UBC Social Ecological Economic Development Studies (SEEDS) Student Report

An Investigation into the Feasibility of Rain Gardens as a Stormwater Management Solution

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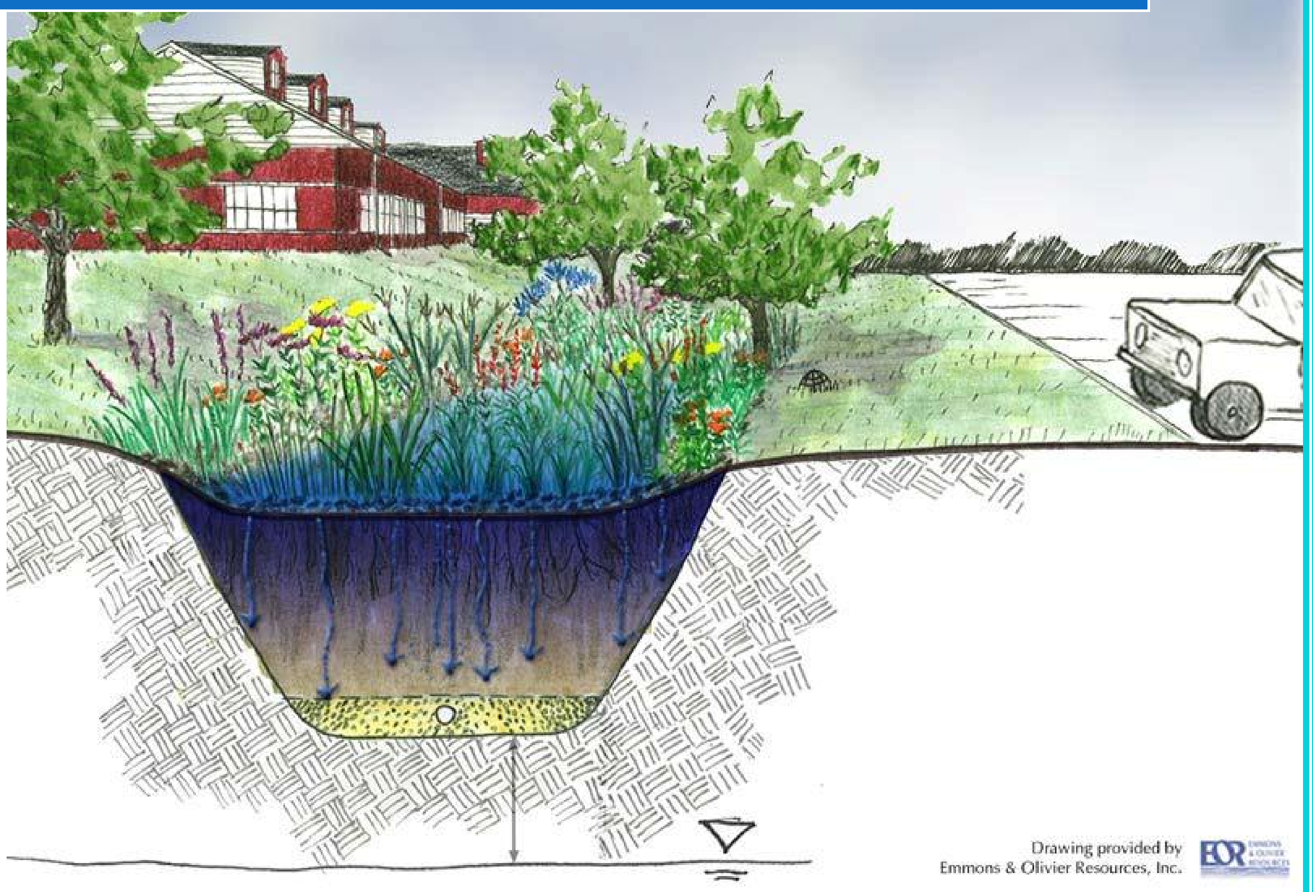

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Abstract

Stormwater pollution is becoming a greater problem in Vancouver with the increase of urbanization. In order to address the problem and to minimize the amount of pollutants discharging into sensitive waterways, UBC is planning to include two rain-gardens in the construction of the new SUB. To analyze the feasibility of rain gardens as a stormwater management solution, a triple bottom line assessment was conducted looking at economic, social, and environmental factors. Based on cost comparisons, case studies and performance reports of rain gardens implemented within the same climate region, academic studies on the social effect of vegetated gardens, and a small student survey, conclusions can be drawn regarding each of the three factors.

An economic analysis determined a rain garden would cost less to initiate and to maintain than a regular garden. Socially, the presence of a rain garden could increase student awareness of UBC's goal in sustainable urban development and raise awareness to an uncommonly known problem of storm-water pollution. Environmentally, a rain garden holds the same benefits as a regular garden in addition to filtering out up to 90% of the chemicals and up to 80% of dissolved solids out of stormwater runoff. Based on these main points, it was concluded that a rain garden is a cost effective method way to filter out stormwater pollutants, add aesthetics, and enhance the natural atmosphere of the university campus.

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Glossary of Terms

Impervious: Impenetrable

Infiltration: Process in which water enters the soil from ground level.

Mulching: Apply a layer of mulch, a protective layer over the soil that helps the soil retain moisture.

Pruning: To cut off twigs or branches

Rhizomatous: A characteristic in which roots are horizontal in position.

Stormwater Runoff: Surface water collected due to heavy rain

Symbiotic: Two dissimilar organisms providing each other with mutual benefits.

Tubers: Plant structure that stores nutrients to survive winter months. Potatoes are an example.

Urbanization: To make or cause urban, to industrialize.

Vegetated Swales: Low-place in a track of land that functions as stormwater infiltration sites along roadways.

Abbreviations

LEED: Leadership in Energy and Environmental Design

SUB: Student Union Building

UBC: University of British Columbia

1 Introduction

The ever increasing **urbanization** and densification of populated living spaces that define what our cities have become has lead to many new problems socially, economically, and environmentally (USEPA, 2008). One of these problems is the issue of stormwater pollution and management. Urbanization causes the redevelopment of land into a usable form for property development and efficient human travel. However, these redeveloped surfaces reduce the surface area possible for water drainage, and therefore affects how water moves to lakes, streams, rivers, and oceans (USEPA, 2008).

