UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

UBC Stormwater Detention: Multiuse Stormwater Detention Infrastructure

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Executive Summary

RAJNS Consulting has prepared final design of a multiuse stormwater detention facility for the University of British Columbia (UBC) and UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program. The project site is located southwest of the Centre for Comparative Medicine (CCM) at the intersection of Southwest Marine Drive and Wesbrook Mall in Vancouver, BC. The site is north of the Point Grey Cliffs which are susceptible to erosion from runoff and infiltration during storm events, which is a main constraint to design. Further, climate change and land use changes are exacerbating these issues. The design includes two distinct elements: a stormwater bioswale with underground water detention tank; and, a structural facility targeted for use by cyclists – a key project stakeholder.

Three stormwater quality improvement methods are integrated into the detention centre. Upon review of past stormwater quality monitoring programs, it was determined that oil and grit separation is necessary to treat stormwater flows from the north and bioretention would provide appropriate quality improvements. Based on a hydrological and hydraulic analysis of the South Slopes Catchment, the detention chamber will consist of 20, 100 m long, 1050 mm diameter interconnected pipe lengths sloped 0.5% to the southeast which tie into Junction S6D-S26A at the inlet and Junction T6D-S25 at the outlet. This design combines natural bioretention soil and HDPE detention chambers to provide water storage in the event of a 100 year, 24 hour storm event.

Through consultation with key stakeholders and considering themes of Resilient Cities, the detention centre will also feature a clubhouse for the UBC Thunderbird Cycling Club. Designed based on BC Building Codes and the National Building Code of Canada the clubhouse will feature showers and change rooms, a repair centre, and ample bicycle storage. Due to the scope of this project, structural design is limited to foundation loading, material selection, and placement planning. The estimated load of the building will be 22.5 kPa which will be transferred to a 1 m deep strip foundation founded on Site Class C type glacial till. The structure will be built with an emphasis on timber design and no retaining walls are required on the site.

Located at the corner of Wesbrook Mall and Southwest Marine Drive the detention centre will act as a gateway to campus. Welcoming visitors, students, and faculty will be two precast concrete stormwater detaining Supertree structures incorporated with the UBC Gateway sign. The Supertrees, 2 m in diameter at the base, will be erected on 4 steel pile and cap foundation via a 4-dowel system to transfer their 7,535 kg load.

Construction is estimated to take 8 months and should begin May 2019. An Environmental Impact Assessment (EIA) is not required for a project of this scale, however, RAJNS has identified potential construction-caused environmental concerns and presents mitigation options. The total estimated cost of the design is $16.34 million, including engineering fees and 30% contingency. The overall design established is a multi-modal and integrated hub for community and university cyclists, elevating UBC's reputation as a global leader in sustainability.

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1 Introduction

The purpose of this report is to present the final design of a multiuse stormwater detention facility for UBC's South Campus to UBC and UBC SEEDS Sustainability Program. Throughout the design process, UBC's Integrated Stormwater Management Plan (ISMP), key stakeholders, and the Vancouver Campus Plan (VCP) were thoroughly consulted to inform the design direction.

The existing stormwater management system servicing UBC's South Campus poses a severe risk of flooding under major storm conditions. The environmentally sensitive Point Grey Cliffs will experience increased erosive damage during major floods which will also negatively impact water quality exiting campus. In addition, climate and land use changes will further negative impacts of flooding on the built and natural infrastructure within the area by increasing the severity and frequency of flooding. Therefore, in accordance with UBC's ISMP, the technical project objectives met by this design are to mitigate potential flooding impacts from major storms, minimize the flooding impacts on the surrounding cliffs in Point Grey and neighbouring water courses, and improve the quality of stormwater leaving campus to standards exceeding those of provincial and federal policy. To achieve the technical design criteria the impacts of land use and climate change were assessed to determine their influence on hydrological, hydraulic, and water quality analysis'. These analyses influenced the stormwater detention system; dictating sizing, orientation, and stormwater improvement methods.

Equally, this final design considers emerging themes of Resilient Cities, most notably, that of multiple uses. Therefore, beyond meeting the technical design objectives, a secondary purpose for this project was determined through analysis of key project stakeholders to understand what groups will use and benefit from this facility. From stakeholder engagement meetings, it was determined the greatest net sum benefit would be the resulting clubhouse for the UBC Thunderbird Cycling Club.

The aesthetic and social design is separate from the technical objectives and is informed by the VCP. The VCP provides specifications to ensure this design will accentuate the natural west coast beauty, achieve a cross-campus design cohesiveness, and realize a design quality befitting to a globally significant University. This objective is achieved through the installation of Supertrees and a UBC gateway structure that will bring attention and notoriety to the detention facility. Further, the clubhouse features locally sourced materials and a west coast inspired design while the selected site plantings drives a cohesiveness among built infrastructure in the South Campus.

The area southwest of the Centre for Comparative Medicine (CCM) on UBC's South Campus has been identified as the optimal location for the installation of a stormwater detention facility. The 1.3-hectare site is located northwest of the intersection at Southwest Marine Drive and Wesbrook Mall. This area is near the UBC Farm and an extensive green area which allows for a seamless integration of the infrastructure project with the existing natural environment and is a relative low point in the South Slopes Catchment as defined in UBC's ISMP.

2 Design Criteria

2.1 Hydrological Analysis

A hydrological analysis of the South Slopes Catchment was completed as defined in the UBC ISMP using the Rational Method. We estimate the 2 year, 10 year, 25 year, and 100 year return period peak flows that will be directed onto the site via underground stormwater networks or overland runoff. Stormwater that enters the upstream reaches of the South Slopes Catchment storm system will flow downstream into the storm sewers adjacent to the site. However, we believe that overland flow from the upper reaches of the South Slopes Catchment will be diverted along major flood pathways, such as West 16th Avenue and Wesbrook Mall.

The South Slopes catchment has an area of 1.5 km^2 and an average slope of 2.1%. Figure 1 shows the South Slopes Catchment area used in the estimate as well as the longest direct overland flow path to the site. Using the future runoff coefficients from the Land Use Assessment we estimate the site's runoff coefficient to be 0.4 by the year 2030. Rainfall intensities for each return period are based on Vancouver Intl A Rain Gauge (ID: 1108395). Using the Hathaway formula, we estimate the time of concentration for the overland flow of the South Slopes Catchment to be 1.4 hours.

Figure 1: South Slopes Catchment

We used the rainfall intensities for the 1.4 h design storm to determine their associated peak flow. Rainfall intensities and peak flows for each return period are outlined in Table 2. Calculations of all design flows are found in Appendix A.

Table 2: Return Period Rainfall Intensities & Design Flows

Return Period	Intensity (mm/hr)	Peak Flow (m^3/s)
2 year	8.9	4.1
10 year	14.4	6.6
25 year	18.0	8.2
100 year	24.6	11.3

Rainfall volume of the 10-year and 100-year return period storms are required to assess the rainfall pattern over the catchment and site. Using the Vancouver Intl A Rain Gauge (ID: 1108395) IDF table we estimated the volume for the 2, 10, 25, and 100 year storms at durations of 1, 2, 6, 12, and 14 hours. We developed a hyetograph for the 10 year and 100 year return period 24 hour storm. Applying a factor of 30% for climate change, we estimate a rainfall intensity of 3.89 mm/hr for the 10-year 24 hour storm and 5.42 mm/hr for the 100 year 24 hour storm. The corresponding 10 year 24 hour storm and 100 year 24 hour storm cumulative depths from the IDF table are 93.24 mm and 130.00 mm, respectively. Calculations of the rainfall volumes for the various storms considered are found in Appendix A.

A SCS Type 1A distribution was applied to form the rainfall distribution due to its predominant application throughout the rain forested areas of the pacific northwest. Figure 2 displays the resulting hyetographs for the 10-year and 100-year return period design storms.

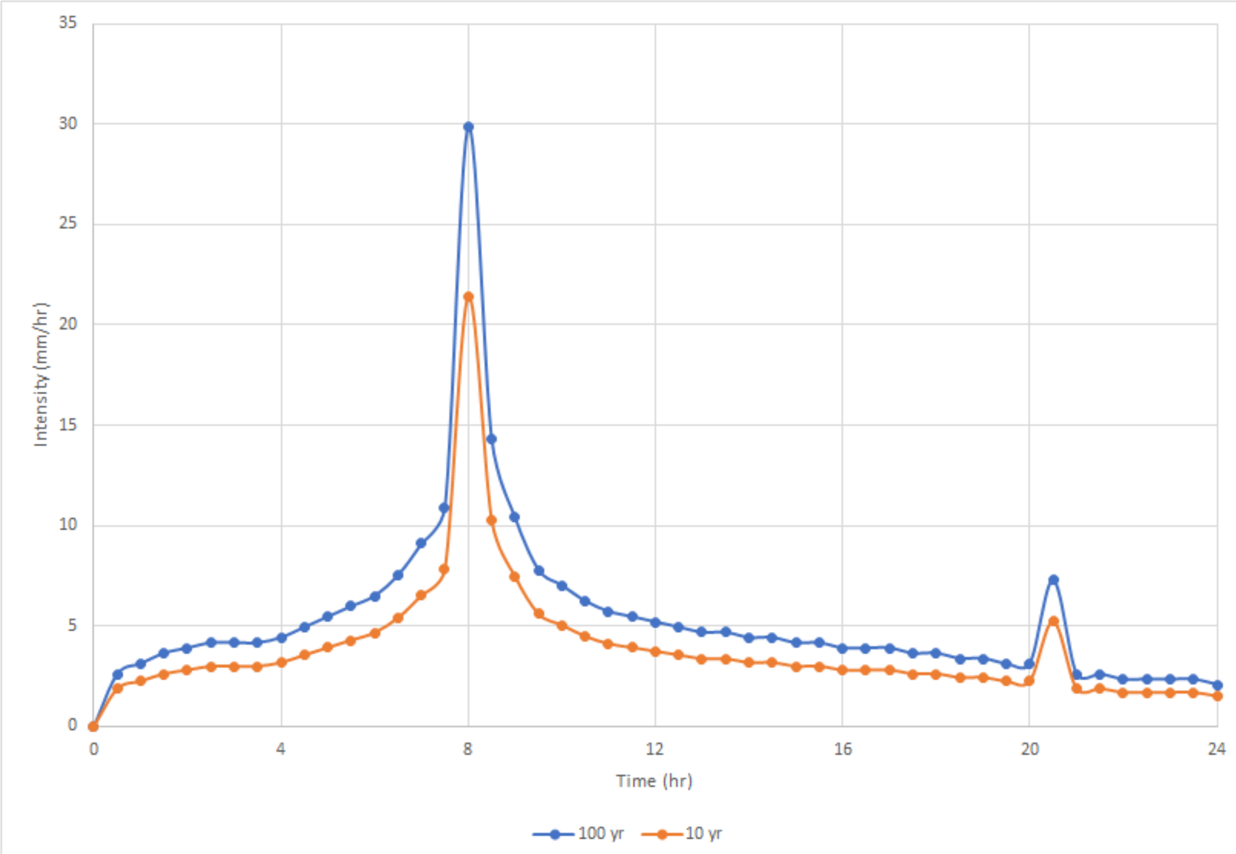

Figure 2: 10 year and 100 year 24 hour Hyetographs

Under the applied rainfall distribution pattern, the maximum intensity experienced is 21.4 mm/hr for the 10 year 24 hour storm, and 29.9 mm/hr for the 100 year 24 hour storm.

2.2 Hydraulic Analysis

The primary purpose of site redevelopment is to integrate strategies that will minimize potential flooding from large storm events, minimize erosion of the Point Grey cliffs, and improve the quality of stormwater leaving campus. To assess the extent of flooding that would be incurred on site we reviewed existing stormwater patterns, runoff patterns, and infiltration. The EPA SWMM model provided by the University of British Columbia was used to model the capacity of the existing stormwater system as well as the surface of the South Slopes Catchment to assess its need for storage.

We aim to mimic naturalized flow conditions, and therefore require estimates of peak flow of the site catchment contributing area under pre-development conditions. To estimate the required volume of storage we assessed the difference in runoff volume between pre-development and post-development conditions. Estimates are completed on a per hectare basis and then scaled to reflect the entirety of the South Slopes Catchment area. The catchment parameters outlined in Table 3 are applied to the model to reflect pre-development and post-development conditions.

Table 3: Catchment Parameters

Catchment Parameter	Pre-Development	Post-Development
Area (Ha)	1	1
Width (m)	100	100
% Slope	2.1	2.1
% Impervious	10	80
N-Imperv: Mannings N for impervious area	0.025	0.025
N-Perv: Mannings N for pervious area	0.25	0.25
Dstore-Imperv: Depth of depression storage on impervious area (mm)	2	2
Dstore-Perv: Depth of depression storage on pervious area (mm)	10	5
%Zero-Impverv: Percent of impervious area with no depression storage	5	20

We ran the model under the 100 year return period 24 hour design storm and produced the runoff hydrographs for pre-development and post-development conditions outlined in Figure 3.

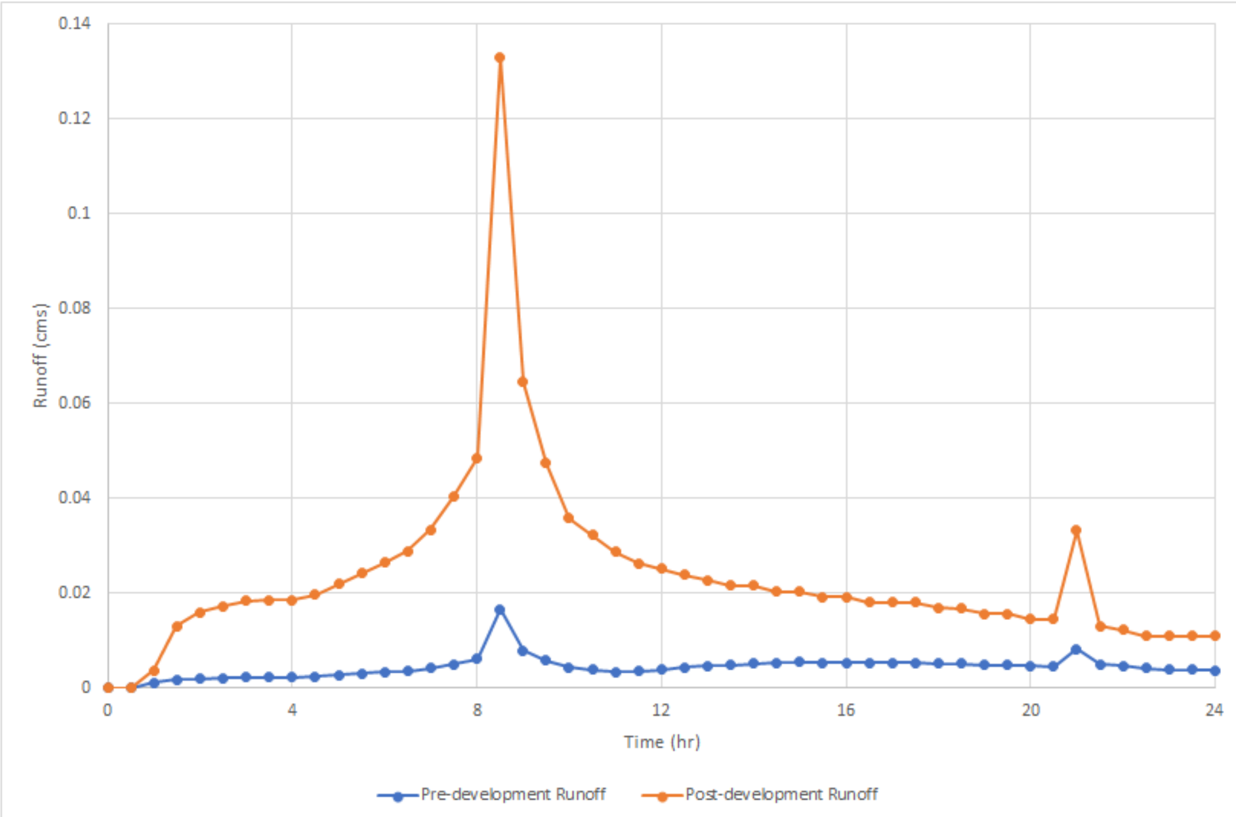

Figure 3: 100 year 24 hour Per Hectare Runoff

We determined the peak flow under pre-development and post-development conditions for the 100 year 24 hour storm to be 0.02 m3/s per hectare and 0.13 m3/s per hectare, respectively. We used 0.02 m3/s per hectare as the maximum allowable outflow, therefore, any additional flow must be retained by the stormwater system.

To determine the required volume to be retained per hectare, we determined the volumetric difference between the pre-development and post-development flows that would maintain flow below 0.02 m3/s. The yellow line in Figure 4 represents acceptable post-development runoff flow rates per hectare. We estimate that 1119.3 m3 of storage is required per hectare of land. The blue shading represents the volume of stormwater that must be retained in storage.

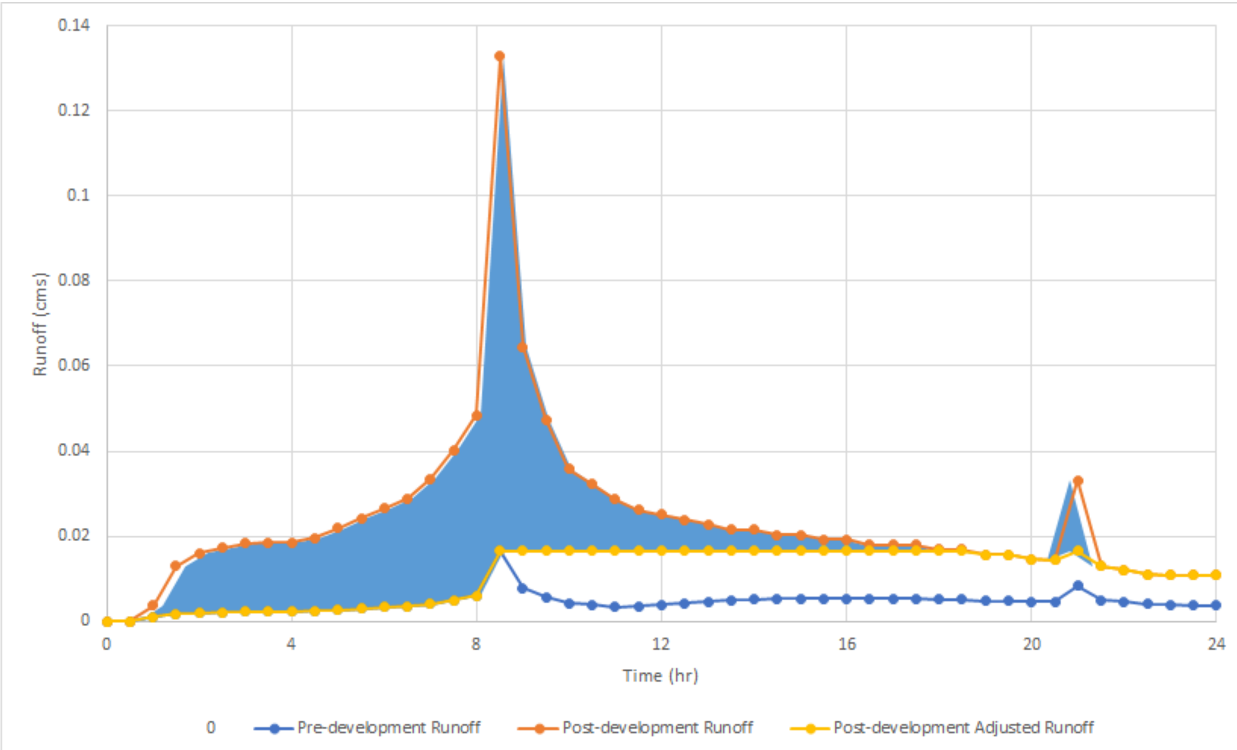

Figure 4: 100 year 24 hour Runoff Volume to be Detained

Given the site's total catchment area of 1.27 ha we estimate the overall storage requirements for the site to be 1422 m3.

2.2.1 Site Hydraulics

Unlike the surrounding area within the South Slopes Catchment, the site itself is intended to maintain close to naturalized conditions following development. A lower impervious percentage will allow for increased infiltration of runoff. Subcatchment C-USL-44 from the EPA SWMM model appropriately represents the site's expected runoff conditions. The percent impervious cover of the catchment is approximately 7% and the catchment slope is approximately 2.5%. Figure 5 displays the rainfall and runoff expected on the subcatchment under the 10 year 24 hour design storm.

