Hamilton Township (Mercer County)
Hydrology Report

Developed by the Rutgers Cooperative Extension Water Resources Program
Funded by Hamilton Township, Mercer County, New Jersey

September 9, 2011

Acknowledgements

The *Hamilton Township (Mercer County) Hydrology Report* has been produced by the **Rutgers Cooperative Extension Water Resources Program**. Principal author was **Steven Yergeau, Ph.D.**, Post-Doctoral Associate, under the supervision of **Jeremiah Bergstrom,** Senior Research Project Manager and **Christopher Obropta, Ph.D., P.E.**, Associate Extension Specialist.

Support material and guidance was provided by **Richard Watson, P.E., P.P., C.M.E.,** Director of the Department of Water Pollution Control (Hamilton Township), **Richard Williams, P.E., P.P., C.M.E.,** Hamilton Township Engineer, **Lester Finch**, Chairman, Hamilton Township Environmental Commission, and **Haig Kasabach,** Hamilton Township Environmental Commission and Planning Board.

Funding for this project was generously provided by the **Township of Hamilton, Mercer County, NJ**.

Table of Contents

Executive Summary

In June 2011, the Rutgers Cooperative Extension (RCE) Water Resources Program partnered with Hamilton Township to evaluate watershed and stormwater management issues and develop recommendations for improving and protecting water resources in the community. The partners are working together to complete a Township-wide evaluation of water resource management needs and to set forth priorities and recommendations for actions needed to address hydrologic issues.

The hydrologic plan document compiles a thorough inventory of existing information and data related to water resource management, planning, policy, and actions in Hamilton Township. The inventory includes:

- **Infrastructure;** storm sewer system and outfall mapping, detention basin and stormwater management facility information
- **Plans;** municipal stormwater plans, natural resource inventory/mapping, watershed-based plans, and geographic information system (GIS) data
- **Policies;** local ordinances, master plan and statutes; state regulations and standards; and federal guidance

RCE Water Resources Program has completed the evaluation outlining the Township's current water resources management issues and hydrologic functions. The plan includes detailed GIS mapping and a summary of water resource related issues. Finally, the evaluation outlines opportunities for improving policy and management practices to protect hydrologic function, improve water quality, and sustain freshwater resources in the Township.

Using this document, the RCE Water Resources Program will develop a series of water resources management goals and objectives. Site investigations of existing stormwater management facilities and watershed resources will also be completed. This information will be compiled into an Implementation Plan that will focus on strategies needed to protect hydrologic function, improve water quality, and sustain freshwater resources in Hamilton Township.

Hamilton Township through its Master Plan and established ordinances has made stormwater management and improving the quality of life of its residents a priority. Land use and stormwater controls are in place to manage stormwater runoff and to not further degrade the water quality of streams, lakes, and rivers in the municipality. However, problems do persist in the municipality despite the efforts of the Township to control and manage stormwater flows.

Flooding occurs in many of the streams within Hamilton Township and water quality is experiencing impairments with elevated heavy metals, nutrients, and sedimentation.

The stormwater problems facing Hamilton Township are related to the increase in developed areas and the associated impervious cover that accompanies it. Programs designed to reduce the amount of impervious cover on new developments through green building techniques, to disconnect the current impervious through rain gardens, rain barrels, or use of pervious pavements, and educate residents of the municipality on their role in improving runoff water quality can help to address many of the problems noted in this report. In addition, projects should be implemented to improve infiltration of precipitation into the ground to alleviate flooding and water quantity issues facing Hamilton Township. This can be done by retrofitting existing detention basin, replacing and disconnecting existing impervious cover, and maintaining natural lands (forests and wetlands) as open spaces.

Expanding new development areas will only exacerbate water quality problems by increasing the frequency and intensity of storm flows and flooding, while also increasing pollution. Hamilton Township has the opportunity to incorporate innovative ways to retrofit or redevelop existing sites, as well as, plan new development including low impact development, to use mixed-use development (projects that integrate different land uses, such as restaurants, residences, offices, and parks), to perform 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 maintain centralized growth areas in the municipality. These approaches can enable Hamilton Township to accommodate growth occurring within its borders while significantly reducing the harm from such development.

Introduction

Stormwater is a major issue that impacts water quality and quantity as land use changes alter the hydrology of a community. As our natural areas become developed, stormwater runoff volumes and peak flows are increased, causing flooding and degrading local water quality. Stormwater is a major contributor to New Jersey's water pollution; it mirrors the land it flows over as it picks up pollutants from the landscape and deposits those pollutants to the nearest waterbody. Although often not the case, stormwater flooding and water quality issues can be addressed simultaneously with comprehensive cost-effective solutions.

The New Jersey Department of Environmental Protection (NJDEP) has recently released new stormwater management and permitting regulations. In the past, NJDEP's Stormwater Management Regulations only concentrated on controlling peak stormwater flows from new developments for large storm events. The new Stormwater Management Regulations focus not only on managing water quantity, but also on improving water quality and promoting groundwater recharge. The new rules also require new development to incorporate nonstructural stormwater management strategies into their designs. Additionally, these new rules provide a recipe for developing Regional Stormwater Management Plans, which aim to minimize flooding, eliminate nonpoint source pollution, and assist municipalities in better managing their stormwater. Stormwater issues are typically addressed on a site by site basis often aggravating issues in the larger community as one site release stormwater that is being detained at the same rate as an adjacent site, creating more flooding problems and high stream flows that cause channel and stream bank erosion. Through regional and community-wide stormwater management planning, water quality and water quantity issues are evaluated on a watershed basis, taking into account how various management strategies can be designed to complement each other minimizing flooding while maximizing water quality improvements and groundwater recharge. While conducting stormwater management on a watershed basis is ideal, often multiple towns are contained within one watershed, requiring them to work together to develop a comprehensive plan then taking the plan recommendations back to their town and implementing the strategies for the good of the watershed, for the good of their town. Ultimately, the NJDEP Stormwater Management Regulations require municipalities to take individual responsibility for managing stormwater along with the associated flooding and pollution. But through proper planning and partnerships with surrounding municipalities, this task can be accomplished in a cost-effective manner.

The NJDEP Municipal Stormwater Permitting Program addresses pollutants entering our waters from certain storm drainage systems owned or operated by local, county, state, interstate, or federal government agencies. These systems are called "municipal separate storm sewer systems" (MS4s) and are regulated by a General New Jersey Pollution Discharge Elimination System (NJPDES) permit to municipalities throughout the State. The permit requirements are divided into two municipal tiers: Tier A municipalities are generally located within more densely populated regions or along the coast (Hamilton Township is a Tier A municipality); Tier B municipalities are generally more rural and in non-coastal areas. New development and redevelopment is addressed, in part, by requiring municipalities to adopt and enforce a stormwater management plan and ordinance in accordance with the NJDEP's Stormwater Management Regulations. These rules focus on requiring the municipalities to clean and maintain their municipal separate storm sewer system (MS4) and pass ordinances that will limit pollution at its source such as Pet Waste Ordinance, Litter Ordinance, Improper Disposal of Waste Ordinance, Wildlife Feeding Ordinance, and others.

Stormwater is a concern because of two main issues: the increased volume of runoff from precipitation events due to developed areas' inability to percolate precipitation back into the ground and contamination of stormwater runoff from pollutants that accumulate on the landscape over which it flows. The increased volume of stormwater runoff leads to flooding, increased erosion of stream banks and loss of groundwater supplies due to a lack of infiltration into aquifers. Stormwater pollutants degrade habitats for aquatic life or impair populations of organisms and have far reaching effects on water supplies as they may contaminate reservoirs, increase costs to treat drinking water and wastewater, and pollute groundwater.

New Jersey is facing serious water resource problems that continue to worsen as development expands at a rapid pace throughout the State. Although the new stormwater management and permitting rules will significantly change the way New Jersey manages its stormwater runoff, the rules only apply to new development. This leaves the stormwater runoff impacts from existing developments to be addressed through the new municipal stormwater permit rules and the implementation plans for total maximum daily loads (TMDLs). The result will likely be voluntary programs that may have little hope for success unless significant funding can be allocated to support public outreach and education programs centered on progressive stormwater management at the municipal level.

Purpose of the Hydrology Report

The purpose of this report is to synthesize available data related to hydrology and stormwater management with respect to Hamilton Township and its authority within the State. Information regarding the township's existing infrastructure, localized flooding issues, watershed drainage, and stormwater management strategies was reviewed. In addition, a series of recommended actions was developed for improving and protecting water resources within Hamilton Township to continue compliance with the actions and intent of stormwater regulations.

The evaluation is used to set priority areas where appropriate agencies can utilize effective watershed restoration tools. Goals of watershed restoration include improvement of water quality, education of local residents, businesses, and municipal staff on nonpoint source pollution reduction, and a measurable reduction in nonpoint source pollution in waterways within Hamilton Township.

Hydrologic Characterization & Assessment

Across America, poor planning of development is allowing farmlands, forests, wetlands, and viewsheds to be consumed at an astonishing rate. Countless acres of naturalized areas have become strip malls, roads, and industrial facilities. This consumption of natural lands and 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 forefront as development threatens to destroy remaining natural spaces. The consequences of these losses are clear: pollutants are elevated in many of the State's waterways, wildlife populations are showing signs of distress due to pollution, beautiful views are lost, and the quality of life of its residents is diminished.

In order to better identify the causes of declining environmental health, we need an understanding of Hamilton Township and the changes that have occurred within its 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.

The results of this project will be used to provide an assessment of Hamilton Township in order to understand the causes of any stormwater problems and to identify appropriate solutions or recommend steps to protect the streams and rivers within the municipality. Information has been collected on soil types, geology, land uses, water quality, flood dynamics, discharges to surface and groundwater, and stormwater controls and is been evaluated regarding its impacts on and from stormwater runoff.

Geography & Topography

Located in Mercer County in central New Jersey, Hamilton Township covers over 40 square miles east of the City of Trenton, the capital of the State (Figure 1). Hamilton was established in 1686 but wasn't incorporated as a township by an Act of the New Jersey Legislature until April 11, 1842, from portions of the now-defunct Nottingham Township. Hamilton Township derives its name from the village of Hamilton Square, which was named for Alexander Hamilton.

The elevations of lands found within Hamilton Township range from approximately 0 feet above mean sea level (AMSL) to 121 feet AMSL (Figure 2). The lowest elevations are in the westerns portion of the municipality, primarily in the area of the Trenton-Hamilton Marsh and the Delaware River (Figure 2). The highest elevations (>100 feet) are found along the Eastern edge of the township (Figure 2). These areas contain the headwaters for waterways such as Edge's Run and Doctors Creek.

Geology

Rock formations exert an influence on soils and therefore on vegetation and agriculture, drainage rates, water transportation, water supply, and types of land use suitable for placement. Due to the variable resistance to erosion exhibited by the sedimentary and metamorphic rock formations in Hamilton Township, stream patterns and topography are controlled by outcrop patterns and the orientation of the underlying bedrock. The majority of Hamilton Township lies within the Coastal Plain Physiographic Province, with a portion of northwestern part of the municipality within the Piedmont Province (Figure 3).

The Coastal Plain in New Jersey is characterized by extensive sedimentary deposits of Cretaceous (<135 million years ago) to Pliocene (>5 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 (Owens *et al.*, 1998). Bedrock formations within the Piedmont range from Middle Proterozoic (1,600-1,000 million years ago) to Upper Cretaceous (100-65 million years ago) in age. This bedrock consists of consolidated rock exposed at or near the ground surface. Groundwater is stored in bedrock aquifer systems and is transmitted along fractures in this bedrock system. The Coastal Plain consists of unconsolidated deposits and groundwater is stored and transmitted through the openings or spaces between the unconsolidated 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 (United States Geological Survey [USGS], 2009).

Geology has a large influence on water resources in Hamilton Township. The unconsolidated nature of the sediments in the Coastal Plain Province has two major implications from the standpoint of water resources. First, streams and rivers of the Coastal Plain Province are typified by large amounts of alluvial sediment because of the erodibility of the underlying deposits. This may result in water quality degradation through sedimentation of streams and increased water treatment costs.

Second, the lack of cementation of the buried sediments means that the sandy units have a great deal of open pore space between the sand grains. Water moves more easily through these spaces, so the sediments serve as very productive aquifers. Increasing development in Hamilton Township also increases the amount of impervious cover. This has the effect of decreasing the amount of water flowing into the aquifer by diverting precipitation over the landscape to streams and not downward into the soil. Placement of new development, and therefore impervious cover, out of areas that have high value for recharging the aquifers will help to maintain water levels for drinking, irrigation and industrial use. Planning for and purchasing open spaces in areas of high groundwater recharge will also ensure that these areas maintain their supplies of ground and drinking water.

With many formations containing deposits of glauconitic soils (Englishtown, Woodbury, and Merchantville Formations; Figure 4), use of infiltration detention basins and septic systems in residential development is a concern for Hamilton Township. Glauconitic soils are easily compacted which makes them unsuitable for septic systems and can lead to a loss of infiltration capacity. The major limiting factor in determining the suitability of septic system placement is based on the fact that the underlying soils may percolate too slowly or not at all after compaction, which lowers the capacity of a residential septic system or infiltration basin to perform properly. Easily compacted glauconitic soils may prevent proper percolation through the soil for these types of water control systems.

Soils

The soils that underlie an area exert an influence on the types of vegetation that grow, agriculture that can be performed, drainage patterns and rates, water transport, water supply, and the types of suitable land uses that may be developed on them. Soils are classified based upon their textures, composition, and ability to drain water. Soils surveys have been performed and mapped by the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) for the State of New Jersey. As previously discussed, the majority of Hamilton Township lies within the Coastal Plain Physiographic Province, with a portion in the northwestern part of the municipality falling within the Piedmont Provinces (Figure 3). The Coastal Plain Physiographic Province soils are dominated by sands, silts, clays and gravel while the Piedmont Physiographic Province has sands, silts and some clay dominating the soil. Most of the soils in the Piedmont are underlain by hard bedrock at a depth of anywhere from 2 to 20 feet.

Hydrologic Soil Groups

Based upon the various compositions of sands, silts, and clays found within them, soils infiltrate water to varying degrees. Higher proportions of sands and lower amounts of clay help to promote percolation and higher proportions of clays generally impede infiltration. Sands and larger particles in soil have more pore spaces between them, allowing for the transport of water. Clays and silts, on the other hand, are smaller particles with fewer spaces between them which impede water movement. A soil's ability to drain water, especially from precipitation, is evaluated and reported as the hydrologic soil group. Much of Hamilton Township contains soils classified as hydrologic soil group A, covering approximately 27.8% in the entire municipality (Figure 5; Figure 6; Table 1). Hydrologic soil group A represents soils with a high rate of infiltration and is representative of the coarse soils seen in the Coastal Plain Physiographic

Province. The second most common soil group, hydrologic soil group B, underlies 23.8% of the municipality (Figure 5; Figure 6). These soil groups are classified as having moderate infiltration rates due to the moderately coarse textures of the soil (Table 1).

Hydrologic soil group C is characterized by slow infiltration rates due to the fine textures of these soils, which comprise 11.9% of soil groups in the Township (Table 1; Figure 6). Soils in hydrologic group D are found primarily as streambeds within Hamilton Township, and cover approximately 13% of the township's area (Figure 5; Figure 6). Class D soil groups have very slow infiltration rates since most of these soils are clayey or have an impervious layer near the surface (Table 1).

Stormwater quantity and flooding issues could be exacerbated in Hamilton Township due to the covering of areas with high infiltration rates with impervious cover. By creating a layer that prevents rain fall and snowmelt from getting into the soil, stormwater flows have a direct pathway to local waterways and stormwater collection systems. This direct connection increases both the flow rate to these waters and systems, but also the volume of water that reaches them. By breaking this direct connection, and allowing waters to flow back into the ground, these events may be ameliorated.

Table 1: Hydrologic soil group definitions.

Hydrologic Soil Group	Definition
A	High infiltration rates. Soils are deep, well-drained to excessively-drained sands and gravels.
B	Moderate infiltration rates. Deep to moderately deep, moderately well and well drained. Soils that have moderately coarse textures
B/D	Dual hydrologic groups are given to certain wet soils that can be adequately drained. The first letter applies to the drained condition, the second to the undrained. Moderate to very slow infiltration rates.
C	Slow infiltration rates. Soils with layers impeding downward movement of water, or soils that have moderately fine or fine textures.
C/D	Dual classification. Slow to very slow infiltration rates.
D	Very slow infiltration rates. Soils are clayey, have a high water table, or are shallow to an impervious layer.
Source: USDA NRCS, 2002	

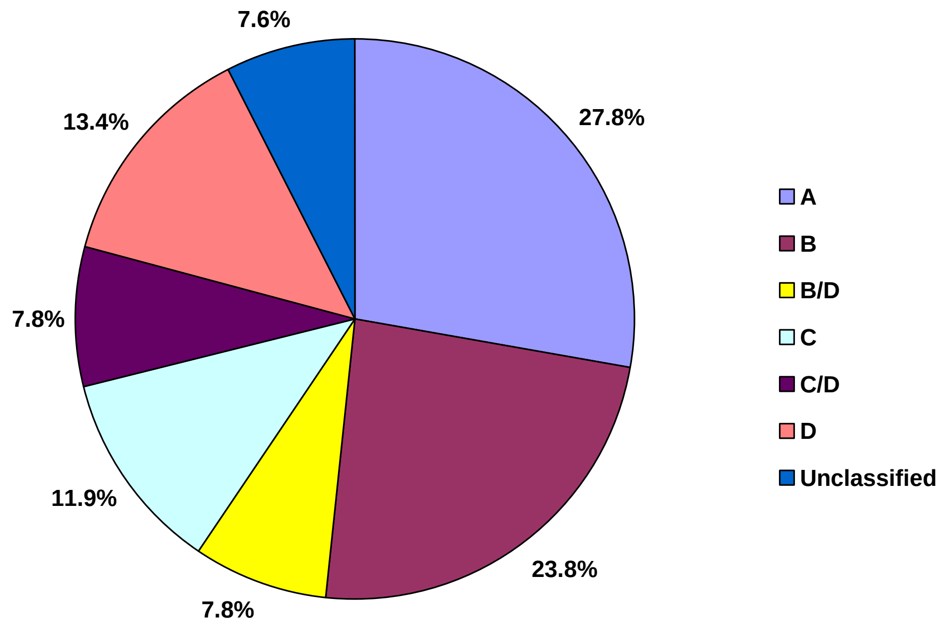

Figure 6: Hydrologic soil groups in Hamilton Township (Mercer County). (Letter classifications are defined in Table 1).

Potential for Acid Soils

Sediments resulting from historical marine and esturaine deposition with sulfide-bearing (pyritic) materials have the potential to form sulfuric acids. If left in an undisturbed state, they are benign. The development of sulfuric acids occurs when sulfide minerals, such as pyrite and/or elemental sulfur, in these sediments oxidize upon exposure to the air through drainage or earth-moving operations. The overall acid-sulfate, soil-forming process involves a complex chain of reactions that connect the oxidation of iron sulfides to the release of iron oxyhydrates and sulfuric acids (New Jersey Geological Survey [NJGS], 2010).

Only Coastal Plain soils in Hamilton Township have the potential to form acids (Figure 7). The Englishtown, Magothy, Merchantville, and Woodbury Formations are all areas of potential acidic soil formation (Figure 7). These formations contain some form of pyritic material that can act as a catalyst to create sulfuric acids under proper conditions. The majority of Hamilton Township's agricultural areas are located in these formations (Figure 7; Figure 8).

Production of acids from these soils can have a number of effects on the natural and man-made environments. Flushing of acidic leachate to surface waters can damage aquatic areas through fish kills and loss of aquatic macroinvertebrates. Contamination of groundwater with heavy metals can occur due to metals becoming soluble, and therefore mobile, in acidic environment. Damage can occur to municipal infrastructure (pipes, tanks, culverts) through corrosion of these materials which may lead to their failure. Crop production can be affected, as amendments need to be added to the acidic soils to reduce their acidity and possible deleterious effects on the vegetation. Development and redevelopment activities that include earth-moving need to take precautions when working within sediments with the potential to form acidic environments so as to minimize the impacts of any formed sulfuric acids.

