ENVS 3502: Final Report

Best Stormwater Management Designs using Bio-retention Retrofits at Dalhousie University

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1.0 Introduction

Water used by homes, businesses, and/or industries for washing, flushing, or manufacturing processes contains waste products, often referred to as wastewater or sewage. In many municipalities this water is collected and transported through a network of underground pipes to a centrally operated water treatment facility. Here the wastewater is treated, disinfected and discharged into a nearby body of water. The 2009 Halifax Harbour Solutions Project (HHSP) implemented advanced primary-level treatment facilities for the municipal sewer outfalls and were designed to hold four times the average dry weather flow (ADWF) (Halifax Regional Municipality (HRM), 1999). However, the Halifax peninsula region has a combined sanitary/stormwater sewer system (HRM, 1999) meaning that stormwater (surface runoff) enters the same pipes as the wastewater, ultimately increasing the volume of water that needs to be treated by the water treatment facility. Due to this combined system, storm events can cause system overflows, resulting in frequent and temporary discharges of untreated effluent into the harbour (HRM, 1999).

Halifax is a coastal city that has much of its surfaces paved or occupied by buildings. These impermeable surfaces result in less stormwater infiltrating into the ground and additional runoff either directly or indirectly into Halifax's surrounding waters. Direct runoff occurs at locations similar to the west end of South Street that provides a paved surface leading into the Northwest Arm. In this case there is no buffer to remove any of the potentially harmful contaminants from the runoff before it enters the Arm. The indirect sources of stormwater runoff into the harbour come from the city's combined stormwater and sewage pipelines that, as mentioned above, have the potential to release untreated wastewater into the environment (HRM, 1999).

1.1 Project Description

This project was designed to reduce Dalhousie University's contribution to the stormwater surges that cause the city's treatment facilities to overflow by answering: **What external bio-retention retrofit designs can Dalhousie University apply to their campus in order to uphold best stormwater management practices (BSWMP) and how can these designs be transferable to properties of different spatial and economic scales across the HRM?**

Designing Best Stormwater Management Practices (BSWMP) at Dalhousie University was worth studying because the current state of the campus allows for flooding and green-space over-saturation. This flooding and over-saturation would likely to lead to future water-damage maintenance costs as well as increases in stormwater runoff into the city's already burdened treatment facilities. If this project's proposed designs are successfully implemented, Dalhousie can become a leader in stormwater management retrofits and act as a role model for other HRM properties. Therefore the storm events that currently render the municipal treatment facilities useless, would no longer contribute the great volumes it does today, protecting the harbour environment and the HRM population.

This study offers BSWMP designs for three economic ranges that Dalhousie can use to effectively mitigate any areas that are prone to stormwater issues. The main goal when offering different economic ranges for the designs is to allow the Dalhousie community to make a choice as to the extent and costliness of their retrofit. The variety in the designs will also allow them to pick and choose different aspects of the BSWMP retrofits that can fit within their budget. If the study's proposed designs for the targeted areas on campus are implemented, the currently untreated water will pass through a bio-retention area and ultimately reduce Dalhousie's contribution to Halifax's volume of stormwater runoff. Finally, by looking at the costs as well as the efficiency of different external retrofits, for both parking areas and buildings, the results of this study developed an accessible "retrofitting guideline" for different scaled property owners to mix and match designs.

2.0 Literature Review

Stormwater management is a relatively new concept, due to increasing impervious groundcover such as roofs, sidewalks, driveways, lawns, patios, and roads. While forested and grass areas allow 70-90% of precipitation to infiltrate into the ground, 80-95% of precipitation which comes in contact with the impervious surfaces in developed areas, does not (Davis & McCuen, 2005, p. 2). The water running off these surfaces carries an increased amount of pollutants which ultimately end up in surrounding bodies of water, causing varying degrees of site-specific damage and change and supporting the need for management.

Initially, stormwater was attempted to be controlled by installing curbs, gutters and storm drains. The storm drains were connected by underground pipes and collected water that disposed into nearby streams. This was not effective because the water was simply being removed from the developed area and disposed elsewhere, causing problems to other parts of the watershed (Davis & McCuen, 2005, p. 6). Therefore a need for on-site stormwater management approaches arose to mitigate the high volumes of stormwater that was flowing into the storm drains, and increase the percentage of permeable surfaces to allow for more precipitation to infiltrate the ground. This meant a shift from "end of pipe" approaches which deal with stormwater after it has runoff impervious sources, to "source controls" such as: dry ponds, wet ponds, constructed wetlands, vegetation swales, rain gardens, rain barrels, green roofs, cisterns, storm water planters, and French drains. These controls deal with stormwater at the source and are less expensive than "end of pipe" controls (Field, Shea, & Chin, 1993, p.

47). The use of such source controls would allow Dalhousie to take ownership of their contribution to the burdened storm drains.

Contaminated waters pose a huge threat to human health from the exposure to poor-quality drinking water, contaminated seafood and polluted recreational water areas. If excess stormwater is mismanaged and large pools of water are left stagnant, mosquitoes can be attracted to breed in the area and this can encourage the spread of harmful diseases. This poses a huge environmental and health concern for people and wildlife in the affected area. Heavy metals including copper, zinc and lead are commonly found in runoff from impervious surfaces such as roofs, roads, and parking lots. Carcinogenic effects, resulting from high levels of polyaromatic hydrocarbons (Gaffield, Goo, Richards & Jackson, 2003) have escalated in recent years in conjunction with rapid industrial growth and increased traffic volumes. With regard to road and parking lot pollutants, street sweeping is a preventative measure that cities can implement to reduce pollutants. Conducting sweeps "once a week on highways and every three days in residential areas", solids and nutrients can be removed from 10% to 60% (Gaffield et al, 2003).

By applying appropriate treatment and stormwater management practices, public health can be protected at the lowest cost, that being, preventative measures so health impacts are reduced, requiring less future costs due to health issues. Gaffield et al (2003) reported that out of the 99 million U.S citizens suffering from acute gastrointestinal illnesses each year, approximately 6% to 40% can be directly linked to contaminated drinking water as a result of the mismanagement in water treatment areas. Contaminated runoff from excessive rainfall is one of the primary factors jeopardizing the sanitation and legitimacy of drinking water in Halifax.

During storm events there is an accumulation of contaminants as water flows off the impermeable surfaces and enters the environment at a much faster rate than would occur naturally, increasing sediment and nutrient loadings in surface waters (Brezonik & Stadelmann, 2002). Consequently, the biota that primarily remove the collected contaminants are restricted due to the minimal time that the stormwater has to interact with the surrounding ecosystem (Hsieh & Davis, 2005). This gives rise to the innovation of bio-retention which can be described as a process that uses vegetation or microbes to mitigate stormwater contamination. Through bio-retention, storm water is able to filter slowly through various layer combinations composed of rocks, sands, mulches, soils, and/or plants (Centre for Watershed Protection, 2011). This process facilitates the removal of contaminants and sedimentation from the water, at the same time allowing for a slower, more natural integration of the water back into the environment. The following literature review will discuss the importance of Dalhousie using different bio-retention techniques that are used for stormwater management.

2.1 Rain Barrels

Rainwater harvesting has been in practice for centuries, dating as far back as ninth-century BC, where Carthaginian-Romans in ancient Sardinia used cisterns to collect water for public and private use (Crasta, Fasso, Patta & Putzu, 1982). Today, rainwater-harvesting systems (RWHS) are often used in rural communities where potable water is not accessible or where traditional groundwater sources have been contaminated (Michaelides & Young, 1983). It has only been in recent years that RWHS have been sought as a solution for reducing stormwater runoff and its associated pollutants.

Modern rainwater harvest systems are low-cost and can range in size from small rain barrels attached to residential homes up to large underground cisterns, such as the rainwater cistern located in the Mona Campbell Building on Dalhousie's Studley campus. The collected rainwater can either be treated with ultraviolet light and filters to make it potable, or it can be used directly as grey-water for irrigation, landscaping, and/or toilet flushing. There are several key factors to designing a RWHS, including: the building's roof size, average volume of rainfall, and the intended use of the collected rainwater. These factors are also considered when determining the size and material of the cistern and if the water storage should be above or below ground. These factors, along with the consumption patterns of the individual installing the RWHS, can reduce the property's water flow to combined stormwater-sewage systems (CSS) by 30%-60% (Herrmann & Shmida, 1999). RWHS can also help reduce a property's soil erosion and flooding potential through the redirection of the flow around buildings. The general maintenance of RWHS is often low cost and simple to do, although underground cisterns may be difficult to clean. Most above ground maintenance is required 3-4 times a year, which can easily be done by the property owners. Some barrels are designed with dual compartments, where only the primary section needs to be cleaned.

It is important to note there are several limitations to these BMP designs. Stormwater contamination from atmospheric and organic sources often makes the collected water non-potable until it has been treated. Lye (1992) performed a study that looked at 83 Nova Scotia rainwater cisterns revealed that 8% of the cisterns tested positive for fecal coliformes, 50% contained other coliformes, and 95% contained the bacteria *Pseudomonas*. These bacteria can be harmful to humans as they often develop a resistance to antibiotics. Also, the improper screening of rain barrels can offer a breeding ground for mosquitoes, however most municipalities have strict guidelines in place to ensure the proper fitting of screens (HRM, 2006).

The final drawback associated with this particular stormwater practice is its restriction to temperatures above freezing. Because of this, it is essential to empty external cisterns / rain barrels before freezing temperatures arrive, as the water will freeze and expand, which could in turn cause damage to the structure. This will likely be an issue in Halifax's winters. A solution to some of the RWHS limitations would require a connection to other BMPs, in what is called a treatment train (HRM, 2006). Treatment trains commonly consist of rain barrels, or other storage tanks, connected to French drains, drainage ponds or rain gardens. This helps deal with the draining of barrels once they have reached capacity, and overflow during particularly heavy downpours. Careful selection of roofing, gutter and cistern material can reduce the amount of contamination that is present at the end of the system. However, the roof top catchment will unavoidably be affected by the atmospheric environment (Thomas & Green, 1992).

