Policy Analysis

Riverbank Erosion Along the Delaware River

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Executive Summary

Our group was given the task of looking into Easton’s problem with riverbank erosion. It was crucial for us to define and understand the problem before we jumped into formulating a solution. We found evidence that proved that a devegetated bank would increase the rate of riverbank erosion. Some of our findings also showed that riverbank erosion leads to channel widening which can cause dangerous changes to the river’s floodplain. This can cause many citizens to panic and fret, and for good reason. We were able to estimate the property value of all of the area on or bordering the floodplain to be nearly 184,000,000 dollars, and this value could only increase. This led us to look into possible policy alternatives that could solve this problem. The solutions we came up with are as follows: planting riparian grasses, planting shrubs, planting trees, allowing Japanese knotweed to grow, laying down erosion control matting, soil bioengineering, systematic planting of mixed vegetation, and educating the public. We found both positives and negatives for each solution. Then we chose our evaluative criteria which were long-term effectiveness, short-term effectiveness, cost-efficiency, administrative feasibility, short-term feasibility, and social acceptability. We then evaluated each alternative based off this criteria. We found that systematic planting received our highest score with planting shrubs and laying down erosion control matting tying for our second highest scores. Our recommendation to the city of Easton is to lay down erosion control matting in the winter to immediately begin combating erosion. Also we recommend planting shrubs and trees during the colder months but before the ground freezes. Then we would recommend planting grass seed once it warms up and the ground thaws. This will lead to a healthy, fully-grown, effective, and beautiful systematically planted riparian buffer for the summer. This plan will see to the end of riverbank erosion along Easton’s banks of the Delaware.
Policy Analysis: Bank Erosion

Section 1: Problem Analysis

The Delaware River flows through the city of Eason, Pennsylvania. It separates the Easton Red Rovers from their rivals across the river the Phillipsburg Stateliners. Recently in order to deal with a growing problem of invasive species, the city decided to spray pesticides. They sprayed pesticides twice. This killed all the riparian vegetation along the riverbanks on the Easton side of the Delaware by Scott Park in downtown Easton. Now without the riparian vegetation, there is not only an aesthetic problem; there is a lack of root-reinforcement which will cause a new problem. This new problem is bank erosion. The newly exposed bank is in danger of serious erosional issues that might have awful consequences. The erosional issues will not go away without the proper measures. If nothing is done on the Easton side of the Delaware, the bank will become unstable and problems will result due to the instability of the sediment.

The removal of about three hundred yards of vegetation separating the edge of the river from the concrete wall that supports the walkway has sparked controversy. The main concern with the removal of the vegetation is that without their roots to hold the sediment in place, erosion will occur on a very large scale and the movement of the sediment will change the current floodplains. The fear of erosion is legitimate, as our research will depict.

Bank erosion is defined as the wearing away of sediment that creates banks of a stream or river. Bank erosion is disparate from the erosion of the bed of watercourse, which is referred to as scour. Stream bank erosion cuts the roots of trees by the stream. It occurs as streams begin cutting deeper and deeper and widen channels as peak flows increase or local protective
vegetation is increased. It is the erosion of material from the side of river material, not only by fluvial processes but also by groundwater sapping, surface wash, and slope failure. Rates of erosion vary with bank composition and moister content, bank devegetation and speed of flow. Rates of erosion are highest on the outer bank of meander bends or where the bars in the channel have diverted the thalweg (the line defining the lowest points along the length of a river bed or valley). Bank forms are reflected by many factors such as the nature of materials: fine cohesive materials tend to fall through, while coarse materials steep and may have talus slopes at the base. If a cohesive layer overlies coarser materials, it is possible that undercutting forms overhangs that collapse periodically. Such collapsed blocks may protect the base of the bank (NRAW, 2006).

Rivers and streams are called dynamic processes as they are constantly changing. The natural process of riverbanks can produce favorable outcomes. For example, these processes have caused the formation of the productive floodplains and alluvial terraces common to the middle and lower reaches of many of Australia's river systems. It is natural for streams to want to meander. In brief, not all slowly eroding banks are “bad” and in need of repair. Thus, even stable river systems have some eroding banks. However, the rate of erosion is much lower in stable systems than in unstable systems. In Easton, as we will see later, without the proper growth of riparian vegetation, the bank is unstable. An unstable bank has much higher erosion rates (RBE, 2011).

Mechanisms of stream bank erosion can be classified into two core groups, which are bank scour and mass failure. In almost every situation of bank instability, both bank scour and mass failure are present. Bank scour can be defined as the direct removal of bank materials by the physical actions of water. It is hegemonic in small streams and in the upper reaches of large streams and rivers. The second group of stream bank erosion, mass failure, includes slumping
and bank collapse. It happens where large pieces of bank material become unstable and thus topple into stream or river in single events. Mass failure is usually associated with the scouring of lower reaches, and is dominant in lower reaches of large streams (RBE, 2011).

Many factors account for river and stream formation; these factors are both complex and interrelated. They include the amount of water supply, amount and rate of the supply of water and sediment into stream systems, catchment geology, and the type and extent of vegetation in the catchment. Natural happenings such as flooding can engender brusque and dramatic changes in rivers and streams, causing bank erosion. However, land use management and the overclearing of catchment can also stimulate bank erosion. Thus, poor land management practices are the only man-made factors of erosion as all of the other factors are natural processes. All these factors affect banks in complex manners, possibly resulting in accelerated rates of erosion that can affect stability for decades. In Easton, the riverbank was mismanaged, by being devegetated which will increase the erosion rate. This problem must be addressed before we see some of the brutal consequences the increased erosion rate can cause (RBE, 2011).

When the velocity and turbulence of water are more powerful than the weight of soil particles and their cohesive strength, erosion occurs. The more cohesive the soils, the more there is resistance to erosion. Without any type of riparian vegetation protecting the soil, there is much less resistance to erosion. Anything that changes the direction of flow or increases water velocity can cause pockets of erosion (NRAW, 2006).

When looking at a study down on the Nepean River in southeastern Australia, the root cause of bank erosion is uncovered. The study, done by Hubble and Rutherfurd, had a hypothesis that the Upper Nepean’s “bank-failure and related channel widening is more likely on devegetated banks than vegetated banks”. The study looks at a particular area of the Nepean
River during a flood-dominated regime between 1949 and 1992. This study found that ninety-two percent of the banks that were devegetated prior to the flood-dominated regime of 1949-1992 have failed sections before 1970. The eight percent that did not fail were in areas of meanders, bends in the river. They also concluded that ninety-five percent of vegetated banks remained stable during the 1949-1992 flood-dominated regime (FDR). Many of the five percent that failed were located adjacent to devegetated bank areas that also failed. From this data one is able to derive that the majority of the pre-1970’s failures along the Nepean occurred predominately in areas of devegetation along the bank. The vegetated banks, for the majority, did not fail. It is fair to infer that having a presence of bank vegetation protects the riverbank from failing. This is thought to happen due to the bank sediments being reinforced by the roots of the trees, or root reinforcement. Hubble and Rutherfurds hypothesis was “the widespread bank failure documented for the upper Nepean River was caused by the coincidence of FDR (an increase in the number and sized of floods) with clearing of vegetation (riparian trees) from the bank slopes, and the failures resulted from a reduction in bank-soil shear-strength arising from the absence of root reinforcement.” (Hubble and Rutherford, 2010).

The same study looked and modeled to separate situations: one was whether a bank with substantial cover of trees are by design more resistant to a failure during a flood event than a bank with lack of vegetation and the other was to determine if banks with substantial tree cover are by design more resistant to a flood event if the bank-toe has been removed than a devegetated bank. When modeling these scenarios, root-reinforcement data is used. This has been used more increasingly over the last decade to evaluate bank stability. It is indicated in the results of these studies that devegetated banks of similar slope and composition of sediment to the ones in the modeling are more likely to fail than a vegetative bank with all the same features. It was found in the model that “nearby sections of devegetated bank(s) with similar
composition and geometry also collapsed”, while nearby vegetative banks were stable (Hubble and Rutherfurd, 2010).

