South Campus Stormwater Detention Facility

Detailed Design Report

Angelica Wong, Bryan Lui, Cristina Oliveira, Jason Chen, Lily Truong, Minwoo (Chris) Park

University of British Columbia

CIVL 446

April 8, 2016

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UBC SOUTH CAMPUS STORMWATER DETENTION SYSTEM

DETAILED DESIGN REPORT

CLIENT

Social Ecological Economic Development Studies
Sustainability Program

DATE

April 8, 2016

MINWOO + ASSOCIATES LTD.
900 Jervis Street, Suite 305
Vancouver, BC V6E 2B4
TEL: 778-863-6482
EMAIL: mail@minwooassociates.com

PROJECT TEAM 12

Angelica Wong
Cristina Kei Oliveira
Minwoo Chris Park
Bryan Lui
Jason Chen
Lily Truong

EXECUTIVE SUMMARY

MINWOO + Associates Ltd. has prepared a detailed design report for the University of British Columbia (UBC) South Campus Stormwater Detention System. The purpose of this report is to provide consultation and engineering design services for the UBC South Campus Stormwater Detention System. The project objectives are to protect UBC campus assets and human life from major storms, reduce cliff erosion and minimize flow impacts on creeks. It is also fundamental to meet UBC's principles of sustainability and provide a long-term solution as per the UBC Integrated Stormwater Management Plan.

The recommended design consists of four decentralized underground stormwater detention systems throughout South Campus with unique landscaping to accommodate community use and values. This includes a community garden in Acadia Park, a garden maze at the intersection of SW Marine Drive and Wesbrook Mall, and a rainwater-harvesting unit at the UBC Farm. All components will include modular drainage cells, called Eco-Tanks, as a sustainable method of underground stormwater detention. The volume capacity for the components incorporates a factor of safety and accounts for projected changes in impervious surfaces and/or rainfall intensity throughout its service life. Detailed drawings provide specifications and dimensions for all the components in the system.

A stormwater model analysis has been carried out using EPA SWMM to examine the performance of the proposed system after integration with the existing stormwater network. The model was used in the optimization of the design details by analyzing flow rates, and specifying the operation and maintenance of the infrastructure and components.

Based on the design details and specifications, the cost estimate for this design is determined to be CAD $4,690,240 excluding tax with a construction schedule spanning from April to December 2016. The report also includes a sensitivity analysis of design parameters, environmental and social impact analysis, and additional recommendations.

Overall, the design meets project objectives and key criteria for the implementation of a successful system. It incorporates elements reflecting the values of the Wesbrook Mall Community and the University Neighbourhood Association, while achieving a positive social and sustainable impact. By integrating the proposed design into the existing UBC South Campus Stormwater Detention System, the system will be better suited to manage minor storms, prevent severe flooding during large storm events, and reduce cliff erosion.

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1.0. INTRODUCTION

In the past two decades, UBC South Campus has gone through transformative development, and it is now a thriving residential hub with increasing commercial and institutional spaces. As such, this level of development has increased the amount of impervious surfaces and thus stormwater surface runoff. There is a need for a more robust stormwater management plan on the South Campus in order to reduce high flows into creeks, minimize potential cliff erosion, and safeguard human life and assets in the event of a major storm. The scope of the project is to design a stormwater detention system that can manage a 10-year and a major 100-year storm event in the UBC South Campus. The purpose of this report is to provided consultation and engineering design services for the UBC South Campus Stormwater Project.

MINWOO + Associates Ltd. (MINWOO) has been retained by the University of British Columbia Social Ecological Economic Development Studies (SEEDS) Sustainability Program for the consultation and engineering design of the UBC South Campus Stormwater Detention System. The detailed design report elaborates on the stormwater detention system design with emphasis on material requirements, external dimensions, and operating parameters of individual detention site components.

This report includes an overview of the project and the constraints, a description of the stormwater detention system design, and detailed specifications of individual design components. Other sections include a stormwater management modeling analysis, an anticipated schedule of implementation, final construction plans, a Class A cost estimate, a sensitivity analysis of the design parameters, and an assessment of the environmental impact.

2.0. PROJECT DESCRIPTION

2.1. SITE OVERVIEW

UBC is located on the Point Grey Peninsula bounded by sea cliffs, residential areas in Wesbrook Village and Pacific Spirit Regional Park. The focus of this Project is within the South Campus as shown in Figure 1. It has a total landmass of 178.4 hectares (Piteau Associates, 2002) and is bordered by Acadia Road and Binning Road on the east, South West Marine Drive on the southwest, and Thunderbird Boulevard and West 16th Avenue on the north.

Key locations of the South Campus where surface flooding is anticipated during a 100-year storm event include Acadia Park, the intersection at West 16th Avenue & Wesbrook Mall, TRIUMF, and the intersection at South West Marine Drive & Wesbrook Mall (GeoAdvice, 2013).

Figure 1 – UBC South Campus and University of Endowment Lands Boundaries.
Source: Adapted from https://maps.google.ca by Bryan Lui (2015).

The South Campus Catchment Area (South Campus) initially held large tracts of undeveloped land. However, a rise in residential, commercial and institutional development in the area has increased the amount of hard surface on campus over the last two decades. This resulted in an expansion of surface run-off as well as the potential of flooding during high and sustained precipitation. Precedent stormwater modeling studies performed by Urban Systems and GeoAdvice consultants on May 25, 2011 and June 11, 2013, respectively, and analysis during preliminary design confirmed that the South Campus is at high risk of substantial flooding in excess stormwater of 7200 m3 during a 100-year storm event.

2.2. PROJECT SCOPE AND OBJECTIVES

The scope of this project is to design a stormwater detention system that can manage a 10-year and major 100-year storm event. The proposed stormwater detention design shall encompass discharging stormwater flows to the outfall creeks at controlled levels and meet water quality requirements as set out in Section 36 of the Fisheries Act (1985) and guided by Metro Vancouver's Liquid Waste Management Plan (Metro Vancouver, 2010).

Design objectives include safeguarding human life, mitigating impacts to UBC campus assets and livelihood, and reducing cliff erosion during major floods and frequent minor storms. The design should also adhere to UBC's principles of sustainability, demonstrate environmental stewardship, and provide a long-term solution, integral in the 2015 UBC Integrated Stormwater Management Plan. Sustainability will be attained through:

- Protection and enhancement of the natural environment through conservation or development of natural capital
- Provision for ongoing prosperity through conservation or development of economic capital

- Creation of community and social cohesion through conservation or development of social capital

2.3. KEY ISSUES

As stated above, precedent stormwater modelling studies have determined that significant surface runoff in the South Campus can occur during a major storm event. As a result, existing negative impacts need to be eliminated or mitigated. Existing negative impacts include the following:

1 Damage to UBC property and livelihood assets caused by overland flooding.
2 Damage to riparian habitats and fish living near the creek discharge due to contaminated water quality in surface runoff.
3 Continuous cliff erosion near the unnamed creek as shown in Figure 1 and on the south end and west side of the South Campus due to increased quantities of sustained precipitation discharge (Metro Vancouver, 2010).

2.4. HYDROGEOLOGICAL BACKGROUND

A typical soil profile surrounding the UBC peninsula cliffs consists of silts, clays, sands and glaciomarine deposits. Profile layers are described below in Table 1.

Table 1 – Soil Profile Layers of UBC Peninsula Cliffs

Elevation From Sea Level (m)	Soil Layer
68 to 69	**Capilano Sediments:** Beach gravels, glaciomarine silt to clay loam
65 to 68	**Vashon Drift:** Sandy, loamy till
20 to 65, 10 to 12 and 0 to 3	**Quadra Sand Unit Q1:** Fine to coarse sand, with minor silt and gravel
12 to 20 and 3 to 10	**Quadra Sand Unity Q2**: Interbedded silt, fine sand and minor peat

It is recommended that a geotechnical investigation be carried out to confirm the underlying soil conditions and bearing capacities where proposed detention facilities are to be constructed.

Boreholes and water level monitoring performed by Sonic Drilling Ltd. and Mud Bay Drilling Company Ltd. suggest that the water table is at a depth of 45 to 60 m below ground surface (Piteau Associates, 2002). There exists both an Upper and Lower Aquifer below the Vashon Drift in between the Quadra Sand layers. When precipitation occurs, water seeps into the ground and rests on top of the underlying low permeability till layer where it flows either along the surface of the till layer or seeps through it. Organic living matter will intercept some of the water that flows on the surface while the rest of the surface water will flow out from the cliff face. The water that seeps through the till layer, makes it into the underlying Upper and Lower Aquifers of the Quadra Sand layer and discharges along the cliff face or at slightly below sea level where it discharges into the beach deposits and is not visible. Water that flows from or out of the cliff face is an underlying origin of cliff erosion.

Precipitation falling on South Campus can be redirected or transferred by evapotranspiration, surface runoff, or infiltration into the ground; the latter two contribute to cliff erosion and water quality contamination. Evapotranspiration takes significant time and is unlikely to be the main method of precipitation removal. Infiltration into the ground is becoming increasingly limited by the rapid land development currently taking place and the increasing ratio of non-permeable lands (such as roads and buildings) to green-field sites. As such, precipitation is less likely to seep into the ground. Nonetheless, flow over land surface is and will remain the main method for removal of precipitation. Therefore, UBC will require an improved runoff management system in place to control the increased quantities of runoff over a short duration of time and prevent issues as outlined in Section 2.3 – Key Issues.

3.0. DESIGN CRITERIA AND CONSTRAINTS

3.1 DESIGN CRITERIA

A design criterion was used in choosing and optimizing the design to meet and exceed the project objectives. The criteria considered in the design are listed in Table 2 below.

Table 2 – Criteria Description

Criteria	**Description**
Cost	Design option cost
Community Acceptance and Aesthetics	Community acceptance on the proposed design
Environmental Concerns	Use of sustainable materials, practices, and considerations in the design
Constructability	Construction efficiency, complexity, duration, and disruption
Area Usage	Optimal use of available space
System Lifespan	Design's functional use and years in operations
Operation and Maintenance	Work and funding involved in the operation and maintenance of the system
Vulnerability	Sensitivity and resilience of the design to potential disasters

3.2 DESIGN CONSTRAINTS

3.2.1. Jurisdictional Boundaries and Regulations

UBC's Point Grey Campus does not fall under any regional municipalities. It is an independent authority that sets its own regulations and practises complying with the provincial and federal jurisdiction. However, the Point Grey Campus is adjacent to South West Marine Drive, which is owned by the Ministry of Transportation and Infrastructure (MOTI) where culverts are transporting stormwater from the South Campus to the outfalls cross. Stormwater in the area flows through ditches along MOTI's roads and reaches the culverts that end at the outfalls to the Pacific Ocean under the jurisdiction of the Federal Department of Fisheries and Oceans (DFO). Additionally, a portion of the stormwater in the South Campus flows to Metro Vancouver's Pacific Spirit Regional Park (PSRP). See Figure 1 below for the jurisdictional boundaries surrounding South Campus. Therefore, not only does the stormwater detention facility require compliance with UBC's regulations, it must also comply with regulations under MOTI, DFO and Metro Vancouver.

Figure 2 – Jurisdiction Map.
Source: Adapted from https://maps.google.ca by Bryan Lui (2015).

3.2.2. Space Limitations

The South Campus is surrounded by forest along the south side, the west side, and partially on the north. Logging trees is strictly regulated by the UBC Campus and Community Planning, and entails a complicated process and additional permits. Undeveloped fields, which are suitable for stormwater management facilities, are limited in area or occupied by research facilities such as the UBC Farm and TRIUMF. Therefore, careful considerations must be taken in determining feasible locations for stormwater detention facilities.

3.2.3. Environmental Concern

Stormwater in the South Campus flows down to outfalls located in the Pacific Spirit Regional Park, exposing its natural habitats to danger. The destruction of natural habitats due to the uncontrolled quality, quantity, and flow rate of stormwater could lead to a severe impact on the ecosystem in the area. The existing cliffs are prone to erosion owing to its geological characteristics; hence, controlling the quantity and flow rate of the stormwater is significantly important.

3.2.4. Local Flooding Areas

The four flooding areas mentioned above in Section 2 - Project Description also influence the arrangement and location of the stormwater system components. It is important to ensure stormwater, at different locations of South Campus, is simultaneously captured in controlled levels to eliminate flooding at the four local flooding areas during a 100-year storm event.

3.2.5. Geological Characteristics

The South Campus generally slopes toward southwest as shown in Figure 3 below. When making decisions on stormwater detention facility locations, the site topography is considered in order to minimize the number of required pumps and instead rely on gravity conveyance to transport stormwater to proposed detention facilities.

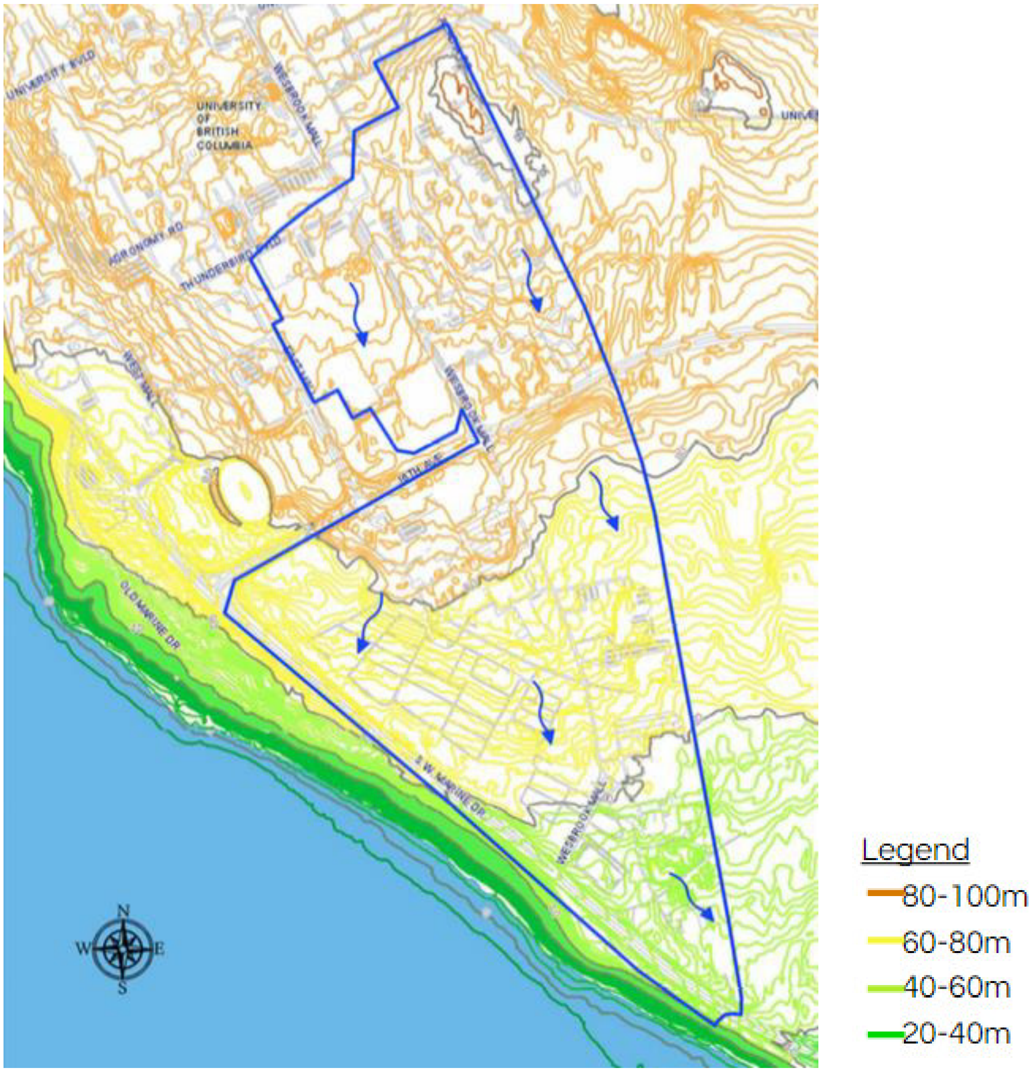

Figure 3 – UBC South Campus Contours and Hydrogeological Flow.
Source: Adapted from https://maps.google.ca by Bryan Lui (2015).

Based on the information on the hydrogeological research done by Pottinger Gaherty Environmental Consultants Ltd., the South Campus' geologic composition is a low permeability cap near the surface, limiting vertical infiltration. Taking this into consideration, an assumption is made in the calculations for the volume of stormwater received in the detention systems that the proportion of infiltrated water volume to total stormwater volume would be as follows:

Table 3 – Proportion of Infiltrated Volume to Total Received Stormwater at Different Locations

Location	**Infiltrated Volume to Total Received Volume**
UBC Farm	50%
Pacific Spirit Regional Park	50%
Vegetated areas along SW Marine Dr.	20%
Acadia Park	20%
West 16th Avenue	20%
Other Paved areas	0%

A safety factor applied to all components of the design accounts for potential increased imperviousness due to further development or existing soil conditions, which will be discussed in Section 13 - Sensitivity Analysis.

3.2.6. Economic Concerns

The available budget for the construction of stormwater detention facilities has not been identified by the UBC Campus + Community Planning. The economic aspects in engineering designs play a highly significant role. With a fairly limited budget that most educational institutions have, it is always beneficial to accomplish a project at a reasonably low cost while meeting or exceeding design requirements and performance quality.

3.2.7. Construction Planning

The work tasks and construction sequences have been defined based on the design for the specified detention facility. Concurrently, the construction method will be developed with the detailed design. The detention facilities are located either at residential areas or constricted spaces. Therefore, the movement of heavy and large equipment such as excavators and trucks is restricted. In order to minimize traffic disruption on campus, road traffic control will be implemented to direct vehicular and pedestrian flow. See Section 15 – Construction Work Plan for further details.

3.3 ASSUMPTIONS

According to Acadia and Toronto Roads Updated Preliminary Geotechnical Report by exp Services Inc. (2015), the regional water table is situated approximately 45 to 60 m below grade. Therefore, it is reasonable to assume that the location of the water table has a negligible impact on the design.

The existing South Campus stormwater system's information, such as the pipe diameters, configurations, elevations and roughness coefficients, are identified in the *UBC Storm Model Base Physical* EPA SWMM file, provided by the client. These parameters are assumed to be the most recent and representative of the current network.

Pacific Climate Impacts Consortium (2012) suggests that in the 2050s, the Lower Mainland is expected to receive a precipitation 7% greater than the 1961 to 1990 baseline. Considering the average yearly precipitation of Vancouver during 1981 to 2010 being 1,457 mm, the 7% increase by the 2050s is calculated to be 102 mm (Current Results, 2015). This projected increase in precipitation has been taken into account with a safety factor of 1.5 during design; therefore, the impact of climate change on the project is regarded as insignificant demonstrated in Section 13 – Sensitivity Analysis.

4.0 STAKEHOLDER VALUES ANALYSIS

4.1 UBC SUSTAINABILITY VISION

UBC began their journey to become a global leader in sustainability in 1990. Since then UBC has made remarkable achievements in diverse fields. One of the best examples that UBC strives to become a sustainability thought and practice leader is that UBC has developed the 20-Year Sustainability Strategy for The Vancouver Campus and actively made efforts to achieve their Sustainability Targets in greenhouse gas emissions, waste, transportation, green buildings, community and teaching, learning and research. In 2015, the Vancouver Campus successfully made 33% reduction on greenhouse gas emissions compared to the level in 2007 and the strategy aims to reduce greenhouse gas emissions by 100% until 2050 (UBC Sustainability, 2014b).The Integrated Stormwater Management Plan is not particularly included in the Sustainability Targets. However, UBC's desire to promote sustainable and regenerative practices on the Vancouver Campus is the driving force of the existing and upcoming stormwater management projects.

4.2 UNIVERSITY NEIGHBOURHOOD ASSOCIATION VALUES

The University Neighbourhood Association's (UNA) vision includes bringing new rental and family housing opportunities, providing sustainable development, and offering quality community amenities to UTown@UBC. It is a vibrant residential community in the Point Grey campus that accommodates over 18,000 students, faculty, staff and other residents. By providing cultural amenities, shops, services, parks, and public transportation all within walking distance, the UNA's five neighbourhoods – Chancellor Place, East Campus, Hampton Place, Hawthorn Place, and Wesbrook Place – help residents of UTown@UBC live in a place where innovative, sustainable and green building designs are actively involved (UBC Sustainability, 2014a).

5.0 DESIGN OVERVIEW

5.1 DESIGN COMPONENTS

The proposed stormwater detention system consists of four underground facilities with a variety of surface features. These are located at: (1) Acadia Park with an overtop community garden, (2) The intersection of West 16th Avenue and Wesbrook Mall, (3) The UBC Farm with a rainwater harvesting element, (4) The intersection of Wesbrook Mall and SW Marine Drive with an overtop maze garden. All component locations are shown below in Figure 4. A detailed description of each component and their specifications are provided in Sections 6 to 9, and detailed design drawings attached as Appendix B – IFC Drawings.

Figure 4 - Design Component Locations.
Source: Adapted from https://maps.google.ca by Bryan Lui (2015).

The volume design of the components is based on the necessary storage volume to prevent major surface flooding during a 100-year storm within their respective catchment areas. To reduce creek and cliff erosion from minor and major storm events, all the detention components have been designed for a discharge rate of 0.2 m^3/s. As such, the design seeks to safeguard human life and assets. The design is also devised to meet sustainability criteria, which includes community acceptance and safety, minimal environmental impact, reduced vulnerability, and improved discharge water quality. See Appendix A – Design Calculations for stormwater volume calculations.

5.2 SUSTAINABILITY APPROACH

UBC places a strong emphasis on pursuing a sustainable engineering solution to its infrastructure development. Consequently, it is important to implement sustainable engineering solutions in the stormwater management system. In order to have a sustainable approach, the proposed design consists of green solutions such as the use of Eco-Tanks and the incorporation of rainwater harvesting, a community garden, and a hedge maze.

Green solutions improve and enhance existing brownfield sites through the development of natural capital and conservation at Acadia and the UBC Farm. The UBC Farm will have the additional feature of using captured stormwater for irrigation, thus reducing reliance on potable water mains. Such green solutions are also aesthetically pleasing, act as a social hub, and are welcoming features in the communities at Acadia and Wesbrook Place. This increases social capital in the surrounding neighbourhoods. Furthermore, economic capital is conserved since three of the proposed detention facilities (Acadia, West 16th Avenue and UBC Farm) are located at already-developed or brownfield sites and will not reduce the area for future income generating property. To a lesser extent, green solutions will contribute to the development of local economic prosperity since they require annual landscaping maintenances services.

The detention system design will also qualify for sustainable site credits (for other surrounding development projects) as per LEED NC-2009 in SSC 6.1 – Rate and Quantity and SSC 6.2 – Treatment (Kipkie, Vancouver LEED Users Group).

