Recommended Funding and Retrofits for Stormwater Management of the Hart Brook Watershed in Lewiston, ME

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Recommended Funding and Retrofits for Stormwater Management
of the Hart Brook Watershed in Lewiston, Maine

Community-Engaged Research in Environmental Studies
Bates College

Written by:
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Amy Wyeth

December 12th, 2013
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...for contributing valuable insight and guidance, without which this report would not have been possible.
Executive Summary

The Hart Brook watershed is 3.3 square miles and drains into the Androscoggin River. In 2002, the EPA determined Hart Brook to be an impaired watershed. Accordingly, the city of Lewiston is required by the Clean Water Act to improve the water quality of Hart Brook so that it meets the class B standards laid out by the Maine Water Classification Program. In order to meet these standards, the city of Lewiston will need to fund and implement stormwater retrofits throughout the watershed. This report provides the realistic funding options to implement these retrofits in Lewiston. Additionally, we provide specific retrofits that we recommend as the best options based on cost, effectiveness, and location within the watershed. From our research we deduced that funding for the retrofits should come from the CIP (Capital Improvement Program). Currently, a significant portion of this money is going to the CSO (combined sewage overflow) project, although it is projected to end in 2015. Once this project is over, a significant amount of funding could become available for the Hart Brook Watershed Management Plan. Once this funding is available, we recommend the implementation of bioretention retrofits in both the industrial and residential communities. Additionally, in industrial areas with large areas of impervious surfaces and pollution we recommend permeable pavement, and where this is not feasible, sand filters. Finally, in Lewiston owned land downstream on Hart Brook just before the DEP sample site, we recommend a constructed wetland that would treat a large volume of water for pollutants before reaching the Androscoggin.
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1. Introduction

Regardless of location, rivers and streams in the United States (and worldwide) are inundated with pollution from a variety of sources. Specifically to this project, pollution from impervious surfaces and stormwater runoff contribute significant levels of pollution into the Hart Brook, and ultimately the Androscoggin River. Stormwater is rain or snowmelt that comes off of impervious surfaces and ultimately runs into bodies of water. During this process, stormwater runoff collects various types of materials such as sand, fertilizers, oils and refuse, contributing largely to the levels of pollution in various watersheds that absorb this runoff (USEPA 1995).

The pollution caused by stormwater runoff is particularly prominent in urbanized areas with high levels of impervious surfaces. Impervious surfaces are areas comprising of materials that reduce permeability to water including asphalt, gravel and concrete. Urbanized areas contain many impervious surfaces such as residential buildings, industrial areas, complex road networks and parking lots. Within the context of stormwater management, impervious surfaces greatly increase the volume of stormwater runoff due to their impermeability. Additionally, they increase the pollution and sediment load that gets carried into bodies of water, such as the Hart Brook, because they collect on these surfaces. Other impervious surfaces, non-related to man-made materials, can include soils characterized with high nutrient saturation, high clay content or frozen textures (Barnes et al. 2002). In addition to producing a large volume of stormwater runoff, impervious surfaces also prevent the absorption of precipitation into the soil, where it is naturally filtered by sediments and roots, greatly helping to remove pollutants from the watershed.
To alleviate the pollution of bodies of water from untreated stormwater, best management practices (BMPs) can be implemented within the watershed. These BMPs encompass a wide array of stormwater retrofits. Retrofits can include modifying, upgrading and creating infrastructures that treat stormwater before it enters a body of water. Some examples of retrofits are bioretention, filtration systems and wetland areas, which all act in different ways to both slow
the flow of water and filter sediment and pollution from the stormwater before it drains into the closest body of water.

One example of a body of water polluted by stormwater runoff is the Hart Brook, a tributary stream to the Androscoggin River, located in Lewiston, ME. The small brook has a watershed that covers 3.3 square miles beginning in a heavily industrialized area, moving into residential and a less industrialized area before it finally empties into the Androscoggin River. As the brook moves downstream within the watershed, pollution accumulates from stormwater runoff from the large impervious surface areas within the watershed. Over 22% of the watershed itself contains impervious surfaces, contributing to its classification as an impaired watershed (Woodard and Curran 2007).

Hart Brook is a Class B watershed according to the qualifications set by the Maine Water Classification Program, which are based on the use of the water along with the water quality standards set by the state (Maine Revised Statuts 2012). While each state has different standards and uses different methods to classify watersheds, all states are required by the Clean Water Act to meet these set standards. In 2002, the Environmental Protection Agency declared Hart Brook an impaired watershed due to the fact that it did not meet any of the Class B water standards set by the state of Maine (City of Lewiston 2008). Even worse, in 2003 Hart Brook was classified as “not-attaining” meaning that not only did the brook not meet the Class B standards, but it didn’t meet the standards of class A, B, or C (TMDL Assessment Summary). The table below is from last years report on Hart Brook and compares the water quality of Hart Brook to the water quality required by the Class B standards. Briefly, Hart Brook has low concentrations of dissolved oxygen, high levels of sedimentation and E. coli, and pollution levels that hinder aquatic life (Kim et al. 2012).
Table 1. Table showing the Class B standards as qualified by the Maine Water Classification Program compared with the current standards of Hart Brook (Kim et al. 2012).