Another example of the advantages of a vegetated bank compared to a devegetated bank is shown when the bank toe is removed. This causes a vegetative bank to go from stable to unstable, while causing a devegetated bank with the same profile to be in complete failure following a flood event. This adds to the fact that toe erosion and channel widening are more likely to trigger failure in a devegetated bank than a vegetated bank (Hubble and Rutherfurd, 2010).

It was shown that in the case of the Nepean River, its banks would have remained stable and better resisted erosion if the riparian forest was not removed from the area. The banks that remained vegetated remained stable. The erosion problem was mostly caused by “contemporaneous occurrence of a FDR with the clearing of vegetation (riparian trees) from bank slopes.” This root cause of channel widening was much less of a problem and almost non-existent in the vegetated areas along the river. So it can be stated that the removal of riparian vegetation “amplified the response of these banks to the natural climate-driven increases in flood height and frequency”. Channel widening was more pronounced in devegetated banks than would have been in vegetated banks (Hubble and Rutherfurd, 2010).

This study proved that channel widening, and the resultant effect of severe flooding, was more likely to occur in areas that were devegetated. Removing vegetation causes a bank to go from stable to unstable. While the severe damage is only during flooding events, the devegetation allows for the problem to get worse. The final conclusion of the study was as follows: “the riverine response to FDR-DDR (drought-dominated regime) style climatic-cycling would have been relatively limited if there had not been anthropogenic clearing of riverside trees. In most cases on the upper Nepean River it was the absence of riparian vegetation that
As you can see from the study on the Nepean River, the vegetation along the riverside should not have been removed from the Delaware because it caused the riverside to be susceptible to severe consequences. An article entitled “Cumulative Effective Stream Power and Bank Erosion on the Sacramento River, California, USA” written by Eric W. Larsen, Alexander K. Fremier, and Steven E. Greco, discusses many of the horrible effects that can arise from a problem with bank erosion. One of the main points that the article raises is that bank erosion can determine the pattern of channel migration. Channel migration can cause rivers to create a new floodplain. This makes establishing riparian vegetation critical. Channel migration also causes erosion on riparian, agricultural, and urban land. The erosion can also be harmful to infrastructure by scouring bridge foundations or endangering pumping facilities. Clearly bank erosion is a problem of much importance, especially in Easton, which houses the foundation of multiple bridges (Larsen et. all, 2006).

The Delaware River’s current as it splits Easton and Philipsburg is very strong, causing waves to rapidly beat up and down the banks. These consistent waves cause the sediment that composes the banks to move; the problems that arise from this are how much sediment is moved and where it is moved to. Once enough sediment is moved the anatomy of the river changes and these changes can have a profound effect on floodplains. As sediment is moved along, with it is the land adjacent to the river. In an area like Easton, this could over time start to cause the riverbanks to recede back towards the city. This land loss and mutation of floodplains are the reason the city of Easton wants to stop erosion from occurring along its bank of the Delaware River.
Many studies have been conducted on the effects that vegetation has on erosion. This question is almost always raised during public riparian restoration projects, because the maintenance of natural beauty is always appreciated by the public. One such study was conducted on the rivers of Eastern Pennsylvania by a group of geologists and environmental engineers for the Geological Society of America (Allmendinger et. all).

The study yielded results that concluded: river banks “are migrating laterally almost 9 times faster in non-forested reaches than in the forested ones.” This supports the argument of those in favor of planting vegetation. Because the current lack of vegetation will expedite erosion, the City of Easton will need to plant some sort of riparian vegetation to stop any permanent change to the floodplains (Allmendinger et. all).

Another problem that should concern the citizens of Easton is the flooding possibility. A floodplain is the calculated amount of flood water expected on average in a certain number of years. More specifically a 100 year flood is the expected amount on average every 100 years, so each year that expected amount of flooding has a 1% chance of occurring. As seen in the floodplain map of Easton, the Federal Emergency Management Agency’s (FEMA) defined 100 year floodplain gets dangerously close to the streets and homes in Easton. In it, a significant part of the Delaware River we’ve been studying surrounds the local park and over a dozen streets. Although 1% may seem like a miniscule chance, in reality it’s only increasing and getting more likely to occur. Erosion is a huge source of flooding. The mud walls keep water levels in and protect the city, but as they slowly disappear, they lower the barrier causing more reason to panic and fret.

One thing that makes erosion even more important is the ever-increasing climate. With the recent increases in temperature, floods are highly more likely, and more powerful. With the expected 2 degree increase in temperature that is already close happening, scientists predict
much worse storms to ensue (Bernstein et. all, 2007). That means treacherous hurricanes, and pounding rainstorms, that not to mention will also occur more often because of climate change. Hurricane Sandy just hit, one of our worst hurricanes since Katrina, an example that things are changing for the worse. If the problem of erosion is left alone, this could mean tragedy for Easton. Any one of these horrific storms could cause complete bank failure. This would result in flooding of many of the streets of Easton.
Figure 1: The current 100 year and 500 year floodplains for Easton
Figure 2: Estimating the damage of the current 100 year floodplain.
If you reference the attached floodplain (Figure 1), you can see that the natural floodplain already covers some of the streets. Using the program ArcGIS, our group created a map showing the total damage that would be done if this flood hit, and calculated the total value of all the total properties affected. As seen in Figure 2, this value amounts to nearly 184,000,000 dollars, which is a very significant amount. One can infer that with an unstable or even failed riverbank due to erosion, the floodplain would cover even more areas in Easton. This would cause even more immense damage to homes and businesses. Not to mention the incalculable emotional trauma a severe flooding event can have on the citizens. It would take a significant amount of time and numerous amounts of dollars to clean up the damage caused by a severe flood. And all of these would be avoidable if the problem of bank erosion is not ignored. The issue must be put on a higher priority since it is not going away; it is only getting worse with time. Each day that the problem is ignored, is another day in which a severe weather event could cause irreparable damage to the city of Easton due to an unstable bank due to erosion.

The biggest problem with the replanting of riparian vegetation along Easton’s bank of the Delaware River would be insuring that the initial problem the city of Easton remedied in the beginning would not reoccur. When vegetation grows uncontrollably, the risk of invasive species growing increases drastically. This results in a less secure riverbank and an overall less beautiful area. The correct type of vegetation must be planted to ensure that it can thrive in a riparian environment and also hold the sediment in place. And another factor that must be considered when choosing the type of vegetation to plant would be the aesthetic beauty of the plant. A low maintenance plant would be ideal, and if planted strategically and systematically the beauty of the riverbank could increase. With the correct type of riparian vegetation planted, the sediment of the riverbanks will be cemented in place, therefore managing the erosion of the banks.
Bank erosion is an often overlooked problem that can lead to severe problems. Look at the Nepean River for example. The lack of vegetation caused harmful damage to the river and erosion to spread. Easton is ignoring an already proved problem. Vegetation is critical in preventing bank erosion. And yet Easton sprayed harmful pesticides killing all of the important riparian vegetation that was protecting the riverbank against erosion. Bank erosion causes instability and can lead to dangerous shifts in the channel including channel widening. But the city of Easton still has no vegetation along much of the banks of the Delaware River. Not only this but the river has lost almost all of its attractiveness, losing its appeal and causing local citizens to complain. Without the proper precautions, bank erosion can be a serious issue for the stability of the Delaware River and leave Easton with many problems that could have been avoided. Something must be done about the bank erosion before this problem gets any worse. Is it really worth risking the safety of nearly 27,000 people by continuing to ignore the problem with bank erosion along the Delaware River?

Section 2: Policy Alternatives

There is a growing problem with bank erosion along the Delaware River on the Easton banks along Riverside and Scott parks (see Section 1 for more information). Our research has made it clear that due to the devegetation along the riverbanks, the problem of bank erosion surfaced and will worsen without the proper action. This paper will look into and discuss the positives and negatives of different solutions to the problem. Our solutions are as follows: plant riparian grasses, plant a mix of medium depth root shrubs and deep root shrubs, plant trees,
allow the Japanese knotweed to grow back, use erosion control matting or blankets with and without plants, soil bioengineering, systematic planting of different types of riparian vegetation, and educating the public on the issue. The solutions we have come up with mostly deal with direct spending at the root of the problem. Our only different policy alternative deals with educating the public on the issue. Each alternative will have its benefits and detriments. Our initial thinking is that it may take a combination of these policies in order to truly solve the problem of bank erosion.