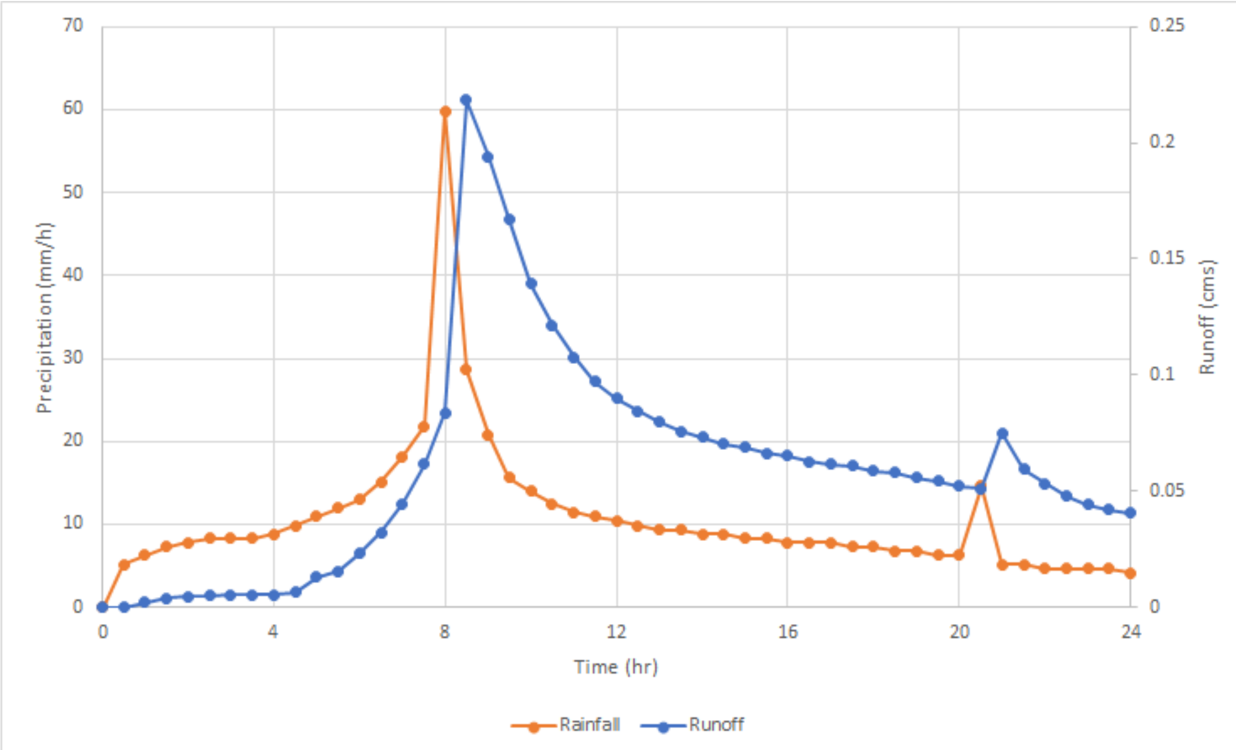

Figure 5: Rainfall and Runoff of Subcatchment C-USL-44 under 10 year 24 hour Design Storm

The runoff hydrograph indicates a peak runoff of 0.22 m^3/s will be experienced within the area. As previously stated, post-development overland runoff levels are to be managed to mimic pre-development runoff conditions. Minimal changes are expected to be made to impervious cover on the site, however removal of existing trees will reduce the site runoff coefficient and the impact of climate change will result in a slight increase in runoff flows. It is expected that bioswales and rain gardens included in the site design will have sufficient capacity to retain this excess runoff for the 2 year, 5 year and 10 year storms. These features will also easily adapt to the fluxes of seasonal rainfall trends.

2.3 Stormwater Quality

Although UBC has monitored stormwater discharges from campus in the past, monitoring programs were inconsistent and irregularly run. The current stormwater quality for the South Slopes Catchment is unknown as the discharge data available for review is relevant to the North Catchment, via the spiral drain, shown at the top of Figure 6 below, taken from the UBC ISMP, the project site is noted at the bottom of the figure.

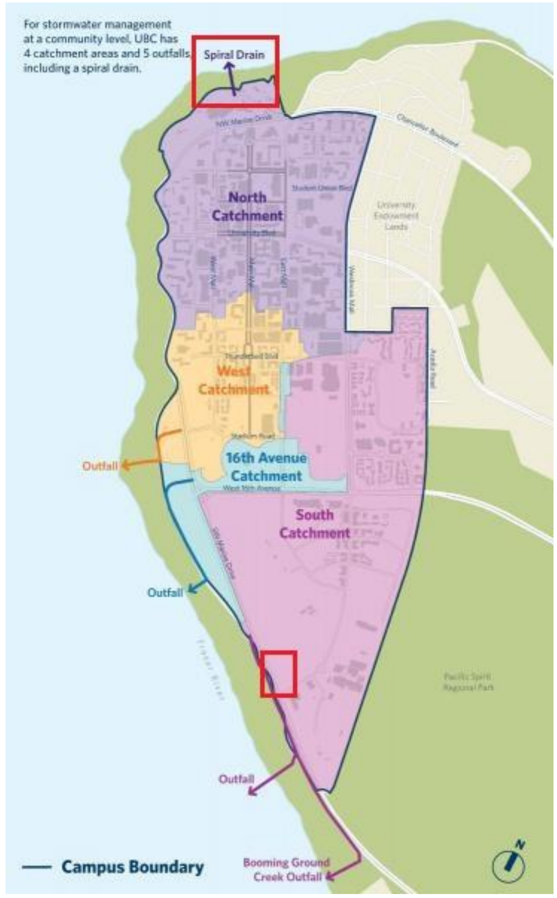

Figure 6: Spiral Drain and Site Location (UBC Vancouver Campus: Integrated Stormwater Management Plan, 2017)

Effluent from UBC Farm is expected to contain substances listed under Section 4 of the CAN/CGSB-32.311-2015 Report, Organic production systems: Permitted substances lists. Outside the impacts associated with runoff from UBC Farm, the data available for the North Catchment should closely reflect the conditions of the South Slopes Catchment. Stormwater discharge from the North Catchment resembles that of Lower Mainland municipalities. Stormwater quality in the Lower Mainland is most impacted by heavy urbanization which introduces contaminants via road drainage and naturally occurring groundwater which exceeds quality guidelines for heavy metals.

2.4 Soil Classification

Based on the provided geotechnical assessment report for Wesbrook Mall and 16th Avenue, the soil classification at Wesbrook Mall and Southwest Marine Drive can be interpolated to be class C and the groundwater table to be negligible. Type C class sites are typified by dense soil and soft rock.

2.5 Stakeholder Requirements

As a multi-use stormwater infrastructure, the secondary use of the site caters to bicyclists including UBC students, staff and faculty who cycle, and various UBC Thunderbird Sports teams (Cycling Team, Cycling Club, Triathlon Club). Consultation with the UBC Cycling Team revealed stakeholder requirements including: a sizeable clubhouse with secure bike storage; washrooms with shower and change room facilities; and, a workshop area to repair bicycles. Ventilation and passive airflow features can aid in drying of wet cycling equipment. The road onsite will be paved asphalt to accommodate narrow road bike tires. Undercover bike locks and repair stations will be installed and seating areas provided outside the clubhouse structure.

3 Major Project Components

3.1 Detention Chamber

The detention chamber will be installed in the southeast corner of the site. The design incorporates semi-perforated aluminized corrugated metal pipes to detain a catchment runoff volume of 1422 m^3. The chamber will consist of 20 pipes, 1070 mm in external diameter and 100 m long. The intake into the system will be connected to Junction S6D-S26A through a 26.6 m long, 1050 mm diameter PVC pipe. A weir will be placed at the pipe inlet to regulate flows entering the chamber. The outlet of the chamber system will be connected to the flow regulation box and pump, which then connects to the system at Junction T6D-S25 with a 125.9 m long, 400 mm diameter PVC pipe. The chambers will be sloped at 0.5% towards the southwest of the site. The pipes have been designed to be 80% full. A general detail of the chamber plan, profile, and cross section is shown in Appendix E.

3.1.1 Flow Regulation Tank

The detention chamber connects with the Flow Regulation Box. The flow regulation box consists of two chambers as shown in Figure 7. In the lower chamber, there is a pump to lift water into the upper chamber. In the upper chamber, there is an orifice on the wall. The exit of the flow regulation box will connect with the existing storm sewer. The design criteria of a flow regulation box are to limit the maximum outflow rate to less than 1.2 m^3. Our design can achieve this goal by carefully selecting the size of the orifice on the wall. In a small storm event, storm water flows into the system at a rate less than 1.2 m^3 and the flow regulation box will discharge the storm water immediately. In a large storm event, water can quickly gather into the lift station and start to discharge at an optimum rate earlier, hence requiring a smaller detention chamber. The flow regulation box is 3 meters in diameter and 6 meters in height. The flow regulation box will be constructed on the south-east side of corner of the project site. To limit the maximum flow rate to less than 1.2 m^3, Bernoulli's Equation is used to find the relation between orifice size and maximum allowed water level in the tank as shown in Figure 8. A diameter of 400 mm and maximum water level of 2.4 m above the orifice is used in our design. The pump curve and efficiency curve are provided in Appendix B.

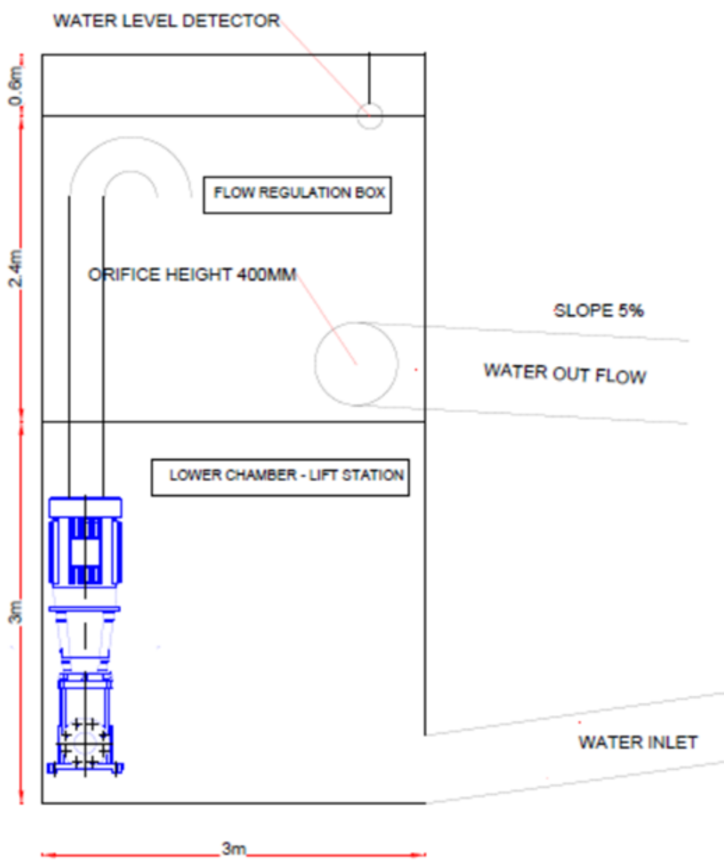

Figure 7: Schematic View of Flow Regulation Box

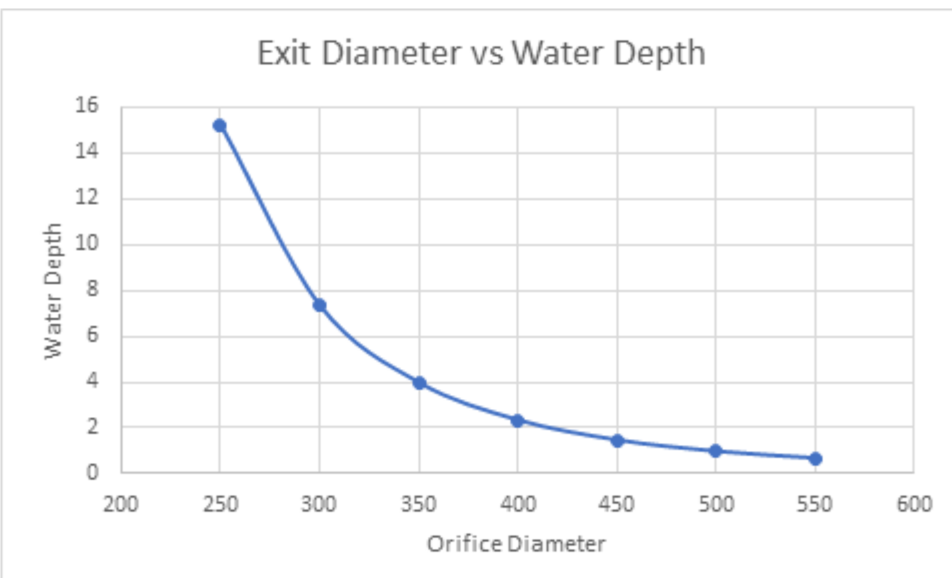

Figure 8: Relation Between Orifice Size and Water Depth

3.2 Water Quality Improvement

3.2.1 Rain Garden

On-site source control measures were designed to allow better management of rainwater and to reduce the overland flow rate. The rain garden will be built around the site to collect overland runoff from the site and adjacent CCM property. Using the simplified rainfall capture method, the depth of the top soil required to capture the rainfall, as well as the required rock pit depth, was calculated. The parameters used to calculate the top soil depth are based on Metro Vancouver Storm Water Source Control Design Guidelines 2012. Table 4 summarizes design parameters used to calculate the topsoil depth.

Table 4: Design Parameters

Area	17249 m^2
Impervious Percentage	20%
Evaporation Rate	1mm/day
Porosity of Rock Pit	35%
Infiltration Rate	1.5mm/hr
2year, 24hr -Rainfall IDF data	2.3mm/hr
Wilting Point	0.05
Width of Rain Garden	2m
Length of Rain Garden	280m

The Calculation of topsoil layer and rock pit in the rain garden were based on the assumption that the proposed rain garden is 2m wide. The rain garden will be place around the South and East side of the site. By using IDF curve provided by Regional IDF provided by Metro Vancouver, the total input volume was calculated as 137.3 m^3. To capture all of the run-off, A rain garden with 0.45m top soil and 0.4m drain rock depth will be installed as illustrated in Figure 9.

The calculated values obtained using the Simplified Rainfall Capture Method are listed below in Table 5.

Table 5: Rain Garden Design Result

Input Volume	137.3 m^3
Evaporation	6.06 m^3
Infiltration	20.16 m^3
Growing Medium Absorption	50.4 m^3
Top Soil Depth	0.45m
Rock pit Depth	0.4m

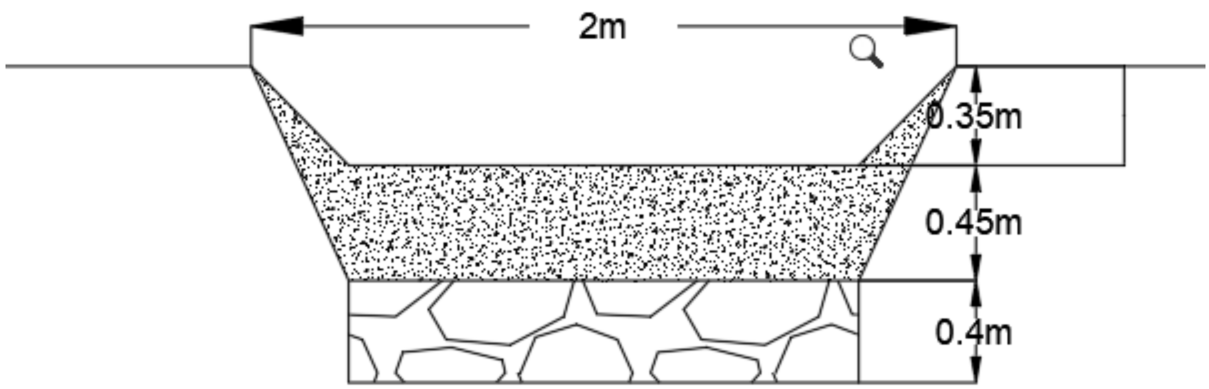

Figure 9: Rain Garden Cross Section

3.2.2 Bioretention Filtration

Stormwater entering the detention chamber will be treated through biofiltration and bioretention to decrease levels of pollutants to levels in compliance with federal and provincial water quality legislation. To improve the quality of stormwater leaving the detention facility, a bioretention filter will be installed to a depth of 450 mm at all locations outside of the paved bike path, club building and Super tree footprint, and rain garden areas. A soil mix of 40% compost and 60% screen or utility sand will provide an infiltration rate of 25 to 50 mm/hr. The primary expected storm flow contaminants at the detention centre will be heavy metals from existing groundwater conditions and effluent from UBC Farm which will contribute substances listed under Section 4 of the CAN/CGSB-32.311-2015 Report, Organic production systems: Permitted substances lists. Bioretention and biofiltration methods have been shown to significantly decrease the concentration of heavy metals and the expected substances from UBC Farm in effluent (Improving Stormwater Quality, 2016).

3.2.3 Geomembrane Liner

To avoid infiltration into the upper soil strata which has been found to cause erosion at the Point Grey Cliffs, an impermeable, geomembrane liner will be placed below all installations which facilitate infiltration.

3.2.4 Oil and Grit Separator

In compliance with the Stormwater Quality at UBC report, an oil and grit separator will be installed to treat stormwater contaminated by road drainage entering the detention facility. Site topography dictates storm flows will not be entering the detention facility through the south side. To the west of the site, storm flows will traverse UBC Farm prior to entering the detention facility so will contain fractional amounts of road drainage. Therefore, the intake system will be installed along the northeast edge of the detention facility to accept the primarily road drainage storm flows from Wesbrook Mall and the grounds of the Centre for Comparative Medicine (CCM) prior to entering the site of the detention facility. The intake system will consist of a 170 m long, 800 mm half pipe which runs parallel to the northeast edge of the site. The half pipe will be covered by grating to allow water and mid-sized particulates to pass through while ensuring large debris does not enter the system. A 0.5% slope from the west to east will allow storm flows to flow through to the oil and grid separator, detail shown in drawing C-05.

The oil and grit separator is designed for the 2 year, 24 hour storm event such that oils and greases will float to the top on the intake side of the barrier and grits and other particles will settle to the bottom while the treated water will flow to the outlet side.

3.3 Structural Components

This project features two main structural elements: the UBC Supertree gateway structure and UBC cycling clubhouse building providing storage and public washrooms.

3.3.1 Supertrees

The Supertrees will act as a beacon and gateway structure for community members entering the south end of campus. The Supertrees will be erected upon a pile and pile cap foundation. The design of the Supertrees themselves will be subcontracted out.

A pile cap foundation with four 0.4 mm diameter steel piles which the base of the Supertrees will connect into using 4 dowels to transfer the Supertree load down into the piles is proposed. The base of the two Supertrees will be approximately 2 m in diameter with a pile cap foundation that will pass the edge of the Supertree base by 0.5 m yielding a foundation with a diameter of approximately 3 m. The approximate weight of the of the Supertrees is 7535 kg including the weight of the concrete, steel, solar and plant panels. The soil bearing capacity for the glacial till on site is approximately 12 200 kg/m2. Given these values, a minimum pile cap area of 0.5 m^2 is estimated and will be achieved due to the diameter of the trunk base. Calculations of this foundation is found in Appendix A.

and detailed drawings of the foundation can be found in Appendix E.

3.3.2 Clubhouse Design

The clubhouse superstructure will feature locally sourced timber construction and typical basement retaining wall foundation design giving the building a basement for storage. The clubhouse will also feature a green roof and a covered entrance with bike racks. The building footprint itself will be 630 m². The loading on the building is estimated to be: 3.5 kPa dead load and 4.79 kPa live load for the main and first floor with a service limit state snow load of 1.64 kPa and roof loading of 2 kPa and 2.4 kPa for the dead and live loads, respectively.

The building foundation is a strip foundation with a minimum depth of 1 m for frost protection with special considerations for drainage. As noted, the site soil is glacial till and some special considerations may need to be accounted for when completing detailed design of the foundation. The building's loading is estimated to be 22.5 kPa, the load of the soil was calculated at 18.7 kN/m², and the soil surcharge was calculated to be 2.8 kN/m² which is used in the design of the foundation layout. It is important to note that the slab must be installed prior to backfill over 1 m in height to avoid sliding of the foundation. Detailed design drawings of the foundation can be found in .