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Class B Standards</th>
<th>“Hart Brook Watershed Management Plan” Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved Oxygen</td>
<td>&gt; 7 ppm; 75% saturation</td>
<td>Sometimes &gt; 7 ppm, but more often &lt; 7 ppm</td>
</tr>
<tr>
<td>Habitat Criteria</td>
<td>Unimpaired</td>
<td>Observations of sedimentation</td>
</tr>
<tr>
<td>Aquatic Life Criteria</td>
<td>Discharges should not cause adverse impact to aquatic life. The receiving waters</td>
<td>Aquatic life population issues</td>
</tr>
<tr>
<td></td>
<td>should be able to support all indigenous aquatic species without detrimental</td>
<td></td>
</tr>
<tr>
<td></td>
<td>changes to the existing ecosystem.</td>
<td></td>
</tr>
<tr>
<td><em>E. coli</em> Bacteria Levels</td>
<td>Between May 15th and Sept. 30th: <em>E. coli</em> should not exceed an instantaneous</td>
<td><em>E. coli</em> average level of 330 mpr/100mL</td>
</tr>
<tr>
<td></td>
<td>level of 236/100mL and an average level of 64/100mL</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. A graph showing the levels of Chloride and Sulphate at three sites in the Hart Brook indicating salt from roads is reaching Hart Brook (Kim et al. 2012).

In order to comply with the Clean Water Act, the city of Lewiston is mandated to increase the quality of the stream. This can be achieved through the implementation of stormwater Best Management Practices, or BMPs, which provide an array of solutions to
decrease stormwater pollution from impervious surfaces. In particular, stormwater retrofits are needed on the Hart Brook to slow down the volume of stormwater entering the brook and minimize the influx of pollutants contributing to its listing as an impaired watershed. Different retrofits vary in their efficiencies and the locations where they are the most effective. This report contains recommended retrofits for Hart Brook in subsequent sections based on research.

As implementing these retrofits can be expensive, a Compensation Fee Utilization Plan (CFUP) is required for all impaired watersheds by the Maine DEP to help fund the necessary retrofits (Maine DEP 2011). The CFUP for Hart Brook was implemented in 2007 and requires new developments to pay a fee for every acre of impervious surface that they intend to construct. The money collected from Hart Brook’s CFUP is to be used exclusively for funding stormwater BMPs, such as the installation of stormwater retrofits, within the Hart Brook watershed. Unfortunately, the Hart Brook CFUP is highly ineffective and has only raised $3,340 since 2007, which is not even enough to fund the least expensive stormwater retrofits (Kim et al. 2012). Alternative funding strategies will be discussed in detail in the results section.

The purpose of this report is to call attention to the fact the Lewiston is required by the Clean Water Act to restore Hart Brook so that it meets the Class B standards set by the Maine Water Classification Program. Restoring the watershed requires the implementation of stormwater retrofits that will treat stormwater runoff before it reaches Hart Brook and, ultimately, the Androscoggin River. Based off of our research, we will propose specific retrofits and general locations that we think will be the most effective and cost efficient along with the most realistic ways to fund these retrofits to the city of Lewiston.
2. Methodological Approach

To provide recommendations for funding strategies and specific retrofits for stormwater management, we reviewed a wide range of academic literature as well as identified case studies to supplement our decisions. We began by researching the economics of stormwater retrofits—specifically the structures used to fund these practices—and related these figures to potential funding opportunities within the city of Lewiston. By compiling cost estimates from other cities that have also implemented stormwater retrofits and comparing these to estimates by the EPA, we came up with estimates of the cost of implementation. We then met with Justin Early (project engineer for the city of Lewiston) and David Hediger (city planner in Lewiston). Both informed us about the most realistic sources of funding within Lewiston and how much money these funds would likely be able to contribute (see supplemental methods for a more detailed explanation of the funding options we researched and later ruled out). With a more informed background of the economic aspect of implementing stormwater retrofits, we continued our research looking at a variety of different retrofits available for stormwater management. We did this by looking at reviews from case studies and scientific literature that directly tested the effectiveness of different retrofits as well as the best locations to place these retrofits. In order to make sure that the retrofits we researched were relevant within the context of Lewiston, we focused on case studies that were primarily located in highly developed cities with similar amounts of available space.

