UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Stormwater Management Options

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INTRODUCTION

This report is a synthesis of the work done by Group 3 on the development and implementation of different approaches to stormwater management for South Campus. The options developed include: a retention pond and irrigation system, hydroelectricity generation, and swales & raingardens. This report presents criteria and indicators that were used to assess how well each option met the needs of South Campus, and our final recommendations. This report gives a high-level overview of the options, and all of the detailed low-level calculations are included in the relevant appendices.

INTRODUCTION TO UBC STORMWATER MANAGEMENT

UBC is an academic and research facility, a sole owner-occupier of the UBC Endowment Lands, and a site of numerous public institutions. These attributes generate a unique opportunity: to challenge and to improve current water management practices with sustainability in mind. There is a growing need for water usage, its treatment, efficient infrastructure, and wise stormwater management practices. Addressing the above could result in environmental preservation, social benefits and lessened financial stress. This brief focuses on the South Campus, since it is an area with vast developmental and environmental strains (UBC, 2009)

CURRENT SOURCES AND DEMANDS FOR WATER AT UBC

As of 2011, UBC has an annual water consumption of approximately 3.9 million cubic meters of water (Paderewski, 2012) (Hood & Seabrooke, 2011). All of this water is potable (drinkable) water that comes to UBC from the Capilano Reservoir, and approximately 75% of this water does not get recycled after its initial usage (UBC, 2010). Cooling, research applications, showers, washrooms, and other applications inside building use most of the water; the remaining 11% is used for irrigation. See Appendix A, figure 1 for a breakdown of the current end users of water at UBC.

UBC consumes 3 m^3 (1 m^3 = 1000 L) of water per square meter of land; comparatively, Australian universities consume less than 1 m^3 of water per square meter of land (UBC, n.d.). Figure 2, Appendix A illustrates the composition of UBC's average water demand and figure 3 shows that UBC's water consumption has been slowly decreasing for the last decade.

In addition to the potable water that flows into UBC there is an independent stormwater management system that is designed to take care of rainwater and discharge it into the sea without damaging the soil at the cliffs. The system consists of an intricate infrastructure of mainly PVC and concrete pipes that, together with ditches, establish a flow path for the rainwater. There was a metering system in place at the former intersection of Westbrook and South Campus Road. The data for May 2007 through April 2008 is included in Appendix E. The current water needs of South Campus are difficult to establish. Some of the key areas of irrigation and water consumption on South Campus such as the UBC farm, the Plant Operations Nursery, and Botanical Gardens didn't start metering their water consumption until the beginning of April 2011. The Botanical Gardens, the largest water consumer of South Campus besides TRIUMF, used approximately 14000 cubic meters during November 2011, with the UBC farm coming in second with 9717 cubic meters during the same time period.(Waleed Giratella, UBC Sustainability Office, 2012)

Current infrastructure for stormwater at UBC

The current pipeline infrastructure for South Campus is quite extensive. There is a 1050mm diameter concrete pipe running all way from 16th Avenue down Wesbrook Mall to the former junction of South Campus road. From this point on it branches out to several 400mm and 700mm diameter concrete pipes. This pipeline continues after TRIUMF, with the 1050mm running all the way down to Southwest Marine Drive. Aside from these mains there are multiple 100-300mm diameter PVC pipes running crisscross through the Botanical Garden Nursery, the Plant Operations Nursery, and the UBC Farm. In addition to this there are numerous ditches that are also connected to this system. The South Campus area does have a reservoir under Nobel Park for retention purposes. Please see the Figure 2 in Appendix B for details.

Jurisdictions or Populations Affected by Change in the System

There are several major entities currently serviced by the water distribution and stormwater infrastructure of the South Campus area, including: the University Neighbourhoods Association (UNA), which represents the roughly 5000 residents of the new Wesbrook Place neighbourhood south of 16th Avenue, the UBC Farm, the UBC Botanical Gardens, TRIUMF, FPInnovation, and the National Research Council facility. Modifying the handling of stormwater would affect these groups in a myriad of ways. For example, infrastructure capable of handling higher volumes may have prevented flooding at TRIUMF in October of 2009 when heavy rainfall resulted in knee-high water at the facility (Ubyssey, 2009). The UBC Farm, Botanical Gardens, and Plant Operations Nursery use nearly 26 million litres of city water each year (UBC, 2009), which could be significantly reduced through the use of stormwater reclamation for irrigation purposes. Furthermore, the landscaping throughout the campus and the playing fields north of 16th avenue are all possible candidates for stormwater irrigation.

Current Cost Implications at UBC

UBC purchases its potable water from Metro Vancouver. Table 1 includes the rates for water purchases for the past decade:

Table 1: Annual Water Cost (Athreya, 2011)

	2001	2009	2011
Peak Season (June – Sept)	$0.21/m^3$	$0.66/m^3$	$0.88/m^3$
Off-Peak Season (Oct – May)	$0.21/m^3$	$0.53/m^3$	$0.68/m^3$
Amount Spent on Water Usage	$1,390,000	$2,500,000	$2,900,000

In 2011, 8% of the total water expenditure for the year ($232,000) was spent on irrigation (Paderewski, 2012). Compared to other places in Canada, UBC has an advantage of paying low rates for water: in Manitoba the rate is $1.25/m^3, and in Edmonton the rate is $1.95/m^3 (Grant, 2002).

There are also costs associated with the various infrastructures in place on the UBC campus. The cost of maintaining the water treatment plants at UBC is approximately $1,300,000 per year. Included in the treatment plant category are the bio-filtration system, the south campus water re-circulation system, and the Iona wastewater treatment plant (Athreya, 2011).

Current environmental impacts of system (both to UBC and surrounding areas)

The current UBC Stormwater Management Plan adopted in 2009 is claiming to enhance the sustainability of the campus and its ecosystems. More specifically, it is aiming to minimize the pollution of air, water and soil. However, campus development and inadequate stormwater management pose erosion risks along the Point Grey Bluffs, as well as contaminated stormwater entering the Fraser River and the Strait of Georgia (UBC, 2009) South Watershed patterns cause erosion at the Booming Ground Creek due to increasing summer base flows with campus development (UBC, 2009). Though a detention tank exists in Nobel Park, it is insufficient for storm events larger than 1 or 5 year (UBC, 2009). Fish habitat has also been reported to deteriorate as the campus develops (UBC, 2009).

The geology of the Point Grey Bluffs makes it susceptible to erosion by stormwater seepage. The Point Grey Bluffs are composed of a thin layer of organic topsoil over an impermeable layer of glacial till. Underneath, there is a layer of sand (Upper Aquifer) followed by an impermeable layer of silt and another layer of sand below sea level (Lower Aquifer). The stormwater passing through the topsoil is redirected at the glacial till towards the cliff, thus eroding the face of the cliff (UBC, 2009).

Non-storm discharge water contamination was measured in 2005 for the following parameters: turbidity, pH, water hardness, temperature increase, and metals concentrations. Measurements at Cutthroat Creek were used as a standard, since the creek contains relatively undisturbed ecosystems and shares its geology with the rest of drainage creeks on campus. Though the data isn't very recent, it gives a good insight into the polluting agents present (Fowler, Robinson, & Phillips, 2005)

Options Introduction

The following section introduces the three different options that we have developed in order to improve the stormwater management at South Campus. The introductions cover the high-level issues of each option, and all of the low-level issues such as technical calculations and cost estimates are included in the relevant appendices.

Retention Pond & Irrigation System

Description of Technology

Retention ponds capture stormwater runoff and store it. The ponds fill with stormwater and release it over a period of days until normal depth is reached. Retention ponds can range from being concrete-lined to vegetated basins and permanent pools. (CASQA, 2003)

URL: http://www.gotalgae.com/retention_ponds.htm

The retention pond would be dug where the wetlands are currently located on the UBC Farm. It would be 90m long, 30m wide, and 2m deep, giving the pond a capacity of 5,400m^3. At this depth, an impermeable layer of soil is hit so it is only necessary to line the sides of the pond with concrete. The retention pond will be filled with plants that act as a natural filter and have the ability to reduce pollutants, like metals, oil, bacteria, and nitrogen, by almost 100%. Refer to table 1 and 2 in Appendix C for a detailed list. There will be a 10m buffer zone all around the pond. A low energy pump will be installed to push the filtered stormwater through to the drip irrigation pipes on the UBC farm. Two hundred metres of piping will be installed parallel to existing pipes running up from the retention pond up to the main road. Then, 100 metres of piping will be installed on either side to spread the water to crops that currently use drip irrigation.

Cost Implications

- Costs quite high compared to other stormwater control systems
- Requires frequent inspections, water quality testing, and equipment maintenance. For a detailed breakdown, refer to table 3, Appendix C**.**
- Capital costs: $486,700
- Annual maintenance costs: $5,670

Stormwater Hydroelectricity Generation

Description of technology and its state of current development

Hydroelectric generation is a technology used the world over. Its capability can range from powering a house using a small stream to powering millions of houses with massive river dams. Micro hydro, defined as power plants that produce less than 2 MW (BC Hydro, 2011), is on the smaller end of the spectrum, and requires less waterpower than its larger relatives.

URL: http://www.newmillshydro.com/products/item/7/crossflow-turbines/

The flow of stormwater through UBC's South Campus area has the potential to generate electricity using a micro hydro plant. The energy generated could be used immediately, either through connection to loads on South Campus or to the university's grid, or it could be stored for later use.

There are two methods for establishing a power plant of this size at UBC: run-of-the-river or damming (Pembina Institute, n.d.). The main advantages of the former are that it does not require a reservoir, so the local ecology and hydrology of the surrounding areas is not affected. The main downside of this option is that it may not deliver a stable supply of energy due to the nature of the water source (precipitation). There will be large differences between the seasonal peak water flows and nominal water flows, so the resulting power levels will fluctuate similarly.

The second option has the advantage of a stable, easily stored energy supply; the reservoir can be opened and power generated on an as-needed basis. However, this feature often means the local hydrology and ecology at the location of the dam or reservoir is disturbed.

The option presented in this document is a combination of the two, which will use the Nobel Park detention tank as a form of underground reservoir, while the turbines and generation station, located near Marine Drive, will be similar to those found in run-of-the-river projects, allowing the expected variable flow rates to be efficiently utilised. Further, the electricity generated will be stored as hydrogen, through the electrolysis of water, to allow for use at a later date. If the 1.95 m diameter Marine Drive pipe were used as a retention facility, stormwater could be stored there during the wet months and, using the electricity stored as hydrogen from the hydro plant, could be pumped back uphill to areas of South Campus for use as irrigation (e.g.: UBC Farm, Botanical Gardens, Plant Ops Nursery).

