RUTGERS
New Jersey Agricultural
Experiment Station

Draft

Impervious Cover Assessment
for
Warren Township, Somerset County, New Jersey

Prepared for Warren Township by the
Rutgers Cooperative Extension Water Resources Program

February 5, 2015

Introduction

Pervious and impervious are terms that are used to describe the ability or inability of water to flow through a surface. When rainfall hits a surface, it can soak into the surface or flow off the surface. Pervious surfaces are those which allow stormwater to readily soak into the soil and recharge groundwater. When rainfall drains from a surface, it is called "stormwater" runoff (Figure 1). An impervious surface can be any material that has been placed over soil that prevents water from soaking into the ground. Impervious surfaces include paved roadways, parking lots, sidewalks, and rooftops. As impervious areas increase, so does the volume of stormwater runoff.

Figure 1: Stormwater draining from a parking lot

New Jersey has many problems due to stormwater runoff, including:

- Pollution: According to the 2010 New Jersey Water Quality Assessment Report, 90% of the assessed waters in New Jersey are impaired, with urban-related stormwater runoff listed as the most probable source of impairment (USEPA, 2013). As stormwater flows over the ground, it picks up pollutants including animal waste, excess fertilizers, pesticides, and other toxic substances. These pollutants are then able to enter waterways.

- Flooding: Over the past decade, the state has seen an increase in flooding. Communities around the state have been affected by these floods. The amount of damage caused also has increased greatly with this trend, costing billions of dollars over this time span.

- Erosion: Increased stormwater runoff causes an increase in the velocity of flows in our waterways. The increased velocity after storm events erodes stream banks and shorelines, degrading water quality. This erosion can damage local roads and bridges and cause harm to wildlife.

The primary cause of the pollution, flooding, and erosion problems is the quantity of impervious surfaces draining directly to local waterways. New Jersey is one of the most developed states in the country. Currently, the state has the highest percent of impervious cover in the country at 12.1% of its total area (Nowak & Greenfield, 2012). Many of these impervious surfaces are directly connected to local waterways (i.e., every drop of rain that lands on these impervious surfaces ends up in a local river, lake, or bay without any chance of being treated or soaking into the ground). To repair our waterways, reduce flooding, and stop erosion, stormwater runoff from impervious surfaces has to be better managed. Surfaces need to be disconnected with green infrastructure to prevent stormwater runoff from flowing directly into New Jersey's waterways. Disconnection redirects runoff from paving and rooftops to pervious areas in the landscape.

Green infrastructure is an approach to stormwater management that is cost-effective, sustainable, and environmentally friendly. Green infrastructure projects capture, filter, absorb, and reuse stormwater to maintain or mimic natural systems and to treat runoff as a resource. As a general principal, green infrastructure practices use soil and vegetation to recycle stormwater runoff through infiltration and evapotranspiration. When used as components of a stormwater management system, green infrastructure practices such as bioretention, green roofs, porous pavement, rain gardens, and vegetated swales can produce a variety of environmental benefits. In addition to effectively retaining and infiltrating rainfall, these technologies can simultaneously help filter air pollutants, reduce energy demands, mitigate urban heat islands, and sequester carbon while also providing communities with aesthetic and natural resource benefits (USEPA, 2013).

The first step to reducing the impacts from impervious surfaces is to conduct an impervious cover assessment. This assessment can be completed on different scales: individual lot, municipality, or watershed. Impervious surfaces need to be identified for stormwater management. Once impervious surfaces have been identified, there are three steps to better manage these surfaces.

1. ***Eliminate surfaces that are not necessary.*** For example, a paved courtyard at a public school could be converted to a grassed area.

2. ***Reduce or convert impervious surfaces.*** There may be surfaces that are required to be hardened, such as roadways or parking lots, but could be made smaller and still be functional. A parking lot that has two-way car ways could be converted to one-way car ways. There also are permeable paving materials such as porous asphalt, pervious concrete, or permeable paving stones that could be substituted for impermeable paving materials (Figure 2).

3. ***Disconnect impervious surfaces from flowing directly to local waterways.*** There are many ways to capture, treat, and infiltrate stormwater runoff from impervious surfaces. Opportunities may exist to reuse this captured water.

Figure 2: Rapid infiltration of water through porous pavement is demonstrated at the USEPA Edison New Jersey test site

Warren Township Impervious Cover Analysis

Located in Somerset County in central New Jersey, Warren Township covers approximately 19.6 square miles. Figures 3 and 4 illustrate that Warren Township is dominated by urban land uses. A total of 49.5% of the municipality's land use is classified as urban. Of the urban land in Warren Township, rural residential is the dominant land use (Figure 5).

The literature suggests a link between impervious cover and stream ecosystem impairment starting at approximately 10% impervious surface cover (Schueler, 1994; Arnold and Gibbons, 1996; May et al., 1997). Impervious cover may be linked to the quality of lakes, reservoirs, estuaries, and aquifers (Caraco et al., 1998), and the amount of impervious cover in a watershed can be used to project the current and future quality of streams. Based on the scientific literature, Caraco et al. (1998) classified urbanizing streams into the following three categories: sensitive streams, impacted streams, and non-supporting streams. Sensitive steams typically have a watershed impervious surface cover from 0 – 10%. Impacted streams have a watershed impervious cover ranging from 11-25% and typically show clear signs of degradation from urbanization. Non-supporting streams have a watershed impervious cover of greater than 25%; at this high level of impervious cover, streams are simply conduits for stormwater flow and no longer support a diverse stream community.

The New Jersey Department of Environmental Protection's (NJDEP) 2007 land use/land cover geographical information system (GIS) data layer categorizes Warren Township into many unique land use areas, assigning a percent impervious cover for each delineated area. These impervious cover values were used to estimate the impervious coverage for Warren Township. Based upon the 2007 NJDEP land use/land cover data, approximately 12.4% of Warren Township has impervious cover. This level of impervious cover suggests that the streams in Warren Township are likely impacted.