In 1998, a study titled *Water Pollution from Urban Stormwater Runoff in the Brunette River Watershed, BC* by Hall et al. showed through water quality analysis of tributary streams over the course of a year excessive levels of fecal coliforms, and suspended solids containing trace metals such as copper, lead, zinc, and manganese, as well as hydrocarbons, were present in the water. These levels were shown to be in excess of existing water quality standards, and were dependent on the amount of surrounding imperviousness (Hall et al., 1998). In a more recent ongoing study being done by the State of Washington's Department of Ecology stated that storm flows and base flow (river flow when not raining) are the largest contributors to pollution in the waters of Puget Sound. The effect is compounded during heavy storms (SWDE, 2011).

Since Vancouver receives an average of approximately 1200mm of precipitation (both rainfall and snowfall) annually (Environment Canada, 2010), the amount of **stormwater runoff** can be significant and temporary flooding in low areas are evident, especially at some locations at UBC. In conjunction with the large area of **impervious** surfaces in Metro Vancouver, runoff pollution can be considered a valid environmental concern.

The **LEED** Canada guidelines for new construction contains two credits dedicated to stormwater management, credit 6.1 and 6.2 detailing the rate and quantity, as well as treatment of stormwater (USGBC, 2009). Credit 6.1, as described in the LEED document, aims to reduce impervious surface cover such as concrete and stone walkways in favour of on-site infiltration and filtration of pollutants from stormwater runoff. This credit requires that for sites with current imperviousness of less than 50% to implement a stormwater management plan to prevent the amount of runoff after development to exceed the amount before development or for sites with more than 50% current imperviousness to implement a management plan to decrease the

amount of stormwater runoff by 25% (USGBC, 2009). Credit 6.2 involves the quality control of the stormwater design category. This credit aims to limit natural water pollution via management of stormwater runoff. The basis of the credit requires the treatment of stormwater runoff from 90% of the average annual rainfall via methods such as **pervious** pavement, rain gardens, **vegetated swales**, and rainwater recycling. It also requires that the treatment method be able to remove 80% annual total suspended solids (particulate pollutants) (USGBC, 2009).

To promote the opportunity to educate students and visitors regarding on-site rainwater management, and also to obtain the credits described in the previous paragraph for the LEED certification, the **UBC** New **SUB** design team has developed a novel natural stormwater treatment plan that shapes the landscape and building rainwater drain systems to better direct the flow of rainwater. To provide adequate filtration prior to entering the city's stormwater sewers, the New SUB landscape team plans to implement at least two rain gardens (or infiltration basins) in the plaza area surrounding the New SUB. The larger of the two, 12 by 15 metres, will be located in the Main Square while the smaller, 10 by 12 metres, will be located in the south entry plaza facing East Mall (UBC SUB Team and Associates, 2010).
It is anticipated that this rain garden implementation will adhere to the design principles set by the UBC SUB landscaping team and described in the 100% Schematic Design Report. Highlights of these design principles include the aim of creating a landscape that will apply strategies in on-site rainwater management via rain gardens and become a model for sustainability for other institutions. The design team also intends to create a landscape that reflects the beauty and biodiversity of the surrounding environment, and serves as an educational tool for rainwater management strategies (100% Schematic Design Report, 2010).

With these design principles in mind, this report will assess the feasibility and effectiveness of the use of rain gardens in stormwater management. More specifically, this report will provide a detailed triple bottom line assessment considering not only the environmental and social aspects mentioned in the landscaping design team's design principles, but also the economic aspects of implementing a rain garden. As described in the "What is a Rain Garden?" subsection, many design considerations go into the implementation of an effective rain garden. For the purposes and requirements of the APSC 262 course, this report will focus on the vegetation design aspect of rain gardens while two other groups working on the rain garden feasibility analysis will focus on soil toxicity and water filtration and drainage rate.

2 The Rain Garden

A rain garden is a vegetated area that allows stormwater runoff to be absorbed and filtered before it gets sent to the sewage system. Normally, this water would be treated at a water treatment plant before it is released into the ocean. However, due to heavy rain, most runoff water cannot be treated quickly enough; hence it is directly released into the ocean. Therefore the rain garden provides an on-site filtration step for the storm water before it reaches the ocean. The two most significant components of a rain garden are the vegetation and the filtration and drainage systems. A cross section of a typical large scale rain garden can be seen in Figure 1.

The first important component of the rain garden is the vegetation. In most cases, the plants that are used in a rain garden are usually native to the garden's location. This can help make the garden easier to maintain, for it is already capable of handling the local weather and rain amount. The roots of plants and soil can help provide a bio-filtration for the runoff water. Micro organisms can "form a **symbiotic** relationship with the higher plants" (Wolverton, 1988). This relationship will result "in increased degradation rates and removal of organic chemicals from the waste water surrounding the plant root systems" (Wolverton, 1988). This means that the activities of micro organisms in the soil and roots provide an efficient solution to filtering wastes that have been flushed into the garden by rain water. In order to allow more water to be processed by the garden, a thick layer of drain rocks is laid underneath the garden to create a reservoir for the water.

The second component for a rain garden is the drainage paths. These paths help direct storm water into the gardens and are usually laid with drain rocks. As for the rain gardens at UBC; trench drains will be placed around the garden at the main square to collect rain water from around the area and the Knoll. These trench drains are proposed to be spaced out bricks on the ground that allows rain water to collect and be transported, while keeping the ground leveled for walking. This is shown in Figure 2. The smaller rain garden will be located at the lowest point of the campus where rain water will naturally be flowed towards it from all directions. These pathways can also provide a route to the sewers for overflowed water.

