ubc botanical garden & centre for plant research
SUSTAINABLE COMMUNITY AMENITIES

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University of British Columbia

April 04, 2014

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SUSTAINABLE COMMUNITY AMENITIES
FINAL REPORT

S.H.&O. DESIGN
(CIVIL 446 TEAM #2)

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EXECUTIVE SUMMARY

S. H. & O. Design was asked to provide a detailed design of several projects to upgrade the UBC Botanical Garden and Center for Plant Research (UBCBG). Eight potential projects were identified by the client. These projects were intended to be desirable and useful facilities that would make the current botanical garden more sustainable and attractive to visitors. To meet the requirements of the client we determined the most practical approach was to design three separate projects, each corresponding to a civil engineering discipline. The table below provides a summary of these designs. Water resource management is the main engineering discipline covered, encompassing both hydrology and water treatment.

Engineering Discipline	**Hydrology**	**Water Treatment**	**Municipal Engineering**
Project	Stormwater collection	Treatment and retention pond	Picnic shelters and benches
Cost	$24, 000	$77, 000	$64, 000
Start	December 12, 2014	October 9, 2014	April 7, 2014
End	December 29, 2014	December 29, 2014	May 9, 2014
Days of Construction	12 days	52 days	25 days
Days on Site	12 days	32 days	15 days

The stormwater collection and treatment and retention pond will decrease the amount of potable water the garden uses, in turn making the garden more sustainable. The retention pond will be a water feature to attract visitors. The picnic areas and benches will increase the frequency of garden visits and connect the garden to the rest of the UBC campus. All designs follow the guidelines set out in the UBC Vancouver Campus Plan (Campus and Community Planning, 2010).

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1. PROJECT INTRODUCTION

The goal of this project is to develop sustainable community amenities at the UBC Botanical Garden (UBCBG) which will increase visitorship and create an environmentally and family friendly environment. This will be achieved by incorporating picnic areas throughout the garden, implementing a treatment/stormwater retention pond, along with a connected stormwater collection system that will provide the pond with a more sustainable source of water. The three sub-projects will work to solve the garden's existing problems of low attendance, unsustainable potable water use in the cattail pond, and lack of water features and community attractions. This multifaceted approach provides the garden with a cost-effective solution to the aforementioned issues, and allows for project staging and potential future expansion.

The three sub-projects were chosen because they best suit the three types of sustainability UBC is aiming to achieve: social, ecological and economic sustainability. The picnic areas will bring together students, staff, and visitors to achieve social sustainability. The water collection system connected to the treatment pond will provide ecological sustainability by reducing the volume of potable water used by the garden for irrigation. The three sub-projects were selected because they can be implemented at a low cost. This was achieved by selecting materials and methods that promote cost-effective, durable, and low maintenance structures and systems.

An overall plan view of the location of the three sub-projects is included in Figure 1, on the following page.

Figure 1: Plan view of project locations

2. SCOPE OF WORK

SH&O's scope of work for the detailed design of the UBCBG Sustainable Community Amenities projects is as follows:

- Design of a stormwater collection system, treatment and retention pond, and picnic areas
- Design rationale and justifications
- Implementation plan for the designs
- Schedule of implementation and construction
- Estimated labour and material cost of the three projects

The following items are ***not*** covered in our scope of work:

- Construction services
- Structural, transportation, or geotechnical design

3. HYDROLOGY: STORMWATER COLLECTION

The following section outlines the design for a stormwater collection system, located at the garden service yard, which will connect to the treatment and retention pond.

3.1. Introduction

Within the UBC Botanical Garden are numerous ponds and streams, which are currently routing storm water away from the garden and to both the trail seven creek outfall and the Botanical Gardens Creek Outfall as shown in Figure 2. These outfalls have been causing erosional damage, leading to increasingly unstable ground conditions near the cliff. In order for the ponds to remain full, potable water is being used despite the heavy amount of precipitation experienced each year. In particular, the cattail pond located on the east side of the UBCBG is unable to retain water as it either permeates the coarse till soil bed of the pond, or simply continues through to the connecting stream system.

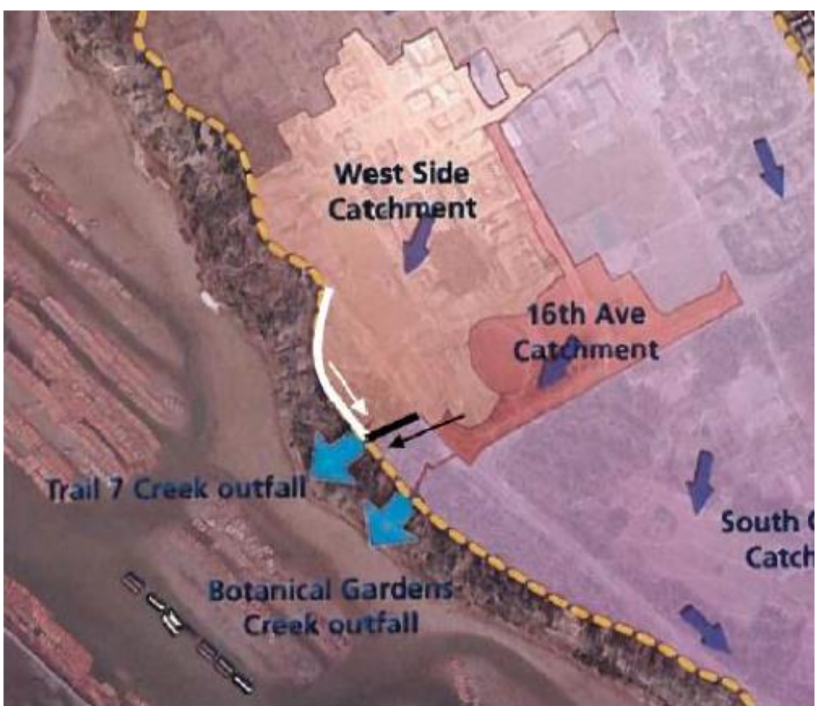

Figure 2: Creek outfall and UBC catchment area locations (Chand et al. 2012)

The average yearly rainfall experienced by UBC is enough to maintain a steady level of water in the cattail pond throughout the fall and winter (when precipitation is highest). The ponds and connecting stream systems in the garden often dry up during the summer months when precipitation is lowest due to the permeable till type soil bed of the pond. The average monthly precipitation data for Vancouver in 2013 can be seen in Figure 3.

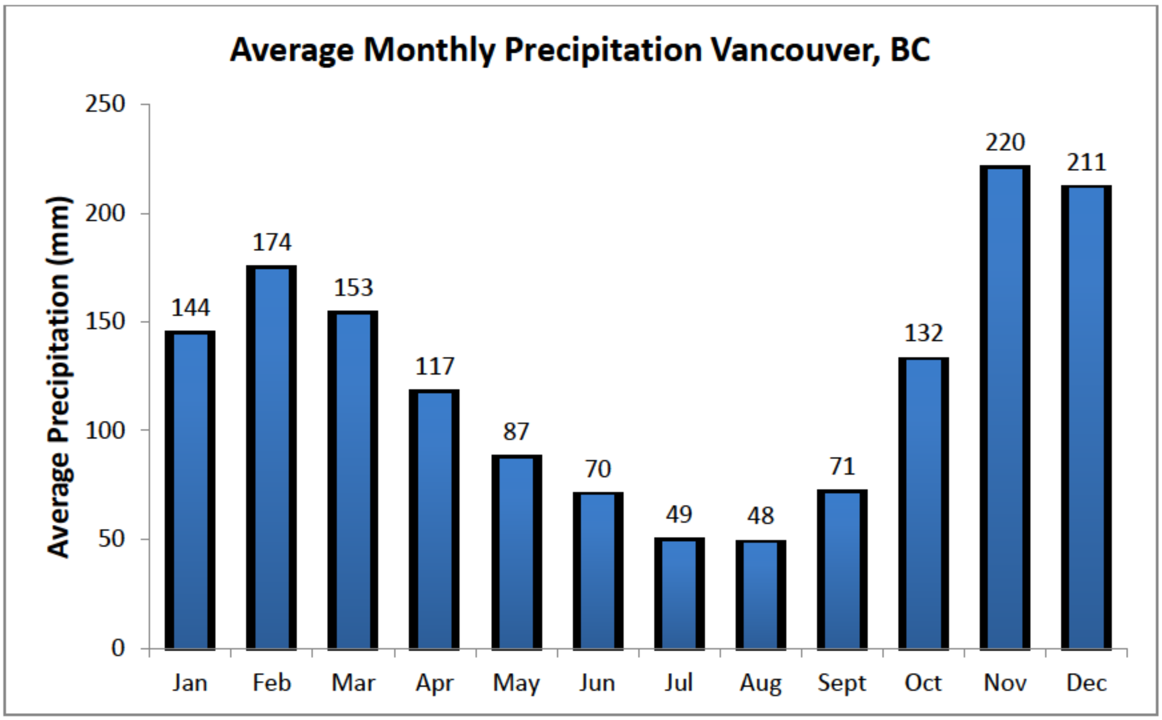

Figure 3: Average monthly precipitation, Vancouver, BC

Using hydrological engineering principles and design guidelines, this section details how rainfall can be harvested to fill the newly renovated cattail pond (section 4.0), minimizing the rather wasteful use of potable water in the garden. Note that this initiative complies with the Water Action Plan that UBC is currently developing (Water Action Plan, 2011).

