SWM Engineering: Stormwater Management on Shelton Ave, Alexandria

2019

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Executive Summary

The main objective for SWM Engineering was to improve the lives of the residents of Alexandria borough as it relates to the impact of stormwater on everyday life. During nearly every moderate rain event flooding occurs within the borough. In order to begin to reduce this issue of flooding a course of action must be set forth. Before any infrastructure design can be started, the problems within the borough must be identified and quantified. SWM Engineering not only designed a solution to an individual problem but also aided the borough in their path towards preparing a grant application for outside funding.

In order to identify the most problematic areas within the borough and quantify the water flow behavior at those locations, the computer software programs ArcGIS and the Virginia Tech Penn State Urban Hydrologic Model (VTPSUHM) were used. These programs are useful for watershed delineation, which allows SWM Engineering to determine how much water flows through a given point for a storm of a certain intensity. These data will be presented to the borough for use with grant applications and to determine the location where immediate action is required. Additionally, to identify the current problem with the channel along Shelton Avenue, the channel was modeled using the StormWater Management Model (SWMM) to see where and when flooding would occur for a 10-yr, 24-hr storm.

The second objective of SWM Engineering is to present the Borough of Alexandria with a stormwater infrastructure design which will directly improve conditions for residents. After much debate, it became evident that the channel along Shelton Ave must be redesigned in order to reduce flooding downstream from that location. The most realistic and effective solution to this particular issue was a heavily debated topic, but after much discussion the options considered were a grass-lined channel with reduced flow, a riprap lined channel, or a reinforced grass lined channel. All designs will allow for better water flow which minimizes flooding. Due to aesthetic reasons, along with making sure the channel was feasible, a reinforced lined channel with grass was chosen in order to be able to convey enough water, while also being aesthetically pleasing.

The new channel was designed, and then modeled using SWMM again. The culverts will be resized to be 5 feet in diameter, so that they will not impede flow. The channel design was constrained to have a maximum bottom width of 8 ft, and top width of 20 feet, and to handle a peak flow of 130 cfs. This peak flow is much less than the peak flow that would be coming to the channel currently, which is approximately 220 cfs. Therefore, to deal with the extra flow Best Management Practices, or BMPs, will be utilized upstream of the site to deal with the extra water. The cross sectional area of the reinforced channel will be 48ft2. This design proved successful, through modeling using SWMM, and will be given to the Borough of Alexandria as the recommendation.

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1.0 Introduction

In Pennsylvania, a storm event occurs on average every 72 hours (NOAA, 2018). The resulting water must be correctly managed in order to prevent any problems downstream of the water flow. There are numerous ways to deal with these events, ranging from infiltration into the ground to constructed wetlands, which store water and release it at a controlled rate. For a single location, there are numerous solutions that could be implemented to resolve any issues, but more often than not there is usually a system that will function the most successfully. Within Alexandria, a combination of multiple pieces of infrastructure are necessary to address the issues experienced from rainfall. Our goal is to provide data to the community in the form of stormwater flow quantification for various points of interest within the borough, and to redesign an existing piece of infrastructure to mitigate stormwater issues.

Part of the solution to the issues experienced by Alexandria will be a redesign of the channel adjacent to Shelton Ave. This channel has been filling with sediment within the upper section, which has caused water to begin ponding within the channel even during dry periods. As well, during intense rain events, this piece of infrastructure often overtops its banks and adds to flooding issues on the main street. Throughout this report, multiple options will be considered to improve the current situation on Shelton Ave. Additionally, data will be provided for various points throughout the borough so that the information is available for future grant opportunities. The Borough will be provided with flow modeling for points across the area and a choice of solutions for the problematic area along Shelton Ave.

1.1 Initial Problem Statement

Alexandria, a small borough of approximately 350 people in an area of 0.11 square miles (Alexandria, 2014) that sits along the bank of the Frankstown branch of the Juniata River, has been experiencing a large amount of stormwater related issues. Due to the low budget of the borough, which is usually around $65,000 per year, there is a lack of funding to update and improve the existing stormwater infrastructure. As engineers, our job is to work with the community to help solve some of these issues and aid in collecting data to be used in a grant application. Our two primary goals are to produce data using Geographic Information System (GIS) to prove the need for monetary assistance in the form of grants, and to design a piece of infrastructure which helps mitigate the effects of stormwater on the town, specifically a section of Shelton Avenue. Upon completion, we plan to deliver useable GIS data and a functioning design of a component to add to the existing stormwater system, which will improve the borough's ability to handle storm events.

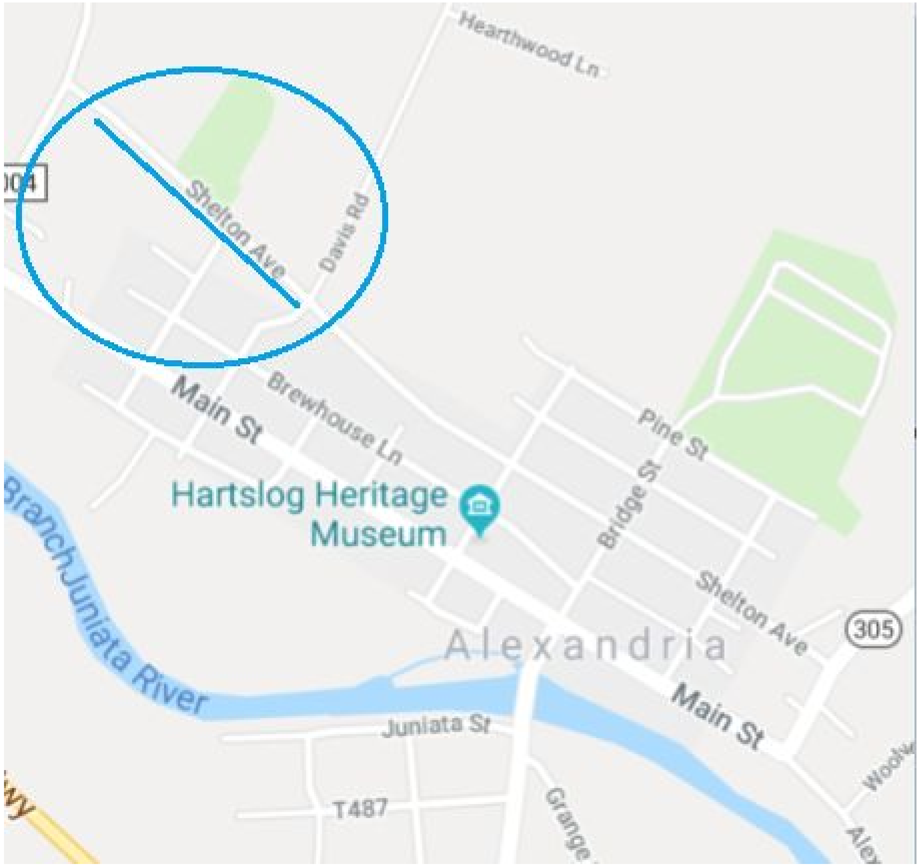

Figure 1: Map of Alexandria

Figure 1 shows a map of Alexandria. It can be clearly seen where Shelton Ave is located, as marked by the blue circle, as well as Shelton Ave's relation to the Juniata River. The blue line indicates where the channel to be redesigned is located.

1.2 Objective and Description of Design Problem

The objectives of this project are to quantify stormwater flows for the entire town of Alexandria PA, with a focus on Shelton Ave where a channel designed will be implemented. The design should be able to handle a 10 year storm while being safe, practical, and aesthetically pleasing. The design should not infringe on the roadway that is currently there, and should minimize cost of implementation, as well as be easy to maintain. Additionally, the stormwater quantification data must be applicable to grant proposals that the borough will be developing.

2.0 Sponsor Needs Assessment

2.1 Gathering Input

2.1.1 Site Visit

The primary starting point for gathering input was communication through email, phone calls, and site visits with Rebecca Smith, our sponsor and contact on the Alexandria Borough Council. Meetings and communication were key in understanding the desires and capabilities of the borough. Alexandria is a small community with limited resources, and this was greatly taken into consideration throughout the planning and design process.

Our first case of gathering input came as a site visit with the sponsor on Friday September 14, 2018. During this visit, we walked some of the problematic areas, took pictures, and discussed some of the preliminary thoughts and ideas provided by the sponsor. Several pictures of the channel are shown in Figures 2-3. We were informed that, during certain storm events, of varying size and intensity, a sheet of water up to a few inches deep runs southwest from the channel located along Shelton Ave through the town and eventually to the Frankstown Branch of the Juniata River. We were informed that this water can cause severe flooding in the lower-lying sections of town, and the sponsor indicated that addressing this flooding from the channel would most likely be one of the main design concerns.

In addition to our preliminary site visit, we contacted Huntingdon County Web Mapping Services to obtain files and mapping layers for ArcGIS quantification work. Then, on Monday March 11th, more information about the area was gathered. All of the relevant culverts were recorded. Each culvert's diameter and length were measured by using a tape measure.

Figure 2: Beginning of Channel, East End

Figure 3: End of Channel Emptying into Park Stream, West End

2.2 Weighting of Customer Needs

Table 1. Customer Needs Table

#	**Customer Needs**	**Weight (1-5)**
1	Stop flooding on roadway	5
2	Control sediment within channel	4
3	Minimize area impacted	2
4	Aesthetically pleasing	2
5	Safe	5
6	Environmental impact	4
7	Low cost	5
8	Sustainable	4
9	Cultural impact	1
10	Alignment with ethics/value	3

11	Easy maintenance	4
12	Innovative solution	3
13	Sewer Constraints	5
14	Slope Constraints	5

(where 1 = less critical need and 5 = essential need)

The channel is to be designed firstmost for functionality with the most economically viable design, with all other aspects following. As such, flooding and low cost are weighted as 5's. Safety is another significant factor for any ethical engineer, which gives the safety need a rating of 5 as well. Controlling sediment, easy maintenance, sustainable, and environmental impact all keep the channel free of debris and minimize any complications that may arise as time progresses and the channel becomes worn. These needs are also highly important, with a weight of 4. In recognition of the practical implementation of a functional design, two categories for sewer and slope constraints had to be added. The two constraints dictated the outcome of the design process and were weighted as a 5's. All other needs become less important, but still necessary, when compared to highly weighted specifications.

3.0 External Search

3.1 Journal Articles

3.1.1"Experimental Studies of Factors in Determining Sediment Trapping in Vegetative Filter Strips"

Along with flooding during storm events, Alexandria experiences a great deal of erosion which causes downstream impacts on infrastructure. This article addresses how a vegetative filter strip can help in removal of sediment from stormwater. Effects of multiple design factors on the capture rate of sediment are examined within the article, which will be helpful when designing a filter strip for Alexandria if this is determined to be the best approach. As well, the article offers insight into how the vegetation removes sediment and the expected efficiency for a few sets of conditions. Trapping efficiency for different particle sizes (C.–X. Jin, M. J. M. Römkens, 2001) are detailed which gives insight into designs to remove a desired particle range.

3.1.2 "Sediment traps with guiding channel and hybrid check dams improve controlled sediment retention"

In addition to their flooding issues, Alexandria also has problems with the sediment which is carried by the flow of stormwater. This article talks about ways to remove this sediment and keep it trapped such that it does not enter the waterway the stormwater discharges into. The method discussed in this article is using "hybrid check dams" which slow the flow of water and allow particles to precipitate out. If one of these devices is placed within the designed channel a great deal of sediment could be removed, which would positively impact the downstream area. Within the article design elements and equations (Sebastian Schwindt, Mário J. Franca, Alessandro Reffo and Anton J. Schleiss, 2018) that will aid in the process to produce a working design for the channel are included.

3.1.3 "Design of Grass-Lined Open Channels"

Grass channels are a natural solution to carrying stormwater which limit soil erosion. This article demonstrated the design process in which a grass lined channel should be constructed. Using this information a proposal for the channel design will be able to be constructed which can be combined with another sediment controlling device to reduce transported sediment (D. M. Temple, 1983). As well, this article offers examples of vegetation options for a channel, which can be selected to best match natural vegetation and the needs of the channel.

3.1.4 "Effectively Managing Water"

This book is a resource on how to manage stormwater and all the factors surrounding it. Information included within the text ranges from how to survey a site to the iterative process of channel design. Design steps for pieces of infrastructure such as sedimentation basins, channels, and sediment traps are all found within the book (Jarrett 2018). These are all possible approaches to improve the stormwater system in Alexandria.

3.2 Engineering Standards/Regulations, Patents/Application Notes

3.2.1 Department of Environmental Protection - Municipal Stormwater Regulations

https://www.dep.pa.gov/Business/Water/CleanWater/StormwaterMgmt/Stormwater/Pages/default.aspx

Stormwater Management plan requirements are laid out by the Department of Environmental Protection (DEP) for municipalities. Required steps towards getting a National Pollutant Discharge Elimination System (NPDES) permit if necessary can be found here and information on how to determine if we must follow the MS4 regulations. As well, this website (DEP, 2018) has links towards funding opportunities that may be useful for the borough of Alexandria.

3.2.2 Pennsylvania Department of Environmental Protection: Best Management Practices (BMP) Manual

http://pecpa.org/wp-content/uploads/Stormwater-BMP-Manual.pdf

"The purpose of this guidance manual is to ensure effective stormwater management to minimize the adverse impacts of stormwater on groundwater and surface water resources to support and sustain the social, economic and environmental quality of the Commonwealth" (DEP, 2006). This manual describes the recommended guidelines for site control, volume control, peak rate control, and water quality control. The manual also includes practices for maintaining and conserving the surrounding environment. These practices have been compiled by experts in order for the ease of implementation.

3.3 Existing Products or Design Approaches

3.3.1 “Creating a Stormwater Park in the City Meadow of Norfolk, Connecticut”

In order to control the impact of non-point stormwater flow on a small community (Steve Trinkaus, 2013), a constructed wetland was developed. This concept could be directly applicable to the Alexandria community. By storing water in a constructed wetland, peak flow through the community can be reduced. On a level above stormwater management, this structure is a source of pride in the community where the residents can gather. People are proud to be a part of this innovative solution, a feeling which could easily be seen within the Alexandria community.

3.3.2 “Project Case Study: Linear Park Channels Stormwater”

This article (G.C. Wallace, 2014) presents information on how channels within a newly developed area outside of Las Vegas were designed such that erosion and sediment issues could be minimized. Within the project, synthetic materials were used to line the channels that were previously unlined. As well, the article talks about how the design of the channel focused on the force exerted by the flowing water and how to prevent channel damage due to shear stress. Information is available on how construction was completed on this design, which will be almost as important as the design within our project.

3.3.3 “Investigation of Check Dam`s Effects on Channel Morphology (Case Study: Chehel Cheshme Watershed)”

Check dams allow for sediment within a channel to be reduced without building a large structure or basin. This article presents information on how to construct check dams and what design aspects have the highest success rate of sediment removal (Pak J Biol Sci. 2008). The information within this article will allow a check dam to be constructed within a channel if that is deemed to be the most effective solution to the sediment issues within a channel.

3.4 Other Sources

3.3.1 Green Infrastructure Funding Opportunities (EPA)

The EPA offers grant opportunities to communities looking to build green infrastructure that are very relevant to the Alexandria community. Due to the small size of the borough, funding for stormwater projects is limited and grants will be needed to construct a working piece of infrastructure. This webpage managed by the EPA details how to apply for these grants and shows the trend of increasing funding for stormwater infrastructure over the past years. Exact values for possible grants are difficult to find and have limited accuracy due to the fact that projects such as this have such a varied scope. Rather than the precise value of funding opportunities, this website lists various government agencies which offer funding; each of these can be explored for possible funding.