2.2 Rain Gardens

Rain gardens are an efficient and economical mechanism through which homeowners and business managers can control stormwater runoff on their properties. A rain garden is essentially a landscape feature designed to utilize soils and vegetation that help drain and filter rainwater in a desired location (Obropta, Sciarappa & Quinn, 2006). It is a relatively inexpensive technique that can be applied to new properties or simply as a retrofit to older ones (Toronto and Beach Conservation, 2010, p. 33). Ideally, rain gardens should be implemented in conjunction with other best management practices –such as rain barrels and/or dry wells– in a treatment train to most effectively slow and treat high volumes of stormwater.

The deliberate use of gardens to control water runoff is already well established, and it can be supported through a number of examples over the past quarter-century. In 1995, a subdivision in Somerset, Maryland was developed revolving around rain gardens as a key feature by creating sharp contrasts with the curbs, gutters and sidewalks that frame neighbouring communities (Beier, 1995, p. 5). The inclusion of rain gardens on each property has proven to be a valuable component of Somerset's appeal (Beier, 1995, p. 5).

A further example of the successful implementation of a rain garden is in North Kingstown, Rhode Island. In this case, rain gardens were established on the Town Hall lawn to set an example for the community at the same time as it was protecting Narragansett Bay (University of Rhode Island, 2006). Rain gardens are a cost-efficient and adaptable tool for stormwater management that can be applied to virtually any site where stormwater runoff is an issue and therefore is a viable option for Dalhousie's campus.

2.3 French Drains

French-drains have been used for many years to relieve basements of the water leakage often experienced by older homes and buildings during heavy rainfall. As water runs off roofs, whether it is into eaves-troughs and downspouts or directly off the roof, the water enters the ground in close proximity to the home or building, and eventually degrades the foundation enough for leakage to occur. A French-drain helps transport storm water runoff from the roof, away from the home or building by catching it in a trench filled with gravel and/or sand, where it enters a perforated pipe and is absorbed by the ground at a reduced rate. The excess water is then released downslope and away from the home or building.

The use of French-drains is a feasible, cost-effective stormwater management approach that can be implemented on existing residential properties. However, the accumulation of dirt and sediment along the perforations in the pipe can cause the system to back up and if water drainage from the pipes takes over forty-eight hours to empty, it may cause an odour and higher bacteria counts in the water (PA B-Dry Basement Waterproofing Co, 2006). This means regular maintenance is required, potentially four times a year; however, this too is a low cost.

A case study in India, 1993, showed French-drains to be effective on roads when the installation of drains removed all surface runoff from rain and sewage instantaneously, and maintained a dry road surface (Rao, Gupta, & Pradhan, 1993). Another successful use of French-drains can be found under the Clarinton Tiger-Cats' athletic field in Ontario. Several drainage systems were considered for the job, but the field required a slower filtration system so an "EZflow" French drain was selected. At the time of the report, the drain had been in place for one year and functioned perfectly (NDS Inc, 2012).

2.4 Vegetated Swales

Vegetated swales are stormwater management systems that utilize water infiltration in areas of excessive runoff. When implemented, the vegetated swales "provid[e] an opportunity for nutrient uptake through the root system"(Weiss, Gulliver & Erickson, 2005), thus filtering the surplus of water into the local system rather than allowing runoff to pool or contaminate other areas of collection. The application of vegetated swales within parking lots can be effective in the collection, treatment, and reduction of stormwater runoff. Areas with gradual slopes are most suitable for swales, whereas areas with extreme slopes or flat lands would not benefit from a vegetated swale due to limited capacity levels. Swales are a visually appealing stormwater management application thanks to the inclusion of natural elements that are often absent in urban areas. Aside from the aesthetic benefit (Clark & Acomb, 2008) of swales, they also play a crucial role in the pre-treatment of stormwater with coarse to medium sediments

(Clark & Acomb, 2008) that are susceptible to build up in other drainage systems. Rushton (2008) presented an efficient method to manage stormwater runoff in her report that looked at low-impact parking lot designs that reduce runoff and pollutant loads. She suggested decreasing the size of parking stalls by shortening the front end where the vehicle overhangs in order to increase the area and efficiency of the vegetated swale.

Despite the various benefits of vegetated swales such as the aesthetic appeal and sediment filtration, drawbacks do exist, especially with regard to its retention capacity. During low intensity storms the swales are efficient pollutant removers; this does not seem to be the same case for short-term, high intensity storms. During intense storm surges, swales are not as efficient in runoff retention or filtration as they can become saturated and potentially eroded (Yu, Barnes & Gerde, 1993). To best utilize vegetated swales, Ramesh (2011) suggests using them in conjunction with wet ponds, infiltration strips, and/or wet lands, or to use other stormwater management practices specific to the target region. Healthy vegetation growth is required to effectively filter the stormwater runoff, therefore if the swale is heavily shaded or is lacking in soil nutrients, vegetation will not flourish and the swale will not be effective (Ramesh, 2011).

2.5 Permeable Pavement

Finally, permeable pavement is an innovative approach that improves storm water management in small and large-scale developments. This type of pavement can be applied to driveways and sidewalks on residential properties, as well as to parking lots found in industrial and commercial areas. Permeable pavements offer a combination of best management practices that include filtration, bioretention, and infiltration. The structural design allows water to percolate through, reducing the amount and flow rate of surface runoff in the surrounding area. The water quality of the infiltrated runoff can be improved by the addition of filtering materials that reduce the concentration of hydrocarbons, phosphorus and nitrogen (Scholz, 2012, p. 3833).

Urban designs that include permeable pavement have been successfully implemented in North Carolina and researched by the Division of Water Quality within North Carolina’s Department of Environment and Natural Resources (NCDENR) (Hunt, 2012, p. 2). Another example of a case study that illustrates the benefits of permeable pavement is in Portland, Oregon. Portland has a similar combined sanitary/stormwater sewer system as Halifax, and has implemented innovative strategies including the utilization of permeable pavement to reduce the amount of stormwater that flows through sewer pipes and discharges to rivers and streams (Portland Bureau, 2012).

Although permeable pavement has been found to effectively reduce surface runoff and improve water quality, there have been notable drawbacks that should be taken into consideration. The porous pavement structures are susceptible to clogging because the particulates that are infiltrating get stuck in the pores (Ferguson, 2005, p. 48). In cold coastal climates frost damage to the pavement is caused by an increase in underlying soil pressures responsible for supporting the paved surface (Ferguson, 2005, p. 48). Therefore, in order to increase the durability and reliability of permeable pavements, structural adaptations such as the thickness of material, types of binding aggregates, and filter layers should be considered (Ferguson, 2005, p. 48).

3.0 Methods

Through communication with our client, Ashley Sprague of the Ecology Action Centre (EAC), we designed a project that would have transferable results that can be applied to other properties in the HRM. To ensure the best results possible, a mixed-methods approach of both quantitative and qualitative data was used for researching and proposing BSWMP design options on Dalhousie University's campus.

3.1 Site description

Using independent field observations we were able to narrow our study to two sites on campus: the Dunn Parking Lot and the Grad House (including the adjacent empty lawn). The Dunn Parking Lot is located between the Dunn Building and Howe Hall Residences and represents one of several paved parking areas on campus. The parking area is situated on a noticeable slope, with the highest ground being located in the North corner near the Howe Hall building. It slopes downwards towards the southwest corner of the lot, where stormwater tends to accumulate. The second site, the Grad House, represents one of the many small, residential-style buildings on campus. This building was recently constructed on relatively level land, however it is prone to stormwater pooling along its North / North-West boundary. These locations were chosen for the project's retrofit designs because they satisfy the needs of our client and provided innovative strategies and an opportunity for Dalhousie University to more effectively manage stormwater runoff.

3.2 Data collection

Geographic Information Systems (GIS) (ArcMap, 2010) maps were used to quantify slope and elevation as well as provide the corresponding flow directions of stormwater on each of the study sites. This information was important for the initial design process of our retrofits, as it identified the location and scope of the problem areas. The projected GIS results were then supported with groundtruthing as photo documentation.

GIS is often used to examine the spatial data that is essential for designing bio-retention systems. This is because it allows the retrofitter to strategically implement BMPs in areas of water accumulation (Viavattene, Scholes, Revitt & J.B. Ellis, 2008). A case study by Zhen, Shoemaker, Riverson, Alvi & Cheng (2006) demonstrated that the application of GIS could be used to identify and optimize BMPs for specified areas. Continuous development of the GIS software strives to include greater breadths of information and to make the platform increasingly more user-friendly.

This study also examined the cost-effectiveness of each proposed retrofit by comparing their qualitative benefits with the costs of their implementation and maintenance. These benefits are restricted to qualitative data because our study drew on the advice from local stormwater experts and related case studies. As we do not have the time or resources to test each SWM method, we were unable to conduct our own experiments, which would test the effectiveness of our chosen stormwater management techniques.

For each target site, we outlined the benefits to the environment associated with each design, and more specifically with each additional landscape feature. Our findings were presented from lowest to highest cost. We intended to include the costs for each design's required materials, however labour costs for construction and installation were excluded from the analysis due to the wide range of factors affecting each individual case; labour costs vary depending on the company being dealt with. In this regard, our aim was to appeal to various social and geographical demographics and provide accessible information for a broad population, including homeowners and property managers. It was important that the designs and components we suggest follow the rules and regulations of the HRM and province of Nova Scotia. For the Grad House in particular, it was important to ensure that the inflow management met current compliance regulations, Halifax Regional Municipality Charter – Item 348 (HRM, 2011).

For primary data collection interviews were conducted with expert participants and a business/property owner. The goal of the interviews was to ask questions revolving around the proposed retrofits' ability to retain stormwater on site and the feasibility of the designs to be implemented on Dalhousie's campus. Through this data collection we aimed to find the level of stormwater retrofits that experts believed was feasible and would most likely be implemented on campus. This information was then incorporated into the design analysis to ultimately determine the most efficient and feasible design option for both the Grad House and the Dunn Parking Lot.

