South Campus Stormwater Detention Facility

Detailed Design Report

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University of British Columbia

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KREW Hydraulic Consulting Ltd.

UBC SEEDS Sustainability Program

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EXECUTIVE SUMMARY

Stormwater modeling has indicated that significant flooding may occur on the University of British Columbia's (UBC) South Campus under an intense rainfall. This is of concern to the university, since the quantity and quality of stormwater from such an event may cause damage to UBC assets and also threaten streams that carry this water to the ocean. A 10-year or 100-year flood on campus could lead to cliff failure along the southeast banks due to erosion, and may also damage the riparian habitat. An improved stormwater management system is required to mitigate flooding and environmental damage during large storms.

KREW Hydraulic Consulting has developed a detailed design for a stormwater detention facility that manages the 10-year and 100-year stormwater flows from the South Campus at UBC. Some of the key criteria and considerations in the development of the detailed design include effectively designing the stormwater detention tanks, achieving LEED Gold water treatment requirements, and planning the construction of the retention pond.

The design consists of three underground detention tanks strategically placed throughout the south catchment and a single large retention pond. The underground detention tanks are located at Thunderbird Arena, the RCMP parking lot, and Save-On-Foods. The retention pond is situated near the intersection of SW Marine Dr. and Wesbrook Mall, as this location will allow the pond to collect and store water from all regions of the catchment.

The detention tanks are sized to hold water from a 25-year flood event, and the retention pond is large enough to handle any additional water above a 25-year and up to a 100-year flood event. By utilizing underground retention tanks, it is ensured that the retention pond remains dry for the majority of rainfall events, allowing the retention pond to be used for storage and other site operations. A treatment system will be implemented to ensure the stormwater will meet all environmental regulations and requirements before it is discharged into the ocean.

KREW Hydraulic Consulting has completed the detailed design report, which includes final construction plans and specifications for the performance of the stormwater detention system. Detailed engineering calculations and drawings for the project are included as appendices. The current construction schedule consists of 128 working days from May to October 2016, and the total cost of the project is approximately $2.54 million.

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1 Introduction

The University of British Columbia's South Campus is at risk of significant flooding, which may cause damage to UBC assets and threaten streams carrying this water to the ocean. The quality and quantity of stormwater in a 10-year (Q10) and 100-year (Q100) flood event could damage the riparian habitat and can cause cliff erosion. A stormwater detention facility located in the University's South Campus would reduce or eliminate the risks imposed by an extreme flood event.

This report presents the detailed design for a stormwater management system, which will mitigate flooding on UBC's South Campus under intense rainfalls. Section 2 discusses the key project constraints and specific design criteria. Section 3 presents a full description and rationale for the detailed design. Sections 4 to 8 provide detailed design information relating to the hydrological, geotechnical, structural, and environmental design aspects. Sections 9, 10 and 11 present the construction work plan, project schedule and cost estimate, respectively.

The following table outlines each team member's contributions to the various tasks and roles in the development of the detailed design report.

Table 1: Team Member Contributions

Tasks & Roles	Team Members
Introduction & Formatting	Kayle Rizzo
Projects Constraints	Brian Luk, Kayle Rizzo
Hydrological Analysis	Tyler Mann
Geotechnical Analysis	Jason Stewart
Structural Design	Kayle Rizzo
Stormwater Treatment	Brian Luk
Retention Pond Design	Dilveer Dhillon
Project Schedule	Jason Stewart
Work Plan & Cost Estimate	Jordan Eccles

2 Project Design Criteria

This section provides a description of the key issues, the design criteria, and the approaches taken to successfully meet the design requirements. The following sub-sections outline the technical requirements, environmental constraints, societal impacts, UBC policies, government regulations, and construction planning requirements.

2.1 Technical Requirements

The stormwater management system is required to control the quality and quantity of stormwater in a 10-year and 100-year flood event. The primary technical requirements include flood volume reduction, water quality control, and erosion management.

2.1.1 Flood Volume Reduction

The stormwater detention system must reduce the total runoff volume caused by increased urban development and subsequent impervious areas. Additionally, the water collected over natural pervious areas (such as fields and forested areas) should be returned to shallow groundwater via infiltration. As a result, the design will incorporate stormwater storage in three detention tanks and a retention pond to provide sufficient stormwater collection capacity for large flood events.

Furthermore, the design addresses the issue of minor flooding at Wesbrook Mall and Marine Drive during a 10-year event and the significant flooding and property damage during a 100-year event. In order to minimize the risk of overland flows, detention tanks are strategically placed across South Campus.

2.1.2 Water Quality Control

The stormwater detention system should control the quality of stormwater runoff. Past contaminant testing indicates that UBC's stormwater runoff contains sediment and metals that are potentially harmful to the surrounding ecosystem. The use of stormwater filtration systems has been implemented in the detailed design to meet the water quality requirements.

2.1.3 Erosion Management

The stormwater detention system should restrict the post-development peak runoff flow rate to match the volume, shape and peak rate of pre-development flows during 24-hour precipitation events (Chilibeck & Sterling, 2001). By limiting the runoff flow rate during precipitation events, pipe and cliff erosion can be minimized. The flow rate of runoff is managed by the introduction of a flow monitoring and control system within the pipe network.

2.2 Environmental Constraints

The detention facility will be implemented according to the design guidelines provided by the UBC Vancouver Campus Plan. These guidelines require LEED Gold Standard as a minimum for this system and reaching LEED Platinum Standard is encouraged. Specific to this project, LEED Credits SSc6.1 and SSc6.2 (standards for stormwater management) are mandatory for this facility.

Metro Vancouver has developed an Integrated Stormwater Management Plan (ISMP) to ensure environmental quality and protect communities from localized flooding. While UBC is not subject to Metro Vancouver’s regulation, the stormwater detention facility has been developed using Metro Vancouver’s ISMP as a reference.

2.3 UBC Policies

UBC’s Vancouver campus lands are located in the unorganized territory of the Greater Vancouver Regional District (Metro Vancouver) and as such are outside of government jurisdiction. The stormwater detention facility has been designed in accordance with the planning policies and development controls established by UBC. The project adheres to the requirements outlined in the UBC Vancouver Campus Plan and the UBC Land Use Plan.

2.4 Government Regulations

The stormwater management system meets the government laws and regulations shown in Table 2. The system complies with the following regulations and has been designed according to their requirements.

Table 2: Government Laws & Regulations

Level of Government	Applicable Regulations
Federal Government	• Fisheries Act • Canadian Environmental Protection Act
Provincial Government	• Water Act • Environmental Management Act

2.5 Construction Planning Requirements

A building permit is required for all construction regulated under the BC Building Code and the UBC Development & Building Regulations. As the construction value of the project exceeds $2.5 million, an independent Coordinating Code Consultant (CCC) will be contracted to perform a third-party review for compliance with the Building Code as required by Campus & Community Planning. Section 9 of the report provides detailed information regarding the construction work plan.

2.6 Societal Impacts & Public Engagement

To implement a stormwater management system to serve the campus community's needs, KREW Hydraulic Consulting offered the public an opportunity to provide feedback on the proposed detention facility. A public information session was held on October 20th and an online consultation was available from October 15th to October 22, 2015. The information collected from the information session and online survey has been thoroughly considered during the preliminary design phase.

KREW Hydraulic Consulting has identified the stakeholder groups presented in Table 3 as requiring information and consultation throughout the duration of the project.

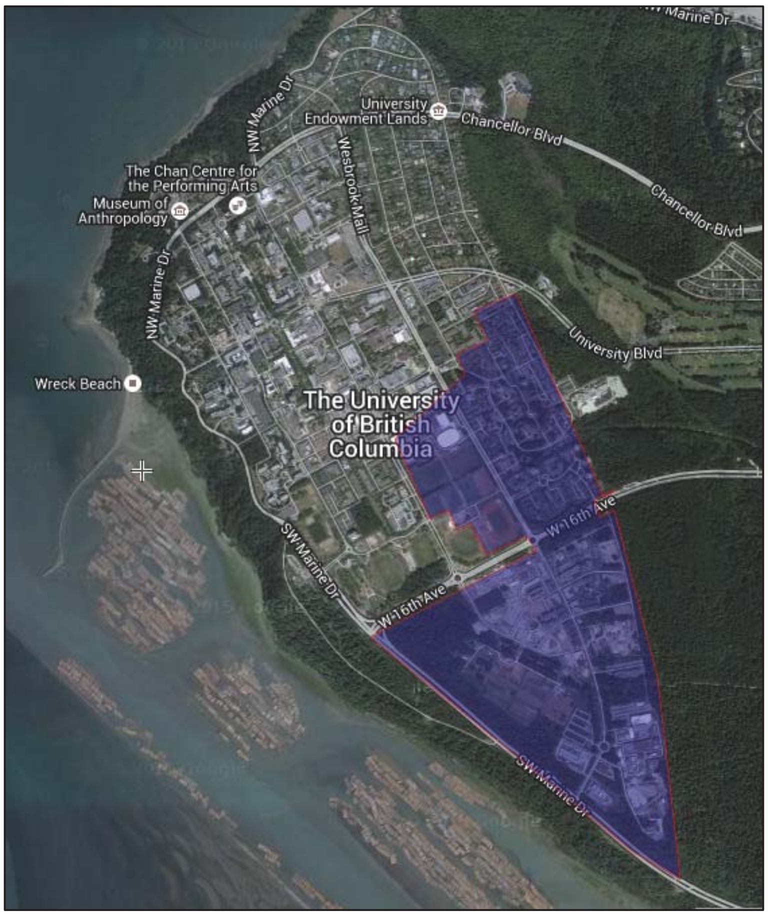
Table 3: Stakeholder Groups & Stakeholders

Stakeholder Groups	Stakeholders
Client	• University of British Columbia
Community	• University Neighbourhoods Association • Pacific Spirit Park Society
Government	• B.C. Ministry of Transportation and Infrastructure • Metro Vancouver Sewage and Drainage District

KREW Hydraulic Consulting will provide notification to the stakeholders through email, phone calls and in-person meetings throughout the duration of the project. Additionally, public information will be provided on the UBC website and updated on a weekly basis.

3 Design Description

The stormwater retention system will consist of three underground concrete detention tanks and a single retention pond located strategically throughout the south campus. The design will mitigate flooding across the south campus and reduce erosion at the outfalls during intense rainfalls. All upgrades to the existing stormwater system will be confined to the south campus catchment, as shown in Figure 1 below.



Source: Adapted from Google Maps Nov 2015

Figure 1: UBC South Catchment Overview

3.1 Design Overview

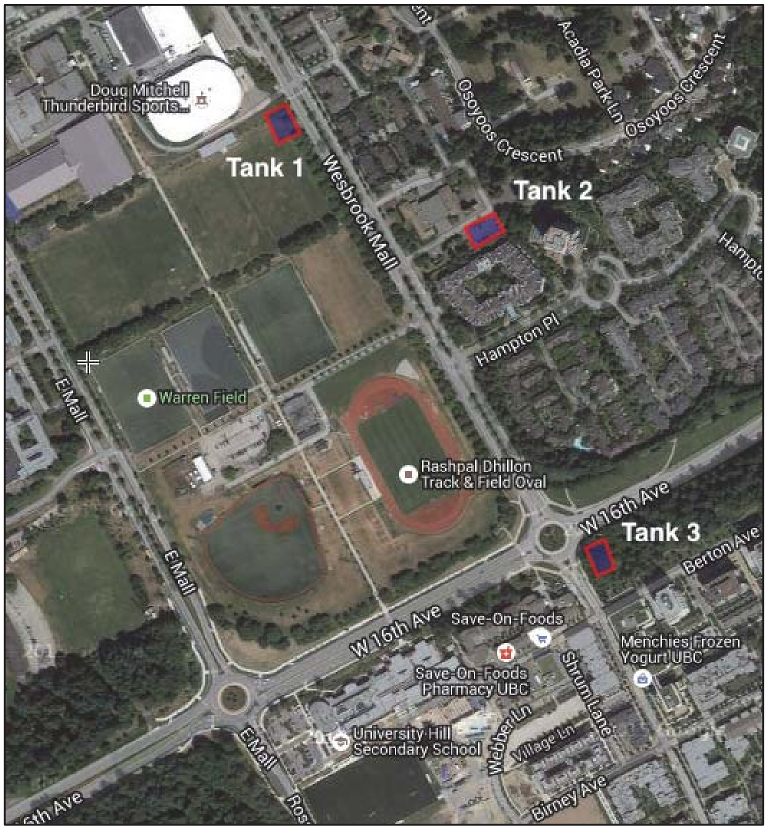
The following bullet points illustrate the key features of the optimized design:

- Multiple underground detention tanks, throughout the catchment prevent the system from backing up and overflowing at any location.
- Strategic tank placement will minimize the need to reroute pipes, which will in turn reduce cost.
- Retention pond allows design to maintain versatile and usable green space while providing a large water storage capacity for intense rainfall events.
- Grit separator and filtration system will ensure quality of stormwater effluent.

3.2 System Layout

In order to prevent localized flooding in any region of the south catchment, the detention tanks were dispersed through the entire catchment. Currently there are two existing underground detention tanks in the south campus catchment. One tank is located under Nobel Park and the other under the TRIUMF laboratories. Therefore, the locations of the three new underground tanks were chosen such that they could collect and store stormwater in the other regions of the catchment.

The three new underground tanks are all located north of the existing tanks. Utilizing this tank layout allows the water which falls in the upper portion of the catchment to be collected and stored immediately. This approach allows the existing tanks to better serve their own portion of the catchment and prevents back-ups and flooding due to the existing flow capacity of the system. An overview of the locations of the three underground detention tanks is provided in the following figure.



Source: Adapted from Google Maps Nov 2015

Figure 2: Underground Detention Tank Locations

The total storage capacity of the existing and new underground tanks will allow the retention pond to remain dry in all flood events up to a 25-year (Q25) event. This will provide an opportunity for UBC's Plant Operations to utilize the pond as a storage facility. As shown in Appendix A, the retention pond will have a bypass pipeline and flow valve placed ahead of the pond connecting directly to the outfall, to ensure the pond remains dry during floods up to a Q25 event. The flow rate and storage capacity of the system will be monitored to give warning when the retention pond is required for stormwater storage.

The retention pond is located near the intersection of SW Marine Dr. and Wesbrook Mall for two reasons. Firstly, under intense flood events the pond will be able to collect and store water from all regions of the south catchment. Secondly, the location of a retention pond requires a relatively large open space with minimal interference, which is provided in the southern most part of the catchment. An overview of the location of the retention pond is shown in Figure 3 below.

Source: Adapted from Google Maps Nov 2015

Figure 3: Retention Pond Location

The 2D design drawings showing the layout and dimensions of the detention tanks and the retention pond can be found in Appendix A. Site photos for the locations of the detention tanks and retention pond are presented in Appendix G.

The dimensions and locations of the three underground detention tanks and retention pond are summarized in the the following table.

Table 4: Retention Tank and Pond - Dimensions and Locations

	Dimensions	Location
Tank 1 **(Thunderbird Arena Tank)**	Length – 16 m Width – 16 m Depth – 2 m Tank Volume – 500 m^3	Southwest of Wesbrook Mall and Thunderbird Boulevard. South of Doug Mitchell Thunderbird Sports Center.
Tank 2 **(RCMP Parking Lot Tank)**	Length – 15 m Width – 15 m Depth – 2 m Tank Volume – 450 m^3	Northeast of Westbrook Mall and Hampton Place. UBC RCMP Parking Lot.
Tank 3 **(Save On Foods Tank)**	Length – 19 m Width – 19 m Depth – 2 m Tank Volume – 750 m^3	Forested area southeast of the roundabout connecting Wesbrook Mall and West 16th Avenue.
Retention Pond	Slope- 1:3 Top Length – 60 m Top Width – 60 m Bottom Length – 45 m Bottom Width – 45 m Pond Volume – 6400 m^3	Forested area northwest of SW Marine Drive and Wesbrook Mall intersection.

A combination of corrugated high-density polyethylene (HDPE) pipe and reinforced concrete pipe (RCP) will be used to connect the tanks to the existing stormwater system. The decision to use HDPE or RCP will be based on the compatibility of the existing pipe being connected. The length of this additional piping will vary for each of the tank locations, and will depend on the distance of the tanks from the main pipe network. HDPE piping will also be used to construct the bypass line for the pond.

3.3 Design Advantages

The underground retention tanks are sized to hold water from a Q25 flood event and the retention pond is large enough to handle any additional water above a Q25 and up to a Q100 flood event. By utilizing underground retention tanks, it is ensured that the retention pond remains dry for the majority of rainfall events, allowing the retention pond to be used for storage and other site operations. The detailed design also has the following benefits:

- Prevents localized flooding in all regions of the south catchment.
- Limits alterations to the existing stormwater collection system.
- Removes oil and grit efficiently from the stormwater run-off.
- Minimizes concrete requirements during construction, therefore reducing the project's CO_2 emissions.
- Controls system outflow which mitigates cliff erosion.
- Creates natural retaining system through use of retention pond.

4 Hydrological Analysis

This section provides a description of the stormwater modelling, flood volume analysis, and system flow rate calculations.

4.1 Stormwater Modelling & Analysis

To obtain the needed flood data for analysis, the rain fall intensity of a Q100 storm event had to be determined. This analysis was started by calculating the time of concentration for the existing system in the southern catchment. Using SWMM software, constant rainfalls were modeled for a period of 24 hours while monitoring the outfalls for constant discharge. The time taken to get a constant discharge was recorded as the time of concentration for that rainfall intensity. After multiple trials an average value of 6 hours was calculated. The rainfall intensity for a Q100 storm event was determined using the calculated time of concentration in conjunction with a duration-intensity graph and was found to be 10mm per hour for a duration of 6 hours. The calculations for the time of concentration and rainfall intensity can be found in Appendix B.

4.2 Flood Volume Analysis

To obtain flood runoff volumes, a runoff coefficient needed to be determined. Using satellite images, the non-permeable and developed areas of the catchment were summed to find the total area of non-permeable ground. In order to accommodate for the expected future development in the southern catchment, the area of non-permeable ground was increased by 25%. The impervious fraction was then calculated to be 0.27 using the ratio of non-permeable area to the total area of the catchment. The impervious fraction was used to determine the land classification from Table 5 below.

Table 5: Common Impervious Fraction

Land Use	Total Impervious
Parks & Agricultural	0.25
Single Family Residential	0.80
Multi-Family Residential	0.85
Commercial	0.95
Industrial	0.95
Institutional	1.0

Source: Richmond Storm Drainage Guidelines

Based on the previous table the land classification was determined to be at the upper end of parks and agricultural. Using Table 6, a runoff coefficient of 0.3 (30%) was selected as the most suitable option.

Table 6: Runoff Coefficients

Land Use Type	Coefficient (1:10 year)
Agricultural (cultivated)	0.10-0.25
Single Family Residential	0.70
Multi Family Residential	0.75
Commercial	0.90
Industrial	0.90
Institutional	0.80
Parks/Grasslands	0.25
Roofs or Pavement	0.95

Source: Richmond Storm Drainage Guidelines

Taking the total area of the catchment to be approximately $1.8km^2$, a total rainfall intensity of 10mm/hr for a duration of 6 hours, and having only 30% of the storm water reach the catchment system, the flood volume was calculated to be 32000 m^3.

4.3 System Flow Capacity

Using the calculated flood volume and assumptions in the following paragraph, the volume and discharge of each tank was calculated. In efforts to determine the maximum allowable discharge of each tank, calculations were performed assuming the tank is full, therefore providing the maximum head and flow. Additionally, the rainfall intensity was considered constant over the entire catchment area.

After determining feasible locations for each of the tanks, the catchment area upstream of each tank was determined. The area ratio of each tank catchment was individually multiplied by the total system discharge. This provides a retention unit size that is capable of holding all stormwater upstream in the system, while discharging stormwater at a rate that meets the discharge restrictions of the outfall. These area ratios and tank sizes can be found tabulated in Appendix B.

A key design requirement is maintaining a low discharge velocity at both of the system outlets, to minimize erosion and eliminate the requirement of rip-rap and armoring. Using Vancouver's storm drainage guidelines, the discharge velocity is restricted to a maximum 1 m/s. In order to maintain a conservative design, the discharge velocity used was 76% of the maximum, resulting in a system discharge velocity of 0.76 m/s.

The discharge of each retention unit was designed based on the total system discharge. The tank discharge was selected based on the incoming flow and the tank size. Using these parameters, different flows were analyzed through an iterative procedure until the desired results were obtained. The outlet discharge of each retention unit can be seen in Table 7.