3.3.2. PENNVEST Website

PENNVEST is Pennsylvania's funding source for municipal projects especially for smaller communities. Most of the funding provided through this organization is not a grant, but rather a low interest loan. A loan is not ideal for the Alexandria community but it is an option that must be considered due to the low interest nature of the loans through PENNVEST. The interest rate can be lower than 1%, but a community must first apply and be approved for these low rates. A consultation with PENNVEST would offer more precise value of the interest rate.

3.3.3 NOAA Hydrometeorological Precipitation Frequency Data Server

NOAA has information on the size and frequency of storms for every area within the United States. This will be useful when designing stormwater infrastructure and when quantifying flows for Alexandria. Some forms of infrastructure must be designed for a storm with a specific return period; NOAA grants access to this information.

4.0 Ethics

4.1 Sustainability Ethics

The goal of biological engineers is to promote a positive change within the areas they work and to stay true to the basic concepts of sustainability for which we stand. Within this project, these concepts are extremely important, and any work that is conducted has a potential environmental impact. A stormwater project such as this offers an opportunity to positively impact a community and their outlook on sustainability. As well, this project has potential economic and human health impacts within Alexandria. This project should reduce flooding during large rain events which not only destroys property but increases breeding habitat for insects, such as mosquitos that carry disease.

In order to adhere to these values, the team will monitor the impact on sustainability that the project poses to the community. A proper design that follows all standards, such as the Best Management Practices manual, will positively impact the sustainability of Alexandria and protect the local environment for future generations to enjoy. The most important aspect of this project, from a sustainability perspective, is that it will not only improve the lives of people in Alexandria but it will also improve water quality within the Frankstown Branch of the Juniata River where all of the town's stormwater flows to.

4.1.1 Identify Sustainability Issues

There are numerous sustainability issues that arise from the addition of stormwater infrastructure in a small community. First and foremost, the budget of the borough is relatively small when compared to the cost of stormwater management practices. This limited budget affects how much the issue can be mitigated. For this reason, a grant is an ideal solution so that funding is provided. Without a grant, the borough could not afford such an extensive project such as redesigning high flow locations throughout the town. In the context of a channel, flow must be properly managed so as to improve conditions downstream, and to minimize flooding in areas where this occurred. Several problems emerge from this consideration. If the channel improves flooding of a certain area, but increases the flow downstream to the point where flooding occurs there, the channel is ineffective. The citizens of Alexandria who live downstream would experience increased effects that were not previously encountered. Directly impacting the citizens in a negative way is against the ethics of an engineer. Additionally, constructing the channel could have negative impacts on the surrounding area, as heavy machinery being brought into the area introduces pollution that would not normally be expelled into the air and the soil in the area would be compacted, decreasing infiltration and increasing flooding.

Table 2: Summary of Sustainability Issues

Sustainability Issue	Impact on Design
A channel has the potential to not mitigate stormwater problems for surrounding properties.	Other designs and areas of interest must be considered to determine what will be effective.
The budget of the borough is relatively small, so a grant is needed.	Design should be simplified in order to avoid unnecessary costs and keep grant amount reasonable.
Heavy machinery needed for the channel construction could harm the surrounding environment through exhaust, pollutants, effects on soil, etc.	Unavoidable if channel is necessary, but should be kept to a minimum. An over-engineered channel will require more work than necessary, keep channel design to minimum specifications.
Citizens of the borough will want a project that benefits them and community.	If no one benefits from the channel, grant money and opportunity will be wasted.
Flow through the channel could generate a high quantity of water moving into the natural stream in the adjacent park, causing that stream to overflow its banks.	This affects surrounding properties of the park. The quantities need to be properly analyzed downstream.

4.2 Ethics analysis

4.2.1 Ethical issue

One important ethical issue related to this project is that the design could benefit one part of the town more than others. Other parts of the town need to have the storm sewer system mapped, need to stop flooding on other roadways, and need to have a better water outlet into the Juniata River; however through this project it was chosen to just focus on this area of Shelton Avenue, and not any other area. This would only impact a select few residents that live around this area which could be seen as unfair, and our efforts could be going to another project that could have a bigger impact on more residents.

4.2.2 Stakeholders

One group of stakeholders are the citizens of Alexandria that would see the positive impact of the new stormwater conveyance channel. They need to prevent the flooding that occurs during even mild rainstorms. They benefit from a new channel as this may stop the flooding of basements of properties that are down the slope from the channel. As they are citizens, they need the channel to have no unnecessary negative impacts so that they can live safely and peacefully. Conversely, residents downstream might be negatively affected due to increased flow from the channel.

Another stakeholder would be the citizens of Alexandria that would not directly be impacted by this new stormwater channel. They would still need to worry about flooding in their basements, and on the streets directly adjacent to their homes while their neighbors lived in peace.

The environment downstream from the channel could be impacted by the new stormwater channel that is put in. The environment could be either harmed by the increased sediment load if not properly taken care of, or could be helped by decreasing the amount of sediment going into the stream. Also, if there is much nitrogen and phosphorus going into the stream, which could have been removed with our design, this could lead to more pollution of the Chesapeake Bay or any water body downstream of the site.

The borough council is a major stakeholder, as they are responsible for all the projects that would be undertaken in the borough. As mentioned above, some residents will be positively affected by the implementation of a channel, some will be negatively affected, and some will see no change. Those who are negatively impacted or not impacted at all by the channel will feel as though the time and money spent on the project was a waste, and a better use of resources could have been executed.

4.2.3 Values

The values that could be jeopardized by the ethical issue are values of compassion, environment, equity, and fairness. Compassion could be jeopardized by only helping a portion of the citizens in the town while not helping others. This would make it so that others are left still suffering, and depending on how many people this helps or hurts, it may not be ethical or compassionate using the ideas of utilitarianism. The same argument goes for fairness and equity. It might not be fair or equitable as it does not help the most people, and may leave some with increased problems. It also may jeopardize the value of environment; if the channel is not properly installed or designed, it may be harmful to the environment. Removing sediment and vegetation due to channel redesign may decrease water quality being outputted from the channel, which would impact the stream into which the channel discharged.

4.2.4 Potential solutions

One solution to this issue is to also solve some of the other problems the town has, in addition to solving the problem on Shelton Ave. This however is not a realistic solution as there is not enough time for the group to complete all of that work in the short amount of time allotted to this project.

Another possible solution is to go ahead with the plan to correct the flooding on Shelton Ave, and just leave the rest of the town as it is. This is a much more reasonable plan, as there is only so much time to help this town, and doing something for the town is better than not doing anything for them. There will be two proposed solutions to the problematic area along Shelton Ave for the borough to consider. The first solution will be a riprap lined channel which will convey the entirety of the flow for a 10 year-24 hour storm. An alternative will be to implement upstream BMP's which reduce flow to the channel along Shelton Ave and design the channel with a grass lining that has water-quality benefits.

Additionally, once a single project is funded and implemented, additional projects may gain more exposure from the state government to get additional funding. Flow quantifications done in GIS and a large scale SWMM model for the entire borough will provide a sound foundation for future projects.

5.0 Engineering Specifications

5.1 Establishing Target Specifications and Specification Analysis

5.1.1 Target Specifications

All target specifications for the channel are listed in Table 3. Some specifications are simply minimizing the value, such as preserve natural landscape and impact to surrounding infrastructure. The distance from the street and distance to the American Legion property are limiting factors. Additionally, a sewer pipe is located underground on the American Legion property approximately 10 feet from the channel. Flow rate specifications were derived from flow quantifications done in GIS as detailed in section 5.1.2b. The channel will be redesigned for a 10 year, 24 hour storm as prescribed on page 8-38 of the pennDOT drainage manual (pennDOT, 2015). This is a storm that has the intensity and precipitation volume that occurs on average every 10 years, lasting a period of 24 hours. Once the value for flow into the stream is calculated, channel specifications for how much water needs conveyed can be found. Ideally, money received from grants would be maximized so as to cover all expenses needed, once those values are established. Maintenance on the channel should be minimized, ideally three times a year, so as to minimize workload on citizens.

Table 3: Target Specifications

Specification	**Limits of Range**	**Ideal Range or Value**	**Units**
Preserve natural landscape	n/a	Only involve landscape within the existing channel	n/a
Flow rate to conveyance	>= 219	>= 219	cfs
Do not impact surrounding infrastructure	0	No existing physical infrastructure changed	n/a
Sediment Removal	>85	85-100	%
Do not infringe on resident properties	Current width of channel must not be exceeded in design	<= 20	feet

Grant money	150,000 > x > 5,000	> 50,000	$
Minimize maintenance	< 3	0-3	times a year

5.1.2 Specification Analysis

5.1.2a Initial Survey

A preliminary survey of the channel and surrounding topography was performed such that channel dimensions and slope were found. This survey was performed with a specialized bench level system which serves the primary purpose of measuring elevations. Using this equipment and a measuring tape, a very accurate estimate of the channel slope was calculated. During the survey, the channel was split into two sections.

In the first section, between 6th and 7th Street, the channel maintains a rather even slope. From a flooding perspective, this is the most problematic section of the channel, where it had been seen overtopping its banks during intense storm events. Because of this issue, an intense survey was performed on this section of the channel with measurements being taken at the top of both sides of the channel, and at the water level on both sides of the channel. The average slope of this section is 0.36%, which offers very little hydraulic gradient to induce the flow of water. Over the 400 feet of channel length in this section, there is only 1.44 foot drop. Throughout the channel, there are areas where the slope is inverted and the grade is backwards, causing ponding of water. This phenomenon is demonstrated within the survey data with readings where the elevation is higher than the previous downstream measurements within the channel.

The second section of the channel between 7th Street and Barree Road was surveyed in less detail due to the dense brush and constant features within the channel. Within the straight portion of the channel before it enters an “S-Curve” on its way into the natural stream, the average slope is 0.45% over a length of 580 feet. Below this section of the channel is an area that requires more advanced equipment to survey, which includes cutbacks where significant erosion is present. The lowest section of the channel where the most erosion is present also has a much more substantial slope than the rest of the channel, which will induce this erosion.

Figure 4: Surveying Channel Section 1, Facing East

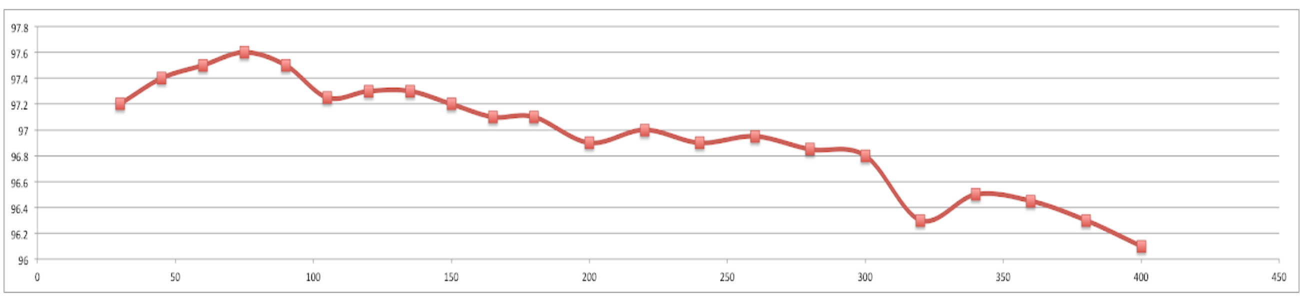

Figure 4-b: Survey Bottom Side Profile

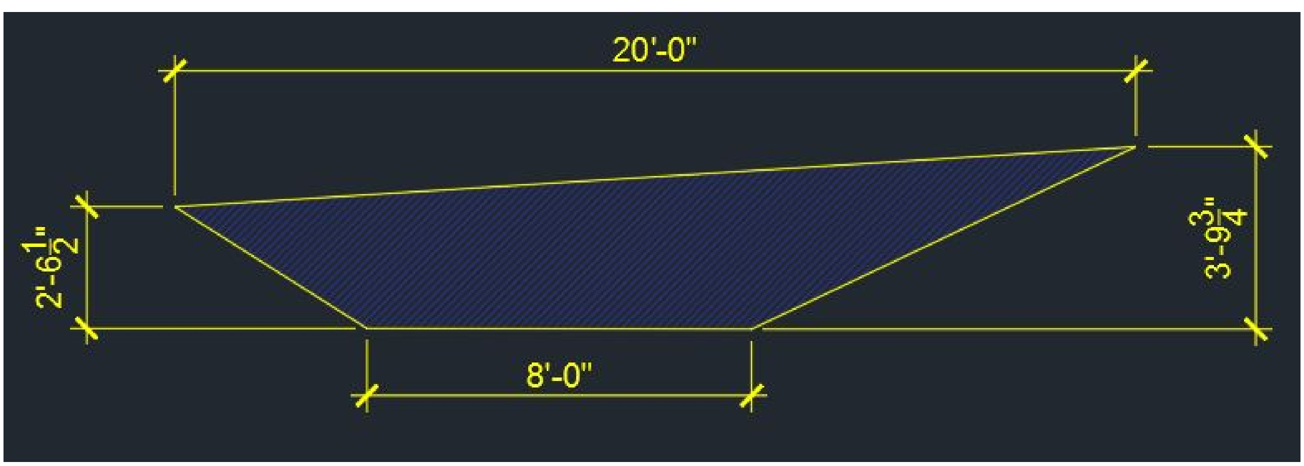

Figure 4-c: Average Cross Section of Existing Channel

The most intensive portion of the survey focused on the upper portion of the channel where the most prevalent issues occur. Figure 4-b above shows the profile of the channel which was surveyed, where the upper portion of the channel begins at x=30 feet and the end of the profile is the entrance to the downstream culvert. This figure highlights the inconsistency of the channel bottom and how sediment which has accumulated distorted the bottom of the structure. The initial bump in the early portion of the channel is from the pool which formed due to the sediment which is visible in figure 2.

5.1.2b Flow Quantification Work

An analysis of the flow into the channel was conducted using ArcGIS and VTPSUHM. In ArcGIS, first the watershed was determined for two points of interest: the beginning of the channel and the south-east end of town. Next, the land use and the hydrologic soil group of the area were found, which can be found in the appendix. The land use information in combination with the hydrologic soil group information was used to calculate the curve number for the areas.

The runoff values were calculated using the TR55 Tabular Method in VTPSUHM. The time of concentration was found by using the SCS Segmental (TR55) equation for sheet flow for the first 100 feet, and then the concentration flow equation for the remaining distance. Sheet flow is usually only present for the first 100 feet, so that is why that distance was used. The channel flow equation was not used while calculating the time of concentration as there is no channel that the water is flowing into before it reaches the channel next to shelton. Additionally, when calculating the travel time, it was calculated for the furthest distance away from the inlet of the channel, as this will make the time of concentration the true time of concentration when all of the water will be hitting Shelton Ave. The time of concentration used was 6.35 minutes for the channel next to Shelton Ave, and 8.24 minutes for the watershed of the town, by Route 305.

Finally, VTPSUHM was utilized to calculate the peak flow for different 24 hr storms, using the information from both ArcGIS, and the other calculated values in VTPSUHM. The peak flow rates can be seen in Table 4, and the hydrograph of the flow can be seen in Figures 6a and 6b.

During the SWMM analysis of the channel another check was done to ensure the peak flow rate for a 10-year, 24-hour storm was correct. SWMM used the curve number method (CN) to estimate a runoff hydrograph for a type two storm. Using estimated curve numbers and amount of impervious area a peak flow of approximately 215cfs was produced. This value confirms the the results from both the combination of ARCmap and the PA channel multiplier which were used in previous steps of the design process.

The watershed for the start of the impaired channel, as seen in Figure 5, was evaluated to be 75.58 acres, and the average curve number of this area was determined to be 80.21. The watershed for most of Alexandria, as can be seen in Figure 6 was determined to be 181.75 acres having an average curve number of 81.05. A curve number is a parameter used to predict runoff due to rainfall, while taking into account infiltration.

