UBC Social Ecological Economic Development Studies (SEEDS) Student Report

UBC Botanical Garden Redevelopment Proposal

Christopher Young, Daniel Tse, Eduardo Fujiwara Ceravolo, Noppanat Rangsimahariwong, Terilyn Brito, Terrence Tang

University of British Columbia

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Christopher Young
Terilyn Brito
Terrence Tang
Daniel Tse
Eduardo Fujiwara Ceravolo
Noppanat Rangsimahariwong

Group 9
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Executive Summary

The Botanical Garden at the University of British Columbia is a display, research, and conservation collection of over 7000 temperate-climate vascular plants. It is currently located in the SW quadrant of the Vancouver campus: along SW Marine Drive, bounded approximately by 16^{th} Avenue and Stadium Road. It is comprised of the Asian Garden and North Garden. One primary issue faced by the UBC Botanical Garden and other gardens is the challenge of staying relevant. This redevelopment plan aims to give new meaning to what 'Botanical Garden' are and why they exist. This proposal is for preliminary design of engineering works. It contains elements from hydrotechnical, structural, and transportation engineering disciplines while addressing three main concerns:

Concern 1: Inefficient water management practices for public displays and irrigation;
Concern 2: A lack of community engagement, cohesiveness, and interest; and
Concern 3: Inadequate vehicle parking capacity and inefficient visitor movement patterns.

To address these concerns, eight proposal components have been developed. A brief description of the proposal component is given below. Estimated costs include materials and labour, exclude design and engineering fees (35%) and contingency fees (15%), and are rounded for clarity.

Proposal Component	Concern	Remediation Measures	Total Costs (2013 CAD$)
Smart Irrigation System	1	Conservation of water by means of real-time monitoring of atmospheric and soil conditions	$ 27,000.00
Bio-Filtration Channel	1, 2	Methods to treat stormwater runoff to remove heavy metals; opportunities to showcase the phytoremediating properties of common and exotic plants	$ 6,000.00
Water Retention System	1	Retention of winter rainfall for use during summer months; reduce peak flows in stormwater runoff leaving UBC campus	$ 66,000.00
Greenhouse and Café	2	Provision of a year-round, indoor facility for visitors; create meeting places for students, professors, and the general public	$ 760,000.00
Parking Lot	2, 3	Improved visitor vehicle capacity; incorporation of a green roof design on the parkade to generate discussion on the sustainability of transportation	$ 400,000.00
Parkade			$ 14,000,000.00
Overhead Walkway	2, 3	Improved visitor movement patterns across SW Marine Drive; unique architecture and public visibility of the Walkway to engage and interest the general public	$ 920,000.00
Value Added	2	Increased profile and visibility of the garden through family- and public-oriented facilities and amenities such as picnic areas, improved signage, and beautification measures	$ 51,000.00

An implementation plan which rationalizes capital costs against visitation rates and public perception on a timeline with four development phases is given in the table below.

Phase	Proposal Component	Timeline	Goal
I	Value Added Parking Lot	1 – 2 years	Short-term feasibility and increased visitation rates
II	Bio-Filtration Channel Greenhouse and Café	3 – 4 years	Development of public attractions and infrastructure
III	Smart Irrigation System Water Retention System	5 – 6 years	Improved water management through functional upgrades
IV	Parkade Overhead Walkway	7 – 10 years	Long term planning for future campus development

1.0 Introduction

1.1 Purpose and Scope

The Botanical Garden at the University of British Columbia serves a unique function for the University. Not only is the garden a display collection of vascular plants, it is a research base and conservation means. The historical funding and development of Botanical Garden has translated in a largely "inward looking" focus. One primary issue faced by many gardens is the challenge of staying relevant. Hence, this redevelopment plan aims to give new meaning to what Botanical Garden are and why they exist.

This proposal is for preliminary design of engineering works. The site extents considered in this proposal fall along the area surrounding the corridor along SW Marine Drive bounded by 16th Avenue and Stadium Road. It includes the existing Garden parking lot and entrance, the Carolinian Forest, existing amphitheatre, Great Lawn and Cattail Marsh, and various areas within the Asian Garden and North Garden. However, the southernmost extents of the Asian Garden (Greenheart Canopy Walkway) and the BC Native Garden are not considered in this proposal.

While this proposal redefines the popular perception and visibility of the Garden, it makes all attempts to integrate the Garden's existing mission into design:

> *The mission of the Garden is to assemble, curate and maintain a documented collection of temperate plants for the purposes of research, conservation, education, community outreach and public display.*

1.2 Concept Specifications

This proposal contains aspects from hydrotechnical, structural, and transportation engineering. It seeks to address three main concerns:

Concern 1: Inefficient water management practices for public displays and irrigation;
Concern 2: A lack of community engagement, cohesiveness, and interest; and
Concern 3: Inadequate vehicle parking capacity and inefficient visitor movement patterns.

To address these concerns, seven proposal components have been developed. Table 1 outlines how each proposal component addresses these concerns.

Table 1: Proposal Components and Remediation Measures

Proposal Component	Concern	Remediation Measures
Smart Irrigation System	1	Conservation of water by means of real-time monitoring of atmospheric and soil conditions
Bio-Filtration Channel	1, 2	Methods to treat stormwater runoff to remove heavy metals; opportunities to showcase the phytoremediating properties of common and exotic plants
Water Retention System	1	Retention of winter rainfall for use during summer months; reduce peak flows in stormwater runoff leaving UBC campus
Greenhouse and Café	2	Provision of a year-round, indoor facility for visitors; creates meeting places for students, professors, and the general public
Parking Lot	2, 3	Improved visitor vehicle capacity; incorporation of a green roof design on the parkade to generate discussion on the sustainability of transportation
Parkade		
Overhead Walkway	2, 3	Improved visitor movement patterns across SW Marine Drive; unique architecture and public visibility of the Walkway to engage and interest the general public
Value Added	2	Increased profile and visibility of the Garden through family- and public-oriented facilities and amenities such as picnic areas, improved signage, and beautification measures

1.3 Proposal Components

This proposal contains the following components:

- Preliminary designs complete with supporting details such as drawings, sketches, and estimated costs;
- An implementation plan which rationalizes capital costs against visitation rates and public perception for several predicted development phases. In other words, the implementation plan valuates components of the proposal against each other in terms of economy and feasibility; and
- Key points of the implementation plan are given as recommendations.

Due to space constraints, certain details and calculation are not included in this report. They are available upon request, should further details be desired.

2.0 Water Management

UBC is “committed to innovation and action that keeps the University at the forefront of best practices in sustainability” (UBC Sustainability, 2011, p.2) through teaching, research, and operations that promote the vision of using the campus as a living laboratory (UBC Board of Governors [BOG], 2010). As our team works towards developing a rainwater and stormwater management plan that satisfies the needs of the UBC Botanical Garden, it must be understood that stormwater management practices and techniques must account for the hydrogeology of the UBC campus and concerns regarding erosion of the cliffs located on the periphery of the Pacific Spirit Regional Park. The UBC Water Action Plan describes the actions, strategies, and targets required to achieve a closed loop water system at UBC, and delineates five focal priorities: rainwater harvesting, efficient landscape irrigation, reduced water use and wastewater generation, water use management in building operations, as well as education and engagement (UBC Sustainability, 2013). Climatologists estimate that over the next 30 years, climate change will likely affect the timing and frequency of precipitation events and resulting stormwater flow patterns (UBC BOG, 2010). Therefore, any design implementations must be regularly evaluated and updated as necessary with respect to new risks. In accordance with Policy 39 of the Vancouver Campus Plan, our focus with respect to stormwater management for the garden is to develop strategies and an action plan that utilizes a natural systems approach with respect to managing runoff and minimizing adverse impacts downstream by minimizing stormwater flow outside of the UBC boundaries (UBC BOG, 2010). Our proposed plan is to implement a stormwater retention facility and re-use this water for irrigating the Botanical Garden using a Smart Irrigation System coupled with micro-irrigation sprinklers.

2.1 Water Consumption in the UBC Botanical Garden

One of the primary reasons for implementing a Smart Irrigation System with micro-irrigation sprinklers and for re-using stormwater runoff is to reduce the consumption of potable water in the Botanical Garden, providing both environmental and economic benefits. Currently, all of the water that is used for the water features, ponds, irrigation, toilets, sinks, and taps within the Botanical Garden, is acquired from the Capilano Reservoir (Justice, 2013). UBC purchases water from Metro Vancouver and redistributes it to the final consumers across campus. In 2013, the peak season (June 1 to September 30) and off-season (October 1 to May 31), water rates for UBC were \$1.6101/m^3 and \$1.2876/m^3 respectively for potable water (UEL Administration, 2013). Table 2, below, has been adapted from a UBC Social Ecological Economic Development Studies (SEEDS) Student Report and portrays the consumption of water in the UBC Botanical Garden for irrigation purposes in 2011. The demand reached a maximum value of 123.6 m^3 on August 23, 2011 (Shen & Wong, 2013). The final column of this table has been added, and cost figures are based on 2013 water rate figures. For time periods that span the peak-season and off-season (ie. 2011-May-20 to 2011-Jun-21 and 2011-Sept-16 to 2011-Oct-24), it was assumed that half of the total water consumed for that given time period was consumed in the peak-season and off-season respectively to determine an approximate cost figure.

Table 2: Water Consumption for Irrigation Purposes at the UBC Botanical Garden in 2011

Date	Meter Reading (m^3)	Monthly Demand (m^3)	Cost ($)
2011-Apr-21	100	-	
2011-May-20	550	450	$579.42
2011-Jun-21	3003	2453	$3,554.03
2011-Jul-21	5840	2837	$4,567.85
2011-Aug-22	9180	3340	$5,377.73
2011-Sept-16	12270	3090	$4,975.21
2011-Oct-24	13785	1515	$2,195.01
2011-Nov-21	14005	220	$283.27
2011-Dec-21	14005	0	-
2012-Jan-24	14005	0	-
CUMULATIVE DEMAND AND COST		13905	$21,532.53

Off-Season Rate ($/m3)	Peak-Season Rate ($/m3)
1.2876	**1.6101**

(Shen & Wong, 2013)

2.2 Contaminants in Stormwater

Inherently, as stormwater flows overland across roads, it acquires contaminants such as suspended solids, organic materials, ions, and heavy metals. The following table (Table 3) shows a list of heavy metals, their source, and their range of concentrations in the stormwater in the Trail 7 outfall, measured in February – March, 2005.

Table 3: Heavy Metal Contaminants Found in Stormwater in the Trail 7 Outfall at UBC.

Metal	Source	Concentration Range (mg/L)
Aluminum	Engine brake wear, vehicle components	0.05 – 0.2
Arsenic	Herbicides, road salts	0.001 – 0.008
Cadmium	Phosphate fertilizers	0.00008 – 0.00012
Copper	Brake linings	0.125 – 0.2
Iron		0.25 – 0.45
Lead	Oil additives, brake wear	0 – 0.0005
Mercury		0 – 0.0001
Zinc	Motor oil, grease	0.01 – 0.02

(Fowler, Robinson, & Phillips, 2005)

Before re-using this water for irrigation purposes and to prevent redistributing these contaminants throughout the garden, the stormwater will be pumped from the stormwater retention facility and filtered in one of two ways. The water required for irrigating the garden on the east side of SW-Marine Drive will be filtered biologically using a bio-filtration channel in the North Garden, while the water required for irrigating the Asian Garden west of SW-Marine Drive will be filtered using a centrifugal separator. While both of these methods provide exceptional filtration, it also presents an opportunity for researchers and students to compare the filtration capabilities of the bio-filtration channel to mechanical separation methods.

The following sections will outline our proposed design elements with respect to re-using captured stormwater for irrigation purposes within the Botanical Garden. These elements include installing a Bio-Filtration Channel for filtering stormwater, installing a micro-irrigation system, and coupling this system with a Smart Irrigation System for optimal water use efficiency and to enhance savings in annual expenses.

2.3 Bio-Filtration Channel

As required for irrigation in the garden on the east side of SW-Marine Drive, stormwater from the retention reservoir will be pumped up to a bio-filtration channel, the proposed location of which is in the same location as the current cattail marsh. Wetlands are capable of removing high concentrations of particulates, dissolved contaminants, sediment, nutrients, heavy metals, toxic materials, floatable materials, oil and grease, while reducing the chemical oxygen demand through filtration, settling, and biological processes of wetland plants and bacteria (VCSQMP, 2001). Wetlands are very efficient at managing intermittent periods of light and heavy influent flows such as stormwater runoff (Hoban, 2002). As water flows through the wetland, waste material is strained out by submerged plants, plant stems, roots, leaves, and plant litter, upon which waste-consuming bacteria also becomes attached. The plants serve to filter waste, control flow rates, and provide surface area for bacteria and treatment to occur. Additionally, surface plants and emergent plants shade the water surface and help to control algae growth within the wetland. The bacteria are able to consume waste material and produce methane, carbon dioxide, and new cellular material that can subsequently be used by plants and other bacteria. The required hydraulic retention time of the wastewater in the wetland depends on the strength of the influent, the specified permissible treatment level, as well as climatic factors (temperature, evapotranspiration rates, precipitation, etc). Generally, biological treatment occurs more rapidly in warmer temperatures. Thus the size of the system is governed by that which is required in order to retain the stormwater for the longer retention times during the winter months (Hoban, 2002).

The proposed design will involve creating a combined pond-wetland system with distinct depth zones within the wetland shallow marsh area in order to enable the growth of wetland vegetation. The wetland is filled with a relatively impermeable compacted clay or bentonite soil or lined with an impermeable synthetic liner to reduce loss of water percolating into the soil below. Soil is placed on top of this liner in order to enable the growth of vegetation. The bed of the wetland is generally relatively smooth with no large protruding bumps or ridges, and has a minimal slope of approximately 0.5% to promote the flow of water through the wetland towards the micro-pool outlet (Hoban, 2002). The side slopes should be no steeper than 5:1 and the embankment side slopes near the outlet should be less than 3:1. The length to width ratio should be between 3:1 and 4:1 in order to prevent short-circuiting (flow velocity higher than desired) or having dead areas within the wetland (VCSQMP, 2001). The current cattail marsh has an average length to width ratio of approximately 7:1. Douglas Justice noted that the Botanical Garden would not like to change the overall size of the marsh. We have taken this into consideration in our design.