Table 7: Retention Unit Outlet Discharges

Tank	Size (Original) m^3	Drainage (m^3/hr)
1	500	350
2	450	315
3	750	525
Existing	2100	1474
Pond	6400	1025

To adequately control the discharge of each retention unit a restricted pipe diameter was used. The pipe diameter is determined based on the tank discharge, making each tank an outlet controlled unit. As it is infeasible to replace all the pipes in the system only a small length of pipe after the tank will be replaced, creating a restriction until the water feeds into the mainline. Using orifice flow principals and solving for the pipe area, the required pipe diameter was determined. It should also be noted that a vena contracta of 0.611 was used in design and sample calculations can be found in Appendix B. The following table outlines the required outlet pipe size to achieve the needed discharge from each tank.

Table 8: Retention Unit Outlet Pipe Size

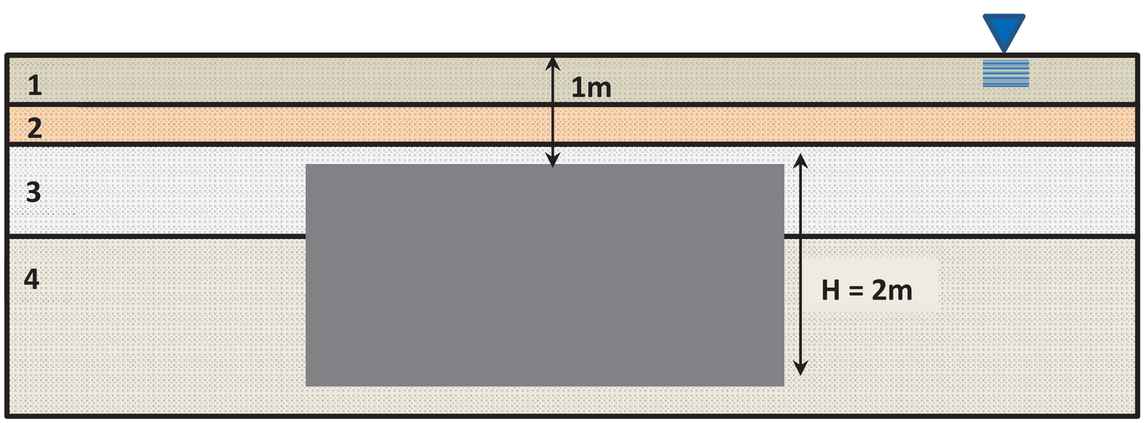
Tank	Q (m^3/hr)	Diameter (m)
1	350	0.19
2	315	0.18
3	525	0.23
Pond	1025	0.37

5 Geotechnical Analysis

KREW Hydraulic Consulting has used given borehole data to estimate soil properties, and corresponding loads on the underground detention tanks. Due to the lack of borehole logs near our proposed locations, KREW would recommend completing two more logs to acquire more robust data to accurately model bearing capacity, as well as completing a liquefaction assessment.

5.1 Lateral Earth Pressure

To prevent side-wall failure of the detention tanks, the side walls are designed based on the factored lateral earth pressures. Live loads above the tank also have a horizontal component, however we have assumed that with a 1m depth of cover, the horizontal magnitude of the live loads will be negligible. It should be noted that only the empty scenario of the retention tank has been included, as this is the governing loading case. The following figure presents the soil stratigraphy used in the geotechnical design.



Layer	Soil Description	Depth (m)	Thickness (m)	γ (kN/m³)	ϕ'(°)	Ka
1	*Well graded sand*	0 - 0.5	0.5	18.5	33	0.295
2	*Gravel with medium sand*	0.5 - 0.7	0.2	19.5	35	0.271
3	*Sand with trace silt*	0.7 - 1.5	0.8	18	30	0.333
4	*Sand, gravel, trace silt*	1.5 - 3.0	1.5	18	32	0.307

Source: Jason Stewart (Feb 2016)

Figure 4: Soil Stratigraphy & Properties used for Design

In the borehole log data, the water table was shown at a 2m depth below the surface. As our proposed retention tank locations are not exactly where the borehole was recorded, the water table was assumed to be just below the ground surface to account for any uncertainty and seasonal changes. Furthermore, this increases the lateral earth pressure applied to the side of the tank, decreases the bearing capacity of the soil, and increases the liquefaction potential, thus making it the governing design scenario. The total lateral earth pressure along the side wall of the retention tank was found to be 30 kN/m^3.

5.2 Bearing Capacity

The detention tanks were designed on the assumption that slab-on-grade construction would be acceptable due to the large bearing area of the tanks. A full bearing capacity calculation can be found in Appendix C. Initially, a factor of safety of 1.5 was used for the reduction of the allowable load, however an additional factor of safety of 2 was applied to account for the water table being above the structure. Overall, a factor of safety of 3 was used. As mentioned above, more borehole log data should be collected to decrease the uncertainty in the actual soil conditions below the tank. If soft clays or weak soil are present below the tank, ground improvement methods such as vibro/dynamic compaction may be necessary.

5.3 Liquefaction & Settlement Assessment

KREW Hydraulic Consulting did not perform a liquefaction assessment due to the lack of data below the slab-on-grade elevation of 3 meters. During a seismic event, loose granular soils lose their shear strength due to cyclic loading. Consequently, structures built on these soils are at risk of collapse or failure; although the consequence of a tank failing during a seismic event is low to the public, the cost (quantitative risk) associated with the tank failure is high. Therefore, densification may be required to decrease liquefaction potential.

If there are fine grained soils below the tank, settlement will have to be assessed. Depending on the percentage of fines and stress history, surcharge loading will be required to achieve consolidation. It should be noted that elastic settlement can also occur in sands, however this is less of a concern in the proposed excavation locations, as most of them have been paved and would have undergone some compaction for previous road construction and pavement.

6 Structural Design

The structural design and analysis of the underground detention tanks requires reference to several codes and guideline documents. The National Building Code of Canada (NBCC), and the BC Building Code (BCBC) were used to determine the design loads on the tank structure. The reinforced concrete design code (CSA A23.3) was used to design the tank structure. In order to meet LEED requirements, several documents on "green concrete design" were consulted. The following section provides detailed structural design information for the underground detention tanks.

6.1 Concrete Mix Design

When Portland cement is produced there is a significant amount of CO2 emitted from the calcinations of limestone. If the amount of CO2 emitted can be reduced a system is considered to be "more green". To reduce the CO2 consumption, the amount of cement in a concrete mix must be reduced. To ensure that the concrete used on this site is "green" and thus conforming to UBC's goal to become more sustainable we propose to use supplementary cementing materials (SCM) to offset the cement used reducing the CO2.

All structural elements will use a 30 MPa mix design that incorporates 30% supplementary cementing materials, which reduces cement demand while increasing pozzolanic cementing efficiencies. The SCM recommended for this mix design is Fly Ash as it is readily available in Greater Vancouver at a competitive price. The concrete will be designed according to F-1 specifications for concrete exposed to freezing and thawing in a saturated condition, such as freshwater control structures. The material proportioning in the 30 MPa structural concrete mix is as follows:

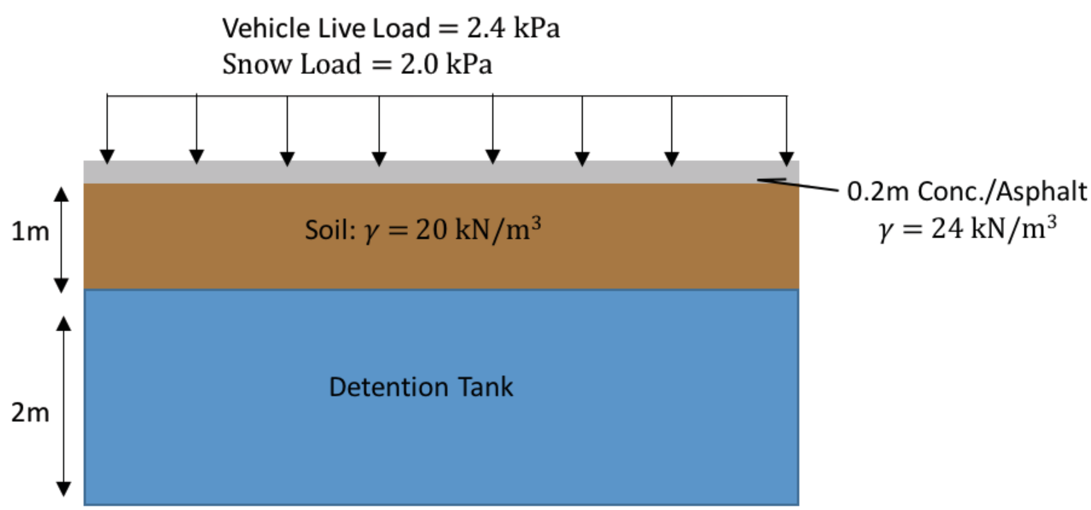
<u>30MPa Structural Mix</u>

- 210 kg Cement (300 kg minus SCM replacement)
- 90 kg SCM (30% replacement)
- 1100kg Coarse Aggregate
- 750kg Fine Aggregate
- 150 kg Water (0.5 w/c ratio)

The mix proportions were based on the following general rules. Use 10kg of cement per 1 MPa of required strength where 20-30% can be replaced with a SCM (supplementary cementing material) like fly ash or blast furnace slag to reduce cement demand. The aggregate is approximately 80% of the total weight (with 60% of that being coarse aggregate, and 40% being sand). The approximate density and water-to-cement ratio are 2300 kg/m^3 and 0.5 respectively.

6.2 Structural Loading & Analysis

The following subsection provides a summary of the design loading and analysis for the detention tank elements subjected to gravity loads. The gravity loads which are applied on the underground tanks are dead load (includes soil load), vehicle live load, and snow load. The magnitude of the load was determined in accordance with NBCC 2010. The following figure presents the gravity loads applied on the underground tanks.



Source: Kayle Rizzo (Feb 2016)

Figure 5: Gravity Loading On Detention Tank

A structural model of the tanks was created using SAP 2000. The loads shown above were applied along the top slab of the detention tank. Based on the NBCC requirements it was determined that the governing loading case for the structure is:

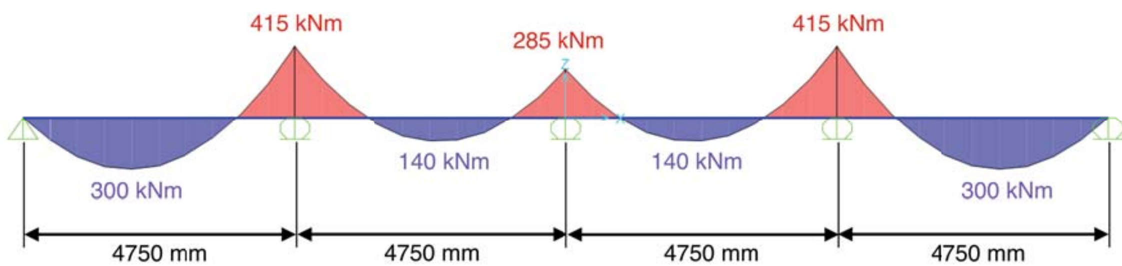
Governing Load Combination: 1.25 DL + 1.5 LL + 0.5 SL

The structural model was analysed using the governing load combination. Based on the analysis, the maximum moment and shear force in the top slab are:

Max Shear Force = 500 kN

Max Bending Moment = 415 kNm

The moment diagram for the top slab, produced by SAP 200, is shown in the figure below.



Source: Kayle Rizzo (Feb 2016)

Figure 6: Detention Tank Top Slab Moment Diagram

Based on the results of the structural analysis the member size and required reinforcing for each element is determined. To determine the size of the tank walls the lateral earth pressures must be calculated.

6.3 Structural Concrete Design

The detention tanks have been designed in accordance with the National Building Code of Canada (NBCC), and consist of the following structural elements: strip footings, top and bottom slabs, slab bands, perimeter walls, and columns. The design calculations for the structural elements are provided in Appendix D.

6.3.1 Slab Design

The top slab is designed to transfer the vertical loads which are applied on the top surface of the tank to the columns and down into the footings. The top slab is 300mm thick and reinforced with 15M bars @ 400mm in both directions. The bottom slab is 200mm thick and reinforced with 15M bars @ 600mm in both directions. The top slab is thicker than the bottom slab as it is subjected to larger bending moments caused by the weight of the soil above. The bottom slab is fully supported by the soil below, reducing the required thickness and rebar spacing.

6.3.2 Slab Band Design

The slab bands are essentially wide beams which run along the column lines to effectively transfer the loads from the slab into the columns. The slab bands reduce stress concentrations in the slab and prevent punching shear. Furthermore, the use of the slab bands minimizes the overall thickness required for the top slab. The slab bands are 600mm wide x 400mm deep and are reinforced with 5 – 25M longitudinal bars.

6.3.3 Column Design

The columns are distributed evenly throughout the tanks to support the top slab and prevent excessive deflections. The columns transfer the load from the slab bands directly down into the strip footings. The columns are 300mm in diameter and reinforced with 8 – 20M longitudinal bars and 10M spiral ties.

6.3.4 Perimeter Wall Design

The perimeter walls of the tanks are designed to resist both the gravity and lateral loads. The walls are designed to support the edges of the top slab as well as resist the lateral earth pressures which a maximum when the tank is empty. The walls resist both axial and bending forces simultaneously. The walls are 300mm thick and reinforced with 20M vertical bars at 200mm and 15M horizontal bars at 400mm.

6.3.5 Strip Footing Design

The strip footings are designed to spread the weight of the tank over a sufficient bearing area to prevent excessive settlements of the tank. Based on the bearing capacity of the soil, it was determined that 750mm wide strip footings placed along the column lines would be sufficient to minimize settlements.

Detailed construction drawings for the detention tanks have been prepared and are included in Appendix A. Table 9 provides a summary of the dimensions required for each of the tank's structural elements. The following figure is a 3D model of the detention tanks.

Table 9: Structural Element Sizes & Dimensions

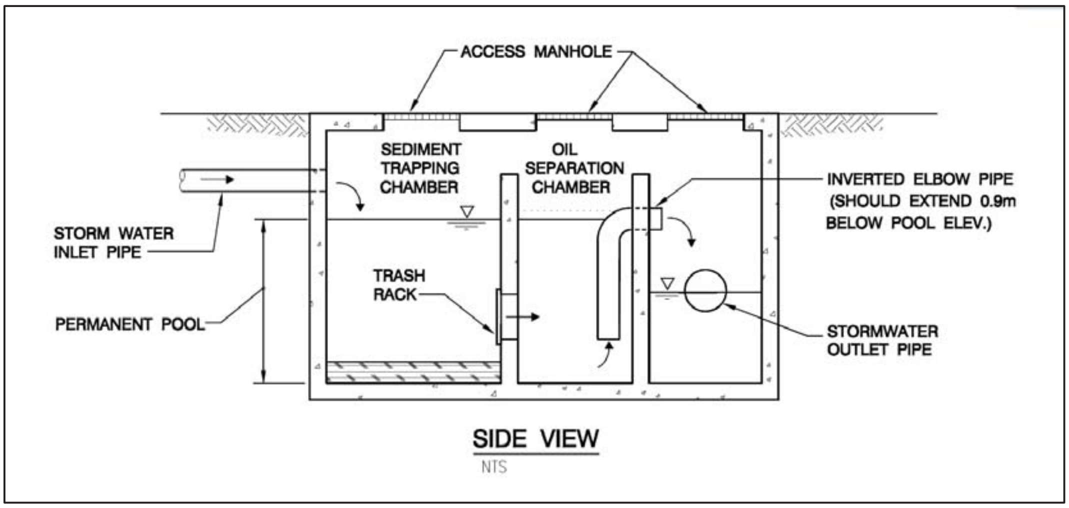
Structural Element	Size / Spacing
Strip Footings	750mm x 400mm Deep (Along Column & Wall Lines)
Top Slab	300mm Thick Reinforced Slab
Bottom Slab	200mm Thick Reinforced Slab on Grade
Slab Bands	600mm x 400mm Deep (Along Column Lines)
Perimeter Walls	300mm Thick Reinforced Slab
Columns	9 – 300mm dia. Columns (Evenly Spaced)

Source: Kayle Rizzo (Mar 2016)

Figure 7: 3D Detention Tank Model

7 Stormwater Treatment

In accordance to the B.C. Water Quality Guidelines and Metro Vancouver's Municipal Water Use Guidelines, stormwater runoff should be treated in order to minimize the amount of sediment and improve the overall water quality before discharging to the environment. The introduction of stormwater treatment tanks, as shown in the figure below, can remove coarse sediment, oil and grease, and large particulates from stormwater. Instead of the traditional 3-chamber oil/grit separator shown below, Stormceptors have been implemented to treat the stormwater prior to discharge.

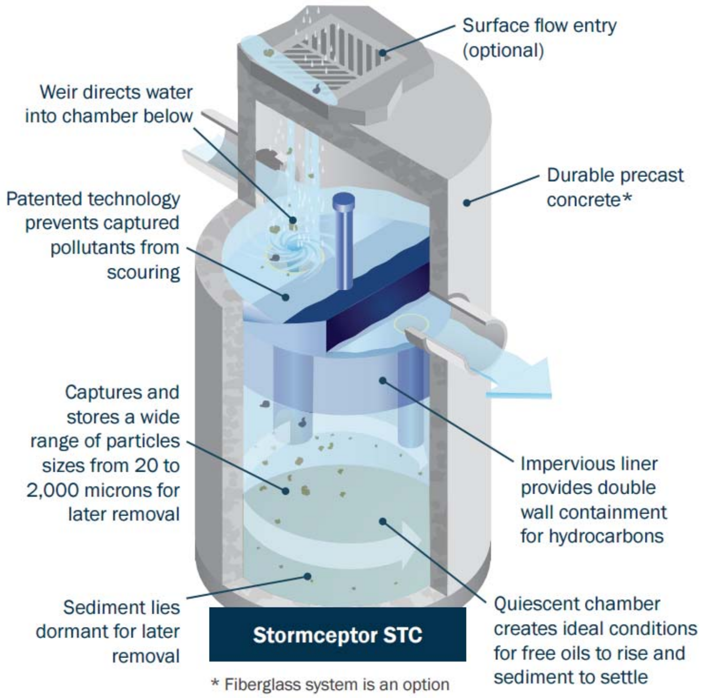


Source: Google Images (Feb 2016)

Figure 8: Traditional 3-Chamber Oil/Grit Separator

7.1 Stormceptor Overview

Stormceptor, provided by Imbrium Systems, will be installed upstream of the underground detention tanks and retention pond to provide treatment to stormwater runoff. The Stormceptor shown in Figure 9, provides more design flexibility compared to the traditional three-chamber systems, and is easier to access for maintenance and cleaning.



Source: Imbrium Systems (Feb 2016)

Figure 9: Stormceptor STC

7.2 Stormceptor Sizing

To size the Stormceptor model to meet the demands of each individual tank location, PCSWMM for Stormceptor, an advanced stormwater treatment sizing & design software, was used to determine the most appropriate Stormceptor treatment system for the site. Unit sizing is determined based on specific site conditions, including local rainfall data, particle size distribution, drainage area, imperviousness, runoff volume and inlet pipe sizing. Table 10 shows the input data used in the modelling software.

Table 10: Input Data for PCSWMM for Stormceptor

Parameter	Tank 1	Tank 2	Tank 3	Pond
Drainage Area	18 ha	16 ha	27 ha	43 ha
Imperviousness	27%	27%	27%	27%
Runoff Ratio	30%	30%	30%	30%
Inlet Pipe Sizing	500 mm	500 mm	1000 mm	1000 mm

The water quality objective is set to achieve a Total Suspended Solid (TSS) removal rate of 70%. The recommended Stormceptor model based on the PCSWMM program analysis is presented in Table 11 below. A detailed sizing report that includes projected performance calculations can be found in Appendix H.