A policy alternative already in consideration by the city of Easton is the planting of riparian grasses. When assessing the different types of vegetation along the bank and which will be most effective, it is important to understand root-reinforcement. It has been proven that vegetated banks help deter bank erosion over unvegetated banks (see Section 1). This is mainly due to the effects roots have on the soil. The roots affect these different properties of soil: infiltration rate, aggregate stability, moisture content, shear strength and organic matter content. In various ways, all of these properties help control erosion. Roots help increase the soil’s shear strength in two ways: by mechanical reinforcement and by removal of water (De Baets et. al, 2008).

The size and strength of the root is important when choosing the correct vegetation. A finer root is more effective than a thicker root (Price and Lovett, 2002). A study was done on the strength of different types of plants (grasses, shrubs, trees, etc.) when reinforcing soil. The findings were that vegetation with many small fine roots did a better quicker job of reinforcing the soil than say a tree with large thick roots. Tree roots only matched the strength of grass roots after given a much longer period of growth. The study found that the fibrous root (grasses and the rush Juncus) had an overall quicker and greater effect on soil reinforcement than a tap root (trees, herbs, shrubs, etc) (De Baets et. al, 2008).
A huge benefit of riparian grass when used in a riparian buffer zone is that it improves the water quality. A study was done in central Pennsylvania on the effectiveness of a narrow grass buffer on holding sediment in place. The initial studies showed that on a small scale grass was able to retain fifty percent of the sediment. When looked into further it was found that grass was very effective in trapping sediment. It also showed promising signs in helping reduce channel widening. A huge benefit of riparian grasses is the rapid colonization of the plant. This rapid colonization is a positive to reestablishing a riparian buffer zone quickly. So the combination of rapid colonization and trapping of sediment make riparian grasses a viable option for vegetation in the riparian buffer zone (Carline and Walsh, 2007).

Another policy alternative to consider is the planting of a mixture of deep root shrubs and medium root shrubs. Shrubs are a natural riparian buffer. According to Pennsylvania Stormwater Best Management Practices Manual, a riparian buffer is a permanent area of trees and shrubs located contiguous to streams, lakes, ponds, and wetlands. Shrubs have economic, environmental, and aesthetic values. One very important characteristic shrubs have is that they protect soil from the wind, the sun, and heavy rainfall. It is evident from our problem analysis that the wind, the sun, and rain downpours exacerbate erosion. Another helpful characteristic of medium size shrubs, like Gooseberries and Currants, is their ability to hold soil with their extensive root systems. Shrubs are able to protect the ground from damage, hold the soil in place, and absorb excess water. Large shrubs are also efficient as they can absorb large amounts of water and their roots are able to fix the soil in place. Small shrubs can also be used for the same purpose (PSBMP, 2006).

When deciding which shrubs to use, it is important to consider a selection criterion. First, it is important to have a variety of shrubs. Having different types of shrubs is critical to stopping erosion. Different shrubs have different comparative advantages. For example if the soil is deep, shallow-rooted shrubs can be used in planting. This does not provide a total solution; it
will be used only to make sure that the top 1-2 feet of soil is tied together. A mix of deep-rooted shrub must be also planted to guarantee that the soil is tied together at deeper levels of depth. It is also important to consider soil depth. The deeper the soil, the more necessary it is to plant deep root shrubs. A mixture of different plant structures that provide enough room to maximize the root area is necessary to provide the proper root reinforcement of the soil (Jaden and Weber, 1997).

In addition, certain shrubs are more adapted to particular types of soil. For instance, *Amelanchior alnifolia* or serviceberry is more adapted to dry soils, while *Crataegus douglasii* or black hawthorn adapts better in wet soils. Some shrubs thrive on areas with more water. This makes them better suited to wetter areas. For instance, Alder bushes require plenty of moisture when first planted. This protects the soil from erosion by removing the excess moisture. Other species, such as Roses (which are especially low growing) are able to absorb water, but also are able to tolerate dry conditions (Jaden and Weber, 1997).

The most important thing is to select shrubs that are a native to the riparian environment. In fact, native shrub species are more adapted to climate and rainfall patterns in Easton. This often makes irrigation unnecessary, as the native species are usually adapted to rainfall patterns. It also makes establishing healthy colonization of shrubs easier since they are more resistant to the pre-existing conditions of the riparian environment. Not only is imperative to choose a native shrub species, but the planted shrubs must be disease and pest resistant in order to support a healthy riparian buffer zone (Pitt, 2003).

In short, choosing the right type of shrub depends on many different variables (soil depth, weather, riparian environment, etc.). While choosing the correct shrub is important, it is also important to plant the shrubs at the correct spacing. Generally, small plants such as small shrubs should be spaced at least 5 feet apart, while trees require at least 15 feet of space. Both
the correct shrub and the correct location is critical when planning a riparian restoration project (Pitt, 2003).

Besides just shrubs, planting trees is another policy alternative we are considering. Trees have great characteristics in helping combat bank erosion. Trees are able to hold the soil in place and reduce the erosive effects of wind, rainfall, and sun. As we proved in the problem analysis, clearing vegetation causes bank erosion. The best trees for erosion control have a quick growth rate. Also, they have deep root systems, which can grow down into the subsurface of the ground and make soil more still. There are variety types of trees that are deep-rooting and appropriate in order to control erosion. The best strategy to using trees is to plant them in a mixture with plants, shrubs, and groundcovers. Trees that are appropriate for erosion control are: hybrid poplars, basswood, Silver Maple, White Willow, European Black Alder, Willow trees, Pine trees, Cascara tree, etc. When selecting which trees to use, it is important to consider the temperature requirements for the trees. Many trees cannot live under a certain temperature limit. Thus, like in the case of shrubs, weather and physical conditions of Easton are important to consider when selecting trees. It is smart to use a native species of trees as they are more suited to Easton’s riparian environment. Equally important factors include disease resistance and life span. Trees with these characteristics will have the best chance of survival and have the greatest effect on erosion (Terry).

A policy alternative that may have been overlooked by many would be to let the invasive species of Japanese Knotweed to regrow and act as the riparian root reinforcement that the bare banks of the Delaware need. Japanese Knotweed was a gift from Easton’s neighbors upstream, and due to its extremely invasive nature, it came to stay. The city of Easton was able to successfully eradicate it through the application of herbicides, however the Japanese Knotweed was not the only plant that was killed, all of the riparian vegetation was killed by the herbicide. Now, the lack of vegetation has created an increase in the movement of the
sediment that composes the banks of the Delaware River. The problem of erosion must be solved, and a possible solution would be to permit the Japanese Knotweed to grow back.

As we showed in the problem analysis, the addition of plants to river banks drastically decreases the rate of erosion. Japanese Knotweed is noted as being very effective in preventing erosion by the Pennsylvania Department of Conservation and the Natural Resources (DCNR). Underground, the anatomy of the plant consists of a rhizome and an extensive network of roots. A rhizome is an underground extension of the stem from which the roots protrude. The entire root system can extend a maximum of seven meters horizontally, and three meters deep. Japanese Knotweed grows in very dense colonies, meaning that the sediment in the area of a colony would be held tightly by the roots. For this reason Japanese Knotweed would be a viable solution to combat the erosion that is currently occurring (Rhoads and Block, 2002).

In riparian regions, Japanese Knotweed grows easily because of the species tolerance to a wide spectrum of soil types, salinity, pH, available sunlight, and temperature. This resilience is a major contributor to the justification for its listing on the World Conservation Union’s list of the world’s one hundred worst invasive species. On the other end of the spectrum, this resilience makes it a dependable deterrent to erosion, which is what the city of Easton needs (Rhoads and Block, 2002).