3. Results and Discussion

3.1 Funding Options

From our research, we recommend that the most realistic way to fund stormwater retrofits within the Hart Brook watershed is through capitalizing on the completion of the CSO
(Combined Sewer Overflow), which is projected to end in 2015. The CSO project is focused on separating sewer and stormwater pipeline systems to enhance their efficiency. Currently, around $2 million is going into the CSO program annually and ideally, once the CSO program is complete, this money can go toward retrofits for the Hart Brook watershed (Maine DEP 2012). The CSO is funded by the Capital Improvement Program (CIP), which in turn is funded by sewer fees and the stormwater utility taxes. In order to receive funding from the CIP, proposals must be presented and subsequently approved. If specific retrofit proposals within the Hart Brook watershed are approved, the city of Lewiston (through the CIP) will contribute further to the Hart Brook Watershed Management Plan. Currently this plan has been getting $100,000 per year, which supplemented with funding from the CIP that is currently going toward the CSO, would be able to fund the implementation and revamping of stormwater retrofits within the Hart Brook watershed (City of Lewiston 2012).

3.2 Summary of Recommended Retrofits

<table>
<thead>
<tr>
<th>Retrofit</th>
<th>Advantage</th>
<th>Recommended location</th>
<th>Cost Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioretention</td>
<td>-Inexpensive relative to large volume of water treated</td>
<td>-Both industrial and residential</td>
<td>$6,500 per bioretention area (37 m$^2$ or .01 acres (typically))</td>
</tr>
<tr>
<td></td>
<td>-Prevents flooding</td>
<td>-Next to parking lots, roads, or other impervious surfaces</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Aesthetically pleasing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constructed wetland</td>
<td>-Treats a large volume of water before it reaches the Androscoggin</td>
<td>-Downstream of Hart Brook just before DEP sampling site</td>
<td>-$26,000 per acre</td>
</tr>
<tr>
<td></td>
<td>-Improves overall health of the area</td>
<td>-Lewiston owned property</td>
<td>-$520 per year (upkeep)</td>
</tr>
<tr>
<td>Permeable pavement</td>
<td>-Stores large volume of water and can recharge local aquifers</td>
<td>-Industrial area in replace of parking lots and other large impervious surfaces</td>
<td>-$41,000 per system</td>
</tr>
<tr>
<td></td>
<td>-Effectively removes toxins</td>
<td></td>
<td>-$200 per acre per year (upkeep)</td>
</tr>
<tr>
<td>Sand filters</td>
<td>-Very effectively removes toxins from water</td>
<td>-Industrial area particularly near “hot spots”</td>
<td>$18,500 per acre</td>
</tr>
<tr>
<td></td>
<td>-Relatively inexpensive</td>
<td>-Along parking lots and other large areas of impervious surface</td>
<td></td>
</tr>
</tbody>
</table>
3.3 Bioretention

The first retrofit we recommend is bioretention. Bioretention is a natural way in which sedimentation, chemicals, and bacteria are removed from stormwater runoff. Bioretention units consist of a soil bed, trees, and other plants, which naturally filter out sedimentation and pollutants through processes including evapotranspiration, infiltration and microbial decomposition (Bitter and Bowers 1994). The filtered water is either carried into an underground drainage system or it enters subsoil layers and reenters the respective watershed, in this case, the Hart Brook watershed. In addition to removing pollutants from stormwater runoff, bioretention systems can also be used to reduce peak runoff flows, effectively reducing flooding potential (New Jersey 2009). Bioretention units are generally used in areas with as it provides an angle to direct water into the system; typically slopes 20% or lower are ideal. Bioretention systems can be used in both residential and industrial areas and are functional throughout most seasonal periods (DeBusk et al. 2010). We therefore recommend this retrofit for spaces next to parking lots in industrial areas as well as alongside roads in residential areas. Bioretention systems result in a reduction in the volume of stormwater runoff from 40%-97% and remove on average 50% of total suspended solids (Ahiablame et al. 2012; Luell et al. 2011). Economically and physically, bioretention is very feasible as it offers limited environmental impact and also provides aesthetic value. Cost analyses for this retrofit are mostly construction costs. Costs can potentially increase depending on how much reconstruction is needed near parking lots or in residential areas to create the correct slope for the bioretention system. We found the average cost of a bioretention system to be around $6,500 (USEPA Bioretention 1999).
3.4 Constructed Wetland

We also recommend a constructed wetland for the Hart Brook watershed. Similarly to bioretention, wetlands have been recognized for their ability to remove pollutants in a natural way (USEPA Constructed Wetland 1999). There are two different types of constructed wetlands. The first is called a subsurface flow constructed wetland, and treats stormwater by filtering it through a constructed rock or gravel system underground. The second type is free water surface constructed wetlands, which filter stormwater through the soil with planted vegetation. We are recommending the latter be used because it is less expensive to maintain. Additionally, free water surface constructed wetlands offer aesthetic value, increase vegetative and wildlife diversity, and greatly reduce downstream flooding potential (USEPA Constructed Wetland 1999).