Climate

Hamilton Township lies in the Central Climate Zone of New Jersey, which has a northeast to southwest orientation, running from New York Harbor and the Lower Hudson River to the great bend of the Delaware River in the vicinity of the City of Trenton. This region has many urban locations with large amounts of pollutants produced by the high volume of automobile traffic, residential air conditioning and heating systems, and industrial processes. The concentration of buildings and paved surfaces in these areas serve to retain more heat, thereby affecting local temperatures. Because of the asphalt, brick, and concrete, the observed nighttime temperatures in heavily developed parts of the zone are regularly warmer than surrounding suburban and rural areas. This phenomenon is often referred to as a “heat island” (Office of the NJ State Climatologist, 2011).

The northern edge of the Central Climate Zone is often the boundary between freezing and non-freezing precipitation during wintertime. In summer, the northern reaches often mark the boundary between comfortable and uncomfortable sleeping conditions. Areas to the south of the Central Climate Zone tend to have nearly twice as many days with temperatures above 90 degrees Fahrenheit than the 15 to 20 commonly observed in the central portion of the State. Based on recorded observations from years 1895 through 2000 for Southern New Jersey, Hamilton Township receives, on average, 44.60 inches of precipitation annually, and the mean temperature is 53.0 degrees Fahrenheit (Office of the NJ State Climatologist, 2011).

Trends in long-term precipitation from 1895 to 2010 indicate that average annual rainfall is increasing for the State and Southern New Jersey. Annual mean precipitation for New Jersey was 43.86 inches from 1895 through 1970, 1971 through 2000 it was 47.20 inches, and for 2001 through 2010, it was 48.58 inches (Office of the NJ State Climatologist, 2011). For Southern New Jersey, the mean annual precipitation was 43.67 inches from 1895 through 1970, 46.00 inches from 1971 through 2000, and 47.46 inches for 2001 through 2010 (Office of the NJ State Climatologist, 2011). Increasing mean annual precipitation will burden stormwater control systems installed prior to the year 2000, if these increases were not incorporated into their design. Detention basin design for stormwater runoff began to appear as a stormwater management practice in the late 1960s to control peak runoff rates from new development sites. The decades-old design approach may not be effective in managing increasing annual precipitation and could contribute to flooding and system failure in the future.

Land Use

Land uses constantly change to reflect the needs of a municipality. As more residents move into an area, such as Hamilton Township, more homes and associated infrastructure are needed to provide basic services to these residents. Septic and sewer systems, roadways and transit areas for travel, water supply pipes, electrical grids and lines, and telecommunications systems need to accompany new developments. For much of the State of New Jersey, many of the newly developed areas and their associated infrastructure are being placed on former agricultural lands. Water quality becomes a concern for the urbanizing regions because of the proximity to streams and brooks of the agricultural lands being converted and the increase in impervious surfaces which connect precipitation events to these nearby waterways.

Hamilton Township is dominated by urban land uses (Figure 8; Figure 9). Approximately 59.0% of the municipality is comprised of residential properties. Residential, single unit, medium density development comprises 39.6% of these residential properties. Single unit, medium density development has been defined by the NJDEP as residential urban/suburban neighborhoods greater than $^1/_8$-acre and up to and including $^1/_2$-acre lots (Anderson *et al.*, 1976). These areas generally contain about 30 to 35% impervious surface areas (Anderson *et al.*, 1976). Urban land use also includes land used for commercial, industrial, recreational, and transportation purposes including residential developments.

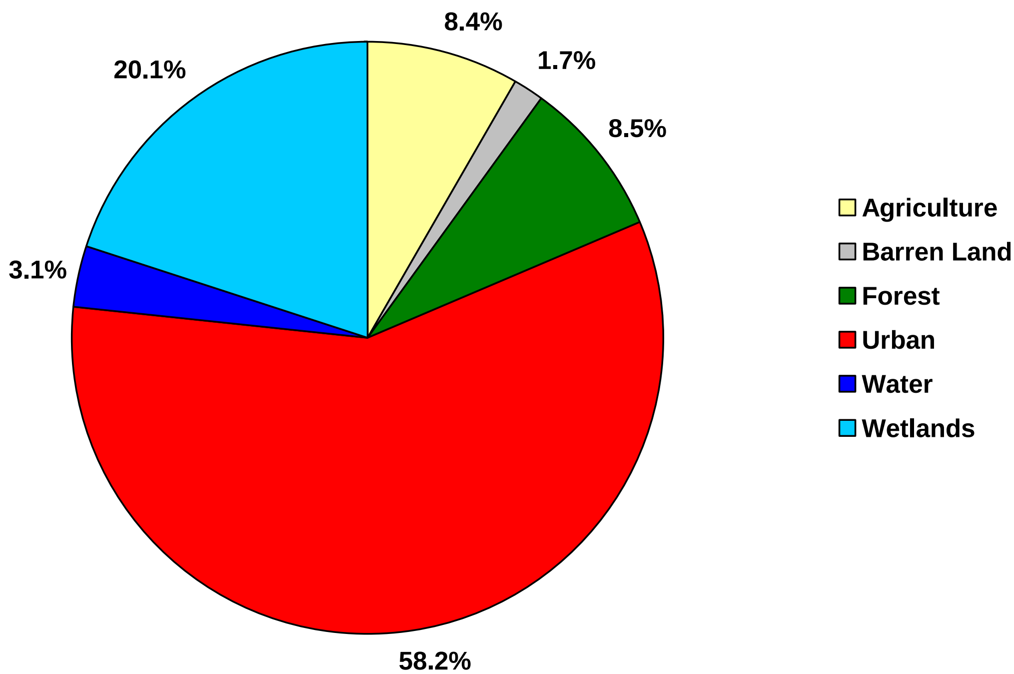

Figure 9: 2007 Land uses within in Hamilton Township (Mercer County).

Natural lands (forests, wetlands, and water) make up approximately 31.7% of Hamilton Township (Figure 8; Figure 9). These areas generally have lower amounts of impervious cover than urban areas as they lack the associated infrastructure mentioned previously. In addition, these natural areas help to improve the negative impacts experiences with stormwater. Forests improve water quality by filtering pollutants, reducing floods by slowing stormwater and providing habitat to a variety of plant and animal species. 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.

Impervious Cover

The loss of natural lands, including wetlands and agricultural and riparian areas, to development has resulted in significant hydrological alterations in Hamilton Township. Urbanization alters watersheds by clearing vegetation, changing land uses, and fragmenting the landscape with development. Shaw (1994) identified five major effects on hydrology due to urbanization: 1) a higher percentage of precipitation is converted to surface runoff; 2) precipitation is converted to runoff at a faster rate; 3) peak flows in streams are elevated; 4) low flow in streams is decreased due to reduced inputs from groundwater storage; and 5) stream water quality is degraded. These effects are echoed by Ehrenfeld (2000) as likely to occur in wetlands, with direct hydrological changes in wetlands commonly occurring by filling, ditching, diking, draining, and damming.

Increasing impervious surfaces associated with urbanization account for many of the alterations to watershed hydrology. Urbanization converts natural habitats to land uses with impervious surfaces (such as asphalt and concrete) that reduce or prevent soil infiltration of precipitation. Impervious surfaces create surface runoff with greater velocities, larger volumes, and shorter times to flow concentration (Brun and Band, 2000). Increased impervious surfaces contribute to decreased groundwater recharge by reducing available groundwater recharge area (Rose and Peters, 2001). The rapid routing of water to urban streams reduces surface and shallow subsurface storage, which results in lower long-term groundwater recharge, and subsequently, reduced groundwater discharge during the period of baseflow (Rose and Peters, 2001). Reductions in baseflow can: 1) cause a decline in water quality as pollutants become more concentrated; 2) degrade riparian habitats as water levels decrease; and 3) interfere with navigable waterways (Brun and Band, 2000). Large amounts of impervious surfaces have negative impacts by increasing the amount of water and associated contaminants and sediments that flow through the watershed. This runoff, when managed improperly, is a major pathway for the transportation of pollutants such as debris, fertilizer, bacteria, and/or petroleum products. These pollutants are washed directly into the streams, creeks, and their tributaries located in Hamilton Township, ultimately degrading the surface water quality and necessitating the development of total maximum daily loads (TMDLs). Stormwater runoff also causes recurrent flooding problems in many municipalities in New Jersey, the destruction of habitat along the streambank, and may contribute to manhole discharges.

Based upon the 2007 NJDEP land use/land cover data, Hamilton Township has a mean impervious cover of 15.8%, with many areas within the municipality containing 0% impervious cover (Figure 10). Many of these areas conicide with wetlands and agricultural lands located within the municipality (Figure 10). Areas with 30% to 50% impevious cover are located in many of the residential neighborhoods. As mentioned previously, these areas generally contain about 30 to 35% impervious surface areas (Anderson *et al.*, 1976).

In developed landscapes, stormwater runoff from parking lots, driveways, sidewalks, and rooftops flows to drainage pipes that feed the sewer system. The cumulative effect of these impervious surfaces and thousands of connected downspouts reduces the amount of water that can infiltrate into soils and greatly increases the volume and rate of runoff that flows to waterways. Disconnection is the process of diverting the first flush of stormwater runoff from impervious areas to smaller distributed best management practices (BMPs) for stormwater control and separating roof downspouts from the sewer system. By redirecting runoff from paving and rooftops to pervious areas in the landscape, the amount of directly connected impervious area in a drainage area can be greatly reduced.

For disconnection to be safe and effective, runoff must flow into a suitable receiving area. Stormwater must not flow toward building foundations or onto adjacent property. Typical receiving areas for disconnected runoff include lawns, landscaping, infiltration beds, gardens, and other BMPs. Soil amendments can be used to increase soil permeability if necessary. However, site constraints such as small or non-existent lawns may dictate that runoff be directed into a rain garden or, most commonly, an infiltration practice.

Volume reductions occur through infiltration and evapotranspiration in the receiving area. The potential exists for disconnected stormwater runoff to be completely taken "out of the system" by spreading out and infiltrating over pervious surfaces and BMPs. Stormwater that eventually flows onto an impervious surface and then into the storm sewer should at a minimum be initially detained by flowing over rough, pervious surfaces such as grass.

Disconnection decreases the peak discharge by reducing the volume of runoff that enters the sewer and by increasing the discharge time over which it enters. Also, paving and roofs are inherently distributed over a drainage area. Connected systems concentrate and centralize runoff, causing peak discharges from individual properties to accumulate in a relatively small number of manmade conveyances. By contrast, individual on-lot disconnection helps to keep separate the peak discharge from each individual property.

Stormwater runoff contains deposited atmospheric pollutants, debris, petroleum hydrocarbons, sediment, particles of roofing material, nutrients, and wildlife droppings. The concentrations of these pollutants are reduced as stormwater infiltrates and is broken down into soils and is taken up into plant roots through a distributed and disconnected stormwater management approach.

Conversion of areas with high impervious cover by designating areas within Hamilton Township for increased stormwater infiltration through BMPs, such as rain gardens, is one method to reduce stormwater flow and does not require setting aside large tracts of land for construction. The general theory is to provide portions of the landscape where stormwater typically flows overland and changing the nature of the surface such that some of the stormwater volume is allowed to infiltrate into the ground. This requires permeable soils that allow stormwater to quickly seep into the soils before becoming saturated to the point of inefficiency. This would spread the load of stormwater control over a large number of smaller infiltration areas, including individually-owned properties in residential areas in the form of rain gardens or infiltration strips.

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

Additional information on impervious cover will be incorporated into the Implementation Plan after field visits are completed by the RCE Water Resources Program. These surveys will evaluate a number of areas within Hamilton Township to seek opportunities for disconnection of impervious cover by residents and other property owners through rain gardens or rain barrels and replacement of asphalt and concrete with pervious pavement. Based upon this field survey, additional recommendations on reducing impervious cover within the municipality may be developed.

Hydrology

Waterbodies

Hamilton Township contains portions of four major watersheds: Assunpink Creek, Delaware River, Crosswicks Creek, and Doctors Creek (Figure 11). There are approximately 90.5 miles of rivers and streams within the municipality; these include the Assunpink Creek along the northern edge of town, Miry Run and its tributaries, Pond Run and tributaries, Edges Brook, Back Creek, Doctors Creek and tributaries, and a section of the Delaware River (Figure 12). Hamilton Township is within NJDEP's Watershed Management Areas (WMA) 11 and WMA 20 (Figure 11).

Lakes and ponds located within Hamilton Township include Hamilton Veteran's Park Lake, Gropp Lake, and Spring Lake (Figure 12). The largest of these Spring Lake (61.96 acres) and the smallest of these is Veteran's Park Lake (16.14 acres) (Figure 12). Of these four waterbodies, only Spring Lake is natural, while the others are man-made. The purposes for creating these lakes and ponds include recreation (Gropp Lake) and water supply (Veteran's Park Lake). The waterbody designated Dam Site 21 along Miry Run (Figure 12) was created for stormwater and flood control (NJDEP, 2011).

These man-made impoundments and lakes in Hamilton Township may be accumulating sediments and sediment-bound nutrients and harboring potential sinks for other stormwater pollutants. If these impoundments are functioning as a sink for water quality contaminants, then it is likely that the water quality of the lake and its sediments are impacted. Nutrients that are accumulating in these waterways can create eutrophic conditions represented by algal growth and excessive vegetation, loss of dissolved oxygen, and lake filling. The NJDEP maintains a statewide lake monitoring program, but none of the lakes within Hamilton Township are included in the monitoring network at this time.

Wetlands

Wetlands are dynamic ecosystems that are characterized by factors that affect their structure and function. The United States Army Corps of Engineers ([USACE], 1987) defines wetlands as “areas inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.” The National Research Council (1995) defines a wetland as an “ecosystem that depends on constant or recurrent, shallow inundation or saturation at or near the surface of the substrate. The minimum essential characteristics of a wetland are recurrent, sustained inundation or saturation at or near the surface and the presence of physical, chemical and biological features reflective of recurrent, sustained inundation or saturation.” Hydrology plays a critical role in wetland development and ecosystem structure and function. Wetland functions include the ability to provide critical habitat for many species of plants and animals, flood control through storage and retention of floodwaters, water quality protection, trap anthropogenic contaminants and recreational opportunities for surrounding residents (Ehrenfeld *et al.*, 2003). To aggregate information available on wetland hydrology, Bullock and Acreman (2003) reviewed 169 studies on the hydrologic functions of wetlands. They concluded the following: 1) the majority of studies determined that wetlands either increase or decrease a particular component of the water cycle and this has led to the notion that wetlands perform hydrological functions; 2) most studies show that floodplain wetlands reduce or delay floods; 3) there is strong evidence that wetlands evaporate more water than other land types; 4) two-thirds of the studies conclude that wetlands reduce the flow of water in downstream rivers during dry periods; and 5) many wetlands exist because they overlie impermeable soils or rocks and there is little interaction with groundwater (Bullock and Acreman, 2003). Basic hydrologic information, such as seasonal water balance and groundwater table dynamics, is needed to gain a better understanding of wetland ecosystem functions (Sun *et al.*, 2002).

Hamilton Township contains 5,181.2 acres of wetlands, covering about 20% of the township’s area (Figure 13; Figure 9). The majority of these are deciduous wooded wetlands, covering 3,267.1 acres of the municipality (Figure 13). These are generally found in non-tidal lowlands associated with primary, secondary and tertiary watercourses, and isolated wetlands. Included under this heading are all forested wetlands (regardless of tidal influences) dominated by deciduous trees. Deciduous wooded wetlands are closed canopy swamps dominated by deciduous trees normally associated with watercourses, edges of marshes, and isolated wetlands. The important canopy species includes Red Maple (*Acer rubrum*), Black Gum (*Nyssa sylvatica*), Green Ash (*Fraxinus pennsylvanica*), Black Willow (*Salix nigra*), Swamp White Oak (*Quercus bicolor*), Willow Oak (*Q. phellos*), Southern Red Oak (*Q. falcata*), Sweet Gum (*Liquidambar styraciflua*), and Sycamore (*Platanus occidentalis*) (Anderson *et al.*, 1976).

Wetland functions can be impaired if the surrounding watershed is highly urbanized (Ehrenfeld, 2000). More lands are being converted to urban areas to accommodate the growing population on the planet, sometimes at the expense of wetlands. For example, Hasse and Lathrop (2003) used geographic information systems (GIS) land use and land cover data from the New Jersey Department of Environmental Protection to determine the loss of undeveloped lands to urban land uses between 1986 and 1995 for New Jersey. Lands converted include many areas formerly occupied by farmlands, forests, and wetlands that were converted into residential areas. This urbanization was responsible for a total loss of 10,433 hectares (ha) of natural wetlands between 1986 and 1995 (Hasse and Lathrop, 2003). New development in Hamilton Township should incorporate controls to minimize its impact on the municipality's remaining wetlands.

Vernal Pools

Vernal pools are confined wetland depressions, either natural or man-made, devoid of any breeding fish populations. There is no outflow from these depressions, which causes them to fill up during precipitation events (Lathrop *et al.*, 2005). After serval months or a period without precipitation, these areas dry up, preventing long-term populations of fish from permenantly establishing in the vernal pools. They provide critical habitat for a variety of species of amphibians, especially because they lack fish populations that would normally prey on them. Many of the amphibians that utilize vernal pools as breeding habitat are endangered or of special concern in the State (Lathrop *et al.*, 2005).

In 2001, the NJDEP Endangered and Nongame Species Program (ENSP) partnered with the Rutgers Univeristy Center for Remote Sensing and Spatial Analysis (CRSSA) to begin mapping vernal pools across the State (Lathrop *et al.*, 2005). The areas mapped represent potential areas for the location vernal pools, but require field verification by citizen volunteers. These potential vernal pools represent possible breeding habitats for amphibians and other vernal pool obligate and facultative species. In its present state, this database reveals potential vernal pool "hotspots," which are areas of likely amphibian populations (Lathrop *et al.*, 2005).

There are 80 potential vernal pool sites within Hamilton Township (Figure 12). Out of these, only one has been field surveyed and certified as actual vernal pool habitat. Because they are depressions that retain precipitation, vernal pools have the potential to act as temporary storage for stormwater runoff. Surveying these locations and determining their storage capability may help with stormwater and flooding issues in the township.

Groundwater Recharge

Groundwater is not in an endless supply. Water needs to enter the subsurface to recharge and reinvigorate groundwater. Land use activities can disrupt the natural water cycle and the flow of water back into the soil and can diminish water supplies. As impervious cover increases with developed areas, water that would normally infiltrate back into groundwater supplies is diverted as runoff. In an area preserved with natural cover (forests, fields, and wetlands), studies estimate that approximately 50% of precipitation infiltrates into the ground, 10% flows over the land as runoff, and 40% is evaporated back into the atmosphere (Schueler and Holland, 2000). Hamilton Township, with 15.8% impervious cover, is estimated to drop to 42% of the precipitation infiltrating into the ground, 20% of the precipitation flowing away as runoff, and 38% evaporating into the atmosphere (Schueler and Holland, 2000). This is common for areas with up to 20% impervious cover.

Therefore, not all areas, even if left in their natural state, infiltrate water into the subsurface water equally. Different types of soils and the overlaying land uses allow for different rates of infiltration. The underlying geology also plays a role in the capacity of water to percolate. In a developed area like Hamilton Township, the location of suburbanization and urbanization becomes important. Water quality also is an issue as locating heavy development near areas that contain highly permeable soils can cause increased pollution of groundwater from polluted runoff percolating through those soils.

In Hamilton Township, there are 9,669.8 acres (or 37.9% of the entire municipality's area) found within areas of high groundwater recharge (Figure 14). High groundwater recharge is defined as a rate of greater than 10 inches per year (in/yr). These areas need to remain within a naturally permeable landscape to replenish groundwater supplies to the region.

Areas with no groundwater recharge (defined as 0 in/yr) make up 12.3% (3,133.3 acres) of the township's area (Figure 14). Many of the areas classified as having no groundwater recharge include wetlands, hydric soils, and open waters. These areas were not included in the calculation of township area with no recharge. The groundwater recharge model used to develop the groundwater recharge rates does not fully include the complexity of these areas. Because of a lack of data on these types of areas, hydric soils, wetlands, and open waters do not have a calculated groundwater recharge rate. The direction of groundwater and surface water for wetlands is dependent upon a host of site-specific factors that can change seasonally. Hydric soils are recognized as groundwater discharge areas or areas of saturated soils. Therefore, wetlands, hydric soils, and open water can be recharge or discharge areas, both, or neither with respect to groundwater. Specific surveys need to be conducted in there areas to determine the exact nature of the relationship they have with groundwater and their capability to recharge groundwater supplies.

