land Use/Land Cover Data 1986, 1995, and 2002.

*Negative percent changes represent a loss in acreage while positive numbers represent a gain in acreage.

FORESTS

Forests improve water quality by filtering pollutants, reducing flooding by slowing stormwater, and providing habitat to a variety of plant and animal species. It has been shown that the best predictor of the presence of an

unimpaired benthic macroinvertebrate community is the total area of forested land located upstream of a sampling site (USGS, 1998).

In 1986, the largest land use category within the Heathcote Brook Watershed was forested lands. In both 1995/97 and 2002, the amount of forested lands in the Watershed was exceeded by urban development. The rate of loss of forest and wetlands to development has slowed over time, yet the overall loss is significant. Between 1986 and 2002, 17.5%, or 284 acres, of forest in the Heathcote Brook Watershed were lost to development. In 1986, 27.6%, or 1619.2 acres, of land in the Heathcote Brook Watershed were forested. In 2002, 24.6%, or 1440.5 acres, of land in the Heathcote Brook Watershed were forested (Graphs 4 and 5). Forested lands are found throughout the Watershed (Figure 14).

AGRICULTURE

In 1986, 14.1%, or 825.9 acres, of the Heathcote Brook Watershed was agricultural lands. According to 2002 data, 10.3%, or 601.9 acres, of land in the Heathcote Brook Watershed was used for agriculture. This represents a loss of over 27% of available agricultural lands in the Heathcote Brook Watershed over a 16-year period (Graphs 4 and 5).

The rate of loss of agricultural lands to urban development has increased over time with 26.1 acres of agricultural lands lost between 1986 and 1995/97, and 74.8 acres of remaining agricultural lands lost between 1995/97 and 2002 (Graph 4). The loss of agricultural lands, as well as the remaining parcels, is particularly concentrated in the southwestern portion of South Brunswick Township. Many of the remaining agricultural lands are located near streams and wetlands, probably used to irrigate the crops or water livestock on many of the regions farms. However, the remaining agricultural lands have become fragmented and much of this land is also adjacent to urban development (Figure 14).

According to the 2002 Land Use data, the majority of agricultural lands in the Heathcote Brook Watershed are considered crop and pasture lands, consisting of 480.7 acres, or 79.9% of the total agriculture acreage. Most of the remaining lands are characterized as orchard/vineyard/nursery/horticultural areas with 104.0 acres, or 17.3%.

URBAN/DEVELOPED

In 2002, urban development was the largest land use category in the Heathcote Brook watershed. Approximately 34.7% of the Heathcote Brook Watershed, or 2033.6 acres, consists of urban areas that provide residential, recreational, commercial, and industrial uses (Graph 4 and Figure 16). This is a gain of more than 41% from 1986, when there were 1440.6 acres of urban land in the Heathcote Brook Watershed. Urban development has occurred at a steady, even pace with a 21% gain occurring between 1986 and

1995/97 (9-11 years) and a 20% gain occurring between 1995/97 and 2002 (7-9 years). Urban development occurred throughout the Watershed.

Development occurs at the expense of other land uses. In the Heathcote Brook Watershed there has been a gain in urban area and losses of forest, wetlands, and agricultural lands (Figure 15). Between 1986 and 1995/1997, 338.2 acres were developed. Of this amount, 161.7 acres, or 47.8%, were converted from forested areas and 146.6 acres, or 43.4%, were converted from wetland areas. Although development in wetlands is regulated and often prohibited, minor wetland disturbances (less than 0.25 acres) are allowed through NJDEP approval of general permits. These wetland disturbances cover activities such as road crossings, dam repair, and stormwater outfall structures and do not require mitigation, or the creation of new wetland areas (with the exception of general permits approved for underground utility lines, hazardous site investigation and cleanup, landfill closures, and redevelopment of previously disturbed areas). In addition, the New Jersey Freshwater Wetlands Protection Act went into effect in July 1988. Prior to this, wetland disturbances were only regulated by the federal government, which allowed up to one acre of disturbance without mitigation. These factors most likely account for the 146.6 acres of wetland areas lost to development. Only 26.1 acres, or 7.7%, were originally considered agricultural. Between 1995/1997 and 2002, 319.4 additional acres were developed. These newly urban areas had previously been considered forest (122.4 acres, or 38.3% of the converted acreage), wetlands (90.4 acres or 28.3%), and agriculture (74.7 acres or 23.4%).

The majority of the urban/developed land is classified as low density, single unit residential neighborhoods (Figure 16) and is found mainly in the Kingston, Monmouth Junction/South Brunswick Terrace areas, and between Route 1 and Route 27 in the central portion of the watershed. These areas are typified by residences on lots between ½ acre and 1 acre in size; this category is generally characterized by impervious coverage around 20-25% (USGS, 1976).

The next most abundant type of urban/developed lands are the residential, medium density, single unit developed areas (Figure 16). These are found mainly between Routes 1 and 27 and in the Monmouth Junction/South Brunswick Terrace areas. This classification contains single units on lots sized between 1/6 acre and ½ acre, which is characterized by around 30-35% impervious coverage (USGS, 1976).

Rural, single unit residential areas are mainly scattered along Route 27 and Ridge Road (Figure 16). This category contains single unit neighborhoods built on lots from one to two acres in size. These areas generally consist of impervious surface areas of about 15-20% or less (USGS, 1976). Also of note is the industrial/commercial complexes land use, unsurprisingly found mainly along Routes 1 and 27 as well as along Ridge Road for the purposes of transporting goods and services (Figure 16). This category is defined as

LAND USE

consisting of major transportation routes, utilities such as sewage treatment plants and power lines, power substations, and communication facilities and are generally considered to have a high percentage of impervious surface coverage (USGS, 1976).

The Heathcote Brook Watershed is situated as a major aquifer recharge area for the Potomac-Raritan-Magothy, Brunswick, and Stockton Formation aquifers, as discussed in the Water Supply section of this report and shown in Figure 9. Approximately 44.8% of the Heathcote Brook Watershed, or 2621 acres, are in high groundwater recharge areas (Figure 17). However as of 2002, 32.6% of the high groundwater recharge areas, or 855.7 acres, have been developed, mainly in South Brunswick Township. This is an increase from 24.3% of the high groundwater recharge areas, or 636.9 developed acres, in 1986. Within areas of high groundwater recharge, the increase in urban acreage seems to have come at the expense of agricultural lands. Agricultural acreage, as a percentage of the land use within high groundwater recharge areas, fell from about 30% in 1986 to 22% in 2002. Forested lands, on the other hand, have remained steady, consisting of 40-42% of the high groundwater recharge acreage.

WETLANDS

Wetlands are areas inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted to saturated soil conditions (U.S. Army Corps of Engineers, 1987). Wetlands vary widely because of regional and geographic differences in soil types and climate, and therefore have a variety of essential functions and values associated with their roles in the environment. Water quality is improved as wetlands filter excessive nutrients, sediment, and other pollutants through abundant plant life and help reduce flooding and storm surges by acting as natural retention basins. Wetlands are also excellent nurseries for a variety of wildlife, since wetlands process nutrients efficiently and retain those nutrients. These nutrients become essential building blocks for wildlife and vegetation.

Of the 5854.7 acres in the Heathcote Brook Watershed, 1686.8 acres were wetlands according to 2002 data, representing 28.8% of the entire Watershed (Graphs 4 and 5, Figure 14). However, more than 257.2 acres, or over 13%, of available wetlands in the Heathcote Brook Watershed have been lost since 1986. Most of the wetlands lost since 1986, approximately 237 acres, has been due to urban development. Wooded wetlands account for over 84% of the wetlands in the Heathcote Brook Watershed, or 1414.5 acres. Deciduous wooded wetlands are common in the northeastern United States and provide habitat for many critically important species of wildlife. Deciduous wooded wetlands are dominated by species of trees such as red maple (*Acer rubrum*), black willow (*Salix nigra*), swamp oak (*Quercus bicolor*), and sweetgum (*Liquidambar styraciflua*). The next most abundant wetland type is

scrub/shrub wetlands; however this only accounts for 3.6% of the total, or 60.7 acres. In descending order of abundance from there, the Heathcote Brook Watershed also has minimal amounts of managed wetlands (3.5%), wetland rights-of-way (3.5%), disturbed wetlands (2.9%), agricultural wetlands (2.1%), and a minuscule amount of herbaceous wetlands (0.3%).

The majority of the wooded wetlands found in Heathcote Brook Watershed are found in South Brunswick and Franklin, mainly along the mainstem of Heathcote Brook, as well as the unnamed tributary and Carters Brook (Figure 14). The location of these areas is critical to maintaining healthy streams in the Watershed, as forested wetlands are important collection and treatment areas for polluted runoff. Many studies have determined the effectiveness of the riparian forests or buffers in improving water quality:

- ◆ A 50-meter wide riparian forest buffer in an agricultural watershed of the Chesapeake Bay removed about 89% of the nitrogen that entered the forest from runoff (Peterjohn and Correll, 1984).
- ◆ Riparian forests can reduce phosphate levels in runoff and floodwater by 50% (Gilliam, 1994).
- ◆ A forested wetland overlaying permeable soil may infiltrate up to 100,000 gallons of water per acre per day (Anderson and Rockel, 1991).

IMPERVIOUS COVER

Impervious cover is any surface that prohibits the movement of water from the land surface into the underlying soil. Buildings, paved surfaces (such as driveways, roofs, roads, airport tarmacs, cement walkways), exposed bedrock, and even severely compacted soils and lawns are considered impervious.

An increase in impervious surfaces in a watershed interferes with the natural flow of water into aquifers and local water bodies. Areas that are impervious could prevent the percolation of water into aquifers and can impair local groundwater resources by decreasing recharge. Impervious surfaces could also increase the amount of stormwater runoff, which increases the frequency and intensity of local stream flooding. Because this stormwater runs directly into streams, often with no filtration through a streamside buffer, these floods can cause accelerated erosion. Since water does not have time to percolate into the soil naturally, substances carried by the runoff get carried to streams and lakes and contribute to water quality degradation. Research has shown that stream ecosystems and water quality degrade as the amount of impervious surface within an area increases (Center for Watershed Protection, 1998). The first limit to impervious cover appears at approximately 10%, where sensitive elements are lost from stream systems. A second limit appears at approximately 25% impervious cover, where there is a shift to poor stream conditions that include diminished aquatic diversity, water quality, and habitat functioning (Center for Watershed Protection, 1998). Several studies show stream stability, habitat quality,

macroinvertebrate biodiversity, fish abundance and diversity, and wetland plants and amphibians are all compromised at 10-15% imperviousness (Schueler and Holland, 2000).

Based on the 2002 Land Use coverage, Heathcote Brook Watershed has an average impervious cover of 12.9%, or 753.7 acres. But specific areas are covered in much higher amounts, suggesting some water quality degradation (Figure 19). Many impervious areas are rated at 26% or higher for lands in this region. This shows that those areas with over 25% impervious surface are highly developed and could be contributing to water quality problems as the Heathcote Brook flows into the Millstone River.

In general, all areas with over 25% impervious coverage coincide with the urban/developed land areas (Figures 16 and 19) and are congregated close to the Route 1 and Route 27 corridors. It is not surprising that the areas rated as having 76-100% impervious coverage are nearly all located on the transport/utility and industrial/commercial complexes land uses.

It should be noted that NJDEP has identified Heathcote Brook, Carters Brook, and an unnamed tributary as candidates for designation as Category 1 (C1) waterways (NJDEP, 2006b). The basis for these nominations is that the lands surrounding waterways have less than 10% impervious cover or the waterways are located within protected NJ State open space. C1-designated waterways are afforded a higher level of protection from development. If the NJDEP accepts these nominations, the State anti-degradation policies and a proposed 300-foot buffer will protect these tributaries:

- ◆ The anti-degradation policies assure that water quality is maintained at a level necessary to protect the intended use of the waters, and establishes more protective criteria for any new or expanded discharges to these waters.
- ◆ NJDEP requires a 300-foot setback buffer on either side of the stream to protect C1 waters. This is included in the new Stormwater rules (NJAC 7:8-5.5h).

The 300-foot buffer along C1 waters will decrease the amount of impervious cover adjacent to streams; minimize impacts from stormwater runoff; provide floodwater storage, erosion control, and groundwater recharge; and maintain biological habitats and diversity.

RIPARIAN CORRIDORS

Of special note are riparian corridors, which are vegetated areas that lie along the sides of streams. These areas are usually transitional zones between wetland and upland areas and are generally comprised of grasses, shrubs, trees, or a mix of vegetation types. Riparian corridors can be found in agricultural, forested, suburban, and urban landscapes. These areas are the first and last lines of defense for the streams they surround in terms of

nonpoint source pollution control. When left as natural areas, riparian corridors provide erosion control by plant root growth, stormwater control by slowing water flow, and habitat for many species of plants and animals. Land use changes to these areas have the most detrimental effects on water quality.

In the Heathcote Brook Watershed, the riparian area is based on the width of the 100-year flood prone areas, streamside hydric soils, streamside wetlands and associated transition areas, and a 150-foot or 300-foot wildlife passage corridor, depending on stream order (Figure 20) (New Jersey Water Supply Authority, 2000b). Many of these lands have undergone conversion from one land use category to another between 1986 and 2002 (Figure 21). Originally riparian areas totaled 2756.1 acres, or 47% of the Heathcote Brook Watershed. By 1986, 393.7 acres had been converted to urban areas (316.6 acres) and agricultural areas (77.1 acres). Of the remaining 2362.4 acres of riparian area, 224.5 acres (or 9.5%) had been converted to urban areas between 1986 and 2002 and only about 2 acres (or 0.08%) were changed to agricultural land use. As of 2002, the remaining riparian areas totaled 2135.9 acres or only 36.5% of the Watershed. While most of this area is composed of wetlands (1669.7 acres or 78.2%), the rest is made up of forested areas (447.7 acres or 21.0%), and water (only 16.8 acres or 0.8%, Figure 20). The riparian wetland area is mainly made up of forested wetlands (1465.9 acres or 87.8% of the riparian wetlands).

PLANNING AREAS

The New Jersey State Development and Redevelopment Plan has established planning areas throughout the State designated for a variety of uses (New Jersey State Planning Commission, 2001). Several of these planning areas (PAs) are designed to limit growth of development and preserve historical, cultural, and environmental resources.

In the Heathcote Brook Watershed, PA4 (Rural), PA4b (Rural-Environmentally Sensitive), PA5 (Environmentally Sensitive), and PA8 (State Park) lands are found throughout the entire portion of Franklin Township contained within the Watershed and in a small area along the mainstem of Heathcote Brook and Carters Brook in South Brunswick Township (Figure 22).

The majority of the lands in these PAs are wetlands, forest, and agricultural lands (Figure 22). Current Federal and State regulations restrict development in wetlands. Wetlands and forested areas have been more prone to development than other land uses within the Heathcote Brook Watershed (Graph 4, Graph 5, and Figure 15). Agricultural and forested areas in these PAs are also located within high groundwater recharge areas (see Water Supply section and Figure 17) and most of those areas also contain critical habitats (Figure 4). Therefore, these areas become vital to protecting threatened and endangered species and potential drinking water supplies.

The rest of South Brunswick Township and the entirety of Plainsboro Township within the Heathcote Brook Watershed consist of State Planning Areas PA 1 (Metropolitan Planning), PA2 (Suburban Planning), and PA3 (Fringe Planning) (Figure 23). These planning areas are designated for growth and provide areas for redevelopment and future development. PA3 aims to accommodate growth in centers and provide buffers to the rural and environmentally sensitive planning areas.

ASSESSMENT

Land use changes constantly reflect the needs of the municipality. As more residents move into an area, more homes and infrastructure are needed to provide basic services to those residents. This is reflected in both the increasing population in the Heathcote Brook Watershed and the increasing developed areas from 1986 to 2002 (Figure 15). Many of the newly developed areas are being placed on forested lands (43%), wetlands (36%), and agricultural lands (15%). Water quality becomes a concern for the urbanizing regions in the Heathcote Brook Watershed because of the increase in impervious cover. Decreasing the rate of conversion of forest, wetlands, and agricultural lands, and protecting stream corridors and riparian areas becomes increasingly important for water quality protection.

Increases in the amount of impervious cover in the Heathcote Brook Watershed result from this increasing urbanization. This has the effect of decreasing biological diversity in nearby streams, increasing the frequency of flooding, and decreasing the amount of water recharging the groundwater supply. Placement of new development, and therefore impervious cover, out of areas that have high value for recharging groundwater supplies will help to maintain water levels for drinking, irrigation, and industrial use (see Water Supply section for more details). Prioritizing open space acquisition with consideration of high recharge area attributes will also help maintain groundwater levels. These strategies should be used in conjunction with water conservation education programs to proactively protect water supplies.

Studies show that limiting the amount of impervious cover alone will not benefit water quality. Maintenance of an adequate forest in conjunction with reduced impervious cover will help to keep aquatic biological populations healthy (USGS, 1998). Maintaining impervious cover below 10% and forest cover at least at 65% has been shown to preserve water quality (Center for Watershed Protection, 2003). With forest cover in the Heathcote Brook Watershed at 24.6% in 2002, efforts to reforest portions of the region should be a priority. And with the average 2002 impervious cover totaling 12.9% in the Watershed, efforts to reduce existing, and limit planned, impervious cover through low impact development and redevelopment is crucial.

Riparian corridors are being increasingly encroached upon by urban areas in the Heathcote Brook Watershed (Figure 21). These areas are particularly sensitive to change, as they are the natural buffers that protect the stream itself from a variety of pollution sources. Placement of new construction in the Watershed needs to be sensitive to, or avoid altogether, the riparian corridors in order to maintain ecological integrity. On the positive side, most of the riparian corridor (78.2%) is made up of wetlands (Figure 20). These wetland areas are already largely under development protection, and South Brunswick Township, which has enacted a stream corridor ordinance, and Franklin Township, which includes stream corridor protection language in their land use ordinance, have protections in place to control further development in riparian areas. It is important that these Townships uphold the integrity of each of these ordinances to prevent further degradation. Acceptance by the NJDEP of the nomination of Heathcote Brook and its tributaries as C1 waterways will also aid in protecting these corridors.

NJDEP also recently adopted new Flood Hazard Area Control Act Rules (N.J.A.C 7:13). These rules outline the standards for development in riparian areas adjacent to surface waters throughout New Jersey. NJDEP has adopted these new rules to better protect the public from flooding hazards, preserve the quality of surface waters, and protect the wildlife and vegetation that depend upon riparian habitats. The rules establish that all streams must have either a 50, 150, or 300-foot buffer depending on their classification.

Areas within the Heathcote Brook Watershed have been planned for limited growth (Figure 22). These areas contain mostly wetlands, forest, and agricultural lands. Since the agricultural and forested areas in the Heathcote Brook Watershed are located within high groundwater recharge areas (see Water Supply section) and most of those areas also contain critical habitats, these lands should be targeted as a high priority for preservation (Figures 4 and 18). Agricultural areas could be preserved through farmland preservation programs. The preservation of these areas will benefit the habitats needed for threatened and endangered species as well as increase the amount of water reaching drinking water supplies (see Landscape and Water Supply sections).

LAND USE

WATER SUPPLY

Water is a necessary component for life on Earth. Aquatic ecosystems, however, are competing for the very resource that forms the basis of their existence. Multiple uses of water for agricultural irrigation, recreational fishing and boating, and commercial industrial uses have severely strained a resource that cannot be easily replenished. Less than three percent of all water on the planet is fresh water and less than 15% of that is available in surface and groundwater (USGS, 1999).

Watersheds are not comprised of surface water alone. The groundwater present in the pore spaces of soil and rock is an important component of the watershed. In fact, groundwater is New Jersey's major source of potable water (NJDEP, 2005a). Evaluating the health of one aspect alone presents a partial picture of the true quality of water in an area.

AQUIFERS

USEPA has designated two sole source aquifers in the Millstone Watershed. The Northwest New Jersey Sole Source Aquifer extends across the northwestern portion of the Millstone Watershed and coincides with the Piedmont Physiographic Province; the Coastal Plain Sole Source Aquifer, coinciding with the Coastal Plain Physiographic Province, exists in the southeastern portion of the Millstone Watershed (Mulhall, 2004). A sole source aquifer is defined as one that provides more than 50% of the drinking water for that area. The Heathcote Brook Watershed falls entirely within the Northwest New Jersey Sole Source Aquifer where groundwater is stored and transmitted through openings or voids between sediment particles.

The New Jersey Geological Survey (NJGS) has ranked aquifers with respect to their ability to sustain significant water supply wells based on data compiled for high capacity wells throughout New Jersey. Wells with yields (i.e. the measure of the volume of water that can be pumped from a well) in excess of 500 gallons per minute have been installed in aquifers ranked 'A'; those ranked 'B' can sustain wells with yields between 251 and 500 gallons per minute. Wells with yields ranging from 101 to 250 gallons per minute can be found in aquifers ranked 'C', while those ranging from 25 to 100 gallons per minute can be found in 'D' aquifers. The lowest ranked aquifers, 'E' aquifers, can only support wells with demands of less than 25 gallons per minute. The NJGS ranking system for aquifers does not indicate that all wells installed within these aquifer systems are capable of sustaining the yields suggested by their ranking.

There are five aquifers of various rankings within Heathcote Brook Watershed ranging from the 'A' ranked Potomac-Raritan-Magothy Aquifer System to the 'E' ranked Diabase. Not surprisingly, the aquifers essentially coincide with the geologic formations (Figures 8 and 9).

Potomac-Raritan-Magothy Aquifer System:

The sands of the Magothy Formation form the Upper Potomac-Raritan-Magothy (PRM) aquifer and are found in the northern section of the Heathcote Brook Watershed (Figures 8 and 9). Data compiled by Pucci, et al (1989) indicate that the unconsolidated PRM aquifer system beneath the Millstone Watershed has a very high capacity to transmit groundwater as compared to other geologic units found beneath the watershed. Since the PRM aquifer system is capable of supporting very high yielding wells and major water supply systems, NJGS gave it an ‘A’ ranking. With the capability of pumping over 500 gallons per minute, the PRM aquifer is the most prolific in the Heathcote Brook Watershed. Because the Magothy Formation is widely exposed at ground surface in the Millstone Watershed, this aquifer system is highly susceptible to contamination by surface or shallow subsurface discharges (Mulhall, 2004).

Passaic Formation:

The fine-grained sandstones, shales, and thin-bedded siltstones of the Passaic Formation serve as primary water-bearing layers. Massive siltstone beds often confine these layers. In the Passaic Formation, vertical to near vertical joints may interconnect water-bearing layers. In the Heathcote Brook Watershed, the Passaic Formation is contained within the Brunswick Aquifer (Figure 9). The NJGS ranks the Brunswick Aquifer as a ‘C’ aquifer indicating that these rocks have moderate capacity to support major water-supply wells (Mulhall, 2004). ‘C’ Aquifers have an average yield from high capacity wells of 101-250 gal/min.

Well data compiled for Hunterdon and Mercer Counties (Kasabach, 1966; Widmer, 1965) indicate a median yield for the Passaic Formation ranging from 10 to 15 gallons per minute. Based on this data, the Passaic Formation has a significantly greater capacity to transmit water than the Lockatong Formation, but a slightly lower capacity to transmit water than the Stockton Formation. A USGS study (Lewis-Brown, 1995) found that unlike the Stockton Formation, the median yields and median specific capacities for the Passaic Formation are not significantly changed with depth. The results of the USGS assessment for the Passaic Formation indicate that drilling to depths greater than 200 feet most likely will not provide significant additional yield.

Stockton Formation:

The coarse-grained sandstones of the Stockton Formation are primary water-bearing layers, often confined by less permeable siltstones (Lewis-Brown, 1995). USGS studies indicate that the Stockton Formation is one of the higher yielding bedrock aquifer systems in the Millstone Watershed. It is found in the southeastern section of the Heathcote Brook Watershed (Figures 8 and 9). Since the NJGS ranks the Stockton Formation aquifer system as a ‘C’, it is considered to be a good groundwater resource (Mulhall,

2004). Like the Passaic Formation, this 'C' aquifer is capable of pumping 101-250 gallons per minute.

Studies conducted in Mercer and Hunterdon Counties (Widmer, 1965; Kasabach, 1966; Lewis-Brown, 1995) indicate an actual median yield ranging from 12 to 19 gallons per minute for the Stockton Formation. Additionally, the Stockton Formation appears to have a higher capacity to transmit water than other Millstone Watershed bedrock formations. With a probability of intersecting additional water-bearing fractures at depths greater than 100 feet, it has been found that drilling to greater depths can significantly increase ultimate well yields (Mulhall, 2004).

Lockatong Formation:

The Lockatong Formation is found in a wedge just north of the Stockton Formation in the Heathcote Brook Watershed (Figure 9). Consisting of fine-grained siltstone, shale, and sandstone, USGS and other studies have determined the formation is a poor yielding aquifer (Widmer, 1965; Kasabach, 1966; Lewis-Brown, 1995). Ranked as a 'D' aquifer by the NJGS, the Lockatong Formation is considered a poor water resource (Mulhall, 2004). The average yield of high-capacity wells within a 'D' aquifer is 25 to 100 gallons per minute.

Based on data from Hunterdon and Mercer Counties (Widmer, 1965; Kasabach, 1966; Lewis-Brown, 1995) the Lockatong Formation has a much lower capacity to transmit water than the Stockton Formation. It is a poor yielding aquifer with a median yield ranging from only 5 to 7 gallons per minute (Mullhall, 2004). USGS data indicate that drilling to greater depths will not increase the well yield (Lewis-Brown, 1995).

Jurassic Diabase:

The Jurassic Diabase, consisting of extremely hard, resistant igneous rock, is a very poor yielding aquifer system. Located in the northern half of the Heathcote Brook Watershed, the Jurassic Diabase has been ranked by the NJGS as an 'E' aquifer system indicating the formation's low capacity to support water-supply wells (Figure 9). The average yield of high-capacity wells within 'E' aquifers is less than 25 gallons per minute.

According to the studies done in Hunterdon and Mercer Counties (Widmer, 1965; Kasabach, 1966; Lewis-Brown, 1995), the diabase is a very low yielding aquifer system with a median yield of only 5 to 6 gallons per minute. Drilling wells to greater depths provides additional storage capacity but not additional yield. (Mulhall, 2004)

WELLHEAD PROTECTION AREAS

In order to retrieve water for use in everyday life, wells are drilled to a desired depth into an aquifer containing potable water. This water is pumped out of the wells for household, agricultural, or commercial uses. There are different

types of wells regulated by the State. Individual domestic wells are used for single homes for potable purposes. Public community wells (PCWs) supply water systems that service at least 15 connections used on a year-round basis or supply at least 25 year-round residents (New Jersey Geological Survey, 2003). The source of a well and the structure built over it are referred to as the wellhead.

Protecting the wellhead from future and present contamination will protect the population from deleterious health effects. Wellhead protection areas (WHPAs) are delineated at the surface and represent the area that contributes water to a well in a defined time period (New Jersey Geological Survey, 2003). The WHPA is divided into three tiers based upon the time of travel (TOT) that it takes for water at a given point to reach the well when pumped. TOTs are helpful in determining the risk of contamination to a well. A Tier 1 WHPA has a TOT of two years, Tier 2 has a TOT of five years, and Tier 3 has a TOT of 12 years (New Jersey Geological Survey, 2003).

There are no designated wellhead protection areas within Heathcote Brook Watershed and, therefore, no KCSs located within a WHPA.

GROUNDWATER RECHARGE

Groundwater is not in endless supply. Water needs to enter the land's subsurface in order to recharge and reinvigorate groundwater. Land use activities can disrupt the natural water cycle and the flow of water back into the soil, and can diminish water supplies. As impervious cover increases with developed areas, water that would normally infiltrate back into groundwater supplies is diverted as runoff. This runoff volume is not only greater, but occurs more frequently and at higher magnitudes. In an area preserved with natural cover (forests, fields, and wetlands), studies estimate that approximately 50% of precipitation infiltrates into the ground, 10% flows over the land as runoff, and 40% is evaporated back into the atmosphere (Center for Watershed Protection, 1998). The Heathcote Brook Watershed, with 12.9% impervious cover (based on 2002 land use coverage), may drop to 42% of precipitation infiltrating into the ground, 20% of the precipitation flowing away as runoff, and 38% evaporating into the atmosphere (Center for Watershed Protection, 1998). This is common for areas with 10 to 20% impervious cover. For the whole Millstone Watershed, with an average impervious cover of 8.8% (based on 1995/97 land use/land cover data), it has been estimated that 14.2% of precipitation infiltrates into the ground, 31.6% flows over the land as runoff, and 54.2% is evaporated back into the atmosphere (New Jersey Water Supply Authority, 2000c). As little as 10% watershed impervious cover has been shown to cause stream degradation in many regions of the country, with more severe degradation seen as impervious cover increases (Schueler, 1994; Schueler and Holland, 2000).

Therefore, not all areas, even if left in their natural state, infiltrate water into the subsurface water equally. Different types of land use allow for different

WATER SUPPLY

rates of infiltration. The underlying geology also plays a role in the capacity of water to percolate. In a developing watershed like the Heathcote Brook Watershed, the location of suburbanization and urbanization becomes important. Water quality also is an issue. Locating heavy development near areas that contain highly permeable soils can cause increased pollution of groundwater from runoff.

In the Heathcote Brook Watershed, there are 2621.5 acres, or 44.8% of the entire watershed area, found within areas classified as high groundwater recharge (Figure 17). High groundwater recharge is defined as that portion of the geologic formation where soil and land use allow for increased recharge of precipitation into the soil at the rate of greater than 10 inches per year.

Of the 2621.5 acres classified as high groundwater recharge areas, 588.8 acres, or 22.5%, were in agricultural lands in 2002; 855.7 acres, or 32.6%, were in urban/developed areas; 1062.8 acres, or 40.5%, were forested; and the remaining acreage was water, wetlands, and barren land (Figure 17).

According to the New Jersey Water Supply Authority's 2002 report, *Ground Water in the Raritan Basin*, between 1986 and 1995 the Raritan Basin (of which both the Millstone Watershed and the Heathcote Brook Watershed are part) lost 5% of its recharge capability. The Heathcote Brook Watershed exceeded this overall average, losing an average of 0.8 inches, or 10.2%, of its groundwater recharge capability between 1986 and 1995 (NJWSA, 2002). It is likely that additional recharge capability has been lost since 1995 as development progressed.

The most likely reason for the loss of groundwater recharge is an increase in urban/developed areas in high groundwater recharge zones since 1986 (see Land Use section for more information). Urban areas increased by 218.8 acres in areas of high groundwater recharge between 1986 and 2002. This increases impervious areas that prevent water from percolating back into the soil.

ASSESSMENT

Groundwater recharge is important for maintaining water supplies, both for drinking water and for sustaining flows in rivers and streams. For example, one study discovered that dry weather stream flows dropped 20-85% after development occurred in several Long Island, NY watersheds, increasing impervious surfaces and reducing the ability to recharge groundwater (Schueler and Holland, 2000). The loss of groundwater recharge in the Heathcote Brook Watershed, as reported in the groundwater section of the Raritan Basin Watershed Management Project (NJWSA, 2002), shows how poor planning can impact groundwater recharge areas. Much needs to be done to increase efforts to protect high recharge areas and prevent further losses. Possible strategies include placing limitations on impervious surface,

preserving lands in high recharge areas, and planning growth in the most appropriate areas.

Ensuring that both groundwater and the surface water it replenishes are clean and healthy for both water supply and recreational purposes is another important aspect to consider. Agricultural areas located above high groundwater recharge zones have the potential to contaminate groundwater aquifers via the use of chemicals (especially ecologically harmful chemicals like pesticides). Municipalities and farmers have several tools at hand to help them protect this important resource, such as regulations or ordinances on the use of chemicals or the implementation of best management practices regarding pesticide use or reducing impairment from agricultural water runoff.

The preservation and protection of lands in high recharge areas can be accomplished by the purchase of such lands. To narrow down the most important properties for determining which lands to purchase, the overlap area of key preservation criteria can be used. For example, key criteria such as areas of high groundwater recharge, areas with critical habitats for the protection of threatened and endangered species, and riparian areas can be considered (Figure 18). Properties that meet the criteria for all three of these areas could be ranked highest for potential preservation. The Raritan Basin Watershed Alliance developed the Water Resources Protection Open Space Criteria. This document acknowledges that preserving open space is an effective means of protecting water resources and outlines the criteria to be used when determining if a piece of property protects water resources. The criteria is available on their website at http://www.raritanbasin.org/technical_reports.htm

The major aquifers in Heathcote Brook Watershed (the PRM, Stockton, and Passaic systems) represent potential drinking water supplies, if not for the towns located in this watershed, then for other municipalities throughout the State. The groundwater found within these aquifers also feeds the local streams, maintaining the stream flows for all to enjoy. It is critical that future plans for growth consider the high groundwater recharge areas during planning efforts to protect underlying sources of drinking water and to maintain stream flow for future generations.

WATER SUPPLY

WATER QUALITY

Assessing water quality is an important way to gauge the response of streams and lakes to surrounding land uses, pollutant loadings, seasonal changes, and human activity. It can also gauge community awareness on the importance of clean and healthy water.

Nonpoint source (NPS) pollution, often associated with suburban development and activities, is of particular concern in this watershed. NPS pollution comes from numerous, diverse, or widely scattered sources that together have an adverse effect on the environment. The USEPA has stated that NPS pollution, or pollution from runoff, is currently one of the leading causes of water quality degradation (USEPA, 1996). Fertilizers and pesticides from yards, farms, and golf courses; animal wastes (from farm animals, pets, and wildlife); sediments from construction and erosion; detergents; and toxic chemicals from cars, household cleaning, and yard care are all examples of NPS pollution.

Under Sections 305(b) and 303(d) of the Clean Water Act, each state is required to monitor the health of its waterways, produce a list of waterways not meeting Surface Water Quality Standards, and report these to the USEPA. These lists are produced every two years and are used to establish the timeline in developing a total maximum daily load (TMDL) for the impaired waterways. A TMDL is the maximum quantity of a particular pollutant that can enter a waterway without affecting the designated use of that waterway (Jarrell, 1999). Currently, the NJDEP produces a list that combines the waters assessed in the State (305(b) listings) and those assessed and not meeting State designated uses (303(d) listings) into one list, the Integrated List of Waterbodies (Integrated List).

Water quality data was gathered from a variety of sources (Figures 24, 25, and 26). SBMWA staff collected fecal coliform and total coliform (i.e. bacteria) data at seven Heathcote Brook sites from May 2005 to September 2006 under wet and dry weather conditions. USGS collected fecal coliform at one site on Heathcote Brook since 1975 and analyzed the samples using three different methods. SBMWA has also monitored one Heathcote Brook site since 1993 for a variety of parameters using volunteers. The USEPA has incorporated biological monitoring at sites within the Heathcote Brook Watershed for inclusion on the State's Integrated List (NJDEP, 2004a). The biological assessment data was gathered from the NJDEP's Ambient Biomonitoring Network (AMNET) 1993-94 and 1999 reports and Round 3 Data for the Raritan River drainage basin (NJDEP, 1995; NJDEP, 2000a; NJDEP, 2005b). Visual assessments were collected from reports performed by two AmeriCorps Watershed Ambassadors trained by NJDEP and SBMWA staff.

Visual assessments provide an overall sense of water quality through qualitative surveys. Biological assessments give information on long-term water quality as the organisms studied may have resided in a particular stream for months; however, these do not reveal the source of impairments. Chemical assessments reveal detailed information on the quality of waterways. However, each round of chemical assessments gives a snapshot of a particular time and location, and only long-term

monitoring is able to reveal significant trends.

VISUAL ASSESSMENTS

Visual assessments are a valuable tool in obtaining a gross evaluation of impacts on the health of the riparian and stream environment. However, observational data can be difficult to compare between areas. An effort to quantify these observed characteristics was used, based upon visual assessment protocols used by the NJDEP (USDA, 1998; USEPA, 1997; USEPA, 1999). During the visual assessments, a score was given to each of twenty-one parameters (i.e., water color, bank stability, channel alteration, riparian vegetation, etc.). Where applicable, these parameters were scored on a scale of 1 to 4. In most cases, a score of 1 represents pristine conditions while a score of 4 represents severe problems. The exception is tree canopy, where a 1 represents poor conditions and a 4 represents ideal conditions. It should be noted that the results be used with caution, since the data are based on qualitative judgments and observations.

