CHARACTERIZATION AND ASSESSMENT OF THE DUCK POND RUN WATERSHED

ACKNOWLEDGEMENTS

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Cover photo: SBMWA bacteria sampling Site DPR1, located just upstream of where Duck Pond Run crosses North Post Road in West Windsor Township

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES & GRAPHS

LIST OF FIGURES

FIGURE		PAGE

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 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 due to 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 various human activities or land uses and nonpoint source pollution as the major causes (NJDEP, 2008a). NJDEP estimates that stormwater runoff, both rain and snowmelt, accounts for 60% of the pollution in surface waters (NJDEP, 2008b). Additionally, 84% of the assessed rivers and streams in New Jersey are impaired for drinking, recreational, or fishing uses, and 45% of the assessed rivers and streams in the Nation are impaired (USEPA, 2007). According to NJDEP Land Use/Land Cover data from 1986 and 2002, over 21,000 acres of land were developed in the Millstone Watershed during those years, 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 the Millstone 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 the most effective management efforts are generally confined to subwatersheds on the order of 20-50 square miles (Center for Watershed Protection, 1998). This smaller-scale 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 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). 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 protect an unimpaired subwatershed. 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. Analyzed individually in the appropriate section of the report (i.e. Landscape, Known Contaminated Sites, Soils, Water Quality), this information is 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 that municipalities and planners can take to protect and improve the health of the Duck Pond Run 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, remedies should focus 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 exceptional water quality that need to be preserved. The Stony Brook-Millstone Watershed Association (SBMWA), with 59 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;
- Work with municipalities to integrate their vision and environmental protection goals for the municipality into zoning and ordinances;

- Open space acquisition planning; and
- StreamWatch, our successful, long-term water quality monitoring program.

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 on Duck Pond Run (NJDEP, 2004a and 2006d). Thus, NJDEP has made determining the sources of fecal coliform and reducing levels in streams a priority for their work. NJDEP funded SBMWA to conduct more intensive bacteria monitoring along Duck Pond Run and determine ways to reduce bacteria levels in the stream.

The Duck Pond Run Watershed was the sixth subwatershed chosen by SBMWA 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 Heathcote Brook was the fifth. The Duck Pond Run Watershed is located within the southern 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 Duck Pond Run Watershed to take appropriate actions to protect, enhance, or improve water quality. For this report, when discussing the entire Duck Pond Run area, it will be referred to as a watershed.

This report is intended to relay the past and present status of the Duck Pond Run 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 Duck Pond Run 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 Duck Pond Run Watershed to work together to provide a vision for this area and strive to protect the environment and quality of life that we all value.

LANDSCAPE

A foundation for the Duck Pond Run Watershed needs to be laid in order to fully begin assessing the region. That foundation takes the form of understanding the Township that decides what happens within its borders and to the Watershed, the waterways that meander through the landscape, the populations of residents who impact 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 Duck Pond Run Watershed covers 3,668 acres (approximately 5.7 square miles) contained entirely within West Windsor Township in Mercer County (Figure 2 and Table 1).

Table 1: Municipalities within the Duck Pond Run Watershed.

Municipality	County	Acres in the Duck Pond Run Watershed
West Windsor Township	Mercer	3,668

Duck Pond Run flows approximately 3.8 miles west and north through West Windsor before flowing into the Delaware and Raritan Canal west of Route 1, a drinking water source for hundreds of thousands of people. Historically, prior to Canal construction, it emptied into Stony Brook, just before it joins Carnegie Lake (Figure 2). Currently Duck Pond Run only connects to Stony Brook under flood conditions. There are a few unnamed tributaries to Duck Pond Run, which increase its length to 9.0 miles.

HISTORY

The West Windsor area, originally inhabited by Lenni Lenape Indians who were hunters, fishermen, and farmers was first explored in 1634 by an English captain known as Thomas Yong. Yong's party met and traded with the Lenni Lenape Indians during their time there. West Windsor was initially established in 1682 when William Penn signed a treaty with the Lenni Lenape; however the physical extent of the Township changed over time. In 1731 when the area was known as New Windsor Township, it also included Princeton Township, Princeton Borough, and East Windsor. According to a historic document in the office of the Secretary of State, the original Township of Windsor was organized March 9, 1750 and is supposedly named in honor of Windsor, England. The Township remained as originally organized until 1797 when a division was effected by an Act of the New Jersey Legislature, naming that portion east of the division line East Windsor and the portion west of the division line West Windsor. At the time, West Windsor was officially incorporated but still included a portion of Princeton Township and Princeton Borough. On February 11, 1813, a portion of West Windsor Township was set off to form a part of the Borough of Princeton and the Township of Montgomery. The current borders for West Windsor were defined in 1855.

Upon incorporation in 1797, West Windsor was governed by a Township Committee, which had both executive and legislative authority until 1993. In May of 1993, West Windsor residents voted to change their form of government from a Township Committee to a Mayor Council form.

The earliest farming settlements in West Windsor were made at Penn's Neck and Dutch Neck. The first settlers at Penn's Neck were the Schenck and Conover families from Monmouth County. Other early farming villages include Clarksville, Edinburg, Grovers Mill, and Port Windsor/Mercer.

Martians from Orson Wells' produced radio drama, based on H. G. Wells book War *of the Worlds*, landed on a farm near Grovers Mill. Many people believed the fictional radio newscast was real, resulting in widespread panic. A monument exists today at Van Nest Park near Grovers Mill Pond to commemorate this historical radio broadcast.

Construction of the Delaware and Raritan (D&R) Canal fundamentally changed Duck Pond Run, essentially disconnecting the tributary from the Stony Brook except under flooding conditions. The D&R Canal was built from 1830 to 1834, mainly dug by hand by Irish immigrants, linking the Delaware River at Bordentown and the Raritan River at New Brunswick. Canal use reached its height in the post-Civil War years, had its last profitable year in 1892, and closed in 1932 having been rendered obsolete by the railroads. The State of New Jersey then took over the Canal, using it as a water supply. The D&R Canal State Park was established by the State of New Jersey in 1974 adding recreation to its current functions.

POPULATION

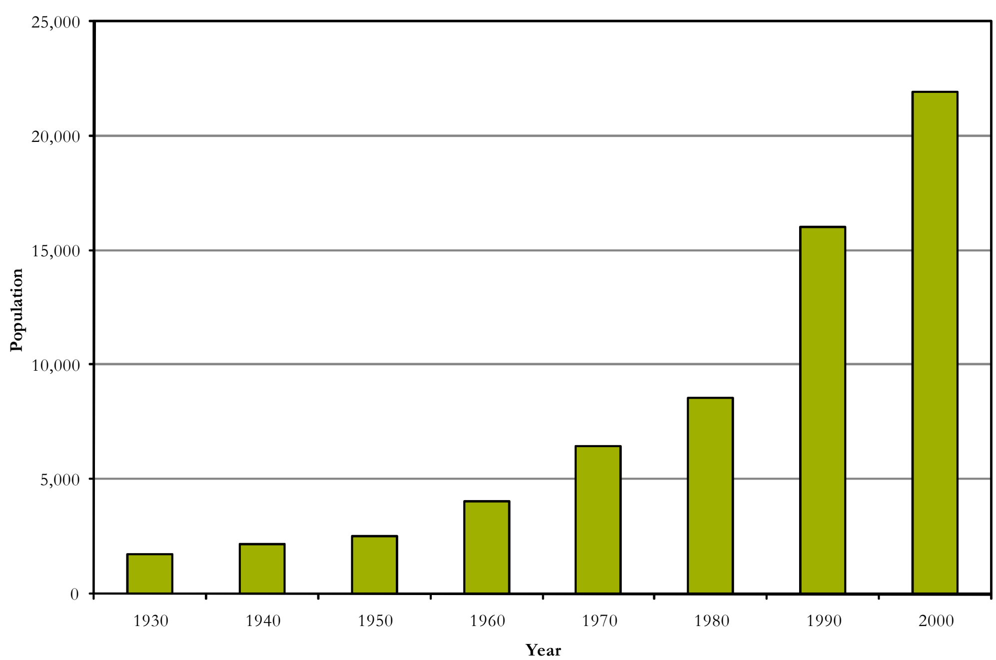
People within a watershed have both direct and indirect impacts on water quality and therefore have opportunities to responsibly manage and improve water quality. Increasing populations in the Duck Pond Run Watershed are adding to the pressures of waste disposal and water treatment, an increased need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

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

According to US Census data, within West Windsor the total population increased more than 1,180% over 70 years, from 1,711 people in 1930 to 21,907 in 2000 (Graph 1, Table 2, and Figures 3 and 4). This increase is at an average rate of 288 people per year. In 30 years alone, between 1970 and 2000, the population within West Windsor increased at the rate of 516 people per year. With such an increasing population in the only municipality that constitutes Duck Pond Run Watershed, local governance needs to thoughtfully plan out the future direction of development within the borders of West Windsor Township.

A high density of residents is found in West Windsor with an average of 1,088 residents per square mile in 2000. This is a 9.3% increase from 1990, when the population density was 987 (New Jersey State Data Center, 2001; Figure 4). Much of the density is distributed west of Route 1 and east of the Northeast Corridor train tracks (Figure 4).

Graph 1: Historical population of the West Windsor Township. *



* The population figures listed are for West Windsor Township as a whole and not just for the portion found in the Duck Pond Run Watershed. Source: US Census data.

Table 2: Population changes in West Windsor from 1930 - 2000. *

Municipality	1930 Population	2000 Population	% Population Change
West Windsor Township	1,711	21,907	+1,180%

Table 3: Population changes in West Windsor from 1970 - 2000. *

Municipality	1970 Population	2000 Population	% Population Change
West Windsor Township	6,431	21,907	+241%

* The population figures listed are for West Windsor Township as a whole and not just for the portion found in the Duck Pond Run Watershed. Source: US Census data.

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 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 needed to survive in our area (food, shelter, and clean water.). Loss of animal species can be linked to loss of resources 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.

Mercer County supports a large diversity of endangered or threatened vertebrate, invertebrate, and plant species (Table 4, Appendix L). Critical habitats for such species cover 47.5% (1,742 acres) of the Watershed (Figure 5 and Table 5). Many of the critical habitats 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 State Threatened Species (a patch of habitat where state-listed threatened species have been documented) (Figure 5). The Duck Pond Run Watershed is home to one recorded state threatened species: the barred owl (*Strix varia*).

There is a documented nesting area for herons, a species of special concern, in West Windsor (Figure 24). New Jersey Department of Transportation (NJDOT) implemented a remediation project in the Township about 5-10 years ago, excavating a large pond and creating a wetland. About 4-5 years ago nesting herons were documented as having taken up residence there. The Township is working with the Audubon Society to monitor this expanding heronry. Twenty-five nests were found in 2007 and 29 in 2008 (West Windsor EC member, verbal communication).

Table 4: Number of endangered/threatened species in Mercer County, based on August 2004 data. *

County	Vertebrates	Invertebrates	Plants
Mercer	17	9	30

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

Table 5: Percentage of acreage in Duck Pond Run Watershed designated as critical habitats.

Municipality	Acres in the Duck Pond Run Watershed	Critical Habitat Acreage	% of Township Acreage in Watershed Designated as Critical Habitats
West Windsor	3,668	1,742	47.5

ASSESSMENT

The sprawl pattern of population growth found in West Windsor Township has a more detrimental impact on water quality than clustering development in town centers. As agricultural lands, forested areas, and lands adjacent to wetlands 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 and also 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, environmental degradation 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 sensitive 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 West Windsor Township's Master Plan and decision-making committees. To balance development with environmental protection, West Windsor must incorporate these alternatives into their Master Plans.

By providing alternatives to traditional development, West Windsor will protect the environment, especially the sensitive habitats and the wildlife that live in them. The large percentage of critical habitats within the Duck Pond Run Watershed is being threatened by development, and West Windsor Township needs 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 maintaining open space through planned development, West Windsor could also continue to purchase open space and establish conservation easements to restrict development from these sensitive habitats.

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 such as hiking, bird watching, and canoeing. Open spaces provide places where people can escape the confines of urban and suburban living.

Since the entirety of Duck Pond Run is contained within West Windsor Township, the residents need to be especially aware of their roles in impacting and improving water quality in the Duck Pond Run Watershed. (See Protecting Water Quality's second and third findings in the Findings and Recommendations section, pages 78-86.)

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 in Table 6 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 of 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, 2005a). CKEs are used to make decisions about the appropriate treatment and/or replacement of contaminated drinking water supplies. The CEA is a designation given when the New Jersey Ground Water Quality Standards (NJGWQS) for contaminants have been exceeded and will not be met for the term of the remediation (NJDEP, 2005a). 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 mainly 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.* A recent May 2008 update to the known contaminated sites listing has come out on the NJDEP Site Remediation Program website. It lists an additional site within Duck Pond Run, but

There are currently ten known contaminated sites (KCSs) in Duck Pond Run Watershed (Figure 6 and Table 6). Three are located along Route 1, four are on Quakerbridge Road, one is on Penn-Lyle Road in the eastern section, and the remaining two are located west of Route 1. Known contaminated sites are classified by category and remedial level. All of the KCSs in Duck Pond Run 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).

The Princeton Motor Lodge, Windsor Arco, and 3713 Route 1 Princeton LLC, all located along Route 1, are listed with C2 remedial levels. Remedial level C2 is associated with more complicated contaminant discharges, multiple spill sites and discharges, more than one contaminant, and impacted or threatened soil and groundwater (Table 6). Both the Windsor Arco and 3713 Route 1 Princeton LLC sites have a defined CEA, indicating that the groundwater at the sites has exceeded NJGWQS.

The American Cyanamid Company site also has a defined CEA (Figure 6), again indicating that the groundwater at the site has exceeded NJGWQS. There are four separate listings for the American Cyanamid property, all with the same address: American Cyanamid Company, American Cyanamid South Facility, American Cyanamid Agricultural Research, and BASF Corporation. Each of those sites is listed at remedial level D. This indicates sites with highly complex contamination, usually with multiple contaminants of soils, groundwater and possibly surface water, and potable water resources. Since groundwater replenishes surface water, sustaining flows in rivers and streams, extensive groundwater contamination can affect surface water quality as well.

American Cyanamid is also a Resource Conservation and Recovery Act (RCRA) site and is listed on the 2008 Corrective Action Baseline, which includes USEPA's 1,968 highest priority sites (http://www.epa.gov/ epaoswer/hazwaste/ca/facility.htm). These RCRA sites are equivalent in severity to those on the National Priority List/Federal Superfund list, but still have viable operators and ongoing operations at the site. They are complex, high priority sites where hazardous substances have been released. Congress enacted the RCRA in 1976 to protect human health and the environment from potential hazards of waste disposal, to conserve energy and natural resources, to reduce the generation of waste, and to ensure that wastes are managed in an environmentally sound manner. Run by USEPA and 41

Table 6: Known Contaminated Sites in Duck Pond Run Watershed.

Preferred ID	Site Name	Address	Remedial Level*
008696	3713 Rt 1 Princeton LLC	3713 Route 1 & Penns Neck Circle	C2
020434	American Cyanamid Company, BASF Corp., American Cyanamid Agricultural Research	Quakerbridge Road	D
003541	American Cyanamid, South Facility	Quakerbridge Road and Clarksville Road	D
254163	Blue Rose Corporation	119 Penn-Lyle Road	C3
033880	Princeton Country Club	1 Wheeler Way	C1
021547	Princeton Motor Lodge	3520 Route 1 & Meadow Road	C2
033244	Princeton Theological Seminary CRW Apts	199 Loetcher Place	C1
026399	Windsor Arco	Route 1 & Emmons Drive	C2

* 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.
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.

authorized states and territories, the RCRA Corrective Action Program requires responsible parties to investigate and clean up hazardous releases themselves. According to USEPA's RCRA Corrective Action Site Progress Profile for American Cyanamid Company (also known as Wyeth Holdings Corp., BASF Corp., American Cyanamid Agricultural Research, or Princeton Land LLC), the site on Quakerbridge Road was assessed in 1987 and the solution for cleanup was selected and implemented in 1996. There have been no violations or enforcement actions reported in the last five years.

Blue Rose Corporation is located in the eastern section of Duck Pond Run on Penn-Lyle Road and is considered a C3 remedial level site. This site will involve a multi-phased remediation action because the source is either unknown or there is uncontrolled discharge to the surrounding soil and/or groundwater. It is a recent addition to the listing of known contaminated sites.

The remaining two sites, Princeton Country Club and Princeton Theological Seminary, both located west of Route 1 and north of Duck Pond Run, are listed at remedial level C1. These are relatively simple sites, with only one or two very localized contaminants.

ASSESSMENT

There are some significant known contaminated sites in the Duck Pond Run Watershed (nine in a 5.7 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.

The Duck Pond Run Watershed has many areas with high recharge to groundwater (see Water Supply section and Figure 18 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. American Cyanamid Company and 3713 Route 1 Princeton LLC appear to be located on such high recharge areas. By working to contain and clean up these potential sources of groundwater contamination, West Windsor 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 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 (NJPDES) database. This database contains information of all active permitted NJPDES 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 January 18, 2008. 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 permitted point source dischargers in the Duck Pond Run Watershed (Figure 7). The point source dischargers to surface water in the Duck Pond Run Watershed are American Cyanamid Agricultural Research, a major industrial thermal discharger; Exxon Service Station, a petroleum hydrocarbon remediations; Princeton Land LLC, an industrial wastewater discharger; and West Windsor Township, a Tier A municipal stormwater discharger. As was indicated in the Known Contaminated Sites section, American Cyanamid is also known as BASF Corporation and Princeton Land LLC among other names. Note that the point source dischargers in Figure 7 are located according to company location, not discharge pipe location on Duck Pond Run.

It is important not to understate the impact of wastewater discharge to Duck Pond Run. Streams experience reduced flows after prolonged dry periods in the summer. The ratio of effluent water to baseflow, particularly in these summer months, may be a problem. Since the baseflow is lowered, the majority of the stream water can be treated effluent. If problems happen at the plant and treatment of the effluent does not take place, then water quality degradation may occur due to higher levels of contaminants in the effluent.

PERMITTED DISCHARGERS TO GROUNDWATER

There are no active permitted discharges to groundwater in the Duck Pond Run Watershed (Figure 7).

ASSESSMENT

Point source dischargers in the Duck Pond Run Watershed need to work within the guidelines of their active permits in order to maintain the health of Duck Pond Run. West Windsor 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. 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 West Windsor Township at 271 Clarksville Road did not have any violations from the time their water quality permit was issued through June 2008. The Exxon Service Station received a violation in 2000 due to the failure to submit a Community Right to Know Survey, which was rectified shortly thereafter. American Cyanamid was cited for failure to submit the required annual remediation surcharges in 2004 and 2005; however, there were no water quality violations from this site. The company subsequently paid the fees. Princeton Land LLC violated their permit in May, August, September, and October of 2002 when chronic toxicity testing of *Ceriodaphia* (water fleas) indicated that effluent toxicity would affect freshwater organisms. Princeton Land LLC was assessed a penalty of $16,000 for the violation and has met all permit requirements since that time.

GEOLOGY

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 and metamorphic rock formations in the Watershed, stream patterns and topography are controlled by outcrop patterns and the orientation of the underlying bedrock. The Duck Pond Run Watershed straddles the Piedmont and Coastal Plain Physiographic Province line, with the majority of the Watershed falling in the Piedmont (Figure 8). Bedrock formations within the Piedmont range from Middle Proterozoic (1600-1000 million years ago) to Upper Cretaceous (100-65 million years ago) in age. The Coastal Plain in New Jersey is characterized by extensive sedimentary deposits of Cretaceous (145-65 million years ago) to Pliocene (5.3-1.8 million years ago) age. The deposits are mostly unconsolidated; that is, they have not been cemented into rock but rather are relatively loose sediments. Because of this, the material is easily eroded, and the present landscape of the Coastal Plain is largely the result of this erosion (Owen et al., 1998). Six geologic formations are present within the Duck Pond Run Watershed: the Stockton Formation, Gneiss Granofels and Migmatite, Metabasalt, the Wissahickon Formation, the Potomac Formation, and the Magothy Formation (Figure 9).

In the Piedmont Physiographic Province, which coincides with the USEPA designated Northwest New Jersey Sole Source Aquifer, bedrock consists of consolidated rock exposed at or near the ground surface. In this area groundwater is stored in bedrock aquifer systems and is transmitted along fractures, joints and bedding planes. The Coastal Plain consists of unconsolidated deposits and coincides with the USEPA designated Coastal Plain Sole Source Aquifer. Groundwater in this area is stored and transmitted through the openings or spaces between sediment particles. Over 75% of the fresh water supplies for the Coastal Plain comes from groundwater, with high-capacity public supply wells commonly yielding over 500 gallons per minute (USGS, 2001). For more detail on the aquifers, refer to the Water Supply section.

Following are brief descriptions of the geologic units occurring in the Duck Pond Run Watershed, listed in stratigraphic order from oldest to youngest (from Owens et. al., 1998; Figure 9). It is interesting to note that nearly all of the igneous and metamorphic rocks found within the Millstone Watershed are located in the Duck Pond Run Watershed (Gneiss Granofels and Migmatite, Metabasalt, and Wissahickon Formation).

Gneiss Granofels and Migmatite (Middle Proterozoic): This unit probably represents metasedimentary and metavolcanic rocks that have been heavily injected and migmatized by felsic magma. The Gneiss Granofels are mostly of intermediate composition, ranging from felsic to mafic, and contain a wide variety of rock types including graphitic schists and marble. The Gneiss Granofels and Migmatite form a nearly north-south running band in the southeastern portion of Duck Pond Run, encasing a metabasalt lens and covering nearly 9% of the watershed.

Metabasalt (Late Proterozoic): The metabasalt is a sequence of conformably layered volcanic rock ranging from a texture so fine that it cannot be seen with the naked eye to fine-grained. This probably indicates that the rock formed by solidifying at or near the surface under rapidly cooling conditions. The Metabasalt appears as a lens encased within the Gneiss Granofels and Migmatite unit on the geologic map of Duck Pond Run Watershed (Figure 9) and covers only 3% of the watershed.

Wissahickon Formation (Late Proterozoic to Lower Cambrian): The Wissahickon occurs in a narrow band (less than ½ mile wide) running nearly North-South in the southeastern portion of the Watershed. It is a fine- to medium-grained biotite-quartz-plagioclase schist and gneiss containing thin amphibolite layers. The Wissahickon is encountered beneath almost 8% of the Duck Pond Run Watershed.

Stockton Formation (Upper Triassic): The Stockton Formation is the oldest of the Triassic-Jurassic rocks within the Duck Pond Run Watershed and the most extensive geologic formation covering nearly 65% of the Watershed. It occurs in the central and northwestern portion of the Watershed. Composition ranges from coarse-grained arkosic sandstone to mudstone, siltstone, and shale. Maximum thickness of the formation 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 local sandstone (Coastal Environmental Services Inc., 1995; Hunter and Porter, 1990).

Potomac Formation (Upper Cretaceous): This unit occurs as a narrow belt (less than ½ mile wide) that overlies the Magothy and underlies the Wissahickon Formations in the eastern portion and covers only about 7% of the Watershed. The Potomac consists of predominantly fine- to coarse-grained sand interbedded with variegated clays and can reach 148 feet in thickness. Although the Potomac Formation has very little area of exposure within the Duck Pond Run and Millstone Watersheds, the sands of this formation dip to the southeast beneath younger formations (Mulhall, 2004). The Potomac Formation is part of an important aquifer system, the Potomac-Raritan-Magothy Aquifer.

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 easternmost portion of the Duck Pond Run Watershed at the border of the Coastal Plain-Piedmont rocks and covers nearly 9% of the Watershed. The sands of the Magothy Formation, together with the contiguous Raritan and Potomac Formations seen farther to the south and east in the Millstone

Watershed, serve as an extensive and regionally very important aquifer system underlying nearly all of the New Jersey Coastal Plain and reaching 4,100 feet in thickness in southernmost New Jersey (USEPA, 1988). 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 10). The recharge area for the entire system occurs in a belt along the inner (western) edge of the Coastal Plain, where the formations reach the surface before thinning out and giving way to the Piedmont rocks to the northwest.

ASSESSMENT

The geologic formations of the Duck Pond Run Watershed mainly 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 and metamorphic rock formations in the Watershed, stream patterns and topography are controlled by outcrop patterns and the orientation of the underlying bedrock.

The geology of the Duck Pond Run Watershed is also directly related to water supply and the aquifer systems. Duck Pond Run straddles two sole source aquifers, the Northwest New Jersey Sole Source Aquifer and the Coastal Plain Sole Source Aquifer (Mulhall, 2004). NJDEP and USEPA 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 Potomac and Magothy Formations are part of the P-R-M Aquifer System and have the highest average yield of high capacity wells. The Stockton Formation has a moderate average yield; and the igneous and metamorphic rocks, comprised of the Gneiss Granofels and Migmatite, Metabasalt, and Wissahickon Formation, have the lowest yield of the aquifers within the Duck Pond Run Watershed (see Water Supply section).

SOILS

The soils that underlay a watershed exert an influence on the types of vegetation that grow, agriculture that can be cultivated, drainage patterns, water transportation, water supply, and types of suitable land use.

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 four soil associations that underlie the Duck Pond Run Watershed (Figure 11). The Quakertown-Chalfont-Lehigh series underlies a small portion in the northwestern tip of the Watershed; the Atison-Manahawkin-Berryland series is seen in the central portion of the Watershed. The Downer-Sassafras-Hammonton series is the most extensive soil series and is found in the central-southern part of the Watershed. And the Mattapex-Matapeake-Chillum series is seen in the northwestern portion and at the southeastern tip of the Watershed and is the second most extensive soil series (USDA, NRCS, 2006; Figure 11).

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. The most extensive soil group within the Duck Pond Run Watershed is classified as hydrologic soil group B, covering 1,318.1 acres out of a total of 3,668.0 acres (35.9%) in the whole Watershed (Figure 12). Hydrologic soil group B represents soils with a moderate infiltration and surface runoff rate and consists of soils that are moderately coarse-textured. Most of this hydrologic soil group underlies the urban developed and agricultural areas in West Windsor Township (Figures 12 and 15).

The second most common hydrologic soil group in the Duck Pond Run Watershed is group C, covering 765 acres or 29% of the Watershed and representing slow infiltration rates (Figure 12). Category C soil groups have slow infiltration rates since most of these soils are moderately fine- or fine-textured and have layers impeding downward movement (Figure 12). Runoff from soils in group C will be high due to these moderately fine-textured soils' slow infiltration rates.

Soil group A covers 17.1% or 629 acres of the Duck Pond Run Watershed, representing high infiltration rates and low runoff rates due to the soil's sandy and gravelly texture. Soil group C/D, covering 443 acres or 12.1% of the Watershed, is a dual hydrologic group, which is a designation given for certain wet soils that can be adequately drained. The first letter applies to the drained condition, the second to the undrained. C/D soils have low to very low infiltration rates and high to very high runoff rates (Figure 12).

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. The majority of the soils in the Duck Pond Run Watershed, 63.8%, are classified as having moderate erodibility (Figure 13). Some key areas of highly erodible soils totaling 34.1% of the Watershed are found scattered throughout, but particularly adjacent to the riparian areas (Figure 13).

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 highly erodible soils appears to coincide with wetlands and developed areas (Figures 13 and 15). However, some of the agricultural areas within Duck Pond Run Watershed are located on highly erodible soils. The Conservation Reserve Enhancement Program (CREP) 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 provide a drainfield for 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 (SBMWA, 2002). 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 three to five years depending on how heavily the system is used (SBMWA, 2007a). 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 Duck Pond Run Watershed, there are many areas that are considered unsuitable for the placement of traditional septic systems due to geology and soils (Figure 14). These areas are found throughout the watershed with much of it concentrated in the southeast section. Many areas within the Duck Pond Run Watershed are suitable for conventional, soil replacement, or mound septic systems (Figure 14). Soil replacement septic systems work by installing the system in the ground and replacing the native soil with fill material (NJDEP, 1999). Mound septic systems are tanks installed above ground, which are covered with fill (NJDEP, 1999).

The entire Duck Pond Run Watershed is designated for sewer service areas (Figure 14). 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. According to the West Windsor Township Sanitary Sewer Map there are no designated septic service areas within the Duck Pond Run Watershed; however, there may be older, isolated sections where the original houses were built with septic systems and still have them. The Township Master Plan states a policy to establish public sewer systems in all moderate and higher density development areas. Therefore all future development is likely to be sewered within the Duck Pond Run Watershed.

ASSESSMENT

The characteristics of the soils in the Duck Pond Run Watershed are aligned to their overall composition in the Piedmont and Coastal Plain (see Geology section for more detail). The majority of these soils is moderately coarse to coarse and infiltrates water into the subsurface at a slow rate with moderate to high runoff rates. Therefore much of the water that lands on the watershed enters the streams as runoff. Stormwater management in the Duck Pond Run Watershed should be looked at in order to deal 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 Duck Pond Run Watershed is categorized as having medium to high erodibility. These erodible soils may increase sediment loads to streams during storm or flood events. In conjunction with the visual assessment data and observations during the biological assessments (see the Water Quality section for more details), this may already be happening in the Duck Pond Run Watershed. Visual assessments document the existence of good riparian buffers throughout Duck Pond Run, which protects streambanks from erosive overland flow, and only occasional segments exhibiting extensive erosion problems were noted. It is important to protect these buffers and maintain them as such to minimize erosion of the highly erodible soils found along Duck Pond Run. However, increased flashy flows in the stream resulting from increasing development may be leading to the documented erosion. Streams experiencing heavy sedimentation undergo smothering of aquatic macroinvertebrate habitat and subsequent loss of biological diversity, clogging of fish gills, and reducing plant productivity by the reduction of sunlight availability. Maintenance of soil integrity in areas with highly erodible soils can be done by encouraging environmentally friendly construction, properly implementing soil and erosion control Best Management Practices (BMPs), retrofitting existing stormwater BMPs to increase infiltration and reduce stormwater flows to the stream, and encouraging forested areas.

The extensive sewer service areas that cover the Duck Pond Run Watershed increase the potential for development to occur if it hasn't occurred already. The Master Plan indicates that all future moderate and higher density development areas will be sewered. West Windsor Township needs to preserve lands in these sewer service areas, reducing development pressure. Preservation can occur via conservation easements, open space acquisitions, and environmentally sensitive zoning. The Township could also target preservation in lands that are acceptable septic areas in order to minimize development and impervious cover. When comparing lands susceptible to development (Figure 15), the suitable septic areas (Figure 14), and the land use in areas with critical habitats and high groundwater recharge (Figure 19), there is quite a bit of overlap on the current agricultural lands. These then become high priority areas for preservation from development. Figure 24 includes lands already preserved as open space.

LAND USE

The population of the Duck Pond Run Watershed is 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, 1995/1997, and 2002 (Graphs 2 and 3; Figure 16).

Land use information comes from the NJDEP land use/land cover data interpreted from photographs taken during flyovers of the State in 1986, 1995/1997, and 2002, but development has occurred in the six years since the last flyover. Forests, agriculture, urban/developed land, and wetlands will be discussed in more detail as they account for the majority of land usage in this Watershed. The remainder of the land use in the Watershed is made up of either water (59.6 acres, or 1.6% of the Duck Pond Run Watershed) in the form of streams, lakes, ponds, and other waterbodies; or barren land (52.0 acres, or 1.4% of the Watershed) seen as developing land (Graphs 2 and 3). Barren lands typically represent a temporary condition, as these areas are often due to clearing of land in the process of becoming part of the urban land use category.

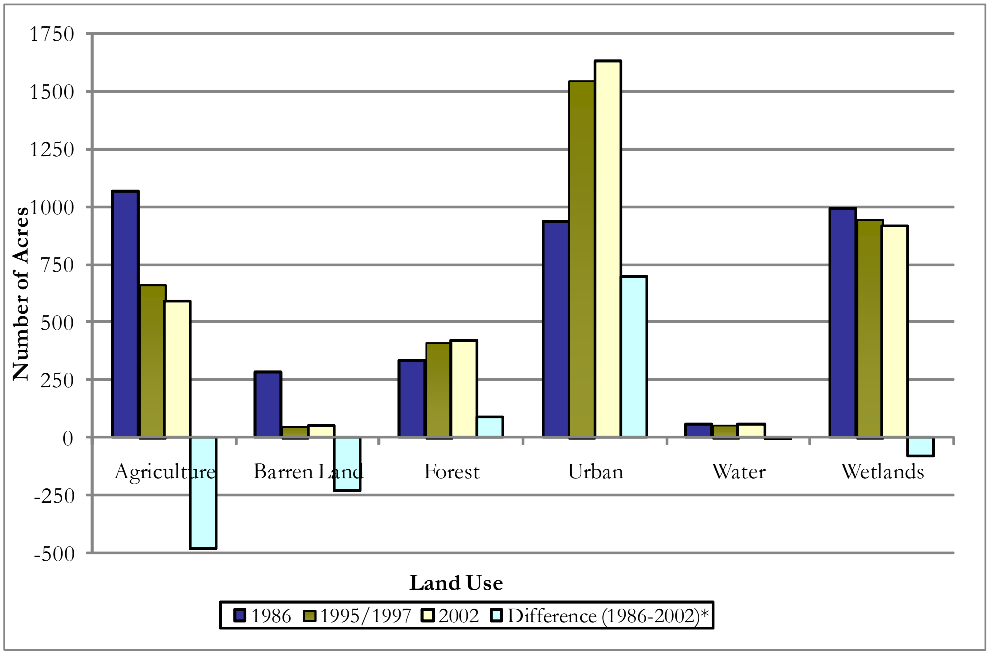
In the Duck Pond Run Watershed, land use has changed substantially in the years between 1986 and 2002. There has been a significant gain in urban area with a minor gain in forested area and losses of agricultural lands and wetlands (Figure 16 and Graph 2). Between 1986 and 2002 the landscape draining to Duck Pond Run has changed not only due to shifts in land use, but also from increases in population and local preservation efforts. For example, West Windsor Township and the Friends of West Windsor Open Space have preserved over 1000 acres since 1993. To accommodate the increasing population, mainly agricultural lands and some wetlands have been developed to provide housing and services for new residents. The changes in land use were a loss of 613.9 acres to development from 1986 to 1995/1997 with 74.2% being contributed by agriculture and wetlands. Between 1995/1997 and 2002 only 85.8 acres were developed, 88% of which had been agricultural. The total loss to development between 1986 and 2002 was 699.7 acres, 79.9% previously consisting of wetlands and agricultural lands.

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).

Since 1986 there has been a slight gain (86.6 acres by 2002) in forested lands in the Duck Pond Run Watershed (Graph 3). Forested lands made up 9.1% or 332.2 acres of the watershed in 1986, while in 1995, 11.3% or 413.0 acres was forest, and in 2002, 11.4% or 418.8 acres was forest (Graphs 2

Graph 2: Changes in acreage of land uses in the Duck Pond Run Watershed from 1986 to 2002.



Source: NJDEP Land Use/Land Cover Data 1986, 1995.1997, and 2002.
*Negative numbers represent a loss in acreage while positive numbers represent a gain in acreage.