Streamflows & Flood Dynamics

Floods can range from catastrophic events over large areas to minor occurrences affecting a few properties. Many factors go into determining the severability of flooding: season, precipitation amount, level of land development in drainage area, tidal influences, proximity to local waterways, and the condition of the floodplain. Floods are classified based upon their expected rate of occurance. A 100-Year Flood is expected to occur once every 100 years, or have a 1% rate of occuring in a given area. A 500-Year Flood is expected to happen once every 500 years, or have a 0.2% chance of happening. Note that these are the relative rates at which these events are expected to occur, and not aboslutes (i.e., a 100-Year Flood will can occur many times within a century and does not necessarily mean it will only happen once every century).

Historically, flooding has occurred in Hamilton Township primarily due to the Delaware River, Assunpink Creek, and Crosswicks Creek (Federal Emergency Management Agency [FEMA], 2010). These rivers have their flow and stream heights monitored by the USGS. The Delaware River monitoring site is north of Hamilton Township in the City of Trenton. The remaining two monitoring sites for Crosswicks Creek and Assunpink Creek are located in Hamilton Township (Figure 15). The USGS gage at Assunpink Creek (USGS Gage #01463620) has available data going back to 1971, and the Crosswicks Creek gage (USGS Gage #01464500) goes back to 1938. Flooding is recorded when the measured stream height is above an estimated flood height established by the USGS. The flood heights are 12.00 feet for Crosswicks Creek and 8.00 feet for Assunpink Creek (USGS, 2011). Peak flows (in cubic feet per second, cfs) and stream gage height (in feet) are available for both sites and the recorded water heights show several instances of flooding for both Assunpink Creek (Table 2) and Crosswicks Creek (Table 3).

Table 2: Dates of peak flows and heights for the USGS monitoring gage on Assunpink Creek (USGS Gage #01463620). Note that any gage height above 8.00 feet is considered at flood stage.

USGS Gage ID	Date	Discharge (cfs)	Gage Height (ft)
1463620	8/28/1971	1,500	10.90
1463620	2/3/1973	776	8.58
1463620	12/22/1973	638	8.14
1463620	7/21/1975	1,050	9.36
1463620	1/28/1976	357	6.46
1463620	3/23/1977	145	5.41
1463620	1/26/1978	921	8.66
1463620	2/25/1979	865	8.72
1463620	4/1/1980	147	5.48
1463620	5/16/1981	84	4.89
1463620	6/20/1992	196	5.64
1463620	12/13/1992	582	7.66
1463620	1/29/1994	589	7.69
1463620	3/10/1995	140	5.22
1463620	1/21/1996	480	7.23
1463620	10/19/1996	362	6.65
1463620	5/12/1998	313	6.38
1463620	9/17/1999	662	8.00
1463620	8/15/2000	179	5.52
1463620	12/18/2000	294	6.27
1463620	5/19/2002	102	4.86
1463620	2/23/2003	220	6.38
1463620	12/14/2003	248	6.66
1463620	4/3/2005	229	6.51
1463620	1/4/2006	235	6.56
1463620	4/16/2007	1,010	9.25
1463620	2/14/2008	185	5.97
1463620	12/12/2008	239	6.60
1463620	3/16/2010	377	7.38

Table 3: Dates of peak flows and heights for the USGS monitoring gage on Crosswicks Creek (USGS Gage #01464500). Note that any gage height above 12.00 feet is considered at flood stage.

USGS Gage	Date	Discharge (cfs)	Gage Height (ft)
1464500	9/22/1938	4,100	13.00
1464500	9/1/1940	3,360	12.05
1464500	2/8/1941	1,270	8.47
1464500	2/8/1942	566	5.08
1464500	7/8/1943	1,460	9.10
1464500	9/15/1944	2,470	11.05
1464500	7/5/1945	1,960	10.12
1464500	11/29/1945	1,430	9.20
1464500	8/9/1947	737	6.31
1464500	2/14/1948	2,360	10.77
1464500	12/31/1948	1,300	8.95
1464500	3/24/1950	530	5.10
1464500	3/31/1951	1,090	8.03
1464500	3/13/1953	1,840	9.92
1464500	9/12/1954	1,460	9.26
1464500	8/13/1955	1,950	10.10
1464500	7/14/1956	1,360	9.07
1464500	12/17/1956	926	7.27
1464500	2/28/1958	2,130	10.40
1464500	3/7/1959	819	6.74
1464500	9/13/1960	3,200	11.99
1464500	3/23/1961	1,610	9.52
1464500	3/13/1962	1,870	9.97
1464500	3/7/1963	1,150	8.33
1464500	1/22/1964	859	6.94
1464500	2/9/1965	638	5.75
1464500	9/22/1966	1,420	9.18
1464500	3/7/1967	1,840	9.78
1464500	6/13/1968	1,920	9.94
1464500	7/30/1969	1,340	8.73
1464500	4/3/1970	1,460	9.03
1464500	8/28/1971	4,640	13.93
1464500	11/30/1971	1,430	8.96
1464500	11/9/1972	1,720	9.53
1464500	12/21/1973	2,380	10.73
1464500	9/26/1975	1,610	9.27
1464500	1/28/1976	1,480	8.92

USGS Gage	Date	Discharge (cfs)	Gage Height (ft)
1464500	3/23/1977	734	6.77
1464500	9/1/1978	4,860	14.18
1464500	2/25/1979	3,440	12.36
1464500	4/10/1980	1,390	8.97
1464500	5/12/1981	607	6.14
1464500	7/29/1982	1,230	8.53
1464500	4/17/1983	1,430	9.06
1464500	5/30/1984	3,180	11.97
1464500	9/28/1985	754	6.80
1464500	4/17/1986	1,920	10.04
1464500	7/2/1987	1,860	9.93
1464500	1/21/1988	652	6.26
1464500	7/6/1989	4,070	13.22
1464500	10/21/1989	1,360	8.89
1464500	1/12/1991	1,700	9.63
1464500	6/6/1992	982	7.77
1464500	12/12/1992	3,450	12.37
1464500	1/29/1994	3,060	11.81
1464500	5/30/1995	606	6.33
1464500	1/20/1996	3,510	12.46
1464500	10/20/1996	2,320	10.71
1464500	5/10/1998	1,920	10.04
1464500	9/17/1999	3,570	12.54
1464500	8/4/2000	887	7.55
1464500	3/31/2001	1,980	10.14
1464500	3/21/2002	434	5.85
1464500	2/24/2003	2,310	11.82
1464500	2/7/2004	2,050	11.20
1464500	4/3/2005	951	8.20
1464500	10/14/2005	2,120	11.33
1464500	4/16/2007	2,860	13.04
1464500	2/14/2008	966	8.62
1464500	12/12/2008	1,550	10.36
1464500	3/14/2010	3,390	12.84

Extensive and natural floodplains can help to alleviate flooding issues affecting Hamilton Township. The flood zone has been delineated by FEMA in their 1996 Q3 data which was developed by scanning the current effective map panels of the existing paper Flood Insurance Rate Maps (FIRMs), although the digital layer is not intended to replace the paper FIRMs. There are extensive areas within Hamilton Township that have the potential experience flooding due to either a 100-Year or 500-Year Flood event (Figure 16). Approximately 3,981 acres are within the 100-Year Flood zone and 844 acres are in the 500-Year Flood zone (Figure 16). The largest delineated flood zone is located in the southwestern part of the municipality, along the Delaware River, and is comprised primarily of the Trenton-Hamilton Marsh complex (Figure 16).

Riparian Corridors

The New Jersey Water Supply Authority (NJWSA) defines riparian areas as undeveloped areas adjacent to streams that are either within the 100-year floodplain, contain hydric soils, contain streamside wetlands and associated transition areas, or are within a 150-foot or 300-foot wildlife passage corridor on both sides of a stream or other waterbody (NJWSA, 2002). Riparian zones are important natural filters of stormwater runoff, protecting aquatic environments from excessive sedimentation, pollutants, flooding, and erosion. They supply shelter and food for many aquatic animals and also provide shade, an important part of stream temperature regulation. Disturbances, such as development within the riparian zone, invasive species encroachment, or dumping of landscaping waste, can impact the functions of healthy riparian areas.

The extent of riparian corridors within Hamilton Township is dictated by the classification of the streams by the State and through township ordinance. As the waters within the township are designated as Category 2 waters, riparian corridors, or stream buffer conservation zones (SBCZ), extend 75 feet from the top of the bank for a total SBCZ of 150 feet (Hamilton Township, New Jersey, Land Use Development Code, Chapter 155 – Stream Buffer Conservation Zone). This zone covers over 1,500 acres (Figure 17). The largest land use that occurs within the 150 foot SBCZ is wetlands, which cover 784.8 acres (50.5% of total land use within the riparian buffer) (Figure 18). Developed areas cover 317.5 acres (20.4% of total land uses within SBCZ) (Figure 18). Riparian zones are instrumental in water quality improvement for both surface runoff and water flowing into streams through subsurface or groundwater flow. A decrease in riparian areas due to increasing urbanization within the SBCZ may contribute to poor surface water quality conditions, increased streambank erosion, and heightened flooding.

Stormwater Detention Basins

The original use of stormwater management basins was to mitigate floods; at that time they were commonly known as flood control detention basins. Basins were designed on a site-by-site basis to limit the peak flow rate at the site's outlet by temporarily storing water. This is done by allowing large amounts of stormwater to fill the system and limiting the outflow using a small opening at the lowest point of the structure. Flood control detention basins were often constructed to control extreme storm events, specifically 2- to 100-year storms (Emerson *et al.*, 2005). Small storms events and the quality of the water were generally not affected by these types of basins.

Detention of stormwater runoff began to appear as a stormwater management practice in the late 1960s to control peak runoff rates from new land-development sites. This was initially applied to control 10-, 25-, 50-, or 100-year storm flow rates. Later, several jurisdictions mandated detention to control 2-year peak flow rates in order to manage stream bank erosion (Barfield *et. al*, 2004). Although detention basins have been constructed to reduce peak stormwater runoff rates since the early 1970s, it is only since the late 1980s that sufficient information has been available to design these basins to address stormwater quality. Subsequently, the Federal Clean Water Act shifted the focus of stormwater detention design from flood control to stormwater quality control (Guo, 2009). To meet new requirements in the Stormwater Management Regulations for stormwater quality, new design approaches are being applied on new development projects. Existing detention basins need to be assessed and retrofit solutions developed. Numerous detention basins can be retrofitted to address water quality and management techniques adapted to more cost-effectively protect water resources in the community.

In Hamilton Township, detention basins have been mapped is several ways (Figure 19). Stormwater basins are included as an urban land use within the NJDEP's land use/land cover dataset. The township has compiled an inventory of individual tax parcels that contain detention basins. Currently over 300 detention basins have been identified and mapped in Hamilton Township (Figure 19). This effort, however, is incomplete and there are plans for the township to finish mapping the basins (R. Williams, personal communication, 6/13/2011). The areal extent of the 322 basins derived from engineering drawings is 202.6 acres (Figure 19).

These detention basins are supported by an extensive network of inlets, manholes, and pipes which transport stormwater throughout the municipality (Figure 20). Inventorying and mapping this infrastructure can help guide Hamilton Township in both maintaining current systems and assessing existing function and needs.

Additional details on basin facilities and designs will be incorporated into the Implementation Plan after field surveys are completed by the RCE Water Resources Program. These field surveys will evaluate a select number of basins and facilities to determine their functionality in helping to alleviate stormwater issues facing Hamilton Township. Based upon this evaluation, additional recommendations on maintaining and retrofitting detention basins within the municipality may be developed.

Surface Water Quality

Stream Classification

The NJDEP classifies waters within the State to properly manage their uses and quality. Water quality criteria are developed according to a waterbody's designated uses. Almost all waters within Hamilton Township are classified as FW2-NT, except for a small portion of a tributary in the Assunpink Creek Watershed in the northern part of the municipality, which is classified as FW2-NT/C1 (Figure 21). FW2-NT waters are freshwater systems that are subjected to man-made wastewater discharges or increases in runoff from anthropogenic activities (FW2) and are not used for either the production or maintenance of trout populations (NT) (NJDEP, 2011). FW2-NT/C1 waters are FW2-NT systems as described previously, but the Category One (C1) status protects the water from "measureable or calculable changes in water quality" based upon ecological significance, water supply, recreational value, or fisheries sustainability (NJDEP, 2011).

FW2 refers to waterbodies that are used for primary and secondary contact recreation; industrial and agricultural water supply; maintenance, migration, and propagation of natural and established biota; public potable water supply after conventional filtration treatment and disinfection; and any other reasonable uses. NT waters are not suitable for trout due to physical, chemical, or biological characteristics, but can support other fish species (NJDEP, 2011). To evaluate the health of waters within the State, water quality data are compared to the designated water quality criteria. Water quality criteria are developed according to a waterbody's designated uses and it classification.

Water Quality

In accordance with Section 305(b) of the Clean Water Act, New Jersey assesses the overall water quality of the State's waters and identifies impaired waterbodies through the development of a document referred to as the *Integrated List of Waterbodies*. Data from the 2008 *Integrated List of Waterbodies* indicates that watersheds within Hamilton Township are experiencing water quality impairments due to turbidity/total suspended solids (TSS), nutrients (total phosphorus [TP]), heavy metals (lead and mercury), and polychlorinated biphenyls (PCBs) (Table 4) (NJDEP, 2009). These pollutants are typical for stormwater runoff from urban areas (Göbel *et al.*, 2007).

Table 4: Water quality impairments from NJDEP's 2008 Integrated List of Waterbodies. (14-Digit hydrologic unit code (HUC14) numbers correspond to subwatersheds in Figure 23.)

HUC14	Subwatershed Name	DO	TP	TSS	Turbidity	PCB	Arsenic	Lead	Mercury
02040105230050	Assunpink Creek (Shipetaukin to Trenton Road)						Yes		Yes
02040105240030	Miry Run (Assunpink Creek)	Yes							
02040105240040	Pond Run			Yes	Yes				
02040105240050	Assunpink Creek (below Shipetaukin Creek)	Yes	Yes				Yes	Yes	Yes
02040201030010	Duck Creek & Upper Delaware River to Assunpink Creek					Yes			Yes
02040201050050	Crosswicks Creek		Yes				Yes		Yes
02040201050070	Crosswicks Creek		Yes	Yes	Yes	Yes	Yes		Yes
02040201060030	Doctors Creek (below Allentown)								
02040201070010	Back Creek(above Yardville-Hamilton Square Road)		Yes						
02040201070020	Crosswicks Creek (below Doctors Creek)		Yes		Yes	Yes	Yes		Yes
02040201070030	Shady Brook/Spring Lake/ Rowan Lake					Yes			Yes
02040201090030	Lower Delaware River Tributaries					Yes			Yes

Permitted Dischargers

The NJDEP classifies waters within the State according to a waterbody's designated uses. As mentioned previously, almost all waters within Hamilton Township are classified as FW2-NT (Figure 21). FW2-NT waterbodies are designated for primary and secondary contact recreation; industrial and agricultural water supply; maintenance, migration, and propagation of natural and established biota; public potable water supply after conventional filtration treatment and disinfection; and any other reasonable uses (NJDEP, 2011). The NJPDES program protects New Jersey's ground and surface water quality by assuring the proper treatment and discharge of wastewater (and its residuals) and stormwater from various types of facilities and activities. Permits are issues through the NJPDES programs to limit the amount of pollutants discharged into the State's groundwater, streams, rivers, and ocean. The types of regulated facilities can range from very small users such as campgrounds, schools, and shopping centers to larger industrial and municipal wastewater dischargers. Permitted facilities are required to monitor the volume and quality of discharge to remain in compliance with permitted volumes and pollutants.

There are 51 NJPDES permitted discharges in Hamilton Township (Figure 22). Twenty of these permits are for industrial stormwater discharge (Figure 22). Two of these permits have been revoked, for Railway Express, Inc. The remaining 18 permits are for five facilities: Demag Delaval Turbomachine (11 permitted pipes); Consumer Oil Corporation (1 permit); Tran DPG (1 permit); ExxonMobil Corporation – Trenton Terminal (1 permit); and Clayton Block Company, Inc. (4 permitted pipes). 'Stormwater' means any water resulting from precipitation (including rainfall and snow) that runs off the land's surface, is transmitted to the subsurface, is captured by separate storm sewers or other sewerage or drainage facilities, or is conveyed by snow removal equipment (NJDEP, 2004). Stormwater discharge is the discharge of stormwater from areas of the industrial site related to manufacturing, processing, or raw materials storage.

There is one discharger permitted to discharge to groundwater: Bordentown City Water Treatment Plant (WTP) (Figure 22). Bordentown City manages their facility located off of I-195 in Hamilton Township on the border with Bordentown City (Figure 22). The permit allows for a discharge to an on-site infiltration pond.

Biological Assessments

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

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

1. Taxa Richness: Taxa richness is a measure of the total number of benthic macroinvertebrate families identified. A reduction in taxa richness typically indicates the presence of organic enrichment, toxics, sedimentation, or other factors.
2. EPT (Ephemeroptera, Plecoptera, Trichoptera) Index: The EPT Index is a measure of the total number of Ephemeroptera, Plecoptera, and Trichoptera families (i.e., mayflies, stoneflies, and caddisflies) in a sample. These organisms typically require clear moving water habitats.

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

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

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

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

- Non-impaired sites have total scores ranging from 24 to 30,
- Moderately impaired sites have total scores ranging from 9 to 21, and
- Severely impaired sites have total scores ranging from 0 to 6.

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

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

The NJDEP Bureau of Freshwater & Biological Monitoring maintains five AMNET stations within Hamilton Township (AN0115 – Miry Run, AN0117 – Pond Run, AN0125 – Crosswicks Creek, AN0126B – Pleasant Run, and AN0131A – Back Creek) (Figure 23). These stations were sampled during several rounds from 1992 through 2006 by NJDEP under the AMNET program (Table 5). In general, the biological condition of waters within Hamilton Township over the years has been assessed as being severely to moderately impaired, and the habitat has been assessed as suboptimal for macroinvertebrates within the municipality (Table 5).

Table 5: Summary of AMNET results for stations within Hamilton Township (NJDEP, 1994; NJDEP, 1996; NJDEP, 1999; NJDEP, 2003a; NJDEP, 2008; NJDEP, 2010).

Station	Date	Impairment Status (NJIS)	Habitat Assessment (Score)
AN0115	3/4/1992	Moderately Impaired (12)	~
AN0115	3/5/1998	Moderately Impaired (15)	Marginal (92)
AN0115	5/15/2003	Moderately Impaired (12)	Suboptimal (140)
AN0117	3/4/1992	Severely Impaired (0)	~
AN0117	3/5/1998	Severely Impaired (6)	Suboptimal (139)
AN0117	6/3/2003	Moderately Impaired (9)	Suboptimal (141)
AN0125	1/17/2001	Moderately Impaired (15)	Suboptimal (118)
AN0125	6/1/2006	Moderately Impaired (15)	Suboptimal (142)
AN0126B	2/15/2001	Moderately Impaired (12)	Suboptimal (138)
AN0126B	6/1/2006	Severely Impaired (6)	Suboptimal (118)
AN0131A	2/15/2001	Moderately Impaired (18)	Suboptimal (155)
AN0131A	6/13/2006	Severely Impaired (6)	Suboptimal (152)

Total Maximum Daily Loads (TMDLs)

Many waters across the country have their water quality assessed to determine what remediation measures should take place to maintain good water quality or to improve impaired waters. One method of managing water, it to develop a total maximum daily load (TMDL) from the data collected. The TMDL calculates the maximum pollutant load that a water body can assimilate and still meet water quality standards, and it then allocates allowable loads to point and nonpoint pollutant sources. A TMDL is thus akin to a ‘‘pollution budget.’’ Loads from natural background sources and a margin of safety are accounted for in setting load allocations for point and nonpoint sources.

TMDLs are developed by the NJDEP, and approval is given by the USEPA. In accordance with Section 305(b) of the Clean Water Act, New Jersey assesses the overall water quality of the State’s waters and identifies impaired waterbodies through the development of a document referred to as the *Integrated List of Waterbodies* (NJDEP, 2009). Within this document are lists that indicate the presence and level of impairment for each waterbody monitored. The lists are defined as follows:

- **Sublist 1** suggests that the waterbody is meeting water quality standards.