3.2. Overall Design

The proposed stormwater collection system will be located at the site of the service lot just north of the cattail pond on the east side of the garden as seen in Figure 4. The combination of paving and grading the lot will create a smooth and impervious catchment area of about 600m^2, ensuring maximum runoff volumes and providing the garden with a more maintainable and practical service area.

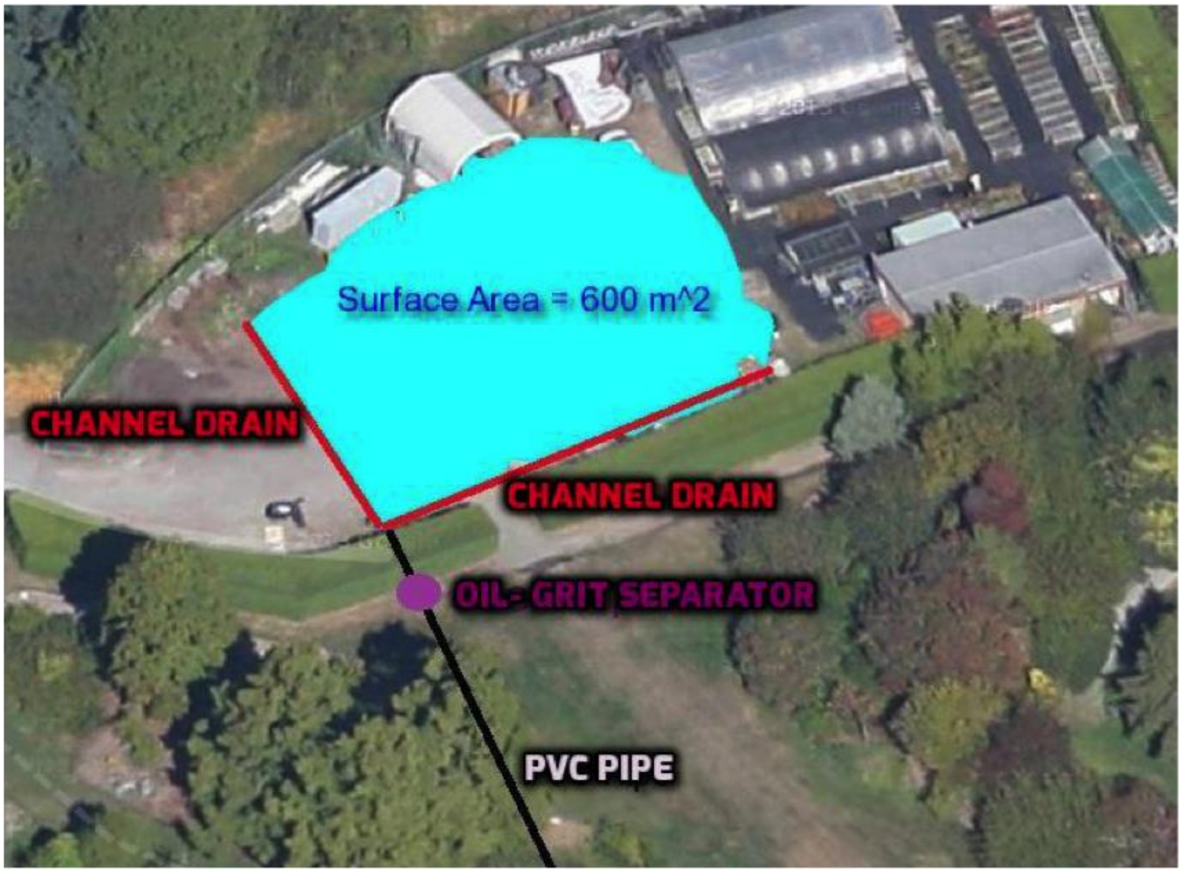

Figure 4: Overall stormwater collection system

Two Channel Drains will be installed on the west and south side of the service lot, each approximately 20-30 meters in length. Figure 5 and Figure 6 display a typical channel drain, and a typical channel drain cross-section respectively. Channel drains were selected as opposed to standard grate-style stormwater drains as they allow for a higher degree of collection and minimal losses.

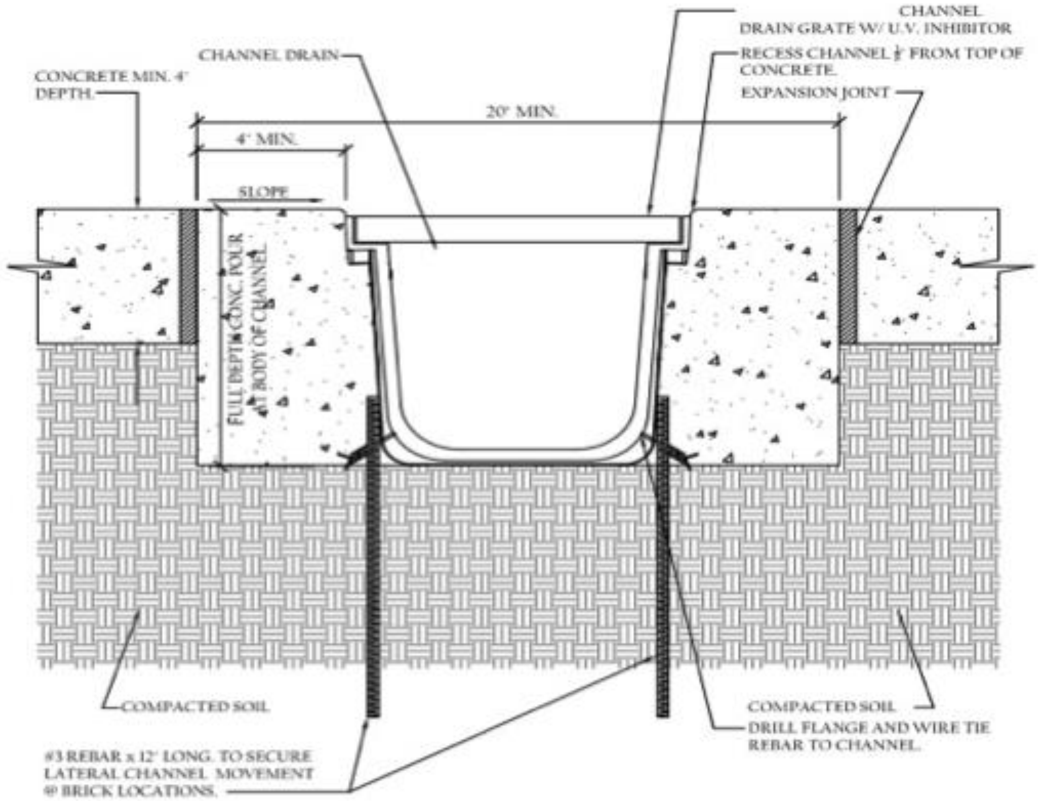

Figure 5: Typical channel drain cross-section

Figure 6: Typical channel drain

Once the water runs through the two sloped channel drains, it is then conveyed through a 30-meter-long 4" PVC pipe buried approximately 30 cm underground, at a 3% slope. The pipe will be connected to a 60 cubic feet oil-grit separator, based on size guidelines from the US Department of Transportation. Figure 8 shows the side view of a typical oil-grit separator. The water passes through the first chamber of the separator, which removes sediments, before travelling through the second chamber where oil and grease is separated. Since the service lot often has vehicles and equipment occupying it, removal of sediments and oil is crucial to maintain the cleanliness of the water in the pond. After passing through all of the chambers, the water then continues through the pipe to the pond where it is discharged.

Based on rainfall data from 2013, and the size of the catchment area, it is estimated that water collected per year from the service lot would be around 900 m^3. See Figure 7 for expected monthly runoff volumes.