The pond (forebay) serves as a retention area that allows for settling and trapping suspended sediment, removing over half of the total suspended solids and a portion of the BOD from the influent, while also reducing the inflow velocity of water into the shallow marsh. In addition, the pond dilutes chlorides from stormwater runoff that enter the system which can potentially inhibit the diversity of vegetation within the system. Douglas Justice and Patrick Lewis note that the bed of the marsh currently fills in with silt and organic matter relatively quickly, requiring dredging every 2-3 years. The forebay and micro-pool at the outlet of the wetland are the only relatively deep bodies. These zones are typically between 1.5 to 6 feet in depth, and thus can sustain submerged and floating species, but few emergent species. The forebay bed is relatively level such that that the flow into the wetland will be distributed evenly across the width. It has a berm at the downstream end with a baffle structure to restrict the flow into the wetland. The outlet micro pool is typically maintained at a depth of 4 – 6 feet and allows for increased hydraulic retention time. A drain with a low flow outlet valve is placed at the downstream end of the micro-pool to release water from the wetland if required. This orifice is protected with a trash guard made of mesh wire that extends 6 inches below the normal pool water level (South Carolina DHEC, 2005). The forebay and micro-pool should comprise 25-50% of the total wetland area (VCSQMP, 2001). An optional addition is to have a return-flow pipe that enables water to be re-circulated through all or a portion of the wetland for a higher level of treatment.

The varying depth zones within the proposed wetland will optimize the pollutant removal efficiency, while promoting diversity in the flora, and preventing dominant plant species, such as cattails from flourishing in the wetland. It was noted that the garden's current marshland is significantly dominated by cattails. The two principal depth zones are the "deep-water zone" comprised of the forebay and the outlet micro-pool, and the "shallow-water zone" comprised of the high marsh and low marsh areas. The depth within the "shallow-water zone" ranges from approximately 0 – 18 inches, which supports the growth of a high density of emergent wetland plant species. The bed of the wetland in this region will be relatively level in the transverse direction, which will maintain sheet flow at a desired velocity (South Carolina DHEC, 2005).

In accordance with these aforementioned constructed wetland design specifications, the proposed wetland will have the following characteristics shown in Table 4 below. Information regarding the depths of each sub-zone is readily available upon request. Below Table 4, Figure 1 shows a conceptual 3D model of the proposed design. Additionally, the length of the wetland section itself was reduced to approximately 40.1m, with an average width of 10m, resulting in an average length to width ratio of 4:1. The flow path of water within the wetland is controlled by using internal berms and shelves, as well as baffles between each of the three key regions. This helps control the flow between each zone, promote sheet flow, prevent short-circuiting, and maintain the required hydraulic retention time within the wetland. The overall slope within the wetland is fixed at approximately 0.5% and lined with an impervious synthetic liner to eliminate infiltration into the well-drained till and sand below. The total surface area and volume of the entire system are 862.74 m^2 and 449.83 m^3 respectively. Note that the total volume of the outlet micro-pool (157.71 m^3) is 3.4 times the peak one-day water demand for the garden on the west side of SW-Marine and 1.4 times the peak one-day water demand for the entire Botanical Garden.

Table 4: Description of Total Surface Area and Volume for Each Major Zone Within the Bio-Filtration Channel

Zone	Average Depth (m)	Surface Area (m^2)	Volume (m^3)
Deep Pool	0.9	202.98	183.19
Wetland	0.3	389.87	108.93
Outlet Micro-Pool	0.6	269.88	157.71

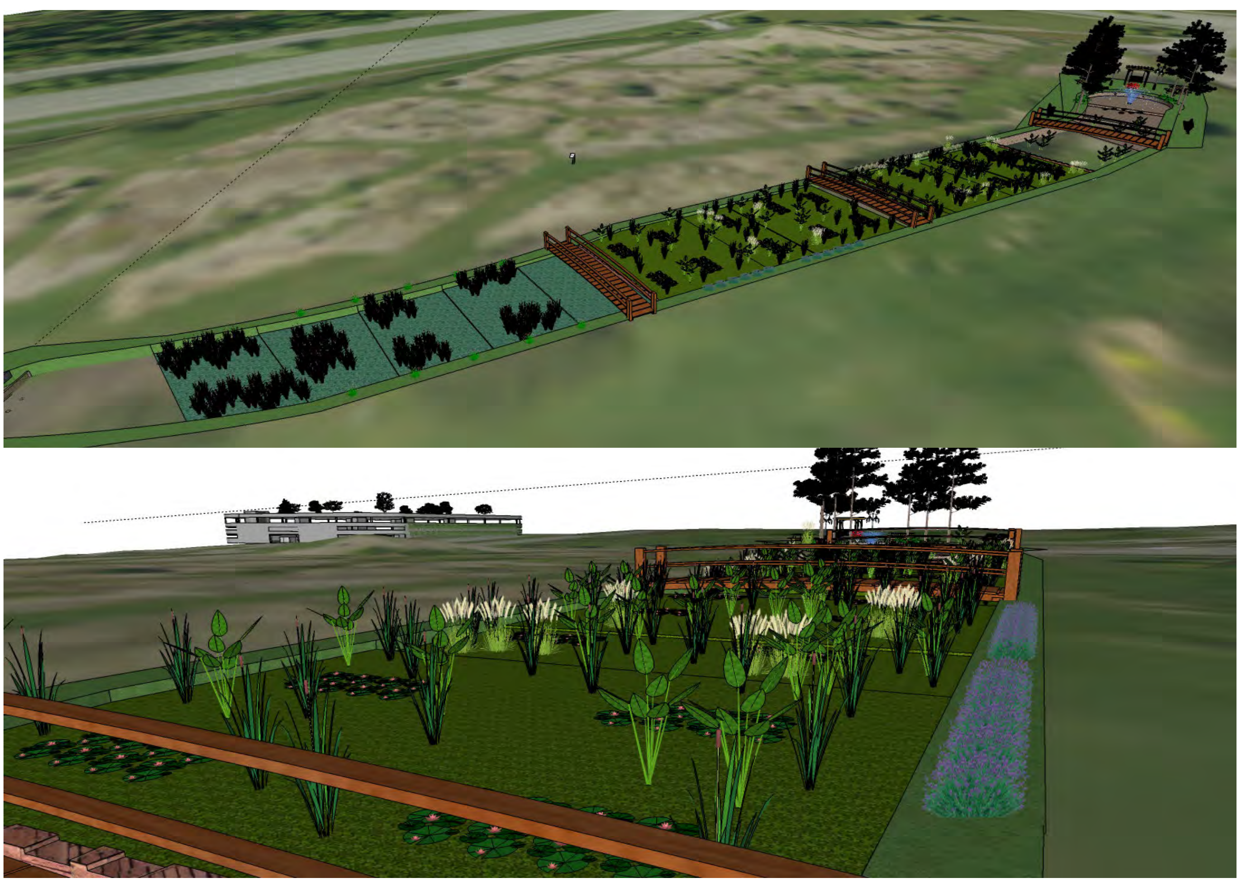


Figure 1: Bio-Filtration Channel (top and side views)

Some suggestions of plant species to include in the Bio-Filtration Channel are shown in Table 5 below:

Table 5: Suggested Wetland Plant Species for the Bio-Filtration Channel.

Always Underwater	Frequently Inundated (can survive wet/ & dry soils)		Upland Plants (well-drained soils)
Arrowhead	Smartweed	Creeping Wild Rye	Oaks
Phragmites	Spikerush	Cord Grass	Spruce
Pickle Weed	Pickerel Weed	Switch Grass	Alpine Grass
Cattail	Tules	Reed Canarygrass	Bluejoint
	Common Reed	Barnyard Grass	Timothy
	Rush	Maple	Ryegrass
	Sedges	Poplars	Creeping Bentgrass
	Alkali Bulrush	Willows	

[1](VCSQMP, 2001) [2](Center for Watershed Protection, 2013)

2.3.1 Bio-Filtration Channel Maintenance

It is important to assess the erosion, flow channelling, and sediment accumulation/dispersion immediately following all storm events that produce more than 2 inches of rainfall. A "sediment cleanout stake" is installed in the forebay to help monitor sediment accumulation and determine when dredging is necessary. Sediment from the forebay should not exceed 50% of the pool's initial volume. Likewise, sediment that accumulates in the permanent pool should be removed when it exceeds 25% of the pool's volume. This typically occurs every five to ten years, depending on the efficiency of the structures limiting sediment flow into the pool. In order for the wetland to preserve its optimal operation efficiency, the depths of the various zones within the wetland must be properly maintained. Especially during high flow seasons, it is important to clean debris from the inlet and outlet structures and orifices regularly. Likewise, the vegetation must be monitored regularly, and invasive/dominating species should be contained as much as possible to promote diversity within the wetland while maintaining a minimum of 50% surface area coverage. Embankment side slopes should be mowed frequently and also inspected for undercutting and erosion. If plants are becoming inundated with sediment, it is preferable to remove these plants to reduce further accumulation of sediment and organic matter in the bed of the wetland (South Carolina DHEC, 2005). The main wetland area should be cleaned over two growing seasons: clean one half of the basin in one growing season, and the second half during the subsequent growing season. This practice will minimize the impact on the wetland (VCSQMP, 2001). It should be noted that the plants will accumulate high concentrations of metals, nutrients, and other toxic pollutants from the stormwater, and therefore must be harvested and disposed of accordingly to prevent re-contaminating the water (Hoban, 2002).

2.3.2 Bio-Filtration Channel Conceptual Construction Cost Estimate

Please refer to Table 6 on the following page for a conceptual construction cost estimate for materials and labor for the constructed wetland described above with a surface area of 863m^2 (0.0863 ha) and total excavated volume of 450 m^3 (588.58 yd^3) using RS Means data from Utah (statewide) in 2009. Note that a location adjustment factor of (106.6/83.2 = 1.28125) (Brightwell, 2011) and a time index factor of (9666.46/8570 = 1.1279) to adjust from 2009 to 2013 is used. (ENR, 2013) To adjust to mid-2014, the 2013 average Canadian inflation rate of 0.94% is used (Triami Media BV, 2013). It is assumed that the soil is in "normal condition", and excavated material is deposited as spoil.

Table 6: Conceptual Cost Estimate for the Construction of the Bio-Filtration Channel

Cost Item	Description	Unit Price (Include O & P)	Total Cost
Equipment/Installation[1]	Scraper – Common Earth Excavation, Bulk Scraper, 1500 ft haul	2.79/ yd^3	$1642.14
Labor[1]	Scraper Operator	$0.87/$yd^3$	$512.06
Mobilization[1]	6% of installation costs	$0.22/$yd^3$	$129.49
Operation & Maintenance (Annual)[1]		$0.18/$yd^3$	$105.94
Total Construction Cost			$2283.69
Construction Cost Adjusted for time and location			$3331.36
Vegetation Establishment[2]	18 species and cover crop (seeds)	$1, 914/ ha	$165.18
Total Construction and Vegetation Establishment Cost			$3496.54
Total Annual Operation & Maintenance Cost Adjusted for Time and Location			$154.54

[1](USDA NRCS, 2012) [2] (Kadlec & Wallace, 2009)

2.4 Meeting Irrigation Demands in the UBC Botanical Garden with Captured Stormwater

In order to replace the potable water source with that from the proposed stormwater retention facility, the pump installed in this facility must be able to meet the peak garden demands for irrigation; approximately 125 m^3/day in accordance to Table 2 above (excluding the Native Garden which is currently connected to a separate municipal source). Approximately 70% of this demand is required for the Asian Garden, while the remaining 30% is consumed on the east side of SW-Marine Drive (Justice, D., personal communication, October 25, 2013). The proposed irrigation system is capable of reducing this demand by 30-50%, and therefore to be conservative, we assumed a reduction in peak demand of 25%. Assuming the Native Garden is approximately 4500 m^2 in area, and that 75% of this area (3375 m^2) is irrigated at a peak rate of 5cm/week, the peak flow required for this area is an additional 24.1 m^3/day. Therefore, the required peak flow rates for the east and west sides of the garden, assuming irrigation is only done during the evenings on a 12-hour cycle, are 16.8 GPM and 23.8 GPM respectively.

An example of a pump system capable of meeting these demands is described herein. The system will be composed of a 2 HP (230V) 4" Berkeley submersible pump (MS Stainless steel series pump with a Pentek XE Series motor), capable of providing up to 50 GPM (Pentair Ltd., 2013). This pump will be installed directly into the stormwater retention facility with a self-cleaning LAKOS PC screen to keep debris away from the intake structure and prolong the life of the pump. (Claude Laval Corporation [CLC], 2013) A Pentek Intellidrive Constant Pressure Controller will also be installed on the ground level to adjust the motor speed to meet fluctuating water demands and maintain constant pressure in the system (Penatair, 2013b). The mainline carrying water to the Asian Garden will have a LAKOS ILB-ILS Separator installed, which is capable of removing up to 98% of the sand, grit, and other fine solids down to 74 microns in size. It is a centrifugal separator with no moving parts or filter elements to replace. A pressure loss of 5-12 psi can be expected with this unit (CLC, 2013). The power cost associated with operating these components of the overall system, based on 2013 BC-Hydro Residential rates, is approximately $138.00 for the critical 16-week irrigation period. There is a power source available for this pump at the proposed location for the stormwater retention facility. Please refer to Table 7 for an outline of the principal costs associated with this pump system.

Table 7: Cost of Pump System for the Stormwater Retention Facility

Item	Cost
4" MS Stainless Steel Series Submersible Pump (2HP) Pump End[1]	$1, 171.00
Pentek XE Series Motor[1]	$782.00
Motor Control Box[1]	$213.00
Pentek Intellidrive Constant Pressure Controller[1]	$1, 721.00
LAKOS PC Screen[2]	$2,270.00
LAKOS ILB-ILS Separator[2]	$1,151.50
TOTAL COST	$7,308.50

[1] (Pentair, 2013) [2] (CLC, 2013)

As mentioned earlier, the irrigating water for the garden on the west side of SW-Marine Drive will be taken directly from the stormwater retention facility and filtered using an ILB-ILS Separator. A suggested system for meeting the irrigating demands of the garden on the East side of SW-Marine Drive includes a Berkeley ¾ HP (230V) 4" submersible pump end (MS+ stainless steel series) with a Pentek XE series motor and CSCR control box (Pentair Ltd., 2013). This pump will be installed with a Pentek Intellidrive Constant Pressure Controller to adjust the motor speed of the pump and meet fluctuating water demands throughout the garden while maintaining constant pressure (Pentair, 2013b). This pump end has a maximum capacity of 20 GPM, which exceeds the 16.8 GPM peak required flow rate for the entire North Garden and Native Garden. It will take water from the outlet micro-pool of the bio-filtration channel. The total cost of power for operating this unit through the critical 16-week irrigating period will be approximately $51.86, based on BC-Hydro's current residential rate of 6.90 cents/kWh. The cost of this pump system is shown in Table 8 below.

