Rockland County
Green Infrastructure Analysis
May 11th, 2016

Team Members:
Sarah LeClerc
Travis Lacey
Brendan Wilton
Taylor Carden

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Project Definition and Plan

Mission Statement

Rockland County's sources of potable water cannot accommodate the demands of the continuously growing population and development. Potential solutions in the form of green infrastructure will be compared based on criteria as defined by an appointed task force. Implementing green infrastructure will increase infiltration and aims to increase the available potable water for Rockland County as it continues to grow and flourish.

Problem/Opportunity

Rockland County is the southernmost county in New York State and it occupies an area of 199 square miles along the Hudson River. A map of Rockland County can be seen in figure 1. According to US census data from 2010, the population was about 312,000. The anticipated growth of population in Rockland from 2010 to 2014 is 3.9%, which is more than twice the population increase for the entire state of New York, at 1.8%. With this increase in population, there also comes a demand for increase in development. More development will lessen the available pervious area in the county. Instead of water being infiltrated into the ground, it is turning into runoff. Runoff water is lost to the potable water system as it enters the storm sewers since many of these run into the main sewer system.

Current Situation

As it stands the county currently relies heavily on the Lake DeForest Reservoir for its potable water needs. However it has become evident that given the rapid rate of expansion in population and development the reservoir's ability to sustain the county's water needs will begin to undergo considerable strain within the next few decades. While the county has considered the possibility of establishing a desalination facility to pull water from the Hudson River, a Task force has been formed in order to explore alternate options in terms of effective stormwater catchment, harvesting and green infrastructure technologies.

By implementing green infrastructure techniques the county aims to reduce the high levels of runoff and instead infiltrate this water into the ground. The infiltration of this water will begin to recharge the aquifers located around the county in order to increase their consistent supply potential. The goal is for the overall strain on the reservoir to be reduced. The additional benefit is that the county will have a more sustainable hydrologic model for decades to come.

The goal of infiltration is one that is unique. Green infrastructure is most commonly implemented with the primary goal of stormwater management. While design of green infrastructure for infiltration will also achieve stormwater management, it calls for slightly different design aspects, such as no underdrains, since the goal is to keep all stormwater on site until it can be infiltrated.

The focus of this analysis is to discover which combinations of green infrastructure technologies will be most effective for typical impervious area scenarios and examine the costs of implementing them. Figure C1 shows impervious areas in the county along with average rainfall, and depth of unconsolidated deposits. Site location will not only be determined based on the land cover situation but also on how effective the site will be on aquifer recharge based on distance to groundwater, subsurface flow and soil conditions that influence infiltration. These technology ratios and effective site locations will form the basis of the Rockland County green infrastructure strategy.

Figure 1. Map of Rockland County

Stakeholders

The stakeholders are as follows:

- Rockland County Taxpayers
- Local Government
- Advisors(Dr. Elizabeth Fassman-Beck and Dr. Leslie Brunell)
- Task Force on Water Resources Management
- Municipalities (United Water)
- Rockland County Green Infrastructure Analysis Team

The Rockland County Taxpayers have a need for potable water. They need a sustainable source of potable water. This is the most important need of the stakeholders since this is where the entire green infrastructure analysis project stems from. All the other needs of the stakeholders are detailed in table 1 below.

Table 1. Stakeholder Needs

Stakeholder	**Need(s)**
Rockland County Taxpayers	A sustainable and economical source of potable water
Local Government	A conceptual green infrastructure site design, maintenance plan,
Advisors (Dr. Fassman and Dr. Brunell)	Overseeing the Rockland County Green Infrastructure Analysis t Rockland County
Task Force on Water Resources Management	Providing a solution to Rockland County in the form of Green Infr
Municipalities (United Water)	Providing drinking water to the citizens of Rockland County
Rockland County Green Infrastructure Analysis Team	Design and choose Green Infrastructure that will work best with t along with considering opinions from the Task Force on Water R

Project Scope and Resources

The business purpose is to create a standard design method to increase infiltration in Rockland County, NY. The project goals are to finish by April 2016, keep the project economically feasible, and to provide the Task Force on Water Resources Management with a design to help aquifer recharge. The project work statement is to analyze existing infiltration, design standard methods to aid infiltration, perform economic analysis of methods, and to outline and standardize preferred method(s). The key deliverables are the site selection, proposed green infrastructure techniques, economic analysis, aquifer recharge analysis, and a maintenance manual. The proposed designs are permeable pavement, infiltration basins, and rain gardens. The project will be excluding any green infrastructure technologies that are not the chosen solutions of permeable pavement, infiltration basins, and rain gardens. On a general analysis, the southwestern portion of the county has the most potential for infiltration so the detailed analysis will be performed on that region and the rest of the county will be excluded.

This project is being completed under the advisory of the Stevens Institute of Technology Staff comprised of Dr. Leslie Brunell and Dr. Elizabeth Fassman-Beck, as well as the Rockland County Task Force on Water Resources Management. The Task Force Work Group, who attends the monthly meeting with the Rockland County Green Infrastructure Analysis Team, is comprised of Patricie Drake, Ed Knyfd, Kevin Maher, Marcy Danker, Margie Turrin, Nicole Liable, and Patsy Wooters.

The Rockland County Green Infrastructure Analysis team from Stevens Institute of Technology is responsible for developing a feasibility study of potential implementation of Green Infrastructure throughout Rockland County to increase surface water storage and augment aquifer recharge. The team will accomplish this project by analyzing existing infiltration and site conditions throughout Rockland County, designing standard methods to aid infiltration, performing economic analysis of infiltration methods in order to find the most cost effective solution, and to outline a standardized and preferred solution method to assist with the infiltration of water through the use of Green Infrastructure.

Background

Requirements

Many of the requirements for this project were determined by the team and the task force in collaboration. The Rockland County Green Infrastructure Analysis team must quantify the relative infiltration potential of various Green Infrastructure technologies, consider a range of site and soil conditions in Rockland County, use the US EPA Stormwater Calculator, and design alternatives. The team must also perform a literature review about infiltrated water augmenting aquifers, perform an economic analysis, and create and operations and maintenance manual. When creating the conceptual design, all codes, standards, and regulations must be obeyed.

Constraints and Assumptions

As with any project, there are challenges and constraints that must be considered. There are many criteria that the green infrastructure solutions must be designed for, and none of them will be completely met. It is up to the task force and the team to indicate the importance of each requirement in relation to one another. There is limited availability to meet with the task force due to scheduling and travel time.

Another challenge the group faces is a lack of statistics available. The US EPA Stormwater Calculator is a priceless tool that pulls from collected data and provides information on soil type, soil drainage, etc. for a given location. However, this information is only available for a small portion of the county. Additionally, there are no accessible storm gauges within the county. Rockland is bordered to the west by the Ramapo Mountains, and to the east by the Hudson River. While the county isn't particularly large in terms of square acreage, there is a vast difference between the precipitation patterns throughout it.

Obtaining GIS data was a major challenge. There was some data available publicly online through various sources, however, most of this data was on individual interactive mapping applications so this data could not be cross-analyzed. Due to the licensing agreement and legal department approvals, a large amount of GIS data from the Rockland County GIS Portal was not made available to the team until early December 2015.

Something that is difficult to quantify when designing green infrastructure for certain places is human reaction to the implementation of the design. Residents of Rockland County may have reservations about proposed construction in populated areas, a decrease in parking availability, or designs that may not be aesthetically pleasing. Infiltration basins are a wonderful resource, but often times are overlooked as wasted space. Another challenge anticipated is trouble conveying proper maintenance techniques to proprietors with green infrastructure on their properties. It is of the utmost importance that these methods get proper maintenance or they will not function.

While the stormwater calculator can predict the infiltration in a certain area and the literature review can predict the amount of water replenishing the aquifer, the true results will not be known until the green infrastructure is put into place. It must also be assumed that the infiltrated water can be pumped up as a water source. This is a desktop study and the team will not see the results of physical construction.

Applicable Codes/Standards/Regulations

Below is the list of codes and permits that apply to our feasibility study:

- Overall Design
    - **New York State Stormwater Management Design Manual** - provides designers with a general overview on how to size, design, select, and

locate stormwater management practices at a development site to comply with State stormwater performance standards
    - **New York Standards and Specification for Erosion and Sediment Controls** - provides standards and specifications for selection, design and implementation of erosion and sediment control practices

- Construction
    - **General Permit for Stormwater Discharges from Construction Activity** - the construction company must apply for this permit before commencing construction activity on a project that will involve soil disturbance of one or more acres
    - General permit applications for work on property adjacent to a County Road Right-of-Way

- Construction Safety
    - **OSHA** - Occupational Safety and Health Administration

- State Pollutant Discharge Elimination System (SPEDES) Permits
    - **Multi-Sector General Permit of Stormwater Discharge Associated with Industrial Activities (MSGP)** - requires facilities to develop Stormwater Pollution Prevention Plans and report the results of industry specific monitoring to the New York State Department of Environmental Conservation
    - **Municipal Separate Storm Sewer System (MS4s)** - This permit requires that a stormwater management plan is developed in order to reduce the amount of pollutants carried by stormwater during storm events

Design Standards for each green infrastructure technology are typical throughout the area that they will be implemented. There are few, if any, alterations to the typical profile sections shown in figures 2, 3, and 4, and these alterations will be considered on a case by case basis.

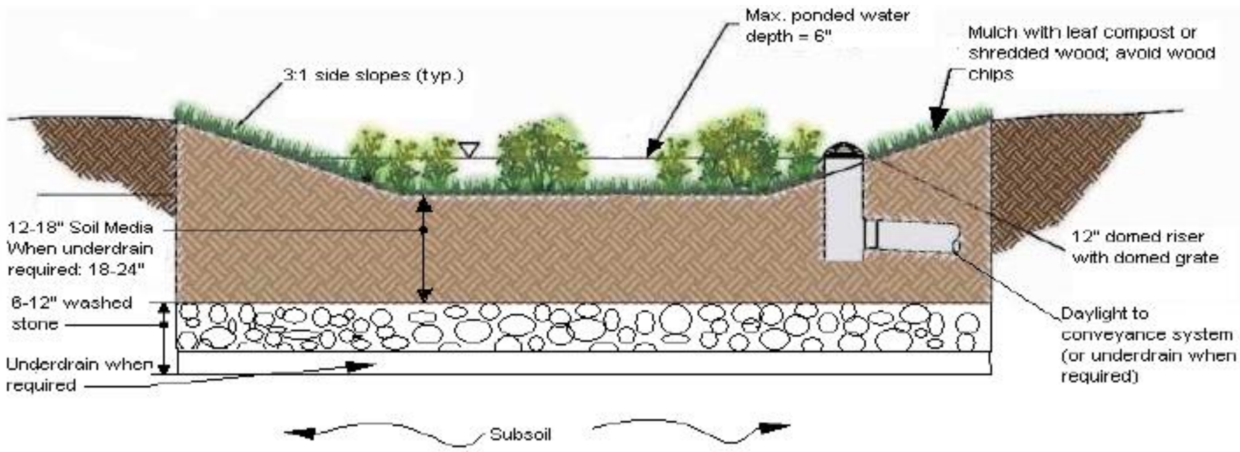


Figure 2. Typical Rain Garden Profile

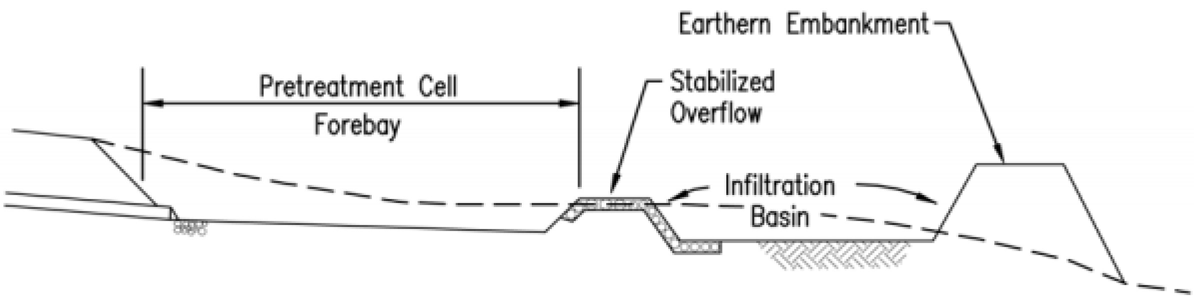


Figure 3. Typical Infiltration Basin Profile

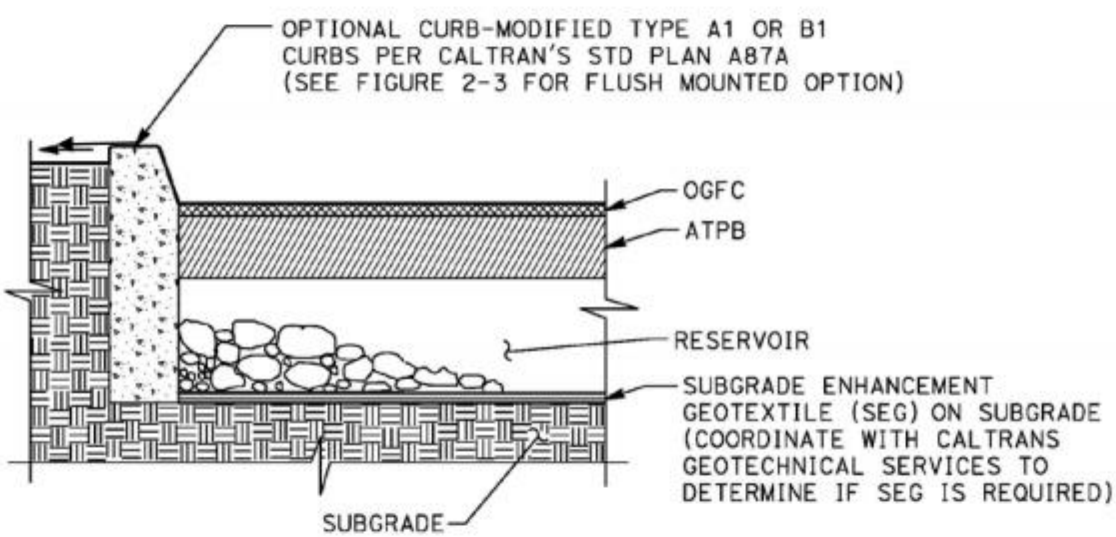


Figure 4. Typical Permeable Pavement Profile

Located in Appendix C, table C1 and table C2 are taken from the New York State Stormwater Management Design Manual that outline design requirements for the green infrastructure technologies.