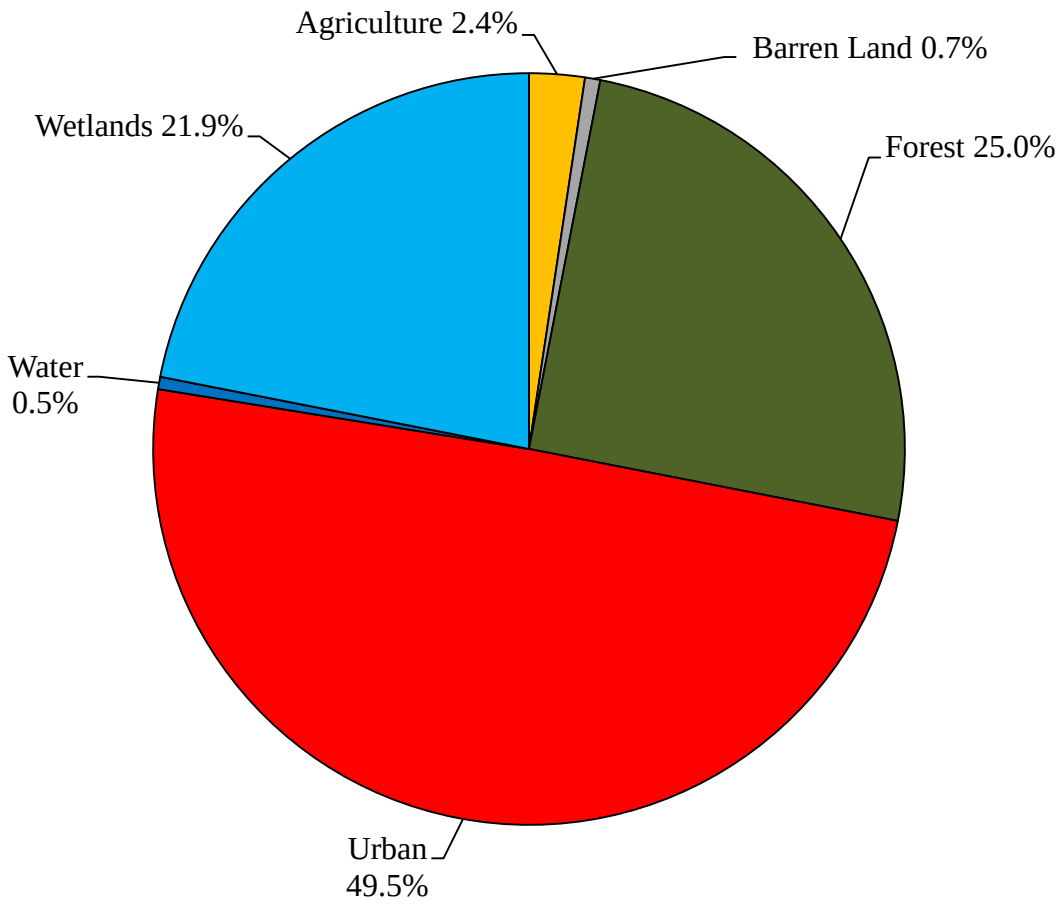


Figure 3: Pie chart illustrating the land use in Warren Township

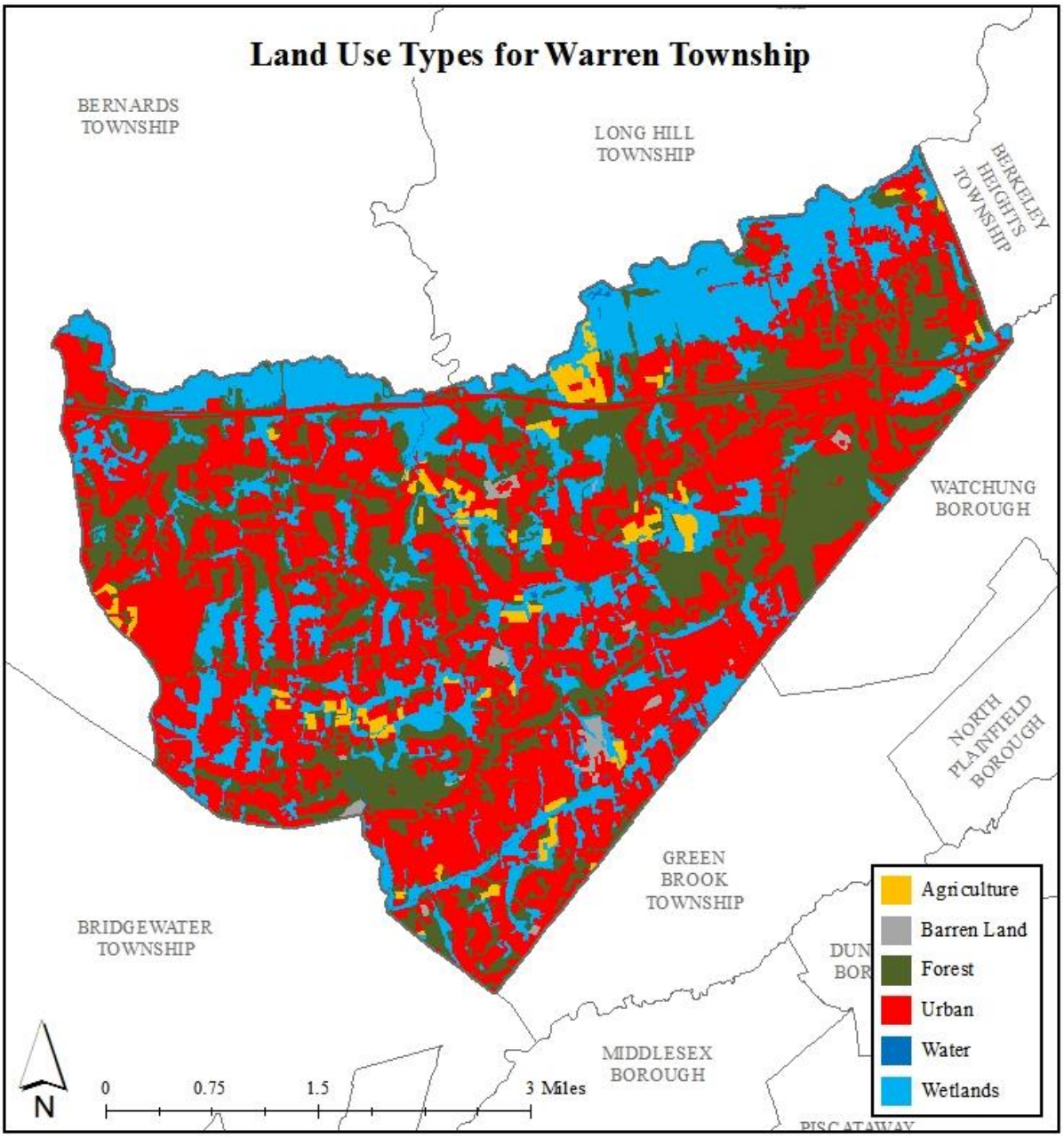


Figure 4: Map illustrating the land use in Warren Township

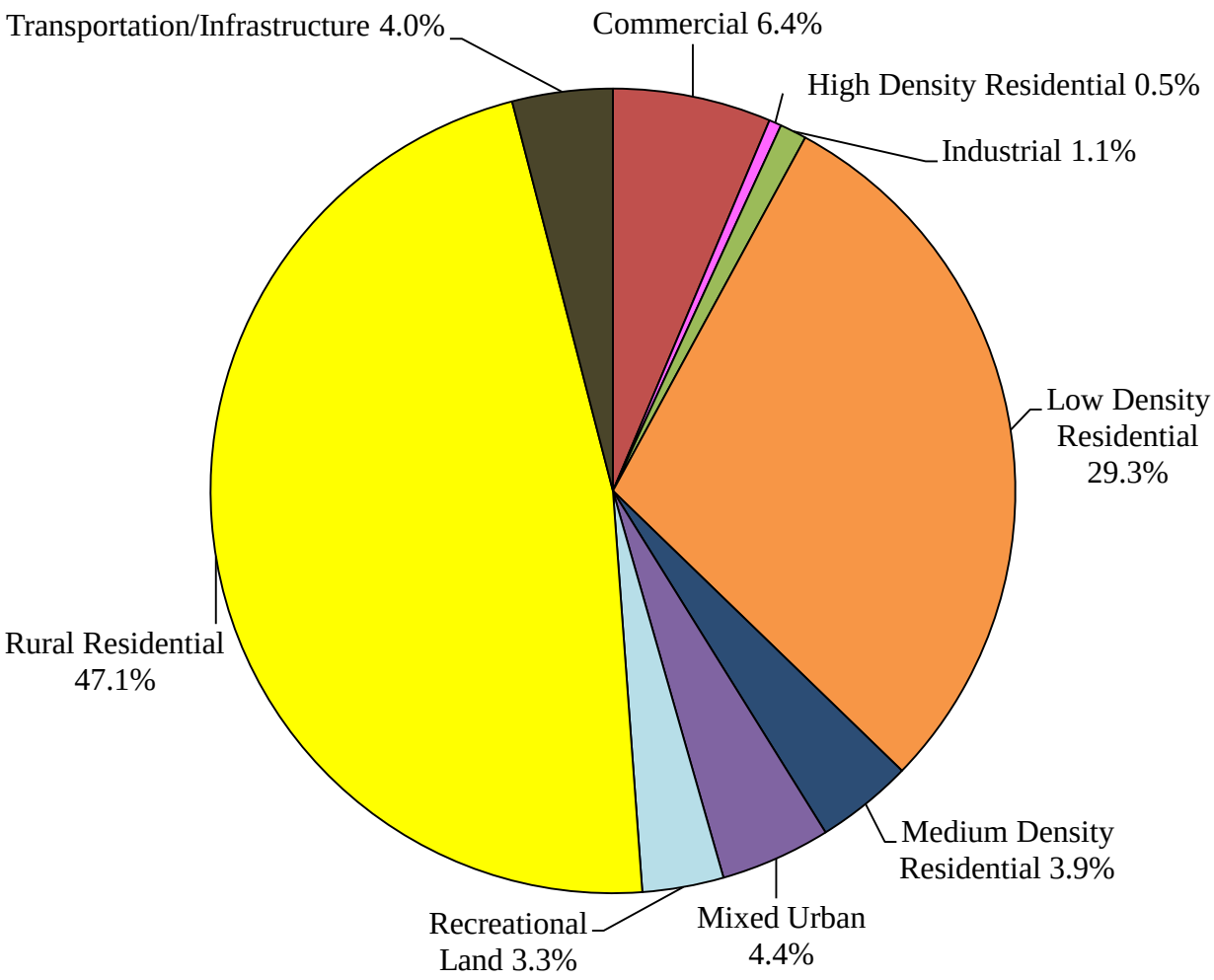


Figure 5: Pie chart illustrating the various types of urban land use in Warren Township

Water resources are typically managed on a watershed/subwatershed basis; therefore an impervious cover analysis was performed for each Raritan River subwatershed within Warren Township (Table 1 and Figure 6). On a subwatershed basis, impervious cover ranges from 0% in the Harrisons Brook subwatershed to 13.2% in the Dead River subwatershed. Evaluating impervious cover on a subwatershed basis allows the municipality to focus impervious cover reduction or disconnection efforts in the subwatersheds where frequent flooding occurs.

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. Stormwater runoff volumes (specific to Warren Township, Somerset County) associated with impervious surfaces were calculated for the following storms: the New Jersey water quality design storm of 1.25 inches of rain, an annual rainfall of 44 inches, the 