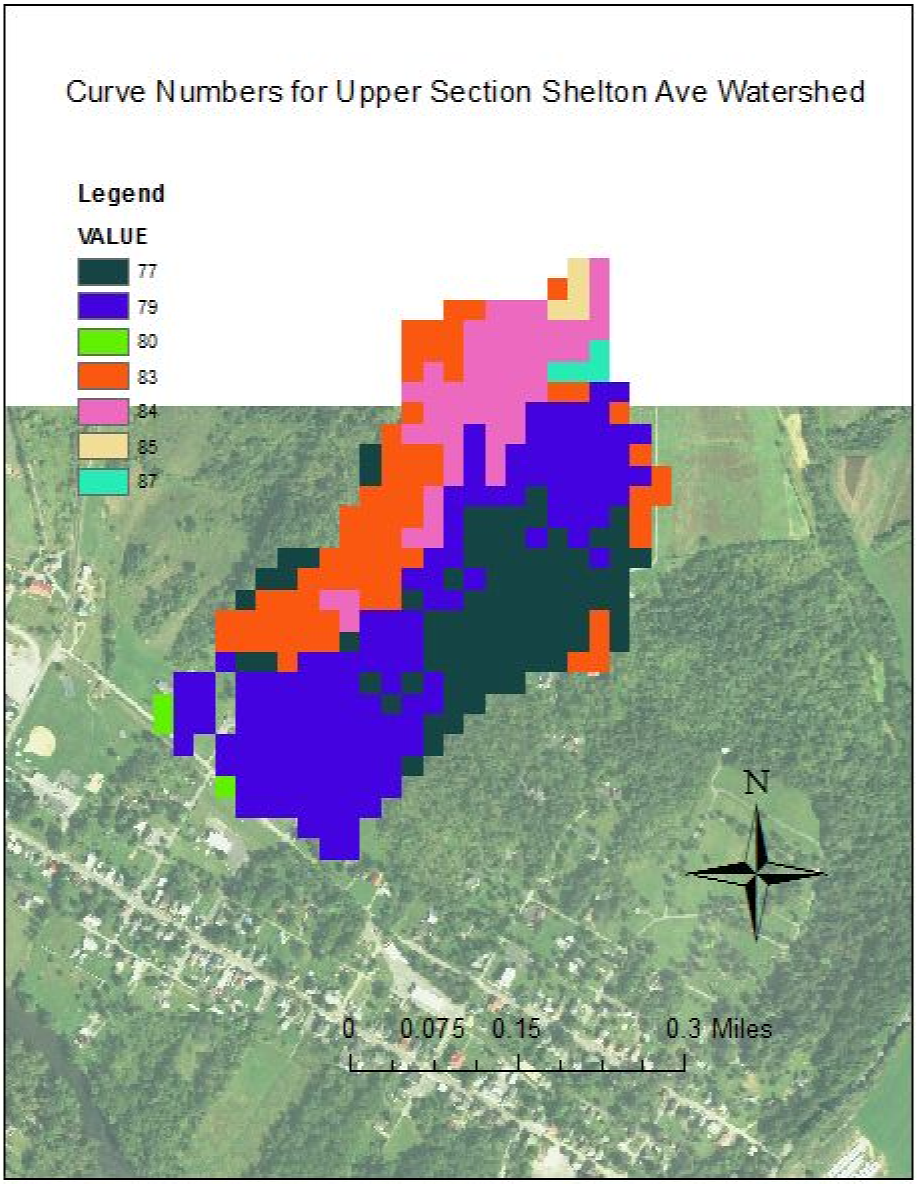

Figure 5: Map of the Curve Numbers for the Watershed at Shelton Ave

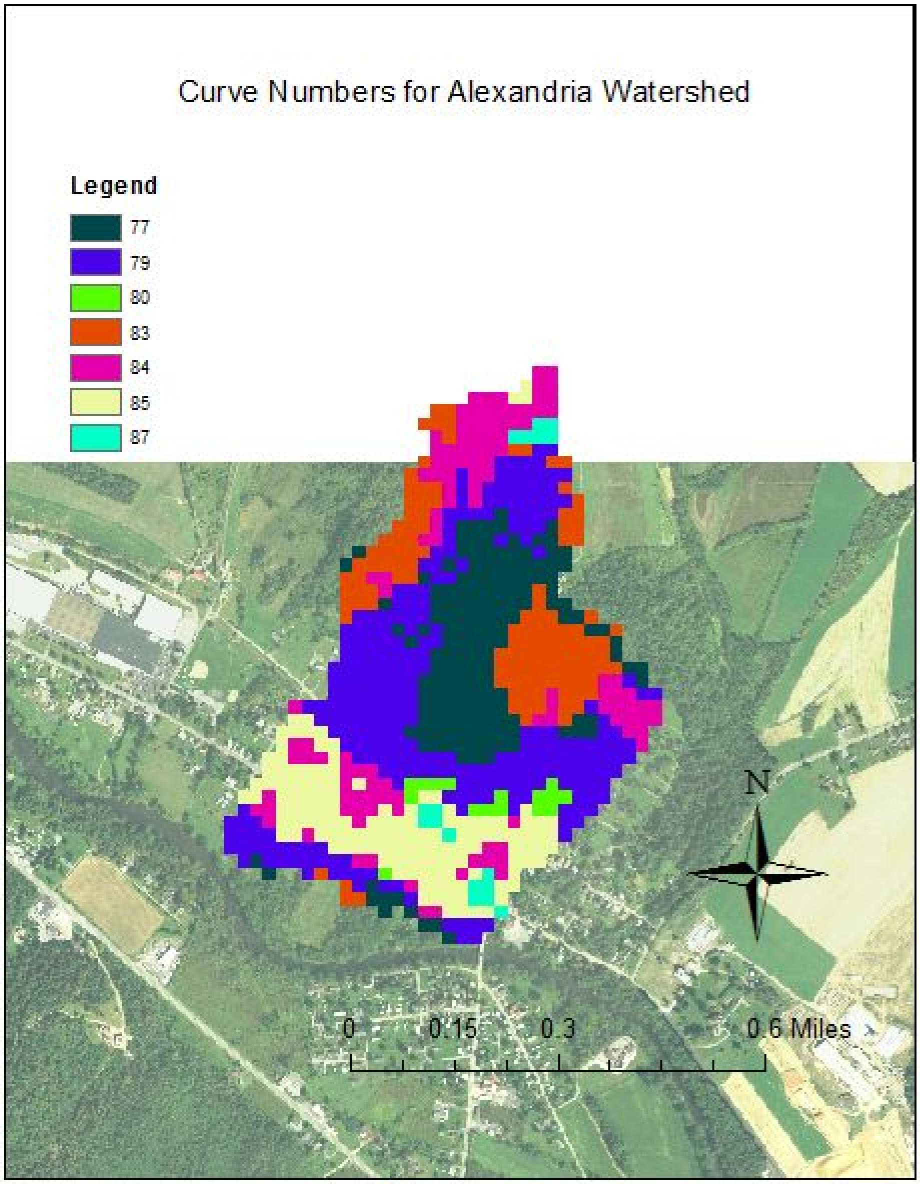

Figure 6: Map of the Curve Number for the Watershed at Route 305

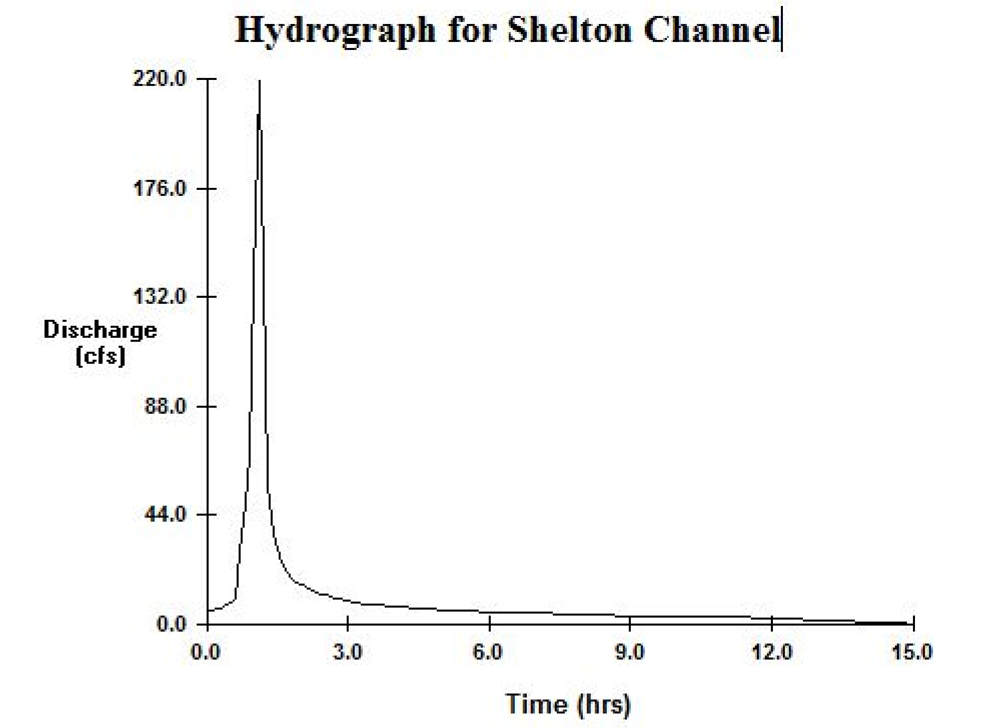

Figure 6a: Hydrograph for a 10yr 24hr Storm for the Channel next to Shelton Ave

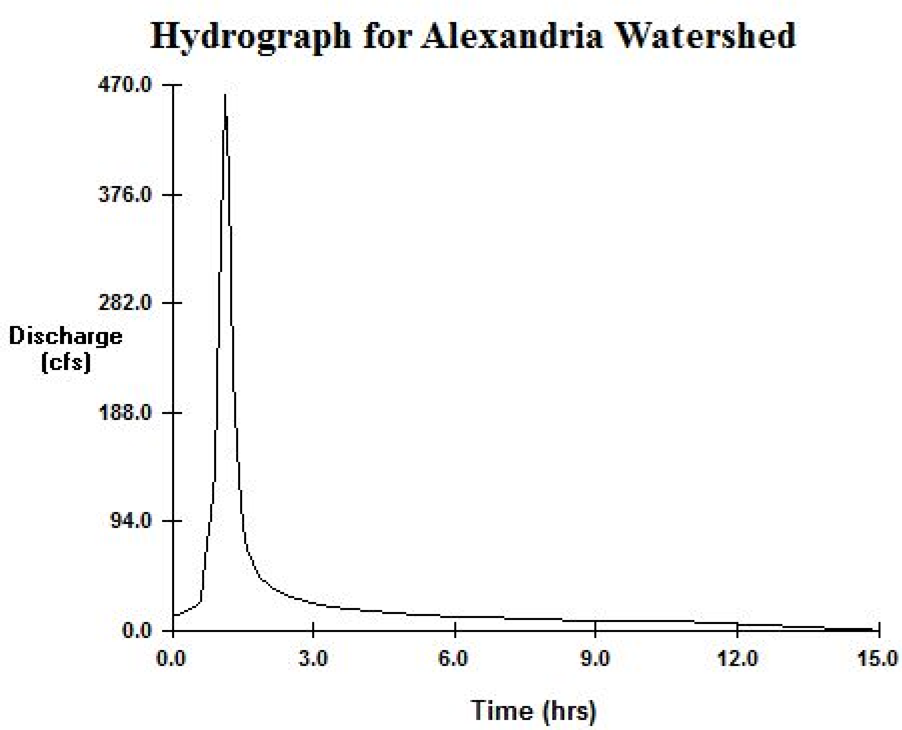

Figure 6b: Hydrograph for 10yr 24hr Storm for Alexandria Watershed

Table 4: Maximum Runoff for Different Watersheds and 24-hr Storms in Alexandria

Year Storm	Precipitation for 24 hr Storm (in)	Runoff for Watershed for Shelton Ave (cfs)	Runoff for Watershed for Route 305 (cfs)
1	2.21	77.26	164.99
2	2.65	112.01	238.14
5	3.3	168.79	357.25
10	3.83	218.56	461.37
25	4.6	294.78	620.50
50	5.25	360.92	755.85
100	5.94	385.45	902.27

5.2 Relating Specifications to Customer Needs

Table 5 relates customer needs to specifications that will need to be fulfilled with the design. Different specifications of the design will help fulfill multiple different needs of the sponsor. For example, making sure that the sediment is removed from the water will not only help control need number 2 (control sediment within the channel) but will also contribute to needs 5, 6, 8, 9, and 10. The needs of the sponsor will be accomplished by one, or many of the different design specifications that have been established.

Table 5: Relating Customer Needs to Specifications

		1	2	3	4	5	6	7	8
	Specification / Need	Preserve natural landscape	Flow rate to conveyance	Do not impact surrounding	Cost effective	Sediment removal	Do not infringe on resident properties	Grant money	Minimize maintenance
1	Stop flooding on roadway			x					
2	Control sediment within channel	x	x			x			
3	Minimize area impacted	x		x			x		
4	Aesthetically pleasing	x		x					
5	Safe		x			x			
6	Environmental Impact	x	x			x			
7	Low cost							x	x
8	Sustainable	x	x	x	x	x			x
9	Cultural impact	x		x		x	x		
10	Alignment with ethics/values	x		x		x	x		x
11	Easy maintenance				x				x
12	Innovative solution							x	
13	Sewer Constraints			x					
14	Slope Constraints					x			x

6.0 Concept Generation and Selection

6.1 Concept Generation

6.1.1 Concept 1: Channel with Check Dam

Within either the existing or redesigned channel, a series of check dams can potentially be installed. "A check dam is a small, sometimes temporary, dam constructed across a swale, drainage ditch, or waterway to counteract erosion by reducing water flow velocity" (IDEQ, 2005). The use of these structures will remove sediment from the water as it travels along the channel. These structures can be made from stone, wood, or concrete but due to the large amount of riprap which is already present within the channel it will be cost effective to recycle that material. The design of a check dam is dependent on the slope of the channel and flow rate within the channel, along with numerous other design considerations. A check dam should be implemented in a channel with a slope of 50% or less (IDEQ, 2005). Chapter 6 of the Pennsylvania Stormwater BMP manual will be referenced within the design process as well.

Figure 7: Example of a Check Dam

A foreseeable issue with this system is removal of the sediment from the check dams; further investigation into a simple maintenance system will be required. Large amounts of sediment have been swept into the stormwater system in recent years, especially directly upstream of the channel of interest. This sediment could quickly fill check dams above a level where they are functional, thus removing the primary purpose of the infrastructure. Constant maintenance and oversight will be required for the check dam system which could prove to be problematic.

A large issue with the use of the check dam system is the fact that these structures require a large amount of slope to be present within the channel. Within the channel along Shelton Ave there is less than 1% slope which is not nearly enough to sustain check dams. If required, a portion of the channel could be forced into a scenario where one section has a steep slope but at the expense of a later portion of the channel.

6.1.2 Concept 2: Channel with Sediment Trap

A sediment trap within the designed channel allows sediment to precipitate out of the flow while the water travels through the channel. By putting an impermeable boundary at the end of the channel such as a concrete outlet or a semi-permeable boundary such as a riprap dam, flow could be slowed. When water height within a channel rises, the velocity of that water must drop in order to maintain a constant volumetric flow. This decrease in velocity not only increases the residence time within the channel, which has potential to decrease the peak flow of the system, but water speed will also fall to a range where a portion of particle sizes will fall out of suspension.