5.2.1 ECO-TANKS

The underground water detention system will consist of Eco-Tanks, a group of lightweight modular drainage cells that form a cage-like structure depicted in Figure 5 below. Eco-tanks are made of 100% recycled polypropylene and allows for 95% voice space. This type of system permits the options of inflow by surface infiltration or pipes. It also requires less excavation compared to traditional concrete tanks, and is easy to transport to site.

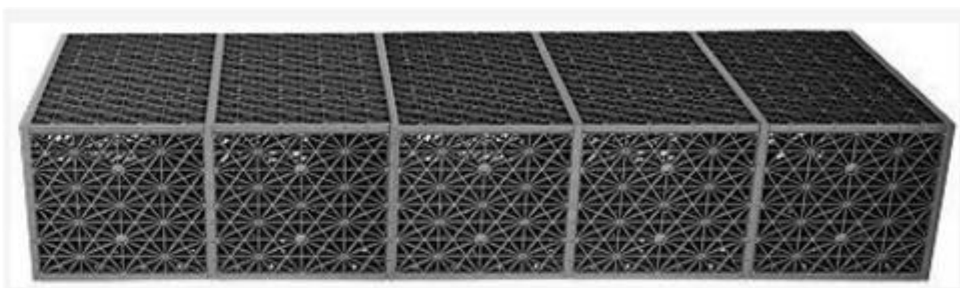

Figure 5 – Penta Size Flo-Tank © Eco-Tanks.
Source: Retrieved from Atlantis America Green Cities for Life at http://www.atlantisamerica.com (2015).

Atlantis Penta D Raintanks, or equivalent, should be used as the Eco-Tanks for underground detention. Each individual tank has dimensions of 0.685 x 0.408 x 2.17m (length x width x depth), and a storage capacity of 576 liters. A specification sheet with the compressive strength capacity and other structural parameters is included in Appendix C – Material Specifications & Standards. When the tanks are installed, they are wrapped in geotextile fabric to keep soil from entering the tanks' void space. A polypropylene liner can be included if the tanks are intended to detain water without underground infiltration. A layer of sand is often placed over the tanks, which increases infiltration rates and serves as a filtration mechanism for better quality discharge. The bottom of tank should be a minimum of 3.2m below the finished ground surface to allow for adequate soil cover and protection from frost.

5.3 DESIGN LIFE AND MAINTENANCE

5.3.1 DESIGN LIFE

The estimated service life of the design is determined based on the life of the modular drainage tanks since they are the most prominent feature in the system. Other materials and components involved will be considered under maintenance and upkeep.

Recycled polypropylene drainage modules are a relatively new product for stormwater use. As such, different producers and commercial venues do not specify a service life for the product. However, polypropylene is commonly used in piping and a service life for the recycled polypropylene drainage cells can be inferred from it. A report by The European Plastic Pipes and Fittings Association (TEPPFA, 2014) on polypropylene pipes specifies a service life of 100 years, based on theoretical considerations and empirical data showing no significant reduction of properties after 23 years of service life. The report considers factors such as thermo-oxidative degradation, mechanical integrity (stress and strain), effects of sewer water, and excavation. As a material, polypropylene is strongly affected by UV exposure as it can reduce its strength and limit its life span (INEOS Olefins & Polymers USA, 2007).

Although the material geometry and method of use presented in the TEPPFA report (2014) is not the same, the report aids in understanding the material in a more holistic manner. In the case of this design, the Eco-Tanks will not be exposed to UV radiation since they will be placed underground, and will not be affected by sewer water. However, in this design, the material will be made of recycled polypropylene and comprises of a different geometry and loading. Under these considerations, the design is estimated to have a 70-year design life.

5.3.2 Maintenance

In order for the proposed system to continue operating efficiently throughout its design life, regular maintenance will be required. During installation of the Eco-Tanks, inspection and maintenance ports should also be installed (Atlantis Water Management, n.d.). The inspection ports allow for camera probing of the tank interior, while maintenance ports allow for high-pressure backwash of the facility in case of sediment accumulation. Inspections should be carried out semi-annually, and after heavy rainfall events (Rainwater Management, 2014).

The ground surfaces above the detention facilities will also require regular maintenance. This includes trimming of the hedge maze, and landscaping of the facilities at West 16th and the UBC Farm. The community garden at Acadia Park is to be maintained by the neighbourhood residents.

The components of the stormwater harvesting system at UBC Farm will require regular inspections to ensure proper filtration of stormwater prior to use for irrigation. Both the oil-and-grit separator and pump will require monthly inspections, and cleaning when deemed necessary.

5.4 DESIGN BENEFITS

This design supports the South Campus aesthetics and considers the integration of community values. The community garden is a surface feature that provides neighbourhood residents a place to grow vegetables, promoting community building. The stormwater harvesting component at the UBC farm is a feature that represents UBC's commitment to sustainability ingenuity and appreciation. Lastly, the maze garden will provide a unique community feature and a new gateway to the South Campus. Overall, the components are chosen to suit the location and are designed for safety and community aesthetics, especially since the South Campus is largely residential.

Environmental concerns are reflected in the choice of Eco-Tanks as a more sustainable alternative to concrete tanks, in terms of the material and method of construction. The use of Eco-Tanks also allows for straightforward implementation of filtration techniques to improve the quality of stormwater before discharge into outfall creeks. Where necessary, filters can be placed alongside the Eco-Tank assembly. In cases where stormwater infiltrates into the Eco-Tanks, the water must trickle down through an overlying layer of sand which serves as a natural filtration method to remove sediments. This design also considers the overall environmental impact of implementation and discusses mitigation and offset plans in Section 12 - Environmental Impacts and Considerations

By having a decentralised and mixed approach to stormwater detention, the design becomes less vulnerable and more resilient to any natural disasters or unforeseen events, whether at the surface or subsurface, that could compromise the system. The decentralised and diverse design allows for the system to still function and retain storm water, although limited, in case of a loss in capacity of one of the components.

6.0 COMPONENT 1: COMMUNITY GARDEN DETENTION AT ACADIA PARK

6.1. DESIGN OVERVIEW

The detention facility of the Acadia component is at the intersection of Acadia Park Lane and Fairview Avenue, adjacent to the UBC Acadia Commons Block. This location is situated in a residential district. After installation of the tanks, a proposed community garden is constructed on the overlying area, offering Acadia neighbourhood residents a place to grow vegetables and build community values. As shown in Figure 6the garden is composed of 40 standard garden plots whose width, length, and height are 5ft, 10ft, and 1.5ft respectively. Three catch basins whose diameter is 6 inches are installed to help collect rainwater sitting on the garden floor. A wooden fence is installed all around to prevent vandalism and trespassing. Overflow pipes connect the system to the existing stormwater system.

Figure 6 – Community garden Plot Arrangement.
Source: Adapted from https://maps.google.ca by Chris Park (2016).

6.2. DESIGN SPECIFICATION

The underground tank will have a storage capacity of 1425 m^3, covering a surface area of approximately 730 m^2. A total of 2600 Eco-Tanks will be required at this location. Layers of clean sand, clear crush gravel, and mulch are required above the tank. Details of this component are illustrated in Drawing 2, 6, and 7 of Appendix B.

7.0 COMPONENT 2: DETENTION AT WEST 16TH AVENUE AND WESBROOK MALL

7.1. DESIGN OVERVIEW

A detention facility at the intersection of West 16th Avenue and Wesbrook Mall is located at the northeast corner of the intersection. This will reduce the potential for surface flooding at this key location. Due to space limitations in the area, it will have the smallest storage capacity of the proposed components. The existing grass vegetation at ground surface will be restored to its original state after installation of the Eco-tanks.

7.2. DESIGN SPECIFICATIONS

The underground tank will have a storage capacity of 1000 m3, covering a surface area of approximately 500 m^2. A total of 1760 Eco-Tanks will be required at this location. Details of this component are illustrated in Drawings 3 and 8 of Appendix B.

8.0 COMPONENT 3: RAINWATER HARVEST AT UBC FARM

8.1. DESIGN OVERVIEW

Underground Eco-tanks at the southwest corner of the UBC Farm will be one of the largest components of the proposed system, acting as storage for stormwater from the southwest portion of South Campus. This component provides a method of stormwater harvesting for irrigation purposes. However, stormwater a filtration system will need to be implemented to ensure adequate water quality

An oil-and-grit separator with manhole and bypass should be installed upstream of Eco-tanks for initial treatment of stormwater, the process of which will remove up to 61% of Total Suspended Solids, 52% of heavy metals, and 50% of oil and grease. The surface of the eco-tanks should be covered with a layer of filter media (geotextile, sand and gravel) to clean rainwater collected on the surface of the facility. Additional tanks should be installed for storage capacity along with a recovering pump for irrigational use.

8.2. DESIGN SPECIFICATIONS

The underground tank will have a storage capacity of 2475 m^3, covering a surface area of approximately 1225 m^2. A total of 4366 Eco-Tanks will be required at this location. Details of this component are illustrated in Drawings 5 and 10 of Appendix B.

9.0 COMPONENT 4: MAZE GARDEN DETENTION AT SW MARINE DRIVE AND WESBROOK MALL

9.1. DESIGN OVERVIEW

The facility at the north corner of the intersection of SW Marine Drive and Wesbrook Mall will be the other large component of the proposed system, matching the capacity of the component at the UBC Farm. The majority of flows from the other facilities, and from the existing stormwater main will flow to this location, with the stormwater being released at controlled rates. This location is along a key route into UBC. Therefore it is proposed to implement a maze hedge garden as landscaping after construction of the detention facility. This will act as an interactive feature for the UBC community, as well as creating a south gateway to UBC. A rendered image of the maze hedge garden is shown in Figure 7.

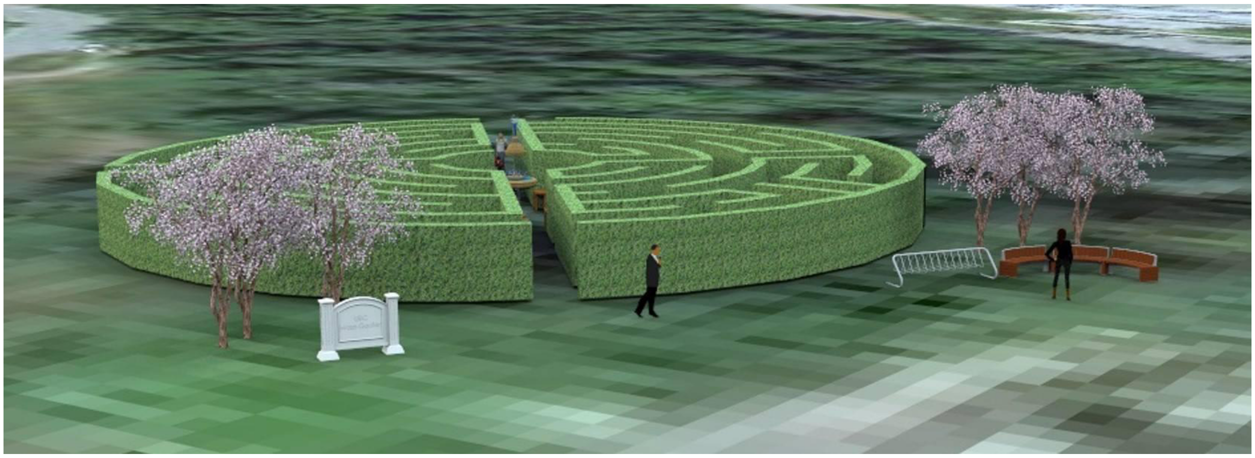

Figure 7 – Maze Hedge Garden.
Source: Adapted from https://maps.google.ca by Angelica Wong (2016).

9.2. DESIGN SPECIFICATIONS

The underground tank will have a storage capacity of 2475 m^3, covering a surface area of approximately 1225 m^2. A total of 4366 Eco-Tanks will be required at this location. Details of this component are illustrated in Drawings 4 and 9 of Appendix B.

10.0 SYSTEM MODELING

10.1 EPA SWMM MODEL

In order to better understand the performance and integration of the proposed design components, the components were integrated into UBC's provided EPA Base Stormwater Management Model (EPA SWMM 5.1). The purpose of the model is not to design but to serve as a tool for understanding the potential behaviour of the design under certain conditions. The Base Storm Model includes the stormwater pipe network for the entire campus under a 1 in 10 year storm condition and the laid-out sub catchment areas with their appropriate perviousness coefficient considerations.

A storm hydrograph was developed in order to simulate a 1 in 100 year storm event and can be seen below in Figure 8. A factor of 1.5 taken from the 24 hour IDF curve was added to the 1 in 10 year hourly rainfall pattern to scale for a 1 in 100 year event.

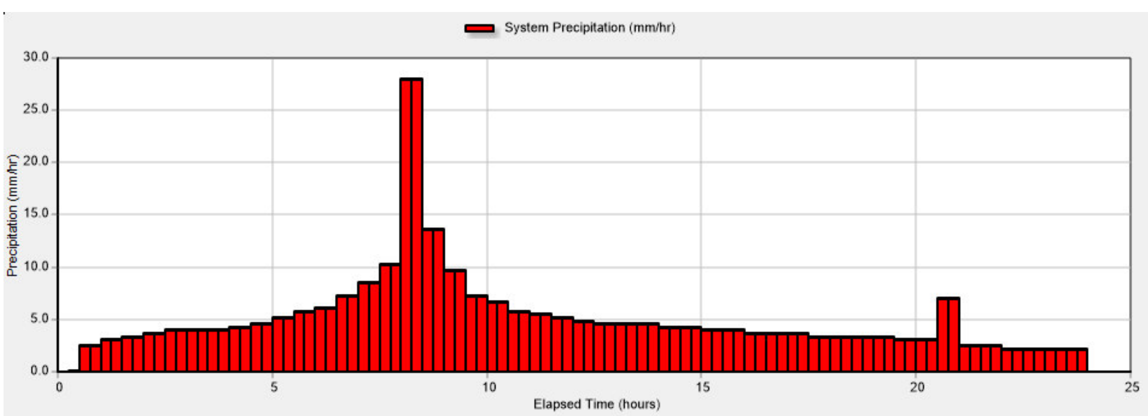

Figure 8 – 1 in 100 Year Storm Hydrograph.

A simple topographic map was scaled and added to the model to serve as a reference for street locations and approximate elevations, as can be seen below in Figure 9. However, surveying should be conducted in order to incorporate more accurate elevation values, which informs pipe lengths and slopes.

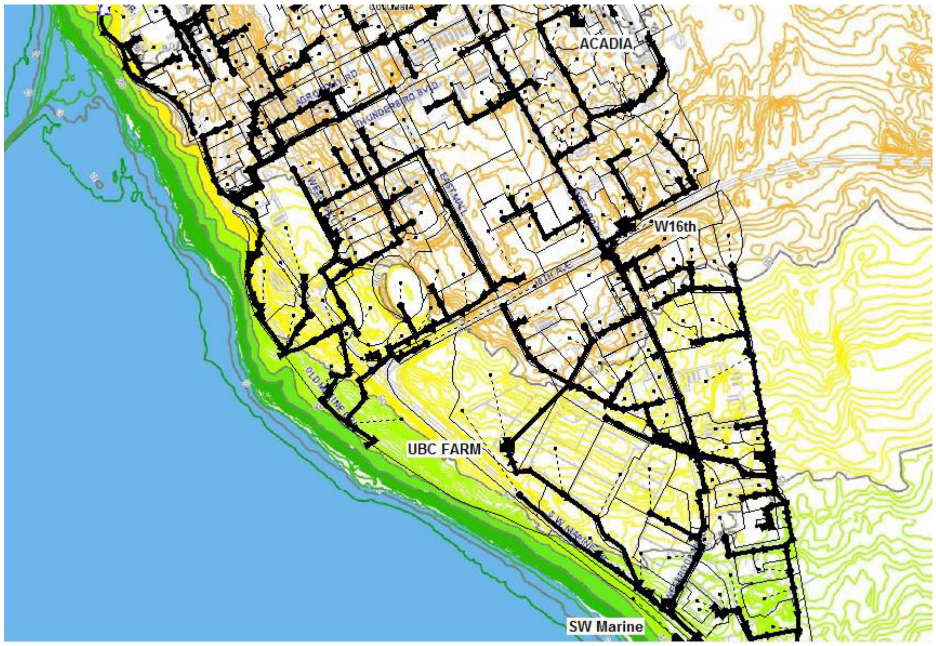

Figure 9 – Modified Base Model with Topographic Contours.

10.2 NETWORK INTEGRATION

All four detention components were added to the model with additional pipes connecting them to the rest of the network. Storage curves were created for each component based on the designed detention volumes and dimensions. Storage nodes were placed in the positions of their designed locations and with an inlet elevation based on approximated surface elevations. The distance from the invert of all components to the surface elevation includes 0.9 m of topsoil and 2.17 m of tank depth. A summary of the parameter inputs for each storage node can be seen in Table 4.

Table 4 – Storage Node Input Summary

Storage Node	Depth (m)	Area (m^2)	Invert Elevation (m)
Acadia	2.17	35.6 x 20.4	94.43
West 16th Ave	2.17	8.2 x 60.3	84.93
UBC Farm	2.17	30.2 x 40.4	67.78
SW Marine and Wesbrook Mall	2.17	30.2 x 40.4	49.43

These storage nodes were connected to adjacent pipes in order to allow for inflow from its upstream areas. The pipe roughness for all inflow connections were 0.013 and the pipe diameters were similar to that of adjacent pipes. The outflow connections were modeled as "Orifices Links" in order to control the outflow for each storage unit. Smaller values for orifice height and discharge coefficient were chosen for storage locations requiring more controlled outflows. The UBC Farm had a discharge coefficient of 0.1 to allow for more retention due to the rain harvesting component. Since the detention volumes were designed and calculated based on an outflow of 0.2 m^3/s, the orifice parameters were mostly arranged to follow suit. A summary of the input parameters for the inflow and outflow connections are presented below in Table 5 and a diagram of each integrated component are shown in Appendix B.

Table 5 – Inflow and Outflow Link Input Summary

Storage Node	Inflow connection (node)	Inflow Pipe Diameter (m)	Orifice Outflow connection (node)	Circular Orifice Height (m)	Circular Orifice Discharge Coefficient
Acadia	J9D-S291A	0.4	J9D-S291	0.40	0.4
West 16th Ave	N8D-S265A	0.75	N8D-S264	0.35	0.4
UBC Farm	P6D-S284	0.6	USL-71	0.40	0.1
SW Marine and Wesbrook Mall	T6D-S25	1.4	USL-50	0.35	0.4

10.3 MODEL PERFORMANCE

The overall system performance was analysed in terms of the changes of storage unit depth, orifice outflow rates, and the overall system outfall discharge rate. All tables and graphs for the model performance for both minor and major storms are provided in Appendix D – SWMM Network.

Minor Storm Event

The storage unit summary report table in Appendix D shows the average percent in which the component is full during storm event, the maximum percent full, the hour of peak volume, and the maximum outflow that occurs during the 24 hour period. The report also shows a graph of the water depth in the storage unit at every hour. For a 10 year storm, W16th Av., UBC Farm, and SW Marine Drive components quickly increase depth with time, reaching full or near-full capacity during peak hour before reducing depth through discharge. The UBC Farm depth however, remains at a high depth with a low discharge rate in order to allow for harvest after. Overall, the four components were full for a maximum of 66% of the time. The orifice outflow volume remained at a desired level below 0.2 m^3/s. The final outfall discharge was on average below the desired rate of 1.2 m^3/s which is important for reducing avoid cliff erosion. Due to the larger frequency of minor storms, cliff erosion from the outfall discharge is the main concern in the system performance.

Major Storm Event

For 100 year storm, a similar pattern is observed for the storage units, however full capacity is reached quicker and remains full for a larger percent of the time. There is also an increase in maximum outflow rate from each component. Both storm events demonstrated room for the Acadia component to receive more inflow volume. This can be done through further pipe rearrangement in order to cover a larger catchment area than what is delineated in the model. The orifice outflow volume remained at a desired level below 0.2 m^3/s and the outfall flow rate was on average 1.6 m^3/s. During a major storm, the main concern is adequate overland flood routing rather than cliff erosion. For the peak time of 8:15 am shown in Figure 10 – Node Flooding and Link Capacity at 8:15 AM for a 1:100 Year Storm.below, some of the conduits are operating at full capacity, however none of the nodes show signs of local flooding.

Figure 10 – Node Flooding and Link Capacity at 8:15 AM for a 1:100 Year Storm.

10.4 MODELING ASSUMPTIONS AND LIMITATIONS

The SWMM of the detention components was integrated into an existing base model. As such it was assumed that the information provided by the base model was the most accurate and recent for the purpose of this project. This includes impervious land area, catchment runoff coefficients, node elevations and any updates in the stormwater pipe network. There was no information on when the base model was created, what kinds of assumptions were used, and any limitations that were found. The model also approximates sub-catchment areas and considers all the runoff for that area to be received by one point outlet. The proper implementation of the components into the system will require a topographic survey in order to know the ground elevation at each location. It will also require considering other underground utilities that may be in the way of pipe connection. This will inform the slope and pipe length required.

11.0 ADDITIONAL RECOMMENDATIONS

11.1. FIELD INVESTIGATIONS AND TESTS

Further field investigations and tests are required to confirm the existing site conditions and ensure no construction conflicts exist on site. Underground utilities locate and surveying should be completed prior to any field tests. This is to ensure that existing underground utilities are properly located on site and drawings are the most up to date. If there are any discrepancies between the drawings and existing conditions found on site, the drawings will need to be updated and any design conflicts found are to be resolved immediately.

Once the utilities locate and surveying is complete, borehole testing and test pits need to be done to determine soil type and conditions. These tests will confirm the soil conditions and locations of any hazardous and/or contaminated soils, should it exist.

11.2. BIO-FILTER SWALE ENHANCEMENT

When combined with trees, swales are an excellent tool for filtering groundwater, reducing soil runoff, capturing water for agriculture, and creating rich, green landscapes. Appropriate to both dry and humid temperatures, steep slopes and flatlands, urban and rural areas, swales hold water for several days, until it is gradually absorbed into the soil (Creating Sustainable Landscapes, 2015). Swales capture runoff and direct the flow of water to a pool or detention tank. For these reasons, upgrading the existing swale along South West Marine Drive will enhance the road runoff sheet flow routing and the water quality. The side slopes of the swale should be graded to a maximum slope of 3:1 (Kerr Wood Leidal Associates Ltd., 2012).