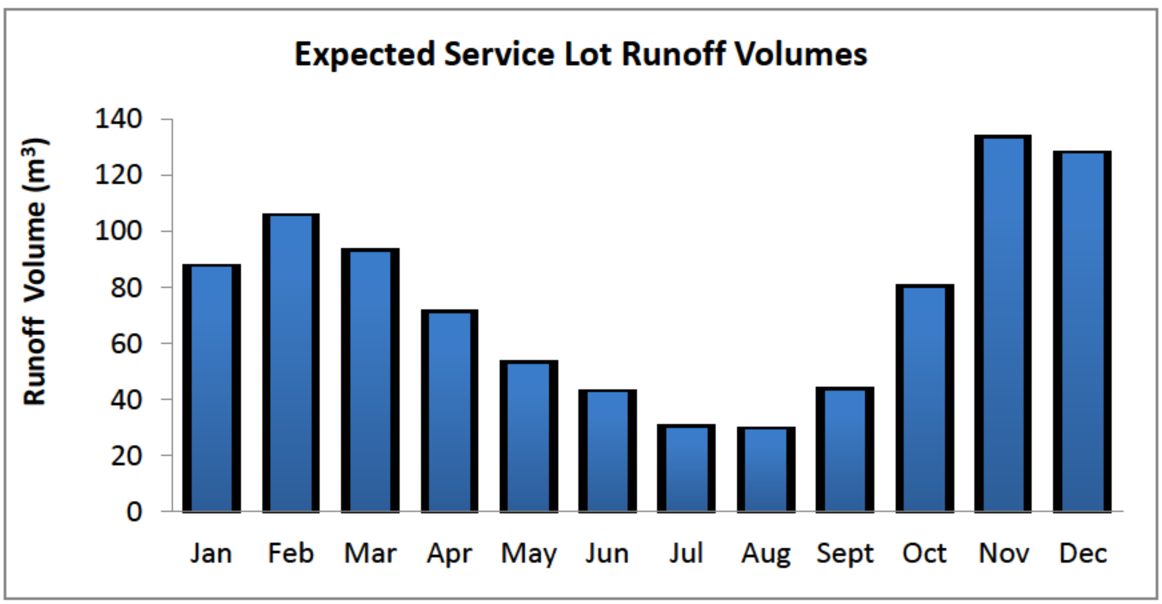

Figure 7: Expected service lot runoff volumes

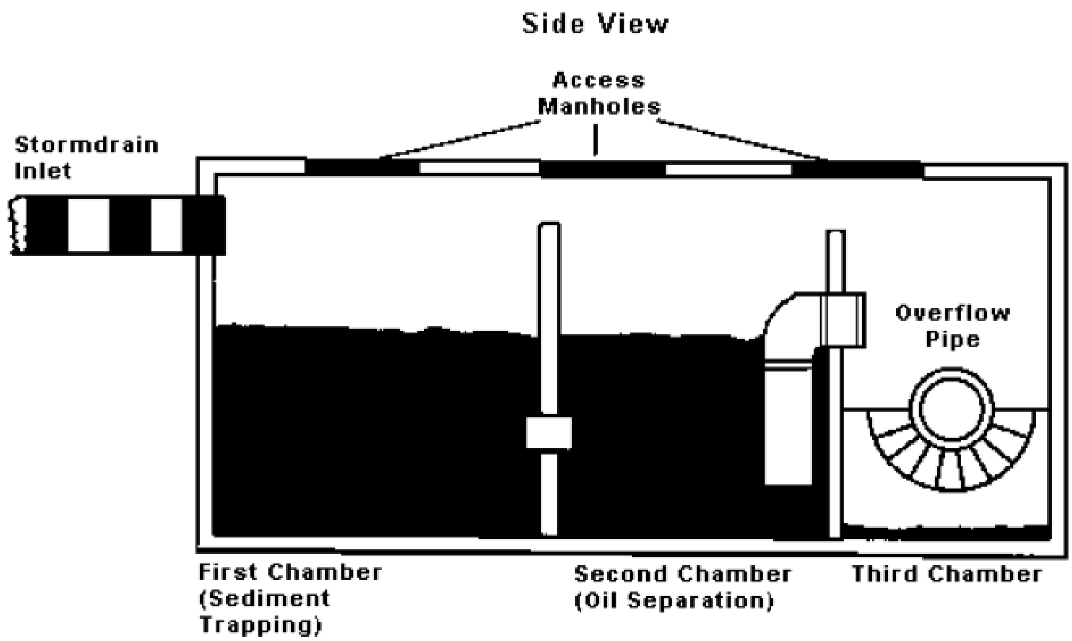

Figure 8: Side view of a typical oil-grit separator

3.3. Detailed Design

The following detailed design focuses on the sizing of the PVC pipe that will convey collected stormwater to the retention pond.

3.3.1. Pipe Sizing

The pipe size and slope was checked to be adequate using Bernoulli's equation:

$$\frac{v^2}{2} + gz + \frac{p}{\rho} = \text{constant}$$

Since the water first goes through the oil-grit separator before travelling through the 30-meter long pipe, the velocity head of the runoff is considered to be negligible. Thus the pressure head, which is created due to the elevation difference between the oil-grit separator and the treatment pond, has to be greater than the head loss due mainly to friction through the pipe for the water to flow down to the pond. Assuming the elevation difference is 1 meter and laminar flow through the pipe, the velocity through the pipe was calculated to be around 4.5ft/s. Based on the Hazen-Williams equation and experimental numbers for PVC pipes, the head loss was found to be around 0.5m for the selected pipe (Construction Dewatering and Groundwater Control, 2007). Note that further calculations need to be conducted using different flows and hydraulic diameters.

3.3.2. Peak Runoff Estimation

In order to estimate the peak yearly runoff from the newly paved service lot, the rational method, as well as precipitation data was utilized. Lengths and areas were estimated using Google Earth. Rainfall intensity and time of concentration were found using Figure 24 and Figure 25 found in Appendix A. It was assumed that the slope of the lot would be an average of 2%, and the design storm frequency was assumed to be 2 years due to the small size of the service lot and its purpose in the garden. Peak flow was then calculated in order to ensure the conveyance system is able to handle flows even during large storms.

The following rational method formulas were utilized:

Flow: $\mathrm{Q} = 0.0028\mathrm{CiA}$; Time of concentration: $T_c = 0.0195 * \mathrm{L}^{0.77}\mathrm{S}^{-0.385}$

Table 1: Rational method input data and results

Length, L	40 m
Slope, S	2%
Area, A	0.06 ha
Storm Frequency	2 years
Runoff coefficient, C	0.9
Rainfall Intensity, i	40 mm/hr
Peak Flow, Q	0.005 m^3/s
Time of Concentration, Tc	1.51 minutes

3.4. Cost

Table 2 below displays the estimated cost for each element of the stormwater collection system, along with a total estimated cost of $24, 300. The relatively low capital cost for the stormwater system makes it a practical and worthwhile investment for the garden. Costs for the service lot upgrade were determined by using typical unit costs utilized by the Alberta Transportation Industry as well as the Asphalt Institute. The oil-grit separator (US Department of Transportation), channel drains (NDS Pro), and PVC pipe (US Plastic) costs are also summarized below. A more detailed cost estimate is provided in Appendix C.

Table 2: Water collection cost summary

Item	Cost
Placement of granular base:	$300
Asphalt material cost:	$7,500
Asphalt transportation cost:	$500
PVC pipe cost:	$500
Channel drain cost:	$4,000
Oil- grit separator cost:	$5,000
Labour cost:	$6,500
TOTAL ESTIMATED COST:	**$24,300**

3.5. Schedule

Work was scheduled based on eight hour work days, Monday to Friday. The Gantt chart in Appendix B outlines the implementation of the stormwater collection system, including the construction schedule for the upgrade of the service lot. Note that the construction period lasts for 12 days. It is also important to note that this system should be built either after, or in conjunction with the treatment and retention pond (section 4.0). A summary of the proposed construction schedule is shown below in Table 3. A more detailed schedule including the gantt chart can be found in Appendix B.

Table 3: Stormwater collection construction schedule summary

Task	Start	Finish	Days
Prepare Surface	December 12	December 18	5
Cover Soil with Asphalt	December 19	December 22	2
Install Drains/Pipes/OGS	December 19	December 24	5
Landscape	December 26	December 29	2
Total	December 12	December 29	12

4. WATER TREATMENT: TREATMENT AND RETENTION POND

The second project, which will be connected to the stormwater collection system described in Section 3 is the treatment in retention pond. The system objectives and design are described here.

4.1. Introduction

The current pond in the garden is overrun with cattails, is mostly hidden from the public's view, and lacks access for research purposes. Water bodies provide an enjoyable sight containing the natural flows of water and flora and fauna life that it supports along its edges and in the depths. At the UBCBG, it can provide a space for treatment and containment of water for future uses as well as a research facility for passive water treatment. Several issues have been outlined with the current state of the pond and around the Gardens, for which some solutions are presented in Table 4.

Figure 9: Current pond north end (Photo by Sophia Piche)

Table 4: Issues and solutions for UBCBG pond

Item	*Issue*	*Proposed Solution*
1	Involvement of research groups within the Garden	Treat inflow water through a series of pond, also called "facultative lagoons"
2	Destruction and damage to the pond edges during research projects	Equip the pond with defined access points to edges and deeper sections
3	Expensive and repeated dredging and cattail removal process	Minimize the need for continuous dredging and removal of cattails in the pond
4	Lack of public viewing and enjoyment of the pond	Add bridges and a landscaped pond area for recreational use

There are other benefits for the garden related to stormwater and irrigation linked to the pond, which are not mentioned in this report.

4.2. Overall Design

The pond includes three distinct zones for settling, filtration and retention. Overall pond dimensions were kept within the existing pond footprint as desired by Douglas Justice (UBCBG Associate Director) and as shown in Figure 10.

Figure 10: Pond layout

The major field of civil engineering used in this design is water treatment with a biological and chemical focus. Water treatment and environmental engineering are related by goals of sustainability, minimizing waste, resource recycling, and maintenance of environmental quality. The garden's treatment and retention pond will apply principles from both disciplines to effectively collect, treat, and offer re-usable stormwater for irrigation within the pond.

Criteria matrices were used to evaluate the options for redevelopment of the pond. As an example, the table comparing the benefits of re-vamping the current pond or creating a more complex three pool structure is shown in Table 5. Scales of 1-5 (1 as the most desirable) were used for the weighting of options. The final selection is for three tiers of pools instead of a continuous pool.

Table 5: Decision matrix

Options		**3 Tiers of Pools**	**Continuous Pool**
Criteria	*Weighting*		
Environmental/ Sustainable	20%	2	4
Constructability	10%	3	1
Capital Costs	20%	5	1
Annual Costs	10%	2	3
Revenues	15%	2	5
Fits Garden's Mission	10%	1	3
Visitor Volume	15%	3	5
Final Score	100%	2.75	3.2
Selection		**3 Tiers of Pools**	

4.3. Detailed Design

The three tiers of the pond are designed for peak rain flow from the Stage 1 collection area of the service lot discussed in section 3 and garden demands. However, future connections to larger drainage areas will maximize the pond's capabilities as an irrigation source for the garden.