- **Sublist 2** states that a waterbody is attaining some of the designated uses, and no use is threatened. Furthermore, Sublist 2 suggests that data are insufficient to declare if other uses are being met.
- **Sublist 3** maintains a list of waterbodies where no data or information are available to support an attainment determination.
- **Sublist 4** lists waterbodies where use attainment is threatened and/or a waterbody is impaired; however, a TMDL will not be required to restore the waterbody to meet its use designation.
    - **Sublist 4a** includes waterbodies that have a TMDL developed and approved by the USEPA, that when implemented, will result in the waterbody reaching its designated use.
    - **Sublist 4b** establishes that the impaired reach will require pollutant control measurements taken by local, state, or federal authorities that will result in full attainment of designated use.
    - **Sublist 4c** states that the impairment is not caused by a pollutant, but is due to factors such as instream channel condition and so forth. It is recommended by the USEPA that this list be a guideline for water quality management actions that will address the cause of impairment.
- **Sublist 5** clearly states that the water quality standard is not being attained and a TMDL is required.

According to the *2008 Integrated Water Quality Monitoring and Assessment Report's Integrated List* (NJDEP, 2009), many of the streams and rivers in Hamilton Township are placed on Sublist 5 for water quality impairments, indicating the need for establishing TMDLs for water quality management (Figure 23). Currently, three water bodies have TMDLs already in place: Miry Run, Doctors Creek, and Spring Lake (Figure 23). Miry Run and Spring Lake have total phosphorus (TP) TMDLs, and Doctors Creek has a TMDL targeting fecal coliform (bacteria). An 86% reduction in fecal coliform loading to Doctors Creek is needed to achieve water quality standards (NJDEP, 2003b). TP loads need to be reduced by 22% in Miry Run to meet regulated water quality standards (NJDEP, 2007b).

The section of Delaware River that flows along the southwestern edge of Hamilton Township is placed on Sublist 3 indicating insufficient data is available to determine if water quality problems exist (Figure 23).

Stormwater Policies & Ordinances

Hamilton Township recently adopted a master plan that specifically outlined two goals related to stormwater: (1) Provide effective stormwater management and reduce impacts of flooding throughout the Township; and (2) Plan for capital improvements to ensure that the Township's infrastructure (roads, stormwater management, sewer, water, telecommunications, and similar facilities) and community facilities are properly developed and maintained (Clark Caton Hintz, 2011). The protection and health of waterways depends largely upon land use laws and policies aimed to manage stormwater, direct discharges, and treat drinking water supplies. Planning should protect the natural environment and ensure the vision laid out for Hamilton Township in its Master Plan becomes focused and sustainable. This planning presents a challenge as it must balance natural resource protection, historical quality, and economic growth. As an option to address issues related to stormwater, municipalities can enact ordinances to comply with the Stormwater Management Regulations enforced by the NJDEP.

Overview of Select Township Ordinances

The following are descriptions of ordinances or sections of the ordinance code incorporated into the Municipal Code of Ordinances or the Municipal Land Development Code for Hamilton Township. The ordinances described below were selected based upon their relevance to stormwater management or the hydrological function of the landscape. This list does not fully encompass all of the ordinance in Hamilton Township related to stormwater issues or development, but does provide an overview of the types of stormwater regulations the township has put forth to curtail stormwater.

Improper Disposal of Wastes

Municipal Code of Ordinances: Chapter 86, Section 14

<u>Purpose:</u> *"To prohibit the spilling, dumping, or disposal of materials other than stormwater to the municipal separate storm sewer system (MS4) operated by the Township of Hamilton in Mercer County, New Jersey, so as to protect public health, safety and welfare, and to prescribe penalties for the failure to comply."*

<u>Prohibited Conduct:</u> *"The spilling, dumping, or disposal of materials other than stormwater to the municipal separate storm sewer system operated by the township is prohibited. The spilling, dumping, or disposal of materials other than stormwater in such a manner as to cause the discharge of pollutants to the municipal separate storm sewer system is also prohibited."*

Illicit Connection

Municipal Code of Ordinances: Chapter 86, Section 15

<u>Purpose:</u> *"To prohibit illicit connections to the municipal separate storm sewer system(s) operated by the Township of Hamilton in Mercer County, New Jersey, so as to protect public health, safety and welfare, and to prescribe penalties for the failure to comply."*

<u>Prohibited Conduct:</u> *"No person shall discharge or cause to be discharged through an illicit connection to the municipal separate storm sewer system operated by the township any domestic sewage, noncontact cooling water, process wastewater, or other industrial waste (other than stormwater)."*

Stream Buffer Conservation Zone

Municipal Land Development Code: Chapter 155, Sections 10-20

<u>Purpose:</u> *In recognition of the fact that values afforded by functional stream buffers contribute to the welfare of residents, the following regulations have been enacted to provide reasonable controls governing the conservation, disturbance, restoration and management of existing stream buffers for all perennial and intermittent streams, and all lakes, ponds and reservoirs within the township by establishing a stream buffer conservation zone (SBCZ). The specific purposes and intent of this article are to: (1) Regulate the land use, siting, and engineering of all development in the SBCZ to be consistent with the intent and objectives of this ordinance and accepted conservation practices. (2) Prevent excessive nutrients, sediment, and organic matter, as well as biocides and other pollutants, from reaching surface waters by optimizing opportunities for filtration, deposition, absorption, plant uptake, biodegradation, and*

denitrification, which occur when stormwater runoff is conveyed through vegetated buffers as stable, distributed sheet flow prior to reaching receiving waters. (3) Provide for shading of the aquatic environment so as to moderate temperatures, retain more dissolved oxygen, and support a healthy assemblage of aquatic flora and fauna. (4) Provide for natural organic matter (fallen leaves and twigs) and large woody debris (fallen trees and limbs) that provide food and habitat for small bottom dwelling organisms (insects, amphibians, crustaceans, and small fish), which are essential to maintain the food chain. (5) Increase stream bank stability and maintain natural fluvial geomorphology of the stream system, thereby reducing streambank erosion and sedimentation and protecting habitat for aquatic organisms. (6) Conserve the natural features important to land and water resources, e.g., headwater areas, groundwater recharge zones, floodway, floodplain, springs, steams, wetlands, woodlands, and prime wildlife habitats. (7) Work with state laws and other ordinances that regulate environmentally sensitive areas to minimize hazards to life, property, and stream features and assist in the implementation of pertinent state laws concerning erosion and sediment control practices."

Flood Damage Protection

Municipal Land Development Code: Chapter 157, Sections 1-126

<u>Purpose:</u> *"It is hereby found that the Assunpink Creek, Miry Run, Pond Run and other waterways in the Township of Hamilton are subject to recurring flooding, most recently in 1971 and 1975; that such flooding damage endangers life and public and private property and facilities; that this condition is aggravated by development and encroachments in the floodplain; and that the most appropriate method of alleviating such conditions is through regulation of such developments and encroachments. It is, therefore, determined that the special and paramount public interest in the floodplain justifies the regulation of property located therein as provided in this chapter, which is in the exercise of the police power of the municipality; for the protection of the persons and property of its inhabitants; and for the preservation of the public health, safety and general welfare. Among the purposes of this chapter are: (1) To prevent loss of life. (2) To prevent the installation of structures which increase flood heights. (3) To prevent excessive property damage. (4) To reduce public expenditures for emergency operations, evacuations and restorations. (5) To prevent damages to transportation and utility systems. (6) To remove the impediment to community growth created by recurrent flooding. (7) To prevent*

further unwise development in unprotected floodplains, thus reducing future expenditures for protective measures. (8) To prevent pollution of watercourses during floods by preventing the placing and storing of explosive, toxic and otherwise dangerous materials within the special flood hazard area. (9) To preserve, protect and enhance the natural environment of the floodplain. (10) To protect individuals or corporations from buying lands which are unsuited for intended purposes because of flood hazard. (11) To protect the public from dangers caused by materials being swept onto or nearby downstream lands. (12) To protect and enhance the public's health by minimizing the degradation of stream water quality. (13) To protect wildlife and fishing areas by preserving and enhancing the environment of the floodplain. (14) To regulate the construction of or substantial improvement to buildings and other facilities in locations that would likely be damaged by floods or where they would be washed away and cause damage to downstream properties. (15) To prevent installation of structures and restrict land uses which would increase the size of the floodplain and/or the stream velocities, erosion and siltation."

Stormwater Control

Municipal Land Development Code: Chapter 158, Sections 1-13

Purpose: *"It is the purpose of this chapter to establish minimum stormwater management requirements and controls for "major development," as defined in section 158-2, and to: (1) Establish standards and regulations for the management and discharge of stormwater runoff from land development projects and other construction activities; (2) Reduce artificially induced flood damage to public health, life, and property; (3) Minimize increased stormwater runoff rates and volumes; (4) Minimize the deterioration of existing water courses, culverts, bridges, dams and other structures that would result from increased rates of stormwater runoff; (5) Induce water recharge into the ground wherever suitable infiltration, soil permeability, and favorable geological conditions exist; (6) Prevent an increase in nonpoint source pollution; (7) Maintain the integrity and stability of stream channels for their biological functions, as well as for drainage, the conveyance of floodwater, and other purposes; (8) Control and minimize soil erosion and the transport of sediment; (9) Reduce stormwater runoff rates and volumes, and nonpoint source pollution; (10) Minimize public safety hazards at any stormwater detention facility constructed pursuant to subdivision or site plan approval; (11) Maintain high water* *quality in all streams and other surface water bodies; (12) Protect all surface water resources from degradation; and (13) Protect groundwater resources from degradation.*

Recommended Actions

This report highlights the condition of Hamilton Township's waterways and its efforts to control and manage stormwater. The results of this stormwater evaluation represent an opportunity to properly plan the landscape of Hamilton Township in an environmentally responsible way and to work proactively to protect water quality. Overall, waterways are experiencing moderate degradation due to stormwater impacts. Sedimentation is partly due to the makeup of the underlying soils and geology. While this condition is natural, many other factors are amplifying the problem. Increases in populations in Hamilton Township, and associated land use changes, are adding to the amount of impervious surfaces within the municipality, which augment the frequency and intensity of stormwater, flooding and erosion. As lands are developed, the infrastructure necessary to convey stormwater is needed for these areas.

Recommendations listed below were developed based upon the information gathered and presented within this Hydrology Report. Future work by the RCE Water Resources Program will involve field evaluation of stormwater basins and areas of impervious cover in Hamilton Township. The purpose of these field surveys is to locate opportunities for improving the functionality of stormwater basins or areas to reduce impervious cover through disconnection through rain gardens and rain barrels or use of pervious pavements instead of traditional concrete and asphalt. Results from these surveys will be used to develop specific recommendation and strategies for the community to be incorporated into the Implementation Plan.

Specific actions recommended by RCE Water Resources Program are as follows:

- If not already accomplished, a stormwater model for Hamilton Township should be developed so that estimation of future scenarios (management, development, or implementation) can be assessed as to their impact on water quality and quantity. Use of computer models to evaluate hydrology has become commonplace. Models are mathematical representations of reality that allow researchers and resources managers the opportunity to perform trial-and-error scenarios on physical structures or environmental landscapes. The ability of models to vary different input parameters in order to simulate and evaluate multiple scenarios is ideal for water management. The method generally followed when modeling hydrology is to monitor a system to be modeled, model the system of interest, and alter the model in some way to represent/predict changes in the system.

- The township should conduct an impervious cover analysis. This analysis would evaluate existing land use to identify the extent of impervious cover and include recommended strategies for disconnecting impervious areas from direct discharge into MS4 system. Disconnected impervious cover would allow stormwater to be detained or infiltrated prior to flowing into the MS4 system, reducing the pollutant loads and increased flows impacting Hamilton Township.
- Detention basins within Hamilton Township need to undergo a thorough, detailed evaluation with an assessment of these facilities, their function, and development of recommendations for repair, rehabilitation, enhancement, and long-term maintenance. Detention basins are primarily used for flood water abatement and control of stormwater quantity. The function of these basins can include water quality improvement and infiltration to groundwater through proper design of new basins or retrofitting of existing basins. The results of this evaluation will be used to determine the proper course of action for the future management of this form of stormwater infrastructure.
- With the extensive availability of GIS compatible data for the Township, an intern should be hired to develop a database of detention basins and stormwater infrastructure for Hamilton. Information to include in this database can include location (i.e., street address and lot and block), results from the detailed evaluations suggested above, ownership, date of any maintenance performed, types of maintenance performed, and other actions necessary to ensure proper functioning.
- A ‘site suitability’ map for stormwater control devices should be developed and used by Hamilton Township that incorporates information that would affect the type of devices needed on a site by site basis. Information to be used includes groundwater recharge rates, hydrologic soil groups, geologic formation and soil types, and flood frequencies.
- Preliminary site investigations of existing riparian areas should be conducted to identify degraded riparian zones to be restored, disconnected/bypassed riparian zones lacking

stormwater function, and high quality riparian zones to be protected and/or preserved. These areas could potentially be listed as SBCZ through the current Township ordinance.

- Water quality monitoring of the lakes in Hamilton Township needs to be undertaken in order to understand the impact of land use changes on the lakes and the impact of the lakes on the water quality of the various streams in the municipality. Lake monitoring should follow the same sampling protocols as used by the NJDEP Bureau of Freshwater & Biological Monitoring's Ambient Lake Monitoring Network so that the results may be incorporated into any State assessments.

References

Anderson, J.R., E.E. Hardy, and J.T. Roach, 1976. A Land-Use Classification System for Use with Remote-Sensor Data. United States Geological Survey. Professional Paper 964.

Barfield, B., M. Clar, and T. O'Connor, 2004. Stormwater Best Management Practice Design Guide. Basin Best Management Practices, Volume 3. EPA/600/R-04/121B.

Brun, S.E. and L.E. Band, 2000. Simulating Runoff Behavior in an Urbanizing Watershed. Computers, Environment and Urban Systems. 24:5-22.

Bullock, A. and M. Acreman, 2003. The Role of Wetlands in the Hydrologic Cycle. Hydrology and Earth Systems Sciences. 7(3):358-389.

Clark Canton Hintz, 2011. Hamilton Township Master Plan, Mercer County, NJ. Trenton, NJ. Available for download at, http://www.hamiltonnj.com/filestorage/55696/73499/Adopted_Master_Plan.pdf

Ehrenfeld, J.G., 2000. Evaluating wetlands within an urban context. Urban Ecosystems. 4:69-85.

Ehrenfeld, J.G., H.B Cutway, R. Hamilton IV, and E. Stander, 2003. Hydrologic Description of Forested Wetlands in Northeastern New Jersey, NJ – An Urban/Suburban Region. Wetlands. 23(4):685-7000.

Emerson, C.H., C. Welty, and R.G. Traver, 2005. Watershed-Scale Evaluation of a System of Storm Water Detention Basins. Journal of Hydrologic Engineering. 10(3), 237-242.

Federal Emergency Management Agency (FEMA), 2010. Flood Insurance Study, Volume 1 of 3: Mercer County, New Jersey (All Jurisdictions). Flood Insurance Study Number 34021CV001A.

Göbel, P., C. Dierkes, and W.G. Coldewey, 2007. Storm Water Runoff Concentration Matrix for Urban Areas. Journal of Contaminant Hydrology. 91:26-42.

Guo, J.C.Y., 2009. Retrofitting Detention Basin with Water Quality Control Pool. Journal of Irrigation and Drainage Engineering. 135(5):671-675.

Hasse, J.E. and R.G. Lathrop, 2003. Land Resource Impact Indicators of Urban Sprawl. Applied Geography. 23:159-175.

Lathrop, R.G., P. Montesano, J. Tesauro, and B. Zarate, 2005. Statewide Mapping and Assessment of Vernal Pools: A New Jersey Case Study. Journal of Environmental Management. 76:230-238.

National Research Council, 1995. Wetlands: Characteristics and Boundaries. National Academy Press. Washington, DC.

New Jersey Department of Environmental Protection (NJDEP), 1994. Ambient Biomonitoring Network Delaware River Drainage Basin: 1992 Benthic Macroinvertebrate Data. Trenton, NJ.

NJDEP, 1996, Ambient Biomonitoring Network Lower Delaware River Drainage Basin: 1995-96 Benthic Macroinvertebrate Data. Trenton, NJ.

NJDEP, 1999. Ambient Biomonitoring Network, Watershed Management Areas 1, 2, and 11: Upper Delaware Region: 1998 Benthic Macroinvertebrate Data. Trenton, NJ.

NJDEP, 2003a. Ambient Biomonitoring Network, Watershed Management Areas 17, 18, 19 and 20: Lower Delaware Region: 2000-2001 Benthic Macroinvertebrate Data. Trenton, NJ.

NJDEP, 2003b. Total Maximum Daily Loads for Fecal Coliform to Address 27 Streams in the Lower Delaware Water Region. Division of Watershed Management, Trenton, NJ.

NJDEP, 2004. New Jersey Stormwater Best Management Practices Manual. Division of Watershed Management. Trenton, NJ.

NJDEP, 2007a. Standard Operating Procedures, Ambient Biological Monitoring Using Benthic Macroinvertebrates, Field, Lab, and Assessment Methods. Bureau of Freshwater and Biological Monitoring Document No. BMNJ2. Available for download at, http://www.nj.gov/dep/wms//bfbm/download/AMNET_SOP.pdf.

NJDEP, 2007b. Total Maximum Daily Load for Phosphorus to Address HUC: 02040105240030-01 Miry Run Watershed, WMA 11, Northwest Water Region. Division of Watershed Management, Trenton, NJ.

NJDEP, 2008. Ambient Biomonitoring Network Northeast Water Region, Upper Delaware and Wallkill River Drainages, Watershed Management Areas 1, 2, and 11, Round 3 Benthic Macroinvertebrate Data (Volume 1 of 2). Trenton, NJ.

NJDEP, 2009. 2008 New Jersey Integrated Water Quality Monitoring and Assessment Report. Bureau of Water Quality Standards and Assessment. Trenton, NJ.

NJDEP, 2010. Ambient Biomonitoring Network Lower Delaware Water Region, Watershed Management Areas 17, 18, 19, and 20, Round 3 (2006-2007) Benthic Macroinvertebrate Data (Volume 1 of 2). Trenton, NJ.

NJDEP, 2011. Surface Water Quality Standards, N.J.A.C. 7:9B. Trenton, NJ.

New Jersey Geological Survey, 2010. http://www.nj.gov/dep/njgs/geodata/dgs09-2.htm. Digital Geodata Series DGS09-2 Coastal Plain Sediments with Potential to Form Acid (Sulfate) Soils, Downloaded on August 12, 2011.

New Jersey Water Supply Authority (NJWSA), 2002. Surface Water and Riparian Areas of the Raritan River Basin. NJWSA. Clinton, NJ.

Office of the NJ State Climatologist (ONJSC), 2011. http://climate.rutgers.edu/stateclim/. ONJSC at Rutgers University, Downloaded on August 22, 2011.

Owens, J.P., P.J. Sugarman, N.F. Sohl, R.A. Parker, H.F. Houghton, R.A. Volkert, A.A. Drake, Jr., and R.C. Orndorff, 1998. Bedrock Geologic Map of Central and Southern New Jersey, Scale 1:100,000, 8 cross sections, 4 sheets, each size 58x41, I-2540-B. Published in digital format in 2000 in New Jersey Geological Survey CD Series CD 00-1, Bedrock Geology (1:100,000-scale) and Topographic Base Maps (1:24,000- and 1:100,000-scales) of New Jersey.

Rose, S. and N.E. Peters, 2001. Effects of Urbanization on Streamflow in the Atlanta area (Georgia, USA): A Comparative Approach. Hydrologic Processes. 15:1441-1457.

Schueler, T.R. and H.K. Holland, 2000. The Practice of Watershed Protection. Center for Watershed Protection. Ellicott City, MD.

Shaw, E.M., 1994. Hydrology in Practice, 3rd edition. Chapman & Hall, London, England.

Sun, G., S.G. McNulty, D.M. Amatya, R.W. Skaggs, L.W. Swift Jr., J.P. Shepard, and H. Riekerk, 2002. A Comparison of the Watershed Hydrology of Coastal Forested Wetlands and the Mountainous Uplands in the Southern US. Journal of Hydrology. 263:92-104.

United States Army Corps of Engineers (USACE), 1987. Corps of Engineers Wetlands Delineation Manual. Wetlands Research Program Technical Report Y-87-1. USACE Waterways Experiment Station, Vicksburg, MS.

United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), 2002. http://soildatamart.nrcs.usda.gov/. Soil Survey Geographic (SSURGO) Database for Mercer County, New Jersey, Downloaded on October 20, 2009.