4.0 Results

4.1 GIS

The GIS images show the areas of concern on both the Grad House (Figure 1) and the Dunn parking lot (Figure 2). The elevation maps were used to determine flow direction, perpendicular to the contours (left panel in both Figure 1 and 2) where the accumulation maps were used to outline the areas of concern at both the Dunn parking lot and the Grad House (right panel in both Figure 1 and 2, respectively).

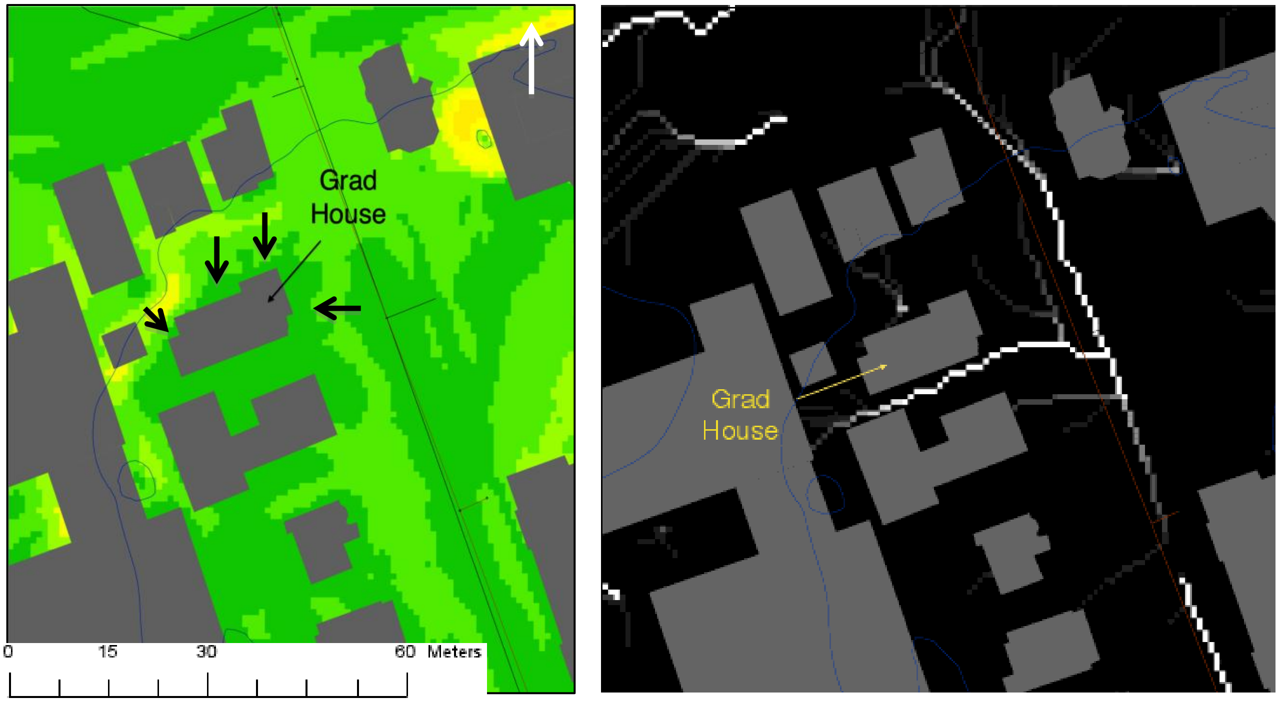

Figure 1. The Grad House's GIS maps showing (left) the elevation where light green is representative of high elevation and dark green is representative of low elevation, arrows show the direction of flow, and (right) stormwater accumulation where the white lines show the areas of concern in regards to stormwater management.

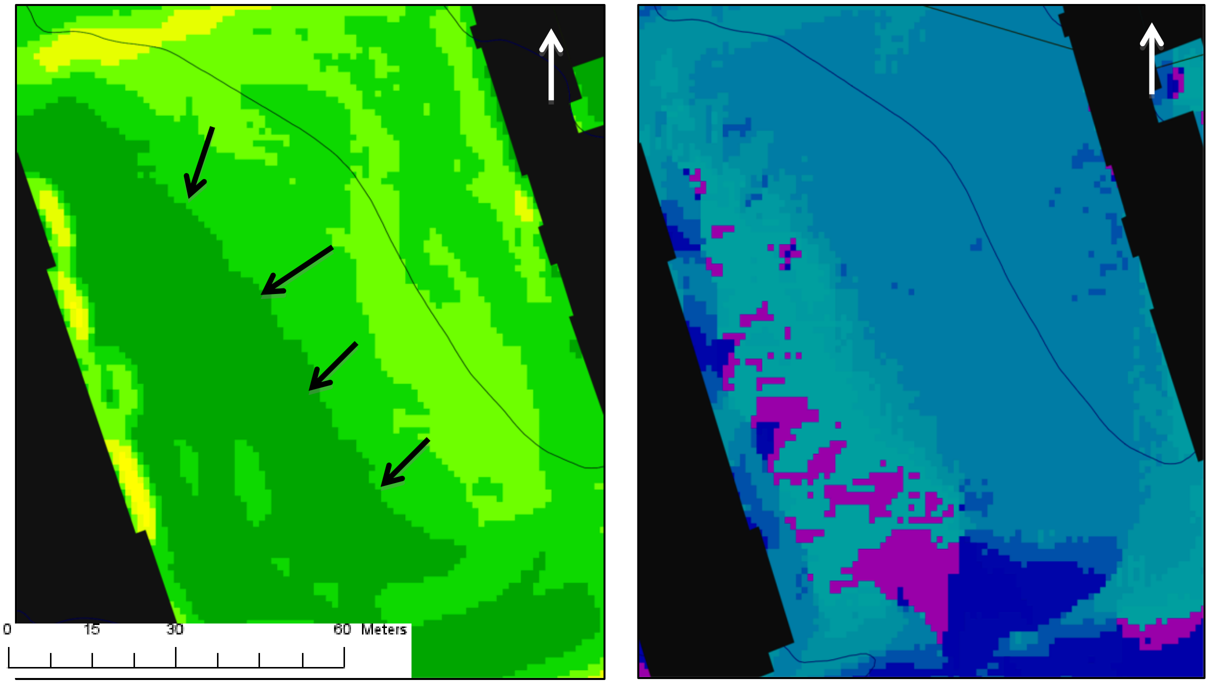

Figure 2. The Dunn Parking lot's GiS maps showing (left) the elevation where light green is representative of high elevation and dark green is representative of low elevation, arrows show the direction of water flow, and (right) stormwater accumulation where dark blue regions are the areas of concern in regards to stormwater management.

4.2 Design Components

The following components were determined to be most suitable for managing stormwater in Halifax, Nova Scotia.

4.2.1 Rain Barrels

Halifax's Stormwater Inflow Reduction Program highlights the use of downspouts as a way to distribute rainwater runoff from roofs, onto the ground and away from homes' foundations, by suggesting home owners install and use rain barrels in the non-winter months (HRM, 2012). According to the Canada Mortgage and Housing Corporation (CMHC), these downspouts should extend 1.8m (6ft) from your own basement walls/foundation, and should not release the water near your neighbour's; instead they suggest making sure the water is flowing downhill, away from homes, and/or into gardens or barrels (CMHC, 2009). Following these suggestions, rain barrels (Figure 3) with overflow features can be installed around the perimeter of a house, with overflow directed into rain gardens and/or downhill from the foundation of the building.

To allow for greater collection of rainwater during the non-winter months we suggest multiple rain barrels that can vary in size, be set up around the perimeter of a home. It is important to attempt to match the catching capacity of the barrel with use of the water before they are installed for rainwater harvesting to make them as efficient as possible. Potential uses include: gardening, washing of vehicles, process water (for cooling systems in buildings), and to offset the cost of drinking water, as everything above is currently using municipally supplied potable water (according to a personal interview with Rochelle Owen, April 9, 2012).

Filtration screens or lids usually come as part of the rain barrels, and are used to avoid water contamination by small animals, insects and leaves (HRM, 2012). The barrels generally have a twofold purpose; they slow the rate of stormwater entering into the HRM's combined sewage system and/or they provide non-potable water for landscaping, gardening and outdoor washing (cars, driveway, house siding, etc), decreasing the volume of water entering into the sewer (HRM, 2012). When determining the size of the barrels to install one should take into account the use for the collected water and the size of the roof (see Box 1 – Appendix B for formula). For example, if a homeowner plans to use the rainwater for landscaping or washing, they might choose a barrel with a larger catchment capability. This would be calculated with the roof area and the average rainfall in a 24-hour period. Using local HRM weather data we determined that the peak rainfall occurs in October at an average of 9.63 mm over 24-hours (HRM Weather, 2011). Estimating a roof area of approximately 81.1m2, a simple calculation (Box 1 of Appendix B) can then be used to determine the estimated volume of roof runoff; in this case it is roughly 781 L of rainwater for a 24-hour storm event. Using this number, it was determined that 200L and 400L rain barrels

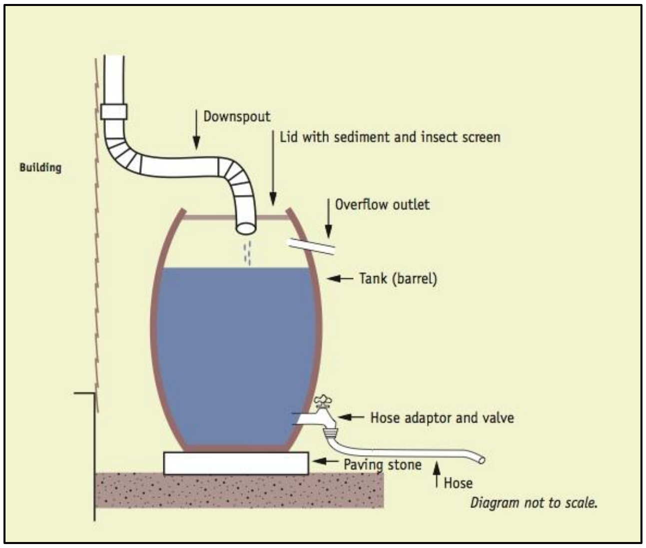

Figure 3. (top) Cistern diagram retrieved from the Nova Scotia Environment Rain Barrel Publication, 2009. (bottom) Cistern as seen in the Grad House designs in Section 4.4

outfitted with overflow outlets and hose adapter valves would be most efficient (NS Environment, 2009).