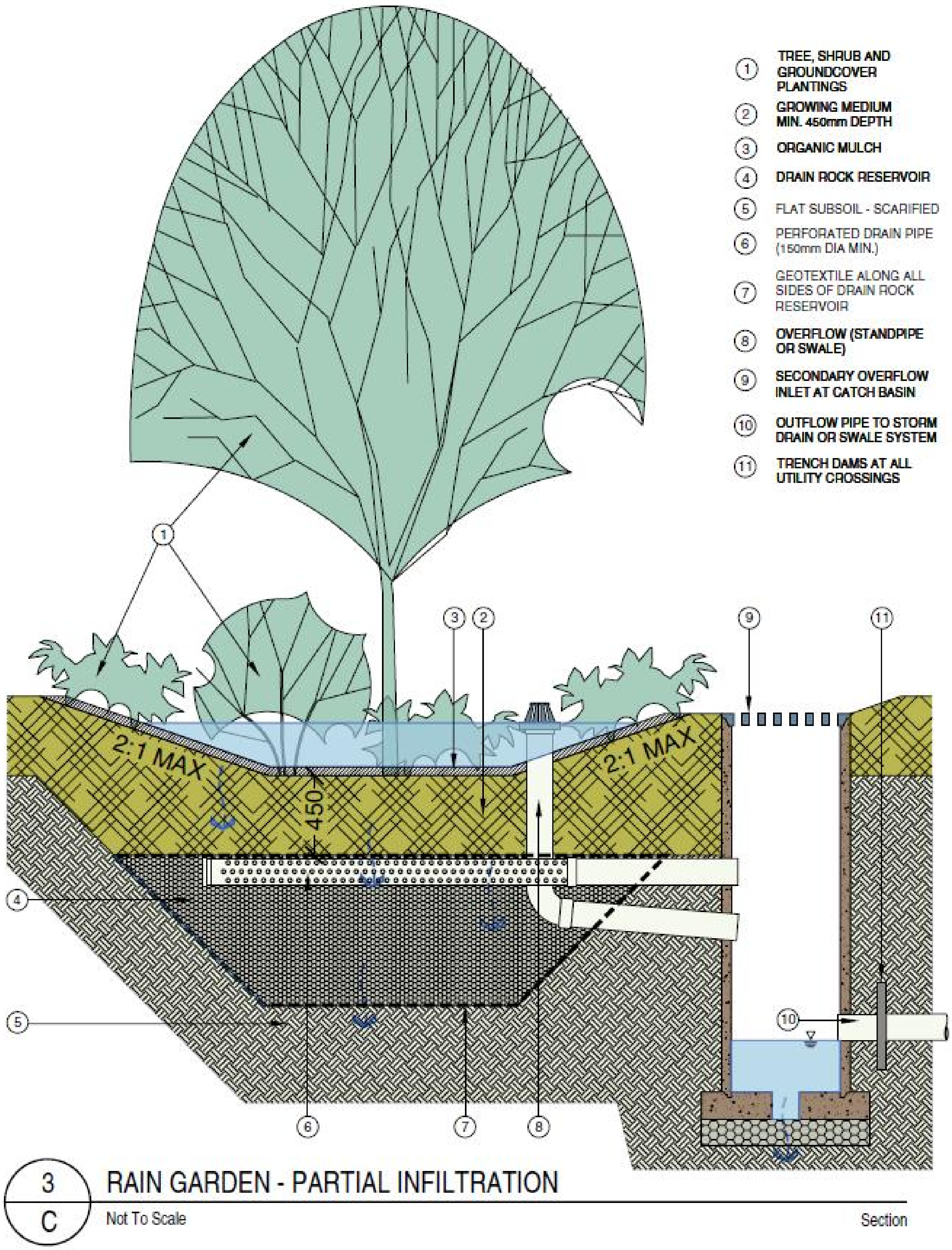

Figure 1 - Cross section showing the typical components of a rain garden including the planting medium, the drainage rockbed, and the overflow and drainage plumbing (Metro Vancouver, 2005).

Figure 2 - Drainage to Rain Garden (UBC SUB Team and Associate, 2010)

3 The Economic Factors

One aspect to consider when building a rain garden, are the economic factors. The economic factors are important as it contributes to the overall cost estimate for the SUB project and is a major factor in the feasibility of the garden. Theses cost factors will be split into sections, the capital and the maintenance costs. The costs will be analyzed in detail for each section. In addition, the costs of rain gardens and typical landscaping will be compared.

3.1 Capital Costs

Both rain gardens are elliptically shaped; Figure 3 shows the larger rain garden roughly sized at 12m wide by 15m long and Figure 4 shows a rain garden with 10m wide and 12m long. Both rain gardens elliptically shaped hence their areas are calculated using the formula to calculate ellipses. Therefore the size for the main plaza garden is 117.81m^2 and the south plaza rain garden will be 94.25m^2.

The total area that the rain gardens will be implemented on is 212.06m^2. The 100 percent schematics report provides data showing that the garden will be 450-600mm in depth (UBC SUB Team and Associates, 2010).

The Washington State University (WSU) has developed an extensive handbook about building rain gardens for homeowners in Washington (Hinman, 2007). This university is located just south of Vancouver and it shares identical weather conditions. Therefore the sample cost provided in their rain garden handbook is a suitable reference to estimate the initial cost the proposed rain garden at UBC.

