UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Stadium Neighborhood Underground Parkade and Water Storage

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Stadium Neighborhood Underground Parkade and Water Storage Project

Final Design Report

University of British Columbia - UBC SEEDS Sustainability Program
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Shearwater Designs - Team 22
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Executive Summary

Shearwater designs has been retained by UBC Campus and Community Planning to design an integrated stormwater and parkade structure. The structure will improve stormwater detention infrastructure, handle changing land uses due to the proposed Stadium Neighborhood development, and provide parking for the new Thunderbird Stadium. The project aims to integrate sustainable design with UBC athletics to showcase UBC's commitment to sustainability. This report and its proposed design emulate UBC's objectives as stated in the UBC Integrated Stormwater Management Plan [1].

The project is located northeast of the intersection of Southwest Marine Drive and West 16th Avenue. The design features a 3500 m^3 underground water detention vault that feeds an infiltration trench and adjacent bioswales for overflow. A three level parkade will be constructed on top of the detention vault, with entry on West 16th Avenue. A Green roof and rain gardens are incorporated into the parkade exterior.

The current estimated cost of this project will be $12 million with an annual maintenance cost of $32,000. The project's latest construction start date and earliest construction finish date are May 1st 2019, and December 28th 2019, respectively.

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1.0 Project Overview

1.1 Objective

As a part of the Stadium Road Neighbourhood project, the aging Thunderbird Stadium will be upgraded and relocated to the site of the existing parking lot on East Mall and W 16th Ave. The current stadium will be replaced by residential buildings. With the removal of the existing stadium parking lot, there is a need for new parking infrastructure. This development has the potential to increase the impervious surface in the area, thus increasing the runoff. One of the concerns with runoff on the UBC campus is the potential erosion of nearby cliffs west of campus. Flooding from large storms is also a growing concern with the impacts of climate change. UBC Campus and Community Planning is seeking solutions to manage stormwater using natural stormwater management techniques in the vicinity of the new Stadium Road Neighborhood. The objective of this project is to design a mixed-use parkade and stormwater management system to serve the new development and address the growing flooding concerns, in accordance with UBC Vancouver Campus Integrated Stormwater Management Plan (ISMP) [1]. The team aims to achieve the following with the design of this mixed-use parkade and stormwater management system:

1. Promote UBC's commitment to sustainability and innovation by incorporating naturalized and innovative stormwater management systems to accommodate a 1 in 100 year storm volume
2. Combine the activities of UBC Athletics with sustainable infrastructure to showcase innovation as sustainable design at UBC
3. Address the anticipated increase in demand for both motorized and non-motorized parking for the new Stadium Road Neighborhood

The proposed site for the mixed-use parkade and stormwater management system is a forested plot of land on the northside of W. 16th Ave, between SW Marine Dr. and East Mall. It is south-east of the existing Thunderbird Stadium and adjacent parking lot. A walking pathway runs along W. 16th Ave, which will have to be removed and replaced. The parkade will connect directly to W. 16th Ave, so traffic routing must be integrated with existing traffic flow. Excavation will be done directly adjacent to W. 16th Ave, so care must be taken to minimize the impact on the bearing soil of the roadway. The elevation above sea level of the site varies from 75.0 m (most southwest corner) to 89.0 m. Figure 1 below is an overhead photo of the proposed site generated from the Google Earth Pro program.

Figure 1: Site Overhead

1.2 Design Methodology

The mixed-use parkade and stormwater management system was split into 3 main design components:

- Parkade structure
- Hydraulic substructure
- Natural systems

The parkade structure has the capacity to replace the existing parking infrastructure at Thunderbird Stadium, while aiming to reduce congestion and idling time. The long term vision for the parkade is to transition parts of the parkade into a community/recreation space. The hydraulic substructure is designed to control peak flows of the 100 year, 24 hour storm and infiltrate at the 2 year, predevelopment rate to achieve net zero water leaving the site, as stated. The natural systems are designed to handle overflow from the dry detention vault and provide resilience to the stormwater management system. They will also add to the aesthetic of the development, showcasing sustainability at a visible location on campus.

1.3 Design Criteria and Assumptions

The project was designed according to various standards and guidelines. These guidelines are referenced directly in the following design summaries, and are listed below.

Parkade Structure:

- BC Building Code (BCBC) 2018 [2]
- National Building Code of Canada (NBCC) 2015 [3]
- Vancouver Parking and Loading Design Supplement (VPLDS) [4]
- CSA S413 Parkade Manual [5]

Dry Detention Vault:

- Metro Vancouver Best Management Practices Guide for Stormwater [6]

Soakaway Pits:

- Metro Vancouver Stormwater Source Control Guidelines 2012 [7]
- BRE Soakaway Design [8]

Natural Systems:

- Metro Vancouver Stormwater Source Control Guidelines 2012 [7]
- Climate Projects for Metro Vancouver 2016 [9]

The following table outlines the member contributions for the development of this final design report.

Table 1: Member Contributions

Member/ Task	**Paulina Buskas**	**Julia Dunlop**	**Daniel Luo**	**Wesley Prahalad**	**Steven Rintoul**	**Luthfi Subagio**
Hydraulic and Hydrological Analysis	✔					✔
Hydraulic Design	✔				✔	✔
Natural Systems Design			✔			✔
Structural Design		✔		✔		
Geotechnical Design				✔		
Design Coordination	✔	✔	✔	✔	✔	✔
Construction			✔	✔	✔	✔
Cost Estimate	✔			✔	✔	✔
Scheduling				✔	✔	
Drafting		✔	✔			

2.0 Analysis and Assessments

2.1 Overview

Analysis and assessments for the project have been completed and are described in depth in the *Preliminary Design Report* [10] submitted in November 2018. Further analysis and additional Seismic analysis are described below.

2.2 Geotechnical Analysis

A geotechnical investigation was not completed at the site. Further geotechnical investigation of the site should be completed prior to detailed foundation and excavation design. For purposes of preliminary design, geotechnical conditions of the site are taken from the investigation done by GeoPacific Consultants Ltd. for UBC Properties Trust for the proposed Mixed Commercial/Residential Development Lot 10, UBC South Campus, Wesbrook Drive at 16th Avenue, Vancouver B.C. [11].

The subsurface geotechnical profile is interpreted from the UBC HydroGeo 2002 Report done by Piteau Associates Engineering Ltd. [12]. A profile is interpreted at a cross section approximately 1 km north of the site, which is taken to represent the profile of our site, given the lack of geotechnical information closer to the site. At Lower Mall, the subsurface profile consists of 0.5 m of surface soil, underlain by approximately 5 m of surface till, and 55 m of a Quadra sand. The water table of the Point Grey Peninsula is located at an estimated depth of 60 meters below the project's location. There is a low risk of contaminating the groundwater with infiltration techniques. The surface till unit was treated as a loamy sand, which has a hydraulic conductivity of 1.7×10^{-5} m/s according to [12], while the Quadra

Sand has a hydraulic conductivity of 4.8 x 10^{-4} m/s according to the Piteau report [12]. These hydraulic conductivity values are used in the design of the soakaway pits described in Section 4.4.

2.3 Seismic Assessment

The parkade structure was analyzed under seismic conditions using the equivalent static force method according to the BCBC 2018 [2]. Utilizing the seismic information provided in the (NBCC) [3] Appendix C, the maximum shear force at the base of the structure was found to be 47.5% of the structures weight. This force was then divided correspondingly to the shear walls on each floor, assuming a non-flexible diaphragm. This structure was categorized with normal importance and class E soil. See Appendix A for complete calculations.

2.4 Hydraulic Analysis

A hydrological assessment of potential impacts incurred by the Stadium Neighborhood project was conducted. The stormwater flows from the 16th Avenue Catchment were assessed using the computer program EPA SWMM 5.1, as directed in the UBC Technical Guidelines [1]. Due to the increased development of the Stadium Road Neighborhood, it is expected that the imperviousness of the land will increase by 15%. The computer program was manipulated to reflect this change of impervious surfaces, therefore the neighborhood was set to 67% impervious. Stormwater flows and volumes were evaluated at Junction 26 (JUNC-26) as shown in Figure 2. As all overland stormwater from the upper section of the catchment travel through this point, the junction was determined to be the most representative of the area.