11.3. ADDITIONAL PIPE CONNECTIONS

Additional pipes will need to be installed in order to connect the detention components to the existing stormwater pipe network. The Stormwater Management Model from Section 10 – System Modeling provided a general overview of how this arrangement can be achieved. However, more detailed information on the current pipe network arrangement, specific locations, and elevations as well as details on other underground utilities is needed. Pipe network arrangements should follow the subsequent recommendations:

- Adjust slope to maintain velocity between 0.6 and 3.0 m/s
- Maintain a roughness coefficient of 0.013 and same material as existing pipes
- Maintain a minimum depth underground of 1.5 m
- Maintain a vertical utility clearance of at least 0.3m
- Include an inlet offset of 5 cm after a manhole connection
- Include additional catch basins directing water into detention tanks

Most of these requirements are outlined in greater depth under the City of Vancouver Utilities Design & Construction Manual.

12.0 ENVIRONMENTAL IMPACTS AND CONSIDERATIONS

It is important for any new project to consider the potential impacts that can incur on the environment, especially since sustainability is a core principle at UBC. Based on the 2013 – 2014 Annual Sustainability Report, UBC's overarching sustainability goals for Operations and Infrastructure include reducing greenhouse gas emissions by 33% of 2007 levels, conserving water and reducing waste. Key potential environmental impacts for this project have been identified as follows:

- Cutting trees and clearing natural environments
- Impacting natural habitats
- Impacting cliff erosion and creek morphology
- CO2 footprint from the use of materials, transportation and construction
- Pollution of water, soils, and noise from construction waste and practices

When considering environmental impacts, a project can address potential issues either through the design of the system, mitigation plans, or offsetting mechanisms.

As discussed previously in Section 5 – Design Overview, the stormwater system has been designed in a way to reduce environmental footprint and protect the creeks and cliff from erosion. The design relies on water detention rather than depending on infiltration, which aids in providing cliff stability. The retention and controlled discharge also helps in avoiding creek and cliff erosion. The use of recycled polypropylene eco-tanks accounts for a much smaller greenhouse gas footprint compared to the typical use of concrete. The choice in materials also aids in reducing construction impacts from runoff pollution as well as the necessary amount of transportation of the lightweight drainage tanks and equipment for construction. The design also creates space community based ecosystem services through the integration of a community garden, rainwater harvest, and a campus maze.

Potential sources of impact from the construction phase must be mitigated through the inclusion of a waste plan for minimizing and diverting construction waste. UBC's Technical Guidelines set a goal for diverting at least 75% of construction waste from disposal. A list of considerations for environmental impact mitigation during construction is as follows:

1. Water management
    a. Prevent water pollution from runoff
    b. Plan water use to reduce waste
    c. Prevent soil pollution from construction runoff and waste
2. Solid Waste Management
    a. Minimize total construction waste
    b. Re-use materials as much as possible
    c. Reduce landfill waste by identifying recyclable materials
3. Air and Noise Pollution Management
    a. Reduce construction noise and vibration
    b. Prevent air quality deterioration from dust

However, even with the design considerations presented and mitigation plans for the construction phase, there will still be environmental impacts on the site which cannot be avoided. These kinds of impacts require offset plans in order to reduce their magnitude. The main impact in this situation is the necessary tree removal at the intersection of Wesbrook Mall and South West Marine Drive. The detention at this location will require a surface area clearance of approximately 30 m x 40 m. A plan must be prepared to replant trees in an appropriate location on campus in order to offset the environmental impact at this site. Nonetheless, the proposed landscaping at this site will allow for some degree of environmental offsetting and benefits for the community.

13.0 SENSITIVITY ANALYSIS

It is important to conduct a sensitivity analysis of the design parameters in order to understand the possible output responses any change may induce. For this design, the most important output to consider is the total storage volume required for detaining a 100-year storm event. The main parameters involved are the assumed imperviousness and thus runoff coefficients as well as the rainfall intensity.

These parameters are important to characterise as they may change during the design life of the system. Imperviousness may increase with future developments in the South Campus that have not yet been defined. Rainfall intensity for a 1 in 100 year storm may also change due to climate change, which predicts an increased frequency and intensity of large storm events (Pacific Climate Impacts Consortium, 2012). The Intensity-Duration-Frequency curves used for the detention volume calculation are based on historical data and not predicted values for future storms.

Based on these considerations a sensitivity analysis was conducted to determine if the factor of safety used in the design for the total storage volume required was appropriate for a certain level of change. The degree of change in the parameters and the consequential outputs are shown in Table 6 below. The full detailed sensitivity analysis is provided in Appendix E – Sensitivity Analysis. Imperviousness and rainfall intensity were increased by 25% and 7% respectively to reflect development, climate change and a more conservative calculation.

Table 6 – Sensitivity Analysis Summary

Required Detention Volume	**Volume (m^3)**
Base Conditions	3,460
Base Conditions with Factor of Safety	7,240
Increased Imperviousness	5,160
Increased Rainfall Intensity	3,190
Increase in both parameters	5,820

This analysis shows that the detention volume used in the design, which is 7,240 m^3 and includes a factor of safety of 1.5 within its flow calculation, is able to accommodate the predicted changes in the surface characteristics and increased rainfall intensity.

14.0 SCHEDULE

The stormwater detention system comprises of four construction sites: South West Marine Drive and Wesbrook Mall, West 16th Avenue and Wesbrook Mall, the UBC Farm and swale enhancement along South West Marine Drive, and Acadia Park. The construction of the stormwater system will take approximately eight months. For all construction sites, the required permits, selection of contractors and subcontractors, additional geotechnical testing and analysis, and construction site layout will be completed before construction commences. The expected completion date of detailed design is mid-April with the tendering period for the contractor to follow. Therefore, construction is expected to start on the first week of May and finish on mid-December. Table 7 below summarizes the milestone dates for the project.

Table 7 – Project Schedule Key Dates

Project Phase	**Date**
Detailed Design Completion	Mid-April 2016
Construction Start Date	Beginning of May 2016
Construction Completion Date	Mid-December 2016

Construction will first commence at South West Marine Drive and Wesbrook Mall as the construction practices employed on that specific site are complex and required a longer duration. Due to equipment's availability, construction at UBC Farm will follow immediately after the removal of trees at SW Marine Drive is completed. The detention facilities at Acadia Park and West 16th will be constructed concurrently with the larger facilities. For a detailed construction schedule see Appendix F – Construction Schedule. The construction order is strategically planned out to ensure efficiency, be cost effective, and minimize disturbance to local residence and traffic users.

15.0 CONSTRUCTION WORK PLAN

An overview of the anticipated construction activities will be presented below.

Pre-Construction Activities

Prior to any construction or enhancement activities within UBC South Campus, the following pre-construction activities will be implemented throughout the construction period:

1) Obtain construction related permits
2) Finalize subcontractors tendering process and award contracts
3) Conduct a topographic survey with a licensed survey team to establish the limits of the construction, confirm elevations, and verify that existing conditions are suitable. Also, contact BC One call to locate existing utilities before any excavation activity commences.
4) Approve work plans from the subcontractor. Anticipated work plans include:
    - A detailed construction work plan that describes the method for executing the work.
    - A health and safety plan that defines the requirement and protocols to be followed in order to maintain a safe and healthy work environment.
    - An environmental monitoring plan that mitigates negative environmental impacts. This plan should cover water, solid waste, air pollution and noise monitoring plans.
    - A quality control / assurance plan to ensure the work is being performed according to the specifications, codes and standards.
5) Complete geotechnical site analysis. See Section 11.1 – Field Investigations and Tests.
6) Make initial material purchase.

The construction activities will consist of mobilization to the site, site preparations, clearing and grubbing, excavation, landscaping and demobilization.

Mobilization

Upon the award of the contracts, mobilization of labour, equipment, materials, and tools will proceed. During this phase, the primary staging area is selected at each site. The construction activities taking place at this area include the installation of a chain link fence around the perimeter, a construction entrance, temporary employer/visitor parking, and the placement of an aggregate base layer. As the foundation of the staging area progresses, the installation of two temporary field office trailers (contractor trailer and first aid trailer) will commence. Storage facilities and laydown area will also be installed. There will only be one safety trailer located at the intersection of SW Marine Drive and Wesbrook Mall.

Site Preparation

Site preparations will begin at the maze garden and progressively move to the other components in the following order: UBC Farm, Acadia Park, and West 16th. The anticipated site preparation activities will include the installation of temporary utilities, temporary roads for excavation activities, traffic control measures, and the establishment of excavation limits as well as work zone delineations.

Clearing and Grubbing

A large number of trees will be removed at the intersection of SW Marine Drive and Wesbrook Mall and is expected to take approximately 50 days. This activity will be performed using a track excavator with a specialized grapple attachment. The debris will be sized and staged for off-site disposal by the transportation subcontractor. During clearing and grubbing, a reasonable amount of effort will be taken when removing large trees in order to avoid unnecessary damage to the surrounding area. The same procedure will be employed at West 16th for the removal of a smaller number of trees.

Excavation

Once clearing and grubbing is completed, the excavation activities will commence. The sites are located throughout UBC South Campus; thus, the work performed is sensitive to issues related to dust and noise due to the proximity of neighbouring homes. The environmental project coordinator will provide quality assurance by monitoring the dust and noise from the project.

Once the limits and the ground conditions are confirmed and deemed suitable for construction purposes, the excavation will officially commence. Since the excavation does not overlap for any of the sites, there will only be one excavator available at any time on the project. Temporary construction signage will be installed at the perimeter of the open excavation to prevent accidents. For all sites, the excavation will be executed to minimum depth of approximately 3.5 meters. The fill will be removed from the site temporarily until it is time for backfilling. The trucks are expected to arrive every hour. The majority of the fill excavated is not anticipated to be classified as a hazardous material. However, if the material is deemed hazardous, the fill will be disposed to a licensed waste disposal facility.

Installation of Eco-Tanks and Backfill

The installation of eco-tanks follows the same procedure for all sites. The duration of the installation is dependent on the area size of the detention facility. These tanks will be assembled on site and it is expected to take 9 minutes per penta-size tank. Since the tanks are assembled at the location it will be used, no cranes or additional equipment is required to move these pieces. At the UBC Farm, a harvesting system will be installed by the subcontractor. After every ten rows of tanks are installed, they will be backfilled.

Landscaping

The landscaping for each site is unique. Some sites will require more time to complete due to the complexity of the over-top feature. Refer to Appendix F for the duration of the landscaping for each site. The subcontracted company is responsible to complete the landscaping according to the design.

Demobilization

All equipment and temporary facilities will be removed from site subsequent to completion of tasks and when deemed unnecessary to keep on site.

16.0 COST ESTIMATE

The capital construction cost estimate, based on a quantity take off of IFC drawings, is CAD $4,690,240 excluding tax. The cost estimate is produced at a Class A level - Issued for Tender with an estimated +/- 25% level of accuracy and a contingency of 20%. The allowance for contingency is not an accuracy measure, but is based on "known unknown" factors that are assumed in the detailed design phase.

Although scope has increased to accommodate a community garden at Acadia and a garden maze at Marine Drive, the overall cost for the project is lower than the preliminary design estimate. This is due to the decrease in contingency allowance needed to offset project risk because detailed design has eliminated some previous unknowns and assumptions from preliminary design. Furthermore, the total costs for the project include a lump sum fee for engineering and inspection services during construction. Table 8 provides a summary of individual components cost of each facility and a total cost of the entire system.

Table 8 – Summary of Class A Detailed Cost Estimate

Detention Facility	**Direct Costs**	**Contingency and Engineering Costs**	**Costs Before Tax**
Rain Garden at Acadia	$768,200	$193,640	$961,840
Detention Tank at West 16th Avenue	$547,200	$139,440	$686,640
Detention Tank at Marine Drive	$1,264,400	$312,880	$1,577,280
Rain Harvest at UBC Farm	$1,170,400	$294,080	$1,464,480
Total Costs	**$3,750,200**	**$940,040**	**$4,690,240**

While pipe connection material and installation costs are included to allow integration of detention facilities into the existing stormwater main, the cost estimate excludes engineering and construction costs related to the upgrade, replacement and restoration of the pipe infrastructure network outside the immediate proximity of the detention facilities. See Appendix G - Class A Cost Estimate for the quantity take-off and a detailed analysis of the cost estimate, including the basis of estimate, qualifications, assumptions and exclusions.

During its life cycle of 70 years, the detention system is expected to incur annual maintenance and operation costs, a rehabilitation cost at 30 years and a second rehabilitation cost at 50 years. Expected inflation is calculated at 3% and also at a low and high estimate of 0% and 5% respectively. Annual maintenance costs are assumed to grow by 2% annually. Table 9 provides a present worth summary of total expenses occurring at the end of 30, 50 and 70 year intervals.

Table 9 – Life Cycle Cost at 3% Inflation and 2% Growth of Maintenance Costs

	Detention System
Life Span	70 years
Capital Cost	$4,690,240
Rehabilitation Cost at 30 Years (PW)	$463,516
Rehabilitation Cost at 50 Years (PW)	$692,354
Annual Operating Cost	$19,410
Total Expense at 70 Years (PW)	$6,789,556
Total Expense at 50 Years (PW)	$5,895,544
Total Expense at 30 Years (PW)	$5,182,755

Rehabilitation is not required at 70 years since the system would reach the end of its design life-cycle and the stormwater facilities would be disposed. See Appendix G - Class A Cost Estimate for an in-depth analysis of the life-cycle costs including assumptions, variables, and calculations of estimated expenses.

17.0 CONCLUSION

The proposed design for the UBC South Campus Stormwater Detention System presented in this report, seeks to better manage minor storms and prevent severe flooding from large storm events in order to protect the community as well as the environment. Through an evaluation of the key issues and design constraints pertinent to the project, a detailed design for an underground stormwater detention system was produced.

The design incorporates a decentralised approach and uses underground modular drainage cells to store water, with components located at key points around the UBC South Campus. It embodies the aesthetic components and sustainability criteria desired as well as reflect a resilient design capable of operating for at least 70 years. Community growth is also promoted, through the incorporation of a community garden and hedge maze. The volume capacities for the components in this design incorporate a factor of safety that accounts for changes in impervious surfaces and/or rainfall intensity. The schedule breakdown conveyed in this report indicates an expected constructed timeline of eight months for the entire project. The anticipated cost of construction of all components based on the design details and including contingencies, is CAD $4,690,240 excluding tax.

Through the integration of this design into the existing UBC South Campus Stormwater Detention System, the overall system will be better suited to manage minor storms and reduce cliff erosion as well as prevent severe flooding during major storm events. It will also aid in UBC's vision of sustainability through its positive social and environmental impacts.

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APPENDIX A – DESIGN CALCULATIONS

Design Calculations

Rainfall Data (Based on IDF Curve for "VANCOUVER INTL A BC 1108395")				
Time [minutes]			**8**	**1440**
Rainfall intensity [mm/hr]			**80**	**4.4**
Requirements for 100-Year Storm Event				
Location	**Plan Area x1.5 FS [m2]**	**Runoff Coefficient**	**Outflow Rate [m3/2]**	**Storage Volume Required [m3]**
Acadia Park	97500	0.80	0.20	1450
West 16th Avenue & Wesbrook Mall	79500	0.80	0.20	940
UBC Farm	229500	0.50	0.20	2680
SW Marine Drive & Wesbrook Mall	204000	0.50	0.20	2170

Notes:

* Storage volume calculations based on rational method, with peak flow over a 24 hour period during a 100-year storm event

$$Peak\ Flow\ Q = ciA\ [\frac{m^3}{s}]$$

$$Inflow\ Volume = Qt\ [m^3]$$

$$Outflow\ Volume = Dt\ [m^3]$$

$$Required\ Volume = Inflow\ Volume\ - Outflow\ Volume$$

Where:
$Q = Peak\ Flow$
$C = Runoff\ Coefficient$
$i = Rainfall\ Intensity$
$A = Catchment\ Area$
$D = Outflow\ Rate$

* Required storage volume values in the above table rounded up from calculated values

Assumptions:

* Runoff coefficient based on area of impervious surfaces
* Outflow rate based on total outflow of entire stormwater detention system
* Plan areas determined from contour maps from City of Vancouver GIS (VanMap)

Acadia Park

Time	Rainfall Intensity	Peak Flow	Inflow Volume	Outflow Volume	Required Volume
[minutes]	[mm/hr]	[m3/s]	[m3]	[m3]	[m3]
5	104.02	2.25	676.10	60.00	616.10
6	93.94	2.04	732.77	72.00	660.77
7	86.19	1.87	784.37	84.00	700.37
8	80.00	1.73	832.00	96.00	736.00
9	74.91	1.62	876.41	108.00	768.41
10	70.63	1.53	918.13	120.00	798.13
11	66.96	1.45	957.59	132.00	825.59
12	63.79	1.38	995.09	144.00	851.09
13	61.00	1.32	1030.88	156.00	874.88
14	58.53	1.27	1065.17	168.00	897.17
15	56.31	1.22	1098.11	180.00	918.11
16	54.32	1.18	1129.85	192.00	937.85
17	52.51	1.14	1160.49	204.00	956.49
18	50.86	1.10	1190.15	216.00	974.15
19	49.35	1.07	1218.90	228.00	990.90
20	47.95	1.04	1246.81	240.00	1006.81
25	42.34	0.92	1375.89	300.00	1075.89
30	38.24	0.83	1491.22	360.00	1131.22
35	35.08	0.76	1596.23	420.00	1176.23
40	32.56	0.71	1693.16	480.00	1213.16
45	30.49	0.66	1783.53	540.00	1243.53
50	28.75	0.62	1868.45	600.00	1268.45
55	27.26	0.59	1948.74	660.00	1288.74
60	25.96	0.56	2025.05	720.00	1305.05
65	24.83	0.54	2097.89	780.00	1317.89
70	23.82	0.52	2167.66	840.00	1327.66
75	22.92	0.50	2234.70	900.00	1334.70
80	22.11	0.48	2299.29	960.00	1339.29
85	21.37	0.46	2361.66	1020.00	1341.66
90	20.70	0.45	2422.01	1080.00	1342.01
95	20.09	0.44	2480.51	1140.00	1340.51
100	19.52	0.42	2537.33	1200.00	1337.33
105	18.99	0.41	2592.57	1260.00	1332.57
110	18.51	0.40	2646.37	1320.00	1326.37
115	18.05	0.39	2698.81	1380.00	1318.81
120	17.63	0.38	2750.00	1440.00	1310.00
135	16.51	0.36	2896.77	1620.00	1276.77
150	15.56	0.34	3034.70	1800.00	1234.70
165	14.76	0.32	3165.11	1980.00	1185.11
180	14.06	0.30	3289.06	2160.00	1129.06
195	13.44	0.29	3407.36	2340.00	1067.36
210	12.90	0.28	3520.68	2520.00	1000.68
225	12.41	0.27	3629.56	2700.00	929.56
240	11.97	0.26	3734.46	2880.00	854.46
255	11.57	0.25	3835.76	3060.00	775.76
270	11.21	0.24	3933.78	3240.00	693.78
285	10.87	0.24	4028.81	3420.00	608.81
300	10.57	0.23	4121.08	3600.00	521.08
315	10.28	0.22	4210.81	3780.00	430.81
330	10.02	0.22	4298.18	3960.00	338.18
345	9.77	0.21	4383.36	4140.00	243.36
360	9.54	0.21	4466.50	4320.00	146.50
375	9.33	0.20	4547.72	4500.00	47.72
390	9.13	0.20	4627.15	4680.00	-52.85
405	8.94	0.19	4704.89	4860.00	-155.11
420	8.76	0.19	4781.04	5040.00	-258.96
435	8.59	0.19	4855.68	5220.00	-364.32
450	8.43	0.18	4928.90	5400.00	-471.10
465	8.27	0.18	5000.77	5580.00	-579.23
480	8.13	0.18	5071.35	5760.00	-688.65
495	7.99	0.17	5140.72	5940.00	-799.28

510	7.86	0.17	5208.91	6120.00	-911.09
525	7.73	0.17	5276.00	6300.00	-1024.00
540	7.61	0.16	5342.03	6480.00	-1137.97
555	7.49	0.16	5407.04	6660.00	-1252.96
570	7.38	0.16	5471.07	6840.00	-1368.93
585	7.28	0.16	5534.17	7020.00	-1485.83
600	7.17	0.16	5596.37	7200.00	-1603.63
615	7.08	0.15	5657.71	7380.00	-1722.29
630	6.98	0.15	5718.22	7560.00	-1841.78
645	6.89	0.15	5777.93	7740.00	-1962.07
660	6.80	0.15	5836.87	7920.00	-2083.13
675	6.72	0.15	5895.07	8100.00	-2204.93
690	6.64	0.14	5952.55	8280.00	-2327.45
705	6.56	0.14	6009.33	8460.00	-2450.67
720	6.48	0.14	6065.45	8640.00	-2574.55
735	6.41	0.14	6120.91	8820.00	-2699.09
750	6.33	0.14	6175.75	9000.00	-2824.25
765	6.26	0.14	6229.97	9180.00	-2950.03
780	6.20	0.13	6283.61	9360.00	-3076.39
795	6.13	0.13	6336.67	9540.00	-3203.33
810	6.07	0.13	6389.18	9720.00	-3330.82
825	6.01	0.13	6441.15	9900.00	-3458.85
840	5.95	0.13	6492.59	10080.00	-3587.41
855	5.89	0.13	6543.52	10260.00	-3716.48
870	5.83	0.13	6593.95	10440.00	-3846.05
885	5.77	0.13	6643.90	10620.00	-3976.10
900	5.72	0.12	6693.38	10800.00	-4106.62
915	5.67	0.12	6742.40	10980.00	-4237.60
930	5.62	0.12	6790.98	11160.00	-4369.02
945	5.57	0.12	6839.12	11340.00	-4500.88
960	5.52	0.12	6886.83	11520.00	-4633.17
975	5.47	0.12	6934.13	11700.00	-4765.87
990	5.42	0.12	6981.03	11880.00	-4898.97
1005	5.38	0.12	7027.53	12060.00	-5032.47
1020	5.33	0.12	7073.64	12240.00	-5166.36
1035	5.29	0.11	7119.38	12420.00	-5300.62
1050	5.25	0.11	7164.74	12600.00	-5435.26
1065	5.21	0.11	7209.75	12780.00	-5570.25
1080	5.17	0.11	7254.41	12960.00	-5705.59
1095	5.13	0.11	7298.71	13140.00	-5841.29
1110	5.09	0.11	7342.69	13320.00	-5977.31
1125	5.05	0.11	7386.33	13500.00	-6113.67
1140	5.01	0.11	7429.64	13680.00	-6250.36
1155	4.98	0.11	7472.64	13860.00	-6387.36
1170	4.94	0.11	7515.33	14040.00	-6524.67
1185	4.91	0.11	7557.72	14220.00	-6662.28
1200	4.87	0.11	7599.80	14400.00	-6800.20
1215	4.84	0.10	7641.60	14580.00	-6938.40
1230	4.80	0.10	7683.10	14760.00	-7076.90
1245	4.77	0.10	7724.33	14940.00	-7215.67
1260	4.74	0.10	7765.27	15120.00	-7354.73
1275	4.71	0.10	7805.95	15300.00	-7494.05
1290	4.68	0.10	7846.36	15480.00	-7633.64
1305	4.65	0.10	7886.51	15660.00	-7773.49
1320	4.62	0.10	7926.40	15840.00	-7913.60
1335	4.59	0.10	7966.04	16020.00	-8053.96
1350	4.56	0.10	8005.43	16200.00	-8194.57
1365	4.53	0.10	8044.58	16380.00	-8335.42
1380	4.51	0.10	8083.49	16560.00	-8476.51
1395	4.48	0.10	8122.16	16740.00	-8617.84
1410	4.45	0.10	8160.60	16920.00	-8759.40
1425	4.43	0.10	8198.81	17100.00	-8901.19
1440	4.40	0.10	8236.80	17280.00	-9043.20