It is important to note that these rain barrels can only be used under above-freezing conditions, and need to be drained after particularly heavy rainfalls. While the overflow outlet allows for some natural drainage from the cistern during extreme storm events, the barrels will quickly reach full capacity if not manually drained. Ensuring the barrels are placed on level land is critical, and it is often suggested that they be placed on patio or landscaping stones that offer a solid, flat base for the barrels to rest on (Nova Scotia Environment Publication 2009). This can reduce the occurrence of tipping during high wind events, and prevent the barrel from sinking into the ground (Nova Scotia Environment Publication, 2009).

If a home or property manager feels rain barrels are an unfeasible option for their property, downspout extensions and splash pads can be purchased to direct stormwater from the roof onto a green area away from the foundation of a home; they are readily available at many home renovation stores (Home Depot, Canadian Tire), are simple to install, and are relatively inexpensive. Disconnecting roof downspouts from wastewater sewers in existing homes typically costs $100 per downspout; this includes splash pads, downspout extensions and labour (Credit Valley Conservation, n.d.). However, if the homeowner has the materials, tools and is prepared to do the labour, the cost could be reduced to around $25 (Toronto Homeowner's Guide, 2009). It is still recommended that these downspout extensions and splash pads be directed to release roof runoff approximately 1.8 m from the home's and surrounding homes' foundation (HRM, 2011).

4.2.2 Rain Gardens

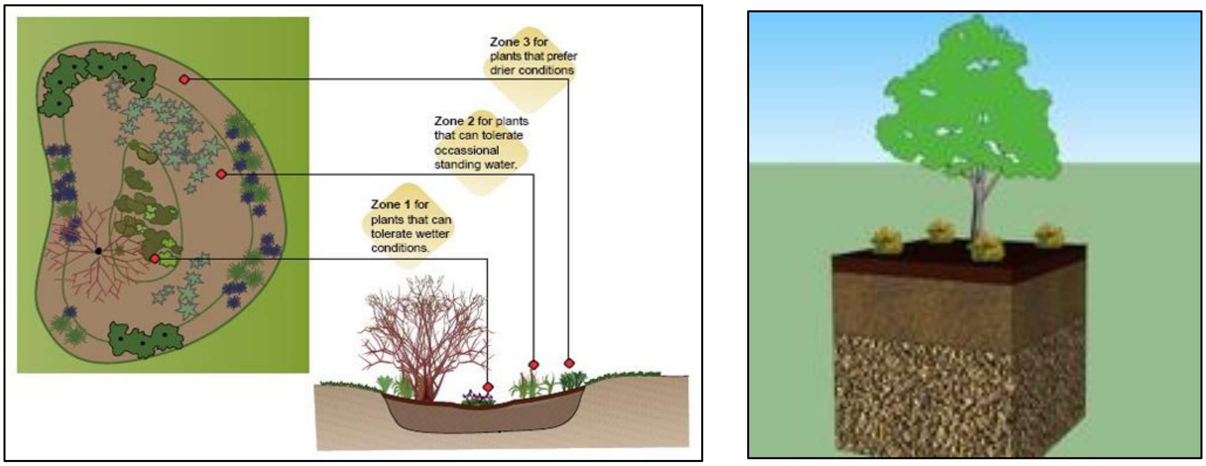

Figure 4. (left) Rain garden diagram retrieved from Clean Annapolis River Project. (n.d.). Managing Stormwater in Annapolis Royal . ***Annapolis River*****. Retrieved April 8, 2012, from http://annapolisriver.ca/projects_raingardens.php (right) Rain garden as per the Grad House designs in Section 4.4**

Rain gardens (Figure 4) are a relatively inexpensive stormwater technique that can be applied to new properties or simply as a retrofit to older ones. In order to control stormwater runoff, a property's problem areas are targeted, and aesthetically pleasing collections of native flora are planted to increase the local bio-retention capacity. Rain gardens can thrive in areas of intense water flow, and by encouraging stormwater runoff to infiltrate the ground they naturalize drainage patterns that have been altered by impervious surfaces (CARP). Rain gardens can be used in different scaled retrofit designs by increasing their number and size. The gardens should be strategically placed to treat areas of extreme flow accumulation (CARP). Ensuring that the rain gardens are the proper dimensions (including depth) to effectively mitigate stormwater is an important step, and will vary considerably depending on the soil type of the property (see Box 2 – Appendix B).

Native plants are preferred for rain gardens because they are best suited to the local soil and climate, making them heartier and more effective in the prevention of soil erosion [please refer to Native Flora table in Appendix A]. Rain gardens are zoned vertically—usually divided into three tiers—with the deepest level comprising plants that are most resistant to water, through to the topmost level where plants thrive in slightly drier conditions (Figure 4 - left; CARP). In the construction of rain gardens, it is important to remember that the garden's length must be at least two times larger its width (NJAES). The slope of the lawn determines the depth of a rain garden, and this typically ranges between 10 and 20 cm (WDNP). It is recommended that gardens not be placed on a slope greater than 12% (CMHC, 2011).

Rain gardens are low maintenance during growing months and no maintenance through the winter. To cut maintenance levels even further, they can be built with a top layer mainly composed of ornamental stone and pebbles; these allow for water to pool and slowly filter back into the soil, without the need to care for or maintain plants.

4.2.3 French Drains

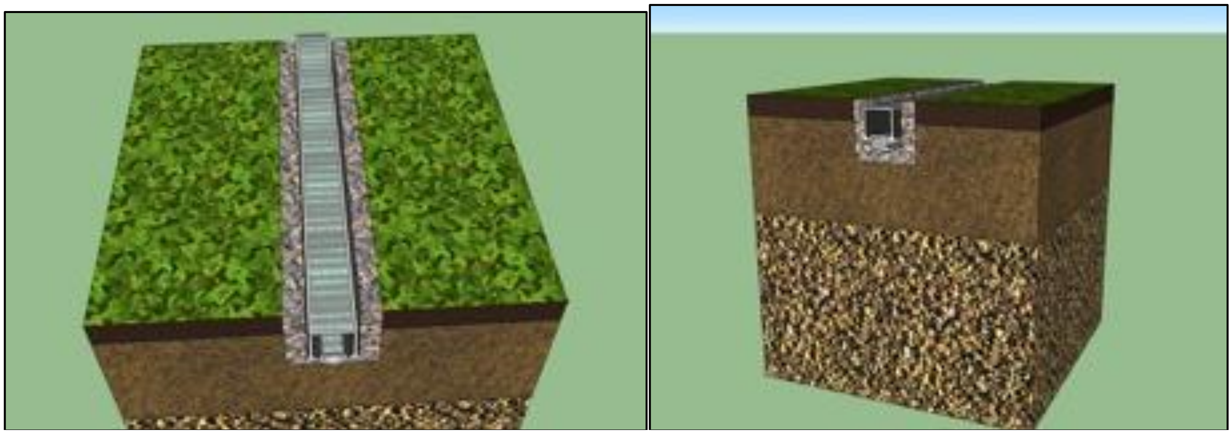

Figure 5. French Drains as seen in the Grad House designs in Section 4.4

French Drains (Figure 5) are useful tools when faced with the challenge of directing stormwater runoff downhill and away from the foundations of homes or towards more suitable areas for excess water, such as rain gardens. This is because they collect the stormwater runoff from building-roofs when it eventually hits the ground and then carries it away from the foundation through a covered in-ground pipe to prevent the erosion and the flooding of basements.

French drains require that a small trench be dug around the perimeter of the home or building, with a slope of no less than 2 cm/m (Exterior French Drains, 2008) and a section of low-cost PVC perforated pipe be laid in the bottom of the trench (PA B-Dry Basement Waterproofing Co, 2006). The trench then needs to be filled in with gravel, and covered with a layer of filter fabric to prevent sediments from seeping through the gravel layer and clogging the perforations in the pipe (PA B-Dry Basement Waterproofing Co, 2006). Grass and other vegetation can then be planted right over the French Drain's trench, making it discreet and aesthetically pleasing (Exterior French Drains, 2008).

4.2.4 Vegetated swales

Vegetated swales (Figure 6) are a beneficial tool for reducing the onsite volume of stormwater runoff through increased infiltration and groundwater recharge. The vegetation, soil, aggregate material, and microbes combine to act as a natural filtration system, absorbing and retaining excess amounts of stormwater on sloped landscapes or areas prone to flooding (Structural BMP Criteria, 2003, p.2). Aside from being a storm water management tool, vegetated swales have a natural and aesthetic appeal, as well as having the ability to improve biodiversity within a given landscape. Vegetation for these areas should be water resistant and close growing to increase retention capabilities, as well as having tolerance to cold and wet climates like that of Nova Scotia. To promote native species, vegetation should be selected from the NS Native Flora table (Appendix A).

There should be approximately 2 to 8 inches of permeable soil on top of a filter fabric layer to ensure that no plant or soil material clogs the aggregate layer base (Stormwater Management Planning and Design Manual, p 11). This aggregate base should be 30-60 cm of aggregate material (gravel, sand, etc.) for most efficient runoff filtration and capacity (Structural BMP Criteria, 2003). Also, a 20 meter PVC perforated pipe is used to link the vegetated swale to the reservoir; the pipe should be restricted to a 7.5 cm diameter to reduce the flow rate. To decrease the costs of projects, the amount of aggregate material, which is quite costly, could be reduced from 40 cm (used in this project design) to 30 cm.