3.4 Environmental and Social Consideration

3.4.1 Sustainability

Creating a sustainable campus is a key goal of the Vancouver Campus Plan, a guiding design criterion for our infrastructure. As such, the stormwater management system will promote a natural systems approach using rainwater. Technical design and sizing of stormwater management features is based on future rainfall scenarios with consideration for climate change. Where possible soil, drainrock, and vegetation are of local varieties and are sourced locally. In accordance with the Vancouver Campus Plan, the design uses native and edible plants in low maintenance and simple landscaping schemes in a pesticide-free regime. Low Impact Design features include a green roof over the Clubhouse, rain gardens and bioswale to capture run-off leading into an oil-grit separator, and passive air conditioning in the Clubhouse building. To increase infiltration, permeable pavement will be used in the bicycle parking area and surrounding the outdoor picnic benches.

The green infrastructure components can all contribute toward LEED certification if UBC SEEDS wishes to pursue this. Overall, the choice to incorporate a cycling hub with the stormwater features on site makes it a uniquely sustainable project. It sets UBC apart as a world leader in stormwater management and sustainable transit. Appendix E.

3.4.2 UBC Gateway Structure

The Vancouver Campus Plan indicates that two Gateway structures will be located at West 16th Avenue and SW Marine Drive and at West 16th Avenue and Wesbrook Mall. The location of our project site is classified as a secondary gateway. As a gateway, our site will instil pride and identity in UBC's community showcasing it to visitors around the world. The gateway structure is to be fabricated by a sub-contractor off-site and will be constructed of sustainable and rust-proof steel. The dimensions of the gateway structure are 2.5 meters high, 1 meter deep, and 3.5 meters wide. It will be located at the south-east corner of the site and cohesive with the style of the Supertrees. The foundation will be similar to the Supertrees, 1 meter deep pile cap concrete.

4 Standards and Software Packages

The standards used throughout conception, design, and planning include:

- UBC Technical Guidelines (Technical Specifications for Architects and Engineers);
- Canadian Environmental Quality Guidelines and the British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife, and Agriculture Summary Report (March 2018);
- BC Building Code; and
- National Building Code of Canada.

The software packages and their purposes used in project completion include:

- EPA SWMM 5.1: Used to model the stormwater system, South Slopes Catchment, and 10-year and 100-year return period design period storms for the Hydraulic Assessment; and,
- AutoCAD: Used to generate preliminary design drawings and final IFC drawings.

5 Technical Considerations

5.1 Vancouver Campus Plan

The VCP influenced the social and aesthetic objectives throughout the design process. The VCP provides specifications to ensure this design will accentuate the natural west coast beauty, achieve cohesive design across campus, and realize a design quality befitting to a globally significant University. Land use changes are also detailed in the VCP and informed changes to the runoff coefficients considered in the hydrological and hydraulic analyses.

5.2 Integrated Stormwater Management Plan

UBC's ISMP influenced the identification of major technical design criteria and was consulted for catchment delineation, zoning requirements, and current stormwater quality.

5.3 UBC Technical Guidelines

The UBC Technical Guidelines provided several documents outlining technical design criteria governing several components of the project. This list includes procurement and contract requirements, in addition to concrete, masonry, metals, fire suppression, plumbing, and earthwork specifications.

5.4 UBC Construction TMP Terms of Reference

The UBC Construction Traffic Management Plan (TMP) terms of reference and project information for was used to develop a TMP for this specific project. This document outlines necessary information required before the project can be approved.

5.5 Draft Plan for Construction Work

5.5.1 Construction Activities and Anticipated Timelines

A list of primary construction activities and the anticipated timelines are presented in the following paragraphs:

Site Mobilization (early May 2019)

Site mobilization is expected to last for one week and includes installing a fence around the site, installation of temporary construction trailers, and running temporary services. The construction laydown area will be on the south end of the site, adjacent to SW Marine Drive.

Excavation (May, July, & August 2019)

Excavation will be completed in three sections and involve removing a depth of approximately 1 m of soil (volume of 30,050 m^3). The first excavation period will be three days in May for the structural foundation. The second excavation period will be three days in July for the pump, oil and grit separator and rain gardens. The final excavation will take place over three days place for the detention tank. Approximately half the excavated volume will be stored onsite and reutilized as a landscaping soil for the bioswale and rain gardens.

Drive Piles and Pour Foundations (May 2019)

Once excavation is completed, the piles will be driven into the ground and the slabs will be poured. The piles will support the Clubhouse building, as well as the Supertrees, Gateway structure and the oil and grit separator.

Clubhouse Building (June - December 2019)

Once the piling is completed, the Clubhouse Building will be constructed. Construction of the Clubhouse is the activity with the longest duration.

Stormwater Infrastructure (July 2019)

Once excavation and piling is completed, the pump and oil and grit separator infrastructure will be installed. The pump installation will include formwork, concrete pouring and installation. The oil and grit separator is pre-fabricated and will be installed along with a half pipe drainage grate and, finally, tied into the detention tank area. The detention tank will be installed last, first by lining the excavated area with geotextile lining, then assembling the pipes making up the tank, and then finishing installation and tie-in.

Equipment Installation (August 2019)

Enclosures with equipment pre-installed will be placed on concrete pads, followed by mechanical and electrical connections.

Supertree and Gateway Structure Installation (September 2019)

Once piling is completed, the Supertree and Gateway structures will be erected. These features will be constructed off-site by sub-contractors. The Supertrees will then be encased with steel mesh and planting.

Planting, Landscaping and Paving (September - October 2019)

Planting and landscaping will commence as soon as all the equipment is in place. The asphalt road will be graded and paved during the same period.

Outdoor Fittings (November 2019)

Following planting and paving, the bike racks, bike tool bars, picnic tables, garbage receptacles and signage will be installed on site. The lighting features will be installed and connected.

Startup and Commissioning (December 2019)

Once installation is completed, the startup and commissioning will take place followed by operation of the facility, which is planned for December 2019.

5.5.2 Potential Negative Effects from Construction Activities and Mitigation Measures

Construction of the proposed mulituse stormwater infrastructure and cycling hub will be completed using conventional construction methods and will follow standard construction best management practices. The contractor will be responsible for the detailed methods of construction. Outlined below are potential negative environmental effects of from construction activities along with proposed mitigation measures. The final decision regarding mitigation measures to be employed will be the responsibility of the contractor.

The construction process with the greatest potential for negative environmental effects is construction of the foundation for the Clubhouse building. This work requires the use of various pieces of heavy equipment, which will be on site at different periods of the construction process. Potential heavy equipment includes bulldozers, front-end loaders, small trucks, backhoes, bobcats, dump trucks, compactors, ready-mix concrete trucks and cranes.

Part of the construction process will include planting numerous native species and trees in the surrounding area of the detention tank. There are also several trees that will be removed during excavation. The tree removal application process for the UBC Campus will be followed to minimize issues.

5.6 Construction Schedule and Cost Estimate

The updated construction schedule and cost estimate can be found in Appendix C and Appendix D. The construction will take approximately 8 months with the longest construction activity being the Clubhouse Superstructure. The final cost is estimated to be $16.34 million including 30% contingency, before engineering fees and GST.

5.7 Service Life Maintenance Plan

5.7.1 Detention Chamber

The detention chamber will be equipped with several 8-inch diameter cleanouts placed on the manifolds. The top of the cleanouts can be accessed from ground level and provide an access-point for vacuum or water-jetting hoses used to clean the system. Cleanout should be conducted a minimum of once every year. The rain garden and bioswale features will require periodic checking for exposed soil. Re-mulching will be conducted on an ongoing base as needed. A cover of vegetation and rocks should be maintained regularly. Maintain a cover of decorative rock around the inlet and overflow area to protect the soil. Bi-annual vacuuming of permeable pavement should be completed to inhibit sediment build-up and invasive plant species growth.

During inspections, elevations of sediment height should be taken from each riser and cleanout. These elevations should be recorded on the Inspection and Maintenance log sheet. Also during the inspection, personnel should be looking for blockages to inlet or outlet stubs. Inspection of the pre-treatment unit upstream of the system should always be inspected at this same time. Refer to the manufacturer's recommendations for inspecting and maintaining the pre-treatment unit.

5.7.2 Oil and Grit Separator

Once per year the oil and grit separator must be serviced by a vac truck; all effluent and sediment particles in the tank be removed. Ease of service is facilitated by the installation of the access hatch for the oil and grit separator being installed in the northeast corner of the site. Locating the access hatch at this location, detailed in the Site Plan, Appendix E, drawing C-01, will facilitate access to the tank via the boom arm of a vac truck pulled into the northeast entryway of the detention facility. This locating of the vac truck during servicing will impede entering cyclist traffic from the northeast, leaving the southwest entry open, and leave clear Wesbrook Mall for vehicular traffic. The use of an oil grit separator will reduce the frequency of maintenance and service required for the detention tank because water entering the tank will be semi-treated.

5.7.3 Rain Garden

The rain garden is designed to have longevity and little maintenance. Maintenance is required to remove sediments accumulated.

5.7.4 Pump and Flow Regulation Box

Inspection for the pump in the flow regulation box is once per year as recommended by the manufacturer.

5.7.5 Clubhouse

According to research by RDH Consulting, the service life maintenance timeline for an average building - similar to the Clubhouse building - is shown in Figure 10: Building Service Life Maintenance Timeline. We predict that large asset renewal expenditures will likely be required during Stage 3 and Stage 4 of the building's lifetime.

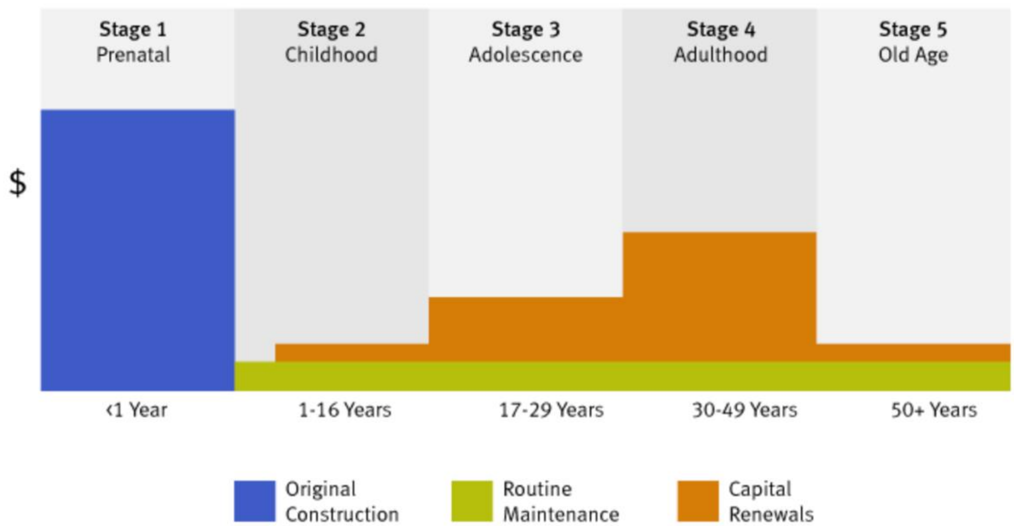

Figure 10: Building Service Life Maintenance Timeline

5.8 Traffic Management Plan (TMP)

As the construction activities of this project will impact the public domain and activities on campus, a traffic management plan is required. The main objectives of this plan are to maintain public safety, minimize impact on the university, and provide adequate access for all modes of transportation. As mentioned in the Technical Considerations section, this plan was developed in accordance with the UBC Construction Traffic Management Plans terms of reference and project information form.

Project Information

Project Owner	UBC Properties Trust
Contact Information	Lead Contractor: Jorden Hutten - 778-887-6959 Key Onsite Staff: Nicole Peterson - 604-323-8612 Will Markson - 778-290-5708 Becky Rousell - 778-469-2356

Time Periods	Monday to Friday, 7am to 5pm
Affected Areas	Intersection of Southwest Marine Drive and Wesbrook Mall

Communications

Notification of delay	Communication and notification of construction activities and associated traffic changes will be posted online

Construction Traffic

Employees	Approximately 15-20 employees will be working on site at all times
Vehicles	Approximately 2-3 construction vehicles will be arriving and departing the site during peak hour on any given day
Times	Construction traffic will arrive primarily between 6 to 7am when material delivery needs to be done, but this may vary
Access Route	Construction vehicles may access the site via Wesbrook Mall
Delivery Location	A location south of the site adjacent to Southwest Marine Drive has been identified for delivery
Storage Location	A location west of the site adjacent to Southwest Marine Drive has been identified for material storage

Traffic Management Measures

Basis	This TMP is consistent with the Manual of Uniform Traffic Control Devices for Canada and BC Manual of Standard Traffic Signs
Traffic Management	See Figure 8 below for temporary traffic control measures
Detour Routes	Right westbound lane of Southwest Marine Drive will be blocked off during construction hours, all westbound traffic will use a single lane
Signs	See Figure 8 below for temporary signage

Buildings	Closest buildings to the construction, the CCM and NRC, both should not be majorly obstructed by construction activities
Bicycle Parking	No current bicycle parking on site; however this will be made available upon completion of construction
Transit	49 UBC bus stop westbound will be temporarily moved 200 meters west of its original location, eastbound stop will be unaffected
Parking	Roadside parking will be prohibited on both Southwest Marine Drive and Wesbrook Mall within 200 meters of the site
Emergency Vehicles	Access to site from Wesbrook Mall
Clean-up	Contracted with UBC Operations for duration of project

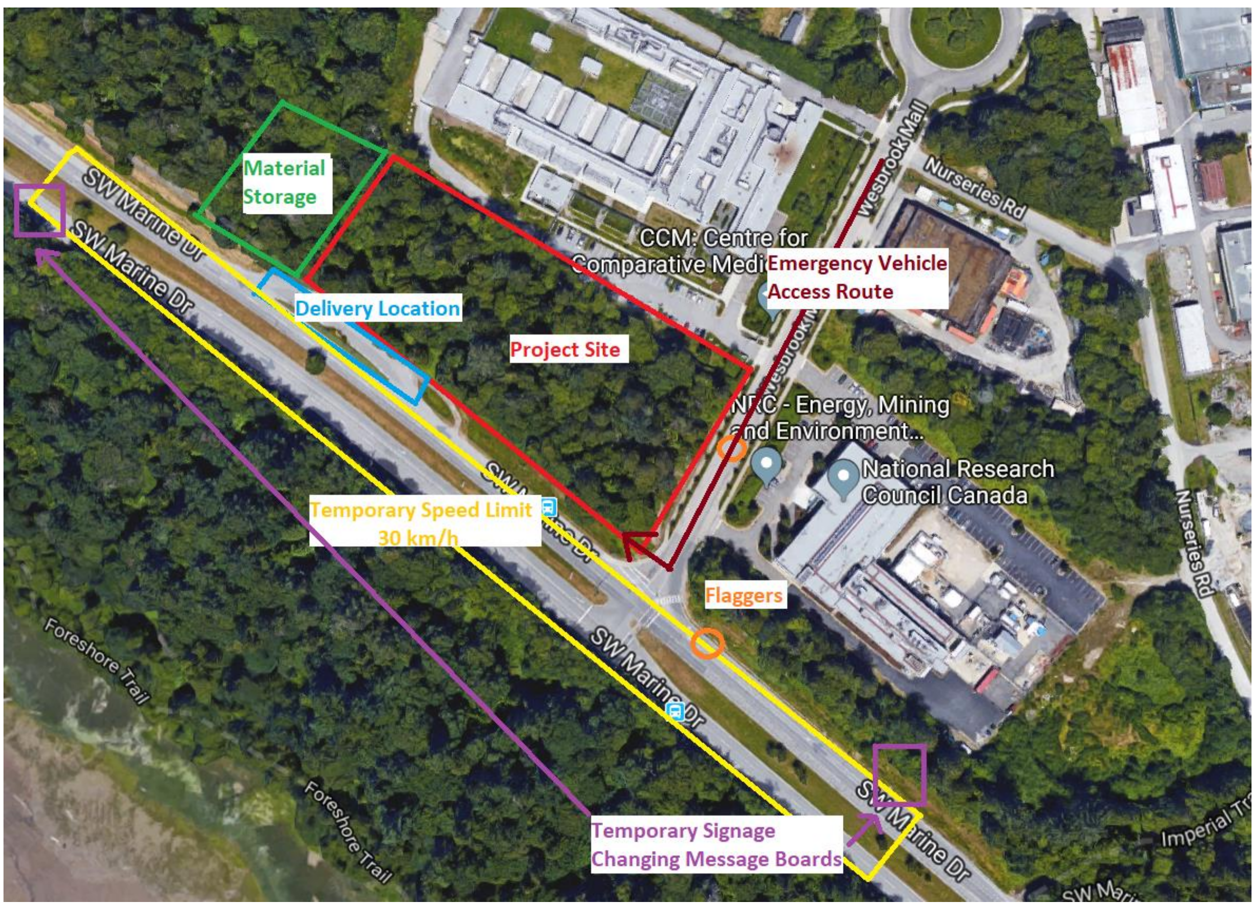

Figure 8 : Temporary Traffic Control Measures and Signage

6 Conclusion and Recommendations

Specifications and design drawings provided for the multiuse stormwater detention facility located on UBC's south campus are to be executed by the general contractor. It is ultimately the discretion of the contractor and sub-contractors to follow the industry construction standards and to use best judgement.

Stormwater management features have been designed to detain a 100-year storm scenario. This is a conservative design and was chosen to address the uncertainty in future storm events that is presented with changing climate. It is recommended that a periodic flow monitoring program may be useful to track flows through the detention tank.

As mentioned in the service life maintenance plan, it is recommended that in the first year of operation the tank is flushed at least twice. The system may benefit from occasional CCTV filming to ensure no bottlenecks.

Finally, it is recommended that the structural elements on site are regularly maintained through UBC Building Services. The UBC Cycling Club and other sports teams that will use this site as a Clubhouse should share in upkeep responsibility through funding and sponsorship. This design will stand out as a uniquely sustainable and multiuse hub for cyclists and the UBC Community as a whole.