Table 8: Cost of Pump System for Bio-Filtration

Item	Cost
4" MS+ Stainless Steel Series Submersible Pump (3/4HP) Pump End, PENTEK Motor, CSCR Control Box	$1, 203.00
Pentek Intellidrive Constant Pressure Controller	$1, 721.00
TOTAL COST	$2,924.00

(Pentair, 2013)

2.5 Micro-Irrigation System

While visiting the garden and discussing the inefficiencies of the current irrigation system with Andy Hill, he noted that many of the visitors to the garden note the negative aesthetic effects of the current irrigation system. Visitors feel that the visible sprinklers take away from the visual appeal of the garden. Therefore, our team has investigated the use of discreet micro-irrigation sprinklers. Using a micro-irrigation system alone can reduce water consumption by 25 – 50% due to reduced runoff during cool periods and reduced losses due to evaporation during warm periods. The proposed system uses primarily spinner-type sprinklers, although drip-irrigation could also be used where appropriate. Mr. Justice expressed little interest in the idea of using drip-irrigation due to the fact that the well-drained soils within the garden would not allow the water to spread laterally and the root-zone between the emitters would not be effectively watered. However, it should be noted that the following system will allow for the integration of drip-irrigation and for the use of other sprinkler types (ie. misters, micro-jet, and/or traditional overhead sprinklers) as well. There are a number of manufacturers that have developed many variations of micro-sprinklers. The following table outlines one company's alternatives of spray and rotator type sprinklers for the irrigation system for the Botanical Garden.

Table 9: Available Pivot-Type Spinner Sprinklers from Nelson Irrigation Corporation

Sprinkler Type	Mounting	Operating Range (psi)	Throw (m)	Spacing (m)
Orbitor (High Uniformity)	Drops	10 – 20	10 – 18	3.35 – 6.10
Spinner (Gentle Application)	Drops	10 – 20	9 – 17	3.35 – 5.79
Accelerator (In-Canopy)	Top/Drops	6 – 15	<17.7	3.35
Sprayhead (In-Canopy)	Drops	6 – 40	2 – 20	3.35
Trashbuster (Open Body)	Top/Drops	*Depends on nozzle		
Part Circle R3000		15 – 30		
Part Circle S3000		10 – 20		
Part Circle D3000		10 – 20		

(NIC, 2013)

The sprinkler in the table above that we would like to draw your attention towards is the "T3000 Trashbuster", which was developed with an open-body design specifically for land application of wastewater. The 3000 FC nozzle, used in conjunction with this sprinkler type, has a built-in flow control that regulates the pressure at the nozzle and also allows debris to pass through with relative ease (NIC, 2013). Each sprinkler is composed of 5 components: a cap, plate, body, nozzle, and adaptor. A number of different plates are available for these rotator sprinkler types, which allow the user to alter the spray pattern of the sprinklers to suit different plant types, topographies, or purposes (germination, irrigation, or chemigation). Different nozzles are available for all of these sprinklers as well, which will allow for different ranges of flow rates (0.34 – 31.10 GPM) at specified pressure values between 6 psi and 50 psi. The 3TN nozzles are interchangeable with all 3000 series sprinklers and the nozzles are color-coded for easy identification in the field. This allows the operator to meet changing demands for flow rate throughout the garden quickly and easily (NIC, 2013).

The number of sprinklers that would be required can be estimated through data acquired for the water demand in the garden in 2011 (previously shown in Table 2). Mr. Justice estimated that the garden applies approximately 5cm/week during the peak weeks in the summer. During the August peak water demand for the garden (3340 m^2), flows average 754 m^3/week. Therefore, the actual irrigated area receiving 5cm/week is approximately 15,078 m^2, in addition to the Native Garden (4500 m^2). Therefore, the total irrigated area requiring this peak flow can be estimated to be around 20,000 m^2. Understanding that the sprinklers must overlap 150% for uniform application and the specified spacing given above in Table 9 is head-to-head spacing, each sprinkler can cover an area of 11.2 m^2 to 37.2 m^2. Assuming that sprinklers and plates will be selected to achieve maximum throw and optimal uniformity, we will conclude that maximum spacing throughout the garden can be achieved, and thus each sprinkler will cover an area of approximately 37.2 m^2. Therefore, approximately 550 sprinklers will be required throughout the garden.

Each sprinkler will require a feed-tube assembly to connect the sprinkler adapter to the 3/4 inch or 1 inch riser. It is estimated that there are approximately 350 risers currently in the garden and that these can be re-used. It is likely that a PVC stake adapter, one barb and an additional 3 feet of flexible PVC feed-tube per sprinkler will be required for each of these. The remaining 200 risers to be installed will require a feed-tube assembly with a ¾ " stake, PVC stake adapter, and tubing with a barb adapter, at a unit cost of approximately $5.11 each. (NIC, 2012) Given that our system will re-use stormwater for irrigation purposes, we would recommend the use of the T3000 Trashbuster Sprinkler, coupled with a R3000 rotator cap/motor and a 3000FC Nozzle (which eliminates the need for the additional pressure regulator at the sprinkler). The total costs associated with the chief components of the proposed micro-irrigation system described in this section are outlined in Table 10 below.

Table 10: Principal Material Costs for Micro-Irrigation System

Item	Number	Cost Per Unit	Total Cost
T3000 Trashbuster Sprinkler	550	$32.38	$17,809.00
PVC Stake Adapter and Barb	350	$2.00	$700.00
10mm Flexible PVC Feed-tube	1000 feet	$160/500 feet	$320.00
Feedtube Assembly	200	$5.11	$1022.00
TOTAL COST			$19,851.00

(NIC, 2012)

2.6 Smart Irrigation Systems

Currently the irrigation requirements of the Botanical Garden are monitored manually and the garden is irrigated on a pre-determined schedule, primarily using overhead irrigation systems. This system is highly inefficient for several reasons. Foremost, the pre-determined irrigation zones and schedule does not account for many hydrologic factors, individual plant and soil requirements, or terrain. Nor does it adjust the irrigation pattern in response to these factors. Overhead nozzle irrigation systems are largely inefficient as the water that is delivered under pressure elevates the air humidity increasing losses due to evaporation, while also decreasing leaf transpiration and limiting root growth (Lasat, n.d.). Furthermore, the Botanical Garden currently spends about $1500 per year to manually operate the current irrigation system for the critical 16-week irrigation period (based on estimates of labor hours given by Andy Hill).

Our team recommends installing a recent innovative development in sustainable irrigation practice, referred to as a *smart irrigation system*. These systems are currently being used worldwide for agricultural, industrial, commercial, and residential applications. Measuring systems are installed that monitor evapotranspiration, soil moisture, heat/chill monitoring, frost prediction, wind speed and direction, solar radiation, relative humidity, and temperature (soil and ambient air). Subsequently, this data is available as input to crop management models, as well as for assisting in integrated pest management, disease prediction, growing degree days, and frost forecasting. Wind speed and direction is also used for irrigation monitoring as well as for planning fungicide, pesticide, and fertilizer applications. The evapotranspiration monitoring stations estimate plant water requirements by calculating ET_o (potential evapotranspiration of a given crop, in mm/day) using the Penman-Monteith equation (IEI, 2013). This equation accounts for net solar radiation received at the crop's surface, the soil heat flux density, mean temperature, relative humidity, saturation vapor pressure deficit, specific heat, and atmospheric pressure, and wind speed (Chieng, 2013). The system also utilizes soil moisture sensors that provide additional useful information for irrigation monitoring systems. A box would be installed in the garden containing a microprocessor and antenna that receives local real-time weather information from satellites. The system then adjusts the irrigation schedule accordingly and predicts approximately when the irrigation cycle will need to begin again based on this weather forecast data input.

A wireless computer receives data from soil moisture and temperature sensors at regular intervals and determines which irrigation zones require water, based on pre-determined threshold values that account for plant growth stages and seasonal temperature fluctuations. At the end of the irrigation time window, the soil sensors determine whether the irrigation run time must be increased or decreased in order to reach the desired soil moisture level during the following irrigation cycle. This saves time for the garden operating staff by no longer having to manually adjust the irrigation system in response to weather and seasonal temperature fluctuations. It also leads to improved plant health, meaning that they are less susceptible to diseases and pests. Also, leaching of fertilizers into the groundwater is minimized as over-watering will never occur (PlantCare, 2013). The system can be customized according to different types of plants and their specific water requirements (Chen, 2011). These systems account for such factors as soil type, terrain, plant types, and sun exposure and can reduce water consumption by 30 – 50 % (KORE, 2013).

The price for the smart irrigation system itself depends on the number and variety of sensors, the complexity of the system, and the number of irrigating zones/stations, among other factors as well. Mr. Hill has estimated that the current number of irrigation zones in the garden is around 57. However, given that the high flow demand and pressure requirements of the current overhead sprinklers restrict the size of the current zones, several of these current zones could likely be combined to reduce the overall number of zones with a micro-irrigation system with lower flow and pressure requirements. Given that the aforementioned sprinkler types all have interchangeable plates and nozzles to meet different watering needs, garden areas and/or specific plants with differing water requirements can be in the same zones and receive different volumes of water for the same irrigation period. For the Botanical Garden, a smart irrigation system will cost in the range of $1,000 to over $10,000, depending on the options selected. Some examples of systems and optional add-ons and systems available from one company are shown in the Table 11 below.

Table 11: Examples of Costs for Components of a Smart Irrigation System from Calsense

Component	Cost
Calsense 48 Station ET2000e Controller	$3,950.00
Calsense ET Gage + Controller Interface	$1810
Calsense Rain Gage + Controller Interface	$1010
Calsense Wind Gage + Controller Interface	$980
Calsense Soil Moisture Sensor	$199
Calsense 1-inch Brass Flow Meter	$575
Calsense 1.5" PVC Flow Meter	$490

(USBR, 2012)

Some systems have online water management services to allow the operator to control the system wirelessly from any PC, receive email alerts, and have online and phone customer service. These extra services typically require an annual fee that can range from $60 to over $200 per year. (USBR, 2012) For conceptual design purposes, we will assume that the Botanical Garden would like to begin with an intermediate system, and therefore take the average cost of $5,500.00 for the smart irrigation system (controller, sensors, gages, etc.) and an annual software/service fee of $100 per year.

2.7 Summary of Total Costs for Irrigation System

The total costs associated with the implementation of the entire proposed irrigation system (pumps, micro-irrigation system, and smart irrigation system) and operating costs (power for pumps, based on residential rates, and software/service fees) are tabulated below in Table 12. Considering that most of the current irrigation system (mainlines, risers, valves, etc) could be re-used and do not need to be replaced, a conservative estimate for the labor installation costs for this system are taken to be 5% of the total material implementation costs in addition to the rental of a rubber track mini-excavator. This assumes installation of the system takes one week. These values should be compared to the current expenses for potable water consumption ($21,500 per year) and labor expenses of $1500 per year. Therefore, the total costs outlined below will be recovered within 2 operating years.

Table 12: Total Cost of Implementing the Entire Proposed Irrigation System (Excluding Bio-Filtration Channel)

Component System Implementation Costs	**Cost**
Water Retention Facility Pump and Filtration Unit	$7,308.50
Bio-Filtration Channel Pump Unit	$2,924.00
Micro-Irrigation System	$19,851.00
Smart Irrigation System (estimate)	$5,500.00
TOTAL MATERIAL IMPLEMENTATION COST	$35,583.50
Installation Labor Costs (5% of material costs)	$1,779.18
Rubber Track Mini-Excavator Rental ($1000/week)[1]	$1,000
TOTAL MATERIAL AND LABOR IMPLENTATION COST	$38,362.68
Annual Operating Costs	
Water Retention Facility Pump (Power)	$138.31
Bio-Filtration Channel Pump (Power)	$51.86
Smart Irrigation System (Software/Service)	$100.00
TOTAL ANNUAL OPERATING COSTS	$290.17

[1](BobcatRental.ca, 2013)

In summary, the implementation of the bio-filtration channel, micro-irrigation system, and Smart Irrigation System will provide UBC and the Botanical Garden with a number of economic, environmental, and 'research and development' benefits. The bio-filtration channel, while requiring minimal capital investment, will serve as extra storage for stormwater, filter contaminants from this water, provide research opportunities for students and faculty with respect to hyperaccumulating plants, and provide an aesthetically pleasing anchor to attract people to this area of the garden. Reusing stormwater with the combined micro-irrigation and Smart Irrigation systems will reduce stormwater flow leaving the garden and optimize water use within the garden (thereby improving the health of the plants), while being more aesthetically pleasing to the garden's visitors. This system will significantly reduce potable water consumption within the garden, providing UBC with over $20,000 in savings each year, and also reduce the labor expenses associated with manually operating the current irrigation system, saving the UBC Botanical Garden over $1500 per year.

2.8 Water Retention

2.8.1 Geometry and Location

Providing a reservoir at the UBC Botanical Garden will facilitate appreciable benefits throughout variable seasonal demands. The current reliance on potable water at the garden may be significantly reduced if not completely negated by the implementation of a storage tank. Sized at approximately 6000 m^3, the reservoir will be located in the green space currently being considered for development just upslope of the moon gate exit into the east garden, which is adjacent to the storm sewer collection point, as shown in **Error! Not a valid bookmark self-reference.**. The proximity of this tank to the storm sewer tie-in will be an added convenience for intercepting flow that has potential for detrimental erosion of rock creek and the outfall at the western cliffs along the periphery of UBC.