High-level cost implications

An up-front expenditure of approximately $300,000 for the hydro generation station and $400,000 for the generation, storage, and combustion of hydrogen is anticipated. For a more detailed breakdown of the estimated capacity and cost, see Appendix E.

Energy Generation

Based on flow measurement data collected from May 2007 through April 2008, a system in place could generate approximately 74,600 kWh over the year from the hydro plant. If this energy is stored in the form of hydrogen, the total energy available when the hydrogen is combusted would be approximately 39,600 kWh (see Appendix E).

Swales and Raingarden

Overview:

Precipitation at the UBC South Campus amounts to 47 inches per year, which calls for adequate management of groundwater resources and stormwater run-off (UBC, 2005). Since the area is being converted from a forest to residential area, with potential student and faculty housing, there is a need to preserve local ecosystems and groundwater patterns. Swales and raingardens will intercept and naturally filter stormwater, especially during the storm events (Low-Impact Delevelopment). This will reduce creek erosion and increase the amount of native vegetation used in the implementation.

URL: http://www.portlandonline.com/bes/index.cfm?a=63096&c=36055

Potential sites at South Campus:

There are numerous sites throughout South Campus that could have swales (see Appendix B, Figure 2):

- Wesbrook Mall (South Campus Road to Marine Drive) = 1730 ft ($26,000) Figure 1: Swales & Raingarden
- Nurseries Road (Wesbrook Mall, past Imperial Trail) = 1375 ft ($20,600)
- Marine Drive (North edge of Farm to Wesbrook Mall) = 2200 ft ($33,000)

The site where a ~2000 ft^2 raingarden could be implemented (see Appendix B):

- At the corner where Pacific Spirit Park and South Campus meets (361,700 ft^2)
- This area is able to drain the whole South Watershed (Planning Group Sustainable Stormwater Management, 2004)

DESIGN GUIDELINES

The key issue to consider when choosing a location is that there should be sufficient water flow through that area to ensure optimal performance of the swales and raingardens.

The swales along Wesbrook Mall (South Campus Road to Marine Drive) can stop the extra water from the Nobel Park retention pond (~1600 m^3 versus ~780,000 m^3 of stormwater in December) from travelling towards the creek. It will connect to the swales along Nurseries Road (Wesbrook Mall, past Imperial Trail), and then towards the raingarden. The side slopes of the swale should not exceed 3 to 1 (1m wide, 3m deep) (Appropedia, 2011). The treatment depth should not exceed 2/3 the depth of the grass in the swale (Appropedia, 2011). It will be lined with gravel to stop stormwater from infiltrating into the soil. A perforated 300mm drainpipe installed in the gravel layer. The swales along Marine Drive (North edge of Farm to Wesbrook Mall) can be connected to the unused pipe on Marine Drive for water retention.

A raingarden should serve as an endpoint of swale flow. It will have an overflow system that will be connected to the creek. The raingarden will need irrigation for the first 2 years of its establishment (Low-Impact Delevelopment). The water for irrigation can be provided by pumping stormwater from the swales. The raingarden is modelled after the Glencoe Raingarden (Planning Group Sustainable Stormwater Management, 2004), since the soils at the site closely resemble the impermeable soils of UBC. Water overflow will be retrofitted to the existing stormwater system on South Campus.

COSTS OF INSTALLATION, OPERATION AND MAINTENANCE:

Table 2: Swales & Raingarden Cost Estimation

Swales (Taylor, 2000)	Raingarden (Portland Bureau of Environmental Services, 2007)
• E.g. Langley, BC alternative stormwater management • $15 per foot • Yearly maintenance: $1000-5000	• E.g. Glencoe Raingarden (1900 ft^2) drains an area of approximately ~45,000 ft^2 • Cost: $98,000 • Yearly maintenance: $1000-$2000

Criteria and Indicator selection

In order to establish which option will be most successful we developed a comprehensive matrix that evaluates different criteria and the indicators associated with them. Below you will find a short summary of each criterion, and the indicators that we deemed important to each of them. For a comprehensive list of all the criteria, their indicators and our evaluation of them, refer to Appendices F and G**.**

Water Conservation

Water conservation was established as one of the more important criteria that should be evaluated, since this is where there options have to most to gain. Economic and social aspects are of course important too, and they are evaluated by other criteria. However, they all are secondary to the water conservation.

The following indicators evaluate water conservation:

- Reduction in potable water usage
- Stormwater reused as irrigation
- Amount of runoff retained

The first indicator was chosen because a decrease in potable water consumption is a desirable change. The second indicator addresses the main benefit of the different options as it accounts for the re-use of a resource that otherwise would be wasted. The third indicator takes was chosen because a decrease in runoff is beneficial to ecosystems, and that there will be less strain on the current stormwater infrastructure.

Aesthetic value

The aesthetic value of a project is important because it can address concerns important to many stakeholders in the different options, especially the residents of South Campus. Since two of our options are highly visible and may introduce intrusive elements into the current design of South Campus, there is a definite need for this criterion.

The following indicators evaluate aesthetic value:

- Place of gathering
- Landscaping evaluation

These indicators were chosen in order to establish how well the different options could be integrated into South Campus, without negatively impacting the aesthetic appeal.

Social Reputation/ Health and Wellbeing

This criterion, much like the aesthetic value criterion is important in order to evaluate and estimate the acceptance of the different option by the stakeholders, as well as social sustainability.

The following indicators evaluate this criterion:

- Community recognition/opinion index via public survey
- Leader in Innovation Index
- The first indicator was choses since it is a good way of estimating how the stakeholders of South Campus, including the residents, will react or be aware of the different options. The second indicator was chosen to establish the exterior recognition of the different options. This indicator looks at how well recognized the different options are inside and outside of UBC. Please see Appendix F for more detail on this.

Student Involvement & Educational Value

Since all of these options are going to be part of UBC, it should be important that they have educational value, and that they have the capability to include student involvement. However, this criterion is secondary in importance relative to some of the other criteria. For more details on this, see the weighting matrix, Appendix G

The following indicators evaluate this criterion:

- Number of students involved in Community Service Learning (CSL) and SEEDS projects
- Establish partnerships with outside organizations
- Number of maps, models, brochures, informational signs present for visitors

Most of these indicators were chosen in order to directly measure or estimate the student and community involvement.

Economic Sustainability

This criterion is the second most important, after Water Conservation. The most beneficial situation for UBC would be for all of the options to economic profits from each option, and they should at least contribute to reduce expenditure.

The following indicators evaluate this criterion:

- Energy expenditures
- Potable water costs
- Sustainable project funding index
- Amount of run-off retained

These indicators were chosen because they estimate profit, expenditure and funding in different ways, see Appendix F for the justifications for the different indicators.

Ecosystem Preservation

Ecosystem Preservation forms together with Water Conservation and Economic Sustainability the backbone of our criteria. This criterion assesses the changes to the existing ecosystem where the options are located, but also the externally added components introduced by the options.

The following indicators evaluate this criterion:

- Concentration of targeted pollutants in stormwater discharge
- Peak stormwater flow (L/sec)
- Yearly stormwater flow (L/sec)
- Reduction in the rate of erosion of Booming Ground creek
- Number of plant species present
- Percent of soil disturbed
- Water measurements: temperature, turbidity, pH, specific conductivity, and metals.

For justifications and a more detailed explanation, see Appendix F.

EVALUATION OF THE DIFFERENT OPTIONS

RETENTION POND & IRRIGATION SYSTEM

WATER CONSERVATION:
Assuming that the retention pond will only be used for drip irrigation crops (which is assumed to be 20% of crops), the pond will reduce potable water consumption by 1943.5m^3. Factoring in evapotranspiration, the amount of run-off retained is 1948.4m^3. See Appendix C for more information.

AESTHETIC VALUE:
Retention ponds can score high on the landscaping evaluation index if aesthetically pleasing plants and fountains are in place. It has the potential to be a place of gathering and social interaction.

SOCIAL REPUTATION:
The retention pond would not likely have much community recognition, as the pond is located on the UBC Farm. The pond will score high on the Leader in Innovation Index because it will receive recognition and all of the changes will be measured: pollutant control, filtering abilities, and amount of irrigation.

STUDENT INVOLVEMENT & EDUCATIONAL VALUE:
The retention pond will increase the amount of students participating in CSL and SEEDS projects as it is new technology and many studies will be performed to evaluate effectiveness. There will be informational signs provided around the farm and the pond. Detailed descriptions will be put on the farm website and blog. There is the potential for partnerships with outside organizations for tours and educational programs.

ECONOMIC SUSTAINABILITY:
The capital costs of this project will be around $486,700. For a breakdown of costs, refer to table 4, 5 and 6 in Appendix C**.** Maintenance costs will be around $5,670 a year. The project only affects the UBC Farm, so there is low probability of increasing government funding for the

project. The retention pond will save $1,515 a year in potable water costs. There is no energy usage so energy expenditures don't apply. (CASQA, 2003)

ECOSYSTEM PRESERVATION:

Peak stormwater flow will be reduced, as it will be diverted to the retention pond. Yearly stormwater flow will be reduced through irrigating part of the farm and evapotranspiration. This will reduce the rate of erosion of the Booming Grounds Creek. Only the soil that will be dug up for the pond will be disturbed. A layer of 5 to 7 species of plants will line the pond, 3 of which will be aggressive colonizers such as the bulrush or pickerelweed. These plants will help filter the water and reduce pollutants by almost 100%. (CASQA, 2003)

STORMWATER HYDROELECTRICITY GENERATION

WATER CONSERVATION:

If the Nobel Park detention tank and the Marine Drive pipe are to be used to store stormwater, it would help to reduce the amount of potable water to be used for irrigation, assuming that the water is of sufficient quality to be used for irrigation. The use of this water for irrigation will also help to reduce the volume of stormwater discharged at Booming Ground creek each year, and the nature of detention/retention facilities will help to alleviate peak stormwater flow.

AESTHETIC VALUE:

Because the detention/retention systems are located underground, they will not affect the landscaping of the areas, nor will they provide a place of meeting. The hydro facility will be located at the base of Wesbrook Mall, and while this is not currently a residential area, it may be visible from the road, and could be viewed negatively.