United States Environmental Protection Agency (USEPA), 1998. http://www.epa.gov/region02/water/aquifer/coast/coastpln.htm. New Jersey Coastal Plain Aquifer, Downloaded on August 22, 2011.

United States Geological Survey (USGS), 2009. http://nj.usgs.gov/infodata/aquifers/. Major Aquifers in New Jersey, Downloaded on August 22, 2011.

USGS, 2011. http://waterdata.usgs.gov/nj/nwis/rt. USGS Real-Time Water Data for New Jersey, Downloaded on August 24, 2011.

Appendix A: Maps

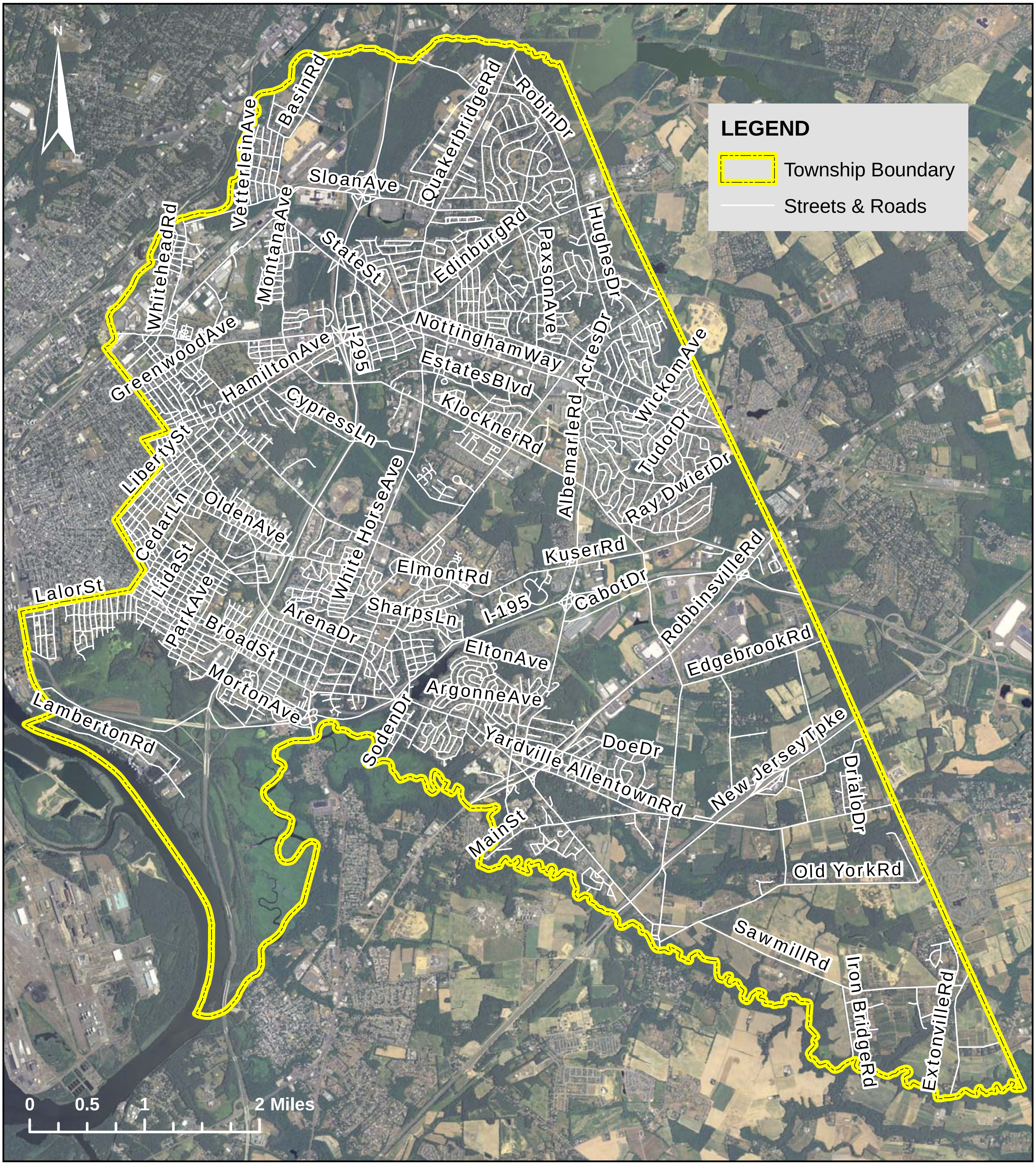

Figure 1: Hamilton Township (Mercer County) boundary.

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

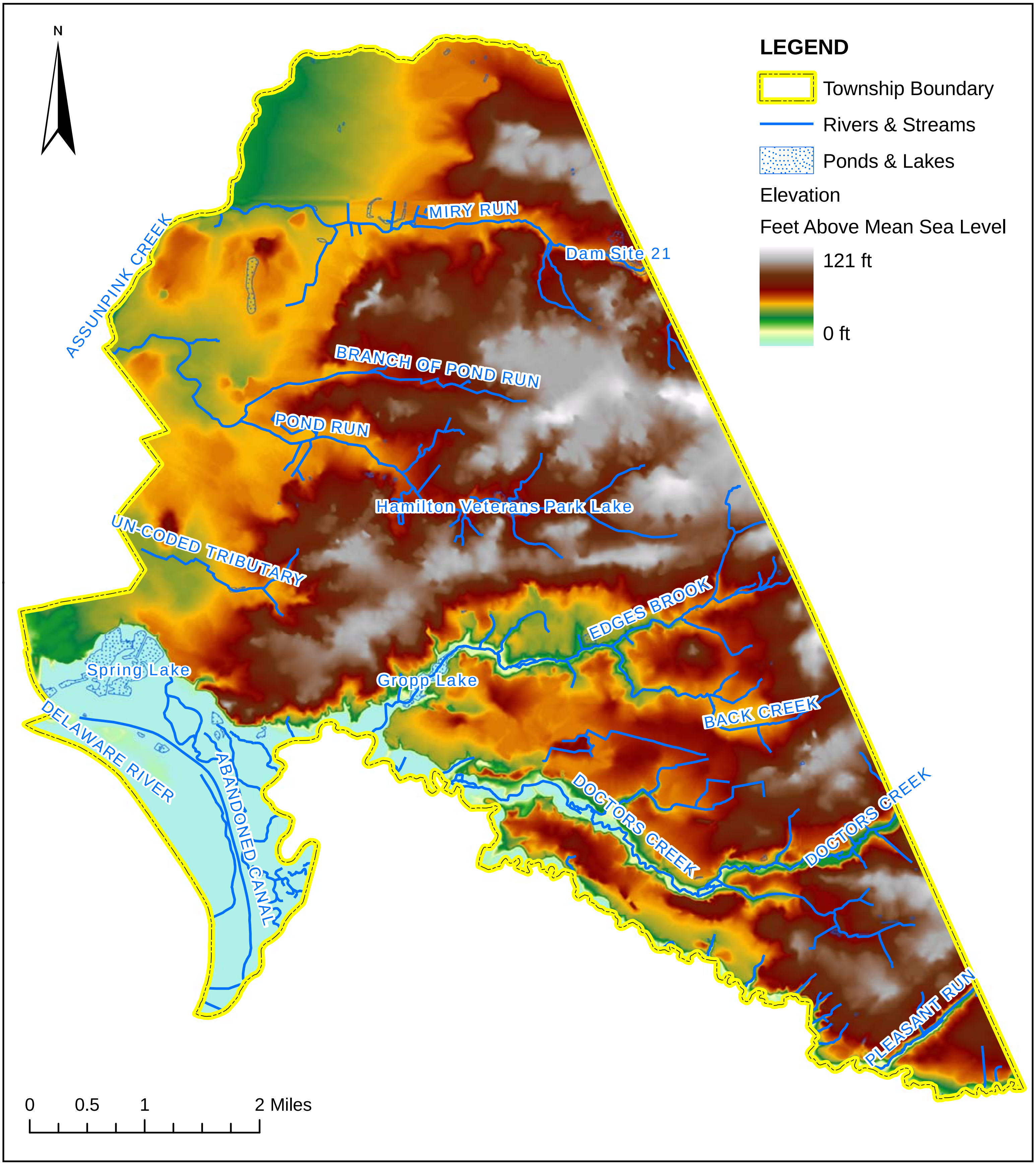

Figure 2: Topography of Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

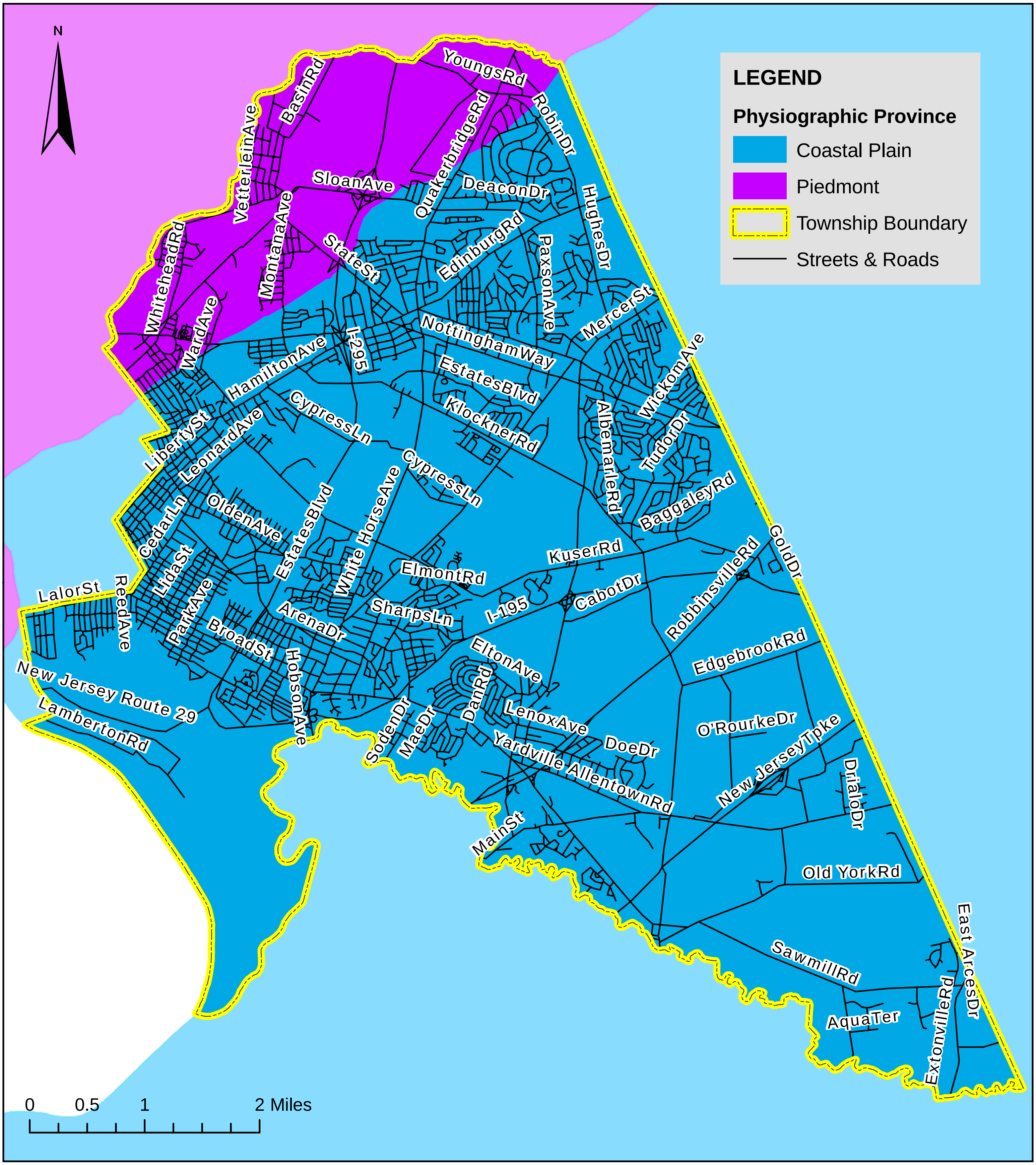

Figure 3: Physiographic provinces of Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station
Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

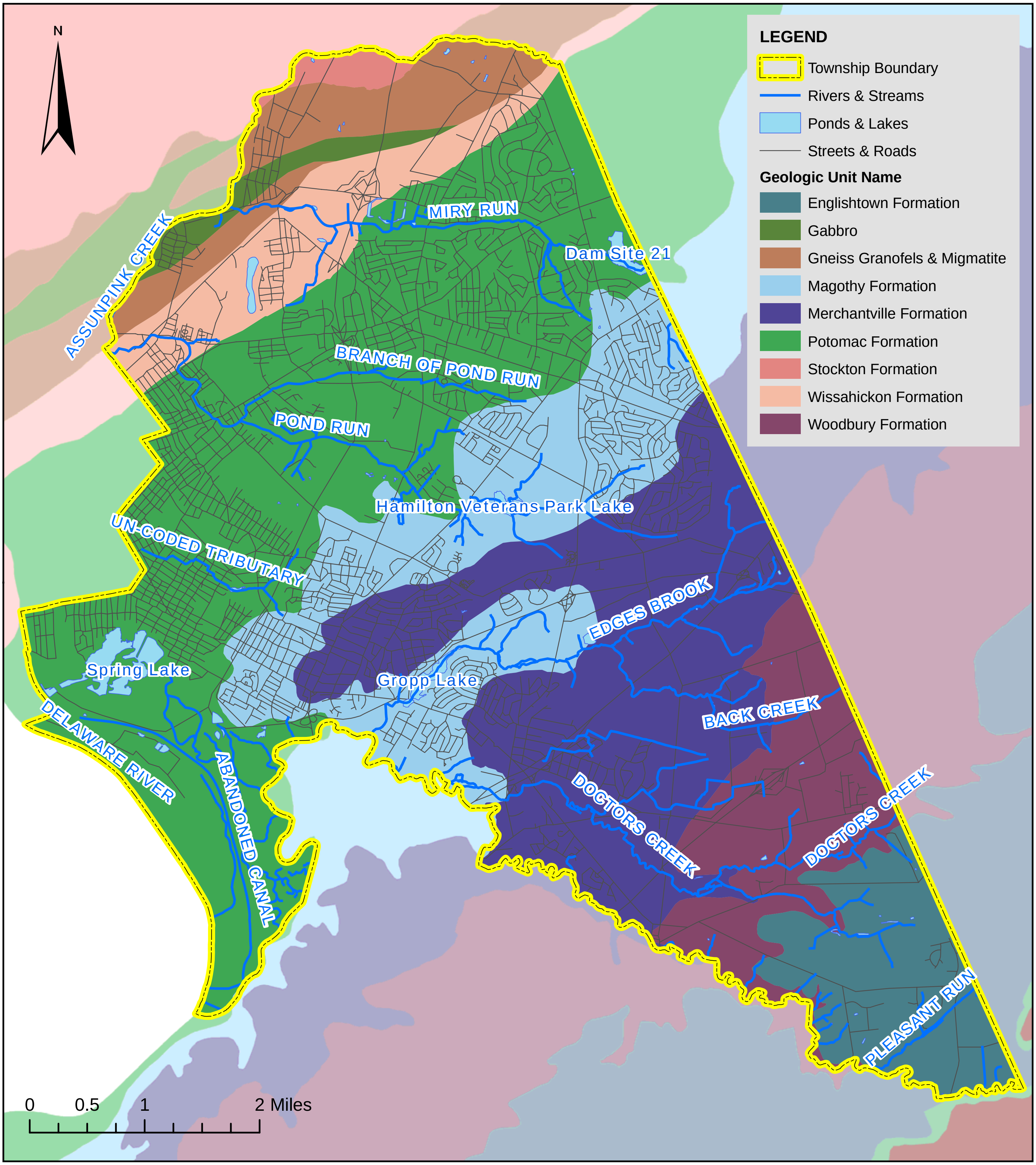

Figure 4: Geology of Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

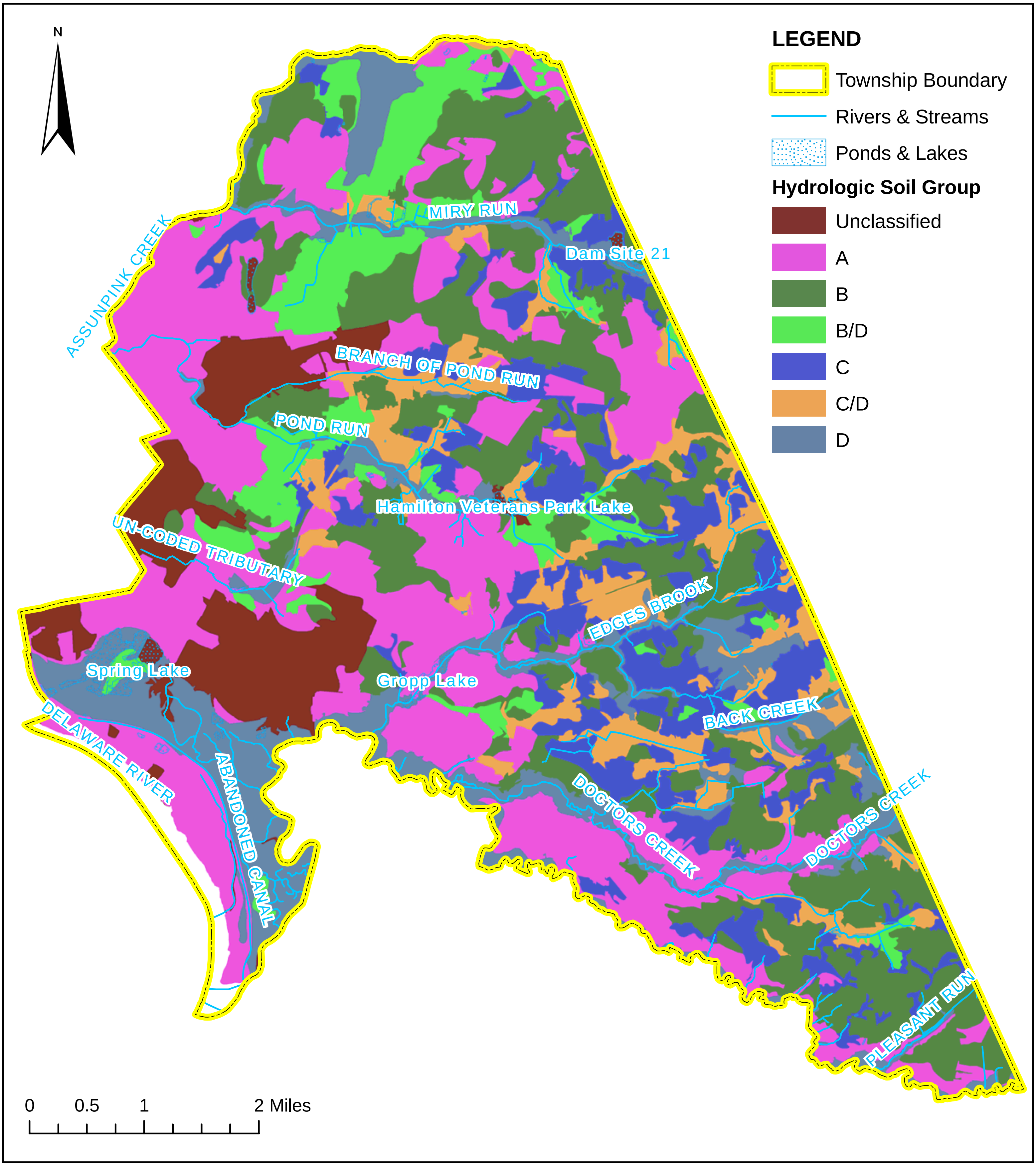

Figure 5: Hydrologic soil groups of Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