Figure 2: Design and location of water tank

A cylindrical underground storage facility would be constructed with a radius of approximately 10-15m depending on root networks of the surrounding mature trees, which will remain in the region proposed for development. The facility will store water for irrigation in the summer and hold stormwater in the winter for gradual release to mitigate erosion concerns related to high flows. Capacity is provided which will protect against major storm events as well as drought events. The storage facility will be made of a high durability polymer rated for commercial storage use. Benefits of underground storage include the reduction in freezing concern, aesthetics, as well as maintaining the overland surface space for cover and other garden activities.

Regulated by bypass valves, the reservoir will accept flows above 200L/s while there is space in the reservoir. Inflow and outflow at the reservoir will be dependent on creek flow. In accordance with industry practice (Johnson, 2013) the reservoir will release flows at a value of 200L/s, approximately equal to a 2-year storm event. Analysis of historical flows and climate data resulted in the classification of flows and required storage design. This data is available upon request. The design volume will provide a synergy to the system by linking the dual purpose of operating in regulating discharge during periods of high flow and providing storage when water is scarce.

2.8.2 Sizing and Flow considerations

Analysis of reservoir sizing was done in order to appropriately mitigate issues related to seasonal extremes of wet and dry conditions. By regulating flows to a value roughly equal to the 2 year storm event, equivalent to approximately 200L/s, the velocities in the creek will be maintained at values averaging 60% lower than current storm values in winter months. This volume of reservoir will also be able to meet the campus plan goal of meeting current development standards with respect to maintaining 90% of flow volumes on site. This ability to vastly reduce flows and regulate a slow release of storm events will be highly beneficial in preventing erosion. For the UBC Botanical Garden, flows were calculated from historical climate and precipitation data as well as specific logger data for the creek which was part of a SEEDS water management study conducted between 2009 and 2011. While the data was useful in the determination of flows, discussions with the author of the report as well as Dr. Jim Atwater, who was the university faculty sponsor of this project, revealed that the data was not without uncertainty. Due to occasional flows above anticipated rates the installed v-notch weir experienced occasional overflow, which would result in underestimating peak flows. Potential for inaccuracies in measurements have been considered in the design of the reservoir system by applying correction factors to flows above the weir design capacity of 300L/s.

Following analysis of flows, it was determined that the constant flow through the reservoir would not require chlorination or remediation of settling concerns due to consistent flushing of the system.

Proposed tie in to the storm sewer system at the catchment-basin east of the moon-gate tunnel will allow easy access to the concentration point of flow, which will have an enormous impact on flow regulation. This storm sewer catch basin is currently a collection point for runoff throughout the watershed and feeds into rock creek. Following correspondence with UBC utilities, as well as UBC Plant the drainage information with respect to Thunderbird stadium was not yet determined to be under-drained or otherwise. This information is still pending from the utilities branch. If the field at Thunderbird stadium is not drained, the runoff potential will be considered and a proposed catchment facility may be recommended in order to route flows towards the stormwater network and reservoir.

2.8.3 High Flow

Regulating valves will allow for easy water capture and release. A bypass valve will be implemented on the upstream end, which will accept flows above the design value. The downstream control will release flows from the reservoir when the creek flow drops below the acceptable design threshold at a rate which will make up the difference. Reservoir sizing will be appropriate to accept flows up to a 72-hour 5-year storm event. Flows which are in excess of the system capacity will remain in the channel bypassing the reservoir. The attenuation of these extreme peaks will be appreciable, with the peak event of the approximate historical 10 year event being analyzed at a reduction of over 35%. This provision of storage for excess water volumes will decrease the impacts of erosion at the western cliffs near the outfall at trail head 7, currently of great concern.

The regulation of flows via retention and moderated release will have the benefit of preventing detrimental erosion over the western cliffs, which cause damage to the beach environments below the outfalls. In addition to the downstream erosion, flow regulation will have benefits within the garden by preventing overflow volumes that have caused damage to the creek bed and surrounding areas due to overflows and backwater events. Recent rainfall events have caused flooding in the western downstream side of the garden along lower Asian way. By reducing flows the impacts on this region will be attenuated, such that extreme culvert resizing will not be required. Current flows at high velocities through this region have caused debris to block the culvert system. By reducing flows, debris will be less likely to become dislodged and cause problems to this region. However, the culvert at the outlet near old southwest Marine Drive is still of moderate concern and modest remediation is required to increase operational efficiency. Current streambed re-grading is recommended along with the addition of a grate on the culvert to prevent the accumulation of material. Proposed re-grading will mitigate current site conditions, which have degraded due to inadequate management of stormwater. Several regions, for example the Lower Asian way culvert shown if Figure 3 below, are recommended for repair.

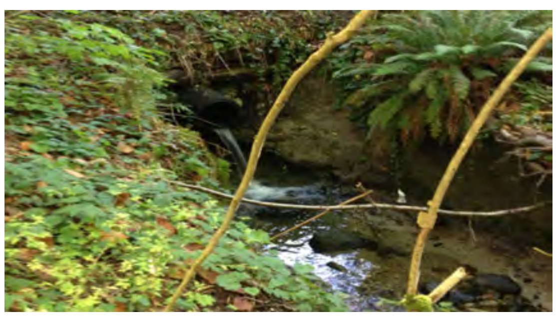


Figure 3: Asian Way Culvert

By capturing portions of the flow during storm events and releasing the water at a more moderate rate, flows in the system can be regulated in order to reduce extreme flows. With the proposed storage, up to a 35% decrease in peak flows during storm events will be observed along with an overall regulation of flows to mitigate frequent smaller storm events. Figure 4 on the following page shows a hydrograph comparing the impacts on recent flows before and after the implementation of the reservoir system. In this plot, the blue values, showing the original hydrograph, have much more extreme peaks which correspond to stormwater related downstream issues. The moderated red curve, showing the regulated hydrograph, reveals how implementing the reservoir system would decrease peaks drastically, while still maintaining average release and keeping a more consistent flow rate in the channel.

Additional environmental benefits are seen through the decrease in reliance on potable water due to the reduced draw from the Capilano and Seymour reservoirs, which currently feed UBC, including the Botanical Garden. Reusing stormwater on site will also reduce the demand on the Iona Island water treatment plant. This reduction in required supply of potable water, as well as treatment, will be large steps towards the UBC campus plan goals of becoming self-sustainable in water management (Item 1 of campus plan). This increase in sustainability will be a large benefit to UBC as well as to the environment.

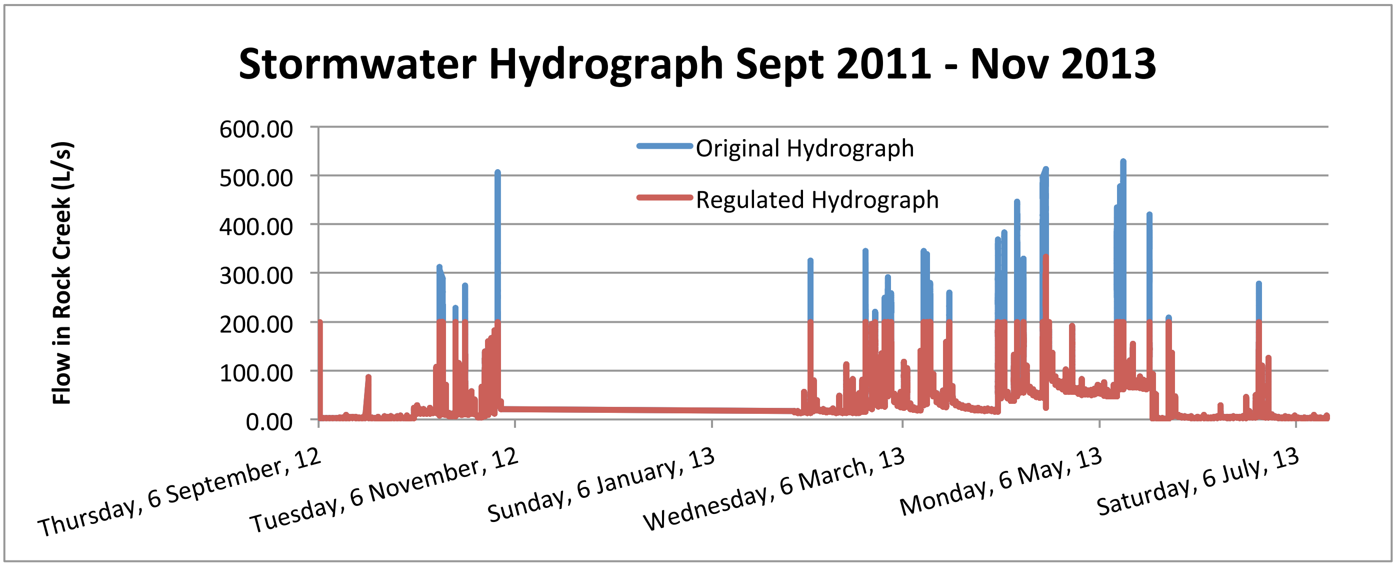


Figure 4: Storm hydrograph

2.8.4 Low Flow Demands

In addition to benefits seen in iconic Vancouver storms, water retention for times of peak demand in dry weather are provided by this reservoir. For summer operations, the reservoir will function as a storage facility able to feed the irrigation system to decrease potable water demand, currently costing UBC upwards of $2,000,000 for supply and treatment across campus (UBC campus plan). The reservoir will have the capacity to provide irrigation demand for the entire garden for up to a 50 day drought. With maximum irrigation demand of approximately 125m^3/day for the peak summer demand, lasting approximately 2-4 weeks, the system will be able to store water for an extended dry season with minimal impact on near creek base flow. Impacts of global climate change may lead to longer spans with no rain. In the event of an extended dry period, base flow of the creek can be drawn down with negligible environmental impact. Additional storage is also available through the proposed bio-filtration channel, which also provides biological treatment of the stormwater runoff.

2.8.5 Cost Analysis

Implementation of this proposed system will have initial construction costs, which will be offset over time by the reduction in operation costs currently spent in the garden on manual regulation of water management through the municipal system. Both costs related to labour and potable water demand will be greatly reduced by this system. Costing estimates are outlined on the following page in

Table 13: Cost Summary of Water Retention. Reduction in operational costs related to labour, potable water supply and treatment expenses will be up to $100,000 annually. A full project cost summary is shown in section 6.0.

Table 13: Cost Summary of Water Retention

Category	Item	Unit Cost	Quantity	Units	Total Cost
Site preparation	Geotechnical Investigation	$ 2,000.00	1		$ 2,000.00
	Site Survey	800	1		$ 800.00
	General Site Preparation	500	1		$ 500.00
Contractor	Foreman	120	80	hours	$ 9,600.00
	Labourers	75	80	hours	$ 6,000.00
	Equipment operators	80	72	hours	$ 5,760.00
	Landscapers	40	16	hours	$ 640.00
	Materials Testing	50	10	hours	$ 500.00
Equipment	Grater	500	3	days	$ 1,500.00
	Backhoe	250	8	days	$ 2,000.00
	Dumptruck	530	8	days	$ 4,240.00
	Packer	300	3	days	$ 900.00
Materials	Piping	10	50	m	$ 500.00
	Tank	5	6000	m3	$ 30,000.00
	Pumps	250	1		$ 250.00
	Valves	100	2		$ 200.00
				Total	**$ 65,390.00**

3.0 Infrastructure – Greenhouse & Cafe

Currently, one significant issue for the UBC Botanical Garden is the uneven distribution of visitors throughout the year. They are highly concentrated in summer and spring. During winter and a great part of fall, the number of visitors falls drastically. Since the admission fees are a vital source of income for the garden, an increase in the total number of visitors, especially if distributed throughout the year, would be a significant improvement.

This issue also affects the gift shop at the garden. Irregular attendance means that the shop's income is very seasonal, and a higher number of visitors distributed throughout the year at the garden would certainly increase its visibility and the number of clients to the shop while distributing visitation throughout the year.

We believe that a well-built and maintained Greenhouse has substantial potential for engaging the public. It would operate as an "anchor" which would draw cliental to the garden during the low seasons by adding a covered attraction. Moreover, the Greenhouse would offer the garden an important space that can be used for research and cultivation of different species of plants that would otherwise perish in BC's temperate climate. A Café has also been considered to further attract more visitors as it provides covered relaxing space, while also expanding the facilities inside the garden. It can also be utilized as a space for individual learning or business meetings.

3.1 Greenhouse Design

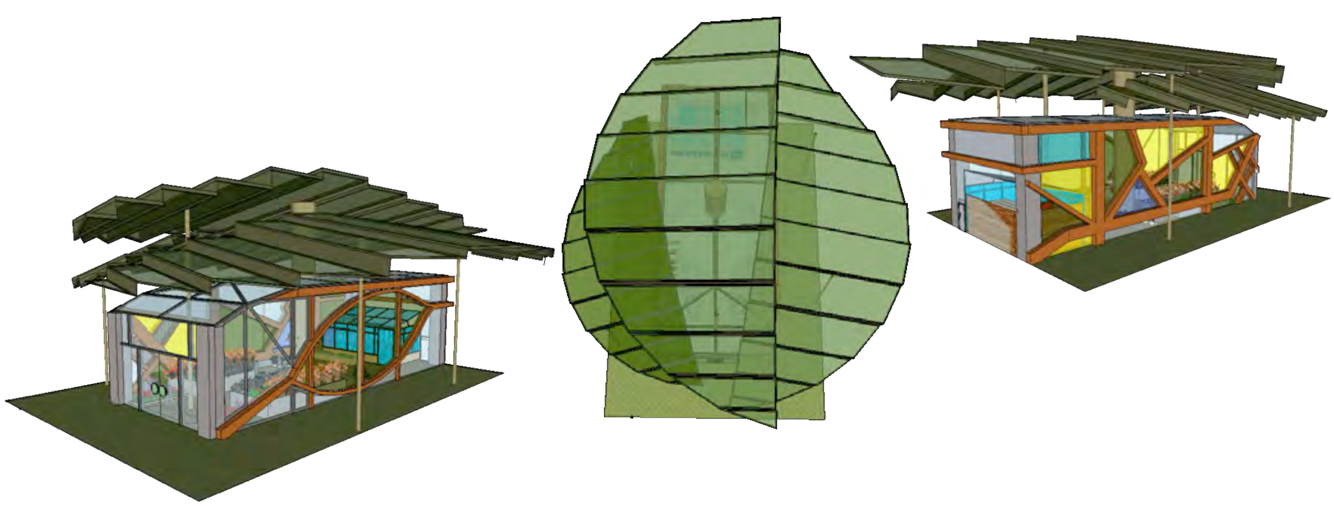


Figure 5: Greenhouse Design

The ambiance of the area surrounding the site had a significant impact on the design of the Greenhouse.