Stormwater wetlands have limited applicability in very urbanized settings due to space restrictions, so for this reason, we recommend this retrofit be placed in the land owned by Lewiston, on 141 Goddard Street in the downstream portion of the watershed that is less developed. As this location is situated downstream, it has the ability to treat water that has collected from the entire watershed before it enters the Androscoggin River. Habitat quality downstream is also improved as the reductions in suspended solids prevent the erosion of banks (USEPA Constructed Wetland 1999). The performance of constructed wetlands is very efficient. It has been found that total suspended solids are removed at a rate of 67%. As the vegetation within constructed wetlands continue to grow, the removal rates of pollutants proportionally increases (USEPA Constructed Wetland 1999). The cost analyses for this retrofit generally include design, construction and maintenance. Granted that this will vary widely depending on state and local permits, the average total cost of this retrofit is $26,000 per acre with an estimated yearly maintenance cost of $520.
3.5 Permeable Pavement

In addition to bioretention systems and constructed wetlands, another retrofit that we recommend for the city of Lewiston is permeable pavement. Permeable pavement is made of a porous material that allows stormwater to be absorbed into the pavement as opposed to running off impervious surfaces in large volumes. In addition to this, permeable pavement can temporarily store absorbed water and allow for the slow infiltration of the stormwater into the subsoil, where it is naturally filtered before reaching the watershed (Ahiablame 2012). Permeable pavement is found to be an effective retrofit in a review done by Ahiablame (2012) because it is efficient at both storing and slowing water flow, and reducing the pollution load of the water when it leaves the retrofit. On average, permeable pavement captures 75-93% of stormwater. It collects almost all runoff, however during intense rainfall events, the retrofit can be filled and excess rain will become stormwater runoff (Ahiablame 2012). While there is a wide range in the literature on the average reduction of total suspended solids (TSS) from stormwater, the minimum percentage of TSS removed from the watershed was 58% while the maximum was 94%. In addition to this 94% to 99% of Copper (Cu), Iron (Pb) and Zinc (Zn) were removed from waters captured by permeable pavement. Another large advantage of permeable pavement is it acts to remove grease as well as bacteria, such as E. coli (which was determined to be a problem within Hart Brook) from the watershed (Ahiablame 2012). We recommend permeable pavement for industrial areas where bioretention is not an option due to reasons such as grading, utility, infrastructure, or spatial restraints. Permeable pavement is also limited by grade however, and cannot be built on a slope greater than 0.5 percent (DeBusk 2010). A cost estimate for the total permeable pavement system is $41,000. In addition to this, permeable pavement requires
yearly vacuum cleaning and high-pressure washing in order to remain effective, which is an additional $200/acre/year (EPA Permeable Pavement 1999).

3.6 Sand Filters

While permeable pavement is found to be an effective retrofit, a majority of the land within industrial Lewiston is already developed, and permeable pavement is only a feasible option if a parking lot or other impervious surface is being rebuilt or there is new construction. This seems unlikely to us due to the minimal funds the Compensation Fee Utilization Plan (CFUP) has brought in since it was started in 2007 as a result of no new development. For this reason, in areas of already developed industry, we recommend sand filters where we would normally recommend permeable pavement. Sand filters are slightly less effective because they are not capable of storing and treating large of volumes of water like permeable pavements (DeBusk 2010). However, for the volume of water that sand filters do treat, they are about as effective or more effective than permeable pavement. Sand filters remove 60-75% of organic matter and virtually 100% of many heavy metals, bacteria, viruses and fecal matter (Gottinger 2011). For this reason, sand filters are particularly useful in “hot spots,” or areas that produce high levels of waste and pollution and are vulnerable to spills or leaks (Schueler et al. 2007). We recommend that sand filters be implemented in developed industrial areas of Lewiston that produce high levels of waste and next to parking lots or roadways. Another advantage of sand filters over permeable pavement is that is cheaper to install with an estimated initial cost of $18,500/acre of impervious surface (EPA Sand Filters 1999).
4. Outcomes, Implication, and Next Steps

With the conclusion of the Combined Sewer Overflow (CSO) program in the next couple of years, funds will become available for the Capital Improvement Program (CIP), which is a realistic source of funding for stormwater retrofits within the Hart Brook watershed. Due to the fact that Hart Brook is an impaired watershed and Lewiston is required by the EPA to improve the quality of the water, it is likely that the Hart Brook Watershed Management Plan will receive the necessary funding to implement these retrofits. With this funding, we recommend four specific retrofits for the city of Lewiston. First, we recommend bioretention systems in both the industrial and residential areas. We also recommend permeable pavement, or sand filters where more practical, in industrial areas to replace or surround large areas of impervious surfaces. Finally, Lewiston owned land downstream, near the DEP sampling site, would make a very good location for a constructed wetland. These retrofits are both economically feasible after the conclusion of CSO, and are found to effectively treat water for sedimentation and other pollutants thereby greatly improving the water quality of Hart Brook.