SOCIAL REPUTATION/HEALTH AND WELLBEING:

The construction required to install a hydro facility at the base of Wesbrook Mall may disrupt traffic entering and exiting campus along Southwest Marine Drive or Wesbrook Mall. The project is not likely to have a high Leader in Innovation Index value, as micro hydro is not a new technology. Its use in a stormwater context, however, is less common.

STUDENT INVOLVEMENT AND EDUCATIONAL VALUE:

The project may have some educational value, either for engineering students in the design and construction phases, or for SEEDS projects to determine the optimal design options. There could also be educational value for the general public, but due to the safety reasons surrounding electricity and hydrogen generation, access to the facility would need to be regulated.

ECONOMIC SUSTAINABILITY:

The hydro option would not likely result in a significant reduction of energy expenditures, as the amount of energy generated will be a fraction of the total annual energy usage of the university. However, it could provide a monetary savings, as the water detained in the Nobel Park and Marine Drive pipes can be used for irrigation, which would reduce potable water expenditures. Additionally, the project may be applicable to the Sustainability Project Funding Index, so funding from government or businesses is a possibility.

Energy and Climate Change Impacts:

There would a net positive change in the energy usage on South Campus, as the energy generated by the hydro plant would likely be used there. However, because the energy is being generated in a GHG-free manner, there will be no emissions that would affect climate change.

Ecosystem Preservation:

Once installed, the hydro plant would not likely affect the concentration of pollutants in the stormwater, nor would it likely have an effect on the number of plant species present or the water quality of the stormwater being discharged.

Use of the Nobel Park and Marine Drive pipes as detention/retention will help to reduce peak stormwater flow, and if water is diverted from these facilities to irrigation, annual stormwater flow will also be reduced. Both reductions will help to reduce the erosion at Booming Ground Creek.

Swales and Raingarden

Water Conservation:

Unless the Nobel Park detention tank or the Marine pipe are used as irrigation sources, up to 1600 cubic meters (tank) and 900 cubic meters (pipe) of potable water could be saved daily in seasons where stormwater flow exceeds these volumes. Amount of run-off retained in the raingarden can be as much as 80% during a 25-year storm event, and as much as 95% during normal rainfall patterns, according to Glencoe Raingarden tests (Planning Group Sustainable Stormwater Management, 2004). An assumption was made that Portland stormwater patterns resemble those of UBC.

Aesthetic Value:

Swales can be a part of Vancouver's Green Streets Program, where people can volunteer to "adopt a swale". A raingarden can serve as a social spot, as well as a community garden. They present a landscaping opportunity.

Social Reputation:

Raingarden and the swales may encourage community building for those who choose to care for it. The opinion of the developments can be gauged by surveying. Both developments may present a significant step in Vancouver's use of natural forms of stormwater management, since the urban use of these is lacking.

Student Involvement and Educational Value:

There are existing research opportunities for SEEDS and CSL students to examine evapotranspiration rates of local species in order to determine which ones are the most efficient in retaining water. Partnerships with Vancouver's Green Streets, or the West Coast Gardeners Co-Op of BC may be established.

Economic Sustainability:

Money will be spent on building swales and the raingarden, but the project also has the potential to generate income, through guided tours, sponsorships, or other commercial and tourism incentives. If any of the retained water gets used for irrigation, there can be significant savings in potable water usage. A business case can be made for the value of environmental preservation via such developments.

Energy and Climate Change Impacts:

Since there will be increased vegetation in the swales and the raingarden, the vegetation can act as a carbon sink for tissue building and photosynthesis. No energy is expected to be used since all the developments are downhill from the Nobel Park tank.

Ecosystem Preservation:

Targeted pollutants, such as hydrocarbons, metals, and minerals will be removed by the use of bioswale and raingarden filtration. Peak stormwater flow can be reduced by 80% (see Water Conservation), and the yearly stormwater flow – by 95%. This scenario reduces the erosion rate at Booming Ground creek. The number of plant species present will increase due to up to 50 species being available for such operations. The amount of soil disturbed will include swale building, in case there are no existing ditches to use. The soil disturbed by the contained raingarden will be re-used in the garden itself.

Recommendations

In order to evaluate the options we proposed, we developed a rating system that would weigh the importance of each indicator outlined above. Each indicator was assigned a value form one to three, one being of minor importance and three being of major importance. We then took each option and evaluated them against each indicator. If the option met the indicator requirement, it would receive the amount of points the indicator was worth. If it did not meet the indicator requirement, it would score a 0. In the end, we tallied up all of the points and the option with the most points was the retention pond and irrigation system, followed closely by the swales and rain garden. Last was the hydroelectricity generation. For the details on exact point breakdowns, please refer to Appendix G.

The five priorities as stated by UBC's water management strategy are: rainwater harvesting, improving the efficiency in landscape irrigation, reducing water use and wastewater generation, managing water use in building operation, and education and engagement (UBC). Two large areas in particular that need improvement are reducing potable water consumption and improving the water efficiency of base flow processes. A goal listed in UBC's water management plan draft is to reduce the potable water used for irrigation. The targets are 50% by 2015 and 75% by 2020 from current levels (Paderewski, 2012). Another area of importance were reducing the cliff erosion caused by the runoff from Booming Grounds Creek.

Every option we proposed had its merits and drawbacks. The swales and rain garden has high peak water retention (up to 80%) and is capable of biofiltration but requires a massive construction and soil disruption. However, maintenance costs will be high. The stormwater hydroelectricity generation project can reduce water consumption and provide a source of energy for UBC, but the associated costs are high and seem to outweigh any future benefits.

We selected the retention pond and irrigation system as the best option we proposed. It is the most well rounded option in terms of meeting all the different types of criteria. The retention pond is a simple, low construction impact option. It makes use of the wetlands on the farm that are currently unusable and turns it into an aseptically pleasing stormwater management tool. It doesn't destroy much of the natural ecosystem. In fact, it will help to improve the ecosystem of the farm as it will bring in more plant species, reduce cliff erosion, and become a natural water filter.

The retention pond meets four of UBC's five main priorities. The first is reducing potable water consumption: with the retention pond, stormwater will be filtered and reused for irrigation on the farm. Irrigation will improve in efficiency, as there will be a new system in place to facilitate drip irrigation. The retention pond also gathers rainwater and will reuse it for irrigation. Lastly, the retention pond will provide opportunities for both UBC students and outside organizations to learn about how this form of stormwater management works. There will be informational signs and guided tours to foster education and engagement. Compared to the other options, the retention pond is also the most affordable as the construction and maintenance costs associated with it are significantly lower.

Moving forward, UBC should hire a professional consulting company to investigate the viability of the retention pond and irrigation system. Blueprints and professional evaluations should be made on the impact of the retention pond and irrigation system. UBC should then begin construction by digging out the area where the retention pond will be and lining the sides with concrete. Plants will need to be selected and planted inside the pond. It would take a year or two before the plants actually grow to be functional.

Pipes will have to be placed leading from the existing ditch to the retention pond and leading from the pond back out to the ditch. A spillway pipe will also be installed, leading from around the center of the pool to the outflow pipe. The spillway pipe is to ensure that the retention pond doesn't overflow. The pump and drip irrigation pipes will have to be installed as the retention pond is getting built up so the whole system will be in place.

The water quality will have to undergo tests to see if the filtered water meets standards for crop irrigation. Pollutant removal percentage should also be measured in order to test the effectiveness of the retention pond. Annual maintenance and landscaping will be required. Sediment removal will have to be performed every ten years. A detailed maintenance schedule is included in Appendix C. The annual maintenance costs for UBC will be around $5,600. Potable water cost savings will be around $1,500 a year. This means that in addition to the $500,000 of capital costs, UBC will have to put in an additional $4,100 of funds into the retention pond.

As retention ponds and irrigation systems are relatively new technologies, there is a lot of room for improvements in the future. It is still unknown how effective the natural filtering system is and whether or not it will meet the standards for crop irrigation. In the future, the scope of this project can be expanded to include irrigating all of the crops grown on the farm. This can be done through installing a more powerful pump to push water out through a spray irrigation system. This will further save UBC's current potable water costs. As it stands right now, potable water is very cheap for UBC to purchase but that amount has been increasing in the last decade. As water becomes scarcer, the costs will rise. It would be beneficial for UBC to have another option, a closed loop water management system that they can rely on to operate the farm and/or use for an emergency water source.

Conclusion

To date, stormwater management has not been adequately addressed at UBC. Solutions with high economic benefits are typically considered over options that focus on environmental protection. We recommend approaching stormwater management from a more ecologically-based perspective through the installation of a retention pond and associated irrigation systems, which will not only provide UBC with the economic benefit of reduced potable water costs, but also reduce stormwater pollution and flow levels in Booming Ground Creek. This will allow UBC to further solidify its reputation as a leader in sustainability and to expand its research domain. This addition will further secure UBC Farm's Green Academic status at UBC for years to come.

Appendix A: Current UBC Water Information

Taken from (Paderewski, 2012)

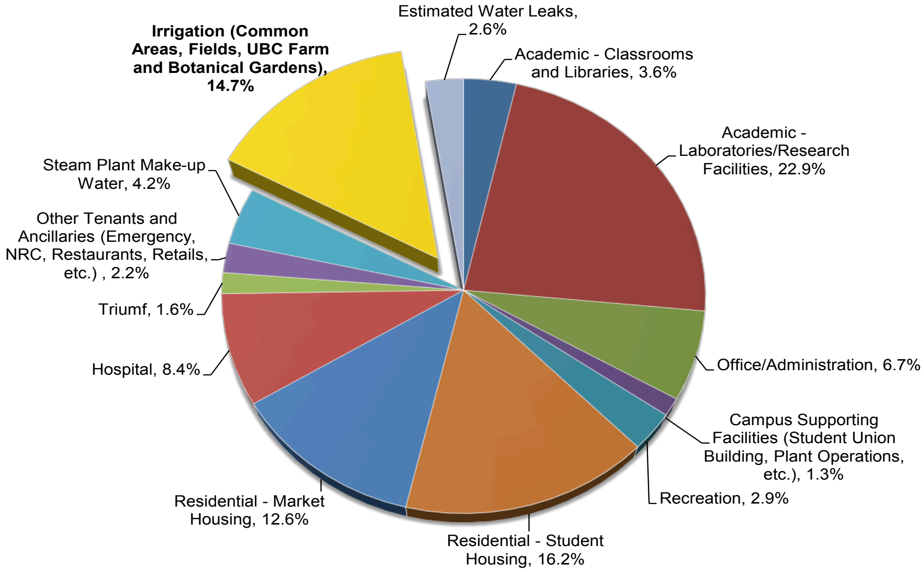


Figure 1: Current End users of water

Taken from (UBC, n.d.)