Information presented for the visual assessments was developed from the collected reports of trained Watershed Ambassadors. Seven navigable stream segments, referred to as “beats,” are located in the Heathcote Brook Watershed along the mainstem of Heathcote Brook, Carters Brook, and an unnamed tributary (Figure 24). All assessments were completed in November and December of 2004, February 2005, and September 2006. The Watershed Ambassadors walked the “beats” after being trained by NJDEP and SBMWA staff on what information to look for and how to assess water quality problems based on their observations. Notable or interesting sites or problems were photographed and recorded to aid in determining stream health.

It should be noted that the information gathered through the visual assessments is most directly applicable to the health of the riparian corridor. The overall health of these stream-buffering areas indirectly aids in determining water quality.

The seven “beats” within the Heathcote Brook Watershed have been designated ‘HCB’ and are numbered sequentially starting with the most upstream “beat”. Beats HCB1, HCB2, HCB4, and HCB7 are located on the mainstem of Heathcote Brook. HCB3 is sited on an unnamed tributary, while HCB5 and HCB6 are located on Carters Brook (Figure 24). The Watershed Ambassadors were unable to collect information on HCB4 due to private property/accessibility constraints and on HCB5 due to time limitations.

Through these assessments, Heathcote Brook is rated as having overall good riparian corridor quality. Results of the assessments varied slightly based on the stream segment surveyed. For some beats, the best rated parameters addressed sedimentation (embeddedness and bank stability) and, the riparian

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Table 7: Visual assessment scores for Heathcote Brook and its tributaries

Visual Assessment "Beat"	Embeddedness Score	Water Odor Score	Water Color Score	Stream Bottom Score	Bank Stability Score	Percent of Tree Canopy Score	Channel Alteration Score	Surface Coating Score	Riparian Vegetation Score
HCB1	1	1	1	2	2	1	2	1	4
HCB2	2	1	2.5	3.5	2	4	2.5	1	2
HCB3	1	1	3	2	2	4	1	1	1
HCB6	2	1	1	2	1.5	3	1.5	1	1.5
HCB7	1.5	1.5	3	3	1.5	4	2	1	1.5

For Beats HCB2, HCB6, and HCB7, the score given is an average score from observations made in different areas of the beat. In most cases, a score of 1 represents optimal conditions and a score of 4 represents poor conditions. The exception is for percent tree canopy, in which a 1 represents poor conditions and a 4 represents optimal conditions.

Information was not collected on Beat HCB4 due to private property/accessibility constraints, and on HCB5 due to time constraints and limited staff.

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corridor (percent of tree canopy and riparian vegetation, Table 7). Scores for tree canopy, bank stability, embeddedness, and width of the riparian zone were good (either rated 1 or 2; 3 or 4 for tree canopy) for most beats along the Heathcote Brook and its tributaries showing that much of the area along the streams is buffered from surrounding land uses and impacts. These scores also show that in most areas the bank is stable and there is minimal erosion and sedimentation. Scores of 1 and 2 for bank stability, which all of the surveyed segments received, indicate stable or moderately stable banks with only minimal erosion or small areas of erosion in 5-30% of the banks that are mostly healed over. The extent of erosion impacts the amount of sediment entering the stream, with more erosion potentially leading to higher sediment levels. Three of the five stream segments surveyed (HCB1, HCB3, and HCB7) rated embeddedness (the extent to which gravel, cobble, and boulders in the stream are surrounded by fine sediment) as a 1. This indicates that gravel, cobble, and boulders present in the stream were only 0-25% surrounded by fine sediment.

For percent tree canopy and riparian vegetation, the stream segments surveyed received scores of 3 and 4 and 1 and 2, respectively. This indicates that there is adequate shade for aquatic life to thrive and there is a good buffer to protect the stream from runoff containing pollutants. An exception to this was HCB1, which received a score of 4 on riparian vegetation and a score of 1 on tree canopy (Table 7). The riparian vegetation category refers to the width of the riparian zone, and a score of 4 indicates that there is significant disturbance due to residential and commercial practices, roadways, and clear cutting of vegetation within 15 feet of the stream. In some areas, there was mowed lawn right up to the edge of the streambank. This is of particular concern since the HCB1 stream segment is the headwaters of the Brook (Figure 24).

The most common problems seen on the visual surveys were the result of urbanization. In some cases, the worst rated scores were for sediment on the stream bottom and embeddedness (the extent to which gravel, cobble, and boulders in the stream are surrounded by fine sediment; Table 7). Two out of the five stream segments surveyed (HCB2 and HCB7) rated sediment on the stream bottom as 3-4 (Table 7). For stream bottom a score of 3 indicates that there is a moderate level of sediment on the stream bottom and a score of 4 indicates that there is a severe level (out of none, light, moderate, and severe). In two stretches (HCB2 and HCB6), the embeddedness was rated as a 2. This indicates that gravel, cobble, and boulders present in the stream were at least 26-50% surrounded by fine sediment (NJDEP, no date). Advanced sedimentation of streams causes loss of habitat for aquatic macroinvertebrates (insect larvae, clams, crayfish, snails, etc.), clogs fish gills, and increases the concentration of metals and organic toxins, which easily combine with sediments (Center for Watershed Protection, no date).

As rural and suburban areas become more developed, it is important to consider the amount of impervious surface and how it affects water quality.

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In the visual assessments, this relates to channel alteration and erosion. For channel alteration, three of the stream segments (HCB1, HCB2, and HCB7) were given a score of 2 or higher (Table 7). A score of 2 indicates that some stream channelization is present, usually in the areas of bridges (NJDEP, no date). In regards to erosion, three of the segments (HCB1, HCB2, and HCB3) were given a rating of 2 for bank stability. Bank stability scores of 2 indicate that the streambanks are moderately stable with small areas of erosion and have between 5% and 30% of their lengths showing signs of erosion (NJDEP, no date). Increased amounts of man-made structures close to the streams and channelization may be increasing flows in the stream due to the imperviousness of these structures and the increased disconnection from the floodplain. Increased flows can heighten natural erosion along the Heathcote Brook, which results in sedimentation of the stream bottom. The sedimentation may also be due to the high erodibility of the soil types in the Heathcote Brook Watershed (Figure 12). Although the visual assessments did not identify erosion and channel alteration as severe problems at this time, they are something to consider as more developments are planned.

In August and September of 2005, SBMWA staff conducted additional visual assessments in the immediate vicinity of the bacteria sample sites. (The Physical Characterization Field Data Sheets are included in Appendix D.) The main differences noted between these assessments and the Watershed Ambassador assessments were due to the time of year when the assessments were conducted. For example, the assessment of Site HCB1 conducted in December 2004 found little to no aquatic vegetation, while there was an abundance of vegetation noted in August 2005. Since aquatic vegetation is expected to be more abundant in the spring and summer than in the winter, this difference does not necessarily indicate a change in water quality. There were no major differences noted in terms of riparian vegetation width, canopy cover, water odor, water color, or water surface coating.

BIOLOGICAL ASSESSMENTS

The organisms that live within a stream system can convey much information about the health of the waterway. One such group of organisms is aquatic macroinvertebrates. These are aquatic insects and their larvae, clams, snails, crayfish, and other animals without a backbone that live in waterways. They are used as indicator organisms because of each species' varying sensitivities to pollution. For example, mayfly nymphs are very sensitive to pollution and are only abundant where water quality is good, while leeches and worms are tolerant to pollutants and can survive in waters with poor water quality.

- Biological data has been collected from NJDEP's AMNET monitoring program (Figure 25 and Table 8). At least 100 organisms are required from each sampling event for that event to be statistically valid for interpretation of results in this report. The

Table 8: Biological assessment data for Heathcote Brook: 1993, 1998, and 2004 (NJDEP Data)

Site	Date	Number in Sample	FBI	Total Taxa Richness	EPT Richness	Percent EPT	Percent Dominance	Scoring for Stream Impairment Biological Assessment
AN0395	10/6/93	100	6.50	16	4	5.00	31.00	Moderately Impaired
AN0395	10/6/98	104	6.90	16	1	1.92	16.35	Moderately Impaired
AN0395	9/16/04	100	7.77	15	1	9.00	38.00	Moderately Impaired
AN0396	10/6/93	104	7.02	9	1	0.96	79.81	Severely Impaired
AN0396	10/6/98	100	4.70	12	4	15.00	39.00	Non-Impaired
AN0396	9/9/04	103	5.46	15	3	6.80	33.01	Moderately Impaired

FBI = Family Biotic Index: Index of the average pollution-tolerance ("sensitivity") of individuals in the sample

Total Taxa Richness = Number of different families in the sample

EPT Richness = Total number of families in *Ephemeroptera*, *Plecoptera*, and *Trichoptera* Orders

Percent EPT = Percent of sample in the *Ephemeroptera*, *Plecoptera*, and *Trichoptera* Orders

Percent Dominance = Percent of sample composed of individuals from one family

Samples should include at least 100 organisms for statistical evaluation.

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organisms from these samples are identified to the family level and the data are entered into a database and rated in a scoring system to determine the level of stream impairment.

Streams are rated numerically and then categorized as “non-impaired,” “moderately impaired,” or “severely impaired” based on the following biological criteria:

- Pollution-tolerance of families collected;
- Number of different families collected;
- Number of pollution-intolerant (“sensitive”) families collected;
- Percent of sample composed of pollution-intolerant individuals; and
- Percent of the sample dominated by one family.

The two NJDEP sampling sites in the Heathcote Brook Watershed are (NJDEP, 2000a) (Figure 25):

- Heathcote Brook at Stouts Lane in South Brunswick Township (AN0395).
- Heathcote Brook at Academy Street in South Brunswick Township (AN0396).

According to the AMNET sampling events from 1993, 1998, and 2004, four of the six sampling events were rated as Moderately Impaired (Table 8 and Figure 25; NJDEP, 1995; NJDEP, 2000a; NJDEP, 2005b).

Site AN0396 was rated Severely Impaired when sampled in 1993, possibly due to significant organic pollution (e.g. pet waste, septic leachate, fecal coliform) (Table 8; NJDEP, 1995). The site is located in a residentially developed area of South Brunswick Township, and this development pattern may have increased the flows to the point that sediments, pet waste, etc. carried by these flows were adversely impacting habitat for aquatic macroinvertebrates, or the habitats were getting washed out completely. However, in 1998 this site was rated Non-impaired. In 2004 it was Moderately Impaired. AMNET Site AN0396, bacteria sample site HCB7, and USGS Site 01401400 are all the same location (Figures 25 and 26).

The 2004 Integrated List states that the Heathcote Brook site at Academy Street in South Brunswick (Site AN0396) is not impaired for supporting Aquatic Life (NJDEP, 2004a). The biological assessment site at Stouts Lane in South Brunswick Township (Site AN0395) was deemed to have insufficient information to determine whether or not it was supporting Aquatic Life (NJDEP, 2004a). The Draft 2006 Integrated List states that Heathcote Brook is impaired for supporting Aquatic Life (NJDEP, 2006c). In 2004, no TMDL for aquatic life was proposed for Heathcote Brook (NJDEP, 2004a). This information is not yet available in the Draft 2006 Integrated List.

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The NJDEP initiated a program in 2000 to evaluate fish communities to determine the health of waterways. Teams of NJDEP staff collect fish, and identify and enumerate the species caught (NJDEP, 2000b). During this collection the following metrics are determined:

- Total number of fish species
- Number of species of bottom dwelling fish that eat insects
- Number of trout and/or sunfish species
- Number of pollution-intolerant species
- Proportion of individuals as white suckers
- Proportion of individuals with broad habitat requirements
- Proportion of individuals as insect-eating members of the family *Cyprinidae*
- Proportion of individuals as trout or proportion of individuals as piscivores (“fish eaters”)
- Number of individuals in the sample
- Proportion of individuals with disease or anomalies (excluding blackspot disease)

This data is combined into an index of biotic integrity (IBI) and is used to develop biological criteria, prioritize sites for further studies, provide biological impact assessments, and assess status and trends of the State's freshwater fish assemblages (NJDEP, 2000b). Since 2000, studies have been conducted in 2001, 2002, 2003, and 2004. However, the sites have changed each year and Heathcote Brook has not been sampled since 2000.

One site along the Heathcote Brook was monitored in 2000 as part of the NJDEP's fish IBI program:

- Heathcote Brook at Academy Street in South Brunswick Township (Figures 25 and 26). (Note that this site is the same as AMNET site AN0396, SBMWA's bacteria sample site HCB7, and USGS Site 01401400.)

The results from the survey performed in 2000 show that Heathcote Brook has an IBI of “good” and that the habitat was assessed as Sub Optimal (on a scale of Optimal, Sub Optimal, Marginal, and Poor; NJDEP, 2000b). This indicates that the habitat present for fish species could improve and that the fish found in this habitat represent a balanced population (NJDEP, 2000b).

The biological data follows a pattern similar to the visual assessments with the stream bottom experiencing some sedimentation and smothering out of habitat that macroinvertebrates need to survive. During all sampling events in 1993 and 1998, it was noted that the stream bottom was mostly cobble, gravel, and sand (NJDEP, 1995; NJDEP, 2000a). Also, the most recent Integrated List published by the NJDEP ranks the biological health of Heathcote Brook as non-supportive of aquatic life (NJDEP, 2006c). The 2004 Integrated List ranks site AN0395 as having insufficient data to

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determine biological health (NJDEP, 2004a). Given the insufficient data at site AN0395 and the inconsistent results at site AN0396, further study of the biological community is needed.

CHEMICAL ASSESSMENTS

Data was downloaded from USEPA's Storage and Retrieval database (STORET) and reviewed. This data was downloaded from both the STORET Legacy Data Center (data prior to 1999) and Modernized STORET (data 1999 to the present) (USEPA, 2004). Heathcote Brook Watershed data from the Legacy version of STORET was from 1975 and 1976. This data was not collected consistently over time or for any particular parameter, with only two days of information available. Likewise, modernized STORET data was only available from three days in 1999 and one day in 2000. Therefore, chemical assessments were not evaluated for the Heathcote Brook Watershed using STORET data.

The 2004 and Draft 2006 Integrated Lists, along with SBMWA chemical data, were also consulted to determine water quality based on chemical assessments. The 2004 Integrated List states that the Heathcote Brook site at Kingston (corresponding to USGS site 01401400, Figure 26) is impaired for fecal coliform (NJDEP, 2004a). The site at Kingston was also listed on the 2004 Integrated List as meeting the water quality standards for phosphorus, temperature, pH, dissolved oxygen, nitrate, dissolved solids, total suspended solids, and unionized ammonia (NJDEP, 2004a). The Draft 2006 Integrated List states that Heathcote Brook is impaired for fecal coliform and an unknown pollutant (NJDEP, 2006c). The unknown pollutant relates to the designated impairment for aquatic life.

SBMWA's chemical action teams (CATs) monitor one chemical monitoring site in the Heathcote Brook Watershed (Figure 26). Chemical monitoring is conducted every other weekend throughout the year. Volunteers monitor six parameters: dissolved oxygen (DO), pH, nitrate-nitrogen, orthophosphates, water temperature, and turbidity. For this assessment, water quality was determined for all six parameters, but three in particular are important to NPS pollution control: DO, nitrate-nitrogen, and orthophosphates. These three are excellent indicators of NPS pollution and eutrophication in waterways.

The site in the Heathcote Brook Watershed currently monitored by SBMWA's volunteers is (Figure 26):

- Heathcote Brook, just east of the D&R Canal (HB3)

Historically, two other sites in very close proximity to Site HB3 were monitored in the Heathcote Brook Watershed by SBMWA's volunteers (Figure 26):

- Heathcote Brook near the D&R Canal, off the towpath at Canal State Park (HB1, washed away 1997)
- Heathcote Brook, just west of the D&R Canal (HB2, replaced HB1)

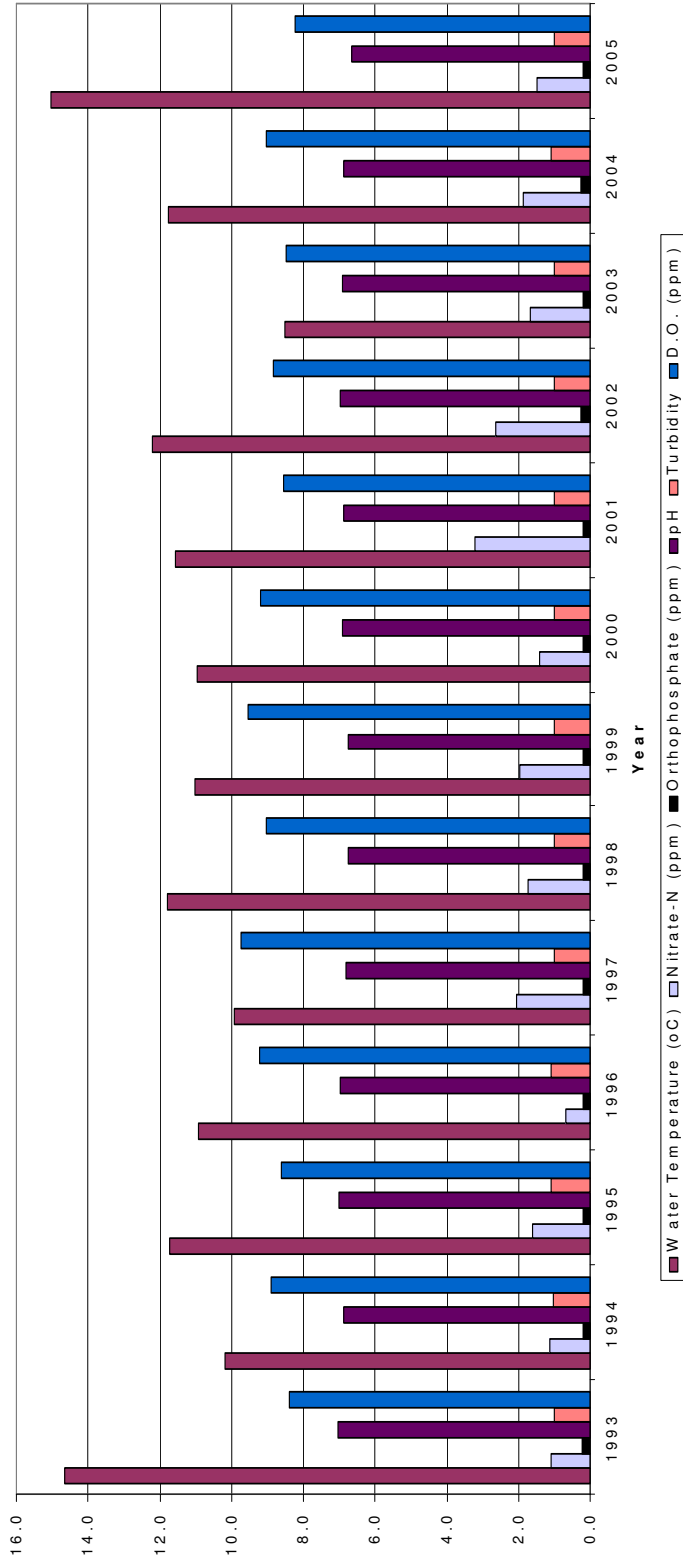
Site HB1 was monitored from the summer of 1993 to March of 1997. Its location was chosen because it provided safe parking and access for volunteers and because it was in close proximity to the confluence with the Millstone River. Sampling at this site allowed SBMWA to assess the overall water quality on Heathcote Brook and determine the inputs into the Millstone River. When this site washed away by heavy stormwater flows, it was replaced by site HB2, which was monitored from 1997 to the fall of 2005. In December of 2005, site HB2 was replaced with site HB3. This change was made due to flows from the D&R Canal and Carnegie Lake influencing the water quality in this area of Heathcote Brook (at site HB2). The location for site HB3 was chosen because it is not influenced by other streams and measures water quality on Heathcote Brook only. Sites HB1, HB2, and HB3 are three distinct sampling sites. However, given their close proximity to one another, their locations could not be separated on Figure 26 due to the scale of the map.

Data was analyzed by annually averaging the value for each parameter monitored (Graphs 6 and 7). Since sites HB1 and HB2 were in very close proximity to each other and are no longer monitored, results for these sites were analyzed together to show historical data for Heathcote Brook (Graph 6). Results for HB3 were analyzed separately to show more recent results (December 2005-September 2007, Graph 7). The historical results show that Heathcote Brook is maintaining good water quality, as many of the parameters meet the State Water Quality Standards of 30⁰C maximum for water temperature, 10.0 parts per million (ppm) maximum for nitrate-N, 6.5-8.5 standard units for pH, 50 Nephelometric Turbidity Units (NTU) maximum for turbidity, and 4.0 ppm minimum for dissolved oxygen (Graph 6; NJDEP, 2006d). A parameter of slight concern is nitrate. Although nitrate levels meet the State Water Quality Standard, studies indicate that healthy stream ecosystems have nitrate levels of less than 1.0 ppm (USEPA, 1997). Nitrate levels were greater than 1.0 ppm every year except 1996.

Recent data from Site HB3 also shows that Heathcote Brook is maintaining good water quality, as many of the parameters meet the State Water Quality Standards for water temperature, nitrate-N, turbidity, and dissolved oxygen (Graph 7). A parameter of slight concern is pH, which is not meeting the 6.5-8.5 State Standard based on data collected from December 2005 to September 2007 (Graph 7). The average pH value of 6.4 shows that the waters of Heathcote Brook are mildly acidic, with 9% of all pH measurements taken below the State Water Quality Standard and 89% of all measurements at the lowest value possible while still meeting the standard (6.5). Another parameter of concern is orthophosphate, with an average

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Graph 6: Chemical assessment data for Heathcote Brook (Sites HB1 & HB2) 1993-2005 (SBMWA Data)

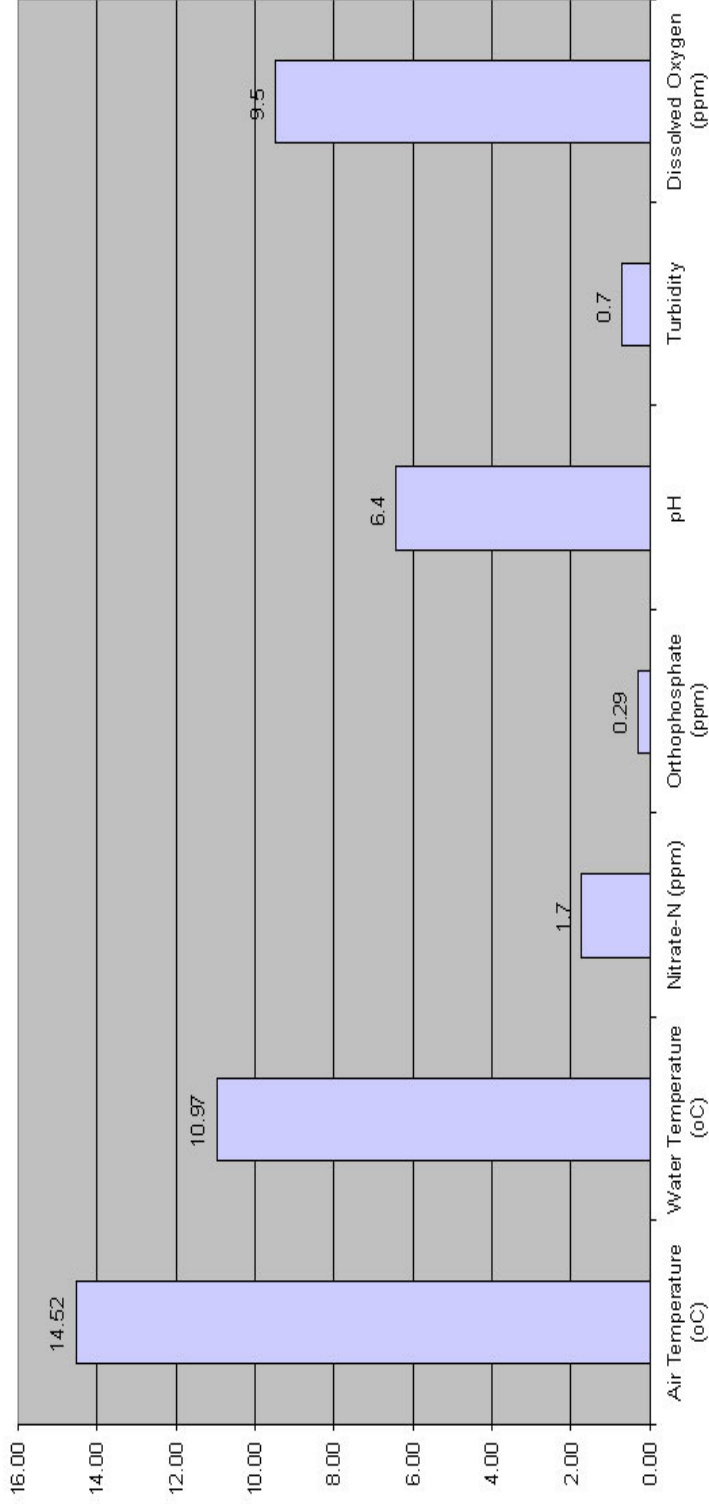


Note: pH measured in Standard pH units. Turbidity measured on a scale of 1-7. A result of 1-2 is equivalent to 0-50 NTU

Note: Data represents annual averages for each parameter monitored from 1993-November 2005.

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Graph 7: Chemical assessment data for Heathcote Brook (Site HB3) 2005-2007 (SBMWA Data)



Note: pH measured in Standard pH units. Turbidity measured on a scale of 1-7. A result of 1-2 is equivalent to 0-50 NTU
Note: Data represents average value for each parameter monitored from December 2005-September 2007.

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above the State Standard for phosphorus of 0.1 ppm. Nitrate-N levels also exceed 1.0 ppm.

Fecal Coliform and Total Coliform:

Because they are commonly found in human and animal feces, the coliform bacteria group has been used as indicators of possible sewage contamination. Not generally harmful themselves, they indicate the possible presence of disease-causing bacteria, viruses, and protozoans that also live in human and animal digestive systems. Therefore, their presence in streams suggests that pathogens may also be present and that primary contact may be a human health risk. Fecal coliform is a bacterium that lives in the intestinal tracts of animals and humans. For recreational waters, fecal coliform was the primary bacteria indicator until NJDEP announced the new State Surface Water Quality Standards in October 2006 when *E. coli* became the chosen indicator of human health risk from freshwater contact (NJDEP, 2006a). This report references the previous Water Quality Standard for fecal coliform of 200 colony forming units (cfu)/100 mL for primary contact and utilizes a 770 cfu/100 mL standard for secondary contact of fresh water (FW) streams (email communication, NJDEP's Bureau of Water Monitoring and Standards). Total coliform is a group of closely related bacteria that live in the soil and water, as well as the gut of animals. Total coliform testing is no longer recommended as an indicator for recreational waters; however, it is still the standard bacterial method for judging the suitability of drinking water because its presence indicates contamination of a water supply by an outsource. Potential sources of coliform contamination include stormwater runoff from areas of land that support livestock, failing septic systems, old and leaking sewer pipes, crop farms, geese, deer, and domestic pets. NJDEP identifies segments of Heathcote Brook as impaired due to fecal coliform and has listed these segments on the Integrated List in 2002, 2004, and 2006 Draft (NJDEP, 2002; NJDEP, 2004a; NJDEP, 2006c). NJDEP has a 2003 USEPA approved fecal coliform TMDL for Heathcote Brook, which calls for a 94% reduction in fecal coliform (NJDEP, 2003c).

In addition to NJDEP and SBMWA sampling, USGS has collected water chemistry samples at one site on Heathcote Brook (Site 01401400, Figure 26) sporadically since 1975. This site coincides with SBMWA's bacteria Site HCB7 and NJDEP's AMNET Site AN0396 (Figures 25 and 26). USGS analyzed samples for fecal coliform using three different analytical methods (Table 9) as well as total nitrogen, organic nitrogen, ammonia, nitrite as N, nitrate as N, nitrite + nitrate as N, phosphorus, and orthophosphate. Some of the more frequently monitored parameter results are shown in Table 10. Because of current NJDEP priorities, this report is focusing on the fecal coliform results. The NJDEP fecal coliform TMDL was written based on results collected between 1998 and 2002 at this USGS site. USGS collected a total of 70 samples between November 1975 and July 2005, mainly during the summer (Table 9). Those samples violated the fecal coliform state standard 81.4% of the time, ranging from 4 cfu/100 mL in February 1977 to greater than 24,000 cfu/100 mL in July 2000.

Table 9: USGS Fecal Coliform Sample Results, Site 01401400 on Heathcote Brook at Kingston


Date	Fecal Coliform (# cfu/100 mL)			Date	Fecal Coliform (# cfu/100 mL) Analytical Method 1	Date	Fecal Coliform (# cfu/100 mL) Analytical Method 1	Fecal Coliform (# cfu/100 mL) Analytical Method 1
	Analytical Method 1	Analytical Method 2	Analytical Method 3					
11/26/75	2,400	60E		4/18/78	130	6/3/98	790	220
3/25/76	220	72E		5/4/78	240	6/11/98	490	5,000
4/22/76	>2400	2100E		6/14/78	920	6/23/98	2400	260
5/25/76	790	360E		2/14/79	13	7/22/98	790	2,200
6/30/76	2200	3300		3/28/79	110	8/24/98	1400	700
7/21/76	490	650E		6/13/79	1100	6/29/00	490	300
8/3/76	80	480E		7/16/79	3500	7/12/00	1100	1,300
10/7/76	1300		330	8/1/79	3500	7/19/00	490	9,000
11/18/76	270		330	2/19/80	33	7/26/00	>24,000	170
2/17/77	3		560	3/31/80	920	8/1/01	330	800
3/30/77	33		52	5/27/80	1100	8/8/01	230	2,800
5/24/77	350		430	7/16/80	1300	8/15/01	170	270
6/15/77	<200		730	8/14/80	230	8/22/01	790	800
7/21/77	330			9/25/80	330	8/29/01	1,100	220
8/10/77	1700			1/27/81	17	7/31/02	1,700	1,300
10/3/77	260			1/18/82	540	8/7/02	170	>16,000
11/7/77	>2400			3/24/82	70	8/14/02	800	
1/12/78	490			5/25/82	2200	8/21/02	1,100	

E: Estimated value

Analytical Method 1: EC broth analytical method (most probable number/100 mL)

Analytical Method 2: M-FC MF (0.45 micron) analytical method (cfu/100 mL)

Analytical Method 3: M-FC MF (0.7 micron) analytical method (cfu/100 mL)

 Data used by NJDEP to determine TMDL

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Table 10: USGS Chemical Sample Results for More Frequently Monitored Parameters, Site 01401400 on Heathcote Brook at Kingston

Date	Total Nitrogen ¹	Ortho-Phosphate ²	Total Phosphorus ³	Total Phosphorus ⁴	Nitrate-Nitrogen ⁵
11/26/1975	0.76		0.11		0.17
3/25/1976	2.2		0.03		2.0
4/22/1976	6.5		0.05		6.1
5/25/1976	3.7		0.03		3.3
6/30/1976	3.1		0.05		2.7
7/21/1976			0.08		
8/3/1976	2.4		0.27		
11/18/1976			0.02		
2/17/1977			0.05		
3/30/1977			0.02		
5/24/1977			0.03		
6/15/1977			0.02		
7/21/1977	4.2		0.01		3.8
8/10/1977	3.8		0.01		3.5
10/3/1977	2.8		0.03		2.6
11/7/1977	1.7		0.39		0.33
1/12/1978	2.9		0.02		2.1
4/18/1978	2.5		0.01		1.9
5/4/1978	2.7		0.01		2.4
6/14/1978	3.7		0.02		2.5
2/14/1979	4.5				
3/28/1979	2.8				
6/13/1979	3.1				
7/16/1979	4.3				
8/1/1979	4.4				
2/19/1980	9.3				
3/31/1980	2.0				
5/27/1980	4.6				
7/16/1980	4.8				
8/14/1980	4.9				
9/25/1980	5.4				
1/21/1981	7.8				
4/9/1981	2.6				
6/8/1981	5.4				
7/27/1981	4.2				
8/11/1981	5.5				
10/1/1981	6.4				
1/18/1982	3.1				
5/25/1982					1.2
12/18/1997			0.03	<0.01	
3/3/1998			0.01	<0.01	
6/3/1998			0.06	0.01	
8/24/1998			0.01	<0.01	
11/18/1998			<0.05	<0.05	
1/26/1999			0.04 (E)	<0.05	
5/26/1999			0.05	0.03 (E)	
8/18/1999			0.06	<0.05	
11/23/1999			0.013	0.005 (E)	
3/21/2000			0.025	0.006 (E)	

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Table 10 (Continued)

Date	Total Nitrogen ¹	Ortho-Phosphate ²	Total Phosphorus ³	Total Phosphorus ⁴	Nitrate-Nitrogen ⁵
6/20/2000			0.066	0.03	
8/3/2000			0.066	0.037	
12/13/2000			0.015	0.007	
2/28/2001			0.017	0.006	
6/12/2001		<0.02	0.116	0.026	
8/7/2001			0.017	0.01	
12/5/2001			0.013	0.005	
2/5/2002			0.013	0.007	
6/15/2002		<0.02	0.086	0.02	
8/7/2002		0.034	0.027	0.016	
11/7/2002	1.4	0.032	0.035	0.018	
2/4/2003		<0.02	0.014	0.005	
5/28/2003	1.4	<0.02	0.055	0.021	
8/5/2003	4.2	0.033	0.039	0.021	
11/5/2003	2.4	<0.02	0.032	0.002	
2/4/2004		<0.02		0.019	
6/8/2004	3.9	0.009 (E)	0.028	0.014	
8/17/2004	1.1	0.027	0.043	0.012	
11/16/2004	2.1	0.01	0.034	0.02	
2/9/2005	1.2	<0.006	0.0225	0.008	
6/2/2005	4.5	0.01 (E)	0.04	0.012	
8/16/2005	3.4	0.016	0.037	0.02	

1= Sample reported in mg/l, Analytical method = unfiltered water

2= Sample reported in mg/l as Phosphorus, Analytical method = filtered water

3= Sample reported in mg/l, Analytical method = unfiltered water

4= Sample reported in mg/l, Analytical method = filtered water

5= Sample reported in mg/l, Analytical method = unfiltered water

E= estimated value

<= Actual value is known to be less than the value shown

The Action Limit for Total Nitrogen is 1.8 mg/l, as described in Limnology, 2nd Edition, Robert G. Wetzel, 1983, Table 13-14.

The NJDEP Water Quality Standard for Total Phosphorus is 0.1 mg/l in streams.

The NJDEP has not established a standard for Orthophosphate.

The NJDEP Water Quality Standard for Nitrate-Nitrogen is 10.0 mg/l. Any value above 10.0 mg/l has violated the standard and indicates water quality problems.

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In May of 2005, SBMWA staff began a study of bacteria levels in the Heathcote Brook Watershed, sampling for fecal coliform and total coliform. When weather conditions permitted, staff collected two water samples per month at seven sites on Heathcote Brook and its tributaries (Figure 26). One of these samples was taken during dry weather conditions (at least four dry days since the last measurable rainfall), while the second sample was taken during wet weather conditions (a storm measuring at least one-half inch, with at least four dry days since the last measurable rainfall). This allowed staff to determine the impact that stormwater runoff has on fecal coliform levels and thus water quality. Information was also collected for weather, temperature, stream depth, and water conditions such as color, odor, and floatables (pollen, leaves, or trash). Due to unfavorable weather conditions, staff was unable to collect one wet and one dry sample each month for five consecutive months. Therefore, sampling continued until mid-September 2006.

The sites in the Heathcote Brook Watershed monitored by SBMWA staff are (Figure 26):

- HCB1: Heathcote Brook, behind Red Roof Inn at Route 1 South and New Road in South Brunswick Township
- HCB2: Heathcote Brook at 264 New Road in Monmouth Junction
- HCB3: Heathcote Brook at Stouts Lane in South Brunswick Township
- HCB4: Unnamed tributary to Heathcote Brook, at Promenade Boulevard in South Brunswick Township
- HCB5: Carters Brook at 11 Carter Brook Lane in South Brunswick Township
- HCB6: Heathcote Brook at unnamed road between 974 and 970 Ridge Road in South Brunswick Township
- HCB7: Heathcote Brook at Mapleton Road in South Brunswick Township

Table 11 shows the bacteria sample results during dry and wet weather; all data sheets, lab reports, the Quality Assurance Project Plan outlining the sampling protocol, and chains-of-custody are included at the end of this report, along with related precipitation records. A table of daily precipitation recorded at Trenton, NJ is shown in Table 12. Graphs 8, 9, 10, and 11 display the sample results for fecal coliform and total coliform under dry and wet weather conditions.