This being said, it is important to think about other additional steps that can be taken to improve the water quality of Hart Brook. Community outreach to industries and residential areas is a very important next step needed for effective stormwater management. Another potential partner that could aid in implementing retrofits and community outreach is the University of Southern Maine for they contain a large area of impervious surfaces. Addressing these individual stakeholders will help address the root of the problem, ensuring that they understand the issues around stormwater runoff and what they can do to reduce it. We learned that the development of new industrial infrastructure, a threshold area must be reached before they can be asked to pay a
stormwater fee. A challenge that can be explored here is identifying how to approach industries and work with them to fund and implement retrofits on or alongside their land.

With respect to residential outreach, it is very essential to educate the general public on the positive effects of stormwater management and how they can individually contribute to this. An example of this would be to encourage residents within the watershed to plant more shrubs and other plants on their property along impervious surfaces, effectively creating bioretention sites that will absorb runoff coming off their property.
6. References Cited:


Department of Chemistry-University of Georgia. "Treatment of Agricultural Waste by use of Constructed Reed-bed Wetlands." (2003). Received from website: http://pgoforth.myweb.uga.edu/


5. Appendices

5.1 Literature Review

5.1.1. Stormwater, Impervious Surfaces, and BMPs

As the world population continues to grow and urbanize, increasingly larger amounts of land are being transformed into built environments. This transformation of land for human purposes has various consequences for adjacent environments and eco-systems, including the increase in impervious surfaces such as parking lots, roofs, and roads. According to the United States Environmental Protection Agency, there are numerous problems associated with stormwater runoff and impervious surfaces in watersheds. Most notably, stormwater runoff is increased by impervious surfaces and consequently alters natural peak flows of streams, alters stream velocity, introduces additional pollutants to streams, increases sediment loads and increases temperatures of streams (USEPA 1995). Each of these disturbances caused by stormwater runoff affects rivers and streams in various ways. Alteration of natural peak flows of streams has negative impacts on stream ecosystems. During a storm event, the stream runs abnormally high as impervious surfaces allow for large quantities of water to flow immediately into the stream. Conversely, stream flows run abnormally low between storms, as there is a lower rate of discharge from the groundwater into the stream (Kim et al. 2012). Both high and low flow rates affect the streams velocity, which negatively affects the streams ecosystem. Low flow rates can lead to decreased levels of dissolved oxygen through the increase of stream temperatures. Additionally, high flow rates can cause erosion of streambeds and increase turbidity (Ibid.). Collectively, the disturbances from increased stormwater runoff can significantly alter aquatic life.
In order to address the numerous disturbances that are caused by stormwater runoff in urban areas with high levels of impervious surfaces, best management practices (BMPs) must be implemented. As approximately 22% of the Hart Brook Watershed consists of impervious surfaces, BMPs are needed to address the stormwater runoff problems that originate from these impervious surfaces (Woodard and Curran 2007). The EPA recommends that stormwater mitigation practices should utilize a systems approach that focuses on several BMPs for stormwater mitigation rather than an individual practice for management (USEPA 2007). The best management practices implement pollution control through the utilization and combination of overall effectiveness and cost of single management practices to result in a comprehensive management practice (Ibid.). While some management practices are not highly effective alone, a combined management practice encompasses the most effective parts of a single practice to create a highly effective system for management (Ibid.). As an outcome of this system, there is no single stormwater retrofit that is recommended for a specific type of stream. Rather, best management practices must be utilized as a systems approach to determine the most effective stormwater retrofits for a stream or river on a case-by-case basis.

Accordingly, the development of a mitigation plan for the Hart Brook Watershed requires a significant understanding of various types of best management practices and their particular use and effectiveness. With a more comprehensive understanding of the benefits and weaknesses of various BMP’s, a best management practice can be implemented for the Hart Brook that utilizes the outcomes of this research to create an effective system of management. One form of stormwater management is low impact development (LID), which manages stormwater at the source through small-scale land development (Ahiablame et al. 2012). The central principles of LID include prevention, rather than mitigation of pollution; management
near the source; reduction of costs; use of natural features for the design; and community empowerment to protect their environments (Ibid.). According to Ahiablame et al., “the main goals of LID principles and practices include runoff reduction (peak and volume), infiltration increase, groundwater recharge, stream protection, and water quality enhancement through pollutant removal mechanics such as filtration, chemical sorption, and biological processes” (Ahiablame et al. 2012, 4255). These goals can be achieved through the use of structural mechanisms such as bioretention, constructed wetlands, wet ponds, swales, permeable pavements, sands filters and green roofs (Ibid.). Each of these structural mechanisms for stormwater mitigation have various advantages and disadvantages. In order to understand the most suitable stormwater retrofit for Hart Brook, it is necessary to closely examine several of these retrofits.