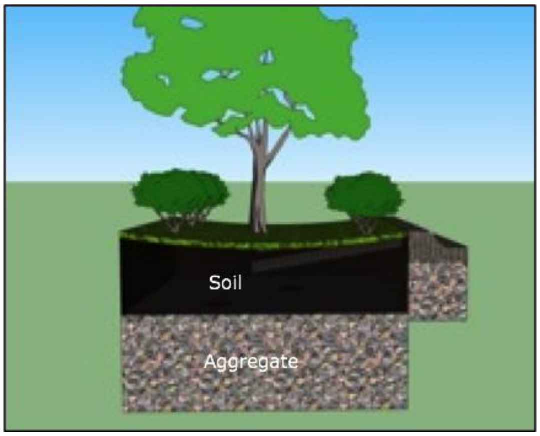

Figure 6. Vegetation Swale

Figure 7. Vegetation Island

Vegetated islands (Figure 7) are great aesthetic additions that are mainly constructed in parking lots. Islands can serve as both natural dividers and as runoff retention areas. Their purpose is to filter surface run-off from the pavement and allow it to percolate into the soil reservoir (Ryerson Woods Conservation, 2004, p.4). Vegetated islands are composed of the same vegetation, soil, and aggregate material as the vegetated swales, however they are typically smaller in size and retention capacity. PVC perforated pipes are also used in the islands to link runoff to the bio-retention area.

4.2.5 Permeable Pavement

Permeable pavement (Figure 8) is composed of porous material with reduced sands or fines and allows water to drain through it; therefore, it is a beneficial implementation for paved areas that have high exposure to heavy rainfalls (Ferguson, 2005, p. 99). In a climate that fluctuates to cold/freezing temperatures like Halifax, the use of permeable asphalt or block pavements is recommended (Ferguson, 2005, p. 99). To maintain the integrity of the permeable pavement's strength in a cold environment the structural layers require 5 to 10 cm of permeable pavement (also referred to as porous asphalt), a choker coarse of 2.5 to 5 cm, and a subbase of aggregate material anywhere from 45 to 90 cm depending on the size and depth of the section (Ferguson, 2005, p. 99). Finally, a subgrade layer should be placed beneath the aggregate subbase as this determines the infiltration capacity of how much water can flow from the aggregate into the surrounding sediment (NPDES, 2009).

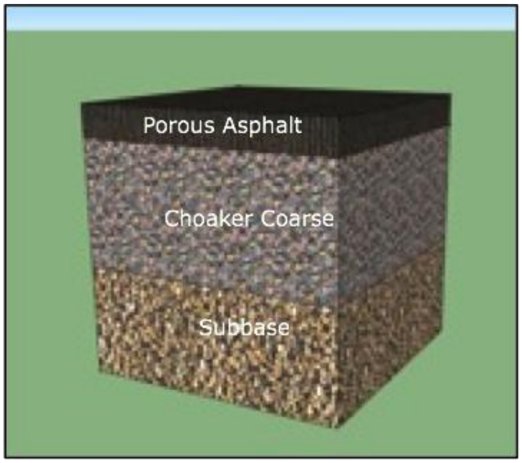

Figure 8. Permeable pavement

4.3 Costs

Table 1. Break down of costs associated with implementing a single unit of the design component (*excluding labour costs).

Category	Material	Unit	Material Cost*
Rain barrels			
	Barrel	200L	$80.00
		400L	$100.00
	Discharge hose	m	$0.82
	Paving/Patio Stone	per stone	$4.72
	Downspout extensions		$11.00
	Splash pads	76x30 cm	$13.98
Rain Gardens			
	Soil/aggregate	m3	$26.16
	Ornamental pebbles	m3	$84.90
	Plants (various)	Per pot/plant	~$3.50
French Drains			
	Perforated Pipes	m	$39.37
	Landscape Fabric	m2	$0.43
	Aggregate	m3	$26.16
	Mulch	m3	$5.48
Vegetation Swale			
	Excavation	m2	$2.69
	Soil	m3	$13.76
	Vegetation	m2	$10.76
	Aggregate material	m3	$26.16
	Filter fabric	m2	$3.92
Permeable Pavement			
	Pavement removal	m3	$15.00
	Excavation	m3	$5.00
	Aggregate material	m3	$26.16
	Filter Fabric	m2	$3.92
	Porous Pavement	m2	$15.55
	Perforated pipes	m	$39.37

4.4 Dalhousie Designs

The HRM Municipality website stated that there is approximately 1200-1400 mm of rainfall (excluding snowfall) every year within the HRM, and suggests that a home with an average roof coverage of 92 m^2 could potentially divert 144,000 liters of water from the sewage system by using a combination of BSWMPs (HRM, 2011). This volume of stormwater can be calculated by home property owners through a simple equation that uses the roof's area to calculate the volume of runoff (see Box 1 – Appendix B). Treatment trains from downspout extensions, to rain barrels, rain gardens, and French drains can be effective in diverting storm runoff and this is why the following designs try to highlight the connectivity of the different BSWMPs.

The following designs include multiple components that were mentioned in Section 4.2 in different arrangements and quantities depending on the need and level of stormwater retention. The Level 3 Design for each site represents the greatest opportunity for Dalhousie to reduce their pressure on the city's combined waste water system followed by Level 2 and Level 1.

4.4.1 Grad House Design Level 1

The first and most basic BSWMP retrofit design for the Grad House and the adjacent lawn (Figure 9) features the use of rain barrels and rain gardens to effectively mitigate storm run off from the Grad House roof and surrounding buildings. In keeping with the problem areas identified in the GIS maps (Figure 1), this design consists of two rain gardens on the north-east side of the house, and two rain barrels on opposite sides of the building. The rain gardens would have an approximate area of 8.875 m2, with a width of up to 2m and a length of 4.5m, and a soil depth of approximately five inches. It was assumed that the soil type on the lawn adjacent to the Grad House was loamy, similar to the soils found through the majority of the Halifax core (Agriculture and Agri-Food Canada, 2011). Using information provided by the Canada Mortgage and Housing Corporation (2011), it was determined that the soil had an infiltration rate of ~10 mm per hour, which coupled with the rain barrels, should easily allow for the effective diversion and filtration of stormwater runoff.

There is an existing downspout on the north-east side of the building that currently empties directly into a large storm drain. To divert this water away from the drain, a 200 L barrel was strategically placed to catch water during storm events. The barrels will be placed on 18 by 18 inch patio stones to help level the placement area, and better distribute the weight of the barrel. The water collected and any overflow was designed to be directed into the drain at a decreased rate, or into the rain garden next to the NE side of the home through the overflow outlet and discharge hoses. It is also recommended that a second 200L rain barrel be placed on the southern side of the home to catch water from another existing downspout, which currently empties out onto the lawn and into the neighbouring construction area.

The two adjacent downspouts located in the middle of the north wall will also need to be disconnected to ensure compliance with Item 348 of the HRM's Inflow Regulations (HRM, 2011). Downspout extensions can then be placed on the disconnected spouts to direct water flow away from the deck, ramp, and foundation of the Grad House.

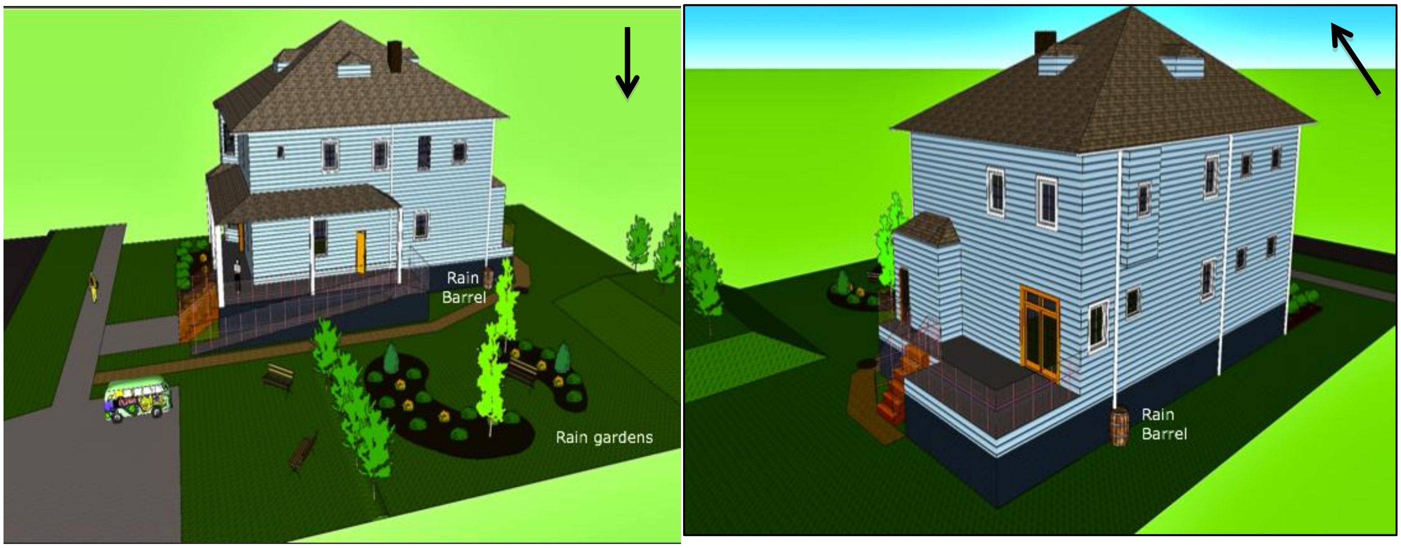

Figure 9. Grad House simulation Design 1 from the (left) North point of view and the (right) South East point of view

Table 2. Cost break down for the First Grad House Design

Material	Quantity	Unit	Cost per Unit	Total
Rain barrels	2	200L	80.00	160.00
Patio Stone	8		4.72	37.76
Rain Gardens	17.75	m2	61.16	1085.59
Downspout extensions	2		11.00	22.00
Splash pad	2		14.00	28.00
Total				**1,333.35**

4.4.2 Grad House Design Level 2

The second Grad House BSWMP retrofit design (Figure 10) involves upgrading the first design through simple additions to increase its efficiency as well as increase the total volume of rainwater diverted from the combined sewage systems. This design features the same gardens as described in the Level 1 design, roughly 8.875 m2 each, as well as the disconnection of the two parallel downspouts on the north wall. However, this design includes the addition of ornamental pebbles to be used as a “splash zone” to mitigate for erosion that can occur when down spouts or rain barrels are emptied directly into gardens (CMHC, 2011; Bannerman, R., Considine, E., 2003) and the addition of a larger rain barrel, 400L. There is also the option to ass a third garden in the south-west corner of the Grad House, but current construction in the adjacent lot would make placing the garden at an appropriate distance from the foundation difficult. Therefore, it was decided that the costs of this third garden would not be included the design breakdown (Table 3).