Overview of Designs

The design can be broken down into three green infrastructure techniques that may be implemented either on their own or in conjunction with one another. These methods and combinations will be compared based mainly on their efficiency and cost. Efficiency in terms of these solutions means that the water is not only absorbed but also directed to aquifers so that it can flow to reservoirs. Secondary considerations include but are not limited to: cost of maintenance, ease of construction, and compliance.

Rain Garden Solution

Rain gardens, are sections of vegetation placed within impervious areas. They are a shallow depression that is planted with deep-rooted plants. The depression insures that water collects specifically in the vegetation, rather than it becoming runoff from the impervious areas surrounding it. Rain gardens are useful in areas like parking lots and roads. They are effective at capturing the water from nearby impervious surfaces, preventing the water from reaching the sewer system. The main downfall of this solution is that it takes away from paved area. This could mean a decrease in parking availability, or smaller roads. While this is a feasible solution that can be implemented, it must be limited so as not to interfere with the needs of the residents. This will be a major consideration when looking into designs for parking lots. Rain gardens are typically about 20% the size of the impervious areas so a solution may be to use the rain gardens as islands between parking spaces as shown in figure 3.

Figure 5. Rain garden implemented in a parking lot

Infiltration Basin Solution

Infiltration Basins are designated areas that collect and hold water temporarily. These basins are typically lined with soil that allows water to flow through it relatively quickly. It is particularly important to pay attention to infiltration rate when designing these basins. The flow rate of water into the ground depends on soil type but can also be affected by sediment that may collect in the water. Infiltration basins can't solve large scale flooding, but they can reduce the effects of storms and prevent flooding or overflow of sewers. A possible location for the infiltration basins may be between the edges of a parking lot and the street.

Figure 6. Empty infiltration basin

Figure 7. Infiltration basin after storm

Permeable Pavement Solution

Permeable Pavement refers to materials that allow water to flow through, but serves the structural purpose of regular pavement. The material can be implemented as regular impervious pavers with loose gravel in between or as manmade pavement mixes that allow water to pass through. One of the greatest advantages is that there would be no loss of functional space. The heat island effect would also be reduced. The permeable pavement would be placed where there is already existing impervious pavement. The biggest concern with permeable pavement would be the maintenance. Anything that can clog the pavement including leaves, debris and even salt would prevent it from serving its purpose. A proposed location would be the parking spaces in a large parking lot.

Figure 8. Impervious pavers with gravel Figure 9. Smooth pavement

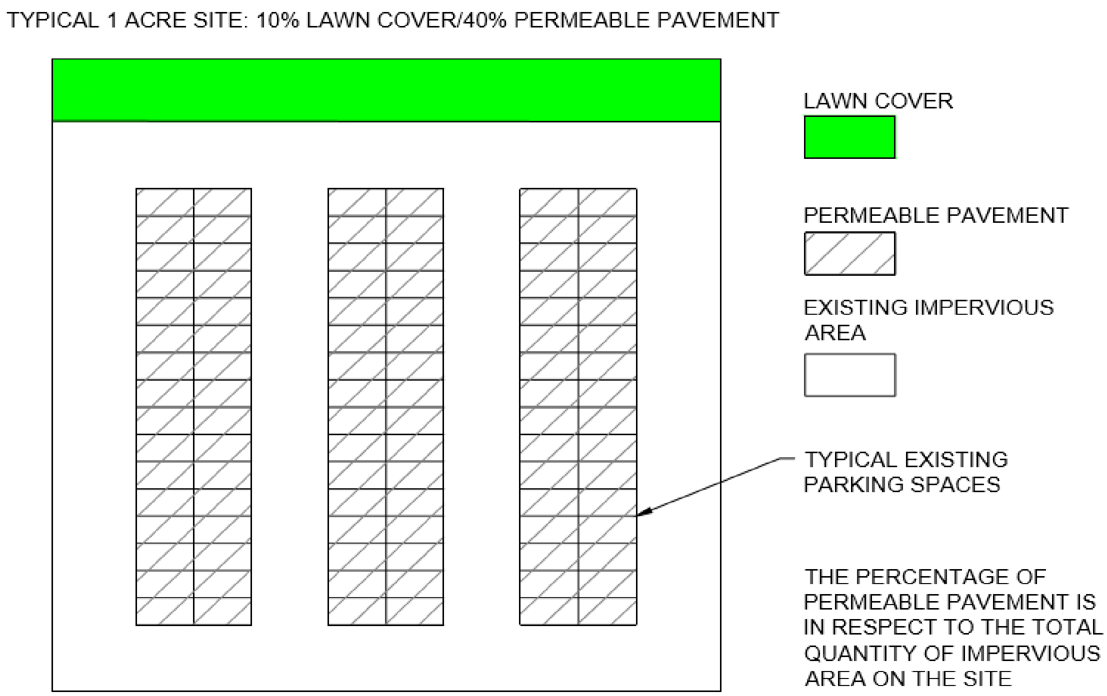


Figure 10.Typical 1 Acre Site with 10% Lawn Cover and 40% Permeable Pavement

Permeable Pavement Types

Permeable pavement exists in three main types: porous concrete, permeable interlocking concrete pavers (PICP) and porous asphalt. Porous concrete requires a minimum batch size, which can be inconvenient and very specific. It also requires a seven day cure, and must be covered for the whole seven days. Additionally, it doesn't cure and withstand cold climates well. Maintenance includes regular (quarterly) vacuuming of the surface, and only using salt that doesn't contain sand.

PICP is the second permeable pavement option. This one is the most labor intensive, because the pavers require a perfectly leveled base coarse. It cannot be maintained with high power vacuuming because that would pull out the loose media between the pavers. If any of the pavers become misaligned, they must all be taken up and then relayed.

Porous asphalt is the third, final, and chosen option. It has the lowest construction cost per square foot. There is no indicated minimum batch size. The cure is only 24 hours and doesn't require covering. For the weather and convenience at this site, it would be most ideal to model permeable pavement as porous asphalt. Porous asphalt was the chosen media for a permeable pavement parking lot at the Lamont-Doherty Earth Observatory at the Palisades, NY. Patrick O'Reilly P.E. was the lead engineer on the Lamont-Doherty project, and served as a professional reference when making this decision. The site is a long-term parking lot that is entirely porous asphalt with a ramp leading into it that is non-porous asphalt. Patrick attested to the fact that the porous asphalt, which typically has a lifetime of 25 years, is in much better condition than the non-porous asphalt, which typically has a lifetime of 20 years.

Figure 11.

Figure 12.

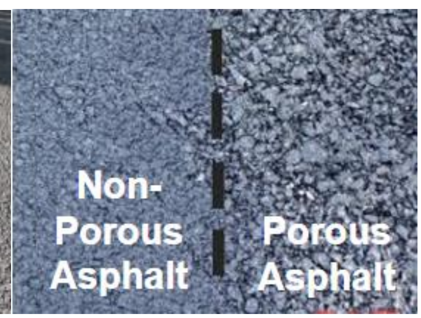


Figure 13.

Environmental Protection Agency Stormwater Calculator

In order to analyze the potential infiltration as well as baseline land and soil conditions of a particular site the team utilizes the EPA's National Stormwater Calculator. This application pulls rainfall, evaporation, soil, and topography information from several national databases in order run a thorough analysis of any particular site in the United States. Once these conditions have been determined the land cover and potential green infrastructure ratios can be set and calculator report can be generated. By settling a baseline condition the GI ratios can be altered and the potential infiltration, runoff and evaporation can be determined and compared against the existing conditions.

Table 2. EPA Stormwater Calculator Report

Parameter	Current Scenario	Baseline Scenario
Site Area (acres)	1	1
Hydrologic Soil Group	C	C
Hydraulic Conductivity (in/hr)	.1	.1
Surface Slope (%)	5	5
Precip. Data Source	RINGWOOD	MIDLAND PARK
Evap. Data Source	DOBBS FERRY ARDSLEY	DOBBS FERRY ARDSLEY
Climate Change Scenario	None	None
% Forest	0	0
% Meadow	0	0
% Lawn	10	20
% Desert	0	0
% Impervious	90	80
Years Analyzed	20	20
Ignore Consecutive Wet Days	False	False
Wet Day Threshold (inches)	0.10	0.10

This site description correlates with Rockland County typical soil conditions based on available data as well as and 90% percent impervious area for a 1 acre site. The precipitation and evaporation data comes from the nearest available gauges from Midland Park, Ringwood and Dobbs Ferry.

Table 3. Ratio of Green Infrastructure Controls Being Implemented

LID Control	Current Scenario	Baseline Scenario
Disconnection	0	0
Rain Harvesting	0	0
Rain Gardens	0	0
Green Roofs	0	0
Street Planters	0	0
Infiltration Basins	0	0
Porous Pavement	40 / 100	0

% of impervious area treated / % of treated area used for LID

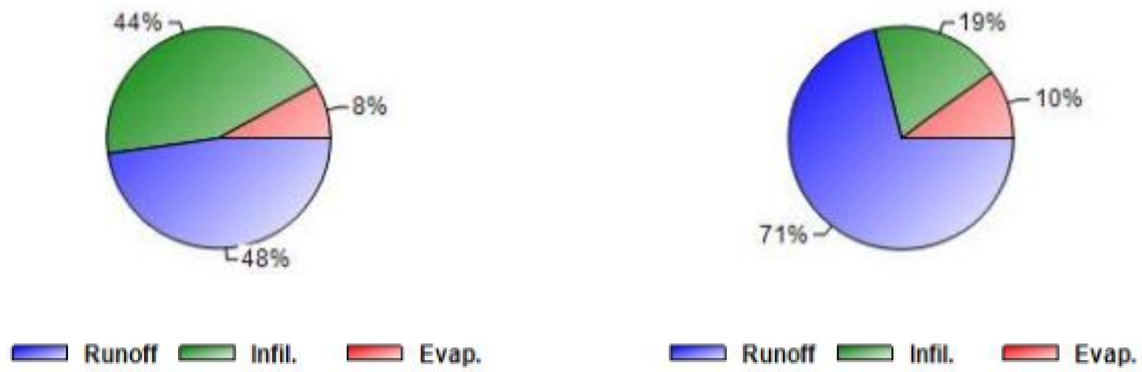


Figure 14. Difference in Runoff, Infiltration, and Evaporation for proposed strategy

Table 3 represents the ratio of green infrastructure controls being implemented within the impervious area of the 1 acre site. Figure 14 illustrates the difference in runoff, infiltration and evaporation for both the proposed green infrastructure strategy and the existing baseline scenario. Utilizing the information from NCS report the quantities of water being displaced as runoff and infiltrating instead can quantified in terms of potentially gained or lost gallons reaching the aquifer. Using the stormwater calculator and any baseline land cover ratio a trend in infiltration effectiveness and the approximate quantities of water gained or lost can be generated as represented in Figure 15 and Table 4.