State standards for fecal coliform have been established for primary (swimming) and secondary (boating) contact recreation in FW2 waters (see glossary for definition). Until recently this standard was a geometric average of <200 colonies/100 mL of water for primary contact and a maximum of 770 colonies/100 mL for secondary contact. In October 2006 the standard was changed to use *E. Coli* as the indicator species.

Table 11: Heathcote Brook Bacteria Monitoring Data 2005 – 2006 (SBMWA Data)

Site #	Site Location	Type of sample (stream, FDUP, EQ BLK)	Sample Event (dry/wet)	Date	Sample Time	Fecal Coliform (#/100mL)	Total Coliform (#/100mL)	Depth (inches)	Temperature (oC)		
HCB 1	Heathcote Brook (HCB) behind Red Roof Inn at Route 1 S and New Road	stream	dry	5/9/05	10:24 AM	640	660	5.0	17.0		
		stream	dry	6/15/05	9:50 AM	750	4800	5.0	24.0		
		FDUP	dry	6/15/05	9:50 AM	620	6500	5.0	24.0		
		stream	dry	8/3/05	9:55 AM	470	10000	5.5	23.5		
		stream	wet	9/15/05	9:54 AM	8000	46000	3.0	22.5		
		stream	“dry”	10/21/05	11:27 AM	1200	1900	10.0	14.0		
		stream	wet	5/12/06	4:50 AM	12000	13000	8.0	15.0		
		stream	wet	6/7/06	1:26 PM	20000	31000	10.0	18.0		
		stream	wet	9/14/06	11:58 AM	3300	3200	11.0	19.5		
		HCB2	HCB at 264 New Road, Monmouth Junction	stream	dry	5/9/05	10:50 AM	18	1030	3.0	14.0
				stream	dry	6/15/05	10:11 AM	640	5200	2.0	24.0
				stream	dry	8/3/05 ^o	NA	NA	NA	NA	NA
stream	dry			9/7/05 ^o	NA	NA	NA	NA	NA		
stream	wet			9/15/05	10:08 AM	1800	29000	3.0	22.5		
FDUP	wet			9/15/05	10:08 AM	1600	29000	3.0	22.5		
stream	“dry”			10/21/05	11:43 AM	140	2200	3.0	13.0		
stream	wet			5/12/06	5:04 AM	2300	2800	13.0	17.0		
stream	wet			6/7/06	1:38 PM	3100	11000	12.0	17.0		
stream	wet			9/14/06	12:16 PM	440	1600	5.0	17.5		
EQ BLK	wet			9/14/06	12:15 PM	<4	<50	5.0	17.5		

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Table 11: Heathcote Brook Bacteria Monitoring Data 2005 – 2006 (SBMWA Data) (continued)

Site #	Site Location	Type of sample (stream, FDUP, EQ BLK)	Sample Event (dry/wet)	Date	Sample Time	Fecal Coliform (#/100mL)	Total Coliform (#/100mL)	Depth (inches)	Temperature (oC)
HCB3	HCB at Stouts Lane	stream	dry	5/9/05	11:20 AM	48	590	26.5	15.0
		stream	dry	6/15/05	10:31 AM	12	3200	27.0	24.0
		stream	dry	8/3/05	10:21 AM	120	100000	24.0	23.0
		EQ BLK	dry	8/3/05	10:21 AM	<4	20	24.0	23.0
		stream	wet	9/15/05	10:24 AM	5700	20000	25.0	23.0
		stream	“dry”	10/21/05	12:01 PM	110	1100	20.0	13.0
		stream	wet	5/12/06	5:24 AM	8100	TNTC*	25.0	17.0
		stream	wet	6/7/06	1:52 PM	700	7300	35.0	17.5
		FDUP	wet	6/7/06	1:52 PM	500	4100	35.0	17.5
		stream	wet	9/14/06	12:35 PM	770	1600	30.0	19.0
HCB4	Unnamed tributary to HCB on Promenade Boulevard between Princeton Gate and Princeton Walk Boulevard	stream	dry	5/9/05	11:45 AM	<4	400	6.0	15.5
		stream	dry	6/15/05	11:03 AM	20	8200	12.0	24.0
		stream	dry	8/3/05 ^{oo}	10:42 AM	NA	NA	NA	NA
		stream	dry	9/7/05 ^{oo}	NA	NA	NA	NA	NA
		stream	wet	9/15/05	10:40 AM	4300	31000	5.0	23.0
		stream	“dry”	10/21/05	12:25 PM	170	1400	3.0	13.0
		EQ BLK	“dry”	10/21/05	12:20 PM	<4	<10	3.0	13.0
		stream	wet	5/12/06	5:40 AM	7300	12000	12.0	16.0
		stream	wet	6/7/06	2:12 PM	6400	20000	12.5	18.0
		stream	wet	9/14/06	12:55 PM	900	1400	4.0	18.5

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Table 11: Heathcote Brook Bacteria Monitoring Data 2005 – 2006 (SBMWA Data) (continued)

Site #	Site Location	Type of sample (stream, FDUP, EQ BLK)	Sample Event (dry/wet)	Date	Sample Time	Fecal Coliform (#/100mL)	Total Coliform (#/100mL)	Depth (inches)	Temperature (oC)
HCB5	Carter Brook at 11 Carter Brook Lane, Princeton	stream	dry	5/9/05	11:10 AM	48	600	4.0	14.0
		FDUP	dry	5/9/05	11:10 AM	56	660	4.0	14.0
		stream	dry	6/15/05	11:42 AM	860	4200	3.0	24.5
		EQ BLK	dry	6/15/05	11:17 AM	<4	10	3.0	24.5
		stream	dry	8/3/05	9:28 AM	250	14000	4.0	23.0
		stream	wet	9/15/05	11:04 AM	7300	34000	4.0	24.0
		stream	“dry”	10/21/05	12:42 PM	400	1500	4.0	14.0
		stream	wet	5/12/06	6:10 AM	3900	8100	9.0	17.0
		stream	wet	6/7/06	1:45 PM	20000	29000	13.0	18.0
		stream	wet	9/14/06	12:39 PM	1800	2200	7.0	19.0
HCB6	HCB at unnamed road between 974 and 970 Ridge Road, upstream of junction with Carter Brook	stream	dry	5/9/05	10:45 AM	76	600	16.0	13.5
		stream	dry	6/15/05	11:20 AM	28	5000	15.0	21.0
		stream	dry	8/3/05	9:04 AM	160	11000	15.0	19.5
		stream	wet	9/15/05	11:22 AM	5000	20000	18.0	22.5
		stream	“dry”	10/21/05	12:39 PM	140	950	17.0	13.5
		stream	wet	5/12/06	5:45 AM	9100	14000	27.0	16.5
		stream	wet	6/7/06	1:30 PM	3100	8200	30.0	18.0
		EQ BLK	wet	6/7/06	1:30 PM	<4	<10	30.0	18.0
		stream	wet	9/14/06	12:20 PM	1000	2000	18.0	18.0

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Table 11: Heathcote Brook Bacteria Monitoring Data 2005 – 2006 (SBMWA Data) (continued)

Site #	Site Location	Type of sample (stream, FDUP, EQ BLK)	Sample Event (dry/wet)	Date	Sample Time	Fecal Coliform (#/100mL)	Total Coliform (#/100mL)	Depth (inches)	Temperature (oC)
HCB7	HCB at Mapleton Road	stream	dry	5/9/05	10:25 AM	84	560	9.0	13.0
		stream	dry	6/15/05	11:02 AM	80	4200	11.5	20.0
		stream	dry	8/3/05	8:42 AM	250	12000	13.5	20.0
		stream	wet	9/15/05	11:40 AM	4600	17000	15.0	22.0
		EQ BLK	wet	9/15/05	11:33 AM	<4	<10	15.0	22.0
		stream	“dry”	10/21/05	12:57 PM	200	1800	9.0	14.0
		stream	wet	5/12/06	5:10 AM	7000	11000	30.0	16.5
		FDUP	wet	5/12/06	5:10 AM	7500	13000	30.0	16.5
		stream	wet	6/7/06	1:15 PM	2900	44000	22.0	18.0
		stream	wet	9/14/06	12:05 PM	1600	3400	20.0	17.0
Detection Limit						4/100mL	10/100mL or 50/100mL depending on dilution factor		
Analytical Method						SM 9222d	SM 9222b		
NJ State Water Quality Standard						200/100mL			

All samples analyzed at New Jersey Analytical Laboratories

∞ Stream dry on sampling day

* TNTC = Too numerous to count (Lab communication indicates this is >15,000)

FDUP = Field duplicate

EQ BLK = Equipment blank

"dry": Approx. 0.07" of rain fell prior to sampling. Project Manager stated this could be considered a dry weather event.



Total Coliform Equipment Blank results are at or above the detection limit

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Table 12: Daily Precipitation Records for Trenton, NJ from National Weather Service Website

Date	Sample Type	Precipitation (inches)	Date	Sample Type	Precipitation (inches)
5/5/2005		0.00	9/10/2005		0.00
5/6/2005		0.00	9/11/2005		0.00
5/7/2005		0.00	9/12/2005		0.00
5/8/2005		0.00	9/13/2005		0.00
5/9/2005	dry	0.00	9/14/2005		0.84
			9/15/2005	wet **	1.76
6/11/2005		0.00			
6/12/2005		0.00	5/7/2006		0
6/13/2005		0.00	5/8/2006		0.02
6/14/2005		0.00	5/9/2006		trace
6/15/2005	dry	0.00	5/10/2006		0
			5/11/2006		0.62
7/30/2005		0.00	5/12/2006	wet	0.27
7/31/2005		0.00			
8/1/2005		0.00	6/1/2006		0.95
8/2/2005		0.00	6/2/2006		1.16
8/3/2005	dry	0.00	6/3/2006		0.63
			6/4/2006		0.03
10/17/2005		0.00	6/5/2006		0.01
10/18/2005		0.01	6/6/2006		0
10/19/2005		0.00	6/7/2006	wet	0.76
10/20/2005		0.00			
10/21/2005	"dry"	0.15	9/10/2006		0
			9/11/2006		0
			9/12/2006		0
			9/13/2006		trace
			9/14/2006	wet	0.64
			9/15/2006		0.31
			9/16/2006		0.22

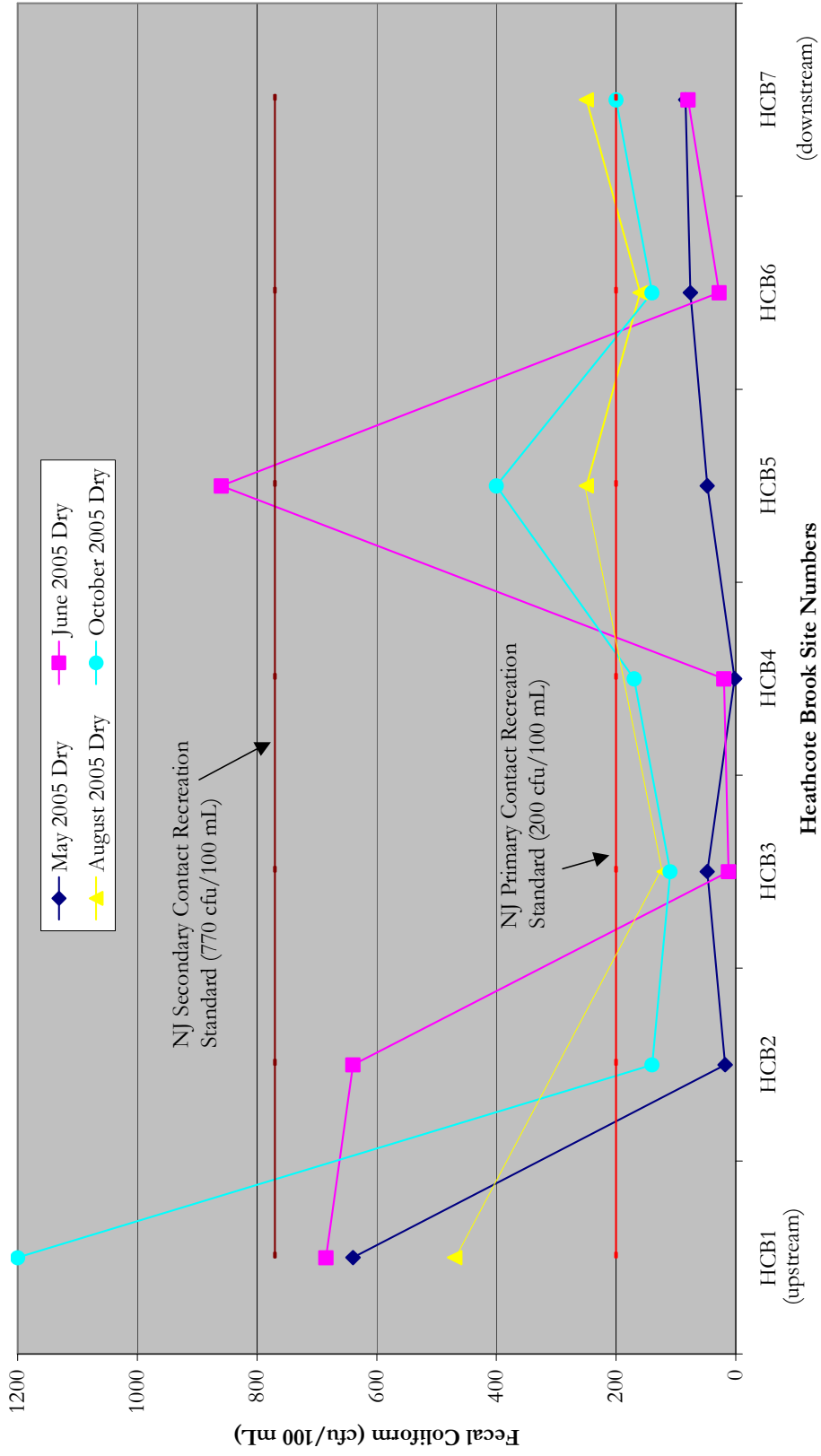
"dry": Approximately 0.07" of rain fell prior to sampling. Project Manager stated this could be considered a dry weather event.

** : Rained 0.84" on 9/14/05. Second pulse came through 9/15/05 in the AM. We caught peak flow for HCB sites 1-5. Probably missed peak at HCB Sites 6 and 7.

Fecal coliform results from dry weather sampling measured between May and October 2005 ranged from less than the detection limit in May 2005 at Site HCB4 to 1200/100 mL at Site HCB1 in October 2005. During that time period, nine samples out of the 26 samples taken (34.6%) violated the swimming state standard (Graph 8). It should be noted that two sites (HCB2 and HCB4) were both dry in August 2005, i.e. without any water, and unable to be sampled. The sites with the greatest number of violations and the highest results were HCB1 and HCB5.

These two sites produced the only results in dry weather to violate the boating standard with HCB1 October 2005 results reaching 1200/100 mL

Graph 8: Heathcote Brook 2005 Fecal Coliform Dry Weather Results (SBMWA Data)



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and HCB5 June 2005 results measuring 860/100 mL. Therefore, under dry conditions Heathcote Brook violated the boating standard only 7.7% of the time. Site HCB1 is located in an urban area behind the Red Roof Inn at the intersection of Route 1 South and New Road, just downstream from a trailer park. Site HCB5 is located on Carters Brook, a tributary to Heathcote Brook, behind 11 Carter Brook Lane in Princeton. At this site sewer pipes closely parallel the stream. If these pipes are not properly maintained and are leaking, they could be a potential source of fecal coliform entering the stream.

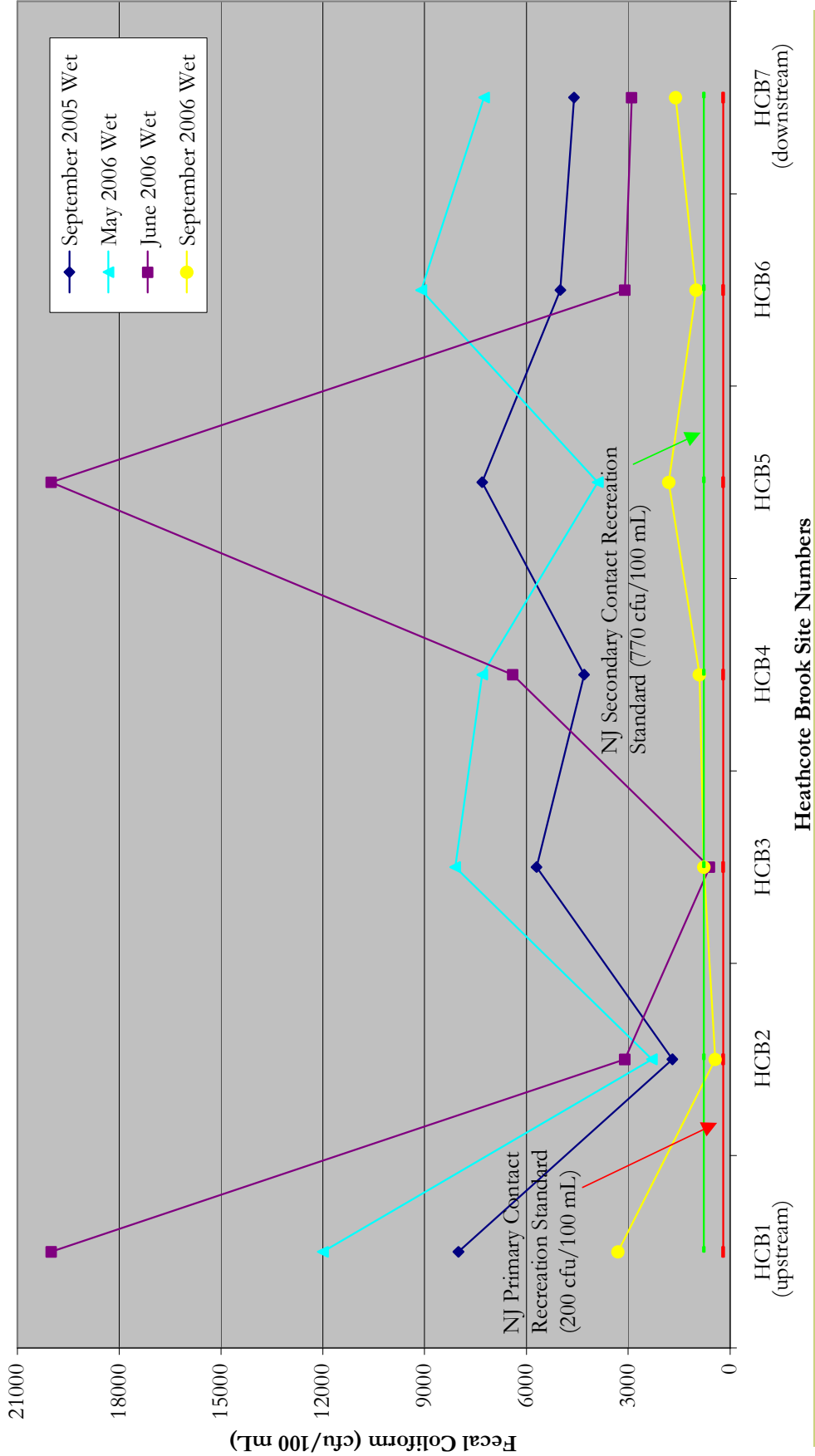
Fecal coliform samples collected under wet weather conditions between September 2005 and September 2006 violated the primary contact state standard (<200 colonies/100 mL) all, or 100% of the time (Graph 9). All but three samples violated the boating standard (770 colonies/100 mL), or violations occurred 89% of the time in wet weather. Daily precipitation recorded at Trenton, NJ is shown in Table 12; hourly details are included in the Appendices. Sample results ranged from 440 cfu/100 mL at Site HCB2 in September 2006 to 20,000 cfu/100 mL at Sites HCB1 and HCB5 in June 2006. Again, the worst sites were HCB1 and HCB5. Fecal coliform levels are expected to be higher under wet weather conditions, particularly those with an extended dry period just prior to sampling, due to the contribution of NPS pollution that gets flushed into the stream by stormwater. This indicates that fecal coliform levels become more concentrated on land during dry weather and then get washed into streams during rainfall events. The effects of failing septic systems and leaking sewer pipes would also be amplified under wet weather conditions due to the addition of stormwater to both of those systems.

Since the primary contact (swimming) state standard for fecal coliform is based on a geometric mean, this statistic has been calculated for each site under dry and wet conditions, as well as the combination for each site (Table 13). Additionally the geometric mean has been calculated for the entire stream. Although the number of samples may not be statistically valid, the results easily show that Sites HCB1 and HCB5 have the highest results under any conditions (HCB1 in dry conditions is 705 cfu/100 mL and 8,922 cfu/100 mL in wet conditions; HCB5 is 259 cfu/100 mL under dry conditions and 5,658 cfu/100 mL for wet). It also shows that the stream as a whole meets the state swimming standard under dry conditions (121 cfu/100 mL), but violates under wet conditions (3,969 cfu/100 mL), and that the stream as a whole violates state swimming standards when weather conditions are not taken into account (692 cfu/100 mL).

Total coliform is currently controlled in drinking water regulations via the Total Coliform Rule, which sets total coliform compliance limits for all public drinking water systems. For systems collecting 40 or more samples per month, no more than 5% of the samples may contain any amount of total coliform. For those collecting fewer than 40 samples per month, no more than one sample may contain total coliform. Any total coliform-positive samples must be further analyzed to determine if specific types of coliform, such as fecal

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Graph 9: Heathcote Brook Fecal Coliform Wet Weather Results (2005-2006) (SBMWA Data)



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Table 13: Geometric Means of Fecal Coliform Data for Heathcote Brook (SBMWA Data)

Site #	Geometric Mean of Dry Data/Site (cfu/100mL)	# Dry Values	Geometric Mean of Wet Data/Site (cfu/100mL)	# Wet Values	Geometric Mean of Wet & Dry Data/Site (cfu/100mL)	# Wet and Dry Values
HCB1	705	4	8922	4	2508	8
HCB2	107	3	1700	4	270	7
HCB3	53	4	2149	4	336	8
HCB4	19	3	3667	4	384	7
HCB5	259	4	5658	4	1210	8
HCB6	83	4	3446	4	535	8
HCB7	135	4	3527	4	691	8
Geometric Mean of Dry for All Sites	121	26				
Geometric Mean of Wet for All Sites			3969	28		
Geometric Mean of Wet & Dry for All Sites					692	54

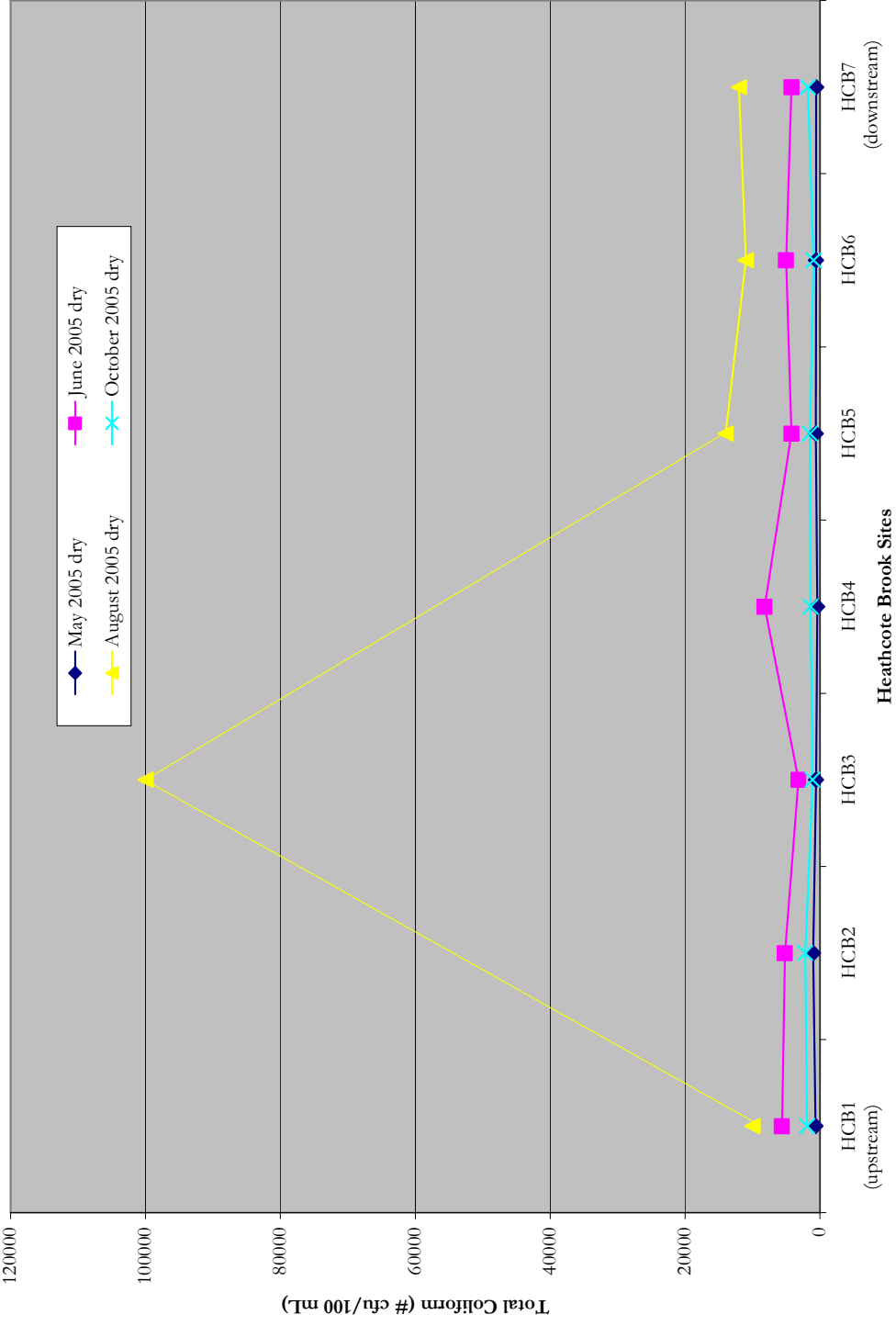
 Violates NJ State Surface Water Quality Standard: geometric average <200 cfu/100mL.

coliform or E. coli, are present and a repeat set of samples must be run for all three parameters within 24 hours. There are no state standards for total coliform in surface water.

Total coliform dry weather sample results were collected between May and October 2005 (Graph 10). Results ranged from 400 cfu/100 mL at Site HCB4 in May to 14,000 cfu/100 mL at Site HCB5 in August with one major spike to 100,000 cfu/100 mL at Site HCB3 in August, an order of magnitude higher than any other samples. It should be noted that two sites were dry in August 2005 (Sites HCB2 and HCB4) and unable to be sampled. There is no apparent consistency of results among sites during the sampling period and no consistency with the fecal coliform data.

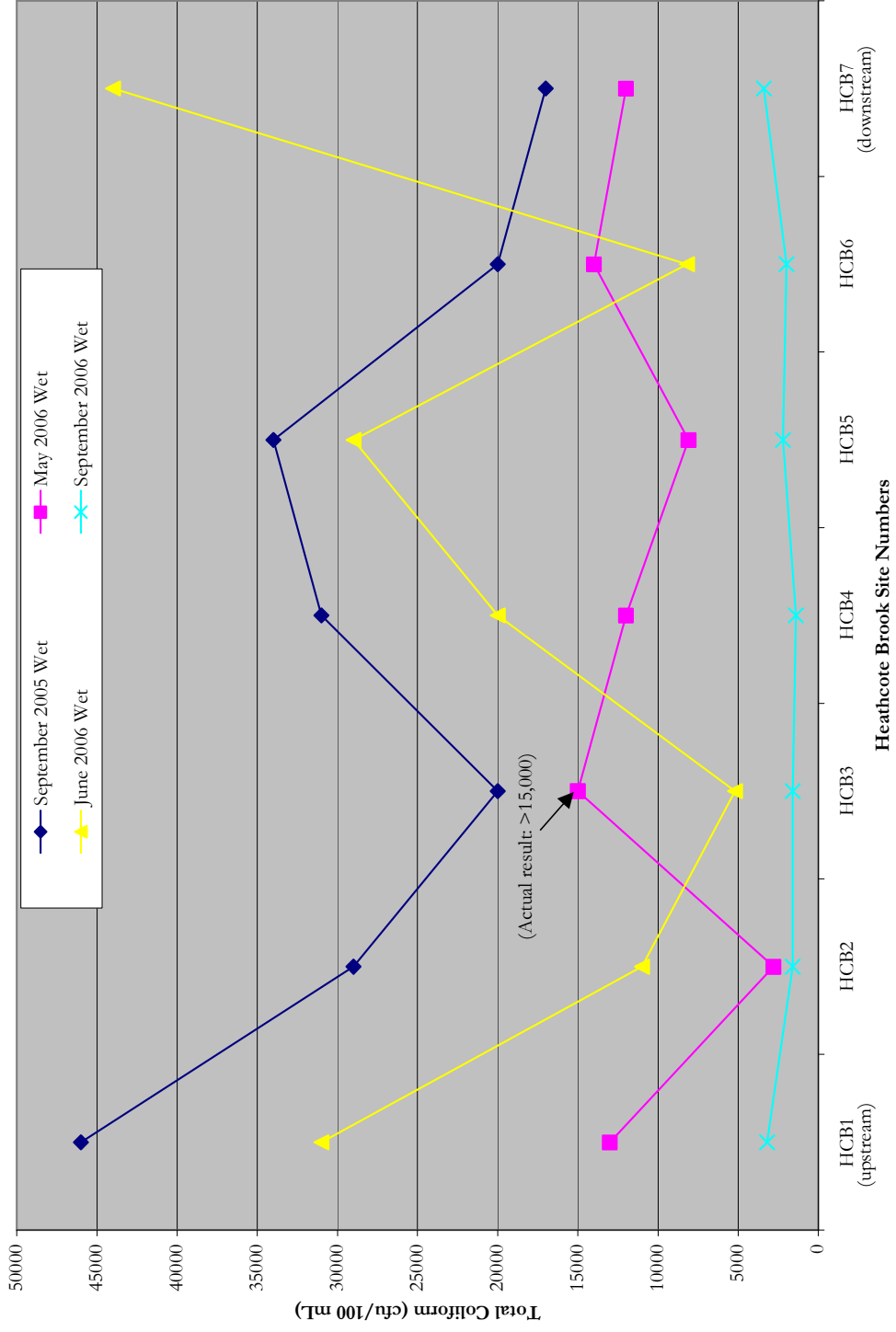
Wet weather samples for total coliform were collected between September 2005 and September 2006 (Graph 11). Results ranged from 1,400 cfu/100 mL at Site HCB4 in September 2006 to 46,000 cfu/100 mL at Site HCB1 in September 2005. It should be noted, however, that Site HCB3 results in May 2006 were too numerous to count and are, therefore, unknown. The Lab did not do enough dilutions to accurately measure total coliform results for this analysis, but indicated that the results were at least greater than 15,000

Graph 10: Heathcote Brook 2005 Total Coliform Dry Weather Results (SBMWA Data)



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Graph 11: Heathcote Brook Total Coliform Wet Weather Results (2005 - 2006) (SBMWA Data)



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cfu/100 mL. Like the fecal coliform data, the results are generally worst at Sites HCB1 and HCB5. Hourly precipitation data for the wet weather sampling days are included in the attachments.

POLLUTANT LOADINGS

NPS loadings of nitrogen, phosphorus, and total suspended solids (TSS) were modeled to calculate pounds per acre per year (lb/acre/yr) of each. A model developed by Princeton Hydro, LLC was used to estimate NPS loadings (specifically, nitrogen, phosphorus, and total suspended sediments) based on land use types within that subwatershed as of 1995. Total acreage of a given land use type is calculated for each subwatershed; a coefficient estimates pounds per acre per year of pollutant runoff for each land use type; and total annual pollutant runoff is thus approximated for the subwatershed as a whole (Souza, 2003 personal communication.). The coefficients are based on studies of watersheds for which there was available monitoring information. Since these studies included watersheds with land use compositions similar to that of the Mid-Atlantic region, the coefficients – and thus the model – will only be valid in regions similar to that of the Mid-Atlantic. Note that the values presented here are estimates of NPS pollutant loads and are not actual field measurements.

The model generally scores agricultural lands high in phosphorus and TSS loadings, developed/urban areas high in all three loadings (nitrogen, phosphorus, and TSS), and other land uses (forest and wetlands) low in all three loadings. This is based upon the fact that impervious cover associated with urban areas increases NPS pollution loadings by preventing stormwater runoff from percolating back into the ground (see Land Use section for more information). The loadings from agricultural areas result from NPS pollution as stormwater runoff gathers and transports fertilizers and recently tilled or exposed soils.

For the Heathcote Brook Watershed, this model was applied using 2002 Land Use data, which had become available after the model was created. Within the Heathcote Brook Watershed, areas along and near the Route 1 corridor and areas in the southwestern portions of the watershed have high estimated loadings for all three parameters (Figures 27, 28, and 29). For phosphorus loadings, the highest levels estimated coincide with many of the agricultural lands in South Brunswick, Plainsboro, and Franklin Townships (Figures 14 and 28). Many of these areas are considered to produce high levels (0.325 - 1.926 lb/acre/yr) of phosphorus (Figure 28). Nitrogen loading estimates for this model in the Heathcote Brook Watershed fall mostly within the lower part of the range (0.000-1.619 lb/acre/yr) (Figure 27). Areas where nitrogen loadings are higher (3.036 – 5.585 lb/acre/yr) coincide with many of the barren and agricultural lands in Plainsboro, South Brunswick, and Franklin Townships. In a stream, the addition of nitrogen, such as from stormwater runoff originating in the areas of higher nitrogen loadings, can result in increased survival of bacteria (Lim & Flint, 1989).

This may be partially contributing to the high bacterial loads seen in Heathcote Brook. TSS loadings in the Heathcote Brook Watershed fall mostly within the low to moderate range (-80.9 – 404.7 lb/acre/yr) for this model. Small areas with higher loadings (404.8 – 1618.8 lbs/acre/yr) coincide with barren and urban lands (Figure 29).

The areas with the lowest estimated loadings in all three pollutants (nitrogen, phosphorus, and TSS) coincide with the wetlands located in South Brunswick and Franklin Townships (Figures 14, 27, 28, and 29).

ASSESSMENT

To best assess water quality, trends in particular indicators need to be determined. Water quality information for the Heathcote Brook Watershed is limited in terms of visual, biological, and chemical assessments, either in terms of the number of monitoring sites or the frequency in which these sites have been monitored. This means that a long-term set of reliable data from one agency or group needs to be obtained. Measurements of the environment are highly valuable, but are very specific to the time and place where they were taken. A long-term (10-20 years) dataset helps to reduce this time/place specificity and increase the likelihood that the measurements accurately reflect the water quality conditions in the stream. Although SBMWA has monitored water quality on Heathcote Brook for 14 years through chemical assessments, it is only at one site. Similarly, USGS has conducted water quality monitoring for numerous parameters at only one site on Heathcote Brook for over 30 years. NJDEP conducts biological assessments, but only on two sites at a frequency of three times in the past 11 years. Additional data would provide a broader picture of water quality and clarify if biological life is able to thrive in Heathcote Brook and its tributaries.

In general, Heathcote Brook does not fully support the breadth and diversity of aquatic life representative of a healthy stream ecosystem (Table 8). This means that there are one or many stressors suppressing the numbers and varieties of aquatic macroinvertebrate populations. These organisms form the food base for many other wildlife species, especially fish, frogs, and some species of ducks.

The most likely stressor affecting the macroinvertebrate communities in Heathcote Brook is the increasing sedimentation noted in SBMWA's visual assessments. Levels of sedimentation were highest in the areas of Heathcote Brook nearest the locations of the biological monitoring sites (Table 7; Figures 24 and 25). The basis for this heightened sedimentation may be due to urbanization of lands (especially during construction when soil is disturbed), soil composition, and erodibility of the Heathcote Brook Watershed itself (see Land Use, Geology, and Soils sections for more details). The majority of soils in the Watershed are classified as “moderate” to “high” in terms of their erodibility (Figure 12). This classification is based upon the

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“K-factor” and measures ability of bare soil to erode. This moderate to high erodibility combined with the significant amount of developed lands seen in much of the watershed likely accounts for much of the sedimentation observed. Additional monitoring is needed to more definitively pinpoint stressors to the biological community.