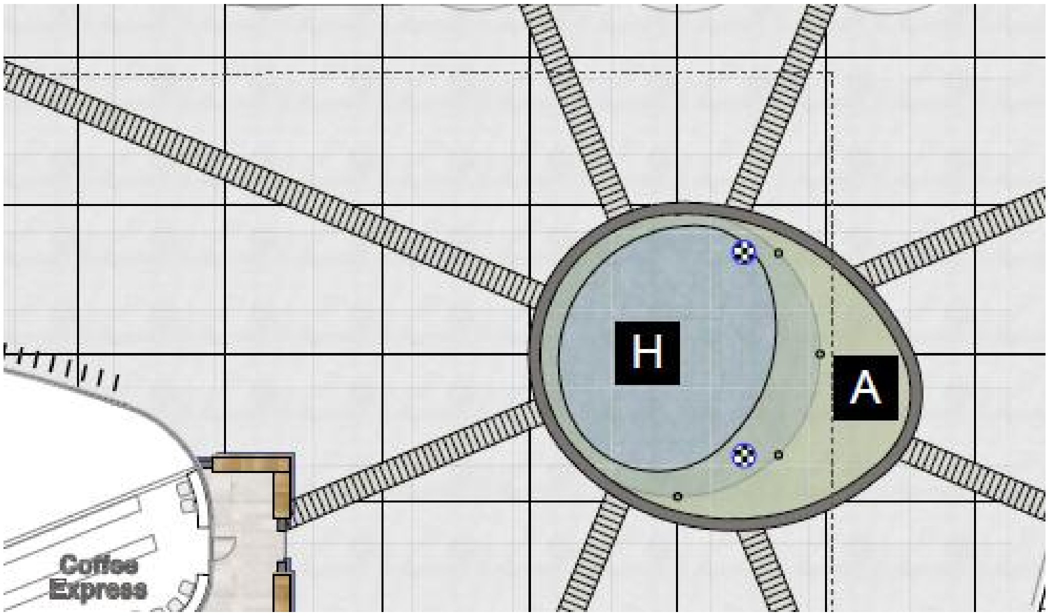

Figure 3 – The Main Square rain garden, the larger of the two features. The radial spokes in this schematic diagram indicates the proposed subsurface drainage features (Figure 2) that will channel runoff from various sources in the SUB area (UBC SUB Team and Associates. 2010).

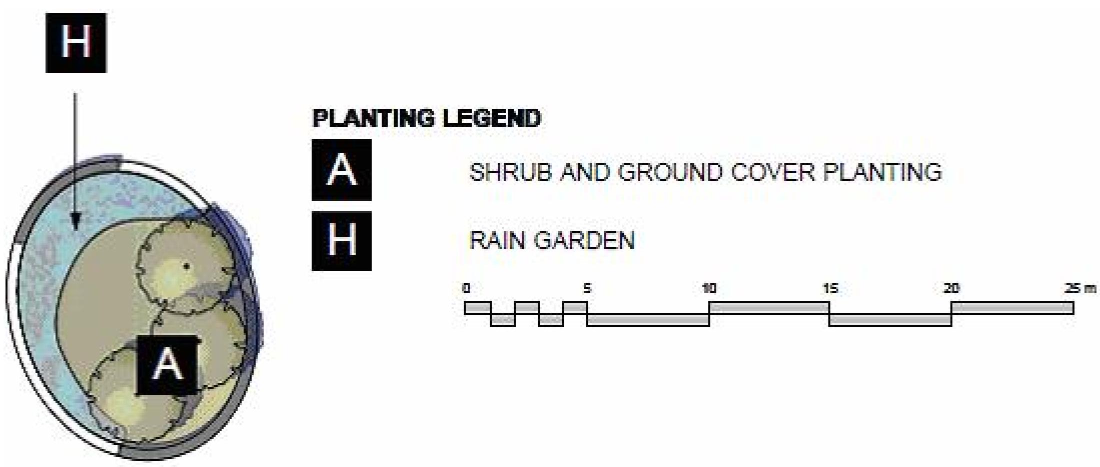

Figure 4 – The South Plaza rain garden and distance measuring scale. This smaller feature will utilize sloping walkways to channel runoff into the garden (UBC SUB Team and Associates. 2010).

From the handbook supplied from the WSU guide, it estimates that the cost for a 250 square feet or roughly 23.24m^2 garden to be $1,410 (Hinman, 2007). This means that the UBC rain garden is approximately 9 time larger. Therefore when scaled directly to the size of the total area planned by UBC, the cost will amount to approximately $12,866 to implement.

Another method to estimate more accurately is to generate a list of costs and find estimates for each cost (Table 1). WSU has provided a list of costs of their report for the construction of their rain garden. Using this data, the list of costs has been reconstructed to estimate a more accurate implementation cost for the rain gardens here at UBC.

Table 1 - Expected costs for materials and equipment necessary to implement a typical rain garden based on the Washington State University guide for rain gardens (Hinman, 2007).

Excavator	**$2,000/ 2 weeks (EZ equipment, 2011) = $3,150** ***Western Washington's rain garden required 2 days of use with the excavator and UBC's rain gardens are approximately 9x their size; hence assuming it takes 18 days to construct, or approximately 2 weeks**
Excavator Delivery	2 trips @ $25/trip (EZ equipment, 2011) = $50
Compost	127.24m^3 @ $10/m^3 (Engineering Services Solid Waste, 2011) = $1,272.40 *Assuming the garden is at max, 0.6 meters deep; hence the total volume of the garden is (212.06m^2) * 0.6m =127.24m^3 in volume
Compost Pick Up	Free
Drain Rocks	1 ton @ $55/tonne (Sharecost Rentals & Sales, 2011) = $55
Overflow and bulk drainage plumbing	27 meters @ $40/3 meters (The Home Depot, 2011) = $360 *Assuming the pipes needed are approximately the combined lengths of the garden: 15m+12m = 27 meters
Vegetation Costs *The plant list is provided by the 100% Schematic Report *Quantity is estimated based on the size of the Rain Gardens *Prices are market value estimates retrieved from plant companies around the world	
Beaked Sedge	$30/oz of seeds (Prairie Moon Nursery, 2011) = $30
Saw Beak Sedge	$15/oz of seeds (Western Native Seed Home, 2011) = $15
Red-Stemmed dogwood	10 pots @ $8/pot (Las Pilitas Nursery, 2011) = $80
Common Rush	$40/oz of seeds (Prairie Moon Nursery, 2011) = $40
'Nana' Dwarf Purple Willow	10 pots @ $6/pot (Planfor, 2011) = $60
Arrowhead	$15/oz of seeds (Prairie Moon Nursery, 2011) = $15
Miniature Cattail	10 pots @ $6/pot (The Grass Emporium, 2011) = $60
Labor Cost:	*The plant list is provided by the 100% Schematic Report *Quantity is estimated based on the size of the Rain Gardens *Prices are market value estimates retrieved from plant companies around the world
1 Excavator operator	8 hour/day @ $16/hour @ 18 days = $2,304
4 Gardeners	8 hour/day @ $16/hour @ 18 days = $9,216
Total Cost	$16,707.40

This cost breakup list provides a more accurate estimate of the initial start up cost for the rain garden. Also the cost comparison between this detailed list and the initial estimation based on proportion only differs by $3,841. Therefore these data suggests that the initial implementation cost should be between but not limited to $12,866 and $16,707.