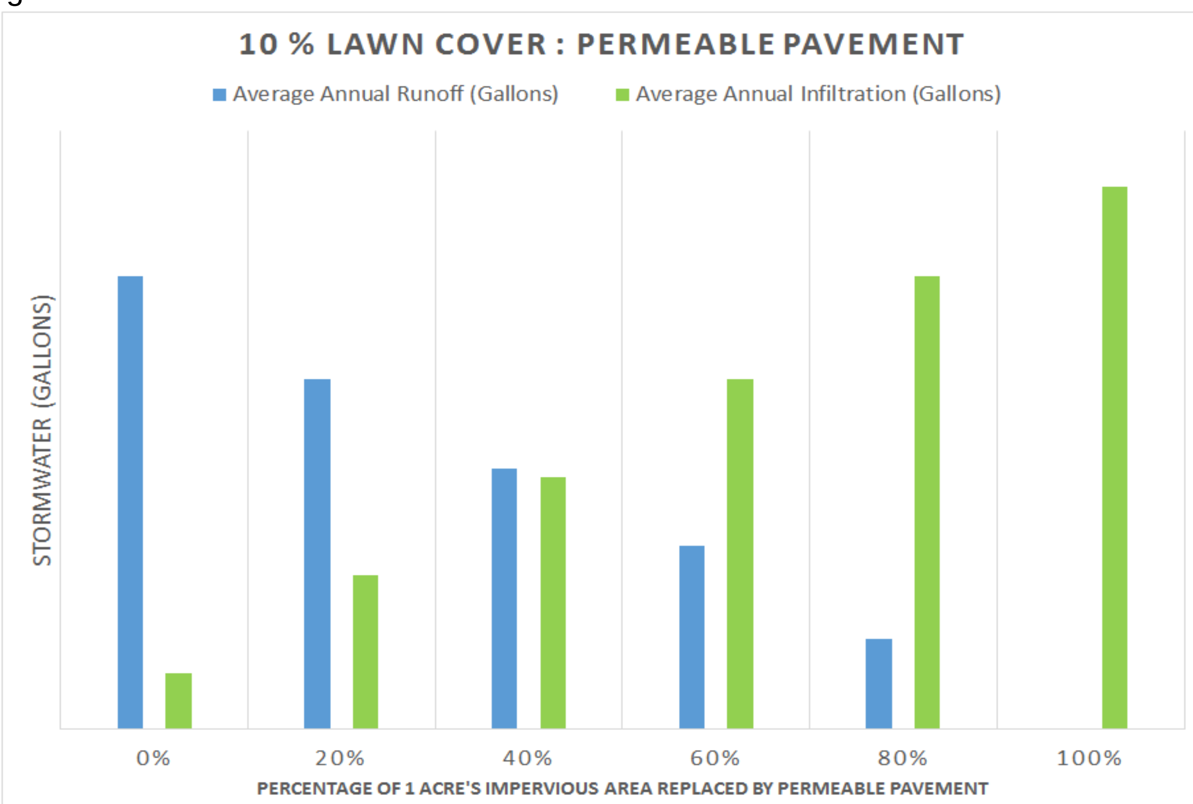


Figure 15. Relationship of Runoff becoming Infiltration Due to Permeable Pavement

Table 4. Quantified Runoff becoming Infiltration Due to Permeable Pavement

10% Lawn Cover: Permeable Pavement Runoff/Infiltration Quantities		
Percentage of Impervious Pavement	Runoff (Gallons)	Infiltration (Gallons)
0%	1,060,000	130,000
20%	770,000	450,000
40%	610,000	590,000
60%	430,000	820,000
80%	210,000	1,060,000
100%	0	1,270,000

By running a series of hydrologic models for each GI control infiltration trends and predictable quantities can be generated for a given land ratio as illustrated in Table 5. These predictions will allow for a dynamic analysis of infiltration effectiveness for a selected site which will play a significant factor in decision matrix and ultimate concept design.

Table 5. Infiltration Increase per Green Infrastructure Technology

Appx Infiltration Increase per 10% Increase of GI Method		
GI Control	Percentage	Gallons
Permeable Pavement	7.2%	110,000
Infiltration Basin	3.0%	33,000
Rain Garden	2.4%	41,000

Budget

Table 6 references the resource and which group is providing the resource to the team. All the resources that are listed in the team's budget are provided free of charge. The project budget is zero dollars because the information that will be provided to the Rockland County Task Force is for use in a fundamental and conceptual study of potential site locations in Rockland County. However, the final design will provide a per acre cost to the Rockland County Task Force in order to allow to decide if the project is feasible based on funding.

Table 6. Budget Sources

Budget	
Resource	**Provided By**
GIS Data	Rockland County GIS Department
MS4s	Rockland County Task Force
Cost for Solution Type	Stevens Institute of Technology
NY State DEC Manual	Rockland County Task Force

Decision Matrix

In order to evaluate the different GI solutions that can be implemented at the site, there are numerous aspects that must be measured and compared. Collaborative work with the Rockland County Water Resources Task Force resulted in a list of criteria that is reflected in a decision matrix. Each proposed solution will be given a score. The alternative with the highest score will be the best recommendation. Scoring will be done out of 100 points, with the following breakdown:

- 40 possible points awarded for the amount of infiltration provided by the GI technology. The infiltration will be measured in gallons infiltrated per year and calculated by the US EPA Stormwater Calculator.
- 40 possible points for cost.
    - 20 possible points for materials cost evaluated as dollar value per gallon infiltrated over the first year. Highest score is awarded to the lowest price. Material cost breakdown can be seen in Table 8.
    - 20 possible points for additional yearly cost of maintenance required. Highest score is awarded to the lowest price. Maintenance cost breakdown can be seen in Table 9.

- 10 possible points for life of material. This is only applicable for porous asphalt vs. non porous asphalt and is calculated by considering the percentage of each type of asphalt on the site.
- 10 possible points for the potential of educational opportunity. The most valuable educational opportunity would be a rain garden, since it can be maintained and observed by virtually anyone. Designs which include a rain garden will automatically awarded the full 10 points. Designs without will be awarded 0 points.

Table 7 shows a blank matrix evaluating different options at the selected site. There is a column available to show the value of the criteria being evaluated and then a column for the points awarded based on that value.

Table 7. Decision Matrix

		Option 1		Option 2		Option 3		Option 4		Option 5	
		Value	**Points Awarded**	**Value**	**Points Awarded**	**Value**	**Points Awarded**	**Value**	**Points Awarded**	**Value**	**Points Awarded**
40	**Infiltration (gallons per year)**										
	Cost										
20	Materials (per gallon infiltrated)										
20	Maintainance (yearly)										
10	**Life of Materials (years)**										
10	**Educational Opportunity**										
Total (100 points possible)			**0**		**0**		**0**		**0**		**0**

Table 8 Material Costs

Material	**Cost (psf)**	**Source(s)**
Impervious Asphalt	$1.50	Fix Asphalt.com http://www.fixasphalt.com/blog/cost-to-pave-parking-lot
Porous Asphalt	$6.00	Green Values Stormwater Toolbox http://greenvalues.cnt.org/national/cost_detail.php
Infiltration Basin	$1.30*	EPA Cost and Benefits of SW BMPs https://www3.epa.gov/npdes/pubs/usw_d.pdf
Rain Garden	$7.00	Green Values Stormwater Toolbox http://greenvalues.cnt.org/national/cost_detail.php

*expressed per cubic inch

Table 9 Maintenance Costs

Method	Cost (per year)	Source
Rain Garden	6% of initial materials cost	US EPA http://w/porouspavement.pdf
Infiltration Basin	4.5% of initial materials cost	American Rivers Organization http://www.americanrivers.org/green-infrastructure-training/green-infrastructure/cost-considerations/
Porous Asphalt	$200 per acre	US EPA http://www.clermontstorm.net/porouspavement.pdf

Design and Evaluation

Site Selection

The site selection process was based on maximizing potential infiltration, however, there were other factors that had an influence on site selection. These other factors were; soil and land characteristics, location of needed recharge, public or private property, aesthetics, functional use of space, and the potential as a demonstration site. The analysis of these factors was performed by using GIS data along with the knowledge and opinions of the Task Force. Figure C2 and C3 are examples of how the GIS data was used in the site selection process. There were various layers in the GIS data the team obtained that displayed soil conditions and land characteristics.

At the suggestion of the Task Force, there are two sites to be considered. The first is a soon to be developed park and ride in Monsey. This area has been facing a lot of stormwater flooding, so GI would aid with runoff reduction. The second site under consideration is a parking lot at Rockland Community College. The proposal would be a retrofit to an existing lot. The Rockland Community College site lies within the capture zone for the Viola Well Field. Suez accesses this well field for drinking water. In recent years it has been underperforming, particularly during the dry months. An added bonus to GI at Rockland Community College is the educational opportunity for students there. The final site selection for evaluation is the Rockland Community College lot.

Figure C3 shows the relation of the Rockland Community College parking lot to the Viola Well Field. That figure also shows how the groundwater flow directions would allow for recharge of the Viola Well Field. Other layers of GIS data were used to determine the soil and land characteristics of the parking lot. Since the site is a public one, it would be easier for the county to obtain funding and the site could be used as a demonstration site for the public. The proposed designs will also minimize loss of functional space by only creating designs that would not take away any of the current parking spaces.

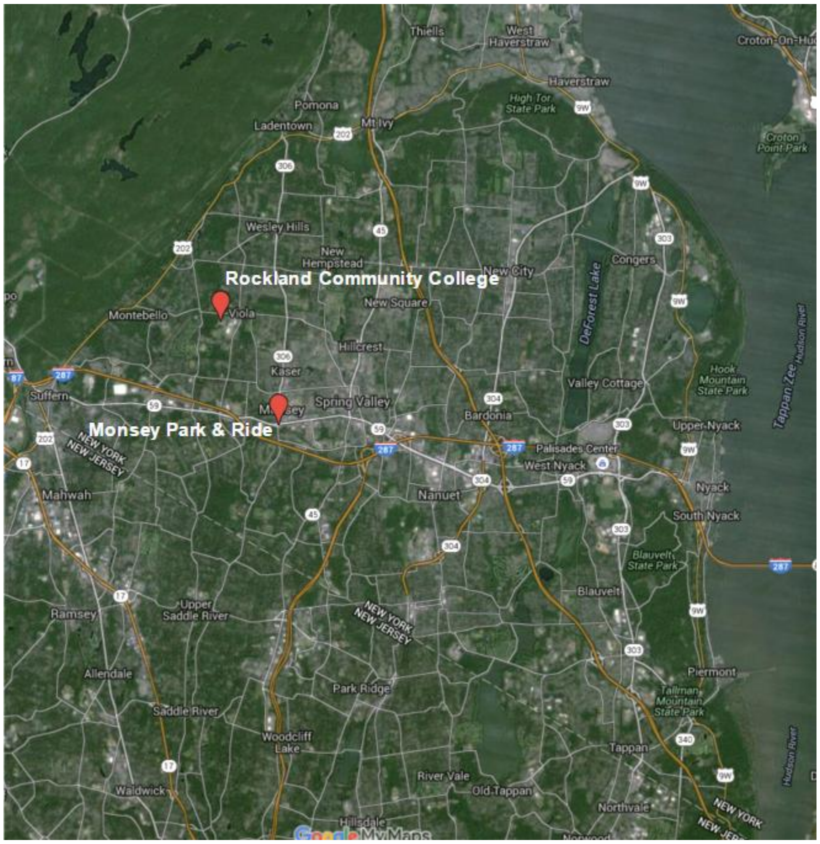


Figure 16. Proposed Site Locations

Site Breakdown

The Rockland Community College parking lot is 7 acres in total. For ease of description, it has been broken down into parts. To the east there are four sections, which are labeled terraces 1, 2, 3 and 4. To the west there is a larger lot that has been labeled the West Lot. The lot slopes down to the North West corner, as can be seen in Figure 17. Each of the terrace lots are at a 6% slope to the west. The West Lot is sloped less than 2% to the west.

Figure 17. Site Breakdown and Elevation Contours

Design Options

After meeting with the Task Force and taking into consideration the site conditions the team devised five possible design options for the Rockland County Community College site. The options that were devised were set up in order to incorporate the use of more than one green infrastructure technology at the site in order to have successful infiltration of water, as well as to serve as an educational tool that professors at the college can use to show their class firsthand how green infrastructure works.

The first option consists of permeable pavement in all parking spaces for the west lot, as well as the four terraced lots. There is also a rain garden in the island between the west lot and the first terrace lot. Figure 18 below, is a plan view of site option 1.