Table 11: Stormceptor Model Recommendation Provided by PCSWMM

Site	Drainage Area	Provided % TSS Removal	Recommended Model
Tank 1	18 ha	71%	STC 14000
Tank 2	16 ha	72%	STC 14000
Tank 3	27 ha	73%	Stormceptor MAX
Pond	43 ha	72%	Stormceptor MAX

Stormceptor STC 14000

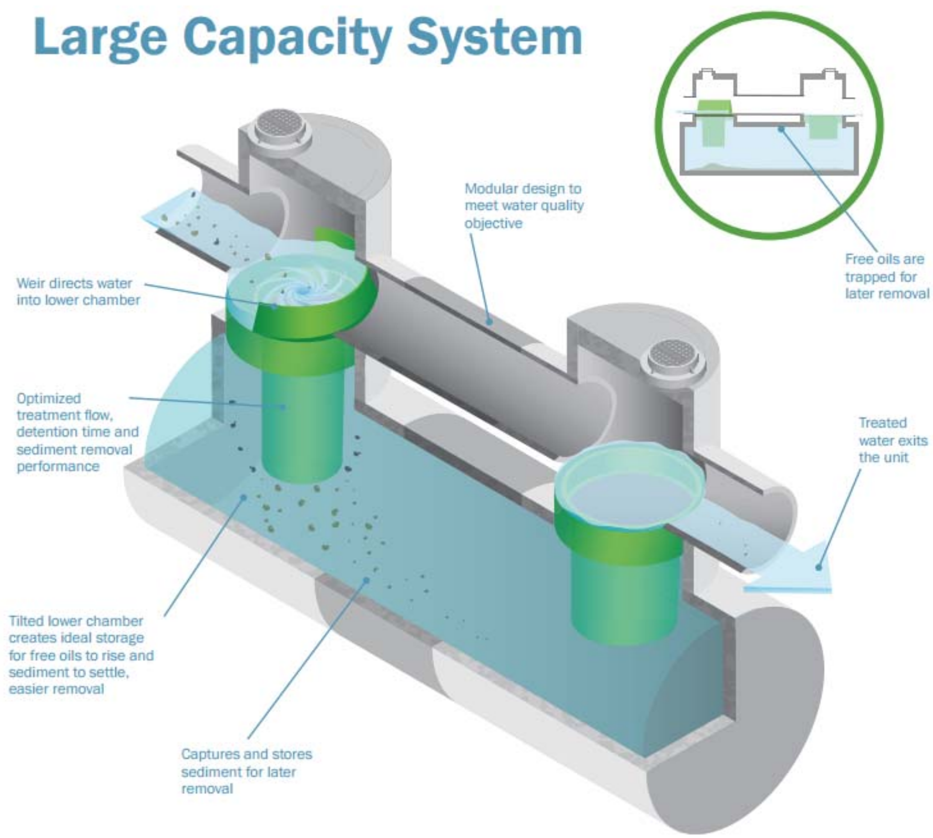
Stormceptor STC 14000 is a Series Stormceptor designed to treat larger drainage areas. It consists of two adjacent Stormceptor models that function in parallel. This design eliminates the need for additional structures and piping to reduce installation costs. Table 12 shows the capacity of the STC 14000.

Table 12: Stormceptor STC 14000 Capacity

Model	Total Storage Volume (L)	Hydrocarbon Storage Capacity (L)	Maximum Sediment Capacity (L)
STC 14000	66410	11700	53890

Stormceptor MAX

Since the drainage area for Tank 3 exceeds the capacity of standard Stormceptor models, Stormceptor MAX is selected to provide treatment for the larger drainage areas. It is a modular stormwater treatment device that will require additional engineering and customization from Imbrium to meet the site's condition. A schematic drawing of Stormceptor MAX is shown below.



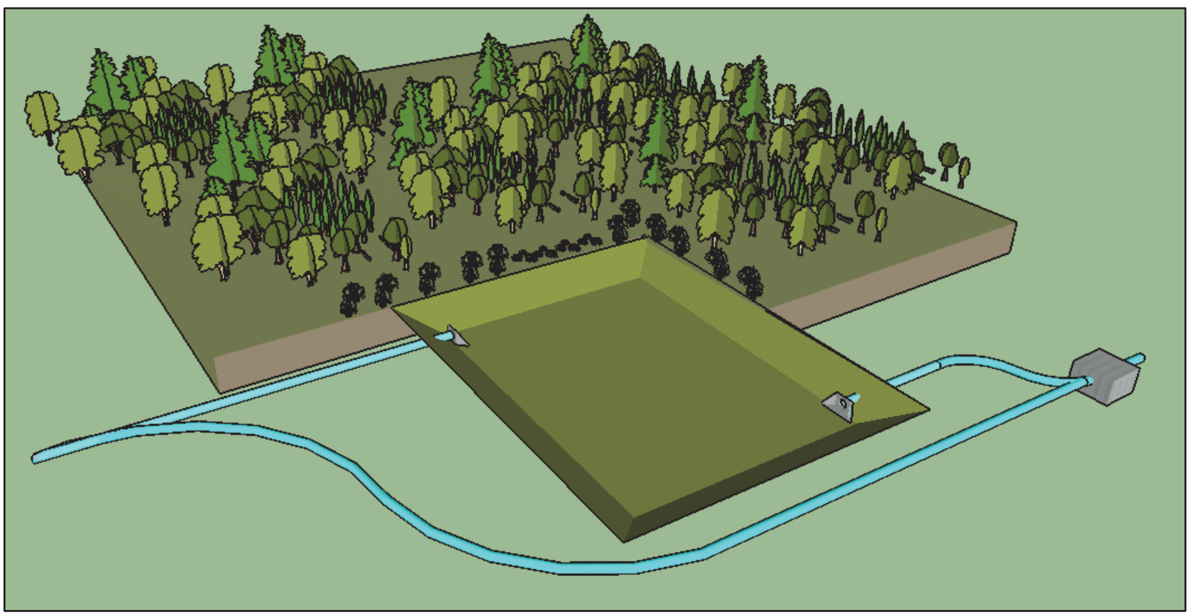
Source: Imbrium Systems (Feb 2016)

Figure 10: Stormceptor MAX

Shop drawings for Stormceptor STC 14000 and Stormceptor MAX are included in Appendix H.

8 Retention Pond Design

The retention pond is designed according to "Best Management Practices Guide for Stormwater – Metro Vancouver" which outlines the general design criteria for a dry retention basin. The pond will provide additional storage capacity for storms exceeding a 25-year flooding event up to a 100-year flooding event. The retention pond is designed to temporarily store stormwater and slowly release it at a controlled rate in order to minimize erosion at the outfall and in order to avoid flooding in downstream areas. A 3D schematic model of the retention pond is shown in the figure below.



Source: Tyler Mann (Nov 2015)

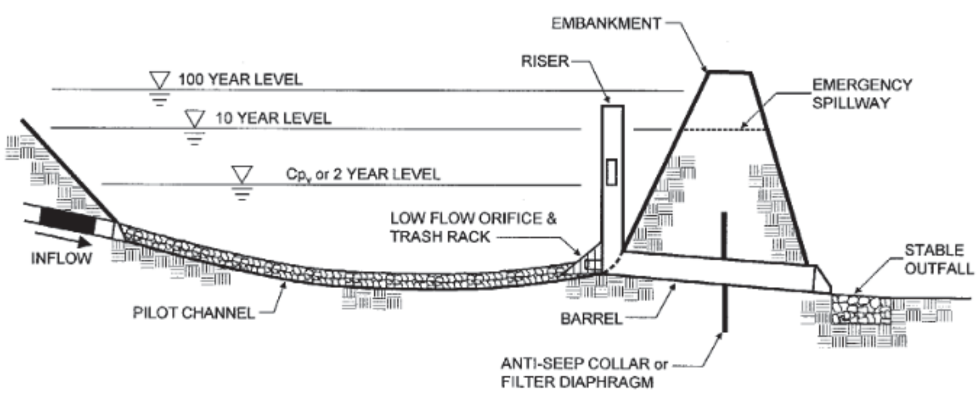
Figure 11: Retention Pond & Filtration System Model

8.1 Design Components

The key design parameters of the the retention pond are as follows:

- The pond will have a total volume of 6400 m^3 at full capacity.
- The pond bottom will have an optimal 2% slope towards the outlet in order to allow complete drainage during flooding events and prevent standing water conditions.
- Non-woven geotextile material will be used to line the pond bottom in order to ensure stormwater does not infiltrate into the surrounding soil.
- Side slopes of the basin will be 3H:1V to ensure slope stability.

A schematic 2D drawing of a typical retention pond is shown below.



Source: Google Images (Mar 2016)

Figure 12: 2D Retention Pond Schematic Drawing

8.1.1 Forebay

The forebay is designed to settle out large sediment from the stormwater during intense rainfalls, in which the upstream Stormceptor MAX is bypassed to maintain sufficient drainage conditions. It will be placed at the inlet, upstream of the main pond, and will trap the majority of the coarse sediment in the stormwater before entering the main retention pond. The forebay volume will be equal to 10% of the total retention pond. The forebay will be separated from the dry basin area by barriers constructed of earth, and rip-rap.

8.1.2 Emergency Overflow

An emergency overflow will be constructed to allow storms exceeding a 100-year design event to pass through the pond with minimal destruction. The emergency overflow will be located on the downstream end of the retention pond to prevent stormwater from overtopping the pond embankment. The excess stormwater will be returned to the system's mainline and discharged.

8.1.3 Berm Embankment / Slope Stabilization

Pond berm embankments will be constructed on native consolidated soil, free of loose surface soil materials, roots, and other organic debris. The embankments will have side slopes of 3H: 1V to ensure slope stability. The exposed earth on the side slopes will be seeded with grasses to minimize soil erosion.

8.1.4 Basin Dewatering

A low flow orifice will be installed at the outlet control structure to slowly allow the release of stormwater over a 24 to 72 hour period. This slow controlled release of runoff will minimize erosion at the outfall. These structures are prone to becoming clogged with debris, therefore a guard will be installed to ensure the low flow orifice is protected.

8.2 Maintenance

Proper upkeep and maintenance is important for the retention pond, as it ensures the pond's continued functionality. Table 13 below outlines the various maintenance requirements after installation of the retention pond.

Table 13: Summary of Maintenance Requirements

Required Maintenance	Frequency
Debris Removal	After large storm event
Grass Cutting	As needed
Invasive Plant Control	Semi annually
Inspection – Outlet Control Structure	Annually
Repair Embankment, Side Slope, or Eroded Areas	Annually, or as needed
Sediment Removal – Forebay & Pond Bottom	Every 5 years

9 Construction Work Plan

Due to the nature of the design, this project will not have one large centralized construction site, rather four smaller zones of construction activity spread throughout the South Campus. This presents unique challenges as all four locations are significantly space-constrained and often near sidewalks and accesses to major arterials. The three small underground tank work sites do not allow for much extra material and equipment storage, so any additional material will be stored at the larger retention pond site. With three underground tanks undergoing construction in tandem, coordinating concrete truck arrival times and optimizing equipment usage will be vital but left to the contractor's discretion. The construction site layout including the total fenced area, tank location, and truck routes, for each of the four locations are presented below.

9.1 Construction Site: Tank 1

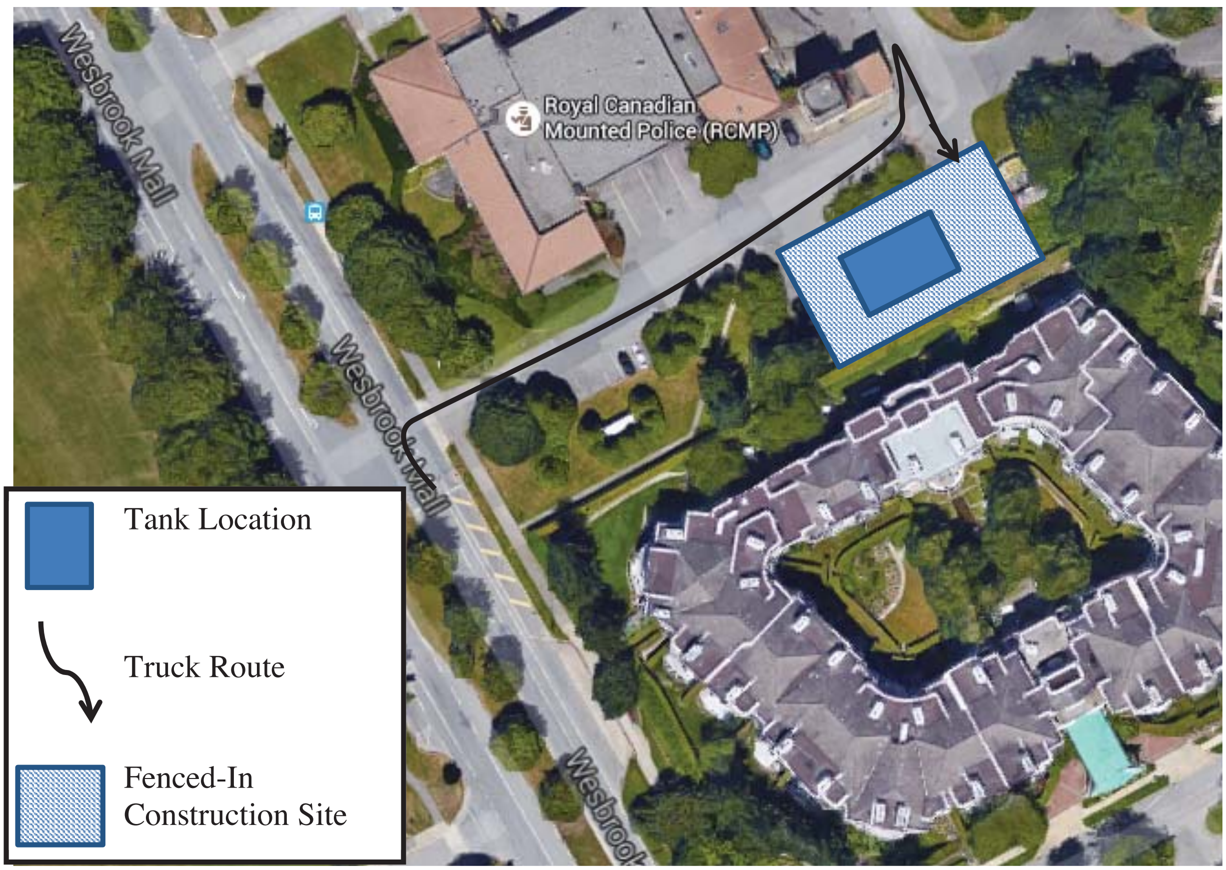
The first tank construction site is located southeast of the Doug Mitchell Thunderbird Sports Centre. This location has relatively clear and easy access for concrete trucks with adequate room to maneuver using the Thunderbird Sports Centre loading bay. One of the challenges of this site is its proximity to the adjacent grass field which is frequently used by UBC sports teams. Proper fencing and safety offsets must be followed to prevent any conflict with competitive and recreational sports being played on the field. The site plan for Tank 1 is shown below in Figure 13.

Source: Adapted from Google Maps (Mar 2015)

Figure 13: Tank 1 Site Plan

9.2 Construction Site: Tank 2

The construction site for tank #2 is located in the southeast corner of the RCMP parking lot. To facilitate the tank construction, 28 parking spots must be temporarily removed as they fall within the required fenced-in construction zone. This site is located off the main arterial of Wesbrook Mall and allows for concrete trucks to maneuver within the parking lot to access the site. This reduces traffic delays along Wesbrook Mall itself and eliminates the need for traffic control personnel at this location. The construction site plan for Tank 2 is shown below in Figure 14.



Source: Adapted from Google Maps (Mar 2015)

Figure 14: Tank 2 Site Plan

9.3 Construction Site: Tank 3

Tank 3 is located at the southeast corner of the roundabout at Wesbrook Mall and W 16th Avenue. This location will require removal of trees to facilitate room for the equipment to maneuver while constructing the tank. In addition, this location does not have an access or parking lot for trucks to park while unloading so the north side parking lane of Berton Avenue will be temporarily removed to allow for trucks to access the site. There is not adequate space for concrete trucks to turn around on Berton Avenue so traffic control personnel will be necessary to ensure traffic is stopped when trucks are backing off the site onto Wesbrook Mall. The construction site plan for Tank 3 is shown below in Figure 15.

Source: Adapted from Google Maps (Mar 2015)

Figure 15: Tank 3 Site Plan

9.4 Construction Site: Retention Pond

The retention pond construction site is the largest of the four and is located at the northwest corner of SW Marine Drive and Wesbrook Mall. This location will house the project site office and any excess materials that cannot be stored on the other three sites. As on sites 1 and 2 an adjacent parking lot and loading bay will provide concrete trucks access to the site and allowing maneuvering to reduce traffic impact on Wesbrook Mall. The construction site plan for the retention pond is shown below in Figure 16.

Source: Adapted from Google Maps (Mar 2015)

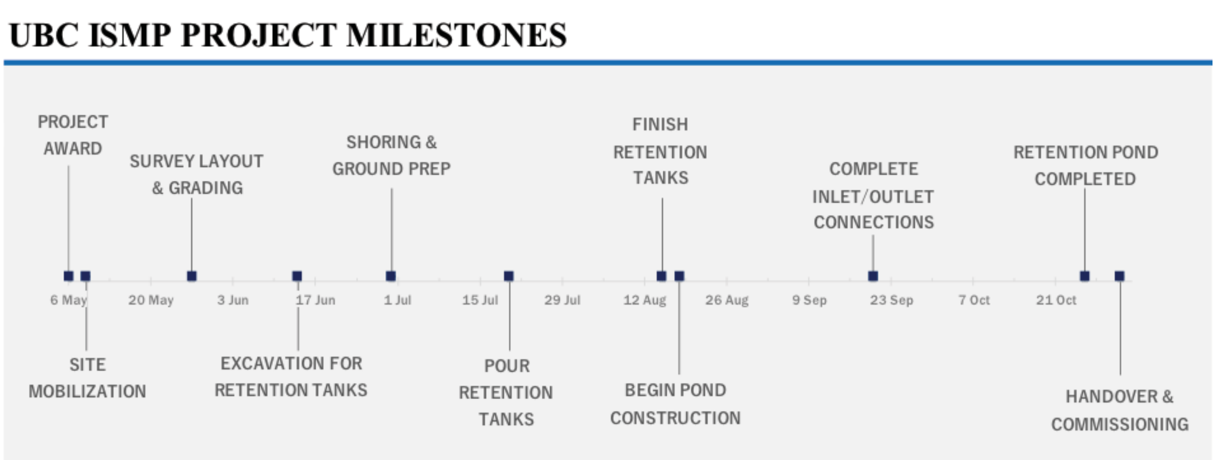
Figure 16: Retention Pond Site Plan

10 PROJECT SCHEDULE

The UBC Integrated Storm-Water Management Plan (ISMP) construction schedule will commence May 16, 2016 with a targeted completion date of October 28th, 2016. This timeframe is beneficial as most of the construction will occur while university classes are not in session, decreasing the impact on the public, and traffic delays. A full Gantt chart and task list can be found in Appendix E. In reference to the Gantt chart, separate tasks have been created summarizing individual tank construction. Although the schedule for each of these tasks looks similar, it should be noted that based on site characteristics, some of the sub-tasks duration may be longer. For example, material and equipment delivery, along with general construction activity will take longer at the Save-On Foods location, versus the RCMP location due to spatial constrictions and traffic. Thus, more time has been allocated to each sub task under “Save On Foods Tank”.

Each of the tanks will be constructed simultaneously, with the construction of the retention pond being the critical path, over 128 work-days, based on 5 day work-weeks. Hold points (inspections) have been included for the placement of the retention tanks, which will be conducted by the Project Manager. Having three separate crews will expedite construction, and further decrease the disruption to the surrounding community at UBC.

For simplicity, a timeline has been included in the figure below, highlighting the key milestones during the project.



Source: Jason Stewart (Mar 2016)

Figure 17: UBC ISMP Project Milestones

Regarding the timeline above, site mobilization will commence prior to any excavation. This will entail fencing the construction envelope, and establishing on-site storage for equipment. Mobilization will only occur after the site hazard assessment and field review have been completed by the Project Director. Subsequently, survey layout and grading will be performed at each site; this task will be ongoing throughout the project for as-built drawings and construction layout.

Excavations for retention tanks will follow, with trenching and pipe connections to the existing storm water system. Thereafter, formwork and rebar placement will be completed after excavations and specified levelling have been accomplished. At this stage, there will be an inspection on forms and rebar, as mentioned above. The retention pond will be constructed after the last tank has been completed, with an expected completion date of October 26th, 2016. This will give adequate time for project closeout documentation (as-built drawings, quality assurance documents) to be submitted to UBC Infrastructure for handover and commissioning.

11 Detailed Cost Estimate

A Class 1 cost estimate has been completed for the final detailed design of the stormwater retention system. The expected cost of this project is $2.54 million with a contingency of 10% to account for variability in assumed unit prices. This contingency has been reduced from the previous 20%, used in the preliminary design stage, to reflect increased certainty in the design.

The cost estimate has been split into two sections. The first is the cost to complete the detailed design, obtain permits, project management, and all construction related activities. The second estimate is for the ongoing operations & maintenance of the proposed facilities.