West 16th Avenue & Wesbrook Mall

Time	Rainfall Intensity	Peak Flow	Inflow Volume	Outflow Volume	Required Volume
[minutes]	[mm/hr]	[m3/s]	[m3]	[m3]	[m3]
5	104.02	1.84	551.28	60.00	491.28
6	93.94	1.66	597.49	72.00	525.49
7	86.19	1.52	639.56	84.00	555.56
8	80.00	1.41	678.40	96.00	582.40
9	74.91	1.32	714.61	108.00	606.61
10	70.63	1.25	748.63	120.00	628.63
11	66.96	1.18	780.80	132.00	648.80
12	63.79	1.13	811.38	144.00	667.38
13	61.00	1.08	840.56	156.00	684.56
14	58.53	1.03	868.52	168.00	700.52
15	56.31	0.99	895.38	180.00	715.38
16	54.32	0.96	921.26	192.00	729.26
17	52.51	0.93	946.25	204.00	742.25
18	50.86	0.90	970.43	216.00	754.43
19	49.35	0.87	993.87	228.00	765.87
20	47.95	0.85	1016.63	240.00	776.63
25	42.34	0.75	1121.88	300.00	821.88
30	38.24	0.68	1215.92	360.00	855.92
35	35.08	0.62	1301.54	420.00	881.54
40	32.56	0.58	1380.58	480.00	900.58
45	30.49	0.54	1454.26	540.00	914.26
50	28.75	0.51	1523.50	600.00	923.50
55	27.26	0.48	1588.97	660.00	928.97
60	25.96	0.46	1651.20	720.00	931.20
65	24.83	0.44	1710.59	780.00	930.59
70	23.82	0.42	1767.48	840.00	927.48
75	22.92	0.40	1822.14	900.00	922.14
80	22.11	0.39	1874.80	960.00	914.80
85	21.37	0.38	1925.66	1020.00	905.66
90	20.70	0.37	1974.87	1080.00	894.87
95	20.09	0.35	2022.57	1140.00	882.57
100	19.52	0.34	2068.90	1200.00	868.90
105	18.99	0.34	2113.94	1260.00	853.94
110	18.51	0.33	2157.81	1320.00	837.81
115	18.05	0.32	2200.57	1380.00	820.57
120	17.63	0.31	2242.31	1440.00	802.31
135	16.51	0.29	2361.99	1620.00	741.99
150	15.56	0.27	2474.44	1800.00	674.44
165	14.76	0.26	2580.78	1980.00	600.78
180	14.06	0.25	2681.85	2160.00	521.85
195	13.44	0.24	2778.31	2340.00	438.31
210	12.90	0.23	2870.71	2520.00	350.71
225	12.41	0.22	2959.49	2700.00	259.49
240	11.97	0.21	3045.02	2880.00	165.02
255	11.57	0.20	3127.62	3060.00	67.62
270	11.21	0.20	3207.55	3240.00	-32.45
285	10.87	0.19	3285.03	3420.00	-134.97
300	10.57	0.19	3360.26	3600.00	-239.74
315	10.28	0.18	3433.43	3780.00	-346.57
330	10.02	0.18	3504.67	3960.00	-455.33
345	9.77	0.17	3574.12	4140.00	-565.88
360	9.54	0.17	3641.91	4320.00	-678.09
375	9.33	0.16	3708.14	4500.00	-791.86
390	9.13	0.16	3772.91	4680.00	-907.09
405	8.94	0.16	3836.29	4860.00	-1023.71
420	8.76	0.15	3898.38	5040.00	-1141.62
435	8.59	0.15	3959.25	5220.00	-1260.75
450	8.43	0.15	4018.95	5400.00	-1381.05
465	8.27	0.15	4077.55	5580.00	-1502.45
480	8.13	0.14	4135.10	5760.00	-1624.90
495	7.99	0.14	4191.66	5940.00	-1748.34

510	7.86	0.14	4247.27	6120.00	-1872.73
525	7.73	0.14	4301.97	6300.00	-1998.03
540	7.61	0.13	4355.81	6480.00	-2124.19
555	7.49	0.13	4408.81	6660.00	-2251.19
570	7.38	0.13	4461.03	6840.00	-2378.97
585	7.28	0.13	4512.48	7020.00	-2507.52
600	7.17	0.13	4563.20	7200.00	-2636.80
615	7.08	0.13	4613.21	7380.00	-2766.79
630	6.98	0.12	4662.55	7560.00	-2897.45
645	6.89	0.12	4711.24	7740.00	-3028.76
660	6.80	0.12	4759.30	7920.00	-3160.70
675	6.72	0.12	4806.75	8100.00	-3293.25
690	6.64	0.12	4853.62	8280.00	-3426.38
705	6.56	0.12	4899.92	8460.00	-3560.08
720	6.48	0.11	4945.67	8640.00	-3694.33
735	6.41	0.11	4990.90	8820.00	-3829.10
750	6.33	0.11	5035.61	9000.00	-3964.39
765	6.26	0.11	5079.83	9180.00	-4100.17
780	6.20	0.11	5123.56	9360.00	-4236.44
795	6.13	0.11	5166.83	9540.00	-4373.17
810	6.07	0.11	5209.64	9720.00	-4510.36
825	6.01	0.11	5252.01	9900.00	-4647.99
840	5.95	0.11	5293.96	10080.00	-4786.04
855	5.89	0.10	5335.48	10260.00	-4924.52
870	5.83	0.10	5376.61	10440.00	-5063.39
885	5.77	0.10	5417.34	10620.00	-5202.66
900	5.72	0.10	5457.68	10800.00	-5342.32
915	5.67	0.10	5497.65	10980.00	-5482.35
930	5.62	0.10	5537.26	11160.00	-5622.74
945	5.57	0.10	5576.51	11340.00	-5763.49
960	5.52	0.10	5615.42	11520.00	-5904.58
975	5.47	0.10	5653.98	11700.00	-6046.02
990	5.42	0.10	5692.22	11880.00	-6187.78
1005	5.38	0.10	5730.14	12060.00	-6329.86
1020	5.33	0.09	5767.74	12240.00	-6472.26
1035	5.29	0.09	5805.03	12420.00	-6614.97
1050	5.25	0.09	5842.02	12600.00	-6757.98
1065	5.21	0.09	5878.72	12780.00	-6901.28
1080	5.17	0.09	5915.13	12960.00	-7044.87
1095	5.13	0.09	5951.26	13140.00	-7188.74
1110	5.09	0.09	5987.11	13320.00	-7332.89
1125	5.05	0.09	6022.70	13500.00	-7477.30
1140	5.01	0.09	6058.02	13680.00	-7621.98
1155	4.98	0.09	6093.08	13860.00	-7766.92
1170	4.94	0.09	6127.89	14040.00	-7912.11
1185	4.91	0.09	6162.45	14220.00	-8057.55
1200	4.87	0.09	6196.76	14400.00	-8203.24
1215	4.84	0.09	6230.84	14580.00	-8349.16
1230	4.80	0.08	6264.68	14760.00	-8495.32
1245	4.77	0.08	6298.30	14940.00	-8641.70
1260	4.74	0.08	6331.69	15120.00	-8788.31
1275	4.71	0.08	6364.85	15300.00	-8935.15
1290	4.68	0.08	6397.80	15480.00	-9082.20
1305	4.65	0.08	6430.54	15660.00	-9229.46
1320	4.62	0.08	6463.06	15840.00	-9376.94
1335	4.59	0.08	6495.39	16020.00	-9524.61
1350	4.56	0.08	6527.50	16200.00	-9672.50
1365	4.53	0.08	6559.42	16380.00	-9820.58
1380	4.51	0.08	6591.15	16560.00	-9968.85
1395	4.48	0.08	6622.68	16740.00	-10117.32
1410	4.45	0.08	6654.03	16920.00	-10265.97
1425	4.43	0.08	6685.18	17100.00	-10414.82
1440	4.40	0.08	6716.16	17280.00	-10563.84

UBC Farm

Time	Rainfall Intensity	Peak Flow	Inflow Volume	Outflow Volume	Required Volume
[minutes]	[mm/hr]	[m3/s]	[m3]	[m3]	[m3]
5	104.02	3.32	994.65	60.00	934.65
6	93.94	2.99	1078.01	72.00	1006.01
7	86.19	2.75	1153.93	84.00	1069.93
8	80.00	2.55	1224.00	96.00	1128.00
9	74.91	2.39	1289.33	108.00	1181.33
10	70.63	2.25	1350.72	120.00	1230.72
11	66.96	2.13	1408.76	132.00	1276.76
12	63.79	2.03	1463.93	144.00	1319.93
13	61.00	1.94	1516.59	156.00	1360.59
14	58.53	1.87	1567.02	168.00	1399.02
15	56.31	1.79	1615.49	180.00	1435.49
16	54.32	1.73	1662.18	192.00	1470.18
17	52.51	1.67	1707.26	204.00	1503.26
18	50.86	1.62	1750.89	216.00	1534.89
19	49.35	1.57	1793.19	228.00	1565.19
20	47.95	1.53	1834.26	240.00	1594.26
25	42.34	1.35	2024.15	300.00	1724.15
30	38.24	1.22	2193.81	360.00	1833.81
35	35.08	1.12	2348.30	420.00	1928.30
40	32.56	1.04	2490.90	480.00	2010.90
45	30.49	0.97	2623.84	540.00	2083.84
50	28.75	0.92	2748.77	600.00	2148.77
55	27.26	0.87	2866.90	660.00	2206.90
60	25.96	0.83	2979.17	720.00	2259.17
65	24.83	0.79	3086.32	780.00	2306.32
70	23.82	0.76	3188.96	840.00	2348.96
75	22.92	0.73	3287.59	900.00	2387.59
80	22.11	0.70	3382.61	960.00	2422.61
85	21.37	0.68	3474.36	1020.00	2454.36
90	20.70	0.66	3563.15	1080.00	2483.15
95	20.09	0.64	3649.22	1140.00	2509.22
100	19.52	0.62	3732.80	1200.00	2532.80
105	18.99	0.61	3814.07	1260.00	2554.07
110	18.51	0.59	3893.21	1320.00	2573.21
115	18.05	0.58	3970.37	1380.00	2590.37
120	17.63	0.56	4045.67	1440.00	2605.67
135	16.51	0.53	4261.60	1620.00	2641.60
150	15.56	0.50	4464.50	1800.00	2664.50
165	14.76	0.47	4656.36	1980.00	2676.36
180	14.06	0.45	4838.71	2160.00	2678.71
195	13.44	0.43	5012.75	2340.00	2672.75
210	12.90	0.41	5179.46	2520.00	2659.46
225	12.41	0.40	5339.64	2700.00	2639.64
240	11.97	0.38	5493.97	2880.00	2613.97
255	11.57	0.37	5642.99	3060.00	2582.99
270	11.21	0.36	5787.20	3240.00	2547.20
285	10.87	0.35	5927.00	3420.00	2507.00
300	10.57	0.34	6062.74	3600.00	2462.74
315	10.28	0.33	6194.75	3780.00	2414.75
330	10.02	0.32	6323.28	3960.00	2363.28
345	9.77	0.31	6448.60	4140.00	2308.60
360	9.54	0.30	6570.90	4320.00	2250.90
375	9.33	0.30	6690.40	4500.00	2190.40
390	9.13	0.29	6807.25	4680.00	2127.25
405	8.94	0.28	6921.62	4860.00	2061.62
420	8.76	0.28	7033.64	5040.00	1993.64
435	8.59	0.27	7143.45	5220.00	1923.45
450	8.43	0.27	7251.17	5400.00	1851.17
465	8.27	0.26	7356.90	5580.00	1776.90
480	8.13	0.26	7460.74	5760.00	1700.74
495	7.99	0.25	7562.78	5940.00	1622.78

510	7.86	0.25	7663.11	6120.00	1543.11
525	7.73	0.25	7761.81	6300.00	1461.81
540	7.61	0.24	7858.94	6480.00	1378.94
555	7.49	0.24	7954.58	6660.00	1294.58
570	7.38	0.24	8048.79	6840.00	1208.79
585	7.28	0.23	8141.62	7020.00	1121.62
600	7.17	0.23	8233.13	7200.00	1033.13
615	7.08	0.23	8323.37	7380.00	943.37
630	6.98	0.22	8412.39	7560.00	852.39
645	6.89	0.22	8500.23	7740.00	760.23
660	6.80	0.22	8586.94	7920.00	666.94
675	6.72	0.21	8672.55	8100.00	572.55
690	6.64	0.21	8757.11	8280.00	477.11
705	6.56	0.21	8840.65	8460.00	380.65
720	6.48	0.21	8923.21	8640.00	283.21
735	6.41	0.20	9004.80	8820.00	184.80
750	6.33	0.20	9085.47	9000.00	85.47
765	6.26	0.20	9165.25	9180.00	-14.75
780	6.20	0.20	9244.16	9360.00	-115.84
795	6.13	0.20	9322.22	9540.00	-217.78
810	6.07	0.19	9399.47	9720.00	-320.53
825	6.01	0.19	9475.92	9900.00	-424.08
840	5.95	0.19	9551.59	10080.00	-528.41
855	5.89	0.19	9626.52	10260.00	-633.48
870	5.83	0.19	9700.72	10440.00	-739.28
885	5.77	0.18	9774.20	10620.00	-845.80
900	5.72	0.18	9847.00	10800.00	-953.00
915	5.67	0.18	9919.11	10980.00	-1060.89
930	5.62	0.18	9990.58	11160.00	-1169.42
945	5.57	0.18	10061.40	11340.00	-1278.60
960	5.52	0.18	10131.59	11520.00	-1388.41
975	5.47	0.17	10201.17	11700.00	-1498.83
990	5.42	0.17	10270.16	11880.00	-1609.84
1005	5.38	0.17	10338.57	12060.00	-1721.43
1020	5.33	0.17	10406.41	12240.00	-1833.59
1035	5.29	0.17	10473.70	12420.00	-1946.30
1050	5.25	0.17	10540.44	12600.00	-2059.56
1065	5.21	0.17	10606.65	12780.00	-2173.35
1080	5.17	0.16	10672.35	12960.00	-2287.65
1095	5.13	0.16	10737.53	13140.00	-2402.47
1110	5.09	0.16	10802.22	13320.00	-2517.78
1125	5.05	0.16	10866.42	13500.00	-2633.58
1140	5.01	0.16	10930.15	13680.00	-2749.85
1155	4.98	0.16	10993.41	13860.00	-2866.59
1170	4.94	0.16	11056.21	14040.00	-2983.79
1185	4.91	0.16	11118.57	14220.00	-3101.43
1200	4.87	0.16	11180.48	14400.00	-3219.52
1215	4.84	0.15	11241.96	14580.00	-3338.04
1230	4.80	0.15	11303.03	14760.00	-3456.97
1245	4.77	0.15	11363.67	14940.00	-3576.33
1260	4.74	0.15	11423.91	15120.00	-3696.09
1275	4.71	0.15	11483.75	15300.00	-3816.25
1290	4.68	0.15	11543.20	15480.00	-3936.80
1305	4.65	0.15	11602.27	15660.00	-4057.73
1320	4.62	0.15	11660.95	15840.00	-4179.05
1335	4.59	0.15	11719.27	16020.00	-4300.73
1350	4.56	0.15	11777.22	16200.00	-4422.78
1365	4.53	0.14	11834.81	16380.00	-4545.19
1380	4.51	0.14	11892.05	16560.00	-4667.95
1395	4.48	0.14	11948.94	16740.00	-4791.06
1410	4.45	0.14	12005.50	16920.00	-4914.50
1425	4.43	0.14	12061.71	17100.00	-5038.29
1440	4.40	0.14	12117.60	17280.00	-5162.40

SW Marine Drive & Wesbrook Mall

Time	Rainfall Intensity	Peak Flow	Inflow Volume	Outflow Volume	Required Volume
[minutes]	[mm/hr]	[m3/s]	[m3]	[m3]	[m3]
5	104.02	2.95	884.13	60.00	824.13
6	93.94	2.66	958.24	72.00	886.24
7	86.19	2.44	1025.72	84.00	941.72
8	80.00	2.27	1088.00	96.00	992.00
9	74.91	2.12	1146.07	108.00	1038.07
10	70.63	2.00	1200.64	120.00	1080.64
11	66.96	1.90	1252.23	132.00	1120.23
12	63.79	1.81	1301.27	144.00	1157.27
13	61.00	1.73	1348.08	156.00	1192.08
14	58.53	1.66	1392.91	168.00	1224.91
15	56.31	1.60	1435.99	180.00	1255.99
16	54.32	1.54	1477.49	192.00	1285.49
17	52.51	1.49	1517.57	204.00	1313.57
18	50.86	1.44	1556.35	216.00	1340.35
19	49.35	1.40	1593.94	228.00	1365.94
20	47.95	1.36	1630.45	240.00	1390.45
25	42.34	1.20	1799.25	300.00	1499.25
30	38.24	1.08	1950.05	360.00	1590.05
35	35.08	0.99	2087.38	420.00	1667.38
40	32.56	0.92	2214.13	480.00	1734.13
45	30.49	0.86	2332.31	540.00	1792.31
50	28.75	0.81	2443.35	600.00	1843.35
55	27.26	0.77	2548.35	660.00	1888.35
60	25.96	0.74	2648.15	720.00	1928.15
65	24.83	0.70	2743.40	780.00	1963.40
70	23.82	0.67	2834.64	840.00	1994.64
75	22.92	0.65	2922.30	900.00	2022.30
80	22.11	0.63	3006.76	960.00	2046.76
85	21.37	0.61	3088.32	1020.00	2068.32
90	20.70	0.59	3167.24	1080.00	2087.24
95	20.09	0.57	3243.75	1140.00	2103.75
100	19.52	0.55	3318.04	1200.00	2118.04
105	18.99	0.54	3390.29	1260.00	2130.29
110	18.51	0.52	3460.63	1320.00	2140.63
115	18.05	0.51	3529.21	1380.00	2149.21
120	17.63	0.50	3596.15	1440.00	2156.15
135	16.51	0.47	3788.09	1620.00	2168.09
150	15.56	0.44	3968.45	1800.00	2168.45
165	14.76	0.42	4138.99	1980.00	2158.99
180	14.06	0.40	4301.07	2160.00	2141.07
195	13.44	0.38	4455.78	2340.00	2115.78
210	12.90	0.37	4603.96	2520.00	2083.96
225	12.41	0.35	4746.35	2700.00	2046.35
240	11.97	0.34	4883.53	2880.00	2003.53
255	11.57	0.33	5015.99	3060.00	1955.99
270	11.21	0.32	5144.18	3240.00	1904.18
285	10.87	0.31	5268.44	3420.00	1848.44
300	10.57	0.30	5389.10	3600.00	1789.10
315	10.28	0.29	5506.44	3780.00	1726.44
330	10.02	0.28	5620.70	3960.00	1660.70
345	9.77	0.28	5732.09	4140.00	1592.09
360	9.54	0.27	5840.80	4320.00	1520.80
375	9.33	0.26	5947.02	4500.00	1447.02
390	9.13	0.26	6050.89	4680.00	1370.89
405	8.94	0.25	6152.55	4860.00	1292.55
420	8.76	0.25	6252.13	5040.00	1212.13
435	8.59	0.24	6349.74	5220.00	1129.74
450	8.43	0.24	6445.48	5400.00	1045.48
465	8.27	0.23	6539.47	5580.00	959.47
480	8.13	0.23	6631.77	5760.00	871.77
495	7.99	0.23	6722.47	5940.00	782.47