Bacteria monitoring along Heathcote Brook and its tributaries supports NJDEP’s designation of this stream as impaired for fecal coliform based on the 2003 Surface Water Quality Standards (NJDEP, 2003d). NJDEP has listed Heathcote Brook on the Integrated List in 2002, 2004, and draft 2006 for fecal coliform impairment and created a TMDL in 2003, approved by USEPA, calling for a 94% reduction (NJDEP, 2003c). SBMWA’s dry weather bacteria monitoring found numerous violations, with the areas of most concern being at the headwaters (Site HCB1) and along Carters Brook (Site HCB5). Since dry weather fecal coliform results should all meet the state standard, the fact that there were numerous violations indicates possible local sources for fecal contamination, which could consist of a large resident geese population in a particular area, livestock with stream access, failing septic systems, or leaking sewer pipes. Since there are no agricultural lands near Site HCB1 and such lands only exist downstream of Site HCB5, the excessive fecal coliform levels at these sites are not due to the effects of livestock. Sites HCB1, HCB2, and HCB3 are in areas currently managed by septic systems (Figures 13 and 26). If those septic systems are failing, they are likely contributing to dry weather violations. Site HCB1 is located in an urban area behind the Red Roof Inn at the intersection of Route 1 South and New Road, just downstream from a trailer park. Possibly there are problems with the septic system at the trailer park. Sites HCB4, HCB5, HCB6, and HCB7 are all located within sewered areas. Site HCB5 is located on Carters Brook, a tributary to Heathcote Brook, behind 11 Carter Brook Lane in Princeton. At this site sewer pipes closely paralleling the stream may be leaking and contributing fecal coliform to Carters Brook. The integrity of this aging infrastructure is brought into question by the bacteria sample results.

Since bacteria results were high at all sites during wet weather events, NPS pollution is likely contributing significant bacterial loads to the Heathcote Brook and its tributaries. The NPS pollution could be contributed from agricultural or urban areas.

Areas with agricultural land use (Figure 14) could contribute to high bacteria levels if livestock are allowed access to streams or if stormwater runs through pastures en route to the streams. The mainstem of Heathcote Brook downstream from Site HCB3 and Carters Brook downstream of HCB5 both run through or near agricultural areas (Figures 14 and 26). Farms in these areas may be contributing agricultural NPS pollution to Heathcote Brook and its tributaries. According to the 2002 Land Use/Land Cover data, nearly 80% of Heathcote Brook’s agricultural lands consist of crop/pasture land.

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For the more urban areas, such as those near Sites HCB1, HCB2, HCB3, and HCB4, bacteria contributions are likely to be resulting from NPS pollution. Stormwater runoff across roofs, lawns, streets, driveways, and sidewalks is accumulating and conveying significant amounts of pollution to the waterbodies. It is possible that fluctuating bacterial loads over the years from Carters Brook have affected the biological monitoring results at AMNET site AN0396 on the mainstem.

NPS pollutant loadings for nitrogen, phosphorus, and TSS in the Heathcote Brook Watershed are found mostly within the low to moderate levels based on the model used in this assessment, with some concentrated areas of high NPS loadings (Figures 27, 28, and 29). Since the Heathcote Brook Watershed already has approximately 35% of its land developed into urban areas and development is on the rise, stormwater management is key to reducing the loadings of NPS pollutants into Heathcote Brook and its tributaries and to protecting areas that currently exhibit low levels of these pollutants. Of special note are the loadings for TSS, as increased sediments in streams can smother habitat for macroinvertebrates and other stream life. Also, since bacteria can be associated with sediment and other particulate matter (Ferguson, et. al., 2003), increased TSS loadings may be contributing to the high presence of bacteria seen in Heathcote Brook.

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FINDINGS & RECOMMENDATIONS

The results of this characterization and assessment represent an opportunity to properly plan the landscape of the Heathcote Brook Watershed in an environmentally responsible way and to work proactively to protect water quality. Overall, waterways are experiencing moderate degradation due to sedimentation in Heathcote Brook and stormwater is impacting the health of waterways. Sedimentation is partly due to the makeup of the underlying soils and geology. While this condition is natural, many other factors are amplifying this problem. Population increases in the Heathcote Brook Watershed, and associated land use changes, are adding to the amount of impervious surfaces, which augment the frequency and intensity of stormwater, flooding, and erosion.

PLANNING FUTURE GROWTH

Finding: Populations in the Heathcote Brook Watershed townships, like the rest of New Jersey, are on the rise. The population went from 82,785 residents in 1990 to 108,852 in 2000, increasing by 31.5%. From 1986 to 2002 developed lands increased from 1440.6 acres to 2033.6 acres, a gain of over 41%. Developed areas are on the increase at the expense of the remaining forest, wetlands, and agricultural areas in the watershed. (See Landscape and Land Use sections for more information.)

Recommendations:

- If not already completed, buildout analyses for each municipality should be conducted. This will allow for predictions of future growth and where current policies could lead. Regulations could be evaluated to determine if they are protective enough for preserving environmental quality.
- One way to balance the population growth with increased development is to plan for and maintain areas as town centers. These areas can be planned as mixed-use developments (projects that integrate different land uses, such as restaurants, residences, offices, and parks) or low impact developments (ecologically friendly site development and stormwater management that aims to mitigate impacts to air, water, and land) for maximum benefit.
- Heathcote Brook Watershed contains many critical habitats for a variety of threatened and endangered species. Critical habitats cover 65.3% (3,718 acres) of the Heathcote Brook Watershed. Many of these critical areas are adjacent to existing developments, putting them under development pressure. The municipalities that make up the watershed should review and reconsider their zoning to coincide with these environmentally important areas, restricting development and fragmentation of these habitats. Also, open space preservation can use critical habitat data as a tool to plan where efforts can be focused.
- When evaluating rezoning and alternative planned developments, accurate scientific information on the carrying capacity of available water supplies, sewer systems, and other infrastructure needs to be considered, in addition to the goals and objectives of the municipality's Master Plan. It is highly recommended that those municipalities not currently in SBMWA's Municipal Assessment Program consider participating. Within the Heathcote Brook Watershed, Franklin Township has completed the Municipal Assessment process, while SBMWA hopes to begin work with South Brunswick and Plainsboro Townships in the near future. Through this

program, SBMWA works individually with each municipality to review the current Master Plan and ordinances, compare these documents to the goals and objectives of each decision-making committee, and provide recommendations of next steps to take to bring these goals and documents into harmony. SBMWA then follows up with the municipality to implement those recommendations deemed the highest priority by that municipality. SBMWA encourages a continued partnership with Franklin Township to implement key recommendations.

- The extensive sewer service areas that cover the Heathcote Brook Watershed increase the potential for development to occur, if it hasn't occurred already. Figure 13 shows the portions of South Brunswick that have already been sewerred. This Township could prioritize the next phase of sewer line installation in those areas that are not suitable for septic and preserve the lands in acceptable septic areas. This would concentrate development in non-septic areas. Maintaining current septic areas as such would also reduce potential for development and could help preserve critical habitats. Likewise, Plainsboro Township needs to preserve lands in their designated sewer service area, reducing development pressure. Preservation can occur via conservation easements, open space acquisitions, and environmentally sensitive zoning. Franklin Township should refrain from sewerred to reduce development pressure and preserve the Township's critical habitats within the Heathcote Brook Watershed.
- Increasing impervious cover and the resultant decrease in the amount of forest, wetlands, and agricultural areas is occurring in the Heathcote Brook Watershed as development continues. As a result, water quality is being affected and will continue to be a concern. One way to protect water quality is by decreasing the rate of conversion of forest, wetlands, and agricultural lands through participation in the New Jersey Farmland Preservation and Green Acres Programs, as well as by working with regional land conservation groups to preserve key tracts of land. Adopting and enforcing stream corridor ordinances and protecting riparian areas through conservation easements would also benefit the Watershed.
- Riparian corridors are being increasingly encroached upon for development in the Heathcote Brook Watershed. These areas are particularly sensitive to land use changes, as they are the natural buffers that protect the stream itself from a variety of pollutant sources. Placing of new construction in the Heathcote Brook Watershed needs to be sensitive to, or avoid altogether, the riparian corridors in order to maintain ecological integrity.

Applicable BMPS and Mitigation Approaches:

- To determine which resources are available in each municipality, South Brunswick and Plainsboro should each conduct a Natural Resources Inventory or an Environmental Resources Inventory (ERI), if not already completed. Such an inventory would document the location and extent of environmentally important and sensitive areas that should be taken into account when determining where development or increased impervious surfaces are to be placed. Franklin Township has already taken steps to complete an ERI by mid-2008 by working with Amy S. Greene

Environmental Consultants. The report will include information on soils, land use, aquifers, water recharge, water quality, air quality, threatened and endangered species, and known contaminated sites.

- To minimize the impacts of development, each Township could conduct a study of the existing public transportation system to encourage its use and suggest changes that may make it more usable.
- The LEED (Leadership in Energy and Environmental Design) Program for existing and new development should be encouraged by the Townships for any proposed development or redevelopment. LEED emphasizes state of the art strategies for sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality. For more information on the LEED Program, visit the website (<http://www.usgbc.org/>) of the U.S. Green Building Council, which developed the Program.
- Before a property can be developed, the owner is required by federal and state law to determine whether wetlands are present. The owner submits a Letter of Interpretation (LOI) Application to NJDEP, which includes wetland delineation maps, soil data, and plant and wildlife reports. A copy of these LOI applications is kept at the municipal hall. It is very important for the Township to review these LOI Applications and have elected or appointed officials walk the site in question to confirm that their understanding of the wetland area agrees with the property owner's delineation. If the Township notices a discrepancy, they can request that NJDEP come to the site and verify or modify the wetland delineation. Once an LOI has been approved by NJDEP, it is very difficult to amend it. When NJDEP approves the LOI Application, this officially determines the wetland classification and its boundaries and buffer size. In turn, this can affect where and how large of a footprint the development can have.
- NJDEP also encourages public comment on the wetland permit applications. Townships should be aware of any pending permits, review them, and provide comments to be able to protect their natural resources and have more control over development.
- Townships can also provide input to NJDEP on wetland mitigation decisions, which require compensation for freshwater wetland disturbances by requiring the developers to provide the creation of at least two acres of wetland for each acre disturbed.

Applicable Model Ordinances:

- The adoption or enforcement of an Impervious Cover Limitation Ordinance applicable to new developments could significantly slow the effects of development and protect high groundwater recharge areas. Princeton and East Amwell Townships have adopted variations on this ordinance, with Princeton limiting impervious cover to an acceptable flat percentage, while East Amwell's stronger ordinance for the Sourlands region imposes a sliding scale percentage depending on the size of the lot involved. An existing ordinance that encompasses both of these variations is in effect in New Castle County, Delaware. This ordinance caps the acceptable impervious surfaces at 20% while imposing a sliding scale

impervious cover reduction for any redevelopment depending on the lot size. New Castle County's overlay ordinance for water resource protection areas is found within Article 10 (Environmental Standards) or Section 40.10.380 and can be found at <http://www.co.newcastle.de.us/CZO/nccportal.asp>.

- Consider creating an ordinance to require the installation of pervious pavement for redevelopment projects. This would serve to actually reduce the impacts of impervious cover. One approach is to mandate the use of pervious pavement for driveways, walkways, and other paved areas such as parking lots. Bethany Beach in Delaware has such an ordinance, which can be found at <http://www.townofbethanybeach.com/documents/500/PourSurfOrd.pdf>. A second approach is to make the requirement part of a "Low-Impact Development" (LID) Ordinance that incorporates LID techniques into a land development ordinance. The Town of Warsaw, Virginia enacted such a mandatory LID Ordinance, which can be viewed at <http://www.riverfriends.org/LinkClick.aspx?fileticket=VlaUwo%2fvYtQ%3d&tabid=86&mid=425>. Although this ordinance does not specifically refer to pervious pavement, that is one of the potential methods for maintaining the pre-development volume of runoff. An incentive-based rather than mandatory approach used by some communities, such as the City of Fitchburg, Wisconsin, is to charge stormwater utility fees to private property owners based on the amount of impervious area on a site. These fees pay for the City's stormwater management program. Property owners can apply for credit on their stormwater bill for properly functioning on-site stormwater management BMPs, beyond what is required by City Ordinance. One such BMP includes pervious pavement. Fitchburg's Stormwater Utility Credit and Rebate application form can be viewed at <http://www.city.fitchburg.wi.us/files/2550961.pdf>.
- The adoption or enforcement of a stream corridor ordinance will prevent further development in this key area while preserving the riparian corridor. South Brunswick Township has passed a stream corridor ordinance and Franklin Township has protective language included in its land use ordinance. To give added protection, Franklin Township should consider establishing a separate stream corridor ordinance. SBMWA's model stream corridor ordinance is included in Appendix H. Some townships in New Jersey are also incorporating critical areas into their stream corridor ordinances, making them much stronger. Each Township should consider including such language in their ordinances and Plainsboro should consider adopting a stream corridor ordinance for their Township.

Finding: Impervious cover prevents the movement of water into the soil. The Heathcote Brook Watershed has an average impervious cover of 12.9%, however many areas are rated at 26% and above (Figure 19). An impervious coverage between 10 and 25% results in the loss of sensitive elements from the stream system while those areas with an impervious cover greater than 25%

experience a shift to poor stream conditions that includes diminished aquatic diversity, water quality, and habitat function. The municipalities also need to be aware that much of the underlying soils in the Heathcote Brook Watershed are moderately to highly erodible and also have slow to very slow infiltration rates, which result in high to very high surface runoff in this region. Water quality impacts due to the erodible nature of the soils in this region have been noted. (See Land Use and Water Quality sections for more information.)

Recommendation:

- Increasing impervious cover will only exacerbate water quality problems by increasing the frequency and intensity of storm flows and flooding, while also increasing the NPS pollution contributions. Municipalities need to incorporate innovative ways to plan developments including low impact development, re-zoning (changing zoning classifications to permit development that is less dense or restrictive), mixed-use development (projects that integrate different land uses, such as restaurants, residences, offices, and parks), conservation design (placing a development on the least environmentally restrictive portion of a property, incorporating water recycling, energy efficiency, and sustainably produced materials into building design), and town-center designation (centralized growth areas through incentives and allows for developing at higher densities). For example, Franklin Township has already zoned many areas in the Heathcote Brook Watershed with a large lot size (requiring three or five acre lots) to encourage less dense development. These methods enable municipalities to accommodate the growth occurring throughout the watershed while significantly reducing the harm from such development. Redeveloping existing urban land uses will also help to maintain or reduce current amounts of impervious cover in those areas.

Applicable BMPs and Mitigation Approaches:

- Disconnect downspouts from stormwater systems at all municipal properties and encourage businesses and residents to do the same. Downspouts should be directed either into a vegetated bed or a rain barrel. Among other things, water from a rain barrel can be used to water nearby vegetated beds, rinse garden tools or muddy boots, or wash the car.
- Install vegetated filters next to roads and sidewalks, enabling the stormwater to enter as sheet flow. This will remove suspended sediments and other pollutants from the stormwater runoff as well as encourage infiltration and the reduction in stormwater volumes entering waterbodies or stormwater systems. (See the NJ Stormwater Best Management Practices Manual, NJDEP, 2004b.)

Applicable Model Ordinances:

- The adoption or enforcement of an Impervious Cover Limitation Ordinance applicable to new developments could significantly slow the effects of development. Princeton and East Amwell Townships have adopted variations on this ordinance with Princeton limiting impervious cover to an acceptable flat percentage while East Amwell's stronger ordinance for the Sourlands region imposes a sliding scale percentage depending on the size lot involved. For more information, see the

references to these model ordinances in the model ordinance section on pages 77-78.

- Consider creating an ordinance to require the installation of pervious pavement for redevelopment projects. This would serve to actually reduce the impacts of impervious cover. For more information, see the references to model pervious pavement ordinances in the model ordinance section on page 78.

PROTECTING & MAINTAINING GROUNDWATER RESOURCES

Finding: There are 13 known contaminated sites (KCSs) in this 9.15 square mile watershed. Twelve of the sites are found within South Brunswick Township alone, one of which is a Superfund Site. (See Known Contaminated Sites section for more information on each KCS and how they affect groundwater.)

Recommendation:

- The large number of KCSs in the Heathcote Brook Watershed warrants that the potentially responsible parties and NJDEP remediate any contamination present, particularly at the Superfund site.
- Until remediation is complete, all parties should monitor, as required, to ensure that contamination is contained and that the potential water supply it feeds and the surrounding areas are protected from potential contamination.

Applicable BMPs and Mitigation Approaches:

- Potentially responsible parties should work with NJDEP to ensure that the appropriate actions are taken to fully remediate the contamination.
- For certain types of contamination, stormwater could be conveyed off site through a vegetated swale to prevent infiltration into the ground where it could contribute to the further spread of contamination.

Applicable Model Ordinances:

- Townships can adopt an ordinance requiring that site plan approval be conditioned upon an applicant providing the completion of a Phase I Environmental Site Assessment Report when a KCS is sold. If the report recommends a Phase II Environmental Site Assessment Report, the report must be done at the request of the purchaser if it has not already been completed. Franklin Township in Gloucester County has amended their site plan approval process to incorporate this change.
- Townships should keep a list of KCSs attached to property record cards to ensure that if a property is sold at a tax sale, the status is made known to the purchaser.

Finding: Much of the Heathcote Brook Watershed (44.8%) contains areas with high groundwater recharge. Between 1986 and 1995 Heathcote Brook lost 10.2% of its groundwater recharge capability due to continued development in high groundwater recharge areas. Groundwater recharge areas need to be protected by ordinances or preserved by their respective municipalities to restrict development in these areas. The municipalities within

the Watershed should use high groundwater recharge areas, in addition to critical habitat data, when setting priorities for additional open space preservation. Reduced development in the high groundwater recharge areas will aid in ensuring that plentiful supplies of water are available for the future and that streams will continue to flow. (See Water Supply section for more information.)

Recommendations:

- Since some of the high groundwater recharge areas are located in agricultural areas in Franklin, Plainsboro, and South Brunswick Townships, these municipalities need to encourage regulations on the use of chemicals (especially ecologically harmful chemicals like pesticides) in the agricultural areas above groundwater recharge zones to prevent possible contamination (Figure 17). If this is not possible, farms need to review and evaluate the many options available to reduce their pesticide use in such areas. For example, participation in the New Jersey Conservation Reserve Enhancement Program (CREP) helps farmers reduce impairment from agricultural water runoff sources in an effort to improve water quality along both impaired and unimpaired New Jersey streams through best management practices (BMPs).
- Municipalities could institute an educational campaign directed at all property owners on the effects of pesticide use on surface and groundwater. Property owners could be encouraged to minimize pesticide use and to join SBMWA's River-Friendly Program for one-on-one guidance as to how to reduce pesticide use or find less toxic alternatives. SBMWA works individually with each property owner to assess current land stewardship practices and provide recommended actions for improvement. The River-Friendly Program focuses on water quality, water quantity, wildlife and habitat enhancement, and education components, all geared towards reducing NPS pollution.
- Municipalities should limit increases in impervious surfaces in the Watershed in order to prevent costly mitigation efforts to restore recharge areas in the future. (See Planning Future Growth, above.)
- Municipalities should prioritize land in high recharge areas for preservation and protection. As an example, identifying lands located above high recharge areas that are also riparian areas and critical habitats for threatened and endangered species (Figure 18) could be one way to target land for preservation. Since listing specific properties in this report could affect their purchase price, SBMWA has chosen not to do so here.

Applicable BMPs and Mitigation Approaches:

- To ensure that groundwater and aquifers maintain adequate water supply, municipalities can require the use of stormwater BMPs, such as infiltration ponds and basins in new developments. These ponds are lined with permeable soils and materials that allow water to be slowly released back into the ground. Other stormwater BMPs that address infiltration include bioretention basins, pervious pavement (see above), vegetated swales, and vegetated filters to capture discharge as sheet flow (NJDEP, 2004b). BMPs such as these should be implemented at each new development or

redevelopment project. However, each site is unique. For information on the use of BMPs under the New Jersey stormwater management rules, see SBMWA's document, *New Jersey's Nonstructural Stormwater Strategies Point System-A Primer*, available at <http://www.thewatershed.org/info/2007NSPSPprimer.pdf>

- In order to minimize the use of pesticides and reduce the harmful effects on people and the environment, New Jersey requires Integrated Pest Management (IPM) to be used in each public, private, and charter school. IPM does not prohibit the use of pesticides, but advocates using the most effective, least-risk option. Pesticides are only used as the last resort under IPM. To further strengthen this policy and protect a widening area of people and the environment, Franklin, Plainsboro, and South Brunswick Townships could join 53 other Boroughs, Townships, and Cities by enacting a resolution requiring IPM to be used in parks and on other municipal properties. In addition to parks, municipal right-of-ways such as roadsides, drainage ditches, swales, or bridge culverts could be included in the municipal IPM program. An example of a model IPM resolution drafted by New Jersey Environmental Federation can be found at: <http://cleanwateraction.org/njef/pfzresolution.pdf>. A resolution such as this could be used to push for enactment of an IPM ordinance, which results in a much stronger policy.

Applicable Model Ordinances:

- Each municipality should adopt or enforce an Impervious Cover Limitation Ordinance for new developments and consider creating an ordinance requiring pervious pavement installation for all redevelopments. (See model ordinance section in the impervious cover finding, above, for more details.)
- To limit the likelihood of inadvertent exposure to pesticides and the resulting health risks, there are numerous configurations of ordinances enacted in New Jersey relating to advance notification of applications. For example, Old Bridge Township in Middlesex County adopted an ordinance requiring notification via a newspaper ad whenever pesticides will be applied on a community-wide or area-wide basis. Similar ordinances have been enacted in the townships of West Milford (Passaic County), Vernon (Sussex County), and Hanover (Morris County), and in the boroughs of Bernardsville, Cresskill, and Tenafly. New York State has taken the notification laws to an even stricter level. The state authorizes local county laws that require commercial applicators to provide written notice to all occupants within 150 feet of the application site, as well as requiring residents applying pesticides on their own private property to post lawn signs if the application covers more than 100 square feet. Information on New York's Neighbor Notification Law, including the text for the law and the NY Department of Environmental Conservation implementing regulations, as well as a list of New York counties that have opted into the law can be found at: <http://www.dec.state.ny.us/website/dshh/pesticide/neighbor.htm>. A citizens' guide to the New York State pesticide notification laws can be found at: <http://www.oag.state.ny.us/>

environment/pesticide_guide.html. Notification laws could also require all applicators to provide information on the amount and type of pesticide applied within the municipality. Each of the municipalities within the Heathcote Brook Watershed should consider enacting some version of the pesticide application notification ordinance.

- To protect critical areas, an ordinance could be passed that would prohibit pesticide use in specific zones such as forests or stream corridors. Many towns in Maine have enacted variations on this theme. For a listing of the different types of municipal pesticide ordinances and the Maine Townships that have adopted them, see http://www.maine.gov/agriculture/pesticides/pdf/municipal_list.pdf. An example of an ordinance adopted by Wells, Maine, which includes language restricting pesticide applications within the special Branch Brook Aquifer Protection District is found within the Land Use Ordinance at http://www.e-codes.generalcode.com/codebook_frameset.asp?ep=fs&t=ws&cb=1006_A. The section of the code that applies is 145-31.G.2. To get there, open the table of contents and click on the “+” sign in front of “Part II – General Ordinances”, “Chapter 145: Land Use”, and “Article V”. Then click on 145-31.
- To prohibit fertilizer applications in certain circumstances that would directly affect water quality, such as during a runoff event, municipalities could adopt the NJDEP’s Fertilizer Application Model Ordinance. This model ordinance can be found at <http://www.state.nj.us/dep/watershedmgt/DOCS/TMDL/Fertilizer%20Application%20Model%20Ordinance.pdf>. The model ordinance could also be modified to create a new ordinance prohibiting pesticide applications under similar circumstances.
- Several counties and townships have executed variations on IPM policies restricting the application of pesticides to very limited circumstances, sometimes referred to as Pesticide-Free Zones (PFZs). For example, Burlington County has established an IPM plan for the county parks that only permits the use of two types of chemical pesticides. Some Townships in New Jersey, including Brick, Chatham, Wall, Irvington, and Ocean City have passed resolutions creating PFZs. NJ Environmental Federation has created a model IPM resolution that includes the designation of PFZs on certain public properties. Clifton, Pine Beach, and Hazlet have all adopted resolutions based on this model. This model resolution can be found at: <http://cleanwateraction.org/njef/pfzresolution.pdf>.

PROTECTING WATER QUALITY

Finding: The nature of Piedmont geology has a large influence on the water resources and environmental quality of the Heathcote Brook Watershed. Sandstones, siltstones, and shales typify the Piedmont Physiographic Province. (See Geology section for more information.)

Recommendation:

- The Magothy Formation is part of the high yielding Potomac-Raritan-Magothy Aquifer system. Since this aquifer is susceptible to groundwater

contamination because of its widespread exposure and high sand content, its outcrop area should be considered when prioritizing areas for protection. This factor could be included with high groundwater recharge areas, riparian areas, and critical habitats when setting priorities for additional open space preservation (see recommendation in Maintaining Groundwater Resources, above). The Magothy Formation and its related aquifer should be considered when making municipal decisions about approving proposed development locations and how strict to be about the related stormwater management practices.

Applicable BMPs and Mitigation Approaches:

- South Brunswick and Franklin Townships could strengthen their stormwater management plans for areas where the Magothy Formation outcrops (see Figures 8 and 9). To protect this susceptible aquifer recharge area, these municipalities can require extensive use of stormwater BMPs for both new developments and redevelopments. Examples of stormwater BMPs that address infiltration include infiltration ponds and basins, bioretention basins, pervious pavement (see above), vegetated swales, and vegetated filters to capture discharge as sheet flow (NJDEP, 2004b).

Applicable Model Ordinances:

- The bedrock formations more resistant to erosion, such as the Lockatong and Jurassic Diabase, tend to form ridges. Protecting the associated steep slopes will reduce the potential for erosion from development activities, stormwater outfall flows, road and driveway cuts and crossings, and tree removal. This has been done by Montgomery Township in their Land Development Ordinance (Section 16-3, 16-6.4, and 16-5.6) and Critical Areas Ordinance and West Amwell in their Stream Corridor Ordinance. For information on how to get access to these ordinances, see Appendix H.
- Townships within the Heathcote Brook Watershed should enact a strong Stream Corridor Ordinance or strengthen their existing ordinance to protect water quality. SBMWA's model stream corridor ordinance is included in Appendix H.

Finding: Much of the Heathcote Brook Watershed is classified as having hydrologic soil group C, covering 3,001.4 acres out of a total of 5,854.7 acres (51.3%) in the entire watershed. Hydrologic soil group C represents soils with a slow infiltration rate, and is representative of the moderately consolidated soils seen in the Piedmont Physiographic Province. The second most common hydrologic soil group in the Heathcote Brook Watershed is group B, covering 28% of the watershed and representing moderate infiltration rates. Runoff from these soil groups will be moderate to rapid due to these moderately fine- to coarse-textured soils' moderate to slow infiltration rates.

Most of the Heathcote Brook Watershed is also assessed as having high K-factors, or high soil erodibility. These areas have the greatest potential for

benefit from soil conservation practices and the greatest likelihood for harm from construction and development.

Based upon the visual assessment data and observations during the biological assessments, the most likely stressor affecting the macroinvertebrate communities in Heathcote Brook is heightened sedimentation. The basis for this heightened sedimentation may be due to the soil composition and moderate to high erodibility of the Heathcote Brook Watershed itself, which is exacerbated by the high amount of developed lands in the watershed. The nature of the Piedmont soils in the Heathcote Brook Watershed is an important factor impacting water quality of Heathcote Brook, especially macroinvertebrate communities and their habitats. (See Water Quality and Soils sections for more information.)

Recommendation:

- Because municipalities rely on their local Soil Conservation Districts (SCDs) to enforce the soil erosion and sediment control regulations, SCDs need to be aware of the characteristics of a site's underlying soils when they review and enforce plans to control and manage soils during construction activities.
- Due to the somewhat consolidated nature of the stones and soils in the Piedmont Physiographic Province, infiltration rates for water entering the ground are moderate to slow. This has the potential to produce a high amount of runoff from storm events. This stormwater runoff needs to be controlled or managed by the municipalities so that it does not degrade water quality or increase the potential for flooding and erosion.
- Maintenance of soil integrity in areas with highly erodible soils can be done by encouraging environmentally friendly construction, properly implementing soil and erosion control BMPs, encouraging forested areas, and increasing or creating riparian buffer zones. Streambank stabilization and planting projects should be encouraged wherever streambanks are actively eroding along Heathcote Brook or its tributaries. Prior to implementation, a thorough scientific assessment should be done to ensure the appropriate location of restorations and appropriate methods used. Farms located within these areas could greatly benefit by working with NJ CREP implementing soil conservation practices.
- Heathcote Brook, Carters Brook, and an unnamed tributary have been identified as candidates for C1 designation. Acceptance by the NJDEP of the nomination of these streams as C1 waterways will aid in protecting the riparian corridors and maintaining the vegetated cover that stabilizes the soils. C1-designated waterways are afforded a higher level of protection from development while minimizing impacts from stormwater runoff; providing floodwater storage, erosion control, and groundwater recharge; and maintaining biological habitats and diversity. South Brunswick and Franklin Townships should actively support these nominations in order to move along the NJDEP acceptance process. The NJDEP Bureau of Water Quality Standards and Assessment is responsible for overseeing the Surface Water Quality Standards, which include stream designations such

as C1. The Bureau can be reached at (609) 777-1753 and more information is available at <http://www.state.nj.us/dep/wms/bwqsa/>.

- The headwaters of Heathcote Brook are located in South Brunswick Township. Residents, businesses, and South Brunswick municipal officials need to be particularly aware of their roles in impacting and improving water quality in this Watershed. The prevention and minimization of NPS pollution is important everywhere along streams, but particularly in the headwaters. Property owners along streams should consider participating in SBMWA's River-Friendly Certification Program to reduce their contribution to NPS pollution. SBMWA works individually with each property owner to assess current land stewardship practices and provides recommended actions for improvement. The program focuses on water quality, water quantity, wildlife and habitat enhancement, and education components, all geared towards reducing NPS pollution in different ways.

Applicable BMPs and Mitigation Approaches:

There are many stormwater best management practices that could be implemented in the Heathcote Brook Watershed to reduce the sediment contribution from stormwater runoff. Such BMPs could also reduce the frequency of flooding, erosion potential, and other pollutant loads. For a detailed listing of potential BMPs, refer to the New Jersey Stormwater Best Management Practices Manual (NJDEP, 2004b).

- The new NJDEP Stormwater Management Rules (N.J.A.C. 7:8) state several requirements for large new developments and redevelopments focusing on minimizing disturbances and impervious surfaces, increasing groundwater recharge, reducing peak flows, and reducing pollutants (such as suspended sediment) carried by stormwater. Key BMPs that increase infiltration and filter out sediments include infiltration basins, bioretention basins, pervious pavement (see above), vegetated swales, and vegetated filters to capture discharge as sheet flow (NJDEP, 2004b). BMPs such as these should be implemented on each new development or redevelopment project. However, each site is unique. For information on the use of BMPs under the New Jersey stormwater management rules, see SBMWA's document, *New Jersey's Nonstructural Stormwater Strategies Point System-A Primer*, available at <http://www.thewatershed.org/info/2007NSPSprimer.pdf>.
- The implementation of stormwater BMP retrofits in areas being redeveloped, or on municipal properties, could result in cleaner water in Heathcote Brook and its tributaries. In this case, existing stormwater management BMPs can be improved to better protect downstream waterbodies. Vegetating existing swales located near Heathcote Brook or its tributaries is one example of a low-cost method that can result in positive changes.
- Agricultural activities (as some of this region is still farmland and many farms are located near streams and in highly erodible areas) need to investigate the use of BMPs to help alleviate sediment loads into area streams. The New Jersey CREP works with farmers to fund and implement such BMPs. For more information about New Jersey CREP,

please visit www.fsa.usda.gov/pas/publications/facts/html/crepnj04.htm. For a comprehensive guide to all the various state and federal grant programs for farmers and other landowners, visit <https://www.njaudubon.org/Conservation/PDF/IncentiveGuide.pdf> for the “Guide to Conservation Incentive Programs For New Jersey Landowners and Farmers”, published by the New Jersey Audubon Society. It includes information on CREP, the Landowner Incentive Program (LIP), Wildlife Habitat Incentives Program (WHIP), Environmental Quality Incentives Program (EQIP), Conservation Reserve Program (CRP), Grassland Reserve Program (GRP), and others.

- Streambank restorations and reforestations are excellent BMPs to increase infiltration of stormwater, filter out pollutants such as sediment and nutrients, stabilize barren soils and streambanks, reduce streambank and sediment erosion, and with time reduce stream temperatures through the creation of shaded areas which results in improved in-stream habitat. Streambank restorations and reforestations should be pursued whenever possible for stream reaches along Heathcote Brook and its tributaries showing signs of erosion and/or minimal vegetation.

Applicable Model Ordinances:

- To help alleviate any heightened sedimentation of waterways within the Heathcote Brook Watershed, municipalities should work with the appropriate Soil Conservation District to ensure that proper measures are taken to contain sediment at construction sites. County Soil Conservation Districts currently approve and oversee Soil Erosion and Sediment Control Plans for sites 0.25 acres in size or more. Best management practices, such as constructing silt fences and covering stockpiles of soil, should be properly installed and maintained for the duration of construction activities. More information on the New Jersey Soil Conservation Districts and their regulations is available at <http://www.state.nj.us/agriculture/divisions/anr/nrc/conservdistricts.html>.
- An ordinance incorporating soil protection will help protect streamside and other vegetation and prevent materials from washing into streams and degrading habitat and water quality post-construction. For example, a stormwater management ordinance (SMO) can address the protection of soils from damage during stormwater runoff. Model SMOs are available from Hunterdon County (<http://www.co.hunterdon.nj.us/pdf/stormwater/HCETModelOrdinanceFINALNov05.pdf>) and from NJDEP (http://www.njstormwater.org/tier_A/pdf/NJ_SWBMP_D.pdf). Stream corridor ordinances also establish protections favorable for soil retention within a riparian buffer. SBMWA is currently updating the model stream corridor ordinance. Please contact SBMWA for guidance; we would be happy to work with any township on this issue. A woodlands protection ordinance protects soil post-construction. Chatham Township has such an ordinance, which can be viewed at: http://www.chathamtownship.org/ORDINANCE_2005-023.pdf. Protecting steep slopes reduces the potential for erosion. This has been done by Montgomery Township in

their Land Development Ordinance and Critical Areas Ordinance and by West Amwell in their Stream Corridor Ordinance (see above).

- A woodlands protection ordinance would help preserve woodlands when land is being developed. The best way to prevent sedimentation in streams is to keep soil anchored on land by the roots of trees, shrubs, and native vegetation. Preserving established woodlands is one of the first lines of defense. Another result of adopting this type of ordinance is to filter out sediments and pollutants from stormwater flow before reaching the waterbody, reducing soil erosion in the streams, and moderating temperature by providing shade and windbreaks. The Hunterdon County Environmental Toolbox contains a model woodlands protection ordinance that can be found at: http://www.co.hunterdon.nj.us/planning/ordinances/toolbox/Environmental_Toolbox-Woodlands.pdf.
- Adoption of an afforestation ordinance would also protect streams from additional sedimentation resulting from development. An afforestation ordinance requires developers to plant trees and shrubs to create a woodlands habitat, regardless of the amount of tree removal from the site. The Hunterdon County Environmental Toolbox (see above) refers to one such ordinance adopted by Washington Township in Mercer County (Ordinance 103-53) which requires that for most zoning districts, a site development plan must “provide a minimum of 20% of the tract area in forest, if less than 60% of the predevelopment site is woodlands and provide a minimum of 40% of site in forest, if greater than 50% of the predevelopment site is in woodlands either through conservation or through afforestation....”

Finding: The visual assessment information, biological data, and bacteria monitoring results show that there are impacts to water quality, mostly stemming from the high amount of developed land in the Heathcote Brook Watershed. The Heathcote Brook is listed in NJDEP’s 2004 Integrated List as impaired due to fecal coliform and as having insufficient data to determine if benthic macroinvertebrate health is attained (NJDEP, 2004a). The Draft 2006 Integrated List of Waters (NJDEP, 2006c) lists Heathcote Brook as impaired for fecal coliform and “Pollutant Unknown”, referring to an impairment of aquatic life. (See Water Quality section for more information.) Since bacteria results were high at all sites, particularly during wet weather, measures should be taken throughout the watershed to reduce bacterial loads to Heathcote Brook and its tributaries.