It is important for us to consider the garden environment when designing this structure, as the focus of our design is to replicate the ambience of the garden and have it blend into the surroundings. The proposed design has been inspired by the garden in that it resembles tree leaves. The leaf design of the Greenhouse showcases the prominent use of coloured windows, which can potentially draw many more visitors to the garden.

The Greenhouse is 25m long x 10m wide x 7m high. This will provide more than 70 m^2 of additional area for plant cultivation and research. It is to be located at the north end of the existing amphitheatre and west of Thunderbird stadium (as shown in Figure 6: Greenhouse Location). It is strategically placed close to the Amphitheatre, as that is where many events are currently hosted. The garden's profitability from these events can potentially increase, as the Greenhouse and the Amphitheatre will complement each other by making each more visible to visitors through a spill-over effect. This location also provides adequate space for the designed Greenhouse (without disturbing the existing structures and trees), and receives maximum potential sunlight for the plants. Morning sunlight is the most desirable for plant's growth because it allows the plant's food production process to begin early (Ross, n.d.). The proposed location has no significant obstacles that block sunlight from the East.

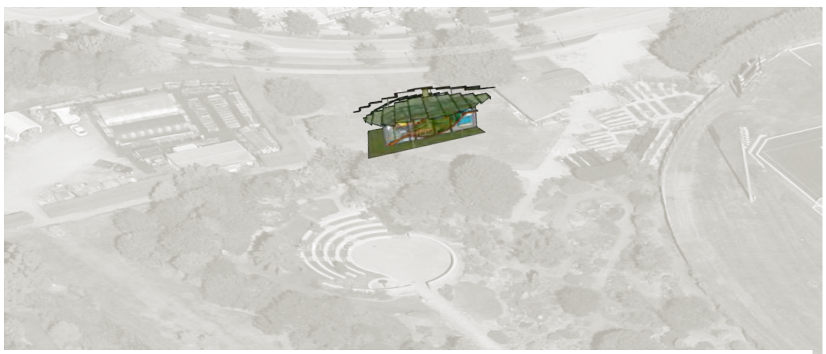


Figure 6: Greenhouse Location

The building materials for the Greenhouse are concrete columns, wood and steel frames, and fiberglass covers. Concrete columns give support to the structure, while the wood and steel frame adds to the nature-inspired design. Fibreglass is chosen over glass for a number of reasons. Not only are the light penetrating properties as good as glass, but it is more durable than glass (Ross, n.d.). In addition, fibreglass is lightweight, has good thermal and acoustical insulation properties, and proffers a pleasant appearance.

3.2 Café Design

Another important feature of the proposed Greenhouse is the Café. The structural design integrates the Café into one section of the Greenhouse (Figure 7: Cafe Design), separated from the planting area by a closed wall. The enclosure is intended to address food safety practices, as the Greenhouse may use fertilizers or pesticides. The Café at VanDusen Botanical Garden sets the precedent for this type of amenity. According to the City of Vancouver, the Café, in addition to the new gateway facility, translates into a 25% increase in visitors and revenue (CoV, 2012). Hence, the design and construction of a Café at the UBC Botanical Garden could be a significant draw for the public.

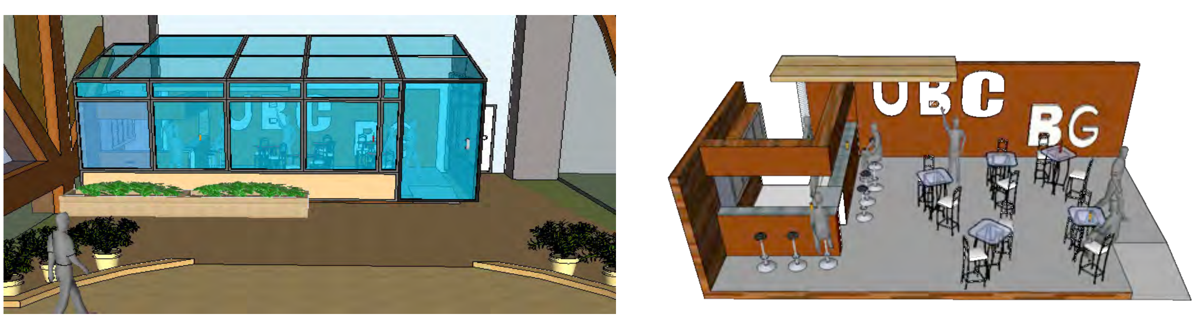


Figure 7: Cafe Design

3.3 Cost Estimation for Greenhouse and Café

The conceptual cost estimate, shown in Table 14 below, was constructed based on the average prices of required materials and their respective quantity needs. The prices were obtained from Alibaba (2013) and precedent projects.

Table 14: Greenhouse Cost Estimation

	unit rate		unit		Total
Reinforced Concrete (300 mm thick)	45	$/m2	1105	m2	$ 49,725.00
Concrete column	30	$/m	72.8	m	$ 2,184.00
Material (fiberglass)	30	$/m2	1846	m2	$ 55,380.00
Aluminum Frames	20	$/m	650	m	$ 13,000.00
Wood Frames	55	$/m2	227.5	m2	$ 12,512.50
Labour + Equipment	2000	$/day	90	days	$ 180,000.00
Miscellaneous (HVAC, lighting, etc.)	300	$/m2	325	m2	$ 97,500.00
Total Construction Cost					$ 410,301.50
Installation (25% of the construction cost)					$ 102,575.38
Architecture Items (10% of construction cost)					$ 41,030.15
Café Items (based on regular small café)					$ 25,000.00
Total Cost					**$ 578,907.03**

As shown in Table 14: Greenhouse Cost Estimation, the total cost for the Greenhouse and café is approximately $600,000. To calculate the cost-benefit for the Greenhouse, we have used a reasonable estimate for the admission fee of $10 per visitor. Following implementation of the first phase of the redevelopment plan, we project the annual increment in visitors to be 1.5%, rising to 5% after implementing the Greenhouse and Café into the garden. It is estimated that the Greenhouse and Café will be constructed in 4 years (the proposed implementation plan for the project is discussed in section 6.0). The current number of visitors to the garden is 45,000 per year, and therefore, it would take approximately 14 months to recover the initial costs of the Greenhouse (Table 15: Cost-Benefit for Greenhouse and Cafe). This analysis was based upon review of similar projects and corrected for size and location.

Table 15: Cost-Benefit for Greenhouse and Cafe

Current visitors	**45000**	**visitors**
Visitors in 4 yrs (assume 1.5% increase annually)	47761	visitors
Ticket cost	10	Dollars
Number of visitors to break-even the price	4103	visitors
Projected annual increment in visitors after greenhouse + café	5	%
Number of years to break-even the price	**1.2**	**years**

4.0 Transportation

The two elements that we are focusing on in the transportation sector of the Botanical Garden redevelopment plan consist of the parking capacity and the pedestrian movement experience. Proposed designs for a new parking lot or parkade, and an overhead pedestrian walkway will be further discussed in terms of their feasibility, design, and cost.

4.1 Parking Lot/ Parkade

The UBC Botanical Garden currently has an 80 space parking lot for visitors, free of charge. But not only is the parking space for vehicle parking, it also functions as a multipurpose area for additional venue space. The problem with the garden's transportation infrastructure is that it cannot accommodate the volume of customers in the peak season or during special events. Visitors will often have to find paid parking elsewhere on campus (nearest public parkade is a 15 minute walk away), or park on old Marine Drive with a risk of having their vehicle towed. There are more options for parking across UBC campus but these would require taking a shuttle to the garden. All of these alternative methods for traveling to the garden can become quite inconvenient, which would be barriers towards visiting the garden. The Botanical Garden has demonstrated that they are ready for a new higher capacity parking facility through their demands during peak season, special events, private events, and in house attractions (such as the amphitheatre, canopy walkways, food garden, and many more).

The current parking lot is an ellipse shape with a green center median. Green space also surrounds the parking lot with trees and plants for water to run-off and drain into the soil. The pavement is crown sloped, which means the center of the space is higher than the perimeter so all water runs off to the outer edges of the asphalt. See Figure 8 for an aerial view of the existing parking lot.

Figure 8: Existing Parkade

An upgrade to the parking facility at the Botanical Garden was deemed as a high priority for the functionality of the garden. The Vancouver Campus Plan (2010) projected the population of UBC to increase 4% by 2017. Being able to house more visitors will benefit the garden with more interest and revenue from the public, and increase the capacity of the garden with more workspace. Further in this section, there will be a discussion of how a new parking infrastructure fits into the "UBC Campus Plan" of creating a vibrant learning environment with sustainable and functional infrastructure. Two designs were conceptualized and investigated in this section. The first one is a very feasible and simplistic option of rearranging and rehabilitating the existing parking lot into a more efficient space. The second option is a more extravagant idea of implementing a multi-story parking facility.

4.1.1 Parking Lot

The rearrangement of the existing parking lot is considered as a simple, direct, and feasible option for parking expansion. Currently there are approximately 80 spaces available within the parking lot and this includes a 6 meter wide by 70 meter long grass center median. The main goal is to increase the capacity, but the redevelopment cannot extend outside the existing footprint of the parking lot. This was stated by Patrick Lewis and Douglas Justice, the garden directors. Accounting for this constraint, the redesign consists of eliminating the grass median, adding two extra rows of spaces, and changing the 90° stalls into 50° angled parking stalls (see Figure 9). This results in a 25% increase in parking capacity.

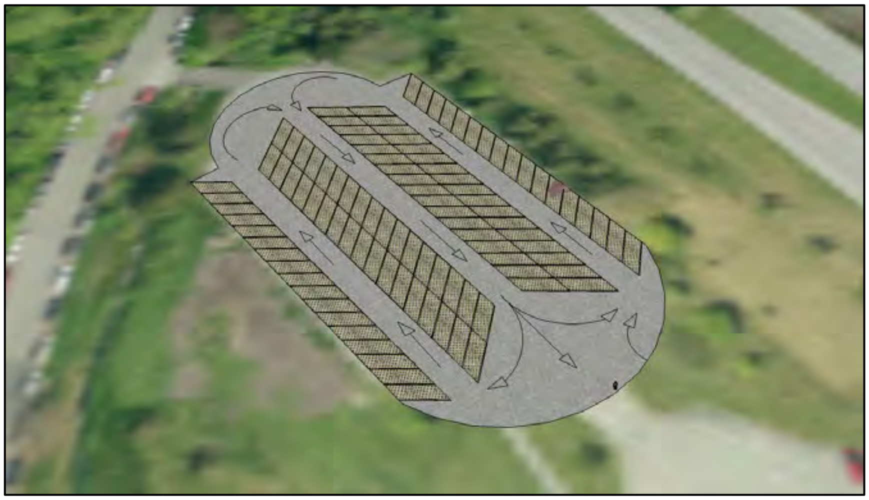


Figure 9: Proposed Parking Lot

The angle parking allows for easier access for vehicles and a smaller required aisle width. The dimensions are specified in Table 16 below and meet the City of Calgary minimum parking dimensions (Dada & Furuya, 2010). Although these specifications are mentioned for the City of Calgary, the City of Vancouver would be quite similar as both cities follow the Canadian Parking Association guidelines (CPA, 2013).

Table 16: Parking Lot Dimensions

Dimension	Measure
Parking Angle	50°
Aisle Width	4.0 m
Stall Length	6.5 m
Stall Width	3.5 m

The redesign of the parking lot shall also include stormwater management methods, as it is a large consideration for parking infrastructure. Parking lot runoff is a major non-point source to community waterways (EPA, 2008). The sustainable goal is to reduce the amount of surface runoff while increasing infiltration and transpiration of stormwater. The existing stormwater features consist of the crown grade of the parking lot, and the outside grass perimeter. Both of these features will be maintained for the proposed parking lot as they allow for source control of stormwater, rather than carrying it to an outfall. The crown slope will allow the water to travel from any point inside the parking lot to the perimeter for grass absorption and retention. The design of the new parking lot can also include bio-retention areas along the perimeter with grass buffer strips, swales, shallow ponding areas, planting soils, drain rock, and bio-filtration plants (such as cattails).

The surface characteristics will also be redesigned for more efficient and sustainable stormwater management. Porous pavement will be installed to replace the existing asphalt to allow the absorption and retention of surface water. Furthermore, traditional asphalt uses virgin stone and non-renewable petroleum based materials leaving a large ecological footprint (EPA, 2008). An example of a type of porous pavement is "Turfstone" which uses interlocking masonry blocks (see Figure 10). The blocks offer structural support as the grass medium collects the water. The sub-base of the parking lot consists of gravel and sand to allow increased permeability. Altogether, this design filters and holds the water while giving the parking lot a natural looking method of stormwater management.

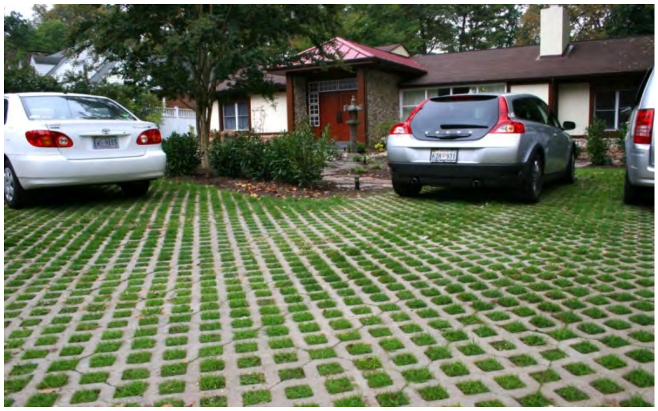


Figure 10: "Turfstone" Parking Surface by Unilock

The great benefit of implementing this system is a parking lot free of stormwater utilities, such as catch basins or PVC pipes. This parking lot acts as a source control for stormwater drainage, reducing the amount of surface runoff, and increasing evaporation and infiltration. For extreme cases of rainfall, the porous pavement will simply reach its capacity and the excess surface runoff will drain to the perimeter bio-retention systems. If it is desired to take this one step further, there is the possibility of setting up the parking lot storm system to tie-in to the Botanical Garden's water retention and irrigation systems for the reuse of the stormwater.