As KREW Hydraulic Consulting is a relatively new and small company, we do not have enough relevant previous projects to estimate reasonable unit rates in-house. Instead, these costs were estimated from publicly available and respected sources like construction industry standard RS Means and Alberta Transportation's Unit Price Averages report for 2014-2015. All unit prices found from these sources have been adjusted for interest and location accordingly. A summary of the cost for each major phase can be found below in Table 14 below. The full detailed cost estimates can be found in Appendix F.

Table 14: Detailed Design Cost Estimate Summary

Detailed Design Cost Estimate Summary	
Phase of Project	**Estimated Cost (Rounded)**
Detailed Design	$205,000
Project Start-Up	$15,500
Engineering & Testing	$352,000
Site Mobilization & Survey	$118,000
Foundations and Concrete	$860,000
Retention Pond	$395,500
Project Close-out & Handover	$79,500
Contingency & Taxes	$457,500
Grand Total	**$2,540,000**

There is expected to be ongoing operations and maintenance costs over the lifetime of the system. Most of the maintenance costs are related to the upkeep of the retention pond, to ensure the inlet and outlet pipes remain clear of debris. General upkeep tasks include: removal of leaves, grass cutting, and weed control. As per manufacturer recommendation, the Stormceptor just upstream of the retention pond and tanks shall be calibrated every six months. In addition, the stormwater pipes attached to the tanks and pond need to be periodically checked for damage and repaired if necessary. It is expected these maintenance tasks will fall under the supervision of UBC's Plant Operations branch, minimizing the cost of hiring a contractor. The estimated yearly operations and maintenance cost of this project will be $40,750. below provides an outline for the cost of monitoring and maintenance activities.

Table 15: Annual Estimated Operations and Maintenance Cost

Item	Interval	Unit	Cost per Unit	Annual Cost
Debris removal	3 times / year	per visit	$5000	$15,000
Grass cutting	5 times/year	per visit	$350	$1750
Invasive plant control	2 times/year	per visit	$350	$700
Stormceptor calibration (x4 Stormceptors)	2 times/year	per visit	$300	$2400
Inspection	1 time/year	per visit	$100	$300
Additional inspection after large rainfall event	12 times/year	per visit	$50	$600
Repair embankment, side slope, or eroded areas	1 time/year	per visit	$5000	$5000
Pipe repairs	3 times/ year	per visit	$5000	$15,000
Total Cost				$40,750

12 Conclusion & Recommendations

A major aspect of the design is to construct a large retention pond on the southern tip of campus. A crucial assumption that KREW Hydraulic Consulting made, was the availability of this land for stormwater use. UBC's current land use plan for the south campus is quite conceptual and the area in which the retention pond is to be built is zoned for academic use. The retention pond will create several new constraints for future buildings that will be constructed in the areas surrounding the pond. Ideally, the retention pond would be designed in conjunction with the anticipated future buildings to ensure maximum integration of land use.

In reference to Section 5.0, it is imperative that adequate borehole data is attained to model soil conditions in the proposed tank locations. If weak layers of soil are present underneath the bottom of the tank, ground improvement methods or complete site relocation may be necessary. Ground improvement methods can become very costly, especially during construction – work will be delayed until the soil has met engineered specifications. In the same way, site relocation would incur large cost over-runs as the tank would have to be redesigned based on unique conditions at a different site.

Prior to any site activity, a pre-construction survey should be completed to record any existing flaws or damages to surrounding infrastructure. Furthermore, settlement monitoring should be implemented on a weekly basis at defined control points once construction has commenced.

UBC's south catchment is very large and with the continued development of the south campus, the strain on the stormwater management system will only increase. Although this increase in demand was incorporated in the design, KREW Hydraulic Consulting encourages UBC to employ new sustainable strategies like rain gardens, green roofs, and disconnected roof leaders to reduce the total impervious area. To have a truly successful and efficient stormwater management system, there must be both adequate infrastructure capacity and steps taken to reduce the overall demand.

13 References

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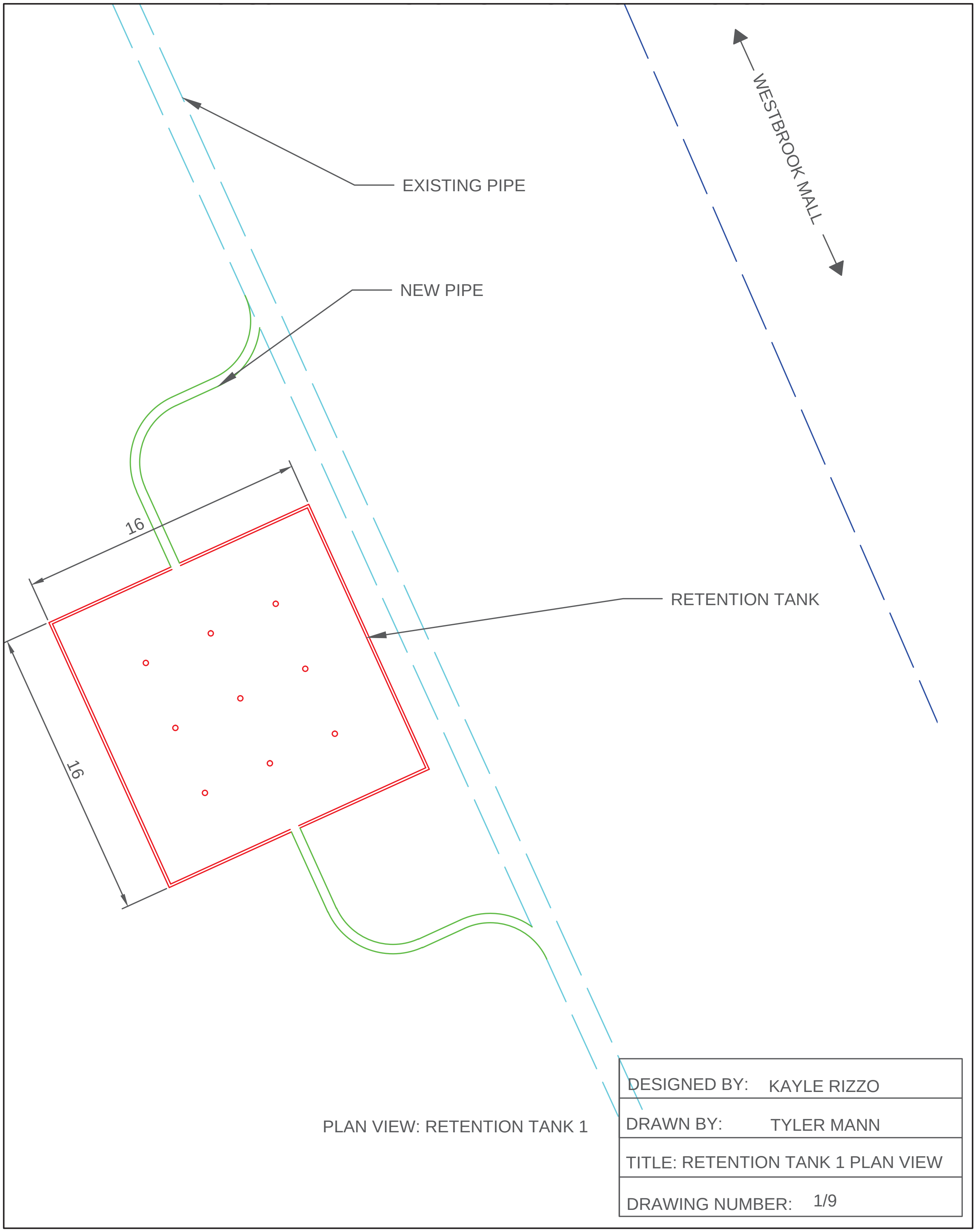
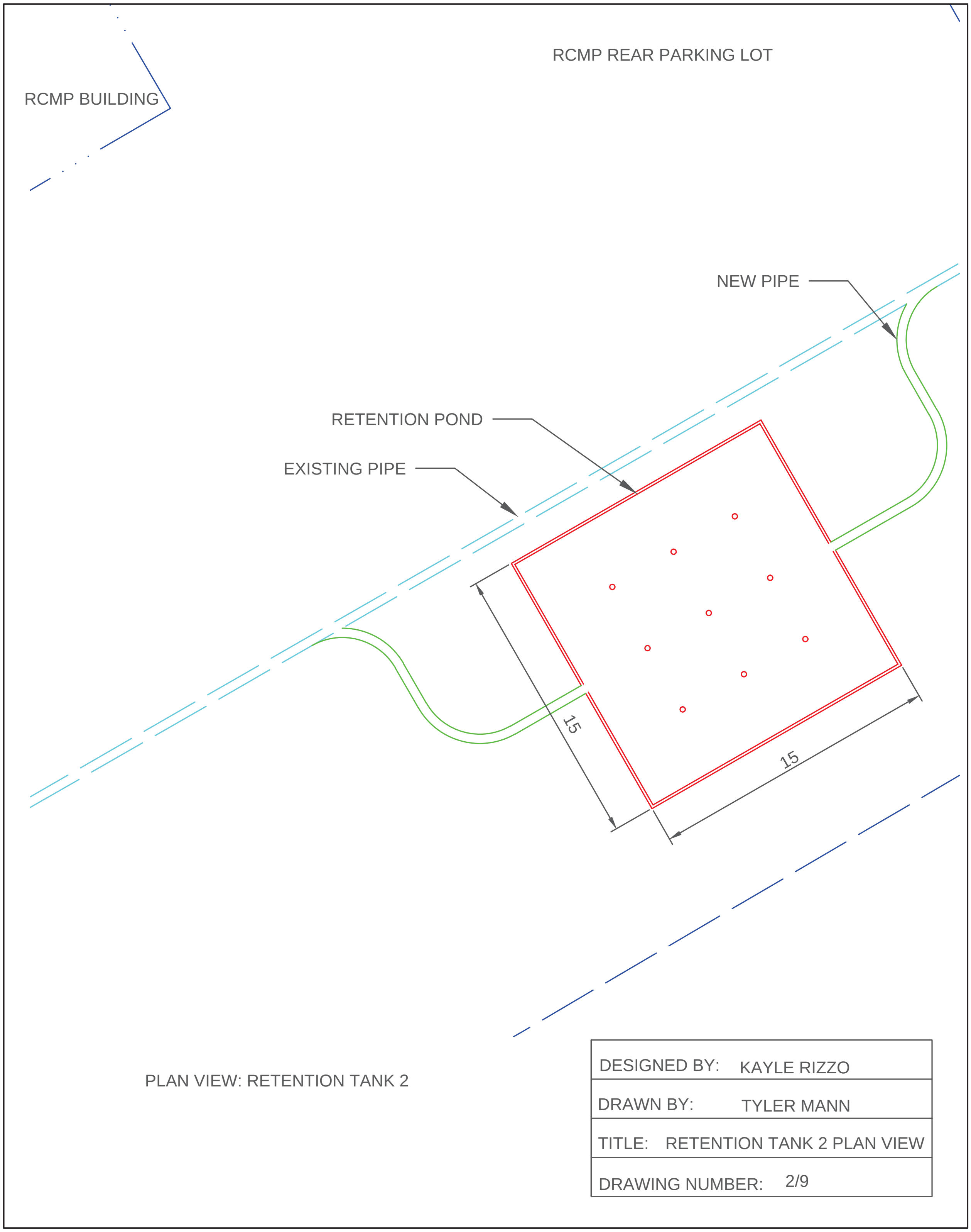
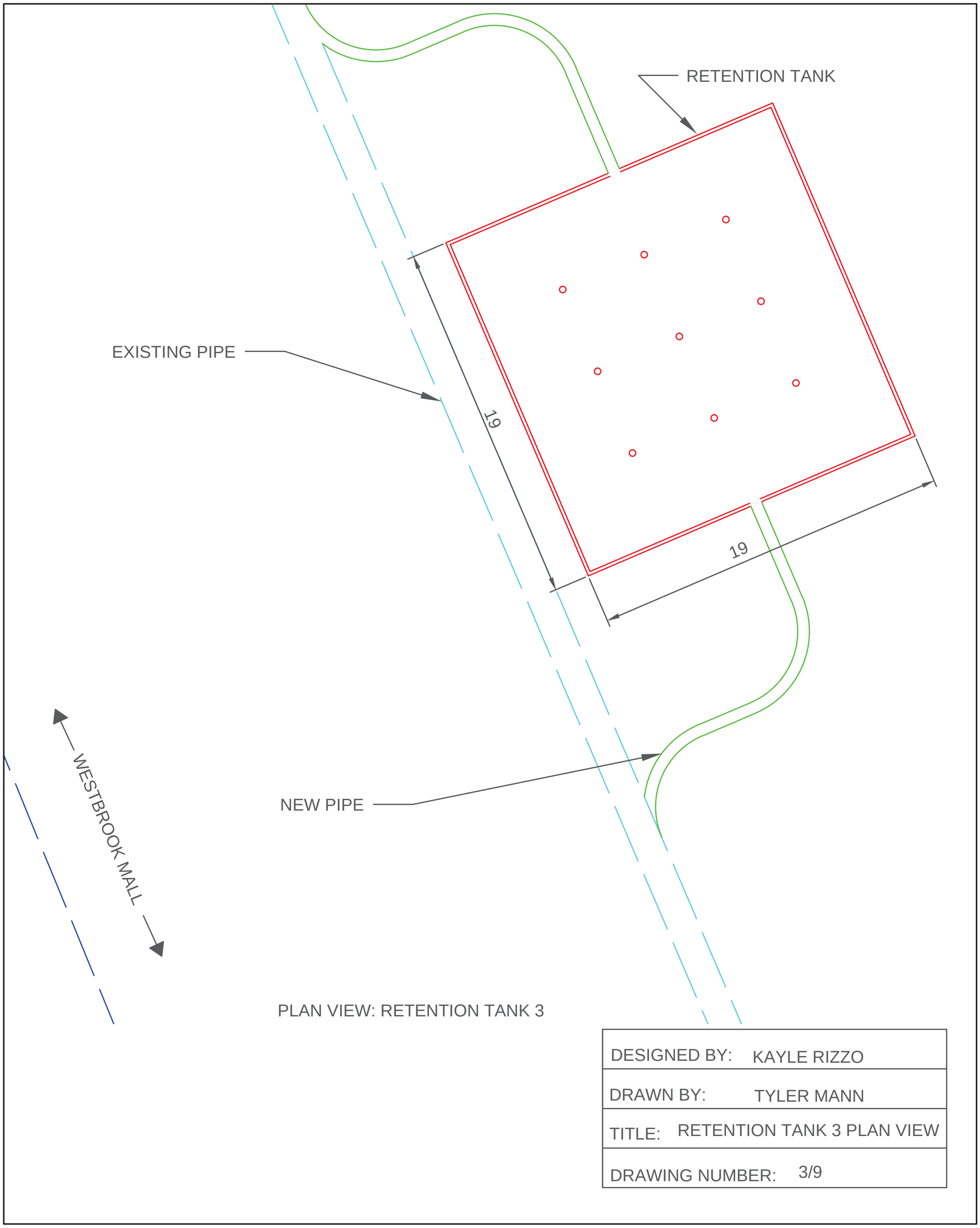
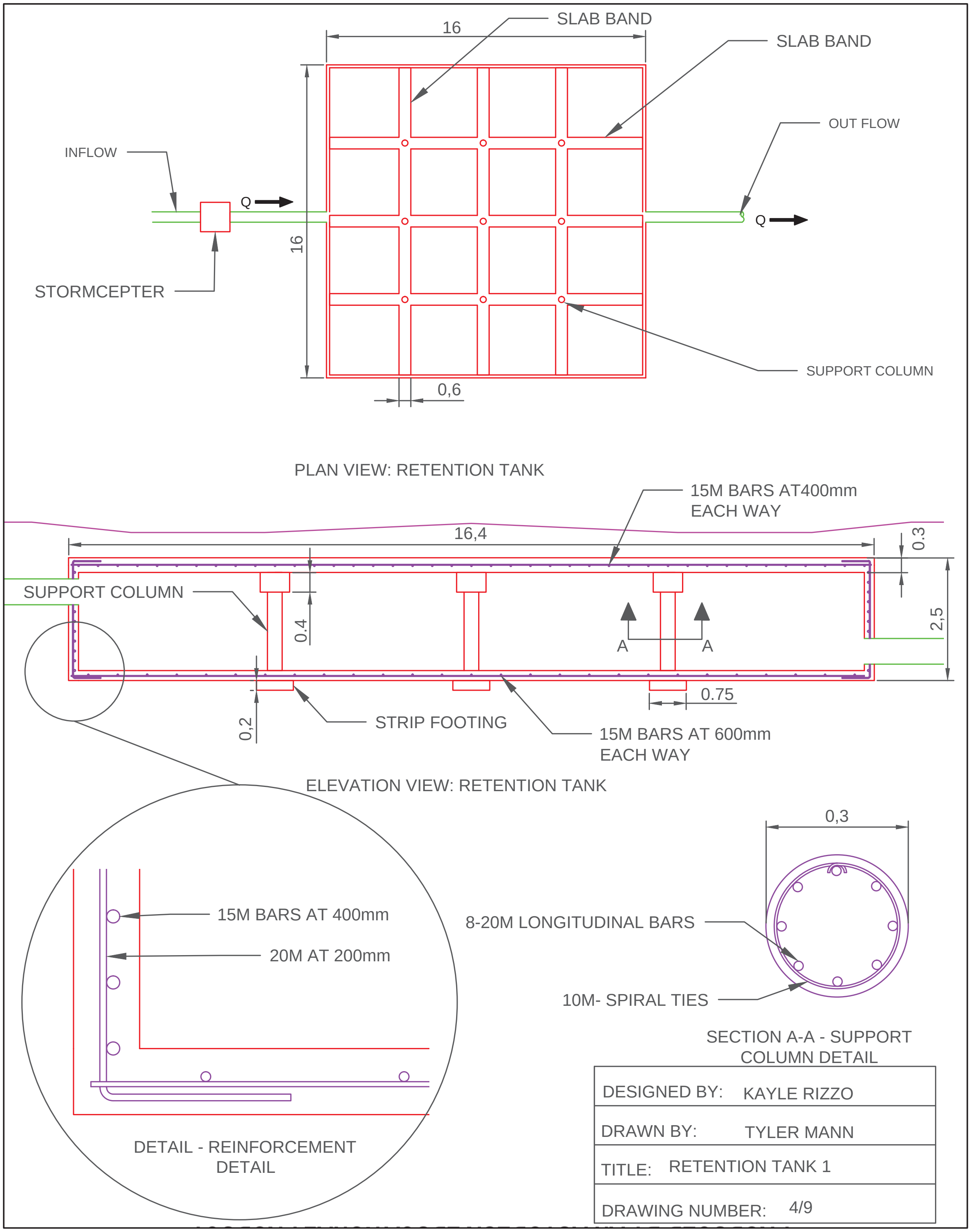
Appendix A – Project Drawings