Since cost is best judged relative to something else, the cost differences of rain gardens compared to regular gardens and landscaping is considered. There are two primary differences between a rain garden and a typical garden. The first difference is that typical gardens do not require drain rocks, storm drain connections, or overflow management features. From the above list of costs, it is noted that drain rocks are relatively low cost as it only costs $55 for one ton of drain rocks. The pipes required for drainage and overflow costs around $360. The second difference would vary depending on the prices of plants. The list of costs estimates that it will cost roughly $300 to buy the plants that are planned for this rain garden. These two main factors contribute a price difference of $715, which does not have a significant impact on the overall cost of building the garden. Therefore; implementing a engineered rain garden would cost approximately identical to regular gardening and typical landscaping barring any design costs.

3.2 Operational and Maintenance Costs

In addition to initial costs, another economic factor that must be accounted for are the maintenance costs. We have contacted UBC Plant Operations' landscape designer, Jeff Nulty for an estimate on the maintenance of the rain garden. He estimates that a medium level maintenance and a high standard of care would be required for the rain garden. For a medium level garden maintenance, Nulty mentioned that it includes weed control, regular trimming of any trees and shrubs, and minor irrigation maintenance and repairs. He estimates that this amount will total to around $2,500 per year (J.Nulty, personal communication, March 12, 2011).

However, the plants that are planned to be used are native to North America. "Native rain garden plants do not need fertilizer, winter protection, or irrigation" (Arboretum, 2006). This is because "native plants are adapted to the climate and soils" (Arboretum, 2006). This suggests that besides typical maintenance such as trimming and weed removal, there should be no need for any replanting or soil renewal. Hence it means that these gardens require little maintenance, which indicates that it is possible that the costs could be lower than Nulty's estimate.

Again, when compared to a regular garden, the maintenance cost difference is mainly based on the types of plants that are being used. If the regular garden uses plants that are native to North America, then there should not be much cost differences. However, if specific plants from other regions are used in the garden, the maintenance cost will increase based on the needs of the plants. For example, some plants might require more attention such as special fertilizers, frequent **pruning**, or frequent watering, than others. While on the other hand, plants that are native to the region do not require much attention besides regular trimming. Overall, a regular garden would potentially cost more, if not the same, to maintain than a rain garden would. Hence economic wise, the costs of maintaining a rain garden is more preferable than a regular garden.

Based on our findings, the rain garden will cost at minimum, $12,866 to implement, and the maintenance cost will average $2,500 a year. Also, rain gardens are more preferable to implement than regular gardens due to its lower start up and maintenance costs.

4 The Social Factors

Since the rain garden will be built beside the new Student Union Building, which is one of the busiest areas on campus, it is important to consider how the students are going to be influenced by the presence of the rain gardens. The social effects of the rain garden were investigated based online peer surveys and previous studies, and they are explained in two different categories, the educational effects and the effects on quality of life on campus. In addition, the social implications for possible job creation were considered.

4.1 Educational Considerations

The online survey was conducted with fourteen UBC students who are not currently taking APSC262 in order to investigate students' awareness of the rain garden, storm water problem, and the new sustainable SUB. In order to find out students' awareness about a rain garden, the question, "Do you know what a 'rain garden' is?" was given with three multiple choice responses:

- Yes, I know what it is.
- I think I have heard of it, but I am not sure what exactly it is.
- No, Never heard of it.

The result shows that only 14% of respondents have heard of the term rain garden but do not know exactly what it is, 86% of them have never heard of what the rain garden is. As expected, few of the respondents knew exactly what a rain garden is. This could correlate to only a small percentage of UBC students having knowledge of rain gardens. For the question, "Are you aware that rainwater runoff on impervious surface can cause significant water problem?," 57% of the respondents answered "yes, I am aware of it", but the rest of them answered "No, I am not aware of it". Based on the result, roughly half of the students were aware of the storm water problems caused by rainwater runoff, but students' awareness about the rain garden is significantly lower despite it is a very cost-effective and environmentally sound solution for the stormwater problem urban cities are facing (DC Greenworks). With a larger number of respondents, more accurate results would have been obtained.

Based on the 100% Schematic Design Report for the new SUB, one of the rain gardens is planned to be built on the south entry side of the SUB, a major pedestrian route (UBC SUB Team and Associates, 2010). The rain garden will have a unique rainwater collection feature such as aggregate paving with glass nuggets, designed to direct the surface flow into the rain garden. This eye-catching design can draw the students' attention and raise the stormwater management issues awareness. (Figure 5) Additionally, the rain garden can be used as an educational site for school instructors to teach students stormwater issues and restoration practices in sustainable related courses or programs. Moreover, with many other sustainable features of the new SUB including the rooftop garden and rainwater cistern, the rain garden could play an important role in enhancing students' awareness about UBC's Sustainability Initiative.

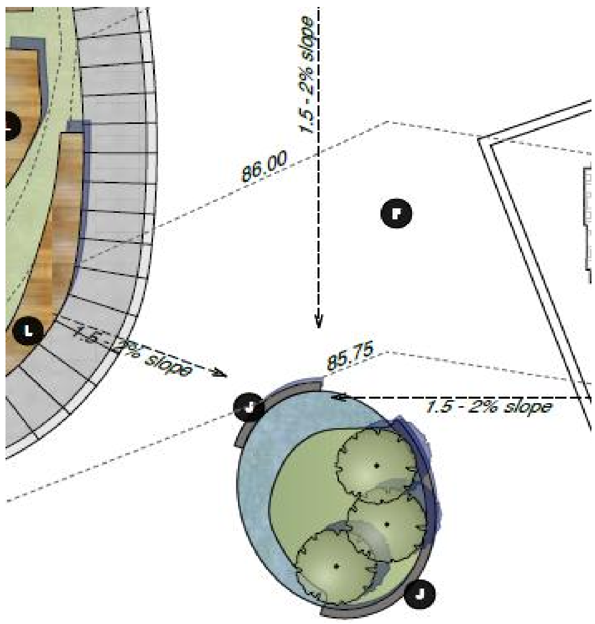

Figure 5 – Overhead schematic of the ~2% sloping gradient of the proposed South Plaza walkway, intended to help guide stormwater into the rain garden (UBC SUB Team and Associates. 2010).