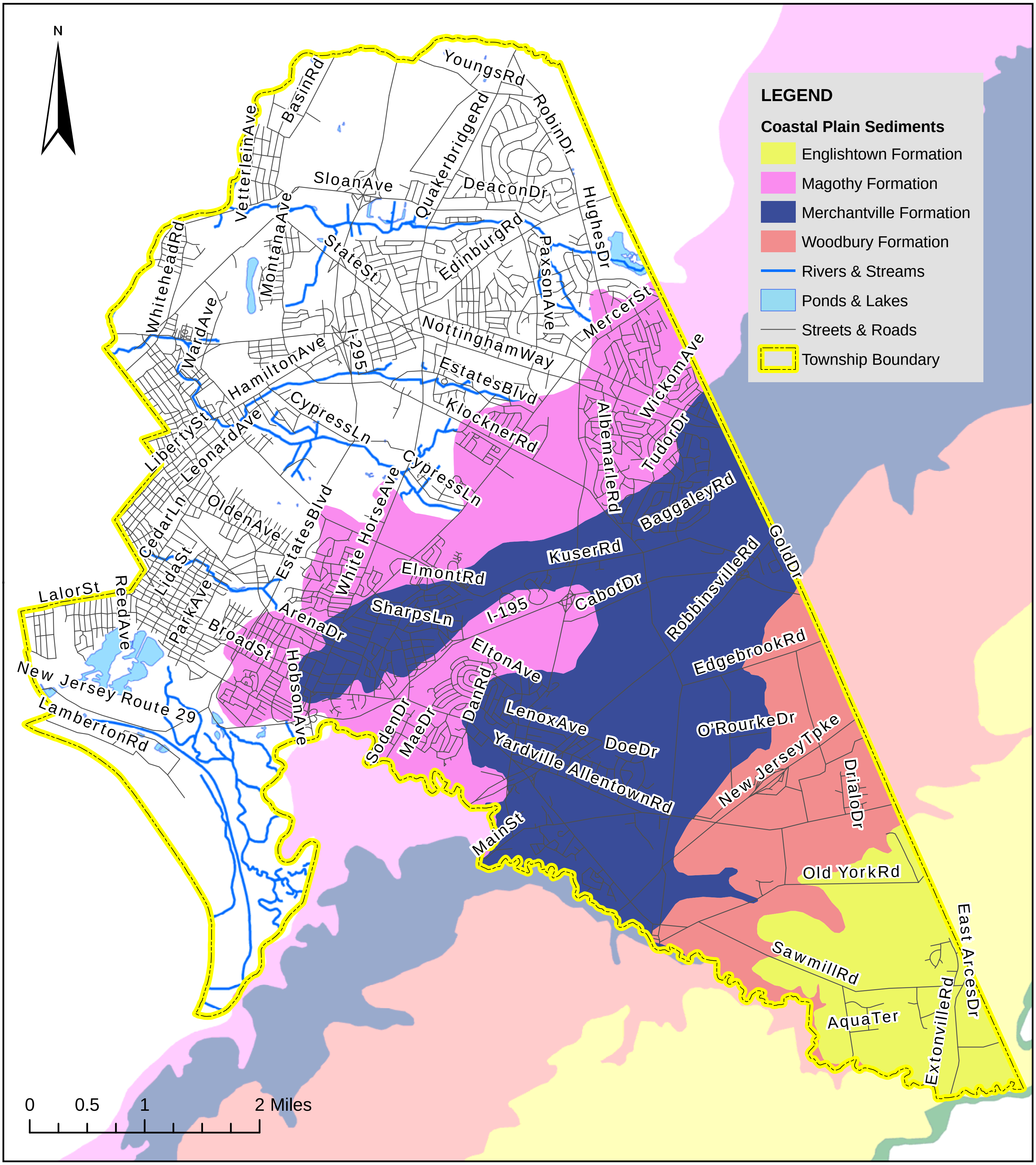

Figure 7: Sediments with potential to form acid soils in Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

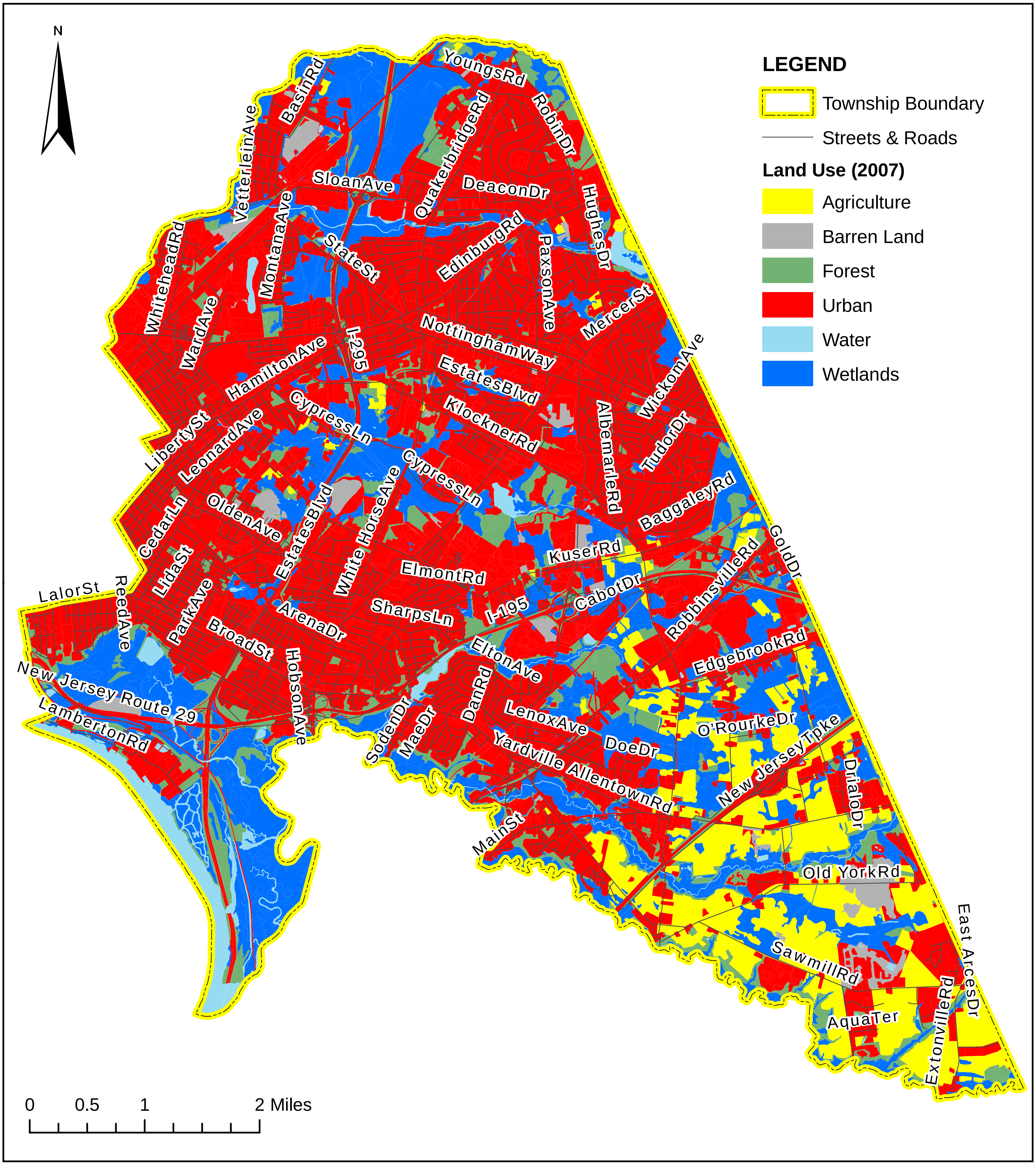

Figure 8: Land uses (2007) in Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station
Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

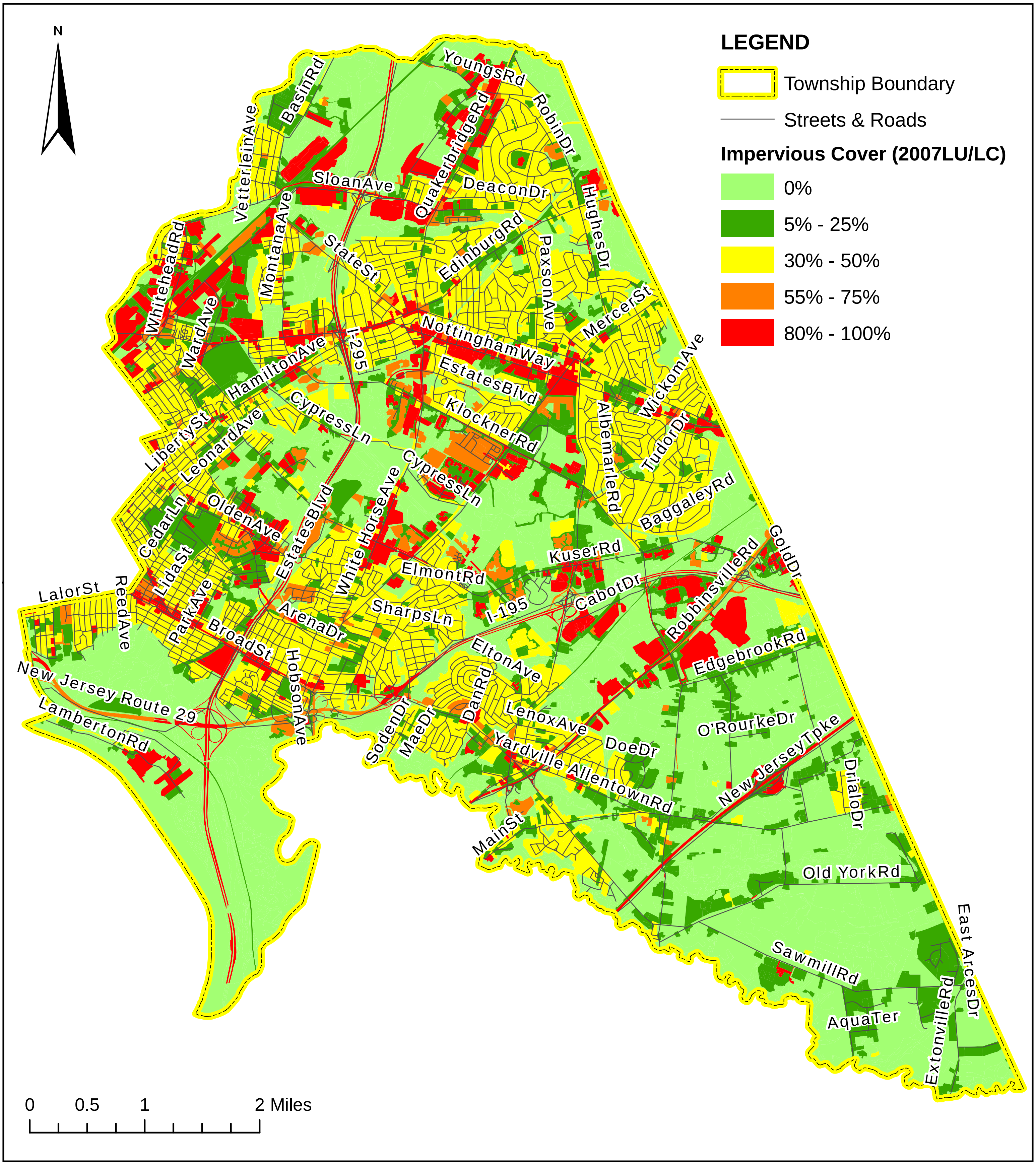

Figure 10: Percent impervious cover in Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

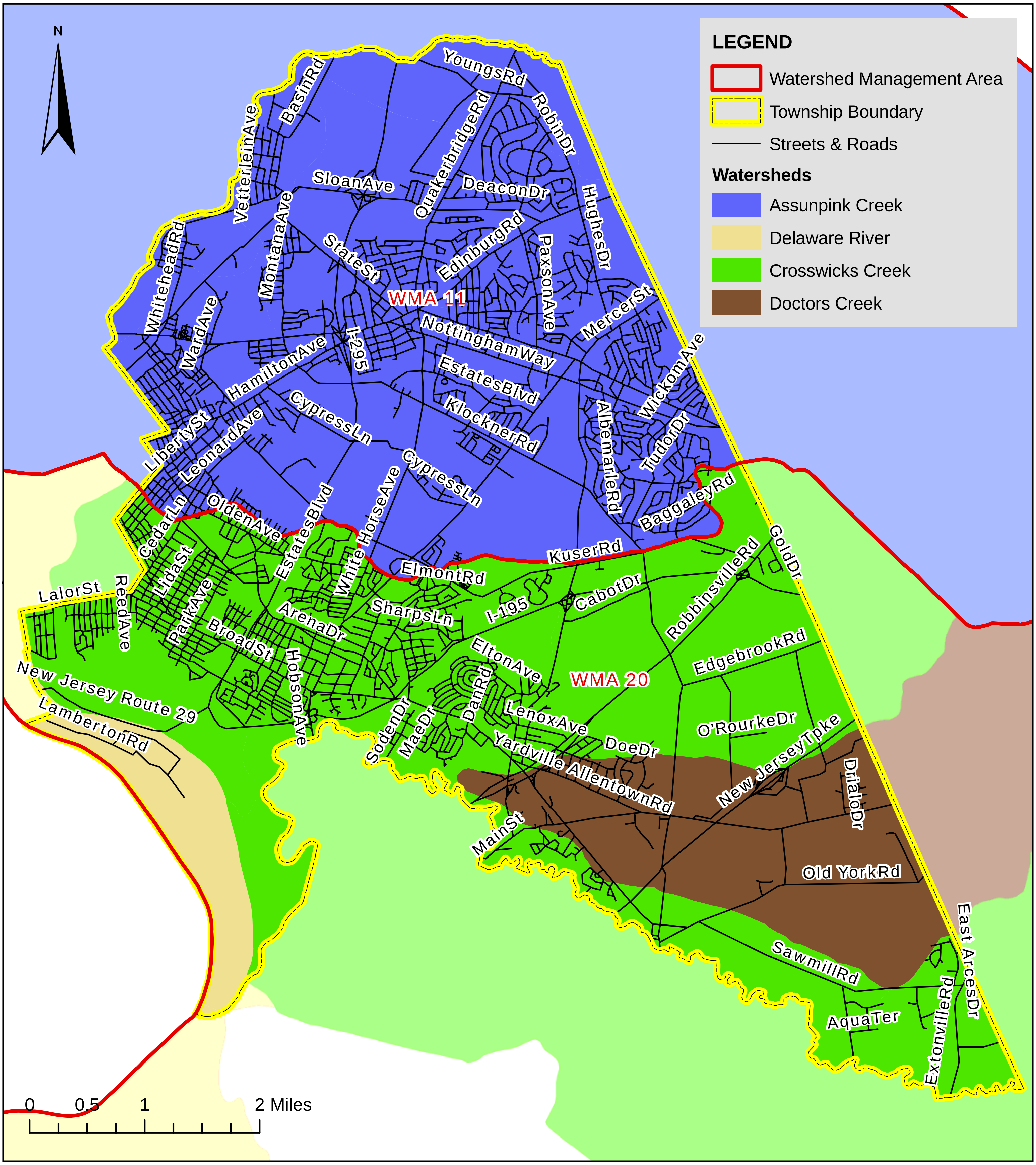

Figure 11: Watersheds in Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

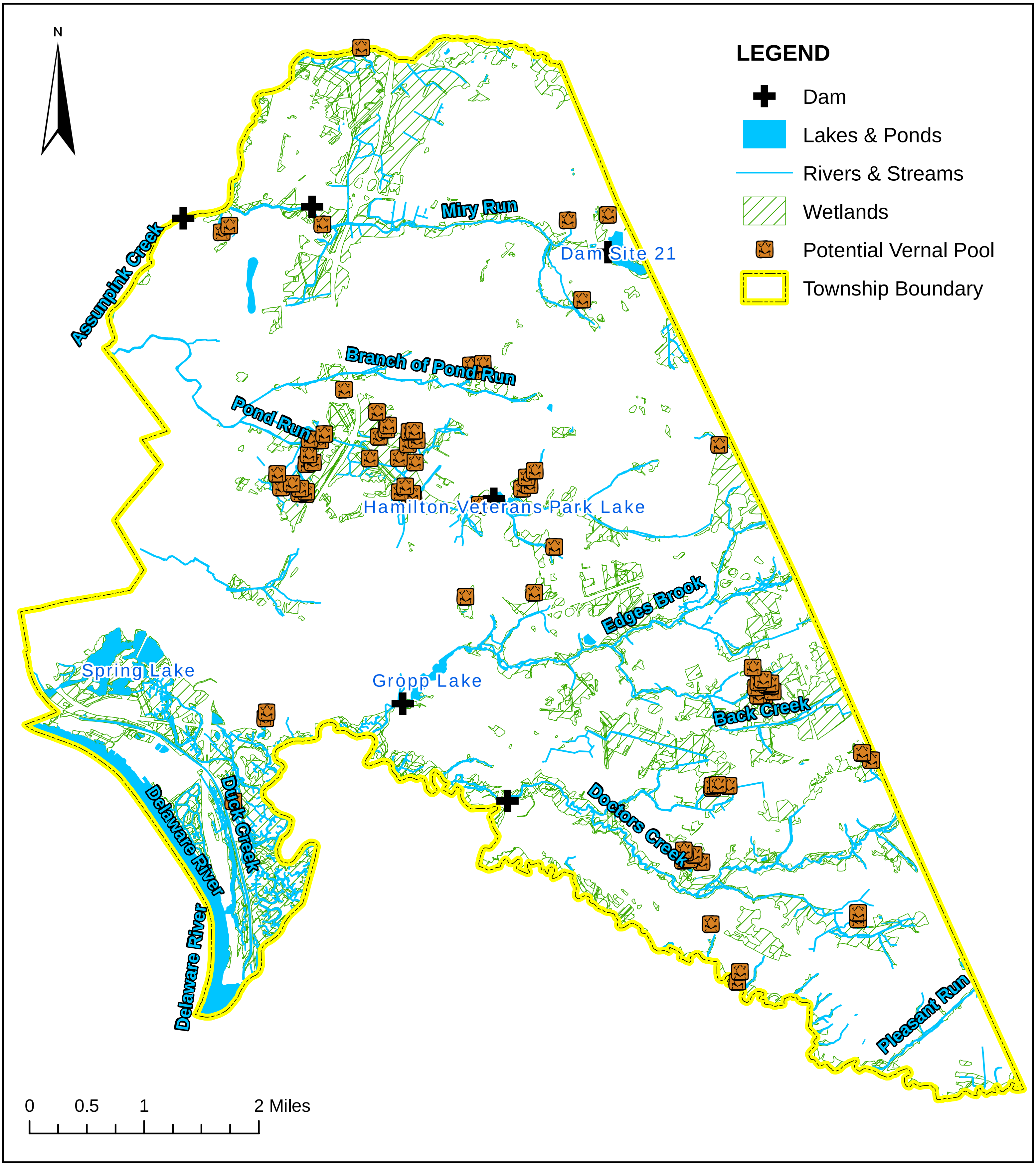

Figure 12: Hydrology of Hamilton Township (Mercer County).