The previously present riparian vegetation was not removed because of the presence of Japanese Knotweed, but because of the fear that the retaining wall was damaged. Now that the wall has been repaired planting can commence, and allowing the Japanese Knotweed to grow would do an excellent job of preventing erosion but could endanger the newly repaired wall. The vast root systems and thick groupings—the characteristics that make it an invasive species—can damage concrete structures like retaining walls. If the Japanese Knotweed were permitted to grow, it would have to be controlled so that it would not cause any damage. The solution to
this would be planting at a safe distance from the wall, and if the Japanese Knotweed began to spread, killing the new plants endangering the retaining wall (Rhoads and Block, 2002).

A different alternative other than just planting vegetation could be the placing of erosion control mats (ECM). According to the Natural Resources Conservation Service (NRCS), an erosion control mat is “a protective mulch blanket or soil stabilization mat applied to the top of prepared soil for a surface vulnerable to erosion” (NRCS). The main purpose of these mats is to prevent wind erosion and to help establish vegetation. ECMs are either synthetically or organically made, and appear in many different shapes and sizes. They can be produced to fit specific needs, and can also be made using various material types. There are over one hundred different types of ECMs out there, so there is a ton of variety. Cost also varies throughout the industry. Since there are so many different options, there’s a wide price range. However, this option would be one of the more expensive ones, depending on which mat is chosen. Placing erosion control mats along the riverbank is a possible alternative to the problem of erosion. Different types of vegetation could be planted, fully protecting the soil against wind erosion. The mats would support and help ensure mature vegetation, preventing erosion (Center for Watershed Protection, 2001).

Soil bioengineering is a very interesting policy alternative. Basically soil bioengineering uses living plant materials to build structures to help stabilize a problem site. It is an effective method for treatment of eroding sites. An important thing to think about when choosing your living plant materials is the type. It is important to choose a type of plant familiar to the habitat. This helps support a healthy riparian restoration. A huge positive to soil bioengineering is its feasibility. It only takes relatively untrained workers or volunteers to implement. The diversity of techniques of soil bioengineering allow for an array of problems to be solved. Some different types of techniques of soil bioengineering are: wattle fences, live bank protection, and live palisades (Polster, 2002).
Wattle fences are short retaining walls made of living cuttings. They are most effectively used on banks with over steepening. Wattle fences are best used in moist environments. The walls are able to hold the soil down while allowing the moisture to drain. This is very helpful in improving the soil's stability (Polster, 2002).

Live bank protection is the use of a wattle fence along the waterside of a riverbank. This creates a woody buffer against further erosion. The construction of this wall must be dense enough to prevent further erosional issues to the actual bank. A great benefit of the live bank erosion is once the cuttings from the wattle wall sprout and begin to grow; there is a good protection against erosion from the resulting vegetation (Polster, 2002).

Live palisades are large cottonwood posts placed in trenches adjacent to an eroding system where vegetation has been cleared. A key to this technique is getting the posts into the water table so that it will grow even during dry weather. The cottonwood is able to establish deep roots in the soil, helping prevent further erosion to the bank. It is important to place the cottonwood post 50 meters apart in order to create a dense cylinder of roots, further strengthening the root system. Riparian cottonwoods are one of the most beneficial riparian vegetation when mature (Polster, 2002).

A very promising policy alternative would be the systematic planting of different types of vegetation. One type of vegetation is rarely the answer in a riparian restoration project. As we saw in the section on trees, they are best used with other types of vegetation in a riparian buffer zone. This remains true for all vegetation. It is imperative to choose a range of different species of vegetation in order to achieve stream bank stability. When looking at the riparian buffer zone in restoration, the zone must be split up into different zones with different vegetation. The difference in vegetation allows for different layers of rainfall to hit. As a result, the force at which rainfall hits the ground is much reduced, increasing the effectiveness of the buffer zone. Grasses and reeds and certain types of shrubs are useful in the lowest zone of the riparian buffer area. This is critical since these types of plants are able to bind soil and resist flood flows,
which are critical in these parts of the buffer zone. The next zone should be rich with shrubs and small trees. Not only should shrubs and small trees be planted in this zone but it also important to have an understory of grasses. Near the top of the buffer zone should be larger trees with shrubs or an understory of grasses. Both this zones help create a canopy to reduce rainfall (trees and shrubs) while the fibrous roots provide strong soil reinforcement (Price and Lovett, 2002).

When picking the species for the riparian restoration it is important to look at the factors affecting the plant. The amount of water and light that a species needs or can live with are extremely important when picking the right riparian vegetation. This is why it is common to use plant species native to the area in a riverbank restoration project. This plant species thrive in this environment and will have the best chance of survival. The choice of different types of plant species may be the most effective way in combating bank erosion. (Price and Lovett, 2002)

Not only is it important to pick the right type of plant, but also it is imperative to choose the correct location of where each species is to be planted. Poorly sited plant growth can cause an increase in flow speed thus causing the erosional problem to get worse. Bank vegetation cannot just be planted on the top of the bank but throughout the entire surface of the bank. Another important factor to take into consideration is the steepness of the bank. If it is to step vegetation will not grow as rapidly as desired. This may require battering the soil to get it closer to a 45 degree. This will allow for the vegetation to colonize much more rapidly. Many different factors on picking the location of the vegetation on the bank hill help or hinder the riparian restoration of the riverbank (Price and Lovett, 2002).

Another possible policy alternative that differs greatly from the other options is educating the public on the issue. The other types of alternatives all deal with direct spending on stabilizing the stream bank. However budgets are tight and it will be near impossible to properly
stabilize the bank without the proper funds. A great way to raise funds for solving the issue is to get more people involved. One can question if people even know about the issues an unstable riverbank can have on their city or their home or their business. Some possible solutions are to hold an assembly in local schools and get the younger generation involved. If school kids get interested, their parents will too. Also holding public info sessions on the issue could be critical in making people more aware of the issue. Another way to educate the public and raise funds would to host a community fund raising event like a carnival or a tricky trey where funds will be raised and awareness and interest on the issue will be spread. Any way to get more people interested in the issue is a way to help solve the problem. Without the proper interest in the problem there will not be initiative or funds to stabilize the riverbank.

The above mention policy alternatives are all possible solution to the problem of bank erosion. Each policy has their own benefits and each has their own detriments. The next step is going to be deciding how to weigh the advantages and disadvantages of each policy alternative against each other. The above mentioned policy alternatives all have the capability to combat bank erosion. Most deal with direct spending while one deals with education. The general feeling is that one policy alone will not fully stabilize the river bank. It appears to be that a combination of different alternatives may be the most effective way to rid Easton of its erosional issues. The next 2 steps will determine if that is true. There are many purposed solutions to Easton’s problem with bank erosion.

**Section 3: Policy Evaluative Criteria**

One of the most important steps when choosing a policy alternative is having the correct evaluative criteria. In this paper we will elaborate on the criteria we feel is most important to the issue of bank erosion along the Delaware River in Riverside and Scott parks. As a reminder, our policy alternatives were: plant riparian grasses, plant medium depth root shrubs, plant deep root
shrubs, allow the Japanese knotweed to grow back, use erosion control matting or blankets with and without plants, soil bioengineering, systematic planting of different types of riparian vegetation, and educating the public on the issue. We discussed each of these alternatives in Section 2. It is important for us to evaluate each policy. This means that the evaluative criteria must be chosen. We have picked out the criteria we feel are most critical to the issue of bank erosion. Our evaluative criteria are as follows: Long-term effectiveness, Short-term effectiveness, Efficiency, Administrative feasibility Short-term feasibility, and Social acceptability. Each criterion was chosen because we feel that the policy that best represents all of these criteria will be the best policy solution for the problem of bank erosion.

Long-term effectiveness is an important criterion to look at. If the policy doesn’t fix the problem of bank erosion in the long run then it is not a very effective policy. We came up with some different approaches to deal with bank erosion. A simple question that must be asked when evaluating the different policies is: does this combat bank erosion? If the answer is no, this is not a plausible solution. If the answer is yes, than a follow-up question is needed: If this policy is implemented how long will it be till the problem of bank erosion resurfaces? This question is more related to the long-term effectiveness of the solution. We feel that the long-term effectiveness criterion is one of the more important. For this reason, we are giving it a weight of times 2 multiplier.