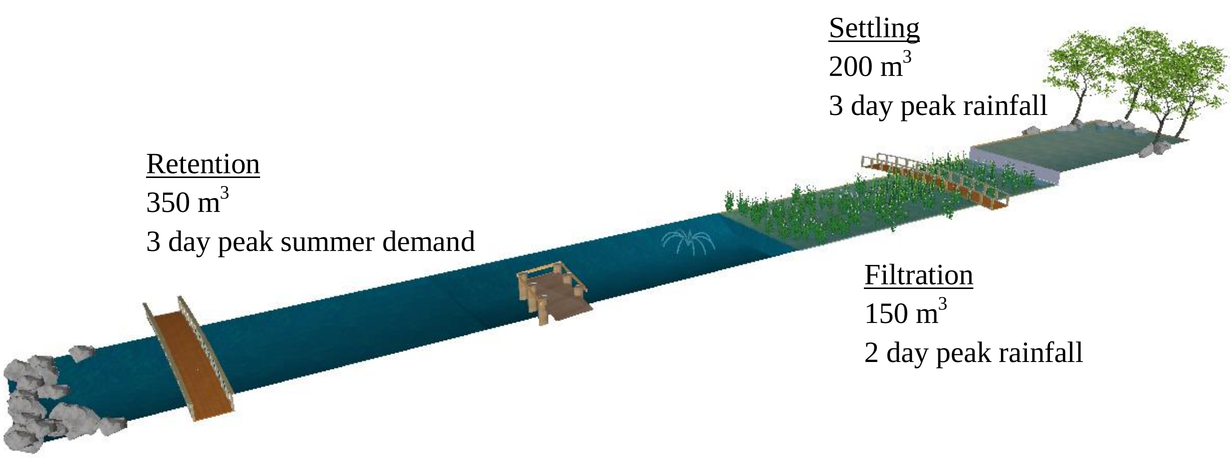

Figure 11: Stage 1 pond sizing

Table 6 contains further details on the system characteristics of each pond tier. Each pool will have multiple similar characteristics to simplify the design while effectively providing service.

Table 6: Pond specifications

Pool	*Pool A*	*Pool B*	*Pool C*
Purpose	Particle settlement	Filtration and cleaning	Storage
*Size**	20 m long x 10 m wide x 1.5 m deep	30 m long x 10 m wide x 0.5 m deep	50 m long x 10 m wide x 1.5 m deep
Flow/ Storage	2 days retention time for settling : 200 m^3	Continuous flow: 150 m^3	3 days of peak summer irrigation capacity: 350 m^3
Vegetation	Minimal, to allow settling and dredging	Cattails, reeds and others	Minimal to maximize water volume and cleanliness
Liner	XR®-3 Fabric for its capacity to contain hydrocarbons from parking and street run-off (Lange)		
Input	Drainage connections	Pool A	Pool B
Output	Pool B & Excess flow drain	Pool C	Creek & Irrigation system

*Side slopes are at 2H:1V to 3H:1V to maximize volumes for settling and storage.

4.3.1. Flow and Capacity

The pond is designed for a capacity up to 100 m^3 per day, or 3000 m^3 per month. This is suitable for three days of heavy 50 mm/hr rainfall over the Stage 1 collection area and three days of peak 120 m^3 summer BG watering and irrigation needs. The main limitation to the pond capacity was maintaining the approximate current cattails area dimensions within the garden, restricting storage volumes.

One of the main design objectives for the pond is its capacity to withstand and still perform under the highly variable flows throughout the year. This is achieved by control structures, described in the next section, and the three pond tiers.

4.3.2. Control Structures

Pool A's outflow will be a variable height outlet structure which will allow sufficient time for settling within the pool, but also accommodate varying water levels that will occur throughout the year, as well as an excess flow outlet structure on the side for high rainfall events when the pool is at maximum capacity shown in Figure 12. The outlet to pool B is formed with a buoyant material attached to the top of a sliding gate as shown in Figure 13.

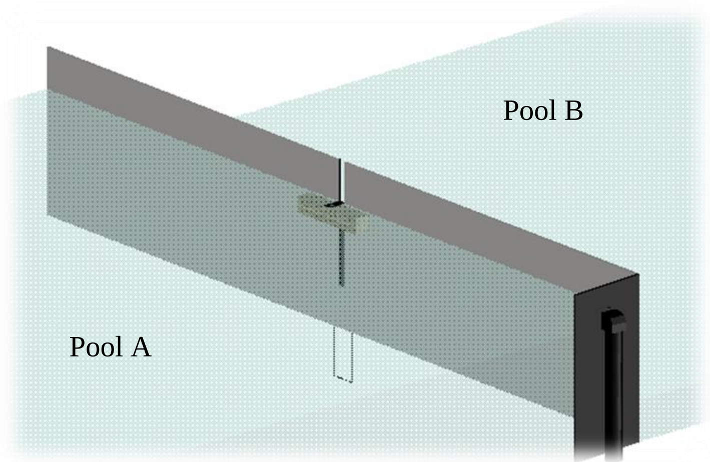

Figure 12: Gate structure

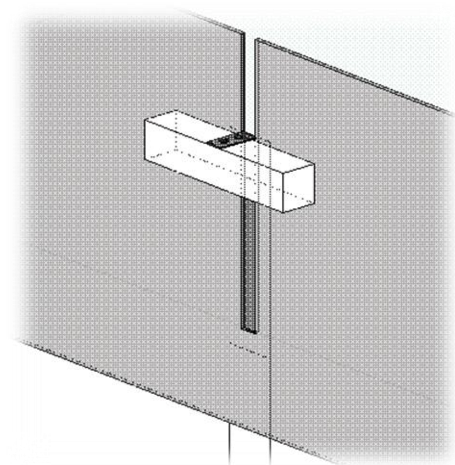

Figure 13: Detail of gate structure

The maximum water height of pool A will be 1.0 m above the water level of pool B to ensure sufficient retention time for settlement, while pool B and pool C will be separated by a 0.5 m control structure that will maintain the 0.5 m flow depth within the treatment pool.

4.3.3. Lining

The pond will be lined with the industry grade XR®-3 Light Duty Geomembrane, which has long term durability, has low thermal expansion and contraction properties, offers chemical resistance and comes in suitably large sizes to minimize field seams. This membrane is suitable for wastewater applications and potable water applications (XR Geomembranes). This liner also has higher puncture resistance, tensile strength, UV resistance and hydrostatic resistance than other PVC, HDPE and Polypropylene liners available on the market.

The base for the liner shall be uniformly sized compacted sand and gravel. This surface shall be free of loose materials and should be relatively dry during liner installation (XR Technologies). The liner shall be placed and anchored as shown in Figure 14.

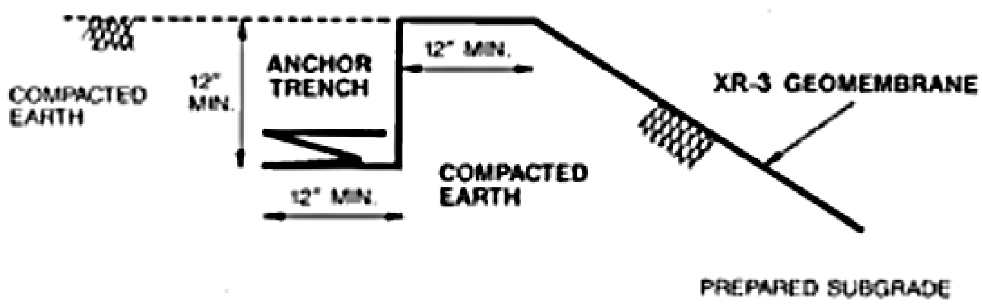

Figure 14: Liner installation detail (XR Technologies) vegetation

The vegetation used in the phytoremediation process can remove heavy metals, contaminants, and other organic pollutants. Using native species helps to lower maintenance costs and avoid the need for pesticides and fertilizers to promote growth (EPA, 2012). These plants include *Sparganium* (bur reed), *Phragmites* (common reed) in the water and *Lolium perenne* (perennial rye grass), *Festuca rubra* (creeping red fescue), and *Poa pratensis* (Kenucky bluegrass) surrounding the pond (Padmavathiamma & Li, 2009). In addition, the currently thriving *Typha* (cattail) flora will be reinstated in smaller, less invasive quantities.

The inclusion of plants and a landscaped area around the pond, as shown in Figure 15 will create an appealing and function space within the garden for visitors and researchers alike.

Figure 15: View of the pond from the southeast corner

4.3.4. Maintenance

The proposed pond and its tiers will need regular maintenance, like the currently existing pond. However, with a settling pond, the primary work of dredging by excavator will be contained within pool A. This will limit the disturbance to the garden by equipment as well, although it is suggested that dredging occurs on a yearly (instead of the current four year cycle) in order to maintain a deeper settling pond and hence maximize its volume capacity. Easy access would be available to equipment through the service yard and over the short 40 m distance to the pond.

Figure 16: Access to the pond

More frequent landscaping work around the pond, as well as any maintenance required for the bridges or fountain could be undertaken by the garden's staff and equipment. Wildlife such as birds should be discouraged from coming to the pond by allowing a continuous flow of water through the pond, discouraging aquatic species from inhabiting the pond and the use of fake predator bird shapes, such as owls and hawks. This will allow the pond to stay cleaner for later use of the water in irrigation as well as a safety precaution for visitors and will avoid flocks of birds towards the food garden.

4.2. Cost

The following table outlines the expected costs for the capital, annual operations and maintenance costs as well as the ultimate system revenues and potential savings when the pond is at ultimate capacity and connected to a sufficiently large catchment area.