2-year design storm (3.3 inches of rain), the 10-year design storm (5.0 inches of rain), and the 100-year design storm (8.2 inches of rain). These runoff volumes are summarized in Table 2. A substantial amount of rainwater drains from impervious surfaces in Warren Township. For example, if the stormwater runoff from one water quality storm (1.25 inches of rain) in the Middle Brook subwatershed was harvested and purified, it could supply water to 158 homes for one year[1].

[1] Assuming 300 gallons per day per home

Table 1: Impervious cover analysis by subwatershed for Warren Township

Subwatershed	Total Area		Land Use Area		Water Area		Impervious Cover		
	(ac)	(mi^2)	(ac)	(mi^2)	(ac)	(mi^2)	(ac)	(mi^2)	(%)
Dead River	3,732.4	5.83	3,714.3	5.80	18.1	0.03	489.6	0.76	13.2%
Green Brook	31.3	0.05	31.3	0.05	0.00	0.00	4.08	0.01	13.0%
Harrisons Brook	0.17	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00%
Middle Brook	3,932.1	6.14	3,916.0	6.12	16.0	0.03	508.4	0.79	13.0%
Upper Passaic River	3,611.2	5.64	3,579.7	5.59	31.5	0.05	394.1	0.62	11.0%
Stony Brook	1,256.3	1.96	1,255.4	1.96	0.85	0.00	153.8	0.24	12.3%
Total	12,563.5	19.6	12,497.0	19.5	66.5	0.10	1,550.0	2.42	12.4%