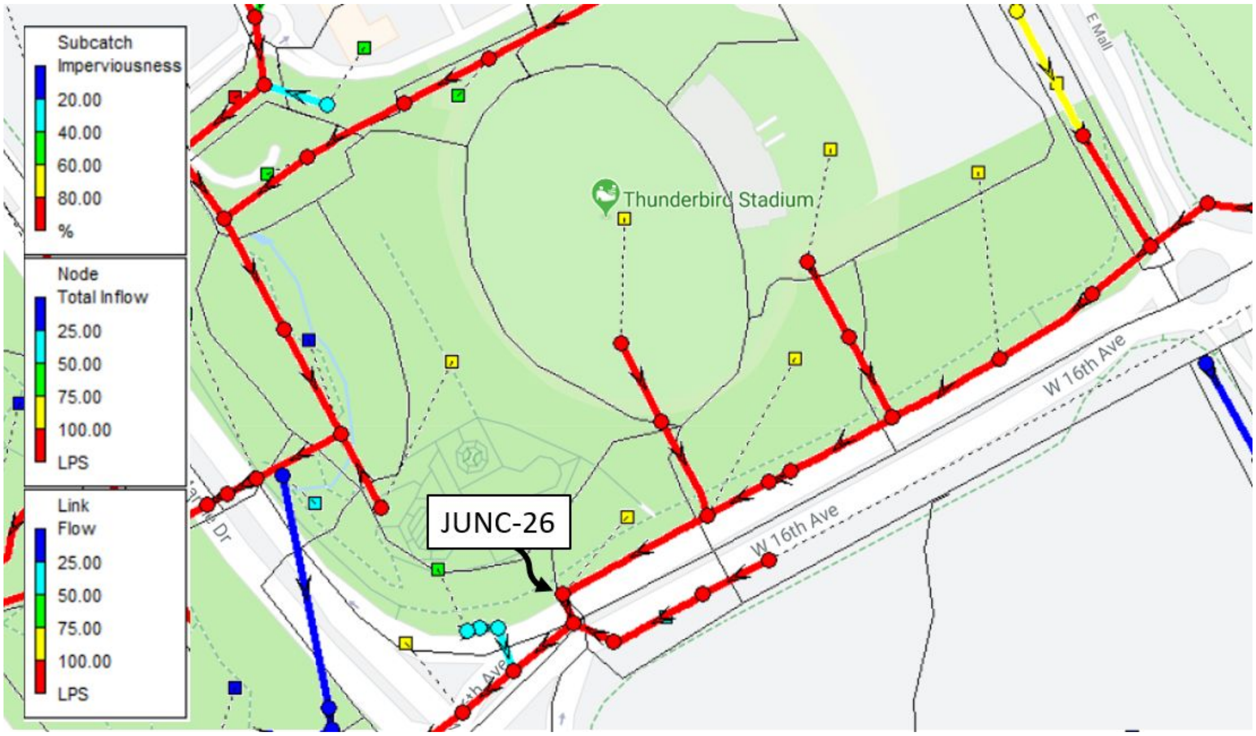

Figure 2: Junction 26 and 16th Ave Catchment During Peak Flow

The total inflow was evaluated at JUNC-26 during both a 100 year and 10 year storm event. UBC has committed to following the Leadership in Energy and Environmental Design (LEED) gold standard guidelines. These standards include regulations that specify detention structures must support the 24-hour storm volume and be discharged at the two-year, pre-development rate [1]. Using the rational method, the two-year, pre-development rate was determined to be 260 L/s at JUNC-26, therefore the detention vault will discharge at this rate.

The flow results of the 100 year storm at JUNC-26 can be seen in Figure 3. The peak flow is 650 L/s at 08:30. Since the allowable discharge is 260 L/s as shown by the orange line, the detained volume is shown by the blue shaded region above the orange line in Figure 3. This area was calculated to be approximately 3300 m^3. Due to the increase in rainfall intensity expected as a result of climate change, the detention volume was rounded to 3500 m^3 . In conclusion, the detention vault was designed with a capacity of 3500 m^3 and will discharge at 260 L/s. Further details regarding the design of the detention vault can be found in Section 4.2.

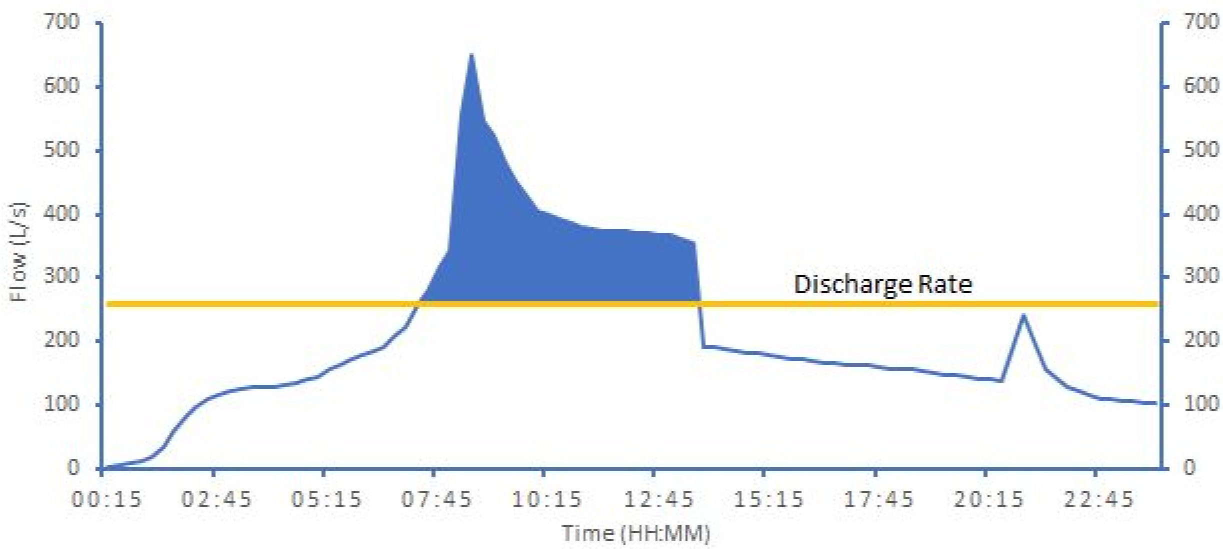

Figure 3: Total Flow During 100 Year Storm at Junction 26

2.5 Life Cycle Assessment

The parkade will initially have capacity for 130 vehicles and 30 bicycles. The long term vision of the parkade is to convert parts of the building into community/recreational spaces as the number of vehicles on site decreases, as per UBC's vision of the reduction of single-use vehicle trips.

3.0 Parkade Structure

3.1 Overview

The parkade structure consists of 4 staggered floors, with 3 floors dedicated to parking and the fourth consisting of a detention vault. The total dimension of the parkade comes to 95 metres by 30 metres with a total depth of 7 metres.

3.2 Layout and Traffic Management

The parkade will house 130 parking stalls, 15 of which are dedicated to electric vehicles and 5 dedicated to handicap. Stall and aisle widths were designed according to [4], prescribing spaces to be 2.5m wide, one way traffic aisles to be 6m, and 2 way ramps to be 12m. The parking garage was designed in an attempt to reduce idling and conserve space. This was achieved through having one way traffic, diagonal stalls and dedicated lanes on W 16th for easy access in and out of the garage. See Appendix E for complete drawings.

3.3 Loading

The structure is subject to many loading conditions. Being an underground structure with a green roof, lateral earth pressure loads and a fully saturated green roof load were analyzed along with structure dead loads and live loads. These loads were established as prescribed in [2].

3.4 Structural System

The structural system consists of slabs, beams and shear walls. These elements were designed for a consistent size throughout the structure. Slabs will be 300 mm thick and run continuously on top of the beams. The beams will spaced every metre and have dimensions of 250 mm by 800 mm that span 15 metres where they will tie into another beam or wall. Shear walls were designed in order to take these loads from the beams as well as lateral and seismic forces. These walls will be 300 mm thick. All components are steel reinforced. See Appendix E for construction drawings and specifications and Appendix A for detailed calculations.

3.5 Foundation Design

The parkade foundation will be 2 m wide strip footings around the perimeter of the structure, with depth of 250 mm. For construction ease, the reinforcement placed in the footings will be the same as the walls. (25M @ 500 mm). See Appendix A for detailed calculations.

3.6 Material Selection

The materials used include cast in place concrete with steel rebar. These materials were selected and designed in accordance to [5]. All concrete used was considered to be exposed to chlorides despite any coverings used. A strength of 30 MPa was chosen with a cement, sand, and aggregate ratio of 1:0.75:1.5 [13]. The steel rebar used has dimensions of 55M, 25M, and 25M for beams, slabs, and walls, respectively.

4.0 Hydraulic Substructure

4.1 Overview

The stormwater detention system consists of an integrated detention structure constructed underneath the second level of the parkade. The structure will capture runoff throughout the West 16th Ave Catchment and discharge into downstream conveyance structures that will lead to the catchment outfall. The controlled release of stormwater from the detention structure will reduce erosion downstream of the site. Of particular importance is the reduction of erosion from the existing stormwater outfall of the W. 16th Ave Catchment.