Table 7: Cost estimate of water treatment and retention pond

ID	Item	Quantity	Unit	Unit Cost		Cost	
1	Excavation & Dredging	1,100.00	m^3			$	31,100
2	Liner	620	m^2	$	14.00	$	8,680
3	Control Structures	3	ea	$	2,000.00	$	6,000
4	Vegetation					$	20,400
5	Additional Options					$	8,500
6	Commissioning	2	ea	$	1,000.00	$	2,000
Capital Expenses						**$**	**76,680**
7	Dredging	100	m^3	$	8.00	$	800
8	Landscaping	1000	m^2	$	1.00	$	1,000
9	Maintenance	1	ea	$	1,000.00	$	1,000
Annual Operation and Maintenance						**$**	**2,800**
10	Water Savings (Ultimate)	13,625.00	m^3		1.3-1.6	$	21,235
11	Research	1	ea	$	5,000.00	$	5,000
Annual Revenues						**$**	**26,235**

4.3. Schedule

Construction will take place during the winter months between November 16 and March 14 when the garden is closed in order to limit the negative impacts to visitors. A conservative two month construction duration is proposed, following three months of collecting funding and 30 days for materials and services procurement. The expected construction schedule outline is included in Table 8 with a detailed Gantt chart found in Appendix B.

Table 8: Pond construction schedule

Task	Start	Finish	Days
Procurement	October 9	November 19	30
Fabrication in Shop	October 23	November 19	10
Site Work	November 20	December 29	32
Testing & Adjustments	December 30	January 16	10
Total	October 9	January 16	82

The work would primarily be contracted out to a contractor with experience with pond construction to maximize value for money and ensure good quality of work. Specialized sub trades for the control structures, vegetation planting and lining would also be involved in the process.

4.3.1. Staging and Expansion

In order to achieve the maximum pond capacity, a large water collection area would be necessary, available with the 16th Ave catchment area shown in Figure 2 (on page 3). However, in order to allow incremental developments along with their associated capital costs, a staged approach is suggested, accommodating the need for funding collection by attachement to successively larger areas within the Garden surrounding. As this pond area becomes a visitor attraction and an important research facility, further income to fund future works will be more easily accessible. The long term implementation plan fits within the UBC Water Action Plan (UBC Sustainability) which aims to develop UBC into a closed loop water system.

The following stages are recommended:

1. Construction of the treatment pond and attachment to the BG service lot drainage system, described in Section 3. Access to the site would be as shown for maintenance in Figure 16.
    a. Modest 3% savings of a few hundred dollars in water costs and allows a time period for review of the system for improvements or changes
2. Creation of an integrated irrigation system with the pond storage section which allows greater automation of watering needs in the garden
3. Attachment of the treatment pond system to the 16^{th} Ave catchment area
    a. 95% savings in current water costs. The remaining 5% is from simultaneous peak summer demands coinciding with low rainfall.

As explained above, it is important to move forward with attachment to greater catchment areas as this will allow great cost savings and increase the sustainability of the BG.

5. MUNICIPAL ENGINEERING: PICNIC AREAS

This section describes the implementation of several picnic areas and benches throughout the garden which will increase visitor frequency and add value to the garden.

5.1. Introduction

Two picnic areas will be located at points S1 and S2 on Figure 17. The bench areas are scattered around the garden and will have two benches per location. A typical arrangement of benches is shown in Figure 18 and at location B4 in Figure 17. Areas of high pedestrian traffic and natural resting spots were chosen as locations for the shelters. Location S2 also has a lot of open space to view the garden and Great Lawn while location S1 is a high traffic area before the tunnel (as seen in Figure 19). Further information on these projects is included in the following sections.

Figure 17: Site plan of picnic areas

Municipal engineering (in the context of this project) deals with land use development planning, strategic planning, coordination of new park projects, and the layout of site plans. Three picnic areas and multiple benches were designed, under the context of a municipal engineer, to meet the requirements of the Scope of Work and Client's request. A practical approach was used during the design process. The requirements of the UBC Campus Plan were followed to ensure this project follows UBC's vision.

Figure 18: Benches at B4

The picnic areas will encourage people to stay longer at the garden and return more frequently. There are currently few outdoor places within the garden to sit and gather. The new picnic areas and benches will add value by encouraging a unique community feel, increasing the visitor experience, and anchoring the Botanical Garden. This will provide a sense of place while showcasing the natural west coast beauty.

Figure 19: Shelter at S2

5.2. Overall Design Description

The UBCBG is located in the south part of the campus in the section known as the Forest Edge District (Campus and Community Planning, 2010). Some design standards for BC Parks as well as precedents from the UBC campus were used to design the picnic areas. Design drawings and specifications for standard shelters, picnic tables, and benches as well as specifications for the supply, labour, materials, and equipment can be found in the Park Facility Standards Guide (Province of British Columbia Ministry of Land and Parks, 2005).

The picnic areas and shelters specifically implement principles 1, 2, and 5 of the universal design principles in The Campus Plan: equitable use, flexibility in use and tolerance for error. The picnic areas allow for the same means of use for all users, encourage a wide range of users with different heights, strengths and ages, and finally provide features with minimal complexity, that are simple in nature (Campus Plan, 2010).

The picnic areas are designed to target families with children, young couples, and small groups. These segmentation areas were targeted to increase the areas of lowest visitor volume to the garden. An orthographic sketch of the picnic shelter and benches at location S1 is shown in Figure 20 and Figure 21 respectively.

Figure 20: Shelter at S1 (looking north)

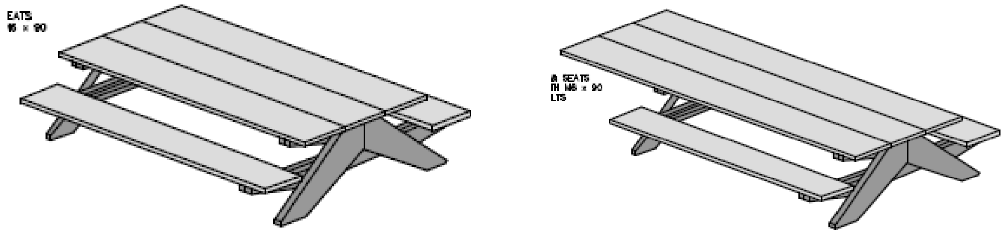

Figure 21: BC Parks picnic table standard

5.3. Detailed Design

The focus of the detailed design is the picnic shelters. We designed our picnic areas to be economically, socially, and ecologically sustainable. The structures identified in this section fall under Part 9: "Housing and Small Buildings" of the BCBC (BCBC, 2010). As a result, a structural analysis of the wooden structure was not performed and design standards from the BC Parks Park Facility Standards Guide were used. A structural engineer will be required, however, to design the foundations for the four posts holding up the roof. The structural engineer will be able to use the existing Geotechnical reports in of the area to determine the size of the footings and amount of rebar required. The most economical and simplest solution will be to have four spread footings, with short pedestals. The structural design of the shelters is not included in this report.

The shelters have a 20' x 25' footprint and are 11 feet high at the low end. They have a sloping roof to allow water to flow into the gutters installed on the low end. Laminated glazing is used to maximize the amount of light under the shelter. This glass may be substituted for corrugated steel, which is much cheaper (this is discussed in section 5.4). The roof is made of heavy timber beams laid out in a perpendicular grid, unlike the roof of the bus shelters on University Boulevard (Figure 22). The picnic shelters, picnic tables, and benches are made primarily out of timber. Wood is a renewable resource, regionally available, recyclable, sequesters greenhouse gases, and is aesthetically pleasing (Tannert, 2013).

Several design precedents from around UBC were used and modified to fit within the Botanical Garden. Figure 22 and Figure 23, below, show the laminated glazing roof used at the bus stop shelters on University Boulevard and paving stone that will be used as the shelter floor. The paving stone allows for easy water drainage, is inexpensive and is easier to install than concrete, without requiring concrete truck access. The paving stone will be laid on six inches of course compacted gravel to provide firm bearing, as outlined in the BC Parks Park Facility Standards Guide (2005).

Figure 22: Laminated glass roof and honeycomb support

Source: www.szolyd.com

Figure 23: Concrete paving stones

Source: www.angelslandscaping.com

5.4. Cost

The cost estimate shown below in Table 9 was assembled using Hanscomb's Yardsticks for Costing 2008. Raw data was based on Vancouver costs in January 2008. Total cost has therefore been adjusted for inflation over 6.25 years at an assumed rate of 2% per annum to approximate April 2014 costs. Additionally, a 20% contingency has been applied to provide for unforeseen complications and mobilisation and access costs.

Table 9: Picnic area cost estimate

ID	Item	Quantity	Unit Cost	Cost
1a	Picnic Shelter (w/ Glazing)	2	$ 34,200	$ 68,400
1b	Picnic Shelter (w/ Steel)	2	$ 13,200	$ 26,400
2	Picnic Table	4	$ 1,200	$ 4,800
3	Bench	16	$ 1,000	$ 16,000

$ 89,200	**w/ Glazing**
$ 47,100	**w/ Steel**
$ 121,100	**w/ Glazing (Adjusted)**
$ 64,000	**w/ Steel (Adjusted)**

The two total costs shown above reflect the two different roofing options for the shelters. Glazing allows more light into the shelter and emphasises adjacent trees while corrugated steel is much less expensive in terms of labour and materials. Total cost of all shelters, tables, and benches is $121, 000 with glazing. When corrugated steel is used, the total cost is almost half the higher price at $64, 000.

5.5. Schedule

It will take 25 business days to construct one picnic shelter, with 15 days on site. Construction was scheduled based on working eight hours a day, Monday to Friday. The work was scheduled to minimize the amount of time on site and maximize the amount of time in the fabrication shop. The schedule is conservative and some contingencies for pour weather and delays were factored in. Table 10, below, outlines the construction schedule. A detained Gantt chart is provided in Appendix B.