Recommendations:

- In order to accurately assess the environmental health of Heathcote Brook, long-term trends in water quality need to be determined. Currently, there is insufficient monitoring data (biological or chemical) on the water resources in this region, especially basic water quality information for many of the area’s tributaries, which have an impact on the Heathcote Brook itself. Intensive monitoring at many sites along Heathcote Brook and its tributaries, particularly in the headwaters and along Carters Brook, needs

to occur to determine the stream's health. For example, to determine if bacteria loads from Carters Brook are affecting biological health measured at AMNET site AN0396, biological monitoring is recommended on Carters Brook. The completion of a visual assessment along segment HCB5 (the headwaters of Carters Brook; Figure 24) could also supply some ideas as to sources of bacterial and biological contamination. Future monitoring could be performed by municipal environmental commissions through the State's Environmental Services Program matching grant, as has been done successfully by other towns. More information on the ESP grant can be found at <http://www.state.nj.us/dep/esp/>.

- To determine the source of fecal coliform impairment seen at Site HCB1, additional monitoring is recommended upstream, within, and downstream of the trailer park located just upstream of the sampling site. This would help to determine if the trailer park is the source of significant bacteria or if an unknown upstream source is at fault. Microbial source tracking could also be performed on bacteria samples to confirm or disprove a significant human contribution.
- Site HCB1 is located just downstream of a trailer park that is apparently hooked up to a septic system. If possible, a history of septic maintenance at the trailer park could be helpful in determining the high bacteria levels seen at this site. Likewise a septic system inspection may be warranted.
- Site HCB5 on Carters Brook also showed high fecal coliform counts, possibly due to the aging sewer pipes that closely parallel the tributary. Additional sampling upstream and downstream of this reach could determine the extent of possible infrastructure problems. Microbial source tracking could also be performed on bacteria samples to confirm or disprove a significant human contribution. If results definitely indicate a sewage component, the sewer pipes should be tested for possible leaks and, if found, plans should be made to repair or replace the pipes. The NJ Environmental Infrastructure Trust has a loan program that assists municipalities in correcting or improving both wastewater and stormwater management systems. Their information can be accessed at <http://www.njeit.org/>.
- Since Site HCB5 is in an area where sewer pipes closely parallel the stream, dye analysis could be used to determine if the pipes are actually leaking. If they are, they could be contributing fecal coliform to the stream. Through this analysis, a dye is added to the pipe. If the dye ends up in the stream, the pipe is leaking.
- If not already done, each township could benefit from an inventory of where and what types of current septic systems are in use, locating each system on a map. Figure 13 shows not only septic suitability based on soils in the watershed, but also which areas are designated sewer service areas and which are currently sewered. While the portion of Franklin Township within the Heathcote Brook Watershed appears to be entirely septic, some portions of South Brunswick and Plainsboro Townships within Heathcote Brook Watershed are also using septic systems. By comparing the inventory map to Figure 13, it may become apparent where

inappropriate septic systems have been installed which might be failing. Since much of Franklin Township within the Watershed appears to be unsuitable for septic (Figure 13) and is not designated as a sewer service area, the Township should determine how residents and businesses within that area are handling their wastewater. Franklin Township could apply for NJDEP 604(b) Water Quality Planning Pass-Through Grants, which fund the development of onsite wastewater treatment system (OWTS) management plans. One step of the plan is to inventory the OWTSs within the Township. NJDEP's Division of Watershed Management website on nonpoint source pollution includes information about 604(b) grants and can be found at http://www.state.nj.us/dep/watershedmgt/nps_program.htm.

- For those Townships where septic systems are utilized, it is recommended that septic education programs on the management and maintenance of existing septic systems be conducted for residents and businesses. The septic inventory map would help to target areas that could benefit from such education programs. Even non-failing septic systems can contribute to nutrient pollutant loading, so it is important to manage and maintain all septic systems. SBMWA has a series of septic system informational fact sheets at http://www.thewatershed.org/wm_library.php. NJDEP also has a webpage about onsite wastewater management, which can be found at: http://www.state.nj.us/dep/dwq/sep_site.htm, with links to additional informational documents.
- For those Townships where sewer systems are utilized, it is recommended that a program be developed and implemented to detect and eliminate any illicit connections to the municipal storm drain system, as is required in the New Jersey Phase II Stormwater Regulations. It is also recommended that the existing sewer system pipes be inspected or tested for potential leaks or breaks and that repairs or replacement be done where problems are found.
- Point source dischargers in the Heathcote Brook Watershed need to work within the guidelines of their active permits in order to maintain the health of Heathcote Brook (Figure 6 and Point Source Dischargers Section).
- Areas with agricultural land use (Figure 14) could contribute high bacteria levels if livestock are allowed stream access or if stormwater runs through pastures en route to streams. This stormwater flow could also pick up and carry fertilizers, pesticides, and sediment to the stream. The farms within Heathcote Brook Watershed, particularly those located downstream of Site HCB3 on the mainstem and of Site HCB5 on Carters Brook, should be encouraged to use BMPs to reduce agricultural NPS pollution and improve water quality. Various programs administered by NRCS work with farmers to fund and implement such BMPs. For more information on the various programs, please see the listings included in the Applicable BMP bullet on page 87.
- Since the Heathcote Brook Watershed is already highly developed, the municipalities in this region need to incorporate stormwater management to help reduce the loadings of nonpoint source pollutants into the Brook and to protect areas currently exhibiting low levels of pollutants. Each

municipality was required by the New Jersey Phase II Stormwater Regulations to adopt a stormwater management plan by the spring of 2005 and to adopt a municipal stormwater control ordinance by the spring of 2006. If they haven't done so already, municipalities need to comply with the stormwater management rules by adopting this ordinance.

- Creating or increasing buffer areas along streams serves to filter out pollutants, including bacteria; encourage recharge; and minimize flooding from stormwater flow. Therefore, streambank stabilization and streamside planting projects should be encouraged wherever appropriate. Creating vegetated areas adjacent to impervious areas also helps to increase infiltration and filter out pollutants (vegetated filters).
- Since everyone contributes to NPS pollution, everyone must be involved in its reduction. The only way to successfully and comprehensively tackle the enormous NPS problem is to work one-on-one with individual property owners and help them target the most appropriate ways to reduce their contribution. Education alone does not do the trick. SBMWA's River-Friendly Program is geared towards doing just that: working with individual homeowners, businesses, golf courses, municipalities, and other landowners to help them reduce their contribution to NPS pollution (SBMWA, 2002). The River-Friendly Program simultaneously works on improving water quality management, enhancing wildlife and habitat, and conserving water. Some sample goals could include creating an Integrated Pest Management plan, reducing mowed areas, buffering waterbodies, increasing wildlife and native habitat areas, planting rain gardens, and installing rain barrels. In addition the program has an education component where the participant either holds a forum to educate others and/or attends educational classes themselves. Each Township within the Heathcote Brook Watershed should encourage their residents and businesses to participate, while serving as a role model by enlisting the municipal properties in the River-Friendly Program.

Applicable BMPs and Mitigation Approaches:

There are many stormwater best management practices that could be implemented in the Heathcote Brook Watershed to reduce the bacteria and other pollutant contributions carried by stormwater runoff. Such BMPs could also reduce sediment loads, the frequency of flooding, and erosion potential. For a detailed listing of potential BMPs, refer to the New Jersey Stormwater Best Management Practices Manual (NJDEP, 2004b).

- The new NJDEP Stormwater Management Rules (N.J.A.C. 7:8) state several new requirements for large new developments and redevelopments focusing on minimizing disturbances and impervious surfaces, increasing groundwater recharge, reducing peak flows, and reducing pollutants carried by the stormwater. Key BMPs that increase infiltration and filter out pollutants include infiltration basins, bioretention basins, pervious pavement (see above), vegetated swales, and vegetated filters to capture discharge as sheet flow (NJDEP, 2004b). BMPs such as these should be implemented at each new development or redevelopment project. However, each site is unique. For information on the use of BMPs under

the New Jersey stormwater management rules, see SBMWA's document, *New Jersey's Nonstructural Stormwater Strategies Point System-A Primer*, available at <http://www.thewatershed.org/info/2007NSPSprimer.pdf>

- The implementation of stormwater BMP retrofits in areas being redeveloped or on municipal properties could result in cleaner water in Heathcote Brook and its tributaries. In this case existing stormwater management BMPs can be improved to better protect downstream waterbodies. Vegetating existing swales located near Heathcote Brook or its tributaries is one example of a low-cost method that can result in positive changes.
- Existing stormwater BMPs within areas not planned for redevelopment could also be retrofitted to make them more effective.

Applicable Model Ordinances:

- Stream corridor ordinances, impervious surface ordinances, woodlands protection ordinances, afforestation ordinances, sediment and soil erosion control ordinances, and soil protection ordinances are all beneficial in dealing with NPS pollution (see above for more details).
- NJDEP has also created a Stream Buffer Conservation Zone Model Ordinance. This ordinance deals with the conservation, disturbance, restoration, and management of existing stream buffers for all waterbodies within a municipality. It can be found online at: <http://www.state.nj.us/dep/watershedmgt/DOCS/pdfs/StreamBufferOrdinance.pdf>.
- For those Townships utilizing septic systems, there are several septic related ordinances that could help to improve the health of the watershed. Several townships within the Millstone Watershed have septic ordinances that provide the buyer rights to have the current owner confirm a working septic system prior to purchase. And ANJEC has a model ordinance that mandates inspection upon sale or transfer of property, as well as every three years. This would ensure that failing septic systems are replaced or repaired when property changes hands. A copy of this model ordinance can be obtained from <https://www.anjec.org/html/ord-modelseptic.htm>. Doylestown, Pennsylvania has an ordinance on the books requiring regular inspection, reporting, and pumping of septic systems. Regular pumping would prolong the life of septic systems and regular inspection would catch failing septic systems at an earlier stage to prevent long-term bacterial contributions. A copy of this ordinance (Article III On-Lot Sewage Disposal Systems [Adopted in 2001 by Ordinance Number 299] of Chapter 136 (Sewers) of the Doylestown General Code) can be found at [http://www.e-codes.generalcode.com/codebook_frameset.asp?t=tc&p=1312%2D136%2Ehtm&cn=420&n=\[1\]\[97\]](http://www.e-codes.generalcode.com/codebook_frameset.asp?t=tc&p=1312%2D136%2Ehtm&cn=420&n=[1][97]).

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AMNET	Ambient Biomonitoring Network
BMPs	Best Management Practices
C1	Category One Protection
CEA	Classification Exception Area
CKE	Currently Known Extent
EPT	Ephemeroptera Plecoptera Trichoptera
FW	Fresh Water (see Glossary)
FBI	Family Biotic Index
GIS	Geographic Information System
IBI	Index of Biotic Integrity
KCS	Known Contaminated Site
MDDNR	Maryland Department of Natural Resources
MGD	Million Gallons per Day
ND	No Date
NJDEP	New Jersey Department of Environmental Protection
NJAC	New Jersey Administrative Code
NJGWQS	New Jersey Ground Water Quality Standard
NJPDES	New Jersey Pollution Discharge Elimination System
NJWSA	New Jersey Water Supply Authority
NRCS	Natural Resources Conservation Service
PA	Planning Area
PCE	Perchloroethylene
PCW	Public Community Well
PRP	Potentially Responsible Party
SBMWA	Stony Brook-Millstone Watershed Association
SCD	Soil Conservation District
SCS	Soil Conservation Service

LIST OF ACRONYMS

STORET	Storage and Retrieval Database
STP	Sewage Treatment Plant
TCE	Trichloroethylene
TMDL	Total Maximum Daily Load
TOT	Time of Travel
TSS	Total Suspended Solids
URWA	Upper Raritan Watershed Association
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	Underground Storage Tank
WHPA	Wellhead Protection Area
WTP	Water Treatment Plant

LIST OF ACRONYMS

100-year flood: Flood level with a 1% chance of being equaled or exceeded in any given year, not the area of flooding that occurs once every 100 years.

alluvial: Relating to mud and/or sand deposited by flowing water.

aquifer: An underground geological formation, or group of formations, containing usable amounts of groundwater that can supply wells and springs.

arkose: A sedimentary rock formed by the cementation of sand-sized grains of feldspar and quartz.

baseflow: The sustained or fair-weather flow of a stream regardless of human-induced inputs.

benthic organism: Any of a diverse group of aquatic plants and animals that lives on the bottom of bodies of water; the presence or absence of certain benthic organisms is used as an indicator of water quality.

clay: A rock or mineral fragment or particle of decayed matter smaller than a very fine silt grain, having a diameter less than 1/256 of a millimeter.

Coastal Plain Physiographic Province or Coastal Plain Province: One of New Jersey's four physiographic provinces situated south of the Piedmont Physiographic Province (Figure 7). The Coastal Plain is relatively flat consisting of unconsolidated sedimentary deposits that range in age from the Cretaceous to the Miocene.

confluence: A place of meeting of two or more streams; the point where a tributary joins the main stream.

deciduous: Describes a tree that loses its leaves during autumn.

detention basin: An impoundment or excavated basin for the short-term detention of stormwater runoff from an area.

dip direction: The vertical angle, measured at an observation point in surveying, between the plane of the true horizon and a line of sight to the apparent horizon.

dissolved oxygen: The volume of oxygen that is contained in water.

endangered species: Living organisms threatened with extinction by man made or natural changes in the environment.

erodibility: The tendency of soil to become detached and washed away during erosion.

GLOSSARY

erosion: The physical removal of rock or soil particles by a transport agent such as running water, wind, glacial ice, and gravity.

eutrophication: The slow aging process during which a lake, estuary, or bay evolves into a bog or marsh and eventually disappears; during the later stages of eutrophication the water body is choked by abundant plant life due to higher levels of nutritive compounds such as nitrogen and phosphorous; human activities can accelerate this process.

evapotranspiration: The loss of water from the soil both by evaporation and by transpiration from the plants growing in the soil.

floodplain: Area of relatively flat, normally dry land adjacent to a stream or river that is covered by water during a flood or severe storm event.

FW: The general surface water classification applied to fresh waters, defined as all nontidal and tidal waters with a salinity, due to natural sources, of ≤ 3.5 parts per thousand at mean high tide.

FW2 waters: General surface water classification applied to those fresh waters that are not designated as FW1 (those fresh waters designated as needing to be maintained in their natural state of quality and not subjected to any man-made wastewater discharges or increases in runoff from anthropogenic activities) or Pinelands Waters.

Geographic Information System (GIS): A computer system designed to manipulate, analyze, and display information that is tied to a geographic location.

gravel: An unconsolidated natural accumulation of rounded rock fragments resulting from erosion, consisting primarily of particles larger than sand grains.

groundwater: The portion of water beneath the land surface that is below the water table and the pore spaces that are filled with water.

habitat: The environment in which a plant or animal tends to live.

headwater stream / headwaters: The beginnings or sources for watercourses; typically, the point in the landscape where sufficient runoff collects in intermittent streams.

hydrology: The science that deals with water (both surface and groundwater), its properties, circulation, and distribution.

impervious cover / impervious surface: Any surface in the landscape that cannot effectively adsorb or infiltrate rainfall, usually associated with urban

GLOSSARY

development; the amount of impervious surfaces has been used as an indicator to predict the severity of water quality impairments to local waterways.

infiltration: The movement of water into soil or porous rock.

infrastructure: The underlying system or network used for organization; most often refers to the road systems, sewer networks, school systems, etc. in a municipality.

macroinvertebrates: These are organisms that do not have a backbone and are visible to the naked eye (for example, certain insect larvae); they are most often used as indicator organisms in water bodies as they exhibit varying sensitivities to pollution.

Natural Heritage Database: A State database containing an inventory of all species of flora and fauna that are threatened or endangered.

nonpoint source pollution: Any source of pollution not associated with a distinct discharge point; pollution from a diffuse source; includes sources such as rainwater runoff from agricultural lands, industrial sites, parking lots, and timber operations, as well as escaping gases from pipes and fittings.

nutrient: Any substance that is assimilated by organisms and promotes growth. Nitrogen and phosphorous are nutrients which promote the growth of algae. There are other essential and trace elements, which are also considered nutrients.

outcrop: The part of a geological formation or structure that appears at the surface of the Earth.

percolation: The slow movement of water through small openings within a porous material.

pervious surface: Any surface with the capacity for transmitting a fluid; also called permeable surface.

Physiographic Province: The division of land area into regions based on terrain texture, rock type, and geologic structure and history. In New Jersey there are four physiographic provinces: Valley and Ridge, Highlands, Piedmont, and Coastal Plain.

Piedmont Physiographic Province /Piedmont Province: One of New Jersey's four physiographic provinces sandwiched between the Highlands and Coastal Plain Provinces (Figure 7). The Piedmont chiefly consists of rolling lowlands and a series of broad uplands formed by the underlying geology consisting of slightly folded and faulted Triassic and Jurassic-aged

GLOSSARY

sedimentary rocks, Jurassic-aged igneous rocks, and some highly metamorphosed Middle Proterozoic to Cambrian-aged rocks.

point source pollution: A stationary location or fixed facility such as an industrial or municipal plant that discharges pollutants into air or surface water through pipes, ditches, lagoons, wells, or stacks; a single identifiable source of pollution such as a ship or mine.

porosity: The ratio of the volume of openings and spaces in a material to the volume of its mass; the quality of being porous.

potable water: Raw or treated water that is considered safe to drink; also called drinking water.

priority species: Nongame wildlife considered to be species of special concern, or species showing evidence of decline, inherent vulnerability to environmental degradation, or habitat modification that would result in their becoming Threatened.

recharge: The process of the absorption and addition of water to the zone of saturation or aquifer.

retention basin: A large depression built as a barrier to reduce flooding and storm surges.

riparian area: Land situated on or adjacent to a stream bank.

runoff: The portion of rainfall, melted snow, or irrigation water that flows across the ground's surface and is eventually returned to streams; runoff can pick up pollutants from air or land and carry them to receiving waters; also called stormwater.

sand: A rock fragment or particle of detritus smaller than gravel but larger than silt.

sediment: Solid fragmented material that originates from weathering of rocks and is distributed by air, water, or ice.

sedimentation: The act or process of forming or accumulating sediment in layers.

septic system: A subsurface system designed to treat waste and wastewater by the use of settling, filtration, and anaerobic bacteria; most often associated with individual residences.

silt: A rock fragment or particle of detritus smaller than fine sand but larger than clay.

GLOSSARY

soil: The upper layer of the Earth's surface that may be dug up or plowed and in which vegetation grows.

species of special concern: A species that is not considered threatened or endangered, but is still monitored by Natural Heritage Database because of its vulnerability to becoming threatened.

statistically valid geometric mean: Since samples must be obtained at sufficient frequencies during periods that will permit valid interpretation of laboratory results, in order for a geometric mean to be considered statistically valid, the State requires a minimum of five samples be collected over a 30-day period (as equally spaced as possible).

succession: The process of plant life maturation over a landscape.

surface water: All water found in rivers, streams, ponds, lakes, marshes, wetlands, as ice and snow, and transitional, coastal, and marine waters.

threatened species: Species that may become endangered if conditions that harm them continue to accumulate.

total maximum daily load: The maximum quantity of a particular pollutant that can enter a waterway without affecting the designated use of that waterway.

turbidity: A measure of the ability of a suspended material to disturb or diminish the penetration of light through a fluid.

unconformably overlain: A sequence of rocks exhibiting a gap or break in the geologic record where one rock unit is overlain by another that is not next in the stratigraphic succession. This usually results from a change that caused deposition to stop for a considerable time and usually implies uplift and erosion with the loss of previously formed deposits.

wastewater: Water that has been used for industrial, domestic, or agricultural practices and has not yet been treated.

watershed: A hydrologic unit in which all surface water runoff egresses through a single, natural hydrologic outlet, and as delineated in the statewide Water Quality Management Plan. Also, all the land area, which contributes runoff to a particular point along a waterway.

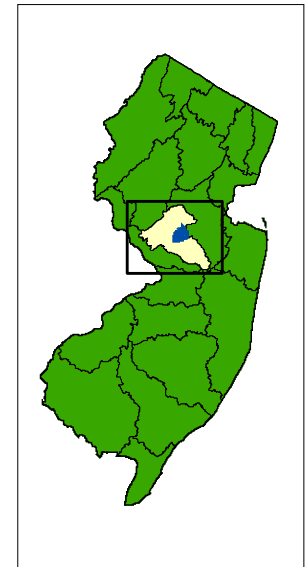
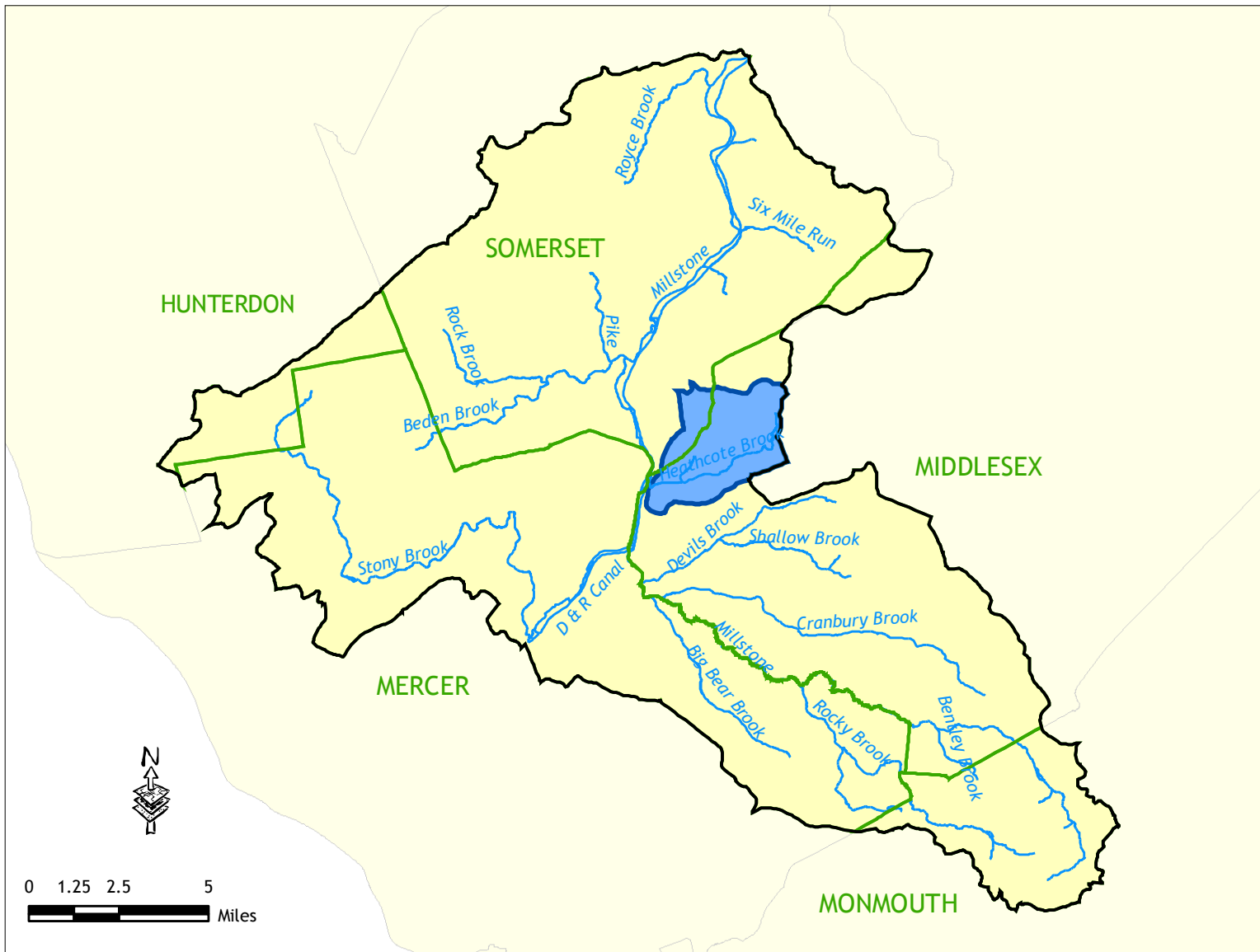
wellhead: The source of a well and the structure built over it.






wetlands: Areas that are soaked or flooded by surface or groundwater frequently enough or for sufficient duration to support plants, birds, animals, and aquatic life. Wetlands generally include swamps, marshes, bogs, estuaries, and other inland and coastal areas, and are federally protected.

GLOSSARY

FIGURES

Figure 1: Heathcote Brook Watershed & Millstone Watershed

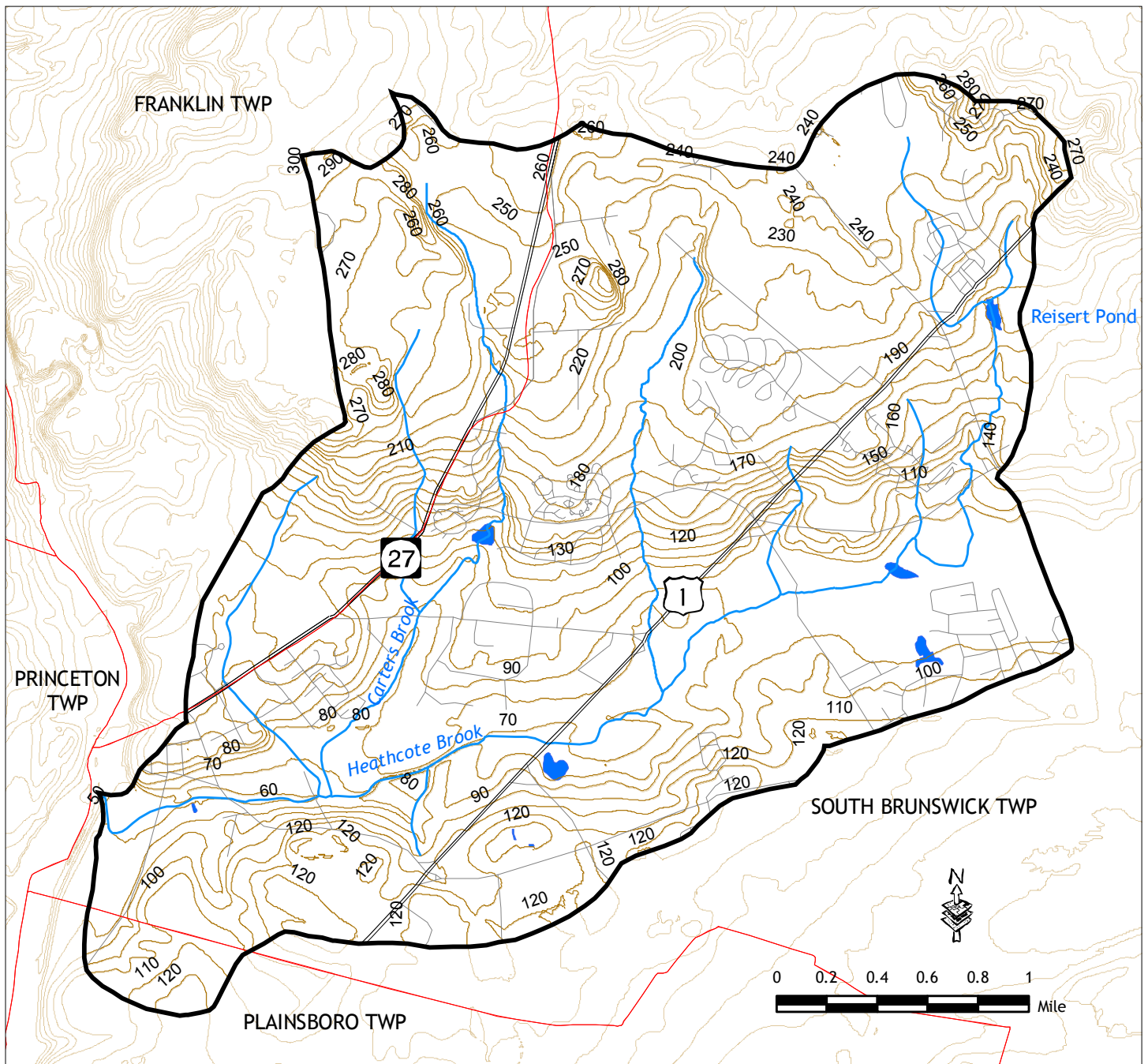








- | | |
|---|---|
|  Millstone Watershed |  County Boundaries |
|  Heathcote Brook Watershed |  Streams |
| |  Streams |



P. Sankalia, A.Rowan 10/04 - Data Source: New Jersey Department of Environmental Protection. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 2: Heathcote Brook Watershed Topography

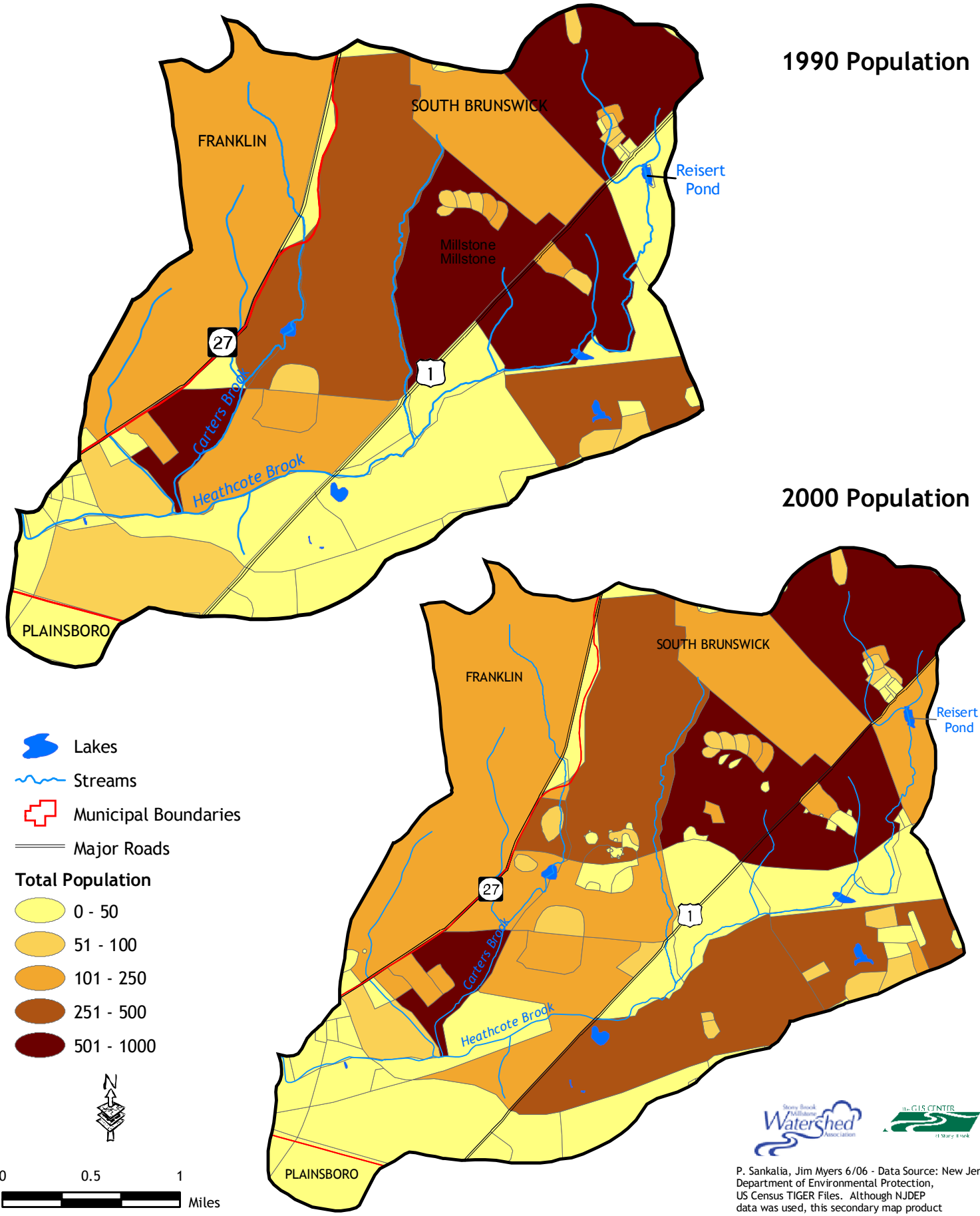


-  Heathcote Brook Watershed
-  Elevation Contours (10ft. intervals)
-  Municipalities
-  Lakes
-  Major Roads
-  Roads
-  Streams



P. Sankalia, A. Rowan 11/03 - Data Source: New Jersey Department of Environmental Protection, US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 3: Population Distribution in Heathcote Brook Watershed By Census Tract



P. Sankatia, Jim Myers 6/06 - Data Source: New Jersey Department of Environmental Protection, US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 4: Critical Habitats in Heathcote Brook Watershed