Short-term effectiveness is another critical criterion in deciding on which policy alternative is the right alternative for the problem. Short-term effectiveness is a little easier to determine than long-term effectiveness. Again like long-term effectiveness the first question must be: does this combat bank erosion? If it doesn’t this is not an effective solution. If it is than a follow-up questions must be asked to determine how effective it is in the short-term. A question one can ask is: How quickly will the bank erosion be combated? Another question could be: How long will it take to see the results of the policy alternative?
Table 1: This table shows our policy evaluative criteria and the descriptions for each possible score. The criteria are scored on a 1 to 5 scale.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-term effectiveness</td>
<td>If the solution prevents the problem from resurfacing within 1-2 years.</td>
<td>If the solution prevents the problem from resurfacing within 3-4 years.</td>
<td>If the solution prevents the problem from resurfacing within 5-7 years.</td>
<td>If the solution prevents the problem from resurfacing within 7-10 years.</td>
<td>If the solution prevents the problem from resurfacing for more than 10 years.</td>
</tr>
<tr>
<td>Short-term effectiveness</td>
<td>If the solution is able to successfully deal with the problem in more than 1 year of implementation.</td>
<td>If the solution is able to successfully deal with the problem within 6 months of implementation.</td>
<td>If the solution is able to successfully deal with the problem within 3 months of implementation.</td>
<td>If the solution is able to successfully deal with the problem within 1 month of implementation.</td>
<td>If the solution is able to successfully deal with the problem within 1 month of implementation.</td>
</tr>
<tr>
<td>Cost-efficiency</td>
<td>If the solutions cost greatly outweighs the solutions effectiveness (both long-term and short-term).</td>
<td>If the solutions cost and the solutions effectiveness (both long-term and short-term) are about equal.</td>
<td>If the solutions effectiveness (both long-term and short-term) greatly outweighs the solutions cost.</td>
<td>If the solution would be easy for the city to carry out given the complexity, manpower, cost, etc.</td>
<td>If the solution would be very easy for the city to carry out given the complexity, manpower, cost, etc.</td>
</tr>
<tr>
<td>Administrative feasibility</td>
<td>If the solution would be very difficult for the city to carry out due to complexity, manpower, or cost, etc.</td>
<td>If the solution would be conceivable for the city to carry out given the complexity, manpower, cost, etc.</td>
<td>If the solution would be easy for the city to carry out given the complexity, manpower, cost, etc.</td>
<td>If the solution would be very easy for the city to carry out given the complexity, manpower, cost, etc.</td>
<td>If the solution would be very easy for the city to carry out given the complexity, manpower, cost, etc.</td>
</tr>
<tr>
<td>Short-term feasibility (0 or 5 scale)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>The solution will receive a 0 if it can’t be implemented in the winter and will receive a 5 if it can be implemented in the winter.</td>
</tr>
<tr>
<td>Social acceptability</td>
<td>If the public would be very unhappy with the aesthetic value of the solution.</td>
<td>If the public would be unhappy with the aesthetic value of the solution.</td>
<td>If the public would be content with the aesthetic value of the solution.</td>
<td>If the public would be pleased with the aesthetic value of the solution.</td>
<td>If the public would be very pleased with the aesthetic value of the solution.</td>
</tr>
</tbody>
</table>
One of the most important forms of evaluative criterion that must be thought about is cost-efficiency. Everyone is trying to spend as little as possible for the best possible results. Determining exactly how much to spend or not to spend is critical, as it opens up possible spending in different areas. This is one of the most important evaluative criteria because you must determine the amount you want to spend and for results you need. In regards to the alternatives we have put forth, cost will certainly play a part in the decision. Some options are more expensive than others, while others are cheaper. A cheaper option could or couldn’t be an effective enough alternative. The cost is weighed with the effectiveness. For this reason, we have chosen to weight cost-efficiency with a times 2 multiplier.

Easton is not a major city. Because of this, the city’s resources are limited making the administrative feasibility of a potential solution extremely important. Citizens play a vital role in government, especially in city planning. A board of volunteers would review the prospective solution and then pass judgment. If a plan were to be enacted, the city’s Public Works Department would have to be deployed to do the physical work needed. This would include planting the vegetation or installing the erosion protection matting. The city of Easton has a small budget for this project that would be used to pay for the labor and any vegetation. Breakdowns in communication could not occur between the board and the Public Works Department. This whole problem of possible erosion arose from a breakdown in communication so extra effort would be needed to ensure that it does not happen again. The chosen course of action would need to be modest enough that it does not call on resources that are unavailable or tasks that are difficult to complete timely. This criterion will take into account the resources needed for the solution and the resources available to the city of Easton.

As each day passes the weather only gets colder and for this reason actions must be taken quickly if anything is to be planted on the riverbank before it becomes too cold for germination. The erosion of the banks is a major problem that will need to be solved short term, even if the solution is a temporary one. Easton’s Public Works Department is already very busy
with cleaning up the aftermath of hurricane Sandy, so their time is very valuable and the department as a whole needs to manage their time effectively. The area of riverbank that would need work is large and would most likely require a lot of manpower, so a plan would need to be likely to succeed to ensure that resources are not wasted. Specific criteria would need to be used to evaluate each plan to ensure that in the short term (about 3 months) the plan could be fully enacted and result in controlling the riverbank erosion. The question poised concerning short-term feasibility would be: can the solution be implemented in the winter or not?

Another piece of criteria that should be used to evaluate the policy alternatives is social acceptability. Social acceptance is the community supporting the decisions that are made. It’s important to try and strive for this acceptance to know that the community approves. However there will always be at least one person who doesn’t agree. For this reason social acceptance isn’t as important as some of the other criteria. It’s good to get as much support from the city as possible, and while some options may get more than others, overall it’s not the most important criterion for evaluating the alternatives. A huge part of social acceptability is the aesthetic value of the riverbank. A question that can be asked to help evaluate the policy is: does this help make the riverbank aesthetically pleasing?

We will be using a 1-5 scale for all of our criteria (except short-term feasibility which will be scored by a 0 or 5 scale, no or yes). Each value is described for each criterion in the attached table (see Figure 3). As stated before both long-term effectiveness and cost-efficiency will be weighted by a times 2 multiplier due to their especial importance.

By laying out the specific criteria for evaluating the policy alternatives, we have begun the process for making our recommendation for the best policy alternative for the defined problem. The best policy alternative will receive the highest score from the evaluative criteria.
Section 4: Assessing Policy Alternatives

The problem of riverbank erosion along the Delaware River has been made clear by our research in Section 1: Problem Analysis. The next step was brainstorming and researching different alternatives to help solve the problem. These alternatives were discussed in Section 2: Policy Alternatives. For a reminder our alternatives are as follows: plant riparian grasses, plant a mix of medium depth root shrubs and deep root shrubs, plant trees, allow the Japanese knotweed to grow back, use erosion control matting or blankets with and without plants, soil bioengineering, systematic planting of different types of riparian vegetation, and educating the public on the issue. In Section 3: Policy Evaluative Criteria, we discussed the specific criteria we would use to assess our policy alternatives (see Table 1 for more information). Finally, this section will be primarily used to assess each alternative based on the criteria chosen in Section 3. Using our acquired knowledge through our research and general reasoning skills we were able to evaluate each alternative based on the selected criteria. The results can be seen in the attached Table 2. The rest of this section will be an explanation on the scores earned by each policy alternative.
Table 2: This table shows our Policy Alternatives Assessment and the scores given for each of the alternatives. The highest possible score the alternatives could have received is a 40.