4.2 Detention Structure

The detention system is a dry detention vault, as described in Section 4.8 - BMP S7 of the Metro Vancouver Best Management Practices Guide to Stormwater [6]. The primary purpose of the dry vault is to control the peak flow. The release rate will be lower than the incoming rate to limit downstream bankfull flow and erosion of the nearby cliffs. The dry vault will empty completely between storms, and fill during peak flow times. Through the hydrological analysis completed in the *Preliminary Design Report*, the required detention volume of the dry detention vault is 3500 m^3. As described in Section 2.4, the detention vault will discharge at the two-year, pre-development rate which was calculated to be 260 L/s.

It is assumed that water entering the detention vault will be directed from the future drainage system of the Stadium Neighborhood area and from the existing drainage ditch along W 16th Avenue. The team assumed that these two stormwater systems would converge near the southeastern corner of the parkade along W 16th Ave. After the two systems meet, they will flow through an oil grit separator as mentioned in Section 4.3. The oil grit separator will enhance the water quality entering the detention vault and further infiltration systems. The water will flow through a 450 mm PVC pipe beneath the entrance of the parkade and will connect to the detention vault underneath the second floor of the parkade.

The detention vault consists of a 40x30x3 m concrete cast-in-place structure. The vault will be divided into two bays via a single baffle running along the center of the structure. The first cell was designed to store 25% of the total volume as directed by [6]. The vault features an orifice pipe at the bottom of the baffle, an outlet to convey the required discharge, and an overflow outlet. Pipe details can be found in Table 2. See Appendix E for construction drawings and specifications and Appendix B for detailed calculations.

Table 2: Pipe Sizing for Dry Detention Vault

Pipe Description	Diameter (mm)	Material	Design Flow	Equation
Inlet Pipe	450	PVC	Peak 100yr	Manning's
Orifice Pipe	350	Concrete	Predevelopment 2yr	Orifice
Outlet Pipe	250	PVC	Predevelopment 2yr	Orifice
Overflow Pipe	450	PVC	Peak 100yr	Orifice

4.3 Preliminary Treatment

The oil grit separator will be located near the southeastern corner of the parkade and will be used before the water enters the detention vault to reduce maintenance of the entire system. The oil grit separator will be a Stormceptor EFO 6, a system verified through the ISO 14034 Environmental Management-Environmental Technology Verification program. The model was chosen in order to handle the peak flow for the 100-year storm. The Stormceptor is used for sediment capture (TSS), oil capture and retention, and scour prevention. A diagram of the oil grit separator can be seen in Figure 4. See Appendix E for drawings and specifications and Appendix B for detailed calculations. The team intends to purchase a Stormceptor EFO 6 from the Langley Concrete Group, a nearby representative of the device.

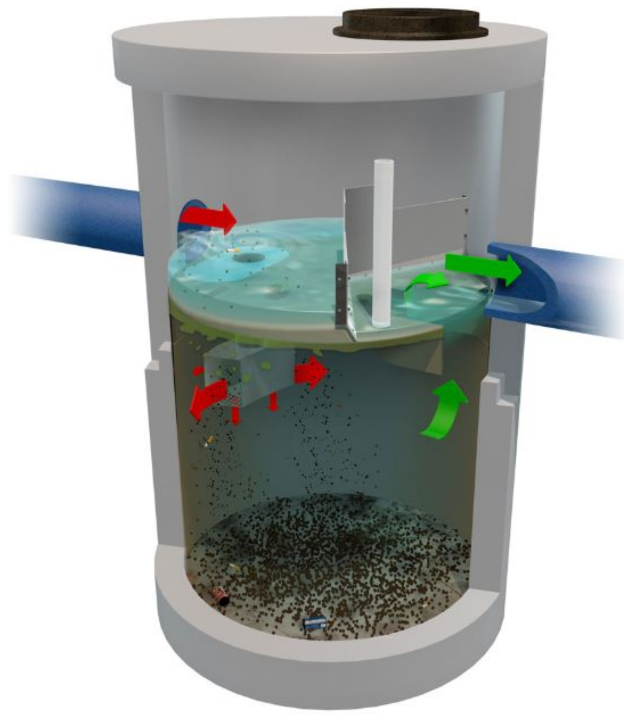

Figure 4: Stormceptor EFO 6 [14]

4.4 Soakaway Pits

The outlet from the dry detention vault is routed to soakaway pits southwest of the parkade. The soakaway pits were designed according to the guidelines for Soakaway Design by BRE [7], and the Metro Vancouver Stormwater Source Control Design Guidelines 2012 [8]**.** The outflow capacity of the soakaway pit is 22541 m^3 in 24 hours, while the design 2 year, 24 hour discharge from the dry detention vault is 22464 m^3. The 250 mm outlet PVC pipe coming from the dry detention vault is split into two (2) 150 mm PVC pipes that lead to twenty-six (26) soakaway pits. The soakaway pits descend 15 m below the 150 mm pipe invert, or 16.3 m below grade. Inside the soakaway pits, 100 mm perforated PVC pipe is surrounded by drain rock at a diameter of 1 m. The pits are spaced at a minimum of 9 m apart, allowing for adequate infiltration into the surface till and Quadra sand layers described in Section 2.2. The soakaway pits are designed further than 300 m from the cliffs west of the site [1]. While [13] outlines the soil conditions in the area of the site, a more detailed analysis of the conditions should be done. Of particular importance is the behaviour of the till and sand layers when they reach saturation. If the soil beneath the road is at risk of significant strength reduction under saturated conditions, the installation of an impermeable barrier may be installed to separate the infiltrating water from road foundation. Drawings of a plan view of the system and a typical profile of a soakaway pit are provided in Appendix E. Detailed calculations are shown in Appendix B.

5.0 Natural Systems

5.1 Overview

The main purpose of the natural systems are to act as a form of bioretention facility. Bioretention is the process of collecting, utilizing, and releasing stormwater with a biological medium. For all natural systems, sod grasses will be used for this purpose. Where applicable, bushes, shrubs, and trees that won't negatively impact the existing ecosystem can be used. The three main natural systems proposed by the team include bioswales, rain gardens, and green roofs.

5.2 Bioswales

The bioswales are designed according to [7]. Bioswales compose of a grassy channel used to collect, store, and infiltrate stormwater into the ground below. The proposed design involves bioswales with ponding weirs to run along the outside of the parkade and as well as along W 16th Ave. Currently, water from the detention structure will be able to collect and discharge a 100-year storm; however, in the event that the detention structure is at capacity (i.e. a storm greater than 100-years occurs), the bioswales will help convey stormwater from the detention structure down W 16th Ave. The ponding weir system will add an additional 96 m^3 of stormwater detention that will be slowly infiltrated into the subsurface. A detailed drawing of the typical design for this project's bioswales can be found in Appendix E. See Appendix C for detailed calculations.

5.3 Rain Gardens

The bioswales are designed according to [7]. Rain gardens are similar to bioswales as they capture rainfall, store water in a bioretention medium, and then release the water into the subsurface. The rain gardens will have full infiltration but may or may not have a reservoir, depending on the geotechnical and site conditions. Either rain garden scenario will require a growing medium of 450 mm and a two (horizontal) to one (vertical) slope towards the garden. At locations that have glacial till below the topsoil, a 5 m deep reservoir with drain rock will be installed in strategic areas. Areas with quadra sand beneath the topsoil do not require a reservoir since water can infiltrate quicker. See Appendix C for detailed calculations.

5.4 Green Roofs

The bioswales are designed according to [7]. The top of the parkade will be composed of an intensive green roof. The roof will have a 600 mm growing medium with a 2% slope towards the drainage piping that will convey excess rainfall into the detention structure below. The top of the roof will contain sodded grass and a rock garden that will be aesthetically pleasing for the UBC Stadium Neighbourhood and will allow the area to be used for community gatherings. The growing medium sizing was based off Vancouver's annual average rainfall with a consideration for climate change. This sizing will allow the roof to capture 54 % of the rainfall that falls directly on the roof. The roof will also provide sound insulation up to 13 decibels. See Appendix C for detailed calculations.

6.0 Construction Plan

6.1 Overview

The construction plan described below is the recommended sequence provided by the team. It is subject to change on bidding and contractor selection. Lists of tasks and construction considerations, as well as an overview of the scheduling are provided below. Construction considerations are listed in the specification sheet in Appendix E. A detailed schedule and work breakdown structure is provided in Appendix F.

6.2 Tasks

The task list below is a summary list of tasks required during the construction period:

1. Site preparation
    1.1. Stripping, grubbing and clearing. Note that tree removal should be done at this stage. The existing path that runs parallel to W. 16th Ave must be removed.
2. Construction of underground parkade structure
    2.1. Installation of excavation support.
        2.1.1. Secant pile walls should be used for excavation support for the parkade structure, as they will be permanent wall supports for the structure.
    2.2. Excavation to bulk excavation level of parkade structure
        2.2.1. Dewatering should be completed when excavation reaches the perched depths of perched groundwater as described in Section 5.4. Consideration must be made for the settlement of W. 16th Ave, when dewatering and excavation are taking place.