510	7.86	0.22	6811.66	6120.00	691.66
525	7.73	0.22	6899.39	6300.00	599.39
540	7.61	0.22	6985.73	6480.00	505.73
555	7.49	0.21	7070.74	6660.00	410.74
570	7.38	0.21	7154.48	6840.00	314.48
585	7.28	0.21	7236.99	7020.00	216.99
600	7.17	0.20	7318.33	7200.00	118.33
615	7.08	0.20	7398.55	7380.00	18.55
630	6.98	0.20	7477.68	7560.00	-82.32
645	6.89	0.20	7555.76	7740.00	-184.24
660	6.80	0.19	7632.83	7920.00	-287.17
675	6.72	0.19	7708.94	8100.00	-391.06
690	6.64	0.19	7784.10	8280.00	-495.90
705	6.56	0.19	7858.36	8460.00	-601.64
720	6.48	0.18	7931.74	8640.00	-708.26
735	6.41	0.18	8004.27	8820.00	-815.73
750	6.33	0.18	8075.98	9000.00	-924.02
765	6.26	0.18	8146.89	9180.00	-1033.11
780	6.20	0.18	8217.03	9360.00	-1142.97
795	6.13	0.17	8286.42	9540.00	-1253.58
810	6.07	0.17	8355.08	9720.00	-1364.92
825	6.01	0.17	8423.04	9900.00	-1476.96
840	5.95	0.17	8490.31	10080.00	-1589.69
855	5.89	0.17	8556.91	10260.00	-1703.09
870	5.83	0.17	8622.86	10440.00	-1817.14
885	5.77	0.16	8688.18	10620.00	-1931.82
900	5.72	0.16	8752.89	10800.00	-2047.11
915	5.67	0.16	8816.99	10980.00	-2163.01
930	5.62	0.16	8880.51	11160.00	-2279.49
945	5.57	0.16	8943.46	11340.00	-2396.54
960	5.52	0.16	9005.86	11520.00	-2514.14
975	5.47	0.16	9067.71	11700.00	-2632.29
990	5.42	0.15	9129.03	11880.00	-2750.97
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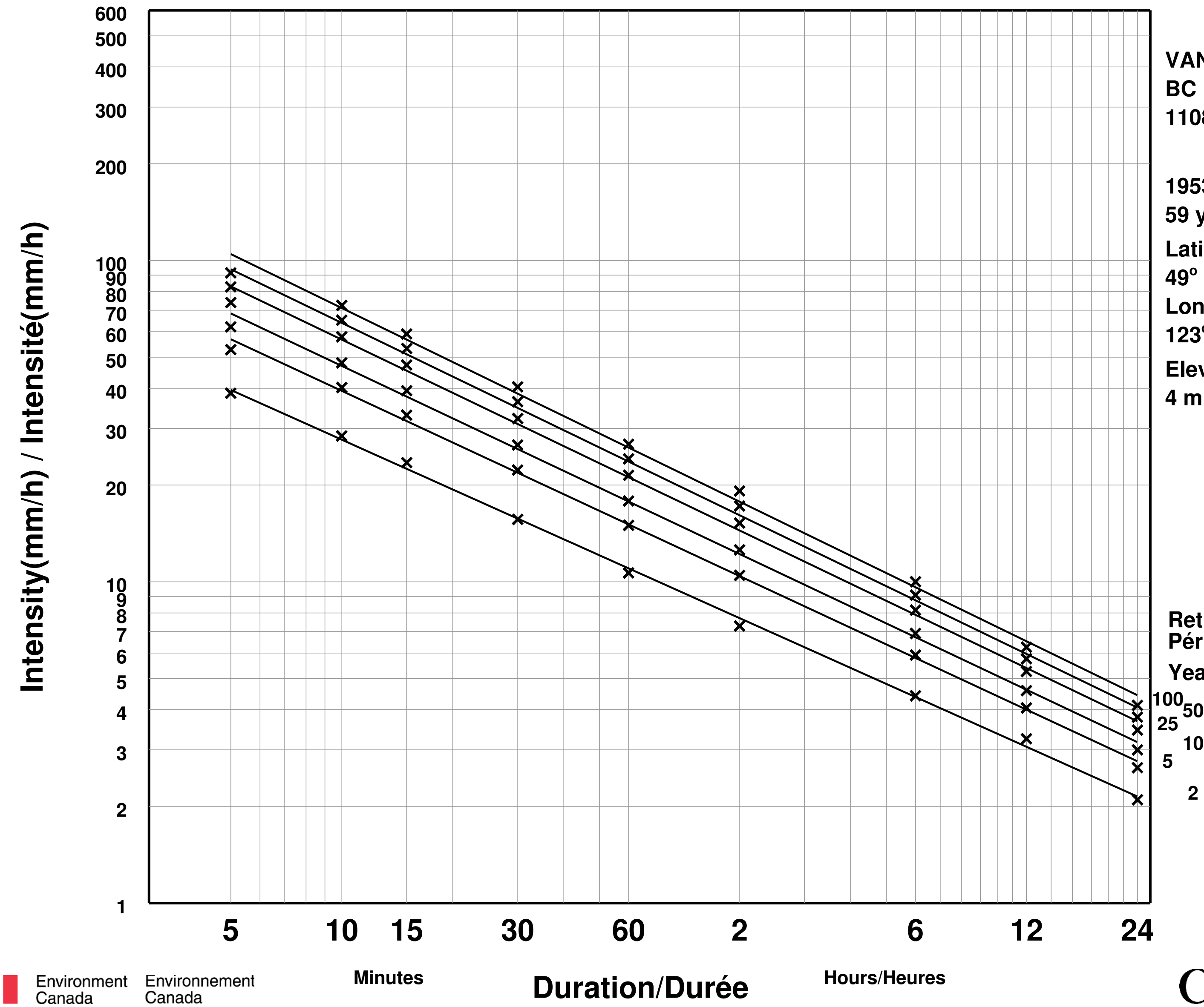
1020	5.33	0.15	9250.14	12240.00	-2989.86
1035	5.29	0.15	9309.95	12420.00	-3110.05
1050	5.25	0.15	9369.28	12600.00	-3230.72
1065	5.21	0.15	9428.14	12780.00	-3351.86
1080	5.17	0.15	9486.53	12960.00	-3473.47
1095	5.13	0.15	9544.47	13140.00	-3595.53
1110	5.09	0.14	9601.97	13320.00	-3718.03
1125	5.05	0.14	9659.04	13500.00	-3840.96
1140	5.01	0.14	9715.69	13680.00	-3964.31
1155	4.98	0.14	9771.92	13860.00	-4088.08
1170	4.94	0.14	9827.74	14040.00	-4212.26
1185	4.91	0.14	9883.17	14220.00	-4336.83
1200	4.87	0.14	9938.20	14400.00	-4461.80
1215	4.84	0.14	9992.86	14580.00	-4587.14
1230	4.80	0.14	10047.13	14760.00	-4712.87
1245	4.77	0.14	10101.04	14940.00	-4838.96
1260	4.74	0.13	10154.59	15120.00	-4965.41
1275	4.71	0.13	10207.78	15300.00	-5092.22
1290	4.68	0.13	10260.63	15480.00	-5219.37
1305	4.65	0.13	10313.13	15660.00	-5346.87
1320	4.62	0.13	10365.29	15840.00	-5474.71
1335	4.59	0.13	10417.13	16020.00	-5602.87
1350	4.56	0.13	10468.64	16200.00	-5731.36
1365	4.53	0.13	10519.83	16380.00	-5860.17
1380	4.51	0.13	10570.71	16560.00	-5989.29
1395	4.48	0.13	10621.28	16740.00	-6118.72
1410	4.45	0.13	10671.55	16920.00	-6248.45
1425	4.43	0.13	10721.52	17100.00	-6378.48
1440	4.40	0.12	10771.20	17280.00	-6508.80

Short Duration Rainfall Intensity–Duration–Frequency Data

2014/12/21

Données sur l'intensité, la durée et la fréquence des chutes de pluie de courte durée



VANCOUVER INTL A
BC
1108395

1953 – 2013
59 years / ans
Latitude
49° 11'N
Longitude
123° 11'W
Elevation / Altitude
4 m

Return Periods/
Périodes de retour
Years / ans

Environment Canada Environnement Canada

Canada

APPENDIX B – IFC DRAWINGS

UBC Stormwater Detention Facility

South Catchment Area

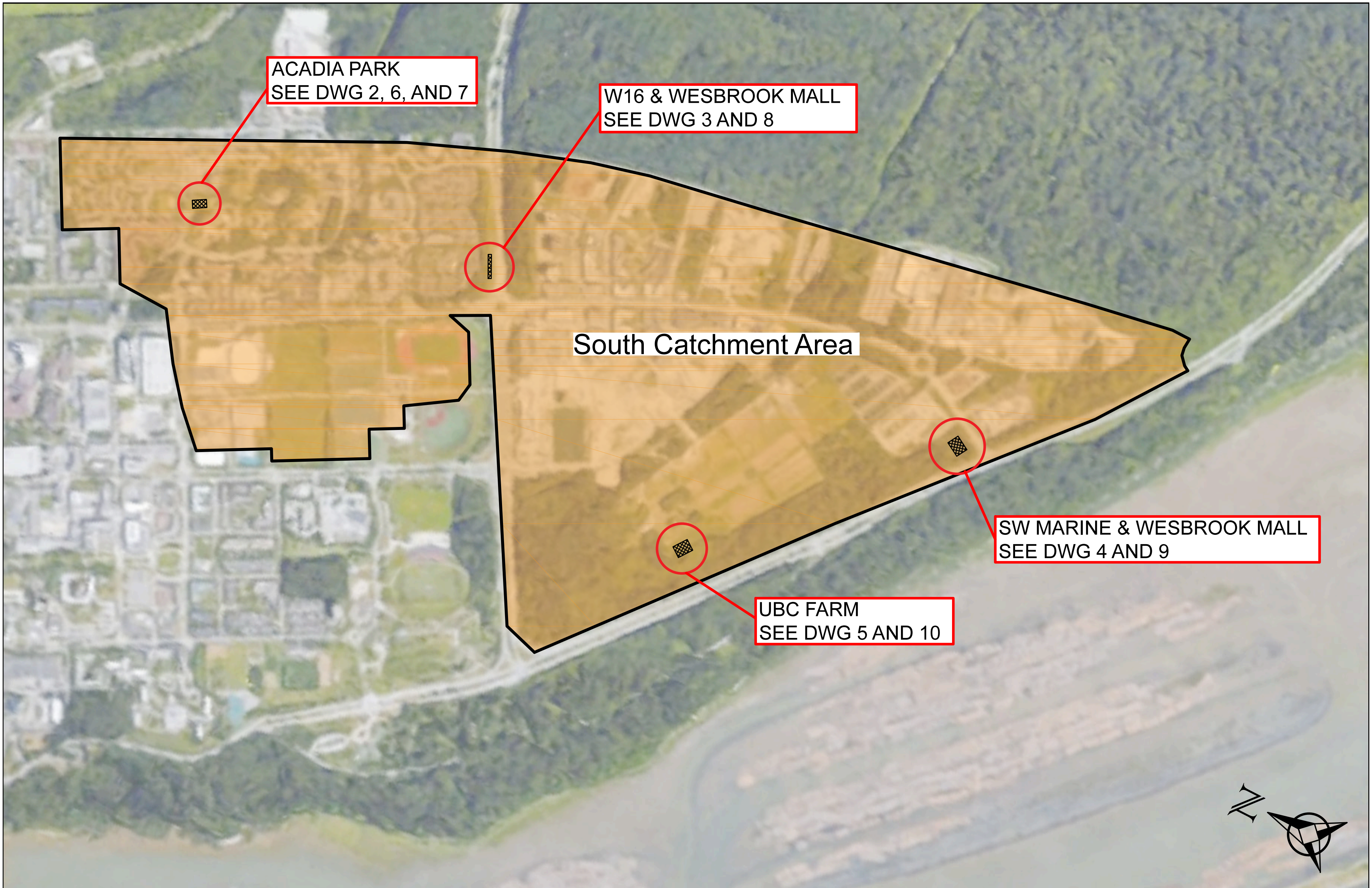
UBC SEEDS (Social Ecological Economic Development Studies) Sustainability Program

Issued for Construction (IFC)

April 4, 2016

Project : 24845 - 01

MINWOO ASSOCIATES



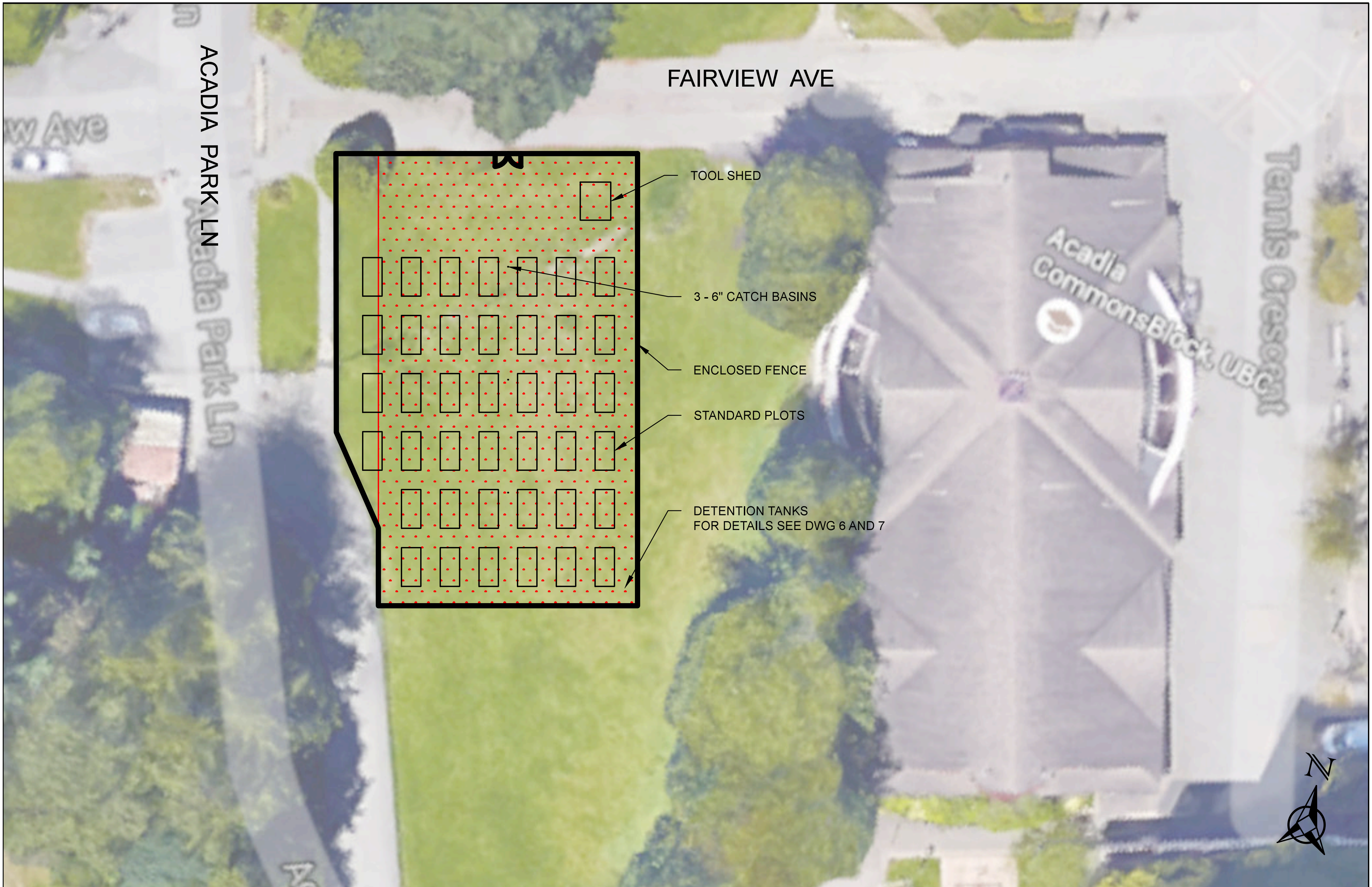
MINWOO ASSOCIATES

UBC Stormwater Detention Facility

South Catchment

Site Plan

PROJECT 24845-01	Dwg No. 1			
Drawn	BL			
Checked	MP			
Scale	1:500	A	DEC.4/15	INITIAL ISSUE
		REV	DATE	DESCRIPTION



MINWOO ASSOCIATES

UBC Stormwater Detention Facility

Acadia Park Community Garden

Detention Tank Layout

PROJECT 24845-01	Dwg No. 2
Drawn	LT
Checked	MP
Scale	1:400

REV	DATE	DESCRIPTION
A	APRIL 4, 2016	IFC

MINWOO
ASSOCIATES

UBC Stormwater Detention Facility

W16th Ave & Wesbrook Mall

Detention Tank Layout

PROJECT	Dwg No.
24845-01	3
Drawn	LT
Checked	MP
Scale	1:500

REV	DATE	DESCRIPTION
A	APRIL 4, 2016	IFC

MINWOO
ASSOCIATES

UBC Stormwater Detention Facility

SW Marine Dr. & Wesbrook Mall Maze Garden

Detention Tank Layout

PROJECT	Dwg No.
24845-01	4
Drawn	LT
Checked	MP
Scale	1:500

REV	DATE	DESCRIPTION
A	APRIL 4, 2016	IFC

MINWOO ASSOCIATES

UBC Stormwater Detention Facility

UBC Farm

Detention Tank Layout

PROJECT	Dwg No.
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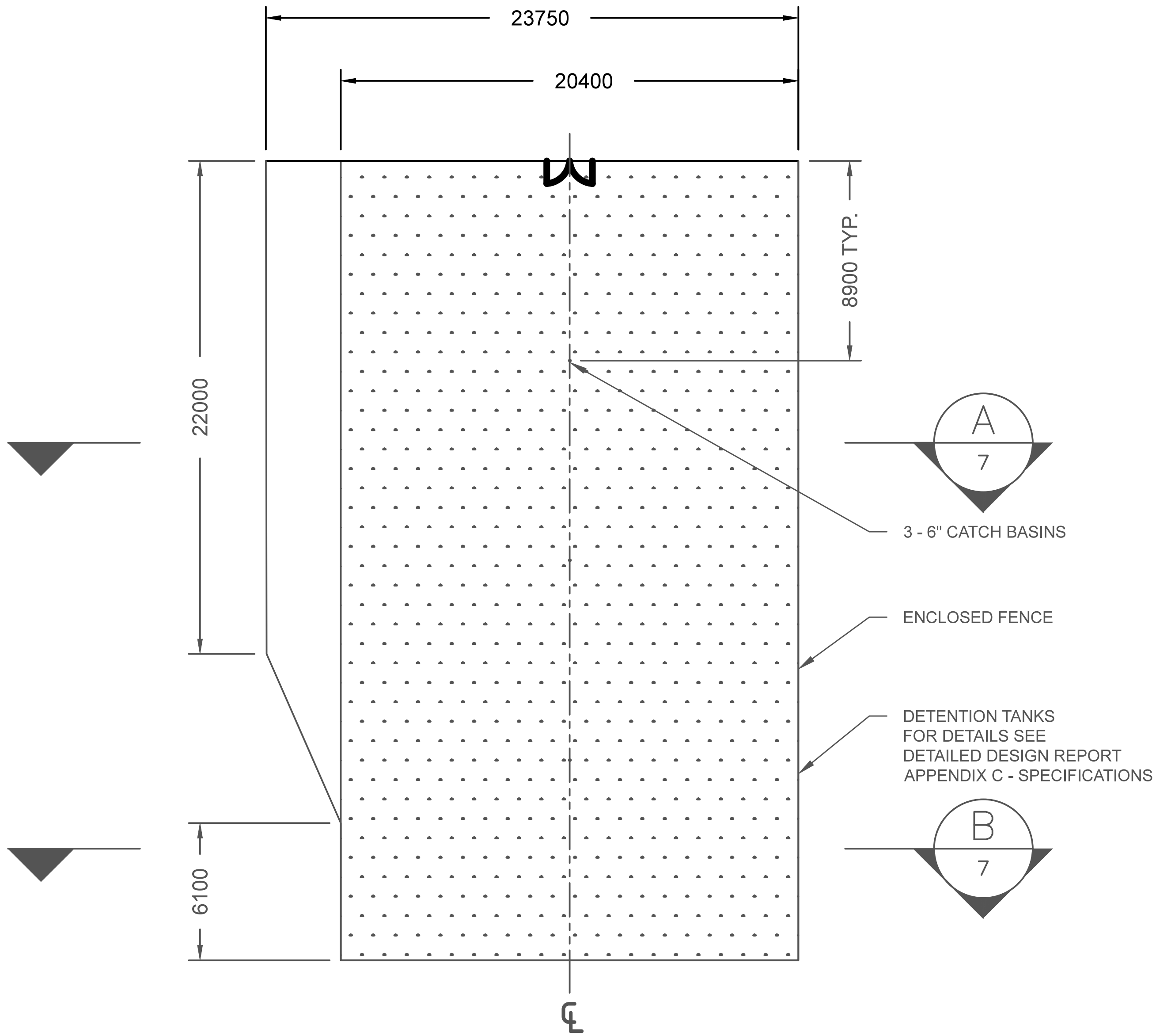
Drawn	LT
Checked	MP
Scale	1:500

REV	DATE	DESCRIPTION
A	APRIL 4, 2016	IFC



PLAN - ACADIA PARK

MINWOO ASSOCIATES	UBC Stormwater Detention Facility Acadia Park Community Garden Detention Tank Plan	PROJECT 24845-01	Dwg No. 6			
		Drawn	LT			
		Checked	MP			
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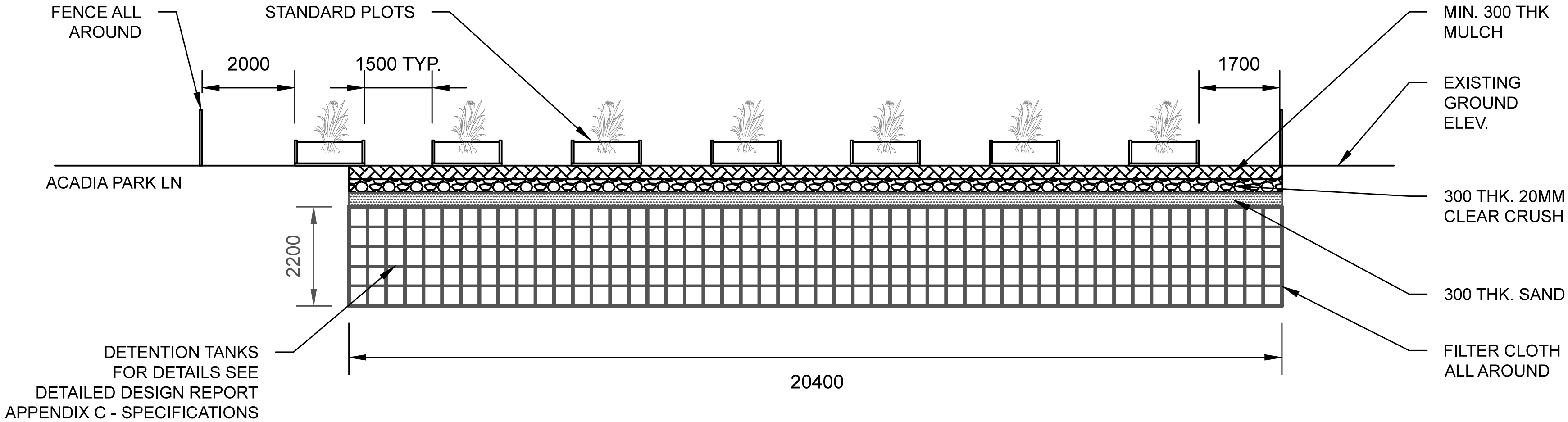
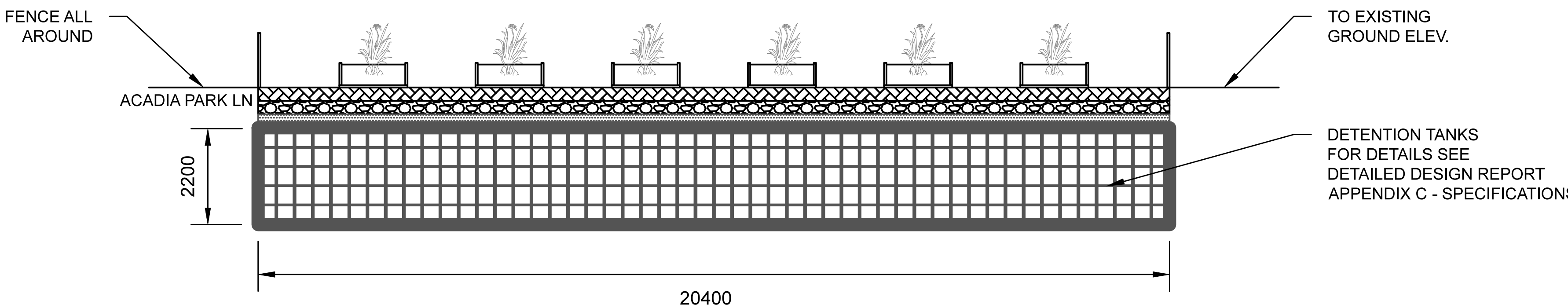
				REV	DATE	DESCRIPTION