5.1.2 Bioretention

Bioretention is a commonly used retrofit for the mitigation of stormwater runoff. Developed in the early 1990s, bioretention utilizes a combination of plants and soils to remove effluents from stormwater runoff (USEPA Bioretention 1999). Specifically, “runoff is conveyed as sheet flow to the treatment area, which consists of a grass buffer strip, sand bed, ponding area, organic layer or mulch layer, planting soil, and plants” (USEPA Bioretention 1999, 2). First, the stormwater runoff goes through (or over) the sand bed to slow it down. The central ponding area of the retrofit is created in a downward grade, so that the runoff will flow into it (Ibid.). The infiltration zone of the ponding area has a depth of six inches. Over a period of days water filters into the soil and is cleansed of pollutants by both the soil and the plants before it is released to the receiving body of water.
Typically, bioretention is used to treat industrial, commercial or residential areas with impervious surfaces (Ibid.). In areas where grading already exists, bioretention is particularly useful because the grading that is necessary for the retrofit has minimal interference with the natural environment (Ibid.). Benefits of this retrofit include effective water treatment, provision of shade to regulated water temperatures, management of excess runoff and it also provides aesthetic values. While the use of bioretention provides numerous benefits for the mitigation of stormwater runoff, as listed above, the retrofit is not without disadvantages. Particularly relevant to Maine is that the soil can freeze in cold climates, which prevents infiltration of runoff into the soil (although this might not be a problem as the ground is not typically frozen during rain storm events). Additionally, if the water table is within six feet of the surface or if slopes are more than 20%, bioretention is not a viable retrofit.

5.1.3 Buffer Strips

An alternative retrofit for stormwater runoff is the use of buffer strips, which utilize groundwater and surface storage (Gilroy and McCuen 2010). Buffer strips trap eroded soil and decrease the speed of stormwater runoff through the use of vegetation on the surface of the buffer strip (Ibid.). In doing so, buffer strips increase infiltration of stormwater runoff into the groundwater. In a study by Gilroy and McCuen (2010), the efficiency of buffer strips is compared with the efficiency of bioretention retrofits. Although this case study was conducted in Central Africa, the results are still widely applicable as the study compared general efficiency of these two retrofits for managing water runoff. The study found that while buffer strips are slightly more effective at controlling stormwater for very small impervious surface areas, bioretention retrofits are otherwise the more effective retrofit as they are able to trap more
sediment and cleanse larger amounts of runoff at a significantly more efficient level (Gilroy and McCuen 2010).

5.1.4 Sand Filtration

In addition to the previously cited examples, sand filter systems are also commonly used retrofits. While sand filters have limited efficacy for controlling flow rate, they are highly effective at removing commonly present pollutants in stormwater runoff (USEPA Sand Filters 1999). Thus, sand filters are particularly useful at improving the quality of water that enters streams and rivers, but are not particularly useful for decreasing sediments that enters streams as a result of erosion. Typically, there are two or three basins or chambers in a sand filter system (Ibid.). The system first removes heavy sediments and floating pollutants in the sedimentation chamber. Following the sedimentation chamber is the filtration chamber, which filters the stormwater runoff through a sand bed to remove any additional pollutants that were not filtered in the first chamber (Ibid.). Finally the water enters the discharge chamber where the treated water is released through a drain either back to surface waters or into a storm drainage structure (Ibid.).

A key benefit of sand filtration systems is that they can be used at steep slopes and take up very little space, unlike bioretention facilities (Ibid.). Additionally, sand filters are particularly useful at sites that are already highly developed since they can be implemented in small areas. “Sand filters are able to achieve high removal efficiencies for sediment, biochemical oxygen demand (BOD), and fecal coliform bacteria. Total metal removal, however, is moderate, and nutrient removal is often low” (USEPA Sand Filters 1, 1999). Despite the benefits for nutrient removal, sand filters have drawbacks in their inability to reduce the velocity of stormwater
runoff. While sand filters are unable to reduce the speed of stormwater runoff, an alternative retrofit is able to slow stormwater in addition to filtering pollutants.