Table 10: Picnic area schedule

Task	Start	Finish	Days
Site Work	April 21	May 9	6
Fabrication in Shop	April 7	April 28	16
Site Installation	April 29	May 2	5
Landscaping	May 5	May 9	5
Days of Construction	April 7	May 9	25
Days on Site	April 21	May 9	15

The heavy timber and laminated glazing roof will be built and assembled in the fabrication shop as one piece. Once the footings and pedestals are poured, backfill will be added and the paving stone will be installed. The four posts and roof will be delivered to site on a flatbed truck and lifted into place using a small truck crane. The truck crane will be able to drive to location S1 using Upper Asian Way Path and location S2 using the service road coming of West 16th Avenue.

6. POTENTIAL BENEFITS TO THE CLIENT: SOCIETAL AND ENVIRONMENTAL CONSIDERATIONS

Whether the stormwater collection system, cattail pond, or picnic areas are implemented individually or together, they all provide significant benefits to the garden. The following table summarizes how all three components of this revitalization project will benefit the garden, as well as the societal and environmental advantages.

Table 11: Project benefits to the UBCBG

Benefits	Stormwater Collection	Treatment and Retention Pond	Picnic Areas
Social	-Improved	-Aesthetic value -Gives visitors a more diverse educational experience	-Serve as gathering places for groups and families -Accessible to all persons
Environmental	-Reduced potable water consumption -Adheres to the Water Action Plan by harnessing rainwater	-Improved water quality - Diminished stormwater runoff - Decreases potable water use for irrigation	-Use of sustainable materials (timber and paving stones) -Ability for water collected in gutters to flow to pond
Economic	-Promotes sustainable water consumption within the garden -Provides the option for future irrigation expansion	-Additional research opportunities -Decreased cost for potable water	-Increase visitorship from a wider array of demographics -Added element of functionality, aesthetics, and

7. IMPLEMENTATION

The picnic areas will be built first, before the height of visitor season, to address the economic sustainability of the garden. They function as a gateway for the rest of the project by increasing revenues and visitor numbers. This subproject is also not the longest or most expensive of the three; this encourages acceptance and support. Minimal mobilisation time and a short construction schedule are key to installation prior to the majority of summer traffic. Shelters are to be built as hubs around which families can explore the garden. The remaining twelve benches are to be placed in pairs where they afford a special viewpoint or service high traffic. Three pairs are to be placed on either side of the garden.

Construction of the water treatment and retention pond will begin second. With the increased funds and interested visitors afforded by the picnic areas, the most costly subproject can be undertaken. Spanning 52 days, the construction of the pond is crucial to the garden's social sustainability. By increasing educational opportunities the pond is the foundation for future additions. By timing the work in the late fall through the end of the year, minimal disruption to the grounds keepers and the public is expected.

The third and final subproject, stormwater collection, is to be constructed partially in tandem with the pond. The collection system is a modular approach to environmental sustainability on the campus. Like the pond, construction should avoid affecting the maintenance of the garden. As the pond is tuned to receive stormwater from outside the garden, further collection can begin. The increased exposure the garden will gain from increased partnership with UBC will draw more visitors and continue the cycle of education and growth.

8. CONCLUSION AND RECOMMENDATION

While the three subprojects have differences in scope, cost, focus, and purpose, they are intended to complement each other in the pursuit of a broader goal. That goal is the sustainability of the UBCBG.

The economic sustainability of the garden is of utmost importance because the budget is so tight and the garden is struggling to be financially viable. Large donations cannot necessarily be depended on to support annual expenses. Therefore the garden must become self-sufficient in this regard.

As the garden's primary visitor demographic ages, the social sustainability of the garden is coming increasingly into question. Sparking interest in new visitors will ensure that they return and continue to support the garden, directly and indirectly. Education is very effective at changing the way the public views the UBCBG and sustainability.

Finally, by implementing stormwater collection, the UBCBG will show that sustainable initiatives are worth investing in. By spearheading stormwater recycling on campus, the UBCBG will help the university on it's way to more widespread initiatives.

Therefore, if the designs and strategies outlined in this report are implemented, the UBCBG will begin to be increasingly environmentally, socially, and economically sustainable.

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APPENDIX A: TABLES AND OTHER RESOURCES

Time of Concentration for Small Drainage Areas (Tc)

Maximum length of flow (m)	Gradient of Drainage Area (percent) 0.05	0.1	0.5	1.0	2.0	5.0
100	13	10	5	4	2	2
200	21	16	9	7	5	4
300	29	23	12	9	7	5
400	37	28	15	12	9	6
500	44	33	18	14	11	7
1000	74	57	31	23	18	13
1500	102	78	42	32	25	17
2000	127	97	52	40	31	22
2500	150	115	62	47	36	26
5000	256	196	106	81	62	44

Generated from $Tc = 0.0195 \times L^{0.77} \times S^{-0.385}$ (theoretical equation)

where L = maximum length of flow (m)
S = grade of drainage area (m per m)
T_c = time of concentration (minutes)
Gradient = the grade expressed in percent

Figure 24: Time of concentration

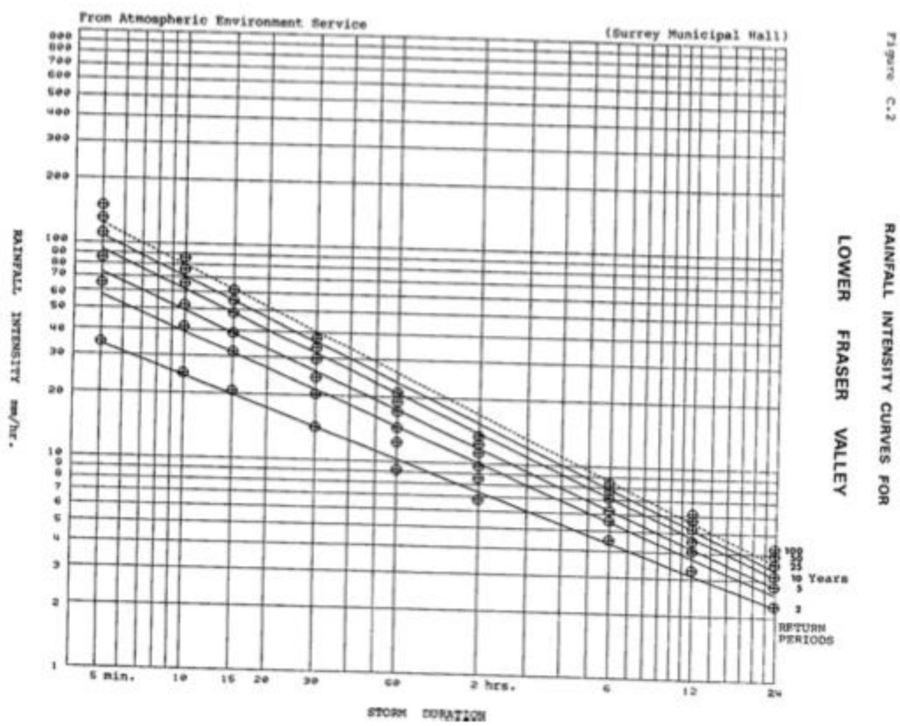
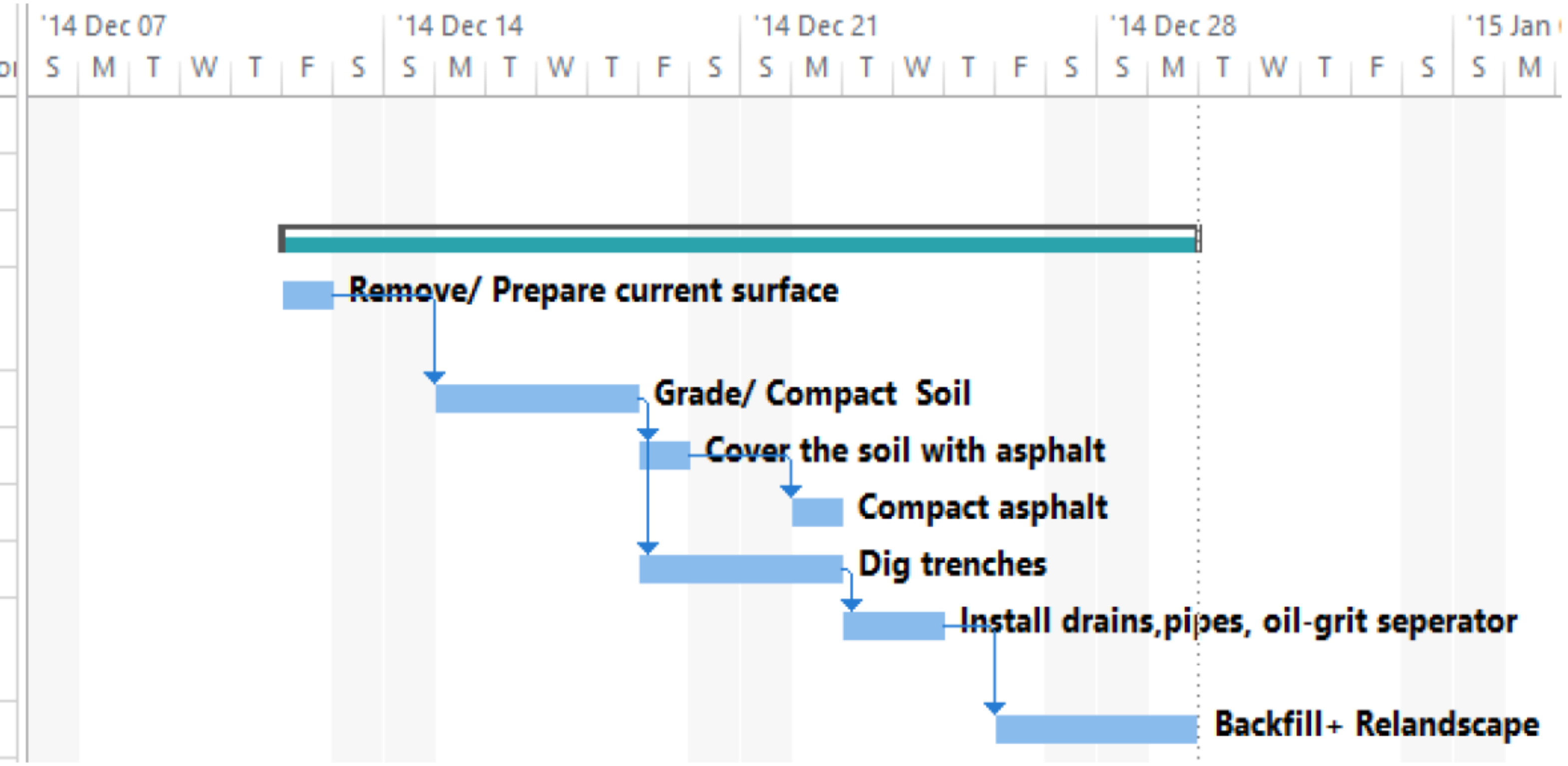