7 References

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Appendix A: Sample Calculations

Peak Flows

Project: Stormwater Project II
Date: 2019-03-19

Hydrological Assessment

Station Name: Vancouver Intl A
ID: 1108395

Area	A (km2)	1.49
Length	L (km)	2.22
Max Elev	Hmax (m)	104
Min Elev	Hmin (m)	57
Avg Slope	S (m/m)	0.021171
Runoff Coefficient	r	0.408

Time of Concentration   tc (Hathaway)
1.426319725 hr

Return Period	**100 yr**		**25 yr**		**10 yr**		**2 yr**	
Coefficient A	A =	32.2	A =	22.5	A =	17.7	A =	10.7
Coefficient B	B =	-0.641	B =	-0.59	B =	-0.561	B =	-0.513
Coefficient t0	t0 =	0.093	t0 =	0.038	t0 =	0.015	t0 =	0
	I = A*(t+t0)^b		I = A*(t+t0)^b		I = A*(t+t0)^b		I = A*(t+t0)^b	
Climate Change Coefficient		30%						
Intensity	I (mm/hr)	24.62741	I (mm/hr)	17.96625	I (mm/hr)	14.41812	I (mm/hr)	8.918063
Intensity w/ Climate Change		32.01563		23.35612		18.74356		11.59348
Volume for Storm Duration Tc		45.66453		33.31329		26.73431		16.53601
Peak Flow	Q100 = CiA/3.6		Q25 = CiA/3.6		Q10 = CiA/3.6		Q2 = CiA/3.6	
	Q100 (m3/s)	8.66406	Q25 (m3/s)	6.320625	Q10 (m3/s)	5.072376	Q2 (m3/s)	3.137424
	Q100 (m3/s) w/CC	11.26328	Q25 (m3/s) w/CC	8.216812	Q10 (m3/s) w/CC	6.594088	Q2 (m3/s) w/CC	4.078651

Rainfall Intensities

Project: Stormwater Project II
Date: 2019-03-19

Hydrological Assessment

IDF for: VANCOUVER INTL A ID:1108395

◉ Total PPT (mm) ○ Intensity rates (mm/h)

T (years)	2	5	10	20	25	50	100
5 min	3.19	4.42	5.24	6.05	6.31	7.11	7.92
10 min	4.60	6.56	8.00	9.49	10.00	11.62	13.36
15 min	5.71	8.07	9.80	11.59	12.19	14.14	16.22
30 min	7.56	10.72	13.10	15.62	16.48	19.28	22.34
1 h	10.41	14.04	16.82	19.82	20.85	24.25	28.03
2 h	14.03	18.56	22.43	26.97	28.60	34.34	41.24
6 h	25.54	32.36	38.25	45.22	47.75	56.66	67.46
12 h	39.05	48.68	54.98	60.98	62.87	68.68	74.39
24 h	50.19	63.03	71.72	80.21	82.93	91.42	99.98

Return Period	**100 yr**	**25 yr**	**10 yr**	**2 yr**
Climate Change Coefficient	30%			
Volume for Storm Duration 1h	28.03	20.85	16.82	10.41
Volume w/ Climate Change	36.439 (mm)	27.105 (mm)	21.866 (mm)	13.533 (mm)
Volume for Storm Duration 2h	41.24	28.6	22.43	14.03
Volume w/ Climate Change	53.612 (mm)	37.18 (mm)	29.159 (mm)	18.239 (mm)
Volume for Storm Duration 6h	67.46	47.75	38.25	25.54
Volume w/ Climate Change	87.698 (mm)	62.075 (mm)	49.725 (mm)	33.202 (mm)
Volume for Storm Duration 12h	74.39	62.87	54.98	39.05
Volume w/ Climate Change	96.707 (mm)	81.731 (mm)	71.474 (mm)	50.765 (mm)
Volume for Storm Duration 24h	99.98	82.93	71.72	50.19
Volume w/ Climate Change	129.974 (mm)	107.809 (mm)	93.236 (mm)	65.247 (mm)

Detention Chamber Dimensions and Orientation

Tank Dimensions

$V_{water} = 1422\ m^3$

Pipe

$D = 1.050\ m$
$A_0 = 0.90\ m^2$

*Assumed pipe is maximum 80% full

$A = 0.90 * 0.8$
$A = 0.72\ m^2$

$$L = \frac{V}{A}$$
$$L = \frac{1422\ m^3}{0.72\ m^2}$$
$$L = 19756\ m$$

*20 pipes of 100 m length will be used

$L = 100.0\ m$

*1/2 a pipe diameter of spacing between consecutive pipes

$$W = 1050 * 20 + \frac{1050}{2} * 19$$
$$W = 31.5\ m$$

Volume of the Tank

$$V_{tank} = n * L * A_0 + 2 * W * A_0$$
$$V_{tank} = 20 * 100.0\ m * 0.9\ m^2 + 2 * 31.0\ m * 0.9\ m^2$$
$$V_{tank} = 1924\ m^3$$

Volume of water in the Tank

$$V_{tank} = n * L * A + 2 * W * A$$
$$V_{tank} = 20 * 100.0\ m * 0.72\ m^2 + 2 * 31.0\ m * 0.72\ m^2$$
$$V_{tank} = 1484\ m^3$$

Tank Orientation

$El_{Inlet} = 55.26\ m$
$D_{Inlet} = 4.1\ m$
$EI_{Outlet} = 51.26\ m$
$D_{Outlet} = 2.23\ m$

*Assume 0.5% slope on all pipes (2.86 degrees)

$D_{Width} = W * \tan \alpha$
$D_{width} = 31.5 * \tan 2.86$
$D_{width} = 1.57\ m$

$D_{Length} = L * \tan \alpha$
$D_{Length} = 100 * \tan 2.86$
$D_{Length} = 5.00\ m$

$D_{Total} = D_{width} + D_{Length}$
$D_{Total} = 1.57\ m + 5.00\ m$
$D_{Total} = 6.57\ m$

Excavation Volume

* Assume 2:1 side slopes

* For ease of construction D_{Total} has been approximated to 7 m

$$V = L * W * D_{Total} + L * D_{Total} * \frac{2 * D_{Total}}{2} + W * D_{Total} * \frac{2 * D_{Total}}{2}$$
$$V = 100 * 31.5 * 7 + 100 * 7 * \frac{2 * 7}{2} + 31.5 * 7 * \frac{2 * 7}{2}$$
$$V = 28471\ m^3$$

Rain Garden

Input Volume

= (Tributary Area) * (Capture Rainfall Amount)

= (Lot area) * (Percent Impervious) * (72% 2-yr, 24-hour rainfall)

= (17300 m2) * (0.2 impervious) * (0.72 * 2.3mm/hr *24hr)

= (17300 m2 * 0.2) * (39.7 mm) = 137.3 m3

Capture Volume

= Evaporation + Growing Medium + Rockpit + Infiltration

= 6 m3 + 50.4 m3 + 20.1 m3 + 78.4 = 154.9 m3

Where:

Evaporation

= (24 hour evaporation) * (surface area)

= (1 mm/day) * (17300 m2 * (1 - 0.65)) = 6.06 m3

Growing Medium

= (Volume of growing medium) * (Field Capacity – Wilting Point)

= (2m * 280m *0.45) * (0.25 – 0.05) = 50.4 m3

Infiltration

= (24 hour infiltration) *(surface area)

= (1.5 mm/hr * 24 hr) *(2m *280m) = 20.16 m3

Rock Pit for the rain garden

= Volume of rock pit* available water content

= rock pit length * width * proposed depth * water content

= 280m * 2 m * 0.3 m * 0.35 = 78.4 m3

Capture Volume > Input Volume, Design is Ok

Orifice Size

$$Maximum\ flow\ rate\ Q = 1.2\ m^3/s = 1200\ L/s$$

$$If\ Orifice\ Diameter\ is\ 400mm$$

$$Cross\ section\ area\ A = \frac{\pi d^2}{2} = \frac{\pi * (400mm)^2}{2} = 0.13m^2$$

$$Flow\ Velocity\ V = \frac{Q}{A} = \frac{1.2\ m^3/s}{0.13m^2} = 9.55\ m/s$$

$$Loss\ Coefficient\ for\ the\ orifice = 0.5$$

$$Velocity\ Pressure = \frac{v^2}{2g} = (9.55\ m/s)^2 \div 2g = 4.65\ m$$

$$Loss\ of\ section = velocity\ pressure * Loss\ Coefficient = 4.65\ m * 0.5 = 2.32m$$

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Supertree Foundation Design:

Loads

Concrete: diameter, $d = 2m$. height, $h = 12m$. $\gamma_{conc.} = 24 kg/m^3$

area $= \pi r^2 = \pi^2(1)^2 = 3.14 m^2$

Mass $= 3.14 m^2 \times 12m \times 24 kg/m^3 = 904.3 kg$

Steel: 5000 kg (see Supertree struc. design)

Planting panels: $3 lbs/ft^2$ (overestimation to account for moisture)
↳ $14.5 kg/m^2 \times 38 m^2 \rightarrow 115 kg$

Solar Panels: 515 kg (see supertree struc. design)

Water Storage: $5m \times 5m \times 2m = 50 m^3 \times 1000 kg/m^3 = 1000 kg$

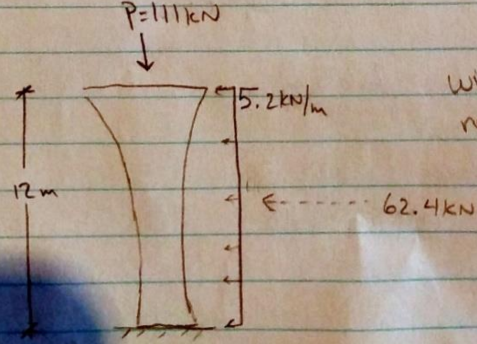
Approx. Supertree mass $= 905 kg + 5000 + 115 + 515 + 1000 = 7535 kg$.

Factored Load

$7535 kg \times 9.81 kg m/s^2 \times 1.5$ (Safety Factor) $\approx 110,900 N \approx 111 kN$ // < 100kN ✓ ok

$f'_c = 30 MPa$ $f_y = 400 MPa$

Wind pressure tables $= 430 Pa$ (N/m^2) $\rightarrow 430 N/m^2 \times 12m = 5.2 kN/m$



wind load resultant $= 5.2 \frac{kN}{m} \times 12m$
$= 62.4 kN$

Hilroy

use 3 piles for foundation → steel tubes
↳ each pile supports 1/3 of DL.

→ Estimated skin friction around pile shafts, $f_s = 75$ kPa (allowable) since moderately dense soil

Pile Capacity:

$$F_c = \pi D L f_s \quad \text{(compression)}$$

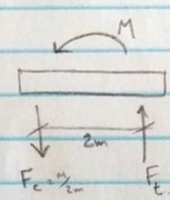
$$F_t = \pi D L f_s \cdot 0.75 \quad \text{(tension)}$$

→ Use 400mm Ø steel tube

$$f_c = \pi (0.4m) \cdot L \, (75kPa) > DL = \frac{111\,kN}{\#\text{ of pile} = 3}$$

min length, L = 0.4m

check F_t > wind load.



$$M = \text{wind resultant} \times \frac{12m}{2} = 62.4\,kN \times \frac{12m}{2}$$

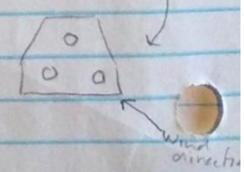
$$M = 374.4\,kNm.$$

$$\therefore F_c = F_t = \frac{M}{\text{dist. between}} = \frac{374.4\,kNm}{2m} = 187.2\,kN$$

$$F_t = \pi D L f_s \, 0.75 > 187.2\,kN$$

$$= \pi (0.4m) L (75kPa)(0.75) = 187.2\,kN$$ all in one pile for the worst case scenario

$$\rightarrow L = 2.65m$$



⇒ That is quite deep ... let's look at using 4 piles. pg. 2

Supertree Foundation Design cont...

Using 4 piles.

just check for wind since it was limiting
→ now 2 piles acting together no matter which way the wind blows.

$f_t = \pi D L f_s \, 0.75 \quad > \quad 187.2\ kN \,/\, \#\text{ of piles resisting}$

$= \pi (0.4_m) L (75\,kPa) 0.75 \quad > \quad \frac{187.2}{2}$

$\rightarrow L = 1.32\ m.$

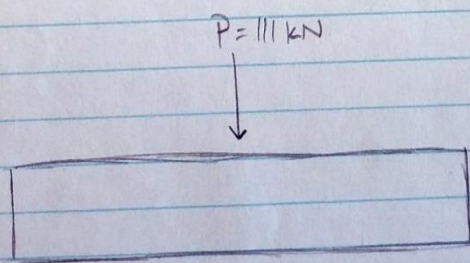
piles:

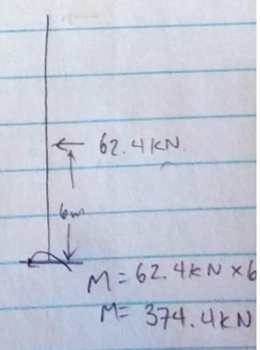
∴ use 4 steel tube piles $\phi = 400\,mm$ $L = 1.4\,m$ //

Pile Cap:

→ Check the pile cap for punching (shear) failure due to the load from the tree = 111 kN //

→ use a ridged pile cap.

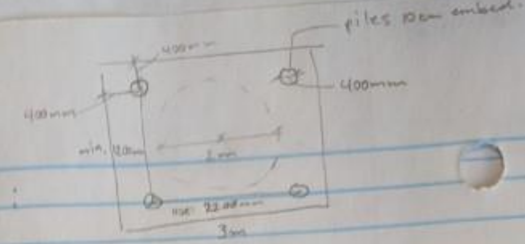




$f'_c = 30\ MPa$ $\quad f_y = 400\ MPa$ $\quad \phi_c \approx 0.65$ $\quad \phi_s \approx 0.85$ $\quad \alpha_1 \approx 0.8$

1. $b = 1m$ $\qquad M_f = 374\ kNm$

2. Estimate Slab thickness
$h = 700\,mm.$



3. Estimate effective slab depth:

$d = h - (\text{cover} + 10_{mm})$ use cover = 40_{mm} for exterior slabs

$= 700 - (40 + 10)$

$\rightarrow d = 650_{mm}$

4. Estimate area of steel, A_s:

$A_s = 0.0015 f'_c \cdot b \left(d - \sqrt{d^2 - \frac{3.85 M_r}{f'_c \cdot b}} \right)$

$= 0.0015(30) \cdot 1000_{mm} \left(650 - \sqrt{650^2 - \frac{3.85(172.6 \times 10^6)}{30 \cdot 1000}} \right)$

$\rightarrow A_s = 777 mm^2$ using 20M $A_b = 300mm^2$ double mat

$S \le A_b \frac{1000}{A_s} = 300 \frac{1000}{770} \rightarrow S \le 390_{mm}$

check meets min: $A_s = 300 \frac{1000}{375} = 1600 \ge 770$ ✓ ok

use S = 375mm double mat

5. check max. tension reinf.

$\rho < \rho_b$ $\rho = \frac{A_s}{b \cdot d} = \frac{1600}{1000(375)} = 0.0043$

$0.0043 < 0.027$ ✓ ok

Steel controlled ✓ ok $\rho_b = 0.027$ (from table A.4)

6. Actual depth, $d = h - \text{cover} - \frac{d_b}{2} = 700 - 40 - \frac{20}{2} \rightarrow d = 650_{mm}$

7. Confirm min. reinf.: & design shrinkage & temp. reinf.

$A_g = b \times h$

$= 1000(700) = 700{,}000\ mm^2$ $A_{s,min} = 0.002 \cdot A_g = 1400_{mm} < 1600$ ✓ ok

8. check spacing

$S \le S_{max} = \min \begin{cases} 3h = 2100 \\ 500_{mm} \end{cases}$ $S = 375 < S_{max} = 500$ ✓ ok

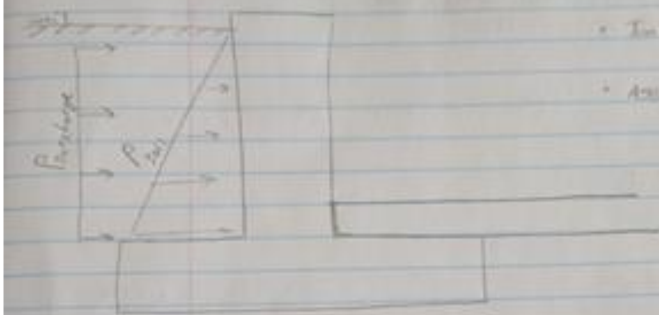
Pile Cap:	double mat 20M bar at 375mm o/c.
	Slab thickness = 700mm

3" clr. from bottom, 2" clr from edges.

0.0762 m 0.0508 m

CIVL 446

Building Foundation Design



- Int - ext grade max = 9'-6"
  = 2.896m
- Assume footing size
  → try 8" wall, 10" footing,
  24" toe, 30" heel

$P_{soil} = 0.33\,(18\,kN/m^3)(2.896 + 0.254)\,m = 18.711\,kN/m^2$

$P_{surch} = 0.33\,(8.4\,kPa) = 2.772\,kN/m^2$

Check stability @ service loading (construction)

Overturning:

TYPE	FORCE	DIST	MOMENT (force × dist)
Soil	(18.711)(2.896 + 0.254)(1/2) = 29.47 kN /per m width	(1/3)(2.896 + 0.254) = 1.050 m	30.94 kNm
Surcharge	2.772 (2.896 + 0.254) = 8.732 kN (per m width)	1/2 (2.896 + 0.254) = 1.575 m	13.753 kNm
	Σ = 38.202 kN		Σ = 44.697 kNm

Righting:

TYPE

pg. 2

Righting:

TYPE	FORCE	DIST.	MOMENT
Soil	(18 kN/m³)(2.896)(0.762) = 39.722 kN (per m strip)	(0.61) + 0.203 + 0.762/2 = 1.194 m	= 47.428 kNm
Footing	24 kN/m³ (1.575)(0.254) = 9.601 kN (per m width)	1.575 m / 2 = 0.787 m	= 7.556 kNm
Wall (stem)	24 kN/m³ (2.896 m)(0.203 m) = 14.109 kN (per m width)		

Σ = 63.432 kN (per m width)

Σ = 65.030 kN m

F.S Sliding

$\frac{P_r}{P_{pushing}}$

pg. 3 of 12

F.S Sliding

Notice no surcharge was included since it won't be there during construction

$$\frac{P_r}{P_{pushing}} = \frac{(39.722\,kN + 9.601\,kN + 14.109\,kN)(0.45)}{\Sigma\ OT\ FORCE} = \frac{28.544\,kN}{38.202\,kN}$$

$$= 0.75$$

∴ Slab must be installed prior to backfill over 4'-0"

F.S OT

$$\frac{\Sigma M_r}{\Sigma M_{OT}} = \frac{65.030\,kN\text{-}m}{44.697\,kN\text{-}m} = 1.45$$

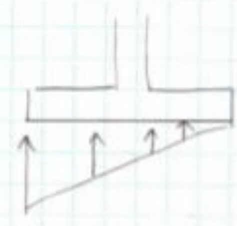
Supposed to be 1.5 or greater - close enough ∴ OK ✓

Bearing

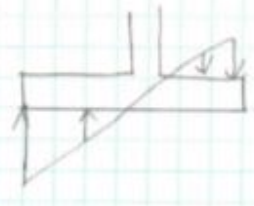
For this calc we will add 20kN/m of building load that represents line load from building above - since bearing calc is based on max gravity load

$$e = \frac{B}{2} - \frac{\Sigma M_{Net}}{\Sigma W} \le \frac{B}{6}$$

If true $\longrightarrow$ $q_{max} = \frac{\Sigma W}{B} + \frac{6 \Sigma W e}{B^2}$



If False $\longrightarrow$ $q_{max} = \frac{2 \Sigma W}{3(\frac{B}{2} - e)}$



Added moment from Building load = $20\ kN/m \left(0.610\ m + \frac{0.203\ m}{2}\right) = 12.190\ kN/m$

ΣM_{net} (INCD Building load) = 65.030 kN-m + 14.230 kN-m = 79.260 kN-m

ΣW (INCD Building Load) = 64.432 kN + 20 kN = 84.432 kN

$$e = \frac{B}{2} - \frac{\Sigma M_{net}}{\Sigma W} \leq \frac{B}{6}$$

(off by 0.005 m from rounding)

$$e = \left(\frac{1.5748\ m}{2}\right) - \frac{79.260\ kN\text{-}m - 44.697\ kN\text{-}m}{84.432\ kN} = 0.378\ m$$

$$\frac{B}{6} = \frac{1.5748\ m}{6} = 0.262$$

0.378 > 0.262 ∴ go with the false formula described above.

$$q_{max} = \frac{2\Sigma W}{3\left(\frac{B}{2} - e\right)} = \frac{2(84.432\ kN)}{3\left(\frac{1.5748\ m}{2} - 0.373\right)}$$

(used spreadsheet e to continue)

$$= 135.83\ kPa$$

(1.53 kPa off spreadsheet due to rounding)

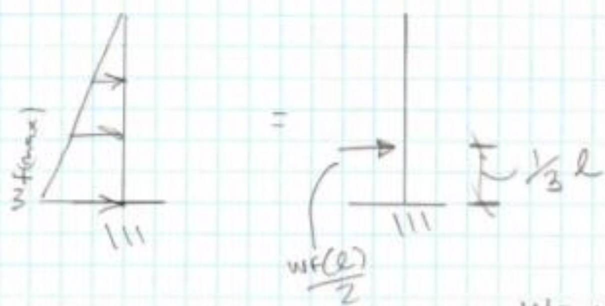
135.83 kPa < 150 kPa ∴ Bearing is OK ✓

WALL/ STEM REINFORCING

* Recalculate moment excluding footing height.

Soil

$P_{soil} = 18\ kN/m^3 \times 0.33 \times 2.896m = 17.202\ kN/m^2$



$\frac{W_F \times l}{2} = \frac{(17.202\ kN/m^2) \times (2.896m)}{2} = 24.045\ kN$

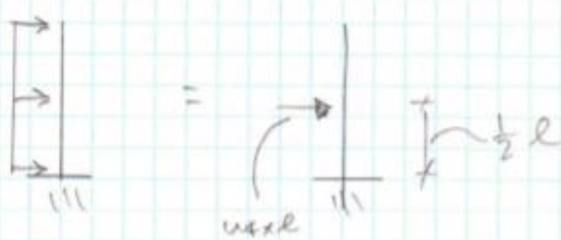
$\Sigma MA = 0$

$0 = MA - 24.908(\frac{1}{3} \times 2.896m)$

$MA = 24.045\ kN\text{-}m$

SURCHARGE

$P_{SURCH} = 8.4\ kPa \times 0.33 = 2.772\ kN/m^2$



$MAX\ MOMENT = \frac{wl^2}{2} \Rightarrow \frac{(2.772\ kN/m)(2.896m)^2}{2} = 11.624\ kN\text{-}m$

$TOTAL\ M = 35.669\ kN\text{-}m$

$TOTAL\ M_F = 1.4(35.669\ kN\text{-}m) = 49.937\ kN\text{-}m$

MIN VERT + HORIZ REIN'F

$\rho = 0.20\%$

$A_s = \rho(bd) = 0.002(1000\text{mm})(144\text{ mm}) = 288\text{ mm}^2$

A of 15M = 200 mm^2

$S = \frac{A_b}{A_s \text{ REQ'D}/m} = \frac{200\text{mm}^2}{288\text{ mm}^2/m} = 0.694\text{ m}$

=> 27.3" o/c

∴ 15M @ 20" o/c.