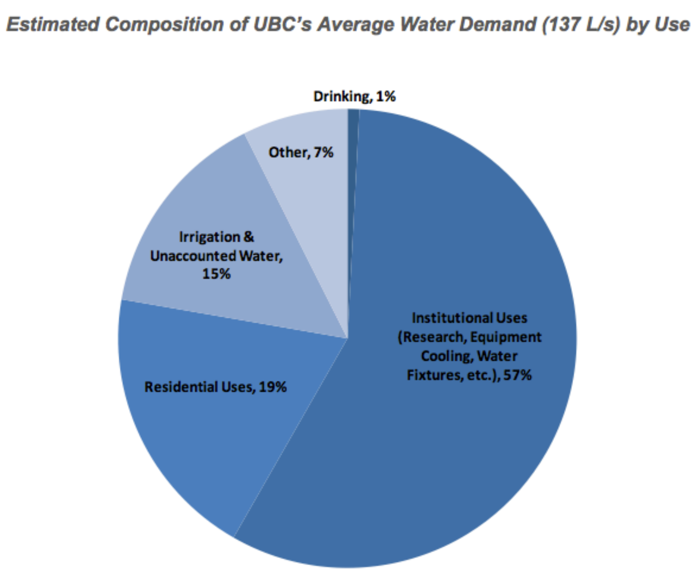


Figure 2: Estimated Composition of UBC's average water demand

Taken from (UBC, n.d.)

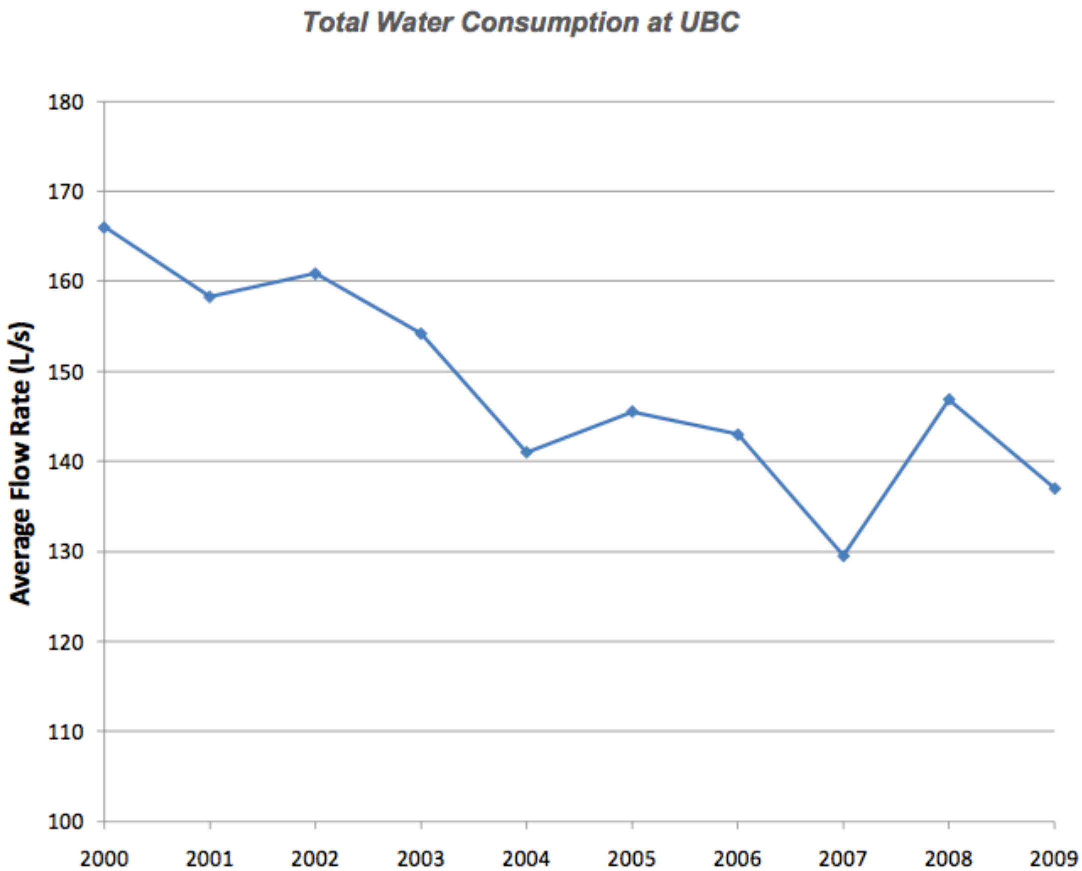


Figure 3: Total Water Consumption At UBC

APPENDIX B: MAPS

Map provided by UBC Utilities Staff.