5.1.5 Constructed Wetland

Another important stormwater management retrofit is a constructed wetland. Wetlands can be conceptualized as “nature’s kidneys,” as the processes that take place in wetlands—chemical, physical, and biological—are able to effectively break down pollutants in water (USEPA Storm Water Wetlands 1, 1999). The natural processes which occur in wetlands make it an effective management practice for the treatment of stormwater management (Ibid.). Constructed wetlands are modeled off of naturally occurring wetlands and treat stormwater through either free water surface (FWS) constructed wetlands or subsurface flow (SF) constructed wetlands. A free water surface wetland includes a shallow pool with vegetation that rises just above the surface water. Stormwater runoff enters the pool as it flows over a soil-lined basin (Ibid.). “In contrast to the FWS wetland, the SF wetland basin is lined with a pre-designed amount of rack or gravel, through which the runoff is conveyed. The water level in an SF wetland remains below the top of the rock or gravel bed” (USEPA Storm Water Wetlands 2, 1999). As the FWS is able to retain larger quantities of stormwater runoff than the SF wetland, it tends to be the most preferred retrofit of the two, especially in areas with high peak flow during storm events (Ibid.).

Some of the central benefits of using wetlands for stormwater management are that they improve quality of water downstream from the site that is treated and improve the quality of both wildlife and vegetative habitats. Habitats and water quality are improved by the reduction of erosion and sediments and the removal organics, nutrients and metals, respectively (Ibid). One
possible drawback of using wetlands for stormwater management is that they have the potential to contaminate groundwater with the pollutants that they are filtering, although the EPA states that this is an unlikely possibility (Ibid.). Furthermore, stormwater wetlands risk blocking fish passage and can act as a heat sink during the summer. Therefore, stormwater wetlands should not be built upstream of temperature-sensitive fish. Both of these risks can be mitigated through the creation of a passage for fish as well as the use of larger plants in the wetland to create shade and reduce temperatures (Ibid.).

5.1.6 Porous Pavement

An additional retrofit for stormwater runoff is porous (permeable) pavement. Porous pavement mitigates the effects of stormwater runoff by allowing snowmelt and rain to percolate through a pervious pavement (USEPA Porous Pavement 1999). The EPA recommends two kinds of porous pavement: pervious concrete and porous asphalt (Ibid.). “Porous asphalt pavement consists of an open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to make it highly permeable to water. Pervious concrete consists of specially formulated mixtures of Portland cement, uniform, open-graded course aggregate, and water. Pervious concrete has enough void space to allow rapid percolation of liquids through the pavement” (USEPA Porous Pavement 1, 1999).

Typically, porous pavement is laid over highly pervious open-graded gravel. Water is able to fill the reservoir that is created from the voids in the pavement and slowly filters into the soil below (Ibid.). Advantages of using porous pavement include the ability to restore aquifers and remove pollutants from stormwater. The EPA does not advise the use of porous pavement near drinking water sites, as the pavement has the risk of contaminating drinking water through
letting certain pollutants pass that it is not designed to filter, such as fuel from vehicles (Ibid.). Porous pavement is therefore recommended for industrial areas, as they typically are not located near sources of drinking water. Additionally, porous pavement is more effective in areas that are not highly trafficked (Ibid.). On average, permeable pavement reduces runoff by 50% to 93% (Ahiaablame et al. 2012).

1.5.7. Case Studies

As all of the previously described stormwater management retrofits are recommend by the USEPA, they have been widely implemented as best management practices. In a case study by DeBusk et al. 2010, the costs and feasibility of stormwater retrofits were evaluated for urbanized areas in North Carolina (DeBusk et al. 2010). The case study examined the New Hope Creek in the city of Durham and found that the most effective retrofits were bioretention, sand filters, and permeable pavement. In particular, bioretention was found to be highly effective for mitigating stormwater in commercial areas with large impervious surfaces such as parking lots (Ibid.). If there was not enough space to allow for bioretention, sand filters and permeable pavement were used (Ibid.).

While the case study by DeBusk et al. 2010 compares the effectiveness of various retrofits, it does not include cost estimates with this comparison. In a report prepared by NRDC, costs of stormwater retrofits are estimated for Philadelphia (Valderrama and Levine 2012). The report discusses numerous different retrofits. Of the retrofits that have been discussed in this literature review, the report finds that porous pavement retrofits tend to be approximately twice as costly as constructed wetlands (Ibid.). These findings are consistent with the costs given by the EPA in our report, although costs of retrofits are approximate and differ from site to site.
One final case study of interest is the Long Creek Watershed in the greater Portland area of Maine. The watershed lies in Portland, South Portland, Westbrook, and Scarborough Maine and has 33% impervious cover (Long Creek 2012 Annual Meeting Presentation). While these retrofits are ongoing, the project intends to utilize permeable pavement, detention ponds, and bioretention, as BMP’s to mitigate stormwater runoff (Edwards and Kelcey 2006). As the Long Creek Watershed lies within a similar landscape as the Hart Brook Watershed, the use of similar retrofits in the Long Creek Watersheds supports the viability of the retrofits that were suggested in this report.