Within the design of this system a balance must be maintained between size and portion of the sediment which is removed. As the size of a particle reduces, the required velocity to cause that piece of sediment to precipitate greatly drops. It will be nearly impossible to remove small particles such as silts and clays due to their physical properties. The majority of the removal by this system will be gravel and sands, but this represents a large portion of the sediment that enters the stormwater system.

A sediment trap requires a period of hydraulic retention time (HRT) within the structure for the particles to precipitate out of the solution which in turn dictates the land required for this structure. In the case of the 10 year-24 hour storm which produces 218 CFS, a sediment trap would have to have a required capacity of over 13,000 cubic feet in order to achieve a 60 second HRT. The example of 60 seconds within the structure is a gross underestimate of the actual time required to remove any substantial amount of sediment and longer retention times would cause the size of the sediment trap to increase greatly. This size requirement coupled with the land constraint on the site makes this concept nearly impossible to implement.

6.1.3 Concept 3: Constructed Wetland

A constructed wetland offers not only a system for reducing peak flows within the stormwater system but also a possible improvement to water quality. “Constructed wetlands are treatment systems that use natural processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality” (EPA, 2017). The main benefits of this system are the improvement of water quality and potential habitat creation for aquatic animals.

The basic concept behind a constructed wetland is diverting runoff into an area which floods, and within this area there exists a system that is adapted to saturated conditions. When the system fills with water the constructed wetland will remove nutrients through microbiological functions as well as releasing water from the system at a controlled rate. Vegetation such as that found within swamps and natural wetlands will be introduced which can sustain life within water, but considerations must also be made for the portion of the system’s life where it does not have a large quantity of water within it. For this project a constructed wetland could be installed within the open grassed area adjacent to the channel if it was made available by the owners. The wetland would be designed and built from materials brought to the site, so no existing soil conditions or information are necessary for wetland construction.

Although the constructed wetland offers a large amount of benefits such as water quality, it also poses a great deal of concerns. For example, the wetland could offer a location for disease carrying mosquitoes to breed. Furthermore, a large area, greater than the channel area, would be required to build a constructed wetland, so land would likely need to be acquired from owners of the surrounding pieces of property. For a watershed in similar size to the one that contributes to the the point of interest at Shelton Ave, a constructed wetland required nearly 14,500 square feet (Trinkaus, 2013). This surface area requirement is much greater than that of the existing channel and in order to obtain this space the property of the neighboring American Legion would be infringed upon.

6.2 Concept Selection and Analysis

Table 6 is a Concept Scoring Chart for the four possible designs that were considered. For some of the selection criteria, very similar scores were given to the three designs, such as "Stop Flooding on Roadway", "Control sediment within channel", "Environmental impact", "Cultural Impact", "Alignment with ethics/values", and "Innovative solution". All four designs seemed to accomplish those criteria very well.

Table 6: Concept Scoring Chart

		Channel with Sediment Trap		Channel with Check Dams		Constructed Wetland		Grass Lined Channed	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Stop Flooding on Roadway	5	5	25	5	25	5	25	5	25
Control sediment within channel	4	5	20	4	16	5	20	3	12
Minimize area impacted	2	5	10	5	10	1	2	5	10
Aesthetically pleasing	2	3	6	4	8	5	10	5	10
Safe	5	2	10	4	20	2	10	4	20
Environmental impact	4	4	16	4	16	5	20	4	16
Low Cost	5	5	25	5	25	1	5	5	25
Sustainable	4	3	12	3	12	5	20	5	20
Cultural Impact	1	5	5	5	5	5	5	5	5
Alignment with ethics/Values	3	5	15	5	15	5	15	5	15
Easy Maintenance	4	3	12	3	12	5	20	5	20
Innovative solution	3	5	15	5	15	5	15	3	9
Sewer Constraints	5	0	0	5	25	0	0	5	25
Slope Constraints	5	5	25	0	0	5	25	5	25
	Total Score	196		204		192		237	
	Rank	2		4		3		1	
	Continue	Alternative		No		No		Yes	

However, there was a large difference with some criteria, such as minimize area impacted. The sediment trap design as well as the channel with the check dams would both require only the existing channel area. However, the constructed wetland would need a far larger area, as the minimum recommended area is 10 acres. Therefore, the cost of the wetland would also be high, due to the large area impacted, as well as additional costs associated with wetlands compared to sediment traps or check dams. One selection criteria that was deemed very important is the "feasibility", as indicated by sewer and slope constraints. A low feasibility score suggests that it is unlikely that the project would be able to continue. The constructed wetland had a rating of only 0, due to a sewer pipe where the constructed wetland would have to be placed. Additionally, if the wetland were to be implemented, its location would have to infringe on private property, which may not be possible. Due to this, even though the constructed wetland scored higher than the channel with sediment trap design, the sediment trap design is the alternative concept, and the grass lined channel with a strong lining is the leading concept. A grass lined channel will be effective at improving water quality and presenting a natural look while effectively conveying the design storm.

7.0 Safety Analysis

Table 7 below provides the potential safety hazards for the channel once installation is complete. Each design consideration (sediment trap, check dams, constructed wetlands) has varying degrees of risk associated with each hazard. Table 7 shows the specific hazard, factors contributing to the hazard, and the potential effect or injury that could occur. Each hazard has a total rating showing how damaging the hazard is. This total is derived from values assigned to the categories of exposure, likelihood, and consequences. These values are multiplied to find the total rating. Exposure is how often the population will be subjected to the hazard, likelihood is how likely the hazard is going to have an effect, and consequences is how severe the outcome of the hazard is.

Table 7: Hazard analysis for each concept

			Sediment Trap				Check Dams				Constructed Wetland			
Hazard	Factorts contributing to hazard	Effect/Injury Potential	Exposure	Likelihood	Consequences	Total	Exposure	Likelihood	Consequences	Total	Exposure	Likelihood	Consequences	Total
Flooding	Improperly constructed channel can lead to flooding of lands and buildings below the channel	Weakening of foundations, destruction of property,	3	3	1	9	3	3	1	9	3	3	1	9
Erosion	Linings and other modifications to channel can increase or decrease erosion of sediment from channel	Channel erosion leads to undesired water flow into areas of concern, and negative enviornemntal effects	4	2	2	16	2	2	2	8	3	1	2	6
Improper Maintenance	Workers lack the knowledgs of safety procedures/ regulations while performing maintenance	Potential non-fatal injury during maintenance while using heavy machinery needed to maintain channel,	2	3	4	24	2	3	4	24	2	3	4	24
Amassing of Insects	Ponded water can lead to ideal breeding grounds for certain insects, which could potentially carry disease	General annoyance of neighboring properties, with potentially dangerous diseases being transmitted	1	2	1	2	1	1	1	1	3	3	1	9
Drowning	Sediment traps have a non-negligible depth	Death of person if fallen into	3	2	5	30	1	1	5	5	2	1	5	10
Sewer Pipe	A sewer pipe is located directly next to the existing channel	Damage to the pipe, which can contaminate the water	0	1	1	0	0	1	1	0	1	5	5	25
						81				47				83

According to the hazard analysis in Table 6, the check dam design is the most safe, with a total score of 47, while the sediment trap and the constructed wetland were far more hazardous with scores of 81 and 83 respectively. The main areas which made the check dam more safe are the hazard of the sewer pipe, which only affected the constructed wetland, and the hazard of drowning, which greatly affected the sediment trap. Another design which is considered is a simple grass lined channel with a reinforced lining. This grass channel would offer nearly identical safety concerns as the channel with check dams and would actually reduce the maintenance requirement, thus making it safer than even the check dam option.

8.0 Special Topics

8.1 Project Management & Ethics Statement

Our group offers a diverse array of skills that when combined results in a more than qualified group of students. All students within the group have experience with ArcGIS which will serve as our main analysis tool for flow quantifications. All team members have knowledge of channel design and best management practices (BMP's) due to coursework on these subjects. Nicole has extensive experience with soils as it relates to their impact on water flow and infiltration qualities. Alex is currently enrolled in a GIS class which means that the information will be extremely fresh in his mind giving us a distinct advantage in this modeling software. Matt and Nate have had internship experience within engineering consulting firms which grants a deeper understanding of the design process and the logistics behind it. The group's resumes can be found in appendix A, which further detail the skill set of each of the members.

The skills of the group also include the strong personal skills and the ethical compass of each of the members. From the beginning of this project the main goal has been to not only help this community but also to only make decisions that uphold the standards that we set. The main team values that we are holding each other to are as follows: to remain in constant communication with each other and our sponsor, make all decisions as a group, disturb as little land as possible to make the biggest impact on the community, design all aspects of the project according to engineering standards such as the BMP manual, and to produce a design that will improve the lives of people within the Alexandria community. All of our goals and standards relate back to our main purpose which is to make a real impact on the community members of Alexandria; any reduction in the impact of the flooding within the borough will improve the lives of the residents.

In order to make the important decisions behind our desire to make an impact, there will be group deliberation and ethical dilemmas to face. Our approach to these obstacles is to quantify the positives and negatives of each aspect of a decision which allows the best and unbiased result to be reached. The most successful approach to produce the best result for the project will be to combine our skills to make group decisions which follow the set ethical standards that were established at the beginning of the project.

8.2 Project Risk Plan

There are various risks that need to be considered when planning for the design and implementation of the channel. These are shown below in Table 9. Each risk is rated with a severity level that shows how detrimental that risk is to the project. Stated are actions to minimize those risks so as to avoid any unnecessary and unwanted complications. If these risks can not be avoided, fall back strategies are provided for each action.

Table 9. Risk plan

Risk	Level	Actions to Minimize	Fall Back Strategy
Weather delays	Low	Complete surveying and site analysis before winter falls/assess weather prior to site visits	Complete surveying and site analysis in unfavorable weather, creating low team morale and potential hazards
Unnecessary/over-expenditures	Medium	Complete thorough analysis of specifications needed and minimize unnecessary features based on these specifications	Cut features that are decided to be unnecessary to bring cost to determined budget
Incorrectly designed channel	Low	Perform and check calculations for flow based on various channel characteristics, such as lining type and shape	Minimize complexity to ensure functionality
Customer Not Satisfied	Medium	Be in constant communication with the sponsor and continually listen to any input they have	Redesign and rectify problems based on customer feedback

8.3 Communication and Coordination with Sponsor

Interactions consist of numerous electronic communication such as e-mail and text, as well as several site visits where sponsor was present. Communication and project updates recurred weekly, via electronic communication every Monday. The first site visit occurred on 9/14/2018, where a project overview was given by the sponsor and the main problematic areas were shown. A second site visit took place on 11/11/2018, where the channel in question was surveyed and measured.

8.3.1 Borough of Alexandria Council Meeting

On Monday March 11th SWM Engineering attended a council meeting in Alexandria. During that time, SWM Engineering presented the preliminary ideas for the channel, and received feedback. The main piece of feedback was that the town did not want a rip-rap lined channel. The other aspects of the design and the assessment of the problem were well received.

8.4 Timeline

Our team still is in the process of determining the exact concept for the design, but we have determined a general idea of a channel redesign alongside Shelton Avenue. Once a specific concept is determined, the next step will be to create a channel design as a deliverable to our sponsor. This design will be based on both sponsor feedback and ideas as well as consultation with professors. By the end of the project, the team must utilize GIS mapping software and the VTPSUHM software to quantify water flow values at multiple points of interest within Alexandria Borough. With these values we will be able to specify channel dimensions, and the team will then create a detailed design model using both AutoCAD and SWMM. When a draft of the design is complete, a cost analysis will be performed to provide the sponsor with an idea of expenses. All designs and the project report will be continuously updated throughout the course of the project to ensure that the best possible deliverables are created. Figure 8 shows a Gantt Chart with our group's anticipated project timeline.

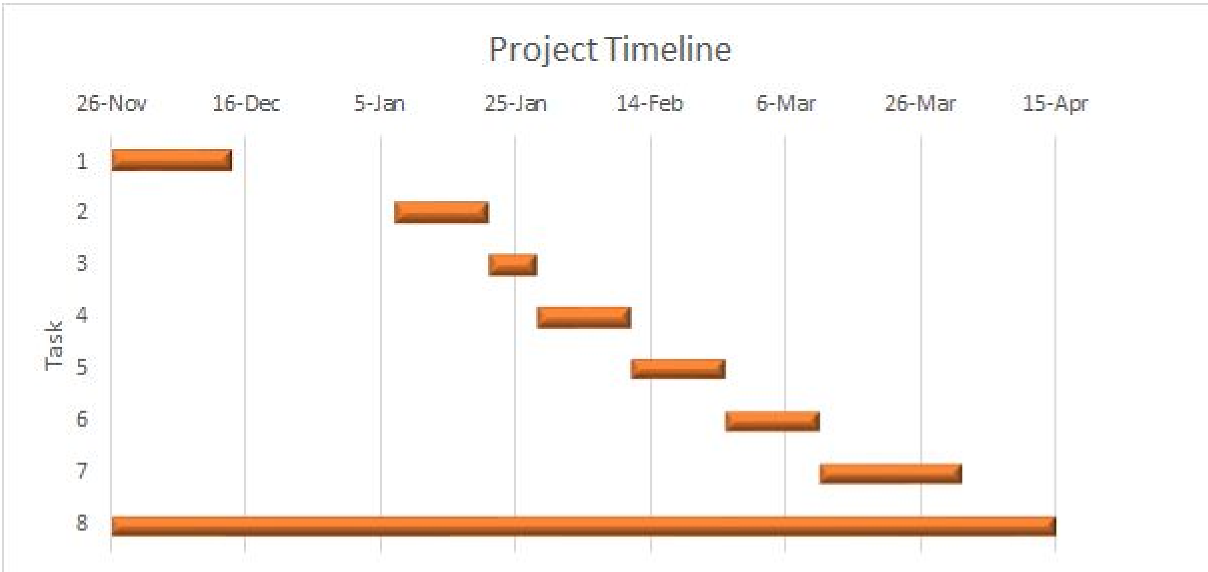

Figure 8. Project Timeline Gantt Chart

Below is a table with the timeline descriptions associated with the task numbers in Figure 8.

Table 10: Timeline Description

Task Number	**Task Description**
1	Model Hydrologic Data using GIS and VTPSUHM
2	Establish Design Concept
3	Establish Channel Dimensions
4	Create Channel Design in AutoCAD
5	Model Design using SWMM
6	Perform Cost Analysis
7	Revise Designs
8	Update Report

9.0 Detailed Design

9.1 Detailed Analysis- calculations for channel design

The initial channel design was conducted using a variety of equations in Microsoft Excel. Some of the key equations in this design process can be found in Appendix C. This design process followed the process outlined in Chapter 6 of the Pennsylvania Department of Environmental Protection Erosion and Sediment Pollution Control Program Manual. A table providing specific details of the proposed channel design can be found in Appendix C. Additionally, drawings for the channel cross-sections can be found in Appendix C.

Using data from ArcGIS it was determined that the channel must able to carry 218.56 cubic feet per second along the channel with a slope of under 1%. A shallow slope makes it extremely difficult to meet this requirement because gravity acts as the driving force for water in the channel, and without a significant slope this force is greatly reduced. The designed channel was intended to fit within the existing channel's footprint, but to meet the required flow capacity the total channel width was calculated to be approximately 23 feet.