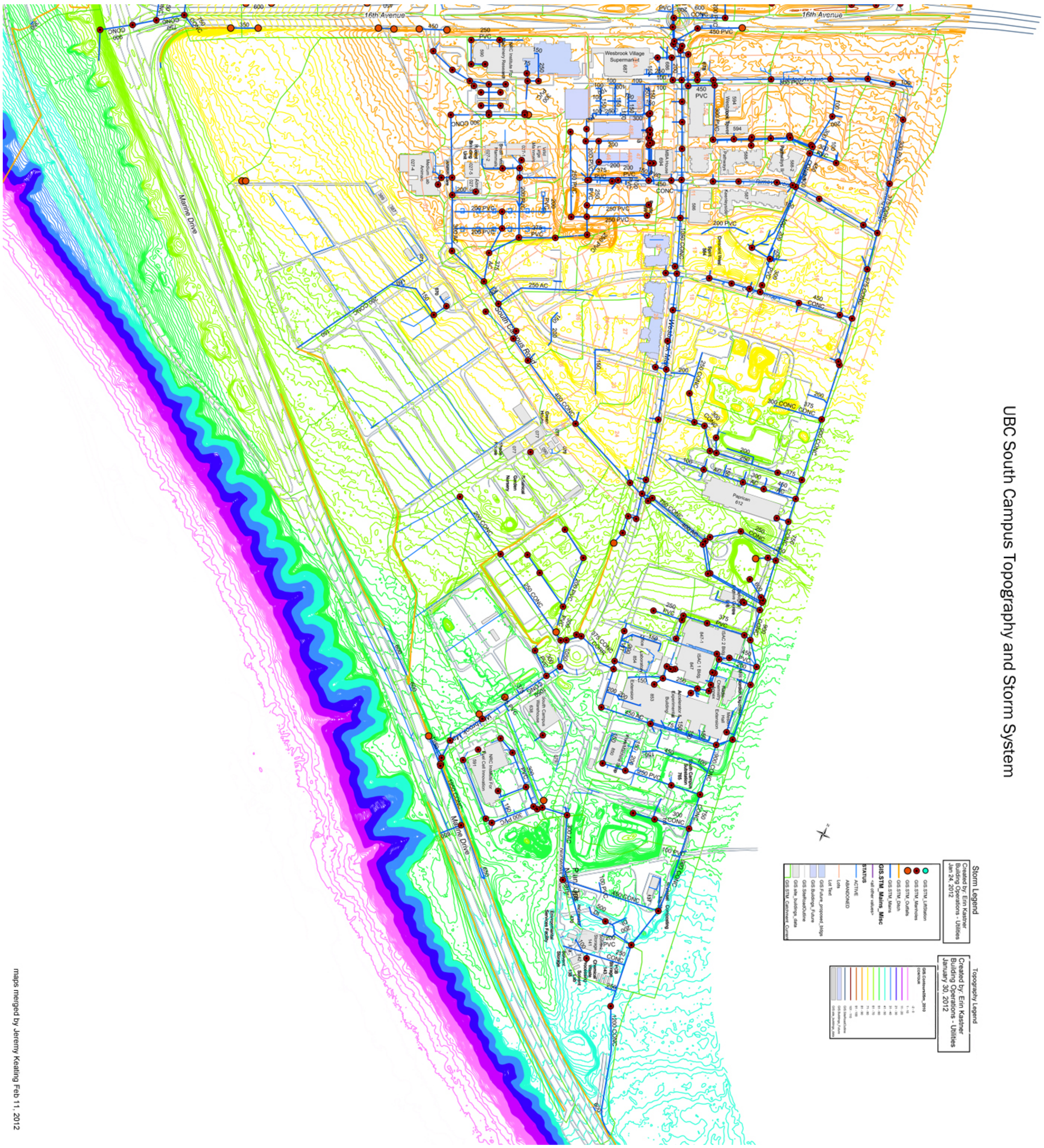


Figure 1: UBC pipe and topography map

Map adapted from: http://www.maps.ubc.ca/PROD/images/pdf/ubcmap_colour.pdf

Figure 2: Location of the different options

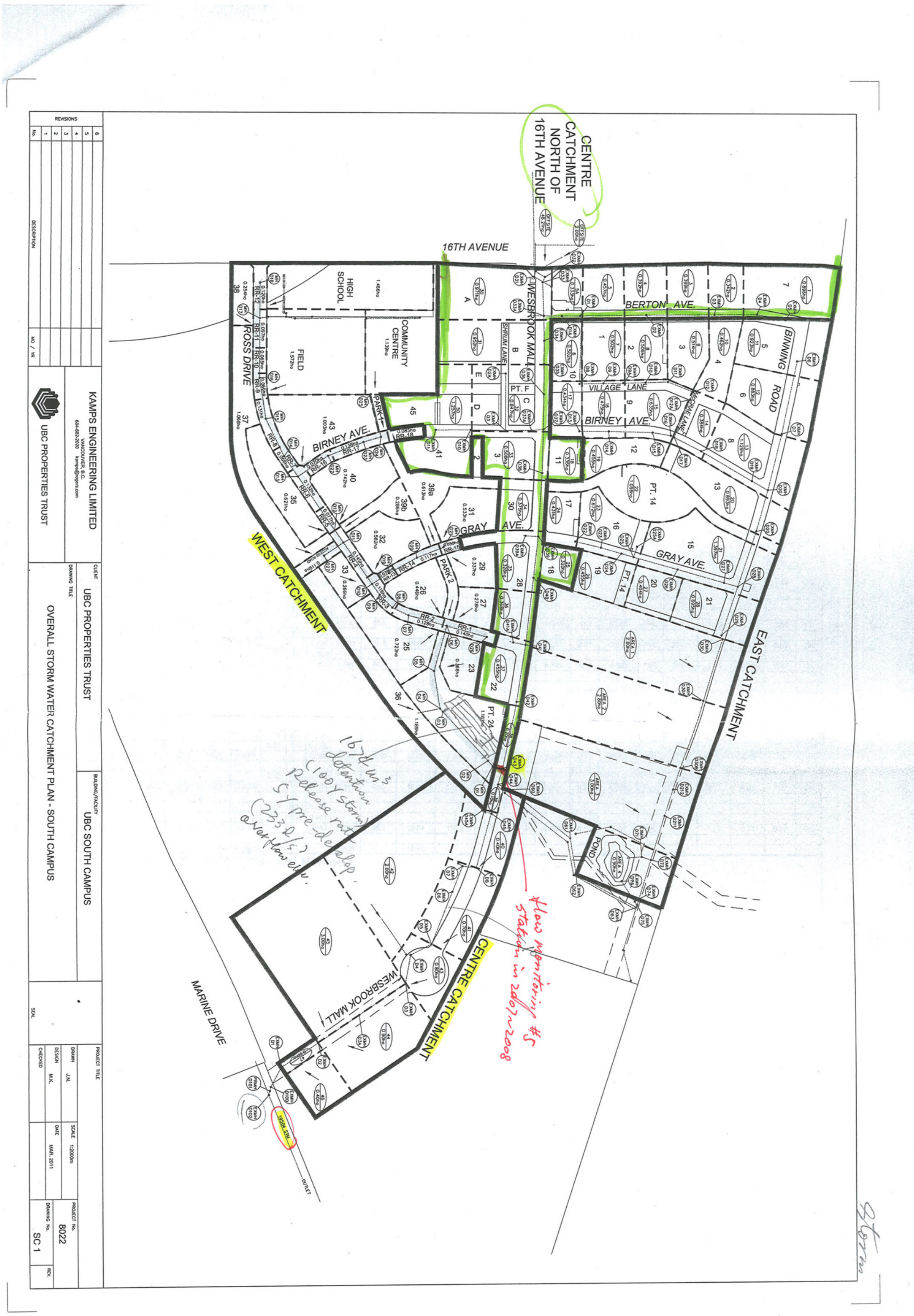


Figure 3: Location of stormwater sampling on South Campus (Kamps Engineering, 2011)

APPENDIX C: IRRIGATION AND RETENTION

Taken from:
http://vwrrc.vt.edu/swc/NonPBMPSpecsMarch11/VASWMBMPSpec13CONSTRUCTEDWETLAND.html

Plant	Zone	Form	Wildlife Value
Arrow Arum *(Peltandra virginica)*	2	Emergent	High; berries are eaten by wood ducks
Broad-Leaf Arrowhead (Duck Potato) ***(Saggitaria latifolia)***	2	Emergent	Moderate; tubers and seeds eaten by ducks
Blueflag Iris* *(Iris versicolor)*	2, 3	Emergent	Limited
Broomsedge *(Andropogon virginianus)*	2, 3	Perimeter	High; songbirds and browsers; winter food and cover
Bulltongue Arrowhead ***(Sagittaria lancifolia)***	2, 3	Emergent	Waterfowl, small mammals
Burreed ***(Sparganium americanum)***	2, 3	Emergent	Waterfowl, small mammals
Cardinal Flower * *(Lobelia cardinalis)*	3	Perimeter	Attracts hummingbirds
Common Rush ***(Juncus spp.)***	2, 3	Emergent	Moderate; small mammals, waterfowl, songbirds
Common Three Square ***(Scipus pungens)***	2	Emergent	High; seeds, cover, waterfowl, songbirds
Duckweed (*Lemna sp.*	1, 2	Submergent / Emergent	High; food for waterfowl and fish

Joe Pye Weed *(Eupatorium purpureum)*	2, 3	Emergent	Butterflies, songbirds, insects
Lizard's Tail *(Saururus cernus)*	2	Emergent	Low; except for wood ducks
Marsh Hibiscus *(Hibiscus moscheutos)*	2, 3	Emergent	Low; nectar
Pickerelweed *(Pontederi a cordata)*	2, 3	Emergent	Moderate; ducks, nectar for butterflies
Pond Weed *(Potamogeton pectinatus)*	1	Submerge nt	Extremely high; waterfowl, marsh and shore birds
Rice Cutgrass *(Leersia oryzoides)*	2, 3	Emergent	High; food and cover
Sedges *(Carex spp.)*	2, 3	Emergent	High; waterfowl, songbirds
Softstem Bulrush *(Scipus validus)*	2, 3	Emergent	Moderate; good cover and food
Smartweed *(Polygonum spp.)*	2	Emergent	High; waterfowl, songbirds; seeds and cover
Spatterdock *(Nuphar luteum)*	2	Emergent	Moderate for food, but High for cover
Switchgrass *(Panicum virgatum)*	2, 3, 4	Perimeter	High; seeds, cover; waterfowl, songbirds
Sweet Flag * *(Acorus calamus)*	2, 3	Perimeter	Low; tolerant of dry periods
Waterweed *(Elodea canadensis)*	1	Submerge nt	Low
Wild celery *(Valisneria americana)*	1	Submerge nt	High; food for waterfowl; habitat for fish and invertebrates

Wild Rice *(Zizania aquatica)*	2	Emergent	High; food, birds
Woolgrass *(Scirpus cyperinus)*	3, 4	Emergent	High: waterfowl, small mammals
Zone 1: -6 to -12 ***OR*** -18 inches below the normal pool elevation Zone 2: -6 inches to the normal pool elevation Zone 3: From the normal pool elevation to +12 inches Zone 4: +12 to +36 inches; above ED zone * Not a major colonizer, but adds color (Aggressive colonizers are shown in **bold** type)			

Table 1: Plant List for Irrigation Pond

Taken from (CMHC, 2012)

Pollutant	Removal Efficiency
Plant Nutrients	
Total Phosphorus	Moderate to High
Total Nitrogen	Moderate
Sediment	
Total Suspended Solids	High
Metals	
Lead	High
Zinc	Moderate
Organic Matter	
Biochemical and Chemical Oxygen Demand	Moderate

Oil and Grease	High
Bacteria	High

Table 2: Pollutant removal efficiency of retention ponds.

Adapted from: http://www.ksre.ksu.edu/library/agec2/mf836.pdf, http://www.pumps2you.com/pumps/Davey-D53A-B-Automatic-Multistage-Drainage-Pump,and (CMHC, 2012)

Cost Category	Type of Cost	Price	Unit	Total Cost
Capital Expenditure	Rip Rap (Inlet/Spill)	\$12.00	m^2	\$32,400
	Rise	\$4,500	n/a	\$4,500
	Outlet Pipe (Concrete, 450mm)	\$250	m	\$12,500
Installation Costs	Excavation	\$12	m^3	\$64,800
	Earthworks	\$4	m^3	\$21,600
	Vegetation Planting	\$1	m^2	\$2,700
Disposal Costs	Sediment Disposal	\$60	m^3	\$324,000
Irrigation System	Pump	\$650	n/a	\$650
	Piping	\$2.73	ft	\$24,200
Total Capital Costs				**\$486,700**
Maintenance Costs	Landscaping	\$2	m^2	\$5,400
	Sediment Removal (every 10 years)	\$1	m^2	\$2,700/10 yr \$270/yr
	Removal Labor	\$120	hr	Depends
Total Maintenance Costs (per year)				**\$5,670**

Table 3: Retention Pond, various costs

	KC	ETO (mm)	Rate (mm/yr)
Spring	0.5	3	1.5
Summer	1.05	3	3.15
Fall	0.9	3	2.7
Winter	0	3	0
		Average (mm/yr)	1.8375
		Average (m/yr)	0.0018375

Table 4: Evapotranspiration Calculations

	Area (m^2)	Evapotranspiration Rate (m/yr)	Evapotranspiration (m^3)
Retention Pond	2700	0.0018375	4.96
Swales	700	0.0018375	1.29

Table 5: Evapotranspiration Data

	Calculation	Amount
Farm Irrigation	Given data	9717 m^3
Evapotranspiration	Calculated already	4.96 m^3
Drip Irrigation Amount (20%)	0.2*9717	1943.5 m^3
Potable Water Saved	1943.5 + 4.96	1948.36 m^3
Potable Water Costs	(0.88 + 0.68)/2	$0.78/ m^3
Cost Savings	0.78*1943.5	$1515.85

Table 6: Potable water and cost saving calculations

APPENDIX D: RAINGARDEN AND SWALES

RAINGARDEN

a) Plant list

   a. Adapted from: Rain Garden Handbook for Western Washington Homeowner (Hinman, 2007)

ZONE 1 **Emergents**: Slough sedge (*Carex obnupta*) and small-fruited bulrush (*Scirpus microcarpus*).
Ferns: Lady fern (*Athyrium filix-femina*) and deer fern (*Blechnum spicant*).
Deciduous shrubs: Stink currant (*Ribes bracteosum*). If the garden is large add black twinberry (*Lonicera involucrata*).

ZONE 2 **Deciduous shrubs**: Snowberries (*Symphoricarpos albus*).
Evergreen shrubs: Evergreen huckleberry (*Vaccinium ovatum*).
Ferns: Sword fern (*Polystichum munitum*) and lady fern.