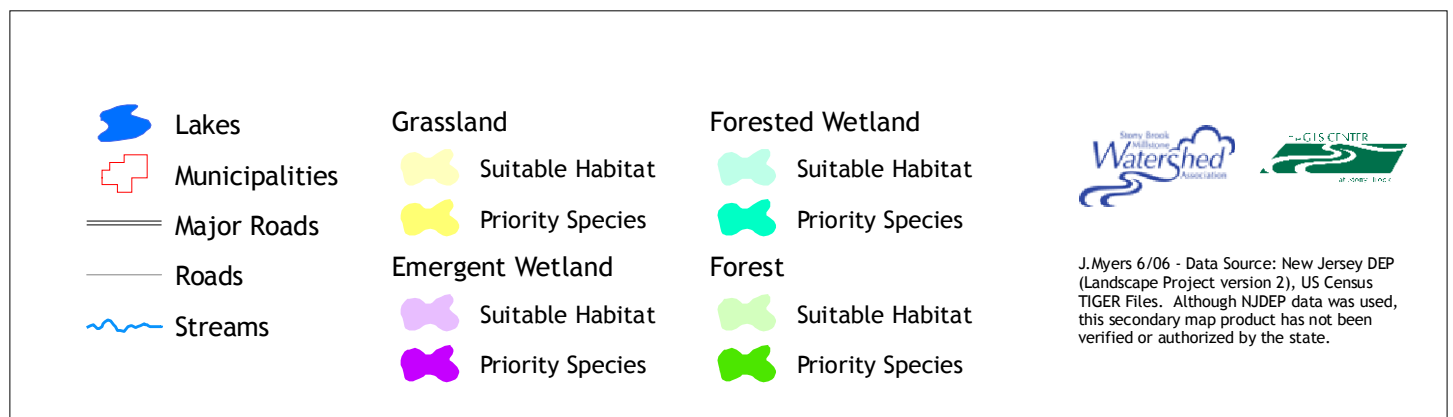
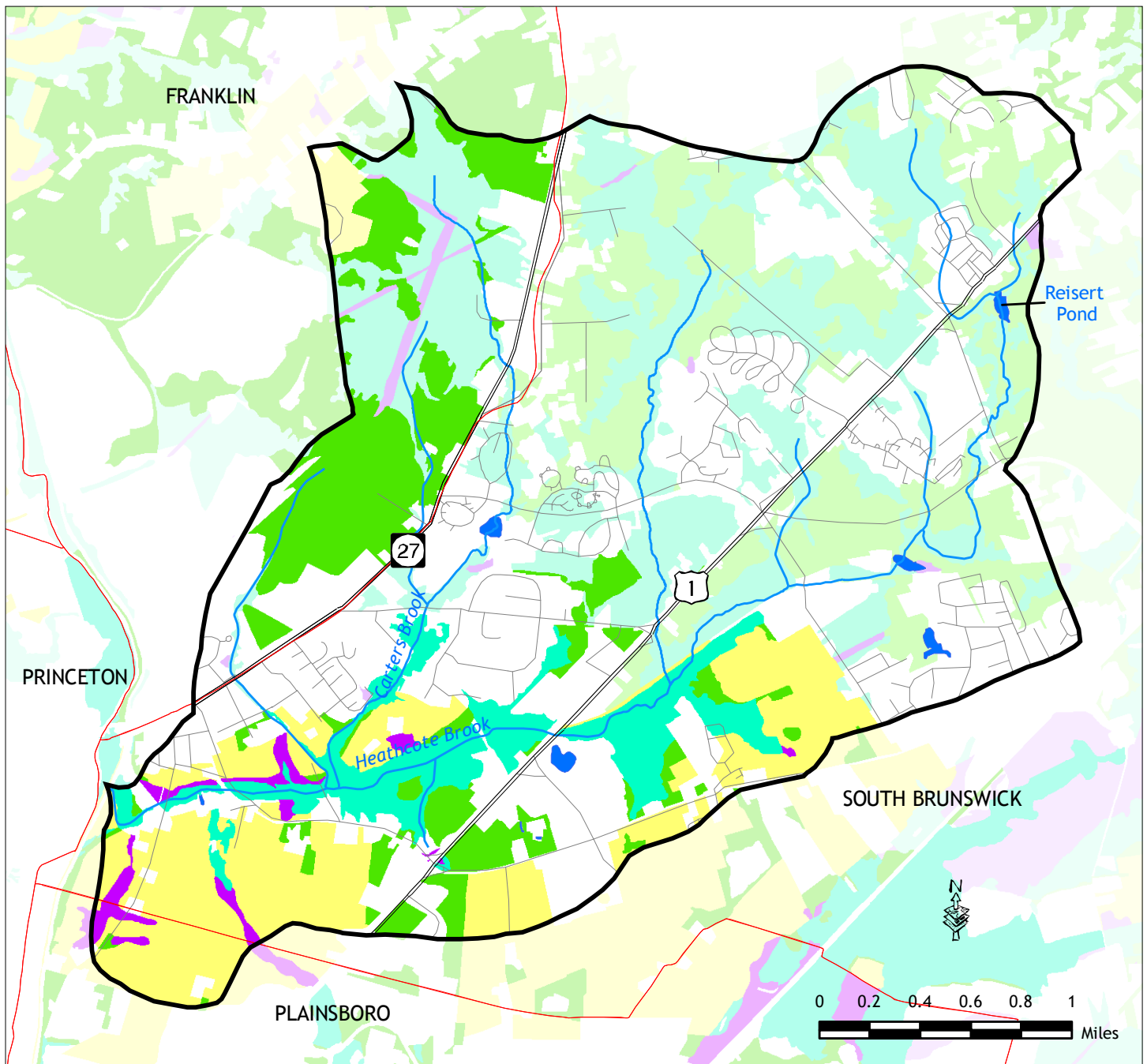
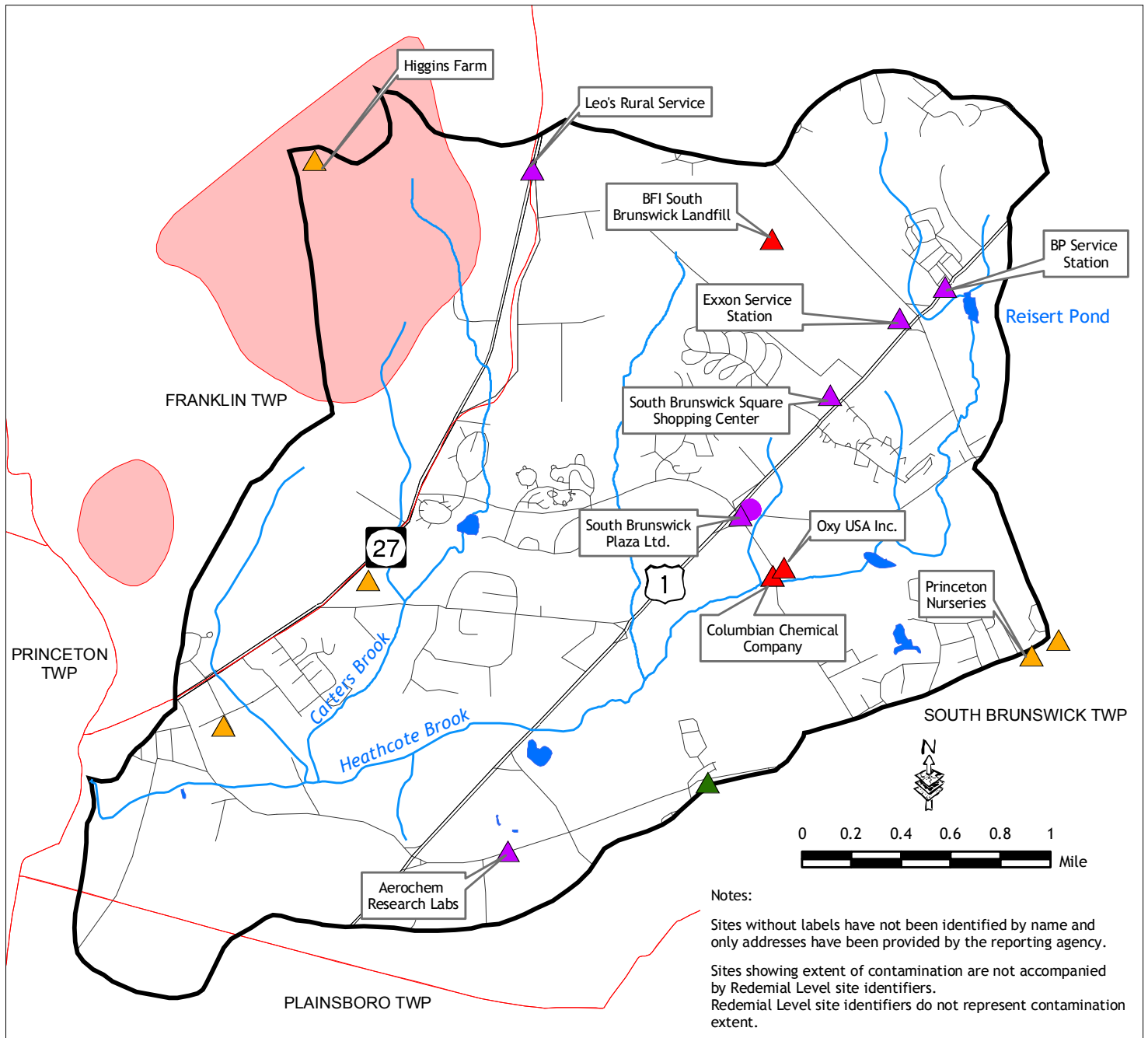


Figure 5: Known Contaminated Sites and Extent of Contamination in Heathcote Brook Watershed



Known Contaminated Site Remedial Levels

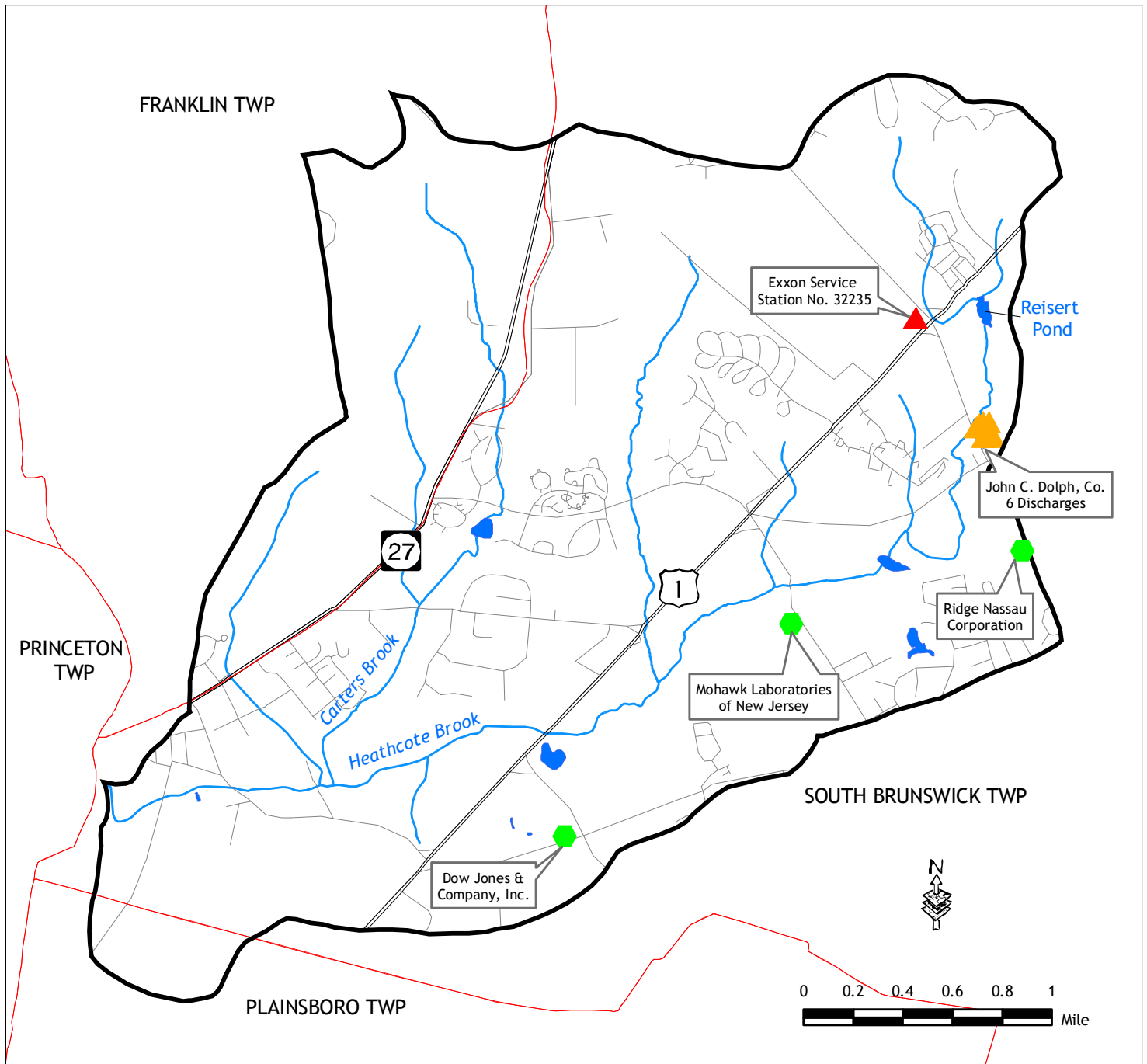
- ▲ B A single phase remedial action with a single contaminant affecting only the soil.
- ▲ C1 Remediation does not require a formal design. The source of the contamination is known or has been identified. There is a potential for ground water contamination.
- ▲ C2 Remediation requires a formal design. The source of the contamination is known OR the release has caused ground water contamination.
- ▲ D A multi-phased remediation with multiple sources/releases to multiple media including ground water.
- ▲ S Should have a Remedial Level but this field was either Blank or designated as "N/A" in Pre-NJEMS data.
- C2 Classification Exception Area









- Currently Known Extent of Groundwater Contamination
- Municipal Boundary
- Major Road
- Road
- ~ Stream
- Lake





P. Sankalia, J. Myers, J. Bisacchino - 12/2007.
 Data Source: U.S. Census Road TIGER Files; New Jersey Department of Environmental Protection (NJDEP), Bureau of Geographic Information Systems (BGIS); and NJDEP Site Remediation and Waste Management (SRWM) Program's Known Contaminated Sites in New Jersey (KCS-NJ) Report, 7th Edition, Spring 2006 - <http://www.state.nj.us/dep/srp/kcs-nj/remlevel.htm>
 This secondary map product has not been verified or authorized by the source agencies.

Figure 6: NJPDES Point Source Dischargers in Heathcote Brook Watershed

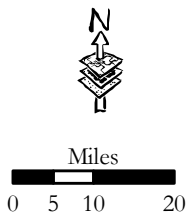
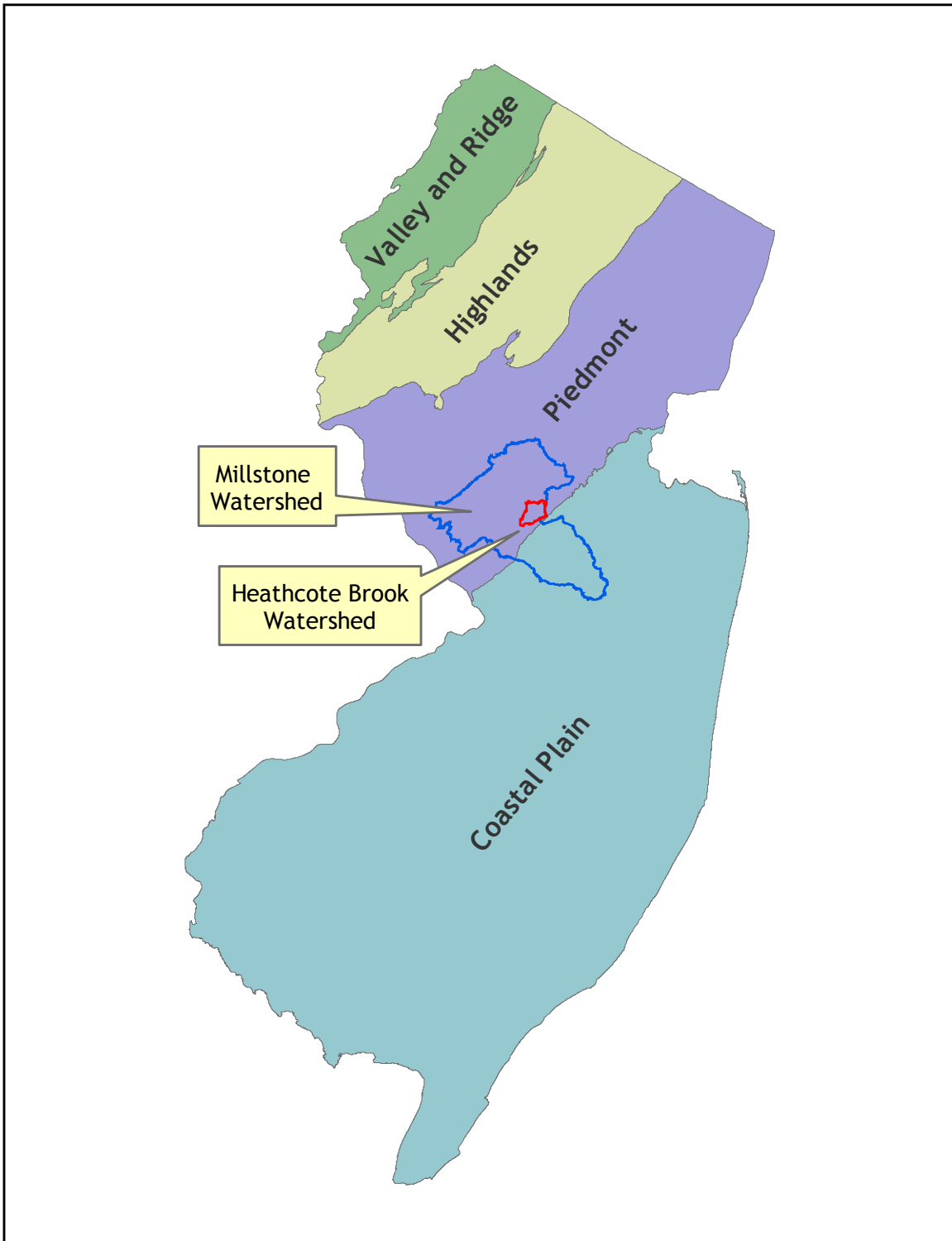


 Municipalities	Surface Water Dischargers
 Major Roads	 Petroleum Hydrocarbon Remediation Outfall Pipe Location
 Roads	 Minor Industrial Storm Water Permit Outfall Pipe Location
 Streams	 Storm Water Permitted Facility
 Lakes	

P. Sankalia, J. Bisacquino 12/2007
 Data Source: New Jersey Department of Environmental Protection, U.S. Census Road TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

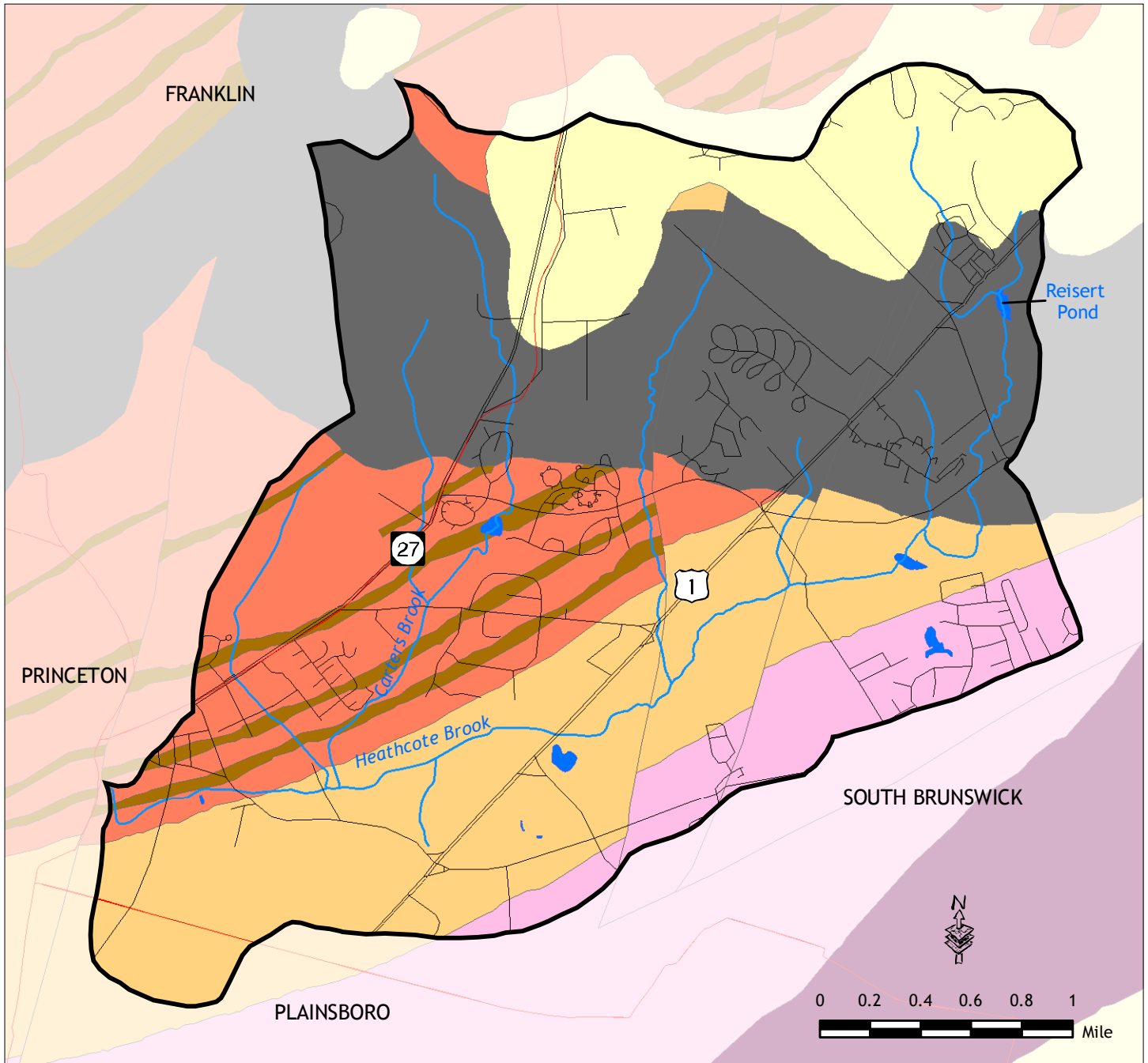
Figure 7: Physiographic Provinces of New Jersey

















J. Myers 6/06 - Data Source: New Jersey Department of Environmental Protection, New Jersey Geological Survey & US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.



Figure 8: Geology of Heathcote Brook Watershed

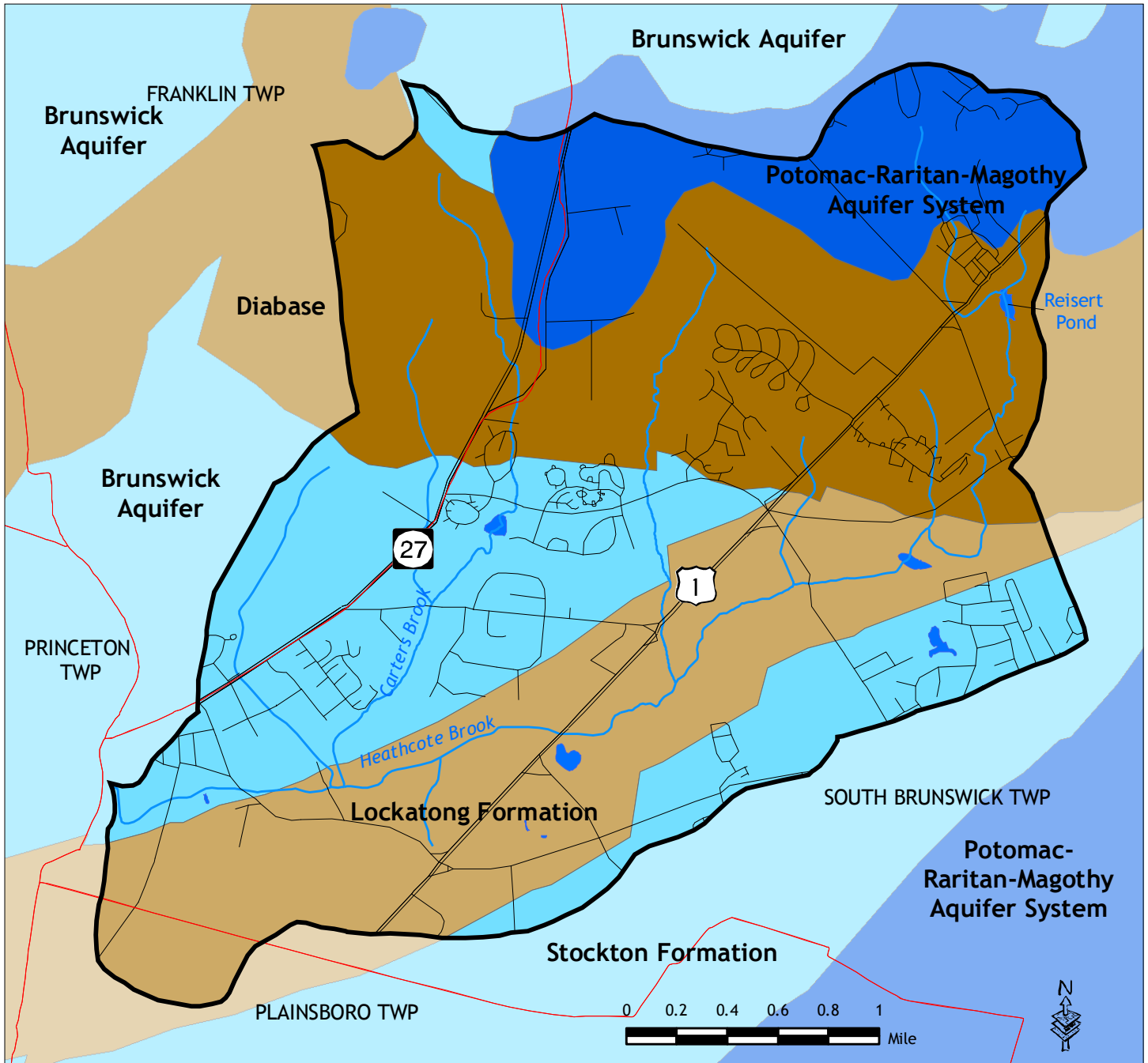












 Lakes	Bedrock Geology
 Municipalities	 Jurassic Diabase
 Major Roads	 Lockatong Formation
 Roads	 Magothy Formation
 Streams	 Passaic Formation
	 Passaic Formation Gray bed
	 Raritan Formation
	 Stockton Formation






P. Sankatia 5/05 - Data Source: New Jersey Department of Environmental Protection, New Jersey Geological Survey & US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 9: Aquifers of Heathcote Brook Watershed

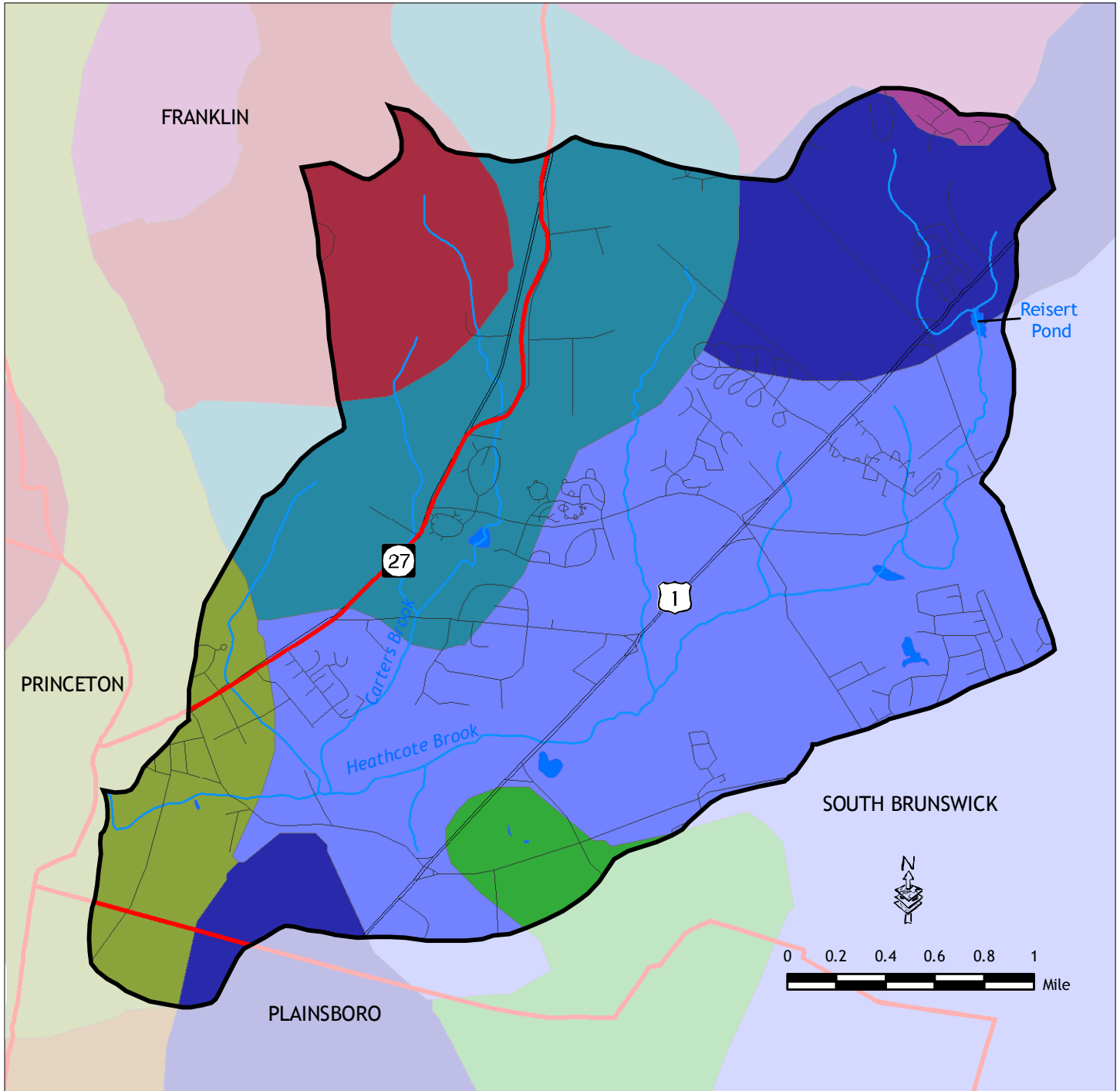


 Lakes	Aquifer Rank
 Municipalities	Average Yield of Hi-Cap Wells
 Major Roads	 A: >500 gal/min
 Roads	 B: 250-500 gal/min
 Streams	 C: 100-250 gal/min
	 D: 25-100 gal/min
	 E: <25 gal/min

P. Sankalia, J. Myers 6/06 - Data Source: New Jersey Department of Environmental Protection, US Census TIGER Files, New Jersey Geological Survey. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 10: Soils Associations in Heathcote Brook Watershed

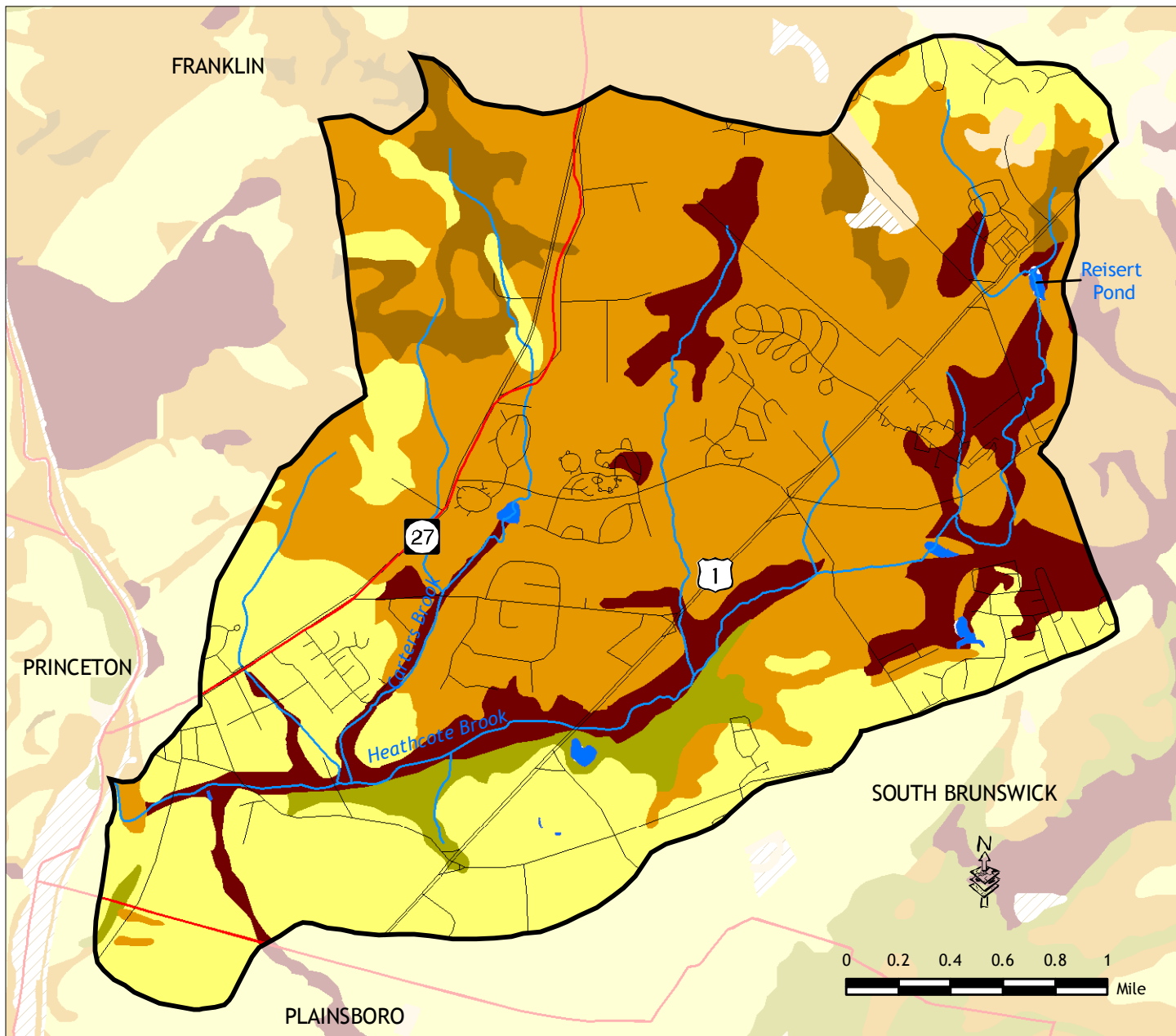


 Streams	Soil Association
 Municipalities	 Atsion-Manahawkin-Berryland
 Lakes	 Downer-Sassafrass-Hammonton
 Major Roads	 Hammonton-Woodstown-Mullica
 Roads	 Matapex-Matapeake-Chillum
	 Neshaminy-Mount Lucas-Lawrenceville
	 Penn-Reaville-Klinesville
	 Pocomoke-Sulfaquents-Manahawkin
	 Rowland-Pope-Birdsboro











J. Myers 9/06 - Data Source: New Jersey Department of Environmental Protection, Natural Resource Conservation Service. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 11: Hydrologic Soil Groups in Heathcote Brook Watershed



Hydrological Soil Groups

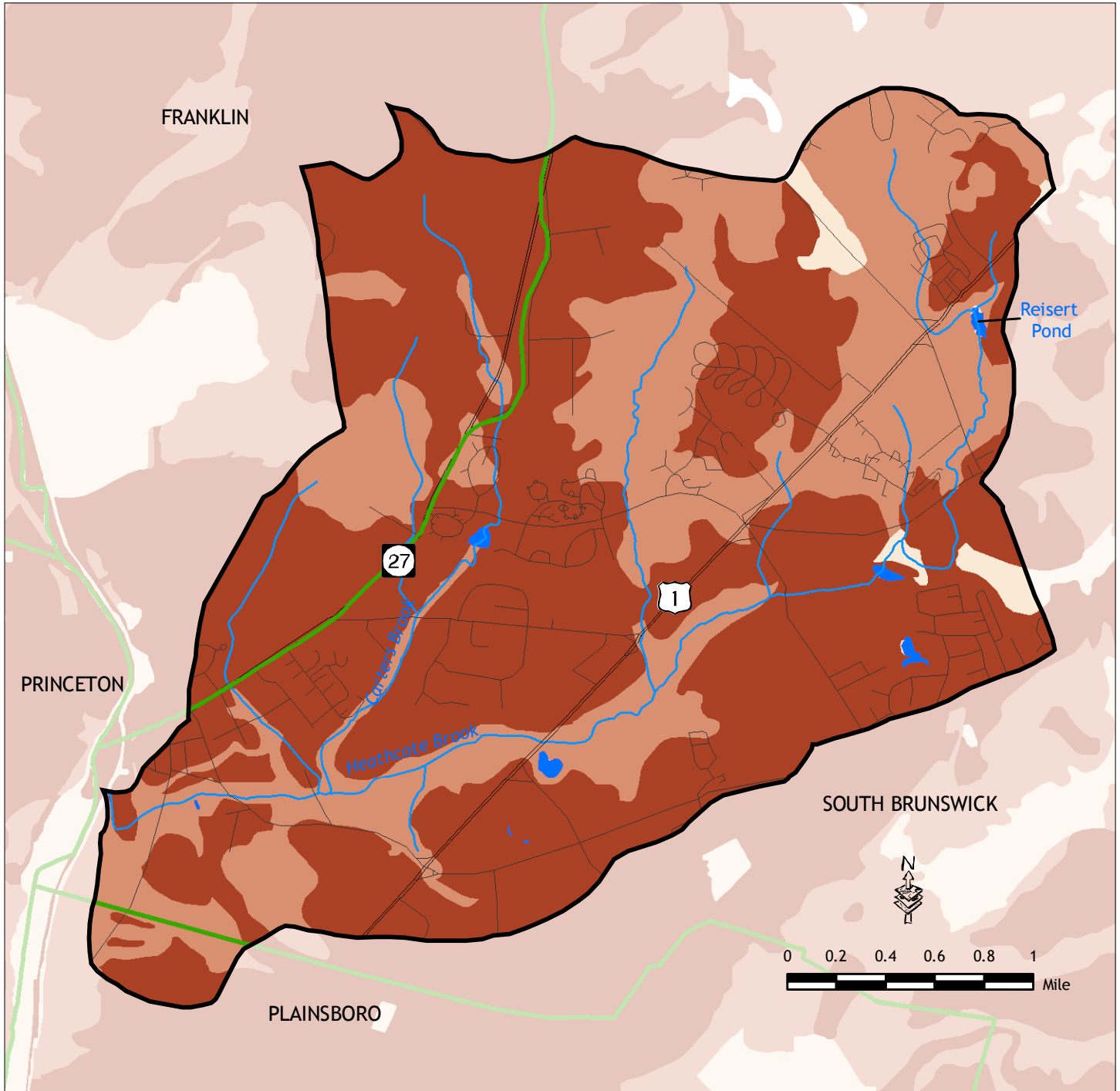
-  Unclassified
-  A High infiltration rates. Soils are deep, well drained to excessively drained sands and gravels.
-  B Moderate infiltration rates. Deep and moderately deep, moderately well and well drained. Soils that have moderately coarse textures.
-  B/D Dual hydrologic groups are given for certain wet soils that can be adequately drained. The first letter applies to the drained condition, the second to the undrained.
-  C Slow infiltration rates. Soils with layers impeding downward movement of water or soils that have moderately fine or fine textures
-  C/D Dual hydrologic group
-  D Very slow infiltration rates. Soils are clayey, have a high water table or are shallow to an impervious layer

-  Streams
-  Municipalities
-  Lakes
-  Major Roads
-  Roads











P. Sankalia 5/05 - Data Source: New Jersey Department of Environmental Protection, New Jersey Geological Survey & US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 12: Soil Erodibility in Heathcote Brook Watershed



Soil Erodibility (K Factor)