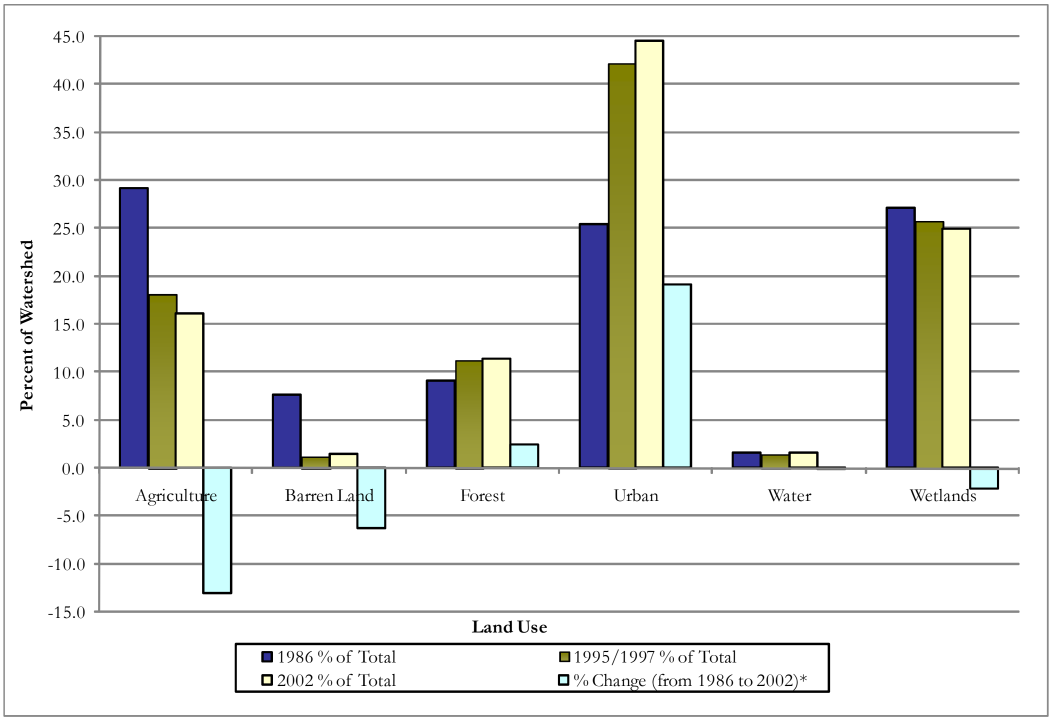
and 3). The woodlands were found scattered in small patches throughout the Duck Pond Run Watershed (Figure 15).

AGRICULTURE

In 1986, the largest land use category within the Duck Pond Run Watershed was agriculture (Graphs 2 and 3). Between 1986 and 2002, a loss of 44.8% of the available agricultural lands located mostly near wetland areas of Duck Pond Run made agriculture the third largest land use category (Graph 3 and Figure 14). In 1986, 29.2% of the Duck Pond Run Watershed, or 1,069.8 acres, was in agricultural use (Graphs 2 and 3). According to the 2002 data, there was only approximately 16.1%, or 590.2 acres, of farmed lands left in the Duck Pond Run Watershed.

Most of the current agriculture is found in the central portion, between Route 1 and the Northeast Corridor train tracks, and in the northwestern tip of Duck Pond Run Watershed (Figure 15). Almost all of the agriculture is located near the streams and wetlands found in the Watershed (Figure 15). In the past, these wetlands provided a good source of water for crops or livestock on many of the region's farms.

Graph 3: Changes in percent of total watershed area of land uses in the Duck Pond Run Watershed from 1986 to 2002.



Source: NJDEP Land Use/Land Cover Data 1986, 1995/1997, and 2002.
*Negative percent changes represent a loss in acreage while positive numbers represent a gain in acreage.

According to the 2002 Land Use data, the majority of agricultural land in the Duck Pond Run Watershed are considered crop and pasture land, consisting of 532.9 acres, or 90.3% of the total agriculture acreage. Most of the remaining lands arecharacterized as "other agriculture" with 35.0 acres, or 5.9%. The Land Use Land Cover Classification System defines "other agriculture" as areas containing miscellaneous agricultural areas such as experimental fields, horse farms, and agricultural access roads (USGS, 1976).

URBAN/DEVELOPED

In both 1995 and 2002, the largest land use category within the Duck Pond Run Watershed was in urban lands (Graphs 2 and 3). In 1986 urban lands accounted for the third largest land use category behind agriculture and wetlands. Approximately 25.4% of the watershed, or 932.9 acres, had been developed into urban areas by 1986, which provide residential, recreational, commercial, and industrial uses (Graphs 2 and 3). In 1995 urban lands jumped up to 42.2% of the Watershed, or 1,546.8 acres and in 2002 urban lands increased to 44.5% of the Watershed, or 1,632.6 acres. This was a significant gain of 75.0% from 1986 to 2002. Currently, the southeastern and northwestern sections of Duck Pond Run Watershed are most heavily developed (Figure 15 and Figure 17).

Development occurs at the expense of other land uses. In the Duck Pond Run Watershed there has been a gain in urban area and losses of agriculture and wetlands (Figure 16). Between 1986 and 1995/1997, 632.5 acres were developed. Of this amount, 312.7 acres, or 49.4% were converted from agricultural land and 223.9 acres, or 35.4% were converted from barren land. Only 55.9 acres, or 8.8% were originally considered wetlands and 40 acres, or 6.3% were originally considered forested land. Between 1995/1997 and 2002 considerably less acreage was developed, only 94.7 acres. These newly urban areas had previously been considered agriculture (54.6 acres or 57.7%), barren land (24.9 acres or 26.3%), and wetlands (11.9 acres or 12.6%).

The majority of the urban/developed land is classified as low density, single unit, residential neighborhoods (Figure 17) and is found mainly in the southeastern section 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 of around 20-25% (USGS, 1976).

The next most abundant type of urban/developed land is the commercial complex/services areas mainly grouped around Route 1 with some additional located near the Northeast Corridor train tracks (Figure 17). This classification includes structures that are used for the sale of products and services, such as malls or shopping centers. These areas have a high percentage of impervious surface coverage.

Another large developed area consists of residential, high density or multiple units located northwest of Route 1. This category contains either high density single units or multiple dwelling units on 1/5-acre lots and are characterized by impervious surface coverage of about 65% (USGS, 1976).

The Duck Pond Run Watershed is situated as a major aquifer recharge area for the Potomac-Raritan-Magothy and Stockton Formation aquifers, as discussed in the Water Supply section of this report and shown in Figure 10. Approximately 42.2% of the Duck Pond Run Watershed, or 1,549 acres, are in high groundwater recharge areas (Figure 18). However, as of 2002, 50% of the high groundwater recharge areas, or 775 acres, have already been developed, mainly around the edges of the Watershed. This is an increase in development from 29.4% of the high groundwater recharge areas, or 455 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 acreages, as a percentage of the land use within high groundwater recharge areas, fell from about 48.4% in 1986 to 28.9% in 2002. Forested lands, on the other hand, have remained fairly steady, consisting of 11.6-16.7% 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 do support under normal circumstances, 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 total 3,667.9 acres in the Duck Pond Run Watershed, 914.8 acres were wetlands according to 2002 data, representing 29.9% of the entire Watershed (Graphs 2 and 3, Figure 15). In 1986, there were 994.6 acres of wetlands. This represents a slight loss of 79.8 acres, or 8.0% of the wetland area between 1986 and 2002. Most of the wetlands lost since 1986, approximately 68 acres, has been due to urban development. Deciduous wooded wetlands account for over 78% of the wetlands in the Duck Pond Run Watershed, which are common in the northeastern United States and provide habitat for many critically important species of wildlife. These 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 majority of the wooded wetlands found in the Duck Pond Run Watershed are found in two large patches southeast of Route 1 (Figure 15). 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 forested wetlands or riparian 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, and 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 waterbodies. Impervious areas prevent the percolation of water into aquifers, decreasing recharge. This can impair local groundwater resources. Impervious surfaces can 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, harmful substances picked up by the runoff get carried to streams and lakes, contributing to water quality degradation. Research shows that stream ecosystems and water quality degrade as the amount of impervious surface within an area increases (Center for Watershed Protection, 1998; Schueler, 1994; Schueler and Holland, 2000). The first limit to impervious areas appears at approximately 10%, where sensitive elements are lost from the 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 function (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 (Booth and Jackson, 1994; Schueler and Holland, 2000). In fact, several additional studies found that the greatest predictor of stream health was the overall amount of impervious surface within a watershed (Goetz et al, 2003; Snyder et al, 2005).

Based on the 2002 Land Use coverage, Duck Pond Run Watershed has an average impervious cover of 16.6%, or 609.5 acres. But specific areas are covered in much higher amounts, suggesting some water quality degradation (Figure 19). Several impervious areas are rated at 26% or higher for lands in this region, which are mainly located adjacent to Route 1 (Figure 19). These areas are highly developed and could be contributing to water quality problems as the Duck Pond Run flows into the Delaware and Raritan Canal.

In general, all areas with over 26% impervious coverage coincide with the urban/developed land areas (Figures 17 and 19) and are congregated close to Route 1 and the Northeast Corridor train tracks. 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.

RIPARIAN CORRIDORS

Of special note are riparian corridors, or vegetated areas that lie adjacent to 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 Duck Pond Run 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). Some of these lands have undergone conversion from one land use category to another between 1986 and 2002 (Figure 21). Based on the above definition of riparian areas, historically Duck Pond Run Watershed had 1,524.5 acres in this corridor. Of that amount, about 80.85 acres (or 5.4%) had been converted to agriculture, 261.5 acres (or 17.2%) became urban, and 20.5 acres (or 1.3%) had become barren land by 1986 for a total loss of 23.8% of the riparian area. By 2002, with conversion to and from various land uses, a total of 44.46 of the historical riparian acres (or 2.9%) remained agricultural, 376.1 acres (or 24.7%) were urban, and only 15.8 acres (or 1.0%) were barren land for a total loss of 28.62% of the riparian area. While most of the rest of this riparian area is composed of wetlands (865.7 acres or 56.8%) as of 2002, the remainder is made up mainly of forested areas (166.3 acres or 10.9%) and water (only 56.2 acres or 3.7%) (Figure 20). The riparian wetland area is mainly made up of deciduous wooded wetlands (681 acres or 78.7% of the riparian wetlands).

It should be noted that NJDEP has previously identified Duck Pond Run and five unnamed tributaries as candidates for designation as Category 1 (C1) waterways (NJDEP, 2006b). The basis for these nominations is that these water bodies all drain to the Delaware and Raritan Canal, a drinking water supply. C1-designated waterways are afforded a higher level of protection from development. If the NJDEP accepts these nominations in the future, the State anti-degradation policies and a proposed 300-foot buffer will protect these streams in the following ways:

- 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 Stormwater rules (N.J.A.C. 7:8-5.5h) and the Flood Hazard Regulations (N.J.A.C. 7:13-10.2j).

If adopted, the 300-foot buffer along C1 waters will prevent increases in 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. SBMWA encourages NJDEP to reconsider this nomination and accepts Duck Pond Run and its tributaries as C1 waterways.

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 those planning areas (PAs) are aimed at limiting growth of development and preserving historical, cultural, and environmental resources.

In the Duck Pond Run Watershed, PA5 (Environmentally Sensitive) and PA8 (State Park) lands are found in small areas in the northernmost tip of the Watershed (PA8), along the Delaware and Raritan Canal (PA8), and along Duck Pond Run between Route 1 and the Delaware and Raritan Canal (PA5) (Figure 22). The majority of the lands in these PAs are wetlands and urban areas (Figure 22). Current Federal and State regulations restrict development in wetlands. The wetland area contains wetland forest critical habitats (Figure 5). Therefore, these areas become vital to protecting threatened and endangered species.

The majority of West Windsor Township within the Duck Pond Run Watershed consists of State Planning Area PA2 (Suburban Planning) (Figure 23). This planning area is designated for growth and provides areas for redevelopment and future development.

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 within the Duck Pond Run Watershed (see Landscape section for more detail) and the increasing developed areas from 1986 to 2002 (Figure 16). Many of the newly developed areas are being placed on agricultural land (50.5%), barren land (34.2%), and wetlands (9.3%). Due to the proximity of converted agricultural lands to waterways, water quality becomes a concern as impervious surfaces increase. Water quality would be better protected by decreasing the conversion of farmlands in the Duck Pond Run Watershed to urban areas through participation in the State's farmland preservation programs, adopting and enforcing a stream corridor ordinance, or protecting riparian areas with conservation easements. West Windsor has significantly reduced the conversion rate of agricultural lands since 1995, but should be diligent in continuing to do so.

Urbanization of the Duck Pond Run Watershed has increased the amount of impervious cover in the region. 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, away from 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 Duck Pond Run Watershed at 11.4% in 2002, efforts to reforest portions of the region should be considered. And with the average 2002 impervious cover totaling 16.6% in the Watershed, efforts to reduce existing, and limit planned impervious cover through low impact development and redevelopment is crucial.

Riparian corridors are being encroached upon slightly by developed areas in the Duck Pond Run Watershed (Figure 20). 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 Duck Pond Run 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 (70.9%) is made up of wetlands (Figure 20). These wetland areas are already regulated under development protection, but West Windsor should enact a stream corridor protection ordinance to help control further development in these areas.

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.

A few minimal areas within the Duck Pond Run Watershed have been planned for limited growth (Figure 22). The areas are mostly wetlands and urban. The wetlands contain critical habitats (Figure 5). Those lands should be targeted as high priority for preservation. The preservation of these areas will benefit the habitats needed for threatened and endangered species (see Landscape section). Due to the restricted nature of these areas designated for limited growth, the Township might consider preserving other priority areas such as those with critical habitats that are also in high groundwater recharge areas (Figure 24).

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 a watershed. In fact, groundwater is New Jersey's major source of potable water (NJDEP, 2005b). Evaluating the health of one aspect alone presents a partial picture of the true quality of water in an area. It is important to be aware that groundwater not only provides drinking water through wells, but depending on the water table level can replenish surface water in gaining streams. Since some streams feed water supply sources, such as Duck Pond Run feeds the D&R Canal, the groundwater in a gaining stream system can still affect drinking water supplies, as does the stream itself. Alternatively a stream's surface waters can replenish groundwater in losing streams. A stream can switch from being a gaining to a losing stream depending on the time of year or if significant water withdrawals raise the water table level.

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 Duck Pond Run Watershed straddles both of these sole source aquifers with the northwestern arm falling entirely within the Northwest New Jersey Sole Source Aquifer where groundwater is stored and transmitted through fractures and openings created after the rock formed. The southeastern arm of the Watershed falls within the Coastal Plain Sole Source Aquifer where groundwater is 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 (gpm) have been installed in aquifers ranked 'A'; those ranked 'B' can sustain wells with yields between 251 and 500 gpm. Wells with yields ranging from 101 to 250 gpm can be found in aquifers ranked 'C', while those ranging from 25 to 100 gpm can be found in 'D' aquifers. The lowest ranked aquifers, 'E' aquifers, can only support wells with demands of less than 25 gpm. The NJGS ranking system for aquifers does not indicate that all wells installed within these aquifer systems are actually capable of sustaining the yields suggested by their ranking, since the data on which the rankings are based were derived throughout the State (Mulhall, 2004).

There are three aquifers of various rankings within Duck Pond Run Watershed ranging from the 'A' ranked Potomac-Raritan-Magothy Aquifer System to the 'D' ranked Igneous and Metamorphic Rocks. Not surprisingly, aquifers essentially coincide with the geologic formations (Figures 9 and 10).

Potomac-Raritan-Magothy Aquifer System:
The sands of the Magothy and Potomac Formations form the Potomac-Raritan-Magothy (PRM) aquifer and are located at the southeastern tip of the Watershed (Figures 9 and 10). 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 there. Since the PRM aquifer system is capable of supporting very high yielding wells and major water supply systems, NJGS ranked it 'A'. With the capability of pumping over 500 gpm, the PRM aquifer is the most prolific in the Duck Pond Run 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).

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 central and northwestern section of the Duck Pond Run Watershed (Figures 9 and 10). Since the NJGS ranks the Stockton Formation aquifer system as a 'C', it is considered to be a good groundwater resource (Mulhall, 2004).

Studies conducted in Mercer and Hunterdon Counties (Widmer, 1965; Kasabach, 1966; Lewis-Brown, 1995) indicate an actual median yield ranging from 12 to 19 gpm 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).

Igneous and Metamorphic Rocks:
The Gneiss Granofels and Migmatite, Metabasalt, and schists and gneisses of the Wissahickon Formation make up the Igneous and Metamorphic Rocks

aquifer (Figures 9 and 10). These crystalline igneous and metamorphic rocks have poor aquifer characteristics and are not considered a significant water resource. NJGS ranked this aquifer as a 'D', therefore these wells have little capacity to support major water supply wells. Widmer (1965) found that wells from this aquifer actually produced sufficient water to meet most domestic water supply demands, but not enough to meet any more significant demand. He found the actual median yield from these wells was only 7 gpm.

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). Public non-community wells (PNCWs) provide water to public individuals other than year-round residents for at least sixty days of the year and can be either transient or nontransient. Nontransient wells serve at least 25 of the same people for six months of the year such as schools, factories, and office buildings. A transient non-community water supply well serves year round for at least 60 days, but does not serve the same individuals during that time period. Examples of nontransient wells include rest stop areas, restaurants, and motels. 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 from groundwater. 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 two different kinds of wellhead protection areas: those around PCWs and those around PNCWs.

Within the Duck Pond Run Watershed, there are two defined WHPAs for PCWs, each owned, operated, and maintained by the Elizabethtown Water Company (Figure 25). (Note that water traveling below the ground's surface can travel outside the surface-delineated watershed.) The two WHPAs overlap in the northwestern corner of the Duck Pond Run Watershed in West Windsor Township (Figure 25). There are three KCSs located within a public community water supply WHPA in the watershed (Figure 25). Both the Princeton Country Club and Princeton Theological Seminary sites are located within Tier 3 of the southwestern WHPA. These sites are categorized at Remedial Level C1, indicating relatively simple sites with known contaminants with a potential to contaminate groundwater. The 3713 Route 1, Princeton site is located within Tier 2 between the two WHPAs. Categorized at Remedial Level C2, this site has a known contamination source or already exhibits groundwater contamination. These KCSs are detailed in the Known Contaminated Sites section of this report. According to NJDEP's Community Water System Source Water Assessment Reports (NJDEP, 2004b), of the 13 PCWs with groundwater sources in the Stockton Formation (Figures 10 and 25), seven are permanent wells in use, five on Harrison Street are no longer in use for unspecified reasons, and one on Harrison Street is no loner in use due to contamination. Therefore, it is likely that one of these KCSs within the WHPA is affecting groundwater water quality.

There is one defined PNCW WHPA at Quakerbridge Road in the south-central portion of the Duck Pond Run Watershed (Figure 25) owned and operated by BASF Corporation. This nontransient system serves about 100 people (in 2003) and consists of five active wells with no surface water intakes (NJDEP, 2005c). Data from the summer of 2003 indicated that all of these wells have a high susceptibility for contamination by radionuclides and radon. Three of the wells had a high susceptibility for volatile organic compound contamination and two of them had a high potential for inorganics contamination. Probably this potential contamination is related to the four KCSs located within Tier 2 of that WHPA, including the classification exception area (CEA) American Cyanamid Agricultural Research (Figures 6 and 25) which has a special permit/management plan in effect. BASF purchased American Cyanamid in 2000. The CEA is a designation given when the New Jersey Ground Water Quality Standards (NJGWQS) for contaminants have been exceeded and will not be met for the term of the remediation (NJDEP, 2005a). When a CEA is designated for an area, the designated aquifer uses are suspended for the term of the CEA. The determination of a CEA 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 American Cyanamid sites (American Cyanamid Agricultural Research, American Cyanamid South Facility, American Cyanamid Company, and BASF Corporation) are all classified at Remedial Level D, indicating multiple sources or releases of contaminants to multiple media including groundwater.

GROUNDWATER RECHARGE

Groundwater is not in endless supply. Water needs to enter the land's subsurface in order to recharge groundwater supplies. 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 aquifers 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% evaporates back into the atmosphere (Center for Watershed Protection, 1998). Using the Center for Watershed Protection guidelines, the Duck Pond Run Watershed, with 16.6% 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. This is common for areas with up to 20% impervious cover (Center for Watershed Protection, 1998). Based on more local data, for the whole Millstone Watershed with an average impervious cover of 8.8% (based on 1995/1997 land use coverage), NJWSA estimates that only 14.2% of precipitation infiltrates into the ground, 31.6% flows over the land as runoff, and 54.2% evaporates back into the atmosphere (New Jersey Water Supply Authority, 2000c). It is likely that the percentage of average impervious cover has increased in the Millstone Watershed in view of the fact that development has progressed since 1995/1997, resulting in even less precipitation recharging groundwater. 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 rates of infiltration. The underlying geology also plays a role in the capacity of water to percolate. In a developing watershed like the Duck Pond Run 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 Duck Pond Run Watershed, there are 1,549 acres (or 42.2% of the entire Watershed area) found within areas classified in 2002 as high groundwater recharge (Figure 18). This 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 1,549 acres classified as high groundwater recharge areas, 448.5 acres (or 29.0%) were in agricultural lands in 2002, 775.0 acres (or 50.0%) were in urban/developed areas, 259.1 acres (or 16.7%) were forested, and the remaining acreage was water, wetlands, and barren land (Figure 18).

According to the New Jersey Water Supply Authority's 2002 report, *Ground Water in the Raritan Basin*, between 1986 and 1995 the Millstone Watershed (of which the Duck Pond Run Watershed is a part) lost nearly 5% of its recharge capability. The Duck Pond Run Watershed well exceeded this overall average, losing an average of 1.58 inches or 21.6% of its groundwater recharge capability between 1986 and 1995 (New Jersey Water Supply

Authority, 2002). It is likely that additional recharge capability has been lost since 1995 as development progressed. Interestingly, Duck Pond Run Watershed lost the greatest amount of recharge capability of all the subwatersheds within the Millstone Watershed between 1986 and 1995.

The most likely reason for the loss of groundwater recharge is an increase in developed/urban areas in high groundwater recharge zones since 1986 (see Land Use section for more information). Urban areas increased by 320 acres in areas of high groundwater recharge between 1986 and 2002, or from 29.4% to 50.0% of the recharge area. This increases the amount of impervious surface that prevents 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, which increased impervious surfaces and reduced the ability to recharge groundwater (Schueler and Holland, 2000). The loss of groundwater recharge in the Duck Pond Run Watershed as reported by 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 surfaces, 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). Contaminated groundwater can not only affect the safety of well water, but in gaining streams can also contaminate the surface waters it feeds. While in areas with losing streams, surface waters contaminated by agricultural stormwater runoff have the potential to contaminate the groundwater it replenishes. Municipalities and farmers have several tools at hand to help them protect this important resource. Such tools include regulations and ordinances on the use of chemicals and implementation of best management practices for reducing pesticide use and water quality impairment from agricultural runoff. The New Jersey Conservation Reserve Enhancement Program (CREP) helps farmers implement such best management practices.

The preservation and protection of lands in high recharge areas can be accomplished by purchasing such lands. To select the most important properties to purchase, West Windsor can focus on the overlap area of key preservation criteria. 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 (Figures 5, 18, 20, and 24). Properties that meet the criteria for all three of these areas could be ranked highest for potential preservation. The Raritan Basin Council 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 public community water supply wellhead protection areas (WHPA) in West Windsor Township are important to note, as there is potential for groundwater contamination due to its proximity to three known contaminated sites: Princeton Country Club, Princeton Theological Seminary, and 3713 Route 1, Princeton. Similarly the public non-community water supply WHPA has extensive known contaminated sites within its boundary, the American Cyanamid sites, with potential for groundwater contamination. Each known contaminated site's wells need to have consistent monitoring by NJDEP to ensure that no contamination is documented in the vicinity of the WHPA.

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 one of the leading causes of water quality degradation (USEPA, 1996) and NJDEP states that stormwater runoff accounts for 60% of pollution in our lakes, rivers, and streams (NJDEP, 2008b). 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 26, 27, and 28). The NJDEP has incorporated biological monitoring at one site within the Duck Pond Run 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) 1994, 1999, and 2004 reports for the Raritan River drainage basin. Biological data was also gathered from one SBMWA site for the years 2001, 2002, and 2003. Visual assessments were performed by a Watershed Ambassador specifically for this report and an SBMWA volunteer as part of our ongoing River Action Team (RAT) volunteer monitoring program, both trained by SBMWA staff. Chemical assessment data was gathered from one USGS site, five NJDEP sites, two sites monitored through the West Windsor Township Environmental Commission, and three sites monitored by developers. Chemical and visual data were also collected at four bacteria sampling sites monitored by SBMWA staff specifically for this report from May 2005 to September 2006 under wet and dry weather conditions.

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 assessment is 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. SBMWA's methodology makes an effort to quantify these observed characteristics, based upon visual assessment protocols used by the USDA's NRCS, the Upper Raritan Watershed Association (URWA), and the Maryland Department of Natural Resources (MDDNR) (USDA, 1998; URWA, 1997; MDDNR, 2000). During the visual assessments, a score was given to each of ten parameters (i.e., water color, erosion, man-made structures, etc.) on a scale of 1 to 4. A score of 1 represents severe problems while a score of 4 represents pristine conditions. These ten parameters were then averaged to determine the overall value for the entire stream segment. Ratings of poor, fair, good, and excellent are given based on the overall value. The stream is rated as good if the overall value ranges from 2.3 – 3.4 and excellent if the overall value is greater than 3.4. 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 a trained Watershed Ambassador and one of SBMWA's RAT volunteers. Four navigable stream segments, referred to as "beats" (a.k.a. reaches), are located in the Duck Pond Run Watershed along the main stem of the Duck Pond Run (Figure 26). All Watershed Ambassador assessments were completed in June of 2004 while the RAT volunteer assessments were collected at one of the beats (DPR3) between 2001 and 2005. The Watershed Ambassador and SBMWA volunteer walked the "beats" after being trained by SBMWA staff about 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.

Note that the four "beats" within the Duck Pond Run Watershed have been given the designation of 'DPR', and are numbered sequentially starting with the most upstream "beat" (Figure 26). All beats are located on Duck Pond Run's mainstem.

The average score for all stream segments in the Duck Pond Run Watershed is 3.5 (Tables 7 and 8). Through these assessments, Duck Pond Run is rated as having overall excellent riparian corridor quality, as indicated by the scores of 3 and 4 for erosion, riparian zone width, and canopy cover (Tables 7 and 8). The final visual assessment scores ranged from 3.3 (good) along the segment of Duck Pond Run (DPR3) that stretches from Meadow Road to Route 1, to a score of 3.7 (excellent) on the Duck Pond Run "beat" (DPR1) which stretches from Penn Lyle Road to North Post Road (Table 7 and Figure 26). Segment DPR3 traverses forests, wetlands, agricultural land, and a small area of developed land, while segment DPR1 is contained in areas with forests, wetlands, and development (Figure 15).

The assessments conducted by the Watershed Ambassador and the RAT volunteer were consistent with each other. The highest rated parameters addressed the riparian corridor and vegetation (Tables 7 and 8). Scores for canopy cover, surrounding vegetation, aquatic vegetation, erosion, and width of the riparian zone were high for the Duck Pond Run (either rated 3 or 4) showing that much of the area along the streams is buffered from surrounding land uses and impacts. The only exception to this was DPR3, which received a score of 2 for erosion during the Watershed Ambassador Assessment (Table 7). This indicates that the streambank is moderately unstable, with 30-60% of the banks within the beat having erosion (SBMWA, 2007b). Scores were also high (either rated 3 or 4) for water color, water odor, and man-made structures.

The most common problems seen on the visual surveys were the result of urbanization. The lowest rated scores were for stream bottom or embeddedness (the degree to which gravel, cobbles, boulders, and other rock substrate are surrounded by fine sediment) and erosion (Table 7). Segments DPR3 and DPR4 were rated as a 2 for stream bottom, while segment DPR3 was rated as a 2 for erosion (Table 7). For stream bottom a score of 2 shows that gravel, cobble, and boulders present in the stream were at least 40% covered by sediment. Erosion scores rated as 2 indicate that the streambanks are moderately unstable and have between 30-60% of their lengths showing signs of erosion (SBMWA, 2007b). The assessments also indicated that some stream channelization (near bridges) and residential development were present along these segments. Bridges and residential development close to the stream are most likely increasing flows into the stream due to the imperviousness of these areas. Increased flows are heightening natural erosion along the Duck Pond Run, which results in sedimentation of the stream bottom. The sedimentation may also be due to the high erodibility of the soil types in the Duck Pond Run Watershed, especially in areas along the stream corridor (Figure 13; see Soils section for more information). 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).

Table 7: Visual assessment scores for Duck Pond Run (Collected by Watershed Ambassador, 2004)

Visual Assessment "Beat"	Flooding Score	Water Odor Score	Water Color Score	Stream Bottom Score	Aquatic Vegetation Score	Surrounding Vegetation Score	Man-Made Structures Score	Erosion Score	Riparian Zone Width Score	Canopy Score	Overall Assessment Score
DPR1	3	4	4	4	4	4	4	3	4	3	3.7
DPR2	3	4	4	3	4	4	4	3	4	3	3.6
DPR3	3	4	4	2	4	3	3	2	4	4	3.3
DPR4	4	4	3	2	4	4	4	3	3	3	3.4
											Average Stream Score = 3.5

Note: A score of 1 represents severe problems while a score of 4 represents pristine conditions.
An average stream score of 3.5 indicates a stream rating of Excellent.
Overall Score: Poor = ≤ 1.1
Fair = 1.2-2.2
Good = 2.3-3.4
Excellent = >3.4

Table 8: Visual assessment scores for Duck Pond Run, Segment DPR3 (Collected by RAT Volunteer, 2001-2005)

Date	Flooding Score	Water Odor Score	Water Color Score	Stream Bottom Score	Aquatic Vegetation Score	Surrounding Vegetation Score	Man-Made Structures Score	Erosion Score	Riparian Zone Width Score	Canopy Score	Overall Assessment Score
2/24/2001	4	4	3	4	4	4	3	3	3	4	3.6
10/8/2001	4	4	3	4	4	3	3	3	3	4	3.5
2/18/2002	4	4	3	4	4	3	3	3	3	4	3.5
5/11/2002	4	4	3	4	4	3	3	3	3	4	3.5
10/12/2002	4	4	3	4	4	3	3	3	3	4	3.5
10/13/2003	4	4	3	4	4	3	3	3	3	4	3.5
2/22/2004	4	4	3	4	4	3	3	3	3	4	3.5
5/30/2005	4	4	3	4	4	3	3	3	3	4	3.5
											Average Stream Score = 3.5

Note: A score of 1 represents severe problems while a score of 4 represents pristine conditions.
An average stream score of 3.5 indicates a stream rating of excellent.
Overall Score: Poor = ≤ 1.1
Fair = 1.2-2.2
Good = 2.3-3.4
Excellent = >3.4

WATER QUALITY

SBMWA staff also collected visual assessment information in the immediate vicinity of the four bacteria sampling locations (Figure 28) during September 2005 as part of the bacteria monitoring project. Observations were collected for riparian vegetation, erosion, canopy cover, channelization, aquatic vegetation, water odor, and water color. The visual assessment Physical Characterization Field Data Sheets are included in Appendix D.

The parameters of the least concern were channelization, riparian vegetation, and water odor. No channelization or water odors were noted at any of the four sites, while all four sites except one have a forested buffer on both sides of the stream. The exception was site DPR4, which is bordered on one side by a golf course.

The most common problems noted during the 2005 SBMWA staff assessments were related to erosion and water color. Sites DPR1, DPR3, and DPR4 exhibited moderate levels of erosion, while site DPR2 exhibited a heavy level of erosion (Appendix D). As streambanks erode, increased sediment levels enter the stream. At all four sites, water color was listed as either turbid or opaque. This indicates that there are moderate to high levels of sediment in the water adversely affecting its clarity. As previously noted, 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).

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 the 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 27 and Table 9) and SBMWA's StreamWatch monitoring program (Figure 27 and Table 10). 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 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:

Table 9: Biological assessment data for Duck Pond Run: 1994, 1999, and 2004 (NJDEP AMNET Data)

Site	Date	Number in Sample	FBI	Total Taxa Richness	EPT Richness	Percent EPT	Percent Dominance	Scoring for Stream Impairment Biological Assessment
AN0394	4/12/94	100	8.04	8	0	0.0	45.0	Severely Impaired
AN0394	4/22/99	100	5.98	15	3	7.0	24.0	Moderately Impaired
AN0394	9/16/04	100	7.95	12	1	1.0	45.0	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 need to include at least 100 organisms for statistical evaluation.

Table 10: Biological assessment data for Duck Pond Run: 2001, 2002, and 2003 (SBMWA Data)

Site	Date	Number in Sample	FBI	Total Taxa Richness	EPT Richness	Percent EPT	Percent Dominance	Scoring for Stream Impairment Biological Assessment
DP1	7/21/2001	111	4.3	6	1	10.8	69.4	Moderately Impaired
DP1	10/20/2001	70	–	–	–	–	–	Too few in sample
DP1	7/27/2002	111	4.1	3	1	1.8	97.0	Severely Impaired
DP1	12/10/2002	106	6.9	6	1	9.4	53.8	Severely Impaired
DP1	3/22/2003	114	5.3	8	1	13.2	36.8	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 need to include at least 100 organisms for statistical evaluation.

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

The only NJDEP sampling site in the Duck Pond Run Watershed (Figure 27; NJDEP, 2000) is:

- Duck Pond Run at Route 1 (Northbound side) in West Windsor Township (AN0394).

According to the AMNET sampling events from 1994, 1999, and 2004 at Site AN0394, two of the three sampling events were rated as 'Moderately Impaired' (Table 9 and Figure 27; NJDEP, 1995; NJDEP, 2000; NJDEP 2008a). However, the site was rated 'Severely Impaired' when sampled in 1994, possibly due to runoff from the adjacent roadway (Table 9; NJDEP, 1995). During the 2004 sampling, NJDEP staff noted significant organic pollution and turbid stream conditions. The site is located on the heavily traveled Route 1 in West Windsor and these conditions may be increasing the flows to the point that sediments carried by these flows are smothering habitat for aquatic macroinvertebrates or the habitats are getting washed out completely.

The only SBMWA biological sampling site in the Duck Pond Run Watershed where data was collected by Biological Action Team (BAT) volunteers from 2001 through 2003 (Figure 27) is:

- Duck Pond Run at Route 1 (Southbound side) in West Windsor Township (DP1).

This site is located just downstream of the Route 1 bridge and was chosen to document the impacts of Route 1. According to the sampling events from 2001 to 2003, two of the five samples were rated as 'Moderately Impaired' (Table 10 and Figure 27). However, Site DP1 was rated 'Severely Impaired' when sampled in both July and December of 2002, possibly due to runoff from the adjacent roadway (Table 10). Consistent with NJDEP's AMNET results, the proximity of Route 1 may be increasing the flows in Duck Pond Run to the point that sediments and other roadway pollutants carried by these flows are smothering habitat for aquatic macroinvertebrates or the habitats are getting washed out completely.

The 2004 Integrated List states that the Duck Pond Run site at Route 1 in West Windsor (Site AN0394) is deemed to have insufficient information to determine whether or not the site supports Aquatic Life and a TMDL related to Aquatic Life was not proposed at that time (NJDEP, 2004a). The 2006 Integrated List states that this site is attaining standards for supporting Aquatic Life (NJDEP, 2006c). Based on NJDEP and SBMWA data indicating that the location has been severely and moderately impaired for macroinvertebrates, SBMWA feels that additional macroinvertebrate sampling is needed on Duck Pond Run to confirm the listing as supporting Aquatic Life.

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). Duck Pond Run Watershed data from the Legacy version of STORET was collected from five sites. This data was not collected consistently over time, with information collected on only two days in 1984. Modernized STORET data was only available from one site (Site number 01401200, Duck Pond Run at Route 1 North) where data was collected over five days in 2000 (only bacteria data) and one day in 2003. Additionally, USGS data was downloaded from the National Water Information System (NWIS) database, which reported data during five days in the 1960's, one day in 1999, eight days in 2000, and one day in 2003 (Figure 28). Five of the days in 2000 and the single day in 2003 were repeats from the STORET data. Because of the very sporadic nature of this data, chemical assessments were not evaluated using these various sources of data. The more standard data is shown in Table 11 with exceedences of the 2006 NJ State Water Quality Standards highlighted.