$d = 203\text{mm} - 51\text{mm} - \frac{15\text{mm}}{2} = 144\text{ mm}$

Bending (moment steel)

$K_r = \frac{M_f \times 10^6}{bd^2} = \frac{(49.937\text{ kN-m})(10^6)}{(1000\text{mm})(144\text{mm})} = 2.5$

$K_r = 2.4 \rightarrow \rho = 0.83$ (Table 2.1 Design of Flexure, concrete manual)

$A_s = 0.0079(1000\text{mm})(145\text{ mm}) = 1145.5\text{ mm}^2$

$S = \frac{200\text{mm}^2}{1145.5\text{ mm}^2/m} = 175\text{ m} \Rightarrow 6\frac{2}{8}"$

∴ 15M @ 6" o/c (This is dowel spec)

* Since we don't need the vert steel to be @ 6" all the way up we could put verts @ 2x (12" o/c) or 3x (18" o/c) the spacing.

How high does dowel need to extend before we can go to one of these spacings?

WALL BAR SPACING – MAX MOMENTS

*Assuming: – c/c = 2" (51mm) from tension face.
- 8" thk wall (203mm)

$d = 203mm - \left(51mm + \frac{15mm}{2}\right) = 144.5mm \rightarrow$ Round Down $= 144mm$

$S = \frac{Ab}{As\ Req'D} \therefore As\ Req'D = \frac{Ab}{S}$

15M @ 20" o/c (MIN REINF)

$As\ Req'D = \frac{Ab}{S} \Rightarrow \frac{200mm^2}{0.508m} = 393.7\ mm^2/m$

$\rho = \frac{As}{bd} = \frac{393.7\ mm^2}{(1000mm)(144mm)} = 0.00273\ (0.27\%)$

From table 2.1 of Concrete Design Handbook

$\rho = 0.27\% \longrightarrow Kr = 0.9$

$Mr = Kr\ bd^2 \times 10^{-6}$ kN-m

$M_{MAX} = Mr$

$M_{MAX} = (0.9)(1000mm)(144mm)^2 \times 10^{-6} = 18.6$ kN-m

(this is rounded down)

15M @ 16" O/C

$$A_s \text{ Required} = \frac{200mm^2}{0.4064m} = 492mm^2/m$$

$$\rho = \frac{492.1mm^2}{(1000mm)(144mm)} = 0.0034 \; (0.34\%)$$

$$\rho = 0.34 \rightarrow K_r = 1.1$$

$$M_{max} = (1.1)(1000mm)(144mm)^2 \times 10^{-6} = 22.8 \text{ kN-m}$$

15M @ 12" O/C

$$A_s \text{ Required} = \frac{200mm^2}{0.3048m} = 656.2 \, mm^2/m$$

$$\rho = \frac{656.2mm^2}{(1000mm)(144mm)} = 0.0046 \; (0.46\%)$$

$$\rho = 0.46\% \rightarrow K_r = 1.47$$

$$M_{max} = 1.47(1000mm)(144mm)^2 \times 10^{-6} = 30.4 \text{ kN-m}$$

(This was rounded down)

15M @ 10" o/c

As Req'D = $\frac{200 mm^2}{0.254 m}$ = 787 mm²/m

$\rho = \frac{787.4 mm^2}{(1000 mm)(144 mm)}$ = 0.0055 (0.55%)

ρ = 0.55% → Kr = 1.73

Mmax = 1.73(1000mm)(144mm)² x10⁻⁶ = 35.8 KN-m

(This was rounded down)

15M @ 8" o/c

As Req'd = $\frac{200 mm^2}{0.2032 m}$ = 984.3 mm²/m

$\rho = \frac{984.3 mm^2}{(1000 mm)(144 mm)}$ = 0.0068 (0.68%)

ρ = 0.68% → Kr = 2.1

Mmax = 2.1(1000mm)(144mm)² x10⁻⁶ = 43.5 kN-m

(This is rounded Down)

15M @ 6" o/c

As Req'd = $\frac{200 mm^2}{0.1524 m}$ = 1312.3 mm²/m

$\rho = \frac{1312.3 mm^2}{(1000 mm)(144 mm)}$ = 0.0091 (0.91%)

ρ = 0.91% → Kr = 2.73

Mmax = 2.73(1000mm)(144mm)² x10⁻⁶ = 56.6 KN-m

USE Moment calculator spreadsheet and max moments to find @ what height the spacing can be reduced:

to 12" o/c → MAX moment = 30.4 KN-m
↳ 2'-0' from top of footing

∴ 24" + (10" − 3" clr) = 31" RU → 32"

to 16" o/c → MAX moment = 22.8 KN-m
↳ 2.5 ft from top of footing

∴ 30" + (10" − 3") = 37" RU → 38"

Summary of spec

15M Dowels @ MAX 6" o/c with Verts tied to every 2nd dowel (12" o/c) with 32' vert portion of dowel /

or

15M Dowels @ MAX 6" o/c with verts tied to every 3rd dowel (18" o/c) with 38" vert portion of dowel.

@ TOE (BTM STEEL)

$$M_F\ toe = \frac{1.5(q_{max})(\text{length of toe})^2}{2} =$$

spreadsheet value

$$\frac{1.5(131.9\,kPa)(0.610\,m)^2}{2} = 36.8\ kN\text{-}m$$

$$d = 254 - 76\,mm - \frac{15\,mm}{2} = 170\,mm$$

$$K_r = \frac{36.8\ kN\text{-}m \times 10^6}{(1000)(170\,mm)^2} = 1.3$$

$K_r = 1.3 \rightarrow \rho = 0.40$

$A_s = \rho b d = 0.0040(1000\,mm)(170\,mm) = 680\,mm^2$

$$S = \frac{200\,mm^2}{680\,mm^2/m} = 0.294\,m \Rightarrow 11\tfrac{4}{10}"$$

So 12" o/c

* Horiz. portion of dowel is used for toe reinf.
  Dowel spacing = 6" o/c
  So Dowels govern 6" o/c.

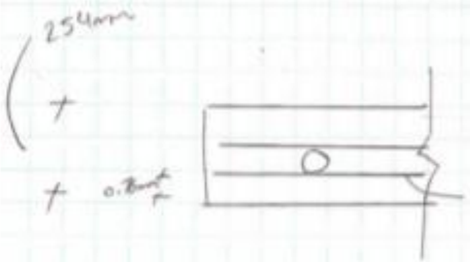
FOOTING REINFORCEMENT

@ Heel (TOP STEEL)

WF Soil = 18 kN/m³ × (2.896 m) × (0.762 m) = 39.722 kN/m

$$M_F = \frac{w_F \ell}{2} = \frac{(39.722)(0.762\,m)}{2} = 15.134\ kN\text{-}m$$

FACTORED ×1.4 = 21.188 kN-m



d = 254mm − 76mm − 15mm − 15mm − 15mm/2 = 140mm

3 rows of 15M

$$K_r = \frac{M_F \times 10^6}{bd^2} = \frac{21.188\ kN\text{-}m \times 10^6}{(1000\,mm)(140\,mm)^2} = 1.1$$

Kr = 1.1 → 0.34%

As = ρbd → 0.0034 (1000mm)(140mm) = 476 mm

$$S = \frac{200\,mm^2}{476\,mm^2/m} = 0.420\,m = 16\tfrac{9}{16}"$$ ∴ 15M @ 16" o/c

Appendix B: Specifications

Detention Chamber

Aluminized Type II (ALT2) Corrugated Metal Pipe (CMP)

Underground Detention and Infiltration Standard Specification

1.0 GENERAL

1.1 This item shall govern the furnishing and installation of Underground Detention and Infiltration Systems for all types, sizes and designations as shown on the plans.

1.2 Contractor shall furnish all labor, materials, equipment and incidentals necessary to install the CMP System, appurtenances and incidentals in accordance with the Drawings and as specified herein.

1.3 A stormwater treatment device upstream of the CMP System is recommended as the appropriate means of pretreating for the purpose of extending the maintenance interval on the CMP System and reducing the life cycle cost. Both engineered solutions shall be provided by a single supplier/manufacturer. Filtration by wrapping a system with geotextile is not an acceptable means of pretreatment.

1.4 Applicable provisions of any Division shall govern work in this section.

1.5 American Association of State Highway and Transportation Officials (AASHTO)

1.5.1 AASTHO Design Section 12 – Soil-Corrugated Metal Structure Interaction Systems

1.5.2 AASHTO Construction Section 26 – Metal Culverts

1.5.3 AASHTO M36 – Standard Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains

1.5.4 AASHTO M274 – Standard Specification for Steel Sheet, Aluminum-Coated (Type 2), for Corrugated Steel Pipe

1.6 American Society for Testing and Materials (ASTM)

1.6.1 ASTM A760: Standard Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains

1.6.2 ASTM A929: Standard Specification for Steel Sheet, Metallic-Coated by the Hot-Dip Process for Corrugated Steel Pipe

1.6.3 ASTM A798: Standard Practice for Installing Factory-Made Corrugated Steel Pipe for Sewers and Other Applications

1.6.4 ASTM A998: Standard Practice for Structural Design of Reinforcements for fittings in Factory-Made Corrugated Steel Pipe for Sewers and Other Applications

1.7 Site layout drawings, product specifications, materials, corrugation, gage, hydraulic storage data and supported calculations of proposed alternatives shall be submitted to the EOR for review at a minimum of 10 working days prior to bid closing.

1.8 Shop drawings shall be annotated to indicate all materials to be furnished and installed under this section, and all applicable standards for materials, required tests of materials and design assumptions for structural analysis:

1.8.1 Before installation of the CMP System, Contractor shall obtain the written approval of the EOR for the stormwater system and the installation drawings.

1.9 All proposed alternatives to the CMP System shall conform to applicable above referenced AASHTO and ASTM specifications. NCSPA provides design service life guidance for certain products up to 100 years in recommended environments.

2.0 <u>MATERIALS</u>

2.1 Aluminized Type II material shall conform to the applicable requirements of AASHTO M274 or ASTM A929. CMP shall be manufactured in accordance with the applicable requirements of AASHTO M36 or ASTM A760.

2.2 The pipe sizes, gauges and corrugations shall be as shown on the project plans. Joint performance requirements are published in Division II, Section 26.4.2, of the current edition of the AASHTO Bridge Construction Specifications.

2.3 Soil tight, gravity flow, non-pressure, drainage pipe joints shall conform to AASHTO M36 and ASTM A760. Minimum joint spacing shall be 10 ft.

2.4 Overlapping of adjacent pipes are not permitted and appropriate banding must be utilized in order to properly secure individual pipes in place.

2.5 Integral End Sections: Each barrel of the CMP System shall either be connected to a fitting composing a manifold for hydraulic distribution or have an integrated bulkhead to resist loading at the end/start of the barrel, end cap sections shall not be permitted.

2.6 Material selected shall be flame resistant and capable of retaining 80% of strength when subjected to a temperature of 400 degrees Fahrenheit for one hour.

2.7 All fittings shall be manufactured prior to arriving on the jobsite to ensure structural integrity. Fitting reinforcement shall be in accordance with ASTM A998 and reinforcing details. Bulkhead design and fabrication does not vary with differing coatings on the steel components.

2.8 The manufacturer of the CMP System shall be one that has regularly been engaged in the engineering design and production of these systems for at least fifteen (15) years and which has a history of successful production, acceptable to the EOR. In accordance with the Drawings, the CMP System shall be supplied by:

Contech Engineered Solutions
9025 Centre Pointe Drive
West Chester, OH, 45069
Tel: 1 800 338 1122

2.9 Sampling, testing, and inspection of metal sheets and coils used for manufacturing the CMP System shall be in accordance with to the above applicable referenced specifications. All fabrication of the product shall occur within the United States.

3.0 PERFORMANCE

3.1 The CMP System proposal shall be sized in accordance to the design provided and approved by the Engineer of Record (EOR). Any Contractor deviating from the design shown on the plans, to include: material, footprint, etc., shall provide to the EOR a summary report on stage-storage curves, design calculations, HydroCAD modeling and engineering drawings.

3.2 The CMP System shall comprise of manhole access with minimum dimensions of 24 inches diameter to provide adequate inspection and maintenance without restrictions and obstructions to entry into interior of the CMP System. Manholes shall be provided to allow full entry into and visual inspection of the complete CMP System, at a minimum as to allow full maintenance of the CMP System. Cleanouts or inspection ports are not acceptable access points for maintenance and inspection nor are any other alternatives which do not allow for full entry into the system.

3.3 CMP spacing, gage (thickness) and stone base thickness can be altered with consultation from Contech Engineered Solutions, LLC.

3.4 The CMP System shall be designed for a minimum HS-20/HS-25 final live loading conditions. The CMP System shall meet HS-20/HS-25 loading requirements with a minimum of 12-inches of cover to bottom of flexible pavement for pipe spans less than or equal to 96 inches and 18 inches of cover to bottom of flexible pavement for pipe spans greater than 96 inches.

3.5 The CMP System shall be designed so as the hydraulic grade line will increase evenly throughout whereas transverse movement from one storage compartment to another shall not be permitted. All storage compartments shall be connected via manifold (or connecting pipe) versus by transporting stormwater through stone.

3.6 A stormwater pretreatment device is recommended upstream of the CMP system as follows:

3.6.1 Infiltration: Where feasible, the selected stormwater treatment device upstream of an infiltration system shall be a filter system and have General Use Level Designation (GULD) for Basic Treatment by the Washington State Department of Ecology or demonstrate equivalent performance in independently verified field testing following a peer reviewed testing protocol, and must be sized consistent with the system producing those results.

3.6.2 Detention: Where feasible, the selected Stormwater treatment device upstream of a detention system shall be a separator system and have GULD for Pretreatment by the WADOE or demonstrate equivalent performance in independently verified field testing following a peer reviewed testing protocol, and must be sized consistent with the system producing those results.

3.6.3 Selected pretreatment stormwater device shall incorporate a physical barrier capable of capturing and retaining trash and debris (i.e.: floatable and neutrally buoyant materials) for all flows up to the treatment capacity of the device.

3.6.4 The application of wrapping a system with geotextile of any branding or material type, that allows the passage of stormwater, shall not be regarded as an acceptable treatment or pretreatment device.

3.6.5 The manufacturer of the selected Stormwater treatment device shall have been regularly engaged in the engineering design and production of systems for the physical treatment of Stormwater runoff for 15 years.

3.6.6 In order to not restrict the Owner's ability to maintain the stormwater pretreatment device, the minimum dimension providing access from the ground surface to the sump chamber shall be 20 inches in diameter.

4.0 EXECUTION

4.1 The CMP System installation shall be in accordance with AASHTO Standard Specifications for Highways Bridges, Section 26, Division II or ASTM A798 and in conformance with the project plans and specifications.

4.2 The CMP System shall be installed in accordance with the manufacturer's recommendations and related sections of the contract documents. Handling & assembly shall be in accordance with National Corrugated Steel Pipe Association's (NCSPA) recommendations.

4.3 For temporary construction vehicle loads, an extra amount of compacted cover may be required over the top of the pipe. The Height-of-Cover shall meet the minimum requirements shown in the table below. The use of heavy construction equipment necessitates greater protection for the pipe than finished grade cover minimums for normal highway traffic.

Minimum Cover (ft) Requirements

Pipe Span (inches)	Axle Loads (kips)			
	18 - 50	50 - 75	75 - 110	110 - 150
12 - 42	2.0	2.5	3.0	3.0
48 - 72	3.0	3.0	3.5	4.0
78 - 120	3.0	3.5	4.0	4.0
126 - 144	3.5	4.0	4.5	4.5

4.4 Minimum cover may vary, depending on local conditions. The contractor must provide the additional cover required to avoid damage to the pipe. Minimum cover is measured from the top of the pipe to the top of the maintained construction roadway surface.

4.5 Refer to the Contech's Corrugated Metal Pipe Detention Design Guide for additional guidance regarding installation, inspection and maintenance.

4.6 The contractor shall follow Occupational Safety and Health Association (OSHA) guidelines for safe practices in executing the installation process in accordance with the manufacturer/supplier installation recommendations.

4.7 Backfill material shall be placed in 8 inch loose lifts and compacted to 90% AASHTO T99 standard proctor density.

4.8 Supplier will conduct an on-site preconstruction meeting with the contractor prior to the scheduled delivery date of the CMP System.

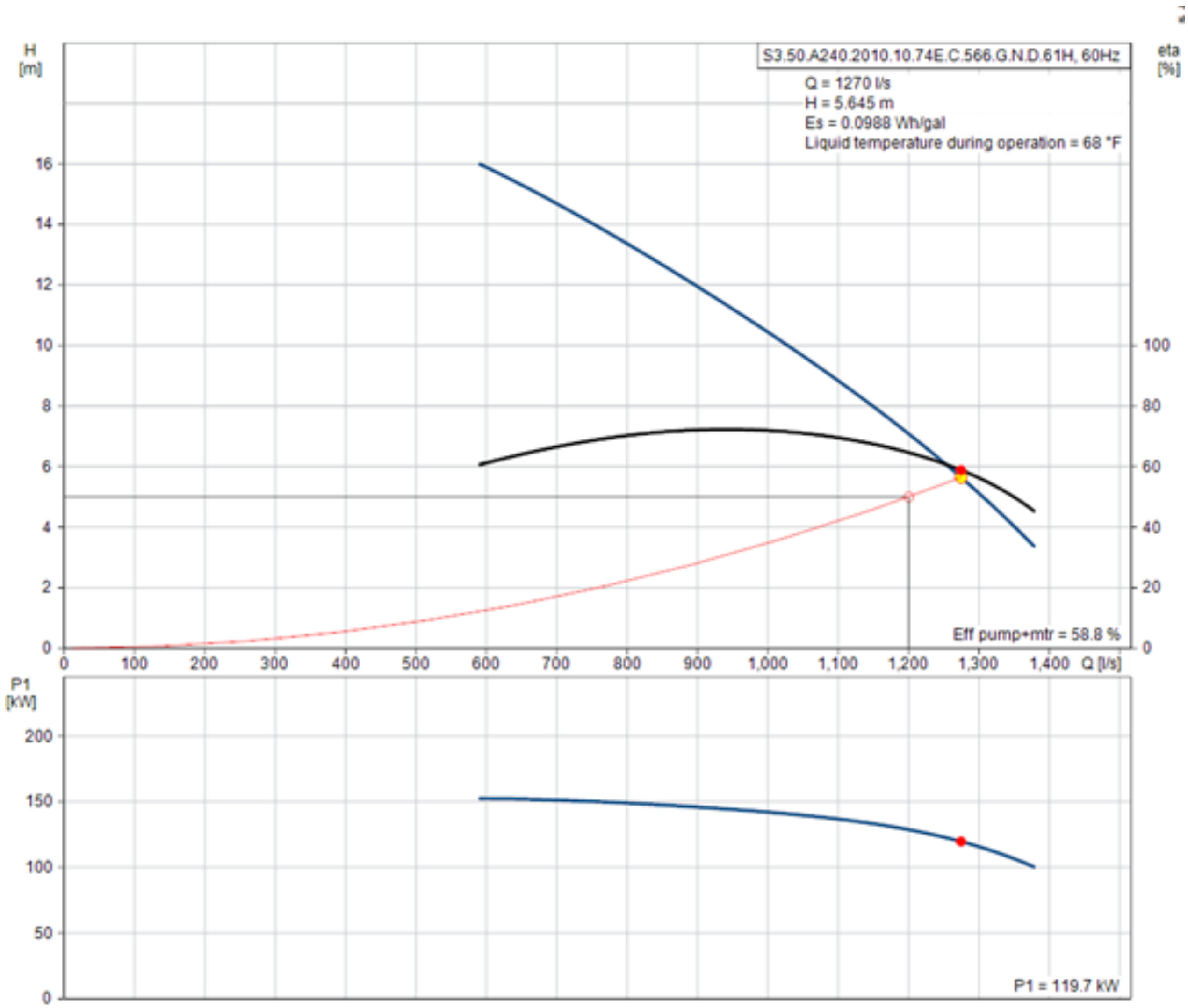
Earthworks

Prior to and during excavation a rigorous dewatering and infiltration monitoring program shall be implemented to avoid seepage into the shallow aquifer. Berms shall be installed in locations consistent with runoff direction to avoid infiltration and, where the monitoring program detects seepage into the shallow aquifer, further berms or other methods as discussed with the earthworks engineer shall be installed to mitigate the seepage.

Outside of the bioretention filter area, excavated soils from the site may be reused as fill provided that any unsuitable material and any building rubble or deleterious material is excluded.

An impenetrable geomembrane liner shall be installed on all exposed subgrade prior to commencement of backfill works.