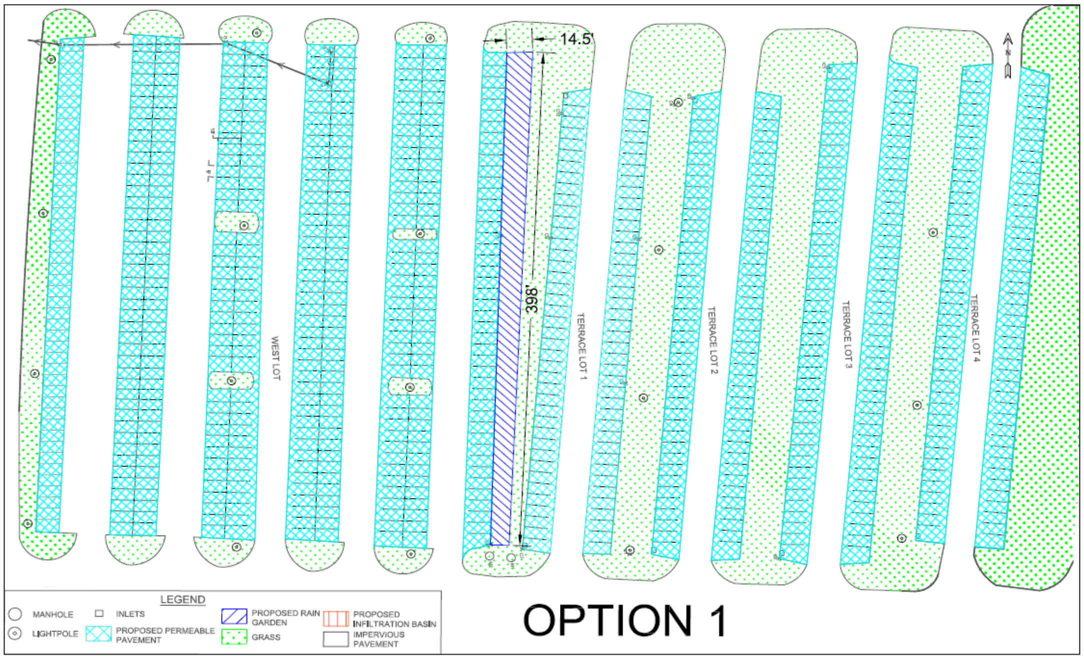


Figure 18

The second options consists of permeable pavement in only the parking spaces of the west lot, and a rain garden in the island between the west lot and the terraced lot. The reason for leaving the terrace lot as regular asphalt is so that any water not infiltrated by the existing islands in between the terrace lots will be collected by the rain garden and infiltrated at that location. The water will reach the rain garden through a series of curb cuts, approximately every five spaces, on the west side of the respective terrace lots. Figure 19 below, is a plan view of site option 2.

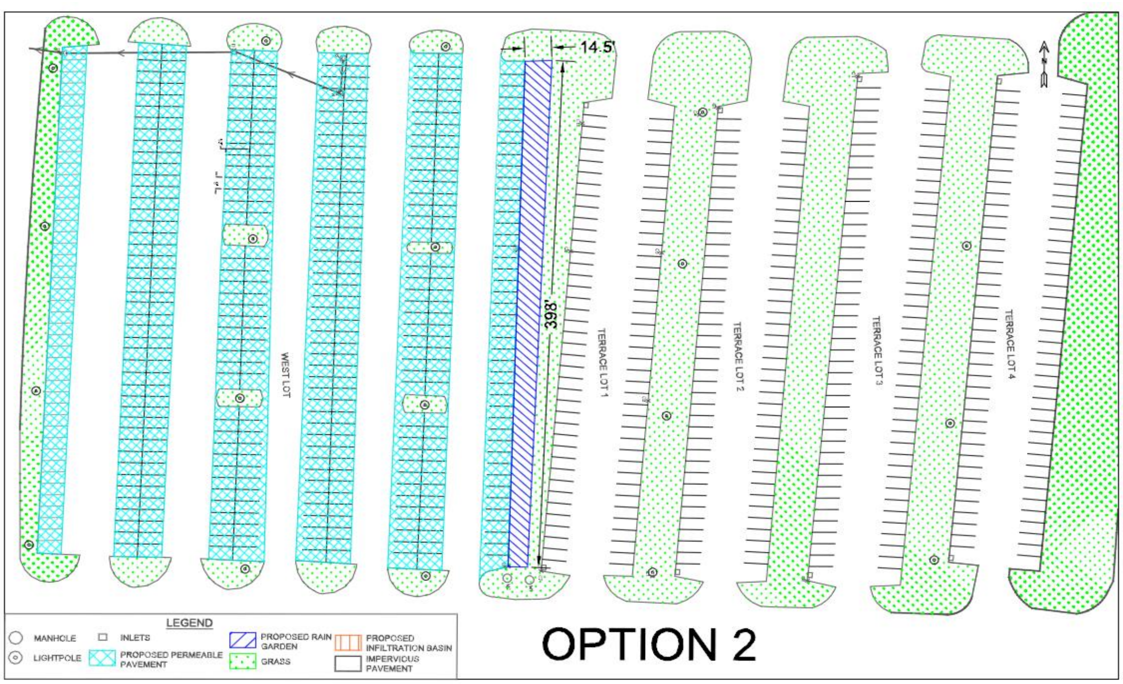


Figure 19.

The third option is very similar to option two; it consists of permeable pavement in the west lot parking spaces, but instead of a rain garden this option is implementing an infiltration basin to collect the water from the terrace lots, which will also remain as regular asphalt. Figure 20 below, is a pan view of site option 3.

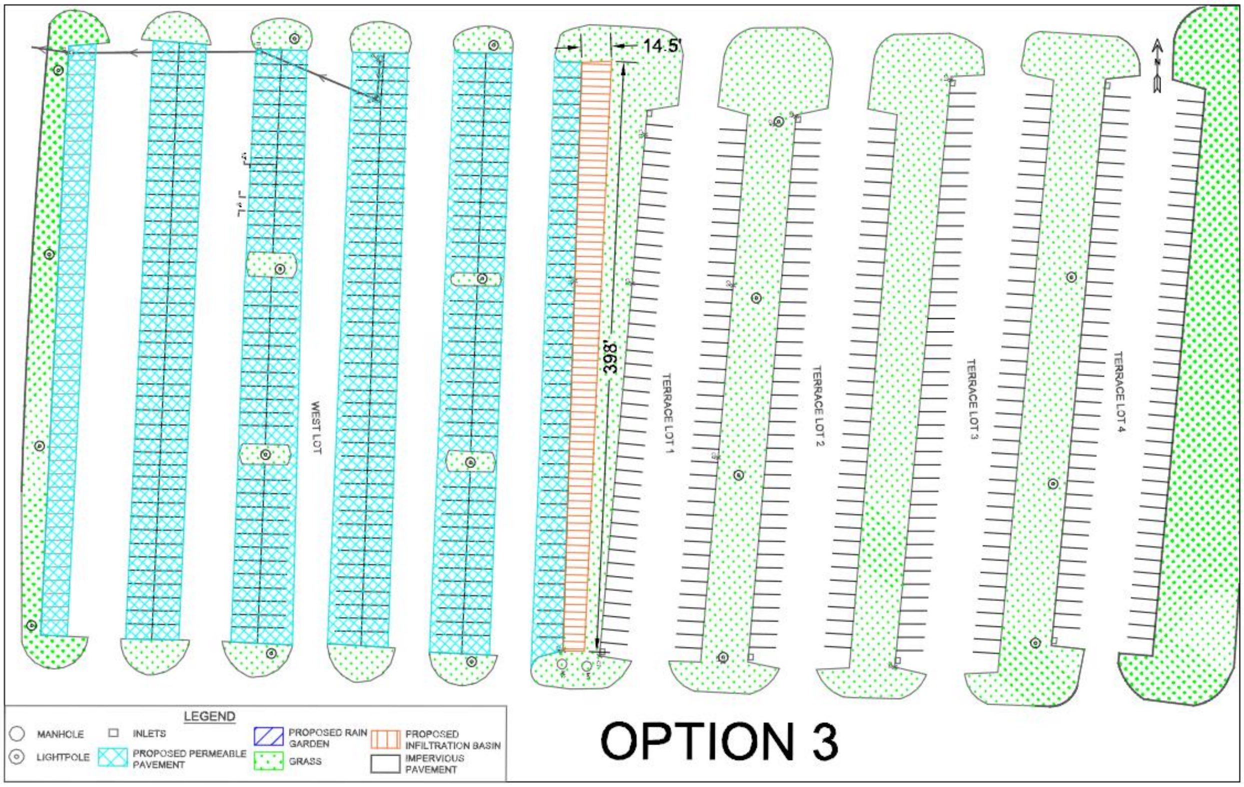


Figure 20.

The fourth option consists of permeable pavement throughout the west lot and the four terraced lots. This option contains permeable pavement in the parking spaces and in the driving lanes. This site option does not require a rain garden or infiltration basin, because any water that falls on the permeable pavement will be infiltrated on that surface. When performing our stormwater calculator analysis on this option, the program determined that little to no water would reach the island where the rain garden and infiltration basin are implemented in the other site options. Therefore, we did not include that technology since it has no major contribution to infiltration in this site plan. Figure 21 below, is a plan view of site option 4.

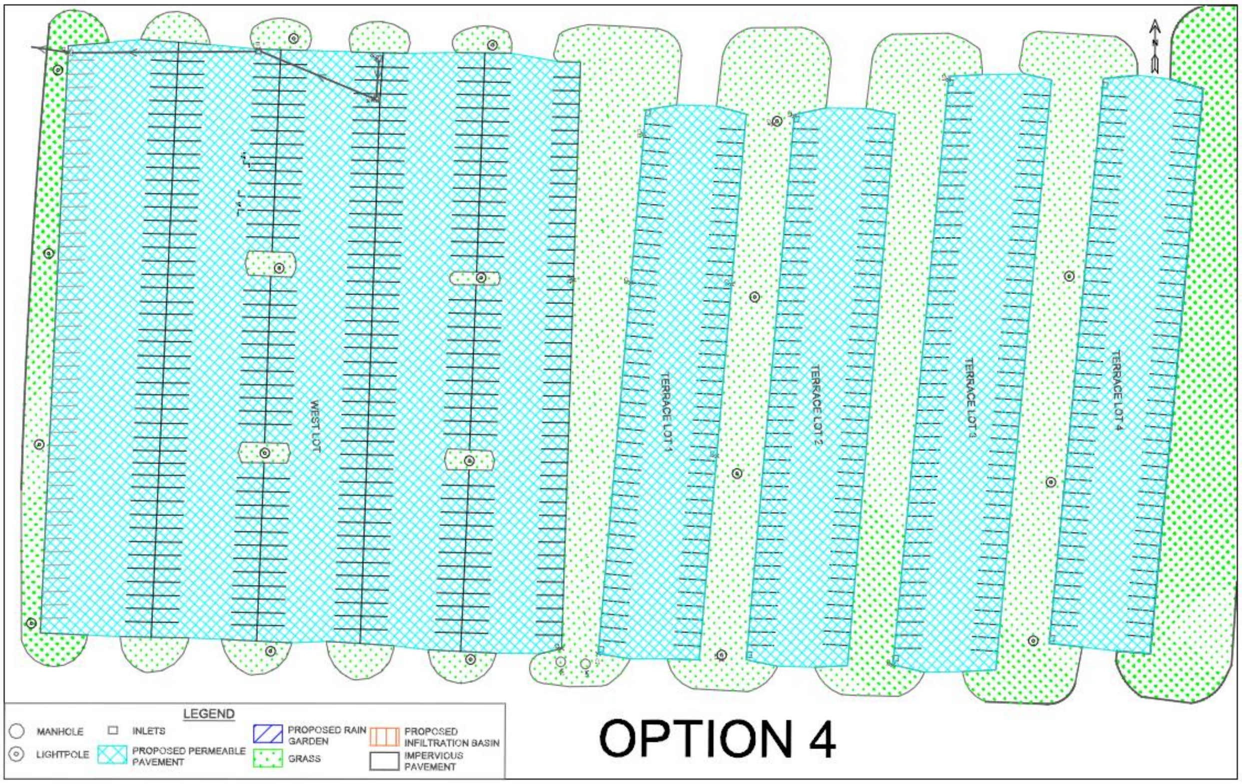


Figure 21

The fifth and final option consists of permeable pavement in all spots of the west lot, as well as terrace lot two, three, and four. Terrace lot one is left as regular asphalt so that any water that hits that parking lot during a storm will runoff into a rain garden that will be placed in the island in between the west lot and terrace lot one. Figure 22 below, is a plan view of site option 5.