4.2 The Effect on Quality of Students' Lives.

The area around the SUB is a major thoroughfare for foot traffic and is a popular social meeting place on UBC campus. Having a rain garden in the centre of campus could affect a number of students' quality of life in positive ways. There are various studies showing that having surroundings with natural environment has positive psychological and physiological effects on human. Based on the research conducted on the students in Texas State University, the students who use campus green spaces tend to feel more positively about their social interaction with peers and their feelings of self-worth on campus (McFarland et al., 2008). The another study shows that having a visual contact with natural environment promotes the restoration from various stresses more effectively than with urban environment (Ulrich et al., 1992; Ulrich et al., 1992). Several other studies shows having a mere view of nature can lower the stress level (Kaplan, et al., 1989; Kaplan et al., 2001; Stigsdotter). Therefore, having the rain garden beside the SUB could benefit a number of students providing direct visual contact with green environment and a place to relax and relieve the stress gained from exams or heavy course loads.

The second rain garden will be located in the square side of the new SUB which is designed for various student activities and events, and there will be seating on the knoll, seat walls, and over-sized wood benches for students. With the knoll and the existing bouquet and turf grass, the rain garden and its additional native plants will be an important part of the natural view decorating the SUB square with green vegetation and such green space will become a great place for students to enjoy various events and activities interacting with their friends. In addition, wildlife attracted by the plants could improve the aesthetics of the rain garden and improve the livelihood of the campus.

The rain garden will also enhance the students' convenience by solving the problem of temporary flooding after moderate rain storms currently existing between SUB and bookstore regions. Based on the survey, 93% of respondents answered that they had experienced inconvenience due to the standing water on campus walkways (Figure 6), and 71% of respondents indicate that they like the idea of having a rain garden beside the new SUB in order to solve the flooding issue. The rain garden will be built with surrounding surfaces sloped towards the rain garden also with aggregated paving which directs surface flow (Figure 5). Therefore, having the rain garden will remove the temporary flooding problem and allow students to freely walk around the new SUB.

Figure 6 – Photos showing the common occurrence of temporary flooding at and around the New SUB location, just after a few hours of moderate rainfall as indicated by the arrows (photos by Peter Woo, 2011).

4.3 Job Creation Suggestion and Effects

Currently all landscaping for the New SUB is expected to be handled by UBC Plant Operations due to contractual agreements. However, the following two suggestions we have developed during the course of our research should be considered as they both have economic and social benefits.

In order to help promote education, the responsibility for maintaining the rain garden can given to the AMS Society; where they can employ students and promote educational values by raising awareness of the functions of the garden. This can help encourage the implementation of future rain gardens around the campus and worldwide.

Furthermore, responsibility for rain gardens could also be given to the UBC Botanical Garden and Center for Plant Research. They can help cut the maintenance costs as students can manage the rain garden. It can also cut the costs of UBC Plant Operations by allowing volunteers via their volunteer program, to maintain the garden. Another benefit this is that UBC Botanical Garden can help promote rain garden information for the general public. Currently its website does not have any official information regarding the implementation and uses of rain gardens.

The information gathered from peers and existing studies implicates that the presence of the rain gardens beside the new SUB can have various positive social effects on students. The natural environment created with the rain garden and other green vegetations around the SUB can provide students with a place for social interaction as well as relieving the stress level gained from school works. The rain garden can also be used as an educational site to raise the awareness of stormwater issues and restoration practices. Moreover, the rain garden could possibly create students' job or volunteering opportunities for its maintenance.

5 The Environmental Factors

The primary intention for a rain garden is with the environment in mind, to contribute in the filtering of urban stormwater runoff and minimization of pollutants in stormwater prior to discharge into environmentally sensitive waterways. The following sections will look at three environmental concerns; how effective are the plants and soil at filtering stormwater runoff, potential wildlife attraction, and long term toxicity effects.

5.1 The Role of the Plants

As mentioned in the Introduction, a rain garden is intended to collect rain-water runoff and filter the water before entering the Vancouver storm drain system. Rain-water runoff collects pollutants such as dirt particles or bacteria on their way to a storm drain, accounting for up to 70% of water pollution. However, when runoff water passes through a rain garden, up to 90% of the chemicals and up to 80% of sediments are removed from the runoff water (Rain Gardens 101). The runoff water is soaked up and filtered by the soil, plants, and root systems. The plants filter runoff water at ground level, while the roots below filter water at sub levels. The roots also increase water **infiltration** and gives soil structure. Plants with horizontally growing roots are preferred in rain gardens, as they provide the soil with distributed structure and optimize water infiltration in the soil. Furthermore, in additional to giving the garden more aesthetics (as discussed in the social factors), the plants preserve native vegetation, attract wildlife, and contribute oxygen to the environment. See appendix A for a comprehensive look at candidate vegetation.

The plants that make up the rain garden are all chosen for their survivability in BC’s cool and wet climate, their ability to treat waste-water., and their ability to fit into campus environment. Because the plants found in the rain garden are native or found in climates similar to BC’s requiring no fertilizers, and have the ability to withstand harsher conditions, less maintenance is required for a rain garden compared to a traditional garden, further reducing the gardens carbon footprint.

5.2 Wildlife Attraction

As mentioned in the social factors section, wildlife attraction boasts additional aesthetics and beauty to the rain gardens. In addition to this, wildlife attraction also has environmental benefits. The rain garden consists of several plants that provide food sources and shelter from predators to small mammals and birds. Small mammals may additionally benefit as some of the plants provide them shelter from larger birds such as crows and seagulls, which are known to aggressively compete with small mammals for food. However, this could also result in an increase of certain wildlife populations which could affect economic and social factors. Wildlife benefits specific to each plant will be discussed in the Plant Guide section.

A possible drawback in this regard is that the temporary body of standing water in the rain garden may become an attraction for mosquito breeding during the summer months. This leads to concerns of disease transmission from mosquitoes such as the West Nile Virus. However, since mosquitoes need around three days to lay and hatch eggs (CRD, 2006).