Pump Specification



Product name	S3.50.A240.2010.10.74E.C.566.G.N.D.61H
Product No.	9.8E+07
EAN	5.7E+12
Technical	
Actual calculated flow	1270 l/s
Max flow	1380 l/s
Resulting head of the pump	5.645 m
Head max	16 m
Actual impeller diameter	22.3 in
Type of impeller	3-CHANNEL
Maximum particle size	5.31 in
Primary shaft seal	SIC-SIC
Secondary shaft seal	SIC-CARBON

Curve tolerance	ANSI/HI11.6:2012 3B
Cooling jacket	with cooling jacket
Materials	
Pump housing	DUCTILE IRON
Pump housing	EN 1563 EN-GJS-500-7
Pump housing	AISI ASTM A536 70-50-05
Impeller	Ductile iron
Impeller	EN 1563 EN-GJS-500-7
Impeller	AISI ASTM A536 70-50-05
Motor	Cast iron
Motor	EN 1561 EN-GJL-250
Motor	AISI ASTM A48 35B
Installation	
Range of ambient temperature	32 .. 104 °F
Type of connection	ANSI
Size of outlet port	24 inch
Pressure stage	PN 10
Maximum installation depth	65.6 ft
Inst dry/wet	DRY/SUBMERGED
Auto-coupling	9.8E+07
Frame range	74
Liquid	
Liquid temperature range	32 .. 104 °F
Liquid temperature during operation	68 °F
Density	62.29 lb/ft³
Electrical data	
Power input - P1	160 kW
Rated power - P2	201 HP
Main frequency	60 Hz
Rated voltage	3 x 460 V
Voltage tolerance	-100
Max starts per. hour	10
Rated current	255/ A
Maximum current consumption	255 A
Starting current	1730 A
Rated current at no load	106 A
Rated speed	712 rpm
Motor efficiency at full load	94%
Motor efficiency at 3/4 load	94%
Motor efficiency at 1/2 load	93%

Number of poles	10
Start. method	star/delta
Enclosure class (IEC 34-5)	IP68
Insulation class (IEC 85)	H
Explosion proof	no
Ex-protection standard	N
Motor protection	KLIXON
Length of cable	49.2 ft
Cable type	H07RN-F AT
Cable size	2X4X70MM2+1X10X1,5MM2
Cable resistance	0.27 mOhm/m
Winding resistance	0.034 Ohm
Cos phi 1/1	0.79
Cos phi 1/2	0.65
Cos phi 3/4	0.75
Controls	
Moisture sensor	with moisture sensors
Water-in-oil sensor	with water-in-oil sensor
Others	
Net weight	8600 lb
Gross weight	8600 lb
Sales region	Namreg

(Pump Curve, 2019)

Bioretention Soil Mix Design

Bioretention soils shall be installed per reference to standard drawing C-07.

Bioretention soils shall comprise of either:

- a 40% compost to 60% screen or utility sand volumetric mix or;
- if topsoil is a component of the mix, 35% compost topsoil mix to 65% screen or utility sand volumetric mix.

The compaction characteristics of the bioretention soil mix will be tested using ASTM D1557 Method B. 85% percent of maximum dry density is the target density where the bioretention soil mix is placed in 225mm lifts and lightly boot packed.

The permeability will be tested using ASTM D 2434 with a target permeability is 25-50 mm/hr.

Compaction and permeability tests will be performed on a 1.0 sq.m lift (225mm).

The screen or utility sand component shall be comprised of 2-4% fines passing #200 sieve The below details the general gradation guideline:

Sieve Size	Percent Passing
⅜"	100
#4	95-100
#10	75-90
#40	25-40
#100	4-10
#200	2-5

Quantitative tests and producer documentation for the compost component should have the following specifications:

- Material must be in compliance with WAC chapter 173-350 section 220, and be made from Type 1, 2, or 3 feedstock. Type 1 feedstock is recycled plant waste, including agricultural, yard, pre-consumer food, and cardboard; Type 2 is manure and bedding; Type 3 is post consumer food, biosolids (sewage sludge), and other materials judged low in contaminants but potentially high in pathogens. Type 4 feedstock is mixed municipal solid waste, industrial solid wastes and other materials judged high risk for toxics, contaminants or pathogens.
- Organic matter content between 45% and 65% as determined by loss of ignition test method.
- pH between 5.5 and 8.0.
- Carbon:nitrogen ratio between 20:1 and 25:1 for most landscapes. A CN ratio of 30:1 to 35:1 is preferred for native woody plantings, especially in restoration projects, because it supports these plants and minimizes weed growth.
- Maximum electrical conductivity of 6 mmhos/cm (or 4 mmhos/cm for sites east of the Cascades where there is less rainfall to leach salts from BSM).
- Moisture content range between 35 and 50%.
- No viable weed seeds.
- Manufactured inert material (plastic, concrete, ceramics, etc.) should be less than 1% on a dry weight or volume basis (as required by WAC 173-350-220).
- Metals should not be in excess of limits in the following table (from WAC 173-350-220).

Metal	Limit (mg/kg dry weight)
Arsenic	≤ 20 ppm
Cadmium	≤ 10 ppm
Copper	≤ 750 ppm
Lead	≤ 150 ppm
Mercury	≤ 8 ppm
Molybdenum	≤ 9 ppm
Nickel	≤ 210 ppm
Selenium1	≤ 18 ppm
Zinc	≤ 1400 ppm

Note: the bioretention soil mix design specification is compiled based on the Washington State University technical memorandum (BIORETENTION SOIL MIX REVIEW AND RECOMMENDATIONS FOR WESTERN WASHINGTON, 2009).

Oil and Grit Separator (OGS)

Follow all instructions including the sequence for installation in the shop drawings during installation. Drawing C-05 provides standard detail, installation sequence provided by Manufacturer.

OGS internal components supplied by the Manufacturer for attachment to the precast concrete vessel shall be pre-fabricated, bolted to the precast and watertight sealed to the precast vessel surface prior to site delivery to ensure Manufacturer’s internal assembly process and quality control processes are fully adhered to, and to prevent materials damage on site.

The OGS vessel shall be cylindrical and constructed from precast concrete riser and slab components. The precast concrete OGS internal components shall include a fiberglass insert bolted and watertight sealed inside the precast concrete vessel, prior to site delivery. Primary internal components that are to be anchored and watertight sealed to the precast concrete vessel shall be done so only by the Manufacturer prior to arrival at the job site to ensure product quality.

Only profile neoprene or nitrile rubber gaskets that are oil resistant shall be accepted. For Canadian projects only, gaskets shall be in accordance to CSA A257.4-14. Mastic sealants, butyl tape/rope or Conseal CS-101 alone are not acceptable gasket materials.

All precast concrete sections shall be level and inspected to ensure dimensions, appearance, integrity of internal components, and quality of the product meets CAN/CSA-A257.4-14 specifications.

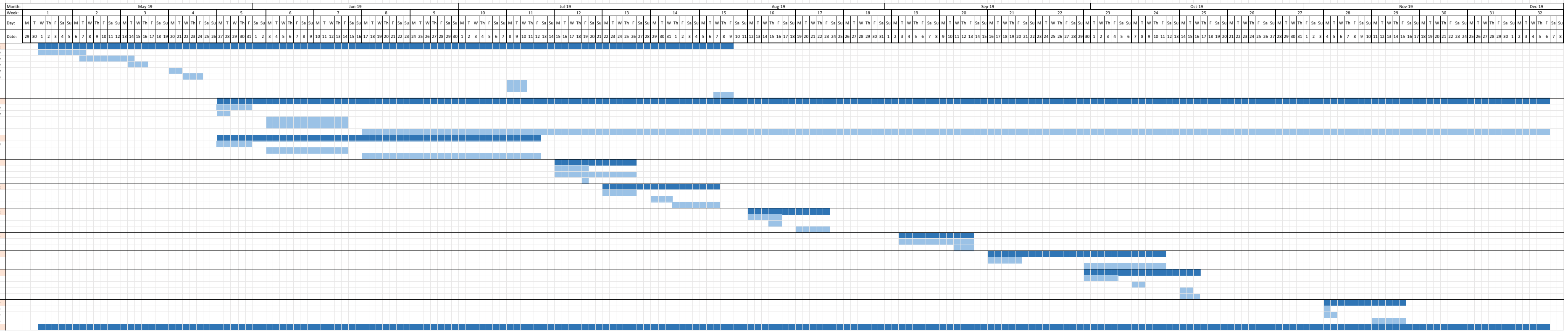
The fiberglass portion of the OGS device shall be constructed in accordance with ASTM D2563, and in accordance with the PS15-69 manufacturing standard, and shall only be installed, bolted and watertight sealed to the precast concrete by the Manufacturer prior to arrival at the project site to ensure product quality.

The installation of the precast concrete OGS stormwater quality treatment device shall conform to CAN/CSA-A257.4-14, CAN/CSA-A257.4-14, CAN/CSA-S6-00. The Contractor shall furnish all labor, equipment and materials necessary to offload, assemble as needed the OGS internal components as specified in the Shop Drawings.

Appendix C: Construction Schedule

RAJNS Consulting
Bicycle Paradise Multiuse Stormwater Detention
Construction Schedule

Description	Duration (working	Start	Finish
1. SITE PREPARATION	**23**	**01-May**	**09-Aug**
1.1 Mobilization	5	01-May	07-May
1.2 Clearing and Grubbing	5	07-May	14-May
1.3 Construction Staging	3	14-May	16-May
1.4 Traffic Management Set-up	2	20-May	21-May
1.5 Excavation for Structural	3	22-May	24-May
1.6 Excavation for Pump, Oil and Grit Separator, and Rain Gardens	3	08-Jul	10-Jul
1.7 Excavation for Detention Tank	2	07-Aug	09-Aug
2. STRUCTURAL - BUILDING	**257**	**27-May**	**06-Dec**
2.1 Formwork for Club House Building	5	27-May	31-May
2.2 Drive Piles for Supertrees and Gateway Structure	2	27-May	28-May
2.3 Delivery and Pour Concrete Superstructure Foundation and Pile Cap Foundation for Supertree	10	03-Jun	14-Jun
4.4 Superstructure Construction	240	17-Jun	06-Dec
3. STORMWATER - PUMP INSTALLATION	**35**	**27-May**	**12-Jul**
3.1 Pump Chamber Formwork	5	27-May	31-May
3.2 Pump Chamber Concrete Pour	10	03-Jun	14-Jun
3.3 Pump Chamber Construction and Installation	20	17-Jun	12-Jul
4. STORMWATER - OIL AND GRIT SEPARATOR	**16**	**15-Jul**	**26-Jul**
4.1 Installation of Prefabricated Oil and Grit	5	15-Jul	19-Jul
4.2 Half pipe drainage grate installation	10	15-Jul	26-Jul
4.3 Tie-in to detention tank zone	1	19-Jul	19-Jul
5. STORMWATER - RAIN GARDENS	**12**	**22-Jul**	**07-Aug**
5.1 Trenching	5	22-Jul	26-Jul
5.2 Geotextile Lining	2	29-Jul	31-Jul
5.3 Placement of Rock, Top Soil, Vegetation and	5	01-Aug	07-Aug
6. STORMWATER - DETENTION TANK	**12**	**12-Aug**	**23-Aug**
6.1 Geotextile Tank Lining	5	12-Aug	16-Aug
6.2 Pipe Assembly	2	15-Aug	16-Aug
6.3 Pipe Installation and Tie-ins	5	19-Aug	23-Aug
7. STRUCTURAL - SUPERTREES & GATEWAY	**12**	**03-Sep**	**13-Sep**
7.1 Supertree Erection and Casing	9	03-Sep	13-Sep
7.2 Gateway Erection	3	11-Sep	13-Sep
8. SOIL WORKS	**15**	**16-Sep**	**11-Oct**
8.1 Insert soil cells and backfill with soil	5	16-Sep	20-Sep
8.2 Infill vegetation and planting	10	30-Sep	11-Oct
9. ROADWORKS	**12**	**30-Sep**	**16-Oct**
9.1 Pave road through site	5	30-Sep	04-Oct
9.2 Grade entrance and exit ramps and pave	2	07-Oct	08-Oct
9.3 Paint green thermoplastic bicycle markings	2	14-Oct	15-Oct
9.4 Installation of Permeable Pavement	3	14-Oct	16-Oct
10. MISCELLANEOUS	**8**	**04-Nov**	**15-Nov**
10.1 Installation of bicycle infrstructure	1	04-Nov	04-Nov
10.2 Installation of Picnic tables, signage, trash	2	04-Nov	05-Nov
10.3 Installation of lighting and connection	5	11-Nov	15-Nov
Total	**402**	**01-May**	**06-Dec**



Appendix D: Cost Estimate

RAJNS Consulting
Bicycle Paradise Multiuse Stormwater Detention Infrastructure
Cost Estimate

Estimated costs before taxes and engineering fees.

Description	Qty	Price	Unit	Total
1. SITE PREPARATION				
1.1 Moblilization and Demobilization	1	$50,000	L.S.	$50,000
1.2 Clearing and Grubbing	7	$1,350	days	$9,450
1.3 Excavation	30050	$45	m3	$1,352,250
1.4 Onsite storage	100	$30	m3	$3,000
1.5 Staging of temporary facilities	1	$20,000	L.S.	$20,000
1.6 Traffic control	1	$40,000	L.S.	$40,000
Site Preparation Total				**$1,474,700**
2. ROADWORKS				
2.1 Grading of entrances and exits	2	$1,200	days	$2,400
2.2 Grading of on-site roadway	5	$1,200	days	$6,000
2.3 Graded gravel (road underlay)	150	$52	m3	$7,800
2.4 Asphalt	112.5	$50	m2	$5,625
2.5 Thermoplastic road paint (bicycle markings)	20	$350	m2	$7,000
Roadworks Total				**$28,825**
3. SOIL & LANDCAPING				
3.1 Sand	550	$48	m3	$26,125
3.2 Crushed Gravel	662.5	$55	m3	$36,438
3.3 Soil Cells	5350	$560	m3	$2,996,000
3.4 Top Soil	5900	$85	m2	$501,500
3.5 Geotextile Membrane	5900	$5	m2	$29,500
3.6 Planting (shubs and aquatic plants)	1	$50,000	L.S.	$50,000
Soil & Landscaping Total				**$3,639,563**
4. STRUCTURAL				
4.1 Concrete foundations	525	$210	m2	$110,250
4.2 Structure (UBC Cycling Club House and Facilties)*	1	$3,500,000	L.S.	$3,500,000
4.3 Supertrees (delivery and installation)	2	$250,000	L.S.	$500,000
Structural Total				**$4,110,250**
5. STORMWATER				
5.1 400 mm PVC Pipe	130	$430	lin.m.	$55,900
5.2 1050 mm HDPE Contech DuroMaxx Detention Chamber	2063	$1,250	lin.m.	$2,578,750
5.3 Oil Grit Separator	1	$62,000	L.S.	$62,000
5.4 Pump and Connection	1	$135,000	L.S.	$135,000
5.5 Half Pipe Grate	1	$75,000	L.S.	$75,000
Stormwater Total				**$2,906,650**
6. MISCELLANEOUS				
6.1 UBC Gateway Structure and Installation	1	$50,000	L.S.	$50,000
6.2 Bicycle Racks	10	$400	each	$4,000
6.3 Public Access Bicycle Tool Rack	2	$930	each	$1,859
6.4 Aluminum Picnic Tables	10	$1,050	each	$10,500
6.5 Traffic signage	6	$119	each	$714
6.6 LED Outdoor Lighting	30	$5,000	each	$150,000
6.7 Supersave Construction Fencing	3937	$48.00	roll (10.16 lin.m)	$188,976
Miscellaneous Total				**$406,049**
Subtotal				**$12,566,037**
Contingency (30%)				$3,769,811
Total				**$16,335,847**

*Cost of UBC Cycling Club House Superstructure is based on estimated cost of UBC Baseball Training Centre

Appendix E: Detailed Design Drawings

MULTIUSE STORMWATER DETENTION INFRASTRUCTURE
BICYCLE PARADISE

ISSUED FOR PERMIT & CONSTRUCTION

GENERAL NOTES

1. BUILDING HAS BEEN DESIGNED IN ACCORDANCE WITH PART 4 OF THE B.C. BUILDING CODE 2012. CONSTRUCTION TO BE IN ACCORDANCE WITH PART 9 THE B.C. BUILDING CODE 2012. THESE DRAWINGS AND SPECIFICATIONS SHALL TAKE PRECEDENCE OVER PART 9 REQUIREMENTS.

2. DESIGN LOADS:

SNOW	
IS ULS	=1.0
IS SLS	=0.9
Ss	=1.0 kPa
Cb	=0.8 kPa
Cs	=1.0
Ca	=1.0
Sr	=0.3 kPa
LIVE (OCCUPANCY)	
VEHICLE PARKING	=8.4 kPa
MAIN FLOOR	=4.79 kPa
ROOF	=2.0 kPa
DEAD	
FLOOR FRAMING	=0.5 kPa
ROOF	=1.0 kPa
WIND	
IW ULS	=1.0
IW SLS	=0.75
q (1/50)	=0.39 kPa
Ce	=1.0

3. IF ANY ITEMS ON THE DRAWING ARE UNCLEAR THE OWNER/CONTRACTOR SHALL OBTAIN CLARIFICATION FROM THE ENGINEER PRIOR TO STARTING WORK.

4. OWNER/CONTRACTOR TO ADVISE ENGINEER WHEN SITE WORK IS IN PROGRESS. ANY WORK COVERED AND NOT INSPECTED MAY NEED TO BE UNCOVERED FOR FIELD REVIEW.

6. THE CONTRACTOR IS RESPONSIBLE FOR ALL TEMPORARY BRACING AND SHORING REQUIRED FOR CONSTRUCTION LOADING AND STABILITY UNTIL THE PROJECT IS COMPLETED. WORKSAFE BC REQUIRES SHORING FOR THE SUSPENDED SLAB TO BE DESIGNED BY A PROFESSIONAL ENGINEER. CONTRACTOR TO DISCUSS WITH ENGINEER PRIOR TO FORMING.

7. THE CONTRACTOR IS RESPONSIBLE FOR ENSURING THAT ALL ROOF RAINWATER AND FOUNDATION DRAINS ARE DISCHARGED IN ACCORDANCE WITH LOCAL AUTHORITY HAVING JURISDICTION.

8. REGARDING BACKFILLING:
   8.1 SECTION B WALLS REQUIRE SLAB ON GRADE TO BE COMPLETED AND CURED PRIOR TO EXTERIOR BACKFILL OVER 4'-0" VERTICALLY.

9. ALL MECHANICAL, ELECTRICAL, PLUMBING, VENTILATION AND DRAINING DESIGN SHALL BE PERFORMED BY OTHERS IF REQUIRED BY THE LOCAL AUTHORITY.

10. ALL WORK TO BE IN ACCORDANCE WITH STRUCTURAL DRAWINGS AND B.C. BUILDING CODE. ALL CHANGES SHALL BE FORWARDED TO RAJNS CONSULTING ENGINEERS PRIOR TO PROCEEDING WITH CONSTRUCTION.

11. RADON GAS PREPLUMB BY OTHERS. PIPING IS TO CROSS STRIP FOOTINGS AT RIGHT ANGLES TO FOOTING. NO DRAIN ROCK IS ALLOWED UNDER BUILDING FOOTINGS UNLESS PRIOR PERMISSION IS OBTAINED FROM STRUCTURAL ENGINEER.

12. REGARDING FROST DAMAGE:
   14.1 CONCRETE SLAB ON GRADE IS TO HAVE TEMPORARY INSULATION PLACED ON TOP OF CONCRETE TO PREVENT FROST FROM DEVELOPING UNDER SLAB PRIOR TO BUILDING BECOMING HEATED.
   14.2 CONTRACTOR RESPONSIBLE FOR PREVENTING FROST FROM DEVELOPING UNDER ALL CONCRETE REGARDLESS OF INSULATION EFFORTS.

13. THE CONCRETE WALL DESIGNS ARE BASED ON THE AVAILABLE LOT GRADING INFORMATION. CHANGES TO LOT GRADING WILL AFFECT THE RETAINING WALL DESIGN. AS A RESULT, CONTRACTOR TO REPORT LOT GRADING CHANGES TO RAJNS PRIOR TO FORMING FOOTINGS AND WALLS. EXTENTS OF EACH WALL TYPE ARE ASSUMED BASED OFF THE GRADING INFORMATION PROVIDED. IT IS THE RESPONSIBILITY OF THE CONTRACTOR TO USE THE APPROPRIATE WALL DESIGN TO SUIT THE GRADING IN DIFFERENT LOCATIONS.