Three possible designs have been proposed in order to meet these requirements which will be available for the brough to choose from. The first design will be a riprap lined channel that conveys the complete 220 cfs of peak flow. In order to meet the flow requirement and not induce a level of shear stress which causes channel erosion the only option is to have a riprap lining. An alternative approach in which the channel lining is grass was developed but this requires a reduction of flow to the site. These reductions will need to be achieved through upstream structures such as multiple BMP's or another channel which diverts flow to another area of the town. After designing the channel iteratively in Excel, in which different variables affecting channel design and capacity were altered for accuracy, a maximized flow rate of approximately 73 cfs was achieved. The third possibility is a channel that uses a reinforcing lining that allows for vegetation to be used within the channel without worrying about shear stress caused by flow to limit the channel's possible capacity. Shear stress is caused as water flows within a channel. As water flows, shear stress causes both vegetation and underlying soil to be ripped up. Maximum permissible shear stress is a function of type of grass used within a channel (for a grass-lined channel) and size of rocks for a riprap-lined channel. Using the Propex Pyramat 25 channel liner, described below, shear stress became a non-factor in channel design and allowed for a maximum flow rate of nearly 130 cfs. Detailed designs are available in Appendix C along with cross sectional drawings of each of the channel options.

9.2 Material/Component Selection Process and Design Optimization

Modeling and design optimization within this project have taken multiple forms and are spread over several software packages in order to encompass the scale. The two most prominent software programs to be used during the design phase are to be Microsoft Excel and SWMM. The existing channel is to be modeled within SWMM, which offers another perspective on the hydrology of the area surrounding the channel. The goal of this modeling process is to demonstrate how the existing channel is not ideal to carry the required flow-rate and how the shear stress will cause channel erosion.

The original thought process for the channel design was to utilize a vegetated channel lining. However, this lining proved to be insufficient to handle the shear stress produced by the flow of water through the channel. To overcome this obstacle, R4 riprap was substituted as the channel lining, as it met the shear stress criteria. Upon discussion with the sponsor, it was determined that riprap was not ideal for use as the channel lining because it did not maintain a natural appearance. As mentioned above, the Propex Pyramat 25 channel liner was used in the third possible design. This channel liner allows for a maximum permissible shear stress of up to 12 square feet per second. Excel's solver function was used in optimizing the channel to carry as much water as possible while still remaining within the limits of certain constraints. The major constraints provided were a shear stress less than the Pyramat 25 maximum, a total channel top width less than 20 feet, a total channel depth less than 4 feet, and a bottom width of the channel less than 8 feet. With these constraints in place, solver was run with the objective of optimizing the channel's maximum flow rate.

Another consideration of the design was the general shape and certain dimensions used for the channel design. A trapezoidal channel cross section was used because the background equations (some of which are shown in Appendix C) allow for easy, linear manipulation during the optimization process. From this selection of a trapezoidal cross section, a side slope of 2:1 was selected because it is a commonly used side slope that allows for significant flow of water while posing a relatively small safety risk. Finally, the overall channel slope of approximately 1% was used in the design. This number was obtained by subtracting the existing heights at either end of the channel and dividing that number by the total length of the channel.

A more detailed analysis of the proposed channel design's effectiveness will be available once the SWMM models are completed. This analysis will determine benefits to each design approach and provide insight into how much flow will need to be reduced in order to have a grass lined channel.

9.3 Sustainability in Design

There were many potential sustainability issues associated with the flooding on Shelton Ave and in designing the channel. SWM Engineering has tried to address all of these sustainability issues in both designs that are being conducted. The design with a redesigned culvert and riprap siding will be referred to as design A, the grass lined channel as design B, and the reinforced channel as design C. In design A, the channel was designed to convey all of their stormwater that will reach the channel. Consequently, the channel was designed to be deeper than expected, being 3.75 feet deep. In design B, the channel will not be able to handle the peak flow, so additional stormwater

BMPs would be implemented to manage any extra flow. Design C will be able to handle more flow than design B, but BMPs will still need to be put in place to account for the extra flow. Therefore, the channel will mitigate the stormwater effectively according to our analysis and the design will directly benefit the residents of Alexandria by decreasing the overland flow, and decreasing the amount of water that would otherwise end up in the residents' homes.

The design of a riprap lined channel is a very simple design. However, the culvert would need to be replaced with a larger one, which would make this design more expensive. The cost can be found in the Economic Analysis Section. A grant should be obtained to cover this if approved, as Alexandria has a relatively small budget. The design of the grass lined channel would keep the culvert as the same size, but additional BMPs would be implemented upstream to mitigate flow. The reinforced channel would have the culverts resized.

There were two additional sustainability issues that were initially considered, one being the potential negative effect of the implementation of the channel, and the other of potentially changing the flow downstream of the channel in the park. The potential negative effect of building the channel cannot be avoided. However, BMPs can be utilized to minimize any negative impacts, such as increased flow. This can be accomplished with infiltration basins upstream to reduce peak flow, which would reduce peak flow at the outlet of the channel. Infiltration basin design is very dependent on site-specific characteristics and requires on-site testing; however, an example of infiltration basin calculations can be found in Appendix D. Additionally, since this is a small area, it would take a relatively small amount of time to construct the channel. Therefore, the harm to the environment from construction from exhaust, pollutants, and soil compaction is negligible. Regarding increased flow into the park stream, design A should not drastically alter this. As the channel is now, much of the water already flows into the stream into the park. Therefore, this will continue to happen, just in a more controlled manner. Design B has more than half the flow diverted elsewhere, which will minimize flow into the park stream. Design C has some flow being diverted to the basin, with the majority going to the channel.

9.4 Drawings

The initial channel design, seen below, utilized only a vegetated bottom and side slope. This design failed because the vegetation could not hold the required shear stress generated by the water flow that would have been required for a 10-year, 24-hour storm.

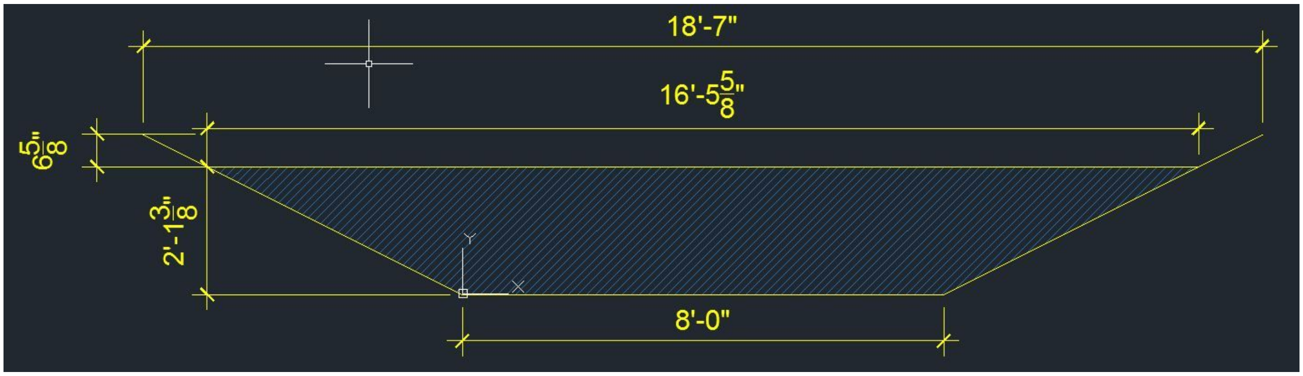

Figure 8. Original Grass Channel Design

The initial channel design that utilized a riprap-lined channel can be seen below. This channel design was not selected because Alexandria Borough emphasized the design of a natural-looking channel not lined with rocks.

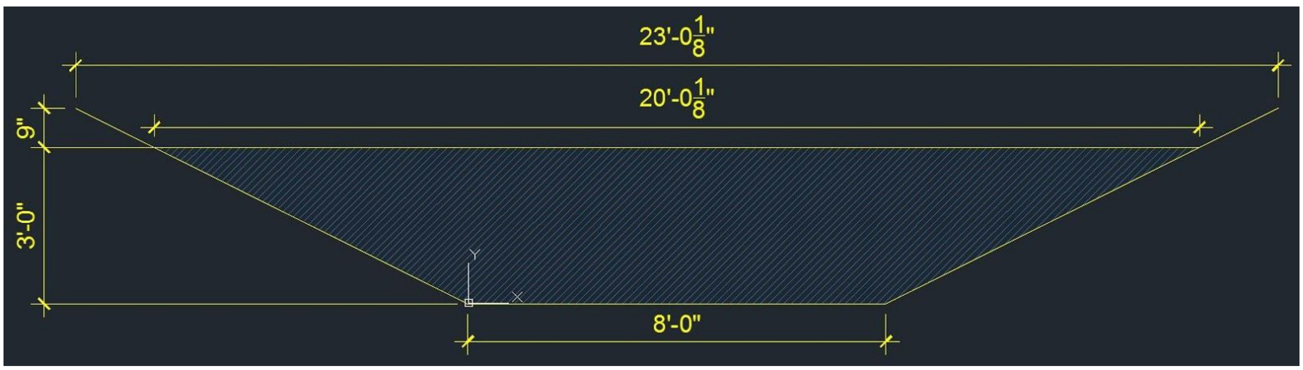

Figure 9. Original Riprap Channel Design

Below is the channel design that utilizes the Propex Pyramat 25 reinforcement material. This channel cross-section is the one selected for this proposal and is able to convey approximately 128 cfs while keeping a grass-lined and natural appearance.

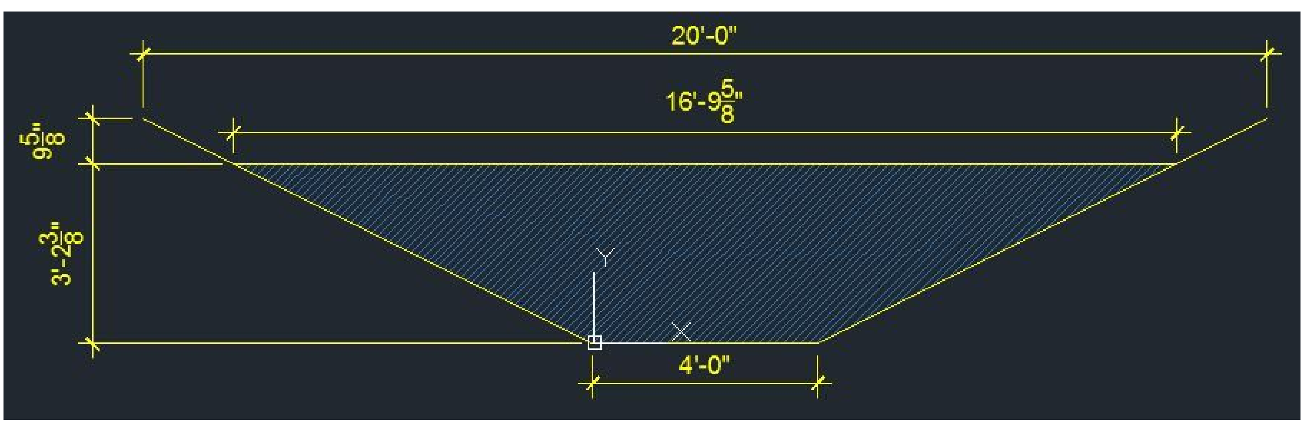

Figure 10. Reinforced Channel Design

9.5 Test Procedure

In order to test the final design and any iterations along the way there will be multiple processes in place which will provide testing data. The majority of analysis will be done within the Storm Water Management Model (SWMM) which will give results in the form of pipe and channel profiles that show the water level at various points during the design storm. During peak flow these profiles will demonstrate if the conveyance system is properly designed to handle flow from the design storm. Testing in SWMM will focus on the culverts within and leading to the channel, along with the capacity of the redesigned channel itself.

The second testing method will be using the hand calculations for the channel design, or in this case these calculations will be done in Excel. Each design for the channel will originate in Excel where it is designed for a maximum capacity using Manning's Equation. During this process a calculation for the shear stress exerted on the lining material is performed which ensures that the erosion potential is not too great for the lining material. Various designs will be tested using this method by varying parameters such as lining material, bottom width, side-slope, top-width, and Manning's roughness. Once a design is determined to be feasible it will be imported to the SWMM file where it will be tested for the design storm (10-Year 24 hour storm) to see if, when paired with redesigned culvert size, it will convey all water without backups or overtopping the banks.

10.0 Final Discussion

10.1 Implementation Process

Provide enough implementation or construction detail such that a person could reproduce the design from your description and pictures (for projects that involve fabrication). Pictures during the construction process are very informative. A few pictures can be inserted here but most should be in the Appendix. Again, if any improvements were made or if any drawings changed from the earlier detailed design report then replace old drawings with new drawings.

If your project involves a conceptual system design, you might use this section of the report to describe how the system would be implemented in practice. For example, the design may be implemented in phases. If you are proposing to incorporate an open channel into a landscape, this would be implemented through a cut/fill process.

In the implementation of the open channel design, the construction of the project is approximated to occur in 12-13 weeks. A general timeline is as follows:

Weeks 1-5: The Engineering firm designs the new channel, infiltration basin areas will be determined

Weeks 5-7: Required Equipment will be ordered and will be sent to the area. Preparation for construction in both the channel area and basin area

Weeks 7-10: The channel and basin will be excavated

Weeks 10-12: Geotextiles will be laid down, and new channel vegetation will be planted.

Weeks 12-13: Extra Equipment will be removed.

During the construction of the project, much of the soil that will be taken out from the current channel will need to be disposed of.

10.2 Test Results and Discussion

Design testing was performed on two subsets of channel designs, one being the existing conditions and the others being multiple redesigned channels. The testing results are output in the form of profiles of the channel and culverts which make up the system. All figures represent the peak flow within the system which will be the condition under which the system will fail if any portion is undersized.

Existing Conditions:

The testing results for the existing conditions is shown in Figure 9 with the upstream culvert having a diameter of three feet and the culvert in the middle of the channel with a diameter of four feet. Using the existing channel structure there is a fairly large deal of failure as evident in the figure below. Flooding is depicted on the thin bars on both sides of the culverts, the most extreme example of the failure is at the most upstream portion shown in the figure. At this point of failure the water is impeded before it even enters the channel because the culvert is undersized. This failure is evident during large rain events where that culvert backs up which potentially causes water to overtop the roadway, because of this the size of the pipe must be increased.

A second failure occurs above the second culvert which, again, is because the small diameter of the pipe impeeds flow. This failure causes the water to pond within the channel and overtop the banks at the bottom of the channel. Overflow issues within the channel and at the downstream culvert will be amplified if water which is impeded by the upstream culvert overtops the road or extreme head forces water through that pipe at a faster rate. Within the model depicted in Figure 9 water which is impounded upstream of the top culvert is not sent to the channel, meaning that the peak flow is only seen at that one point. As has been seen on the site the water can overtop the roadway to enter the channel. Therefore the channel may actually see the peak flow under this condition. If the peak flow is exerted on the currently designed channel the flooding within the channel will only be magnified.