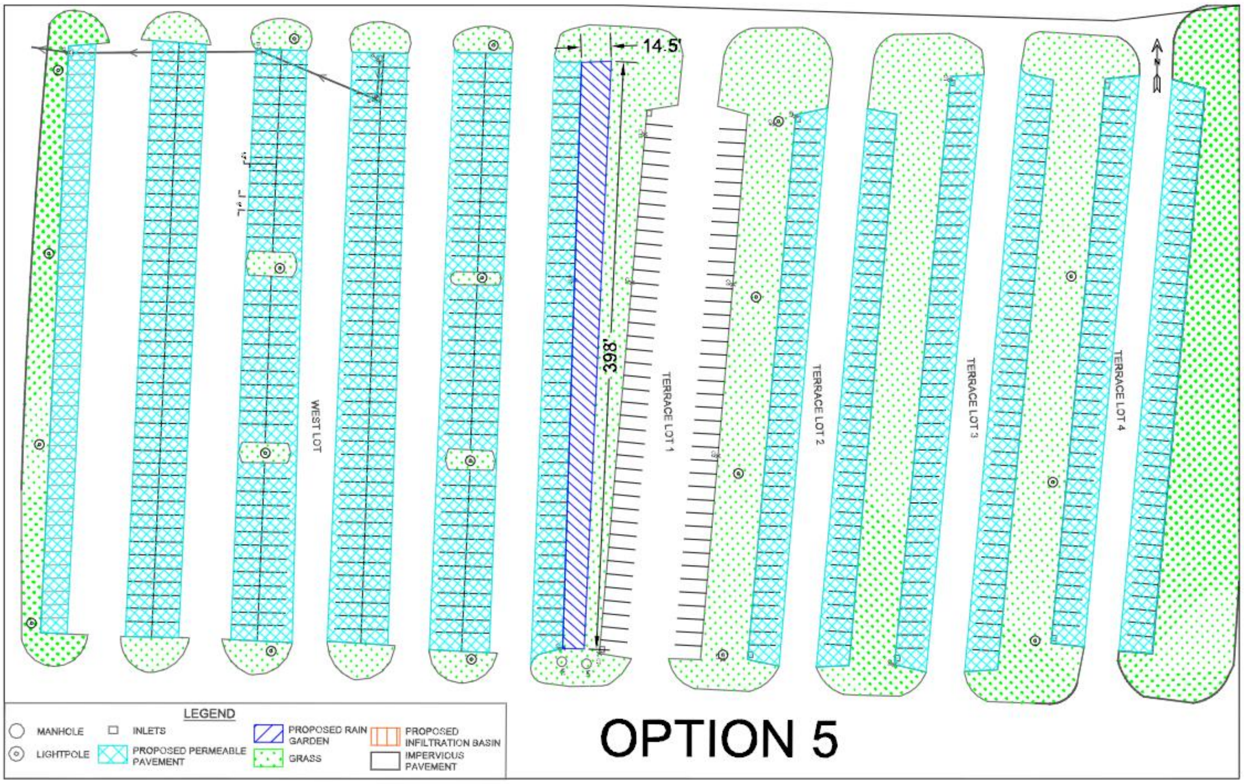


Figure 22

The cross sections were calculated by using the New York State Stormwater Management Design Manual. The New York State Design Manual provides a minimum measurement for the various components that comprise each green infrastructure technology. Upon reviewing the Stormwater Management Design Manual, the team implemented these design minimums into the stormwater calculator to project infiltration rates for the various site options, in order to determine which site option would be most ideal to recommend to the Rockland County Task Force. The Stormwater Management Design Manual also provides recommended materials to use for permeable pavement and for a rain garden. Some examples of the recommendations are: type of stone to use as reservoir course, type of fill media, and suggested plants and trees to implement in a rain garden.

The following are minimum depths and material requirements for permeable pavement which are given in the Design Manual:

- Porous asphalt depth: 3 in. - 7 in.
    - Bituminous mix ½" Nominal Maximum Aggregate Size
- Choker course depth: 4 in. - 8 in.
    - This is the stone course that is in between the porous asphalt and revoir course layers
    - AASHTO No. 57 stone mix
        - This is a self-compacting aggregate blend of size 5, 6, and 7 stone
- Reservoir course depth: minimum 8 in.

    - This is the stone layer that is in between the choker course and subgrade
    - No. 2 Stone
- Subbase Course depth: minimum 20 in.

The minimum depths and material requirements stated by the Design Manual are as follows:

- Recommended max ponding depth: 6 in.
    - This is the depth of water that sits above ground and infiltrates into the soil
- Fill Media depth: minimum 12 in.
    - Special engineered soil mixture that supports healthy growth of plants and helps to remove pollutants from the infiltrating water
- Washed stone layer depth: 6 in. - 12 in.
    - This stone layer consists of stones that range in size from a 1.5 in. to 2 in.

The figures below are plan views of cross sections for permeable pavement and rain gardens that can be implemented in the various site plans. The general permeable pavement cross section will be used for the west lot, while the second permeable pavement cross section that includes a curb will be used for the four terrace lots.

Permeable Pavement Cross Section

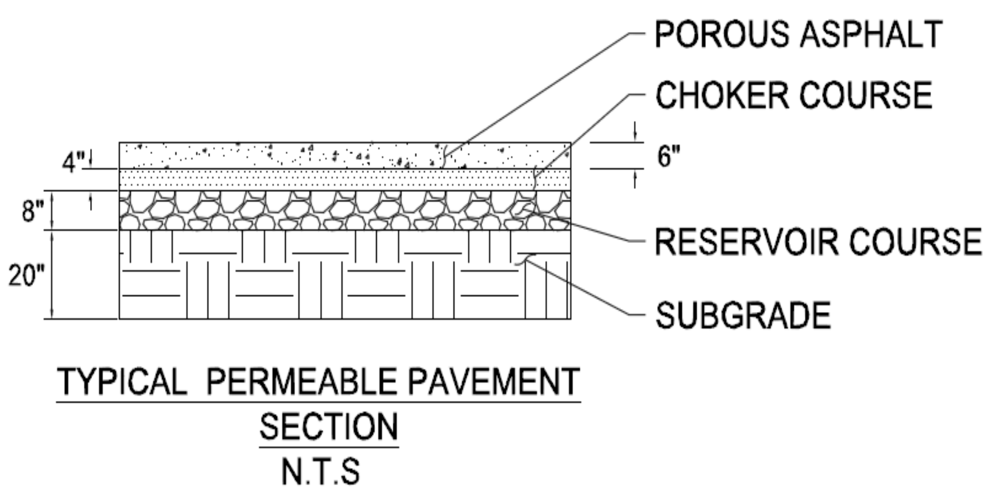


Figure 23.

Rain Garden Cross Section

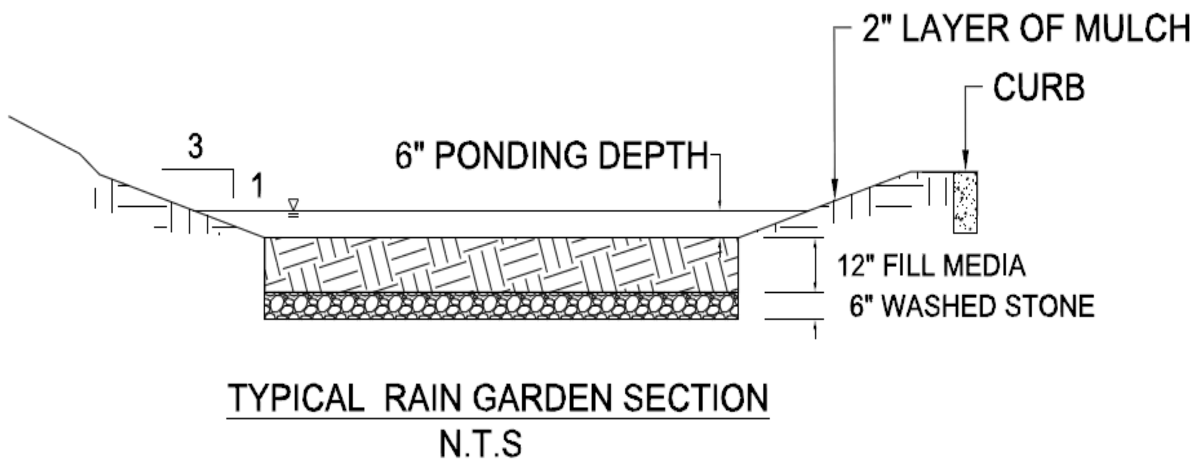


Figure 24.

Terrace Lot Permeable Pavement Cross Section

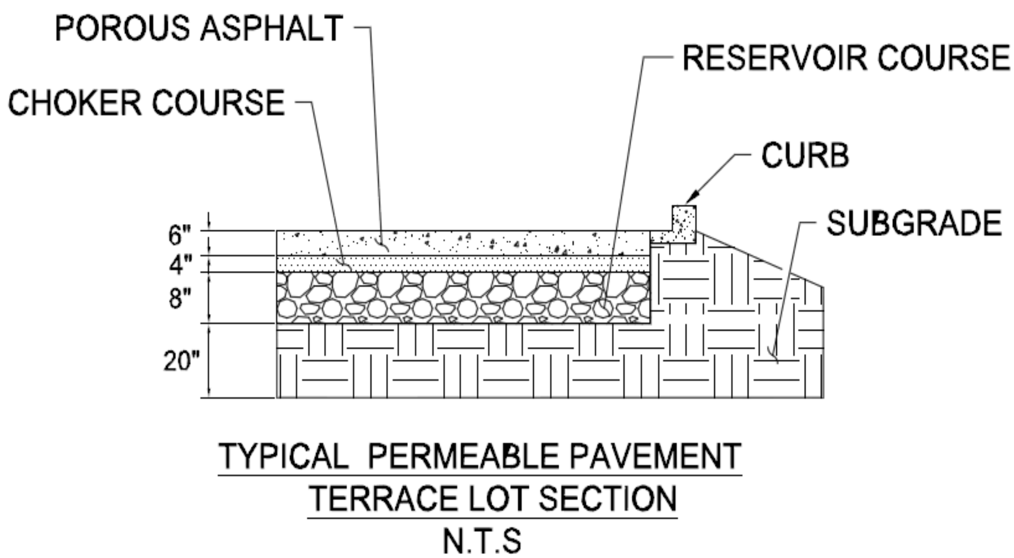


Figure 25.

Design Evaluation

Table 10 shows the final results when all of the collected values were input into the decision matrix. The collection of data to find these values can be seen in Appendix Table C3. The highest scoring option is option 2. The completed decision matrix was discussed with the Task Force on Monday, March 7th, 2016.

Table 10: Completed Decision Matrix

		Option 1		Option 2		Option 3		Option 4		Option 5	
		Value	**Points Awarded**	**Value**	**Points Awarded**	**Value**	**Points Awarded**	**Value**	**Points Awarded**	**Value**	**Points Awarded**
40	**Infiltration (gallons per year)**	9,152,350	40	6,337,270	28	6,435,566	28	9,152,350	40	8,743,680	38
	Cost										
20	Materials (per gallon infiltrated)	$0.10	15	$0.07	20	$0.07	20	$0.16	9	$0.09	16
20	Maintainance (yearly)	$4,034	6	$1,140	20	$1,745	13	$1,140	20	$4,034	6
10	**Life of Materials (years)**	23	9	22	9	22	9	25	10	23	9
10	**Educational Opportunity**	Ideal	10	Ideal	10	-	0	-	0	Ideal	10
Total (100 points possible)			**79**		**86**		**70**		**79**		**78**

Final Recommendation

Phased Construction

After evaluating the options presented to the Task Force, it was suggested that a combination of multiple options be considered in the form of phased construction. This means that the stages of design and construction overlap, and the construction is done in pieces. This shortens the time to complete the project and also allows more flexibility. A benefit to proposed phased construction at the Rockland Community College site would be that the parking lot would never be completely out of service. It also allows the college to budget in sections, and to continue with the construction on a schedule that works with the budget.