West Windsor Township's Environmental Commission contracted to monitor two sites (T1 and T2) on Duck Pond Run between 1982 and 1996, from one to four times per year. And some developers monitored three sites (D6, D7, and D8) on Duck Pond Run between Route 1 South and the D&R Canal from one to three times per year between 1983 to 1987 (Figure 28; Omni Environmental Corp, 1996). Site T1 and D8 are both located at Route 1 South, just downstream of SBMWA's Site DPR3, and Site D6 appears to be identical to SBMWA's Site DPR4. The more conventional data at these five sites are included in Appendix K, again with exceedences of the 2006 State Water Quality Standards highlighted. This data shows trends over time, but may not be indicative of current conditions.

The 2004 and 2006 Integrated Lists were also consulted to determine water quality based on chemical assessments. The 2004 Integrated List states that the Duck Pond Run site at Clarksville (Figure 28, corresponds to USGS site 01401200) is impaired for fecal coliform (NJDEP, 2004a); a TMDL for fecal coliform was submitted by NJDEP and approved by USEPA in 2003 requiring a 99% reduction in fecal coliform (NJDEP, 2003b). The site at Clarksville was also listed on the 2004 Integrated List as meeting the water quality standards for temperature, nitrate, and unionized ammonia (NJDEP, 2004a). There was insufficient information to determine if the site was attaining the standards for phosphorus, pH, dissolved oxygen, dissolved solids, total suspended solids, arsenic, cadmium, chromium, and copper. Please note that the STORET database and Integrated List incorrectly list this site as being at Clarksville, while the associated latitude and longitude

Table 11: USGS (*), NJDEP STORET (#), and NJDEP STORET Legacy (%) data on Duck Pond Run, West Windsor

Site	Date	Water Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Total Ammonia Nitrogen (mg/L as N)	Total Nitrite Nitrogen (mg/L as N)	TKN (mg/L as N)	Nitrite plus Nitrate (mg/L as N)	Total Phosphorus (mg/L as P)	Chlorophyll a (µ/L)	Total Suspended Solids (mg/L)	Nitrate (mg/L as N)
Duck Pond Run (DPR) at Route 1S (NJDEP Site 1719200070, alias DP1)	5/29/84%	15.5	7.60	6.54	0.28	0.028	1.36	1.61	0.11	-	-	-
	7/24/84%	19.0	7.45	7.10	0.05	0.017	0.56	2.53	0.08	-	-	-
DPR at Rte 1N (USGS Site 01401200)	4/21/60*	17.0	-	6.50	-	-	-	-	-	-	-	2.7
	9/6/60*	18.0	-	6.90	-	-	-	-	-	-	-	-
	5/5/61*	8.0	-	6.30	-	-	-	-	-	-	-	-
	9/7/61*	19.0	-	6.60	-	-	-	-	-	-	-	-
	3/30/62*	11.0	-	7.10	-	-	-	-	-	-	-	-
	11/3/99*	12.5	4.20	6.50	0.05	<0.003	0.55	<0.04	0.049	-	-	-
	2/3/00*	1.1	10.80	6.60	<0.03	0.004	0.43	1.97	0.031	-	-	1.96
	5/3/00*	13.0	9.70	6.80	<0.03	0.006	0.49	1.81	0.029	32.3	-	1.81
	8/14/00*	19.0	7.20	7.30	0.22	0.014	1.10	0.27	0.162	7.8	-	0.25
	10/28/03*#	12.9	6.02	6.40	-	-	-	-	-	-	10	-
2006 NJ Surface Water Quality Standard		≤27.8 or 30°C	≥4.0 mg/L	6.5-8.5	Formula (based on Temp, pH, & time of year)	-	-	-	≤0.1 mg/L	-	≤40.0 mg/L	≤10 mg/L

Exceeds New Jersey Surface Water Quality Standard

WATER QUALITY

52

Table 11: USGS (*), NJDEP STORET (#), and NJDEP STORET Legacy (%) data on Duck Pond Run, West Windsor (continued)

Site	Date	Water Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Total Ammonia Nitrogen (mg/L as N)	Total Nitrite Nitrogen (mg/L as N)	TKN (mg/L as N)	Nitrite plus Nitrate (mg/L as N)	Total Phosphorus (mg/L as P)	Chlorophyll a (µ/L)	Total Suspended Solids (mg/L)	Nitrate (mg/L as N)
DPR at Meadow Rd (NJDEP Site = 1719200190, alias DP2)	5/29/84%	15.0	7.50	6.40	0.09	0.024	1.09	0.80	0.12	-	-	-
	7/24/84%	21.0	7.10	6.90	0.05	0.019	0.59	1.67	0.08	-	-	-
DPR at Clarksville Rd (NJDEP Site 1719200215, alias DP3)	5/29/84%	15.0	7.30	6.42	0.09	0.031	1.12	0.76	0.13	-	-	-
	7/24/84%	22.0	6.90	7.06	0.05	0.011	0.59	1.75	0.09	-	-	-
DPR at North Post Rd (NJDEP Site 1719200300, alias DP4)	5/29/84%	16.0	7.00	6.35	1.12	0.021	1.14	0.60	0.17	-	-	-
	7/24/84%	22.0	6.20	6.30	0.05	0.021	0.43	1.23	0.12	-	-	-
DPR at Penn Lyle Rd (NJDEP Site 1719200390, alias DP5)	5/29/84%	18.0	6.50	7.00	0.09	0.025	0.94	0.13	0.31	-	-	-
	7/24/84%	22.5	7.20	6.70	0.05	0.046	0.64	0.56	0.28	-	-	-
2006 NJ Surface Water Quality Standard		≤27.8 or 30°C	≥4.0 mg/L	6.5-8.5	Formula (based on Temp, pH, & time of year)	-	-	-	≤0.1 mg/L	-	≤40.0 mg/L	≤10 mg/L

Exceeds New Jersey Surface Water Quality Standard (highlighted) place it at Route 1 North. Written communication with USGS, the actual data collector for this site, clarifies that the site is actually located at Route 1 North. Table 11 and 12 correctly lists this location at Route 1. The 2006 Integrated List states that Duck Pond Run is impaired for fecal coliform and that a TMDL has been approved by USEPA (NJDEP, 2006c).

Fecal Coliform and Total Coliform:
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, 2006d). This report references the previous fecal coliform Water Quality Standard 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 and humans. 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 by an outside source. Potential sources of coliform contamination include stormwater runoff from land areas that support livestock, failing septic systems, old and leaking sewer pipes, crop farms, geese, deer, and domestic pets. NJDEP identified Duck Pond Run segments as impaired due to fecal coliform and included them on the Integrated List in 2002, 2004, and 2006 (NJDEP, 2002, 2004a, 2006d). NJDEP has a 2003 USEPA approved fecal coliform TMDL for Duck Pond Run, calling for a 99% reduction in fecal coliform (NJDEP, 2003b).

NJDEP collected and analyzed water quality samples from five Duck Pond Run sites on two days in 1984, including fecal coliform. USGS sampled at one of those Duck Pond Run sites (Site 01401200, Figure 28) for 5 days in June and July 2000, also including fecal coliform. Both the 2004 NJDEP Integrated List for Duck Pond Run and the NJDEP fecal coliform TMDL were based on the five sample results collected by USGS in 2000. The USGS samples violated the fecal coliform state swimming standard 100% of the time, ranging from 220 cfu/100 mL on June 28, 2000 to greater than 24,000 cfu/100 mL on July 25, 2000. The NJDEP and USGS fecal coliform results are shown in Table 12. There is no accompanying precipitation data so the bacteria results cannot be correlated with the intensity of storms.

Table 12: NJDEP and USGS Fecal Coliform Sample Results on Duck Pond Run, 1984 and 2000

Site Name	Agency Collecting Data	Date	Fecal Coliform (Most Probable Number/100 mL)
DPR at Route 1S	NJDEP	5/29/84	9200
	NJDEP	7/24/84	110
DPR at Route 1N (Site 01401200)	USGS	6/27/00	2400
	USGS	6/28/00	220
	USGS	7/11/00	490
	USGS	7/18/00	5400
	USGS	7/25/00	>24000
DPR at Meadow Rd	NJDEP	5/29/84	9200
	NJDEP	7/24/84	230
DPR at Clarksville Rd	NJDEP	5/29/84	9200
	NJDEP	7/24/84	170
DPR at N. Post Rd	NJDEP	5/29/84	5400
	NJDEP	7/24/84	330
DPR at Penn Lyle Rd	NJDEP	5/29/84	9200
	NJDEP	7/24/84	170

Data used to determine NJDEP 2004 Integrated List and Fecal Coliform TMDL for Duck Pond Run segments.

The West Windsor Township Environmental Commission contracted to monitor two Duck Pond Run sites (T1 and T2), including fecal coliform, from 1982 to 1996 (Omni Environmental Corp., 1996). Developers also collected fecal coliform and other data at three Duck Pond Run sites (D6, D7, and D8) from 1983 to 1987 (Omni Environmental Corp., 1996). West Windsor Township Site T1 is the same location as Developer Site D8. Since there are no accompanying precipitation records, it is impossible to determine whether high fecal coliform levels are related to rain events. However, the West Windsor samples violated the state swimming standard 66% of the time and the state boating standard 39% of the time, ranging from 4 to 5,800 cfu/100 mL. West Windsor Township Environmental Commission and Developer fecal coliform results are shown in Table 13.

Supported by a NJDEP grant, SBMWA staff began a bacteria study on Duck Pond Run in May 2005, sampling for fecal and total coliform because of the fecal coliform impairment documented in both the 2004 and 2006 Integrated Lists (NJDEP, 2004a and NJDEP, 2006c). The four sites were chosen to get even coverage throughout the stream in spots that were easily accessible. Working under a NJDEP approved Quality Assurance Project Plan, when weather conditions permitted, staff collected two water samples per month at four sites on Duck Pond Run (Figure 28). One sample was taken during dry weather conditions (at least four dry days since the last measurable rainfall),

Table 13: West Windsor TWP & Developer bacteria data on Duck Pond Run, 1982-1996

Site	Date	Fecal Coliform (cfu/100 mL)	Date	Fecal Coliform (cfu/100 mL)
Duck Pond Run (DPR) at Route 1 South (Site T1: West Windsor TWP data; and Site D8: Developer data)	6/9/82	270	12/14/88	2400
	8/13/82	550	3/23/89	23
	7/28/83	100	6/26/89	460
	8/15/83	23	12/15/89	23
	4/11/84	20	5/14/90	460
	7/10/84	>2400	7/25/90	>800
	9/21/84	20	9/19/90	>600
	7/10/85	79	4/3/91	240
	9/23/85	20	7/17/91	1600
T1 data	4/15/86	20	12/5/91	260
D8 data	5/1/86	43	3/17/92	4
	8/4/86	2400	6/16/92	900
	8/7/86	20	9/24/92	1500
	9/30/86	20	12/9/92	8
	12/23/86	20	3/24/93	900
	3/30/87	93	6/23/93	>1600
	5/12/87	20	10/26/94	23
	6/12/87	1100	12/15/94	50
	7/17/87	490	5/24/95	5800
	9/16/87	50	7/26/95	4800
	9/24/87	500	10/19/95	180
	12/17/87	2400	2/26/96	20
	3/17/88	240	5/20/96	440
	6/17/88	2400	9/27/96	21000
	9/21/88	1100		
DPR at Meadow Road Bridge (Site T2: West Windsor TWP data)	6/9/82	660	9/19/90	420
	8/13/82	1053	4/3/91	170
	7/28/83	780	7/17/91	130
	5/1/86	23	12/5/91	280
	8/4/86	460	3/17/92	5
	12/23/86	150	6/16/92	1600
	3/30/87	210	9/24/92	1600
	6/12/87	2400	12/9/92	50
	9/24/87	290	3/24/93	500
	12/17/87	2400	6/23/93	900
	3/17/88	1110	10/26/94	110
	6/17/88	2400	12/15/94	13
	9/21/88	2400	5/24/95	2600
	12/14/88	1100	7/26/95	210
	3/23/89	43	10/19/95	110
	6/26/89	240	2/26/96	30
	12/15/89	93	5/20/96	190
	5/14/90	2400	9/27/96	210
	7/25/90	>800		

Table 13: West Windsor TWP & Developer bacteria data on Duck Pond Run (continued)

Site	Date	Fecal Coliforn (cfu/100 mL)	Date	Fecal Coliform (cfu/100 mL)
DPR near D&R Canal, Princeton Country Club (Site D6: Developer data)	8/15/83	2	4/15/86	20
	4/11/84	20	8/7/86	20
	7/10/84	>2400	9/30/86	20
	9/21/84	20	5/12/87	20
	7/10/85	49	7/17/87	490
	9/23/85	20	9/16/87	20
DPR midway between D&R Canal and Route 1 (Site D7: Developer data)	8/15/83	120	4/15/86	20
	4/11/84	20	8/7/86	20
	7/10/84	>2400	9/30/86	20
	9/21/84	20	5/12/87	20
	7/10/85	33	7/17/87	490
	9/23/85	20	9/16/87	80

while the second sample was to be taken during wet weather conditions (a storm measuring at least 0.5 inches, with at least four dry days since the last measurable rainfall). This allowed staff to determine the impact stormwater runoff has on fecal coliform levels and thus water quality. Additionally, one field duplicate (a second simultaneous sample collected in the field) and one equipment blank (a sample consisting of only deionized water) was collected during each sampling round and sent as blind samples to the laboratory. These quality assurance/quality control samples verify that sampling staff are collecting samples correctly and ensure that the laboratory is analyzing samples cleanly. 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 wet and dry samples each month for five consecutive months. Therefore, sampling continued until mid-September 2006.

The sites on Duck Pond Run monitored by SBMWA staff are (Figure 28):

- DPR1: Duck Pond Run at North Post Road in West Windsor Township
- DPR2: Duck Pond Run at Meadow Road in West Windsor Township
- DPR3: Duck Pond Run at Route 1 North in West Windsor Township
- DPR4: Duck Pond Run near Delaware and Raritan Canal at Princeton Country Club in West Windsor Township

Table 14 shows SBMWA 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 in the Appendices, along with related hourly precipitation records. Daily precipitation recorded at

Table 14: Duck Pond Run 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 (°C)	Comments
DPR1	Duck Pond Run (DPR) at North Post Road	stream	dry	5/9/05	10:40 AM	12	630	11.0	14.0	
		stream	dry	6/15/05	10:12 AM	20	660	13.0	NA	sewer smell
		stream	dry	8/3/05	10:00 AM	24	18000	9.0	24.0	sewer smell
		FDUP	dry	8/3/05	10:00 AM	12	12000	9.0	24.0	
		stream	wet	9/15/05	9:30 AM	17000	68000	10.0	22.5	sewer smell; 2.6" rain total
		stream	"dry"	10/21/05	11:30 AM	96	970	9.0	14.0	manhole repair
		stream	wet	5/12/06	5:22 AM	2200	9800	14.0	15.5	0.89" rain total
		EQ BLK	wet	5/12/06	5:18 AM	<4	<10	14.0	15.5	0.89" rain total
		stream	wet	6/7/06	1:39 PM	550	3300	10.0	17.0	0.76" rain total
		stream	wet	9/14/06	11:50 AM	1300	2300	10.5	18.0	0.64" rain total
DPR2	DPR at Meadow Road	stream	dry	5/9/05	11:00 AM	88	970	28.0	13.0	
		stream	dry	6/15/05	10:34 AM	290	4400	23.0	23.0	
		stream	dry	8/3/05	10:21 AM	96	14000	24.0	22.0	
		stream	dry	9/7/05*	11:06 AM	NA	NA	NA	NA	
		stream	wet	9/15/05	9:59 AM	14000	68000	24.0	22.0	2.6" rain total
		stream	"dry"	10/21/05	11:50 AM	140	1700	42.0	12.5	
		stream	wet	5/12/06	5:45 AM	8300	8600	39.0	16.0	0.89" rain total
		stream	wet	6/7/06	1:58 PM	1900	8200	24.0	17.0	0.76" rain total
		stream	wet	9/14/06	12:08 PM	2800	3000	19.5	17.5	0.64" rain total

Table 14: Duck Pond Run 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 (°C)	Comments
DPR3	DPR at Route 1 N, just after Princeton BMW dealership	stream	dry	5/9/05	10:19 AM	20	760	10.5	13.5	
		EQ BLK	dry	5/9/05	10:18 AM	<4	<4	10.5	13.5	
		stream	dry	6/15/05	9:35 AM	320	5800	9.0	21.0	
		stream	dry	8/3/05	9:33 AM	330	16000	4.0	20.0	
		stream	wet	9/15/05	10:12 AM	5200	46000	11.0	21.0	2.6" rain total
		stream	"dry"	10/21/05	11:11 AM	72	1800	10.0	13.0	
		stream	wet	5/12/06	4:55 AM	8800	16000	21.0	15.0	0.89" rain total
		stream	wet	6/7/06	1:16 PM	260	5200	10.0	17.0	0.76" rain total
		stream	wet	9/14/06	12:36 PM	1500	2600	7.5	17.0	0.64" rain total
		FDUP	wet	9/14/06	12:36 PM	1100	3200	7.5	17.0	0.64" rain total
DPR4	DPR near Delaware & Raritan Canal at Princeton Country Club	stream	dry	5/9/05	11:36 AM	270	760	22.0	15.0	
		stream	dry	6/15/05	11:52 AM	170	3000	17.0	28.5	
		stream	dry	8/3/05	10:56 AM	120	6400	19.0	27.0	
		stream	wet	9/15/05	10:34 AM	5900	40000	23.0	23.0	2.6" rain total
		stream	"dry"	10/21/05	12:12 PM	950	2600	23.5	13.0	
		FDUP	"dry"	10/21/05	12:12 PM	1000	1900	23.5	13.0	
		stream	wet	5/12/06	6:07 AM	11000	13000	24.0	16.0	0.89" rain total
		stream	wet	6/7/06	2:23 PM	1700	30000	23.0	17.0	0.76" rain total
		stream	wet	9/14/06	12:57 PM	1100	1300	22.5	18.0	0.64" rain total
Detection Limit						4/100mL	4/100mL or 10/100mL			
Analytical Method						SM 9222d	SM 9222b			
Action Limit						>200/100mL				

All samples analyzed at New Jersey Analytical Laboratories
* Stream is dry on sampling day

FDUP = Field Duplicate
EQ BLK = Equipment Blank

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

WATER QUALITY

59

Trenton NJ is shown in Table 15. Graphs 4 through 7 display 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 15: 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 and 0.08" fell after sampling. NJDEP Project Manager stated this could be considered a dry weather event.

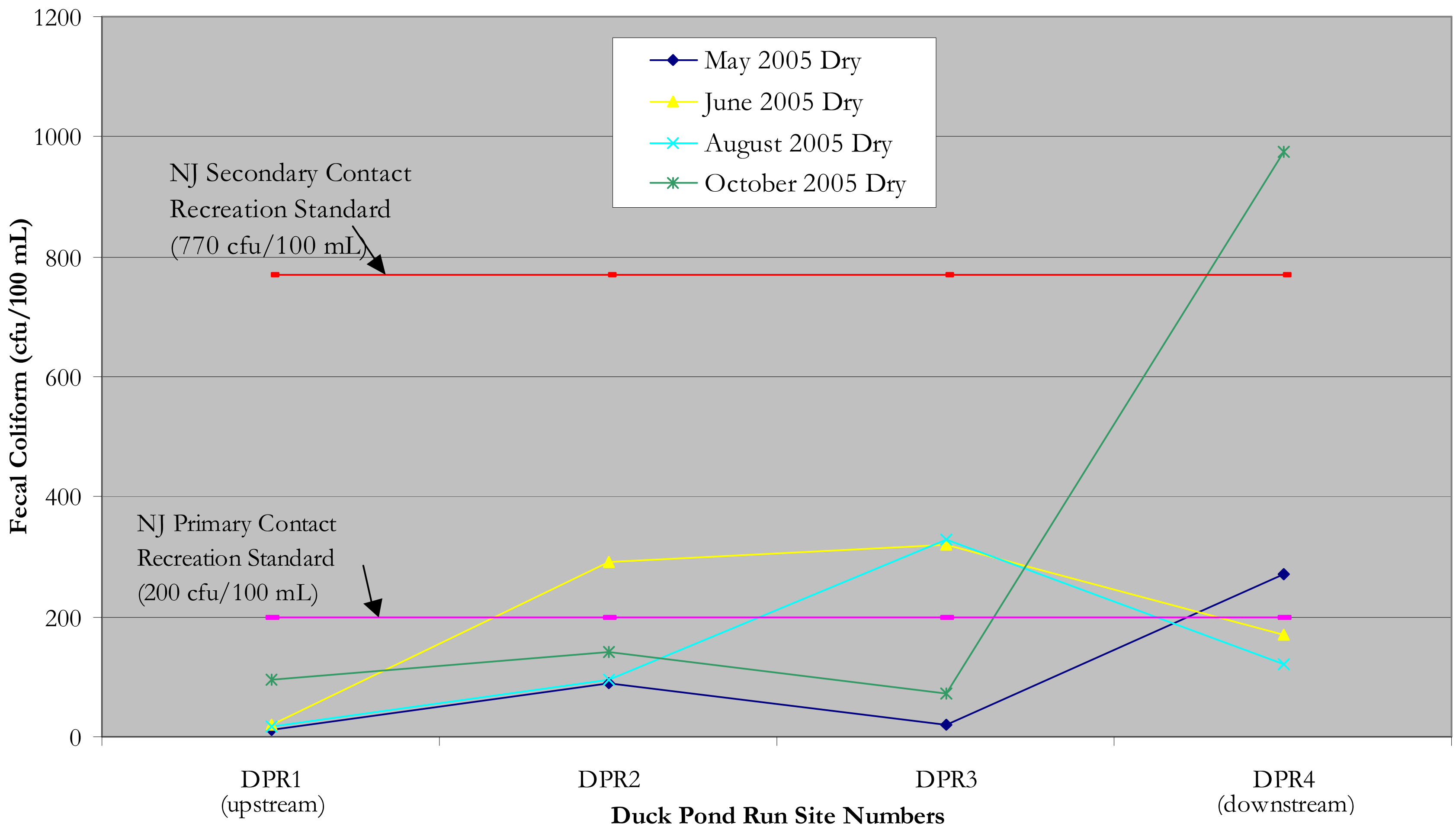
**: Rained 0.84" on 9/14/05. Second pulse came through 9/15/05 in the AM. We caught peak flow for all DPR sites.

§: Rain began 5/11/06 after 10PM and continued until about 6AM on 5/12/06. With the delay in time needed for runoff to affect stream flows, SBMWA feels the samples were collected at peak stormflow in the streams.

Fecal coliform results from dry weather sampling measured between May and October 2005 ranged from 12 colonies/100 mL in May 2005 and again for the field duplicate in August 2005 at Site DPR1 to 1000/100 mL at Site DPR4 in October 2005 for the field duplicate sample. During that time period, five samples out of the 16 samples taken (31.3%) violated the swimming State standard (Graph 4). It should be noted that Site DPR2 was dry on September 7, 2005, i.e. without any water, and therefore, is seen to have water quantity problems upon occasion. The sites with the greatest number of violations and the highest results under dry conditions were DPR3 and DPR4, although not consistently. Only one sample violated the boating standard under dry conditions: Site DPR4 on October 21, 2005 with 950 and 1000/100 mL for the sample and its field duplicate. Therefore, under dry conditions Duck Pond Run violated the boating standard only 6.3% of the time. Site DPR4 is located adjacent to the golf course at the Princeton Country Club, just before it flows into the Delaware and Raritan Canal. 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 5). All but two samples violated the boating standard (770 colonies/ 100 mL), or boating violations occurred 87.5% of the time in wet weather. Daily precipitation recorded at Trenton, NJ is shown in Table 14; hourly details are included in Appendix G. Wet weather sample results ranged from 260 cfu/100 mL at Site DPR3 in June of 2006 to 17,000 at Site DPR1 in September 2005. The particularly high results seen at Site DPR1 are likely related to a leaking sewer line adjacent to the stream. There is a sewer manhole located on the right side of the stream when looking upstream from the bridge, very near the road. The data sheets from that site indicate strong sewer smells near the road, but not in the stream during the June, August, and September 2005 monitoring events. On October 21, 2005 samplers found the manhole had been newly cemented, indicating that the leaking manhole had been fixed. Sampling data supports this theory. There were no sewer smells at that site during any of the remaining sampling events. Effects from the leaking manhole would mainly be seen during wet weather events when storm runoff carried bacteria to the stream. 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 leaking sewer pipes or manholes would also be amplified under wet weather conditions due to the addition of stormwater to that system.

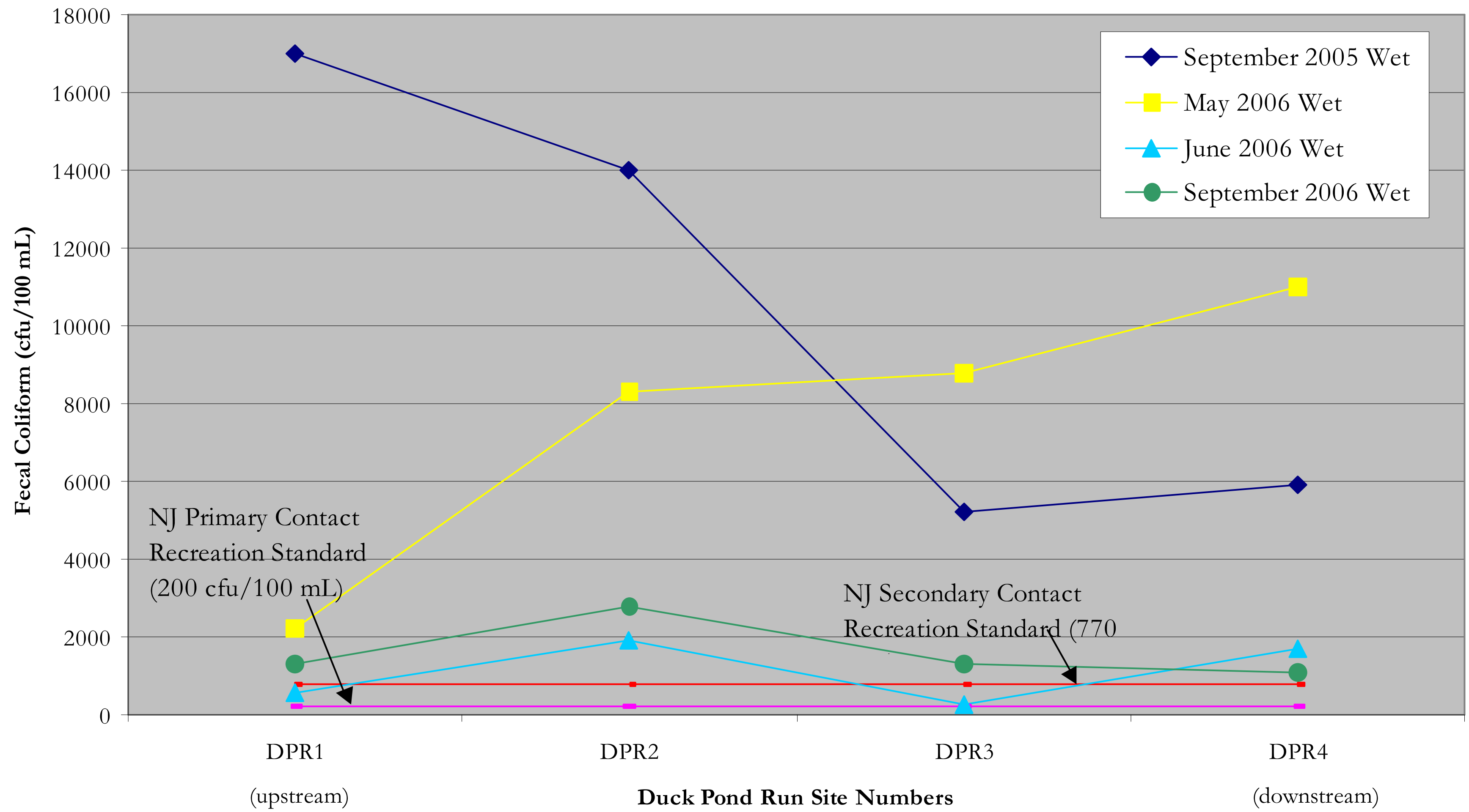
Since the primary contact (swimming) State standard for fecal coliform is based on a geometric mean, this statistic has been calculated for each site under dry and wet conditions, as well as the combination for each site (Table 16). Additionally the geometric mean has been calculated for the entire

Graph 4: Duck Pond Run fecal coliform dry weather results 2005 (SBMWA Data)



WATER UALITY

Graph 5: Duck Pond Run fecal coliform wet weather results 2005 – 2006 (SBMWA Data)



WATER QUALITY

Table 16: Geometric means of fecal coliform data for Duck Pond Run (SBMWA Data)

Site #	Geometric Mean of Dry Data/Site (cfu/100 mL)	# Dry Values	Geometric Mean of Wet Data/Site (cfu/100 mL)	# Wet Values	Geometric Mean of Wet & Dry Data/Site (cfu/100 mL)	# Wet and Dry Values
DPR1	25	4	2274	4	240	8
DPR2	136	4	4986	4	824	8
DPR3	111	4	1983	4	469	8
DPR4	271	4	3319	4	948	8
Geometric Mean of Dry for All Sites	101	16				
Geometric Mean of Wet for All Sites			2939	16		
Geometric Mean of Wet & Dry for all Sites					545	32

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

stream. Although the number of samples may not be statistically valid, the results show that Site DPR4 has the highest results under dry conditions (270.7 cfu/100 mL) and Site DPR1 has the lowest results (25.4 cfu/100 mL). Only one site, Site DPR4, violated the State swimming standard under dry conditions. Under wet conditions the geometric means violate State boating standards at all sites, but Sites DPR2 and DPR4 show the highest results (4,986 cfu/100 mL and 3,319 cfu/100 mL, respectively). The geometric means also show that the stream as a whole meets the State swimming standard under dry conditions (101 cfu/100 mL), but violates under wet conditions (2,939 cfu/100 mL), and that the stream as a whole violates the State swimming standard when weather conditions are not taken into account (545 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 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 samples were collected between May and October 2005 (Table 13 and Graph 6). Results ranged from a low of 630 cfu/100 mL at Site DPR1 in May to a high of 18,000 cfu/100 mL also at Site DPR1 in August. It should be noted that Site DPR3 was dry in September 2005 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.

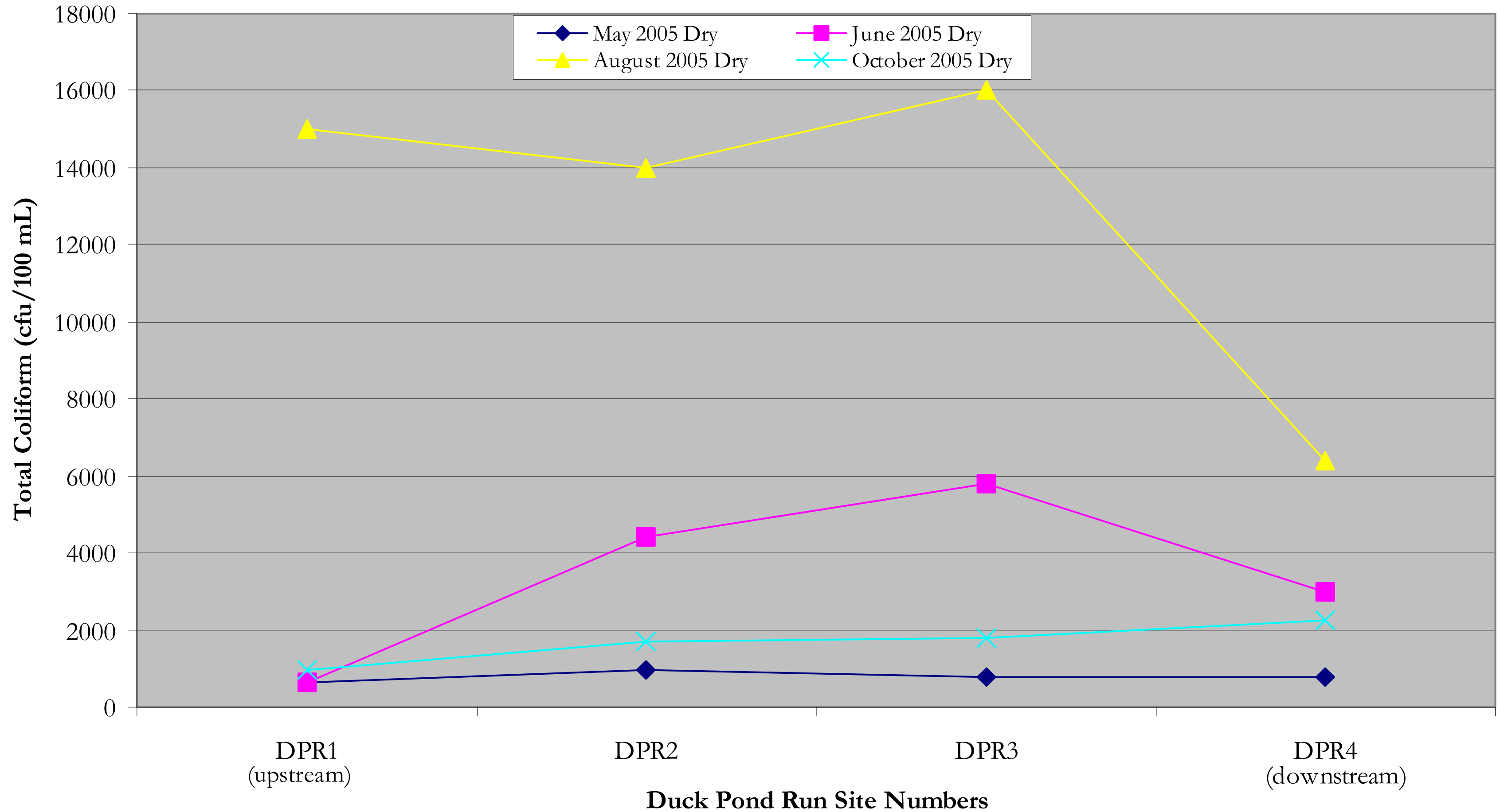
Wet weather samples for total coliform were collected between September 2005 and September 2006 (Table 13 and Graph 7). Results ranged from 1,300 cfu/100 mL at Site DPR4 in September 2006 to 68,000 cfu/100 mL at both Sites DPR1 and DPR2 in September 2005. The results nearly completely follow expected comparative levels based on rainfall amounts. The smallest amount of total rainfall occurred in September 2006 with 0.64 inches recorded at Trenton; the next lowest rain event occurred in June 2006 with 0.76 inches recorded. In May 2006 0.89 inches fell in Trenton; and in September 2005 the most rain fell during the sampling event (2.6 inches). One would expect the highest rainfall to wash more pollutants into the stream and produce the highest coliform results. Graph 7 does indicate that September 2005 had the highest total coliform levels, followed by May 2006 results, then June 2006 results, and lastly September 2006. Hourly precipitation data for the wet weather sampling days are included in Appendix G.

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 TSS) 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 pers. comm.). 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.