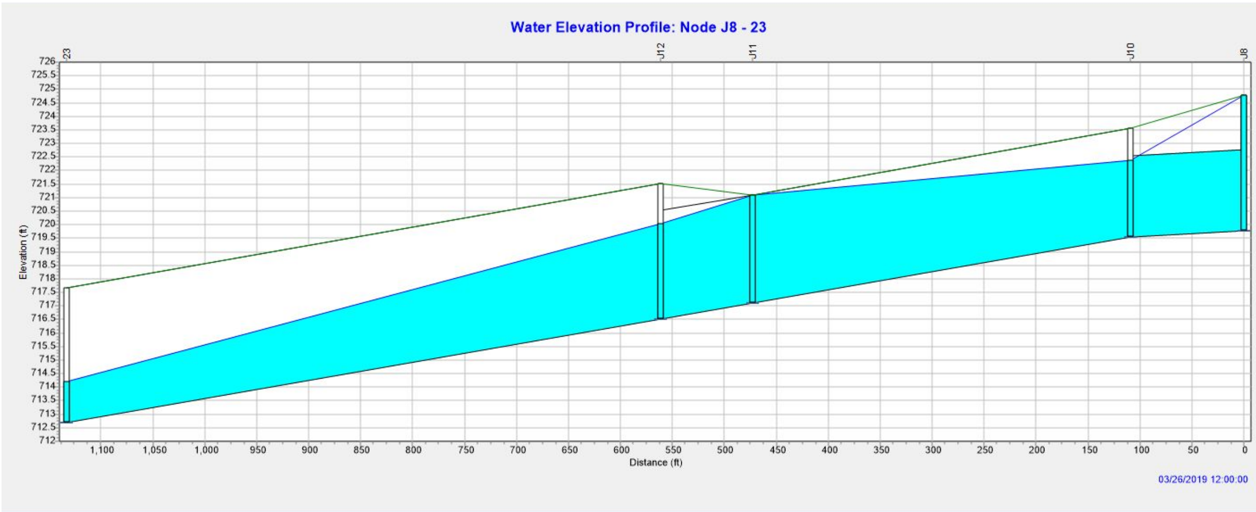

Figure 9: Existing Conditions Flooding

Redesigned Channel:

Due to the evident flooding in the testing of the existing conditions multiple changes must be implemented. Using the design process in excel it was determined, using Manning's Equation, that the channel can convey at an absolute maximum 130 cfs. This then became the design criteria for use in the SWMM software where the optimized channel design was imported into the program. Results from the finalized design are shown in Figure 10 where the new channel is demonstrated along with increased culvert diameter. The testing procedure on this design was a process of testing and then making revisions to optimize the entire system. Although the channel itself could not be elevated to a state where more water can pass through, the culverts could be changed such that they do not impede flow. The final sizing for these culverts is five feet and as is evident in Figure 10 these pipes have no flooding. Within Figure 10 the flow is at the reduced maximum of 130 cfs, which will be achieved using upstream BMP's, and under this condition the channel operates exactly as intended.

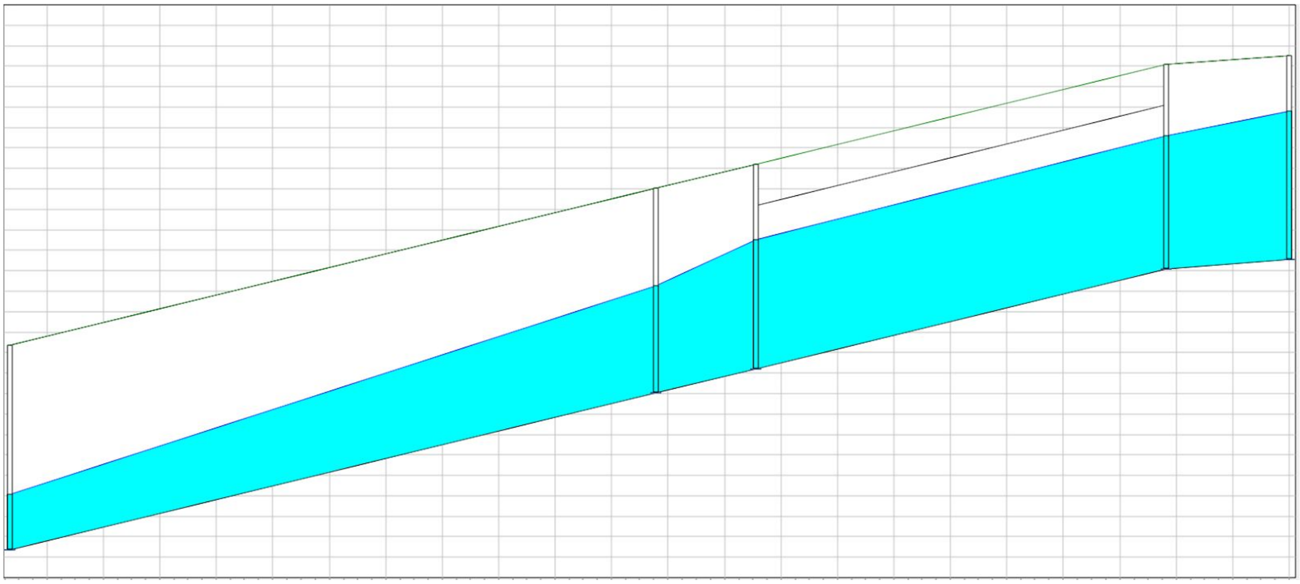

Figure 10: Redesigned Channel Testing

11.0 Economic analysis

Exact specifications and quantities of each item within Table 11 are estimated using the Site Work & Landscape Cost Data RSMeans Catalog found within Penn State's Engineering Library. These costs area averages only and are only meant to represent the average of a range of values presented in the catalog. Furthermore, these estimations are not from a contractor who bid on the project, meaning that large changes could be introduced during the bid process. Cost for the Propex Pyramat 25 lining price was provided by the Propex company.

Table 11: Cost Estimations for Channel

Process	**Unit Cost**	**Units**	**Quantity**	**Total**
Excavation and Hauling	$29	per cubic yard	111 cubic yards	$3219
Rough Site Grading	n/a	n/a	n/a	$1,325
60" Concrete Culvert Pipe	$16.95	per Linear foot	80 feet	$1,356
Lining Material	$6-7	per square yard	2,493 square yards	$14,956-$17,450
Road Paving	$15.50	per square yard	7 square yards	$108.50*
Road Excavation	$15.65	per square yard	7 square yards	$109.55

*Does not include cost of materials/equipment as this changes based on location

The excavation quantity was computed using the difference in cross sectional areas of the existing channel and the designed channel, and then multiplied with the length of the channel section. Each section was drawn in AutoCAD to find the exact area.

Table 12: Channel Excavation Calculations

Section (ft)	**Length of Section (ft)**	**Existing Cross Sectional Area (ft^2)**	**New Cross Sectional Area (ft^2)**	**ΔArea**	**Volume for Excavation (ft^3)**
0 - 45	45	29.68	48	18.32	824.4
45 - 90	45	34.24	48	13.76	619.2
90 - 135	45	34.96	48	13.04	586.8
135 - 180	45	39.02	48	8.98	404.1
180 - 220	40	41.4	48	6.6	264
220 - 260	40	42.34	48	5.66	226.4
260 - 300	40	46.9	48	1.1	44
300 - 340	40	50.54	48	0	0
340 - 380	40	52.3	48	0	0
380 - 400	20	58.56	48	0	0
Total:					2,968.9

12.0 Conclusions and Recommendations

Through an analysis and modeling of the current area surrounding Shelton Ave., the current stormwater system in place can not handle the storm water that is flowing to the channel. Due to this issue, the residents are forced to deal with flooding throughout the town. Therefore, in order to remedy this problem, SWM Engineering is recommending that the channel be redesigned, and the culverts enlarged to be able to handle the required amount of stormwater. Previously, the channel was unable to convey the stormwater from a 10-yr, 24-hr storm. The new channel will be able to handle 128 cubic feet per second, leaving approximately an extra 92 cfs that would need to be attenuated upstream. SWM recommends that BMPs, such as infiltration basins, be implemented upstream to reduce the flow to the required 128 cfs. The addition of these BMPs not only will help with flow reduction, but also in removing excess sediment and nutrients. Removing excess water contaminants proves helpful not only for the environment, but is advantageous for receiving grants for funding, such as the Growing Greener grant.

Before any construction begins on the channel project, a detailed survey using precise equipment, such as Total-Station, must be completed. This survey must set control points which will not be disturbed during construction such that progress can be monitored and the final product can be consistent with the design. As well, a survey using this equipment will give a better idea of the exact dimensions of the existing channel and the amount of material which will need to be removed. Additional surveys must be conducted anywhere which the BMPs are going to be installed upon to accomplish the same effect as the survey on the Shelton Ave channel.

In order to correctly implement these BMP's a detailed study of the watershed that leads to Shelton Ave. must be conducted to determine the best location of these structures. The most practical Best Management Practice (BMP) to reduce the flow to the target value is the implementation of infiltration basins and/or trenches upstream of the channel, within the channel's watershed. An infiltration basin is a shallow impoundment that stores and infiltrates runoff over a level, uncompacted area with relatively permeable soils. Infiltration basins result in high volume reduction and peak flow rate downstream, as well as having water quality benefits. Site selection for this particular BMP should take into consideration the soil infiltration capacity of the desired area, with a larger capacity being more beneficial. In order to determine the soil properties, an in depth site soil survey needs to be conducted by professionals, as the properties will vary widely even within a few hundred feet. These properties will determine the sizing of the basin, and consequently how much flow the basin will reduce at the entrance of the channel. The slope of area should be less than 1%, in order to ensure even distribution and infiltration of the water. Infiltration basins can be planted with natural grasses, meadow mix, or other "woody" mixes, such as trees or shrubs. These plants have longer roots than traditional grass which increases soil permeability. However, native plants should be used wherever possible, which decreases the cost and time of implementation. The cost will vary greatly, depending on several factors, including configuration (one large basin or several small basins), location, and site-specific conditions (native plants, large trees). Excavation is another price factor, but can be avoided by constructing berms (raised banks) on all sides of the desired area, creating the basin without excavation. One large basin will have the same effect downstream as several smaller basins dispersed throughout the watershed, which is helpful if size is a constraint due to land characteristics, property ownership, etc. The basins should be inspected and cleaned at least two times per year and after runoff events in order to clear debris which would affect the runoff and infiltration rate. The entirety of the runoff should drain down within 72 hours. Mosquitoes should not present a problem if the water drains in 72 hours.

It is recommended that the Borough of Alexandria analyze the stream that is located further down in the park, into which the channel is flowing. From observations, it appears that this stream is also undersized for the flow which reaches the channel during nearly any storm event. A study using a program such as HEC-RAS to model flooding behavior within the stream for given flow rates would identify points where flooding is induced by a problematic stream design. Through this process, a new floodplain could be designed and implemented which, in conjunction with the redesigned Shelton Ave. channel, could improve the borough's response to storm events.

The belief of SWM Engineering is that with the implementation of the redesigned channel along Shelton Ave., as detailed in this report, the Borough of Alexandria will see immediate benefits to their stormwater system. In order to correct all current stormwater related issues the borough currently experiences, an array of projects must be completed along with the new channel system on Shelton Ave. The initial steps for these additional projects can be found within this report. The GIS maps found in this report show other problematic areas within the borough. This data will not only provide a starting point for locations of projects, but start additional information for receiving grant funds.

In summary, this report represents a start to a chain of future projects which will steer the Borough of Alexandria towards a more efficient stormwater system. Through the implementation of the redesigned channel along Shelton Ave., the first step will be taken towards the community's goal of reducing flooding while improving the quality of the water which is discharged to the Frankstown Branch of the Juniata river. SWM Engineering believes that if the steps detailed within this report are are implemented, there will be a significant improvement to the stormwater system of the town.

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Appendices

Appendix A, Resumes:

Nicole Rella

973-303-2953

nbr5075@psu.edu

Permanent Address
12 Cambray Road
Montville NJ 07045

School Address
340 East Beaver Ave, Apt 401
State College, PA 16801

EDUCATION: The Pennsylvania State University

B.S. in Natural Resources Engineering *Anticipated May 2019*

B.S. in Environmental Resource Management, Environmental Science option

Minors in Watershed and Water Resources, and Environmental Engineering

SKILLS:

Microsoft Office Suite, Surveying, ArcGIS, VTPSUHM, AutoCAD, soil collection, teamwork and communication skills

RELEVANT COURSES:

Design of Stormwater and Erosion Control Facilities, Measurement and Monitoring of Hydrologic Systems, Legal Aspects of Resource Management, Fluid Mechanics, Principles of Soil and Water Engineering, Stream Restoration

ACTIVITIES:

Penn State Soil Judging Team

- **Placed 5th in individuals in the 2017 Northeast Regional Collegiate Soils Contest**
- **Qualified for Nationals in the 2018 Northeast Regional Collegiate Soils Contest**

President/AG Representative for the ERM Society-University Park, PA *December 2015-Present*

- **Plan meetings and organize activities for the ERM Society**
- **Represent the ERM Society with the College of Agriculture Student Council to network with other clubs and keep up to date with the college**

Vice President of the American Society of Agricultural and Biological Engineers *December 2018-Present*

Penn State Dance Marathon Committee Member- University Park, PA *September 2015-February 2018*

WORK EXPERIENCE:

Penn State University – University Park, PA

Lab Assistant in Soils Lab *May 2017-December 2017*

- **Became skilled in the collection, analysis, and organization of soil samples, using Aardvark, pH testing, and use of mechanical vacuum extractor**

Lab Assistant in Environmental Engineering Lab *May 2018-August 2018*

- **Worked with radioactive materials to help analyze the amount of radium in different soil and water samples due to fracking**

STUDY ABROAD:

Ireland Maymaster course 2018

- **Learned about different land uses, and how different human actions can have varying effects on the land**
- **Experienced a different culture and way of dealing with environmental issues**

Nathan Jones

291 Hillside Drive, Williamsport, PA 17702 | (570) 220-4235 | njones4959@gmail.com

Objective

Seeking a full time engineering position which will allow me to continue succeed as a professional

Education

THE PENNSYLVANIA STATE UNIVERSITY | UNIVERSITY PARK, PA **2015-PRESENT**

- Major: Natural Resources Engineering
- Minors: Environmental Engineering and Watersheds & Water Resources
- Current GPA: 3.74
- Expected Graduation: May 2019

Relevant Coursework

- Hydrology
- Design of Water and Wastewater Treatment
- Fluid Mechanics
- Soil Science
- Bio-Chemistry and Microbiology
- Land Based Disposal
- Thermodynamics/ Heat transfer
- Soils and Water Engineering
- Storm Water Infrastructure Design
- Professional speaking and writing
- Strength of Materials
- Engineering Capstone Project
- Leadership development
- Environmental Engineering

Work Experience

BASSETT ENGINEERING INTERN **MAY 2018- AUGUST 2018**

- WWTP sizing, process design, leachate treatment
- Land development, ACT537 plans, surveying, construction oversight

PIAA WRESTLING OFFICIAL **JUNE 2015-PRESENT**

- Mentor and monitor youth in the sport of wrestling
- Emphasize maintaining a safe environment for children

Relevant Skills

- **PROFESSIONAL:** BioWin by EnviroSim, Excel, GIS, MATLAB, Microsoft Office, AutoCAD, Surveying
- **PERSONAL:** Leadership, Strong interpersonal relationships, adaptability, desire to learn, high motivation, and reliability

Honors and Achievements

- Dean's List (Spring 2016-Spring 2018)
- Howard D. Bartlett Scholarship
- George Shute Scholarship

Clubs and Activities

- American Society of Agricultural and Biological Engineering (Penn State Chapter) Treasurer
- Penn State Engineering Teaching Intern
- Penn State Fly Fishing club

Alex Madura

amadura81@gmail.com ❖ (814) 824-9881 ❖ Erie, Pennsylvania

EDUCATION

Pennsylvania State University — **August 2015 – December 2019**
Bachelor of Science, Biological Engineering, Natural Resources Option — *University Park, PA*
Minor, Environmental Engineering
Minor, Watersheds and Water Resources

- Major GPA – 3.55
- Expected Graduation – December 2019
- American Society of Agricultural and Biological Engineering Member, Penn State Chapter
- Engineering Capstone Team Member

WORK EXPERIENCE

Erie Yacht Club — **May 2016 – Present**
Bartender — *Erie, PA*

- Serve customers in a timely manner
- Work effectively alongside servers and other bartenders
- Resolve problems and complaints of the customers

Erie Youth Soccer Association — **May 2009 – July 2015**
Referee/Field General — *Erie, PA*

- Refereed soccer games for players ages five through eighteen
- Responsible for more than thirty players and four coaches per game
- Resolved complaints and disputes of the coaches, players, and attendees

NASCAR Whelen All-American Series, Lake Erie Speedway — **June 2013 – August 2015**
Cashier — *Erie, PA*

- Responsible for large quantities of cash each night
- Trained new employees
- Assisted customers by addressing concerns and complaints

RELEVANT COURSEWORK

- Soils Science
- Fluid Mechanics
- Measurement & Monitoring of Hydrologic Systems
- Principles of Soil and Water Engineering
- Agricultural Measurements and Control Systems
- Mathematical Modeling of Biological and Physical Systems
- Engineering Properties of Food and Biological Systems
- Engineering Elements of Biochemistry and Microbiology
- Biological Engineering Design I
- Contextual Integration of Leadership Skills
- Contextual Integration of Communication Skills

SKILLS

- **Skills:** ArcMap ArcGIS; AutoCAD 2019; Microsoft Excel/PowerPoint; land surveying; laboratory safety; teamwork; leadership; problem solving; conflict resolution; reliability

Matthew B. Kline

484-619-4869 mbk5180@psu.edu

School Address:
458 E. College Ave, Apt 707
State College, PA 16801

Home Address:
1595 Kaitlyn Road
Allentown, Pa 18103

EDUCATION

Pennsylvania State University – College of Engineering University Park, PA

Bachelor of Science in Biological Engineering
Natural Resource Engineering Option, Minor in Environmental Engineering
GPA – 3.79
Dean's List: All Semesters, Anticipated Graduation: May 2019

Highlights:

- Member – American Society of Agricultural and Biological Engineers (2017-present)
- Member – Engineers without Borders (2014-2016)

EMPLOYMENT

Ott Consulting, Inc. Old Zionsville, PA

Design Technician Intern Summer, 2018

Assisted with design projects for many local projects. Oversaw construction projects on-site for storm sewer and retaining wall installation. Surveyed for existing and proposed structures.