Final Proposal

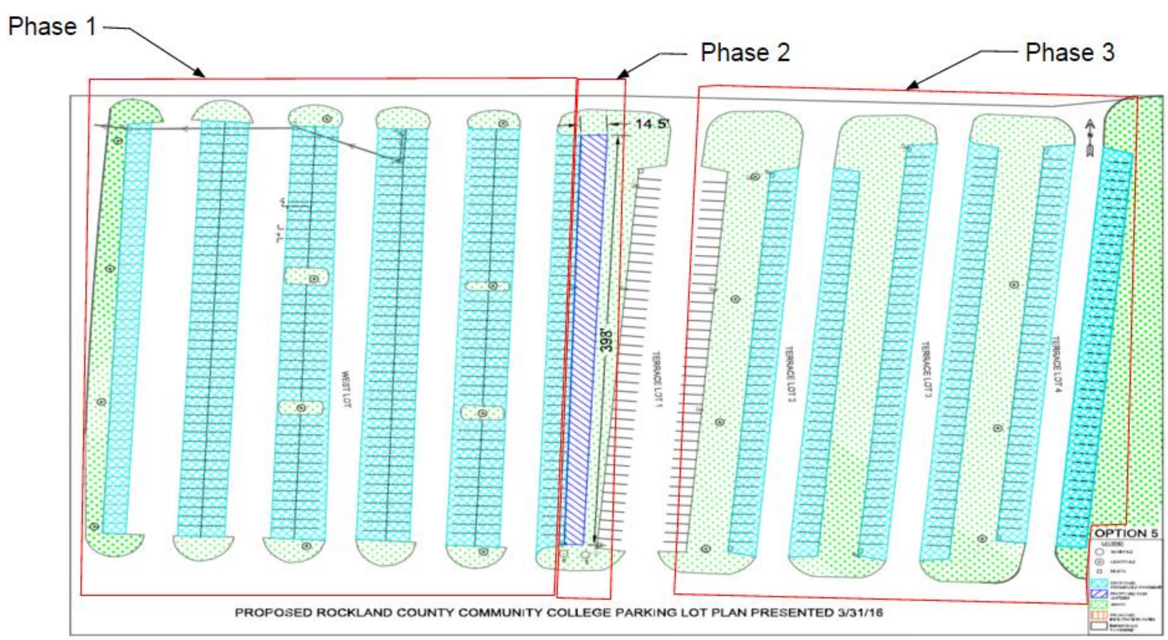


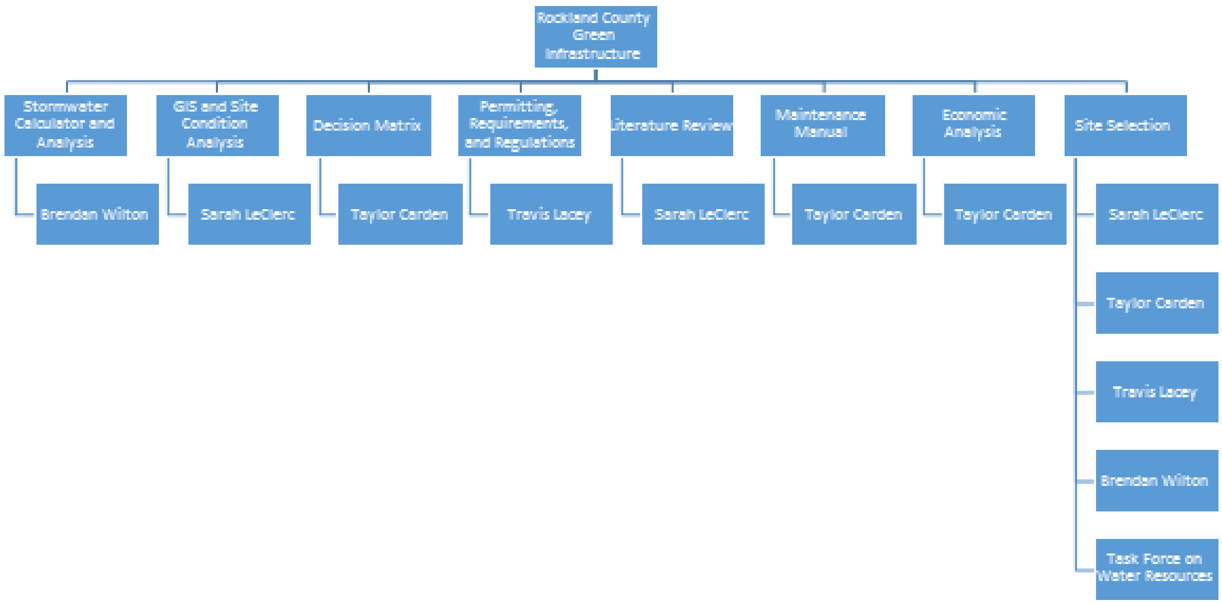
Figure 26. Final Proposed Site Plan

Acknowledgements

Patricie Drake, Task Force Coordinator
Rockland County Soil & Water Conservation District
Kevin Maher, P.E.
Task Force Work Group
County Department of Planning GIS Team
Rockland Community College
USEPA National Stormwater Calculator
QGIS

Appendices

Appendix A: Team Organization Chart



Appendix B: Project Schedule

Fall 2015	
Date	**Objective**
September 29th, 2015	Quantify relative infiltration potential of various GI technologies
October 6th, 2015	Identify various Rockland County site and soil conditions
October 6th, 2015	Use EPA Stormwater Calculator
October 20th, 2015	Proposal Presentation*
October 22nd, 2015	Initial task force meeting
October 27th, 2015	Mission Statement and submit written proposal*
November 3rd, 2015	Design alternatives quantifying infiltration potential
November 17th, 2015	75% Proposal Presentation*
November 19th, 2015	Task force meeting
December 8th, 2015	Final Proposal Presentation*

Spring 2016	
Date	**Objective**
January 25th, 2016	Public Presentation to Rockland County
February 19th, 2016	Site Visit with Workgroup
March 1st, 2016	Progress Presentation*

March 4th, 2016	GIS Data Analysis
March 29th, 2016	Economic analysis performed
March 29th, 2016	Conceptual level site design
March 31st, 2016	Task Force meeting
April 5th, 2016	Progress Presentation*
April 11th, 2016	Analyze aquifer recharge rate
April 18th, 2016	Posters Due*
April 25th, 2016	Final Presentation to Task Force
April 27th, 2016	Design Day Expo at Stevens*
May 11th, 2016	Final written report*

*CE423/CE424 Deliverables

Appendix C: Design Documents

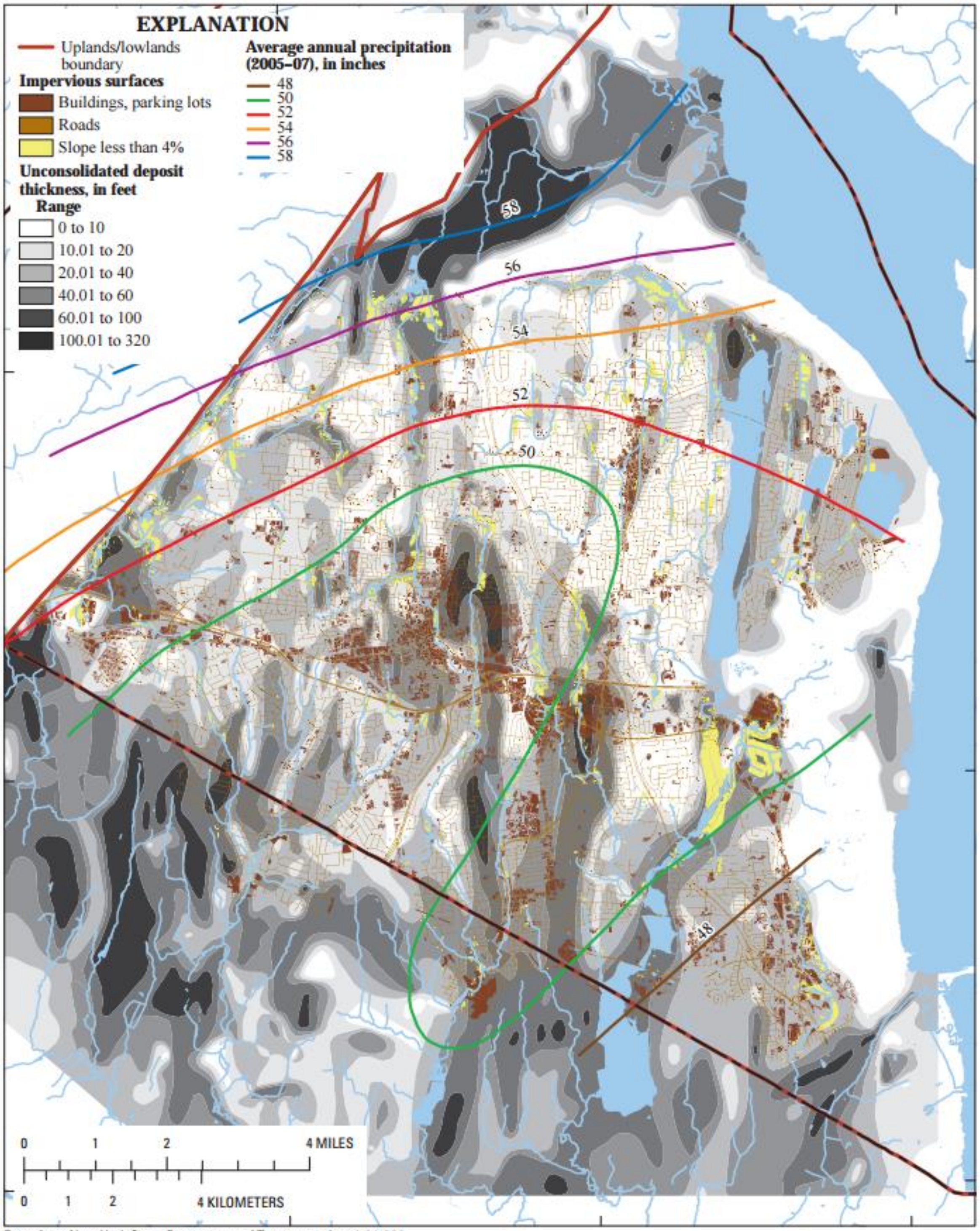


Figure C1. Distribution of factors that affect recharge across the Newark basin aquifer

Table C1. Material Specification for Porous Pavement

Table 5.15 Material Specifications for Porous Pavement				
Material	Specification			Notes
	Porous Asphalt	Porous Concrete	Permeable Paver	
Pavement	3"-7" Bituminous mix ½" Nominal Maximum Aggregate Size ≥18% Air Voids (50 gyrations) Draindown ≤0.3%	4"-8" Portland Cement Type I or II (ASTM C 150), No. 8 (ASTM 33), Agg.:Cement Ratio 4:1 to 4.5:1 Water/Cement Ratio 0.28-0.35	Varied shapes and sizes, 8%-10% surface opening, manufacturer specification, flow rate 5 in/hr or no less than 10% void	
Choker course	4"-8" depth AASHTO No. 57	None	2" AASHTO No. 8 stone over 4" of No. 57	Should be double-washed and clean and free of all fines
Filter Layer	8"-12" No. 2 stone	No. 2 stone	No. 2 stone	Depth based on structural, storage, and hydraulic requirements. Double-washed, clean, free of fines
Drainage Layer	The underlying native soils should be separated from the filter layer by a 3 inch layer pea gravel over a reservoir course with at min. a 4 inch layer of choker stone (AASHTO No. 3 or 5). For design variation of thickness, storage, underdrain measure, and cold climate frost depth consult UNHSC design specification for reservoir course (UNHSC, 2009)			Sand should be placed between stone reservoir and choker stone, on top of underlying native soils.
Underdrain	Where system as a whole needs to meet storage/release criteria and overflow piping to minimize chance of clogging. 4"-6" perforated PVC (AASHTO M 252) pipe, with 3/8-inch perforations at 6 inches on center, solid connectors; each pipe at minimum 0.5% slope, 20 feet apart. Extend cleanout pipes to the surface with vented caps at Ts & Ys.			
Filter Fabric (optional)	Needled, non-woven, polypropylene geotextile with grab tensile strength greater or equal to 120 lbs (ASTM D4632), Mullen Burst strength greater or equal to 225 lbs/sq in (ASTM D3786), Flow rate greater than 125 gpm/sf (ASTM D4491) and Apparent Opening Size US # 70 or # 80 sieve (ASTM D4751). Geotextile AOS selection is based on the percent passing the No. 200 sieve in "A" Soil subgrade, using FHWA or AASHTO selection criteria			
Impermeable Liner	Minimum thirty mil PVC geomembrane liner covered by 8 to 12 oz/yd^2 non-woven geotextile. Required only for Karst region and brown field applications.			
Observation Well	Perforated 4-6 inch vertical PVC pipe (AASHTO M 252), with lockable cap installed flush with the surface with surface cap.			

Table C2. Suggested Plant list for Rain Gardens

Table 5.11 Suggested Rain Garden Plant List	
Shrubs	**Herbaceous Plants**
Witch Hazel Hamemelis virginiana	Cinnamon Fern Osmunda cinnamomea
Winterberry Ilex verticillata	Cutleaf Coneflower Rudbeckia laciniata
Arrowwood Viburnum dentatum	Woolgrass Scirpus cyperinus
Brook-side Alder Alnus serrulata	New England Aster Aster novae-angliae
Red-Osier Dogwood Cornus stolonifera	Fox Sedge Carex vulpinoidea
Sweet Pepperbush Clethra alnifolia	Spotted Joe-Pye Weed Eupatorium maculatum
	Switch Grass Panicum virgatum
	Great Blue Lobelia Lobelia siphatica
	Wild Bergamot Monarda fistulosa
	Red Milkweed Asclepias incarnate
Adapted from NYSDM Bioretention Specifications, Bannerman, Brooklyn Botanic Garden.	