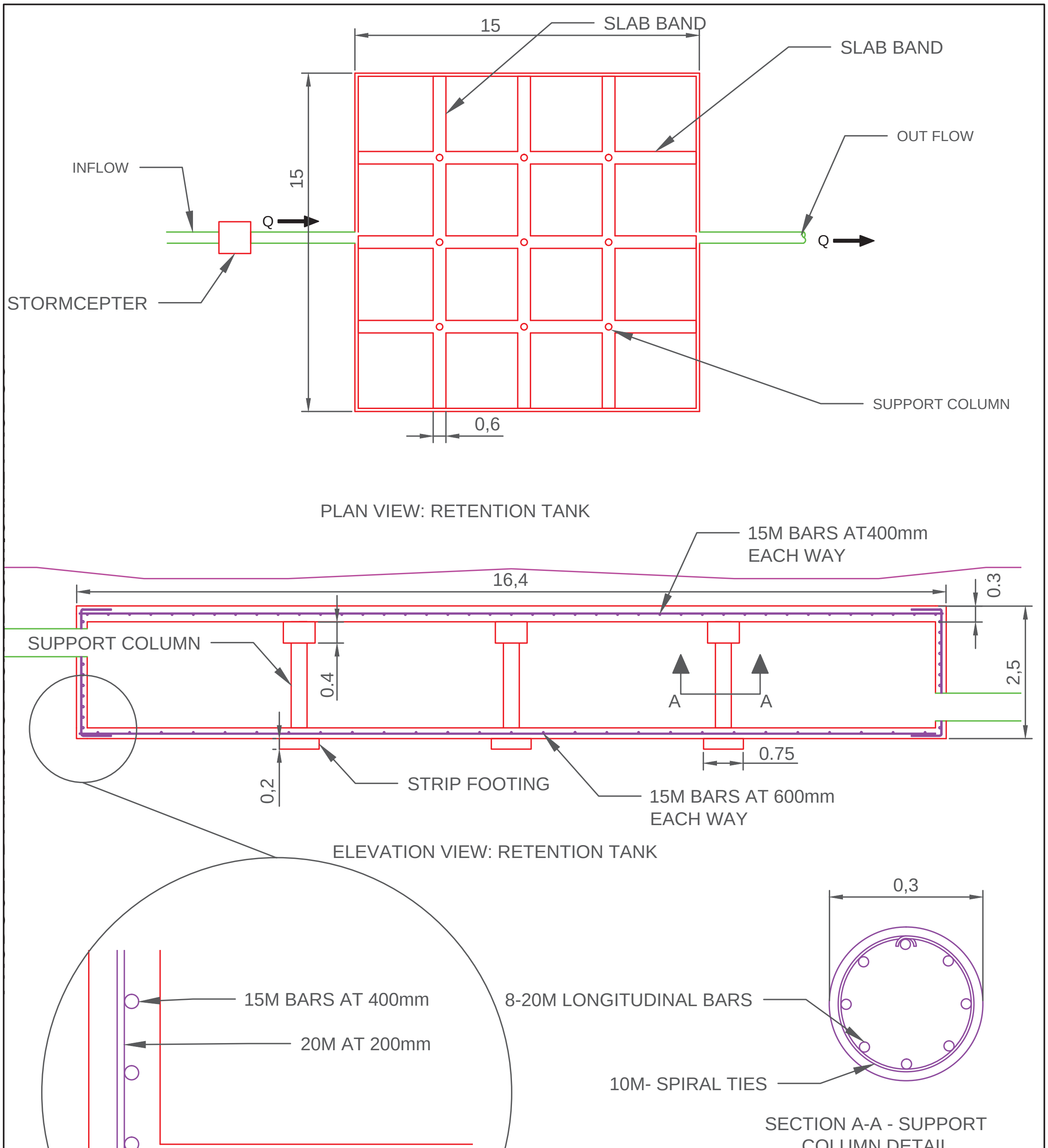



RCMP REAR PARKING LOT
RCMP BUILDING
NEW PIPE
RETENTION POND
EXISTING PIPE
15
15
PLAN VIEW: RETENTION TANK 2
DESIGNED BY: KAYLE RIZZO
DRAWN BY: TYLER MANN
TITLE: RETENTION TANK 2 PLAN VIEW
DRAWING NUMBER: 2/9

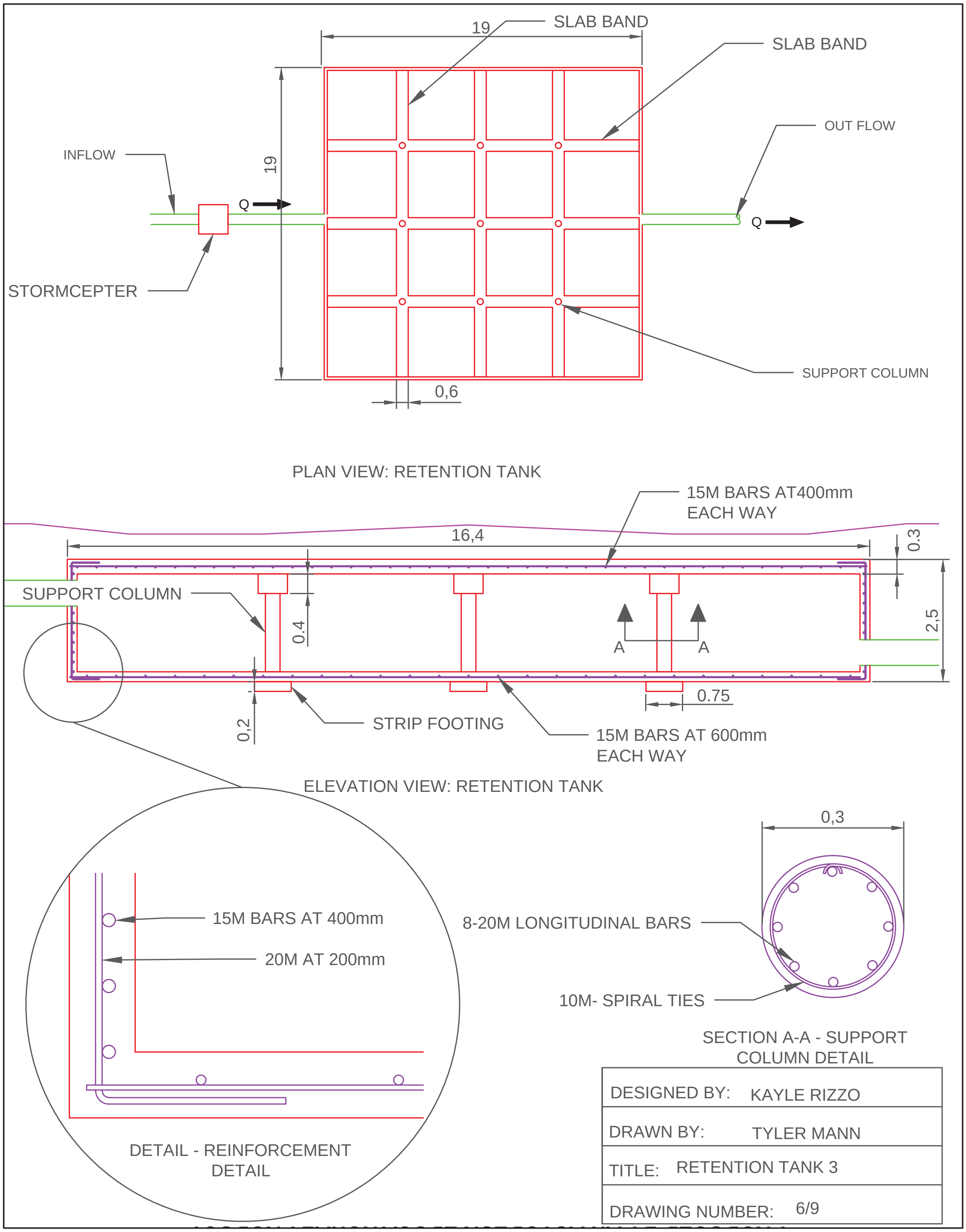

RETENTION TANK
EXISTING PIPE
19
19
NEW PIPE
WESTBROOK MALL
PLAN VIEW: RETENTION TANK 3
DESIGNED BY: KAYLE RIZZO
DRAWN BY: TYLER MANN
TITLE: RETENTION TANK 3 PLAN VIEW
DRAWING NUMBER: 3/9



SLAB BAND
16
SLAB BAND
OUT FLOW
INFLOW
Q
Q
16
STORMCEPTER
SUPPORT COLUMN
0,6
PLAN VIEW: RETENTION TANK
15M BARS AT400mm
EACH WAY
16,4
0.3
SUPPORT COLUMN
0.4
A
A
2,5
0.75
0,2
STRIP FOOTING
15M BARS AT 600mm
EACH WAY
ELEVATION VIEW: RETENTION TANK
0,3
15M BARS AT 400mm
20M AT 200mm
8-20M LONGITUDINAL BARS
10M- SPIRAL TIES
SECTION A-A - SUPPORT
COLUMN DETAIL
DETAIL - REINFORCEMENT
DETAIL
DESIGNED BY: KAYLE RIZZO
DRAWN BY: TYLER MANN
TITLE: RETENTION TANK 1
DRAWING NUMBER: 4/9



DESIGNED BY:	KAYLE RIZZO
DRAWN BY:	TYLER MANN
TITLE:	RETENTION TANK 2
DRAWING NUMBER:	5/9


19
SLAB BAND
SLAB BAND
OUT FLOW
INFLOW
19
Q
Q
STORMCEPTER
SUPPORT COLUMN
0,6
PLAN VIEW: RETENTION TANK
15M BARS AT400mm
EACH WAY
16,4
0.3
SUPPORT COLUMN
0.4
A
A
2,5
0.75
0,2
STRIP FOOTING
15M BARS AT 600mm
EACH WAY
ELEVATION VIEW: RETENTION TANK
0,3
15M BARS AT 400mm
20M AT 200mm
8-20M LONGITUDINAL BARS
10M- SPIRAL TIES
SECTION A-A - SUPPORT
COLUMN DETAIL
DETAIL - REINFORCEMENT
DETAIL
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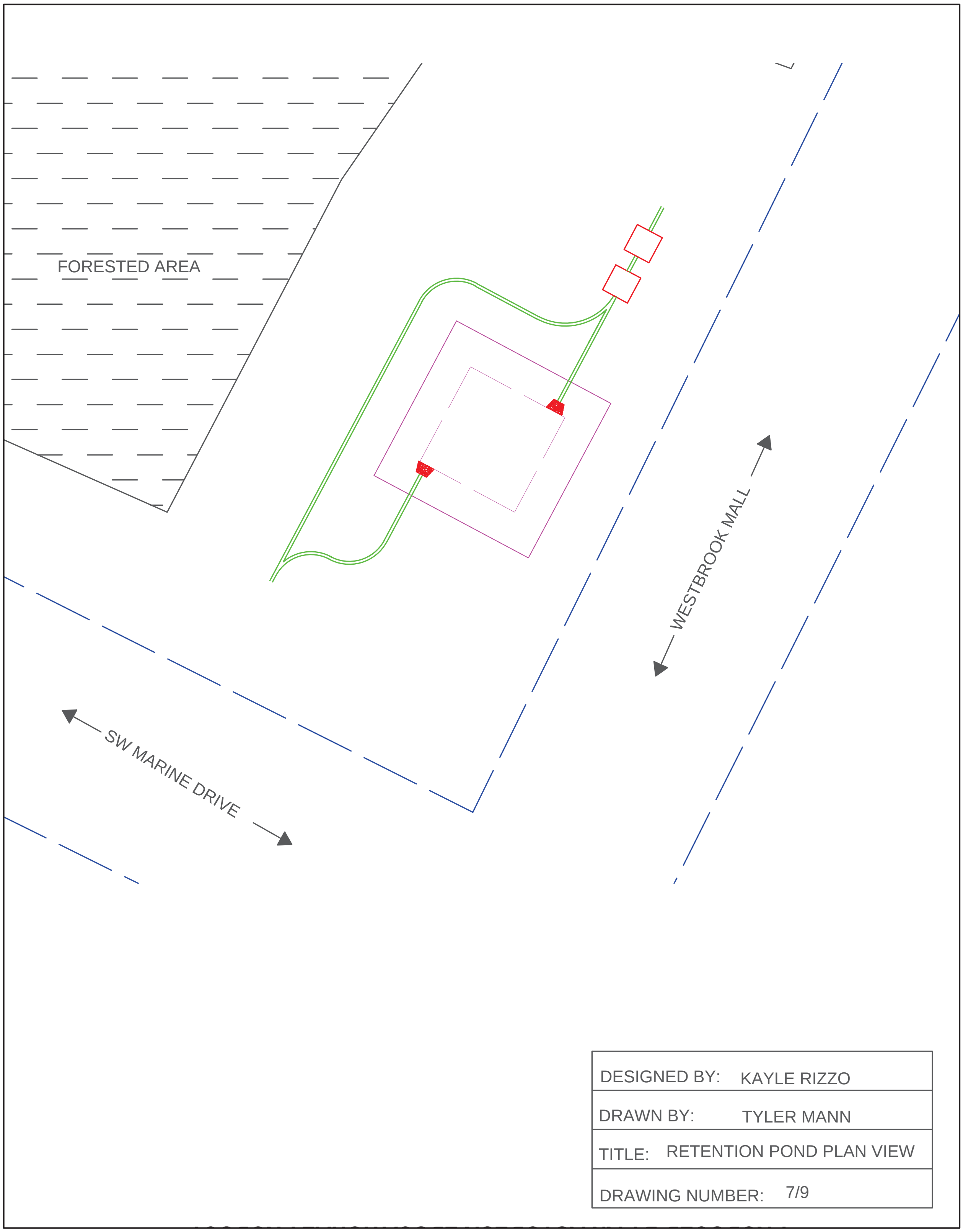
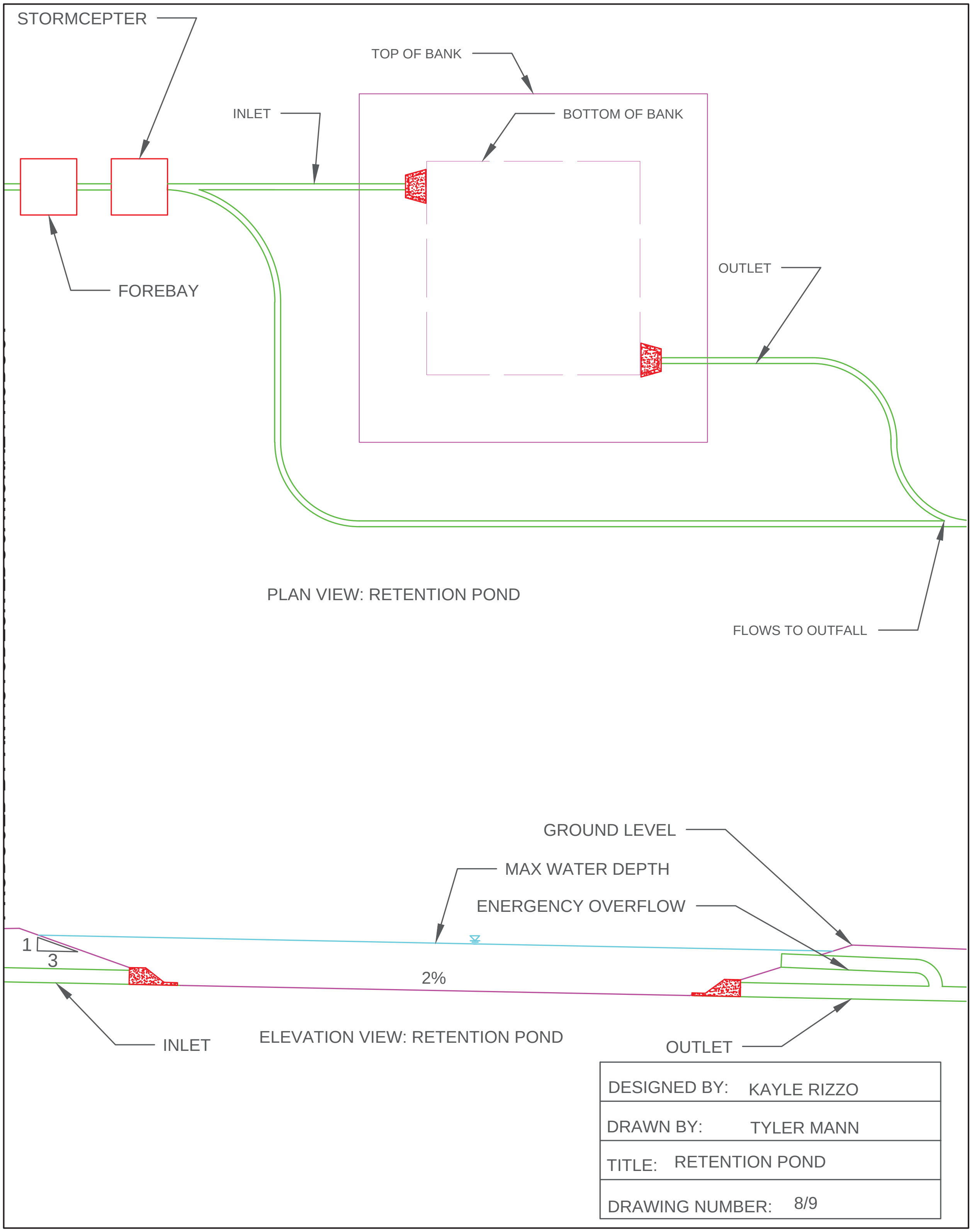
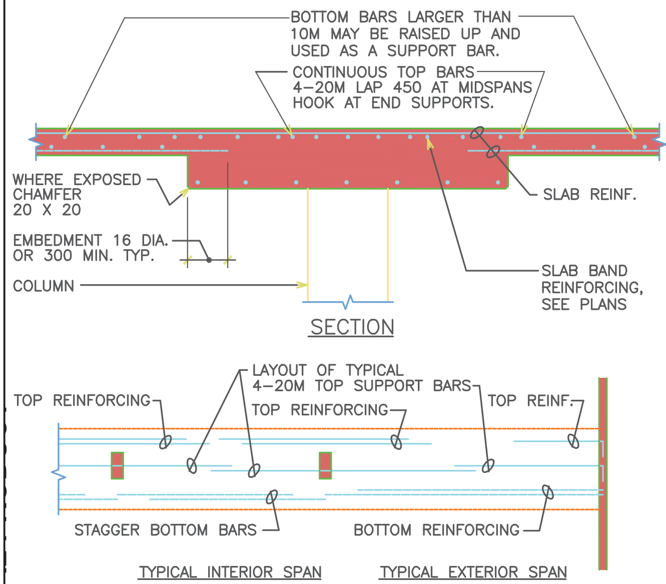
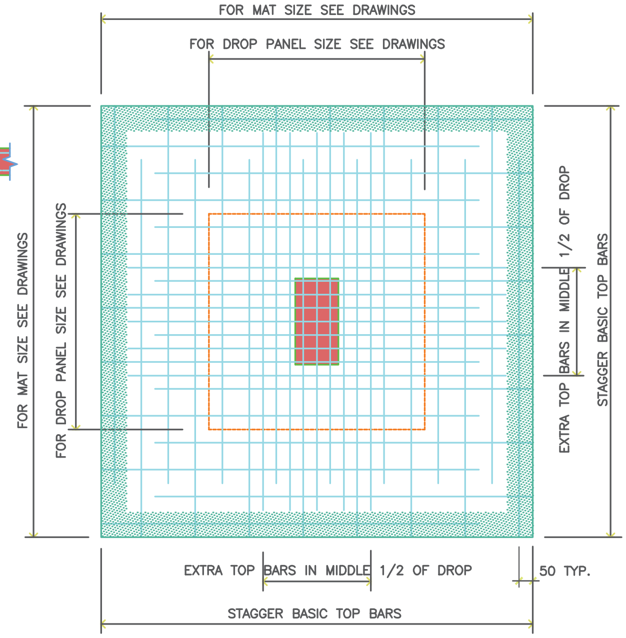
DRAWN BY: TYLER MANN
TITLE: RETENTION TANK 3
DRAWING NUMBER: 6/9


FORESTED AREA
WESTBROOK MALL
SW MARINE DRIVE
DESIGNED BY: KAYLE RIZZO
DRAWN BY: TYLER MANN
TITLE: RETENTION POND PLAN VIEW
DRAWING NUMBER: 7/9

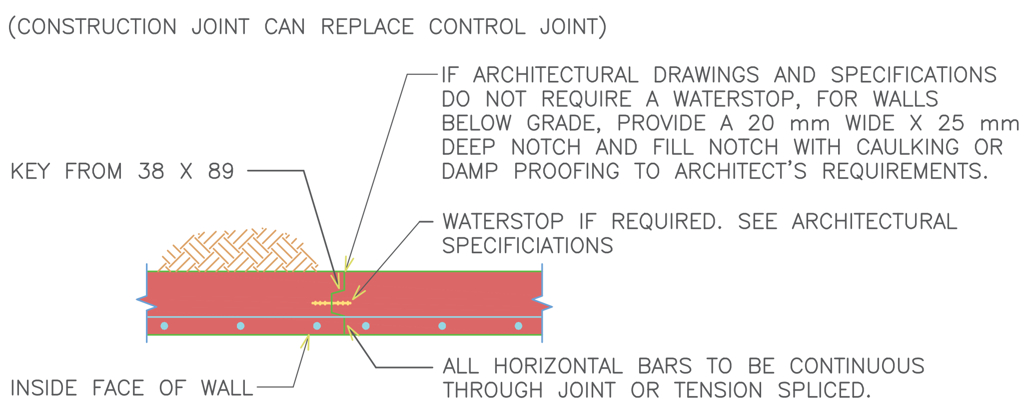

STORMCEPTER
TOP OF BANK
INLET
BOTTOM OF BANK
FOREBAY
OUTLET
PLAN VIEW: RETENTION POND
FLOWS TO OUTFALL
GROUND LEVEL
MAX WATER DEPTH
ENERGENCY OVERFLOW
1
3
2%
INLET
ELEVATION VIEW: RETENTION POND
OUTLET
DESIGNED BY: KAYLE RIZZO
DRAWN BY: TYLER MANN
TITLE: RETENTION POND
DRAWING NUMBER: 8/9