A 6 SECTION
SCALE 1:150



B 6 SECTION
SCALE 1:150

MINWOO ASSOCIATES

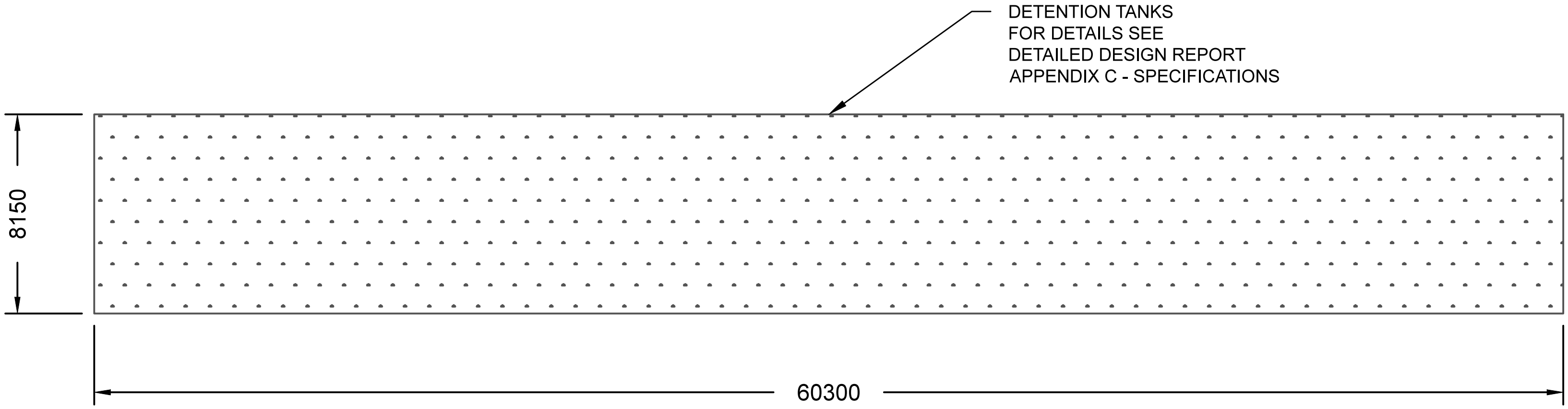
UBC Stormwater Detention Facility

Acadia Park Community Garden

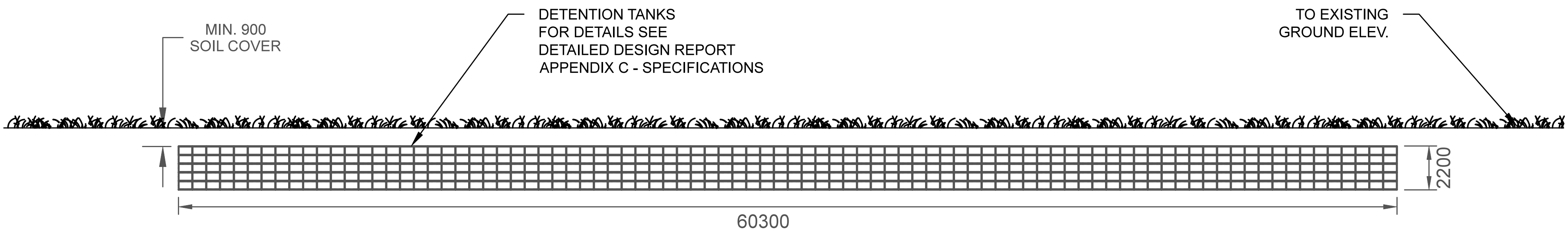
Detention Tank Details

PROJECT 24845-01	Dwg No. 7
Drawn	LT
Checked	MP
Scale	1:150

REV	DATE	DESCRIPTION
A	APRIL 4, 2016	IFC



PLAN - W16TH DETENTION TANK



ELEVATION - W16TH DETENTION TANKS

MINWOO ASSOCIATES

UBC Stormwater Detention Facility
W16th Ave & Wesbrook Mall
Detention Tank Plan and Details

PROJECT 24845-01	Dwg No. 8			
Drawn	LT			
Checked	MP			
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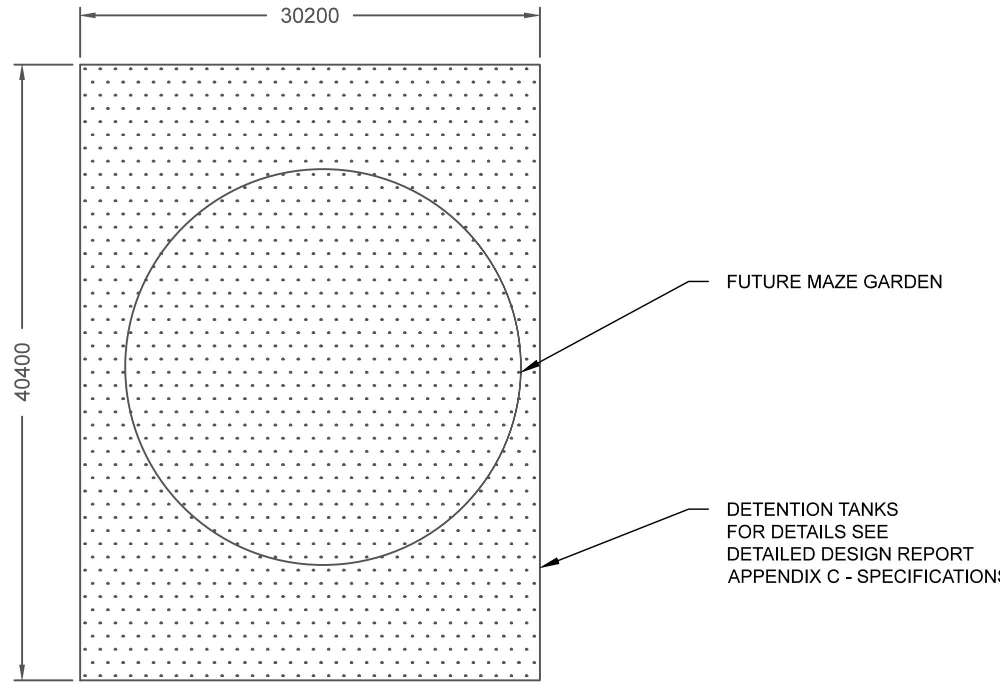
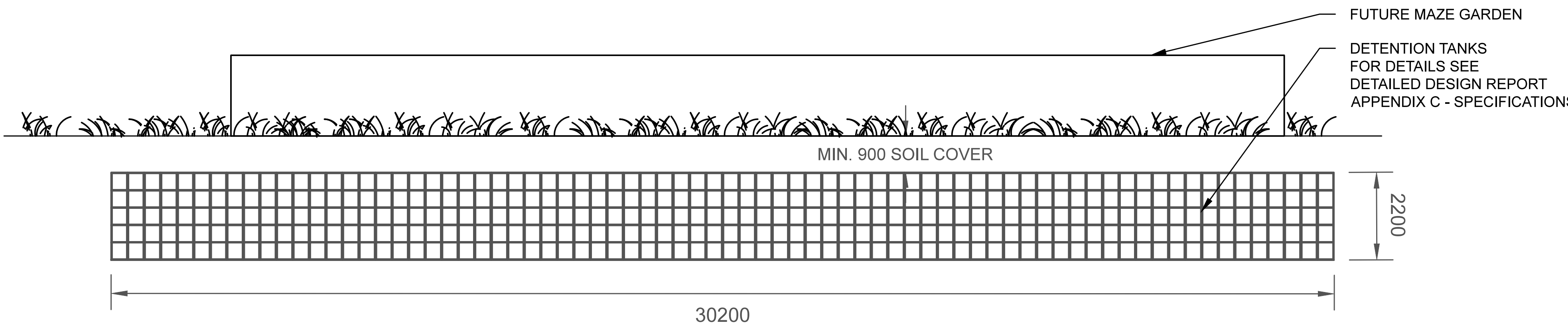
		REV	DATE	DESCRIPTION



PLAN - SW MARINE DETENTION TANK
SCALE 1:500



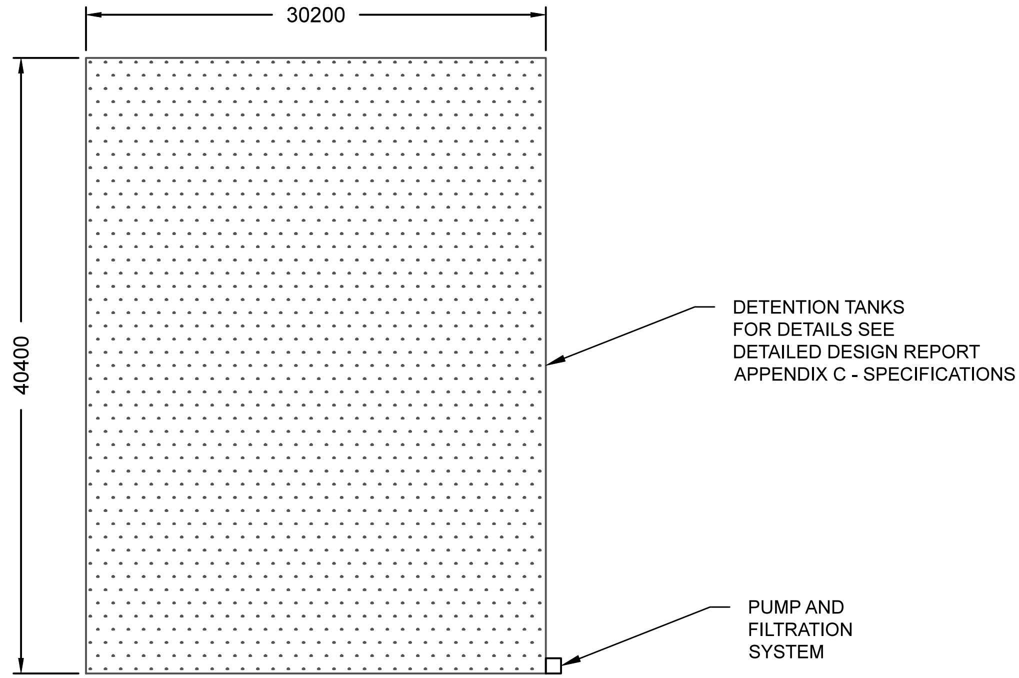
ELEVATION - SW MARINE DETENTION TANKS
SCALE 1:150

MINWOO ASSOCIATES

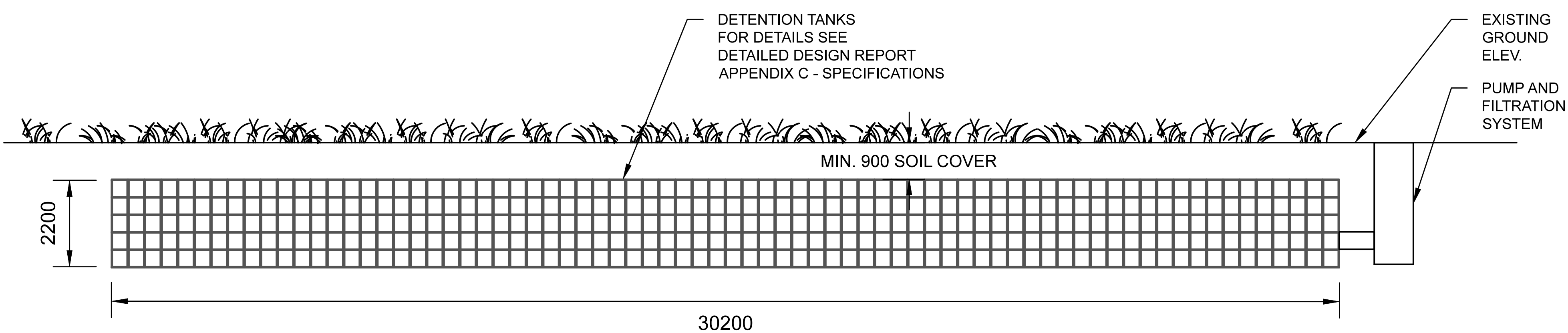
UBC Stormwater Detention Facility
SW Marine Dr. & Wesbrook Mall Maze Garden
Detention Tank Plan and Details

PROJECT	Dwg No.
24845-01	9
Drawn	LT
Checked	MP
Scale	1:150

REV	DATE	DESCRIPTION
A	APRIL 4, 2016	IFC



PLAN - UBC FARM DETENTION TANK
SCALE 1:500



ELEVATION - UBC FARM DETENTION TANKS
SCALE 1:150

MINWOO ASSOCIATES

UBC Stormwater Detention Facility
UBC Farm
Detention Tank Plan and Details

PROJECT 24845-01	Dwg No. 10
Drawn	LT
Checked	MP
Scale	1:150

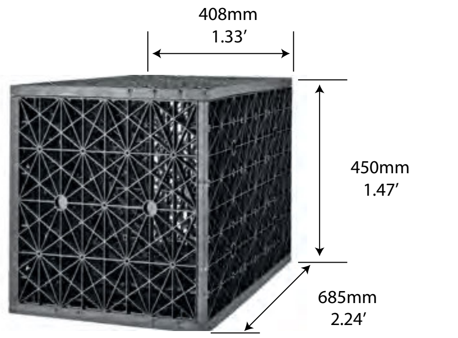
REV	DATE	DESCRIPTION
A	APRIL 4, 2016	IFC

APPENDIX C – MATERIAL SPECIFICATIONS & STANDARDS

Product Description

The Atlantis® D-Raintank® is a modular underground storage system developed through years of research and development that provides a highly efficient method to manage storm water. This subsurface system can be constructed to hold any volume required being limited only by the area available. The Atlantis tanks are assembled from small plates and large plates. Depending on load and design, the quantity of small plates can be increased to up to seven for each module to handle higher loading.

The subsurface nature of the Atlantis® D-Raintank® module frees up space for surface landscaping, driveway or parking lot use while meeting the storm water detention requirements of your local municipality. It is ideal for the construction of infiltration tanks, water re-use tanks and subsurface channels. Sediment can be removed by pretreating storm water by surface infiltration or by purification units used in combination with a lower tank (forebay) installed at inlet with a maintenance port and other maintenance ports dispersed every 50 feet.

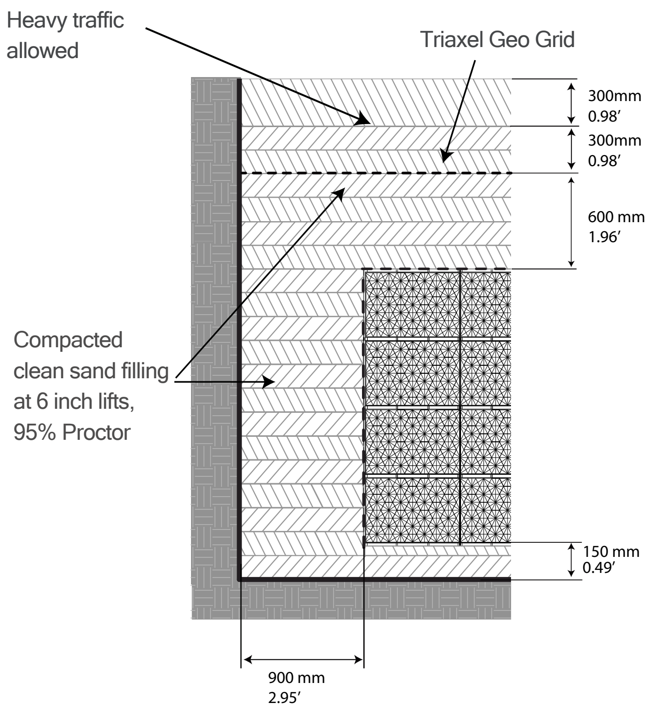


Atlantis® D-Raintank®

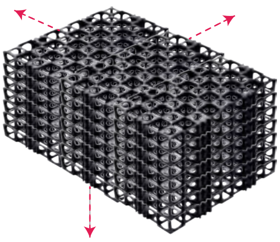
Installation

The installation begins with site excavation, base preparation and compaction to 95% of standard proctor. The base is then covered with a layer of angular stone and sand to a depth of 100 mm. A nonwoven geotextile and /or geomembrane are installed on the base. The Atlantis® D-Raintank® modules are assembled to the desired configuration and placed within the excavation. Piping is installed and then the geotextile and/or geomembrane are wrapped around the installed modules. Place clean sand backfill around the sides of the tanks in 150 mm lifts and compact to 95% and then place sand above the tanks and compact.

Only light hand operated compaction equipment shall be used within one meter of the tanks horizontally and vertically. An RX 1200 geogrid is installed at 300 mm over the structure and extended beyond the edges by 900 mm or as required by the plans to a maximum recommended of 2.287 m. For a repair installation refer to Atlantis. Refer to and follow project specific drawings and specifications.



Laminar Compaction



Atlantis Titan-Tank infinite width, length and height

Maintenance

The Atlantis® D-Raintank® Storm Water Storage System is sustainable and works through infiltration. Surfaces of filter areas should be inspected on a regular basis, particularly after every major precipitation event. Accumulated debris, gross pollutant and/or sediment should be removed.

D-Raintank® - Metric Values

	Mini		Single		Double		Triple		Quad		Penta	
Width	**16”**	408mm	**16”**	408mm	**16”**	408mm	**16”**	408mm	**16”**	408mm	**16”**	408mm
Length	**30”**	685mm	**30”**	685mm	**30”**	685mm	**30”**	685mm	**30”**	685mm	**30”**	685mm
Height	**9.5”**	240mm	**17.7”**	450mm	**34.6”**	880mm	**51.5”**	1310mm	**68.5”**	1740mm	**83”**	2170mm
Tank Volume	**2.47ft3**	0.07m3	**4.49ft3**	0.13m3	**8.82ft3**	0.25	**13.06ft3**	0.37	**17.30ft3**	0.49	**21.54ft3**	0.61
Storm Water Storage Volume	**16.9gal**	64L	**31.7gal**	120L	**61.8gal**	234L	**91.9gal**	348L	**122gal**	462L	**152.1gal**	576L
Number of Plates (large /small)	2/4/2		4/4		7/8		10/12		13/16		16/20	
Tank Weight	**8.81lbs**	4kg	**14.3lbs**	6.5kg	**26.4lbs**	12kg	**38.5lbs**	17.5kg	**52.9lbs**	24kg	**90.3lbs**	41kg
Void Space	Approximately 95% void (90% for 7 plate tank)											
Material	100% PP recycled geocomposite resin											
Biological, Chemical Resistance	Unaffected by molds, algae, natural soil-borne bacteria or most chemicals											
Approx. Underground Temperature Range	**48ºF (±9C)**						39.2ºF (±4C)					

Range H-20 to H-100 + Static Load Crush Vertical Compressive Strength

Atlantis® D-Raintank®		Pedestrian 4 Plate Tank			5 Plate Tank	7 Plate Tank
H-20	Ultimate Static Load Strength (Ton per m2 / PSI)	34PSI	23.9 t/m2	234,42 KN/m2	Car parking lots	Access road

Static Load - apply a Safety Factor of 2 on material

Dynamic load during installation and post use should be calculated by the engineer

Minimum and Maximum Static Cover Depth Over Atlantis® D-Raintank®

Minimum Fill Cover 3 feet / 0.900m	NOTE Minimum compacted fill before any large equipment is allowed to load. Traffic and conditions to engineer details.
Maximum Fill Cover tank 6.5 feet / 2m	

H-40+ Titan Tank — Static Compressive Strength on Crush

52mm HD Module	182 PSI (USA)	1254.84 KN/m2	128 t/m2 (Canada)

H-60+ Hercules Tank

53mm HD Module	394 PSI (USA)	2716.53 KN/m2	277 t/m2 (Canada)

Construction, Traffic and Seasonal Loading (flash foods, snow, permafrost, etc)

The Atlantis System can be used where greater loads are anticipated. These may be areas trafficked by commercial and heavy goods vehicles that includes all vehicles in excess of 4.409lbs (2500kg) gross weight. However, specific design advice should be sought from Atlantis Corporation for these situations.

Design information required to carry out a comprehensive design for these circumstances should include type of vehicle with maximum anticipated vehicle weight.

Parking Lots and Road Safety Factors should be calculated by the Engineer in charge (5 to 7 internal plates).

11 Tons (for a Safety Factor of 2 plus expected cover).

Side and Back Fill - only structurally clean sand & gravel, compacted at 6" lift at 95% proctor.

NOTES:

The design strength above is based on the manufacturer's installation recommendation and to a minimum Safety Factor of 2 on ultimate product crush and compressive strength. An additional dynamic load safety factor should be calculated by the design engineer.

Atlantis tank modules must be installed in vertical dimension to insure maximum strength.

For deep installations or H20 / H35 or more traffic loads consult Atlantis at info@atlantiscorp.com.au.

For more complex or large designs Atlantis Aurora can participate in a consortium as an Environmental Design Company.