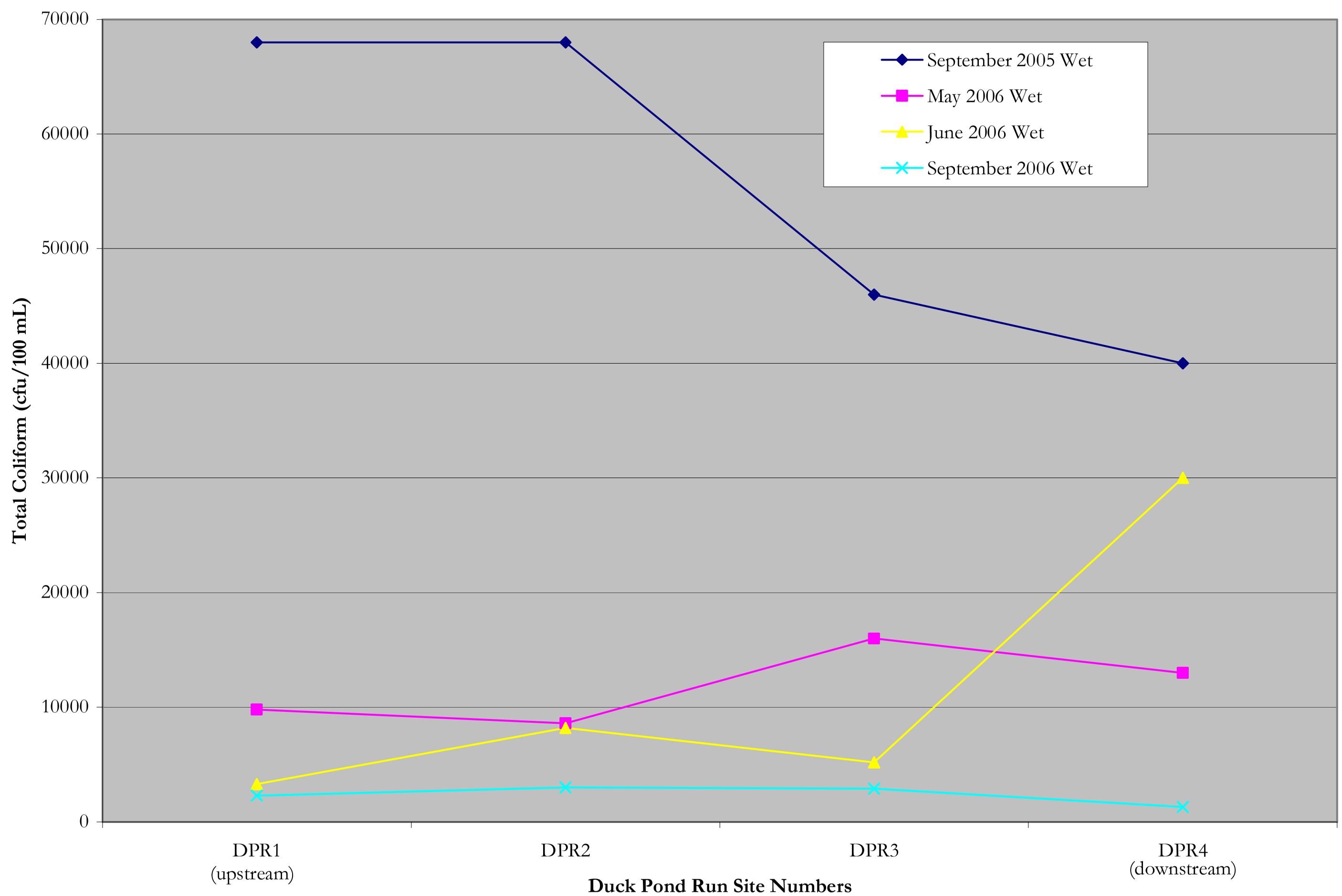
The model generally scores agricultural lands high in phosphorus and TSS loadings, developed/urban areas high in all three loadings (nitrogen, phosphorus, and TSS), and other land uses (forest and wetlands) low in all three loadings. This is based upon the fact that impervious cover associated with urban areas increases NPS pollution loadings by preventing stormwater

Graph 6: Duck Pond Run total coliform dry weather results 2005 (SBMWA Data)
(Note: there are no State standards for total coliform.)



WATER QUALITY

Graph 7: Duck Pond Run total coliform wet weather results 2005 - 2006 (SBMWA Data)
(Note: There are no State standards for total coliform.)



WATER QUALITY

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. Natural wetlands act as biofilters, removing sediments and pollutants from the water. Therefore, the model predicts pollutant loadings in wetland areas will be zero or even negative. For example, phosphorus gets bound into organic matter in wetlands or precipitates out as a solid into the wetland soils, reducing the overall phosphorus levels. Similarly, suspended sediments are likely to settle out in wetlands. This biofilter function of wetlands is one of the reasons preservation of wetlands is so important.

For the Duck Pond Run Watershed, this model was applied using 2002 Land Use data, which had become available after the model was created. Several areas within the Duck Pond Run Watershed have high estimated loadings for nitrogen, phosphorus, and TSS (Figures 29, 30, and 31). For phosphorus loadings, the highest levels estimated coincide with the agricultural lands in West Windsor Township as well as some of the urban/developed lands (Figures 15 and 30). Many of these areas are considered to produce high levels (0.325 – 1.821 lb/acre/yr) of phosphorus. The highest level of nitrogen loading for this model in the Duck Pond Run Watershed is only seen in a few spots, falling within urban/developed areas and along Route 1 and the Northeast Corridor train tracks where nitrogen loading estimates are greater than 4.047 lb/acre/yr (Figure 29). Most of the urban areas west of the train tracks have nitrogen loading estimates between 1.620 and 4.047 lbs/acre/year. Agricultural areas and some additional urban areas are estimated to have nitrogen loadings between 1.620 and 3.035 lb/acre/yr. But much of Duck Pond Run Watershed is expected to have nitrogen loadings of less than 1.619 lb/acre/yr (Figure 29), particularly the urban areas shown east of the train tracks. 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 Duck Pond Run. In general, the lowest nitrogen loadings are predicted at the headwaters and the highest are towards the mouth, particularly near Site DPR4 located adjacent to the Princeton Country Club golf course. TSS loadings in the Duck Pond Run Watershed also fall mostly within the moderate range (between 202.4 and 404.7 lb/acre/yr), including the agricultural areas for this model (Figure 31). The highest levels of TSS loadings (greater than 809.5 lb/acre/yr) coincide with the urban/developed and barren land areas where the nitrogen loadings were highest (Figures 15, 29, and 31).

The areas with the lowest estimated loadings in all three pollutants (nitrogen, phosphorus, and TSS) coincide with the wetlands located throughout the watershed (Figures 15, 29, 30, and 31).

ASSESSMENT

To best assess water quality, trends in particular indicators need to be determined. Water quality information for the Duck Pond Run Watershed is limited in terms of visual, biological, and chemical assessments both in terms of the number of monitoring sites and 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. Additional data would provide a broader picture of water quality, clarify if biological life is able to thrive in Duck Pond Run, and could provide more insight as to the sources of bacteria in the stream. With this in mind, SBMWA started regular monthly chemical monitoring in June 2007 at Site DPR3 using our CAT volunteers for the purpose of long-term monitoring to assess water quality and see trends. It would be beneficial if the other three bacteria sites could also be monitored for pH, nitrate, orthophosphate, and dissolved oxygen to get documentation of ongoing conditions.

In general, Duck Pond Run does not fully support the breadth and diversity of aquatic life representative of a healthy stream ecosystem, as indicated by the moderately and severely impaired stream ratings (Tables 9 and 10). This means that there are one or many stressors that are 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. According to NJDEP, the driving force behind the degradation of aquatic communities and their habitats is believed to be nonpoint source pollutants and the stormwater runoff that transports them (NJDEP, 2007).

The most likely stressor affecting the macroinvertebrate communities in Duck Pond Run is the heightened sedimentation seen in SBMWA's visual assessment (Tables 7 and 8). The basis for this heightened sedimentation may be due to urbanization of lands and the soil composition and erodibility of the Duck Pond Run Watershed itself (see Land Use section, Geology section, and Soils section for more details). The majority of the soils in the Watershed are classified as "moderate" and "high" in terms of their erodibility (Figure 13). This classification is based upon the "K-factor" and measures the ability of bare soil to erode. This high erodibility combined with the developed lands, and the related increase in stormwater runoff, seen in much of the Watershed probably accounts for much of the observed sedimentation.

SBMWA's bacteria monitoring results from Duck Pond Run supports NJDEP's designation of this stream as impaired for fecal coliform based on the 2003 Surface Water Quality Standards (NJDEP, 2003c). NJDEP listed Duck Pond Run on the Integrated List in 2002, 2004, and 2006 for fecal coliform impairment and created a TMDL in 2003 approved by USEPA, calling for a 99% reduction (NJDEP, 2003b). SBMWA's dry weather bacteria monitoring found several violations of the swimming standard, only one of which also violated the boating standard, but with no consistency in location over time. Three of the four sites experienced violations upon occasion (Graph 4). The only site that consistently met State standards was Site DPR1. A leaking manhole adjacent to Duck Pond Run at Site DPR1 was evident through strong sewage smells observed near the manhole but not in the stream starting with the second sample event in June 2005. Indications of repair were seen during the October 2005 dry weather event when fresh cement was observed around the manhole. Clearly this source of contamination required stormwater runoff for conveyance to the stream and was not migrating there through the soils on its own, since Site DPR1 never violated the swimming standard during dry weather. The one wet weather sample taken at this site while the manhole was leaking (September 2005) clearly shows excessive bacterial contamination that is observed downstream at Site DPR2 as well. Samples taken in wet weather after the manhole repair (October 2005) do not exhibit the same extent of contamination.

The dry weather violations seen at the other three sites indicate possible local sources of fecal coliform, because dry weather fecal coliform samples should all meet the State standard. Possible sources of contamination could consist of large local resident geese populations, pet waste, livestock with stream access, failing septic systems, or leaking sewer pipes. Since there are no agricultural lands near Sites DPR2, DPR3, or DPR4, the violations seen occasionally at these sites are not due to the effects of livestock. Similarly, since the Duck Pond Run Watershed is not located within septic service areas of West Windsor Township, failing septic systems may not be contributing to the violations. However, if older septic systems installed prior to construction of the sewer system are still in existence and have not been maintained properly, they may be contributing to the fecal coliform levels in the stream. Site DPR4 is located immediately adjacent to the golf course at the Princeton Country Club, a favored location for geese that may contribute to occasional spikes in bacteria seen at this site. Verbal reports from a West Windsor resident indicate that even though the Township has enacted a pet waste ordinance, which is included within the Stormwater Pollution Prevention Plan (Article IV of Chapter 150), residents are still throwing the scooped and bagged animal waste into storm drains on a regular basis. As a result, pet waste could regularly end up in the stream contributing to higher bacteria counts. The obviously leaking manhole near Site DPR1 brings into question the integrity of existing, aging infrastructure in West Windsor Township. It is possible that other pipes are having similar problems and affecting water quality in Duck Pond Run. The Stormwater Pollution Prevention Plan can be accessed on line at http://www.e-codes.generalcode.globalsearch.asp: search for Stormwater Pollution

Prevention Plan, highlight Township of West Windsor NJ, and click on "GO".

Since bacteria results were high at all sites during wet weather events, NPS pollution is likely contributing significant bacterial loads to Duck Pond Run. The NPS pollution could be contributed from agricultural or urban areas.

It would be beneficial to conduct additional bacteria monitoring along Duck Pond Run, both at the four established sites documented in this report and, if access could be approved, upstream and downstream of tributaries and in areas where the sewer lines closely parallel Duck Pond Run. Additionally source-tracking bacteria samples taken at the four established sites could determine whether the sources of bacteria are from humans or animals.

Several areas within the Duck Pond Run Watershed have high estimated loadings for nitrogen, phosphorus, and TSS (Figures 29, 30, and 31). Phosphorus loadings are estimated to be high (between 0.325 and 1.926 lb/acre/yr) in many of the agricultural lands in West Windsor Township (Figures 15 and 30). The highest level of nitrogen loading for this model in the Duck Pond Run Watershed falls mostly within urban/developed areas where nitrogen loading estimates are greater than 4.048 lb/acre/yr (Figure 29). Agricultural areas and some additional urban areas are estimated to have moderate nitrogen loadings. But much of Duck Pond Run Watershed is expected to have low nitrogen loadings [less than 1.619 lb/acre/yr (Figure 29)]. TSS loadings in the Duck Pond Run Watershed also fall mostly within the moderate range, including the agricultural areas (Figure 31). The highest levels of TSS loadings (greater than 809.5 lb/acre/yr) coincide with the urban/developed areas where the nitrogen loadings were highest (Figures 15, 29, and 31).

Since the highest nitrogen loadings within Duck Pond Run Watershed occur in urban/developed areas, West Windsor Township needs to emphasize stormwater management to help reduce the loadings of these nonpoint source pollutants into the stream. This is particularly important in the control of fecal coliform contamination. Not only are bacteria being carried to the stream by stormwater runoff, but the nitrogen component of the runoff also serves to increase the survival of bacteria once it has reached the stream (Lim & Flint, 1989).

Of special note are the loadings for TSS, as the land use practices modeled in the Duck Pond Run Watershed are providing moderate to high levels of sediment to the streams in this region (Figure 31). This is important, as the soils in this area are already uncemented and therefore highly erodible (Figure 13; see Soils section) and the visual assessments found the streams to be undergoing sedimentation. In 2006 the Soil Conservation District (SCD) became responsible for ensuring that even small projects, in most cases 5,000 square feet or more of soil disturbance, meet the standards for soil erosion and sediment control in New Jersey. Therefore, it is of minimal importance for West Windsor Township to enact a sediment control ordinance to prevent materials from washing into streams and degrading habitat and water quality. However, the Township can and should enact other ordinances to protect soils, trees, and vegetation from degradation during the construction process. For example, a Tree Protection Ordinance protects the soil structure that supports trees from being damaged during construction. Since trees stabilize the soil, this would reduce erosion. Another ordinance could also require phasing for construction projects, or the clearing of land parcels in distinct phases with the stabilization of each phase completed before the clearing of the next. This would prevent erosion because soils would be exposed for shorter periods of time with planting of vegetation occurring prior to the next clearing phase. It would also lessen the compaction of soils because heavy equipment would be confined to areas for shorter periods of time. The Township has already complied with the stormwater management rules and has included a Stormwater Control plan to manage stormwater runoff within the Land Use section (Part II, Chapter 200, Article XXI) of the Code of the Township of West Windsor, NJ. This plan can be accessed online at http://www.e-codes.generalcode.com/globalsearch.asp; search for Article XXI Stormwater Control, highlight Township of West Windsor NJ, and click "GO".

FINDINGS & RECOMMENDATIONS

The results of this characterization and assessment represent an opportunity to properly plan the landscape of the Duck Pond Run Watershed in an environmentally responsible way and to work proactively to protect water quality. Overall, waterways are experiencing moderate degradation due to sedimentation in Duck Pond Run 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 Duck Pond Run 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. The following recommendations are summarized in Appendix M.

PLANNING FUTURE GROWTH

Finding 1:

Populations in Duck Pond Run Watershed's West Windsor Township, like the rest of New Jersey, are on the rise. The population went from 16,021 residents in 1990 to 21,907 in 2000, increasing by 36.7% in just ten years. From 1986 to 2002, developed lands increased from 932.9 acres to 1,632.6 acres, a gain of 75.0%. Developed areas are on the increase at the expense of the remaining active agriculture and wetlands in the Watershed. (See Landscape section for more information.)

Recommendations:

- If not already completed, an up-to-date buildout analysis for West Windsor Township 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.
- Duck Pond Run Watershed contains many critical habitats for a variety of threatened and endangered species (Figure 5). Critical habitats cover 47.5% (1,742 acres) of the Duck Pond Run Watershed. Many of these critical areas are adjacent to existing developments, putting them under development pressure. Since much of the critical habitats exist in the wetland areas, they should currently be protected from development; however a significant portion exists on current agricultural lands. It is important to protect and preserve these farmlands, maintaining them as such, which can be done by encouraging land owners to participate in the New Jersey Farmland Preservation Program, as well as by working with regional land conservation groups to preserve key tracts of land. West Windsor Township 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 West Windsor consider participating in SBMWA's Project for Municipal Excellence. 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 municipal officials.
- The designated sewer service area that covers all of the Duck Pond Run Watershed increases the potential for development to occur, if it hasn't occurred already (Figure 14). West Windsor 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.
- An increase in impervious cover is occurring in the Duck Pond Run Watershed as development continues along with the resultant decrease in agricultural lands and wetland areas. Consequently, 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 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 a stream corridor ordinance and protecting riparian areas through conservation easements would also benefit the Watershed.
- Riparian corridors are being increasingly encroached upon for development in the Duck Pond Run 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. Placement of new construction in the Duck Pond Run Watershed needs to be sensitive to, or avoid altogether, the riparian corridors in order to maintain ecological integrity. Adopting and enforcing a stream corridor ordinance can achieve this goal.
- Planting trees not only minimizes impervious cover, but also has been proven to have financial benefits. According to a University of Pennsylvania study, tree planting raised property values 10% in general and raised values in urban areas as much as 30%, where trees were planted in otherwise vacant city lots (River Network, 2008). Seattle estimated that increasing tree canopy from 18 to 30% would yield more than $44 million in annual benefits, including stormwater mitigation, air cleaning, carbon sequestration, energy savings, aesthetics, and other values (River Network). West Windsor should consider a tree planting program throughout the Township.

<u>Applicable BMPs and Mitigation Approaches:</u>

- To determine which environmental resources exist in West Windsor, the Township should update the Natural Resources Inventory originally conducted in 1979 and revised in 2000. 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 as well as where preservation efforts should be prioritized.

- To minimize the impacts of development, West Windsor Township could conduct a study of the existing public transportation system, 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 West Windsor 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 each LOI application 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. When NJDEP approves the LOI Application, this officially determines the wetland classification and its boundaries and buffer size and becomes very difficult to amend. 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. West Windsor Township 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.
- West Windsor Township can also provide input to NJDEP on wetland mitigation decisions, which require compensation for freshwater wetland disturbances by requiring developers working under individual permits to create at least two acres of wetland for each acre disturbed. This same level of mitigation is required for General Permit (GP) 2 (underground utility lines), GP4 (hazardous site investigation and cleanup), GP5 (landfill closures), and GP27 (redevelopment areas). There is a proposal under consideration at the State level to expand mitigation requirements to also include GP6 (isolated wetlands), 10A and 10B (minor road crossings), GP11 (outfalls), GP18 (dam repair), and GP21 (above ground utility lines).

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.new-castle.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 requirements of a "Low-Impact Development" (LID) Ordinance that incorporates LID techniques into a land development ordinance. Many cities across the country are finding that integrating LID into their existing infrastructure is a cost saving solution to NPS pollution. Portland Oregon found that by combining residential downspout disconnection with LID (their "Green Streets" program), they saved 40% compared to the cost of comparable streets with conventional stormwater gutters and sewers (River Network (2008). The Town of Warsaw, Virginia enacted 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 and enforcement of a stream corridor ordinance will prevent further development in this key area while preserving the riparian corridor. West Windsor Township has protective language included in the land use element of the Master Plan. To give added protection, West Windsor Township should consider establishing a separate stream corridor

ordinance. SBMWA's model stream corridor ordinance is included in Appendix H and can be found at http://www.thewatershed.org/managing_resources.php?id=C0_45_32 (click on "Model Stream Corridor Ordinance"). SBMWA is available to assist West Windsor with ordinance creation through the Program for Municipal Excellence. Some townships in New Jersey are also incorporating critical areas into their stream corridor ordinances, making them much stronger. West Windsor Township should consider including such language in their ordinance.

Finding 2:

Impervious cover prevents the movement of water into the soil. The Duck Pond Run Watershed has an average impervious cover of 16.6%, 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. West Windsor officials also need to be aware that much of the underlying soils in the Duck Pond Run 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.)

Recommendations:

- 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. West Windsor Township needs 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, allows for developing at higher densities). These methods enable West Windsor to accommodate 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. Portland Oregon found that the combination of residential downspout disconnection and the incorporation of green stormwater measures on all street projects could save 40% compared to the cost of comparable streets with conventional gutters and sewers (River Network, 2008).

- 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 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, 2004c.)

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. To see an ordinance that includes both of these variations, see New Castle County, DE's overlay ordinance as noted on pages 75-76.
- 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 76.

PROTECTING & MAINTAINING GROUNDWATER RESOURCES

Finding 1:

There are nine known contaminated sites (KCSs) in the 5.7 square mile Duck Pond Run Watershed. One of the sites is a RCRA site listed on the 2008 Corrective Action Baseline, which includes USEPA's highest priority sites. (See Known Contaminated Sites section for more information on each KCS and how they affect groundwater.) Any of this contamination could percolate through the soil or within groundwater into Duck Pond Run which flows into the D&R Canal, a public drinking water supply. Because of its connection to a drinking water supply, Duck Pond Run was identified as a candidate for C1 designation. It is vitally important to protect this source of drinking water.

Recommendation:

- The large number of KCSs in the Duck Pond Run Watershed warrants that the potentially responsible parties and NJDEP remediate any contamination present, particularly at the RCRA 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 groundwater contamination.
- There is one WHPA in the Duck Pond Run Watershed in close proximity to five public non-community drinking water wells (Figure 25). This

WHPA is important as there is the potential for groundwater contamination due to its proximity to the RCRA-level KCSs (American Cyanamid Agricultural Research, American Cyanamid Company, BASF Corporation, and American Cyanamid South Facility). These sites are located within Tier 2 of the public non-community water supply wellhead protection areas. Because of their proximity to a WHPA, these KCSs need to be the top priorities for remediation in the Duck Pond Run Watershed. Special attention needs to be given to the monitoring of these sites to ensure that public safety is maintained.

- 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.

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.

Applicable Model Ordinances:

- West Windsor can adopt an ordinance requiring that site plan approval be conditioned upon an applicant providing a completed Phase I Environmental Site Assessment Report when a KCS is sold. If the Phase I report recommends a Phase II Environmental Site Assessment Report, the Phase II report must be done at the request of the purchaser, NJDEP, or other authorized party, if not already completed.
- The creation and implementation of an ordinance to provide wellhead protection to the delineated WHPAs by West Windsor Township will ensure that groundwater is protected from possible contamination. Rocky Hill has successfully enacted a wellhead protection ordinance and Montgomery Township's has been adopted pending NJDEP approval. Examples of model ordinances for wellhead protection include SBMWA's *Ordinance Implementation: Wellhead Protection* document that can be downloaded from www.thewatershed.org/images/uploads/Wellhead_Ordinance_Implementation_Package.pdf and a Hunterdon County Environmental Toolbox model, which can be found at http://www.co.hunterdon.nj.us/planning/ordinances/toolbox/Environmental_Toolbox-Well_Head.pdf.

Finding 2: Much of the Duck Pond Run Watershed (42.2%) contains areas with high groundwater recharge. Between 1986 and 1995 Duck Pond Run lost 21.6% of its groundwater recharge capability due to continued development in high groundwater recharge areas. This is the largest loss in groundwater recharge capability of all subwatersheds within the Millstone Watershed during this time period (NJWSA, 2002). Groundwater recharge areas need to be protected by ordinances or preserved by the Township to restrict development in these areas. West Windsor 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:

- 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 guidance as to how to reduce pesticide use and find less toxic alternatives, thus minimizing groundwater contamination in high recharge areas. SBMWA works with property owners, providing recommendations for actions to improve land stewardship practices. The River-Friendly Program focuses on water quality, water quantity, wildlife and habitat enhancement, and education components, all geared towards reducing NPS pollution. For more information on the River-Friendly Program, please visit http://www.thewatershed.org/river_friendly_program.php.
- West Windsor Township 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's applicable Model Ordinances in Finding 1, page 76.) The existence of trees can affect property values, according to a University of Pennsylvania study, which found that tree planting raised property values 10% and could raise urban property values as much as 30% when otherwise vacant lots are planted (River Network, 2008).
- West Windsor Township 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 24) could be one way to target land for preservation. Friends of West Windsor Open Space (FOWWOS) has compiled a list of high priority properties for preservation, which is included in Appendix I.
- Since some of the high groundwater recharge areas are located on agricultural lands in West Windsor Township, the municipality needs to encourage best management practices (BMPs) regarding the use of chemicals (especially harmful chemicals like pesticides) in the agricultural areas above groundwater recharge zones to prevent possible contamination. Farmers also 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) can help farmers reduce impairment from agricultural water runoff sources in an effort to improve water quality along both impaired and unimpaired New Jersey streams through BMPs. CREP is administered through the New Jersey Natural Resources Conservation Service (NRCS). For more information about New Jersey CREP, please visit http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=cep.

Applicable BMPs and Mitigation Approaches:

- To ensure that groundwater and aquifers maintain adequate water supply, West Windsor Township can require the use of stormwater BMPs, such as nonstructural measures including swales and disconnected impervious cover and, when necessary, structural measures such as infiltration ponds and basins in new developments. These ponds are lined with permeable soils and materials that allow water to slowly release 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, 2004c). 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/2007NSPS primer.pdf (SBMWA, 2007c).
- 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 people and the environment, West Windsor Township 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, and 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 support adoption of an IPM ordinance, which results in a much stronger policy.
- Another program that works with farmers to minimize pesticide contamination is the New Jersey River-Friendly Farm Program, which seeks to recognize farms that voluntarily implement best management practices to minimize impacts on the environment, protect water resources, and improve the sustainability and efficiency of the farm itself. It was developed in response to water quality concerns in the Raritan River which is a source of drinking water to over a million people. For more information and an application form, please access the River-Friendly Farm website at: http://njriverfriendlyfarm.org. The benefits of becoming a River-Friendly Certified Farm include public recognition for implementing and maintaining stewardship practices, availability of funding sources to implement conservation practices, new marketing strategies using a River-Friendly Farm label, free technical assistance from a conservation planner, improved water quality in streams while maintaining productive farmland, more efficient use of fertilizers and pesticides, and a healthier soil structure.

Applicable Model Ordinances:

- West Windsor Township should adopt and 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 Planning Future Growth's Finding 1 on pages 75-76 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 are to 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/dshm/pesticid/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. West Windsor 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 its 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 find it, 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, West Windsor 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 implemented 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 county parks that permits the use of only 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 resolution can be found at: http://cleanwateraction.org/njef/pfzresolution.pdf.

PROTECTING WATER QUALITY

Finding 1: The nature of geology has a large influence on the water resources and environmental quality of the Duck Pond Run Watershed, which straddles the Piedmont and Coastal Plain Physiographic Provinces (Figure 8). The majority of the Watershed consists of Piedmont geology typified by sandstones, siltstones, and shales. The southeastern section of the Watershed is made up of Coastal Plain geology consisting of unconsolidated sediments, which has two major implications from the standpoint of water resources. First, streams and rivers of the Coastal Plain are typified by large amounts of alluvial sediment (considering their shallow gradients and relatively sluggish flows) because of the erodibility of the underlying deposits. The soils are easily eroded and carried to other areas of the Watershed. Second, the lack of cementation of the buried sediments means that the sandy units retain a high porosity, making them very productive aquifers. (See Geology and Soils sections for more information.) In either physiographic province, geology, soils, aquifers, and groundwater recharge are all closely linked.

Recommendations:

- Found within the Piedmont Province, the Stockton Formation, consisting of coarse-grained sandstones, is one of the higher yielding bedrock aquifer systems in the Millstone Watershed. Within the Coastal Plain, the Potomac and Magothy Formations form the Potomac-Raritan-Magothy (PRM) aquifer and is the most prolific in the Duck Pond Run Watershed. Both of these aquifers are susceptible to groundwater contamination because of their widespread exposure and high sand content. Their outcrop areas 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 for Finding 2 in Maintaining Groundwater Resources, page 80).
- The Stockton, Potomac, and Magothy Formations and their related aquifers should be considered when making municipal decisions about

approving proposed development locations and how strict to be about the related stormwater management practices. Increasing urbanization also increases the amount of impervious cover. This has the effect of decreasing the amount of water flowing into aquifers by diverting precipitation over the landscape to streams and not downward into the soil. Placement of new development, and therefore impervious cover, outside of areas that have high value for recharging aquifers will help to maintain water levels for drinking, irrigation, and industrial use.

Applicable BMPs and Mitigation Approaches:

- West Windsor Township could strengthen their stormwater management plans for areas where the Stockton, Potomac, and Magothy Formations outcrop (see Figures 9 and 10). To protect these susceptible aquifer recharge areas, West Windsor could require extensive use of stormwater BMPs for both new developments and redevelopments. Stormwater BMPs that address infiltration include infiltration ponds and basins, bioretention basins, pervious pavement (see page 76), vegetated swales, and vegetated filters to capture discharge as sheet flow (NJDEP, 2004c).

Applicable Model Ordinances:

- West Windsor Township should enact a strong Stream Corridor Ordinance to protect water quality. Currently the Township includes language within the Master Plan encouraging stream corridor protection, but no action is required. SBMWA's model stream corridor ordinance is included in Appendix H and can be found at http://www.thewater shed.org/managing_resources.php?id=C0_45_32 (click on "Model Stream Corridor Ordinance"). SBMWA is available to assist West Windsor with ordinance creation through the Project for Municipal Excellence.

Finding 2: Much of the Duck Pond Run Watershed is classified as having hydrologic soil group B, covering 1,318.1 acres out of a total of 3,668.7 acres (35.9%) in the entire watershed. Hydrologic soil group B represents soils with moderate infiltration and surface runoff rates and consists of moderately fine- to coarse-textured soils. Most of this hydrologic soil group underlies the urban developed and agricultural areas in West Windsor Township. The second most common hydrologic soil group in the Duck Pond Run Watershed is group C, covering 29% of the Watershed and representing slow infiltration rates. Runoff from these soil groups will be high due to these moderately fine or fine-textured soils' slow infiltration rates.

Most of the Duck Pond Run Watershed is also assessed as having moderate K-factors, or moderate soil erodibility. However some key areas of highly erodible soils, totaling 34% of the Watershed, are scattered throughout but are particularly found adjacent to riparian areas. These areas have the greatest potential for benefit from soil conservation practices and the greatest likelihood for harm from construction and development.

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

<u>**Recommendation:**</u>

- 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.
- Infiltration rates for water entering the ground in the Duck Pond Run Watershed 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 West Windsor Township so that it does not degrade water quality or increase the potential for flooding and erosion.
- According to the New Jersey stormwater regulations, West Windsor should have already mapped all of their stormwater outfalls. These maps should be on file at the Township Engineer's Office. If not completed, this mapping should be done.
- 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 Duck Pond Run or its tributaries. Prior to implementation, a thorough scientific assessment should be done to ensure the appropriate location of restorations and methods used.
- Farms located within these areas could greatly benefit by working with NJ Natural Resources Conservation Service (NRCS) to implement soil conservation practices through one of their conservation programs, which provides both financial and technical assistance. For more information about these NJ NRCS conservation programs and for links to more details, please visit www.nj.nrcs.usda.gov/programs/#Other%20Programs. 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 Conservation Reserve Enhancement Program (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.

- Create an educational campaign so that farmers, businesses, and residents are aware of programs in which they can participate to improve water quality, i.e. NRCS and various River-Friendly programs. Duck Pond Run was identified as a candidate for C1 designation because it flows into a water supply source. SBMWA encourages NJDEP to reconsider this nomination and accept it as a C1 waterway to 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. West Windsor should actively support this nomination 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/.
- Headwater residents, businesses, and West Windsor Township 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 with property owners and provides recommendations for actions to improve land stewardship practices. The Program focuses on water quality, water quantity, wildlife and habitat enhancement, and education components, all geared towards reducing NPS pollution in different ways. For more information on SBMWA's River-Friendly Program, please visit http://www.thewatershed.org/river_friendly_program.php

Applicable BMPs and Mitigation Approaches:

There are many stormwater best management practices that could be implemented in the Duck Pond Run 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, 2004c).

- 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, 2004c). 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 (SBMWA, 2007c).

- The implementation of stormwater BMP retrofits in areas being redeveloped, or on municipal properties, could result in cleaner water in Duck Pond Run and its tributaries. In this case, existing stormwater management BMPs can be improved to better protect downstream waterbodies. Vegetating existing swales or detention/retention basins located near Duck Pond Run or its tributaries is one example of a low-cost method that can result in positive changes.
- Since some of this region is still farmland and many farms are located near streams and in highly erodible areas, farms need to investigate the use of BMPs to help alleviate sediment loads into area streams. The NRCS works with farmers to fund and implement such BMPs through several different conservation programs. For more information about these New Jersey NRCS conservation programs and for links to more details, please visit www.nj.nrcs.usda.gov/programs/#Other%20Programs. 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 Conservation Reserve Enhancement Program (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.
- Farmers could also get free assistance for soil loss management through the River-Friendly Farm Program administered by North Jersey Resource Conservation and Development Council (see applicable BMP within Finding 2 of the Protecting and Maintaining Groundwater Resources section on page 81; and http://njriverfriendlyfarm.org).
- Streambank restorations and reforestations are excellent BMPs to increase infiltration of stormwater, filter out pollutants such as sediment and nutrients, stabilize barren soils, reduce sediment erosion, and with time reduce stream temperatures through the creation of shaded areas which results in improved in-stream habitat. Seattle Washington estimated that increasing tree canopy from 18 to 30% would result in more than $44 million in annual benefits, including stormwater mitigation, air cleaning, carbon sequestration, energy savings, aesthetics, and other values (River Network, 2008). Streambank restorations and reforestations should be pursued whenever possible for stream reaches along Duck Pond Run and its tributaries showing signs of erosion and/or minimal vegetation.
- Retrofitting detention and retention basins could significantly alleviate sediment and nutrient loads as well as reduce bacteria contributions carried as NPS pollution via stormwater flows. Techniques for creating detention and retention basins have improved significantly over the years. The older,

conventional mowed basins with paved channels for low flow stormwater conveyance are providing minimal benefits. The Township should consider retrofitting such basins by removing the concrete low flow channel, constructing earthen berms to slow the rate of flow allowing more pollutants to settle and filter out, and planting native plants to reduce stormwater volumes.

- To help alleviate any heightened sedimentation of waterways within Duck Pond Run Watershed, municipalities should work with the appropriate Soil Conservation District to ensure that proper measures are taken to contain sediment at construction sites. In 2006 the Soil Conservation District (SCD) became responsible for ensuring that even small projects, in most cases 5,000 square feet (0.115 acres) or more of soil disturbance, meet the standards for soil erosion and sediment control in New Jersey. 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 SCDs and their regulations is available at http://www.state.nj.us/agriculture/divisions/anr/nrc/conservdistricts.html.

Applicable Model Ordinances:

- An ordinance incorporating soil protection will help protect streamside and other vegetation and minimize materials washing into streams and degrading habitat and water quality. 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 recently revised its model stream corridor ordinance. It is included in Appendix H and can be accessed on the web at: http://www.thewatershed.org/managing_resources.php?id=C0_45_32 (click on "Model Stream Corridor Ordinance"). SBMWA is available to assist West Windsor with this ordinance creation through the Program for Municipal Excellence.
- A tree protection ordinance protects the soil structure supporting the trees from being damaged during construction. Since trees stabilize the soil, this would reduce erosion. Such an ordinance also protects the root zone from compaction during construction activities. For tree protection ordinance guidelines, see the University of Georgia's *Natural Resource Conservation: Components of a Tree and Landscape Ordinance, Part II*, which can be found at http://pubs.caes.uga.edu/caespubs/horticulture/resource-conservation4.htm (Section 4: Tree Protection Standards). Or see Penn State's *A Guide to Preserving Trees in Development Projects* at http://pubs.cas.psu.edu/freepubs/pdfs/uh122.pdf.
- The Township could require phasing for construction through its addition to a soil management ordinance. This would dramatically reduce disturbed soil exposure times and prevent erosion problems. Construction phasing

disturbs only one portion of a site at a time with subsequent phases starting after the completion and stabilization of earlier phases. It would also lessen the compaction of soils because heavy equipment would be confined to areas for shorter periods of time. Sample language can be found within an EPA model erosion and sediment control ordinance, within the Design Requirement section, which can be found at http://www.epa.gov/owow/nps/ordinance/mol2.htm. Although it can be difficult to establish specific phasing requirements in an ordinance that can be applicable to plans in general, performance standards for phasing can be established although this requires oversight and enforcement. For example, an ordinance enacted in Plumstead Township, PA includes the following language: "The maximum bare earthen area (without vegetative cover) shall not exceed 5 acres or 20% of the total area of the site at any one time (whichever is greater). Maximum time of exposure for bare areas shall be 10 days before stabilization measures must be implemented." The Plumstead ordinance can be found within Chapter 22, Part 10 at http://www.e-codes.generalcode.com/codebook.frameset.asp?t=tcfull (click on "Chapters" and on "22").