TIMBER

1. ALL DIMENSIONED LUMBER TO BE SPF #2 OR BETTER (UNLESS NOTED OTHERWISE). ALL TIMBER TO BE D.FIR-L #1 (UNLESS NOTED OTHERWISE)

2. ALL FRAMING, BRIDGING NAILING, ETC. TO BE IN ACCORDANCE WITH THE B.C. BUILDING CODE SECTIONS 9-23.

3. ALL WALL & ROOF SHEATHING SHALL BE PLYWOOD CONFORMING TO EITHER CSA STANDARD 0121 OR CSA STANDARD 0151, OR OSB TO CSA 0452.

4. ALL BUILT UP BEAMS TO BE NAILED TOGETHER WITH 3 ROWS OF 3 1/2" NAILS @ 400mm (16") o/c MINIMUM – NO SPLICING OF MEMBERS ALLOWED.

5. ALL BUILT UP POSTS TO BE NAILED TOGETHER WITH 2 ROWS 3" NAILS @ 225mm (9") o/c UNLESS NOTED OTHERWISE ON DRAWINGS.

6. ALL BOLTS FOR TIMBER FRAMING TO BE A-307 GRADE.

7. ALL FASTENERS IN CONTACT WITH PRESSURE TREATED LUMBER TO BE HOT DIP GALVANIZED. NAILS, SCREWS, AND BOLTS TO BE GALVANIZED OR STAINLESS STEEL.

8. ALL POINT LOADS TO BE CHASED DOWN TO FOUNDATION INCLUDING SQUASH BLOCKS THROUGH THE FLOOR SYSTEM.

FIELD REVIEWS

FIELD REVIEW IS AT THE PROFESSIONAL DISCRETION OF OMEGA ENGINEERING SALMON ARM LLP. & IS TO ASCERTAIN GENERAL COMPLIANCE WITH THE STRUCTURAL PLANS & SUPPORTING DOCUMENTS FOR THE INTEGRITY OF THE PRIMARY STRUCTURAL COMPONENTS OF THE BUILDING ONLY. FIELD REVIEW DOES NOT MAKE OMEGA ENGINEERING SALMON ARM LLP. GUARANTORS OF THE CONTRACTOR'S WORK. FIELD REVIEW IS NOT FOR THE BENEFIT OF THE CONTRACTOR(S) & MAY NOT FORM PART OF THE CONTRACTOR'S CONSTRUCTION QUALITY CONTROL, WHICH SHALL REMAIN THE RESPONSIBILITY OF THE CONTRACTOR(S). OMEGA ENGINEERING SALMON ARM LLP. SHALL NOT BE RESPONSIBLE FOR THE ACTS OR OMISSIONS OF THE CONTRACTOR(S) OR FOR THEIR FAILURE TO FULFILL THE INTENT OF THE DESIGN DRAWINGS. OMEGA ENGINEERING SALMON ARM LLP. IS TO BE NOTIFIED 24hrs IN ADVANCE OF ANY WORK REQUIRING A FIELD REVIEW. THE FOLLOWING ITEMS SHALL BE REVIEWED:

1. ALL REBAR PRIOR TO POURING OF FOOTINGS, WALLS & SLABS.
2. FRAMING PRIOR TO SHEATHING.

ABBREVIATIONS

ADJ.	–ADJACENT
b/w	–BETWEEN
BTM	–BOTTOM
BU	–BUILT UP
c/s	–COUNTER SINK
c/w	–COMPLETE WITH
ADJ.	–CONTINUOUS
D&E	–DRILL AND EPOXY
DP.	–DEEP
E.E.	–EACH END
e/w	–EACH WAY
EMBED.	–EMBEDMENT
EQUIV.	–EQUIVALENT
EXIST.	–EXISTING
EXT.	–EXTERIOR
FDTN	–FOUNDATION
FTG	–FOOTING
GALV.	–GALVANIZED
HSS	–HOLLOW STRUCTURAL SECTION
H/T	–HOT TUB
NOM	–NOMINAL

DRAWING LIST

REV:	DESCRIPTION:	BY:	DATE:
	.		
A	PRELIMINARY DESIGN.	RH	26/11/18

AMENDMENTS:

SITE: MULTIUSE STORMWATER INFRASTRUCTURE	C-COVER DRAWING NO.		24567 PROJECT NO.	20/03/19 DATE.
TITLE: SITE LAYOUT	SCALE AT A4.	RH DRAWN.	RH CHECKED.	A REVISION.

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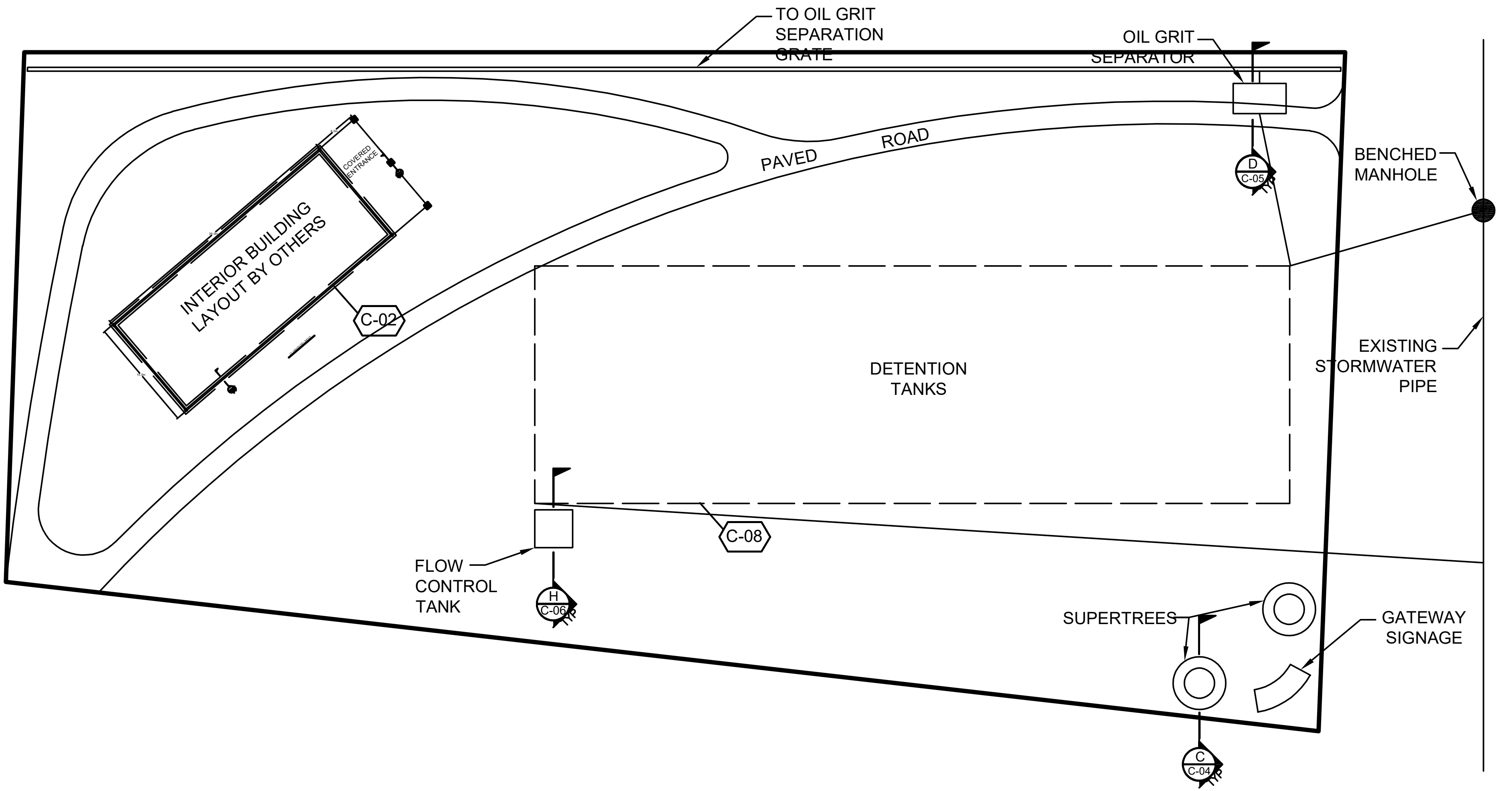

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A	PRELIMINARY DESIGN.	RH	26/11/18

AMENDMENTS:

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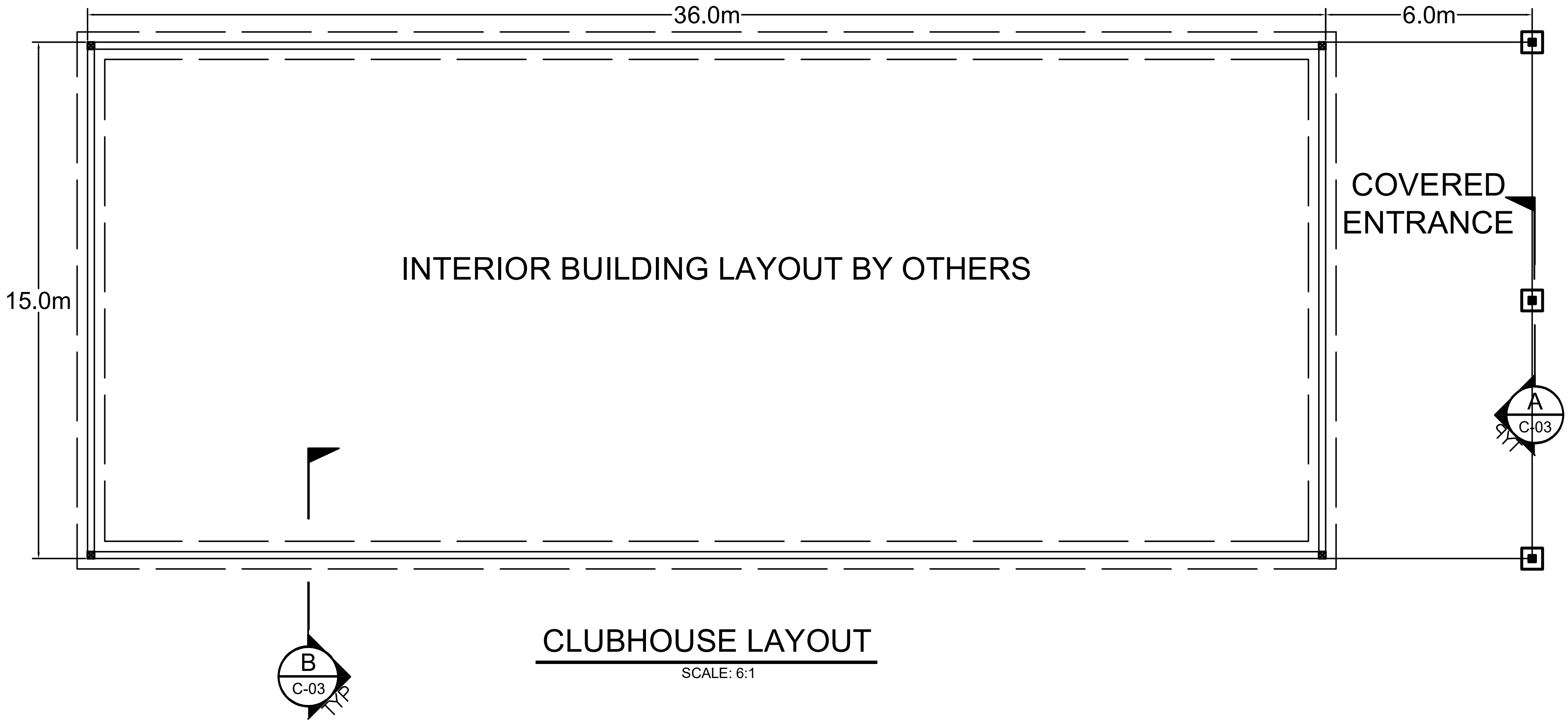

CLUBHOUSE LAYOUT

SCALE: 6:1

REV:	DESCRIPTION:	BY:	DATE:
	.		
A	PRELIMINARY DESIGN.	RH	26/11/18

AMENDMENTS:

SITE:	DRAWING NO.	PROJECT NO.	DATE.
MULTIUSE STORMWATER INFRASTRUCTURE	C–02	24567	26/11/18

TITLE:	SCALE AT A4.	DRAWN.	CHECKED.	REVISION.
CLUBHOUSE BUILDING LAYOUT	25:1	RH	RH	A

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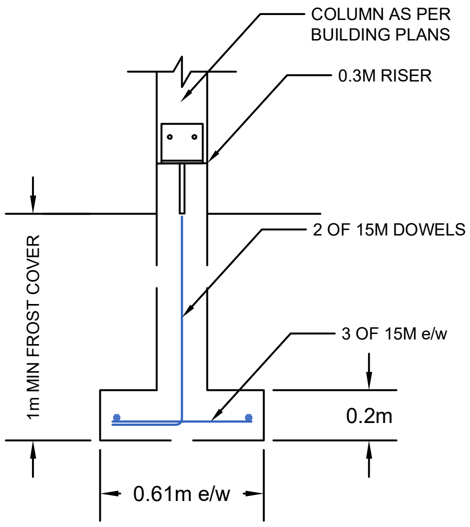
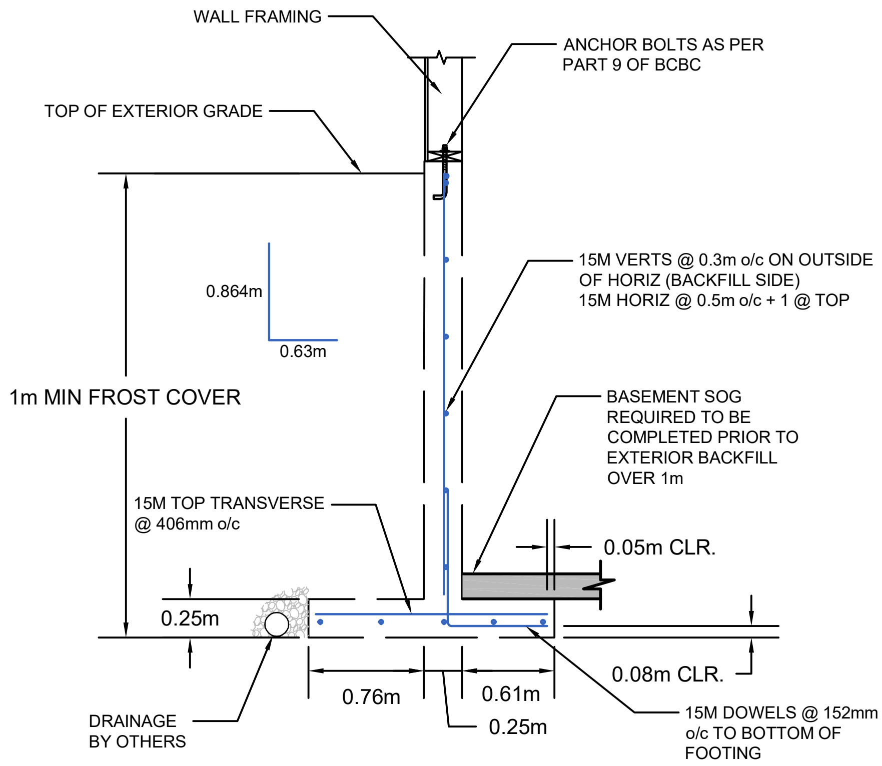


TYPICAL PAD FOOTING

SECTION A

C-02

SCALE: 20:1



BUILDING FOUNDATION

SECTION B

C-02

SCALE: 20:1

REV:	DESCRIPTION:	BY:	DATE:
A	PRELIMINARY DESIGN.	RH	26/11/18

AMENDMENTS:

SITE: MULTIUSE STORMWATER INFRASTRUCTURE		DRAWING NO. C-03	PROJECT NO. 24567	DATE. 26/11/18
TITLE: CLUBHOUSE BUILDING FOUNDATION	SCALE AT A4. 20:1	DRAWN. RH	CHECKED. RH	REVISION. A

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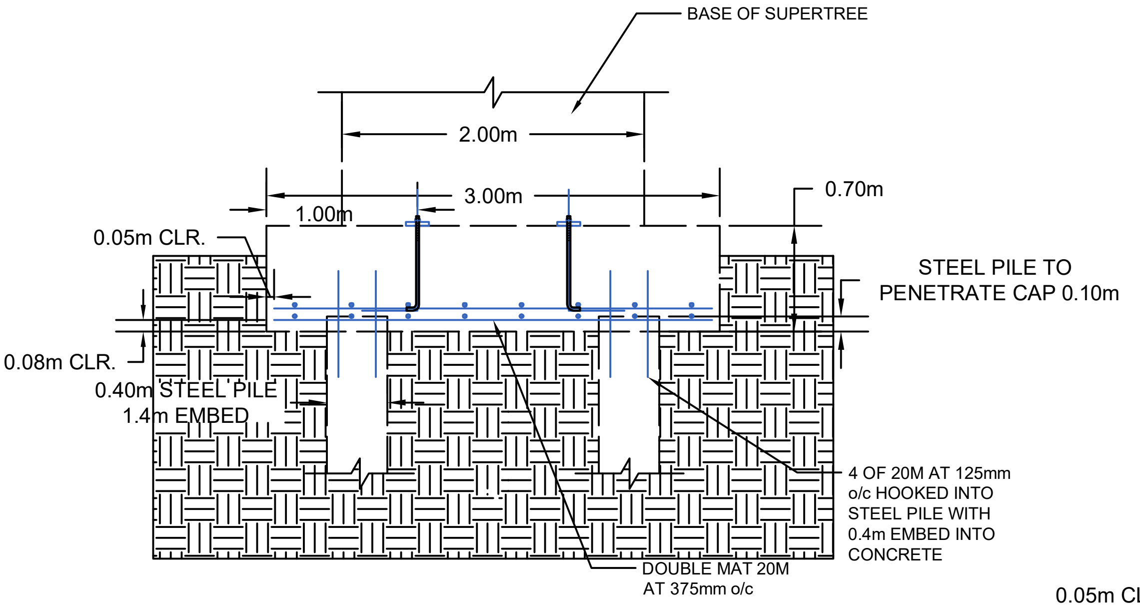
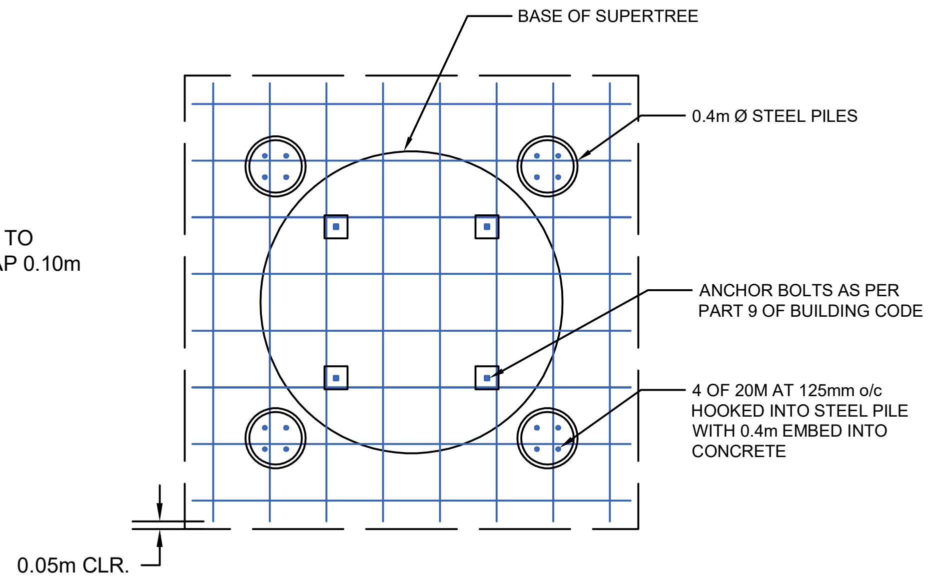


SUPERTREE FOUNDATION
SECTION C
SCALE: 20:1



SUPERTREE FOUNDATION
PLAN VIEW -
SCALE: 20:1

AMENDMENTS:

REV:	DESCRIPTION:	BY:	DATE:
A	PRELIMINARY DESIGN.	RH	26/11/18

SITE: MULTIUSE STORMWATER INFRASTRUCTURE	DRAWING NO.: C-04		PROJECT NO.: 24567	DATE: 26/11/18
TITLE: SUPERTREE PILE CAP FOUNDATION	SCALE AT A4.: 25:1	DRAWN.: RH	CHECKED.: RH	REVISION.: A