<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Long-term effectiveness (x2)</th>
<th>Short-term effectiveness</th>
<th>Cost-Efficiency (x2)</th>
<th>Administrative Feasibility</th>
<th>Short-term Feasibility (0 or 5)</th>
<th>Social Acceptability</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting riparian grasses</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>Planting shrubs</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>27</td>
</tr>
<tr>
<td>Planting trees</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>Letting/Replanting Japanese knotweed</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td>Soil Bioengineering</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>Systematic planting of mixed vegetation</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>32</td>
</tr>
<tr>
<td>Erosion control matting</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>29</td>
</tr>
</tbody>
</table>
The first policy alternative we assessed was the planting of riparian grasses. By referring to Table 2, it is shown that riparian grasses earned a total score of 18. For the long-term effectiveness, we gave planting riparian grasses a 1. We believe that the problem of bank erosion would resurface within 1-2 years of implementation. Even though our research proved in Section 2 that riparian grasses are very helpful to a riparian buffer zone, we believe that in the long-term grass by itself will not be super effective in solving the problem with bank erosion. The grasses root-system will do a sufficient job of holding the sediment in place; however, riparian grasses do not provide any sort of rain cover, and therefore will not be effective in the long-term. In the event of a rain storm, the grasses would be pounded by rain since there is no tree canopy or shrubbery to protect the grass. Also possible is after rainy weather people may walk along the riverbank this sort of traffic may cause the grass to get torn up. Even more concerning than people tearing the grass up, would be extreme weather events tearing the grass up. In the event of a severe storm (such as Hurricane Sandy), the lone riparian grasses would stand little chance of surviving. In the aftermath of the storm, Easton would be left with a bare riverbank, leaving us right back where we started.

For the next criterion (short-term effectiveness), riparian grasses received a score of 4. The riparian grass would be effective in combating bank erosion within 3 months of implementation. Our rationale for this was based of the research done in Section 2. Grass has vast fibrous root-system. These types of roots excel in holding sediment in place. So in the short-term, grass will do a more than adequate job of preventing bank erosion. Another important characteristic of riparian grass is its ability to colonize rapidly. The grass will be able to grow and establish its strong root system within 3 months.

The next criterion that riparian grasses were judged on was cost-efficiency. The score received was a 3. We believe that the cost and benefits are about equal for planting riparian grasses along the riverbank. Our main reasoning behind this is that grass seed is relatively
cheap. Even more important the city of Easton has already invested in grass seed, so no little or no more additional grass seed will need to be purchased. The aspect that is holding the cost-efficiency score down is the fact that the long-term effectiveness of grass is rated so low. Even though the cost of using the grass seed is very low the effectiveness is also very low.

Administrative feasibility was the next criterion to which planting riparian grasses was assessed. It received a score of a 4. This is based off of the generally low complexity and necessity of manpower to perform the task. It does not take very highly trained specialists to lay down grass seed. It also does not take a massive force of workers to accomplish. For these reasons we felt that on the administrative end of things the city would be very capable of implementing the solution.

The final two criteria that were used to assess planting riparian grasses were short-term feasibility and social acceptability. Short-term feasibility is ranked on a 0 or 5 scale. It has a simple yes or no answer to the question: can this solution be applied in the winter? The answer is no. Grass seed would die if implemented in the winter. It is much too cold and dry for the seeds to germinate. Therefore it earned a 0 score. For social acceptability a score of 2 was awarded. This was based on the reasoning that grass by itself would not be too aesthetically pleasing. We feel that the people of Easton would expect more to be done following a huge devegetation of the riverside, than just to plant grass.

The second policy alternative evaluated was the planting of shrubs. As can be seen from Table 2, this policy earned a total of 27 points in our evaluative criteria. This made it one of the more desirable policy alternatives. Planting shrubs was awarded a score of 3 for long-term effectiveness. This score is reflected in the average life expectancy of shrubs. Under this policy, we believe that bank erosion problem will not resurface in at least in 5-7 years. This is less than
the average life-span of 7-10 years for shrubs as we accounted for the worst possible case (TLOYL, 2010).

In terms of short-term effectiveness, shrubs received a score of 4. If properly planted, they are expected to develop new roots and start holding the soil within the first three months. A score of five was not awarded as we believe that even when planted in optimum circumstances, shrubs will at least take a month to grow enough as to establish and expand their roots to have a considerable effect on erosion.

Another criterion in which shrubs are evaluated is cost-efficiency. We assigned them a grade of 3 in this criterion. While shrubs are relatively more efficient than riparian grass (especially in the long run), this is offset by their reasonably more expensive purchasing price and implementation costs. This is the reason behind the same score for these two policy alternative in cost-efficiency. In brief, the costs of planting shrubs are about equal to the benefits this solution brings to the Delaware River bank erosion.

Next, we assessed shrubs in terms of administrative feasibility. Even if planting shrubs is not a very complex task, it is relatively more time consuming than planting riparian grass. Shrubs should be planted with care and specific shrubs might require particular instructions. They do not however necessitate highly-trained skilled workers, but detail-oriented manual labor. Shrubs require maintenance for the first year or two: some shrubs will need protection against the winter, the sun, and the wind; most will require watering in the fall before winter freezes the ground. This is especially important while the weather gets colder and the soil gets drier. In addition, as shrubs grow, pruning is recommended whether to allow more light to enter the canopy or to remove dead or damaged limbs and suckers. All these factors add to the complexity enough for the city of Easton to implement this policy, accounting for the average score of 3 in administrative feasibility criterion (BGGP, 2003).
Moreover, shrubs are reviewed in how feasible they are in the short-term. Assuming that Easton River bank erosion policy will be implemented as early as possible to prevent further complications of the deterioration phenomenon, shrubs are evaluated in their ability to be planted during winter. Although it is recommended to plant them in late summer or early fall so that they can establish their roots before winter freezes the ground, shrubs can indeed be planted any time of the year if the ground is not frozen. Thus, we assigned a score of 5 for short-term feasibility as planting during the winter is possible with the proper precautions.

At last for shrubs, we took into account social acceptability. Unlike grass, shrubs have an aesthetic value and are widely used for ornamental purposes. We believe shrubs on the river bank will be appealing to the eye of locals who will enjoy their aesthetic values. This is the reason for a score of 4.

Besides shrubs, an alternative policy we have considered is the planting of trees. Obviously, trees score a high 4 in long-term effectiveness. Trees have a relatively longer life span. We believe that their strong and long lasting root system will prevent erosion from resurfacing in at least 7-10 years, justifying a score of 4 in long-term effectiveness. Trees however are less effective in the short-term. We believe that they can successfully deal with the problem of erosion within one year of implementation earning a score of 2 for short-term effectiveness. This is a reasonable time for trees to develop enough to hold soil in place and reduce the erosive effects of both wind and water. We kept into account that trees develop relatively slow compared to other alternatives considered thus far.

Trees are more efficient in dealing with erosion in the long term than in the short-term. However, like shrubs, they are relatively costly when their efficiency (especially short-term) is considered relative to riparian grass. Also, trees will require watering and maintenance in early development stages. An assessment of this alternative was done relative to riparian grass and
shrubs. We believe that given trees develop more slowly and affect erosion less in the first few years than in the long run, the associated cost is comparatively higher than the benefits. Hence, we assigned a score of 2 in cost-efficiency.

We also considered the administrative feasibility of planting trees. We believe that carrying out this policy would require significant time and manual labor. As in the case of shrubs, trees do not require highly trained and skilled experts to carry out the planting but labor time is a factor that adds complexity to it and makes trees a difficult to establish policy. Also transportation of living trees can prove costly. This is the reason behind a score of 2 for administrative feasibility.

In terms of short-term feasibility, we assigned a score of 5 for this alternative. This score is determined by whether it is possible to plant trees during winter. According to Virginia Department of Forestry, late winter and earlier spring are optimal times to plant trees, even if they can be successfully planted in the winter of warmer climates. Therefore, it is evident that trees can be planted during winter; hence this alternative scored a 5 in short-term feasibility (Raine, 2008).

We believe that when aesthetically planted in patterns along riverside, trees can provide appreciation natural aesthetic to locals. Indeed, trees can make riverside more beautiful and natural. Also, many trees change color during spring. This provides a beautiful view to locals and visitors of the river. This justifies the score of 4 in social acceptability.

Japanese Knotweed is an invasive species of plant that has a very intricate root system that protrudes from its rhizomes-an underground extension of its stock. The rhizome can extend up to three meters deep and roots can grow off of it up to seven meters horizontally, this entire system firmly cements the plant into the ground. Due to its invasive nature, Japanese Knotweed colonizes close together creating a canopy over the underlying sediment. This
canopy does an excellent job of diminishing the erosive effects of rain by absorbing the each drop and then letting fall to the ground causing little affect to the sediment. By the virtue of being an invasive plant, Japanese Knotweed can thrive in a riparian environment because it is: able to survive cold temperatures, resilience to cutting, and able to quickly re-sprout from its roots. All of these characteristics are great at stopping erosion, but can prove fatal for cement structures like the retaining wall that is present along the Delaware River as it passes through Easton.