TYPICAL SLAB BAND DETAIL



TYPICAL MAT LAYOUT WITH DROP PANNELS



WALL CONSTRUCTION JOINT

NOTES:
1. POND IS CONSTRUCTED BY SOILS ON SITE IF THEY MEET STANDARDS TO BE USED AS ENGINEERED FILL
2.ADDITIONAL SOIL INVESTIGATION MAY BE REQUIRED TO DETERMINE PERMEABILITY AND ABSORPTION CAPACITY.
3. POND IS TO BE CONSTRUCTED TO ENSURE INLET IS AT THE HIGHEST POINT AND OUTLET IS AT THE LOWEST.
4.ROADS AND EXISTING PIPE ARE SHOWN IN APPROXIMATE LOCATIONS AND MAY NEED TO BE ADJUSTED ON SITE
5. TANKS ARE MADE FROM CAST IN PLACE REINFORCED CONCRETE

DESIGNED BY:	KAYLE RIZZO
DRAWN BY:	TYLER MANN
TITLE:	CONSTRUCTION DETAILS
DRAWING NUMBER:	9/9

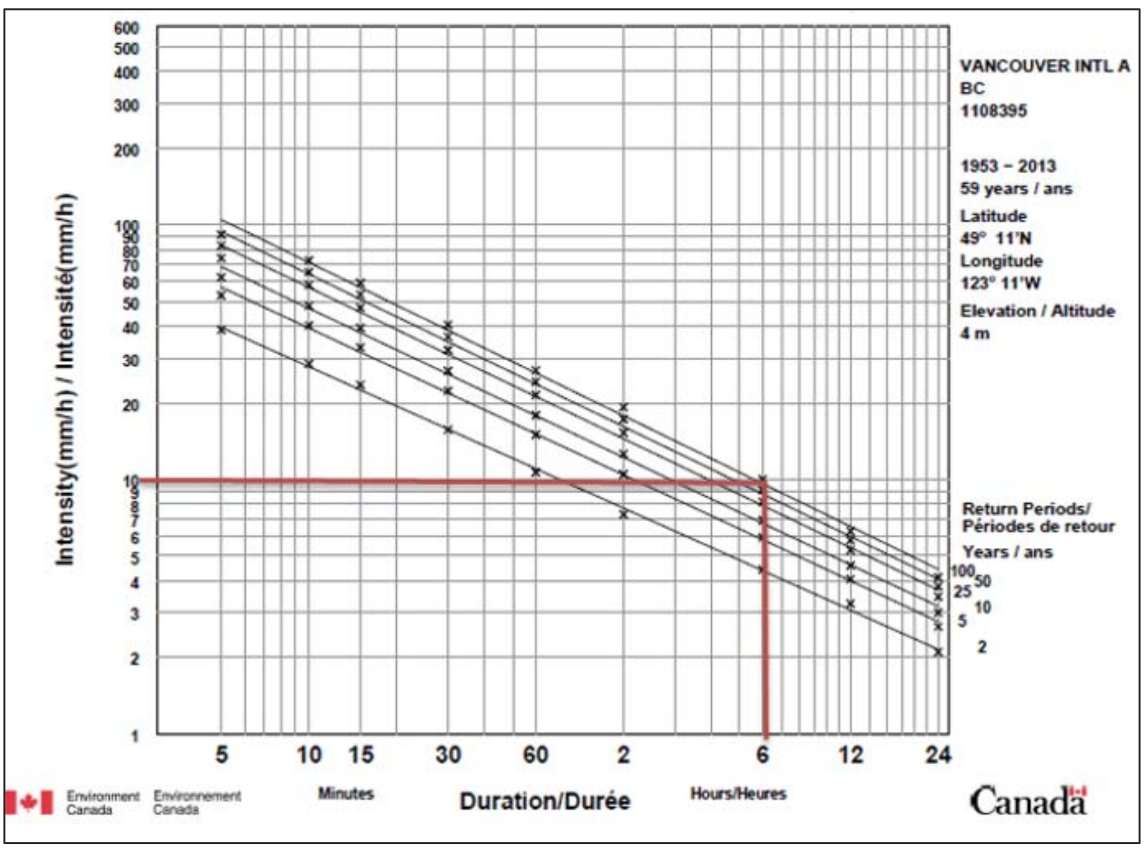
APPENDIX B – HYDROLOGICAL DESIGN CALCULATIONS

Time of Concentration Calculation:

Table 16: Average Time of Concentration At Southern Outfall

Intensity (mm/hr)	Outfall South (hrs)
0.5	9
1	7
2	6.75
3	4.5
4	3
6	4
Average TC	6

Rainfall Intensity Interpretation:



Source: Environment Canada (Nov 2015)

Figure 18: Rainfall Intensity Chart Indicating Design Intensity

Flood Volume Calculation:

Assuming only 5% of rainfall makes it into system the Q100 flood loss volume was calculated as follows:

$$Total\ Volume = Intensity \times Area \times Catchment\ Ratio$$

$$Total\ Volume = 10\frac{mm}{Hr} \times 6\ Hr \times 1{,}800{,}000 m^2 \times 4.6\%$$

$$Total\ Volume = 5000 m^3$$

The Area of Catchment for Each Retention Unit:

Table 17: Area of Catchment for Each Retention Unit

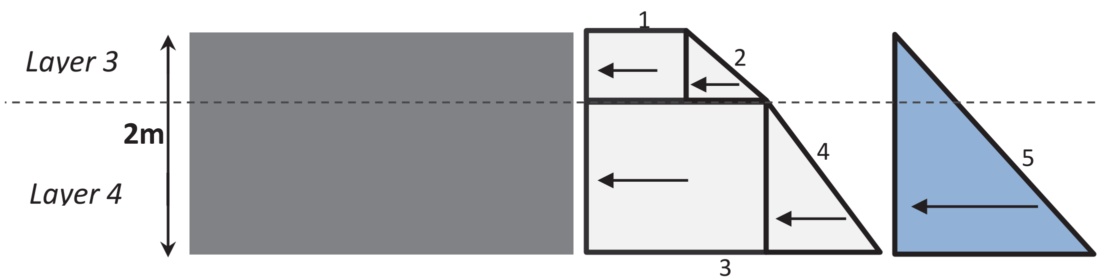
	Drainage areas (m^2)	Percentage of total	Tank Sizing (Q100) (m^3)
Southern Catchment	1,800,000		
Tank 1	180,000	10%	500
Tank 2	160,000	9%	450
Tank 3	270,000	15%	750
Existing Tanks	760,000	42%	2100
Pond	427,000	24%	6400
	Total Tank Storage		10,200

Source: Adapted from Google Maps (Nov 2015)

Figure 19: Catchment Area of Each Retention Unit

Appendix C – Geotechnical Design Calculations

Lateral Earth Pressures:



In the figure above, each stress prism has been identified to summarize the total lateral earth pressure. Layer 3 and 4 have different lateral pressure coefficients (Ka), depending on the friction angle of the soil in question.

Stress prism 1 arises from the total overburden stress, of 1m embedment of the tank:

$$\sigma'_v = \frac{1}{2} * (18.5 - 9.81) + 0.2 * (19.5 - 9.81) + 0.3 * (18 - 9.81)$$

$$\sigma'_{v1} = 8.74\ kPa$$

Stress prism 2 is the stress increase from a depth of 1m to a depth of 1.5m:

$$\sigma'_{v2} = \frac{1}{2} * (18 - 9.81) = 4.095$$

Stress prism 3 accounts for the total overburden stress, so summing 1 and 2:

$$\sigma'_{v3} = \sigma'_{v1} + \sigma'_{v2} = 12.84\ kPa$$

Stress prism 4 is the stress increase from depth of 1.5m to 3m depth:

$$\sigma'_{v4} = 1.5 * (18 - 9.81) = 12.29\ kPa$$

As mentioned above, we have assumed the water table is at ground level. The hydrostatic stress is shown in 5:

$$\sigma'_{v5} = 2 * (9.81) = 19.62\ kPa$$

Finally, the area of each stress block and each corresponding Ka are multiplied to find the total pressure per meter along each sidewall:

$$P_1 = 8.74 * \frac{1}{2} * 0.33 = 1.44\ kN/m$$

$$P_2 = 4.095 * 0.5^2 * 0.33 = 0.338\ kN/m$$

$$P_3 = 12.08 * 1.5 * 0.307 = 5.56\ kN/m$$

$$P_4 = 12.3 * 1.5 * 0.307 * 0.5 = 2.83\ kN/m$$

$$P_5 = 9.81 * 2^2 * 0.5 = 19.62\ kN/m$$

$$\boldsymbol{\sum P_i = 30\ kN/m}$$

Retention Tank Bearing Capacity Check:

Unit weight of water is assumed: 9.81 kN/m^3

$$Hydrostatic\ Bearing\ Pressure = 2m * 9.81\frac{kN}{m^3} = 20\ kPa$$

$$Tank\ Weight = [(2 * 15m * 15m * 0.3m) + (12 * 2 * 0.3m * 0.3m)] * 2400\frac{kg}{m^3}$$

$$Tank\ Weight = 415{,}000\ kg$$

$$Tank\ Bearing\ Pressure = \frac{415{,}000\ kg * 9.8\frac{m}{s^2}}{15 * 15m}$$

$$Tank\ Pressure = 18\ kPa$$

Allowable bearing pressure on medium sand is 145 kPa. (Table 12.3 Budhu, 2010). With a factor of safety of 3 accounting for both the water table being present above the structure, and uncertainty in soil conditions:

$$Q_{allowable} = \frac{145}{3} = 48\ kPa$$

$$48\ kPa\ >\ 38\ kPa\ \checkmark$$

Appendix D – Structural Design Calculations

Appendix D provides detailed design calculations for the individual structural elements of the underground detention tanks. The structural design and analysis below is for the largest tank (i.e. governing design), and is based on the following design loads:

Structural Gravity Loading:

Dead Load = Soil Weight (20 kN/m3) + Pavement Weight (24 kN/m3) = 25 kPa

Live Load = Vehicle Live Load = 2.4 kPa

Snow Load = 2.0 kPa

Based on the NBCC requirements it was determined that the governing loading case for the structure is:

Governing Load Combination: 1.25 DL + 1.5 LL + 0.5 SL

The gravity loads are applied to the tank along the top slab. The top slab is supported by the perimeter walls and the columns. The load that acts along the column lines:

$$w_f = 1.25(25\ kPa) + 1.5(2.4\ kPa) + 0.5(2.0\ kPa) = 35.9\ kPa$$

$$w_f = 35.9\ kPa * 6m = 215\ kN/m$$

A structural model was created for the tank and the design loads were applied. The structural model was analysed using the governing load combination. Based on the analysis, the maximum moment and shear force in the top slab are:

Max Shear Force = 500 kN

Max Bending Moment = 415 kNm

The maximum shear force and bending moment are used to design the structural elements, based on the reinforced concrete design code (CSA A23.3).

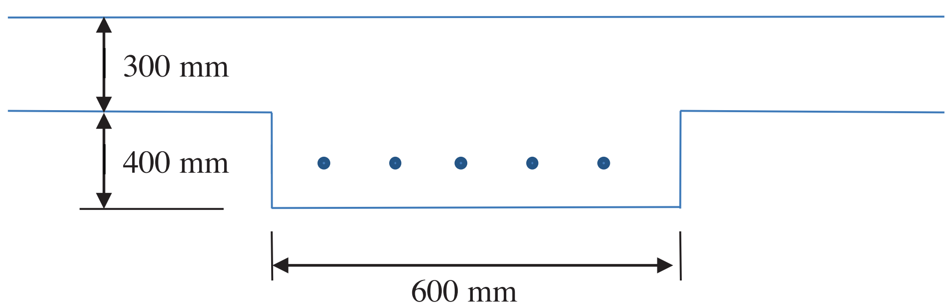
Flexural Member Design (Moment & Shear):

The concrete design parameters (CSA A23.3):

f_y	400 MPa
f'c	30 MPa
φ_s	0.85
φ_c	0.65
α_1	0.805
β_1	0.895

The concrete design was done using an Excel spreadsheet by trial and error. The trial dimensions for the slab / slab band system are as follows:

A_s	2500 mm^2
h	700 mm
d	650 mm
b_f	600 mm
b_t	600 mm



Determination of Neutral Axis:

$$a = \frac{\phi_s f_y A_s}{\alpha_1 \phi_c f_c b} = \frac{0.85 * 400\text{ MPa} * 2500\text{ mm}^2}{0.805 * 0.65 * 30\ MPa * 600mm} = 90\ mm$$

Determination of Moment Resistance:

$$M_r = \phi_s f_y A_s \left(d - \frac{a}{2}\right) = 0.85 * 400\text{ MPa} * 2500\text{ mm}^2 \left(650 - \frac{90}{2}\right) = 514\ kNm$$

$$M_r = 514\ kNm \geq 415\ kNm = M_f \qquad O.K.$$

Check Minimum Steel Yielding Requirements:

$$\frac{700}{700 + f_y} \geq \frac{c}{\beta d} \quad \rightarrow \quad 0.57 \geq 0.14 \quad O.K.$$

$$Therefore\ use\ 5 - 25M\ longitudinal\ bars$$

Determine the shear reinforcement requirement and the shear resistance of the slab:

$$\beta = \frac{230}{1000 + d_v} = \frac{230}{1000 + 0.9 * 650mm} = 0.145$$

$$V_c = \phi_c \lambda \beta \sqrt{f_c} b_w d_v = 0.65 * 1 * 0.145 * \sqrt{30} * 600 * 585 = 182\ kN$$

The shear resistance of the concrete is less than the factored shear force, therefore transverse reinforcement (stirrups) are required:

$$\text{Max Spacing} = 0.7 * \text{d}_v = 400\ mm \quad \rightarrow \quad Try\ 10M\ @\ 250mm$$

$$V_s = \frac{\phi_s A_v f_y d_v \cot\theta}{s} = \frac{0.85 * 200mm * 400Mpa * 585mm * 1.43}{250mm} = 334\ kN$$

$$V_r = V_c + V_s = 182\ kN + 334\ kN = 516\ kN$$

$$V_r = 516\ kN \geq 500\ kN = V_f \qquad O.K.$$

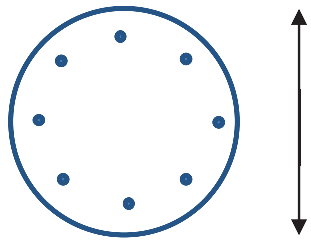
Check shear spacing requirements:

$$V_r\ max = 0.25 \phi_c f_c b_w d_v = 0.25 * 0.65 * 30MPa * 600mm * 585mm = 1711\ kN$$

$$A_v\ min = 0.06\sqrt{f_c}\left(\frac{b_w S}{f_y}\right) = 0.06\sqrt{30}\left(\frac{600 * 250}{400}\right) = 174mm\ (< 200mm) \quad O.K.$$

Column Design (Compression):

Based on the analysis, the maximum column load = 1000 kN



Columns are 300 mm in diameter, 2000 mm tall, and reinforced with 8 – 20M longitudinal bars and 10M spirals.

$$A_g = \frac{\pi d^2}{4} = \frac{\pi(300mm)^2}{4} = 70{,}686\ mm^2$$

$$A_{st} = 8 - 20M\ bars = 8(300\ mm^2) = 2400\ mm^2$$

$$\rho_t = \frac{A_{st}}{A_g} = 0.034 \quad (< 0.08\ max) \quad O.K.$$

Calculate the Axial Resistance of the column shown above:

$$\mathrm{P}_r = P_c + P_s = \alpha_1 \phi_c f_c (A_g - A_{st}) + \phi_s f_y (A_{st})$$

$$\mathrm{P}_r = 0.805(0.65)(30Mpa)(70{,}686 - 2400) + 0.85(400)(2400) = 1888\ kN$$

$$P_r = 1888\ kN \geq 1000\ kN = P_f \qquad O.K.$$

As shown above, the factored resistance is significantly larger than the factored resistance. This is required to resist the bending moments introduced into the columns through the continuous connection at the column ends.

APPENDIX E – DETAILED PROJECT SCHEDULE

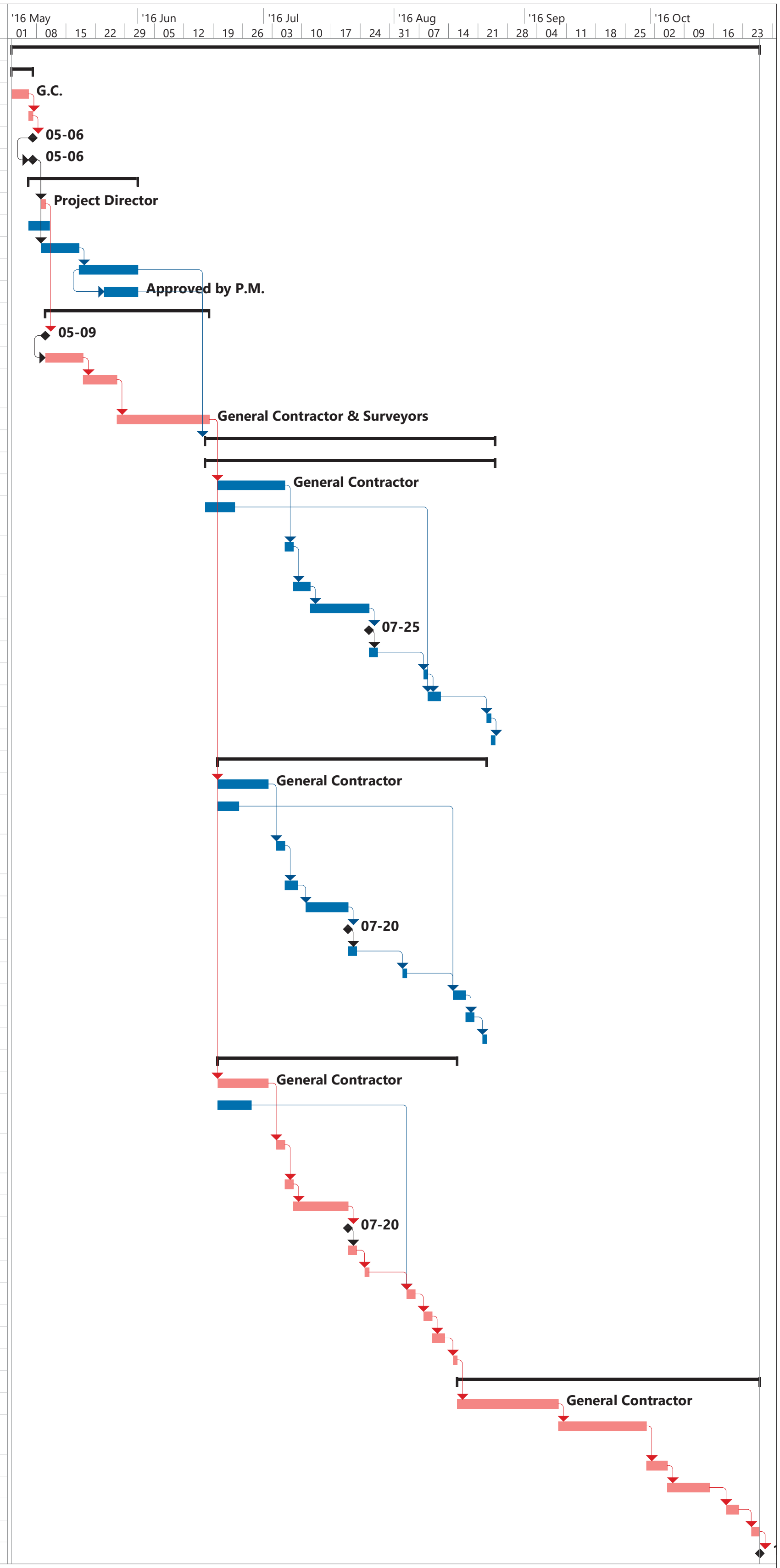
Table 18: Detailed List Of Project Tasks