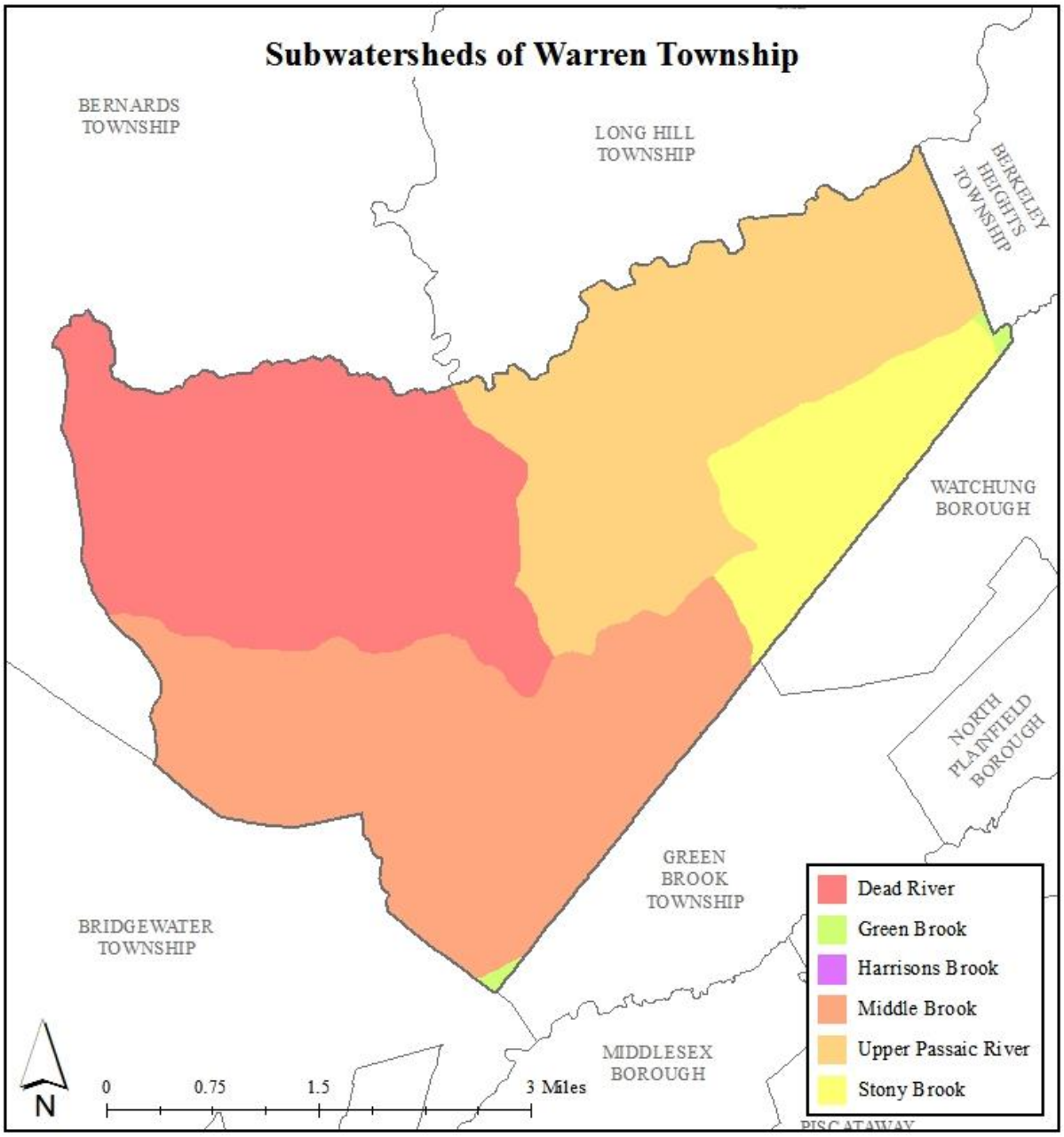


Figure 6: Map of the subwatersheds in Warren Township

Table 2: Stormwater runoff volumes from impervious surfaces by subwatershed in Warren Township

Subwatershed	**Total Runoff Volume for the 1.25" NJ Water Quality Storm (MGal)**	**Total Runoff Volume for the NJ Annual Rainfall of 44" (MGal)**	**Total Runoff Volume for the 2-Year Design Storm (3.3") (MGal)**	**Total Runoff Volume for the 10-Year Design Storm (5.0") (MGal)**	**Total Runoff Volume for the 100-Year Design Storm (8.2") (MGal)**
Dead River	16.6	584.9	43.9	66.5	109.0
Green Brook	0.1	4.9	0.4	0.6	0.9
Harrisons Brook	0.0	0.0	0.0	0.0	0.0
Middle Brook	17.3	607.4	45.6	69.0	113.2
Upper Passaic River	13.4	470.8	35.3	53.5	87.7
Stony Brook	5.2	183.7	13.8	20.9	34.2
Total	52.6	1,851.7	138.9	210.4	345.0

The next step is to set a reduction goal for impervious area in each subwatershed. Based upon the Rutgers Cooperative Extension (RCE) Water Resources Program's experience, a 10% reduction would be a reasonably achievable reduction for these subwatersheds in Warren Township. While it may be difficult to eliminate paved areas or replace paved areas with permeable pavement, it is relatively easy to identify impervious surfaces that can be disconnected using green infrastructure practices. For all practical purposes, disconnecting an impervious surface from a storm sewer system or a water body is an "impervious area reduction." The RCE Water Resources Program recommends that all green infrastructure practices that are installed to disconnect impervious surfaces should be designed for the 2-year design storm (3.3 inches of rain over 24-hours). Although this results in management practices that are slightly over-designed by NJDEP standards, which require systems to be designed for the New Jersey water quality storm (1.25 inches of rain over 2-hours), these systems will be able to handle the increase in storm intensities that are expected to occur due to climate change. By designing these management practices for the 2-year design storm, these practices will be able to manage 95% of the annual rainfall volume. The recommended annual reductions in runoff volumes are shown in Table 3.

As previously mentioned, once impervious surfaces have been identified, the next steps for managing impervious surfaces are to 1) eliminate surfaces that are not necessary, 2) reduce or convert impervious surfaces to pervious surfaces, and 3) disconnect impervious surfaces from flowing directly to local waterways.

Elimination of Impervious Surfaces

One method to reduce impervious cover is to "depave." Depaving is the act of removing paved impervious surfaces and replacing them with pervious soil and vegetation that will allow for the infiltration of rainwater. Depaving leads to the re-creation of natural space that will help reduce flooding, increase wildlife habitat, and positively enhance water quality as well as beautify neighborhoods. Depaving also can bring communities together around a shared vision to work together to reconnect their neighborhood to the natural environment.

Table 3: Impervious cover reductions by subwatershed in Warren Township

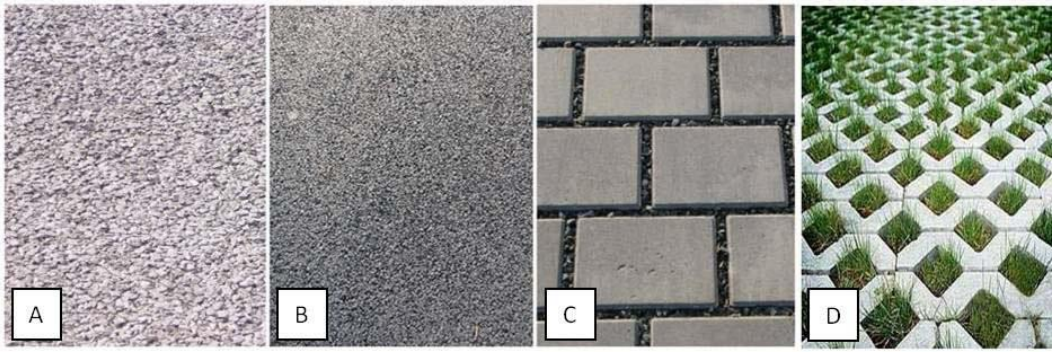
Subwatershed	**Recommended Impervious Area Reduction (10%) (ac)**	**Annual Runoff Volume Reduction [2] (MGal)**
Dead River	49.0	55.6
Green Brook	0.4	0.5
Harrisons Brook	0.0	0.0
Middle Brook	50.8	57.7
Upper Passaic River	39.4	44.7
Stony Brook	15.4	17.5
Total	155.0	175.9