The major difference between the first design and the second is the increase in the roof’s runoff rainwater capture through the addition of the 400L rain barrel at the north-east corner of the house. The total potential catchment volume is now increased from 400 L to 800 L, and could theoretically divert close to 95% of run off associated with a large storm event from entering into the HRM’s sewage system (Nova Scotia Environment, 2009). All three of these barrels are designed to be placed on patio stone foundations, and would have discharge hoses of various lengths to divert the collected stormwater. The 400 L barrel’s hoses would direct that water into the designed rain gardens or other landscaping needs, and into the storm drain at a reduced rate. The two 200 L barrels would also have extended hoses that would be used to water the existing aesthetic garden (not a rain garden) at the front-south side of the Grad House, or used to release overflow further away from the foundation, preferably on a permeable surface.

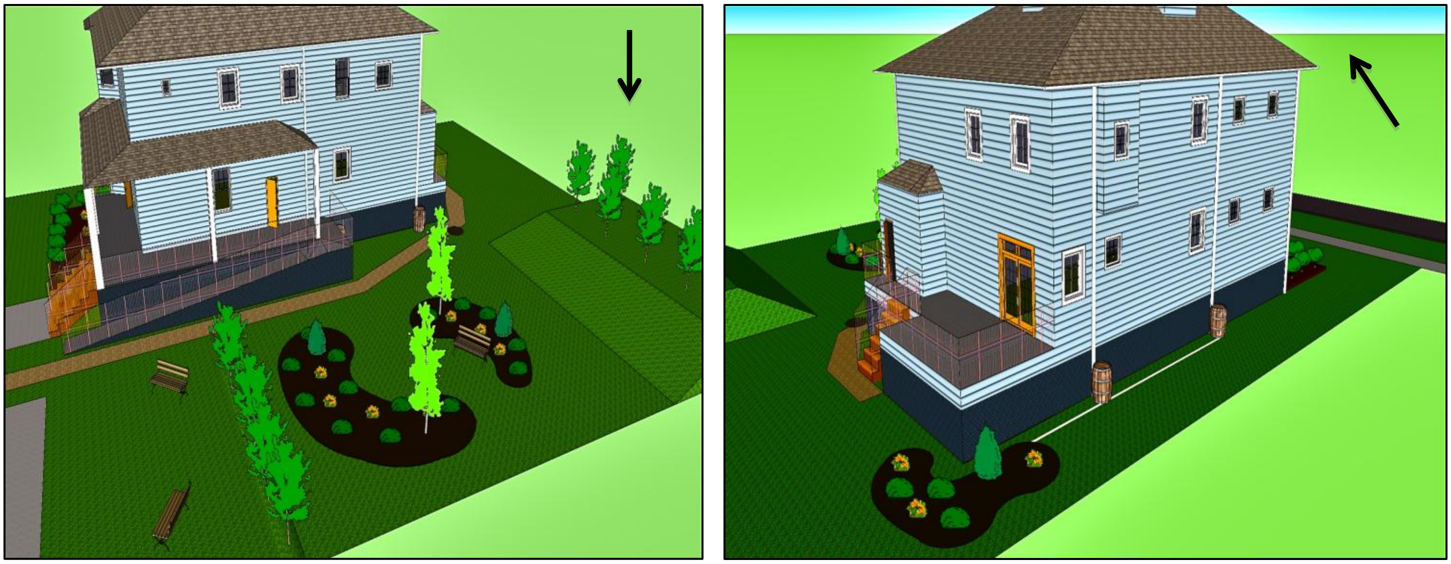

Figure 10. Grad House simulated Design 2 from the (left) North point of view and the (right) South East point of view

Table 3. Cost break down for the Second Grad House Design

Material	Quantity	Unit	Cost per Unit	Total
Rain barrels	2	200L	80.00	160.00
	1	400L	100.00	100.00
Patio Stone	12		4.72	56.64
Hose	3	m	0.82	2.46
Rain Gardens	17.75	m2	61.16	1085.59
Ornamental pebbles	1	m3	84.90	84.90
Downspout extensions	2		11.00	22.00
Splash pad	2		14.00	28.00
Total				**1,539.77**

4.4.3 Grad House Design Level 3

The third retrofit involving BSWMP for the Grad House and adjacent lawn (Figure 11) is the most extensive and expensive of the three designs. It involves a major expansion and addition to the rain gardens that were proposed in the earlier designs, the construction of a third BSWMP, French drains, and the addition of another rain barrel. First, the rain gardens on the north-eastern side of the house have now been expanded to become one single, large garden with an area of 36 m^2. The proposed dimensions are roughly 4 m in width and 9 m in length, with the garden encompassing the existing tree bank in the middle of the lawn. The addition of a second garden is proposed on the opposite side of the existing tree bank, this would have similar dimensions to the gardens proposed in the first two designs (8.875 m^2; 2 m by 4.5 m).

Next, a strategically placed French drain leading from the two downspouts on the north-eastern side of the house are designed to direct stormwater away from the building, onto the lawn and into the smaller of the two rain gardens. This proposed drain would be approximately 9 m in length. If a French drain was excavated in this area, downspout extensions and discharge hoses could be used to mitigate the water out from under the deck and over into the rain gardens. It has also been proposed that a second French drain be constructed on the southern side of the home, approximately 13 m, to direct water into the existing aesthetic garden at the front of the house.

Finally, the total catchment volume of the rain barrels would also be increased slightly by adding a third 200 L barrel to the front-southern corner of the building, near the existing aesthetic garden. This would increase the catchment volume to 1000 L, which holds the potential to divert large volumes of stormwater; +95% of runoff from the Grad House roof could now be diverted from the HRM's combined waste water system, or be retained and allowed to drain more gradually into the system. The other two 200 L rain barrels and the 400 L cistern would be located in the same location as described in the second design, and still be equipped with discharge hoses to allow for the property manager to direct the water flow as needed.

Figure 11. Grad House simulated Design 3 from the (left) North point of view and the (right) South East point of view

Table 4. Cost break down for the Third Grad House Design

Item	Quantity	Unit	Cost per Unit	Total
Cistern	3	200L	80.00	240.00
	1	400L	100.00	100.00
Patio Stone	20		4.72	94.40
Hose	6	m	0.82	4.92
Rain Gardens	44.88	m2	61.16	2744.86
Ornamental pebbles	3	m3	84.90	254.70
Downspout extensions	2		11.00	22.00
Splash pads	2		14.00	28.00
French drains	32	m2	71.44	2286.08
Total				**5,774.96**

4.4.4 Dunn Parking Lot Design Level 1

The first proposed design for the Dunn Parking Lot (Figure 12) does not change the existing impermeable paved surface but instead suggests components to increase the local bio-retention and reduce the amount of water entering the stormwater drains. The main feature of this first proposed design is an 86.25m^2 (57.5 m long and 1.5 m wide) vegetation swale. This vegetation swale is designed in between the Dunn Building and the existing impermeable paved parking area and spans the entire length of the swale (57.5 m). The other component involved in this design is the permeable curb. The permeable curb also spans the length of the parking lot and is situated between the parking area and the swale. The combination of these components will allow for the water that flows along the existing impermeable surface to diffuse through the curb into the vegetated swale as to not erode or flood any one point; approximately 36 m of perforated piping will be used to transport the stormwater to different depths inside the swale. As a result water from the parking lot is now able to be retained in a bio-retention area and remove some of Dalhousie's pressure on the existing stormwater drains. We designed these components along the western edge of the parking lot because this is the area of low elevation (Figure 2, left) where the water that lands on the surface flows.

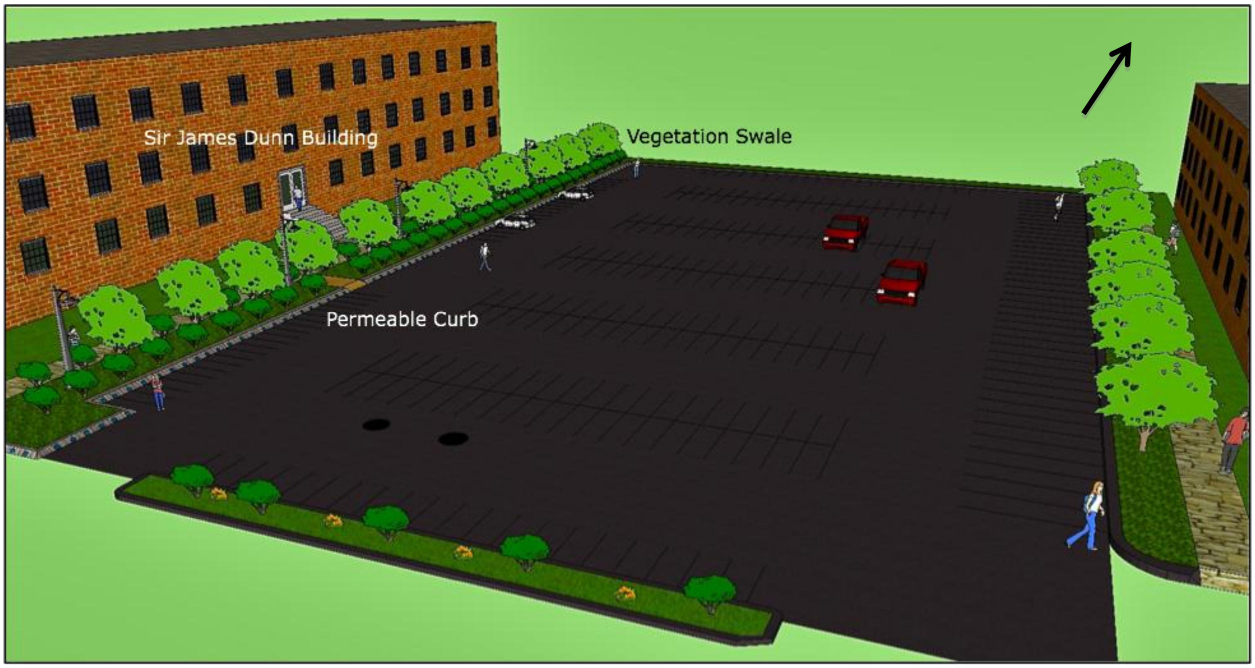

Figure 12. Dunn Parking Lot simulated Design 1 from the South West point of view

Table 5. Cost break down for the First Dunn Parking Lot Design

Item	Quantity	Unit	Cost per Unit	Total
Permeable curb	57.5	m	15.55	894.125
Piping	36	m	39.37	1417.32
Vegetated swale	86.25	m2	57.59	4967.1375
Total				**7,278.5825**