2.3. Construction of base level pad and strip foundations

2.4. Construction of shear wall forms, including dry detention wall concrete

2.5. Bottom slab, foundation, and column concrete pours

2.6. Connection of dry detention vault to existing storm system and to discharge locations

2.7. Placement of temporary vertical supports for second floor slab and ramps

2.8. Second floor and ramp form construction

2.9. Second floor and ramp concrete pours

2.10. Placement of temporary vertical supports for grade level slab and ramps

2.11. Grade level floor and ramp form construction

2.12. Grade level floor and ramp concrete pours

3. Above grade building construction

3.1. Roof construction

3.2. Green roof construction

4. Construction of soakaway pits

4.1. Drilling of soakaway pits with casing and perforated pipe placement

4.2. Drain rock placement

4.3. Placement of pipe bedding material

4.4. Pipe connections and cleanouts

4.5. Backfill and covering with base and subbase for pathway paving

4.6. Pathway paving

5. Bioswale Excavation and Installation

6.3 Scheduling

The construction will commence May 28th, 2019, and will have a target completion date of Mid-December. This time frame allows for minimal disruption to class schedules, while most students are not at the university for summer. This decreases the expected impact on the public via traffic delays. A full Gantt Chart and task list can be found in Appendix F. It is noted that the construction of the soakaway pits can commence simultaneously with the construction of the parkade+detention tank superstructure. The critical path will mainly be the construction timeline of the superstructure, over 180 work-days. Time alloted for inspections is given.

A summary of key project milestones is provided below in Figure 5 below.

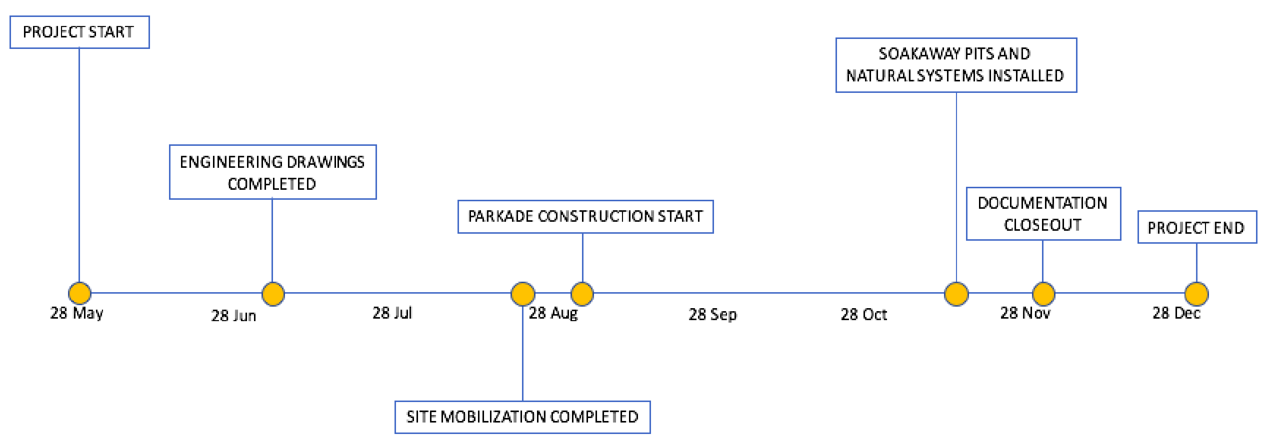

Figure 5: Overview of Project Schedule

7.0 Operations and Maintenance

7.1 Overview

The operations and maintenance of the system will be separated into three parts: parkade structure, hydraulic substructure, and natural systems. The recommendations stated in this section are not limiting, but are meant as a guide. Operations and maintenance will be the responsibility of the owner. This section of the report will also detail the building safety plan.

7.2 Parkade Structure

The team recommends UBC to retain a consultant experienced in building inspection to perform a detailed structural inspection every 2 years as per [5]. Our recommendations include inspection of exposed rebar and concrete spalling, cracking, and chemical degradation. The use of chemical de-icing compounds should be avoided to minimize structural damage, and additional inspection should be considered following days where there is heavy usage of de-icing compounds on roadways.

7.3 Hydraulic Substructure

The team recommends maintenance of the dry detention vault that includes yearly inspection and removal of sediment from the vault interior. This will require a Vac truck whose hose can reach the tank, or the manual removal of sediment by an operator with a pail and shovel. Additionally, the oil-grit separator will require maintenance according to the manufacturers specifications. Structural inspections of the vault should be completed as described in Section 7.2 above. Maintenance of the soakaway pits includes yearly inspections of the cleanouts at the vertical soakaway pits to ensure that they are not clogged.

7.4 Natural Systems

The main component of each natural system to be maintained will be the vegetation. The bioswales, rain gardens, and green roofs, will require weekly visual inspections to insure the vegetation is healthy and growing well. The grass will require to be cut, although the growth rate will vary throughout the year. During spring months, the grass may need to be cut as often as every 10 days; however, this will increase during the summer months. The waste from the cutting should be collected and composted.

The growing medium of the vegetation will also require biannual aeration and replanting. Aeration involves puncturing the growing medium with holes to allow oxygen into the soil. This will help the grass grow and maintain healthy soil. Aeration should occur during spring and fall, after and before the frost season. Replanting should occur if any vegetation dies and earth becomes exposed.

7.5 Safety Plan

All construction workers on the project will be properly trained in their expertise. Every morning of construction will begin with a tailgate safety meeting to go over the required safety checklist. Incidents will be reported and handled accordingly. All workers will also be required to be well aware of the emergency response procedure. The proper personal protective equipment (PPE) will be worn at all times on site during construction. Site specific hazards will be addressed and workers will be well aware of their safety officer and their contact details.

In addition to the general safe construction practices listed above, the parkade structure will include fire exits, fire protection, and a specific marshalling area in case of fire. The parkade will also be well lit to ensure safe access to vehicles and bikes.

8.0 Cost

8.1 Overview

A Class A cost estimate was conducted on the Stadium Neighborhood Underground Parkade and Water Storage Project. An overview of the cost estimate can be seen below in Table 3. The total estimated cost of the project is **$12M** and includes pricing of the permitting, general mobilization, parkade structure, dry detention vault, soakaway pits, and natural systems. Engineering fees, insurance, contingencies, and GST were added to the original sub-total. The detailed Class A cost estimate can be found in Appendix D.

Table 3: Summary of Class A Cost Estimate

Description	Price
Permitting	$20,000
General	$1,100,000
Parkade Structure	$5,200,000
Dry Detention Vault	$180,000
Soakaway Pits	$320,000
Natural Systems	$480,000
Sub-total	$7,300,000
Engineering & General Contractor Fees (20%)	*$1,600,000*
Insurance and Bonding (2%)	*$160,000*
Contingencies (20%)	*$1,600,000*
GST (5%)	*$570,000*
Estimated Total Cost	**$12,000,000**

8.2 Operations and Maintenance

As discussed in Section 7.0, operations and maintenance will be required for all sections constructed. Together, this will cost approximately $32,000 a year. Of note, operations and maintenance of the detention structure, soakaway, and invasive plants in the natural systems are highest in cost. The comprehensive operations and maintenance costs are located in the Class A cost estimate in Appendix D.

9.0 Future Considerations

There are a set of tasks that must be completed as we move from the detailed design phase to the commencement of construction. This section outlines the future considerations that will be addressed.

The current design is based off of geotechnical assessments of the nearby area. To provide a more accurate and appropriate design, bore hole testing of the site should be conducted prior to construction to confirm assumptions. Materials shall be sourced from local suppliers. Specific vegetation and plants will be suitable for the natural ecosystem at UBC. During construction, material testing will occur on a regular basis to ensure the required standards are met.

Discussion with UBC Campus and Community planning will continue throughout construction. Unforeseen changes to design plans and scheduling will be addressed with the use of change orders. Construction shall be completed to conform with all required safety standards.

As climate change is expected to change rainfall patterns, it is recommended for UBC to record all flow values throughout the system during the life of the project. Adjustments to the detention vault and infiltration system shall occur if necessary to reflect climate change impacts.

10.0 References

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[15] UBC Technical Guidelines, *"Electrical Underground Ducts and Manholes*", 2018.

[16] UBC Technical Guidelines, "*Storm Drainage*", 2018.