ZONE 3 **Evergreen shrubs**: Evergreen huckleberry, low Oregon-grape (*Berberis nervosa*).
Ferns: Sword fern.
Herbaceous perennials: Wild ginger (*Asarum caudatum*), inside-out flower (*Vancouveria hexandra*), and western bleeding heart (*Dicentra formosa*).

   b. Zone 1 to Zone 3: plants with lowest to highest ability of tolerating very wet soils.

b) Design Plan:

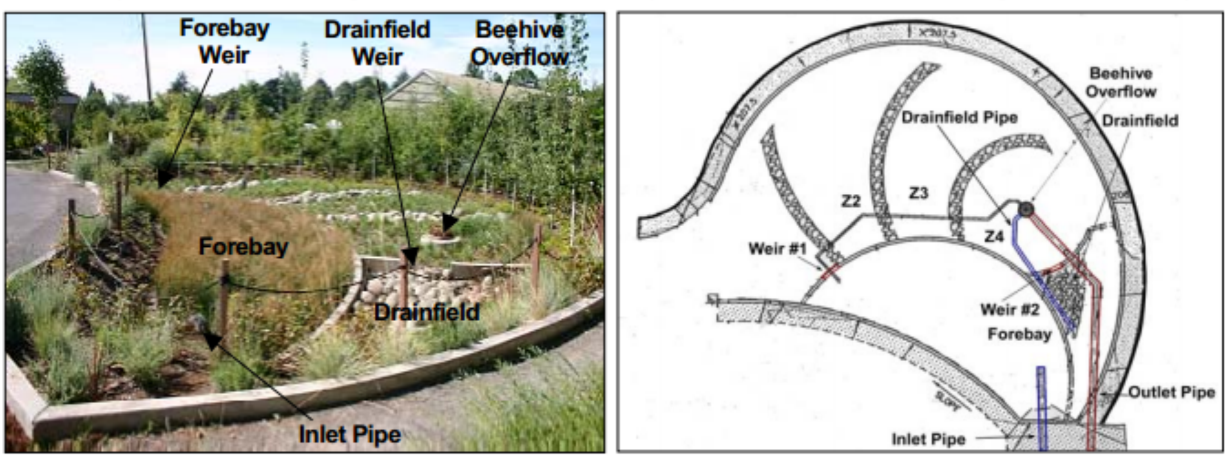


Figure 1: Rain garden example

From: http://www.portlandonline.com/bes/index.cfm?a=63096&c=36055

c) Costs:

a. Adapted from: http://www.portlandonline.com/bes/index.cfm?a=147510&c=45388

• The basic cost of construction • construction contract was $69,500 • cost for installation of the plants – including tilling and mulch	$82,000 $69,500 $12,500
Total:	$98,000

2) *SWALES*

a) Plant list

a. Adapted from: Puget Sound Bioretention Plant List (Low Impact Development, 2006)

* denotes BC native species

COMMON NAME	EXPOSURE	MATURE SIZE	TIME OF BLOOM	COMMENTS
*Adiantum aleuticum** Western maidenhair fern	Shade/partial shade	1-2 feet		Moist to wet soils; graceful, delicate fern; vivid bright green with black stems; spreads through creeping rhizomes; often called *A. pedatum*, but this refers to the related East Coast maidenhair fern; also try *A. capillis-veneris* (Venus-hair fern)
*Andromeda polifolia** Bog rosemary	Sun/partial shade	1-1.5 feet	Spring	Moist to wet soils; low-growing evergreen shrub; white to pink flower clusters; ornamental varieties include 'Blue Ice', 'Grandiflora' and 'Nana'
*Blechnum spicant** Deer fern	Shade/partial shade	1-3 feet		Moist to wet soils; has both evergreen and deciduous leaves; prefers soils high in organic material; is sensitive to frost
Carex spp. Sedges	Sun/shade	varies		A number sedge choices are great options for a bog garden setting; two are listed in Zone 1 of this appendix, but there are many alternative species to investigate, including *Carex mertensii** (Mertens' sedge) and *C. lyngbyei** (Lyngby's sedge)
*Eleocharis palustris** Creeping spike-rush	Sun	To 3.5 feet		Wet soils to shallow water; perennial forming small clumps
*Empetrum nigrum** Crowberry	Sun	To 8 inches	Early spring	Dry to wet/boggy soils; low-growing evergreen shrub; small purplish flowers and purplish-black berries
*Equisetum hyemale** Scouring-rush	Sun/partial shade	2-5 feet		Moist to wet soils; hollow-stemmed, evergreen perennial; spreads through creeping rhizomes; vigorous and persistent; with high silica content; also *E. scirpoides* (Dwarf horsetail); use both with caution - *Equisetum* can be very invasive and difficult to remove once established
*Gaultheria ovatifolia** Oregon wintergreen/ Western teaberry	Partial shade	To 1 foot	Late spring - summer	Moist to wet soils; low-growing evergreen shrub; pink or whitish flowers and red berries; also *G. humifusa** (Alpine wintergreen)
*Glyceria elata** Tall mannagrass	Sun/partial shade	3-4.5 feet		Moist to wet soils; loosely tufted perennial, spreads through creeping rhizomes; also try the taller *G. grandis** (Reed mannagrass)

Common Name	Exposure	Mature Size	Time of Bloom	Comments
Gunnera manicata Gunnera	Sun/partial shade	4-6 feet/ 4-8 ft. spread		Moist to wet organic soils; prefers humid setting; non-native from Brazil and Columbia needing mulching protection in the winter; also referred to as 'giant rhubarb'; huge rounded leaves; needs plenty of space; also *G. tinctoria* from Chile
Hakonechloa macra Japanese forest grass	Shade/partial shade	1-3 feet		Prefers moist, rich soil; slowly spreading perennial grass; green leaves turn coppery orange in the fall
Hosta Plantain lily	Shade/partial sun	To 2.5 feet	Summer	Prefer moist, rich soil; many varieties and hybrids available in a various sizes, foliage textures and colors; thin spikes of blue or white flowers; some are tolerant of sun, but most prefer shade
Juncus spp. Rushes	Sun/shade	varies		As with the *Carex* species, there are a number of native rushes that would work well in a bog garden. Three options are listed in Zone 1 of this appendix. Others to investigate include *Juncus mertensianus** (Mertens' rush) and *J. acuminatus** (Tapered rush)
*Kalmia occidentalis** Swamp-laurel	Sun	.5-2 feet	Spring - early summer	Also known as *K. polifolia*, prefers moist soils; low shrub with aromatic leaves; rose-purple flowers; also try *K. microphylla** (Western bog-laurel) a mat-forming, evergreen shrublet; generally found in wet subalpine conditions
*Ledum groenlandicum** Labrador tea	Shade/partial sun	1.5-4.5 feet	Summer	Moist to boggy soils; evergreen shrub with small white flower clusters; foliage aromatic when crushed
Ligularia dentata Bigleaf ligularia	Shade/partial shade	3-5 feet	Summer	Moist to wet soils; large-leaved, clumping perennial; yellow-orange blooms; not tolerant of high heat or low humidity; try *L. dentata* cultivars 'Othello' and 'Desdemona'; also *L. przewalskii* (Shavalski's ligularia) and *L. stenocephala* (Narrow-spiked ligularia)
*Linnaea borealis** Twinflower	Shade/partial shade	4-6 inches	June - September	Moist or dry soils; evergreen perennial; pink, fragrant, trumpet-like flowers; trailing ground cover; try *L. borealis* on the less saturated margins of a bog garden; may be difficult to establish
Lobelia cardinalis Cardinal flower	Sun/partial shade	2-4 feet	Summer	Wet to moist, rich soils; clumping perennial; tubular, bright red, inch-long flowers; also try *L. siphilitica* (Blue lobelia), another perennial with blue flowers
*Lysichiton americanum** Skunk cabbage	Shade/partial shade	2-3 feet	March	Prefers wet soils; deciduous perennial; has odor that some consider to be skunky especially when blooming; yellow hooded fleshy flower spike; great leaves dominate
Matteuccia struthiopteris Ostrich fern	Sun/shade	To 6 feet		Moist, rich soils; hardy northern fern; clumping narrowly at base with foliage spreading to 3 feet in width
Mimulus spp. Monkey-flower	Sun/partial shade	1-3 feet	Spring-summer	Wet soils; perennial or annual that reseeds nicely and keeps spreading; many species available including natives, *M. guttatus** (Yellow monkey-flower) and *M. tilingii**

Table 1: Raingarden and swales species

b) Design plan:

a. Adapted from: http://www.lakesuperiorstreams.org/stormwater/toolkit/swales.html

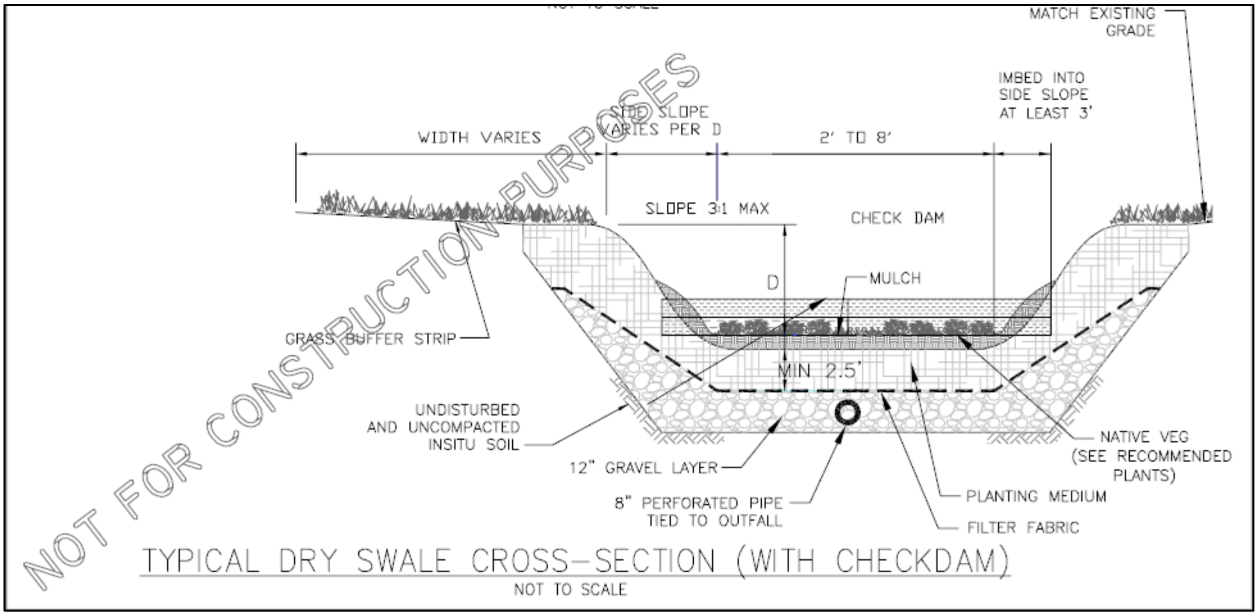
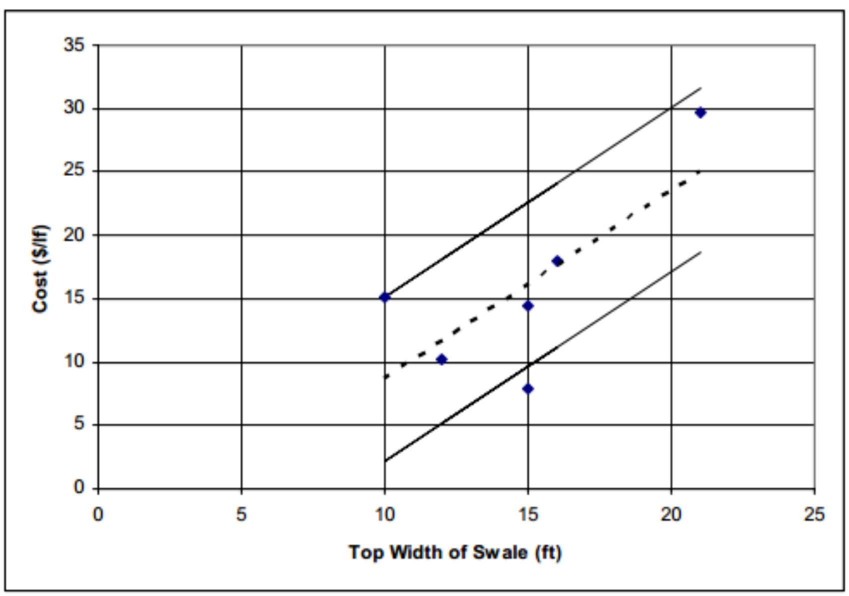