Intellectual Property

Granted Patents in the USA

Utility Patents

US 5.810.510 Underground Drainage System

US 6.648.549 Modular Drainage Channels

US 6.679.946 Drainage Structure

US 7.056.058 Transport Corridor Drainage System

US7.686.540 Transport Corridor Infiltration System

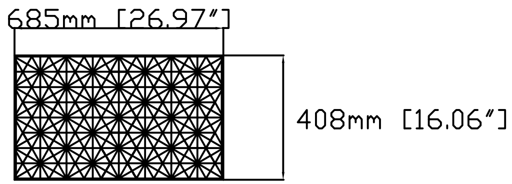
Design Patents

US D 571.023 Paver

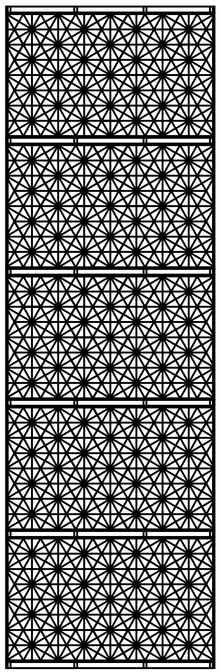
US D 555.809 Paver

US D 596.698 Large Tank Plate

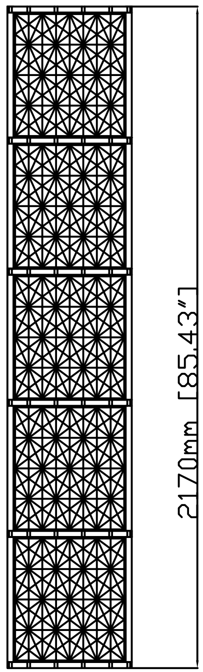
US D 596.699 Small Tank Plate



Plan View



Side View



Front View

Drawing No: AOP 0021

Atlantis®

Water Management for Life

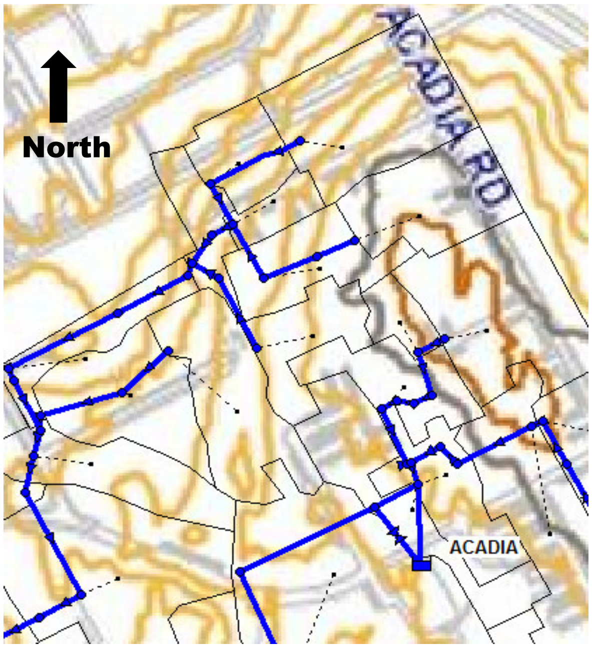
Atlantis® Penta Matrix®/ Flo-Tank®/ D-Raintank® Module - *Part No. 70007*

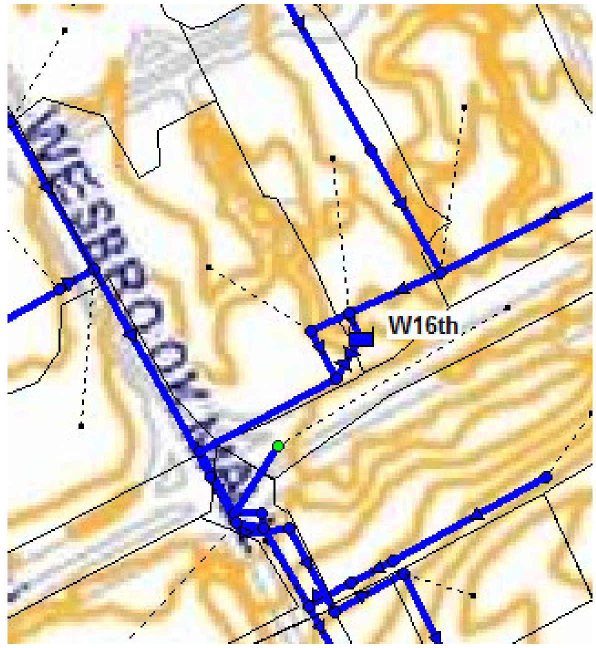
Dimensions (W x L x H)	408mm x 685mm x 1270mm	16.06" x 26.97" x 85.43"
Module Footprint	0.2795 m²	3.011 ft²
Ultimate Compressive Strength	24 t / m²	34 PSI
Gross Volume	0.607 m³	21.47 ft³
Storage Capacity	576 L	152.18 gal

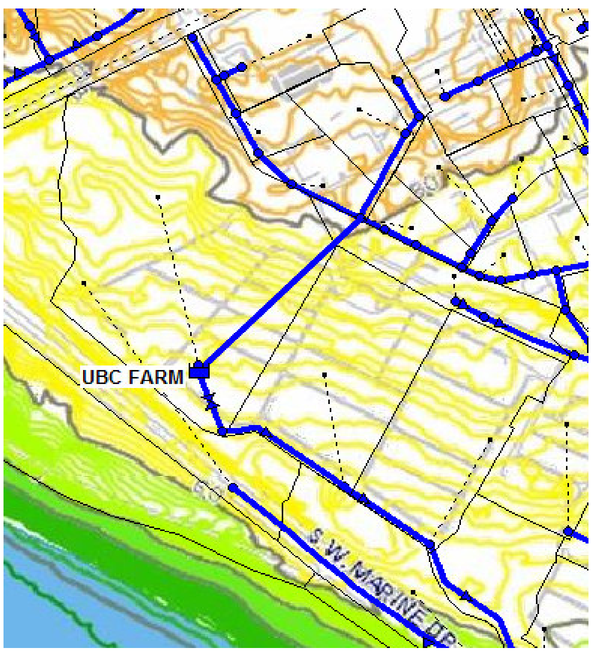
19 August 2009

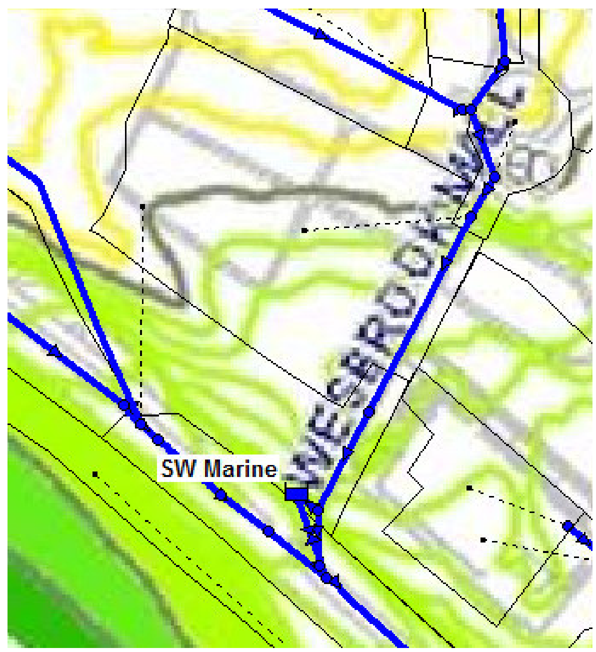
APPENDIX D – SWMM NETWORK

Network Integration Arrangement for Acadia, West 16th Ave, UBC Farm and SW Marine Drive





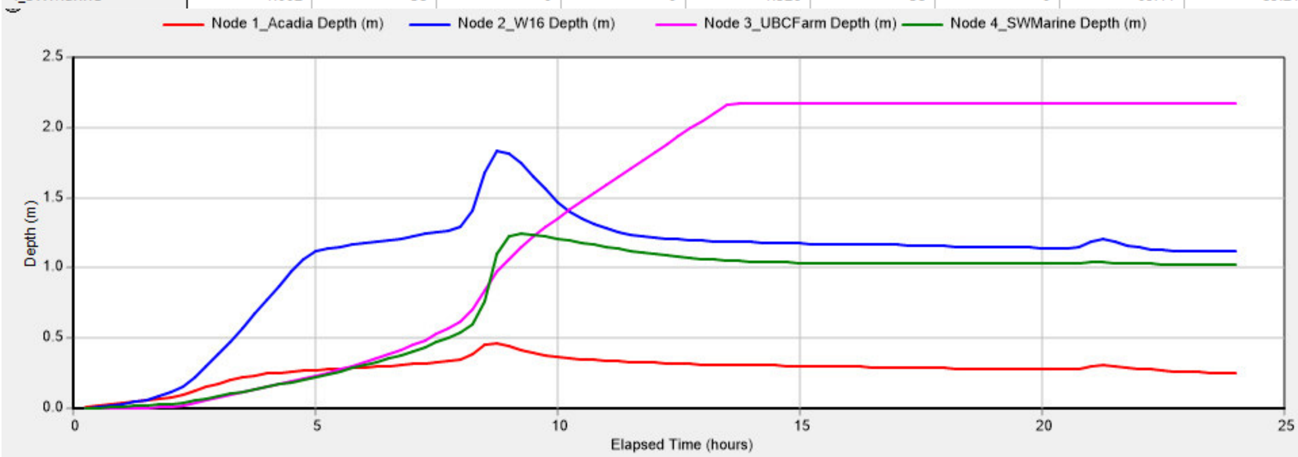




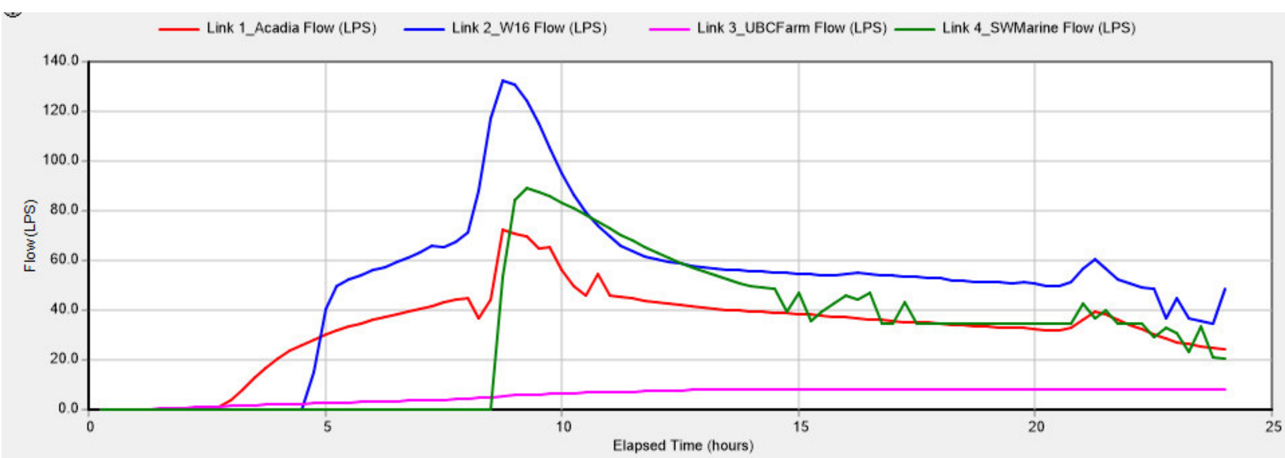
Minor Storm Model Performance

Storage Unit Summary Report for a 1:10 Year Storm

Storage Unit	Average Volume 1000 m3	Average Percent Full	Evap Percent Loss	Exfil Percent Loss	Maximum Volume 1000 m3	Maximum Percent Full	Day of Maximum Volume	Hour of Maximum Volume	Maximum Outflow LPS
1_Acadia	0.215	14	0	0	0.340	22	0	08:39	73.40
2_W16	0.565	53	0	0	0.906	84	0	08:47	145.60
3_UBCFarm	1.409	65	0	0	2.170	100	0	13:32	210.25
4_SWMarine	1.002	38	0	0	1.526	58	0	09:11	89.21



Orifice Discharge Rate for 1:10 Year Storm



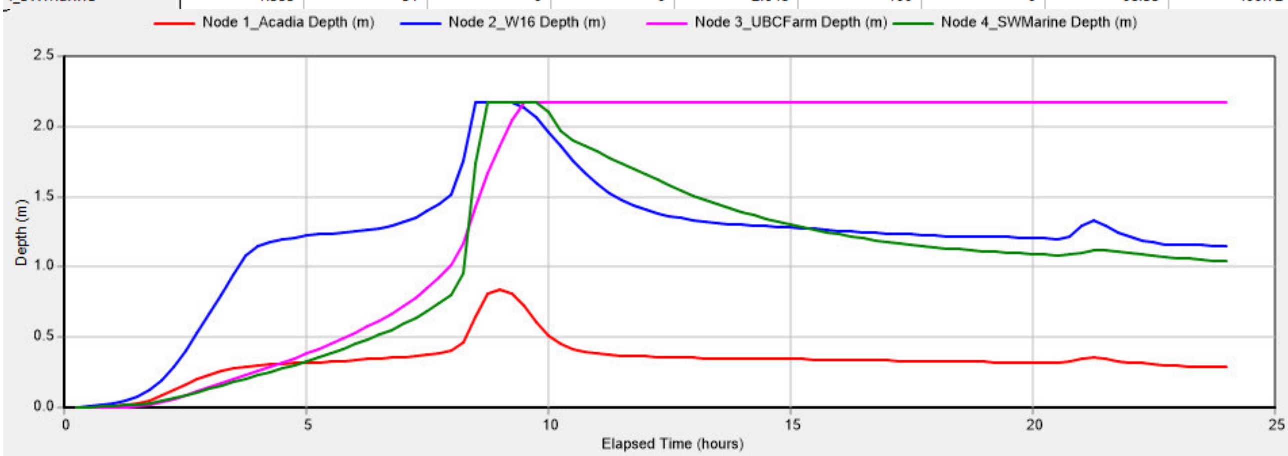
Outfall Discharge Rate for a 1:10 Year Storm

Outfall Node	Flow Freq. Pcnt.	Avg. Flow LPS	Max. Flow LPS	Total Volume 10^6 ltr
South	99.66	1032.27	2759.82	78.048

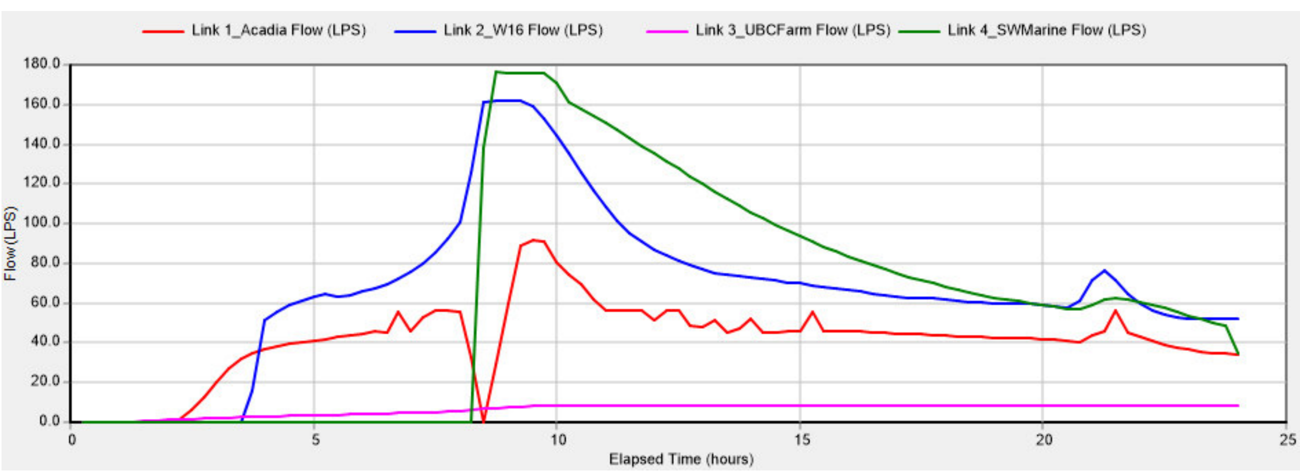
Major Storm Model Performance

Storage Unit Summary Report for a 1:100 Year Storm

Storage Unit	Average Volume 1000 m3	Average Percent Full	Evap Percent Loss	Exfil Percent Loss	Maximum Volume 1000 m3	Maximum Percent Full	Day of Maximum Volume	Hour of Maximum Volume	Maximum Outflow LPS
1_Acadia	0.263	17	0	0	0.610	39	0	09:01	103.42
2_W16	0.646	60	0	0	1.073	100	0	08:27	161.72
3_UBCFarm	1.615	74	0	0	2.170	100	0	09:25	91.14
4_SWMarine	1.353	51	0	0	2.648	100	0	08:35	400.72



Orifice Discharge Rate for 1:100 Year Storm



Outfall Discharge Rate for 1:100 Year Storm

Outfall Node	Flow Freq. Pcnt.	Avg. Flow LPS	Max. Flow LPS	Total Volume 10^6 ltr
South	99.70	1603.52	2938.45	124.067

APPENDIX E – SENSITIVITY ANALYSIS

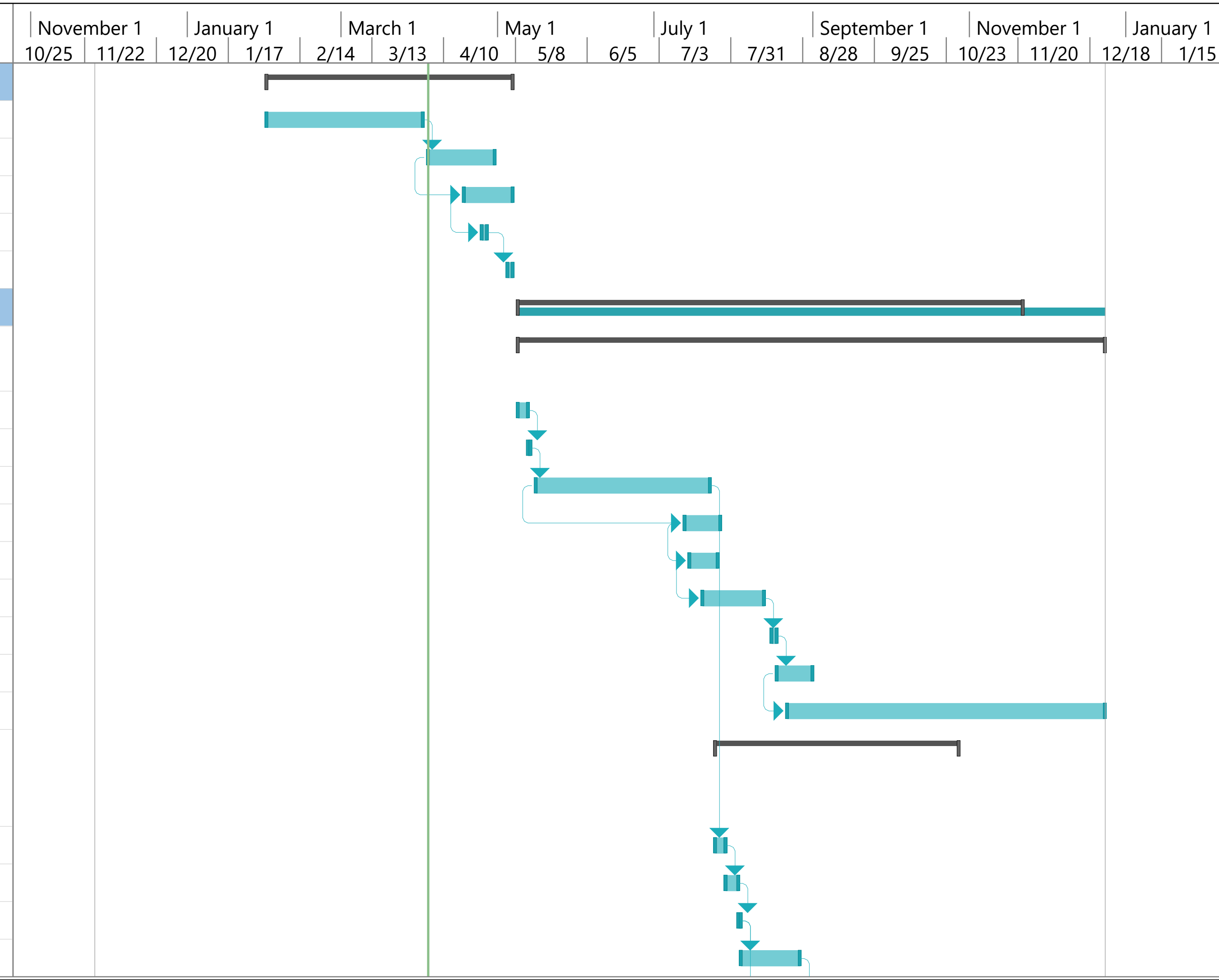
Current Conditions								
	Catchment Imperviousness	Catchment Area (m^2)	Discharge (m^3/s)	Rainfall Intensity		Volume (m^3)	Area with FS 1.5 (m^2)	Volume with FS (m^3)
				I for 8 min (mm/hr)	I for 24 hr (mm/hr)			
Acadia Park	0.8	65000	0.2	80	4.4	650	97500	1450
West 16	0.8	53000	0.2	80	4.4	460	79500	940
UBC Farm	0.5	153000	0.2	80	4.4	1300	229500	2680
Marine Drive	0.5	136000	0.2	80	4.4	1050	204000	2170
Total						3460		7240

Changed Conditions						
	Increased Imperviousness by 25%		Increase Rainfall Intensity by 7%			Increase Both
	Imperviousness	Volume (m^3)	I for 8 min	I for 24 hr	Volume (m^3)	Volume (m^3)
Acadia Park	1	970	85.6	4.71	740	1100
West 16	0.625	680	85.6	4.71	510	760
UBC Farm	0.625	1940	85.6	4.71	1470	2190
Marine Drive	0	1570	85.6	4.71	1190	1770
Total		5160			3910	5820
Percent Change		49%			13%	68%

APPENDIX F – CONSTRUCTION SCHEDULE

UBC SOUTH CAMPUS STORMWATER DETENTION SYSTEM

ID	Task Name	Duration	Start
1	**PRE-CONSTRUCTION**	**70 days**	**Mon 2/1/16**
2	Permitting	45 days	Mon 2/1/16
3	Tendering and Awarding Contracts	20 days	Mon 4/4/16
4	Geotechnical Site Analysis	15 days	Mon 4/18/16
5	Project Material Purchase	2 days	Mon 4/25/16
6	Site Layout	2 days	Thu 5/5/16
7	**CONSTRUCTION**	**141 days**	**Mon 5/9/16**
8	**Maze Garden Detention at SW Marine Drive and Wesbrook Mall**	**165 days**	**Mon 5/9/16**
9	Mobilization	4 days	Mon 5/9/16
10	Establishing Site Office	1 day	Fri 5/13/16
11	Removal of trees	50 days	Mon 5/16/16
12	Excavation	10 days	Wed 7/13/16
13	Shoring	7 days	Fri 7/15/16
14	Assembly and Installation of Eco-Tanks	18 days	Wed 7/20/16
15	Pipe Oveflow Installation	2 days	Tue 8/16/16
16	Backfill	10 days	Thu 8/18/16
17	Landscaping	90 days	Mon 8/22/16
18	**Rainwater Harvest at UBC Farm and Swale Enhancement along South West Marine Drive**	**69 days**	**Mon 7/25/16**
19	Mobilization	4 days	Mon 7/25/16
20	Site Preparation	3 days	Fri 7/29/16
21	Removal of trees	1 day	Wed 8/3/16
22	Excavation	17 days	Thu 8/4/16