APPENDIX A: PARKADE STRUCTURE

Concrete				**Steel**		
phi(c)	0.65			phi(s)	0.85	
f'c	30	MPa		fy	400	MPa
alpha 1	0.805			diameter of long.	55	mm
beta 1	0.895			Area of one long.	2500	mm^2
				Aggregate Size	20	mm
				Diameter of Stirrup	10	mm
				Area of Stirrup	100	mm^2

Parkade			**Beam**			**Slab**		
Length	40	m	b	250	mm	Thickness	0.3	m
Width	30	m	h	800	mm	Length	15	m
Floor Clearance Height	2.3	m	Length	15	m	Trib Width	1	m
			Trib width	1	m			

Loads		Weight	Units	Trib width	Units	Trib Height	Units	Load	Units	Factored	
Dead Load Beam	Slab	2500.0	kg/m^3	1.0	m	0.3	m	7.4	kN/m	9.2	kN/m
	Beam	2500.0	kg/m^3	250.0	mm	800.0	mm	4.9	kN/m	6.1	kN/m
	Snow Load	1.6	kPa	1.0				1.6	kN/m	0.8	kN/m
Live Load Beam	Parkade	2.4	kPa	1.0	m	-	-	2.4	kN/m	3.6	kN/m
	Green Roof	4.8	kPa	1.0	m			4.8	kN/m	7.2	kN/m

Moments	Load	Area	Max	Units	V	Units
Floor 1	26.9	kN/m	757.9	kN*m	202.1	kN
Floor 2	18.9	kN/m	532.4	kN*m	142.0	kN
Floor 3	26.9	kN/m	757.9	kN*m	202.1	kN
Floor 4	18.9	kN/m	532.4	kN*m	142.0	kN

Tension Steel Design					
Clear Cover	40.000	mm			
Number of rows	1.000				
d	730.000	mm			
As	4024.767	mm^2	Use		
a	348.698	mm			
As(min)	547.723	mm^2	Dont Use		
a	348.698	mm			
Mr	760.365	kN*m	Okay		
Number of bars	2.000		1.4*db	1.4*as	30
S	40.000	mm	77	Okay	Okay
row	0.022		Okay		
Z					

Compression Steel Design	Don't Need

Shear Design				
Number of legs	2.00			
dv	657.00			
Beta	0.18			
Vc	105.26	kN		
Shear Reinforcement	Yes			
Vs	96.85	kN		
Av	200.00	mm^2		
s	660.00	mm	600)	1.4
Vr	202.11	kN	Okay	
Vr(max)	800.72	kN	Okay	

Summary			Number per floor	Number of Floors	Total	Units	
Concrete	3	m^3	80	4	960	m^3	
Steel	2.000	bars	80	4	640	bars	55M, 15m

Concrete				Steel		
phi(c)	0.65			phi(s)	0.85	
f'c	30	MPa		fy	400	MPa
alpha 1	0.805			diameter of long.	45	mm
beta 1	0.895			Area of one long.	1500	mm^2
				Aggregate Size	20	mm
				Diameter of Stirrup	10	mm
				Area of Stirrup	100	mm^2

Parkade			Beam			Slab		
Length	40	m	b	250	mm	Thickness	0.3	m
Width	30	m	h	800	mm	Length	15	m
Floor Clearance Height	2.3	m	Length	15		Trib Width	1	
			Trib width	1				

Loads		Weight	Units	Size	Units	Size	Units	Load	Units	Factored	
Dead Load Beam	Slab	2500.0	kg/m^3	1.0	m	0.3	m	7.4	kN/m	9.2	kN/m
	Beam	2500.0	kg/m^3	250.0	mm	800.0	mm	4.9	kN/m	6.1	kN/m
	Snow Load	1.6	kPa	1.0	m			1.6	kN/m	0.8	kN/m
Live Load Beam	Parkade	2.4	kPa	1.0	m	-	-	2.4	kN/m	3.6	kN/m
	Green Roof	4.8	kPa	1.0	m			4.8	kN/m	7.2	kN/m

Moments	Load	Area	Max	Units	V	Units
Floor 1	17.2	kN/m	484.2	kN*m	129.1	kN
Floor 2	12.8	kN/m	359.9	kN*m	96.0	kN
Floor 3	17.2	kN/m	484.2	kN*m	129.1	kN
Floor 4	12.8	kN/m	359.9	kN*m	96.0	kN
Floor 5	12.8	kN/m	359.9	kN*m	96.0	kN

One Way Slab Design					
d	267.500				
As	7824.745	mm^2	Okay		
As(min)	600.000	mm^2			Use
S	191.700	mm	Okay	Okay	191.6995267
a	11.299	mm			
Mr	696.631	kN*m	Okay		
Cracking?					
fs	240				
A	5000				
z	14035.28514				

Shear Design				
Number of legs	2			
dv	240.75	mm		
Beta	0.21			
Vc	179.9946408	kN		
Shear Reinforcement	No			
Vs	-50.9	kN		
Av	200	mm		
s	-461	mm	Okay	Okay
Vr	129.1	kN	Okay	
Vr(max)	4694.625	kN	Okay	

Temperature and Shrinkage			
Asmin	600	mm^2	
S	500	mm	
A bar	200	mm^2	15M
s	333.3333333	mm	Use 300
As	666.6666667	mm^2	

Summary	Amount	Unit	Size	Unit	Number per floor			
Concrete	4.5	m^3/m	1	m	15	Number of floors	Total	Units
Steel	79	bars	10	m	15	5	337.5	m^3
						5	5925	bars 10m of 25M

BCBC 2018

Importance → Normal

LL → core < 4,000 kg: 2.4 kPa

Roof = 1 kPa but Green Roof?

= 4.8 kPa → Footbridge or balcony

Snow → $S = I_s[S_s C_b C_w C_s C_a + S_r]$ → = 1.64 kPa

$I_s = 1$ for ULS

$= 0.9$ for SLS

$C_b = 0.8$

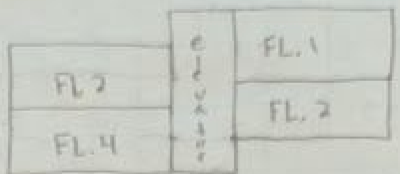
$C_w = 1$

$C_s = 1$ → $\alpha < 30°$

$C_a = 1$

$S_s = 1.8$

$S_r = 0.2$



Earthquake → ESA →

$S(0.2) = 0.848$

$S(0.5) = 0.751$

$S(1.0) = 0.425$

$S(2.0) = 0.257$

$S(5.0) = 0.080$

$S(10.0) = 0.029$

$PGA = 0.369$

$PGV = 0.553$

$I = 1$

Moderately Ductile Shear Walls: $R_d = 2.0$, $R_o = 1.4$

Class D

→ Glacial Till = Stiff Soil

$T_a = 0.05(h_n)^{3/4} = 0.05(7)^{3/4} = 0.2152$

$S(T_a) = \frac{0.751 - 0.848}{0.5 - 0.2}(0.2152 - 0.5) + 0.751$

$= 0.843$

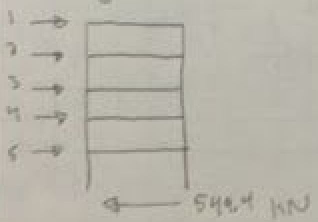
$V = \frac{S(T_a) M_v I_E W}{R_d R_o} = 0.301W$

$\text{Min } V = \frac{S(4.0) M_v I_E W}{R_d R_o} = \frac{0.139W}{2(1.4)} = 0.049W$

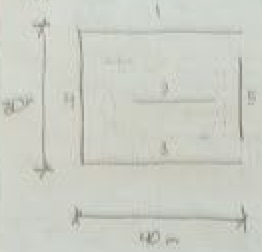
$\text{Max } V = \max \begin{cases} \frac{2}{3}\frac{S(0.2) I_E W}{R_d R_o} = 0.202W \\ \frac{S(0.5) I_E W}{R_d R_o} = 0.268W \end{cases}$ → Governs = 549.4 kN

Acting as if 5 floors 1.5 m high → $F_T = 8.27$ $\Sigma W_i h_i = 7500$

	F	ΣF
1	170.1 kN	170.1 kN
2	151.5 kN	321.6 kN
3	113.63 kN	435.23 kN
4	75.75 kN	510.98 kN
5	37.87 kN	549.4 kN



For



Assuming Flexible Diaphragm

Wall 1&3 = 7.5 m ∴ 1/4 V → 15 m

Wall 2 = 15 m ∴ 1/2 V → 15 m

Wall 4 = 20 m ∴ .5 V → 15 m

Wall 5 = 20 m ∴ .5 V → 15 m

Floor	1 & 3 kN/m	2	4	5
1	2.84	5.67	5.67	5.67
2	5.36	10.72	10.72	10.72
3	7.25	14.5	14.5	14.5
4	8.5	17	17	17
5	9.16	18.32	18.32	18.32