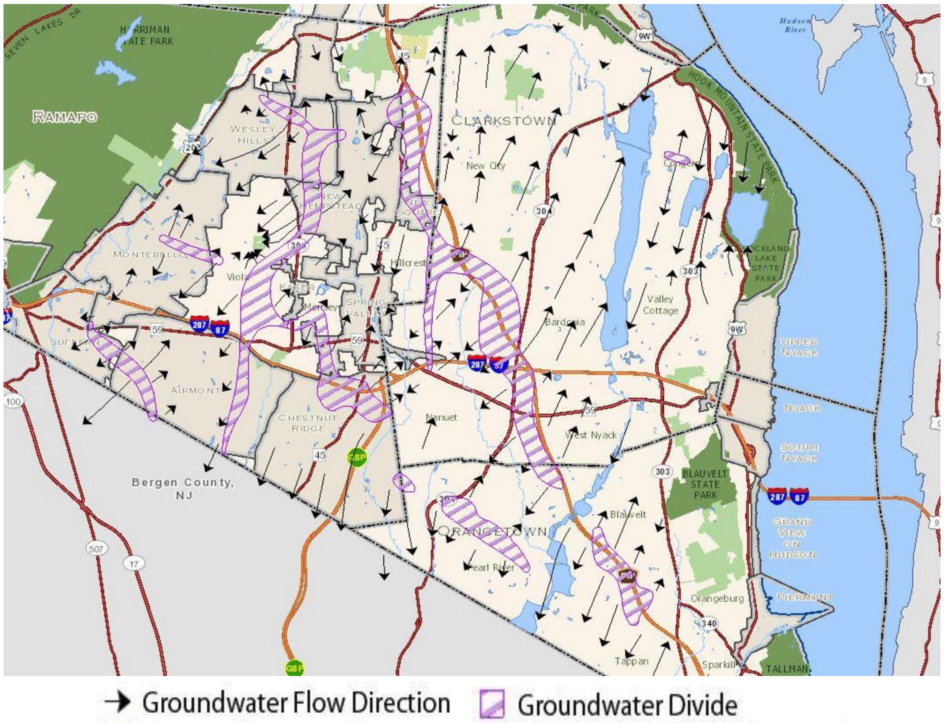


Figure C2. Groundwater Flow Map

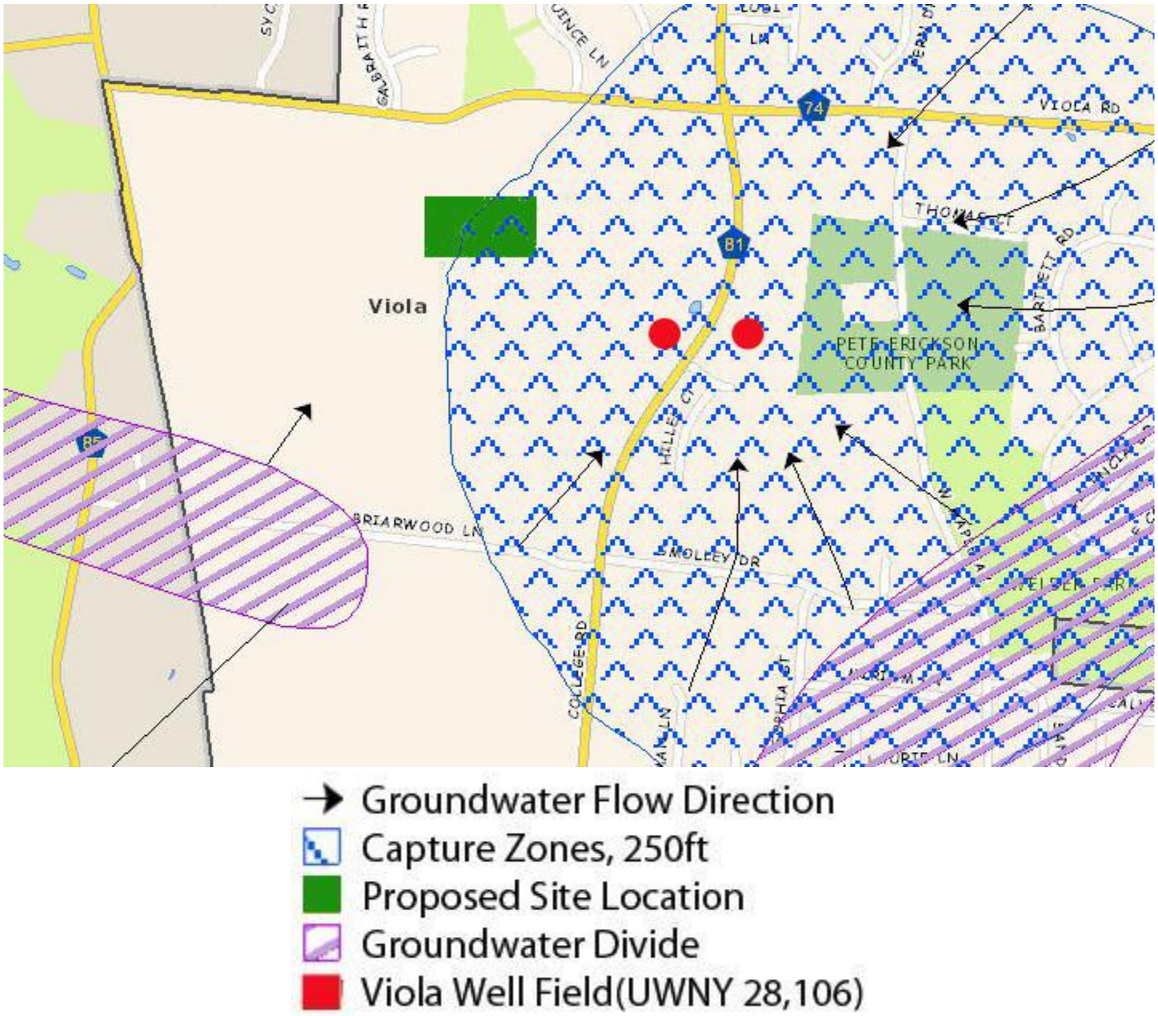


Figure C3. Proposed Site in Relation to Well Field and Groundwater Flow

Table C3: Design Matrix Values

	ft^2	Acres	Cost per material	Total cost	Maintenance	Maintenance Cost (additional, per year)	Infiltration (gal)	Runoff (gal)	Life of Materials (years)
Option 1									
Porous Asphalt	143745	3.30	$6.00	$862,470		$1,140			
Rain Garden	6890	0.16	$7.00	$48,230	6.00%	$2,894			
Pavement	103217	2.37	$1.50	$154,826					
	253852	5.83		$910,700		$4,034	9152350	211800	22.9
Option 2									
Porous Asphalt	76858	1.76	$6.00	$461,148		$1,140			
Pavement	170104	3.91	$1.50	$255,156					
Rain Garden	6890	0.16	$7.00	$48,230					
	253852	5.83		$461,148		$1,140	6337270	3014125	21.6
Option 3									
Infiltration Basin *cubic feet	10335	0.24	$1.30	$13,436	4.50%	$605			
Porous Asphalt	76858	1.76	$6.00	$461,148		$1,140			
Pavement	170104	3.91	$1.50	$255,156					
		0.00		$474,584		$1,745	6435566	2932662	21.6
Option 4									
Porous Pavement	246962	5.67	$6.00	$1,481,772		$1,140			
	246962	5.67	0.00	$1,481,772		$1,140	9152350	211800	25.0
Option 5									
Rain Garden	6890	0.16	$7.00	$48,230	6.00%	$2,894			
Porous Asphalt	128252	2.94	$6.00	$769,512		$1,140			
Pavement	118710	2.73	$1.50	$178,065					
	253852	5.83		$817,742		$4,034	8743680	615860	22.6

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Appendix E: Meeting Minutes

September 15, 2015

For next meeting:

- Come prepared with agenda
- Communicate with Dr. Fassman-Beck

In general:

- Don't put off meetings
- The team's regular scheduled meeting time with Dr. Fassman will be Tuesdays at 10am

Discussion of project

- Need to meet with Rockland County
- Project will include identification of problem and many potential solutions
- Dr. Fassman then shared presentation (*Need to make sure we all have access to this)

Presentation

- Context: RC served by United Water through reservoir
- Estimate for water availability rapidly declining
- Opportunity to make better use of aquifer
- Lots of development exists across RC but no existing stormwater design
- Potentially useful solution
  - Put water back into ground
  - Trying to avoid desalinization and use of Hudson River water
  - RC foresees shortage of potable water within the next 10-25 years
- Rockland County: mix of designated green space and heavily populated areas

Objectives

- This is a desktop study but the team still needs to be familiar with the land
- Quantify the good infrastructure can do
- At least one team member MUST attend GIS class Wednesday nights (CE 537)

Pros/Cons of each type of design

Green Infrastructure (Specifically to augment groundwater)

- Bioretention (rain garden)
  - Best with highly permeable existing soil
  - How much water can the soil absorb and how fast
- Permeable pavement
  - Replacing impervious surfaces

    - Only manages rain directly falling on it
- Non-Infiltrating GI
- Not being considered for this project

USEPA Stormwater Calculator

- Continuous simulation of water collection
- Not widely used yet… released last year
- Incorporates GI technology

Using Calculator

- Specify parameters (acreage, location)
- Calculator will pull existing information
- Can play around with values to test different options

LID (low impact) Controls

- Parameters dictated by NY manual

IMPORTANT: keep track of all data and outcomes entered into calculator to identify BEST possible outcome ****goal of entire project

Matrix of design combinations

Key number we are looking at: percentage of potential infiltration

Things that remain unclear: groundwater mapping

- Need to communicate with GIS people of RC
- Specific requirements of water table distance can be found in NY state code

Keep in mind:

- Planning vs. Engineering Design
- When moving to design, USEPA Stormwater Management Model
    - On horizon for future of this project

Summary and to-do list

Brendan- Attend GIS class on Wednesday Nights

Dr. Fassman- Get added to Canvas portal, make sure presentation is available via Canvas

ALL:

- Become familiar with Rockland County by looking at Google Maps, reading up on the area
- Play around with USEPA storm calculator
    - Download manual
- Look at Rockland County GIS Portal (and develop questions to ask Dr. Fassman)

September 22, 2015

Research on Rockland County

- Significantly more developed than anticipated, four country clubs

- 5 distinct towns, 19 villages, 17 unincorporated hamlets
- 1,800 people per square mile
- 287,000 in 2000 and 318,000 in 2012
- On Stormwater Calculator- none of the rainwater gauges are utilized

Groundwater Level Website (Sarah)

- http://ny.water.usgs.gov/projects/rockland/

GIS (Brendan)

- How extensive of a model do we need?
    - Full data, workbook or student version for a full year with no data?
    - Decision: Student version for full year, since data will be provided by Rockland County task force
- GIS- What is it?
    - John Snow, created it to present map data
    - More of a presentation tool- need it for length of entire project

Stormwater Calculator

- Easy to use
- Which parameters do we need from GIS? **Question for Dr. Fassman

First County Meeting/Questions for task force meeting

- What is the township division where local policies start and end?
- Location of rainwater gauges (if any) in the county?
- General concern for lack of information on groundwater table
- Federal regulation on highways through county, what can we touch?
- What areas are they looking to start with?

To-do

- Sarah- forward email from task force (when received)
- Ask Prof. Brunell to move forward in purchasing GIS software for Brendan
- Ask Prof. Brunell about first task force meeting
- Review ASCE Permeable Pavements and Auckland Bioretention in Dr. Fassman's google drive

September 28, 2015

For Next meeting:

- Complete Stormwater calculator runs for the different variations and fill out table
- Review Heisig report
- Find out Rockland County GIS department contact info

Discussion of project:

- Review Infiltration Notes from Water
- How we can be proactive with our research in lieu of not meeting with the task force yet
    - GI Feasibility

        - Different factors and design parameters that may be site constraints
            - Bedrock needs to be at least 6' below grade
            - Slope of grade
            - Trees that overhang pavement
        - Can be used to fine tune details of scenario runs
    - Making results specific to Rockland County
        - Identify potential sites throughout Rockland County
            - Focus on Pavement heavy areas
    - Using Stormwater Calculator to identify possible locations in the county
        - Compiling list of variables to narrow down potential locations
        - Establish a control site using the data given
        - Use Dobbs Ferry for rain gauge data

To Do:
Taylor- Create Spreadsheet for Stormwater Calculator Data & responsible for soil drainage data in storm water data table
Sarah – Read through report and pull out any important information & follow up with Patricie
Brendan – sort out purchasing GIS software & responsible for topography data in storm water data table
Travis – review infiltration notes from Class on Thursday & responsible for soil type data in the storm water data table

October 6, 2015

- Brendan showed stormwater calculator runs
- Sarah presented important maps from Heisig Report
- Sarah emailed Patricie available days for meetings and sent Data Request Form to Caren Wecera in the GIS Department of Rockland County
- Discussed Project Statement

October 15, 2015

Review Work Plan

1. Quantify the relative infiltration potential of various Green Infrastructure (GI) technologies that meet the stated goals of the TF
    a. Brendan to start running LID scenarios
2. Consider a range of site and soil conditions in Rockland County, technology configurations according to NYS DEC recommendations
    a. http://www.dec.ny.gov/
    b. NYS DEC on stormwater http://www.dec.ny.gov/chemical/8468.html
3. Use a USEPA hydrologic model, the National Stormwater Calculator

    a. Versed
4. Design alternatives analysis quantifying infiltration potential:
    a. For each impervious acre managed by GI technologies
    b. For known combinations of soil type, drainage, topography existing in the County
        i. Retesting for 60% impervious, 40% pervious
    c. Trade-offs amongst GI-specific design parameters
5. Literature review (academic publications) to establish expectations for how much infiltrated water actually augments groundwater

Decide on final information to request from GIS department

- Parcels
- Municipal Boundaries
- Streets
- Census 2010 Boundaries
- Parks
- Planimetric
    - Hydro
    - Driveway
    - Hydro centerlines
    - Parking
    - Roads
    - Sidewalks

Project Scope
https://docs.google.com/document/d/157zMydzeE0XdGMQf0WgvDILagnFBp-RHEsPY1k0UrMg/edit
Presentation
https://docs.google.com/document/d/1SiVkR5FHaL-fQJRjD7EUgnqdQcCmaj6adXBxzB-iK10/edit

October 27, 2015

Review task force meeting with Professor Fassman

- Understanding need to step up and lead task force

Goals for next meeting/Task breakdown

- Create a detailed agenda to keep task force focused
- Site selection- focus very heavily on GIS
    - Take the lead in choosing locations
    - Decisions on obtaining GIS license- may not be needed for actual analysis (team can use CAD) but conveys the information in a much cleaner way for non-engineers