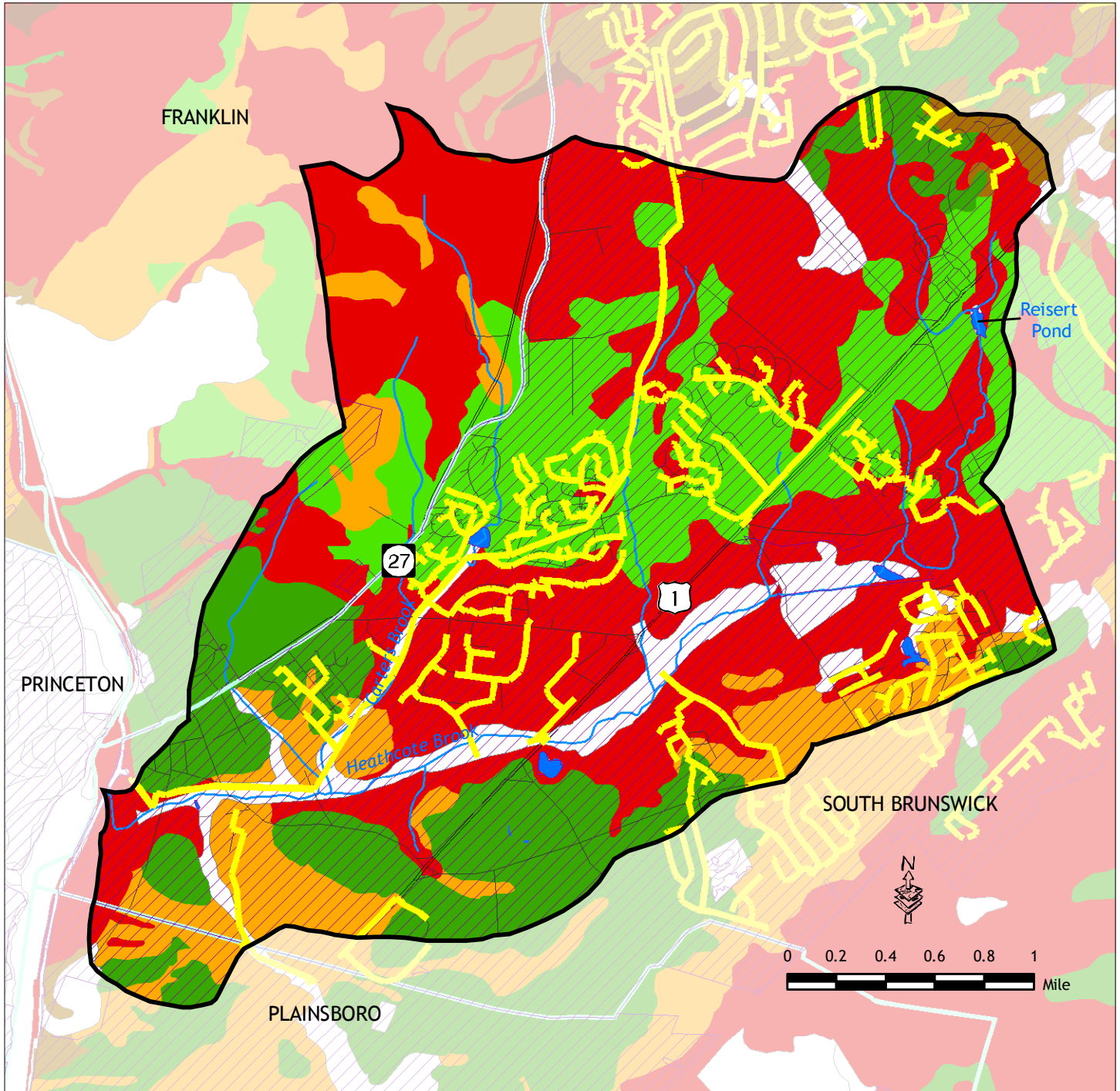
-  Low (0.16 and below)
-  Med (0.17 - 0.31)
-  High (0.32 and above)

-  Streams
-  Municipalities
-  Lakes
-  Major Roads
-  Roads





P. Sankalia 05/05 - Data Source: New Jersey Department of Environmental Protection, New Jersey Geological Survey & US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 13: Septic Suitability in Heathcote Brook Watershed

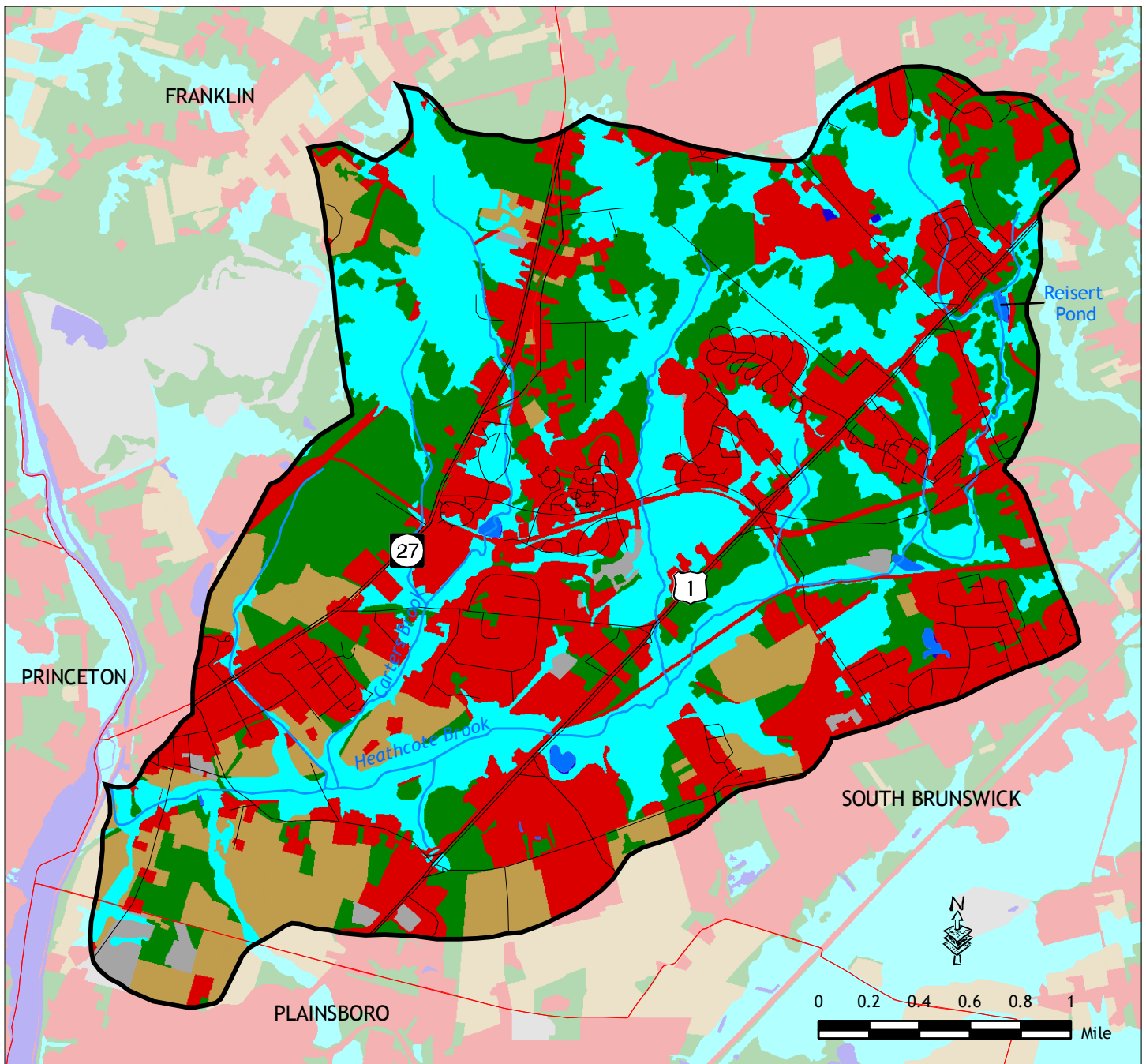


Suitable Septic Installations	Sewer Service Areas
Unclassified	Current Sewer Lines
Conventional	Major Roads
Conventional w/ drains	Roads
Mound	Municipalities
Soil Replacement	Streams
Soil Replacement or Mound	Lakes
Unsuitable for Septic	

J. Myers 07/06 - Data Source: New Jersey Department of Environmental Protection, New Jersey Geological Survey, US Census TIGER Files and South Brunswick Township. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 14: 2002 Land Use in Heathcote Brook Watershed

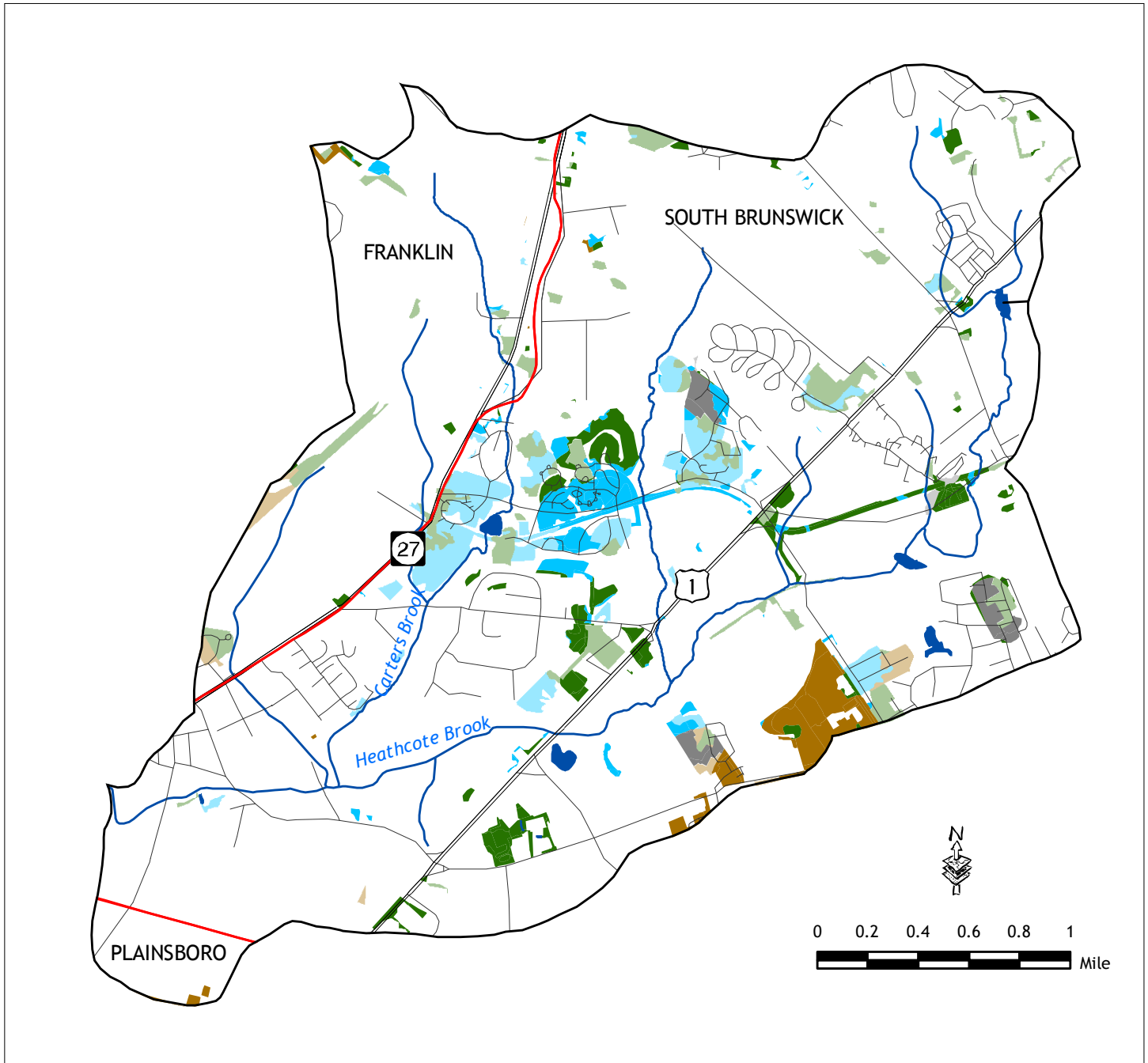













 Lakes	Land Use
 Municipalities	 Agriculture
 Major Roads	 Barren Land
 Roads	 Forest
 Streams	 Urban/Developed
	 Water
	 Wetlands




P. Sankalia, J. Myers 6/06 - Data Source: New Jersey Department of Environmental Protection, US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

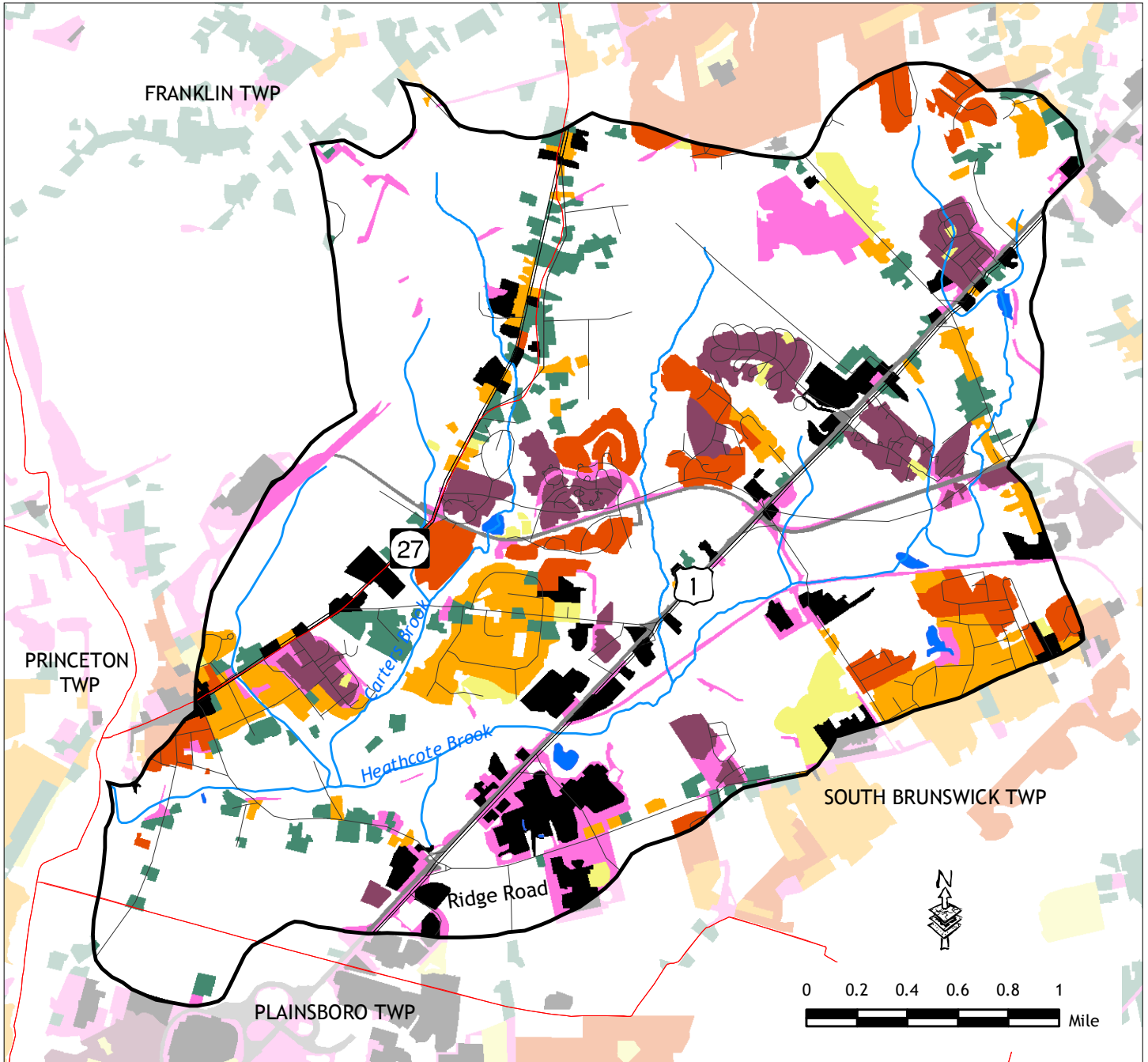
Figure 15: Land Use Changed to Urban/Developed Between 1986 and 1995/97 and Between 1995/97 and 2002 in Heathcote Brook Watershed



 Lakes	 Agriculture	Lighter shades on map indicate conversion to developed between 1986 and 1995/97. Darker shades indicate conversion to developed between 1995/97 and 2002.	 
 Streams	 Barren Land		
 Municipalities	 Forest		
 Major Roads	 Wetlands		
 Roads			

J. Myers 6/06 - Data Source: New Jersey Department of Environmental Protection, US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 16: Urban/Developed Land Use (2002) in Heathcote Brook Watershed



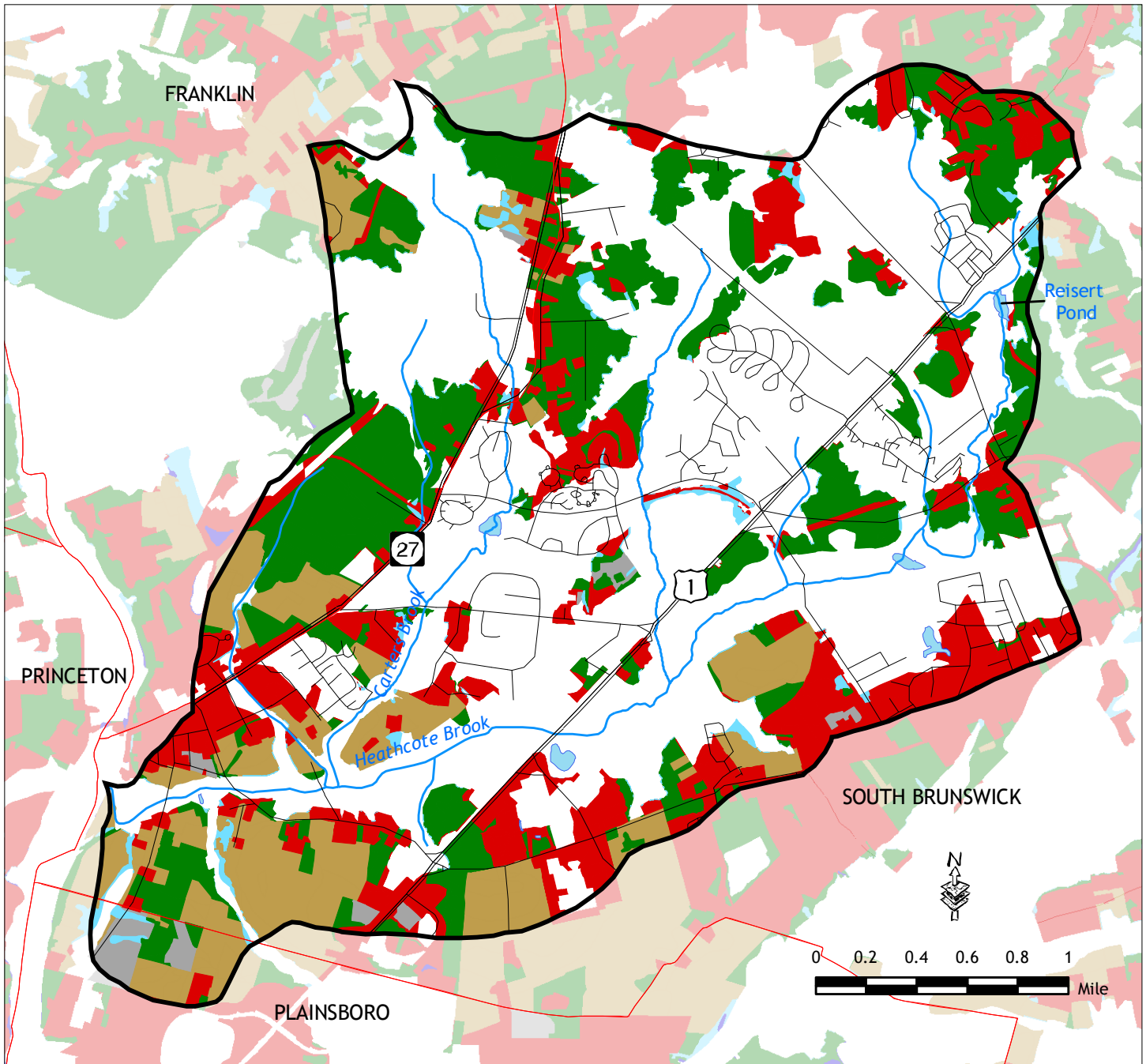
 Lakes	Land Use Categories
 Municipalities	 Transport/Utility
 Major Roads	 Industrial/Commercial Complexes
 Roads	 Residential, Rural, Single Unit
 Streams	 Residential, Low Density, Single Unit
	 Residential, Medium Density, Single Unit
	 Residential, High Density, Multiple Units
	 Recreational Land
	 Other Urban or Built Up


















P. Sankalia, J. Myers, J. Bisacquino 6/06 -
 Data Sources: New Jersey Department of
 Environmental Protection, US Census TIGER Files.
 Although NJDEP data was used, this
 secondary map product has not been
 verified or authorized by the state.
 Project: 16landuse.urban.mxd

Figure 17: Land Use (2002) in Areas of High Ground Water Recharge in Heathcote Brook Watershed



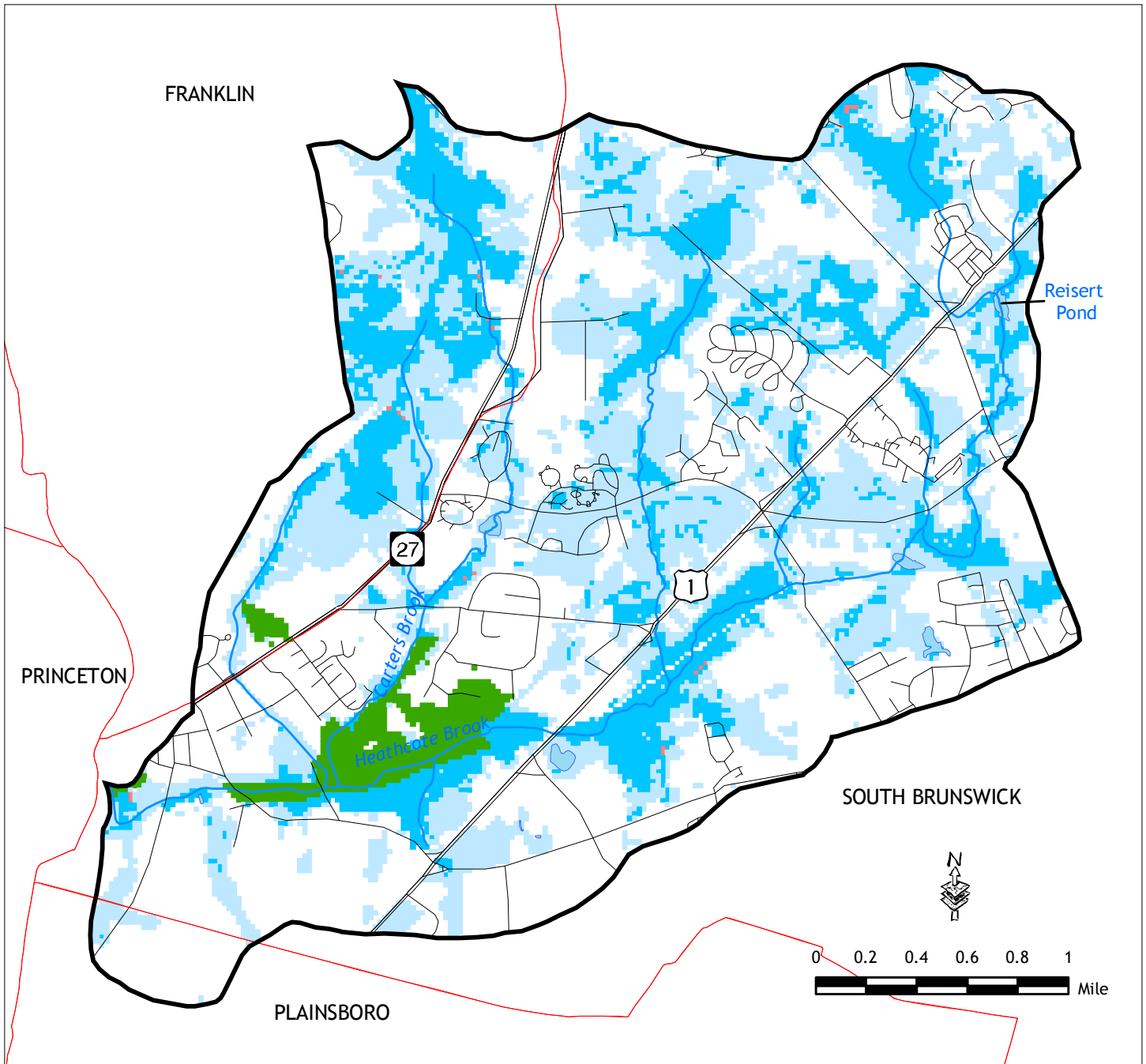
 Lakes	Land Use
 Municipalities	 Agriculture
 Major Roads	 Barren Land
 Roads	 Forest
 Streams	 Urban/Developed
	 Water
	 Wetlands






"High" recharge defined as 10 in/yr or more






P. Sankalia, J. Myers 6/06 - Data Source: New Jersey Department of Environmental Protection, US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 18: Critical Areas for Water Resource Protection in Heathcote Brook Watershed



-  Streams
-  Municipalities
-  Lakes
-  Major Roads
-  Roads

Critical Area Ranking

-  Four
-  Three
-  Two
-  One
-  Open Space

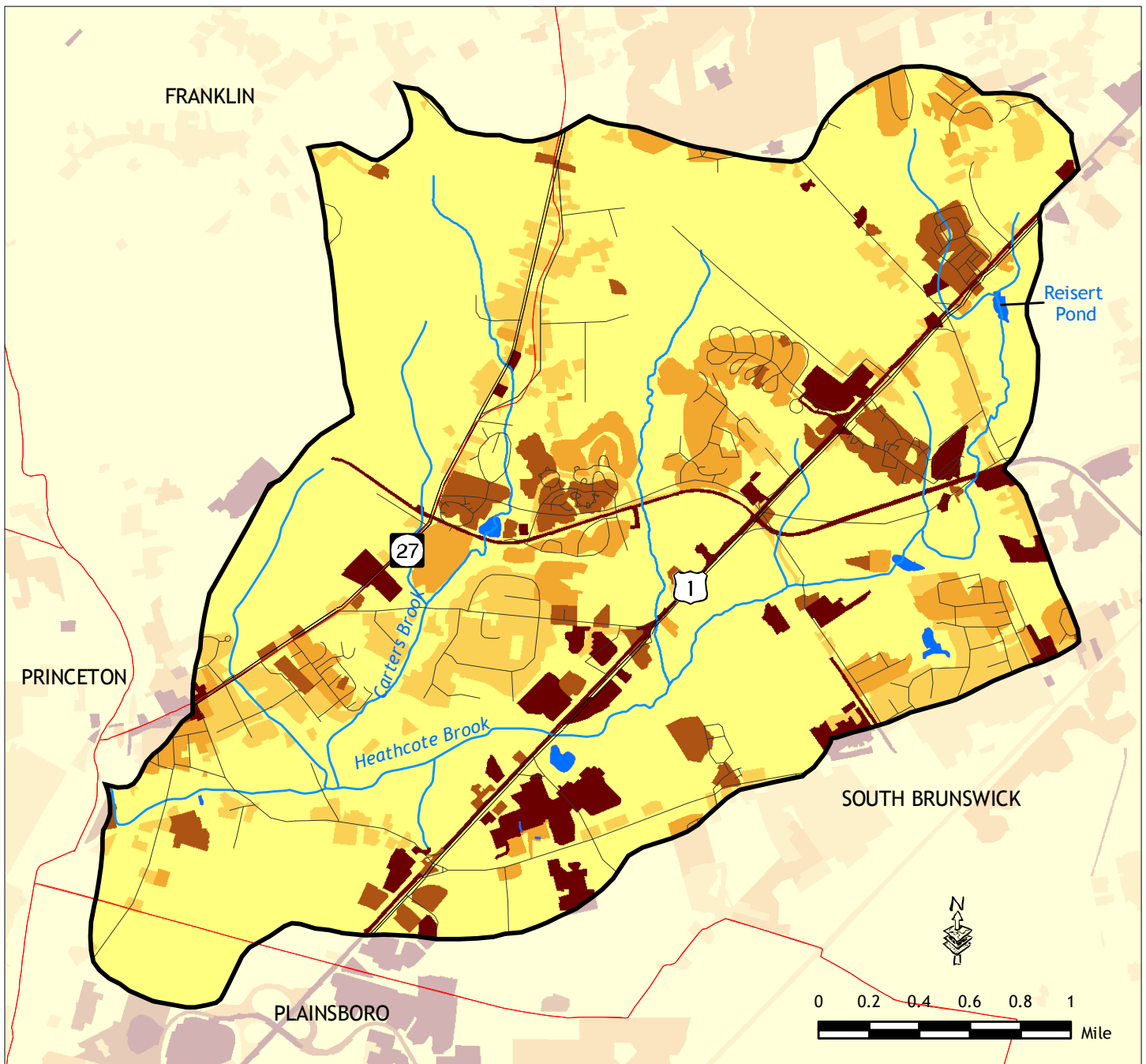
Ranking is based on how many of the water resource protection criteria, listed below, are present.






- a. Areas with high groundwater recharge
- b. Riparian areas
- c. Threatened and Endangered Species habitat in wetlands and dense forest areas
- d. Wellhead Protection Areas








Cartography by Janel A. Bisacquino, The GIS Center at Stony Brook, 11/09/2006.
Data Source: NJ Water Supply Authority and New Jersey Department of Environmental Protection.
This secondary map product has not been verified or authorized by the source agencies.

Figure 19: Impervious Surfaces (2002) in Heathcote Brook Watershed



-  Streams
-  Municipalities
-  Lakes
-  Major Roads
-  Roads

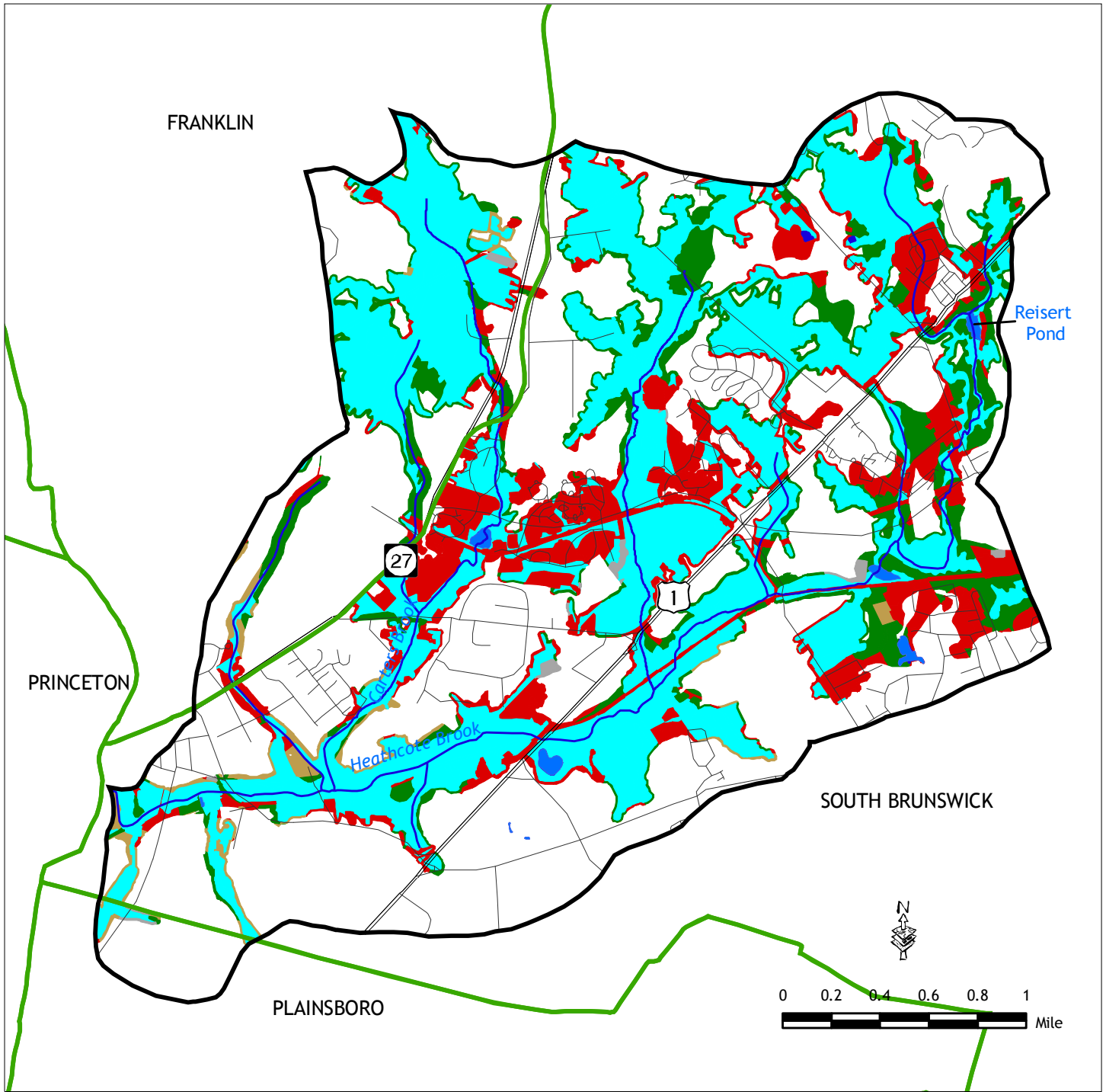
% Impervious Surface

-  0 - 10
-  11 - 25
-  26 - 50
-  51 - 75
-  76 - 100





P. Sankalia, J. Myers 6/06 - Data Source:
New Jersey Department of Environmental
Protection, US Census TIGER Files.
Although NJDEP data was used, this
secondary map product has not been
verified or authorized by the state.

Figure 20: Riparian Land Cover in Heathcote Brook Watershed

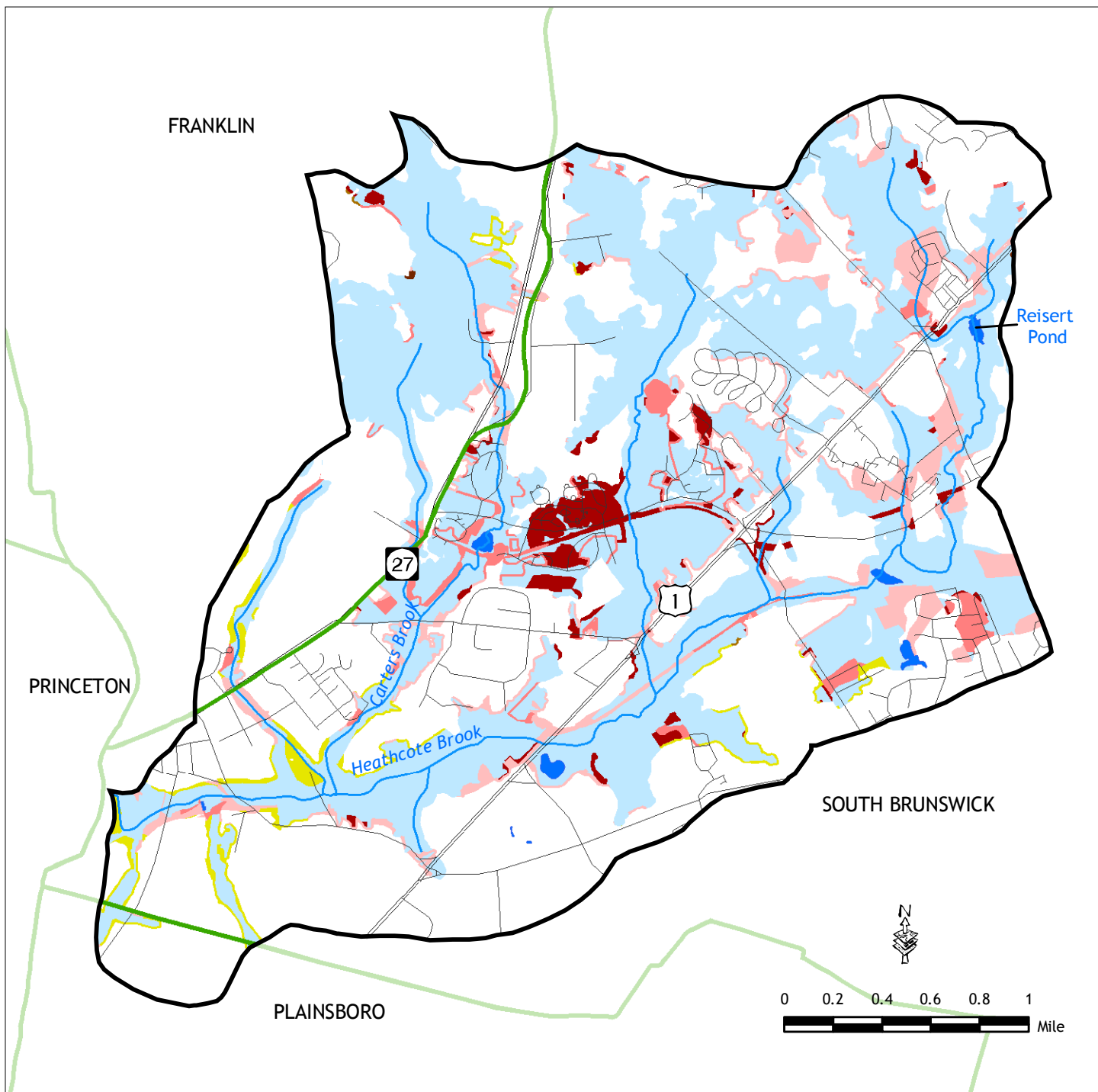


Streams	Riparian Areas
Municipalities	Converted to Agriculture
Lakes	Barren Land
Major Roads	Forest
Roads	Converted to Urban/Developed Land
	Water
	Wetlands









Cartography by Janel A. Bisacquino,
The GIS Center at Stony Brook, 11/22/2006.
Data Source: New Jersey Department of
Environmental Protection, New Jersey
Geological Survey and U.S. Census.
This secondary map product has not been
verified or authorized by the source agencies.