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

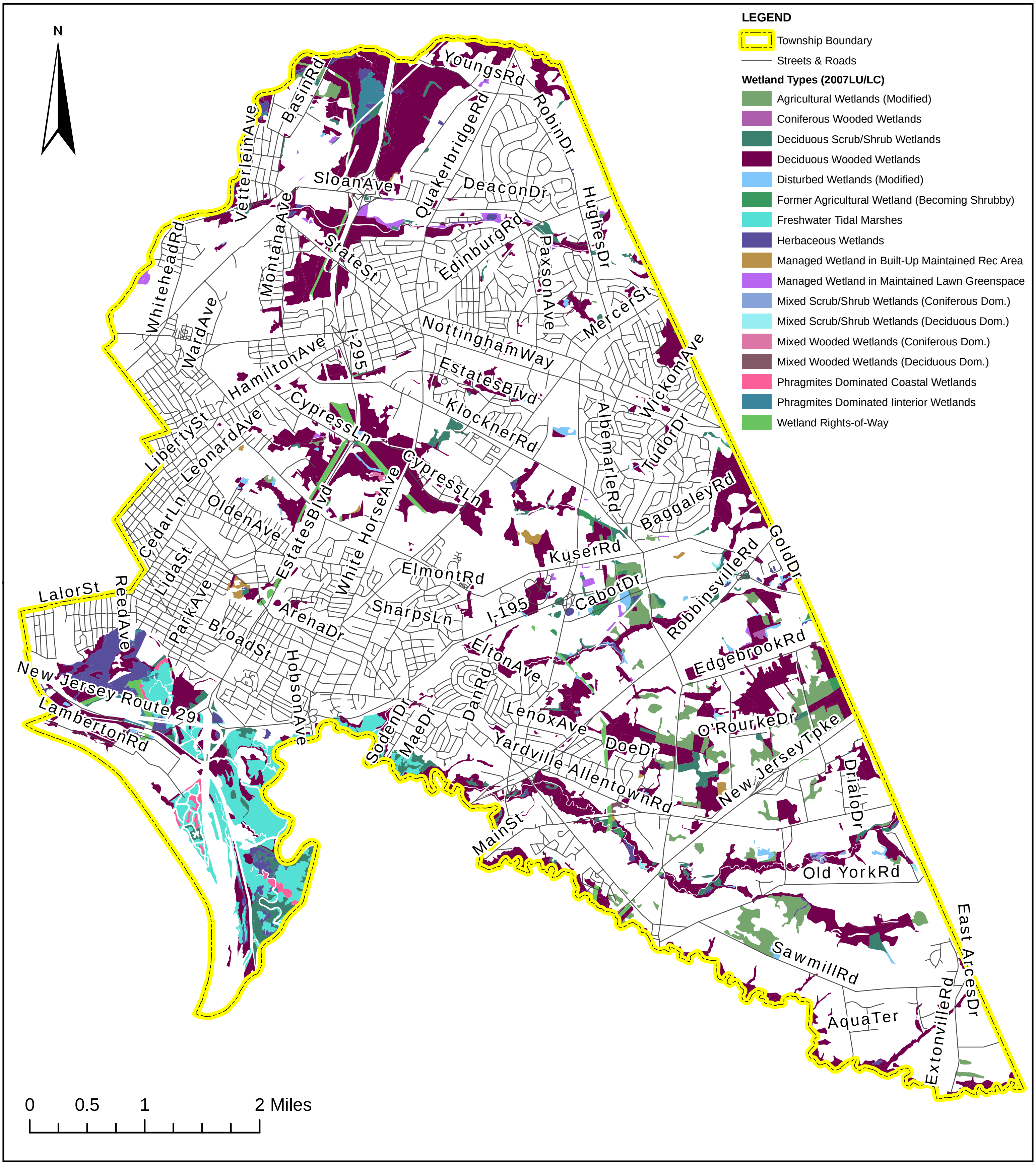

Figure 13: Wetland types (2007 LU/LC) in Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

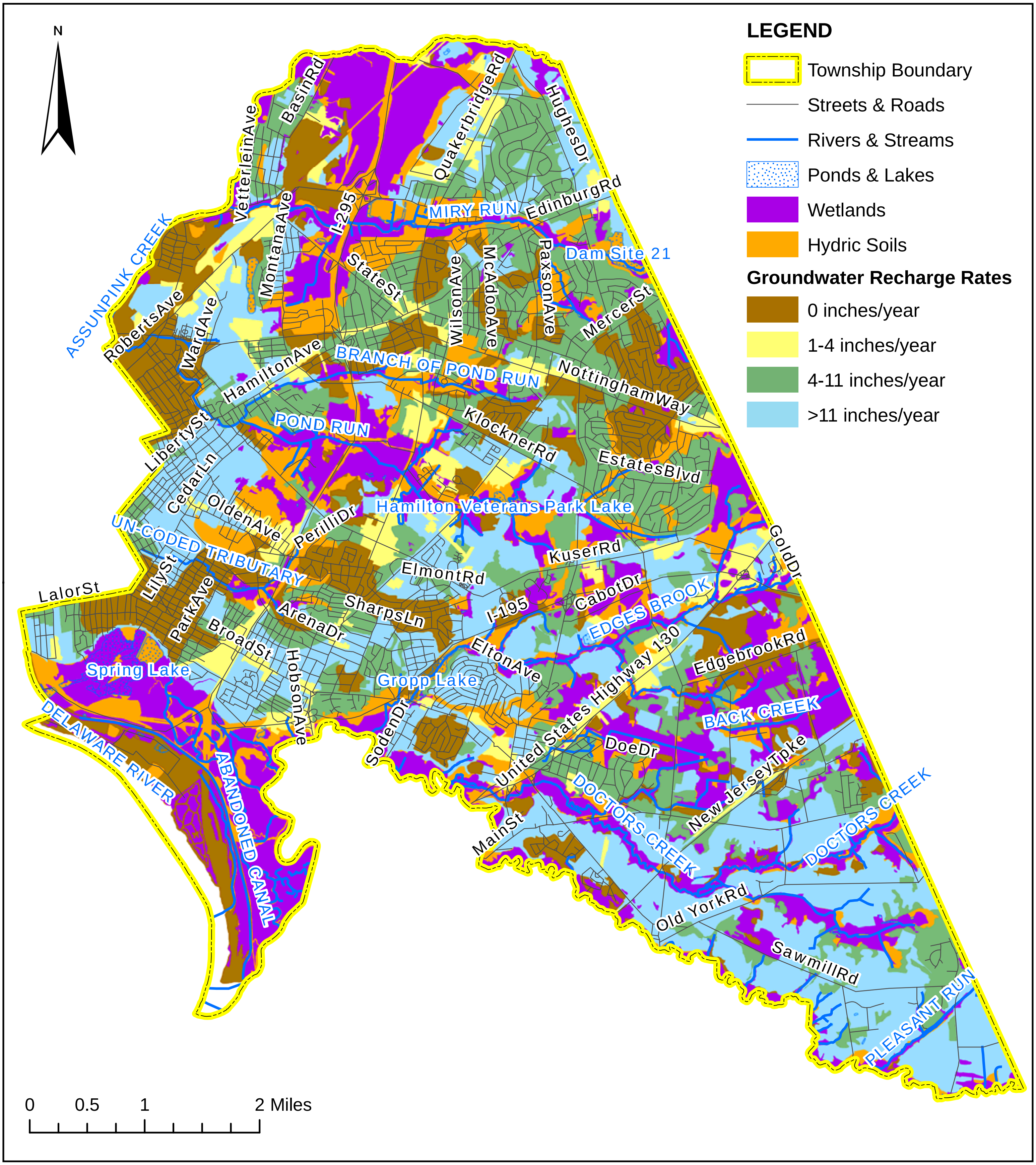

Figure 14: Groundwater recharge areas in Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station
Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

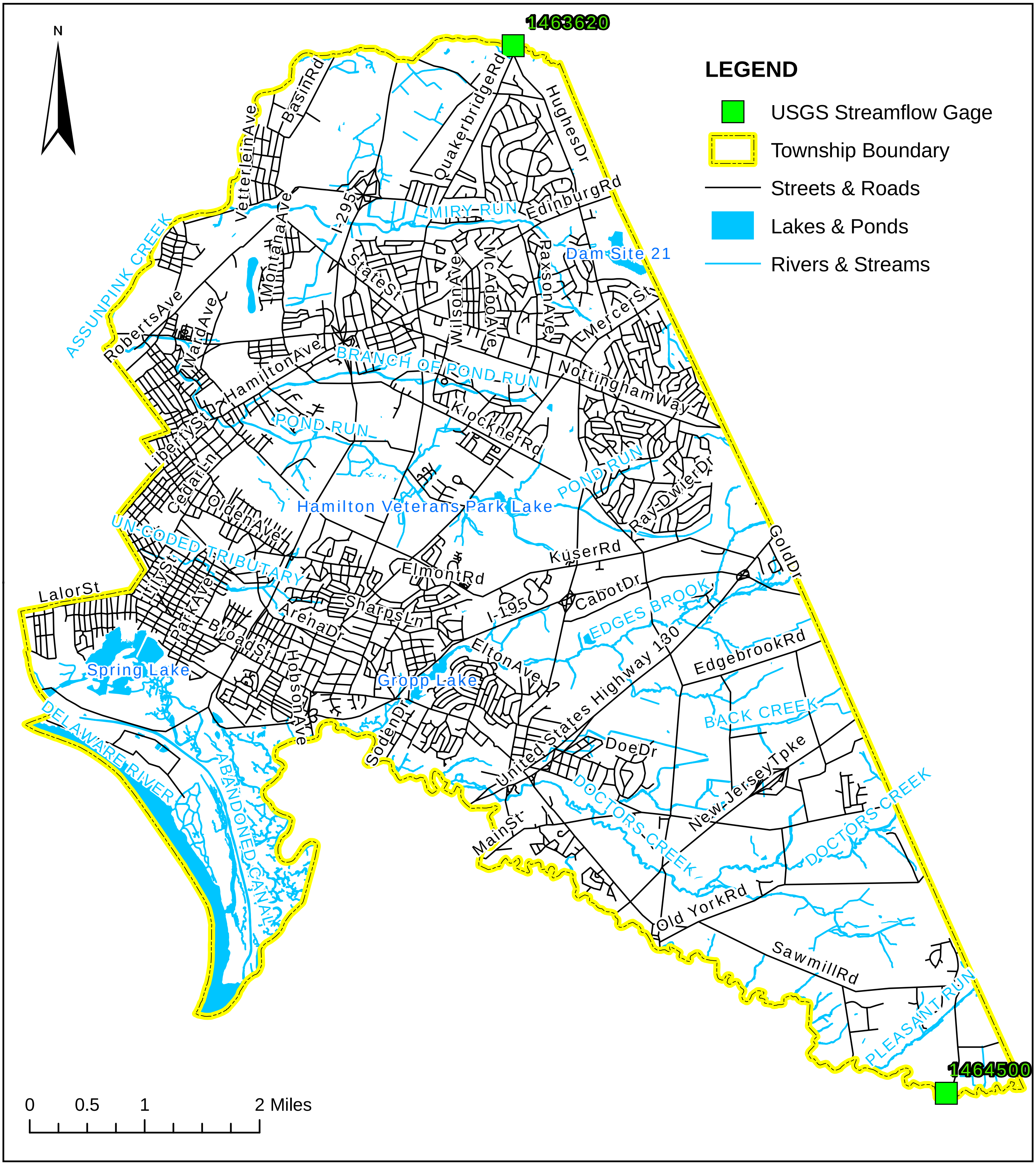

Figure 15: Flow monitoring gages in Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

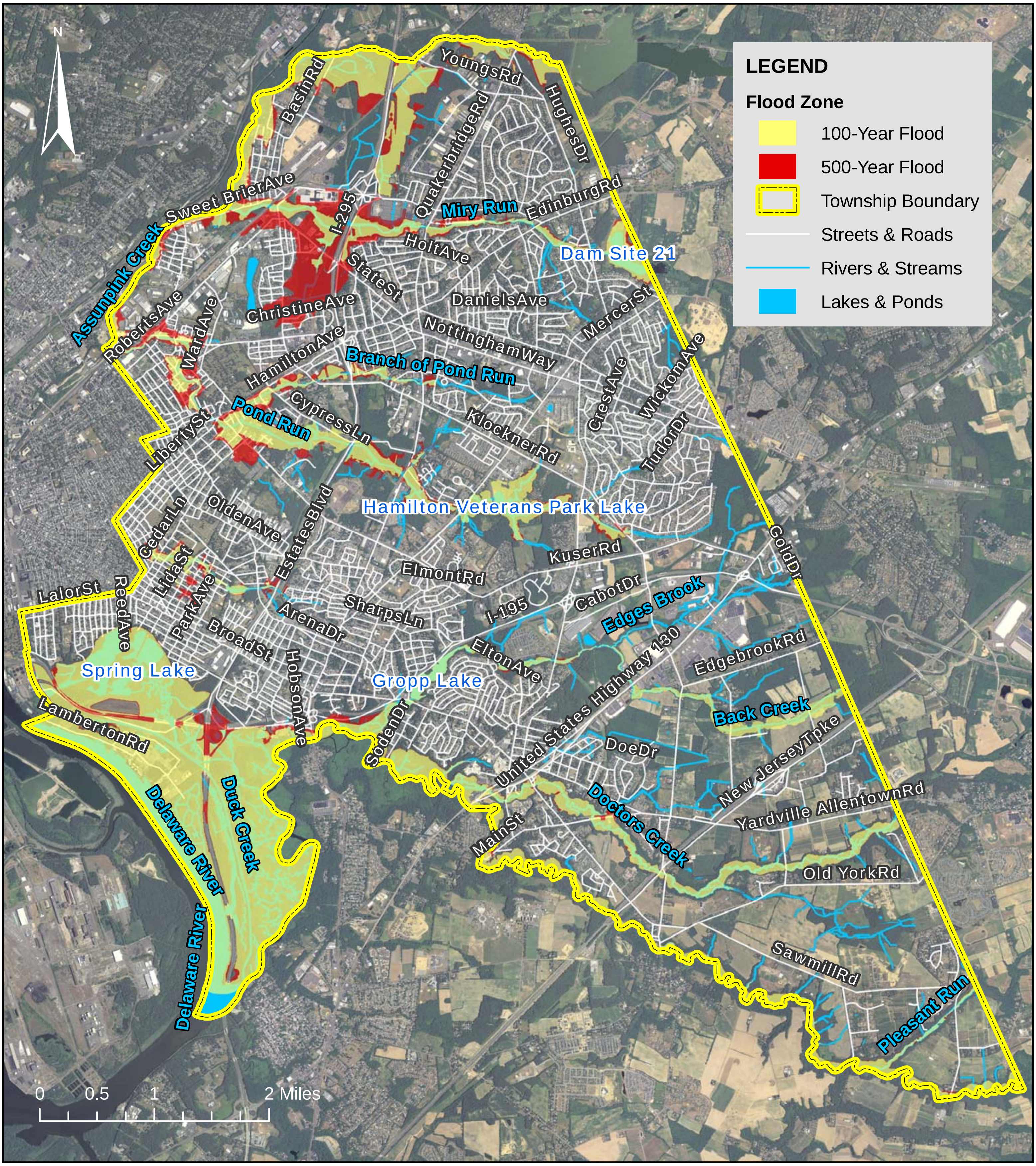

Figure 16: Flood zones of Hamilton Township (Mercer County).

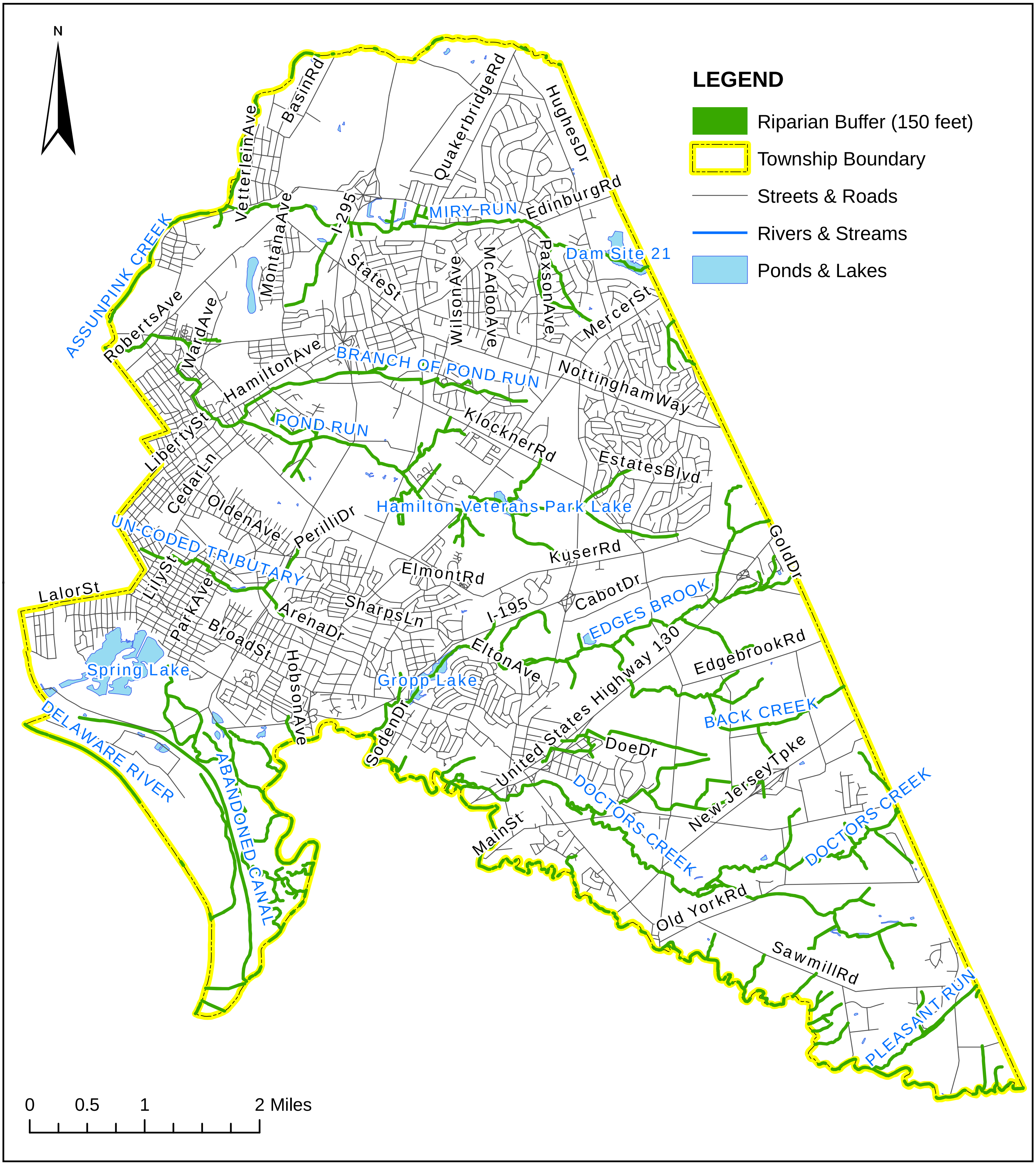

Figure 17: Riparian corridors in Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station
Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

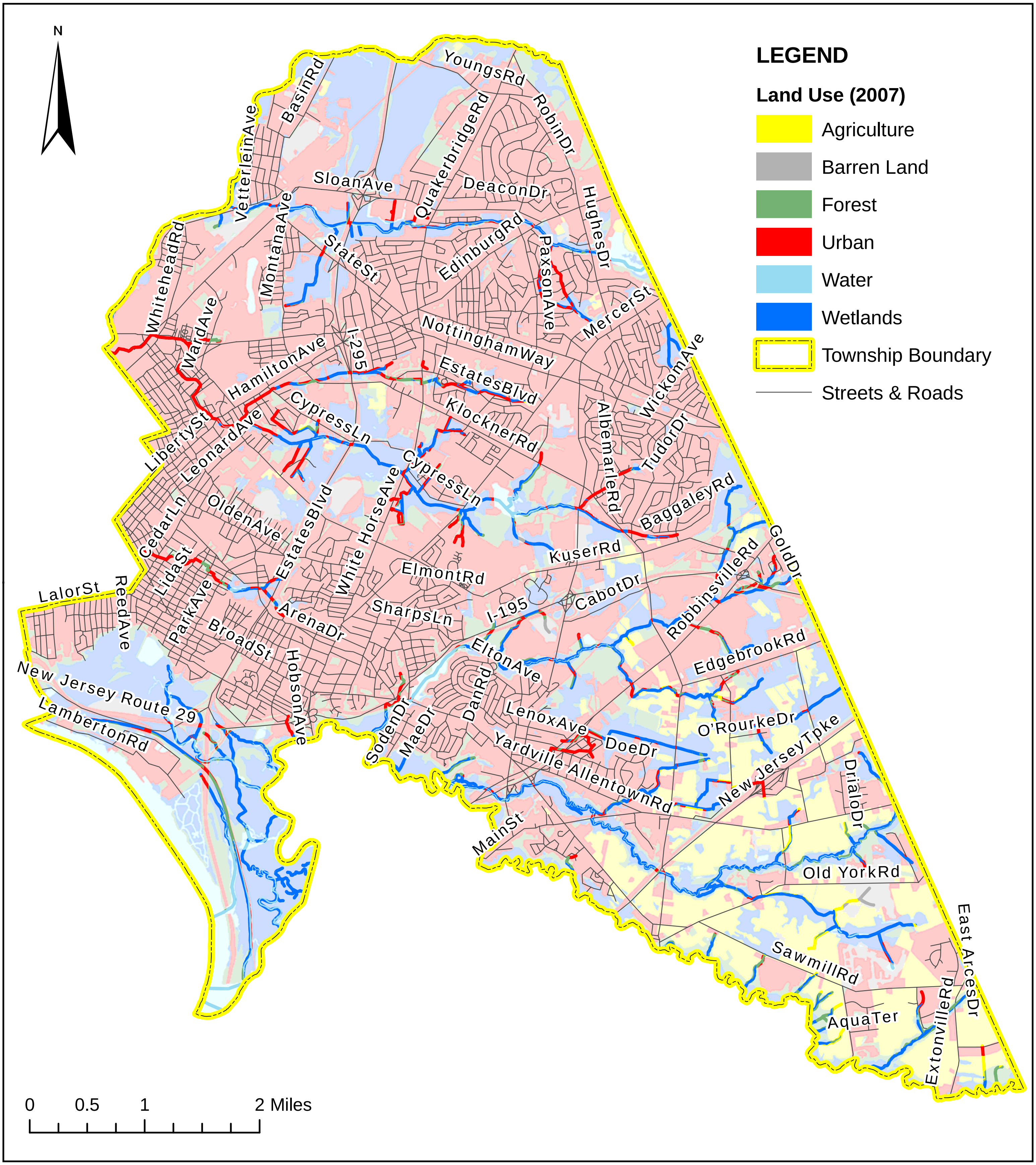

Figure 18: Land uses (2007) located in riparian corridors in Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station
Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