5.1.8. Review of Fee Structures

Stormwater management consists of construction, maintenance and operation, which are funded through the implementation of fee structures. There are many ways in which stormwater management plans can obtain funds, such as through stormwater utility fees, grants, and the fees based on the area of impervious surfaces when there is new development. The efficiencies of these various funding sources are variable in how much money they can realistically generate.

Stormwater management costs can be funded through a system called Intensity of Development (ID). This bases the collection of money on the size of land and its level of development. The higher the amounts of impervious surface cover, the larger the cost per 1,000 square feet and per month. For moderately developed areas with up to 20% of impervious surface the charges are $0.12 whereas heavily developed areas, with impervious cover between 71%-100%, are charged $0.32 (EPA 2009). This is an efficient fee structure as it allows for accurate cost estimates, however it can be cumbersome to review the amounts of area that are impervious (EPA 2009).
Grants are also available to contribute to funding for stormwater management. For example, the Maine Department of Environmental Protection provides the 319 Grant (EPA 2009). This specifically distributes money for projects that reduce sources of pollution to water bodies in Maine (Kim et al. 2012). One of the large issues associated with relying on grants as fee structures is that they are very hard to obtain, as well as they do not provide sufficient or consistent funds for management.

The stormwater utility fee is a service fee included in the taxes of properties depending upon their size. There are over 500 utility systems throughout the USA, and the average stormwater utility fee per a single family home is $11 every three months (EPA 2008). It takes a long time for these fees to accumulate to significant levels, so it is important to highlight the importance of managing stormwater and cleaning water bodies to justify the collection of these funds. In Lewiston, Maine, the fee structure currently in place utilize a stormwater utility fees as well as sewer fees that go towards stormwater management. Unfortunately, this structure does not generate sufficient funds to actually mitigate stormwater runoff within the Hart Brook watershed.

5.2 Supplemental Methods

In the beginning stages of our project, we were focused on how Lewiston could fund the initial costs of implementing different retrofits, many of which we ended up ruling out due to the following rational. Seeing as a lot of stormwater runoff and pollution is the result of high impervious cover within the industrial areas of Lewiston, we thought partnering with industries to build retrofits on their land could be a good option. However, doing this would involve a huge amount of community outreach and education that did not fit within the time frame and focus of
our project. Through meetings with our community partner and Lewiston officials, it became clear that using industrial land and funding was not a realistic option at this point in time.

Next, we looked into revising the current Compensation Fee Utilization Plan (CFUP) so that it would bring in more money so that it could actually be used to fund new retrofits. We familiarized ourselves with the CFUP and determined that its main shortcoming was that it only taxed new development after its implementation is 2007, and seeing as Lewiston (particularly industrial Lewiston) is already developed, there is very little new development in progress. To address this problem, we looked into the feasibility of revising the plan so that all impervious surfaces within the Hart Brook watershed were taxed and not just new development. This would clearly result in a large increase in funding coming into the CFUP. Again, it quickly became evident that doing this, was both unrealistic within the time constraints of our project, and would be very unpopular. Lewiston landowners already pay a land tax and a stormwater utility tax, so adding an additional tax would be unpopular and unrealistic.

Finally, we looked into the feasibility of applying for different grants to fund the retrofits. However, based on the cost estimates we can up with from our research, and the amount of money that grants offer, which is typically a couple thousand dollars, we weren’t sure grants would be able to cover the initial cost of implementing most retrofits. In addition to this, grants need to be continually written and approved, and are not a consistent or reliable source of income. In addition to accounting for the initial funding of retrofits, we also researched the yearly funding needed to upkeep the retrofits. One-time grants would clearly not be helpful in funding these long-term costs. Our thoughts were confirmed in a meeting with Justin Early (project engineer) and David Hediger (city planner) who have much more experience with grants and had similar advice.
5.3 Supplemental Figures

Figure 3. A map of Maine, which specifies the location of the Hart Brook watershed in relation to the lower Androscoggin river watershed (TMDL Assessment Summary 2012).

Figure 4. A map of the Hart Brook watershed, which indicates its different uses of land. The red polygons indicate land owned by Lewiston, Maine (Received from Justin Early 2013).
Figure 5. A typical bioretention system with sloping edges which direct stormwater runoff into the bioretention area. The underground filtration process is also highlighted (USEPA Bioretention 1999).

Figure 6. A permeable pavement retrofit that shows porous asphalt and an underground reservoir for the retention of stormwater, aiding in the efficient filtration of pollutants into lower soils (USEPA Permeable pavement 1999).
Figure 7. A sand filter retrofit system for a parking lot, highlighting the directed flow of stormwater runoff and underground mechanisms that aid the filtration process (Minnesota Pollution Control Agency, 2013).

Figure 8. A cross-section of a constructed wetland showing the combination of plants, sediment, and open water that collects and treats large volumes of stormwater runoff (University of Georgia 2003).