ID	Task Name	Duration	Start	Finish
1	**UBC Stormwater Management Plan**	**128 days**	**May 02**	**Oct 26**
2	**Project Start Up**	**5 days**	**May 02**	**May 06**
3	Tender & award to prime contractor	4 days	May 02	May 05
4	Sign contracts, documentation	1 day	May 06	May 06
5	Project kick-off mtg	0 days	May 06	May 06
6	Submit relevant documents to contractor	0 days	May 06	May 06
7	**Engineering**	**18 days**	**May 06**	**May 31**
8	Site hazard assessment	1 day	May 09	May 09
9	Full budget & expenditure	3 days	May 06	May 10
10	Approval of shop drawings	7 days	May 09	May 17
11	Long lead material procurement	2 wks	May 18	May 31
12	QA/QC Plan Developed	6 days	May 24	May 31
13	**Site Mobilization**	**29 days**	**May 09**	**Jun 17**
14	Set up fencing & signs	0 days	May 09	May 09
15	Clear & grub sites	7 days	May 10	May 18
16	Create storage area for materials/equipment	6 days	May 19	May 26
17	Survey layout & grading	16 days	May 27	Jun 17
18	**Foundations & Concrete Work**	**49 days**	**Jun 17**	**Aug 24**
19	**Save On Foods Tank**	**49 days**	**Jun 17**	**Aug 24**
20	Excavate to required dimension	12 days	Jun 20	Jul 05
21	Trenching & pipe laying to connect existing system	5 days	Jun 17	Jun 23
22	Install lateral earth support (shoring cage, struts)	2 days	Jul 06	Jul 07
23	Levelling & grading	2 days	Jul 08	Jul 11
24	Formwork & reinforcement cages	10 days	Jul 12	Jul 25
25	Site inspection, approval	0 days	Jul 25	Jul 25
26	Pour bottom slab, side walls & supports	2 days	Jul 26	Jul 27
27	Pour top of tank	1 day	Aug 08	Aug 08
28	Inlet & outlet connections	3 days	Aug 09	Aug 11
29	Backfilling & cover	1 day	Aug 23	Aug 23
30	Landscaping & clean up	1 day	Aug 24	Aug 24
31	**Thunderbird Arena Tank**	**46 days**	**Jun 20**	**Aug 22**
32	Excavations to required dimension	10 days	Jun 20	Jul 01
33	Trenching & pipe laying to connect existing system	5 days	Jun 20	Jun 24
34	Install lateral earth support (shoring cage, struts)	2 days	Jul 04	Jul 05
35	Levelling & grading	3 days	Jul 06	Jul 08
36	Formwork & reinforcement cages	8 days	Jul 11	Jul 20
37	Site inspection, approval	0 days	Jul 20	Jul 20
38	Pour bottom slab, side walls & supports	2 days	Jul 21	Jul 22
39	Pour top of tank	1 day	Aug 03	Aug 03
40	Inlet & outlet connections	3 days	Aug 15	Aug 17
41	Backfilling & cover	2 days	Aug 18	Aug 19
42	Landscaping & clean up	1 day	Aug 22	Aug 22

ID	Task Name	Duration	Start	Finish
43	**RCMP Parking Lot Tank**	**41 days**	**Jun 20**	**Aug 15**
44	Excavations to required dimension	10 days	Jun 20	Jul 01
45	Trenching & pipe laying to connect existing system	6 days	Jun 20	Jun 27
46	Install lateral earth support (shoring cage, struts)	2 days	Jul 04	Jul 05
47	Levelling & grading	2 days	Jul 06	Jul 07
48	Formwork & reinforcement cages	9 days	Jul 08	Jul 20
49	Site inspection, approval	0 days	Jul 20	Jul 20
50	Pour bottom slab, side walls & supports	2 days	Jul 21	Jul 22
51	Pour top of tank	1 day	Jul 25	Jul 25
52	Inlet & outlet connections	2 days	Aug 04	Aug 05
53	Backfilling & cover	2 days	Aug 08	Aug 09
54	Concrete patching & replacement	3 days	Aug 10	Aug 12
55	Final parking lot repairs & clean up	1 day	Aug 15	Aug 15
56	**Retention Pond**	**52 days**	**Aug 16**	**Oct 26**
57	Excavate pond area & slopes to spec	18 days	Aug 16	Sep 08
58	Trenching & pipe laying to connect existing system	15 days	Sep 09	Sep 29
59	Inlet connection from Wesbrook Mall	3 days	Sep 30	Oct 04
60	Outlet connection to SW Marine Drive	8 days	Oct 05	Oct 14
61	Backfilling & cover	3 days	Oct 19	Oct 21
62	Landscaping & clean up	2 days	Oct 25	Oct 26
63	Handover & Comissioning	0 days	Oct 26	Oct 26

KREW Hydraulic Consulting Ltd.

ID	Task Name	Duration
1	**UBC Stormwater Management Plan**	**128 days**
2	**Project Start Up**	**5 days**
3	Tender & award to prime contractor	4 days
4	Sign contracts, documentation	1 day
5	Project kick-off mtg	0 days
6	Submit relevant documents to contractor	0 days
7	**Engineering**	**18 days**
8	Site hazard assessment	1 day
9	Full budget & expenditure	3 days
10	Approval of shop drawings	7 days
11	Long lead material procurement	2 wks
12	QA/QC Plan Developed	6 days
13	**Site Mobilization**	**29 days**
14	Set up fencing & signs	0 days
15	Clear & grub sites	7 days
16	Create storage area for materials/equipment	6 days
17	Survey layout & grading	16 days
18	**Foundations & Concrete Work**	**49 days**
19	**Save On Foods Tank**	**49 days**
20	Excavate to required dimension	12 days
21	Trenching & pipe laying to connect existing system	5 days
22	Install lateral earth support (shoring cage, struts)	2 days
23	Levelling & grading	2 days
24	Formwork & reinforcement cages	10 days
25	Site inspection, approval	0 days
26	Pour bottom slab, side walls & supports	2 days
27	Pour top of tank	1 day
28	Inlet & outlet connections	3 days
29	Backfilling & cover	1 day
30	Landscaping & clean up	1 day
31	**Thunderbird Arena Tank**	**46 days**
32	Excavations to required dimension	10 days
33	Trenching & pipe laying to connect existing system	5 days
34	Install lateral earth support (shoring cage, struts)	2 days
35	Levelling & grading	3 days
36	Formwork & reinforcement cages	8 days
37	Site inspection, approval	0 days
38	Pour bottom slab, side walls & supports	2 days
39	Pour top of tank	1 day
40	Inlet & outlet connections	3 days
41	Backfilling & cover	2 days
42	Landscaping & clean up	1 day
43	**RCMP Parking Lot Tank**	**41 days**
44	Excavations to required dimension	10 days
45	Trenching & pipe laying to connect existing system	6 days
46	Install lateral earth support (shoring cage, struts)	2 days
47	Levelling & grading	2 days
48	Formwork & reinforcement cages	9 days
49	Site inspection, approval	0 days
50	Pour bottom slab, side walls & supports	2 days
51	Pour top of tank	1 day
52	Inlet & outlet connections	2 days
53	Backfilling & cover	2 days
54	Concrete patching & replacement	3 days
55	Final parking lot repairs & clean up	1 day
56	**Retention Pond**	**52 days**
57	Excavate pond area & slopes to spec	18 days
58	Trenching & pipe laying to connect existing system	15 days
59	Inlet connection from Wesbrook Mall	3 days
60	Outlet connection to SW Marine Drive	8 days
61	Backfilling & cover	3 days
62	Landscaping & clean up	2 days
63	Handover & Comissioning	0 days



Project: UBC SWMP Project Sch
Date: Mar 12

Task		Inactive Milestone		Start-only		Critical Split	
Split		Inactive Summary		Finish-only		Progress	
Milestone		Manual Task		External Tasks		Manual Progress	
Summary		Duration-only		External Milestone			

Appendix F – Detailed Cost Estimate

Table 19: Detailed Cost Estimate Sheet

ID	Phase	Quantity	Unit	Unit Rate	Amount	Sub-Total
D1	**Detailed Design**					
D1.1	Engineer-In-Training	300	hr	$121	$36,300	
D1.3	Project Engineer	225	hr	$159	$35,775	
D1.4	Specialist Engineer	135	hr	$195	$26,325	
D1.5	Management Engineer	180	hr	$223	$40,140	
D1.11	Technologist (x2)	600	hr	$111	$66,600	
						$205,140
E15	**Project Start-up**					
E15.12	Tender & award to prime contractor	1	N/A	Lump Sum	$10,000	
E15.13	Sign contracts, documentation	1	N/A	Lump Sum	$1,500	
E15.17	Project kick-off meeting	1	N/A	Lump Sum	$2,000	
E15.19	Submit relevant documents	1	N/A	Lump Sum	$2,000	
						$15,500
E17	**Engineering**					
E17.2	Site hazard assessment	1	N/A	Lump Sum	$2,000	
E17.9	Full budget & expenditure	1	N/A	Lump Sum	$15,000	
E17.11	Approval of shop drawings	1	N/A	Lump Sum	$20,000	
E17.18	Long lead material procurement	1	N/A	Lump Sum	$30,000	
E17.22	QA/QC plan developed	1	N/A	Lump Sum	$25,000	
E17.25	Subconsultant - Geotechnical	1	N/A	Lump Sum	$200,000	
E17.25	QA/QC Inspections and Testing	1	N/A	Lump Sum	$60,000	
						$352,000
C01	**Site Mobilization**					

C01.2	Set up fencing & signs	524	m	19.50	$10,218	
C01.8	Clear & grub sites	5000	m^2	10.00	$50,000	
C01.9	Project office set-up	1	N/A	Lump Sum	$5,000	
C01.9	Create storage area for materials	1000	m^2	8.00	$8,000	
C01.10	Survey layout & grading	440	hr	200.00	$88,000	
C01.13	Traffic Control	1	N/A	Lump Sum	$10,000	
						$171,218
C11	**Foundations & Concrete**					
C11.6	Excavate to required dimension	2526	m^3	8.10	$20,461	
C11.8	Trenching	100	m	23.15	$2,315	
C11.21	1000mm Concrete Pipe	100	m	1110.00	$111,000	
C11.25	Install shoring cage, struts	65	m	300.00	$19,500	
C11.02	Levelling & grading	200	m^2	12.00	$2,400	
C11.18	Formwork	842	m^2	80.00	$67,360	
C11.20	Site inspection, approval	1	N/A	Lump Sum	$2,000	
C11.21	Strip Footings	45	m^3	271.00	$12,195	
C11.22	Top Slab	252.6	m^3	271.00	$68,455	
C11.23	Bottom Slab	168.4	m^3	271.00	$45,636	
C11.24	Slab Band	60	m^3	271.00	$16,260	
C11.25	Tank Perimeter Walls	120	m^3	271.00	$32,520	
C11.26	Columns	3.82	m^3	271.00	$1,034	
C11.32	Rebar Cages	842	m^2	130.00	$109,460	
C26.42	Oil/Grit Separator - STC 14000	2	Unit	50000.00	$100,000	
C26.42	Oil/Grit Separator - Stormceptor Max	1	Unit	75000.00	$75,000	
C11.9	Backfilling & cover	842	m^3	10.21	$8,597	
C11.16	Concrete patching & replacement	630	m^2	110.00	$69,300	

C11.12	Asphalt patching & replacement	630	m^2	90.00	$56,700	
C11.4	Landscaping	870	m^2	24.00	$20,880	
C11.15	Offsite earthworks removal	1684	m^3	11.12	$18,726	
						$859,799
C26	**Retention Pond**					
C26.3	Excavate pond area & slopes	6412	m^3	8.10	$51,937	
C26.6	Trenching for inlet/outlet connection	250	m	23.15	$5,788	
C26.7	Inlet Pipe (1000 mm)	50	m	1110.00	$55,500	
C26.8	Outlet Pipe (1000mm)	50	m	1110.00	$55,500	
C26.13	Geotextile	2025	m^2	3.75	$7,594	
C26.15	Riser	113	m^3	220.00	$24,860	
C26.30	Landscaping	2000	m^2	24.00	$48,000	
C26.42	Oil/Grit Separator - Stormceptor Max	1	Unit	75000.00	$75,000	
C11.15	Offsite earthworks removal	6412	m^3	11.12	$71,301	
						$395,480
T01	**Project Close out & Handover**					
T01.01	Remove fencing	524	m	5.00	$2,620	
T01.02	Site Clean Up	5000	m^2	10.00	$50,000	
T01.15	Draft as-built drawings	1	N/A	Lump Sum	$25,000	
T01.17	Submit relevant documents	1	N/A	Lump Sum	$2,000	
						$79,620
					Subtotal	$2,078,757
					Contingency (10%)	$207,876
					GST (5%)	$103,938
					PST (7%)	$145,513
					Total:	**$2,536,083**

APPENDIX G – SITE PHOTOS

Source: Kayle Rizzo (Nov 2015)

Figure 20: Location Of Detention Tank 1

Source: Kayle Rizzo (Nov 2015)

Figure 21: Location Of Detention Tank 2

Source: Kayle Rizzo (Nov 2015)

Figure 22: Location Of Detention Tank 3

Source: Kayle Rizzo (Nov 2015)

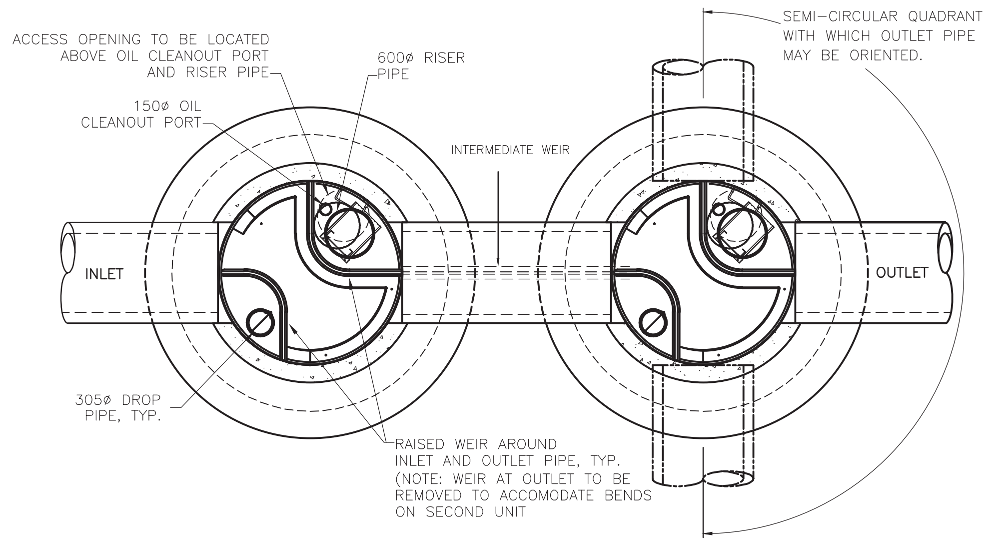
Figure 23: Location Of Retention Pond

APPENDIX H – STORMCEPTOR SIZING & DESIGN

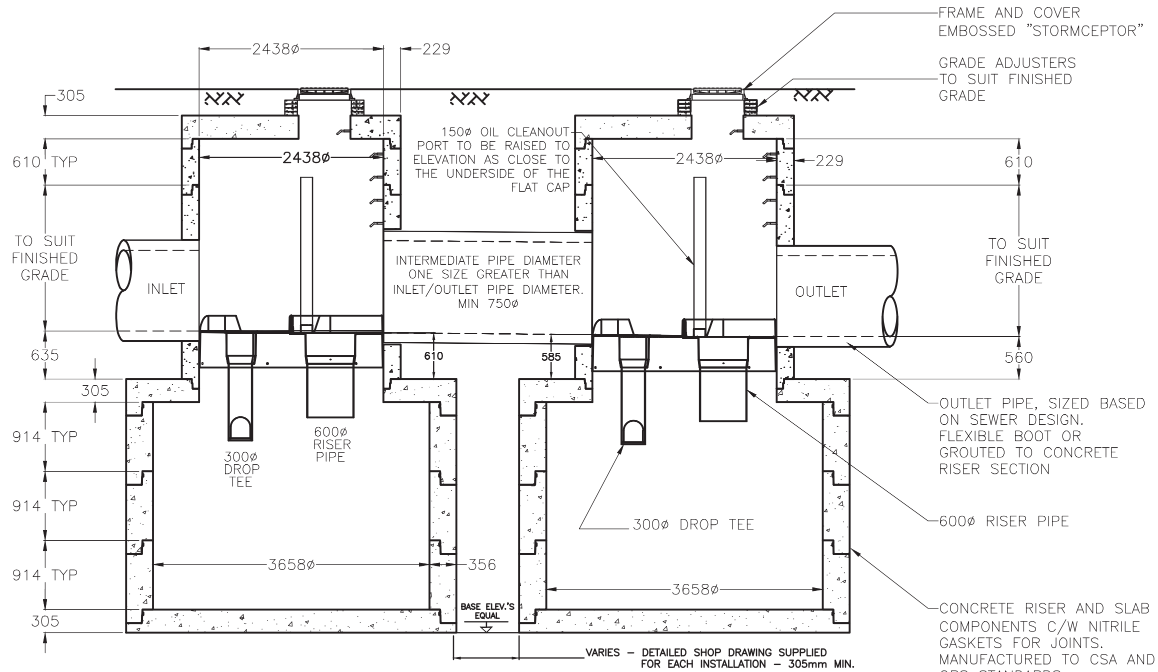
Appendix H provides detailed design calculations and product specifications for the individual Stormceptor treatment units provided by Imbrium Solutions Inc.

DRAWING NOT TO BE USED FOR CONSTRUCTION

THE STORMCEPTOR SYSTEM IS PROTECTED BY ONE OR MORE OF THE FOLLOWING PATENTS:
United States Patent No. 5,753,115 • 5,849,181 • 6,068,765 • 6,371,690 • 7,582,216 • 7,666,303 | Australia Patent No. 693,164 • 707,133 • 729,096 • 779,401 • 289,647 • 2008,279,378 • 2008,288,900 | Canadian Patent No. 2,009,280 • 2,137,942 • 2,175,277 • 2,180,305 • 2,180,383 • 2,206,338 • 2,327,768 | Indonesian Patent No. 007058 | Japan Patent No. 3581233 • 9-11476 | Korea Patent No. 10-1451593 • 0519212 | Malaysia Patent No. 118987 | New Zealand Patent No. 314,646 • 583,583 • 583,008 | South African Patent No. 2010/00683 • 2010/01796 |



PLAN VIEW



SECTION VIEW

I:\IMBRIUM\PRIVATE\CAD\STANDARD PRODUCT LINE\STORMCEPTOR STC\STC - NEW IMBRIUM METRIC TEMPLATE\STC 14000.DWG 1/6/2015 11:34 AM

Stormceptor®

imbrium®
WWW.IMBRIUMSYSTEMS.COM
605 GLOBAL WAY, SUITE 113, LINTHICUM, MD 21231
USA 888-279-8826 CA 800-565-4801 INTL +1-416-960-9900

STC 14000
STANDARD MODEL

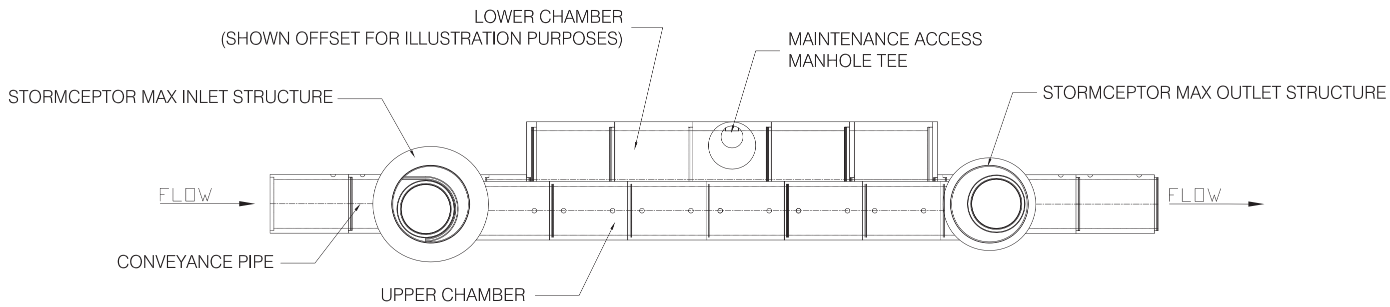
####

REV #	DATE	REVISION DESCRIPTION	BY

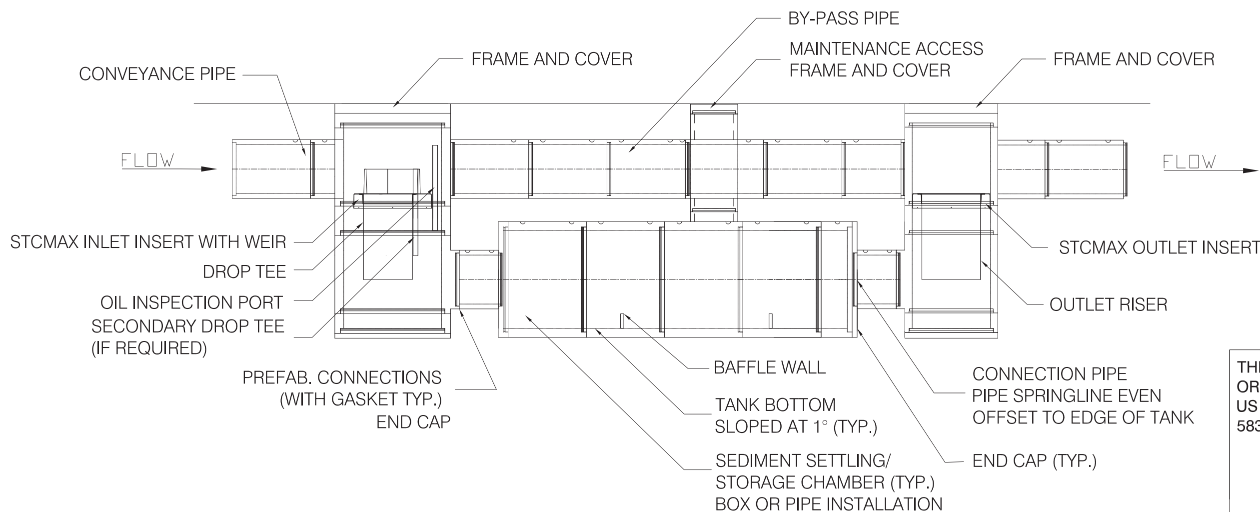
SHEET NUMBER 1 OF 1

DATE: ######## | SCALE: 100 | PROJECT No.: ##### | DRAWN: ### | CHECKED: ###

DRAWING NOT TO BE USED FOR CONSTRUCTION



PLAN VIEW
NTS



PROFILE VIEW
NTS

THE STORMCEPTOR MAX SYSTEM IS PROTECTED BY ONE OR MORE OF THE FOLLOWING PATENTS:
US PATENT NO. 7,582,216, AUS NO. 2008,288,900, NZ NO. 583,583, ZA NO. 2010,01,796, OTHER PATENTS PENDING

FOR SITE SPECIFIC DRAWINGS PLEASE CONTACT YOUR LOCAL IMBRIUM SYSTEMS REPRESENTATIVE. SITE SPECIFIC DRAWINGS ARE BASED ON THE BEST AVAILABLE INFORMATION AT THE TIME. SOME FIELD REVISIONS TO THE SYSTEM LOCATION OR CONNECTION PIPING MAY BE NECESSARY BASED ON AVAILABLE SPACE OR SITE CONFIGURATION REVISIONS.