Figure 2: Swale cross-section

c) Costs:

a. Adapted from: http://www.lrrb.org/pdf/200523.pdf

b. $15/ft



Appendix E: Hydroelectricity Generation

Energy Production

Based on flow measurement data collected from May 2007 through April 2008, a system in place could generate approximately 74,600 kWh over the year from the hydro plant. If this energy is stored in the form of hydrogen, the total energy available when the hydrogen is combusted would be approximately 39,600 kWh. Table 1 summarizes the total power generation, the associated hydrogen production capacity, and the energy generation from the later use of the stored hydrogen.

Monthly average flow rates for South Campus's West Catchment at sampling point D43 (see Appendix B for map) from May 2007 through April 2008 were calculated based on data provided by Erin Kastner of UBC Utilities (UBC, 2008). These averages were used to estimate the total power that could be generated from the water assuming a 20 m elevation change (approximated using the Topography Map in Appendix B, from Nobel Park to Marine Drive).

A crossflow turbine is likely the best style of turbine to be used in this option, due to its ability to handle highly variable flow rates (Mtalo, 2010). As a rough estimate, an 80% efficiency rating for the turbine and associated mechanisms was chosen, though this would be dependent upon flow rates. The amount of power produced was calculated using the following equation:

$$P = k\rho g r H$$

where:

P = power (watts or $kg \cdot m^2/s^3$)
k = efficiency coefficient (no units)
ρ = density of water (constant, 1000 kg/m^3)
g = acceleration due to gravity (constant, 9.8 m/s^2)
r = flow rate of water (m^3/s)
H = head (m)

The energy in kWh was then calculated by multiplying the power, in kW, by 24 hours to determine the kWh produced per day, and by the number of days in each month to determine the kWh/month.

It should be noted that flow data was only available for the West Catchment of South Campus, and that the Centre Catchment, which would also drain to the Marine Drive pipe along the same Wesbrook Mall piping, would provide an additional 68.5 ha of drainage area, over 4 times larger than the West Catchment (Kamps Engineering, 2011). This additional area would provide a significant increase in water flow, and thus power generation. However, because no flow data was available, power calculations could not be provided.

The conversion of electricity to hydrogen would be done through the electrolysis of water. The National Renewable Energy Laboratory's Wind-to-Hydrogen Project outlines conversion rates for this process, which are incorporated into Table 1: for every 62.8 kWh used, 1 kg of hydrogen can be produced (Saur, 2008). At this point, the hydrogen can be stored until it is required, either as hydrogen itself, or to produce electricity.

The conversion of hydrogen into electricity would be performed through a hydrogen combustion engine. For every kilogram of hydrogen burned, approximately 33 kWh of electricity is produced (Fung, 2005), listed as kWh/day from H_2 in Table 1. The sum of these daily values over the course of each month, and subsequently over the course of a year, is also presented in Table 1. The approximately 50% loss of energy from that produced by the hydro plant to that produced by the hydrogen combustion engine shows that if the energy from the hydro plant can be used immediately, significant energy savings can be realised.

Table 5 - Flow Rates and Power Generation from the West Catchment of South Campus

Month	Flow Rate (m^3/s)	kWh/day	kWh/month	Hydrogen (kg/day)	kWh from H_2/day	kWh from H_2/month
May-07	0.0063	23.7	735.0	0.4	12.6	389.7
Jun-07	0.0087	32.7	982.2	0.5	17.4	520.8
Jul-07	0.0067	25.2	781.6	0.4	13.4	414.5
Aug-07	0.0015	5.6	175.0	0.1	3.0	92.8
Sep-07	0.0057	21.5	643.5	0.3	11.4	341.2
Oct-07	N/A	N/A	N/A	N/A	N/A	N/A
Nov-07	0.194	730.1	21901.8	11.6	387.1	11613.5
Dec-07	0.293	1102.6	34181.1	17.6	584.7	18124.7
Jan-08	0.0372	140.0	4339.7	2.2	74.2	2301.2
Feb-08	0.023	86.6	2423.5	1.4	45.9	1285.1
Mar-08	0.036	135.5	4199.7	2.2	71.8	2226.9
Apr-08	0.0375	141.1	4233.6	2.2	74.8	2244.9
		Yearly Total:	74596.8		Yearly Total:	39555.3

Note: poor data was available for October 2007, so it was omitted from these calculations.

Costs

According to Natural Resources Canada, small hydro projects typically have costs of between $1,200 and $6,000/kW (National Resources Canada, 2004). The amount of power produced at the highest flow measured in Table 1 (1102.6 kWh ÷ 24 h) is approximately 46 kW. To allow for slightly higher flow rates, such as during storms, a 50 kW turbine could be considered. Based on the prices above, a hydro station of this size would cost between $60,000 and $300,000. If both the West and Centre Catchments are to be considered, a larger turbine would likely be required due to the higher expected flows.

An example hydrogen electrolyser, capable of producing up to 50 kg of hydrogen per day (well in excess of what is required for this project, and thus allowing for increased capacity for storms), would have a cost of approximately $271,000, a cost of roughly $2,000/kW (Saur, 2008). Assuming operation and maintenance costs are approximately 5% of the capital investment (Levene, 2006), yearly O&M costs of $13,550 could be expected for the electrolyser. Storage of the hydrogen would require a compressor (~$100,000) and storage tanks (~$26,000 plus $1,300 of annual operation and maintenance costs) (Levene, 2006). A variety of hydrogen combustion engines are available; an engine capable of 5 kW has a cost of $9,000 (HGenerators, 2011).

Table 6 – Approximate Costs for Stormwater Hydroelectricity Generation and Storage

Cost Category	Type of Cost	Price
Capital Expenditure	Hydro Plant	$60,000 - $300,000
	Hydrogen Electrolyser	$271,000
	Hydrogen Compressor	$100,000
	Hydrogen Storage Tanks	$26,000
	Hydrogen Combustion Engine	$9,000
Total Capital Costs		**$466,000 - $706,000**
Maintenance Costs	Hydrogen Electrolyser	$13,550
	Hydrogen Storage Tanks	$1,300
Total Maintenance Costs (per year)		**$14,850**

APPENDIX F: CRITERIA AND INDICATOR SELECTION

Criteria	Indicators	Objectives	Justification
Water Conservation	Reduction in potable water system usage and consumption (%, L/year)	Credit 3.2: Reduce potable water use for landscape irrigation by 75 percent or more from established baseline (Sustainable Sites Initiative, 2009). Such reduction can be achieved by using plants with low water requirement or by reusing filtered stormwater (see below).	A decrease in potable water consumption leads to a decrease in energy consumption as water treatment facilities are powered by large amounts of electricity. It also reduces utility costs associated with water pumping and treatments. Potable water is also purchased so decreasing consumption saves UBC money. (Sustainable Sites Initiative, 2009)
	Stormwater reused as irrigation or potable water (L/year)	Credit 3.2: By reusing filtered stormwater, reduce potable water use for landscape irrigation by 75 percent or more from established baseline (Sustainable Sites Initiative, 2009). Similar stormwater filtration can also exist for residential use.	A decrease in stormwater discharge through capturing, filtering, and reusing is will reduce potable water consumption. This will reduce utility costs and money spent on energy and electricity by wastewater-treatment facilities. Sewer overflow and erosion can also be reduced hence creating a better environment for plant and animal life. (Sustainable Sites Initiative, 2009)
	Amount of run-off retained (%, L/year)	Policy 39 To the extent that the unique hydrogeology and cliff-erosion concerns at UBC's Vancouver campus allow, stormwater management strategies will incorporate a natural systems approach in managing runoff volume to mitigate downstream impacts. (From UBC Vancouver Campus Plan)	Retention of water decreases storm water discharge leading to benefits for the ecosystem, decrease in utility and electricity costs from wastewater management facilities, and decreases the maintenance costs on the equipment or pipes used in the storm water collection and treatment system (Sustainable Sites Initiative, 2009). Data collection will have to involve detailed stormwater monitoring not currently in place.
Aesthetic Value	Place of gathering & social interaction. Accessibility to visitors. (yes/no)	Credit 6.8: Provide outdoor gathering spaces of various sizes and orientations to accommodate groups, for the purpose of building community and improving social ties. (Sustainable Sites Initiative, 2009)	Evidence suggests that green surroundings are associated with better social cohesion. According to studies, social wellness leads to better health and wellbeing for people such as increased survival in cancer patients and greater resistance to dementia. (Sustainable Sites Initiative, 2009)
	Landscaping evaluation index of the wetland/detention pond (survey, % of features on site designed as amenities)	Credit 3.7: Integrate visually and physically accessible rainwater/stormwater features into the site in an aesthetically pleasing way (Sustainable Sites Initiative, 2009).	Benefit of people being conscious of precipitation and local climate patterns (Sustainable Sites Initiative, 2009). Aesthetically pleasing and environmentally-friendly detention ponds/wetlands can increase the value of neighbourhood developments, which would be in interest of the developers.
Social Reputation/ Health and Wellbeing	Community recognition/opinion index via public survey: 1- Dislike the development; 2- Indifferent/don't know anything about it; 3- Agree with the purpose of the development.	Assess public opinion about the project. Suggestion for UBC residential areas: inform the community of sustainable development, reinforce sustainable values.	Benefit of people being conscious of precipitation and local climate patterns (Sustainable Sites Initiative, 2009).
	Leader in Innovation Index: 0- Has achieved little	Devise and issue a series of publications on major UBC (including AMS and GSS and	Allows UBC to maintain its reputation as a place of cutting edge sustainability research and innovation.