4.4.5 Dunn Parking Lot Design Level 2

The second design for the Dunn Parking Lot (Figure 13) has the same vegetated swale and permeable curb components that were found in the Level 1 design to serve the same function. The new component added to this design is a permeable pavement section in the impermeable parking area. This is a 210 m^2 area that is designed to further increases the local stormwater retention. This addition of permeable pavement allows the water that is captured in its structure to flow into the vegetation swale, through its porous matrix. This section was placed in the South West corner of the lot as this was found to be the area of accumulation according to the GIS simulation (Figure 2, right). This L-shaped permeable section was also strategically designed to replace 10% of the existing impermeable surface to satisfy the recommendations of the OURHRM Alliance Our Solutions project (OURHRM Alliance 2012).

Another feature of this design is the smaller parking stalls on the permeable surface. This was designed to discourage the parking of larger vehicles and reduce their added pressure that would likely be responsible for the destruction/ physical weathering of the pavement, ultimately extending the life of the permeable section.

Figure 13. Dunn Parking Lot simulated Design 2 from the South West point of view

Table 6. Cost break down for the Second Dunn Parking Lot Design

Item	Quantity	Unit	Cost per Unit ($)	Total
Permeable Pavement	210	m2	65.63	13782.3
Permeable curb	57.5	m	15.55	894.125
Piping	36	m	39.37	1417.32
Vegetated swale	86.25	m2	57.59	4967.1375
Total				**21,060.8825**

4.4.6 Dunn Parking Lot Design Level 3

The final proposed design for the Dunn Parking Lot (Figure 14) has all the same components as the Level 2 design to serve the same function. This design has the addition of two vegetation islands. These are placed at the base of two of the parking space rows to act as an addional bio-retention area, similar to the vegetation swale at a much smaller scale 2m^2 each (2m long and 1m wide). These not only increase the bio-retention of the area but they also increase the visual aesthetic as they are proposed with NS Native Flora (Appendix A).

Figure 14. Dunn Parking Lot simulated Design 3 from the South West point of view

Table 7. Cost break down for the Third Dunn Parking Lot Design

Item	Quantity	Unit	Cost per Unit	Total
Permeable Pavement	210	m2	65.63	13782.3
Permeable curb	57.5	m	15.55	894.125
Piping	36	m	39.37	1417.32
Vegetated swale	86.25	m2	57.59	4967.1375
Vegetated Island	4	m2	57.59	230.36
Total				**21,291.2425**

4.5 Interviews

Two experts and a business owner were consulted to get feedback on the six proposed designs. Dr. Anne-Marie Ryan, from the Department of Earth Science at Dalhousie University, and Rochelle Owen, from the Office of Sustainability at Dalhousie University, were our two experts. They were both presented with the designs, and were asked (1) Which of these designs do you think would retain the most stormwater on site? The experts were then presented with the cost tables associated with each design and asked (2) Which of these designs are most worth it and are likely to be accepted by/ feasible for Dalhousie's campus? Finally, David Pettinger, a resort owner in Tofino, British Columbia with experience in stormwater management planning, provided us with feedback from a property owner's standpoint.

In response to the first question, Dr. Ryan said that she believed the Grad House Level 3 design had the greatest ability to retain local stormwater based on the addition of French drains and the rain gardens located on the slope. For the Dunn Parking Lot, she chose the Level 2 design, as she did not believe that the additional vegetated islands were going to retain significant quantities of stormwater and was concerned about reducing available parking space. Rochelle Owen expressed that the Level 3 designs in both locations would have the greatest capacity for stormwater retention, even though she felt as though the third designs may have been "over designed" since they were developed to be capable of handling the peak stormwater volumes, which are not necessarily the volumes experienced over the majority of the year.

In response to the second question, Dr. Ryan chose the Grad House Level 3 design, even though it was the most expensive, because she believed that the expansion and addition of rain gardens would make the property more aesthetically pleasing while increasing the effectiveness of stormwater management. As for the Parking Lot, Dr. Ryan chose the Level 2 design, as she believed that the addition of permeable pavement was the strongest component, and that the cost increase with regards to the minor increase in stormwater retention that came from the vegetated islands was not worthwhile. Rochelle Owen, on the other hand, did not have a straightforward "this design would be best" answer. For instance, when referring to the Grad House she said that she liked that our designs showcased the effects of different BMPs on a house because the components of our designs could be implemented anywhere and would likely be consulted when Dalhousie tries to address other problem areas. But, with regards to the Grad House property itself, none of the designs would be implemented because there are other areas on campus that are of higher priority, such as in front of the LSC. In discussing the parking lot designs, Rochelle expressed that due to the scheduled repaving of the Dunn Parking Lot area, the third design would definitely be considered and potentially implemented on the site.

Both experts provided meaningful feedback that will be addressed and then discussed in Section 5.0. Dr. Ryan believed our project was limited by the fact that we did not have access to information regarding the water table that is present at each location, as this would influence the depth at which our bio-retention areas would be successful. She also urged us to consider how the high concentrations of salt during winter months may affect the vegetation swale in the Dunn Parking Lot designs, as it would likely ionize the soil making it limited to only tolerant plant species. For this she recommends that the pipes be blocked off during the winter. Another concern of Dr. Ryan's was the retention ability of our proposed vegetation islands; to improve this she suggested that instead of two small islands, we should design one larger one as this would be more cost efficient and cause less of a problem for salting and snow removal in the winter.

Rochelle's feedback was rather positive and more directed towards making our designs more appealing to Dalhousie. First, she told us that if we emphasize that maintaining connected downspouts to the wastewater drains is in violation of municipal by-laws (HRM, 2011) that Dalhousie would be more likely to take action. She also suggested that we focus our designs and proposal towards low maintenance components, as these are always more appealing. Finally, Rochelle believed that the rain barrels' retention capacity and ability to be sources of grey water used elsewhere on campus is an important feature. For example, she suggested that this water could be used for gardening, washing Dal vehicles, as process water for buildings' cooling systems, and to offset the cost of drinking water, as everything is currently using potable water.

David Pettinger is a resort owner in Tofino, British Columbia with experience in stormwater management planning as he has implemented multiple designs on his 40-acre beachfront resort property over a six-year period, 2004 to 2010. The town of Tofino experiences an average of 3,257 mm of rainfall annually (theweathernetwork, 2012), creating a huge demand for efficient stormwater practices; ironically, Tofino faces water shortages in the summer months due to high tourist populations, making rainfall collection systems crucial for a resort of this size.

After Mr. Pettinger reviewed the Grad House and Dunn Parking Lot designs, it was concluded that (due to the high costs) he would most likely implement the Level 2 designs first, then in a two phase process, complete the third design options in following years. He believed that the second Grad House design would be most feasible. However, due to the aesthetic appeal of an additional rain garden and further retention capabilities of a third rain barrel, he felt that the Level 3 design option would be beneficial to the overall stormwater management of the property. Therefore, Mr. Pettinger favoured the Level 2 design as it is "financially appropriate", then said after a year or two, the additions for the Level 3 design would be constructed to break up the financial weight of the third design.

In regards to the most feasible parking lot design, Mr. Pettinger believed that the Level 1 design was the best because of the high costs associated with the porous pavement addition in the Level 2 and 3 designs. However, he did mention that due to the low costs of the vegetated islands he would be inclined to add the islands to his existing lots as part of the Level 1 design.

It is important to note that Mr. Pettinger did say that if there were an incentive or grant provided to businesses that converted 10% of their impermeable surfaces to permeable then he would be more inclined on a financial level to add the porous pavement component proposed in the Level 2 and 3 designs. Regardless, the first parking lot design was said to be most feasible from a property owner's perspective.

5.0 Discussion

In this project we attempted to produce designs that would both reduce Dalhousie University's contribution to the stormwater surges that cause the city's treatment facilities to overflow, and to demonstrate retrofit options that are transferable to other properties in the HRM. By focusing our efforts on external bio-retention retrofit designs, we were able to settle on five BSWMP components: rain barrels, rain gardens, French drains, vegetation swales/ islands, and permeable pavement. By having multiple components in our designs, and utilizing different BSWMPs, we offered flexibility, and the opportunity for retrofitters to chose components as they see fit; this was also done this so that designs can be transferable to projects of different spatial and economic scales within the HRM.

An important part of presenting proposals to Dalhousie's Facilities Management is ensuring that the low maintenance aspects of the proposals are highlighted, as minimal maintenance is a priority in the selection of design components. Due to the inevitable limitations on available funds, committees like Facilities Management are always looking to cut costs by implementing low maintenance projects. Furthermore, retrofits that require regular maintenance can often be neglected or fall into disuse, and are therefore not favoured on a university campus. In the case of the designs in this report, it was a goal to ensure that every BMP proposed is extremely low maintenance for maximum efficiency.