Figure 21: Riparian Land Cover Conversion in Heathcote Brook Watershed



Riparian Land Conversion

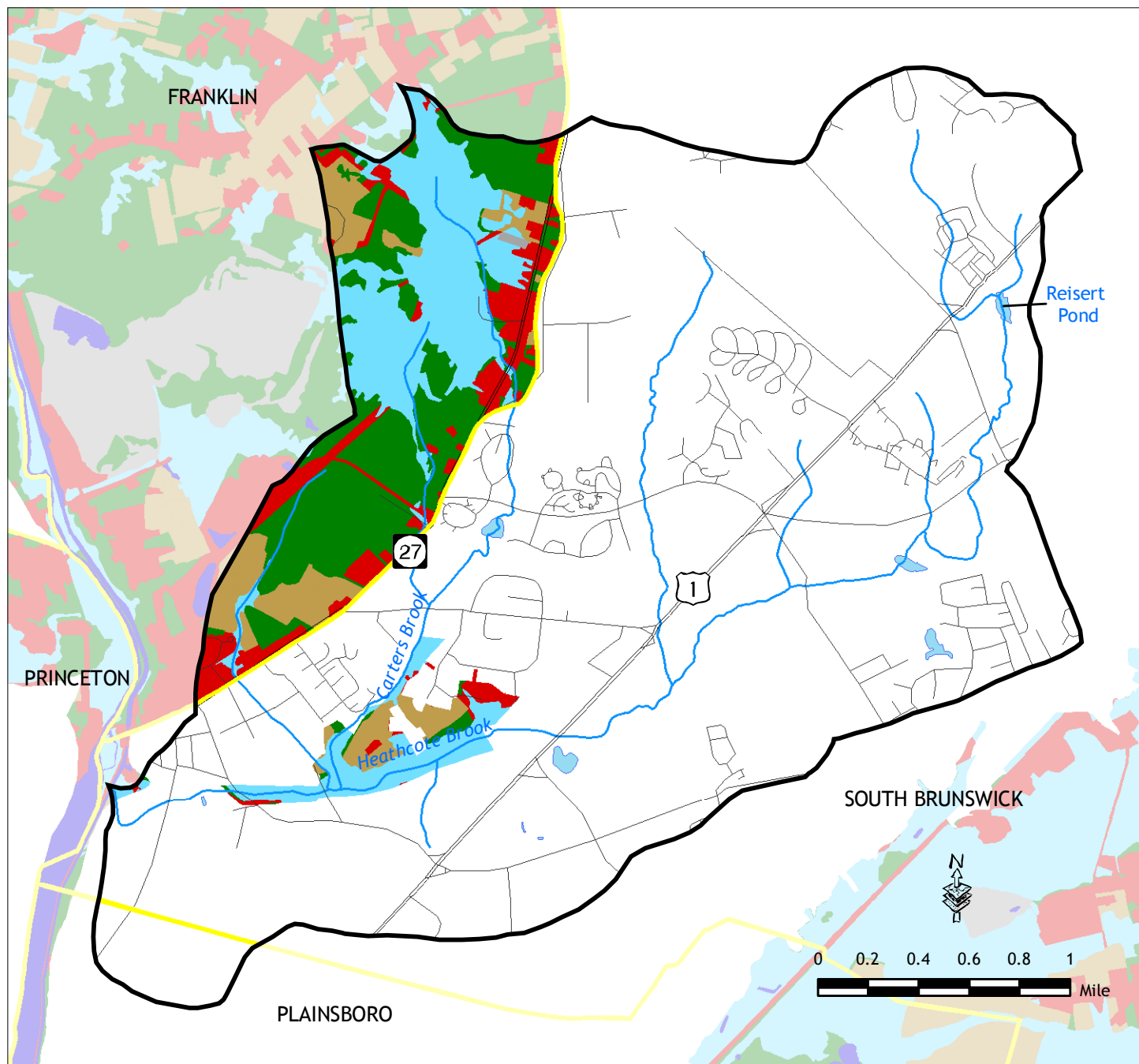
-  Streams
-  Municipalities
-  Lakes
-  Major Roads
-  Roads












-  Agricultural Development before 1986
-  Agricultural Development 1986 to 1995/97
-  Agricultural Development 1995/97 to 2002
-  Urban Development before 1986
-  Urban Development 1986 to 1995/97
-  Urban Development 1995/97 to 2002
-  Remaining Riparian Area





P. Sankatia, J. Myers 6/06 - Data Source: New Jersey Department of Environmental Protection, New Jersey Geological Survey & US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 22: Land Use (2002) in State Planning Areas PA 4, 4b, 5 & 8 in Heathcote Brook Watershed

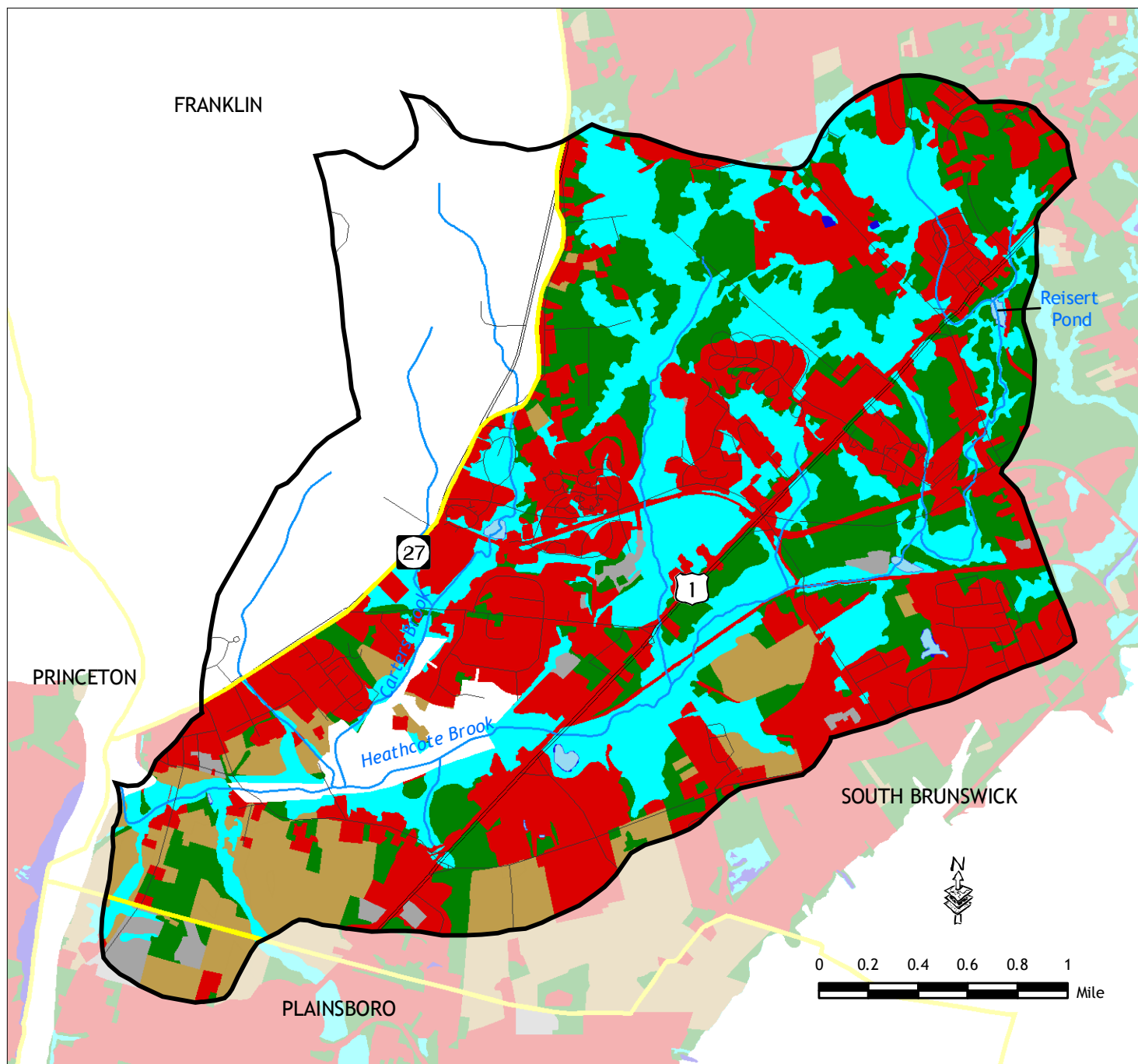













 Lakes	 Agriculture	PA 4 - Rural
 Municipalities	 Barren Land	PA 4b - Rural Environmentally Sensitive
 Major Roads	 Forest	PA 5 - Environmentally Sensitive
 Roads	 Urban	PA 8 - State Park
 Streams	 Water	
	 Wetlands	






P. Sankalia, J. Myers 6/06 - Data Source: New Jersey Department of Environmental Protection, US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 23: Land Use (2002) in State Planning Areas PA 1, 2 & 3 in Heathcote Brook Watershed

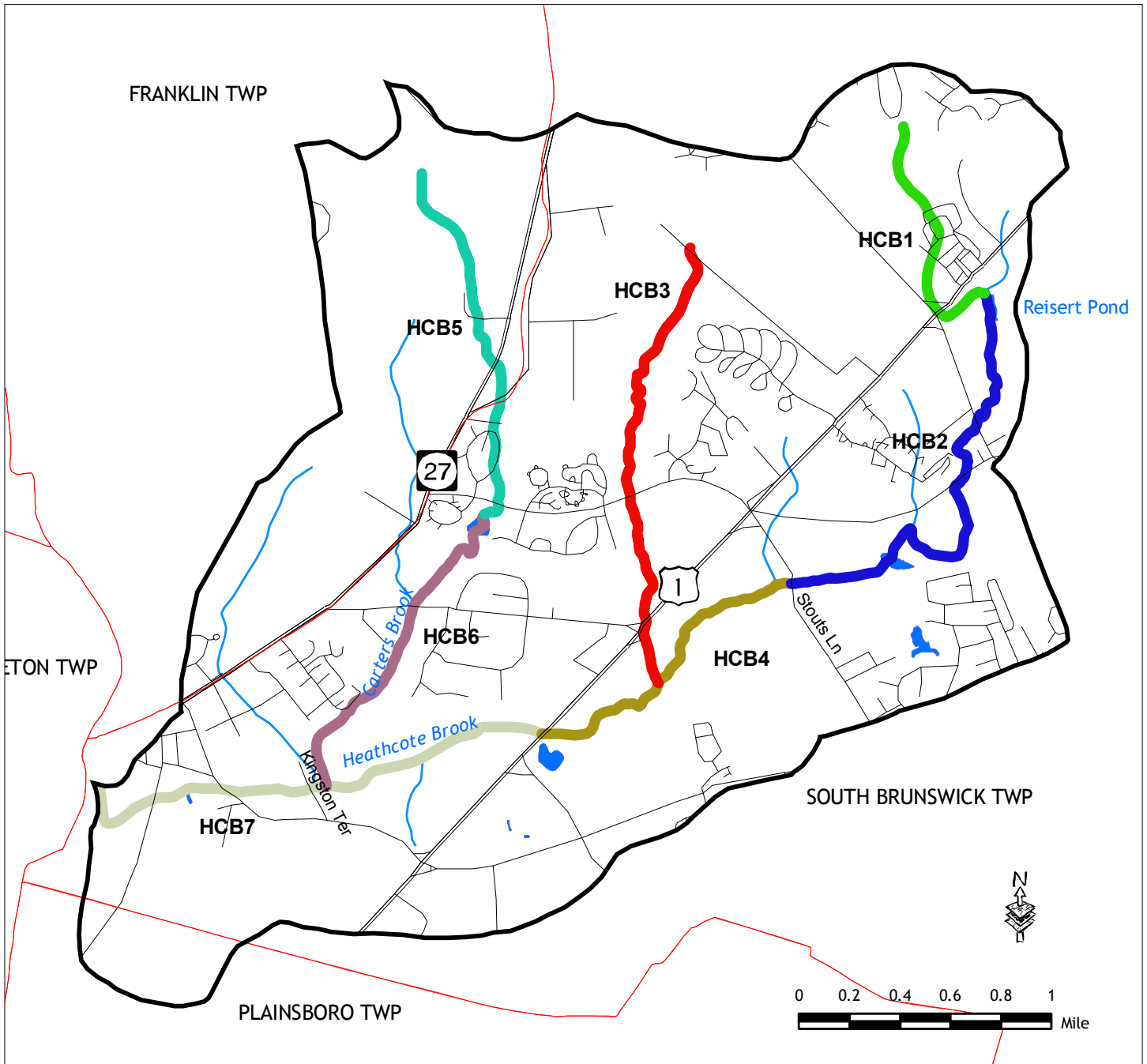














 Lakes	 Agriculture	PA 1 - Metropolitan Planning Area PA 2 - Suburban Planning Area PA 3 - Fringe Planning Area
 Municipalities	 Barren Land	
 Major Roads	 Forest	
 Roads	 Urban	
 Streams	 Water	
	 Wetlands	

P. Sankatia, J. Myers 6/06 - Data Source: New Jersey Department of Environmental Protection, US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 24: Visual Assessment Stream Segments in Heathcote Brook Watershed

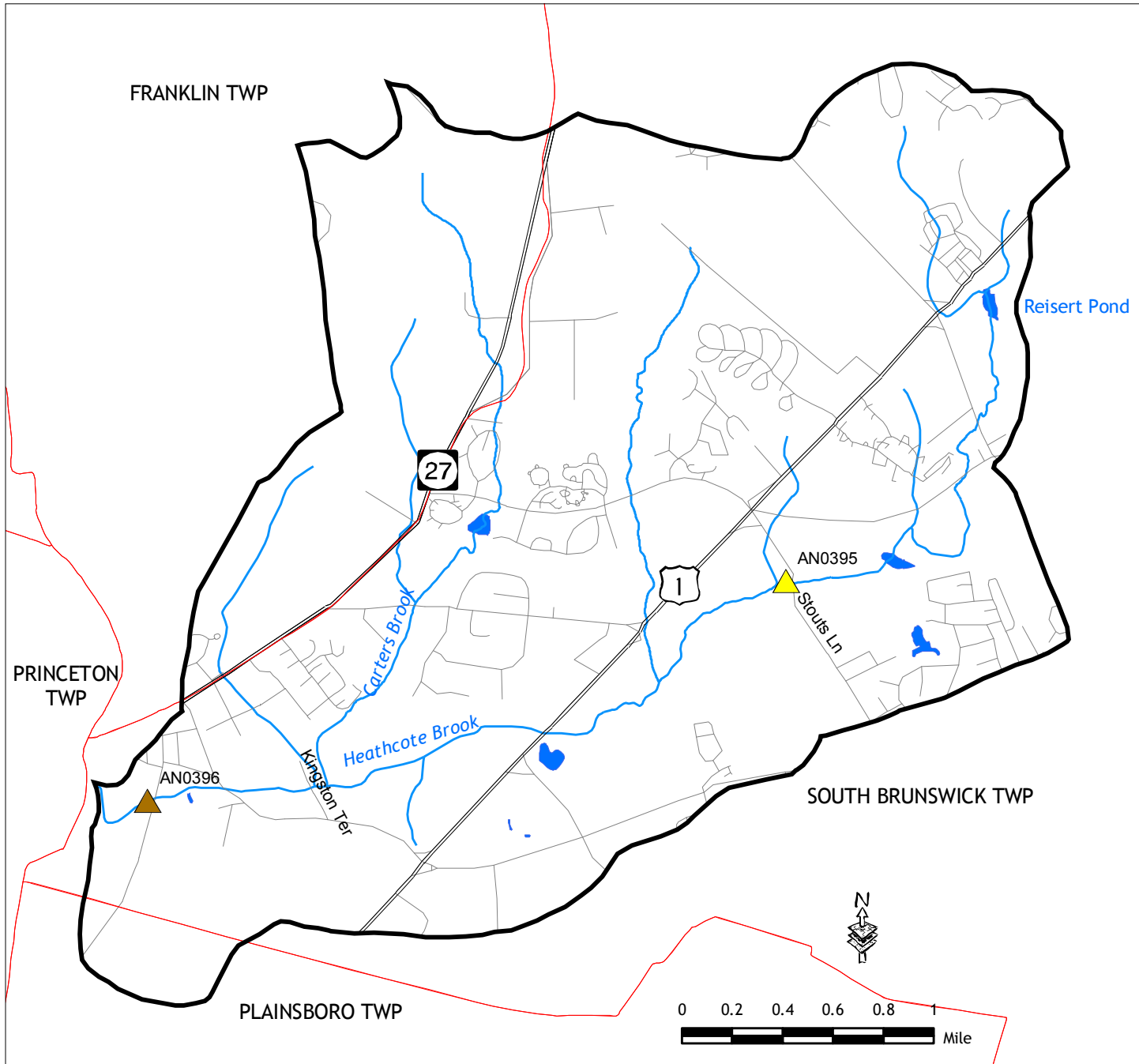









- | | | |
|--|--|--|
|  Lakes | Visual Assessment |  HCB5 |
|  Municipalities | Stream Segments |  HCB6 |
|  Major Roads |  HCB1 |  HCB7 |
|  Roads |  HCB2 | |
|  Streams |  HCB3 | |
| |  HCB4 | |





P. Sankatia, A. Rowan 11/03 - Data Source: New Jersey Department of Environmental Protection, US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 25: Biological Monitoring Sites in Heathcote Brook Watershed

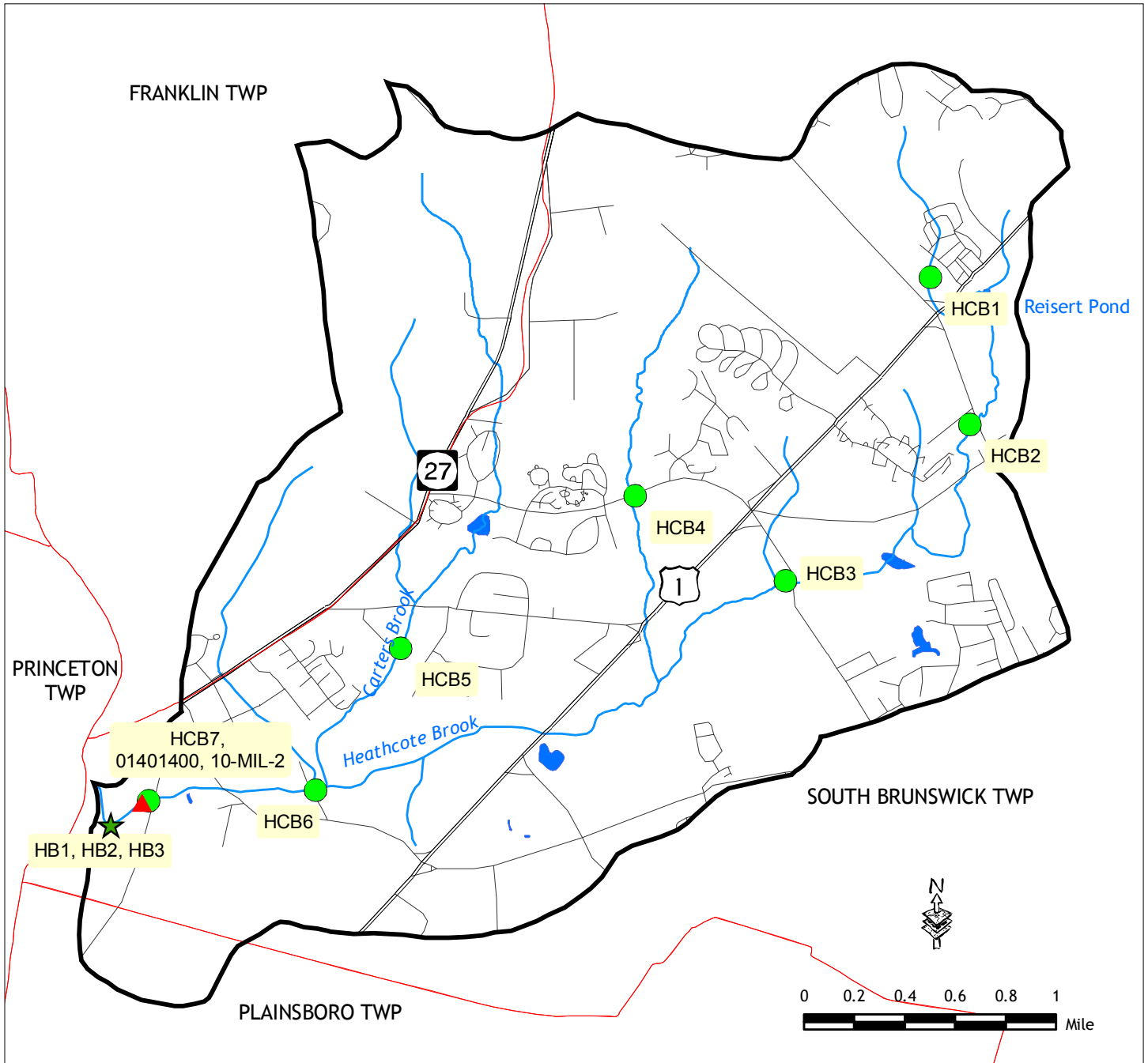










	Lakes	Impairment at AMNET Sites
	Municipalities	Sampling - 1st, 2nd, 3rd Rounds
	Major Roads	 Moderate, Moderate, Moderate
	Roads	 Severe, None, Moderate
	Streams	

J. Myers 7/06- Data Source: New Jersey Department of Environmental Protection, US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 26: Chemical Monitoring Sites in Heathcote Brook Watershed

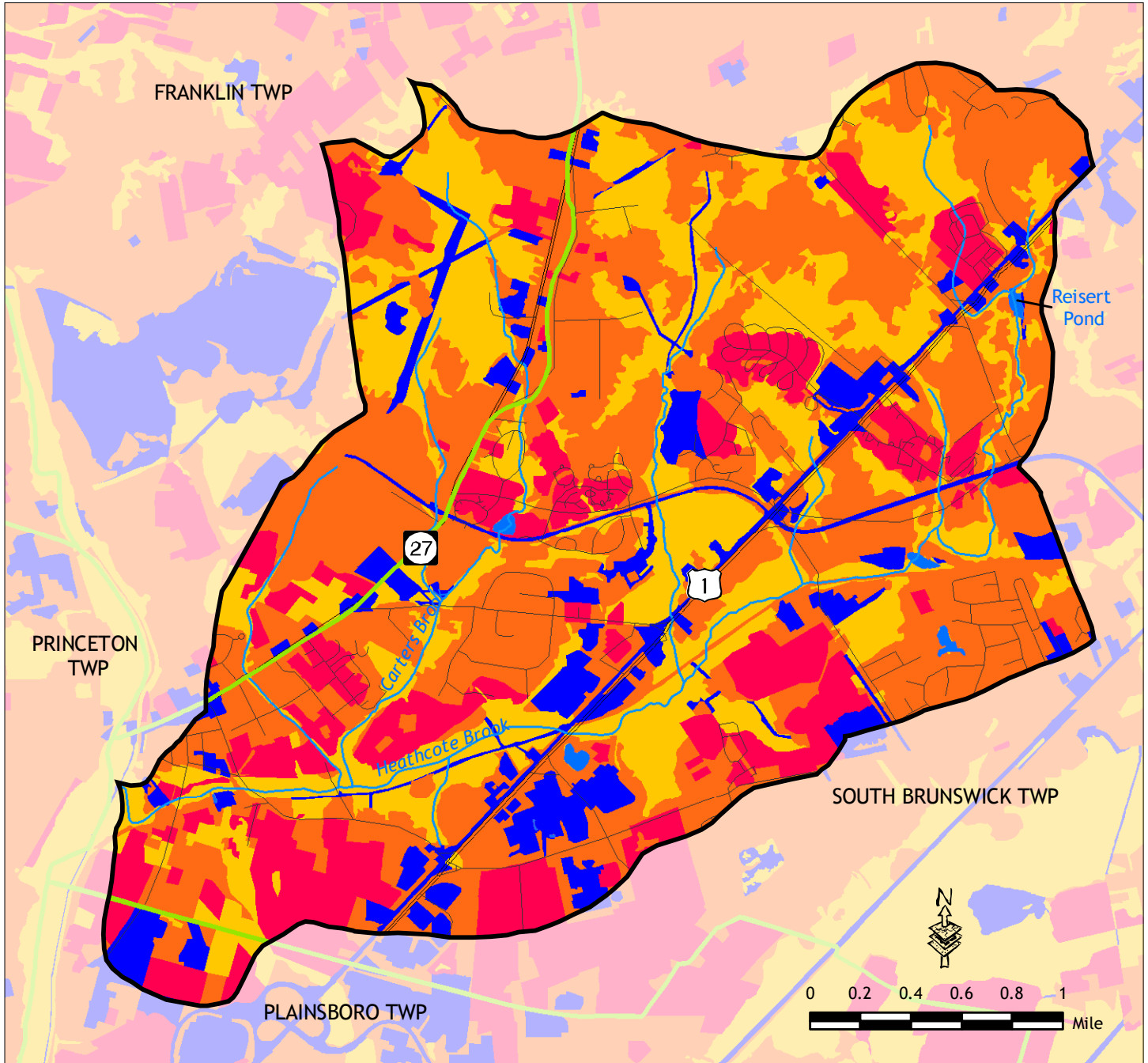












-  Lakes
 -  Municipalities
 -  Major Roads
 -  Roads
 -  Streams
 -  Bacteria Sampling Site
 -  Chemical Action Team Site
 -  USGS Sampling Site
- HCB7 is also USGS sampling site
01401400, 10-MIL-2





J. Myers 7/06- Data Source: New Jersey Department of Environmental Protection, US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 27: Nonpoint-Source Nitrogen Loadings in Heathcote Brook Watershed

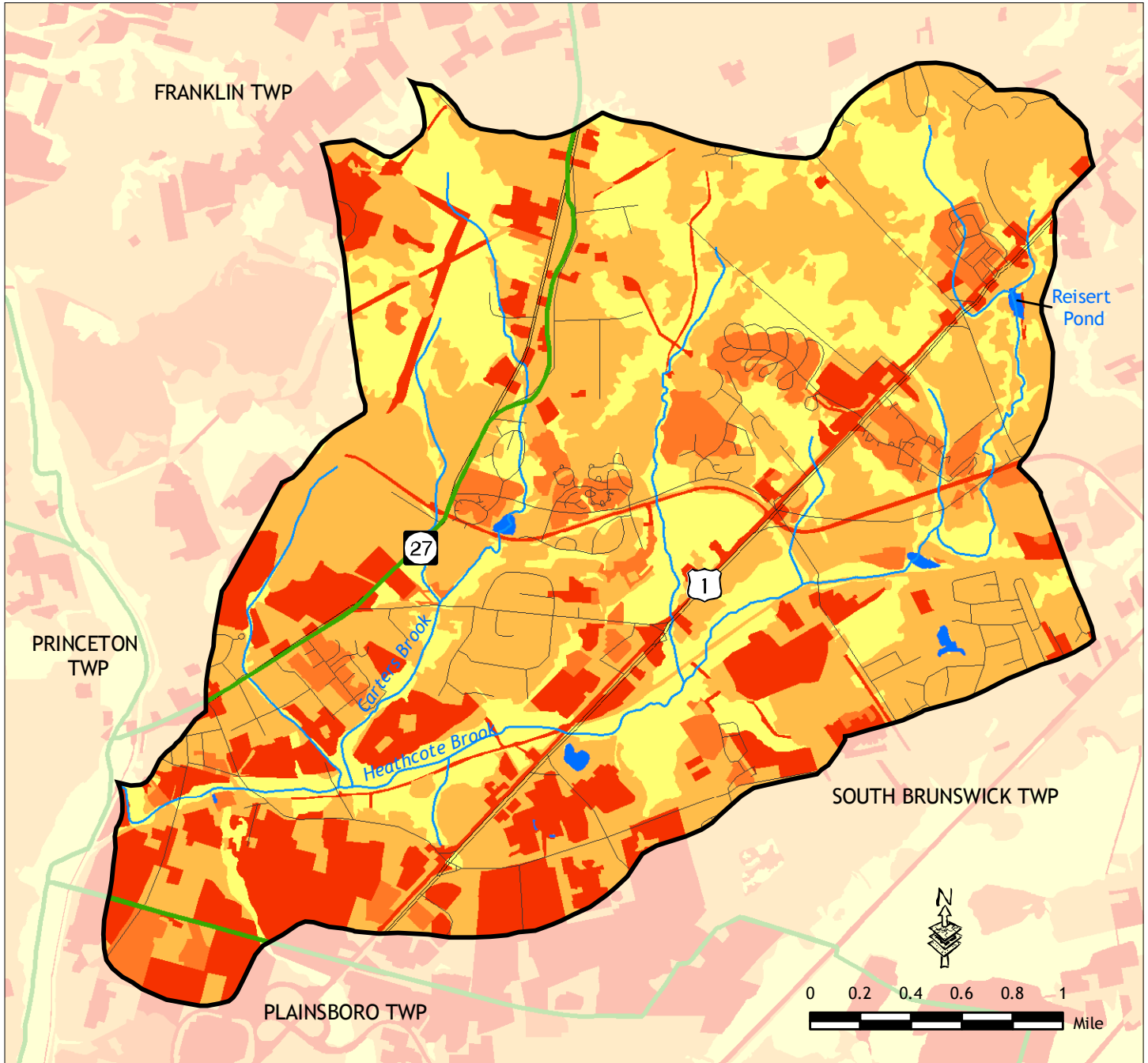












 Lakes	Nitrogen Loadings
 Municipalities	(lbs/acre/year)
 Major Roads	 0.000
 Roads	 0.001 - 1.619
 Streams	 1.620 - 3.035
	 3.036 - 4.047
	 4.048 - 5.585

J. Myers 7/06 - Data Source: Loading calculations based on coefficients from Steve Souza, Princeton Hydro, LLC; New Jersey Department of Environmental Protection, US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

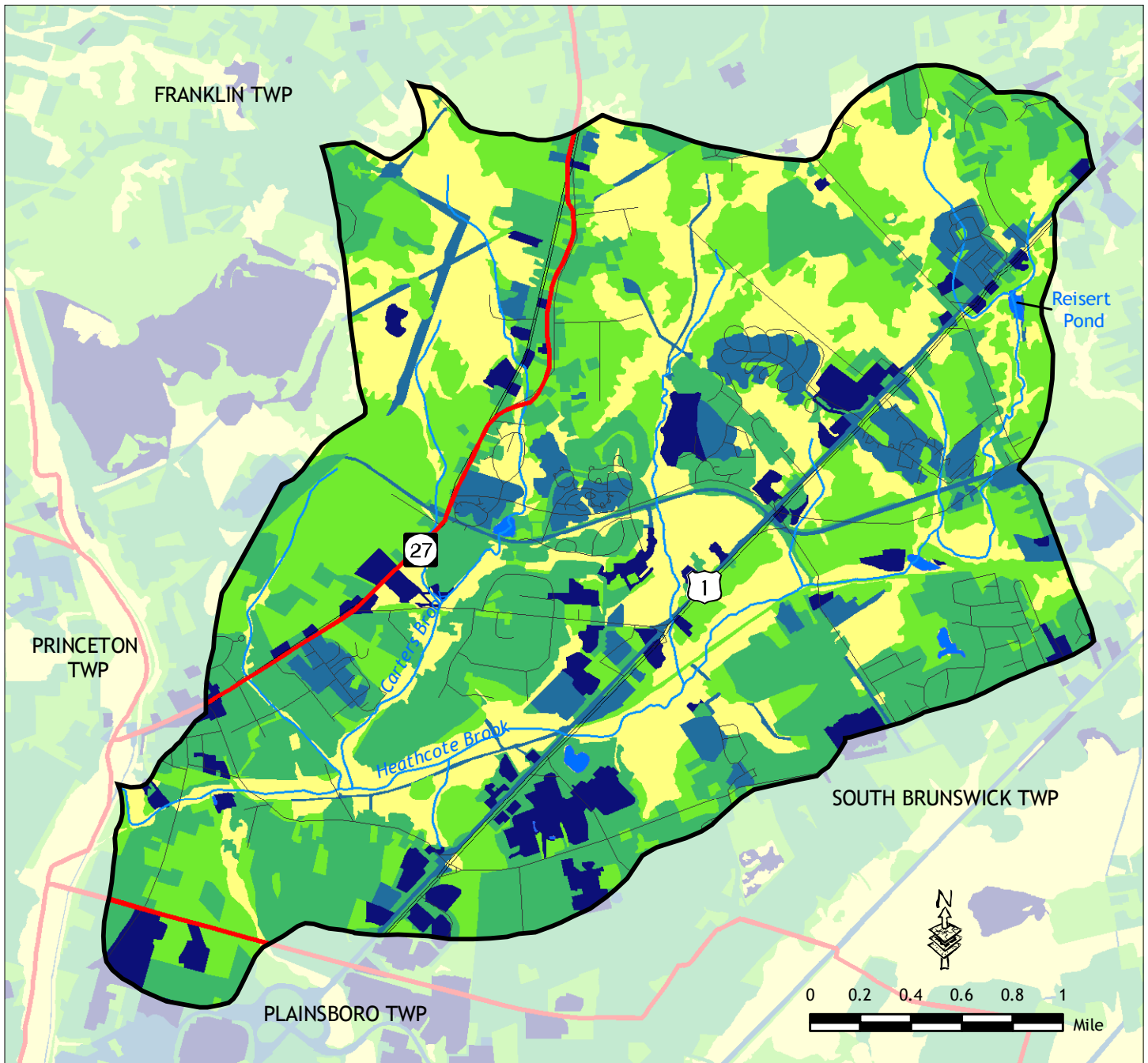
Figure 28: Nonpoint-Source Phosphorous Loadings in Heathcote Brook Watershed













 Municipalities	Phosphorous Loadings (lbs/acre/year)
 Lakes	
 Streams	
 Major Roads	
 Roads	
	 -0.101 - 0.000
	 0.001 - 0.174
	 0.175 - 0.324
	 0.325 - 1.926
	 1.927 - 10.927

J. Myers 7/06 - Data Source: Loading calculations based on coefficients from Steve Souza, Princeton Hydro, LLC; New Jersey Department of Environmental Protection, US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.

Figure 29: Nonpoint-Source Total Suspended Sediment Loadings in Heathcote Brook Watershed



 Lakes	Total Suspended Sediment (lbs/acre/year)
 Municipalities	
 Major Roads	
 Roads	
 Streams	
	 -80.9 - 0.0  0.1 - 202.3  202.4 - 404.7  404.8 - 809.4  809.5 - 1618.8

J. Myers 7/06 - Data Source: Loading calculations based on coefficients from Steve Souza, Princeton Hydro, LLC; New Jersey Department of Environmental Protection, US Census TIGER Files. Although NJDEP data was used, this secondary map product has not been verified or authorized by the state.