Emmaus Aquatic Club Emmaus, PA

Assistant Summer Pool Manager Summer, 2017

Assisted in maintaining and managing five pools managed by Emmaus Aquatic Club. Performed basic pool maintenance by balancing chemicals and monitoring mechanical equipment. Responded to emergencies and other situations as necessary.

Lifeguard Supervisor Summer, 2016-2017

Supervised at various pools managed by Emmaus Aquatic Club. Ensured guards were successfully carrying out their duties in a safe and professional manner.

Lifeguard Summer, 2011-2015

Maintained a safe pool environment for patrons through various duties including: actively watching the patrons in the water, enforcing pool safety policies, conducting routine chemical checks to ensure water quality.

Lower Macungie Lazers Swim Team Macungie, PA

Assistant Swim Coach Summer, 2015-2017

Assisted in directing swimmers during swim team functions such as meets and practices. Instructed swimmers of lesser ability and actively coached the entire team when needed. Additionally, collaborated with head coaches while creating practices and lineups for meets.

SKILLS & ABILITIES

Experienced in AutoCAD, ArcMap ArcGIS, Microsoft Office. Have engaged in multiple coinciding projects. Have taken both leadership and subordinate rolls in teams.

Appendix B, Deliverables Agreement

PENNSTATE

sustainable... communities

Partnerships and Possibilities

Alexandria Borough

Sustainable Communities Collaborative, Fall 2018/Spring 2019

Community Project Partner:

Collaborator #1: Name Rebecca Smith Phone (717)-729-8454 E-mail rjholtry@yahoo.com

University Project Contact:

Course Instructor: Jeffrey Catchmark, BE 460/466, 814-863-0414, jmc102@psu.edu
Megan Marshall, BE 460/466, 814-865-3392, mnm11@psu.edu

Sustainability Institute:

Ilona Ballreich: 814-865-2291 or 814-599-6000 (c) ixb20@psu.edu

Student Team: SWM Engineering

Nathan Jones, nmj5130@psu.edu
Matthew Kline, mbk5180@psu.edu
Alex Madura, ajm6653@psu.edu
Nicole Rella, nbr5075psu.edu

The Project

Problem Statement:

The small borough of Alexandria within Huntingdon County is experiencing a great deal of storm water related issues. Infrastructure to cope with rain events is undersized and outdated. During a storm, especially short intense events, the area's conveyance systems are overwhelmed. Channels and storm sewers alike are overtopped and water flows through the entire town, often resulting in road closures and property damage. Although the community has the desire to make the required changes to improve the performance of their storm water system, there is an inherent lack of funding for improvements. Various grant opportunities are available that could be applicable to the Alexandria community, but grant applications require initial engineering work. Due to the budget issues, funding for preliminary engineering work would place a strain on the community. In order to alleviate this burden, investigation will be conducted by our group of Penn State Biological Engineering students.

Community Partner Objectives:

The true nature of the goal of the project arises from the budgetary issues which is the primary concern of the community partner. Initial engineering work such as flow quantification for various locations around the borough will be conducted along with the production of a functional design of a piece of stormwater infrastructure. Data will be presented to the community in the form of Geographic Information System (GIS) flow quantification results; this information will outline the most problematic areas within the borough. Using this GIS information the borough will be able to draft a strong grant proposal in order to acquire funding for improvements to the storm water system. These areas will then be further investigated to see what form of stormwater infrastructure would best reduce the impact of storm events on the community. One of these areas will be selected for immediate improvement through a new or redesigned piece of infrastructure to be installed. At the conclusion of the project this design will be presented to the community for their consideration as an option to improve their current situation.

Community Partner's preferred mode of communication:

- Phone #: (717)-729-8454)
- e-mail: rjholtry@yahoo.com
- text: Rebecca Smith ((717)-729-8454)

Partner Responsibilities:

- Meet with student team to discuss project (one member of student team will be identified as contact to communicate with sponsor)
- Provide all relevant information regarding the project: data, background information, contact information of applicable resources/personnel if available, etc.
- Be available to answer questions and provide feedback to students and faculty
- Complete sponsor evaluation for student team at end of fall and end of spring semester

Intellectual Property Rights:

Student Participant Project Results provided shall be used solely for Sponsor's internal review and analysis. Any and all rights to the Student Participant Project Results, including all Intellectual Property Rights, if any, shall remain the rights of the individual Student Participants as appropriate under the law regarding rights to and ownership of intellectual property unless there is a separate written agreement addressing the ownership of intellectual property. Prior to any commercial use or *subsequent transfer of any Student Participant Project Results, Sponsor must obtain the appropriate rights from the respective owners.*

Description of Course:
BE 460 – Semester: Fall, Day: T/Th 3:35-5:30 PM. BE 466 – Semester: Spring, Days: T/Th 3:35-5:30 PM. Department: Agricultural and Biological Engineering. College: Engineering. Enrollment: 50

Students will develop skills and techniques for managing and executing engineering design projects in the following fields: agricultural engineering, food and biological processing engineering, and/or natural resource engineering. Projects are sponsored by faculty, industry, or community initiatives and are structured to span two semesters. In the Fall semester, the emphasis is on classroom lectures and project proposal development. In the Spring semester, the emphasis is on hands-on laboratory activities, project execution, and report preparation. Project teams perform all facets of the design process. This includes problem identification, planning of the project, formulation of design specifications, development and evaluation of alternative conceptual designs, development of detailed designs, consideration of safety and design optimization, design implementation, design testing, and analysis and documentation of results. Students improve their writing skills through preparation and refinement of various documents including a design notebook, proposal, statement of work, design specification, status reports, and a final report. Students also present their results in other formats, including poster and oral presentations for both technical and non-technical audiences.

Course Information & Learning Objectives:
- Course Learning Objectives (list below)

The BE 460/466 course sequence is entirely project-based. In BE 460, student teams develop their project proposals and learn some tools that will help them execute their projects. In BE 466, student teams complete and report on their design projects. Upon completing the courses, students should be able to:

01. Interact with a sponsor (supervisor, co-worker, client) to formulate equitable design criteria (time, cost, specifications) for a meaningful engineering project
02. Develop an action plan to complete the project on time and within budget
03. Conceptualize systems to satisfy design criteria
04. Analyze technical and economic merits of design alternatives
05. Work effectively in a team that includes co-workers, customers and vendors
06. Communicate well using verbal, written and electronic methods
07. Develop and improve writing skills
08. Demonstrate professionalism in interactions with colleagues, faculty, and staff
09. Demonstrate an appreciation of economic, global, societal, and ethical issues
10. Demonstrate knowledge of contemporary issues

- Estimated number of students involved in the project: 3-5
- Roles of Student Team Members: Who is doing what?

    Nathan Jones - Sponsor Communication & Speaker
    Matthew Kline - Group Recorder & Drive Organizer
    Nicole Rella - Group Organizer & GIS Lead
    Alex Madura - Notebook and Research Organizer
- Estimated number of hours for completion of the project: senior capstone design project that team will complete over two semesters (in spring, 4 hours per week of scheduled class time are for project work, plus additional time outside class)

University Responsibilities:

- Provide clear instruction to students about the project.
- Provide this project agreement form to students to help define the project, share information and helpful hints about project components;
- Share the date and time of the end of semester event with students and link to evaluation survey
- SCC will visit classes in the first weeks of the semester and conduct a mid-semester check-in with partners and faculty
- As appropriate, facilitate site visit and identify additional stakeholders

Expected Deliverables & Timeline: Use the space below to list major milestones for the project and the expected deliverables during the course of the fall and spring semesters.

- Project Proposal by December 10th
- Update Memos provided weekly
- Design Specifications Report by March 1st
- Final Report by April 29th
- Flow Quantification for various locations in Alexandria Borough by April 29th
- Full Watershed flow quantifications by April 29th
- Channel Design by April 29th

Timeline of Tasks

- **September**
    - Establish date and time for students and community partner to meet
- **November**
    - Complete project agreement/deliverables form by November 16th
- **December**
    - Attend the Campus & Community Sustainability Expo, November 29, 2018 from 4:30 pm to 6:30 pm in the State College Borough Building (246 S. Allen Street)
    - Complete project proposal report and presentation by December 10th
- **January – March**

  - Complete design specifications report
  - Present poster to Industrial and Professional Advisory Council (IPAC)
- **April – May**
  - Present poster at Campus & Community Sustainability Expo, TBD
  - Complete final design report and presentation
  - Provide final deliverables to community project partner

Appendix C, Calculations and Drawings

Some of the important equations used in the process of channel design are shown below.

(1) Hydraulic Radius (R)

$R = \frac{bd + zd^2}{b + 2d\sqrt{z^2 + 1}}$, where b is channel bottom width, z is side slope and d is depth of flow

(2) Velocity of Flow (V)

$V = \frac{1.486}{n} * R^{2/3} * S^{1/2}$, where n is Manning's coefficient, and S is the channel slope

(3) Shear Stress ($\boldsymbol{\tau}$)

$$\tau = 62.4 * d * S$$

(4) Freeboard (F)

$$F = 0.25 * d$$

(5) Cross-Sectional Area (A)

$A = (b * D) + (z * D^2)$, where D is the total channel depth ($d+F$)

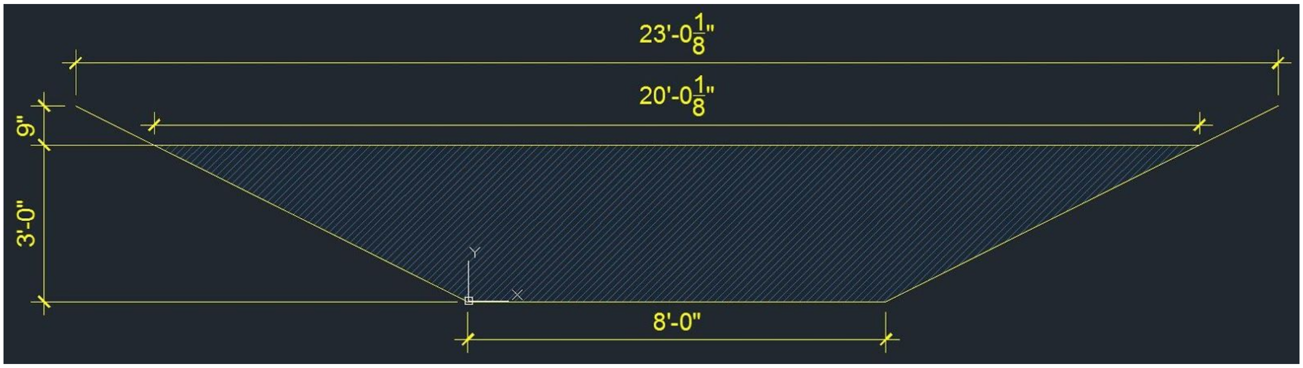


Figure C.1. Riprap Channel Dimensions

Table C.1. Riprap Channel Parameters

Parameter	**Value**	**Units**
Channel Lining	R4 riprap	n/a
Flow Rate	218.56	cfs
Bottom Width	8	ft
Top Width of Flow	~20	ft
Freeboard	9	in
Top Width of Channel	~23	ft
Depth of Flow	~3	ft
Total Depth of Channel	~3.75	ft
Flow Velocity	5.2	ft/sec
Side Slope	2	ft/ft
Cross-Sectional Area	58.2	ft^2
Shear Stress	1.42	lb/ft^2
Manning’s n	0.039	n/a

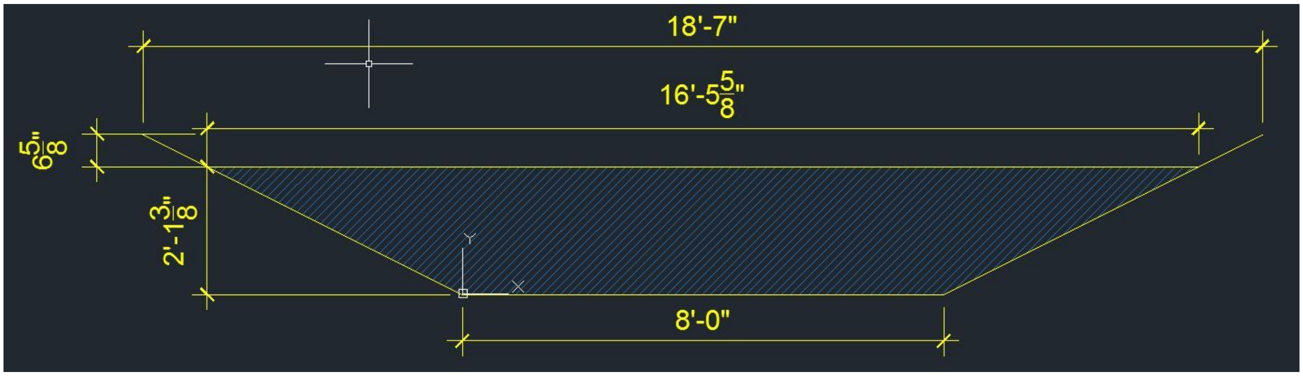
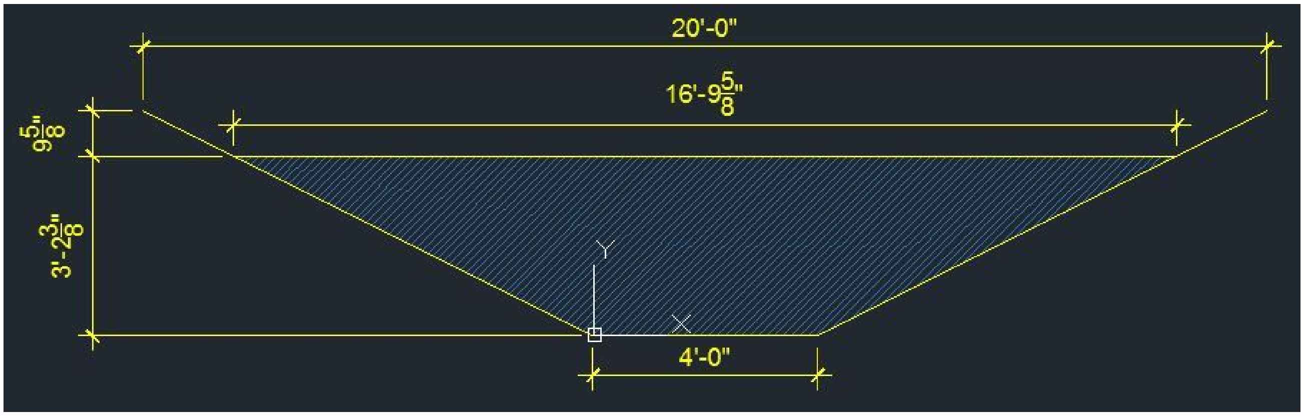