The permeable parking area requires vacuum sweeping twice a year, once in the spring and once in the fall, to remove particles that clog pore space (Ramsey-Washington Metro Watershed District (RWMWD), 2006). It is also important to mention that during winter months, this area should not undergo any treatment for snow and ice accumulation other than ploughing; sand, salt, and other chemicals may clog up the pore space and potentially harm the soils and groundwater under the permeable surface (RWMWD, 2006). If proper maintenance practices are followed, the permeable pavement is expected to last 15-20 years (RWMWD, 2006). Rain barrels need to be emptied before freezing temperatures set in, but for the most part, following installation, vegetated swales, permeable pavement, rain gardens, rain barrels, and French drains all require virtually no maintenance.

In the interview with Rochelle Owen she indicated that Dalhousie University and most other commercial entities, prioritize legal compliance issues above other on-site stormwater management problems. In the Halifax Regional Municipality, it is illegal to direct stormwater inflow back into the wastewater system through a downspout connection (HRM, 2011). For this reason, disconnecting downspouts on the Northeast side of the Grad House, as well as disconnecting all other downspouts on Dalhousie campus, would be the most favoured retrofit implemented by Facilities Management at the university.

In discussing the parking lot designs, Rochelle expressed that due to the scheduled repaving of the Dunn Parking Lot area, the third design would be considered and potentially implemented on the site. As Mr. Pettinger explained, financing a retrofit of this proportion could be difficult, and that it could prove more feasible to implement it in various stages in some instances. There is, however, a huge advantage in the case of the Dunn parking lot because it is scheduled to be repaved in upcoming years. Therefore the additional five to ten percent of the cost needed to add permeable pavement would not pose as a substantial added cost for Dalhousie.

David Pettinger liked the variety of component options presented in each design. “This is important for businesses that cannot afford to do large retrofits all at once due to the high costs”. With regard to business operations, especially within a resort where parking is required, it is not always feasible to implement large-scale retrofits such as repaving. Our designs enable owners to draw from various components, assess the associated costs, and follow through with the stormwater management plan that works best for them. It has been noted that Mr.Pettinger can foresee a business, like his own, implementing all the design components proposed to eventually make up the third final designs, however in order to continue operations and efficient budgeting it would be constructed over a two to seven year period.

A further concern addressed with many of our design components was the height of the water table. Our results were limited by the assumption that the water table was below the depth of our components, but we encourage retrofitters to investigate this on their property. It is an important factor to consider when designing any in-ground retention area, as the retention capacity is only as deep as the height of the water table. For properties with high water tables we recommend trying to implement above ground retrofits such as rain barrels.

Overall, the feedback we received regarding our designs for the Grad House and Dunn Parking lot was positive and addressed our transferable design options. With respect to financial inputs, the feasibility of implementing the third design options for both problem areas were viewed as unlikely and financially unrealistic by the experts and business owner. However, the background information, budget and design options we created allow for individual homes and business owners to implement BSWMPs at a scale and expense most suitable for their property.

6.0 Conclusion

Our project aimed to find the level of stormwater retrofits that experts believed were most feasible and should be implemented on campus, but discovered that offering multiple, interchangeable components was our best deliverable. These components are easy to install and maintain, and also satisfied our client's, Ashley Sprague of the Ecology Action Centre, requests that they be easily transferable to different scaled properties in the HRM. The intent of this project's results are not only to reduce Dalhousie University's pressure on the overburdened combined wastewater system in Halifax, but also to provide the resources for other properties to do the same. We believe that through the delivery of our project to the Office of Sustainability and Facilities Management, our designs and components will be considered for future external retrofits on campus and the posts we created for the EAC stormwater blog will spread this potential to other properties as well. In all, this will hopefully help to reduce stormwater runoff throughout the region and increase awareness of BSWMPs.

Acknowledgements

We would like to send a special thank you out to our experts, Anne-Marie Ryan, PhD and Rochelle Owen, for their meaningful feedback and to the wonderful David Pettinger for his honest opinion and real world insight. A special thank you also goes to Ashly Sprague and the Ecology Action Center for providing us with this opportunity to help out our community.

7.0 Resources

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Appendix A Nova Scotia Native Flora

Native Flora of Nova Scotia
Herbaceous perennial
Blue flag iris
Jack in the pulpit
Swamp milkweed
New England aster
Bloodroot
Marsh marigold
Goat's beard
Turtlehead
Shrub
Wild raisin
Bog rosemary
American elder
Red-osier dogwood
Hobblebush
Bog Labrador tea
Tree
Common serviceberry
Fern
Ostrich fern
Christmas fern
Common ladyfern
Sensitive fern
Cinnamon Fern
Maidenhair Fern

Appendix B Formula Boxes

Box 1

How to Calculate Roof Runoff

This equation is used to estimate the volume of water coming off your roof in storm events:**Roof area (m2) x rainfall (mm) = volume of run off (L)**To find the average rainfall in a 24 hour period near your home, check local weather data. This amount can be anywhere between 5 and 25 mm, depending on your location, and will vary by season.

Example: The area of the roof is **81.1 m29.63 mm** of rain falls within a 24 hour period during peak storm season in the HRM. **81.1 m2 x 9.63 mm = 781 L** This means roughly **781 L** of rainwater runs off the 81.1 m2 roof during large storm events in the HRM. This is the rainfall target volume (RTV).

Box 2

3 Steps to Determine Rain Garden Dimensions:

Calculate Inflow Rate Estimate the area of your roof that will drain into the downspout to be directed into the rain garden, as well as any impermeable spaces draining into the Estimate the lawn area that drains into the garden, and multiply the figure by 20%. Adding these together will give an estimation of the total drainage area (TDA). **Roof(m2) + impermeable surfaces(m2) + [Lawn area(m2) x 20%] = total drainage area(m2)**Using the RTV from Box 1, multiply the TDA by the RTV (converted to m). So, if your RTV is 9.63 mm in 24 hours, and your TDA is 91.1 m2, your inflow in a 24 hour period would be 0.877 m3 of water. **RTV x TDA = Inflow Volume/24 hrs91.1 m2 x 0.00963 m = 0.877 m3**

Determine Infiltration Rate This can range from 1-210 mm per hour, and depends on the soil type in the area the garden will be built. You can check this by looking up the soil type in your region and by doing a simple test; dig a small hole at the location of the garden and fill it with a known volume of water while recording the time it takes to absorbed. Loam, for example, as a minimum infiltration rate of 20 mm per hour; in a 24 hour period it will absorb 480 mm of water. **Convert this to m.** 480mm = 0.48m

Calculating Dimensions Take the Inflow rate and divide it by the infiltration rate; this will give you the area of the rain garden needed to effectively mitigate the rainwater you divert into it.For example:**Inflow Rate / Infiltration Rate = Area needed for garden0.877 m3 / 0.48 m = 1.83 m2**

Please see Chapter 4 of CMHC's Landscape Guide for Canadian Homes for more information and detailed instructions.

Appendix C Schedule

Item no.	Task	Duration (hr)	Start Date	Finish Date
1	Meet client - ID needs and recommendations	1	Feb 1	Feb 1
2	Group Meeting - ID sites and split into task teams	1	Feb 7	Feb 7
3	Location Photos	0.5	Feb 12	Feb 12
4	Group Meeting - discuss project scope and delegate areas of research for each member	1	Feb 14	Feb 14
5	**Research Proposal**		**Feb 15**	**March 3**
	Project Def		Feb 15	Feb 16
	Group meeting - gather all information for preliminary proposal	1.5	Feb 26	Feb 26
	Submit any further changes or additions to preliminary proposal		Feb 26	Feb 28
	Submit proposal to Paul for review		Feb 29	Feb 29
	Group Meeting - review and submit the final preliminary proposal - discuss any need for funding		March 3	March 3

6	Apply for Funding (if decided necessary)		March 3	March 5
7	Group Meeting - discuss presentation objectives - ensure all group members are on track with research	1.5	March 11	March 11
8	Group Meeting - "Halfway Editing". Compile all material up until this point and begin editing and flow of report.	1.5	March 30	March 30
9	Submit rough presentation slides to google doc.	1.5	March 27	March 27
10	Group Meeting - preparation for Pecha Kucha presentations	1.5	March 30	March 30
11	Submit final slides for Pecha Kucha Presentations on OWL		April 1	April 1
12	**Pecha Kucha Presentations**		**April 3**	**April 3**
13	Blog Entry - Blog write up will be completed and posted		April 10	April 10
14	**Final Report Submission** - allocated group member will submit report before midnight.		**Feb 1**	**April 13**

Appendix D Blog Posts

Stormwater Management at Dalhousie University

A group of students enrolled in “Campus as a Living Lab”, a course at Dalhousie University that aims to engage students in efforts to “green” the campus and surrounding areas, have delved into the world of stormwater management. Students, Bridgette DeCoste, Tiara Pettinger, Robyn Pirie, Nicole Power, Michelle Simone and Paul Westlund, chose two areas on campus, the Dunn parking lot and the Grad House, to focus their research. The intention was to create transferable stormwater management designs that could be implemented by homeowners who are interested in managing stormwater on their properties. The students created three levels of increasingly complex designs for both sites and investigated five different management approaches; vegetated swales, permeable pavement, rain gardens, rain barrels, and French drains. The students then presented their designs to experts in the field, as well as with facilities management staff at Dalhousie to determine the most feasible and cost-effective approach to stormwater management on the two sites.

Here are graphics of the third designs for each location

Dunn Parking lot:

Grad House:

Follow this link to the full report.

The most interesting part about this report for the Ecology Action Centre is the transferability of the designs. Because each component of their designs is featured individually as well as a part of the whole system, the report contains a wealth of information directly relatable to any homeowner who's looking into taking on some of these retrofits on their own properties. The report also contains several appendices including tables with a complete breakdown of all the costs associated with these retrofits, and a list of water-loving plants native to Nova Scotia, for installation in the rain gardens.