$V_c = \phi_c \lambda \beta \sqrt{f'_c}\, t\, d_v$

$= 0.65(1)(0.18)\sqrt{30}\,(1000 \cdot 0.8)(100) = 50.47 > 18.32$ ✓ ← no shear reinforcement

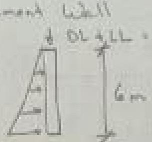
Horizontal ; $A_s = A_{min} = 200 \frac{mm^2}{m}$

Spacing for bars = 300 mm → $S_{max} = 3t$

Moment = 250.575 kN·m/m Axial = 252 kN/m

For t = 100 mm f_y = 400 MPa → M_r = 1367 kN/m ✓ Use 250 mm ✓

Basement Wall



Min thickness = 240 mm (6000/25)
Use 250 mm

Soil $\gamma_o = K_o \gamma_s = 0.5 \cdot 15\ kN/m^3 = 7.5\ kN/m^3$

max $p_o = h_w \cdot \gamma_o = 7.5 \cdot 6 = 45\ kN/m^2$

$P_f = 45\ kN/m^2$

$M_f = 101.3\ kN \cdot m/m = \frac{P_f/2 \cdot h_w^2}{8}$

$V_f = \frac{P_f \cdot h_w}{2} = 135\ kN/m$

① Flexure and axial

$d = t - cover - d_b/2 = 300 - 70\,mm - 15/2 = 222.5\,mm$

$A_s = 0.0015 f'_c b \left(d - \sqrt{d^2 - \frac{3.85 M_r}{f'_c b}} \right) = 3548.89 \frac{mm^2}{m}$

$s \leq A_b \frac{1000}{A_s} = 60\,mm$

$\rho = 0.019 < \rho_b = 0.023$ ✓

② Design for Shear

$V_c = \phi_c \lambda \beta \sqrt{f'_c}\, b_w d_v = 157 \frac{kN}{m} < 135\ kN/m$ → shear reinforcement not required

but need horizontal

$A_{shin} = 0.002 A_g = 600 \frac{mm^2}{m}$

$s \leq A_b \frac{1000}{A_s} = 333\,mm < 500\,mm \;\&\; 600\,mm$ ✓

15M @ 350 mm for horizontal

15M @ 60 mm for vertical

Basement wall design

Properties

fc	25
fy	400
phi c	0.65
phi s	0.85

Thickness

h (mm)	9000	
hu		
(unsup wall h) mm	6800	
t (mm)	272	t= hu/25 per A23.3 Cl.14.1.7.1
t (mm)	300	

Bending + Shear forces

Soil Forces

hw (mm)	6800	
b (mm)	1000	
Ko	0.5	
γ_s (kN/m3)	20	
γ_o	10	
p_o (Kpa)	68	
p_{of} (Kpa)	85	based on load combo 2 (1.25 DL + 1.5 LL)
w_f (kPa)	42.5	
Mf (kN*m/m)	245.65	
Vf (kN/m)	192.6667	

Flexure and Axial

t (mm)	272	greater of hu/25 or 190 mm
t actual (mm)	300	for design purposes

Vertical Reinforcement

db (mm)	25				
Cover	20		therefore 25M@140 mm		
d (mm)	267.5		per m (7 bars)		
Mr = Mf	245.65				
As (mm2/m)	3144.495				
Area bar	490.8739				
Req spacing	156.1058				
Spacing (mm)	156.1058	--->	Space max		
				3t	900
				500mm	500
Max tension check					
p	0.011755	$< p_{b\,=.022}$			
Min Tension check					
Ag	300000				
Avmin (mm2/m)	450	< As = 1963			

Loads

<u>Dead Loads</u>		Trib Width (ı	Trib Height	Load (kN/m	Factored	x2 floors
Slab (kg/m3)	2500	1	0.3	7.5	9.375	18.75
Beam (kg/m3)	2500	0.25	0.8	5	6.25	12.5
Wall (kg/m3)	2500	1	9	225	281.25	281.25
Snow Load (kPa)	1.6	1	-	1.6	2	2
						314.5

<u>Live Loads</u>						x1 floor
Parkade (kPa)	2.4	1	-	2.4	3.6	3.6
Green Roof (kPa)	2.4	1	-	2.4	3.6	3.6
						7.2

Shear Design

Vf (kN/m)	85	= shear due to soil load at bottom			
dv1 (mm)	240.75				
dv2 (mm)	216				
bw (mm)	1000				
Beta	0.185372				
Vc	145.0418	> Vf No Horz Shear Reinforcement Required,			
		Design for min clause standards anyways			
Ag	300000				
Ahmin (mm2/m)	600				
Ab	490.8739				
s (mm)	156.1058	-->	Space max	check	
s (mm)	156.1058			3t	900
Max Tension	0.011755	< $p_{b\ =.022}$		500mm	500

therefore 25M@500mm
per m (2 bars)

Axial Load Resistance

A1 (mm2)	300000		
Bearing Resistance (kN)	4143.75	> DL =	314.5
Factored Axial Resistance			
lb (horz wall length) (mm)	2000	A23.3 CL.14.1.3.1	
Ag	600000		
alpha	0.8		
phi c	0.65		
fc	25		
Ag	600000		
h	6800		
t	300		
Pr (kN)	2590.972	> DL =	314.5

Strip Footing Design

(Simplified)		
Bearing Load (kN)	320	
b (m)	1	
q allow (soil) kPa (sandy clay)	150	
Required Area	2.133333	
Width Footing (m)	2	
Vf (kN/m)	192.6667	
h (mm)	250	
dv (mm)	180	
Vc	388	>Vf , no rebar needed but still add due to code req.
Use same reinforcement		
as walls for deisgn ease	therefore 25M@500mm	

APPENDIX B: HYDRAULIC SUBSTRUCTURE

Hydraulic Design:

Inputs:	
Outputs:	

Pipe	Orifice Pipe	Outlet Pipe	Overflow Pipe
Q (m3/s)	0.26	0.26	0.65
g (m/s2)	9.81	9.81	9.81
C	0.62	0.62	0.62
h (m)	1.5	3	3
A (m2)	0.077	0.055	0.137
D (m)	0.314	0.264	0.417
V (m/s)	3.363	4.757	4.757

Pipe	Inlet Pipe
Q (m3/s)	0.65
n	0.013
Slope (m/m)	0.063
A (m2)	0.148
D (m)	0.435
V (m/2)	4.380

Pipe Description	Diameter (mm)	Material	Design Flow	Equation
Inlet Pipe	450	PVC	Peak 100yr	Manning's
Orifice Pipe	350	Concrete	Predevelopment 2yr	Orifice
Outlet Pipe	250	PVC	Predevelopment 2yr	Orifice
Overflow Pipe	450	PVC	Peak 100yr	Orifice

Settling Tank Length Check:

Inputs:		
Outputs:		
Particle diameter (mm)	0.03	
Particle diameter (m)	0.00003	
Particle volume (mm^3)	0	
Particle density	1500	
Water density	1000	
Settling velocity	0.24525	
Dynamic Viscosity	0.001	
Kinematic Viscosity	0.000001	
Reynolds Number	0.0073575	
	If <2, ok, else see below	
If Re>2, assume transition flow		
Settling velocity	Null	
Reynolds number		
Settling Distance m)	3	
Settling Time (s)	12.2324159	

Required Area of Oil-Grit Separator:

Inputs:	
Outputs:	
HR (m^3/s)	0.027
Q (m^3/s)	0.26
A (m^2)	9.62962963

Design of Soakaway Pits:

Inputs:		
Outputs:		
Parameter	Value	Source/Comment
Inflow, I (m^3)	22464	24 hr, 2 yr outflow from dry detention vault
Infiltration Rate (Till) (m/s)	0.000017	
Infiltration Rate (Quadra Sand) (m/s)	0.00048	Piteau Report
Storm Duration (s)	86400	Metro Van
Depth of Well (m)	16.3	Depth to reach with Auger (1m cover, 150mm pipe, 150mm rock below pipe
Pipe Diameter (m)	0.1	
Pit Diameter (m)	0.66	(24" Dual Rotary Drills available locally)
Area (Till) (m^2)	269.55	Layer approx. 5 m thick below distribtion pipe
Area (Quadra Sand) (m^2)	539.10	Remaining 10 m to final depth
Number of Soakaway Pits	26	Spaced at a minimum of 8m
Outflow (Till) (m^3)	395.91	
Outflow (Quadra Sand) (m^3)	22357.44	
Outflow Total(m^3)	**22753.36**	
Total Volume of Soakaway Pit (m^3)	100.51	
Volume of individual soakaway Pit (m^3)	3.87	
Volume of Drain Rock per soakaway pit (m^3)	3.86	
Total Volume of Drain Rock	100.25	
Storage (m^3)	-289.36	Storage = Outflow - Inflow
Difference (m^3)	-389.87	