- A woodlands protection ordinance protects soil post-construction and preserves woodlands when land is being developed. The best way to prevent sedimentation in streams is to keep soil anchored on land with the roots of trees, shrubs, and native vegetation. Preserving established woodlands is one of the first lines of defense for good soil management. Another result of enforcing this type of ordinance is to filter out sediments and pollutants from stormwater flow before reaching waterbodies, reducing soil erosion in the streams, and moderating temperature by providing shade and windbreaks. Chatham Township has such an ordinance, which can be viewed at: http://www.chathamtownship.org/ORDINANCE_2005-023.pdf. The Hunterdon County Environmental Toolbox also 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 (http://www.co.hunterdon.nj.us/planning/toolbox.htm#ordinances) refers to one such ordinance, within its Woodland Conservation section, adopted by Washington Township in Mercer County (Ordinance 103.53, Natural and Cultural Resource Conservation ordinance). This Washington Township ordinance 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 3: 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 Duck Pond Run Watershed. Because of its connection to a drinking water supply, Duck Pond Run was identified as a candidate for C1 designation. It is vitally important to protect this source of drinking water.

Recommendations:

- In order to accurately assess the environmental health of Duck Pond Run, 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 Duck Pond Run itself. Intensive monitoring at many sites along Duck Pond Run and its tributaries needs to occur to determine the stream's health. It would be beneficial to conduct additional bacteria monitoring along Duck Pond Run, both at the four established sites documented in this report and, if access could be approved, upstream and downstream of tributaries and in areas where the sewer lines closely parallel Duck Pond Run. Additionally source-tracking bacteria samples taken at the four established sites could determine whether the sources of bacteria are from humans or animals. For example the ratio of fecal coliform to fecal strep can indicate whether the source is human or animal, although there is a large range considered inconclusive as well.
- Point source dischargers in the Duck Pond Run Watershed need to operate within the guidelines of their active permits in order to maintain the water quality of Duck Pond Run as it exists today (Figure 6 and Point Source Dischargers Section).
- 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 possible. Creating vegetated areas adjacent to impervious areas also helps to increase infiltration and filter out pollutants (vegetated filters). Vegetating along streams and urban areas has an economic benefit as well. A University of Pennsylvania study found that tree planting raised property values, and Seattle estimated that increasing tree canopy from 18 to 30% would result in more than $44 million in annual benefits, including stormwater mitigation, air cleaning, carbon sequestration, energy savings, aesthetics, and other values (River Network, 2008).
- 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 is not sufficient. SBMWA's River-Friendly Program is geared towards doing just that: working directly with individual homeowners, businesses, golf courses, municipalities, schools,

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 include creating an Integrated Pest Management plan to reduce herbicide and fertilizer use, 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 in which participants either hold a forum to educate others and/or attend educational classes themselves. Each individual property owner has an impact on water quality and the environment, but when the even larger cumulative effect is apparent from all property owners, it can inspire the individuals to change their land stewardship practices to be more environmentally-friendly while still looking good. West Windsor should encourage their residents and businesses to participate, while serving as a role model by enlisting the municipal properties in the River-Friendly Program.

- Anecdotal evidence indicates that even though West Windsor has a Pet Waste Ordinance enacted (Chapter 150, Article IV of the Code of the Township of West Windsor, NJ), many residents, possibly thinking that they are complying, are picking up the pet waste and then discarding it down storm drains. As a result, despite best intentions, pet waste is still reaching streams in the Township and polluting the waters. This could explain some of the bacteria problems in Duck Pond Run. The Township should institute an educational campaign so residents understand what a storm drain is and the benefits of proper pet waste disposal. Part of the education could include an analysis using dog license data to estimate the number of dogs within the Township and the amount of waste produced per day to emphasize the importance of picking up after pets.

Applicable BMPs and Mitigation Approaches:

There are many stormwater best management practices that could be implemented in the Duck Pond Run Watershed to reduce 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, 2004c).

- The 2004 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 NPS pollutants. Key BMPs that increase infiltration and filter out pollutants include infiltration and bioretention basins, pervious pavement, vegetated swales, and vegetated filters to capture discharge as sheet flow (NJDEP, 2004c). 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 (SBMWA, 2007c).

- The implementation of stormwater BMP retrofits in areas being redeveloped or on municipal properties could result in cleaner water in Duck Pond Run and its tributaries. In this case existing stormwater management BMPs can be improved to better protect downstream waterbodies. The older, conventional mowed basins with paved channels for low flow stormwater conveyance are providing minimal benefits. Retrofitting existing stormwater detention or retention basins to increase stormwater infiltration could reduce the volume of stormflows in streams while filtering out pollutants such as bacteria before reaching the stream. An example of an existing detention basin that could benefit from a retrofit is the large one behind the Le Parc development. The Township should consider retrofitting such basins by removing the concrete low flow channel, constructing earthen berms to slow the rate of flow allowing more pollutants to settle and filter out, and planting native plants to reduce the stormwater volumes. Vegetating existing swales located near Duck Pond Run and its tributaries is another 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, for example those on municipal properties.
- Areas with agricultural land use (Figure 15) 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 Duck Pond Run Watershed 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. The River-Friendly Farm Program also works with farmers on these issues. For more information on the various programs, please see the listings included in the applicable Recommendations and BMPs bullets within Finding 2 of Protecting Groundwater on page 80 and within Finding 2 of Protecting Water Quality on pages 85 and 86-87.

<u>Applicable Model Ordinances:</u>

- Since the Duck Pond Run Watershed is already highly developed, West Windsor needs to incorporate improved stormwater management to help reduce the loadings of nonpoint source pollutants into the stream 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. The Township has already incorporated a Stormwater Management Plan into the Master Plan (Section XII; http://www.westwindsornj.org/MasterPlan/Section%2012/Section%2012.pdf). And West Windsor Township has already adopted a Stormwater Control Ordinance (Chapter 200, Article XXI of the Code of the Township of West Windsor, NJ) as well as a pet waste ordinance (Chapter 150, Article IV of the Code of the Township of West Windsor, NJ). They can be viewed at: http://www.e-codes.generalcode.com/codebook_frameset.asp?t=tc&p=1666%2D200%2Ehtm%23ArticleXXI&cn=917&n=[1][144][797]. West Windsor Township needs to be diligent in enforcing these ordinances.

- Stream corridor ordinances, impervious surface ordinances, woodlands protection ordinances, afforestation ordinances, soil management ordinances, tree protection ordinances, phased construction, 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. SBMWA's recently revised model stream corridor ordinance can be accessed on the web at: http://www.thewatershed.org/managing_resources.php?id=C0_45_32 (click on "Model Stream Corridor Ordinance"). SBMWA is available to assist West Windsor with ordinance creation through the Project for Municipal Excellence.
- For those areas of West Windsor still 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 the Association of New Jersey Environmental Commissions (ANJEC) has a model ordinance that mandates inspection upon sale or transfer of property, as well as every three years. This ensures 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, PA has an ordinance on the books requiring regular inspection, reporting, and pumping of septic systems. Regular pumping prolongs the life of septic systems and regular inspection identifies failing septics at an earlier stage to prevent long-term bacterial contributions. A copy of this septic system maintenance 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]. Montgomery Township, NJ has a similar septic maintenance and inspection ordinance which can be accessed at http://70.168.205.112/montgomery_nj/lpext.dll?f=templates&fn=site_main-j.htm&2.0 (Chapter BH:XIII of the Board of Health Code, Sections BH:13-8 and 13-9). Although the entire Duck Pond Run Watershed is in a designated sewer service area, there may be older homes still utilizing septic systems that could benefit from these suggested ordinances as well as the septic service area within West Windsor outside of the Duck Pond Run Watershed.

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LIST OF ACRONYMS

AMNET	Ambient Biomonitoring Network
ANJEC	Association of New Jersey Environmental Commissions
BAT	Biological Action Team
BMPs	Best Management Practices
C1	Category One waterway
CAT	Chemical Action Team
CEA	Classification Exception Area
CFU	Colony-forming Unit
CKE	Currently Known Extent
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
DPR	Duck Pond Run
EPT	Ephemeroptera-Plecoptera-Trichoptera
EQ BLK	Equipment Blank
EQIP	Environmental Quality Incentives Program
FW	Fresh Water (see Glossary)
FBI	Family Biotic Index
FDUP	Field Duplicate
FOWWOS	Friends of West Windsor Open Space
GIS	Geographic Information System
GRP	Grassland Reserve Program
IPM	Integrated Pest Management
KCS	Known Contaminated Site
KCS-NJ	Known Contaminated Sites in New Jersey Report
LEED	Leadership in Energy and Environmental Design
LID	Low Impact Development
LIP	Landowner Incentive Program

LOI	Letter of Interpretation
MDDNR	Maryland Department of Natural Resources
MG/L	Milligram Per Liter
ML	Milliliter
ND	No Date
NJAC	New Jersey Administrative Code
NJDEP	New Jersey Department of Environmental Protection
NJDOT	New Jersey Department of Transportation
NJEMS	New Jersey Environmental Management System
NJGS	New Jersey Geological Survey
NJGWQS	New Jersey Ground Water Quality Standard
NJPDES	New Jersey Pollution Discharge Elimination System
NJ RC&D	North Jersey Resource Conservation and Development
NJWSA	New Jersey Water Supply Authority
NPS	Nonpoint Source Pollution
NRCS	Natural Resources Conservation Service
NWIS	National Water Information System
PA	Planning Area
PCW	Public Community Well
PFZ	Pesticide-Free Zone
PNCW	Public Non-Community Well
PRM	Potomac-Raritan-Magothy (aquifer)
PRP	Potentially Responsible Party
RAT	River Action Team
RCRA	Resource Conservation and Recovery Act
SBMWA	Stony Brook-Millstone Watershed Association
SCD	Soil Conservation District

SMO	Stormwater Management Ordinance
STORET	Storage and Retrieval Database
STP	Sewage Treatment Plant
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
WHIP	Wildlife Habitat Incentives Program
WHPA	Wellhead Protection Area

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.

afforestation: The planting of trees for the purpose of creating woodland or forest.

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

amphibolite: A metamorphic rock composed mainly of amphibole, an iron-magnesium bearing mineral, and plagioclase with little or no quartz.

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

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

bedrock: The solid rock that underlies all soil, sand, clay, gravel, and loose material on the earth's surface. Exposed bare rock is bedrock at the surface.

benthic macroinvertebrate: Any of a diverse group of spineless 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.

conformably layered: The later formation has bedding planes parallel to those of an earlier formation. Disturbance or erosion did not take place during deposition or formation.

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.

drainfield: The part of a septic system where the wastewater is released into the soil for absorption and filtration.

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.

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

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 $\leq$ 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.

feldspar: A group of rock-forming minerals consisting of silicates of aluminum and potassium, sodium, or calcium. Feldspar may constitute 60% of the earth's crust, making it the most widespread of any mineral group, generally light in color.

felsic: An igneous rock composed chiefly of light-colored feldspar and silica minerals.

gaining stream: A stream with a shallow surrounding water table that receives groundwater discharges, adding significantly to streamflow volume. The same stream could be both a gaining and losing stream, depending on the conditions and time of year.

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

gneiss: A coarse-grained metamorphic rock marked by bands of light-colored minerals such as quartz and feldspar that alternate with bands of dark-colored minerals. A type of granite.

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.

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

hydrologic: Dealing with water (both surface water, groundwater, and atmostpheric water), its properties, circulation, and distribution.

hydrologic soil groups: Soils grouped according to their runoff-producing characteristics. The chief consideration is the inherent capacity of soil bare of vegetation to permit infiltration.

igneous rocks: A type of rock formed when molten magma cools and solidifies, with or without crystallization, either below the surface as intrusive (plutonic) rocks or on the surface as extrusive (volcanic) rocks.

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

K-factor: A measure of bare surface soil erosion.

losing stream: A stream with a deep surrounding water table that loses stream water to (recharges) groundwater aquifers. The same stream could be both a gaining and losing stream, depending on the conditions and time of year.

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.

mafic: An igneous rock composed chiefly of one or more dark-colored minerals, mainly iron and magnesium.

marble: A metamorphic rock consisting mostly of calcite and/or dolomite (limestone).

metabasalt: Metamorphic rocks formed when basalts (igneous rocks) are changed chemically, mineralogically, or structurally as a result of high pressures and/or temperatures.

metamorphic rocks: Sedimentary or igneous rocks whose original composition or texture has been changed by recrystallization at high temperatures, pressures, and/or stresses but without melting.

metasedimentary rocks: Metamorphic rocks formed when sedimentary rocks are changed chemically, mineralogically, or structurally as a result of high pressures and/or temperatures.

metavolcanic rocks: Metamorphic rocks formed when volcanic (igneous) rocks are changed chemically, mineralogically, or structurally as a result of high pressures and/or temperatures.

migmatized: The intimate interfingering of magma and invaded rock.

muscovite: A colorless or pale brown mica with potassium. It characteristically splits into thin sheets, exhibiting perfect cleavage in one direction.

Natural Heritage Program: A State program that identifies New Jersey's most significant natural areas through a comprehensive inventory of all rare plant and animal species and representative ecological communities.

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 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.

sandstone: A sedimentary rock that consists of consolidated sand-sized grains, mainly quartz and feldspar, that have been cemented together.

schist: A metamorphic crystalline rock that splits easily into layers.

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.

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

soil series: As established by the National Cooperative Soil Survey, soil series are the finest level of soil classification grouped according to similar soil evolution, soil chemistry, and physical properties.

species of concern: A species that is not considered threatened or endangered, but is still monitored by Natural Heritage Program 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).

stratigraphic: Relating to the vertical position of geological layers in a rock column. This usually relates to relative geological age, since one layer is laid down upon the previous layer in an orderly progression through time resulting in older rocks being lower in any given sequence of undisturbed sedimentary rock.

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.

turbid: Cloudy water caused by suspended material that are generally invisible to the naked eye which diminishes the penetration of light through the fluid.

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

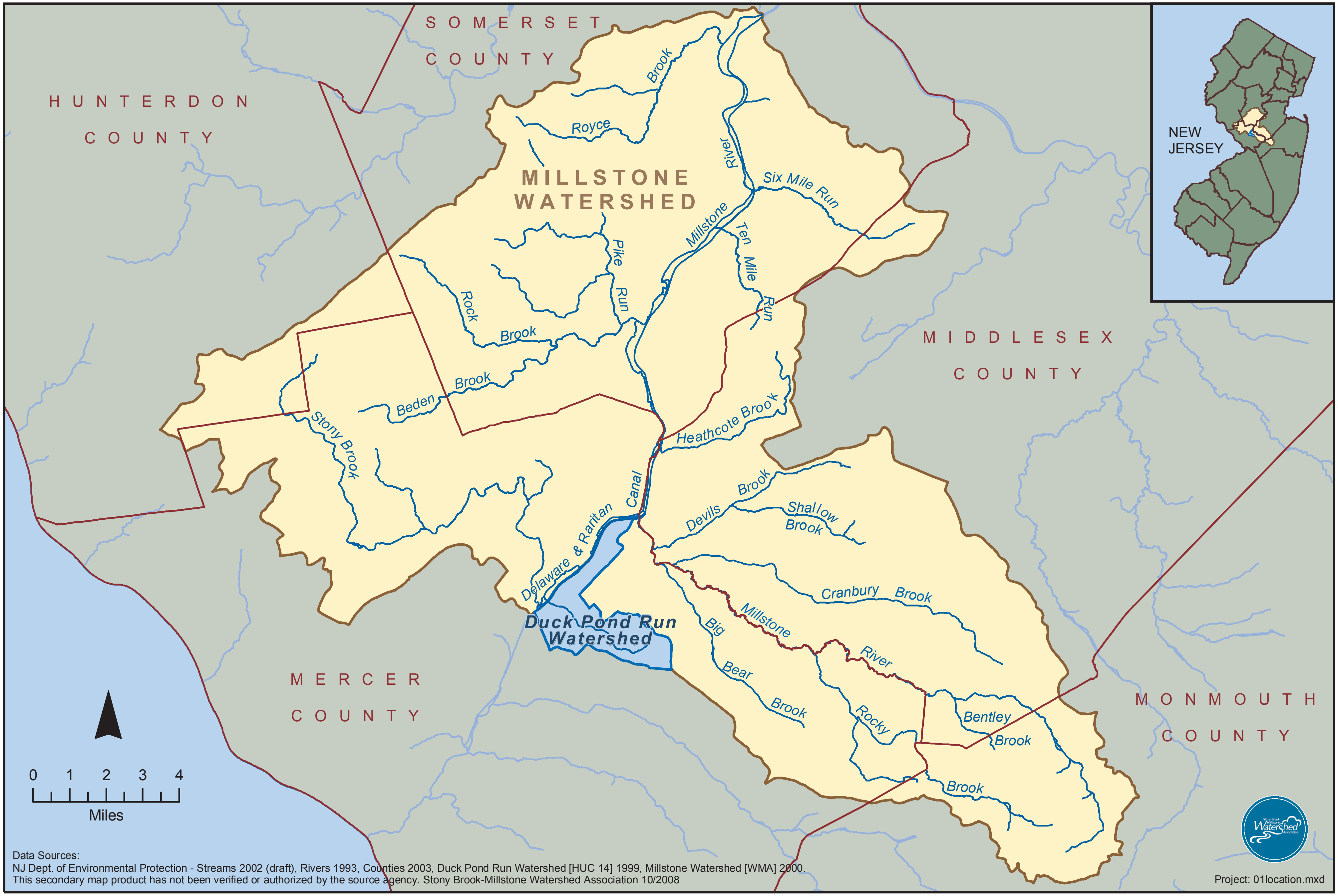
watershed: A hydrologic unit in which all surface water runoff egresses through a single, natural hydrologic outlet, and as delineated in the statewide Water Quality Management Plan. Also defined as all the land area that contributes runoff to a particular point along a waterway.

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.

FIGURES

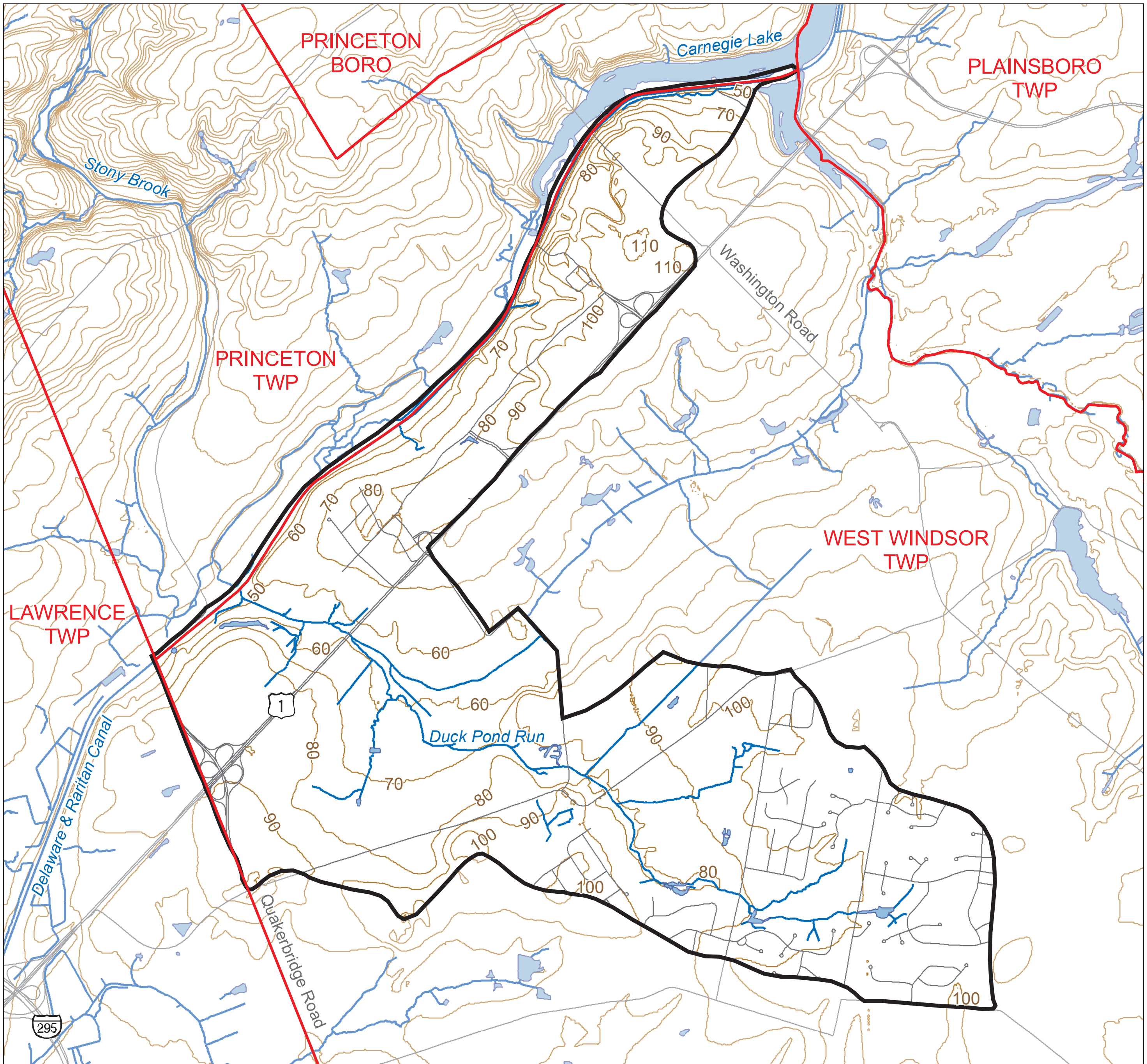
Figure 1: Duck Pond Run Watershed within Millstone Watershed



Data Sources:
NJ Dept. of Environmental Protection - Streams 2002 (draft), Rivers 1993, Counties 2003, Duck Pond Run Watershed [HUC 14] 1999, Millstone Watershed [WMA] 2000.
This secondary map product has not been verified or authorized by the source agency. Stony Brook-Millstone Watershed Association 10/2008

Project: 01location.mxd

Figure 2: Duck Pond Run Watershed Topography



Elevation Contour - 10 foot interval

Watershed Boundary

Municipal Boundary

Stream

Lake

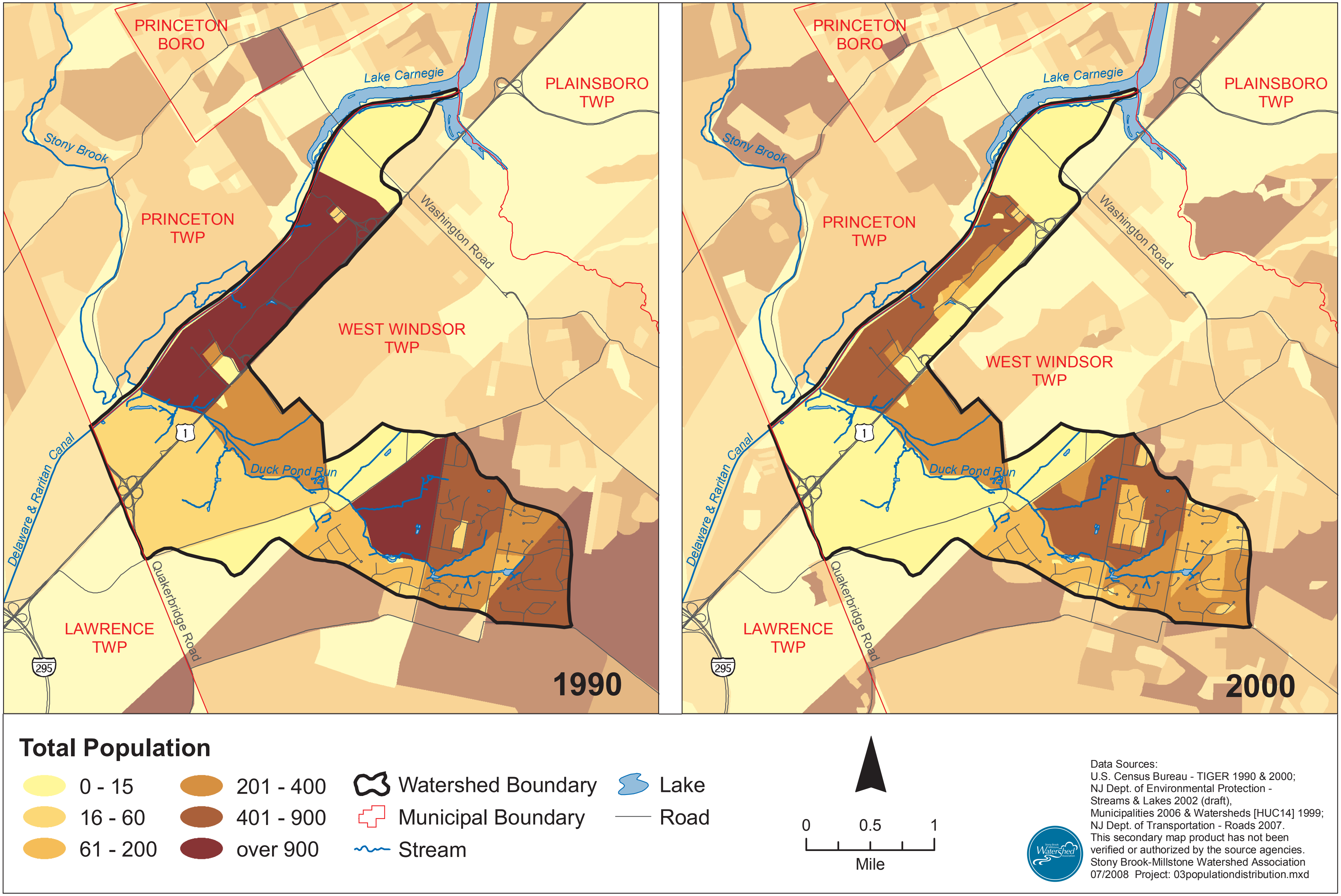
Road

0 0.3 0.6 1

Mile

Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006, Watersheds [HUC14] 1999, Elevation Contours created from 10-meter Digital Elevation Model (DEM) 2000; and NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
07/2008 Project: 02topography.mxd

Figure 3: Population Distribution in Duck Pond Run Watershed by Census Block



Data Sources:
U.S. Census Bureau - TIGER 1990 & 2000;
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006 & Watersheds [HUC14] 1999;
NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
07/2008 Project: 03populationdistribution.mxd

Figure 4: Population Density in Duck Pond Run Watershed by Census Block

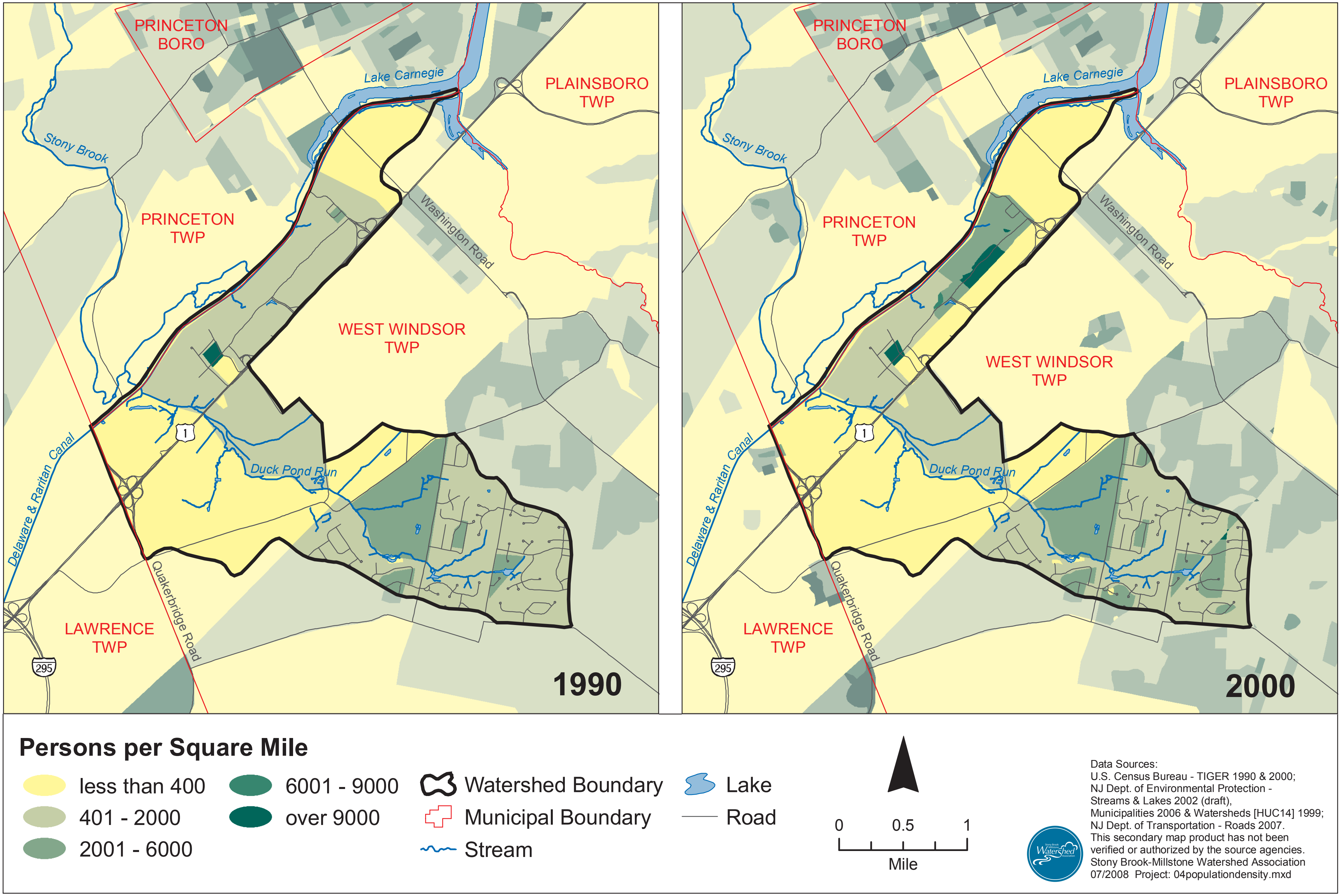
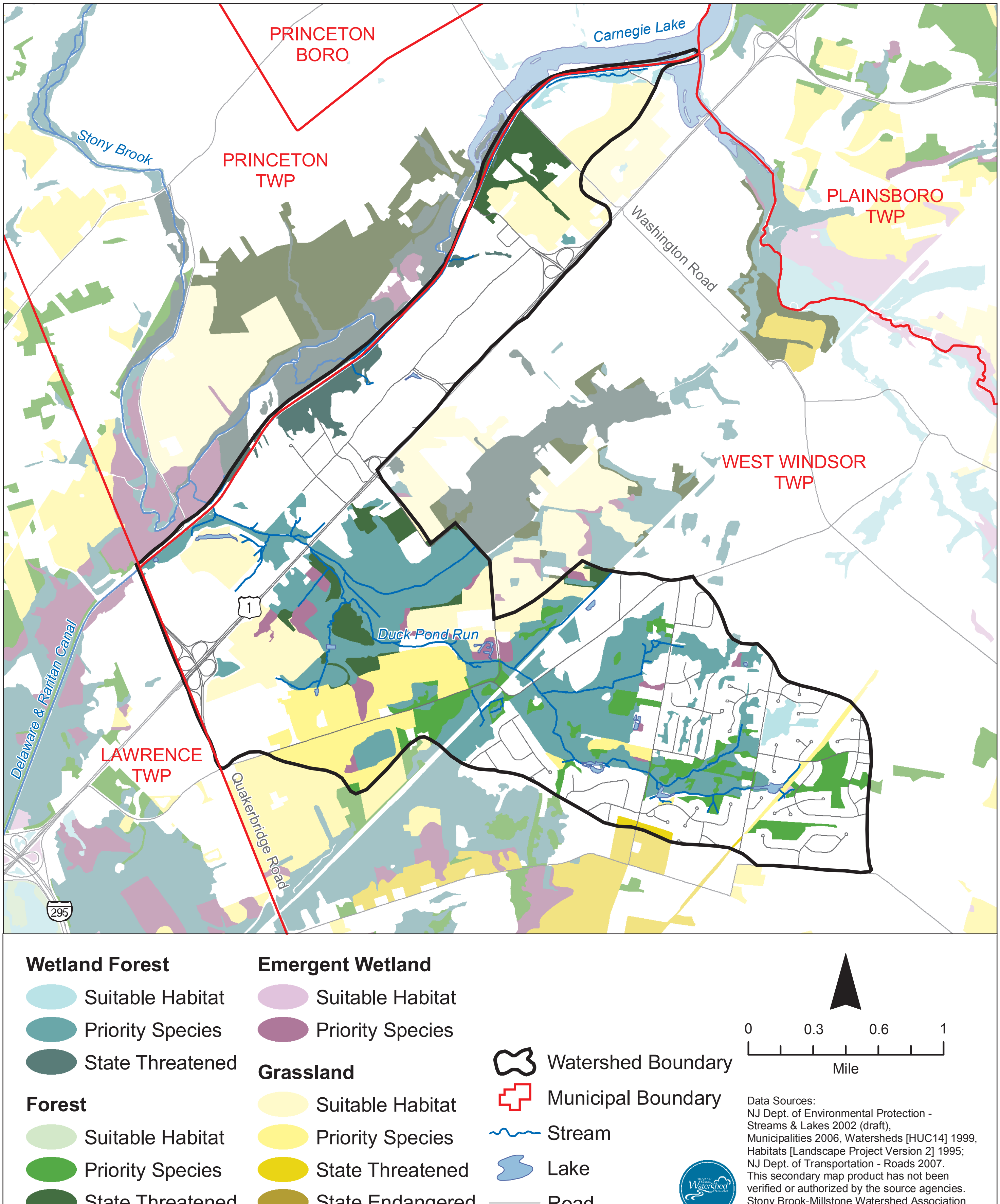
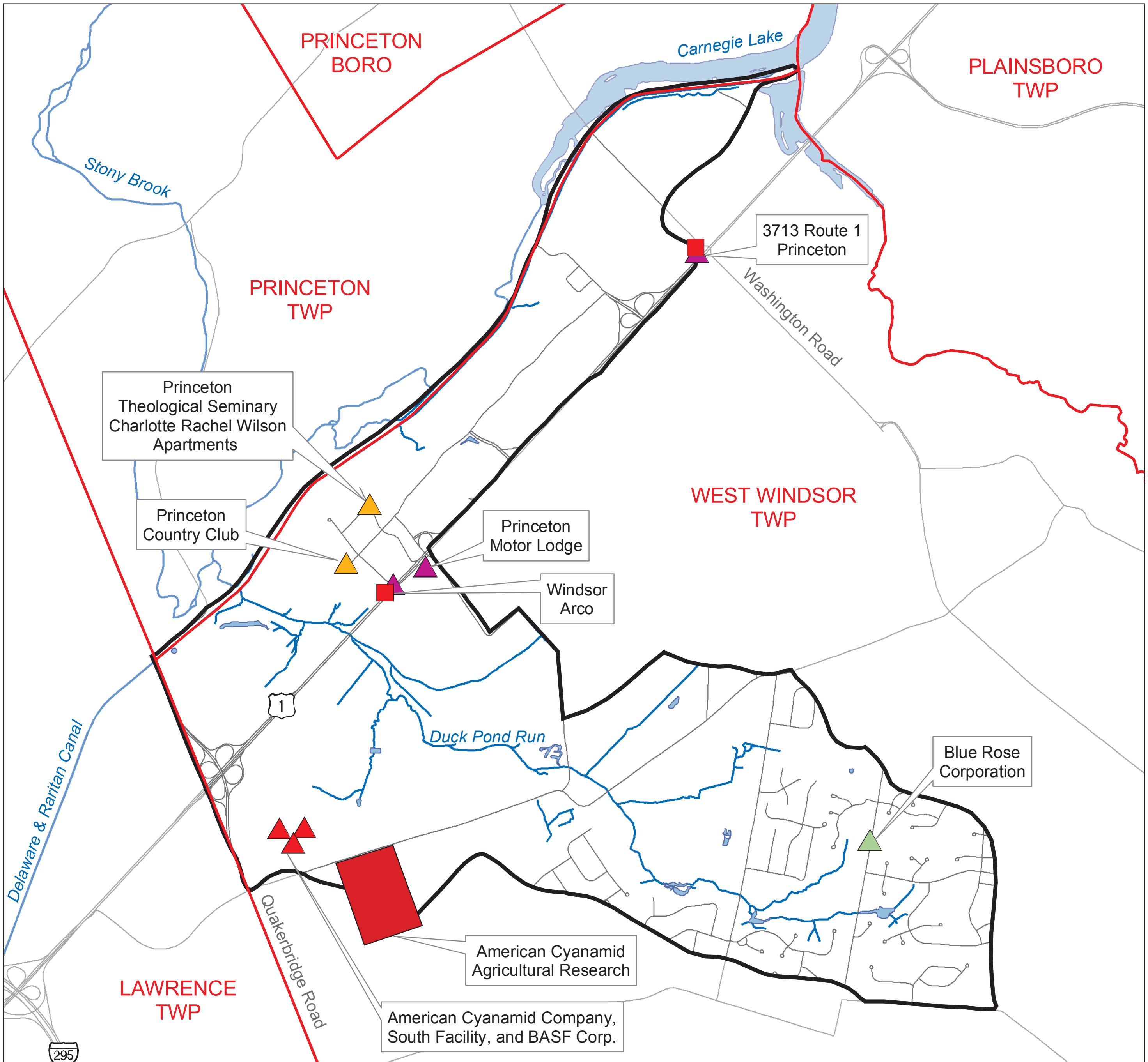