[2] Annual Runoff Volume Reduction =
Acres of impervious cover x 43,560 ft^2/ac x 44 in x (1 ft/12 in) x 0.95 x (7.48 gal/ft^3) x (1 MGal/1,000,000 gal)
All green infrastructure should be designed to capture the first 3.3 inches of rain from each storm. This would allow the green infrastructure to capture 95% of the annual rainfall of 44 inches.

Pervious Pavement

There are four different types of permeable pavement systems that are commonly being used throughout the country to reduce the environmental impacts from impervious surfaces. These surfaces include pervious concrete, porous asphalt, interlocking concrete pavers, and grid pavers.

> "*Permeable pavement is a stormwater drainage system that allows rainwater and runoff to move through the pavement's surface to a storage layer below, with the water eventually seeping into the underlying soil. Permeable pavement is beneficial to the environment because it can reduce stormwater volume, treat stormwater water quality, replenish the groundwater supply, and lower air temperatures on hot days (Rowe, 2012).*"



Permeable surfaces: (A) pervious concrete, (B) porous asphalt, (C) interlocking concrete pavers, (D) grid pavers (Rowe, 2012)

Pervious concrete and porous asphalt are the most common of the permeable surfaces. They are similar to regular concrete and asphalt but without the fine materials. This allows water to quickly pass through the material into an underlying layered system of stone that holds the water allowing it to infiltrate into the underlying uncompacted soil.

Impervious Cover Disconnection Practices

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. There are many cost-effective ways to disconnect impervious surfaces from local waterways.

- Simple Disconnection: This is the easiest and least costly method to reduce stormwater runoff for smaller storm events. Instead of piping rooftop runoff to the street where it enters the catch basin and is piped to the river, the rooftop runoff is released onto a grassed

area to allow the water to be filtered by the grass and soak into the ground. A healthy lawn typically can absorb the first one to two inches of stormwater runoff from a rooftop. Simple disconnection also can be used to manage stormwater runoff from paved areas. Designing a parking lot or driveway to drain onto a grassed area, instead of the street, can dramatically reduce pollution and runoff volumes.

- Rain Gardens: Stormwater can be diverted into shallow landscaped depressed areas (i.e., rain gardens) where the vegetation filters the water, and it is allowed to soak into the ground. Rain gardens, also known as bioretention systems, come in all shapes and sizes and can be designed to disconnect a variety of impervious surfaces (Figure 7).

Figure 7: Rain garden outside the RCE of Gloucester County office which was designed to disconnect rooftop runoff from the local storm sewer system

- Rainwater Harvesting: Rainwater harvesting includes the use of rain barrels and cisterns (Figures 8a and 8b). These can be placed below downspouts to collect rooftop runoff. The collected water has a variety of uses including watering plants and washing cars. This practice also helps cut down on the use of potable water for nondrinking purposes. It is important to divert the overflow from the rainwater harvesting system to a pervious area.

Figure 8a: Rain barrel used to disconnect a downspout with the overflow going to a flower bed

Figure 8b: A 5,000 gallon cistern used to disconnect the rooftop of the Department of Public Works in Clark Township to harvest rainwater for nonprofit car wash events

Examples of Opportunities in Warren Township

To address the impact of stormwater runoff from impervious surfaces, the next step is to identify opportunities in the municipality for eliminating, reducing, or disconnecting directly connected impervious surfaces. To accomplish this task, an impervious cover reduction action plan should be prepared. Aerial photographs are used to identify sites with impervious surfaces in the municipality that may be suitable for inclusion in the action plan. After sites are identified, site visits are conducted to photo-document all opportunities and evaluate the feasibility of eliminating, reducing or disconnecting directly connected impervious surfaces. A brief description of each site discussing the existing conditions and recommendations for treatment of the impervious surfaces is developed. After a number of sites have been selected for inclusion in the action plan, concept plans and detailed green infrastructure information sheets are prepared for a selection of representative sites.

For Warren Township, three sites have been included in this assessment. Examples of concept plans and detailed green infrastructure information sheets are provided in Appendix A. The detailed green infrastructure information sheets describe existing conditions and issues, proposed solutions, anticipated benefits, possible funding sources, potential partners and stakeholders, and estimated costs. Additionally, each project has been classified as a mitigation opportunity for recharge potential, total suspended solids removal, and stormwater peak reduction. Finally, these detailed green infrastructure information sheets provide an estimate of gallons of stormwater captured and treated per year by each proposed green infrastructure practice. The concept plans provide an aerial photograph of the site and details of the proposed green infrastructure practices.

Conclusions

Warren Township can reduce flooding and improve its waterways by better managing stormwater runoff from impervious surfaces. This impervious cover assessment is the first step toward better managing stormwater runoff. The next step is to develop an action plan to eliminate, reduce, or disconnect impervious surfaces where possible and practical. Many of the highly effective disconnection practices are inexpensive. The entire community can be engaged in implementing these disconnection practices.

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Appendix A

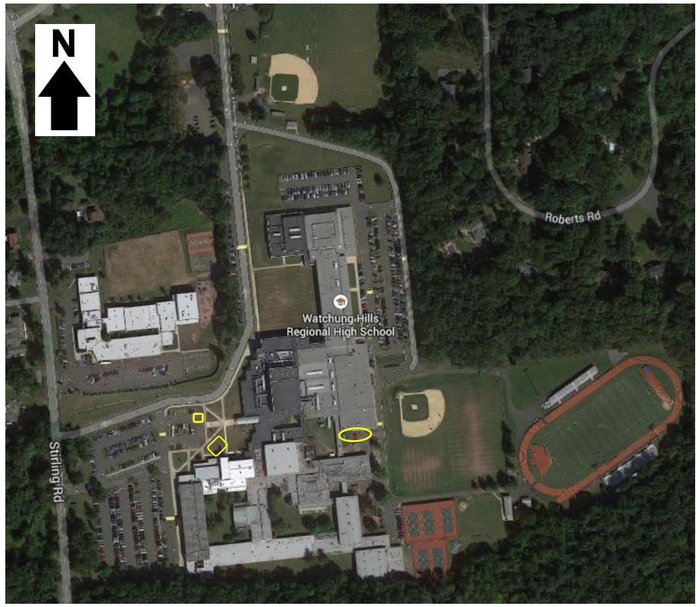
Examples of Impervious Cover Reduction Action Plan Projects