Due to Japanese Knotweed’s tremendous erosion prevention potential, we originally gave it a perfect score of five for long-term effectiveness. However the species poses an imminent threat to the retaining wall and without supervision will eventually start to damage it. With only the problem of erosion in mind, Japanese Knotweed is a solution indefinitely. Yet because it will eventually cause damage to the cement retaining wall, we estimated that it would only prevent the problem from resurfacing for seven to ten years. This determination yielded a final score of four out of five.

Japanese Knotweed thrives in the riparian environment because of its flexibility in regards to the conditions it needs to grow. Like all plants it is produced from a seed and acquires nourishment from sunlight and water. However it does not require much water to grow, and a variance in water pH or salinity does not have a major effect on it. All of these features of Japanese Knotweed would allow it to thrive along the bank of the Delaware River, just as it had. But, Japanese Knotweed would need to be planted and then germinate and finally sprout. This would take time, even more for the plant’s rhizome to grow to its full size so that it could effectively combat erosion.

Full size would not be reached within one month especially with variable weather. Within three months the Japanese Knotweed would grow large enough above and below ground to successfully stop erosion. The roots would have had enough time to lock into the sediment and a canopy would develop that would stop erosion caused by rain. Because
Japanese Knotweed would solve the problem within three months, we gave it a score of four out of five.

Japanese Knotweed is generally an unwanted pest native to Japan, for this reason the acquisition of seeds would be relatively easy and cheap. It is very likely that more Japanese Knotweed is growing along the banks in Easton. If the Easton Department of Public Works were to find some plants they could use those seeds to grow the Japanese Knotweed for only the cost of labor. Assuming no seeds could be obtained, the price of seeds is very cheap.

We deemed in the first two criteria that the planting of Japanese Knotweed would be effective in both the short and long-term. The success that Japanese Knotweed would have greatly outweighs the cost the city would incur implementing this solution. The only two costs would be seeds and labor. The seeds would come at almost no cost, and the labor would be less expensive than other solutions because the planting of seeds is fairly simple.

The inherent problem with the planting of Japanese Knotweed is the fact that eventually it will begin to damage the retaining wall if not constantly monitored. All of the characteristics that make Japanese Knotweed a great candidate for erosion control also make it a danger to cement structures. The Japanese Knotweed was initially eradicated because the City of Easton feared it was damaging the existing retaining wall. To ensure that this will not happen, the city would have to spray pesticides near the wall monthly to ensure this. Because of this added “hidden” cost in the plan and the corresponding man-hours that would be needed, the city would be forced to allocate more of its already scarce time. This was the justification behind giving this solution a two out of five in regards to administrative feasibility.

Given the time frame for the City of Easton to take action, the Japanese Knotweed would have to be planted during the winter. For the category of short-term feasibility we decided that solutions should be judged as either yes or no, and be scored accordingly. Because Japanese Knotweed would need to be planted and then time would be needed to allow the seeds to germinate and then sprout. Unfortunately the seeds would not be able to
germinate and then grow during the winter. For this reason this solution received a grade of zero out of five.

The City of Easton has already removed Japanese Knotweed once, if they were to replant it, citizens would most likely be unhappy. The City of Easton cannot afford to waste money and anything that looks like waste to citizens will make them unhappy. Aesthetically Japanese Knotweed may look unkempt and will most likely start to climb the retaining wall. For this reason we gave the solution of planting Japanese

While assessing the alternative of placing erosion control blankets along the riverbank, through Table 2 it is seen that this alternative earned a total score of 28. While evaluating, we first looked at the criterion of long-term effectiveness, and gave this a 2. With the placement of erosion control blankets (ECB), this alternative can combat bank erosion and last for a somewhat long time. However, by themselves a life span of over 5 years seems improbable. Depending on the mat chosen, our group thinks that the mats will last anywhere from a couple months to 3 years, which is why we gave it a long-term effectiveness score of 2.

For the criterion of short-term effectiveness, the score received was a 5. ECBs can be placed on the riverbank immediately, and will fight against erosion within the month. Therefore the score received is a 5.

The next criterion judged by our group was cost efficiency. Our group decided that the placement of ECBs would receive a score of 4. Although this option is somewhat costly, we all thought that the effectiveness was worth the price. The city of Easton already has erosion control blankets for the riverbank, and if they are taken care of and receive regular maintenance, they will be very efficient for the future.

Administrative feasibility was the next criterion looked at, which our group scored a 4. We judged that carrying out the task of placing these mats along the riverbank would be easy to
carry out. It seems as if blankets have already been placed, and that Easton has the manpower to do so. If this somehow wouldn’t be an option anymore, trained professionals could come in and install ECBs for a relatively low cost. According to the Environmental Protection Agency, the installed cost of ECBs ranges from $6 to $18 per square meter depending on the type of ECB material required, site conditions, and installation-specific factors (EPA, 1992). Even though ECBs have already been laid down, we would assume the costs would be similar.

For short-term feasibility and social acceptability, our final two criterions, we gave the placement of ECBs a score of 5 and 2 respectively. For short-term feasibility, this alternative received a score of 5, because it is clearly possible to place these mats in the winter. For social acceptability, our group determined that a score of 2 was fair. Depending on the erosion control blanket placed along the riverbank, the attractiveness could vary. However most blankets aren’t very attractive, most being made from biodegradable substances such as straw or wood fibers. From this our group concluded that the public wouldn’t be very pleased with the aesthetic value of this solution, therefore gave it a score of 2.

The next policy alternative we assessed was soil bioengineering. The total score awarded to this alternative was 21. The first criterion used was long-term effectiveness. Soil bioengineering received a 3 for its long-term effectiveness score. Based off of our knowledge and research from Section 2, we believe that soil bioengineering would do a solid job in preventing erosion and the problem would probably not resurface for 5-7 years. Basically depending on the type of soli bioengineering used, there would be different results in long-term effectiveness. The best most commonly used technique is the use of wattle fences. These are basically a retaining wall made out of live plant materials. If placed in the proper location along the bank, trees could sprout up and provide additional root-reinforcement. However since there would not be a systematic planting of vegetation the vegetation would be spotty and may need additional work in the future.
For the short-term effectiveness score, soil bioengineering received a 3. We believe that the structures could be constructed and begin combating erosion within 6 months. Taking into account the amount of resources Easton has it would probably take more than 3 months to gather materials, plan, and construct the necessary structures. However it would not take more than 6 months. This would take a significant workforce to complete, and that will be reflected in the cost-efficiency and administrative feasibility criteria.

For the cost-efficiency criterion, soil bioengineering received a score of 2. The cost of acquiring the living plant materials needed is relatively low (WSDOT, 2001). However the cost of labor would be relatively expensive. This sort of project would take multiple months and require a sizable work force. Without the use of volunteers (which is possible since it only requires relatively trained workers), the cost would be pushed into the relatively expensive category. With an average effectiveness score, soil bioengineering has a lower cost-efficiency score.

Soil bioengineering received a score of 1 for the administrative feasibility criterion. It would be very difficult for the city of Easton to carry out this alternative. Soil bioengineering is relatively complex and would need to be planned out correctly in order to be effective. Also working against soil bioengineering is the manpower it would take to implement the project. The number needed would definitely exceed the number at hand currently for the city. Taking into account both the complexity of planning a project and the necessary work force, soil bioengineering scores low in administrative feasibility.