Figure 5: Critical Habitats in Duck Pond Run Watershed



Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006, Watersheds [HUC14] 1999, Habitats [Landscape Project Version 2] 1995;
NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
07/2008 Project: 05criticalhabitats.mxd

Figure 6: Known Contaminated Sites and Extent of Contamination in Duck Pond Run Watershed



Remedial Levels

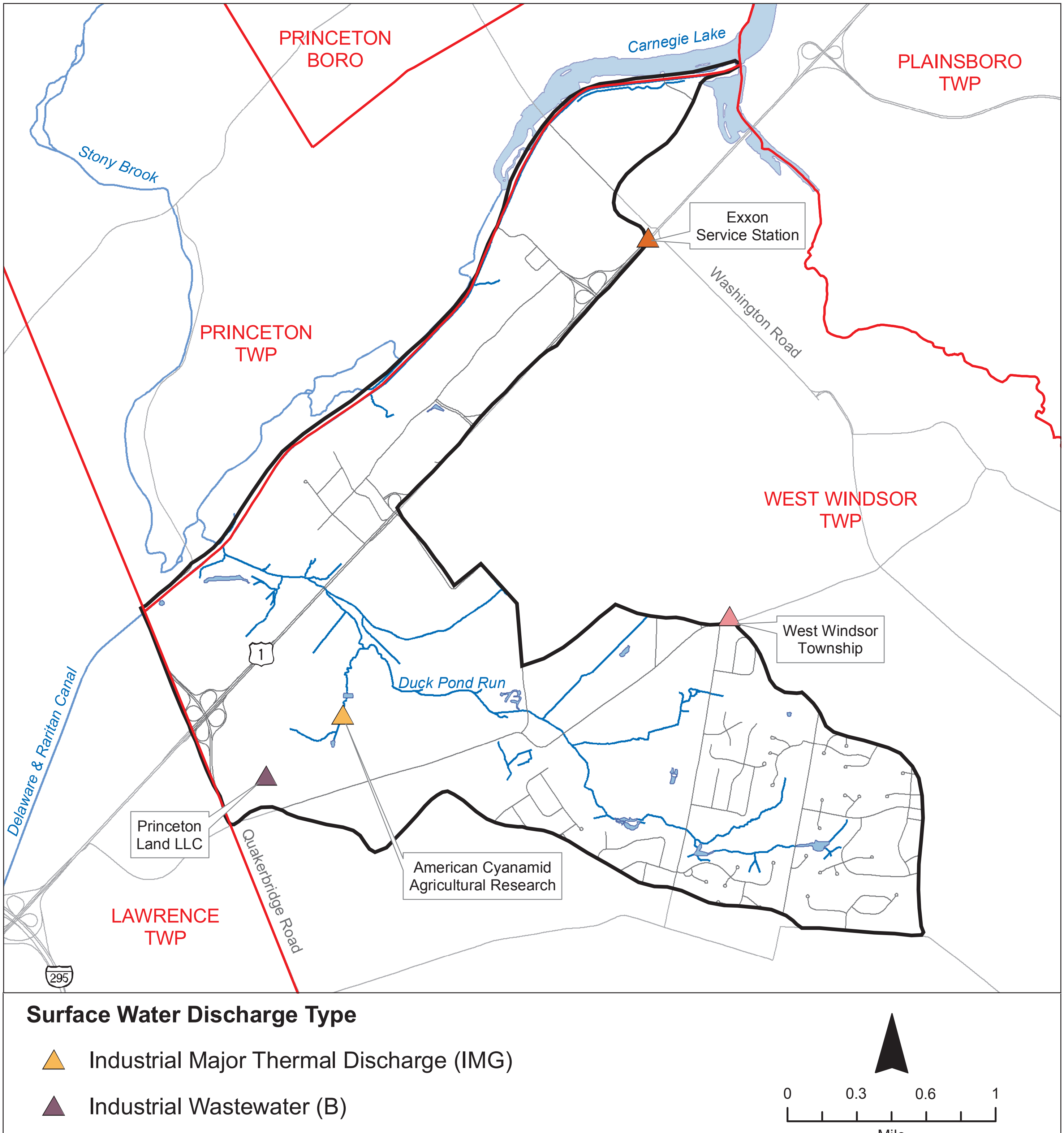
- C1 — Simple sites; one or two contaminants localized to soil and the immediate spill or discharge area.
- C2 — More complicated contaminant discharges, multiple site spills and discharges, more than one contaminant, with both soil and ground water impacted or threatened.
- C3 — Multi-phased remediation action; source is either unknown or there is uncontrolled discharge to soil and/or groundwater.
- D — High complexity and threatening sites; multiple contaminants, some at high concentrations with unknown sources continuing to impact soils, ground water, and possibly surface waters and potable water resources. Dangerous for direct contact with contaminated soils. Usually designated Federal "Superfund Sites".
- Classification Exception Area - Special permit/management plan in effect

Watershed Boundary
Municipal Boundary
Stream
Lake
Road

0 0.3 0.6 1
Mile

Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006, Watersheds [HUC14] 1999, CEAs 2003, Known Contamined Sites reported on Active List 05/09/2008; and
NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
07/2008 Project: 06contaminatedsites.mxd

Figure 7: NJPDES Point Source Dischargers in Duck Pond Run Watershed



Surface Water Discharge Type

- Industrial Major Thermal Discharge (IMG)
- Industrial Wastewater (B)
- Petroleum Hydrocarbon Remediation (B4B)
- Tier A Municipal Stormwater (R9)
- Watershed Boundary
- Municipal Boundary
- Stream
- Lake
- Road

Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006, Watersheds [HUC14] 1999, NJPDES Active Permit List accessed 1/18/2008; and NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
07/2008 Project: 07dischargers.mxd

Figure 8: Physiographic Provinces of New Jersey

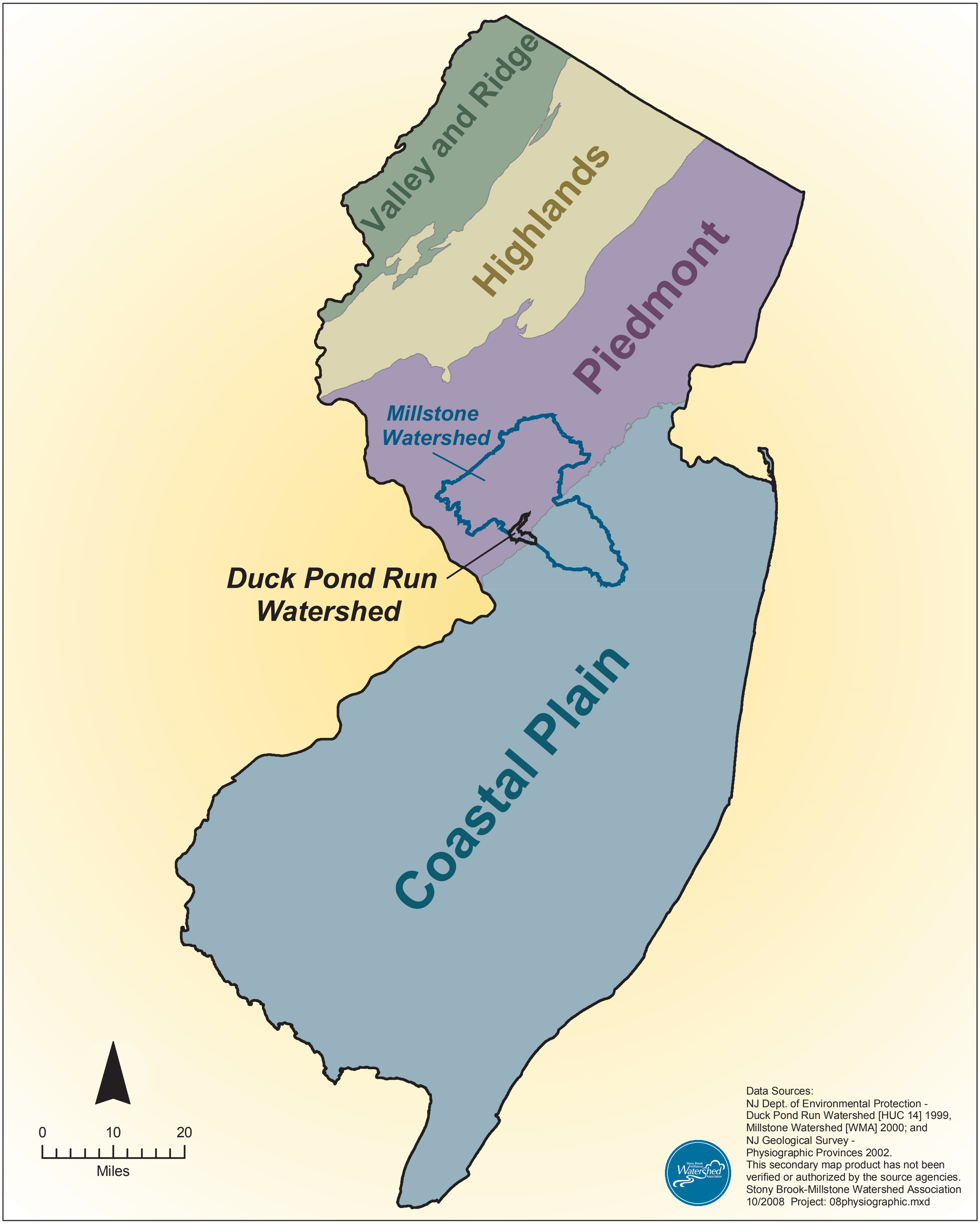
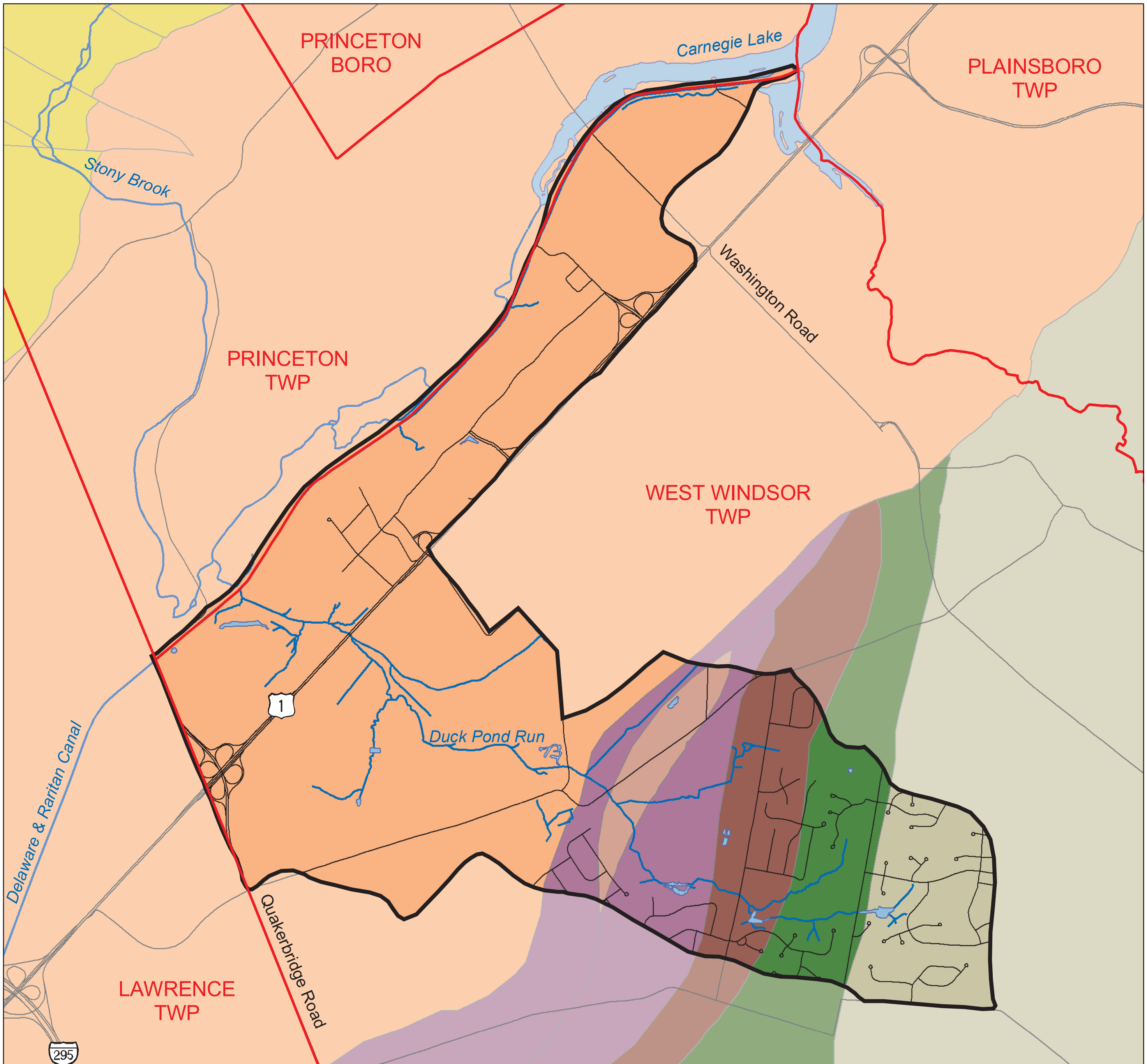


Figure 9: Geology of Duck Pond Run Watershed



Bedrock Geology

- Gneiss Granofels and Migmatite
- Lockatong Formation
- Magothy Formation
- Metabasalt
- Potomac Formation
- Stockton Formation
- Wissahickon Formation

- Watershed Boundary
- Municipal Boundary
- Stream
- Lake
- Road

0 0.3 0.6 1
Mile

Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006, Watersheds [HUC14] 1999;
NJ Geological Survey - Geology 1993; and
NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
07/2008 Project: 09geology.mxd

Figure 10: Aquifers of Duck Pond Run Watershed

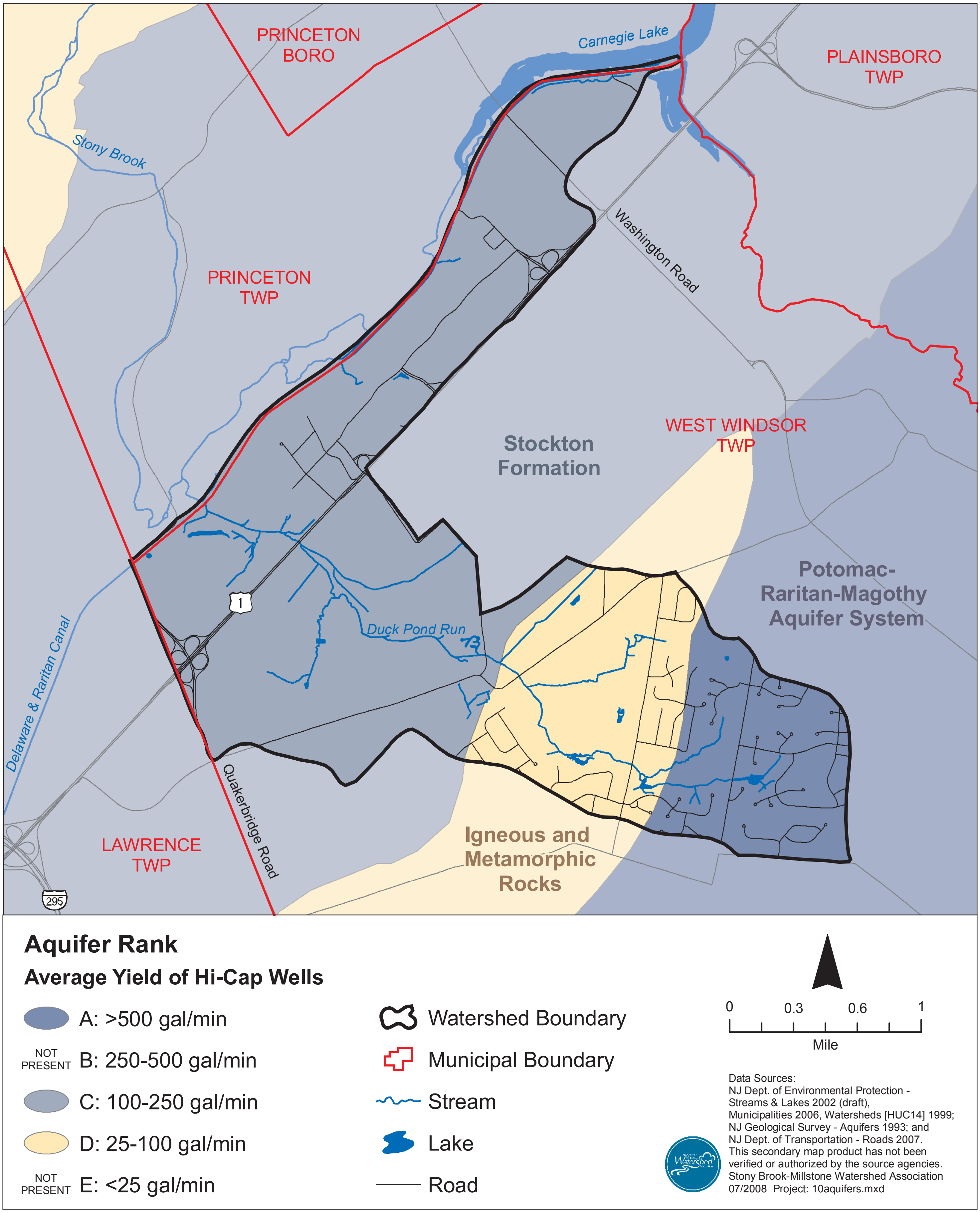
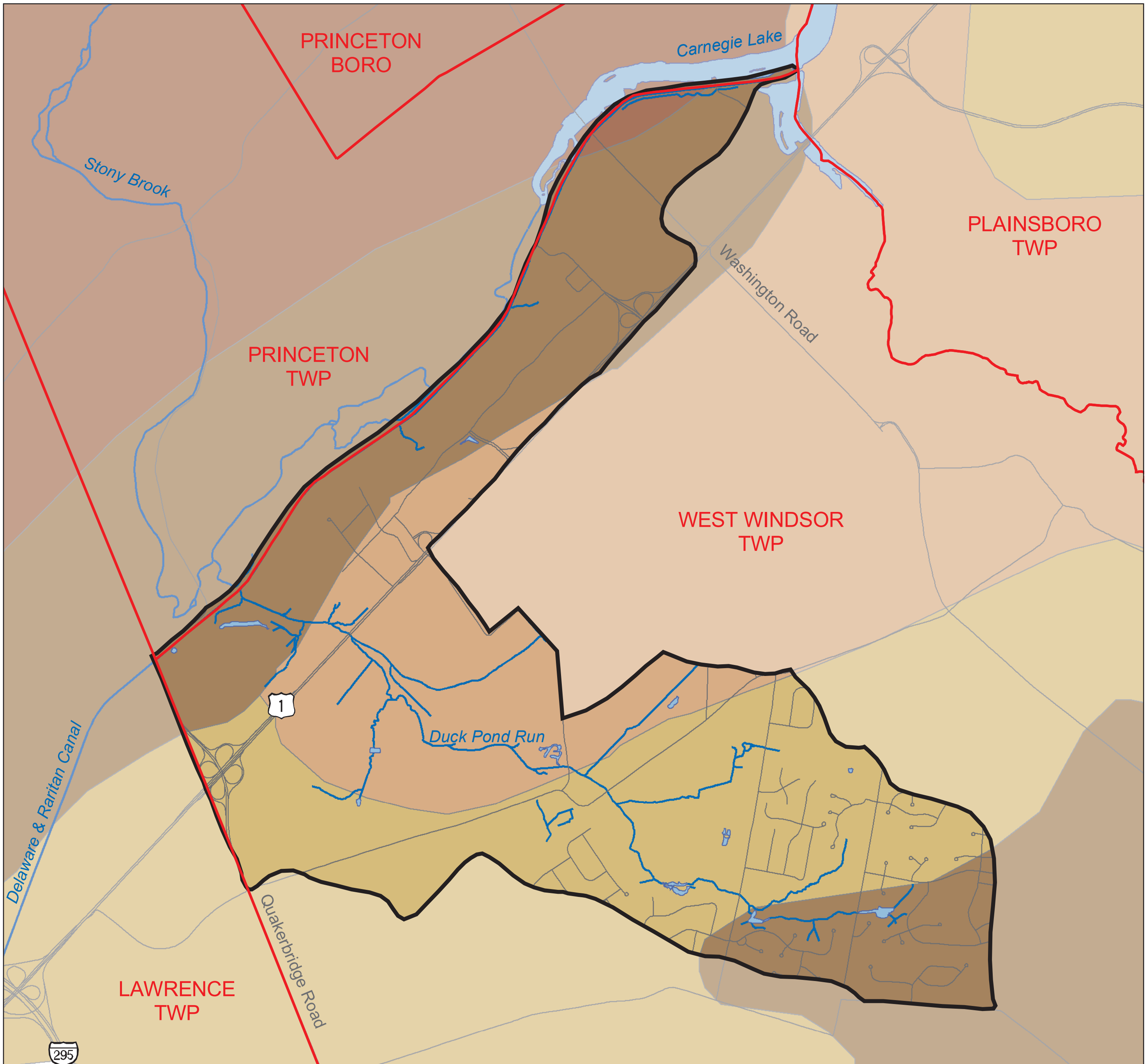


Figure 11: Soils Associations in Duck Pond Run Watershed



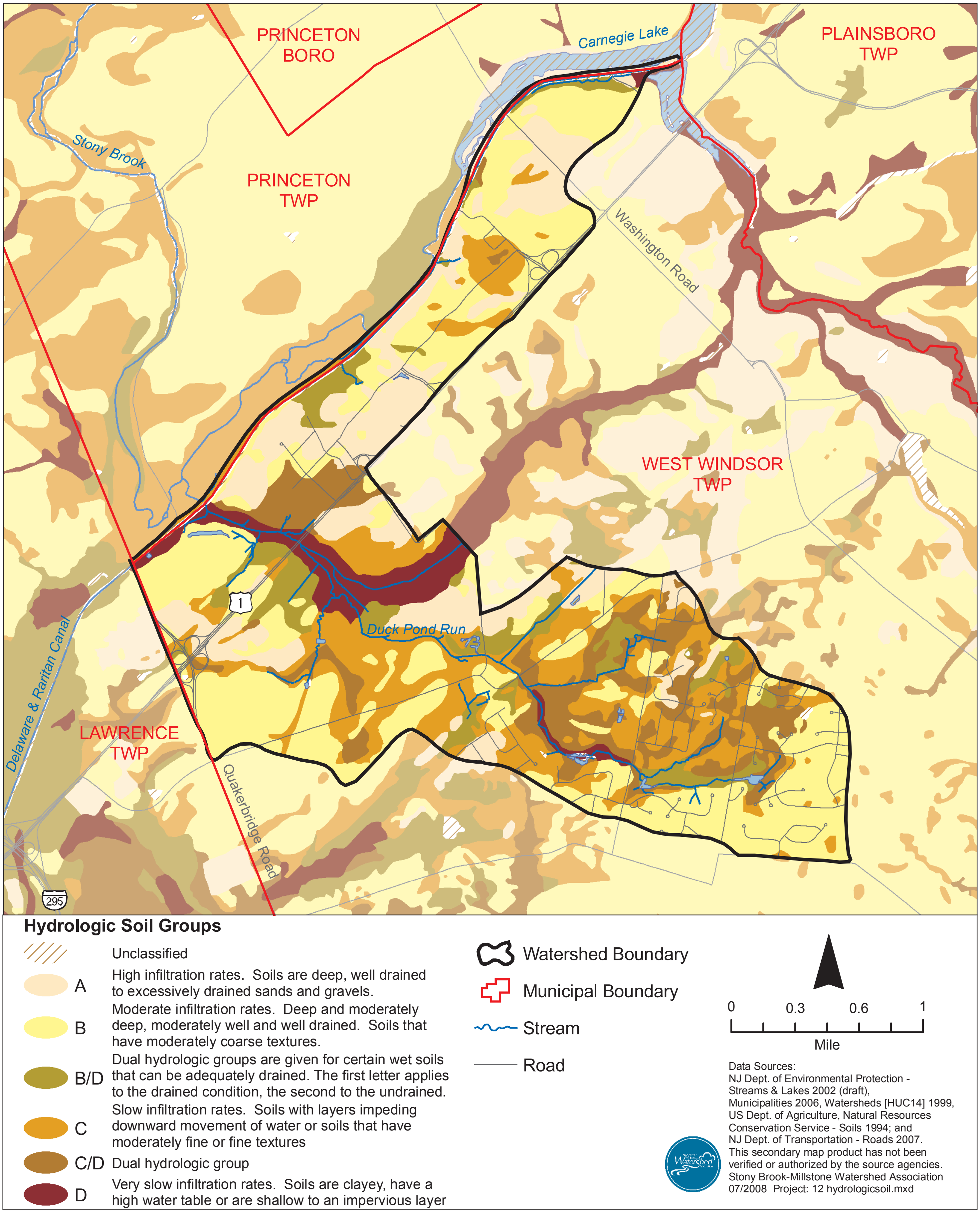
Soil Association

- Atsion-Manahawkin-Berryland
- Downer-Sassafras-Hammonton
- Mattapex-Matapeake-Chillum
- Quakertown-Chalfont-Lehigh
- Watershed Boundary
- Municipal Boundary
- Stream
- Lake
- Road

0 0.3 0.6 1
Mile

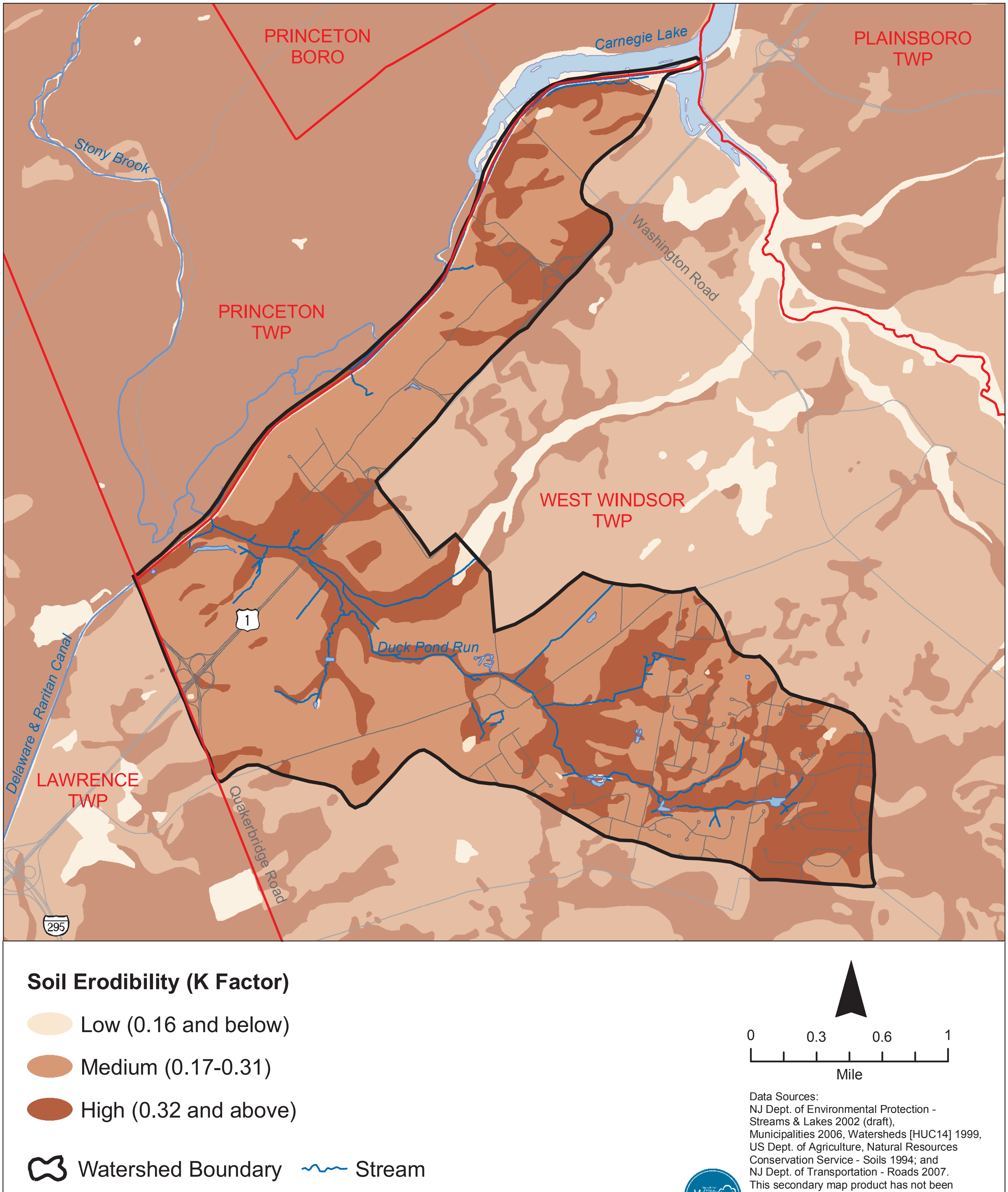
Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006, Watersheds [HUC14] 1999, US Dept. of Agriculture, Natural Resources Conservation Service - Soils 1994; and NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
07/2008 Project: 11soilassociations.mxd

Figure 12: Hydrologic Soil Groups in Duck Pond Run Watershed



Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006, Watersheds [HUC14] 1999, US Dept. of Agriculture, Natural Resources Conservation Service - Soils 1994; and NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
07/2008 Project: 12 hydrologicsoil.mxd

Figure 13: Soil Erodibility in Duck Run Pond Watershed



Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006, Watersheds [HUC14] 1999,
US Dept. of Agriculture, Natural Resources Conservation Service - Soils 1994; and
NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
07/2008 Project: 13soilerodibility.mxd