Concept Plans and Detailed Green Infrastructure Information Sheets

Warren Township
Impervious Cover Assessment
Watchung Hills Regional High School, 108 Stirling Road

RUTGERS
New Jersey Agricultural Experiment Station

PROJECT LOCATION:



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SITE PLAN:

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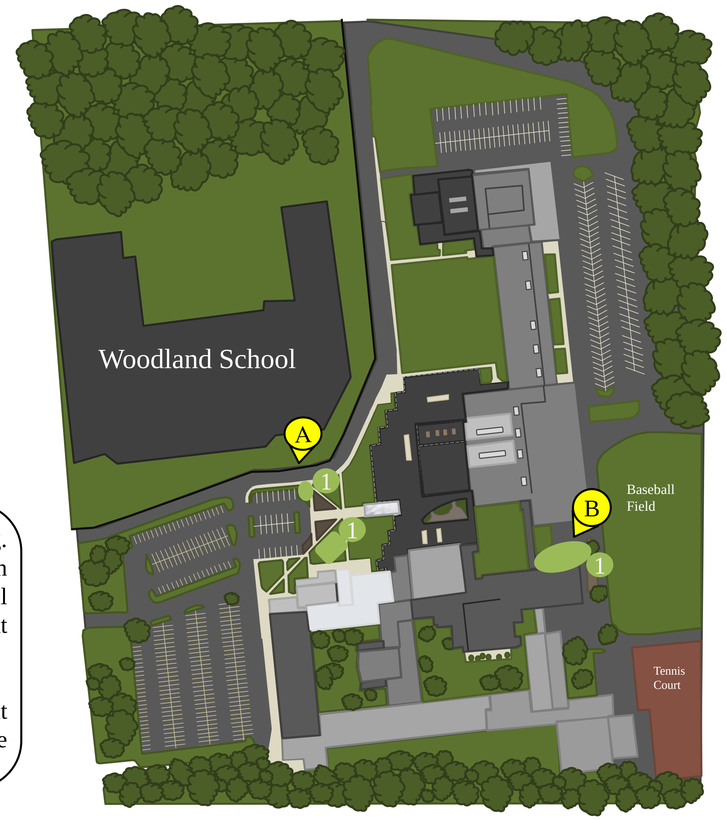
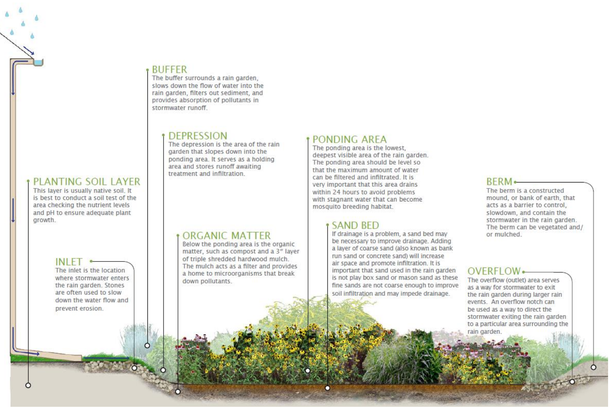


1 **BIORETENTION SYSTEM:** Bioretention systems could be installed in the grass adjacent to the parking lot on the western side of the building. Curb cuts should be installed to allow the flow of runoff into this bioretention system. A second bioretention system could be installed between walkways also located off the western side of the building. A third bioretention can be installed adjacent to the small parking lot near the baseball field to capture roof runoff from redirected downspouts. These system will reduce runoff and allow stormwater infiltration, decreasing the amount of contaminants that reach catch basins.

EDUCATIONAL PROGRAM: The RCE Water Resources Program's *Stormwater Management in Your Schoolyard* program can be delivered at Watchung Hills Regional High School to educate the students about stormwater management and engage them in designing and building the bioretention systems.

1 BIORETENTION SYSTEM



CURB CUTS

EDUCATIONAL PROGRAM

Watchung Hills Regional High School
Green Infrastructure Information Sheet

Location: 108 Stirling Road Warren, NJ 07059	**Municipality:** Warren Township **Subwatershed:** Passaic River
Green Infrastructure Description: bioretention systems (rain gardens) curb cuts youth education program	**Targeted Pollutants:** total nitrogen (TN), total phosphorous (TP), and total suspended solids (TSS) in surface runoff
Mitigation Opportunities: recharge potential: yes TSS removal potential: yes stormwater peak reduction potential: yes	**Stormwater Captured and Treated Per Year:** rain garden #1: 46,800 gal. rain garden #2: 27,600 gal. rain garden #3: 77,900 gal.

Existing Conditions and Issues:
In the front parking lot, there is the possibility of flooding and erosion from large volume storms. In the back of the school near the baseball field, there are two connected downspouts behind a large grass area.

Proposed Solution(s):
The front parking lot could benefit from a bioretention system and curb cuts in the section of grass to the west of the entrance of the school. The runoff from the parking lot would be redirected into the bioretention system where it is filtered and treated before being released into the groundwater. There is a turf grass area between the walkways off the west side of the building that is also a good candidate for a bioretention system. In the back of the school near the baseball field, the connected downspouts can be disconnected and redirected into a newly installed bioretention system in that area.

Anticipated Benefits:
Since the bioretention systems would be designed to capture, treat, and infiltrate the entire 2-year design storm (3.3 inches of rain over 24 hours), these systems are estimated to achieve a 95% pollutant load reduction for TN, TP, and TSS. This bioretention system would provide additional benefits such as aesthetic appeal and expanded wildlife habitat. Rutgers Cooperative Extension could additionally present the *Stormwater Management in Your Schoolyard* program to students and include them in bioretention system planting efforts to enhance the program. This may also be used as a demonstration project for the Warren Township Department of Public Works staff to launch educational programming.