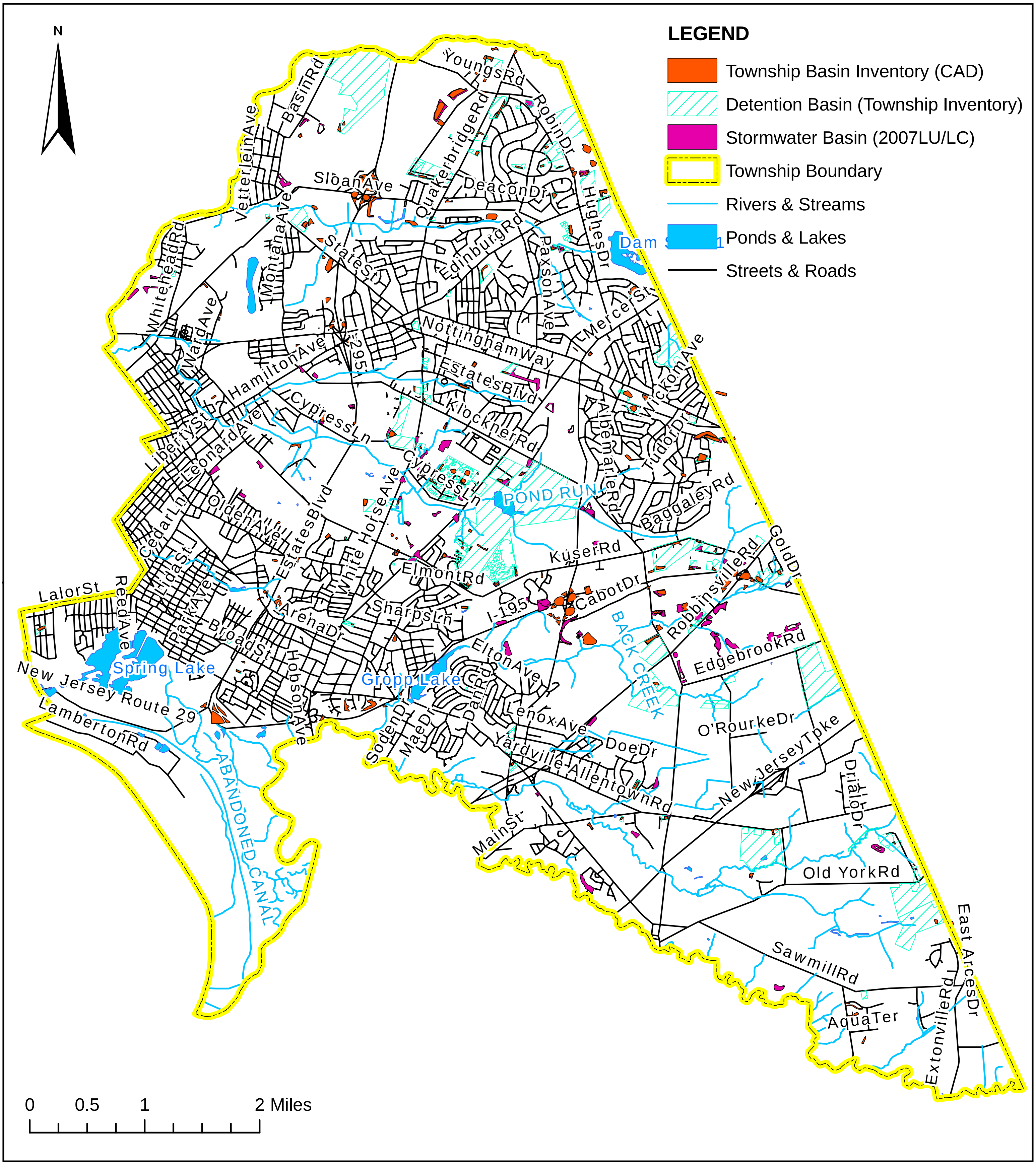

Figure 19: Location of detention basins in Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station
Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

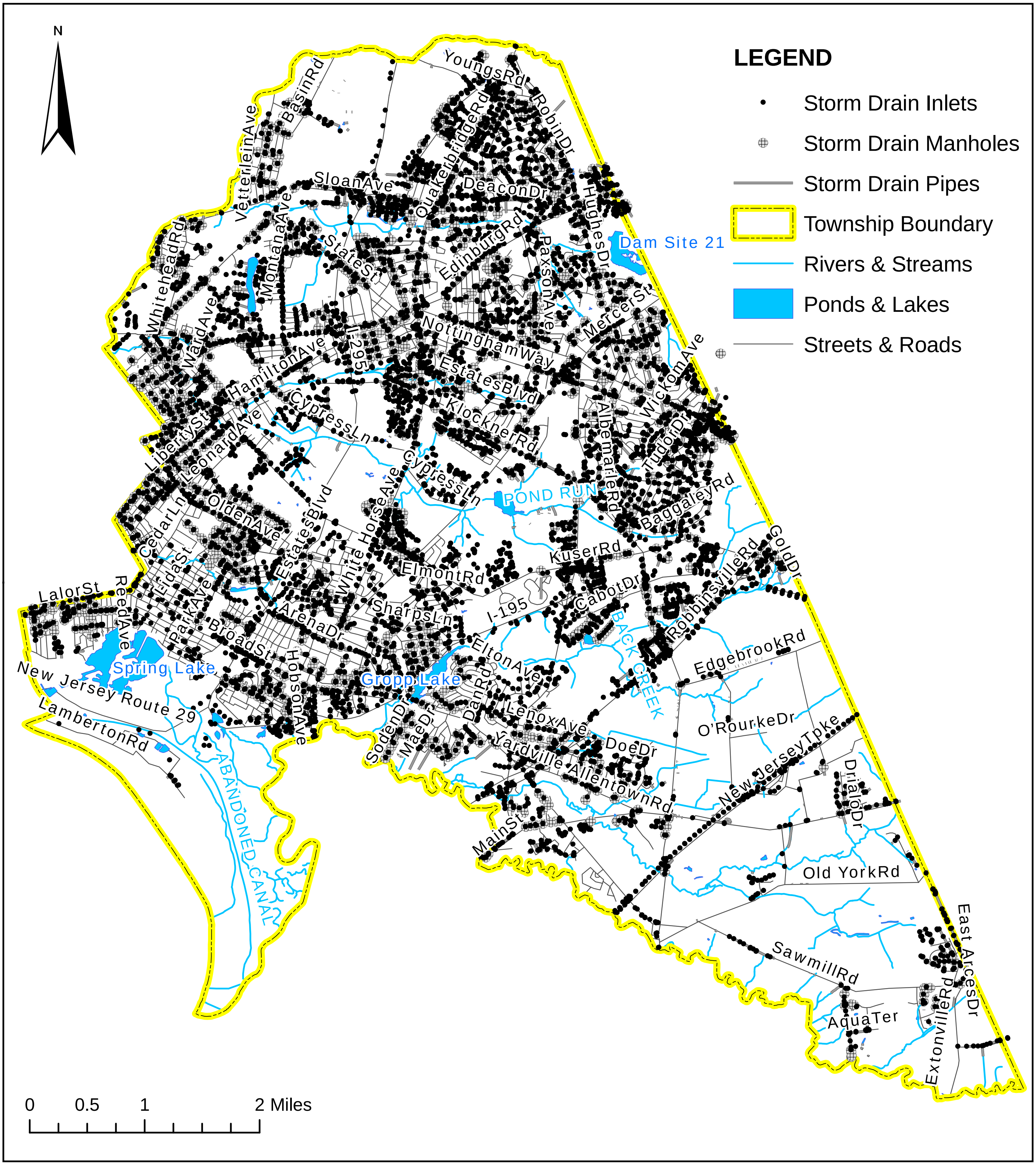

Figure 20: Stormwater infrastructure in Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

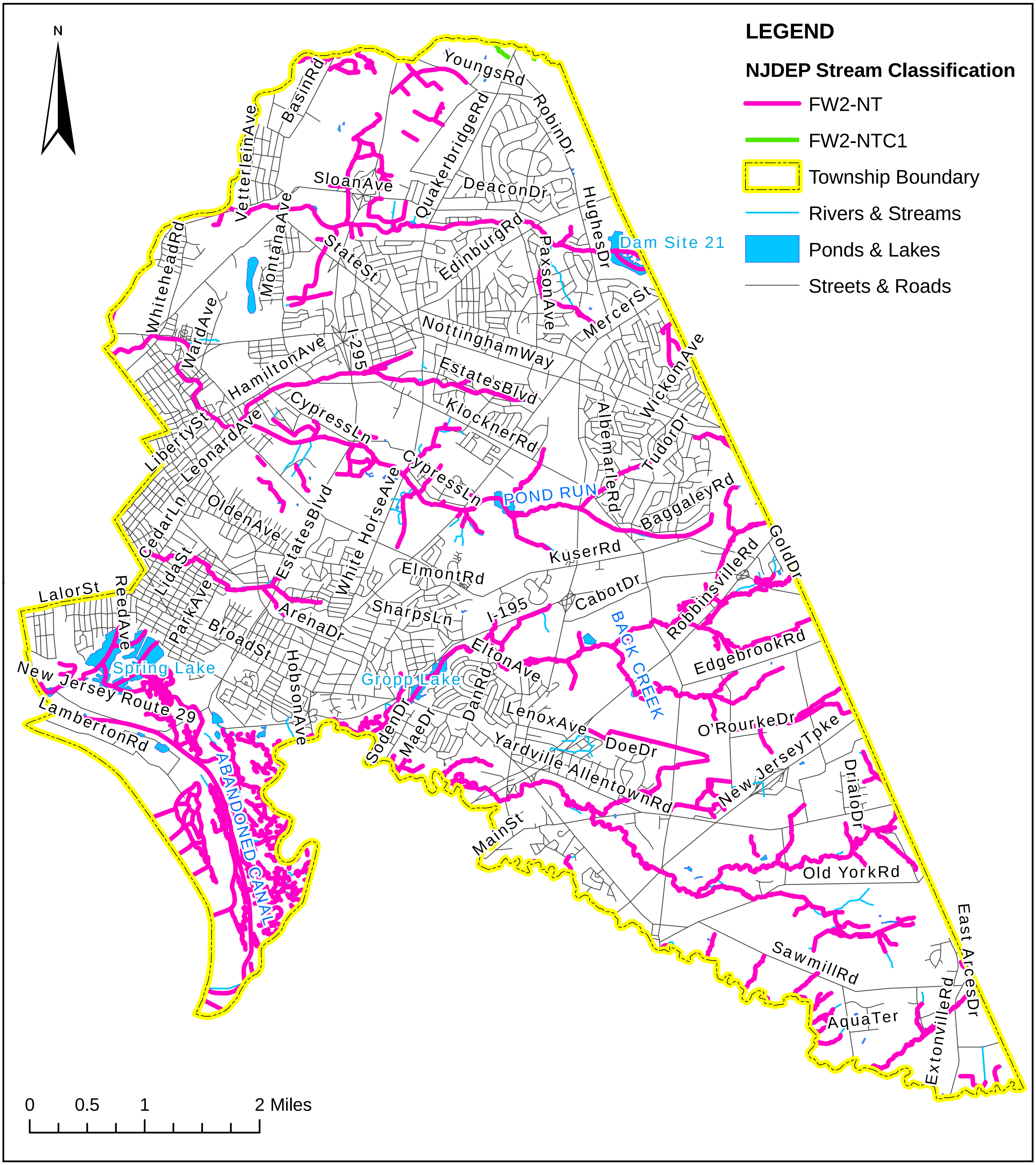

Figure 21: Stream classifications in Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural
Experiment Station

Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

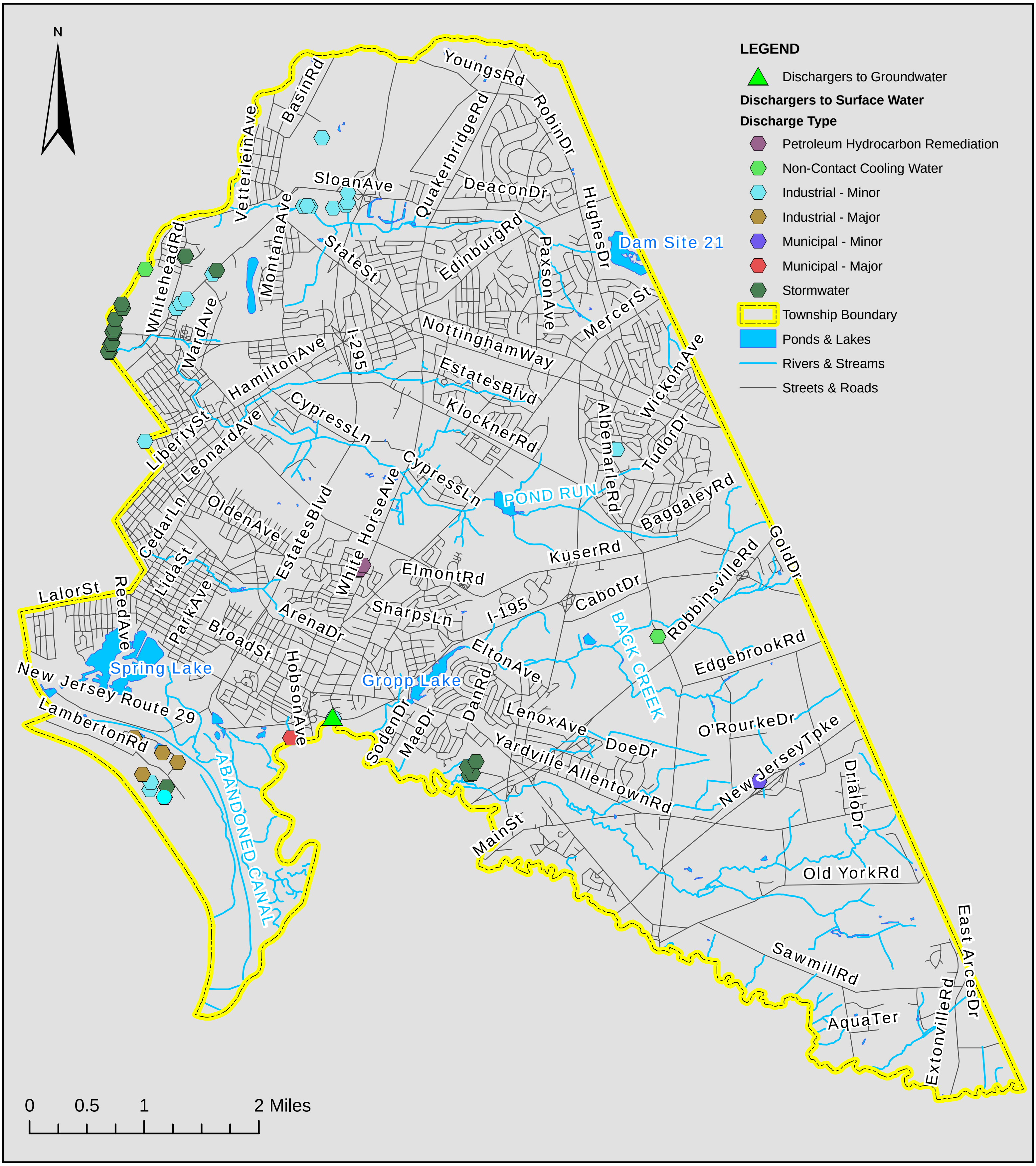

Figure 22: NJPDES dischargers in Hamilton Township (Mercer County).

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

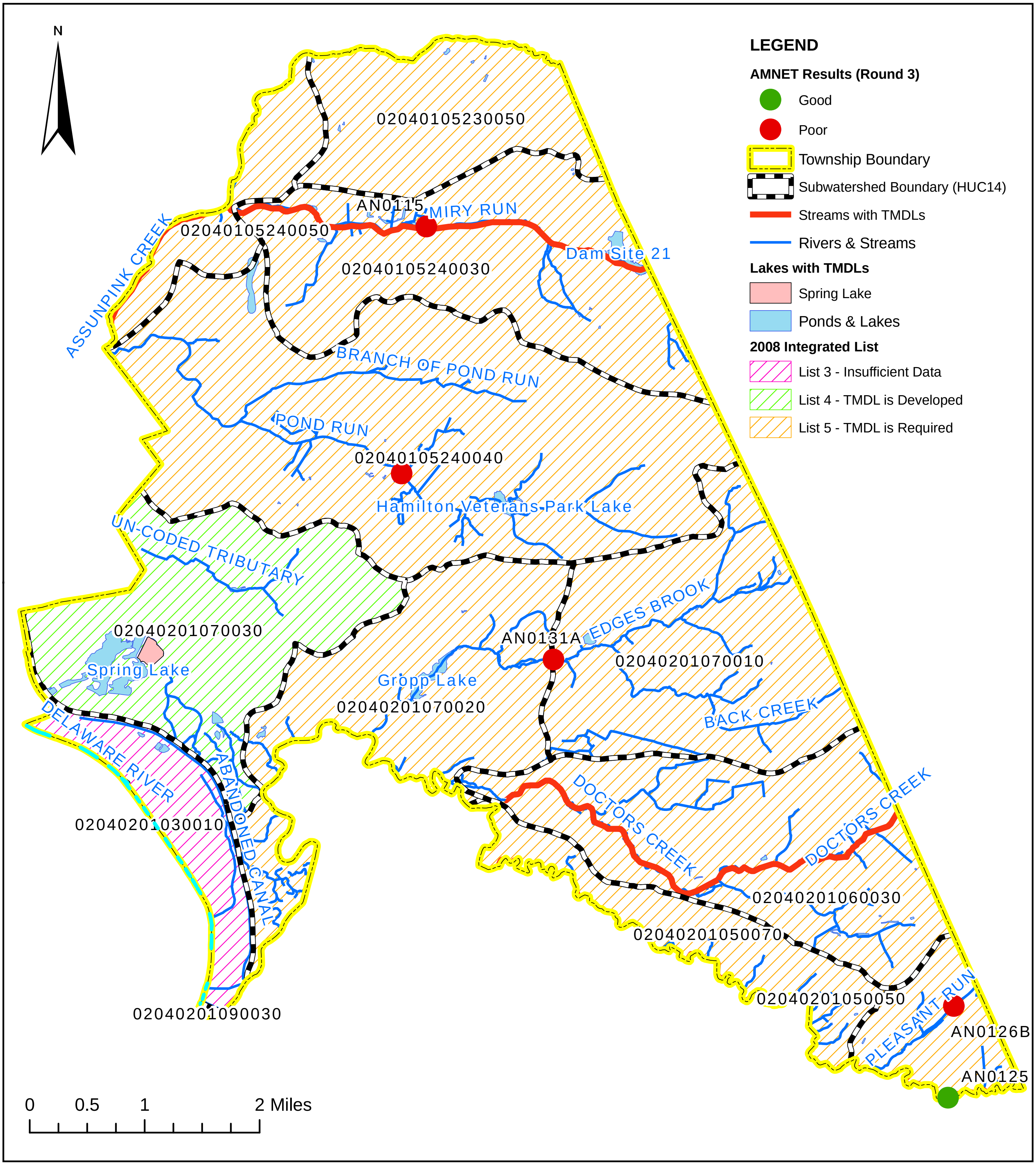

Figure 23: Surface water quality in Hamilton Township (Mercer County).

RUTGERS
New Jersey Agricultural Experiment Station
Water Resources Program

Rutgers, The State University of New Jersey
Rutgers Cooperative Extension Water Resources Program
14 College Farm Road
New Brunswick, NJ 08901
(732) 932-9800
water.rutgers.edu

Rutgers Cooperative Extension Water Resources Program

14 College Farm Road

New Brunswick, NJ 08901-8551

Phone: (732) 932-9800 • Fax: (732) 932-8644

http://water.rutgers.edu/