The estimated cost of the parking lot is described in Table 17, with cost breakdowns in terms of materials and labour. This is a very conceptual cost estimate and should only be used as a general reference. The construction process would take place over a month, with demolition taking place during the first week, followed by filling, grading, stone placement, and landscaping over three weeks. The quantities were referenced from design drawings, and unit rates for materials, labour and equipment referenced from Dr. Sheryl Staub-French's CIVL 400 course (project and construction management) in 2012.

Table 17: Parking Lot Cost Estimate

Quantities						
	Item	**Quantity**	**Unit**	**Unit Price**	**Cost**	
	Porous masonry	3110	m^2	$80.00	$248,800	
	Paint marking		Estimate		$300	
	Subbase	933	m^3	$60.00	$55,980	
	Biolfiltration veg.		Estimate		$10,000	
				Sub Total	**$315,080**	
Labour						
Typ. work	**Workers**	**Crew**	**# units**	**Hours/days**	**Unit Rate**	**Cost**
Surveyors	Transit operator	1	10	Hours	$40	$400
	Rodman	1	10	Hours	$40	$400
Contractor	Foreman	2	160	Hours	$35	$11,200
	Laborers	2	160	Hours	$32	$10,240
	Equipment Operater	1	160	Hours	$34	$5,440
	Stone masons	3	120	Hours	$38	$13,680
Landscape	Laborers	2	120	Hours	$30	$7,200
Equipment	Dozer	1	15	Days	$1,000	$15,000
	Packer	1	10	Days	$450	$4,500
	Backhoe	1	20	Days	$250	$5,000
	Dump truck	1	15	Days	$530	$7,950
					Subtotal	**$81,010**
					Total	**$396,090**

The total cost of approximately $400,000 is quite feasible when looking at the return rate of the garden, with 45,000 visitors to the garden each season (peak periods). If we assume the increase in parking is a 70% direct relation to the increase in visitors, we would expect 7,875 more visitors each season. The rate per person for admission is around $10, so if we equate the additional visitors, the garden would see $78,750 in additional annual revenue. In addition this project could be subsidized by UBC. Despite taking into account the salaries and cost of running the garden, when focusing on the larger capacity for the public to visit the garden, the costs of this parking lot would be recovered within the first couple of years following construction.

4.1.2 Multi-storey Parkade

The idea of building a multi-story parkade is quite prestigious compared to the parking lot redesign, but it is credible in terms of other factors beyond increasing the number of parking spaces. The idea of the parkade will help achieve the "perimeter parking" goals of the UBC Vancouver Campus Plan (2010).

> Policy 22: The destinations for vehicles travelling to campus will be located at the perimeter of the campus, in structured parkades or below-grade parking facilities, with the exception of vehicles with disabled access privileges. Surface parking lots will be discontinued over time, through their use as future building sites or for other interim uses such as recreational areas. – Vancouver Campus Plan (2010)

Having parking located on the perimeter of the UBC campus is a way of encouraging more sustainable methods of transportation, and to conserve the pedestrian friendly atmosphere of UBC. This can be a great benefit to the Botanical Garden because it allows a higher traffic flow of people to come to the garden. Furthermore, surface parking is considered as an inefficient use of space and implementing the parkade will increase the current capacity while offering additional multi-purpose space. This will help adapt campus infrastructure to the projected future campus growth and the long term planning of the garden.

The multi-storey parkade will consist of four floors made of concrete: the first three floors made up of 400 parking spaces and the fourth floor being an open green roof. In addition, there will be a living wall installed on the outside faces of the parkade. Please see Figure 11 for the floor plans, and Figure 12 for the overall 3-D design.

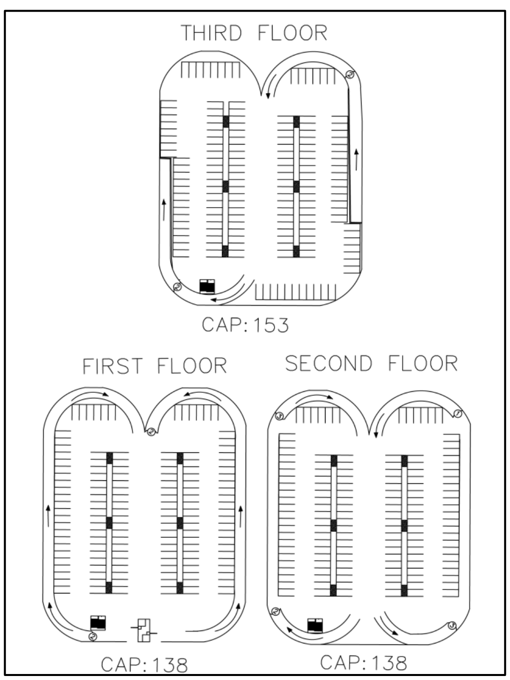


Figure 11: Parkade Floor Plans

Figure 12: Parkade Sketch-Up

The first two floors have parking capacities of 138 spaces, while the third floor has a capacity of 153 spaces. Parking spaces meet the minimum specifications of 5.5m in length, 2.5m in width, and a vertical clearance of 2.0m. Similarly for disabled parking, the spaces are at least 5.5m long, 4.0m wide, and 2.3m high (CoV, 2013). Each of the three floors has an up and down vehicle ramp on the perimeter of the floor and a staircase extending to the fourth floor. The fourth floor green roof is only accessible by the staircase. The footprint of the parkade will be larger than the existing parking lot as its dimensions are 70 meters wide, 90 meters long, and 12 meters high. Planning the position of the parkade might extend into old Southwest Marine Drive and the grass median near Marine Drive. This means consultation with the Ministry of Transportation and UBC infrastructure will be necessary for the planning of this project.

The fourth level will be a large open green roof space. Essentially the garden can use that area for special events, extra garden space, or any other functions. Directors from the garden expressed their desire for multi-purpose spaces for events such as weddings, festivals, sales, tours, fundraisers and many more. Implementing a green roof will involve placing many layers above the concrete slab to contain an environment suitable for vegetation growth while protecting the concrete. See Figure 13 for the design of the layers. This will be implemented throughout the fourth floor and the soil (5 – growing media) can vary depending on the type of vegetation the garden wishes to plant.

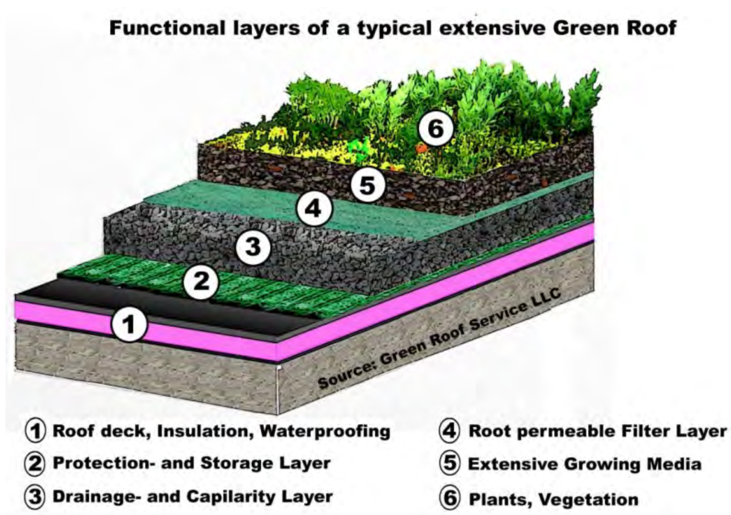


Figure 13: Green Roof Layers (Roof Systems Consultants, 2013)

To further increase the environmental functionality of the parkade, living walls will be installed on the outside perimeter of the structure. These walls are composed of pre-vegetated panels that are fixed to a vertical wall (Green Roofs, 2008). The walls can consist of a large variety of plant species which are supported by the growing media within the panels. Green facades differ from living walls as planting species are meant to climb up the vertical face from the ground, rather than growing directly on the walls.

The primary intent for the green roof and living wall is to act as an environmentally sustainable method for stormwater management while preserving the green aesthetic look of the garden. Stormwater runoff is a major contributor to stream erosion and habitat degradation. Furthermore, impervious asphalt or concrete areas deprive the environment of the water (Johnston, 2013). Having the green roof and living wall will increase pervious areas for stormwater to be retained, allowing the water to be used for irrigation, infiltration, or evaporation back into the atmosphere. In addition, these green modifications reduce the urban heat island effect, and improve the air quality around the parkade from vehicle emissions (Green Roofs, 2008)

The conceptual cost estimate of the multi-story parkade was calculated using a square foot costs method using a project size modifier (Dr. Staub-French, 2012). This method compares the size of our proposed parkade to a typical parkade size and unit cost and scales the unit cost accordingly. It may be noted that larger parkades will experience lower unit costs due to economies of scale. The total cost for building this infrastructure came up to approximately $13 million. Please refer to Table 18 below for these figures.

Table 18: Square meter cost estimate

Square Meter Cost Estimate			
Type	**Unit Rate ($/m²)**	**Total Area m²**	**Cost**
Typical	$561	15143.2	$8,497,001
Proposed (Structure)	$539	20758.5	$11,181,774
Proposed (Green Features)	$278	7011	$1,947,516
Proposed Total			**$13,129,289**

This cost is quite reasonable compared to multilevel parking facilities in other parts of Canada. Table 19 compares the cost of other parkades in terms of the unit cost per stall (Kobayashi Zedda Achitects, 2013). The average unit cost of similar structures in other locations was averaged to estimate that for the UBC Botanical Garden.

Table 19: Cost comparisons

Conceptual Estimates at other Canadian cities			
Location	**Stalls**	**$/stall**	**Total Cost**
Whitehorse		$18,000	
Regina		$30,000	
Campbell River		$25,000	
Kobayashi + Zedd Architects	120	$50,000	$6,000,000
UBC Botanical Garden	400	$30,750	$12,300,000

This may seem like a large capital investment for the garden, but this is intended to be a distant future implementation with consideration for the Vancouver Campus Plan. This parkade will become a paid parking facility along with all the others on campus. The garden could expect a return similar to that which is summarized in Table 20. It is assumed that the parkade would experience 95% capacity during the weekdays because of commuting workers and students. Similarly, the parkade will be 80% occupied during weekends because of special events and the general public's leisure time.

Table 20: Parking revenue

Potential Parking Revenue					
Time	**Hours**	**Demand (%)**	**Spaces Used**	**Rates ($/hr)**	**Payback (day)**
Weekday	8	95	380	$3.00	$9,120.00
Weekend	8	80	320	$3.00	$7,680.00
Per Week				5wkd+2wke	$60,960.00
Per Year				50 wks	$3,048,000.00

In addition, if we assume that the parking increase is a direct reflection of the increase in visitors (similar to the parking lot, estimated to 70%) it can be said that the garden will experience an increase of 126,000 more visitors each season. If each visitor pays $10, this means the revenue of the garden would increase $1.25 million each year. Combining the parking revenue and visitor revenue, it totals to approximately $4.25 million a year in increased revenue for the garden from the implementation of the parkade. Overall, these cost estimates and revenues are very conceptual, and the actual numbers may vary significantly. These conceptual figures should only be used as reference.

4.2 Overhead Walkway

Movement patterns at the Botanical Garden are one transportation component addressed as part of this proposal. This section describes the design of a proposed Overhead Walkway.

4.2.1 Existing Conditions

The existing visitor movement patterns can be understood as the connectivity within the Asian Garden, within the North Garden, and between the two. Each portion of the Botanical Garden is shown in Figure 14. The garden finds itself in a unique situation: SW Marine Drive splits the garden into separate halves (see Figure 14) currently connected only by the underground Moon Tunnel. While visitor movement patterns are largely unhindered in each separate half of the garden, it is inefficient to travel between the halves.

The Moon Tunnel is approximately 46m long by 3m wide. It is made from a large diameter corrugated steel pipe (CSP) culvert lined with an asphalt walking surface. The tunnel is dark (even with the spot lamps) and claustrophobic. The exposed CSP makes the tunnel feel unfinished. The entrance from the Asian Garden is shown in Figure 15.

There exists a network of major and minor pathways to connect the attractions within the garden such as the glacial erratic and Greenheart Canopy Walkway within the Asian Garden. A similar network of pathways, in addition to the open space of the Great Lawn, facilitates connectivity among the Carolinian Forest, Food Garden, and Physic in the North Garden.

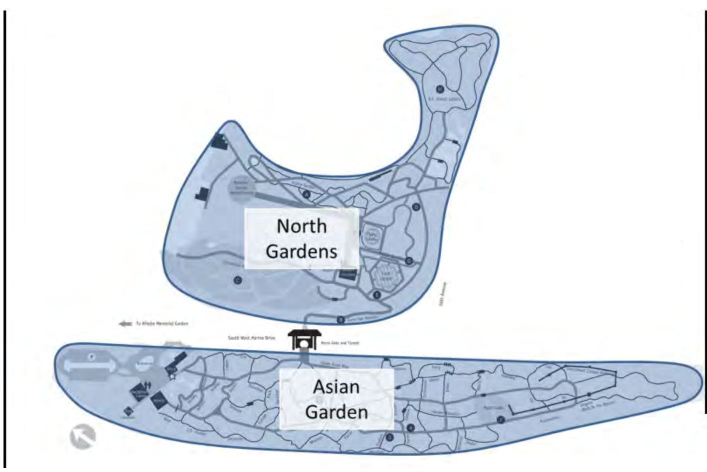


Figure 14: Asian Garden and North Garden

Figure 15: Moon Tunnel Entrance from the Asian Garden

4.2.2 Design Concept

A set of design concepts are proposed as guidelines; functionality, material selection, and environmental considerations were taken into account.

4.2.2.1 Functionality

The Walkway shall have shallow grades to facilitate disabled access (VCP Part 2, 2010) yet maintain suitable vehicle clearance across SW Marine Drive. The optimal alignment places piers which minimize ground disturbance and environmental impacts. The alignment shall minimize pedestrian travel times and provides elevated views of the surrounding campus. Access/exit points shall be located near existing Garden “anchors”, such as the amphitheatre and the proposed Greenhouse and Café. The walkway shall provide safety railings, a non-slip surface wide enough to accommodate wheel chairs and large groups, and a roof structure to shelter visitors from the elements.