Possible Funding Sources:
mitigation funds from local developers
NJDEP grant programs
grants from foundations
home and school associations

Partners/Stakeholders:
Warren Township
students and parents
local community groups (Boy Scouts, Girl Scouts, etc.)
NY/NJ Baykeeper
Raritan Riverkeeper
Rutgers Cooperative Extension

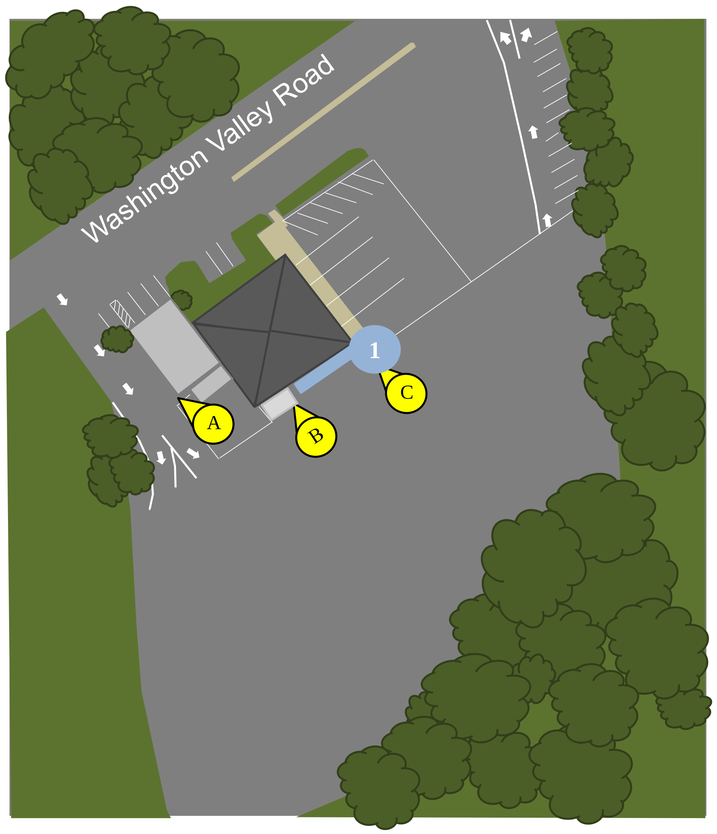
Estimated Cost:
Bioretention system #1 would need to be approximately 450 square feet. At $5 per square foot, the estimated cost of the rain garden is approximately $2,250. Bioretention system #2 would need to be approximately 270 square feet. At $5 per square foot, the estimated cost of the rain garden is $1,350. Bioretention system #3 would need to be approximately 750 square feet. At $5 per square foot, the estimated cost of the rain garden is $3,750. The total project cost would be $7,350.

Warren Township
Impervious Cover Assessment
Washington Valley Volunteer Fire Company, 146 Washington Valley Road

RUTGERS
New Jersey Agricultural Experiment Station

PROJECT LOCATION:

SITE PLAN:



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1 **RAINWATER HARVESTING SYSTEM:** Rainwater can be harvested from the roof of the building and stored in cisterns. The water can be used to wash the fire trucks.

1 RAINWATER HARVESTING SYSTEM

Washington Valley Volunteer Fire Company
Green Infrastructure Information Sheet

Location: 146 Washington Valley Road Warren, NJ 07059	**Municipality:** Warren Township **Subwatersheds:** Middle Brook
Green Infrastructure Description: rainwater harvesting system	**Targeted Pollutants:** total nitrogen (TN), total phosphorous (TP), and total suspended solids (TSS) in surface runoff
Mitigation Opportunities: recharge potential: yes TSS removal potential: yes stormwater peak reduction potential: yes	**Stormwater Captured Per Year:** rainwater harvesting system: 30,000 gal.

Existing Conditions and Issues:

This site contains several impervious surfaces including driveways, parking areas, and a gravel area. These impervious surfaces are directly connected to a storm sewer system. The site's impervious surfaces produce stormwater runoff during rain events. The eastern and southern area of this site have three (3) directly connected downspouts and three (3) disconnected downspouts, respectively. The site visit mainly focused on the eastern section of the fire station. It was noted that three (3) of the most eastern downspouts tied directly into an adjacent trench drain which led to a storm drain system while the remaining three (3) discharged over the impervious surface as sheet flow. The existing pavement was recently refinished and in good condition having a flow pattern slightly west to the nearby trench drain.

Proposed Solution(s):

This site would greatly benefit from a 2,000 gallon stormwater cistern. The three (3) adjacent downspouts on the eastern side of the foundation would have to be simply disconnected. In addition, the existing gutters would have to be modified to divert the stormwater to the cistern. Modifying the gutters is an essential step toward capturing maximum volumes of runoff. This stormwater harvesting reservoir not only captures large amounts of stormwater runoff, it also reduces localized flooding in nearby rivers and streams.

Anticipated Benefits:

A cistern can harvest stormwater which can be used for washing the fire station vehicles or other purposes which cuts back on the use of potable water for nondrinking purposes. Since the rainwater harvesting system would be designed to capture the first 0.75 inches of rain, it would reduce the pollutant loading by 90% during the period it is operational (i.e., it would not be used in the winter when there is chance of freezing).

Possible Funding Sources:

mitigation funds from local developers
NJDEP grant programs

Warren Township
local social and community groups

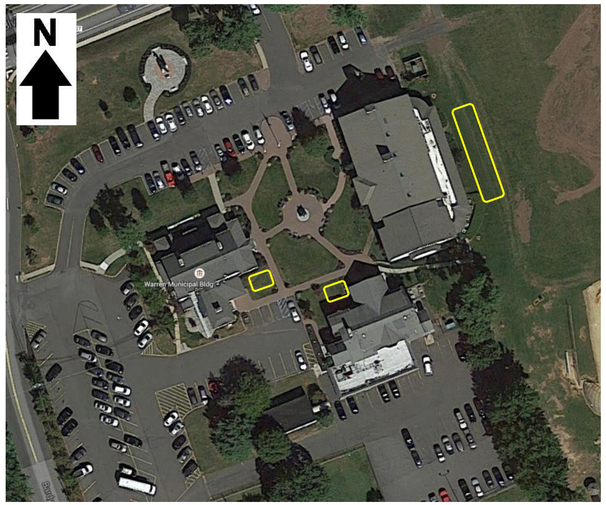
Partners/Stakeholders:
Warren Township
local social and community groups
local residents
Rutgers Cooperative Extension

Estimated Cost:
The stormwater cistern would have a 2,000 gallon capacity and would capture over 29,000 gallons of runoff per year. The estimated cost would be $4,000.