MARK	DATE	REVISION DESCRIPTION	BY
#	#	#	#
#	#	#	#
#	#	#	#
1	7/10/2015	REVISE OUTLET INSERT & DROP TEE	JSK
0	10/01/2014	INTIAL RELEASE	BSF

STANDARD DETAIL

Stormceptor® MAX

Scale = nts

www.imbriumsystems.com
info@imbriumsystems.com

imbrium®
605 Global Way, Suite 113, Linthicum, MD 21090
USA 888-279-8826 CA 800-565-4801 INTL +1-416-960-9900

STORMCEPTOR®

DATE: 10-01-14	
DESIGNED: BSF	DRAWN: BSF
CHECKED: JSK	APPROVED: SP
PROJECT #: #####	PROJECT NAME: #####
SHEET: 1 OF 1	

Detailed Stormceptor Sizing Report – Tank 1

Project Information & Location			
Project Name	CIVL 446 Capstone	**Project Number**	693
City		**State/ Province**	British Columbia
Country	Canada	**Date**	3/29/2016
Designer Information		**EOR Information (optional)**	
Name	a a	**Name**	
Company	UBC	**Company**	
Phone #	123-123-1234	**Phone #**	
Email	lukszeho@hotmail.com	**Email**	

Stormwater Treatment Recommendation

The recommended Stormceptor Model(s) which achieve or exceed the user defined water quality objective for each site within the project are listed in the below Sizing Summary table.

Site Name	Tank 1
Recommended Stormceptor Model	STC 14000
Target TSS Removal (%)	70.0
TSS Removal (%) Provided	71
PSD	NJDEP
Rainfall Station	VANCOUVER - KITSILANO HI

The recommended Stormceptor model achieves the water quality objectives based on the selected inputs, historical rainfall records and selected particle size distribution.

Stormceptor Sizing Summary		
Stormceptor Model	**% TSS Removal Provided**	**% Runoff Volume Captured Provided**
STC 300	16	40
STC 750	36	64
STC 1000	48	64
STC 1500	49	64
STC 2000	53	82
STC 3000	55	82
STC 4000	60	93
STC 5000	60	93
STC 6000	63	97
STC 9000	68	99
STC 10000	67	99
STC 14000	71	100
Stormceptor MAX	Custom	Custom

Stormceptor

The Stormceptor oil and sediment separator is sized to treat stormwater runoff by removing pollutants through gravity separation and flotation. Stormceptor's patented design generates positive TSS removal for each rainfall event, including large storms. Significant levels of pollutants such as heavy metals, free oils and nutrients are prevented from entering natural water resources and the re-suspension of previously captured sediment (scour) does not occur.
Stormceptor provides a high level of TSS removal for small frequent storm events that represent the majority of annual rainfall volume and pollutant load. Positive treatment continues for large infrequent events, however, such events have little impact on the average annual TSS removal as they represent a small percentage of the total runoff volume and pollutant load.

Design Methodology

Stormceptor is sized using PCSWMM for Stormceptor, a continuous simulation model based on US EPA SWMM. The program calculates hydrology using local historical rainfall data and specified site parameters. With US EPA SWMM's precision, every Stormceptor unit is designed to achieve a defined water quality objective. The TSS removal data presented follows US EPA guidelines to reduce the average annual TSS load. The Stormceptor's unit process for TSS removal is settling. The settling model calculates TSS removal by analyzing:

- Site parameters
- Continuous historical rainfall data, including duration, distribution, peaks & inter-event dry periods
- Particle size distribution, and associated settling velocities (Stokes Law, corrected for drag)
- TSS load
- Detention time of the system

Hydrology Analysis

PCSWMM for Stormceptor calculates annual hydrology with the US EPA SWMM and local continuous historical rainfall data. Performance calculations of Stormceptor are based on the average annual removal of TSS for the selected site parameters. The Stormceptor is engineered to capture sediment particles by treating the required average annual runoff volume, ensuring positive removal efficiency is maintained during each rainfall event, and preventing negative removal efficiency (scour).
Smaller recurring storms account for the majority of rainfall events and average annual runoff volume, as observed in the historical rainfall data analyses presented in this section.

Rainfall Station

State/Province	British Columbia	**Total Number of Rainfall Events**	5128
Rainfall Station Name	VANCOUVER - KITSILANO HI	**Total Rainfall (mm)**	24905.7
Station ID #	4201	**Average Annual Rainfall (mm)**	1245.3
Coordinates	49°15'N, 123°9'W	**Total Evaporation (mm)**	600.8
Elevation (ft)		**Total Infiltration (mm)**	18169.0
Years of Rainfall Data	20	**Total Rainfall that is Runoff**	6135.9

Notes

- Stormceptor performance estimates are based on simulations using PCSWMM for Stormceptor, which uses the EPA Rainfall and Runoff modules.
- Design estimates listed are only representative of specific project requirements based on total suspended solids (TSS) removal defined by the selected PSD, and based on stable site conditions only, after construction is completed.
- For submerged applications or sites specific to spill control, please contact your local Stormceptor representative for further design assistance.

Drainage Area	
Total Area (ha)	18
Imperviousness %	27.0

Up Stream Storage	
Storage (ha-m)	Discharge (cms)
0.000	0.000

Water Quality Objective	
TSS Removal (%)	70.0
Runoff Volume Capture (%)	30.00
Oil Spill Capture Volume (L)	
Peak Conveyed Flow Rate (L/s)	
Water Quality Flow Rate (L/s)	

Up Stream Flow Diversion	
Max. Flow to Stormceptor (cms)	

Design Details	
Stormceptor Inlet Invert Elev (m)	
Stormceptor Outlet Invert Elev (m)	
Stormceptor Rim Elev (m)	
Normal Water Level Elevation (m)	
Pipe Diameter (mm)	500
Pipe Material	CIP - cast iron
Multiple Inlets (Y/N)	No
Grate Inlet (Y/N)	No

Particle Size Distribution (PSD)

Removing the smallest fraction of particulates from runoff ensures the majority of pollutants, such as metals, hydrocarbons and nutrients are captured. The table below identifies the Particle Size Distribution (PSD) that was selected to define TSS removal for the Stormceptor design.

NJDEP		
Particle Diameter (microns)	Distribution %	Specific Gravity
2.0	5.0	2.65
5.0	5.0	2.65
8.0	10.0	2.65
20.0	15.0	2.65
50.0	10.0	2.65
75.0	5.0	2.65
100.0	10.0	2.65
150.0	15.0	2.65
250.0	15.0	2.65
500.0	5.0	2.65
1000.0	5.0	2.65

Stormceptor®

Site Name	Tank 1

Site Details

Drainage Area

Total Area (ha)	18
Imperviousness %	27.0

Surface Characteristics

Width (m)	849.00
Slope %	2
Impervious Depression Storage (mm)	0.508
Pervious Depression Storage (mm)	5.08
Impervious Manning's n	0.015
Pervious Manning's n	0.25

Maintenance Frequency

Maintenance Frequency (months) >	12

Infiltration Parameters

Horton's equation is used to estimate infiltration

Max. Infiltration Rate (mm/hr)	61.98
Min. Infiltration Rate (mm/hr)	10.16
Decay Rate (1/sec)	0.00055
Regeneration Rate (1/sec)	0.01

Evaporation

Daily Evaporation Rate (mm/day)	2.54

Dry Weather Flow

Dry Weather Flow (lps)	0

Winter Months

Winter Infiltration	0

TSS Loading Parameters

TSS Loading Function	

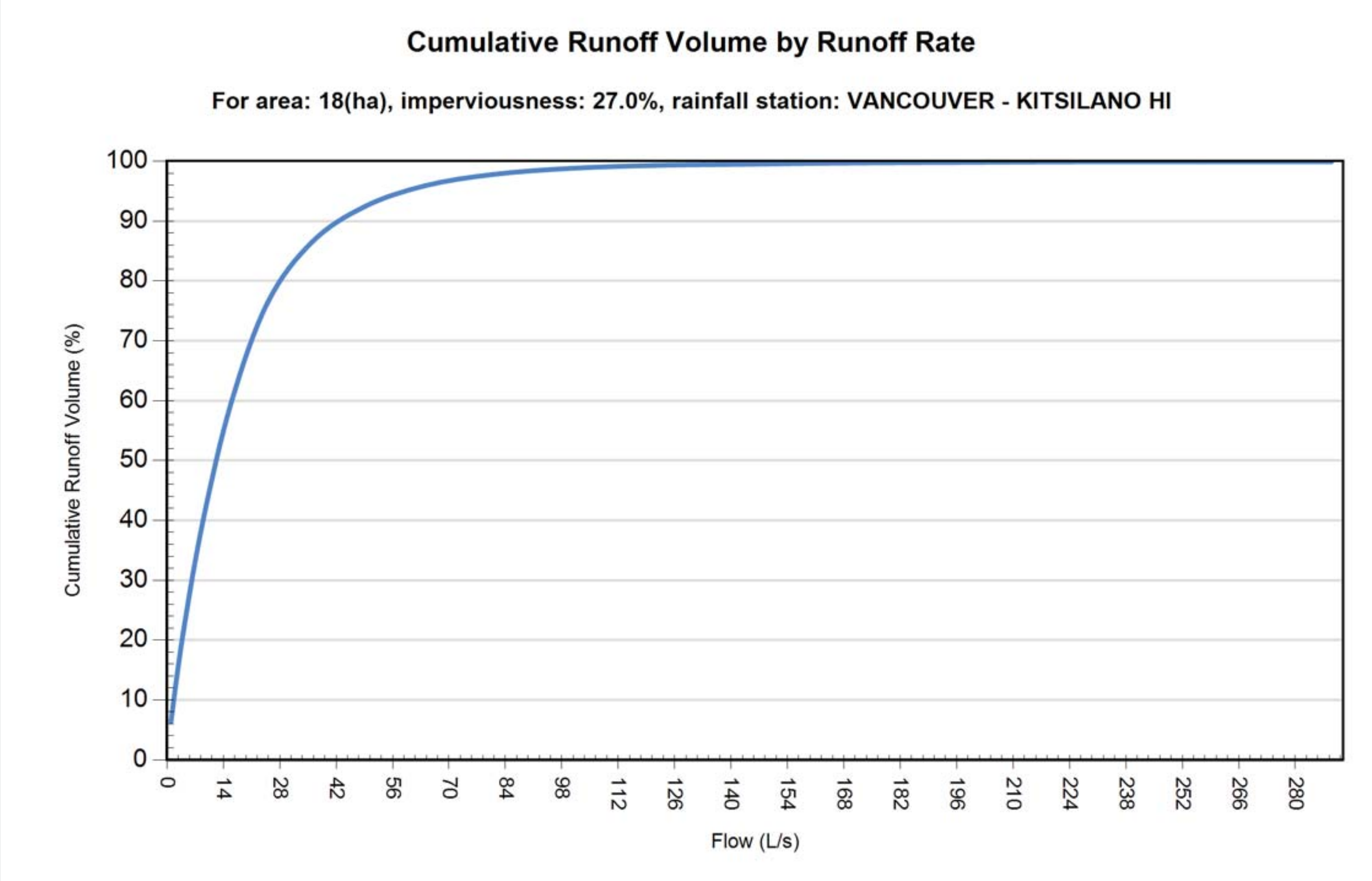
Buildup/Wash-off Parameters

Target Event Mean Conc. (EMC) mg/L	
Exponential Buildup Power	
Exponential Washoff Exponent	

TSS Availability Parameters

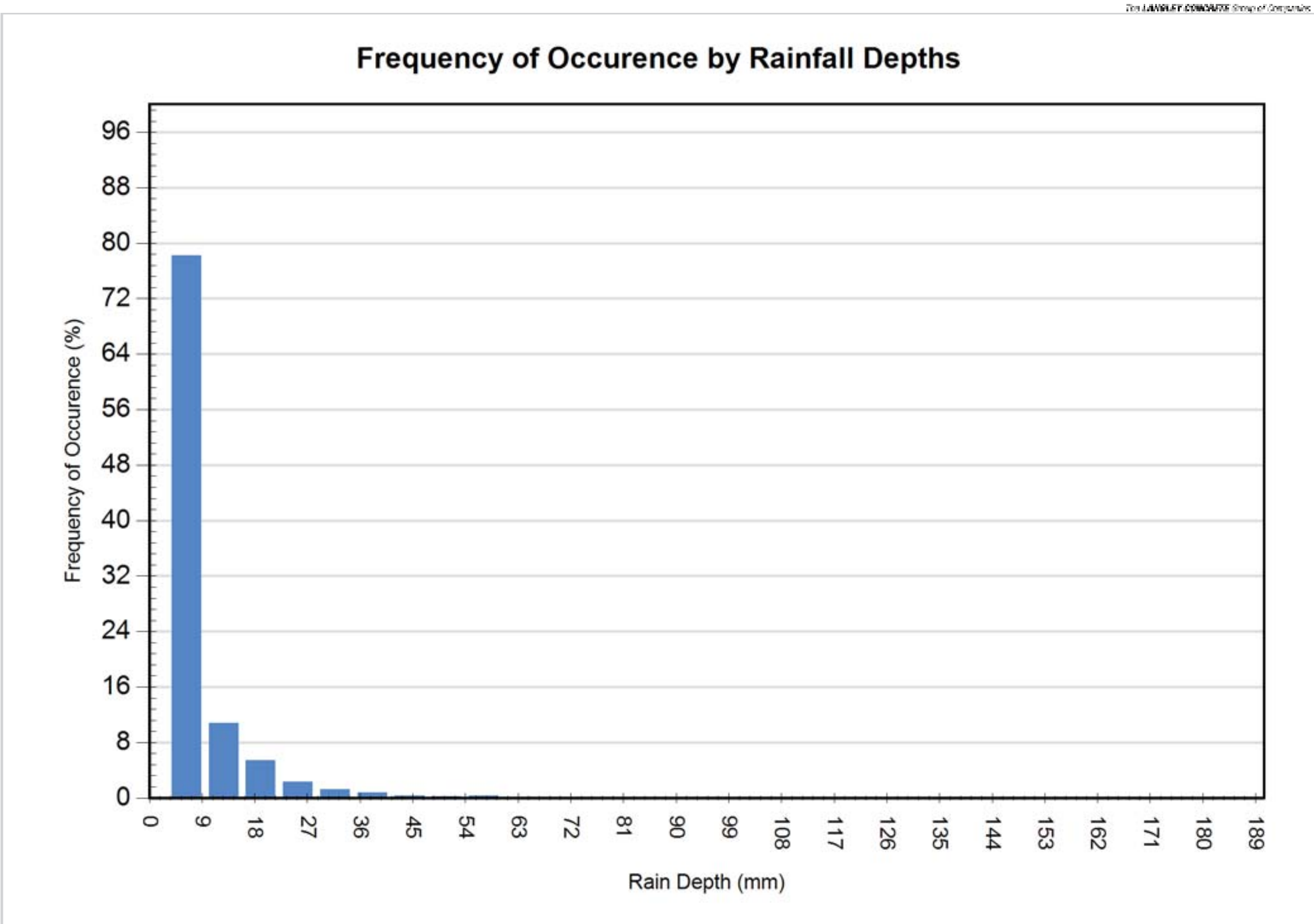
Availability Constant A	
Availability Factor B	
Availability Exponent C	
Min. Particle Size Affected by Availability (micron)	

Cumulative Runoff Volume by Runoff Rate			
Runoff Rate (L/s)	Runoff Volume (m³)	Volume Over (m³)	Cumulative Runoff Volume (%)
1	70.315	1034.782	6.4
4	232.969	872.116	21.1
9	442.61	662.055	40.1
16	661.199	443.817	59.8
25	843.946	260.636	76.4
36	956.122	149.146	86.5
49	1020.913	84.192	92.4
64	1059.22	45.799	95.9
81	1081.098	23.939	97.8
100	1091.39	13.629	98.8
121	1097.026	7.973	99.3
144	1099.903	5.101	99.5
169	1101.654	3.346	99.7
196	1102.762	2.24	99.8
225	1103.481	1.52	99.9
256	1103.932	1.069	99.9
289	1104.243	0.758	99.9


Cumulative Runoff Volume by Runoff Rate
For area: 18(ha), imperviousness: 27.0%, rainfall station: VANCOUVER - KITSILANO HI
Cumulative Runoff Volume (%)
100
90
80
70
60
50
40
30
20
10
0
0
14
28
42
56
70
84
98
112
126
140
154
168
182
196
210
224
238
252
266
280
Flow (L/s)

Rainfall Event Analysis

Rainfall Depth (mm)	No. of Events	Percentage of Total Events (%)	Total Volume (mm)	Percentage of Annual Volume (%)
6.35	4012	78.2	6090	24.5
12.70	555	10.8	5038	20.2
19.05	275	5.4	4288	17.2
25.40	119	2.3	2641	10.6
31.75	63	1.2	1790	7.2
38.10	43	0.8	1499	6.0
44.45	16	0.3	664	2.7
50.80	10	0.2	475	1.9
57.15	15	0.3	806	3.2
63.50	5	0.1	296	1.2
69.85	3	0.1	196	0.8
76.20	3	0.1	219	0.9
82.55	3	0.1	240	1.0
88.90	1	0.0	86	0.3
95.25	2	0.0	182	0.7
101.60	0	0.0	0	0.0
107.95	1	0.0	104	0.4
114.30	0	0.0	0	0.0
120.65	1	0.0	120	0.5
127.00	0	0.0	0	0.0
133.35	0	0.0	0	0.0
139.70	0	0.0	0	0.0
146.05	0	0.0	0	0.0
152.40	0	0.0	0	0.0
158.75	0	0.0	0	0.0
165.10	0	0.0	0	0.0
171.45	1	0.0	170	0.7
177.80	0	0.0	0	0.0
184.15	0	0.0	0	0.0



For Stormceptor Specifications and Drawings Please Visit:
http://www.imbriumsystems.com/technical-specifications