5.3 Long Term Toxicity Concentration Effects

Long term use of a rain garden is expected to contribute to lowest pollution levels found in water. A study found the levels of ammonia-nitrogen in the water exiting the rain garden was significantly lower than in the water entering the rain garden (Dietz, 2011). However, this means chemicals are being left in the soil of the rain garden. Such chemicals may be toxic to the plants, stunting growth and causing discolouring. A high concentration of these chemicals can also reduce the effectiveness of the rain garden. Replacing the soil with new soil will dilute out the toxicity levels. **Mulching** the soil will also breakdown these unwanted chemicals over time. Furthermore, the leafy plants in the garden will absorb heavy metals in from the soil.

Based on these findings, it can be seen that environmentally, the implementation of a rain garden provides a general net benefit to the environment with little to no negative effects. Soil toxicity over time can be managed with regular maintenance, and the potential problem with mosquitoes can be remedied with proper design of the garden's drainage system. The major benefit remains that up to 90% of chemicals and 80% of sediments can be filtered out of stormwater runoff with a properly designed rain garden.

6 Rain garden performance and case studies

Rain gardens have been implemented in various locations around North America. Locations within Vancouver's climate region include Washington State, and Portland, Oregon as well as Vancouver. The Washington State University has created a design guide book for homeowners of western Washington to effectively create small residential rain gardens and to promote sustainable stormwater management with step-by-step instructions and guidelines. More locally, the City of Vancouver has in 2006 implemented natural infiltration basins similar to rain gardens called bio swales along the southwest stretch of Crown Street (5900 to 6200 blocks). In this implementation, shallow swales layered with 30cm of absorbent soil and populated with native plants filter out pollutants from road surface stormwater runoff as the water is absorbed into the swales. In addition to the implementation, the water quality discharge of these swales is monitored by UBC's Institute for Resources Environment and Sustainability in partnership with the city for approximately five years where data collected will be compared to standard gutter stormwater management methods (City of Vancouver, 2006). In addition to this, Metro Vancouver has developed documents for storm water management best practices, which documents design guidelines for rain gardens and bio swales (Metro Vancouver, 2005). Another implementation of a rain garden system much closer to UBC is at the Westbrook Place Neighbourhood. This 24 unit townhouse complex incorporates sustainability design principles including landscape design that integrates native plants with rain water detention and infiltration via several rain gardens on its site (Senga Landscape Architecture, 2009).

The actual performance of a rain garden has been examined by the American Water Resources Association. They monitored several rain gardens in the United States and used three methods to assess them: "Visual Inspection, Infiltration Rate testing, and Synthetic Drawdown Testing". (Asleson et al, 2009). The visual inspection is to look and see if the garden is overflowing. The infiltration rate testing is conducted with infiltrometers. Infiltrometers are devices that "are designed to measure the unsaturated hydraulic properties of soils" (Soil Measurement Systems, 2006). It means that infiltrometers are devices that determine the infiltration rate of a rain garden. The last method of measuring a rain garden is by using synthetic drawdown testing, which is to purposely flood a rain garden with water and observe the rate at which the water is being drained afterwards. All these methods are used to determine the rain garden's filtering capacity. Their conclusion is that these methods of evaluation can then be used to determine if there are any problems regarding the rain garden's performance.

7 Conclusion

Based on the triple bottom line assessment on the feasibility of using rain gardens as a stormwater runoff management solution, it can be summarized that a rain garden definitely holds benefits socially and environmentally. Compared to typical landscaping, only a few changes are required for the function of filtering a majority of the impurities from stormwater runoff. In addition the rain garden has been found to provide the campus with varying aesthetics and educational opportunities in bringing awareness to sustainable stormwater management. Based on these main points, it was concluded that a rain garden is a cost effective method way to filter out stormwater pollutants, add aesthetics, and enhance the natural atmosphere of the university campus.

Since many large rain garden projects in the past also implemented post developmental monitoring of the water quality and drainage rate to validate the design as well as to evaluate the effectiveness of the garden, it is recommended that the UBC SUB Team also implement a plan to actively monitor these parameters over an appropriate amount of time to gauge performance. Stormwater quality at UBC has been monitored previously by UBC in 2002 and more recently as mentioned in section 6 that UBC is monitoring the performance of the Crown Street bio swales project in partnership with the City of Vancouver.

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Appendix A - Candidate Vegetation

The plants are strategically chosen to increase the effectiveness of the rain garden. Native vegetation should be used because they will be better suited to BC's climate, increasing their survivability rate, and require less fertilizer, minimizing maintenance costs. An outline of each plant expected to be incorporated into the new UBC Student Union Building follows. (UBC SUB Team Associate, 2010)

Arrowhead

Figure 7 – Arrowhead, showing its broad wedge shaped leaves and white flowers.[1]

Scientific Name: Sagittaria latifolia

Description: The Arrowhead has broad wedge shaped leaves resembling and arrowhead. They have no stem. Its thick white roots produce edible **tubers**. White three petal flowers appear between the months of July and September (USDA, 2002). The arrowhead is widely distributed throughout North America. They are commonly found the Fraser Valley Region of B.C. The Arrowhead thrives in moist soil and generally grows in small ponds, or near lakes. Spider mites and aphids are pest the Arrowhead is commonly susceptible to.

Function: The Arrowhead is highly **rhizomatous**, a preferred characteristic in rain gardens. Its wide leaves and emergent foliage provides shelter for small mammals. Furthermore, the seeds and tubers of the seeds provide food for small animals.

Possible Substitutions: Any species of the Sagittaria would be a possible substitution for a rain garden because they are rhizomatous in nature and all have broad wide leaves. Examples include the Grassy Arrowhead and Bull-Tongue Arrowhead.

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[1] http://www.flickr.com/photos/42613470@N00/318240609/

Beaked Sedge

Figure 8 - Beaked Sedge, showing the spiky flowers at the top of each stem.[2]

Scientific Name: Carex rostrata

Description: The stems of the Beaked Sedge are long, narrow, and triangular. The flower grows in spikes. Its fruits are triangular. The Beaked Sedge is commonly found in streams and marshes (Rook, 2002). It has a life span of 2-6 years.

Function: The Beaked Sedge is one of the more durable plants in the rain garden, being able to survive in harsh soil conditions and tolerant to frost. Along with the Dwarf Purple Willow and Sawbeak Sedge, the Beaked Sedge acts as a fall back plant in the event, the all the other plants die. Sedges are commonly planted on garden restoration sites due to their preference of such conditions.