	outside recognition with little follow-up. 1 - Has received outside recognition, but no existing plan to track changes. 2 - Has received outside recognition, with some stats tracked. 3 - Has received outside recognition, with all indicators measured.	UBC Students' Union) contributions to sustainability (UBC Inspirations & Aspirations, 2011). ECOL-25. Achieved in 2008/2009, but another published in 2010. Always room for growth.	
Student Involvement & Educational Value	# students enrolled in CSL and SEEDS increasing (yes/no)	Integrate student-driven research projects into the implementation.	An increase in research projects will increase the amount of students and staff that are aware of South Campus ecosystem.
	Have partnerships with outside organizations. (yes/no)	Credit 6.3 Option 3: Create partnerships to extend sustainability education to local community groups (e.g., schools, youth organizations, workforce commissions, church groups, NGOs, informal learning classes, senior centers, community centres). (Sustainable Sites Initiative, 2009)	Educating visitors and students to the sites has the opportunity to spread sustainability practices in the community. Education and awareness are important steps in changing behaviour. (Sustainable Sites Initiative, 2009)
	Number of maps, models, brochures, informational signs present for visitors	Credit 6.3 Option 1: Provide educational or interpretive elements that are interactive (a minimum of two elements or 30 percent of all education elements on site, whichever is greater). They may include, but are limited to the following: website, electronic kiosks, on-site demonstrations and tours. Where applicable, follow the guidelines stated in the low point value. (Sustainable Sites Initiative, 2009)	Interactive elements will allow site users and visitors to integrate understanding of on-site examples of sustainability with experiences that extend beyond the site. However, since tourist activity contributes to erosion, registering some visitor activity may be feasible in capping it.
Economic Sustainability	Energy expenditures ($/year), Reduction? yes/no	Reduce the amount of money spent on outside sources of energy (e.g.: BC Hydro).	Saving the university money. Investment can be redirected to other sustainable projects.
	Potable water costs ($/year), Reduction? yes/no	Reduce amount of money spent on bringing water in from the City of Vancouver.	Saving the university money. Investment can be redirected to other sustainable projects.
	Sustainable project funding index: (high/medium/low probability of increasing amt. of government funding)	Increase the amount of governmental funding for sustainability research, as well as funding from partners (UBC Inspirations and Aspirations, 2011) ECON 02-03. Achieved, but ongoing.	This criterion helps secure multifaceted funding by involving partners and possible stakeholders in sustainability research. More funding means more projects and a heightened reputation for UBC as a sustainability leader.
	Amount of run-off retained (%, L/year)	1) Reduced costs for maintenance of Booming Grounds Creek erosion 2) reduced penalties for water that doesn't meet BC standards 3) reduced costs of stormwater treatment/infrastructure (WERF, 2009).	Saving the university money. Investment can be redirected to other sustainable projects.
Energy &	Net change in energy usage	Reduce non-renewable energy	Aligns with UBC's commitment to

	Climate Change Impacts	of south campus (+ve, -ve)	consumption in institutional & ancillary buildings (such as the TRIUMF labs, the nursery and the farm buildings) by 30% (adjusted for growth) from 2000 levels (UBC Inspirations & Aspirations, 2011. ECOL-14). Achieved 27% out of 30% in 2010. Credit 2.3: Engage users and other stakeholders in site design (Sustainable Sites Initiative, 2009) that doesn't belong to UBC University Town. Reduce non-renewable energy in stormwater processing and filtration.	reduce its energy usage. This indicator reflects both energy consumption in buildings (easily measured with Smart-Meters), as well as energy used for stormwater treatment. Data collection will have to involve detailed stormwater monitoring not currently in place.
	Ecosystem Preservation	Concentration of targeted pollutants in stormwater discharge	Credit 3.6: A minimum of 80% of average annual volume of runoff discharged from the developed portion of the site receives stormwater treatment for pollutants of concern. (Sustainable Sites Initiative, 2009)	Water treated on site can decrease costs associated with energy usage and infrastructure of storm water treatment. Also, this decreases the costs UBC will incur when water doesn't meet certain standards. (Sustainable Sites Initiative, 2009)
		Peak stormwater flow (L/sec)	Reducing peak stormwater flow in Booming Ground creek to pre-South Campus development.	Reducing peak stormwater flow will likely reduce erosion. The main cause of concern with regards to erosion in this area is drainage (Cliff Erosion Mitigation Plan, 2002). Pre-development measurements can be estimated by Cutthroat Creek data.
		Yearly stormwater flow (L/sec)	Reducing yearly stormwater flow in Booming Ground creek to pre-South Campus development.	Reducing yearly stormwater flow will likely reduce erosion. Groundwater flow is the secondary contributor to the erosion (Cliff Erosion Mitigation Plan, 2002). Pre-development measurements can be estimated by Cutthroat Creek data.
		Reduction in the rate of erosion of Booming Ground creek (yes/no)	Reduced Booming Ground Creek erosion in accordance with Policy 39: To the extent that the unique hydrogeology and cliff-erosion concerns at UBC's Vancouver campus allow, stormwater management strategies will incorporate a natural systems approach in managing runoff volume to mitigate downstream impacts. (From UBC Vancouver Campus Plan)	Reduction of erosion of the banks of Booming Grounds creek will allow the natural area to revert to a more ecologically sound habitat. No regular measurement system in place.
		# of plant species present	1) Reduction in non-native species; 2) Reduction in invasive species; 3) Increase in native species; Aligned with Prerequisites 4.1-4.2 to use native plants and to control invasive species, as well as Credit 4.6: Preserve or restore appropriate plant biomass on site (Sustainable Sites Initiative, 2009).	This indicator = total native species/ total species * 100%. The calculation of the total species can be a pointer into the state of ecological diversity of the site. The percentage of native species can pinpoint invasive species if such a percentage is very low (non-native invasive species) or very high (native invasive species). No regular monitoring system currently in place.
		% of soil disturbed	Credit 4.4: Minimize soil disturbance in design and	Healthy soils effectively cycle nutrients; store carbon as organic matter; minimize

			construction. Create vegetation and soils protection zones (VSPZs) where healthy soil exists. (Sustainable Sites Initiative, 2009).	runoff and maximize water holding capacity; absorb excess nutrients, sediments, and pollutants; provide a healthy rooting environment and habitat to a wide range of organisms; and maintain their structure and aggregation. Preserving soil horizons saves money by reducing the need for soil restoration and surface drainage improvements. By limiting grading, sites can also reduce costs for construction machinery and transport of imported soils. (Sustainable Sites Initiative, 2009). Should be measured before construction.
		Water measurements: temperature, turbidity, pH, specific conductivity, metals. Meets regulations for discharge? Yes/No.	Achieve City of Vancouver stormwater standards, as well as the standards set by the Ministry of Water Land and Air Protection in order not to contaminate the run-off site and the surrounding ecosystems.	Can reflect the state of the soil and affect salmonid numbers, as well as the extent of the development at South Campus. Unmet standards will affect the ecological balance of the Booming Grounds creek, the health of people utilizing the area, as well as the fertility of the surrounding soils (Cliff Erosion Mitigation Plan, 2002).

APPENDIX G: CRITERIA AND INDICATOR WEIGHING MATRIX

Criteria	Indicators	Weight	Retention & Irrigation	Swales & Raingarden	Hydroelectricity
Water Conservation	Reduction in potable water system usage and consumption (%, L/year)	3	3	0	3
	Stormwater reused as irrigation or potable water (L/year)	2	2	0	2
	Amount of run-off retained (%, L/year)	3	3	3	3
Aesthetic Value	Place of gathering & social interaction. Accessibility to visitors. (yes/no)	1	1	1	0
	Landscaping evaluation index of the wetland/detention pond (survey, % of features on site designed as amenities)	2	2	2	0
Social Reputation/ Health and Wellbeing	Community recognition/opinion index via public survey: 1- Dislike the development; 2- Indifferent/don't know anything about it; 3- Agree with the purpose of the development.	2	0	2	0
	Leader in Innovation Index: 0- Has achieved little outside recognition with little follow-up. 1 - Has received outside recognition, but no existing plan to track changes. 2 - Has received outside recognition, with some stats tracked. 3 - Has received outside recognition, with all indicators measured.	2	0	0	2
Student Involvement & Educational Value	# students enrolled in CSL and SEEDS increasing (yes/no)	1	1	1	1
	Have partnerships with outside organizations. (yes/no)	2	2	2	2

	Number of maps, models, brochures, informational signs present for visitors	1	1	1	1
Economic Sustainability	Energy expenditures ($/year), Reduction? (yes/no)	3	0	0	0
	Potable water costs ($/year), Reduction? yes/no – factor cost of meter in	3	3	0	3
	Sustainable project funding index (high/medium/low probability of increasing amt. of government funding)	2	0	0	2
	Amount of run-off retained (%, L/year)	3	3	3	3
Energy & Climate Change Impacts	Net change in energy usage of south campus (+ve, -ve)	2	0	0	0
Ecosystem Preservation	Concentration of targeted pollutants in stormwater discharge	2	2	2	0
	Peak stormwater flow (L/sec)	2	2	2	2
	Yearly stormwater flow (L/sec)	2	2	2	0
	Reduction in the rate of erosion of Booming Ground creek (yes/no)	2	2	2	0
	# of plant species present	1	1	1	0
	% of soil distubed	2	2	2	0

	Water measurements: temperature, turbidity, pH, specific conductivity, metals. Meets regulations for discharge? Yes/No.	1	1	1	0
	Total Score		**33**	**27**	**24**

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