Figure 25: Rainfall intensity curves

APPENDIX B: SCHEDULES

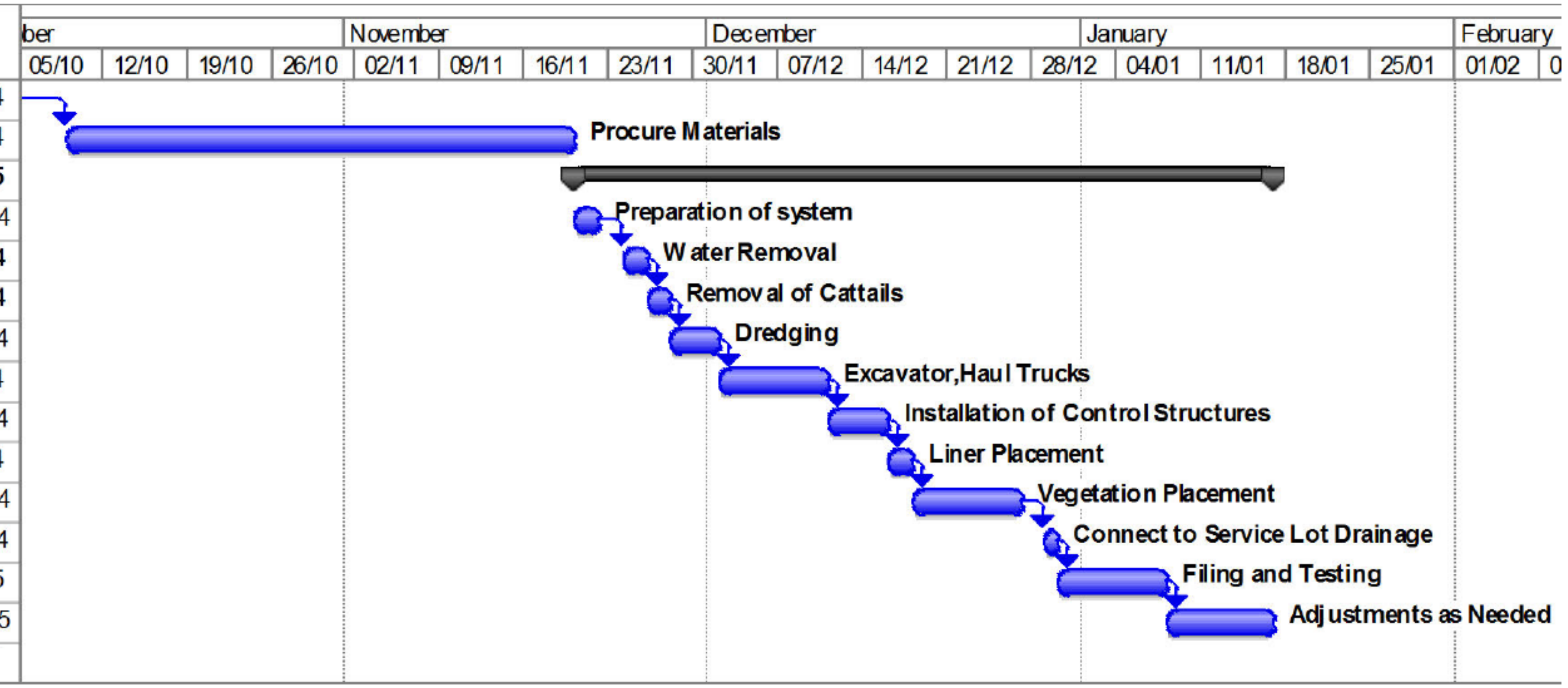
Stormwater Collection System:

Task Name	Duration	Start	Finish	Predecessors
Funding Collection	67 days	Thu 14-05-01	Fri 14-08-01	
Hire Contractor	22 days	Fri 14-08-01	Mon 14-09-01	1
Construction	**12 days**	**Fri 14-12-12**	**Mon 14-12-29**	
Remove/ Prepare current surface	1 day	Fri 14-12-12	Fri 14-12-12	
Grade/ Compact Soil	4 days	Mon 14-12-15	Thu 14-12-18	4
Cover the soil with asphalt	1 day	Fri 14-12-19	Fri 14-12-19	5
Compact asphalt	1 day	Mon 14-12-22	Mon 14-12-22	6
Dig trenches	2 days	Fri 14-12-19	Mon 14-12-22	5
Install drains,pipes, oil-grit seperator	2 days	Tue 14-12-23	Wed 14-12-24	8
Backfill+ Relandscape	2 days	Fri 14-12-26	Mon 14-12-29	9



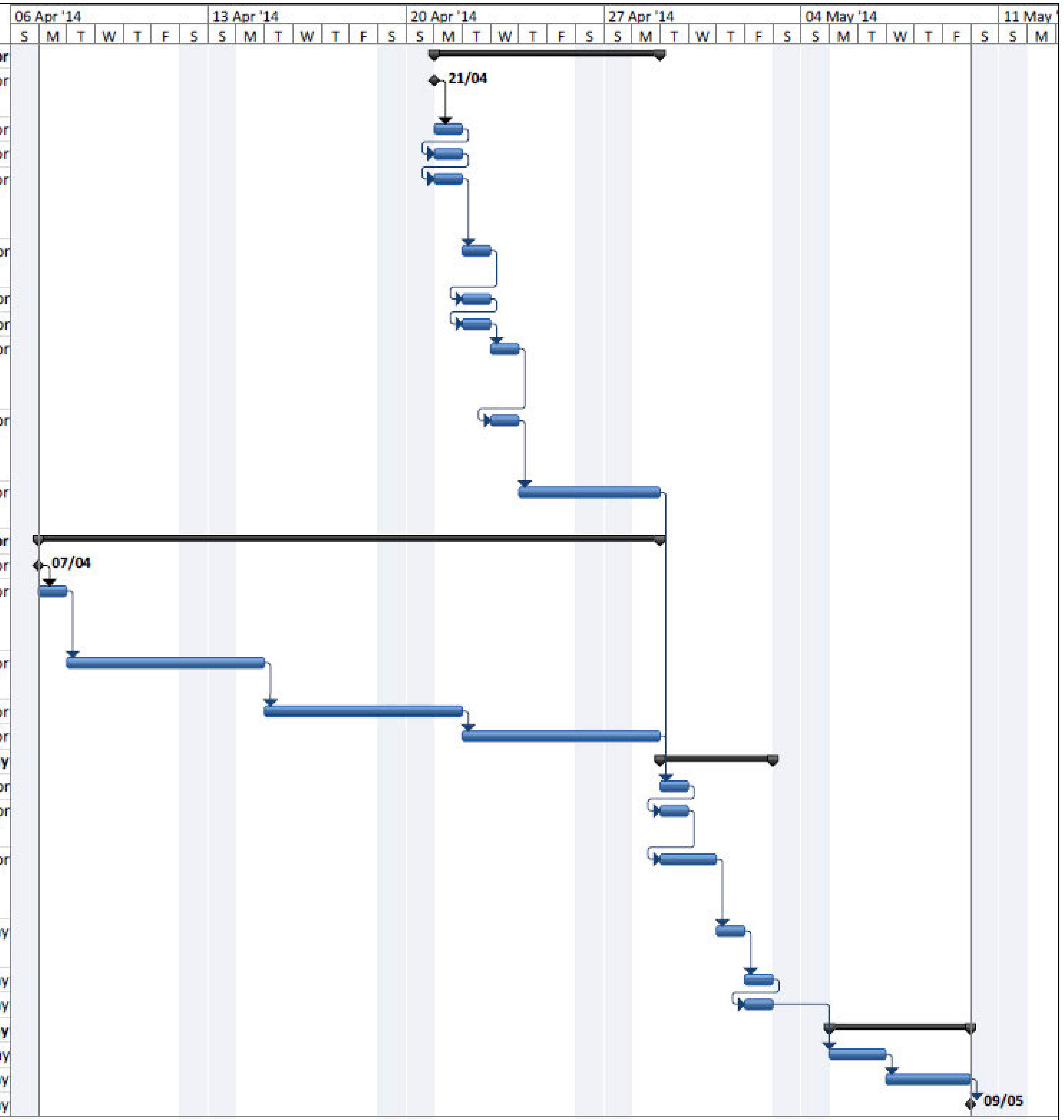
Treatment and Retention Pond:

ID		Task Name	Duration	Start	Finish
1		Funding Collection	3 mons	Thu 20/03/14	Wed 23/07/14
2		Procure Materials	30 days	Thu 09/10/14	Wed 19/11/14
3		**Construction**	**42 days**	**Thu 20/11/14**	**Fri 16/01/15**
4		Preparation of system	2 days	Thu 20/11/14	Fri 21/11/14
5		Water Removal	2 days	Mon 24/11/14	Tue 25/11/14
6		Removal of Cattails	2 days	Wed 26/11/14	Thu 27/11/14
7		Dredging	2 days	Fri 28/11/14	Mon 01/12/14
8		Excavations	1 wk	Tue 02/12/14	Wed 10/12/14
9		Installation of Control Structures	3 days	Thu 11/12/14	Mon 15/12/14
10		Liner Placement	2 days	Tue 16/12/14	Wed 17/12/14
11		Vegetation Placement	1 wk	Thu 18/12/14	Fri 26/12/14
12		Connect to Service Lot Drainage	1 day	Mon 29/12/14	Mon 29/12/14
13		Filing and Testing	1 wk	Tue 30/12/14	Wed 07/01/15
14		Adjustments as Needed	1 wk	Thu 08/01/15	Fri 16/01/15
15		Connect to Further UBC Drainage Networks			



Picnic Areas:

ID	Task Mode	Task Name	Start	Finish
1		**Site Work**	**Mon 21 Apr**	**Mon 28 Apr**
2		Start construction	Mon 21 Apr	Mon 21 Apr
3		Mobilization	Mon 21 Apr	Mon 21 Apr
4		Excavation	Mon 21 Apr	Mon 21 Apr
5		Place and compact first layer of fill	Mon 21 Apr	Mon 21 Apr
6		Set up forms for footings	Tue 22 Apr	Tue 22 Apr
7		Place rebar	Tue 22 Apr	Tue 22 Apr
8		Pour concrete	Tue 22 Apr	Tue 22 Apr
9		Backfill with second layer of fill to grade	Wed 23 Apr	Wed 23 Apr
10		Install water collection and drainage system	Wed 23 Apr	Wed 23 Apr
11		Paving stone shelter floor	Thu 24 Apr	Mon 28 Apr
12		**Fabrication in Shop**	**Mon 07 Apr**	**Mon 28 Apr**
13		Start facbrication	Mon 07 Apr	Mon 07 Apr
14		Detail connections for wooden posts	Mon 07 Apr	Mon 07 Apr
15		Wooden roof structure	Tue 08 Apr	Mon 14 Apr
16		Picnic tables	Tue 15 Apr	Mon 21 Apr
17		Benches	Tue 22 Apr	Mon 28 Apr
18		**Installation**	**Tue 29 Apr**	**Fri 02 May**
19		Install wood posts	Tue 29 Apr	Tue 29 Apr
20		Assemble wood roof	Tue 29 Apr	Tue 29 Apr
21		Put together glass panels and wood roof	Tue 29 Apr	Wed 30 Apr
22		Lift and secure roof to posts	Thu 01 May	Thu 01 May
23		Install rain gutters	Fri 02 May	Fri 02 May
24		Demobilization	Fri 02 May	Fri 02 May
25		**Lanscaping**	**Mon 05 May**	**Fri 09 May**
26		Plant grass	Mon 05 May	Tue 06 May
27		Plant flowers and sh	Wed 07 May	Fri 09 May
28		Finish project	Fri 09 May	Fri 09 May



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APPENDIX C: COSTS

Stormwater Collection Costs

Service Lot Unit Costs		
Purchase Asphalt	$90	/metric tonne
Place GBC	$15	/metric tonne
Transport asphalt	$6.50	/metric tonne
Service Lot Specifications		
Approximate area to be paved:	605	m^2
Thickness of asphalt:	3	inches
Approximate volume of asphalt required:	45.375	m^3
Density of asphalt:	1800	kg/m^3
Mass of asphalt:	82	metric tonnes
Service Lot Costs:		
Placement of GBC	$340.31	
Asphalt material cost	$7,350.75	
Asphalt transportation cost	$530.89	
Stormwater Conveyance System		
PVC unit cost	$3.84	/ft
30m PVC pipe	$376.32	
Channel drain unit cost	$80.00	/section
50 channel sections	$4,000.00	
Oil-grit separator	$5,000.00	
Labour Costs		
Estimated total cost based on 12 day construction	$6500	
TOTAL ESTIMATED COST	*$24, 300*	

Pond Costs and Revenues

ID	Item	Quantity	Unit	Unit Cost		Cost	
1	Excavation & Dredging	1,100.00	m^3			$	31,100
1.1	*Mobilize*	*1*	*ea*	*$*	*2,000.00*	*$*	*2,000*
1.2	*Strip Vegetation*	*300*	*m^3*	*$*	*8.00*	*$*	*2,400*
1.3	*Excavate*	*800*	*m^3*	*$*	*20.00*	*$*	*16,000*
1.4	*Haul*	*1,100.00*	*m^3*	*$*	*7.00*	*$*	*7,700*
1.5	*Survey*	*3*	*day*	*$*	*1,000.00*	*$*	*3,000*
2	Liner	620	m^2	$	14.00	$	8,680
2.1	*Material*	*620*	*m^2*	*$*	*7.00*	*$*	*4,340*
2.2	*Installation*	*620*	*m^2*	*$*	*7.00*	*$*	*4,340*
3	Control Structures	3	ea	$	2,000.00	$	6,000
3.1	*Control Structure 1*	*1*	*ea*	*$*	*2,000.00*	*$*	*2,000*
3.2	*Control Structure 2*	*1*	*ea*	*$*	*2,000.00*	*$*	*2,000*
3.3	*Control Structure 3*	*1*	*ea*	*$*	*2,000.00*	*$*	*2,000*
4	Vegetation					$	20,400
4.1	*Soils*	*300*	*m^3*	*$*	*8.00*	*$*	*2,400*
4.2	*Vegetation (Plants & Planting)*	*300*	*m^2*	*$*	*60.00*	*$*	*18,000*
5	Additional Options					$	8,500
5.1	*Fountain & Pump*	*1*	*ea*	*$*	*500.00*	*$*	*500*
5.2	*Bridges*	*2*	*ea*	*$*	*4,000.00*	*$*	*8,000*
6	Commissioning	2	ea	$	1,000.00	$	2,000
Capital Expenses						**$**	**76,680**
7	Dredging	100	m^3	$	8.00	$	800
8	Landscaping	1000	m^2	$	1.00	$	1,000
9	Maintenance	1	ea	$	1,000.00	$	1,000
Annual Operation and Maintenance						**$**	**2,800**
10	Water Savings (Ultimate)	13,625.00	m^3	1.3-1.6		$	21,235
11	Research	1	ea	$	5,000.00	$	5,000
Annual Revenues						**$**	**26,235**

Picnic Areas Costs

Item	Quantity	Units	Unit Cost	Total	Other Cost	Total Line Cost	
1 X Shelter							
Excavation for paving stones	18.5	CY	$ 157.00	$ 2,904.50	$ -	$ 2,904.50	
Excavation for footings	0.5	CY	$ 157.00	$ 78.50	$ -	$ 78.50	
Place and compact 6" of 3/4 crush	9.3	CY	$ 44.10	$ 410.13	$ -	$ 410.13	
Formwork	4	SF	$ 8.20	$ 32.80	$ -	$ 32.80	
Footing reinforcing and placement	50	#	$ 1.28	$ 64.00	$ -	$ 64.00	
Concrete pour	1	CY	$ 115.00	$ 115.00	$ 500.00	$ 615.00	
Post base hardware	4	units	$ 50.00	$ 200.00	$ 72.00	$ 272.00	
Red cedar columns	22	CF	$ 42.00	$ 924.00	$ -	$ 924.00	
2'x2' concrete pavers, installed	125	units	$ 15.00	$ 1,875.00	$ -	$ 1,875.00	
Wood roof structure	100	BF	$ 4.00	$ 400.00	$ -	$ 400.00	
1/4" laminated roof glazing	500	SF	$ 50.00	$ 25,000.00	$ -	$ 25,000.00	
(Painted corrugated 22ga steel roof)	500	SF	$ 7.95	$ 3,975.00	$ -		$ 3,975.00
Gutter and drainage system	50	LF	$ 5.00	$ 250.00	$ -	$ 250.00	
Site rehab	450	SF	$ 3.00	$ 1,350.00	$ -	$ 1,350.00	
					1 X Shelter	$ 34,175.93	$ 13,150.93
					2 X Shelter	$ 68,351.86	$ 26,301.86
16 X 6' Wood Slat Bench							
Unit cost, installed	16	units	$ 1,000.00	$ 16,000.00	$ -		$ 16,000.00
4 X Wood Picnic Table							
Unit cost, installed	4	units	$ 1,200.00	$ 4,800.00	$ -		$ 4,800.00
						Glazed Roof	Steel Roof
					Jan 2008 Vancouver Total	$ 89,151.86	$ 47,101.86
					Inflation Adjustment	*(1.02)^6.25	
					April 2014 Vancouver Total	$ 100,897.75	$ 53,307.60
					20% Contingency	*1.2	
					Final Total	**$ 121,077.30**	**$ 63,969.12**