Possible Substitutions: Sawbeak Sedge

[2] http://lh6.ggpht.com/_ahmuK21Mr9s/Sv3r8t3amGI/AAAAAAAAQE8/qcKxddtYq1g/Sedge_Beaded_1.jpg

Common Rush

Figure 9 - Common Rush; a tall grass type vegetation[3]

Scientific Name: Juncus effuses

Description: The Common Rush is a slow spreading grass like plant, emerging from a root stock, Native to North America. Its flowers grow in compact clusters up to 4 inches long. Its rhizomatous roots are short roughly six to ten inches long and are finely spread out.(USDA, 2002) The Common Rush can grow up to four feet tall.

Function: The Common Rush has a wide range of uses and may be the most versatile plant in the SUB's Rain Garden. In a rain garden, the Common Rush contributes with its rhizomatous roots. The dense roots also aid in prevent erosion of the soil, and aid in wetland creation (USDA, 2002). It's grass like structure aids in filtering water at above soil levels. If grown in dense clusters, the Common Rush can act as shelters for small animals. Many small mammals and birds depend on the seeds of the Common Rush as a food sources (USDA, 2002). Furthermore, the Common Rush contributes to soil stabilization, up taking nutrients that if accumulated in the soil, would increase soil toxicity. The plant also acts as a host to beneficial bacteria, making it very desirable in waste-water treatment applications (USDA, 2002).

Possible Substitutions: With its wide array of contributions in a rain garden, the Common Rush is difficult to be replaced with a single plant. However, other species of the Soft Rush would be a close substitution.

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[3] http://www.pepiniererustique.com/francais/images/juncuseffusus.jpg

Dwarf Purple Willow

Figure 10 - Dwarf Purple Willow, showing its overall shape[4] as well as its leaves up close[5].

Scientific Name: Salix purpurea 'Nana"

Description: The Dwarf Purple Willow is a short, fast growing shrub, with tough resilient branches The branches are purple at first giving the plant its name, however, over time they will become green. The leaves generally grow in pairs. The Dwarf Purple Willow, native to Europe, thrives in poor soil conditions and cold climates, and requires little maintenance (Ornamental Grasses).

Function: The Dwarf Purple Willow is excellent for erosion control. Combined with its excellent survivability and fast growth, the plant was brought to North America for the very purpose of erosion control along stream banks (Dickerson, 2002). Furthermore, the plant provides cover for small animals. Although fast growing, with regular maintenance, the plant will not be invasive with regular maintenance.

Possible Substitutions: With its unparalleled soil erosion control and survivability, the Dwarf Purple Willow is hard to substitute. However, if so include, the Purple Willow, with the same survivability and erosion control characteristics, is a possible substitution. The Purple Willow, however, can grow up to eight feet tall within two years; hence, additional maintenance is needed (Dickerson, 2002).

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[4] http://sazhaemsad.ru/wp-content/gallery/salix/Salix_purpurea_nana.jpg
[5] http://www.flickr.com/photos/johandahlstrom/2505085621/

Miniature Cattail

Figure 11 - Miniature Cattail[6]

Scientific Name: Typha latifolia 'Miniature'

Description: Miniature Cattails are a shorter species of cattails. They have long green slender stalks and a brown fluffy flower head, similar to the tail of a cat, hence the name. They can grow up to two feet tall (Stevens, 2002). Cattails thrive in ponds and other wet conditions where they are found. They have a high tolerance for floods.

Function: The roots of the Miniature Cattail are rhizomatous. Having the highest water tolerance out of all the plants in the rain garden, the Miniature Cattails can be planted at the lowest depression of the rain garden without too much concern of them being over watered. Because of its water tolerant nature, Miniature Cattails are commonly used for waste water treatment as it can absorb sediments from the waste-water. The roots of the Miniature Cattail can also be a food source for small animals, attracting wildlife (Stevens, 2002). Its seeds however are too hairy and undesirable to birds.

Possible Substitutions: The miniature cattail can be substituted with cattails which would grow much taller, up to 10 meters (Stevens, 2002). However, the functions needed for the rain garden would remain.

[6] http://www.waterfordgardens.com/images/categories/C252.jpg

Red-Stemmed Dogwood

Figure 12 - Red-Stemmed Dogwood[7]

Scientific Name: Cornus stolonifera

Description: The Red-Stemmed Dogwood is a woody shrub generally between 1.4-6m tall. During the Spring-Summer seasons, the bark and leaves of the Red-Stemmed Dogwood bark are green, however, during the winter seasons, the bark and leaves are red, giving the plant its name (Stevens, 2002). The rounded leaves have a pointed tip at the ends. During the summer, white flowers and white berries appear. The plant is native to BC. It prefers to grow in wetlands.

Function: The berries of the Red-Stemmed Dogwood attract a wide variety of birds and small mammals; as a result, one of the main functions of the plant is to attract wildlife. This plant also thrives in nitrogen rich soil, as a result, it soaks up the nitrogen from the storm water runoff. Its red colour also adds a nice contrast to the garden.

Possible Substitutions: There are many different species of Dogwood with similar characteristics in colour, fruit, and climate tolerance, such as the Smooth Dogwood, native to western Canada. The Smooth Dogwood would be an excellent substitute.

[7] http://www.laspilitas.com/s/images/plants/222/Cornus_stolonifera.jpg

Sawbeak Sedge

Figure 13 Sawbeak Sedge, showing its flower at the top of its stem[8]

Scientific Name: Carex Stipata

Description: The Sawbeak Sedge has narrow triangular stems. Its flowers, located at the top of the plant, form in a spiked cone, up to four inches long. (NPWRC, 2006) The plant is naturally found nearby streams and prefers wet conditions and disturbed ground (Sound Native Plants, 2001).

Function: The Sawbeak Sedge's functions are similar to the Beaked Sedge. It has thick roots, its main purpose is to give the soil structure and improve water infiltration. Its preference to disturbed ground means it can survive in harsher conditions such as restoration site. This makes the Sawbeak Sedge one of the more durable plants in the rain garden.

Possible Substitutions: Beaked Sedge

[8] http://farm3.static.flickr.com/2674/4155811402_b5705458d7.jpg