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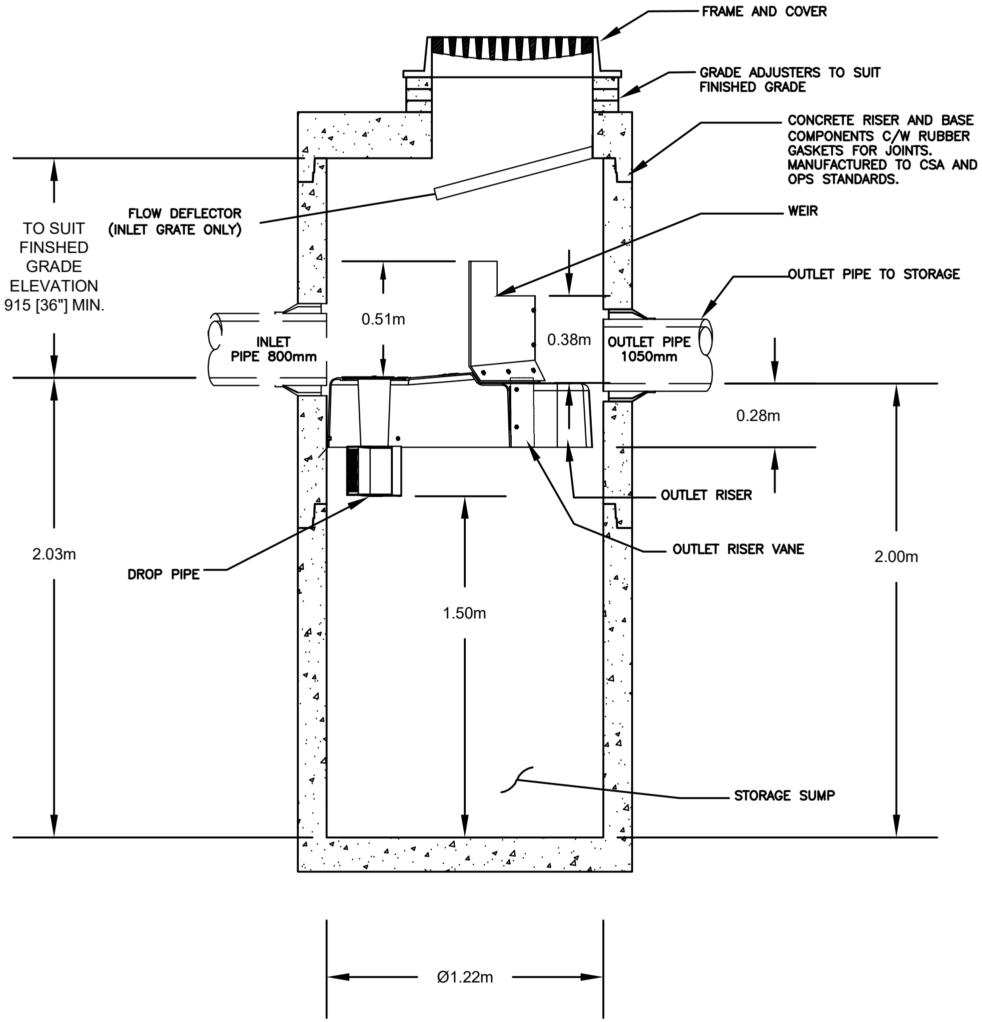
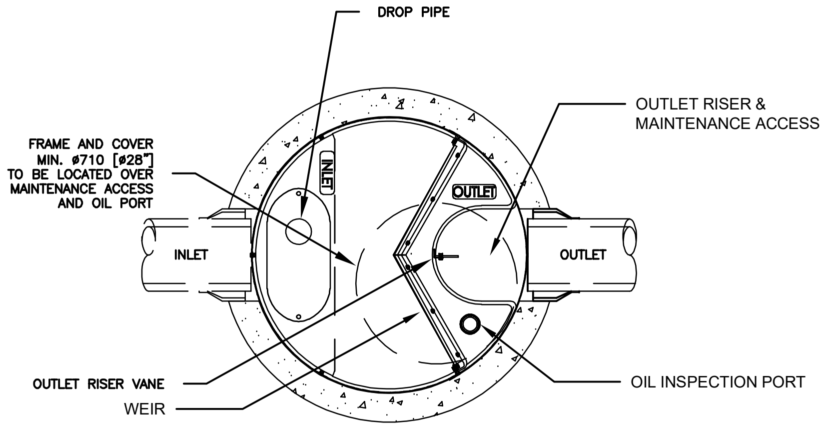


OIL & GRIT SEPARATOR

SECTION D

C-01

SCALE: 30:1



OIL & GRIT SEPARATOR

SECTION E

C-01

SCALE: 30:1

REV:	DESCRIPTION:	BY:	DATE:
A	PRELIMINARY DESIGN.	RH	26/11/18

AMENDMENTS:

SITE: MULTIUSE STORMWATER INFRASTRUCTURE	C–05 (DRAWING NO.)		24567 (PROJECT NO.)	26/03/19 (DATE.)
TITLE: OIL & GRIT SEPARATOR SECTIONS	20:1 (SCALE AT A4.)	RH (DRAWN.)	RH (CHECKED.)	A (REVISION.)

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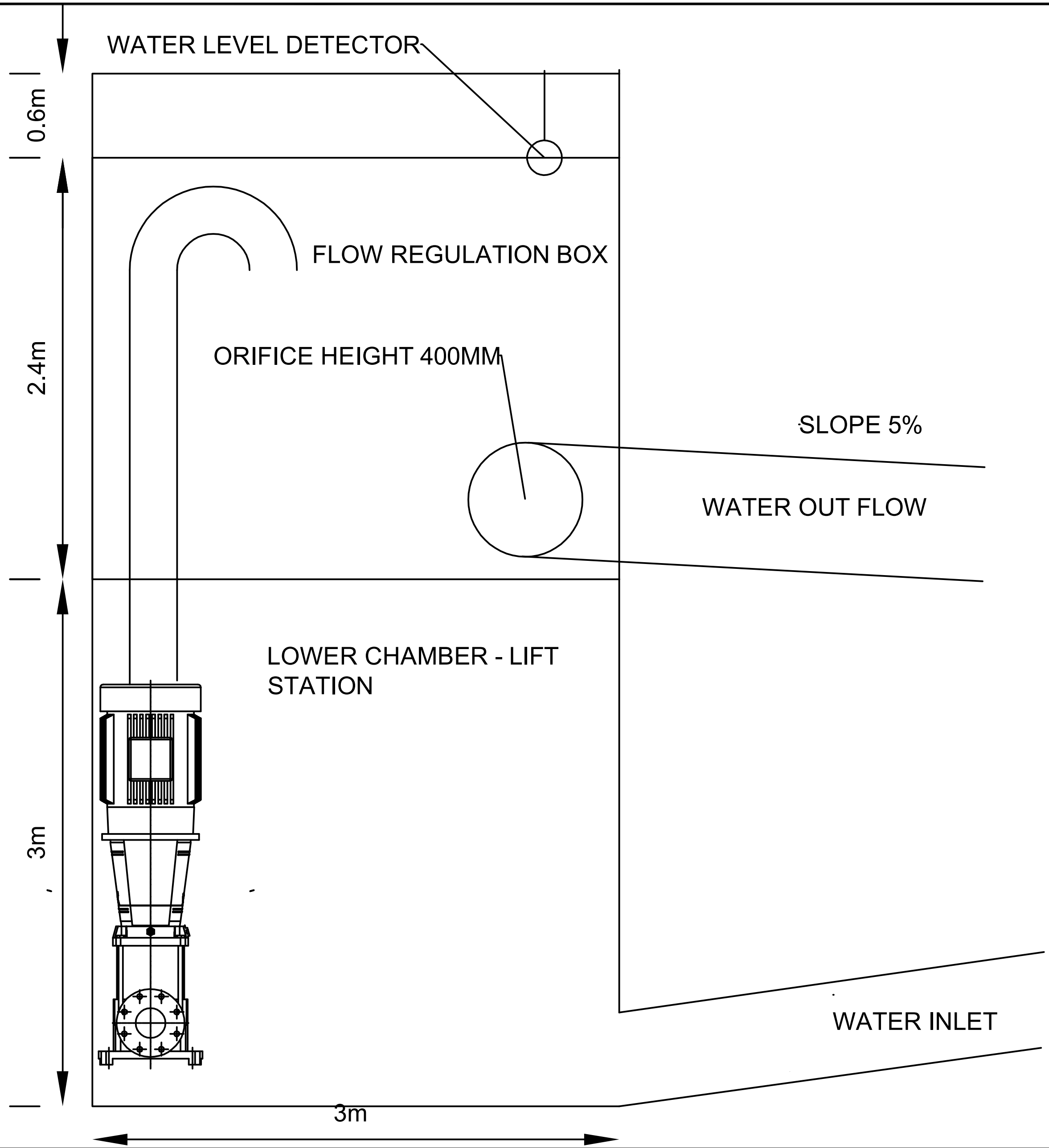

BUILDING FOUNDATION

SECTION H

C-01

SCALE: 20:1

REV:	DESCRIPTION:	BY:	DATE:
A	PRELIMINARY DESIGN.	RH	26/11/18

AMENDMENTS:

SITE: MULTIUSE STORMWATER INFRASTRUCTURE	DRAWING NO. C–06		PROJECT NO. 24567	DATE. 26/03/19
TITLE: FLOW REGULATION TANK SECTIONS	SCALE AT A4. 20:1	DRAWN. HPC	CHECKED. HPC	REVISION. A

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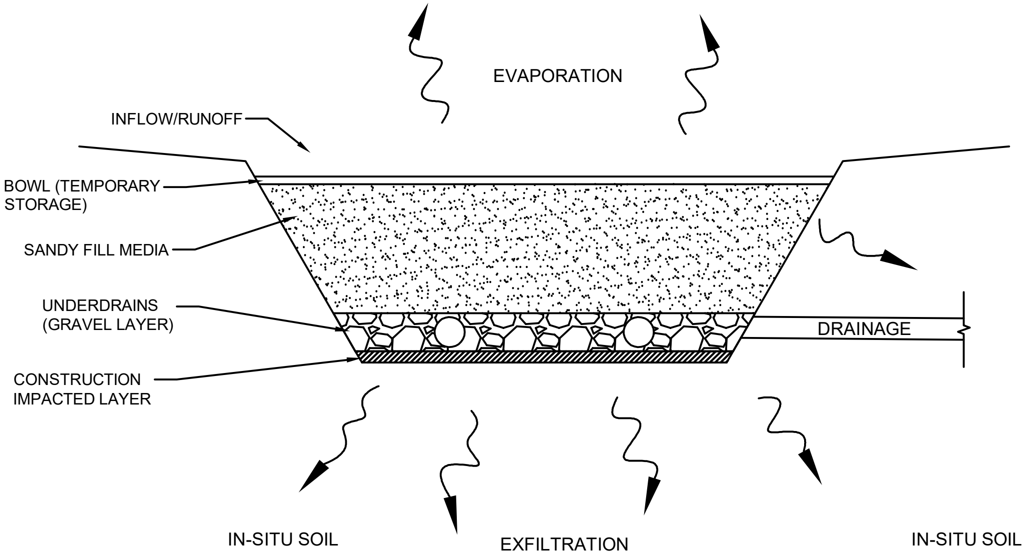
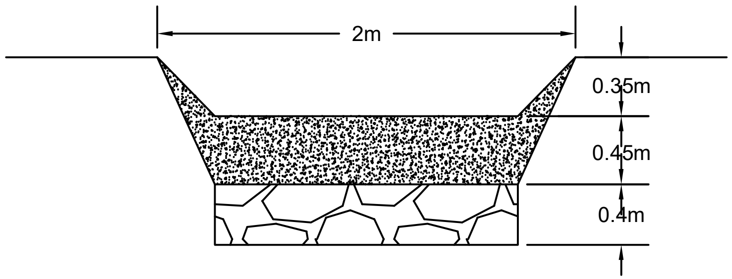


BIO-RETENTION

SECTION F C-01

SCALE: 10:1



RAIN GARDEN

SECTION G C-01

SCALE: 20:1

REV:	DESCRIPTION:	BY:	DATE:
A	PRELIMINARY DESIGN.	RH	26/11/18

AMENDMENTS:

SITE: MULTIUSE STORMWATER INFRASTRUCTURE	C–07 DRAWING NO.	24567 PROJECT NO.	26/03/19 DATE.
TITLE: RAIN GARDENS & BIORETENTION	– SCALE AT A4. / RH DRAWN.	RH CHECKED.	A REVISION.

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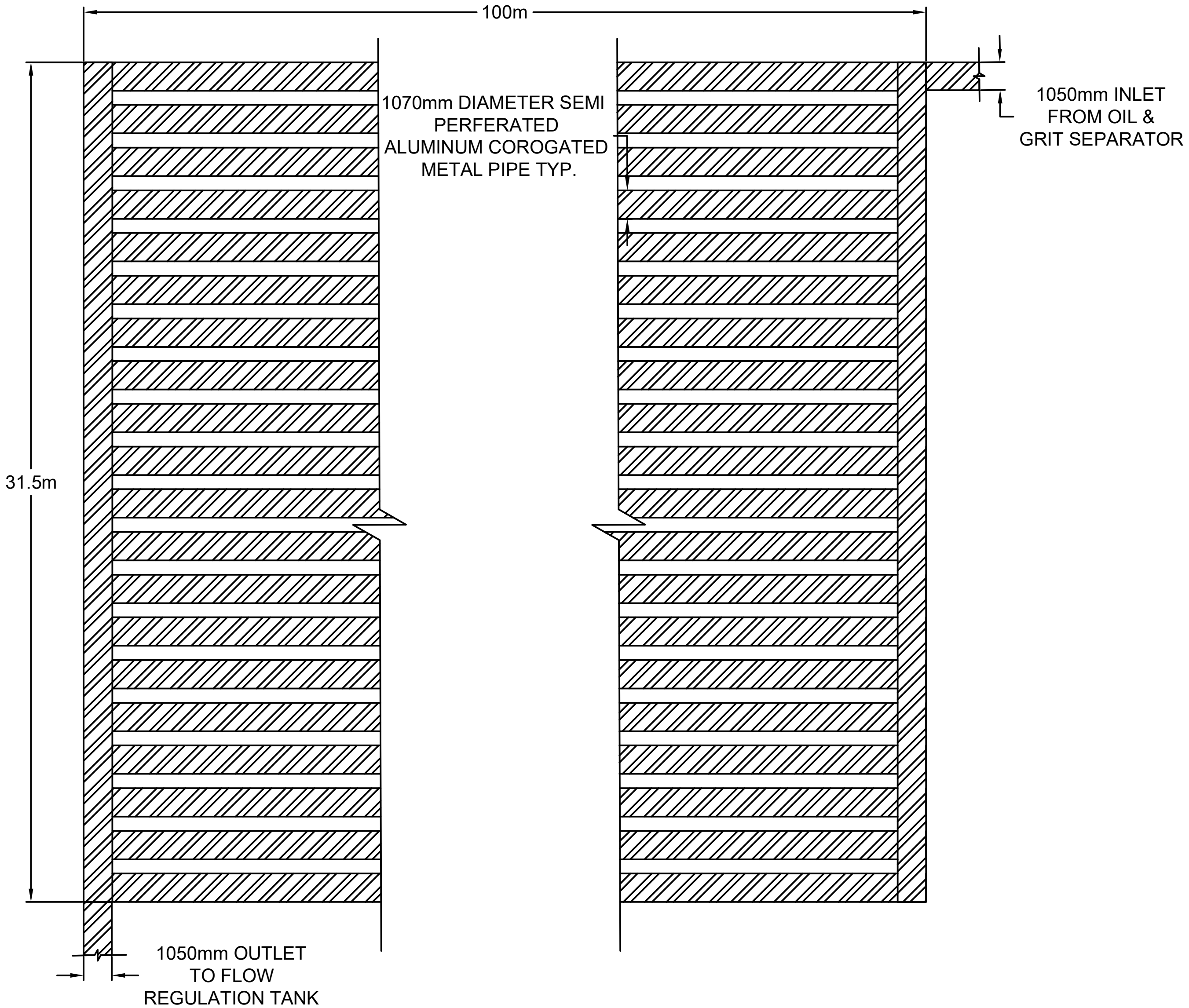

DETENTION CHAMBER
PLAN VIEW

REV:	DESCRIPTION:	BY:	DATE:
A	PRELIMINARY DESIGN.	RH	26/11/18

AMENDMENTS:

SITE: MULTIUSE STORMWATER INFRASTRUCTURE	DRAWING NO. C–08	PROJECT NO. 24567	DATE. 20/03/19
TITLE: DETENTION CHAMBER PLAN VIEW	SCALE AT A4. 4:1 / DRAWN. RH	CHECKED. RH	REVISION. A

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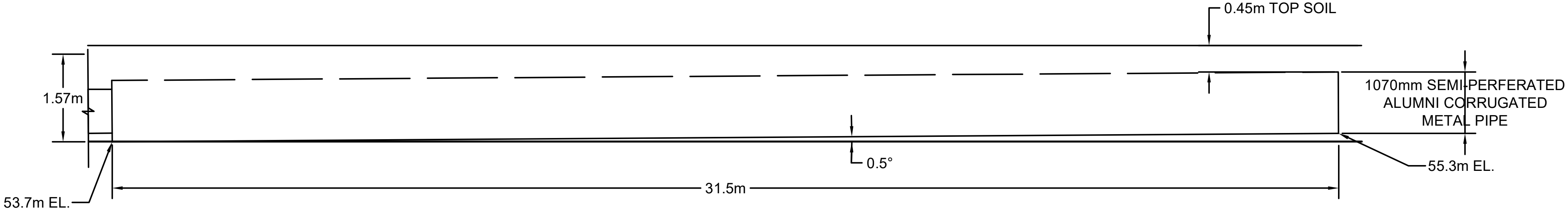

DETENTION CHAMBER
EAST EDGE SECTION

REV:	DESCRIPTION:	BY:	DATE:
	.		
A	PRELIMINARY DESIGN.	RH	26/11/18

AMENDMENTS:

SITE: MULTIUSE STORMWATER INFRASTRUCTURE	C–09 DRAWING NO.		24567 PROJECT NO.	26/03/19 DATE.	RAJNS Consulting
TITLE: DETENTION CHAMBER EAST SECTION	10:1 SCALE AT A4.	RH DRAWN.	RH CHECKED.	A REVISION.	

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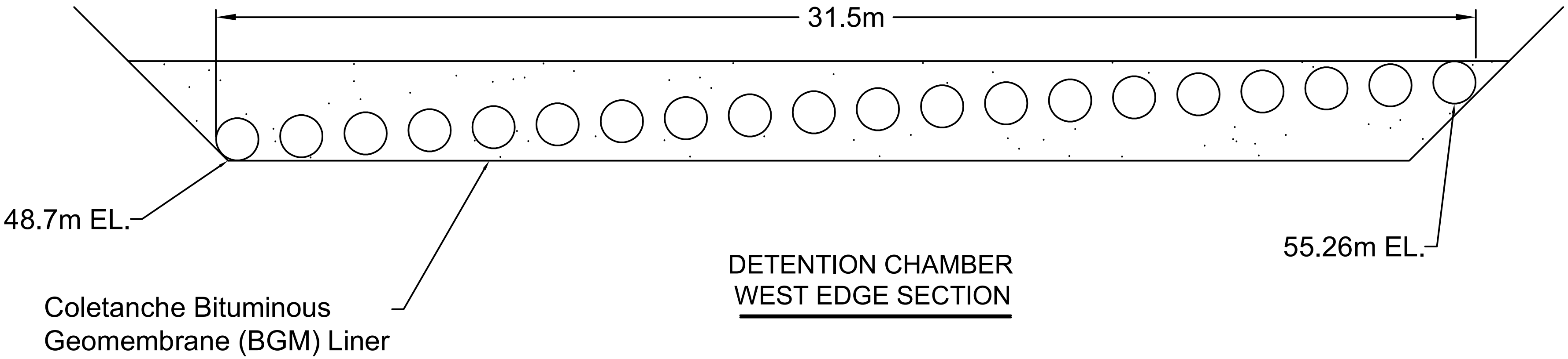

DETENTION CHAMBER
WEST EDGE SECTION

REV:	DESCRIPTION:	BY:	DATE:
A	PRELIMINARY DESIGN.	RH	26/11/18

AMENDMENTS:

SITE: MULTIUSE STORMWATER INFRASTRUCTURE	DRAWING NO. C–10	PROJECT NO. 24567	DATE. 26/03/19
TITLE: DETENTION CHAMBER WEST SECTION	SCALE AT A4. 6:1 / DRAWN. RH	CHECKED. RH	REVISION. A

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