Figure C.2. Grass Channel Dimensions

Table C.2. Grass Channel Parameters

Parameter	Value	Units
Channel Lining	Kentucky bluegrass	n/a
Flow Rate	72.58	cfs
Bottom Width	8	ft
Top Width of Flow	~16.5	ft
Freeboard	~6.5	in
Top Width of Channel	~18.6	ft
Depth of Flow	~2.12	ft
Total Depth of Channel	~2.65	ft
Flow Velocity	2.8	ft/sec
Side Slope	2	ft/ft
Cross-Sectional Area	35.2	ft^2
Shear Stress	1	lb/ft^2
Manning's n	0.06	n/a



Figue C.3. Reinforced Channel Dimensions

Table C.3. Reinforced Channel Parameters

Parameter	Value	Units
Channel Lining	Kentucky bluegrass w/ Propex Pyramat 25 lining	n/a
Flow Rate	128.15	cfs
Bottom Width	4	ft
Top Width of Flow	16.8	ft
Freeboard	9.6	in
Top Width of Channel	20	ft
Depth of Flow	3.2	ft
Total Depth of Channel	4	ft
Flow Velocity	3.85	ft/sec
Side Slope	2	ft/ft
Cross-Sectional Area	48	ft^2
Shear Stress	1.51	lb/ft^2
Manning's n	0.05	n/a

Appendix D, Infiltration Basin Example

Important considerations and procedures for infiltration basin design:

- Soil and infiltration testing must be conducted
- Preferably no removal of existing vegetation
- Proper discharge structure must be designed and built
- 1 foot of freeboard required above 100-year storm elevation
- Avoid compaction of basin surfaces
- Sediment reduction methods should be used before water enters the basin

Volume Reduction:

*Volume = Depth (ft) * Area (sq ft)*, where *Depth* is the depth of water stored in a storm event

ex. *V = 2ft depth * 600 sq. ft. = 1,200 cubic ft.*

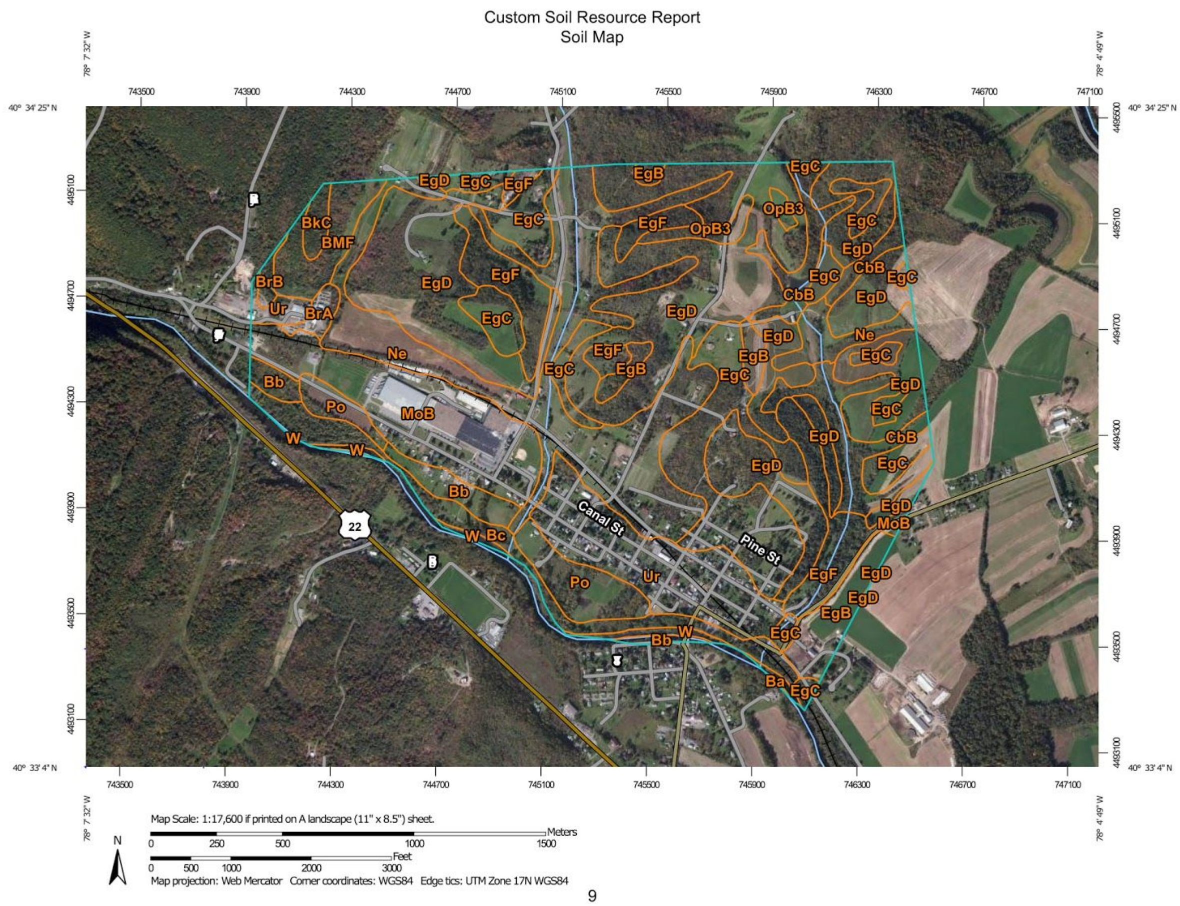
*Infiltration Volume = Bed Bottom Area (sq ft) * Infiltration design rate (in/hr) * Infiltration Period (hr) **

(1/12) inch-to-foot conversion

ex. *IV = 1,000 sq. ft. * 0.2 in/hr * 72 hr * (1/12) = 1,200 cubic ft.*

** Note that these values only represent a simple example calculation of volume reduction and do not specifically apply to areas or values possible for the implementation of an infiltration basin near Alexandria.

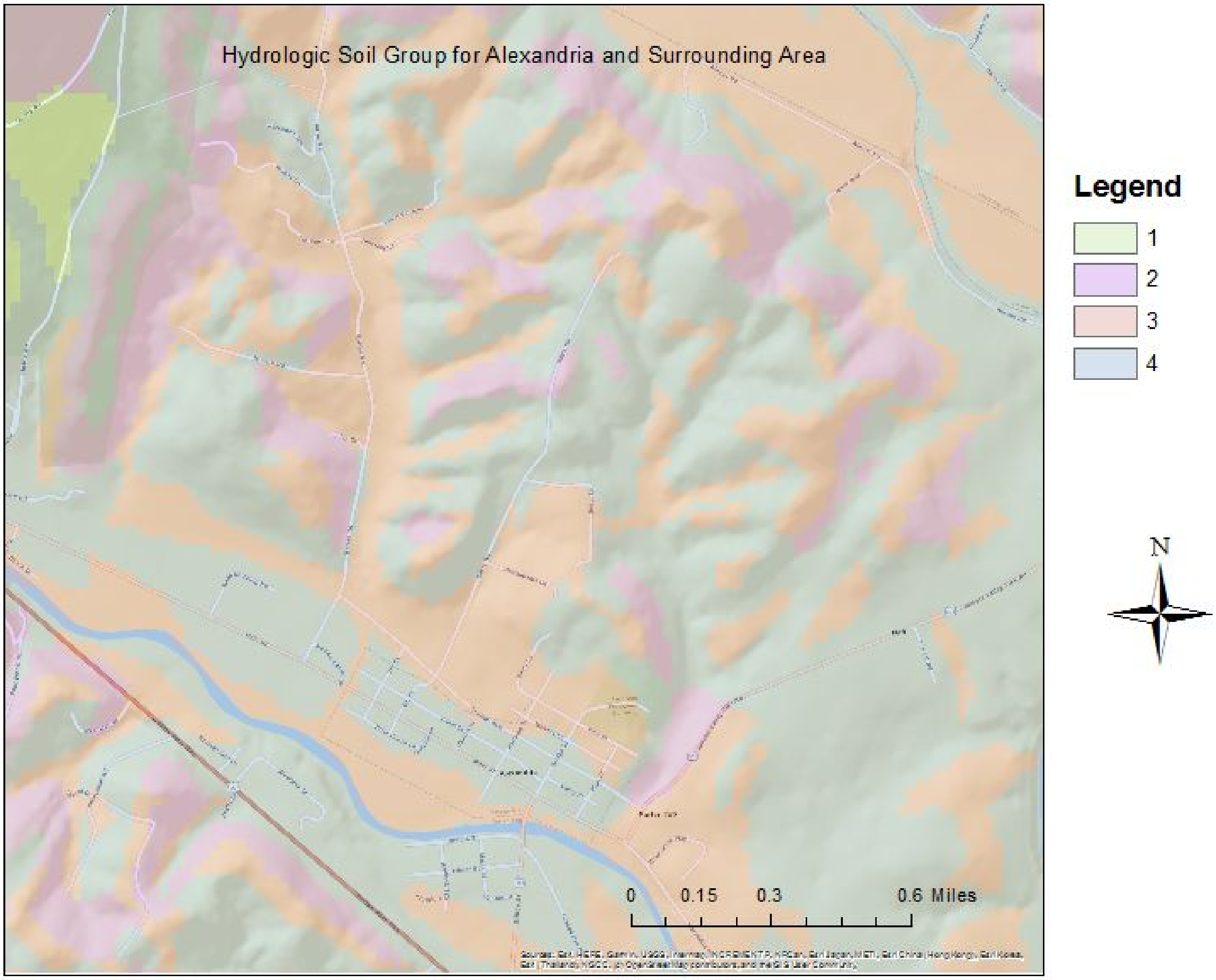
Appendix E, Web Soil Survey

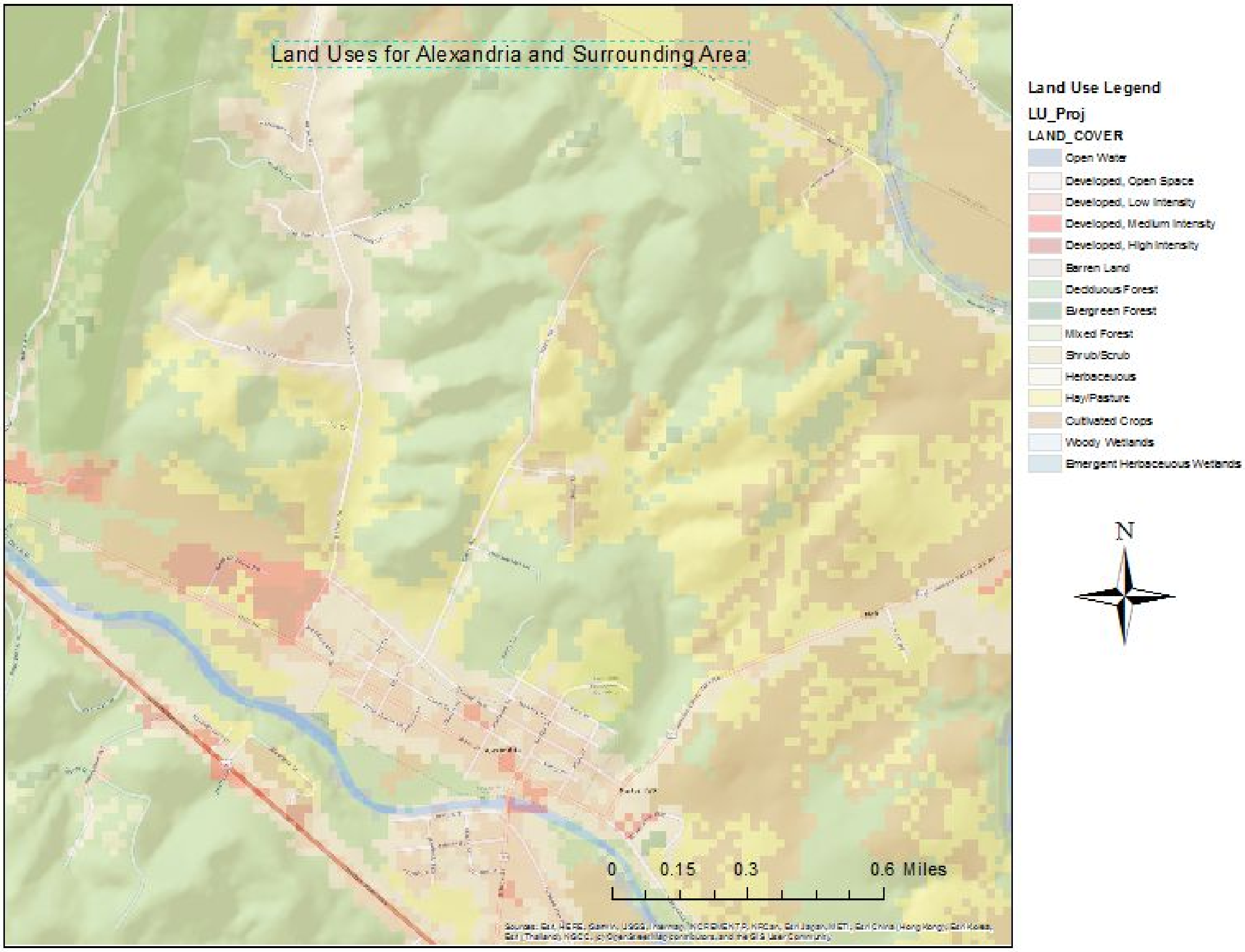


Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Ba	Barbour soils	0.2	0.0%
Bb	Barbour soils, high bottom	18.6	2.0%
Bc	Basher silt loam, neutral variant	34.5	3.7%
BkC	Berks channery silt loam, 8 to 15 percent slopes	5.1	0.5%
BMF	Berks-Weikert association, steep	20.1	2.2%
BrA	Brinkerton silt loam, 0 to 3 percent slopes	4.9	0.5%
BrB	Brinkerton silt loam, 3 to 8 percent slopes	2.7	0.3%
CbB	Clarksburg silt loam, 2 to 8 percent slopes	46.8	5.0%
EgB	Edom-Weikert complex, 3 to 8 percent slopes	30.0	3.2%
EgC	Edom-Weikert complex, 8 to 15 percent slopes	117.0	12.5%
EgD	Edom-Weikert complex, 15 to 25 percent slopes	269.9	28.8%
EgF	Edom-Weikert complex, 25 to 60 percent slopes	54.7	5.8%
MoB	Monongahela silt loam, 2 to 10 percent slopes	70.9	7.6%
Ne	Newark silt loam	149.8	16.0%
OpB3	Opequon clay loam, 3 to 8 percent slopes, eroded	8.5	0.9%
Po	Philo and Basher silt loams, high bottom	29.1	3.1%
Ur	Urban land	65.3	7.0%
W	Water	7.5	0.8%
Totals for Area of Interest		**935.6**	**100.0%**

Appendix F, ArcGIS Maps




Land Uses for Alexandria and Surrounding Area
Land Use Legend
LU_Proj
LAND_COVER
Open Water
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Herbaceuous
Hay/Pasture
Cultivated Crops
Woody Wetlands
Emergent Herbaceuous Wetlands
N
0 0.15 0.3 0.6 Miles