- Look into education at RCC and propose classes
- Assigning roles
    - Travis- working on permit information and grants, specific design and construction of each solution
    - Sarah- location of groundwater tables, GIS information, identifying how much water actually reaches aquifer
    - Brendan- running scenarios in stormwater calculator, consolidating results to observe measurable difference
    - Taylor- economic analysis, matrix for decision making, long term operation and maintenance plans, green infrastructure on private property (look at Seattle)
- Old Castle engineering
    - Suite of permeable pavement
    - Professor Fassman to follow up with contact information from network of contractors
- Presentation from main funding agency in NY
    - Professor Fassman to follow up with this

Review proposal report

November 3, 2015

The Team discussed:

- Brendan explained his data that he collected from the stormwater calculator
    - key is to quantify the amount of recharge based on the data in order to identify which scenario will be most beneficial for the task force
    - Needs to go back and clarify the data on the tables so its easier to understand at first glance
    - How does the calculator identify where the GI solution area is being considered?
    - keep in mind significant digits
- Taylor interpreted the criteria and how to measure each individual option we discussed through a series of decision matrixes
    - Most important: ability to reach the aquifer
    - we can better identify criteria when we can focus in on an area
    - decision matrix:
        - evaluating each GI technology based on each individual site
        - ability to reach aquifer
        - maintenance - need to define (required hours, cost per year to maintain) and the ability to maintain (public or private site)
        - cost - find total cost to install within area and divide that by the units of water that will be infiltrated
- Travis discussed permitting and grants that may be required

    - DEC SPDES general permit for Stormwater discharge
    - MS4 – Municipal Separate Strom Sewer System
    - Green Innovation Grant Program (professor Fassman has more info and contact info- send her a reminder)
    - Towards the end of the project reach out to DEC about MS4 or any other permits that we may require….explain that this is just in the context of a student project and hypothetical, we just want an idea of what might need to be done for a project like this
- Sarah presented possible locations based on given data
    - university lawyer should look into GIS contract sometime this week
    - Provide maps with areas which should be considering based on impermeable surfaces and the flow of the region
    - groundwater data USGS website
- To Do:
    - Brendan- finish all data
    - Taylor, Sarah, Travis - review and understand the DEC design criteria chapters for GI
    - Team - go through basecamp correspondences

November 10, 2015

GIS data

- What is publicly available to view isn't available for download
- Some information not owned by the county and some is, we can request licensing ONLY for what county owns
- Doug will be back from vacation next week to grant licensing
- Conditions of license agreement- you are not allowed to use this information for anything but personal use, NO publishing (potential conflict with senior design expo)
- Rockland county must review and agree to what we requested
- Will move forward next week- Stay in communication with Dr. Fassman, Patricie and Doug
- CRITICAL PATH ITEM.

Sarah on GIS

- Met with Sarath to understand how to download things from the state website
- Having trouble with licensing and will be meeting with him again

Taylor

- Decided on importance of criteria (subject to change- can be found on google drive)

Sarah on GIS

- Will be collecting and presenting overlay where aquifer is and where the water is flowing, focus on parking lots and county owned space

- Mostly consistent rainfall and soil type throughout county

Professor Brunell’s goal for team by end of semester:

- Use decision matrix to hone in on about 6 sites
- Do not go crazy evaluating- a lot of sites can be eliminated immediately if the water flows to Old Tappan reservoir

Stakeholder buy in

- Use public meetings to hear opinions of all of the people who are involved or affected
- Take on board what they want
- Difficult to quantify- will depend on how we present material to the public

Taylor for next week:

- Meet with Sabrina to discuss maintenance plan
- Come back next week with criteria being filled into decision matrix

Sarah

- email Patricie about changing meeting time, preferably to Monday or Wednesday of next week so that Professor Brunell is able to attend with us

Travis

- Started going through state stormwater design manual
- Summarizing and to send out to group- will be available by next week
    - Only focus on things that are relevant to our designs

Brendan

- Clarifying note from last week:
    - When the calculator gives a percentage of infiltration, it is a piece of the previously impervious area, not additional area on to the acreage evaluated
    - If it says 35%- is it 35% of the 80% or 35% of the entire acre total?
        - 35% of the 80%
- In process of cleaning up documents to present
- How much is infiltration affected by percentages?
- Data to show when the infiltration is greater than runoff
- For this week
    - Expand percentages of GI all the way up to 100% (change intervals to 15% rather than 5%, less scenarios)
    - Running 20% lawn and 10% lawn and also 100% impervious for permeable pavement
    - Start adjusting GI parameters for influential
    - Basic visuals to present to task force (showing percentages of acre)

November 17, 2015

The Team discussed the following topics:

- Brendan explained his data that he collected from the stormwater calculator

    - The key is to quantify the amount of recharge based on the data in order to identify which scenario will be most beneficial for the task force
    - Needs to go back and clarify the data on the tables so it's easier to understand at first glance
    - How does the calculator identify where the GI solution is in the area being considered?
    - Verify the units: Inches or acre-inches?
    - Keep in mind of significant digits
- Taylor interpreted the criteria and how to measure each individual option we talked about through a series of decision matrixes
    - Most important: ability to reach the aquifer
    - We can better identify criteria when we can focus in on an area more
    - This is about the decision matrix
        - evaluating each GI technology based on each individual site
        - ability to reach aquifer
        - maintenance – need to define (required hours, cost per year to maintain each technology), also the ability to maintain (private or public site)
        - Cost – find total cost to install within area and divide that by the units of water that will be infiltrated
- Travis discussed Permitting and Grants that may be required
    - DEC SPDES General Permit for Stormwater Discharge
    - MS4 – Municipal Separate Strom Sewer System
    - Green Innovation Grant Program (professor Fassman has more info and contact info- send her a reminder)
    - Towards the end of the project reach out to DEC about MS4 or any other permits that we may require….explain that this is just in the context of a student project and hypothetical, we just want an idea of what might need to be done for a project like this
- Sarah presented possible location based on given data
    - University Lawyer should look into GIS contract sometime next week
    - Provided maps with areas which should be considering based on impermeable surfaces and the flow of the region
    - Groundwater data USGS website
- To Do:
    - Brendan- finish all his data
    - Taylor, Sarah, Travis – review and understand the DEC design criteria chapters for GI

        - Team – Go through Basecamp correspondences that have been occurring between the task force to make sure we understand what they are requesting and suggesting as parameters for this project

December 1, 2015

Topics of Discussion:

- Agenda from Task Force Meeting:
    - GIS data – taskforce received everything from the school and are waiting on the county executive
    - Work Plan - felt that we were on track
    - Updates on all our work - want our presentation info on basecamp
    - Review Site selection criteria
        - went into detail on decision matrix
        - went through their bullet points on what they think is important site selection criteria
        - Task force is focused on demonstration sites
        - Need to be aware of local codes
        - letter "K" on III in criteria, need to consider this a the same time that were are identifying possible sites
            - Permit requirements
            - Rules for amount of parking spaces in each spot
            - Rules for building setbacks
        - Removed letter "L" from criteria
            - find out if Rockland County has combined/separate sewer system for the areas that we are looking into
                - if they are- what is the status on the long term control plan
        - Letter "M" - were looking at sites that are in areas in developed areas so we won't be breaking ground
    - Task force recommended two GIS data: Crass or QGIS
        - Wants our numbers for infiltration in gallons per year
    - Marcy gave us some details on permeable pavement
        - Educate them on the pros and cons of each option
            - ex: porous concrete does not work well in cold climates, but porous asphalt does
    - Water quality volume - volume of runoff you have to capture and treat for water quality (should be in DEC manual)
    - How would we monitor wells:
        - how often should they be checked

            - decreasing runoff could be correlated to show the effectiveness of the GI technologies
- Looking forward:
    - public presentation at town hall on January 25th (5:30-7)
    - Taylor - meet with Sabrina and finalize decision matrix
    - Brendan - reconverting the data to the gallons/year units
    - Sarah - using GIS data
    - Travis - permitting and quantifying the cost for each permit

December 7, 2015

- Worked on TG 403 and CE 423 presentations via Google Drive
- Presentations were completed

Sarah

- Started analyzing GIS data received

To do:

- Finish TG 403 Business Plan
- Final Written Proposal
- Submit Meeting Documentation

March 8, 2016

- Taylor called Lamont-Dougherty
    - Long-term parking, low use
    - Salt and plow
    - All permeable except for 1 high slope lane
    - Non-porous is in worse shape than porous
- Porous pavement has better long term results due to freeze/thaw
- Vacuuming can't hurt
    - Nearby construction
    - Sally Hoyt, energy manager, UNC Chapel Hill can talk to us about maintenance
    - County get 1 vacuum truck
    - See if normal street sweeper works
- Rockland has 3 existing projects
    - 2 rain gardens(piermont library) and 1 permeable pavement(lamont-dougherty)
    - Localize data to more nearby sites outside of Rockland County
        - Westchester and orange county
    - See if 1 time vacuum rental is better than using regenerative as preventative measure
    - Ask Sally Hoyt

- Cost
    - Harder for dividing permeable and regular or is it cheaper for all permeable
        - Success relies on good installer, better binding
        - Big batches are better for quality control etc.
        - Harder to divide maintenance
        - Snow removal
    - Design 2 was most expensive to maintain
    - Remove cents
- Keep main roads, impermeable pavement
- Green spaces staying
- Design 1: permeable in spaces and 1 rain garden in lower terrace
- Design 2: permeable in spaces in flat part and 1 rain garden in lower terrace
    - Curb cut
- Design 3: same as design 2 but with infiltration bases instead of rain garden
    - No curb
    - Some type of fence(decorative guardrail or curb bumps with rock trench)
        - Add mesh to guardrail to prevent garbage
- Add all information to all the designs for a presentation
    - Show reduction in runoff
- Add design 4 with all permeable
- Calculator only models 1 method of GI at a time
- Options are flipped in decision matrix
- Check calculator to see if it is considering the impermeable running in to the permeable pavement

March 15, 2016

- Option 1: all spots
- Option 2: West lot spots
- Option 3: west lot spots with infiltration basin
- Option 4: every area with small rain garden
    - 93% infiltration
    - We can let terrace lot one remain normal pavement
        - To allow rain to reach rain garden for educational purposes
        - Present this as option to task force
        - Make clear what difference in infiltration is
- · Option 5: all spots and rain garden
- Where does it come from? How is it being treated? Where does it end up?
- No rain going to rain garden = expensive garden
- Eastern curb=top of terraced lots

    - NYS Design Manual requires these as berms as to prevent lawn debris
- **Calculate how much area the rain garden can accommodate
    - 6,890ft^2
        - Capture ratio can hold 2-3 terraces
- Include grass in calculation too
    - Possible could put all of east lot
    - More effective demonstration site
    - What to do if only 2 terraces can drain?
    - Just because you can, doesn't mean you should due to maintenance difficulties
- Only the spaces gives 63% infiltration because calculator is assuming rain on impermeable in simply running off
    - We will get same infiltration for all parking lot or just spaces
    - Less material, more difficult construction
    - This needs to be checked with contractor-passed conceptual design
- Capture ratio in calculator
    - Rain garden: ration of garden area to area impervious draining into it
    - Perm pavement: % treated area replaced with permeable pavement
        - Can't do run on in calculator
- Base course was same everywhere but top pavement is different
    - Rough quantity of materials estimate
- Travis presented cross-sections
    - Underdrain required by NYS?
        - Rain garden and pavement?
        - Tell task force if it is required
    - Replace soil with fill media or engineered media
    - Underdrain sits within stone layer
    - Transition zone between fill media and washed stone
    - Check cross sections with ASCE manual
        - Go with ASCE if there is a difference between NYS design manual
        - Tell task force what functional differences there are
    - Need overflow too
    - Might not need choker course
        - Only for PICP

March 29, 2016

- Thursday meeting to task force
    - No need for underdrains
    - Options:
        - All spaces w/ rain garden

        - Lower lot spaces w/ rain garden
        - Lower lot spaces w/ infiltration basin
        - All lower lot w/ rain garden
    - Present options to task force
    - Construction issue not infiltration issue
    - Ask if they would want an estimate
        - Purchase a vacuum truck? Or truck nearby?
    - Final design selection tomorrow
    - Tray 2 prints 11x17
- Cost
    - Have not heard back from Sally at UNC yet
    - $200 per acre pavement maintenance
    - Not including paving and salting costs since those apply to all pavement
        - Less salt need on permeable pavement? UNH?
- Same permitting requirements since we are looking at one site
- No loss of purpose since we are not losing spaces or lots
- Same maintenance measure on both types of pavement
- Call and find out maintenance measures in Rockland county
- Call RCC maintenance lady
    - School could buy vacuum truck
- Lit Review
    - Westchester report measured how much infiltrated water made it to a well field
    - Aquifer recharge
    - What factors control how it reaches aquifer
    - Soil types
    - Fassman will ask if someone has a report in Pennsylvania on groundwater pounding