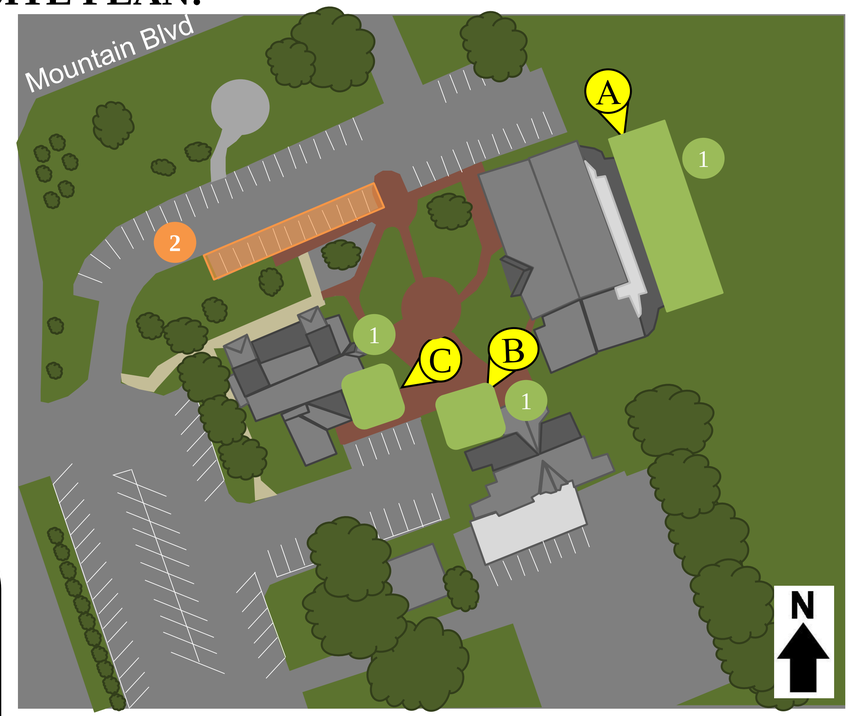
Warren Township
Impervious Cover Assessment
Warren Township Municipal Complex, 46 Mountain Boulevard

RUTGERS
New Jersey Agricultural Experiment Station

PROJECT LOCATION:



SITE PLAN:



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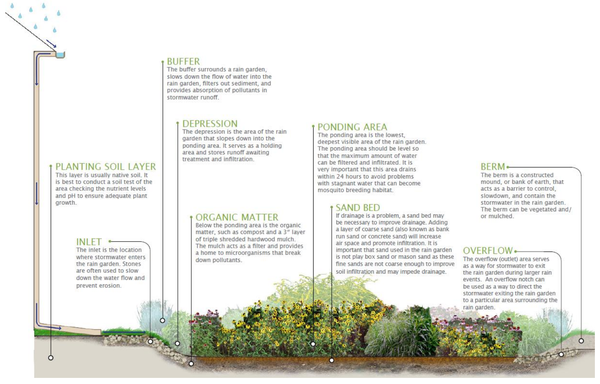
1 **BIORETENTION SYSTEM:** Bioretention systems could be installed in the large lawn on the northeast side of the library, in the grass area in the front of the court building, and near the front of the municipal building where existing downspouts can be disconnected. A bioretention system will reduce runoff and allow stormwater infiltration, decreasing the amount of contaminants that reach catch basins.

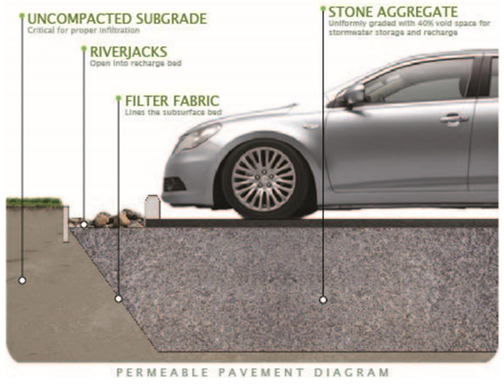
2 **POROUS PAVEMENT:** Porous pavement promotes groundwater recharge and filters stormwater.

EDUCATIONAL PROGRAM: The RCE Water Resources Program's *Stormwater Management in Your Backyard* program can be delivered at Warren municipal building and library to educate community members about stormwater management and engage them in designing and building the bioretention systems.

1 BIORETENTION SYSTEM



2 POROUS PAVEMENT



EDUCATIONAL PROGRAM

Warren Township Municipal Complex
Green Infrastructure Information Sheet

Location: 46 Mountain Boulevard Warren, NJ 07059	**Municipality:** Warren Township **Subwatershed:** Middle Brook
Green Infrastructure Description: bioretention systems (rain gardens) porous pavement youth education program	**Targeted Pollutants:** total nitrogen (TN), total phosphorous (TP), and total suspended solids (TSS) in surface runoff
Mitigation Opportunities: recharge potential: yes TSS removal potential: yes stormwater peak reduction potential: yes	**Stormwater Captured and Treated Per Year:** rain garden #1: 133,600 gal. rain garden #2: 28,600 gal. rain garden #3: 12,000 gal. porous pavement: 182,000 gal.

Existing Conditions and Issues:
The parking lot section west of the Warren Library showed evidence of erosion due to large volumes of ponding water during rain events. On the eastern side of the library five downspouts are directly connected to the storm drain system, delivering large volumes of stormwater to nearby waterways.

Proposed Solution(s):
The parking section west of the library can benefit by replacing the existing deteriorated asphalt with porous pavement. The slope of this section suggests porous pavement is a viable option to reduce peak flow runoff. The grassed area east of the library can be converted to a rain garden. The five existing downspouts would be simply disconnected from the mainline storm drain and redirected to the rain garden. This practice will allow the runoff to be filtered and treated before recharging groundwater. Two additional rain gardens are proposed to be constructed west of the municipal court office and south of the municipal building. These locations appeared suitable for downspout disconnection/redirection while increasing aesthetic value of the Warren municipal complex.

Anticipated Benefits:
Since the bioretention systems would be designed to capture, treat, and infiltrate the entire 2-year design storm (3.3 inches of rain over 24 hours), these systems are estimated to achieve a 95% pollutant load reduction for TN, TP, and TSS. These bioretention system would provide additional benefits such as aesthetic appeal and enhanced wildlife habitat. Rutgers Cooperative Extension could additionally offer the *Stormwater Management in Your Backyard* program to local residents and include them in rain garden planting efforts to enhance the program. This may also be used as a demonstration project for the Warren Township Department of Public Works staff to launch educational programming.

Possible Funding Sources:
mitigation funds from local developers
NJDEP grant programs

grants from foundations
home and school associations

Partners/Stakeholders:
Warren Township
students and parents
local community groups (Boy Scouts, Girl Scouts, etc.)
NY/NJ Baykeeper
Raritan Riverkeeper
Rutgers Cooperative Extension

Estimated Cost:
Porous pavement system #1 would cover approximately 2,050 square feet (13 parking spaces) and have a one foot deep stone reservoir under the surface. At $20 per square foot, the cost of this system would be $41,000. Rain garden #1 would need to be approximately 1,300 square feet. At $5 per square foot, the estimated cost of this system would be approximately $6,500. Rain garden #2 would need to be approximately 650 square feet. At $5 per square foot, the estimated cost of this system would be approximately $3,250. Rain garden #3 would need to be approximately 250 square feet. At $5 per square foot, the estimated cost of this system would be approximately $1,250. The total project cost would be approximately $52,000.