Figure 14: Septic Suitability in Duck Pond Run Watershed

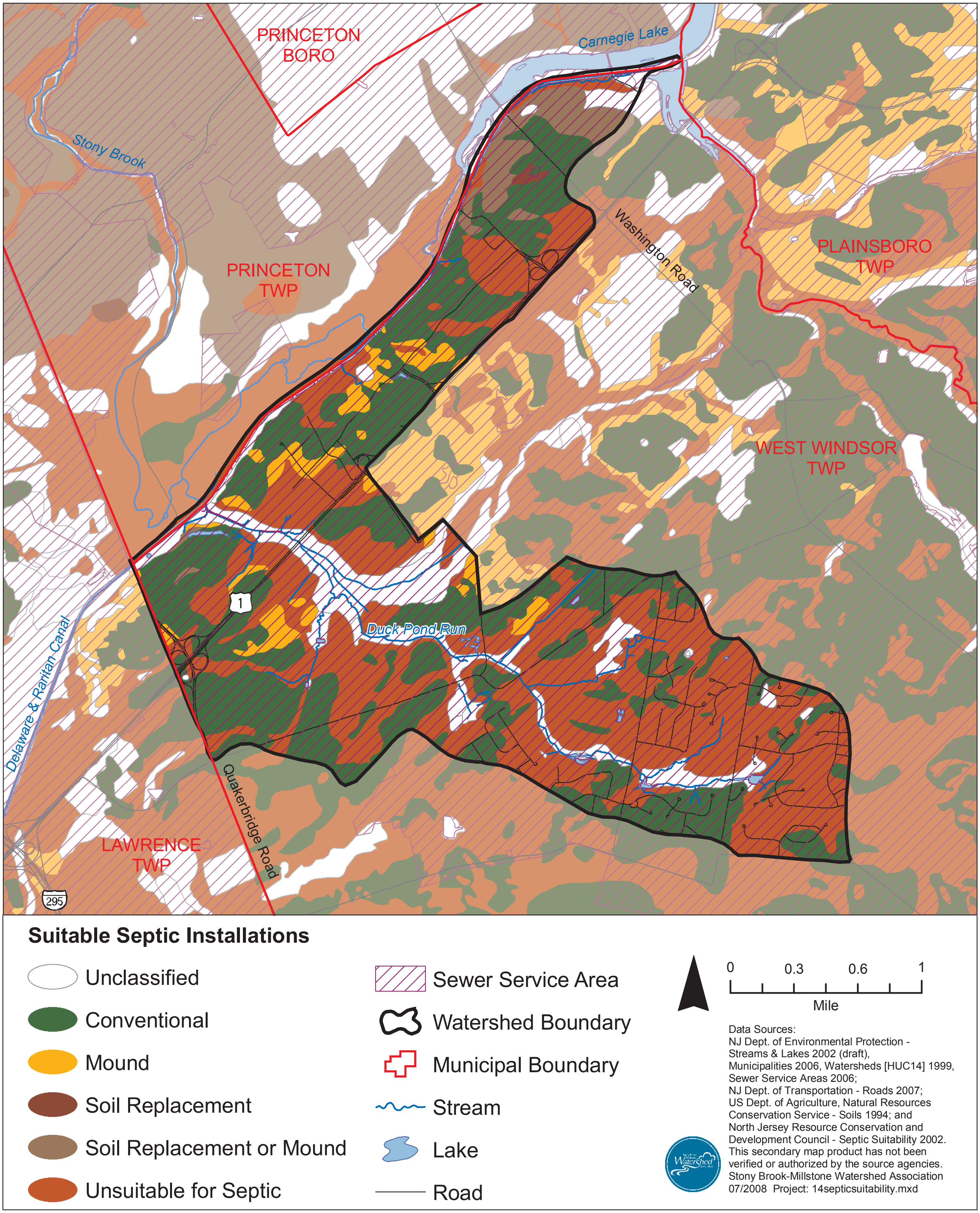


Figure 15: 2002 Land Use in Duck Pond Run Watershed

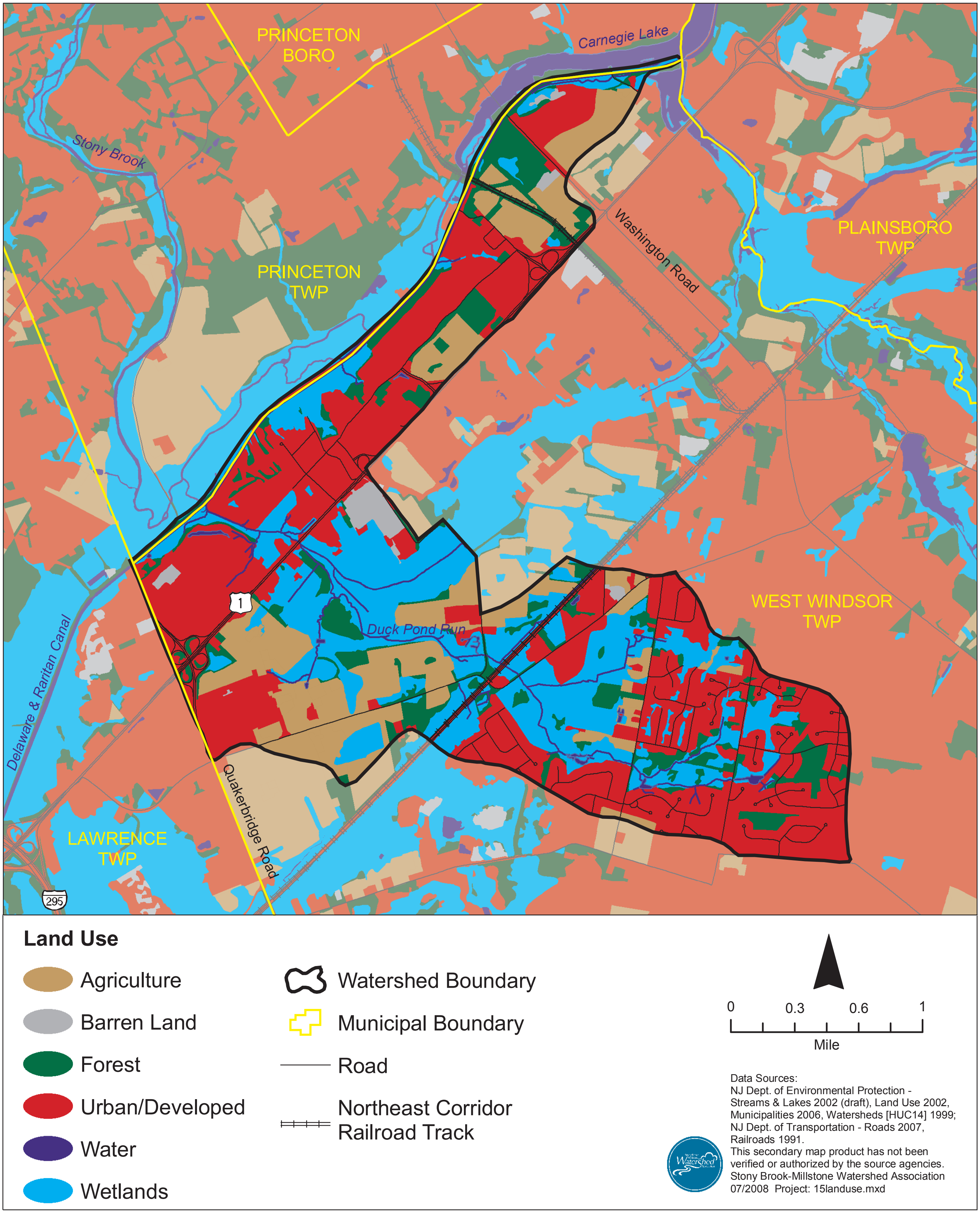
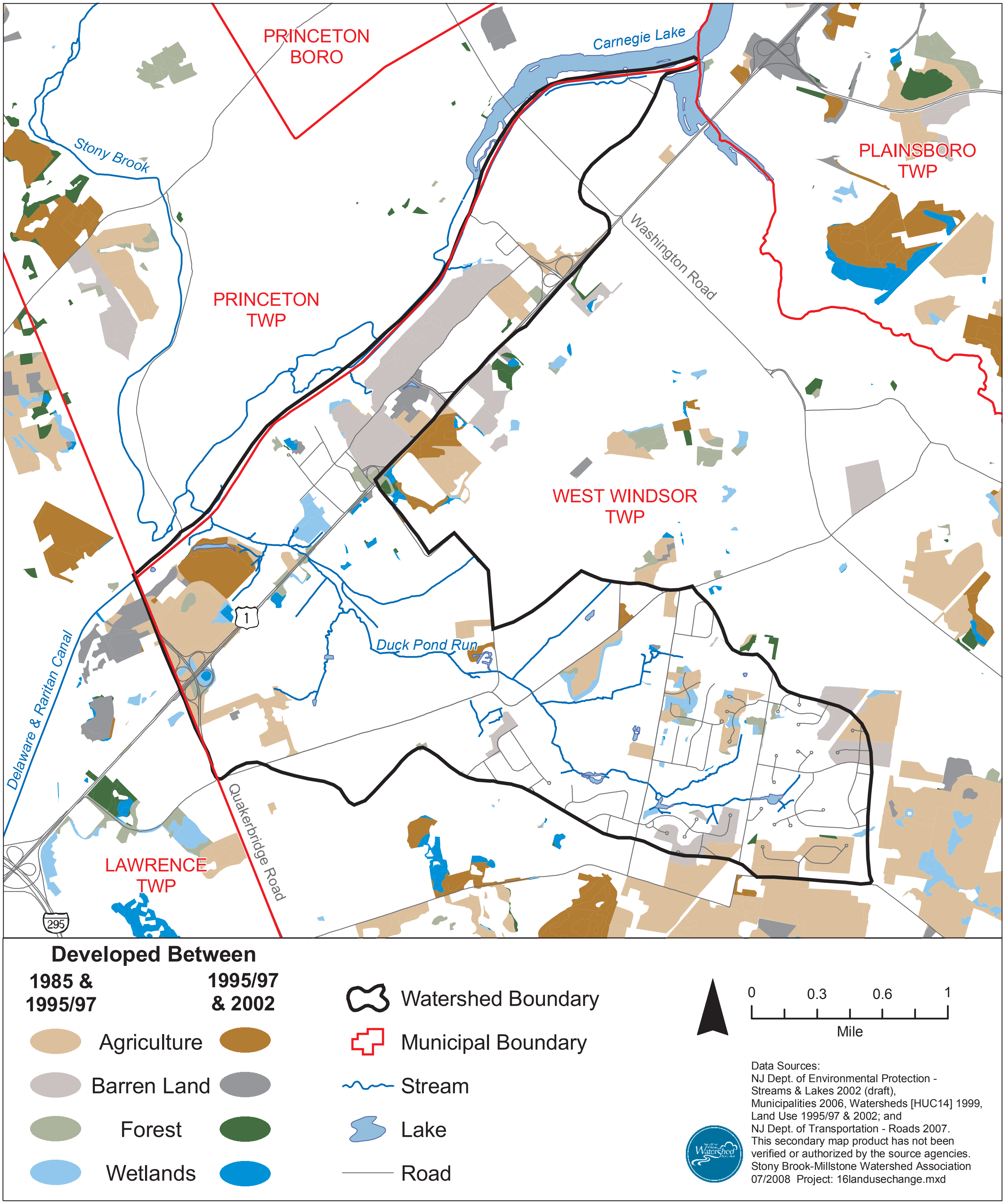
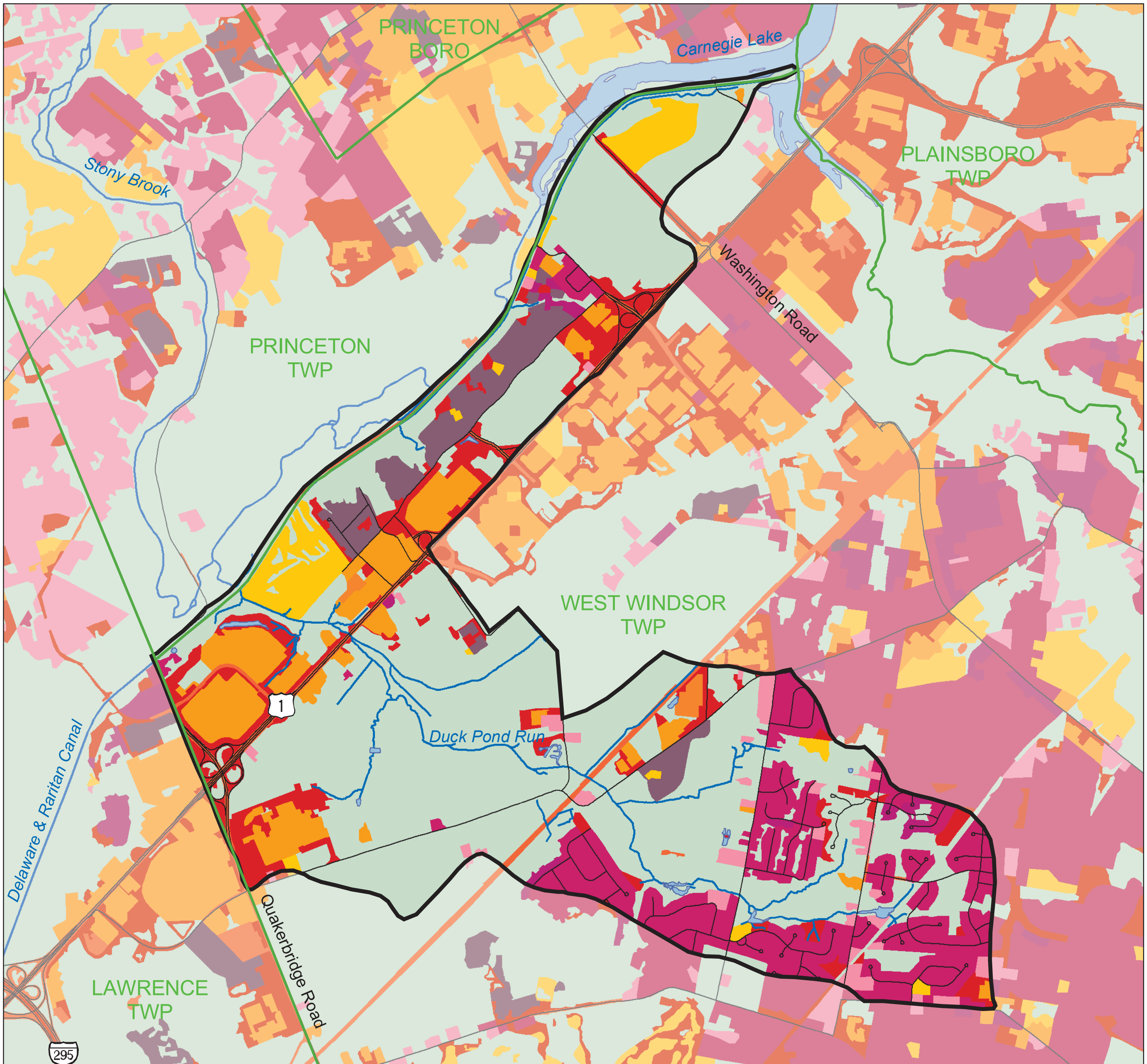


Figure 16: Land Use Changed to Urban/Developed Between 1986 and 1995/97 and Between 1995/97 and 2002 in Duck Pond Run Watershed



Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006, Watersheds [HUC14] 1999, Land Use 1995/97 & 2002; and
NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
07/2008 Project: 16landusechange.mxd

Figure 17: Urban/Developed Land Use (2002) in Duck Pond Run Watershed



Urban/Developed Land Use

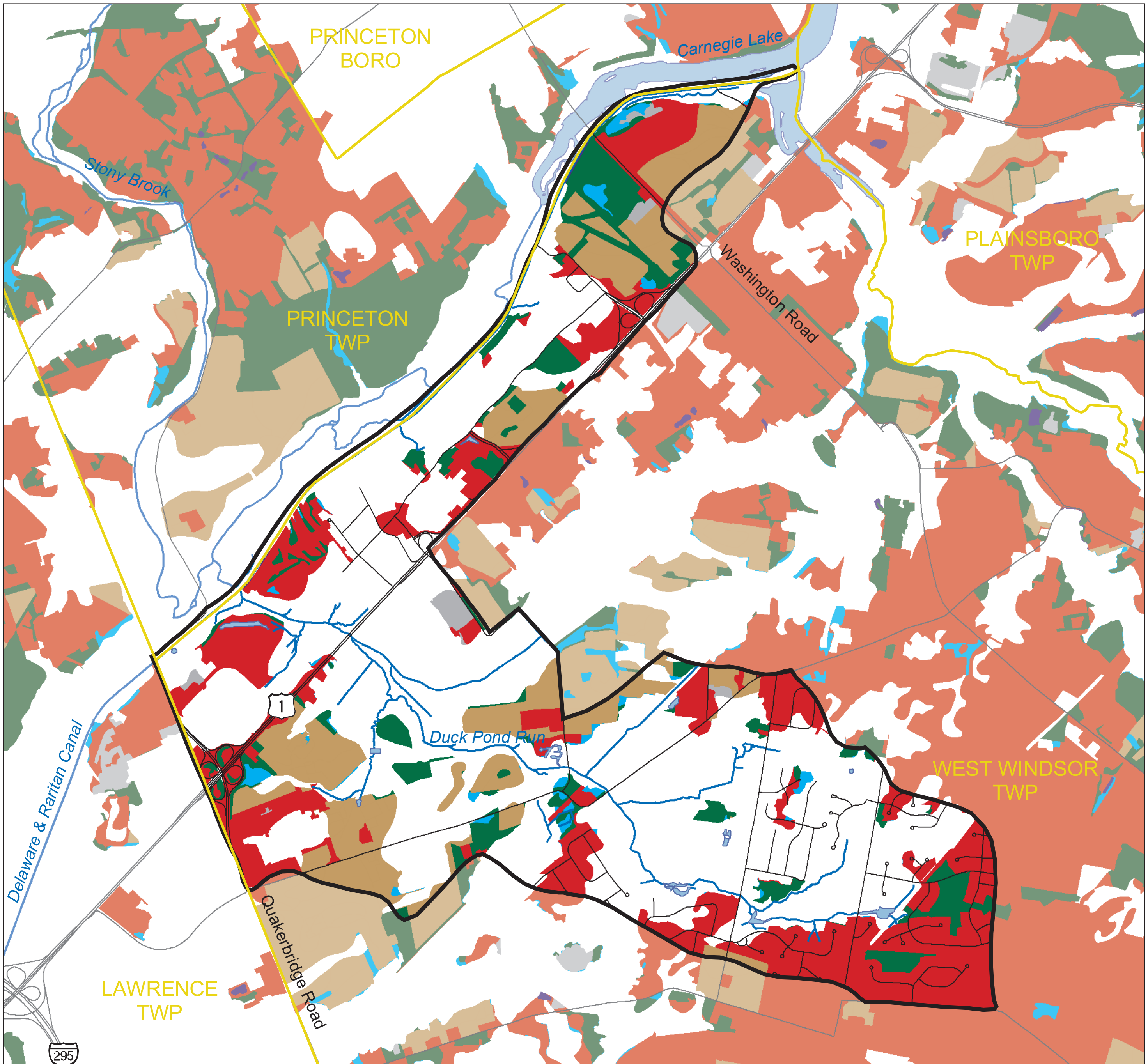
- Non-urban/Undeveloped
- Residential, Rural Single Units
- Residential, Low Density Single Units
- Residential, Medium Density Single Units
- Residential, High Density or Multiple Units
- Athletic Field/Recreational Area
- Commercial Complex/Services
- Industial Complex
- Transport/Utility
- Built-up or Other Urban/Mixed Urban

- Watershed Boundary
- Municipal Boundary
- Stream
- Lake
- Road

0 0.3 0.6 1
Mile

Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Land Use 2002, Municipalities 2006, Watersheds [HUC14] 1999;
NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
07/2008 Project: 17landuseurban.mxd

Figure 18: Land Use (2002) in Areas with High Groundwater Recharge in Duck Pond Run Watershed



High Groundwater Land Use

- Agriculture
- Barren Land
- Forest
- Urban/Developed
- Water
- Wetlands

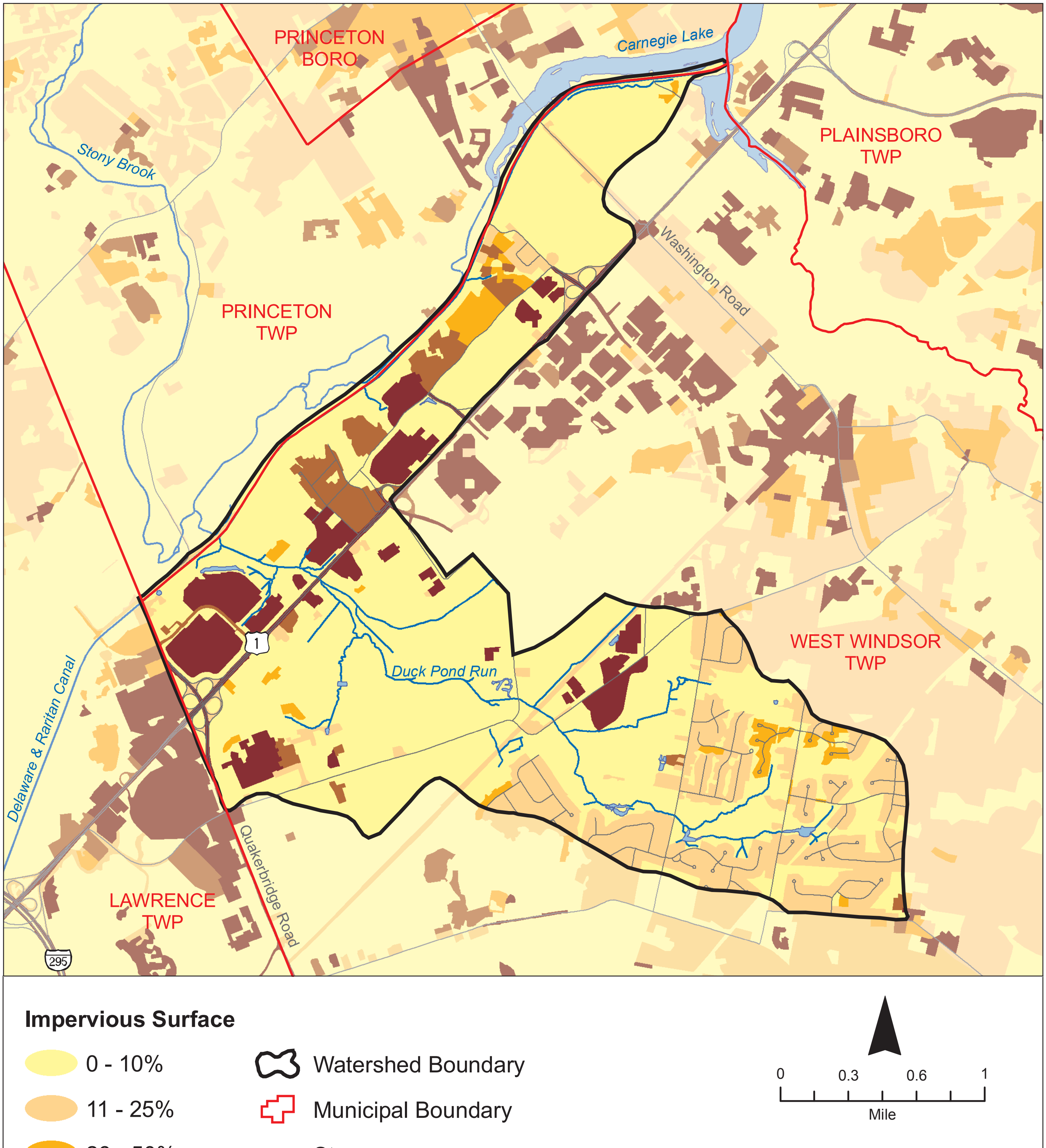
- Watershed Boundary
- Municipal Boundary
- Stream
- Lake
- Road

High groundwater recharge areas have a recharge rate of at least 10 inches per year.

0 0.3 0.6 1
Mile

Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Land Use 2002, Municipalities 2006, Watersheds [HUC14] 1999, NJ Geological Survey - Groundwater Recharge 1997; NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
07/2008 Project: 18landusehighgroundwater.mxd

Figure 19: Impervious Surfaces (2002) in Duck Pond Run Watershed



Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Land Use 2002, Municipalities 2006, Watersheds [HUC14] 1999; NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
07/2008 Project: 19impervioussurface.mxd

Figure 20: 2002 Riparian Land Cover in Duck Pond Run Watershed

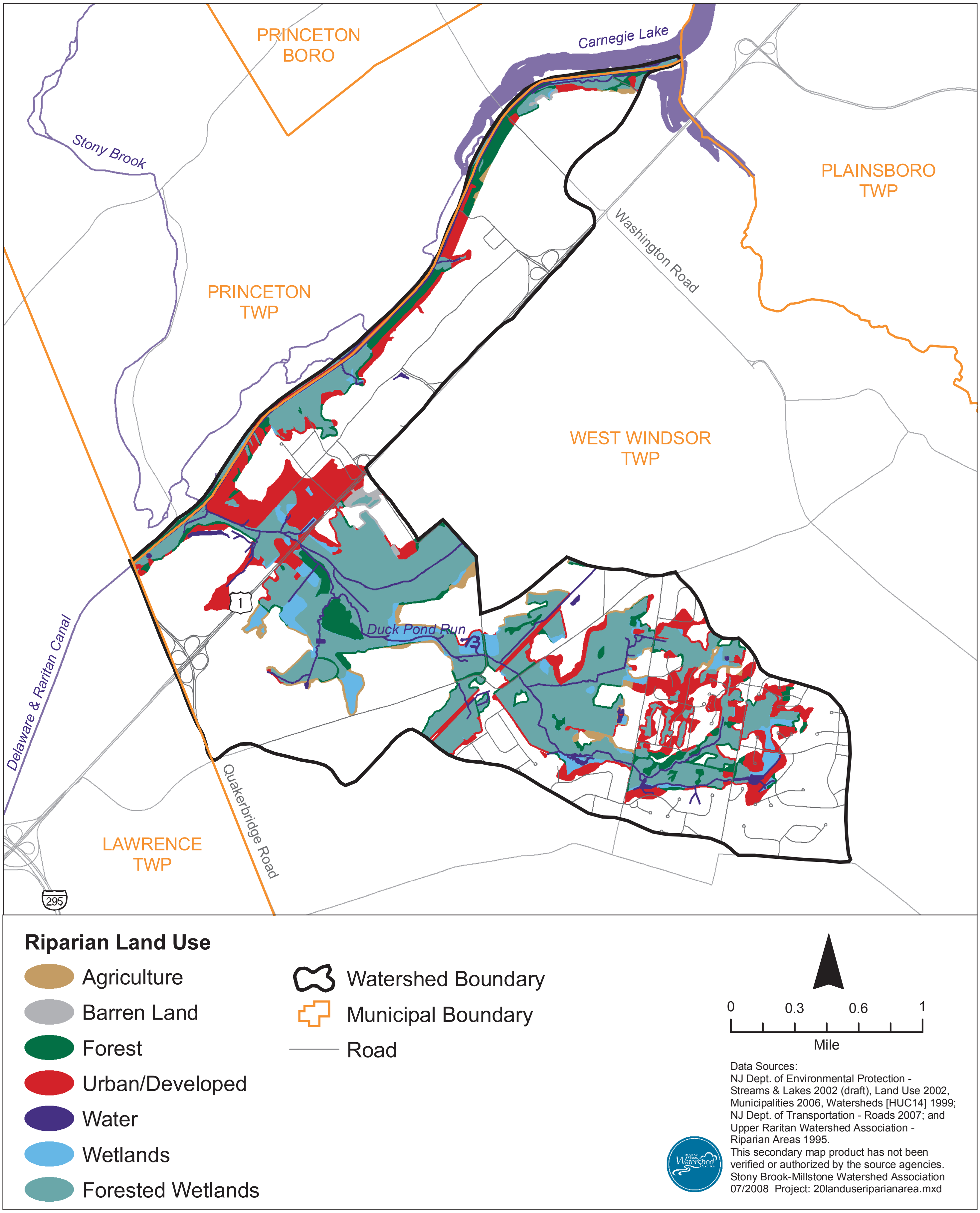
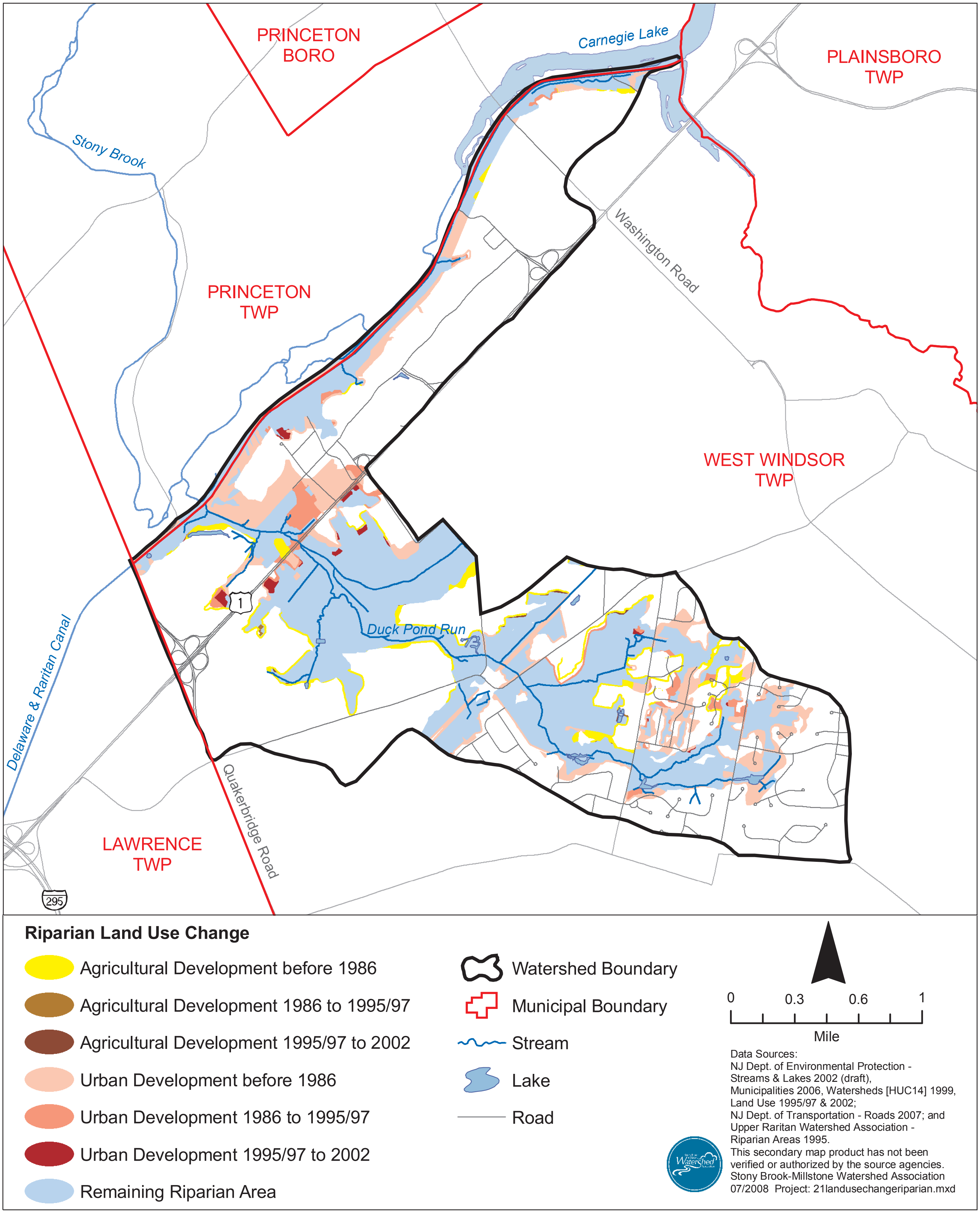
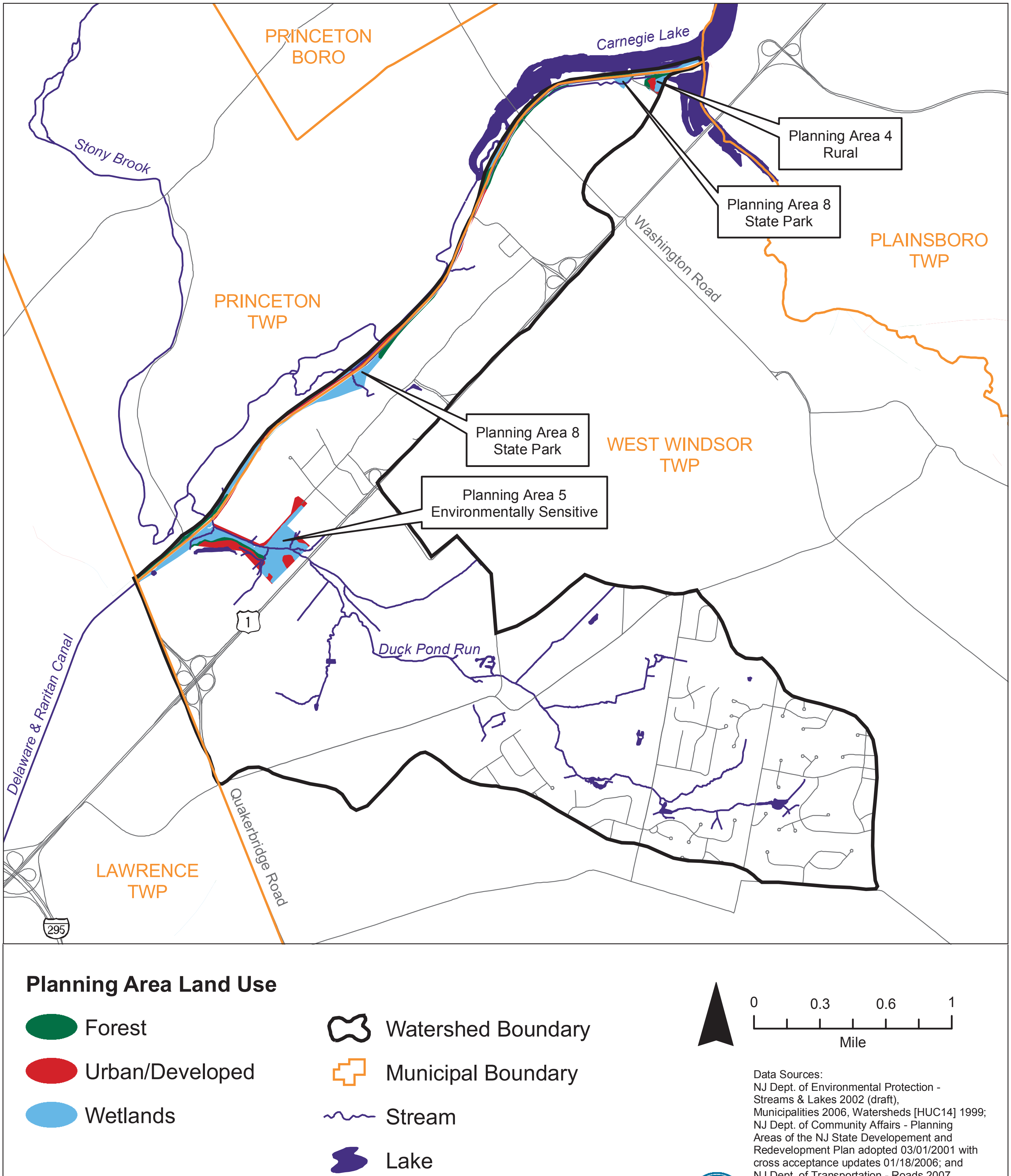


Figure 21: Riparian Land Cover Conversion in Duck Pond Run Watershed



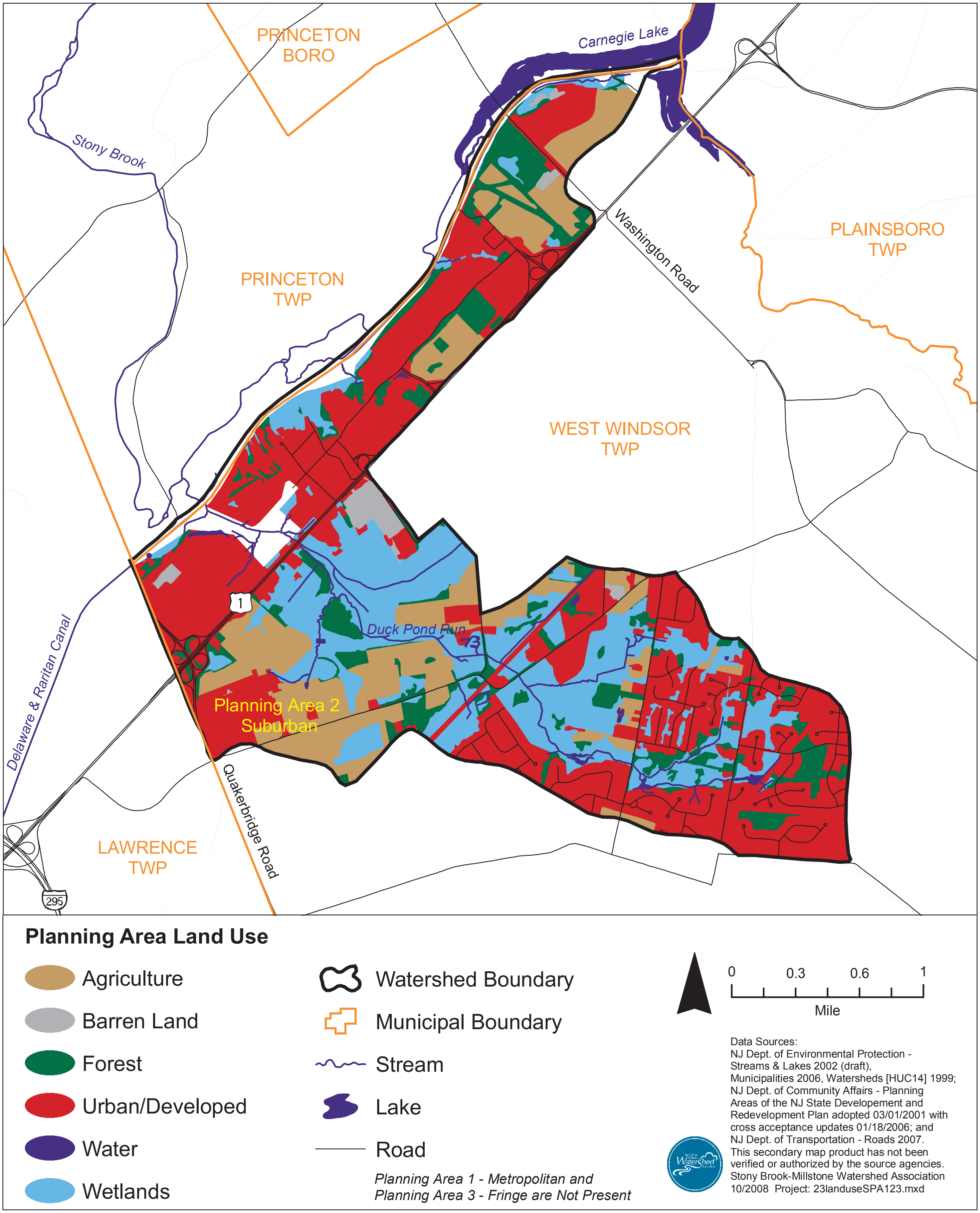
Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006, Watersheds [HUC14] 1999, Land Use 1995/97 & 2002;
NJ Dept. of Transportation - Roads 2007; and Upper Raritan Watershed Association - Riparian Areas 1995.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
07/2008 Project: 21landusechangeriparian.mxd