4.2.2.2 Material Selection

Material selection should reflect a “west coast” design, similar to recently constructed buildings at UBC. The use of wood should be optimized. Wood reflects BC’s large forestry industry and has better environmental performance than materials like concrete. Wood materials could include glulam beams and architectural paneling. Other structural materials such as concrete and steel are to be used minimally. The use of glass reflects the design of recently constructed buildings such as the Earth Sciences Building and Pharmacy; the use of glazing could be extensive.

4.2.3 MCDM & Decision Making

A multiple Criteria Decision Matrix was used to create the final preliminary design. A summary is shown in Figure 16 below. Additional details are available upon request.

	Criterion Name	Sub Criteria Name	Option 1	Points	Option 2	Points	Option 3	Points	Chosen
Criteria 1	Alignment	Start Point	Truck access	20	Parkade	12	Garden office	8	Truck access
		Mid Point	Center Median	6	Through cliff	14			Through cliff
		End Point	Amphitheatre	24	Cliff/Carloinian	16			Amphitheatre
Criteria 2	Width		3.0m	24	5.0m	16			3.0m
Criteria 3	Access Points		Cliff Face	15	Carolnian Forest	35			Carolnian Forest
Criteria 4	Profile		Trapezoidal	24	Arch/Curved	36			Arch/Curved
Criteria 5	Piers	Layout	Through Forest	24	Around Cliff	16			Through Forest
		Size	Circle (1.0 mϕ)	9	Square (0.75m)	21			Square (0.75m)
		Material	Concrete	6	Steel	12	Timber	12	Steel w/ timber
Criteria 6	Slab	Layout	Along Layout	40					Along Layout
		Size	3.0m x 200mm	18	5.0m x 400mm	12			3.0m x 200mm
		Material	Concrete	18	Timber	6	Steel	6	Concrete
Criteria 7	Rail/Barrier	Layout	Along Layout	40					Along Layout
		Size	1.1 B, 1.0 R	21	Full B, 1.0 R	9			1.1 B, 1.0 R
		Material	Glass	12	Steel	12	Wood	6	Glass w/ steel
Criteria 8	Roof	Layout	3.5m high	24	2.5m high	16			3.5m high
		Size	6.0m wide	21	3.0m wide	6	1.0m wide	3	6.0m wide
		Material	Glass	6	Wood	12	Steel	12	Steel w/ wood

Figure 16: Overhead Walkway Multiple Criteria Decision Matrix

4.2.4 Preliminary Design

The preliminary design considers the specifications, estimated costs, and benefits for the Overhead Walkway.

4.2.4.1 Specifications

The specifications are described in terms of architectural elements, structural design, and architectural finishes. Table 21 summarizes the architectural elements of the preliminary design.

Table 21: Overhead Walkway Architectural Elements

Architectural Element	Description
Length × width	• 280m long × 3m wide
Access and Egress	• Near existing Garden Entrance (vehicle service turnaround) • Carolinian Forest • Near the existing amphitheatre and proposed Greenhouse and Café
Alignment	• Alignment reflects physical space constraints of pier placement • "U-Bend" near existing Garden entrance has a radius of 5.0m and allows for gradual grades
Pier Placement	• 0.75m long × 0.75m wide offset 0.5m (from pier centre) from either slab edge • Piers placed according to existing physical space constraints (ie. pier placed in the median of SW Marine Drive) in an alternating pattern
Roofing Details	• 2.0m overhang (north side), 1.0m overhang (south side) • At least 3.0m clearance from the walkway slab to the interior of the roof • Undulating curves with an amplitude of 0.5m to form crests and troughs corresponding to the placement of piers (profile view) • Curved crest/trough centreline corresponding to the placement of piers (plan view)

The structural design utilizes wood, concrete, and steel. Cast-in-place concrete footings, approximately 4m wide × 5m long at an embedment depth of approximately 0.5m support HSS square columns. These columns extend through a 3m wide × 200mm thick cast-in-place concrete slab to the roof. The walkway is at minimum 3.0m above the roadway. 6m long glulam beams are spaced at 20m on centre and attached to a steel joist. Table 22 summarizes the architectural finishes. Figure 17 and Figure 18 illustrate some of these specifications; additional figures available upon request.

Table 22: Overhead Walkway Architectural Finishes

Architectural Finish	Description
Column	• Architectural wooden panelling
Slab	• Exposed aggregate finish
Roof (Top)	• Architectural metal paneling (aluminum or steel or similar)
Roof (Bottom)	• Architectural wood paneling
Railing	• Steel posts spaced at 1.1m on-center spanned by clear glass

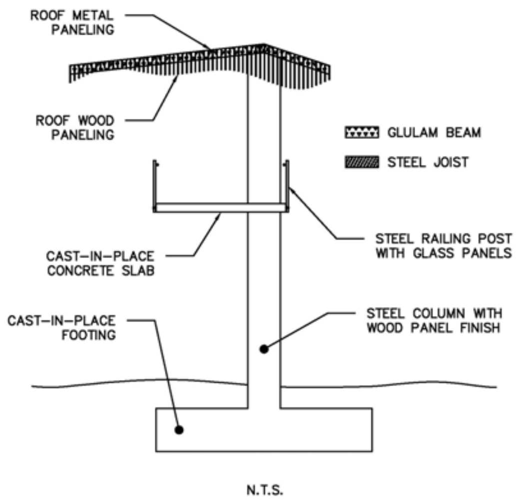
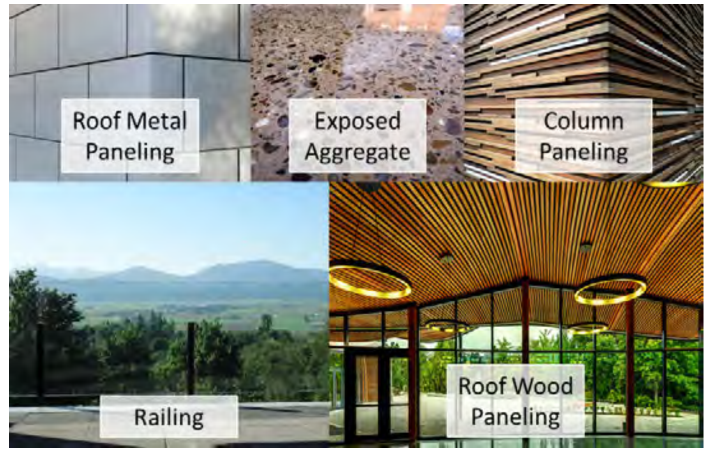


Figure 17: Overhead Walkway Typical Cross Section



From top left, clockwise: (Metal Paneling, 2013); (Unique Touch Concrete Design, 2013); (Column Paneling, 2013); (VanDusen Visitor Centre, 2013); (Marquis Railing Contracting Ltd., 2013)

Figure 18: Example Overhead Walkway Design Finishes

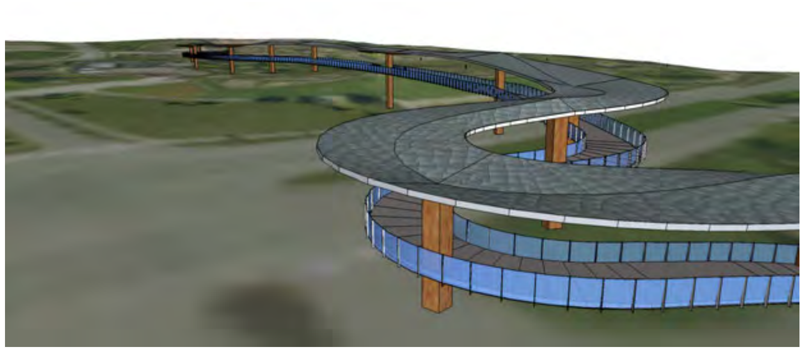


Figure 19: Proposed Overhead Walkway Conceptual Design

4.2.4.2 Estimated Costing

The estimated costs are broken into material and labour/installation costs. Quantity takeoffs and contingency values were utilized and are available upon request should further details be desired. Due to site uncertainty, geotechnical work is priced as lump sum items. The estimated total material cost is approximately $408,000. The estimated total labour and installation cost is approximately $503,000. These costs are detailed in Table 23 and Table 24.

Table 23: Overhead Walkway Material Costs

Quantities					
Category	Item	Quantity	Unit	Unit Price	Extended Cost
Geotechnical program & ground remediation		1	$L.S.$	$ 50,000.00	$ 50,000.00
Substructure	Cast-in-place footings	420	m^3	$ 150.00	$ 63,000.00
	Formwork (footings)	1220	m^2	$ 25.00	$ 30,500.00
Superstructure	Cast-in-place walkway slab	280	m^3	$ 150.00	$ 42,000.00
	Formwork (walkway slab)	1430	m^2	$ 25.00	$ 35,750.00
	Structural steel columns	50	m	$ 400.00	$ 20,000.00
	Structural glulam beams	130	m	$ 200.00	$ 26,000.00
Architectural Finishes	Steel railing posts	690	EA	$ 50.00	$ 34,500.00
	Glass railing panels	690	m	$ 60.00	$ 41,400.00
	Column wood paneling	140	m^2	$ 75.00	$ 10,500.00
	Roof steel paneling	2240	m^2	$ 11.00	$ 24,640.00
	Roof wood paneling	2240	m^2	$ 13.00	$ 29,120.00

Table 24: Overhead Walkway Labour and Installation Costs

Category		Crew	Quantity	Unit	Unit Cost	Extended Cost
Geotechnical program & ground remediation		1	1	*L.S.*	$ 50,000.00	$ 50,000.00
Surveying	Transit operator	1	64	*Hour*	$ 40.00	$ 2,560.00
	Rodman	1	64	*Hour*	$ 40.00	$ 2,560.00
Superintendent		2	224	*Hour*	$ 150.00	$ 67,200.00
Rebar	Foreman	1	56	*Hour*	$ 115.00	$ 6,440.00
	General laborer	2	56	*Hour*	$ 50.00	$ 5,600.00
Carpentry	Foreman	1	80	*Hour*	$ 115.00	$ 9,200.00
	General laborer	2	80	*Hour*	$ 65.00	$ 10,400.00
Concrete	Foreman	1	64	*Hour*	$ 115.00	$ 7,360.00
	General laborer	2	64	*Hour*	$ 65.00	$ 8,320.00
Steel / Welders	Foreman	1	80	*Hour*	$ 115.00	$ 9,200.00
	General laborer	2	80	*Hour*	$ 65.00	$ 10,400.00
Finishes	Foreman	1	160	*Hour*	$ 115.00	$ 18,400.00
	General laborer	3	160	*Hour*	$ 50.00	$ 24,000.00
Equipment	Concrete Pump Truck	1	5	*Days*	$ 15,000.00	$ 75,000.00
	Zoomboom	2	10	*Days*	$ 800.00	$ 16,000.00
	Crane	1	10	*Days*	$ 18,000.00	$ 180,000.00

4.2.5 Design Rationale

The decision to design an Overhead Walkway instead of retrofitting the existing Moon Tunnel is supported by a number of factors. Foremost, the existing Moon Tunnel is still fully functional. Since this proposal focuses on new development, renovations for lighting and wall paneling are not considered. The tunnel has now been a long-standing feature of the garden—demolition and replacement would mean losing this iconic passageway.

The Walkway is an additional option for visitor movement through the garden. Visitors would no longer have to backtrack to exit the garden. Of note, the walkway adds to the operational value and intent of the Greenhouse and Café. Not only would visitors stay dry inside the Greenhouse and Café, since the Walkway is covered they would stay dry when commuting to and from these locations. The Overhead Walkway is a "statement piece" and provides opportunity for visible signage informing UBC students, drivers along SW Marine Drive, local area residents, and the public at large that there exists a unique and valuable collection of plants at the UBC Botanical Garden. Finally, the design complies with a number of policies in UBC's Vancouver Campus Plan. This is summarized in Table 25.

Table 25: Overhead Walkway Design Compliance with the Vancouver Campus Plan

Vancouver Campus Plan	Compliance
Policy 18	The proposed design complies with the "gateway strategy" along 16th Avenue and SW Marine Drive to "signal when one is crossing the threshold into the University's Vancouver campus." (Campus and Community Planning, 2009, p. 16)
Policy 19	The proposed design uses grades that result in a "barrier-free environment".(VCP Part 1, 2010, p. 15)
Policy 25	The proposed design creates "continuity of routes for the east-west pedestrian pathways indicated on Map 2-7" (VCP Part 1, 2010, p. 16). The design facilitates a "pedestrian friendly campus". (VCP Part 1, 2010, p. 7)
Policy 44	The proposed design could function as a form of outdoor public art. As illustrated by Map 2-13 Outdoor Pubic Art, the Botanical Garden has been cited as having "significant opportunities." (VCP Part 2, 2010, p. 65)

5.0 Value Added Design Elements

In addition to the major elements proposed herein this report, we also propose a set of concepts that will add great value to the visitors experience in the garden. These elements address smaller details that could be explored in order to achieve the garden's mission. Keeping that in mind, we have selected several simple, yet very effective concepts that will help the UBC Botanical Garden to fulfill its needs. The value added concepts described within this section are expected to yield significant benefits for the Botanical Garden at a relatively low capital expense, and as such, are to be implemented in the first redevelopment phase, setting the foundation for forthcoming phases. They include items such as a family area, improved signage, a picnic area and a welcome sign.

5.1 Value Added Items

5.1.1 Family area

Figure 20 - Family area and Barbecue place

Located adjacent to the proposed Bio-filtration Channel, this area is designed to be an appealing location for people to visit with family and friends. It includes a barbecue area, benches, gazebos and more, to make the visitors feel comfortable. Solar lamps were added to increase safety and the duration for which people can enjoy the garden during the winter months with less daylight time. The objective of this implementation is to create a relaxing place where people can rest after walking through the garden and to provide a location for small casual events and meetings. The family area will help to enhance the overall experience of families and community groups using this area while enjoying the relaxing atmosphere. The Garden states that its mission is to "assemble, curate and maintain a documented collection of temperate plants for the purposes of research, conservation, education, community outreach and public display" (UBC Botanical Garden, 2013), the family area would definitely bring the community closer to the UBC Botanical Garden, which is essential for a higher community outreach.