The final two criteria used to assess soil bioengineering were short-term feasibility and social acceptability. Soil bioengineering would be able to be applied during the cold months. Therefore it received a 5 for its short-term feasibility. As for social acceptability, it received a 1. The aesthetical value of a wattle fence is low. They just look like wooden walls. The public is expecting an improvement in the aesthetical value that the wattle fences don’t bring.
The next alternative we assessed was the systematic planting of mixed vegetation. This was our projected best alternative going into our research. Following our research, this remained the same; this alternative earned the highest score of 32 during its assessment. For the long-term effectiveness score, systematic planting received a score of 5. We believe that systematically planting a mix of vegetation will be super effective in combating bank erosion. The problem is likely not to resurface for more than 10 years. Based off of our research form Section 2, each type of vegetation had its benefits in combating erosion. Trees allowed for excellent wind, rain, and sun coverage, while also giving some important root-reinforcement. Shrubs also helped with wind, rain, and sun coverage, while having a better root-system for combating erosion. Grass has the best root system for preventing erosion, but has no coverage for wind or rain; two major factors of erosion (see Section 1). Separating the vegetation into 3 different zones will have the best, longest effect on preventing erosion. By utilizing multiple types of vegetation, the riparian buffer has the strengths of each vegetation, providing the most long-term effective solution.

For the next criterion of short-term effectiveness, systematic planting earned a score of 4. According to our research, systematic planting would begin combating erosion within 3 months of implementation. This is mainly due to the fact that trees, shrubs, and grass will be planted. Grass is able to establish a strong fibrous root system very quickly due to its ability to colonize rapidly. Shrubs are also able to establish their root system relatively quick. With the grass and shrubs’ root systems in place, the sediment will be held in place, preventing erosion.

The score received by systematic planting for cost-efficiency was a 3. We believe that the cost of implementing the solution is approximately equivalent to the effectiveness of the solution. The cost of acquiring and transporting the vegetation would be somewhat expensive. However the cost of grass seed would be little to none since the city of Easton has already purchased grass seed. The labor needed to complete this task would be an average sized work
force, thus resulting in an average cost. Working in the favor of the seemingly expensive
solution is the fact that it is the most effective solution. This balances out the expensive aspect
giving systematic planting an average cost-efficiency score.

For the next criterion (administrative feasibility), systematic planting received a score of
2. We feel that this alternative would be somewhat difficult for the city of Easton to implement.
The planting of the vegetation would have to be planned out sufficiently. This would take some
knowledge on the strengths and weaknesses of each plant. This adds to the complexity of the
solution. Also a decently sized work force would be needed in order to implement the plan. They
would need minimal instruction on how to correctly plant the vegetation, but would not need to
be highly trained. Given the complexity and the size of the work force needed, systematic
planting earned a lower administrative feasibility score.

The final two criteria used to assess systematic planting were short-term feasibility and
social acceptability. Systematic planting could be partially implemented in the winter therefore it
received a score of 5. The shrubs and trees could be planted given the correct technique. The
social acceptability score was a 5. Systematically planting different types of vegetation would be
very aesthetically pleasing. The vegetation would be planted in a neat organized manner that
would look beautiful along the side of the riverbank. The public would definitely appreciate the
beauty of an organized riparian buffer. It certainly would be an upgrade from a bare bank or the
previously jumbled vegetation.

Educating the public was our final policy alternative. This alternative would not solve the
problem of riverbank erosion directly. What this alternative would accomplish would be raising
awareness to the public in order to gather interest. The more people the city can get interested
in the problem the more likely the citizens will be willing to help with the solution. The way that
any concerned citizen can help is to donate to help the city gather the necessary supplies and
equipment needed to implement the alternative. Also concerned citizen can volunteer to help Public Works with whatever they need. This could involve planting shrubs or laying down matting. It is crucial to get the public involved when resources are thin.

To review the results of our assessment please refer to table 2. The policy alternative with the top score was the systematic planting of mixed vegetation. This policy alternative received a 32. The next policy alternative was planting shrubs which received a 28. And the third policy alternative was the erosion control matting which received a 26. Our assessment has helped us better understand which policy alternative best will deal with the problem. In our next section we will make our formal recommendation as what is the proper action to take to combat the riverbank erosion.

Section 5: Making the Recommendation

Looking back at sections 1-4, we have defined the problem of riverbank erosion, formulated possible solutions, set up evaluative criteria, and assessed our solutions based off of our criteria. This section will deal with our final recommendation. By understanding the problem thoroughly and looking at our research and our policy assessments, we have decided to go with a mix of our policy solutions. Our overall thought is that it is smart to lay down erosion control matting to the problem site as soon as possible. This will help combat erosion during the cold winter months. Then we will begin implementation of our highest scoring policy alternative, systematic planting of mixed vegetation.

Our group thinks that the best option towards combating erosion in the short term is placing erosion control mats along the riverbank. In our opinion, these mats are the best immediate solution. They effectively prevent wind erosion while also enabling vegetation to be established. One important positive of this alternative is it’s short-term feasibility and effectiveness. While seeking a solution for this problem, it’s hard since some options are not
possible due to the harsh weather conditions. Erosion control mats can be placed in these cold weather conditions and still be perfectly effective. Our group knows that the city of Easton has already placed mats along the river which is good, but more still needs to be done.

Erosion control matting alone will not be enough to effectively protect Easton’s bank of the Delaware River from erosion. For this reason we recommend that the city plants some trees and shrubs before the weather gets too cold. It would not be necessary for all of the trees and shrubs to be planted now, but around half would need to be to ensure proper protection. This can be done in the winter months as long as certain precautions are taken. The most important of these would be to constantly water the roots so that the trees and shrubs can adapt to the cold and dry soil (Peterson, 2012).

Our solution of the systematic planting of mixed vegetation relies on zones to dictate the placement of the vegetation. The first zone, which is located closest to the water, would contain riparian grasses and certain types of shrubs. This zone begins the buffer zone and its location calls for types of plants that are able to bind soil and resist flood flows. The next zone needs to be rich with shrubs and small trees, augmented by an understory of riparian grasses. The top zone should be larger trees with shrubs or a continued understory of riparian grasses (Price and Lovett, 2002). Because the initial planting would have to occur during the winter months where successful growth will only occur with special care, it would be the most cost effective to only plant what is necessary. This is our justification for only recommending the planting of the vegetation that would be in zone two.

Our Recommendation for the type of shrubs that should be planted is the Black Chokeberry bush. The shrub itself is fairly small so the transportation and planting would not be difficult. Due to its manageable size, less people would be needed to plant the Black Chokeberry bushes, saving the city money. Black Chokeberry can thrive in the riparian environment of the Delaware River and does not require much sunlight to grow so it can be planted alongside trees. The best feature is that its roots are sturdy enough to hold the
sediment in place even during flooding. The ability of Black Chokeberry to: combat erosion, grow with trees present, and not require much work to plant them, makes them the best option for riparian restoration (PDOS).

We would recommend that the City of Easton plant Smooth Alder trees. It is the perfect fit aesthetically because it is small enough that it will not block the view of the river, and it is a generally attractive tree. Once again we chose a tree that was small enough that it would only require a few people to do the planting. This tree also would thrive in the riparian environment of the Delaware River in Easton. Smooth Alder trees are very tolerant to flooding and create a large enough canopy to protect the sediment from rainfall. All of these characteristics make the Smooth Alder tree an exceptional choice (PDOS).

Once the winter ends and the weather is conducive to planting, all of the riparian buffer zone would be populated with the riparian vegetation. Zone one would have grass planted throughout the entire zone because its small roots do a quick job of reinforcing the soil in the zone, and also help reduce channel widening (Carline and Walsh, 2007). Riparian grass can even improve the water quality of the river, which is an added bonus of planting in zone one at the water level. Riparian grass would also be planted in zones two and three. This would complete the restoration process for zones one and two. Zone three would receive many Smooth Alder trees and some Black Chokeberry shrubs. Once these zones are populated by mature vegetation, the banks will no longer have a problem with erosion.

Through the systematic planting of mixed vegetation not only is the erosion problem solved, but also are the problems of aesthetic beauty, and the wall would not be in danger of being damaged. Systematic planting was the most aesthetically pleasing of the policy alternatives that we evaluated. Of all of the policy alternatives that we came up with, this option offers the most safety to the retaining wall, granted comparable to other plans, but its ability to deter erosion is far greater, as its evaluated score proves.
With our recommendation of laying down erosion control matting in the winter and planting systematically in the spring, the problem of riverbank erosion along the Delaware River in Scott and Riverside Parks will be solved for the short and long term. We will see a natural and beautiful riparian buffer that will combat erosion for the foreseeable future.
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