APPENDIX C: NATURAL SYSTEMS

Appendix C

Green Roof Calculation

1) Determination of Vancouver's Average Annual Rainfall

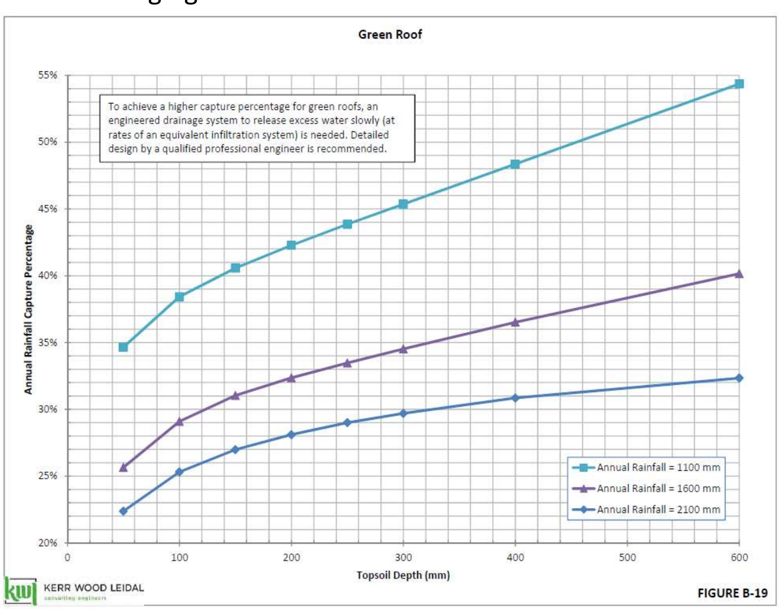
Sorucing from the WeatherStats website the following annual rainfall data was retrieved and used to determine the average annual rainfall.

Year	Annual Rainfall (mm)
2018	1325.4
2017	1172.9
2016	1279.6
2015	1139.2
2014	1236.8
2013	905
2012	1161.3
2011	1045.2
2010	1190.4
2009	1055.6
2008	913.8
2007	1274.4
2006	1175
2005	1183.8
2004	1200.8
2003	1086.2
2002	818
2001	1162.3
2000	979
Average:	1121 mm
CC Average:	**1177** mm

Increase rainfall by 5% to account for climage change by the 2050s
Source: MetroVancouver, "Climate Projections for Metro Vancouver", 2016

2) Determining the topsoil depth of the green roof

The following figure was retrieved from the Stormwater Source Control Design Guidelines by MetroVancouver



In order to maximize the annual rainfall capture percentage a topsoil depth of 600 mm was chosen. Using the figure to the left and the annual rainfall, we can determine that a green roof of 600 mm in Vancouver, will be able to capture approximately 54% of annual rainfall.

APPENDIX D: COST ESTIMATE

Item No.	Description	Unit	Estimated Quantity	Unit Rate	Reference Unit	Conversion	On-Site Price (USD)	Canadian Conversion	Time Adjustment	Price (±15%)
1	**Permitting**									
	Stakeholder Engagement	Lump Sum	1	1,300	LS	$1.00	$1,300.00	$1.00	$1.00	$1,300
	Exavation and Backfill Permit	Lump Sum	1	2,700	LS	$1.00	$2,700.00	$1.00	$1.00	$2,700
	Traffic Management Permit	Lump Sum	1	600	LS	$1.00	$600.00	$1.00	$1.00	$600
	Street and Landscape Permit	Lump Sum	1	500	LS	$1.00	$500.00	$1.00	$1.00	$500
	Planning Processing Fee	Lump Sum	1	5,000	LS	$1.00	$5,000.00	$1.00	$1.00	$5,000
	Development Permit	Lump Sum	1	2,400	LS	$1.00	$2,400.00	$1.00	$1.00	$2,400
	Plumbing + Sprinkler + Fire Protection Permits	Lump Sum	1	4,000	LS	$1.00	$4,000.00	$1.00	$1.00	$4,000
1	**Subtotal**									**$20,000**
2	**General**									
	Survey	Acre	4	2,000	Acre	$1.00	$8,000.00	$1.34	$1.40	$15,008
	Creation of Break Area/Storage Location	m3	1,000	8	m3	$1.00	$8,000.00	$1.00	$1.00	$8,000
	Equipment Mobilization	Lump Sum	100	305		$1.00	$30,500.00	$1.34	$1.40	$57,218
	Traffic Control	Hr	1750	400	hr	$1.00	$700,000.00	$1.00	$1.00	$700,000
	Temporary Fencing	L.M.	1000	7	L.M.	$3.28	$24,108.00	$1.34	$1.40	$45,227
	Tree Removal	EA.	50	1,000	EA.	$1.00	$50,000.00	$1.00	$1.00	$50,000
	16th Avenue Concrete Path Removal	m2	1,500	13	m2	$1.00	$18,750.00	$1.00	$1.00	$18,750
	Removal of existing soil base	m3	6,000	16	m3	$1.00	$96,000.00	$1.00	$1.00	$96,000
	Landscaping/Arborist	Lump Sum	1	100,000	Lump Sum	$1.00	$100,000.00	$1.00	$1.00	$100,000
2	**Subtotal**									**$1,100,000**
3	**Parkade Structure**									
	Excavation	C.M.	20160	2	C.Y.	$1.31	$62,495.19	$1.34	$1.40	$117,241
	Beam Concrete (Including forms (4 uses), concrete, placement, reinforcing steel, and finishing)	C.M.	960	805	C.Y.	$1.31	$1,012,368.00	$1.34	$1.40	$1,899,202
	Slab Concrete (Including forms (4 uses), concrete, placement, reinforcing steel, and finishing)	C.M.	337.5	805	C.Y.	$1.31	$355,910.63	$1.34	$1.40	$667,688
	Wall Concrete (Including forms (4 uses), concrete, placement, reinforcing steel, and finishing)	C.M.	1176.4	805	C.Y.	$1.31	$1,240,572.62	$1.34	$1.40	$2,327,314
	Electrical Services - Lighting, Heating, Systems	Lump Sum	1	25,000	Lump Sum	$1.31	$32,750.00	$1.34	$1.40	$61,439
	Mechanical Services - HVAC, Controls, Plumbing	Lump Sum	1	25,000	Lump Sum	$1.31	$32,750.00	$1.34	$1.40	$61,439
3	**Sub-total**									**$5,200,000**
4	**Dry Detention Vault**									
	Vault Baffle Concrete	C.M.	22.5	805	C.Y.	$1.31	$23,727.38	$1.34	$1.40	$18,113
	450mm DR 35 PVC Inlet Pipe	L. M.	48	836	L. M.	$1.00	$40,128.00	$1.34	$1.22	$65,711
	450mm DR 35 PVC Overflow Pipe	L. M.	5	836	L. M.	$1.00	$4,180.00	$1.34	$1.22	$6,845
	250mm DR 35 PVC Outlet Pipe	L. M.	3	210	L. M.	$1.00	$629.69	$1.34	$1.22	$1,031
	Stormceptor EFO 6 Oil Grit Separator	Lump Sum	1	75,000	Lump Sum	$1.00		$1.00	$1.17	$87,603
	Concrete Waterproofing	C.M.	22.5	8	C.Y.	$1.31		$1.34	$1.40	$191
4	**Sub-total**									**$180,000**
5	**Soakaway Pits**									
	24" Dual Rotary Drilled holes, 16.3 m deep	L.M	423.8	45	L.F	$3.28	$62,552.88	$1.34	$1.40	$117,349
	Drain Rock	C.M.	100.25	42	C.Y.	$1.31	$5,515.76	$1.00	$1.00	$5,516
	25mm Clean Crush Rock	C.M.	30	52	C.Y.	$1.31	$2,043.60	$1.00	$1.00	$2,044
	250mm DR35 PVC Pipe	L.M.	3	94	L.F.	$3.28	$924.96	$1.34	$1.22	$1,512
	150mm DR35 PVC Pipe	L.M.	400	49	L.F.	$3.28	$63,632.00	$1.34	$1.22	$104,200
	100mm DR28 PVC Perforated PVC Pipe	L.M.	416	35	L.F.	$3.28	$47,756.80	$1.34	$1.22	$78,073
	250mm x 150mm PVC Tee	Ea.	1	330	Ea.	$1.00	$330.00	$1.00	$1.00	$330
	150mm PVC Elbow	Ea.	2	74	Ea.	$1.00	$147.00	$1.00	$1.00	$147
	150mm x 100mm PVC Tee	Ea.	26	110	Ea.	$1.00	$2,860.00	$1.00	$1.00	$2,860
5	**Sub-total**									**$320,000**
6	**Natural Systems**									
	Bioswales	C.M.	3000	10	C.Y.	$1.31	$39,240.00	$1.34	$1.40	$73,614
	Rain Gardens	Lump Sum	1	100,000	LS	$1.00	$100,000.00	$1.00	$1.00	$100,000
	Green Roof	Lump Sum	1	100,000	LS	$1.00	$100,000.00	$1.00	$1.00	$100,000
	Landscaping/Arborist	Lump Sum	2	100,000	LS	$1.00	$200,000.00	$1.00	$1.00	$200,000
6	**Sub-total**									**$480,000**
7	**Sub-total for All Tasks**									**$8,000,000**
8	**Engineering & General Contractor Fees (20%)**									$1,600,000
9	**Insurance and Bonding (2%)**									$160,000
10	**Contingencies (20%)**									$1,600,000
11	**Sub-total Construction + Engineering**									**$11,400,000**
12	**GST (5%)**									$570,000
13	**Estimated Total Cost**									**$12,000,000**