5.1.2 Picnic Area

Incorporating a number of picnic tables in close proximity to the family area provides a cost effective method of increasing the potential for attracting more visitors to the garden and for providing incentive for these visitors to prolong their visit, especially in the spring and summer periods. Together with the barbecue area, these features will encourage people to sit and rest while enjoying the natural environment of the garden, and reduce the likelihood that they will merely pass through the garden. Providing more opportunities for people to prolong their visit in the garden is likely to enhance their overall experience and entice them to return to the garden themselves and/or recommend it to their friends and families. Hence, these features will help gain the support of the local community.

5.1.3 Kids' Zone

The proposed kids' zone will be located close to the family area and the designed Bio-filtration channel and include a playground with swings, slides and other features that will help increase the appeal of the garden to parents with young children looking for a safe environment for their children to play. Having an area designed specifically for children will attract these parents who currently may not regard the garden as a place to bring their families because of the lack of children-oriented activities. Providing an opportunity for children to play in designated areas designed for this purpose will prevent them from engaging in activities throughout the rest of the garden that could potentially damage the sensitive plant collections. By encouraging children to visit the garden, they will be more likely to grow up with a good recollection of their experiences here and be more likely to support the garden in the future.

Figure 21 - Playground in Kids' Zone

5.1.4 Statue

In the past, donations from supporters have been a valuable resource for materializing ideas that have greatly improved the garden. The benefactors have served an integral role in helping the garden to achieve its mission. In order to commemorate these supporters, we propose a statue to be made by a local artist and placed in a very visible site adjacent to the family area. While achieving this goal, it will also help attract visitors to this area of the garden and will provide additional appeal to the family area.

5.1.5 Bridges

Figure 22 - Current wetland without bridges

Upon our site-visit to the garden, Patrick Lewis, Director of the UBC Botanical Garden, stated that a current problem with the wetland is that students, scientists and visitors attempting to investigate the plants within the current cattail marsh are unable to get close enough to the plants. Furthermore, some of these guests have been witnessed to cause damage to the periphery of the wetland while attempting to inspect the plants within. Installing three wooden bridges that cross the Bio-Filtration channel at strategic locations would help to alleviate this problem and draw more attention to it. This will serve to enhance the educational experience of visitors to the garden. In lieu of major transformations proposed for the wetland area, the bridges should be built only after the Bio-filtration Channel is constructed.

5.1.6 Informational Signage within the Garden

Improved informational signage inside the garden will entertain curious guests and, with a small adaptation, can encourage people (especially children) to visit the whole garden by introducing a fun ‘treasure hunt’ game. In this family-oriented “game”, children will search for signs strategically placed throughout all of the regions of the garden. These signs will have Quick Response (QR) codes that can be read with smartphones. (Note that in the likelihood that not all visitors have smartphones, visitors could also take pictures of the signs or record answers to a “fun fact” questionnaire by reading the details on each sign). Upon returning to the ‘Shop in the Garden’, those who find all of the signs will be rewarded with a prize such as a small plant or seeds that they can grow at home. The implementation of this conceptual idea is relatively simple and inexpensive because the garden already has a self-guided tour that utilizes QR codes. At the same time, these signs will enhance the educational experience of the garden to visitors by providing additional interesting facts about the Botanical Garden, its research and collections.

Figure 23 - example of sign with QR code

5.1.7 Welcome Sign

There is currently a large number of locals and tourists who drive along South-West Marine Drive regularly and don't realize that one of the greatest Botanical Garden in Canada is located right here at UBC. A vivid and easily recognizable sign promoting the UBC Botanical Garden will be an invaluable asset with respect to promoting the location of the garden and making its presence more visible to the community, thereby helping to attract more visitors. An example of a simple, yet effective sign is shown below in Figure 24. The construction of the parkade and the overhead walkway will provide the most prominently advantageous locations to position the sign. However, since these structural components are proposed to be implemented in the final phases of the overall redevelopment plan, then it is suggested that a temporary sign be located in another visible location adjacent to South-West Marine Drive such as its intersection with Stadium Road.

Figure 24 - Welcome sign example

5.2 Conceptual Cost Estimate of the Value Added Design Elements

The conceptual cost estimate provided in the following table includes the cost of materials and construction for the various design elements described in this section. Many of the elements in this section are widely available in local markets and prices are subject to significant variation depending on quality of design, materials and construction methods. The unit prices incorporated into this cost estimative are based on the prices of average, good quality items available on the market. The main sources for these cost figures were large Internet sale companies, construction guides and local companies' websites. The values displayed are the averages of multiple queried results for each item.

Table 26 - Cost Estimate for Value-Added items

Category	Item	Quantity	Unit	Unit Price	Total cost
Family Area	15 ft octagon gazebo	2	Units	$ 8000,00	$ 16.000,00
	Outdoor grill	2	Units	$ 300,00	$ 600,00
	Outdoor wooden table + benches	2	Units	$ 500,00	$ 1.000,00
	Rock raised flower bed	160	Sq ft	$ 10,00	$ 1.600,00
	Solar lamp post	8	Units	$ 250,00	$ 2.000,00
	Outdoor wooden bench	8	Units	$ 150,00	$ 1.200,00
	Wooden pergola/ ramada	200	Sq ft	$ 31,00	$ 6.200,00
Statue	Statue	1	Units	$ 5.000,00	$ 5.000,00
Bridges	Wooden Bridge	3	Units	$ 1.500,00	$ 4.500,00
Picnic Area	Outdoor wooden table + benches	3	Units	$ 500,00	$ 1.500,00
Signage	Small informational sign	10	Units	$ 300,00	$ 3.000,00
Welcome sign	Large welcome sign	1	Units	$ 1.200,00	$ 1.200,00
Kids zone	Wood and metal playground set	1	Units	$ 5.000,00	$ 5.000,00
Total cost					$ 48.800,00

5.3 Value Added Design Elements Overview

The combination of elements in this section provides a vital enhancement to the UBC Botanical Garden, helping this entity reach its mission and provide the foundation for the subsequent development phases. Each of the elements within this section can be implemented separately as funding becomes available, which helps to alleviate the overall financial burden and facilitates a gentler execution of the redevelopment project. Once implemented, these elements will act in harmony to improve the visitors' experience in the garden and increase its appeal to the community.

6.0 Implementation of the Project

The implementation of the different project elements detailed above, which make up the redevelopment plan, will be split up into four phases. The phases have been developed in order to build off each other and have been prioritized in terms of time, feasibility, cost, visitor demands and the revenue of the garden, while considering the future growth and development of the UBC campus.

Multiple project elements constitute each phase with the timeline of the phases ranging from immediate (within one to two years) to the distant future (seven to ten years). The first phase will create an initial draw to the garden while subsequent phases will build upon this enhancement and incrementally apply the project elements as each phase will be made for feasible by the one preceding.

Within the phases there will be staged development also. For instance, within phase 1 the primary step will be inexpensive items which will encourage visitation duration and frequency, such as picnic tables and informational signs. The final progression of the phase will build upon the increased popularity brought on by initial implementations, thus mandating the redevelopment of the parking lot.

Table 27: Project Phases

Phase	Timeline	Objective	Projects	Project Description
1	1 – 2 years	• First step in enhancing the UBC Botanical Garden • Feasible and cost effective projects for garden's current visitor demand • Increase capacity and visitor experience	Redesigned Parking Lot	Increase current parking facility to accommodate visitors during peak seasons and special events
			Value Added Signage	Enhance visitor experience while attracting public attention and generating more revenue
2	3 – 4 years	• Continuation of last phase in upgrading garden amenities • Attracting public with sustainable and appealing infrastructure	Greenhouse/Cafe	Green aesthetic building which offers congregation and social space
			Bio-Filtration	Natural appeal to public and stormwater management system
3	5 – 6 years	• Improve efficiency of water management system inside the garden • Better care and monitoring of garden collection	Water Retention	Sustainable holding method for consistent water supply throughout each season
			Smart Irrigation	Automated system to relieve worker hours and improve garden operation efficiency
4	7 – 10 years	• Long term planning with consideration for future campus development • Accommodating large volumes of visitors with enhanced visitor movement within the garden • Great returns with garden exposure	Multi-storey Parkade	Significant increase in parking capacity and extra garden space while promoting green stormwater management Part of Vancouver Campus Plan
			Overhead Pedestrian Walkway	Great travel method within garden to create a closed loop route while being a great exposure item to publicize to motorists

Applying these four phases will help benefit the garden in functionality, operations, and public attraction. This sequential order is most beneficial to the garden with respect to visitor demands and garden finances from the start of the development, through to the end.

This development strategy increases the feasibility of each element individually, as well as the project as a whole, thus working to make the Botanical Garden a pinnacle of UBC known on an international scale.

7.0 Total Cost Estimation

Proposed implementation of the project employs a phased approach where four phases will be conducted in which each will build on the foundation of the previous phase. This structure of incremental development will break down costs and increase likelihood of receiving funding through UBC. Total phase and project costs are outlined below wherein estimates are divided into labour, equipment, and materials costs for each item. Cost benefit analysis and more detailed breakdowns are provided where applicable in each of the previous corresponding sections of this proposal.

Table 28: Total Costs by Phase

Phase	Item	Category	Cost
Phase 1	Value Added Items	Labour	$ 800.00
		Equipment	$ 1,200.00
		Materials	$ 48,800.00
		Sub-total	$ 50,800.00
	Parking Lot	Labour	$ 48,560.00
		Equipment	$ 32,450.00
		Materials	$ 315,080.00
		Sub-total	$ 396,090.00
		Phase 1 Total	**$ 694,000.00**
Phase 2	Bio-filtration	Labour	$ 936.00
		Equipment	$ 2,395.00
		Materials	$ 165.00
		Sub-total	$ 3,496.00
	Greenhouse Café	Labour	$ 192,575.38
		Equipment	$ 90,000.00
		Materials	$ 476,331.65
		Sub-total	$ 758,907.03
		Phase 2 Total	**$ 1,184,000.00**
Phase 3	Irrigation	Labour	$ 1,780.00
		Equipment	$ 1,000.00
		Materials	$ 35,583.50
		Sub-total	$ 38,363.50
	Water Retention	Labour	$ 25,800.00
		Equipment	$ 8,640.00
		Materials	$ 31,450.00
		Sub-total	$ 65,890.00
		Phase 3 Total	**$ 162,000.00**
Phase 4	Parkade	Labour	$ 6,564,644.50
		Equipment	$ 3,938,786.70
		Materials	$ 2,625,857.80
		Sub-total	$ 13,129,289.00
	Overhead Walkway	Labour	$ 231,640.00
		Equipment	$ 271,000.00
		Materials	$ 407,410.00
		Sub-total	$ 910,050.00
		Phase 4 Total	**$ 21,797,000.00**

Design and Engineering Fees	35%
Contingency	15%
Project total:	$ 23,837,000.00

8.0 Conclusion and Recommendations

Phased implementation to the proposed redevelopment of the UBC Botanical Garden gives the project feasibility in many regards. Phased enhancements of the garden split up front costs to increase palatability to the UBC funding board. Gradual expansion will allow for development which does not become detrimental to the garden experience at any point in construction. By implementing project components such that each phase builds off the one before it the UBC Botanical Garden will incrementally increase in public perception, thus perpetuating the worth of the following phase.

Phase 1 – Initial Visitation Enhancement
Phase 1 comprises of value added projects and redesign of the current parking lot. The value added items, which are relatively inexpensive, will be the main draw to the Garden. An improvement in signage both outside of and within the garden will draw visitors to the gate as well as direct them through the collections. Simple improvements such as an educational scavenger hunt for children and picnic tables will facilitate a fun- and family-oriented environment enticing people to prolong their stay in the garden, contrary to passing straight through as is current practice. By facilitating this welcoming environment visitors will be able to develop a relationship with the garden, encouraging them to not only stay longer when they visit, but return again and again. This relationship to be built with the garden will thus enhance visitation and merit the final portion of phase 1: the redesign and 25% capacity increase of the current parking lot.
Total cost for phase 1: $694,000

Phase 2 – Construction of Anchors
With the enhanced visitation further infrastructure will be seen as more of an asset to UBC. This allows for implementation of phase 2: the greenhouse café as well as the bio-filtration channel. The greenhouse functions as research facility by providing an additional 70m3 of planting space for temperate plants. The inclusion of a café allows people to observe the collections while patronizing the café thus enhancing garden revenue. As an indoor facility, it is intended to increase visitation during the winter seasons since. The bio-filtration channel functions another anchor. It strives to combine sustainability and horticulture by showcasing the ability of plants to filter contaminated stormwater. Interest in the small bio-filtration facility in the CIRS building at UBC suggests that popularity of this channel would be a notable anchor to the garden. It will also link to a further development in stormwater thus meeting sustainability goals of the campus plan and Botanical Garden alike.
Total cost for phase 2: $ 1,184,000

Phase 3 – Water Management
Moving into the enhancement of sustainability in water management, phase 3 implements systems to meet campus sustainability goals. Construction of a stormwater reservoir and redeveloping the irrigation system facilitates the independence of the Botanical Garden from its current reliance on potable water supply and treatment as well as mitigating erosion concerns. The reservoir has sufficient capacity to retain and moderate storm discharge in the garden which currently causes damage to plants and infrastructure during storm events reducing flows by up to 35%. It is also capable of feeding the irrigation system during the peak summer demand. The redesigned irrigation system increases functionality and efficiency while also decreasing reliance on manual regulation.
Total cost for phase 3: $ 162,000

Phase 4 – Redevelopment Plus
In the final phase, large-scale development is proposed. Targeted at the distant future, this phase includes the parkade structure as well as the overhead walkway. The parkade meets the goal of the UBC campus plan which aims to move parking to the perimeter of campus, thus making the campus core a more pedestrian friendly environment. This structure would be part of the university plan for development which would also benefit the garden by increasing the number of people who will be in a position to see the signage which was improved in phase 1. This results in revenue to UBC through parking, while also encouraging people to visit the garden while they walk to or from their vehicles. With a green roof and living wall it also meets sustainability goals. Likewise, the overhead walkway is a display piece that draws people to the garden. It creates a route for garden visitors to the key anchors: both currently existing as well as part of the redevelopment plan. It makes a loop through the garden, which improves upon the backtracking experience which is currently undertaken by visitors. As a covered walkway, this also entices visitors to explore the garden regardless of the weather thus facilitating year round visitation.
Total cost for phase 4: $ 21, 800,000

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