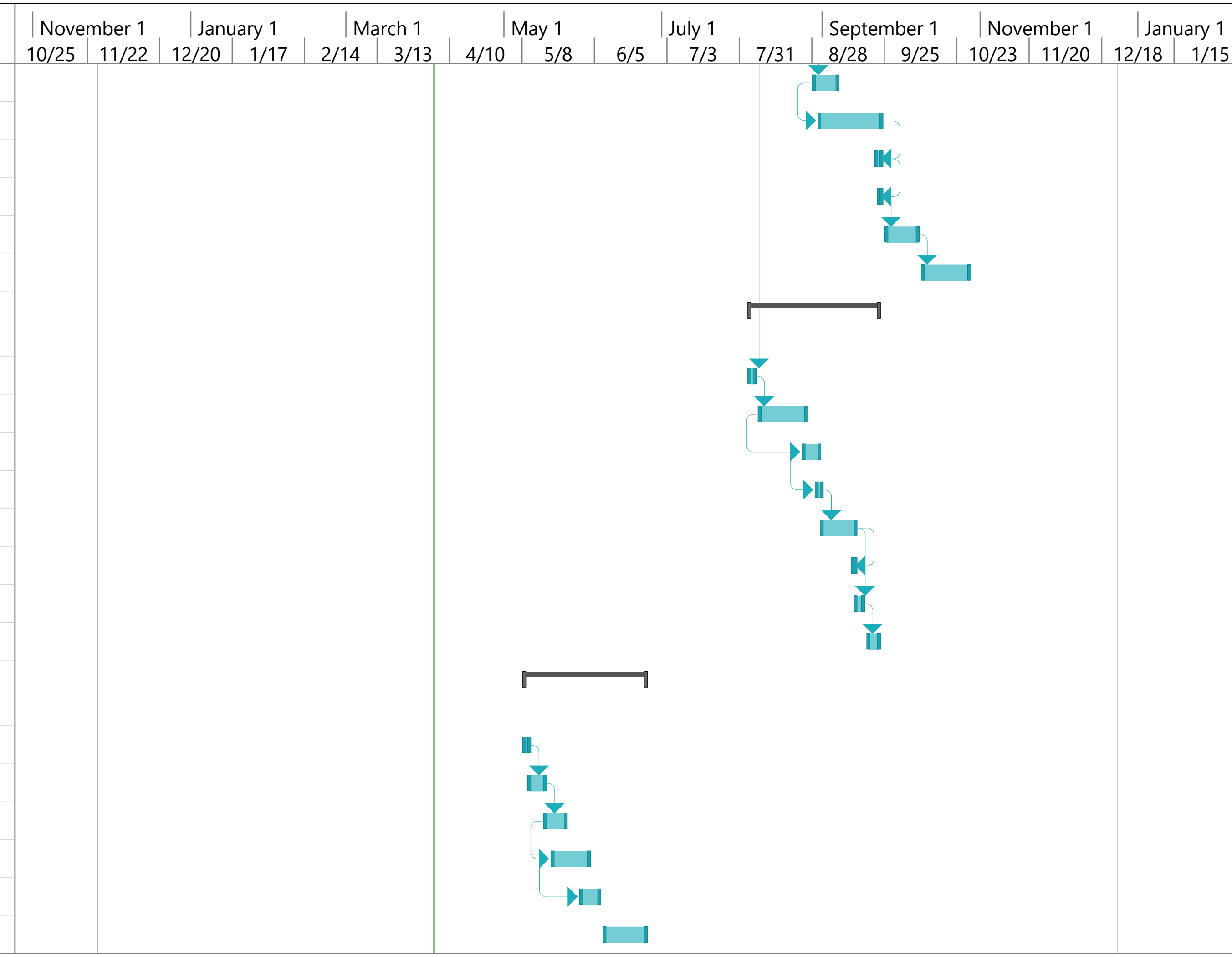


Project: UBC South Campus Stormwater Detention System
Date: Mon 4/4/16

Task	Inactive Task	Manual Summary Rollup	External Milestone
Split	Inactive Milestone	Manual Summary	Deadline
Milestone	Inactive Summary	Start-only	Progress
Summary	Manual Task	Finish-only	Manual Progress
Project Summary	Duration-only	External Tasks	

UBC SOUTH CAMPUS STORMWATER DETENTION SYSTEM

ID	Task Name	Duration	Start
23	Shoring	7 days	Mon 8/29/16
24	Assembly and Installation of Eco-Tanks	18 days	Wed 8/31/16
25	Pump Station Installation	2 days	Thu 9/22/16
26	Pipe Oveflow Installation	1 day	Fri 9/23/16
27	Backfill	10 days	Mon 9/26/16
28	Landscaping	14 days	Mon 10/10/16
29	**Detention at West 16th Avenue and Wesbrook Mall**	**36 days**	**Thu 8/4/16**
30	Mobilization	2 days	Thu 8/4/16
31	Removal of trees	14 days	Mon 8/8/16
32	Excavation	4 days	Thu 8/25/16
33	Shoring	2 days	Tue 8/30/16
34	Assembly and Installation of Eco-Tanks	9 days	Thu 9/1/16
35	Pipe Oveflow Installation	1 day	Tue 9/13/16
36	Backfill	3 days	Wed 9/14/16
37	Landscaping	4 days	Mon 9/19/16
38	**Community Garden Detention at Acadia Park**	**35 days**	**Mon 5/9/16**
39	Mobilization	2 days	Mon 5/9/16
40	Utilities Locate	4 days	Wed 5/11/16
41	Excavation	6 days	Tue 5/17/16
42	Assembly and Installation of Eco-Tanks	10 days	Fri 5/20/16
43	Backfill	5 days	Tue 5/31/16
44	Landscaping	12 days	Thu 6/9/16



Project: UBC South Campus Stormwater Detention System
Date: Mon 4/4/16

Task; Split; Milestone; Summary; Project Summary; Inactive Task; Inactive Milestone; Inactive Summary; Manual Task; Duration-only; Manual Summary Rollup; Manual Summary; Start-only; Finish-only; External Tasks; External Milestone; Deadline; Progress; Manual Progress

APPENDIX G – CLASS A COST ESTIMATE

SOUTH CAMPUS CATCHMENT AREA

STORMWATER FACILITIES DETAILED DESIGN COST ESTIMATE

Date: 8-Apr-16

				COMMUNITY GARDEN AT ACADIA		DETENTION TANK AT WEST 16TH AVENUE		DETENTION TANK AT MARINE DRIVE		RAIN HARVEST AT UBC FARM	
ITEM	DESCRIPTION	UNIT	UNIT COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST	QUANTITY	COST
1.0	**Mobilization + Demobilization**										
1.1	Mobilization	LS		1	$ 15,000	1	$ 15,000	1	$ 15,000	1	$ 15,000
1.2	Demobilization	LS		1	$ 10,000	1	$ 10,000	1	$ 10,000	1	$ 10,000
			Subtotal		**$ 25,000**		**$ 25,000**		**$ 25,000**		**$ 25,000**
2.0	**Site Work**										
2.1	Tree Removal	m^2	$ 50		$ -	480	$ 24,000	1200	$ 60,000		$ -
2.2	Excavation and Disposal	m^3	$ 25	2400	$ 60,000	1800	$ 45,000	4000	$ 100,000	4000	$ 100,000
2.3	Ground Compaction	m^2	$ 30	700	$ 21,000	480	$ 14,400	1200	$ 36,000	1200	$ 36,000
2.4	Backfill	m^3	$ 40	200	$ 8,000	300	$ 12,000	300	$ 12,000	300	$ 12,000
2.5	Landscaping/Arborist	LS		1	$ 45,000	1	$ 6,000	1	$ 60,000	1	$ 6,000
			Subtotal		**$ 134,000**		**$ 101,400**		**$ 268,000**		**$ 154,000**
3.0	**Detention System Components**										
3.1	Supply Eco-tanks	ea.	$ 150	2600	$ 390,000	1760	$ 264,000	4366	$ 654,900	4366	$ 654,900
3.2	Install Eco-tanks	ea.	$ 50	2600	$ 130,000	1760	$ 88,000	4366	$ 218,300	4366	$ 218,300
3.3	Supply and Install Geotextile Filter Fabric	m^2	$ 5	700	$ 3,500	480	$ 2,400	1200	$ 6,000	1200	$ 6,000
3.4	Supply and Install Waterproof Membrane	m^2	$ 30	940	$ 28,200	780	$ 23,400	940	$ 28,200	940	$ 28,200
3.5	Supply and Install Oil and Grit Separators	ea.	$ 15,000		$ -		$ -		$ -	1	$ 15,000
3.6	Pump	ea.	$ 5,000		$ -		$ -		$ -	1	$ 5,000
3.7	Pipe Connections	LS		1	$ 15,000	1	$ 10,000	1	$ 20,000	1	$ 20,000
			Subtotal		**$ 566,700**		**$ 387,800**		**$ 927,400**		**$ 947,400**
4.0	**Miscellaneous Items**										
4.1	Environmental, Geological and Archaeological Assessment	LS		1	$ 12,500	1	$ 10,000	1	$ 15,000	1	$ 15,000
4.2	Geotechnical Testing	LS		1	$ 12,000	1	$ 12,000	1	$ 12,000	1	$ 12,000
4.3	Utility Locate	LS		1	$ 10,000	1	$ 5,000	1	$ 5,000	1	$ 5,000
4.4	Permits	LS		1	$ 8,000	1	$ 6,000	1	$ 12,000	1	$ 12,000
			Subtotal		**$ 42,500**		**$ 33,000**		**$ 44,000**		**$ 44,000**
	Subtotal Component Direct Costs				**$ 768,200**		**$ 547,200**		**$ 1,264,400**		**$ 1,170,400**
5.0	**Contingency and Engineering**										
5.1	Engineering/Administration				$ 40,000		$ 30,000		$ 60,000		$ 60,000
5.2	Contingency (20%)				$ 153,640		$ 109,440		$ 252,880		$ 234,080
	Contingency and Engineering Costs				**$ 193,640**		**$ 139,440**		**$ 312,880**		**$ 294,080**
	Total Component Costs Before Tax (+/- 25%)				**$ 961,840**		**$ 686,640**		**$ 1,577,280**		**$ 1,464,480**
	TOTAL COSTS BEFORE TAX (+/- 25%)										**$ 4,690,240**

1. Basis of the Estimate

- The capital cost estimate is based on an estimated ± 25% level of accuracy and a contingency of 20%.
- Capital costs have been developed based on aggregate cost databases, recent budget quotations, in-house data, and experience from similar projects.
- Costs included are generally based on the current cost of construction in southern BC and do not allow for escalation beyond the base date of the estimate.
- The capital cost estimate is based upon partially completed preliminary design.

2. Key Qualifications

The following qualifications are noted when preparing the capital cost estimate:

- All currency costs are in Canadian dollars.
- The estimate base date is first quarter 2016.
- The estimates of construction labour are based on a Vancouver-based unionized contractor's workforce working a standard 40 hour workweek.
- No specific detailed contract and procurement plans have been developed at this stage.
- This estimate is based on Material Take-Offs (MTOs) and preliminary design drawings.
- No allowances have been included for any hazardous materials identification and removal.
- No allowances have been made for environmental baseline studies, permit applications, or habitat compensation.
- No allowances have been made for pipe infrastructure network upgrades, replacements and restoration.

3. Assumptions of Cost Estimate

The following assumptions are made in preparing the capital cost estimate:

- Environmental, statutory, and regulatory approvals will be in place and will not cause delays in the planned project schedule.
- Permits are in place prior to construction. No allowances have been included in the estimate to cover permitting costs.
- Site access granted per construction schedule.
- Land right-of-way has been established for construction.

4. Exclusions from Cost Estimate

The following items are excluded from the capital cost estimate:

- Escalation past first quarter 2016.
- Disposal of any contaminated soil or reclamation work.
- Owner's costs.
- No allowance for training of the construction personnel.
- All taxes and duties.
- Variations to scope from the date of issue of the estimate.
- Finance and interest charges for project duration.
- Lost time due to severe weather conditions or force majeure.
- Site and soil remediation or removal of in-situ contaminants.
- Extended periods of industrial / labour unrest.
- Delay costs associated with obtaining statutory approvals (e.g., building or development approval).
- Commissioning labour and handover costs.
- Services relating to traffic management and road closures
- Any changes to execution strategy and schedule.

SOUTH CAMPUS CATCHMENT AREA
STORMWATER FACILITIES DETAILED DESIGN MATERIALS TAKE-OFF
Date: 8-Apr-16

Location	Length	Base	Plan Area	Depth	Excavation Volume	Round up	Backfill Slopes	Round up	Total Excavation	Box Arranagement	Number of Boxes	Waterproof Membrane	Round Up
	m	m	m^2	m	m^3	m^3	m^3	m^3	m^3			m^2	m^2
Rain Garden at Arcadia	35	20	700	3.07	2149	2200	169	200	2400	52 x 50 x 1	2600	938.7	940
Detention at West 16th Avnue	60	8	480	3.07	1474	1500	209	300	1800	88 x 20 x 1	1760	775.12	780
Detention at Marine Drive	40	30	1200	3.07	3684	3700	215	300	4000	59 x 74 x 1	4366	1503.8	1510
Rain Harvest at UBC Farm	40	30	1200	3.07	3684	3700	215	300	4000	59 x 74 x 1	4366	1503.8	1510

Location	Front Area	Length	Excavation Volume	Round Up	Plan Area	Round Up
	m^2	m	m^3	m^3	m^2	m^2
Swale	1.44	360	3684	3700	648	700

Note: Based off of IFC Drawings on March 30

SOUTH CAMPUS CATCHMENT AREA
STORMWATER FACILITIES DETAILED DESIGN LIFE CYCLE ANALYSIS
Date: 8-Apr-16

	COMMUNITY GARDEN AT ACADIA	DETENTION TANK AT WEST 16TH AVENUE	DETENTION TANK AT MARINE DRIVE	RAIN HARVEST AT UBC FARM	**TOTAL**
Input Parameters					
Life Span	70 years	70 years	70 years	70 years	
Capital Cost	$ 961,840	$ 686,640	$ 1,577,280	$ 1,464,480	**$ 4,690,240**
Rehabilitation cost at 30 years (PW)	$ 107,700	$ 69,000	$ 145,860	$ 133,460	**$ 463,516**
Rehabilitation cost at 50 years (PW)	$ 146,200	$ 102,400	$ 215,180	$ 218,980	**$ 692,354**
Annual Operation Costs (AW); growth at 2%	$ 5,470	$ 1,290	$ 7,580	$ 5,070	**$ 19,410**
NPV including capital, maintenance and rehabilitation costs					
Total Expense at 70 years					
if inflation = 0%	$ 2,036,119	$ 1,051,512	$ 3,075,153	$ 2,577,308	**$ 8,740,091**
if i = 3%	$ 1,486,432	$ 921,878	$ 2,313,429	$ 2,067,817	**$ 6,789,556**
if i = 8%	$ 1,305,239	$ 879,147	$ 2,062,342	$ 1,899,874	**$ 6,146,601**
Total Expense at 50 years					
if inflation = 0%	$ 1,532,189	$ 864,747	$ 2,364,252	$ 2,026,758	**$ 6,787,946**
if i = 3%	$ 1,280,698	$ 805,438	$ 2,015,751	$ 1,793,657	**$ 5,895,544**
if i = 8%	$ 1,155,475	$ 775,906	$ 1,842,223	$ 1,677,591	**$ 5,451,195**
Total Expense at 30 years					
if inflation = 0%	$ 1,183,747	$ 738,973	$ 1,884,786	$ 1,670,160	**$ 5,477,666**
if i = 3%	$ 1,100,637	$ 719,373	$ 1,769,617	$ 1,593,128	**$ 5,182,755**
if i = 8%	$ 1,036,596	$ 704,270	$ 1,680,872	$ 1,533,769	**$ 4,955,507**

1. **Rehabilitation at 30 Years Assumptions**
   - Cost is sum of Items 3.3 to 3.7 + (Sum of Items 3.1 to 3.2) * 5% + Item 3.4
   - Requires 5% replacement of Eco-tanks due to differential settlement, degradation due to non-environmental factors (creep, impact loads, etc.)
   - Requires complete replacement of all other detention system components
   - Requires backfill after rehabilitation

2. **Rehabilitation at 50 years Assumptions**
   - Cost is (Sum of Items 3.3 to 3.7) + (Sum of Items 3.1 to 3.2) * 10% + (Sum of Items 2.5) * 15% + Item 3.4
   - Requires 5% replacement of Eco-tanks due to differential settlement, degredation due to non-environmental factors (creep, impact loads, etc.)
   - Requires complete replacement of all other detention system components
   - Requires backfill after rehabilitation

3. **Annual Operation Assumptions**
   - Requires regular maintenance of oil and grit separator estimated at 15% of capital cost
   - Requires regular maintenance of pumps and electrical utility fees estimated at 15% of capital cost
   - Requires regular landscaping and gardening services estimated at 10% of capital cost
   - Contingency is 1% of Capital Costs
   - Annual maintenace costs is assumed to grow 2% annually

Cash Flow Analysis				
n = 30 years				
Capital Cost	$ 961,840	$ 686,640	$ 1,577,280	$ 1,464,480
Annual Operations				
inflation rate	0%	0%	0%	0%
growth rate	2%	2%	2%	2%
i0	-1.96%	-1.96%	-1.96%	-1.96%
N years	30	30	30	30
(P/A, i0, N)	41.37944079	41.37944079	41.37944079	41.37944079
(P/A, i0, N)/(1+g)	40.56807921	40.56807921	40.56807921	40.56807921
Operations Cost (AW)	$ 5,470	$ 1,290	$ 7,580	$ 5,070
Operations Cost (PW)	$ 221,907.39	$ 52,332.82	$ 307,506.04	$ 205,680.16
Total Cost at 30 years (PW)	$ 1,183,747	$ 738,973	$ 1,884,786	$ 1,670,160
inflation rate	3%	3%	3%	3%
growth rate	2%	2%	2%	2%
i0	0.98%	0.98%	0.98%	0.98%
N years	30	30	30	30
(P/A, i0, N)	25.88178709	25.88178709	25.88178709	25.88178709
(P/A, i0, N)/(1+g)	25.37430107	25.37430107	25.37430107	25.37430107
Operations Cost (AW)	$ 5,470	$ 1,290	$ 7,580	$ 5,070
Operations Cost (PW)	$ 138,797.43	$ 32,732.85	$ 192,337.20	$ 128,647.71
Total Cost at 30 years (PW)	$ 1,100,637	$ 719,373	$ 1,769,617	$ 1,593,128
inflation rate	8%	8%	8%	8%
growth rate	2%	2%	2%	2%
i0	5.88%	5.88%	5.88%	5.88%
N years	30	30	30	30
(P/A, i0, N)	13.9398592	13.9398592	13.9398592	13.9398592
(P/A, i0, N)/(1+g)	13.66652862	13.66652862	13.66652862	13.66652862
Operations Cost (AW)	$ 5,470	$ 1,290	$ 7,580	$ 5,070
Operations Cost (PW)	$ 74,755.91	$ 17,629.82	$ 103,592.29	$ 69,289.30
Total Cost at 30 years (PW)	$ 1,036,596	$ 704,270	$ 1,680,872	$ 1,533,769
n = 50 years				
Capital Cost	$ 961,840	$ 686,640	$ 1,577,280	$ 1,464,480
Rehabilitation Cost at 30 years (PW)	$ 107,700	$ 69,000	$ 145,860	$ 133,460
Annual Operations				
inflation rate	0%	0%	0%	0%
growth rate	2%	2%	2%	2%
i0	-1.96%	-1.96%	-1.96%	-1.96%
N years	50	50	50	50
(P/A, i0, N)	86.27098948	86.27098948	86.27098948	86.27098948
(P/A, i0, N)/(1+g)	84.57940145	84.57940145	84.57940145	84.57940145
Operations Cost (AW)	$ 5,470	$ 1,290	$ 7,580	$ 5,070
Operations Cost (PW)	$ 462,649.33	$ 109,107.43	$ 641,111.86	$ 428,817.57
Total Cost at 50 years (PW)	$ 1,532,189	$ 864,747	$ 2,364,252	$ 2,026,758
inflation rate	3%	3%	3%	3%
growth rate	2%	2%	2%	2%
i0	0.98%	0.98%	0.98%	0.98%
N years	50	50	50	50
(P/A, i0, N)	39.3750309	39.3750309	39.3750309	39.3750309
(P/A, i0, N)/(1+g)	38.60297147	38.60297147	38.60297147	38.60297147
Operations Cost (AW)	$ 5,470	$ 1,290	$ 7,580	$ 5,070
Operations Cost (PW)	$ 211,158.25	$ 49,797.83	$ 292,610.52	$ 195,717.07
Total Cost at 50 years (PW)	$ 1,280,698	$ 805,438	$ 2,015,751	$ 1,793,657
inflation rate	8%	8%	8%	8%
growth rate	2%	2%	2%	2%
i0	5.88%	5.88%	5.88%	5.88%
N years	50	50	50	50
(P/A, i0, N)	16.02440462	16.02440462	16.02440462	16.02440462
(P/A, i0, N)/(1+g)	15.71020061	15.71020061	15.71020061	15.71020061
Operations Cost (AW)	$ 5,470	$ 1,290	$ 7,580	$ 5,070
Operations Cost (PW)	$ 85,934.80	$ 20,266.16	$ 119,083.32	$ 79,650.72
Total Cost at 50 years (PW)	$ 1,155,475	$ 775,906	$ 1,842,223	$ 1,677,591
n = 70 years				
Capital Cost	$ 961,840	$ 686,640	$ 1,577,280	$ 1,464,480
Rehabilitation Cost at 30 years (PW)	$ 107,700	$ 69,000	$ 145,860	$ 133,460
Rehabilitation Cost at 50 years (PW)	$ 146,200	$ 102,400	$ 215,180	$ 218,980
Annual Operations				
inflation rate	0%	0%	0%	0%
growth rate	2%	2%	2%	2%
i0	-1.96%	-1.96%	-1.96%	-1.96%
N years	70	70	70	70
(P/A, i0, N)	152.9774694	152.9774694	152.9774694	152.9774694
(P/A, i0, N)/(1+g)	149.9779111	149.9779111	149.9779111	149.9779111
Operations Cost (AW)	$ 5,470	$ 1,290	$ 7,580	$ 5,070
Operations Cost (PW)	$ 820,379.17	$ 193,471.51	$ 1,136,832.57	$ 760,388.01
Total Cost at 70 years (PW)	$ 2,036,119	$ 1,051,512	$ 3,075,153	$ 2,577,308
inflation rate	3%	3%	3%	3%
growth rate	2%	2%	2%	2%
i0	0.98%	0.98%	0.98%	0.98%
N years	70	70	70	70
(P/A, i0, N)	50.47636847	50.47636847	50.47636847	50.47636847
(P/A, i0, N)/(1+g)	49.48663575	49.48663575	49.48663575	49.48663575
Operations Cost (AW)	$ 5,470	$ 1,290	$ 7,580	$ 5,070
Operations Cost (PW)	$ 270,691.90	$ 63,837.76	$ 375,108.70	$ 250,897.24
Total Cost at 70 years (PW)	$ 1,486,432	$ 921,878	$ 2,313,429	$ 2,067,817
inflation rate	8%	8%	8%	8%
growth rate	2%	2%	2%	2%
i0	5.88%	5.88%	5.88%	5.88%
N years	70	70	70	70
(P/A, i0, N)	16.68897302	16.68897302	16.68897302	16.68897302
(P/A, i0, N)/(1+g)	16.36173826	16.36173826	16.36173826	16.36173826
Operations Cost (AW)	$ 5,470	$ 1,290	$ 7,580	$ 5,070
Operations Cost (PW)	$ 89,498.71	$ 21,106.64	$ 124,021.98	$ 82,954.01
Total Cost at 70 years (PW)	$ 1,305,239	$ 879,147	$ 2,062,342	$ 1,899,874