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



Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006, Watersheds [HUC14] 1999;
NJ Dept. of Community Affairs - Planning Areas of the NJ State Developement and Redevelopment Plan adopted 03/01/2001 with cross acceptance updates 01/18/2006; and
NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
10/2008 Project: 22landuseSPA44b58.mxd

Figure 23: Land Use (2002) in State Planning Areas PA 1, 2, & 3 in Duck Pond Run Watershed



Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006, Watersheds [HUC14] 1999;
NJ Dept. of Community Affairs - Planning Areas of the NJ State Developement and Redevelopment Plan adopted 03/01/2001 with cross acceptance updates 01/18/2006; and
NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
10/2008 Project: 23landuseSPA123.mxd

Figure 24: Critical Areas for Water Resource Protection in Duck Pond Run Watershed

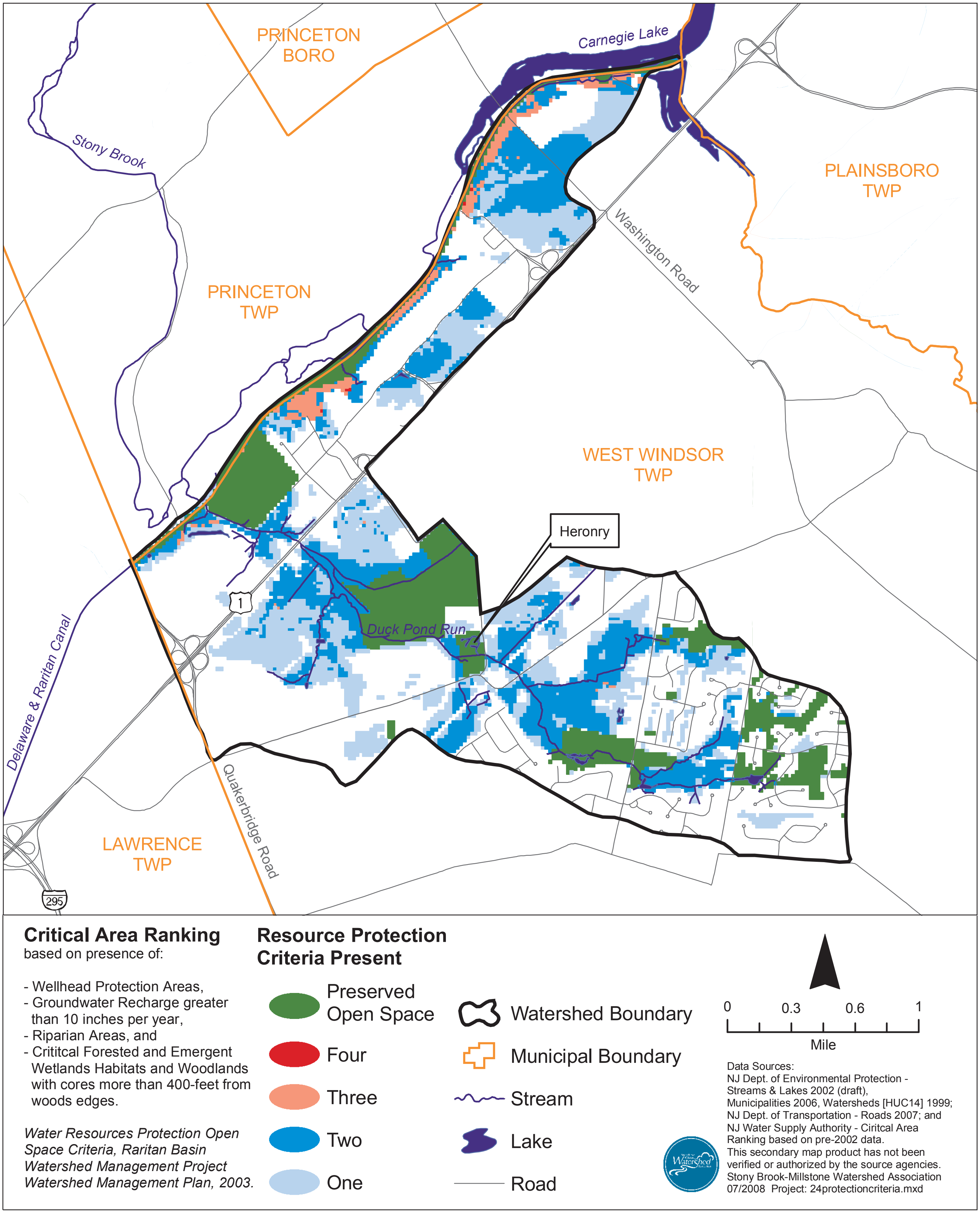
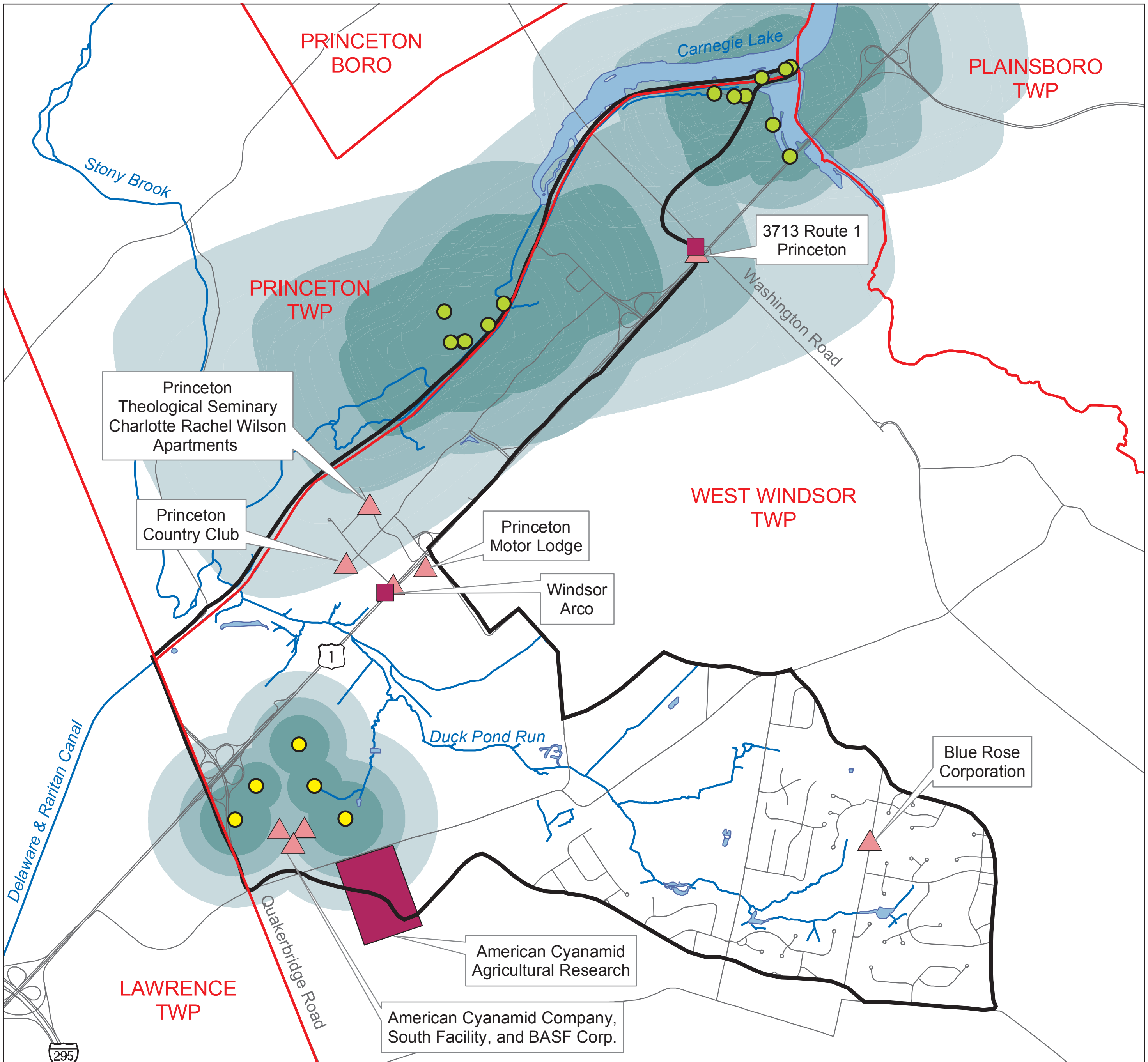


Figure 25: Community Water Supply Wellhead Protection Areas and Known Contaminated Sites in Duck Pond Run Watershed



Wellhead Protection Areas

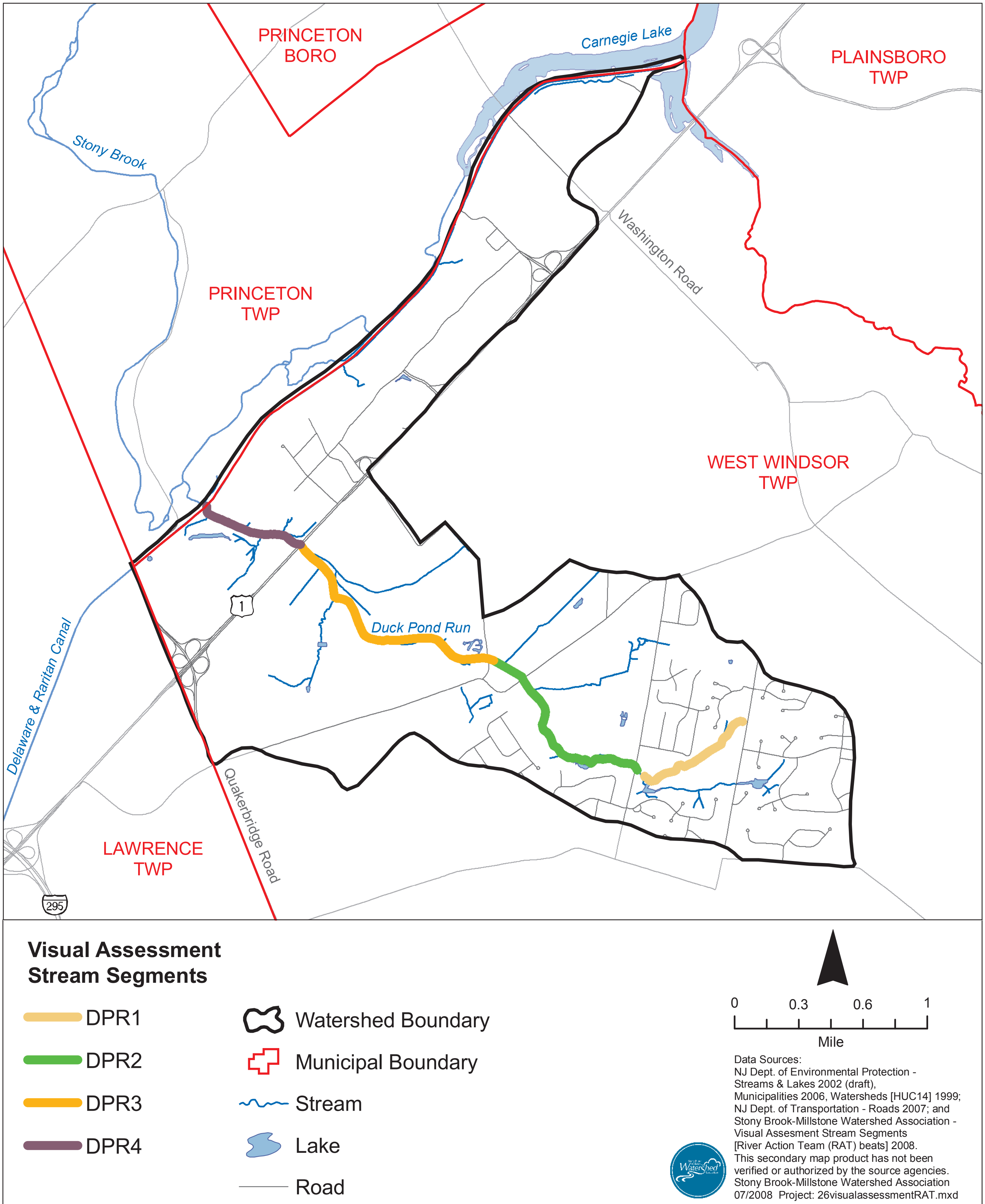
A Wellhead Protection Area (WHPA) is an area calculated around a Public Community Water Supply (PCWS) or a Public Non-Community Water Supply (PNCWS) well in New Jersey that delineates the horizontal extent of groundwater captured by a well pumping at a specific rate over two year (Tier 1), five year (Tier 2) and twelve year (Tier 3) periods of time for unconfined wells.

0 0.3 0.6 1
Mile

- Tier 1 (2 Years)
- Tier 2 (5 Years)
- Tier 3 (12 Years)
- Watershed Boundary
- Public Well
- Non-Community Well
- Contaminated Site
- Classification Exception Area
- Municipal Boundary
- Stream
- Lake
- Road

Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006, Watersheds [HUC14] 1999, CEAs 2003, Known Contamined Sites reported on Active List 05/09/2008;
NJ Geological Survey - Public Wells 2000, Non-Community Wells 2004, Wellhead Protection Areas 2007; and
NJ Dept. of Transportation - Roads 2007.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
10/2008 Project: 25wellheadprotection.mxd

Figure 26: Visual Assessment Stream Segments in Duck Pond Run Watershed



Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006, Watersheds [HUC14] 1999;
NJ Dept. of Transportation - Roads 2007; and
Stony Brook-Millstone Watershed Association - Visual Assesment Stream Segments [River Action Team (RAT) beats] 2008.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
07/2008 Project: 26visualassessmentRAT.mxd

Figure 27: Biological Monitoring Sites in Duck Pond Run Watershed

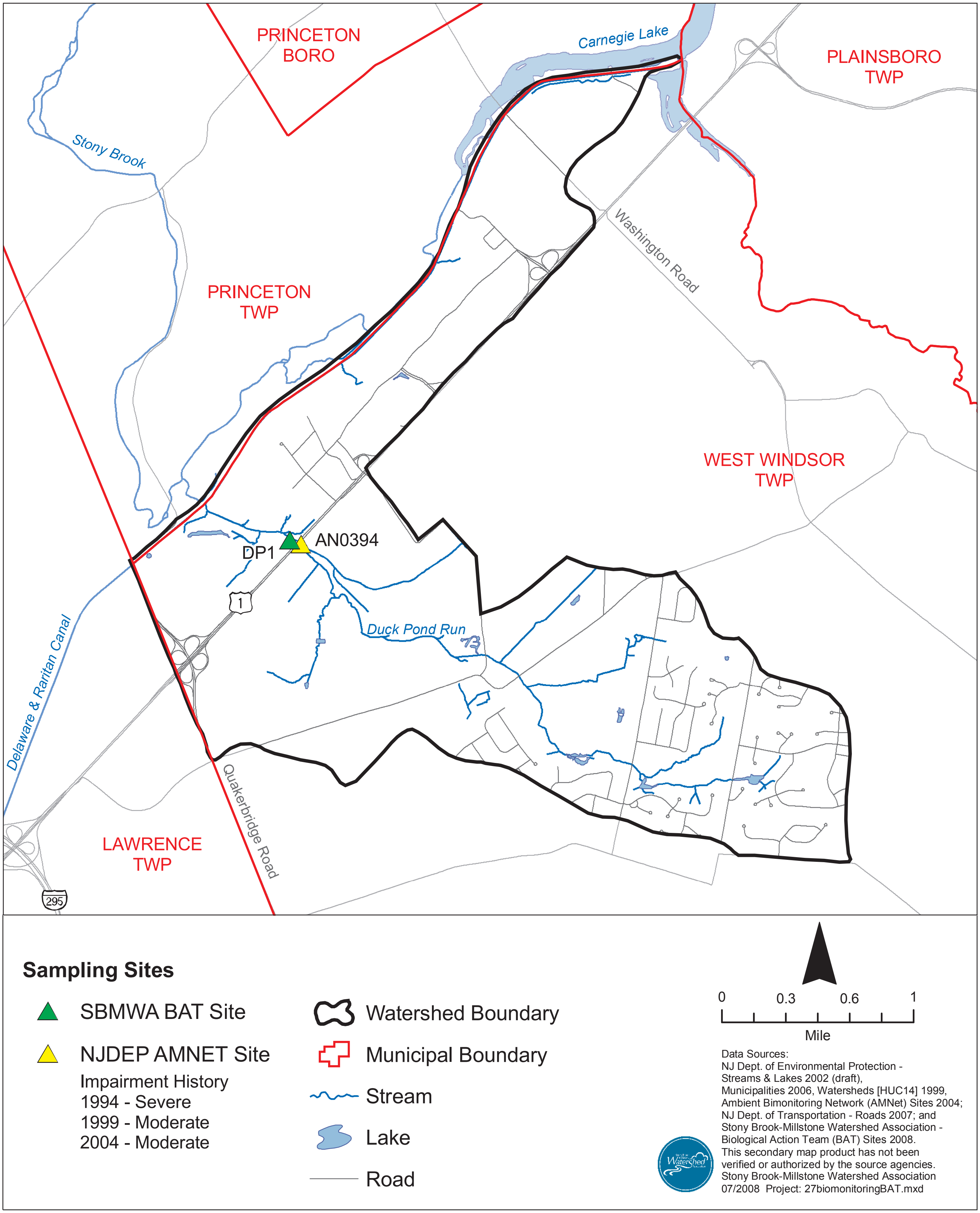
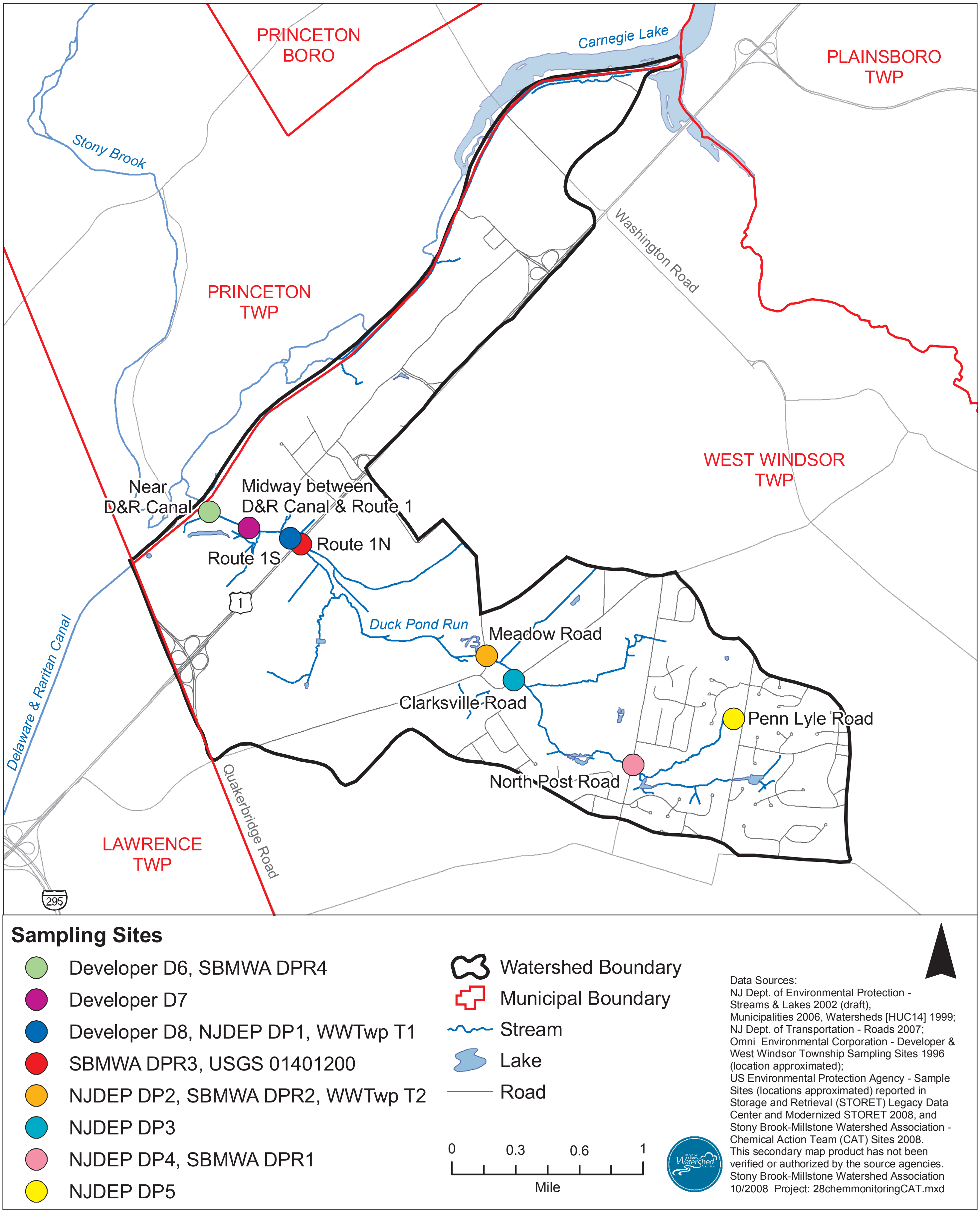
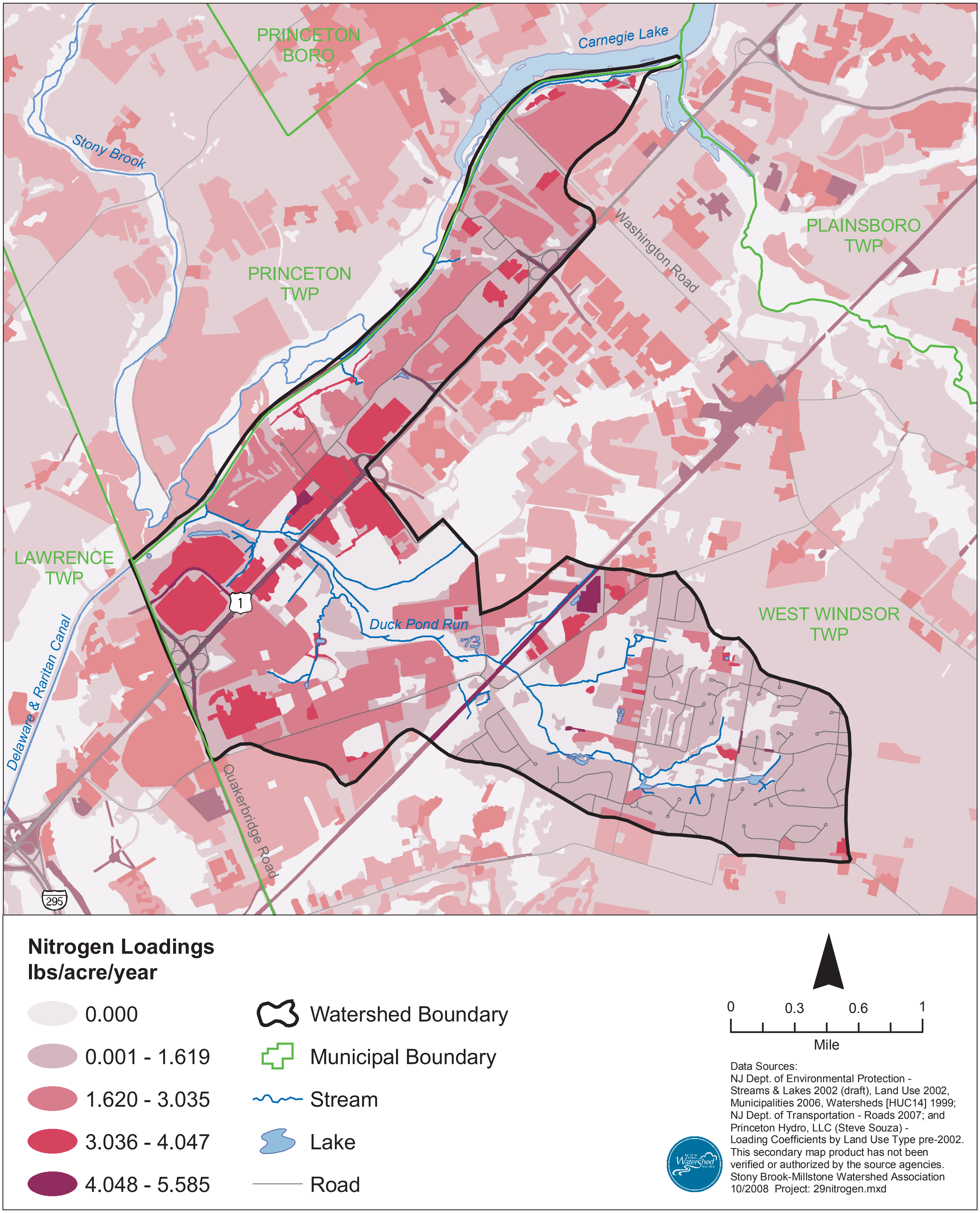


Figure 28: Chemical Monitoring Sites in Duck Pond Run Watershed



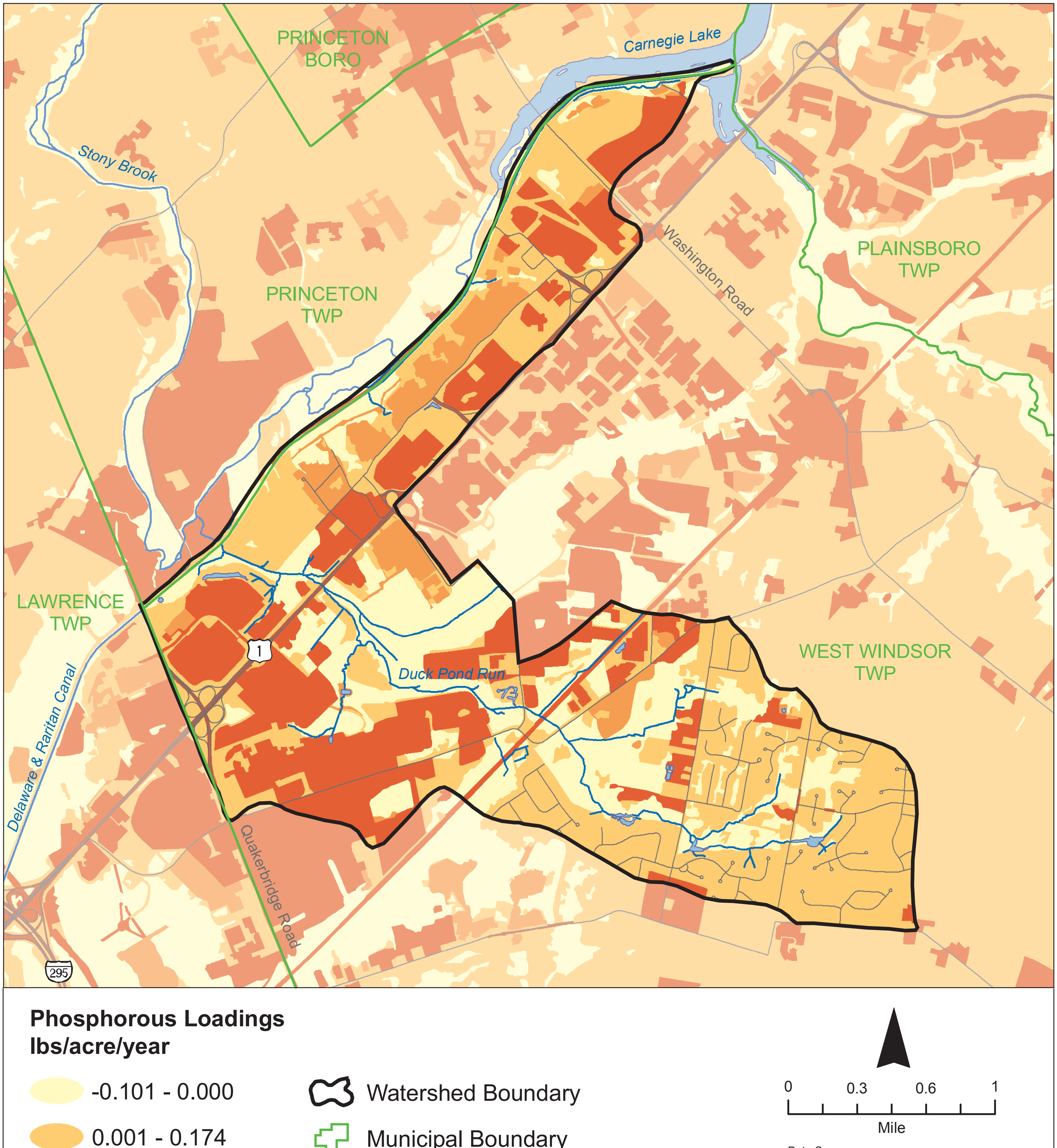
Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Municipalities 2006, Watersheds [HUC14] 1999;
NJ Dept. of Transportation - Roads 2007;
Omni Environmental Corporation - Developer & West Windsor Township Sampling Sites 1996 (location approximated);
US Environmental Protection Agency - Sample Sites (locations approximated) reported in Storage and Retrieval (STORET) Legacy Data Center and Modernized STORET 2008, and Stony Brook-Millstone Watershed Association - Chemical Action Team (CAT) Sites 2008.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
10/2008 Project: 28chemmonitoringCAT.mxd

Figure 29: Nonpoint-Source Nitrogen Loadings in Duck Pond Run Watershed



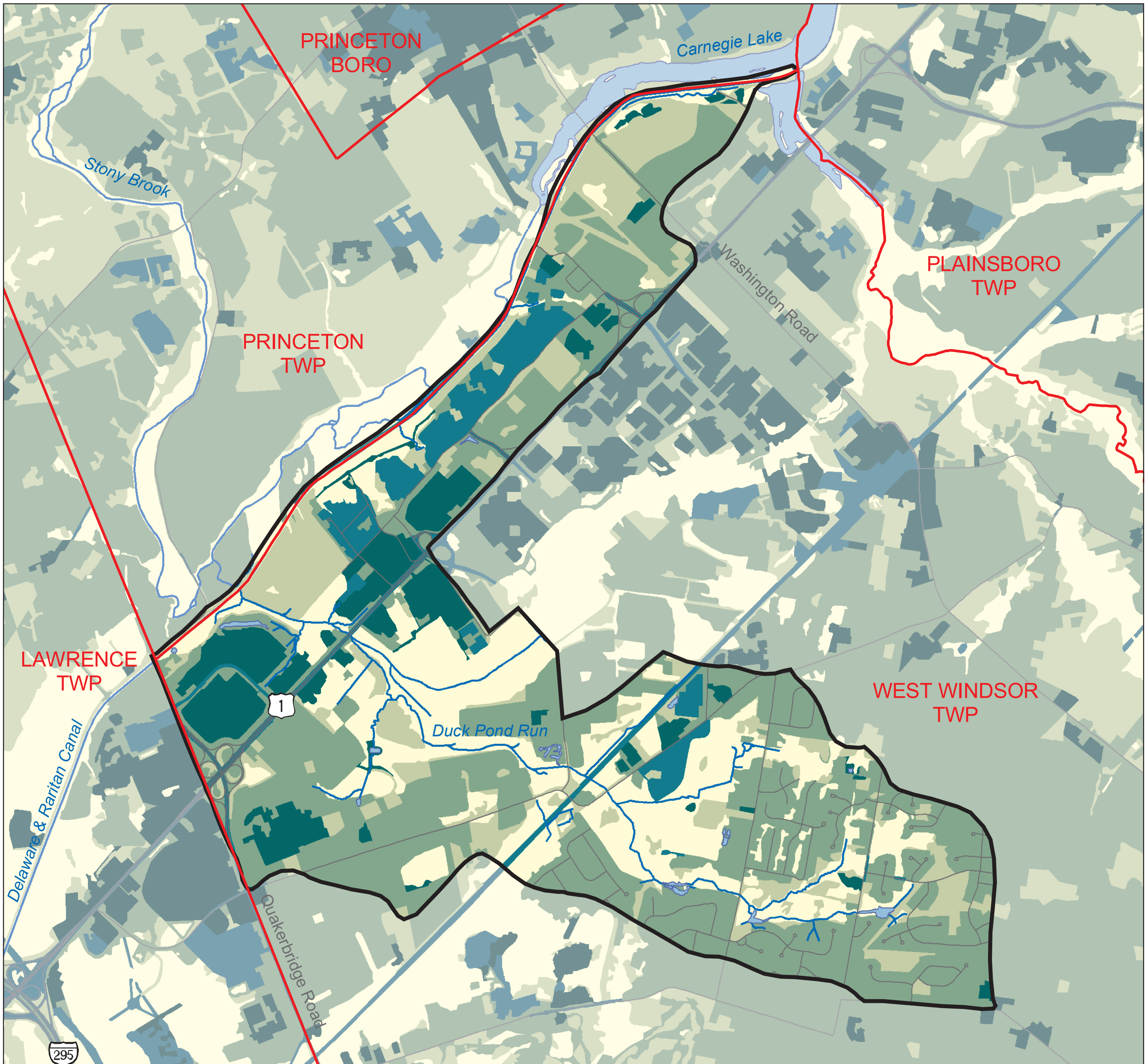
Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Land Use 2002, Municipalities 2006, Watersheds [HUC14] 1999; NJ Dept. of Transportation - Roads 2007; and Princeton Hydro, LLC (Steve Souza) - Loading Coefficients by Land Use Type pre-2002.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
10/2008 Project: 29nitrogen.mxd

Figure 30: Nonpoint-Source Phosphorous Loadings in Duck Pond Run Watershed



Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Land Use 2002, Municipalities 2006, Watersheds [HUC14] 1999;
NJ Dept. of Transportation - Roads 2007; and
Princeton Hydro, LLC (Steve Souza) - Loading Coefficients by Land Use Type pre-2002.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
10/2008 Project: 30phosphorous.mxd

Figure 31: Nonpoint-Source Total Suspended Sediment Loadings in Duck Pond Run Watershed



Total Suspended Sediment Loadings lbs/acre/year

- -80.9 - 0
- 0.1 - 202.3
- 202.4 - 404.7
- 404.8 - 809.4
- 809.4 - 1618.8

Watershed Boundary
Municipal Boundary
Stream
Lake
Road

0 0.3 0.6 1
Mile

Data Sources:
NJ Dept. of Environmental Protection - Streams & Lakes 2002 (draft), Land Use 2002, Municipalities 2006, Watersheds [HUC14] 1999; NJ Dept. of Transportation - Roads 2007; and Princeton Hydro, LLC (Steve Souza) - Loading Coefficients by Land Use Type pre-2002.
This secondary map product has not been verified or authorized by the source agencies.
Stony Brook-Millstone Watershed Association
10/2008 Project: 31suspendedsediment.mxd