	Maintenance & Operations									
	Parkade Inspection	per year	12	200	per year	$1.00	$2,400.00	$1.00	$1.00	$2,400
	Parkade Cleaning	per year	48	150	per year	$1.00	$7,200.00	$1.00	$1.00	$7,200
	Detention Structure Calibration	per year	6	600	per year	$1.00	$3,600.00	$1.00	$1.00	$3,600
	Detention Structure Inspections	per year	6	800	per year	$1.00	$4,800.00	$1.00	$1.00	$4,800
	Detention Structure Additional Inspections after large rainfall	per year	1	1,600	per year	$1.00	$1,600.00	$1.00	$1.00	$1,600
	Soakaway Inspections	per year	6	600	per year	$1.00	$3,600.00	$1.00	$1.00	$3,600
	Soakaway Additional Inspections after large rainfall	per year	6	800	per year	$1.00	$4,800.00	$1.00	$1.00	$4,800
	Natural Systems Grass Cutting	per year	5	500	per year	$1.00	$2,500.00	$1.00	$1.00	$2,500
	Natural Systems Invasive Plant Maintenance	per year	2	600	per year	$1.00	$1,200.00	$1.00	$1.00	$1,200
	Maintenance & Operations Sub-total									**$32,000**

APPENDIX E: DRAWINGS

Soakaway (MetroVancouver, Stormwater Source Control Design Guidelines 2012 [7])

1. Materials:
   1.1. Infiltration Drain Rock: Clean round stone or crushed rock, with porosity of 35 to 40% such as 75mm max, 38mm min (Maryland Dept. Environmental Resource Programs, 2001)
   1.2. Pipe: PVC, DR 35 100mm min Diameter with cleanouts certified to CSA B182.1 as per MMCD
   1.3. Perforated Pipe: PVC, DR 28 100mm min Diameter.
   1.4. Geosynthetics: as per Section 31-32-19, select for filter criteria or from approved local government product list
2. Construction Practices:
   2.1. Isolate the infiltration site from sedimentation during construction, either by use of effective erosion and sediment control measures upstream, or by delaying excavation of 300mm of material over the final subgrade until after all sediment-producing construction in the drainage area has been completed. (Maryland Dept. Environmental Resource Programs, 2001)
   2.2. Prevent natural or fill soils from intermixing with the infiltration Drain Rock. All contaminated stone aggregate must be removed and replaced. (Maryland Dept. Environmental Resource Programs, 2001)
   2.3. Infiltration Drain Rock shall be installed in 300mm lifts and compacted to eliminate voids between the geotextile and surrounding soils. (Maryland Dept. Environmental Resource Programs, 2001)
   2.4. Provide a min. of 150mm of 25 mm or 19 mm clean crushed rock under all pipes
   2.5. Pipe cover below the ground surface be greater than 1.0 m.
   2.6. Ensure effective erosion control practices are in place during the construction period. If fine sediments are deposited on infiltration areas by accident, remove the surface crust prior to opening the infiltration facility.
   2.7. If possible, have stormwater outfalls bypass the proposed infiltration area during construction.
   2.8. Do not place erosion control sediment traps in infiltration areas.
   2.9. Ensure that bottom and sides of excavations are scarified to remove glazing and improve infiltration
   2.10. Avoid the intrusion of road sands and construction traffic sediments into infiltration facilities.

Dry Detention Vault (MetroVancouver, Best Management Practices Guide for Stormwater, S7: Dry Detention Vault and Wet Vault [6])

1. Design Features:
   1.1. The dry detention vault will be divided into 2 cells using a baffle. The first cell will occupy 25% of the total detained volume (WSDOE, 1992)
   1.2. Access via manholes are required
   1.3. The location will ensure ease of access by maintenance vehicles
   1.4. The location will be at least 15 m from steep slopes
   1.5. The vault will empty between storms
2. Materials:
   2.1. Inflow pipe: PVC Class SDR 35, 450 mm minimum diam. to convey 100 year peak flow
   2.2. Orifice pipe: Concrete, 350 mm diam.
   2.3. Outlet pipe: PVC Class SDR 35, 250 mm minimum diam. to discharge the two-year, pre-development flow rate
   2.4. Overflow pipe: PVC Class SDR 35, 450 mm minimum diam. to convey 100 year peak flow
   2.5. Vault: Cast-in-place, reinforced concrete
   2.6. Baffles: Cast-in-place, reinforced concrete

Manholes: (UBC Technical Guidelines, Electrical Underground Ducts and Manholes 2018 [15])
1. Manholes shall have inside dimensions of 1830 mm x 3300 mm x 2000 mm high
2. The manholes must include cast manhole cover, frame, and brick assembly between manhole and lid
3. Materials include: pre-cast manhole assembly, manhole frame, cover, spacer rings, pulling irons, ground rods, sump cover
4. Concrete will not be placed in foundations until soil has been reviewed by the Engineer
5. The sump must have positive drainage and will be connected to the storm water system
6. Operation and Maintenance Requirements:
7. Confined entry procedures will be followed when entering the vault
8. The vault will be inspected annually to remove floating debris and oil
9. Sediments will be removed from the vault when the depth reaches 150 mm
10. Maintenance plan is required and will be written prior to construction

SITE: STADIUM NEIGHBOUHOOD SWM	C 000 DRAWING NO.	31/03/19 IFC DATE.	SHEARWATER DESIGNS Shearwater Engineering 2335 Engineering Road
TITLE: General Notes	NTS SCALE AT A4. / JD DRAWN.	DL CHECKED. / 0 REVISION.	

General Storm Drainage (UBC Technical Guidelines, Storm Drainage 2018 [16])

1. Materials:
   1.1. PVC Class SDR 28 (150 mm diam. And smaller) and SDR 35
   1.2. Concrete reinforced C76 required for all pipes 600 mm in diameter and larger
   1.3. Corrugated HDPE with minimum pipe stiffness of 320 kPa
   1.4. PVC piping preferred for all diam. 300 mm or smaller
2. Design:
   2.1. Rational method shall be used for design of drainage systems of 10 hectares or less. The hydrograph method should be used for catchments exceeding this area
   2.2. All hydrograph modeling shall be completed with a SWMM based program
   2.3. Storm water shall flow only by gravity into the system
   2.4. All storm sewer piping will be designed to have a minimum velocity of 0.6 m/s when flowing full or half full, based on Manning's formula. Velocity exceeding 3 m/s will undergo structural stability and durability assessments

Parking Structure (CSA S413-14 Parkade Manual [5])

1. Materials:
   1.1. Concrete materials will be in accordance with CSA A23.1
   1.2. Floors and roofs made of concrete and subjected to traffic will be considered exposed to chlorides
   1.3. Coarse aggregate abrasion loss shall be limited to a maximum of 35%
   1.4. Sealants will take into account exposure, temperature, traffic, and movement
2. Construction:
   2.1. Elevations of forms will be verified before concrete placement to ensure proper drainage slopes
   2.2. De-icing chemicals are corrosive and should not be used on the formwork
   2.3. Slab surfaces shall not be overworked to avoid scaling
   2.4. Measures shall be taken to avoid evaporation during curing
   2.5. The concrete shall be covered in blankets in cold weather
   2.6. Forms shall only be removed when the concrete is at least 75% of the specified 28 day strength
   2.7. Waterproofing membrane systems may only be installed when the substrate temperature is at least 2 degrees above the dew point
   2.8. Work on the site will be inspected and tested to comply with these specifications and CSA S413-14.

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SITE: STADIUM NEIGHBOUHOOD SWM	C 000 DRAWING NO.	31/03/19 IFC DATE.	SHEARWATER DESIGNS Shearwater Engineering 2335 Engineering Road
TITLE: General Notes	NTS SCALE AT A4. / JD DRAWN.	DL CHECKED. / 0 REVISION.	

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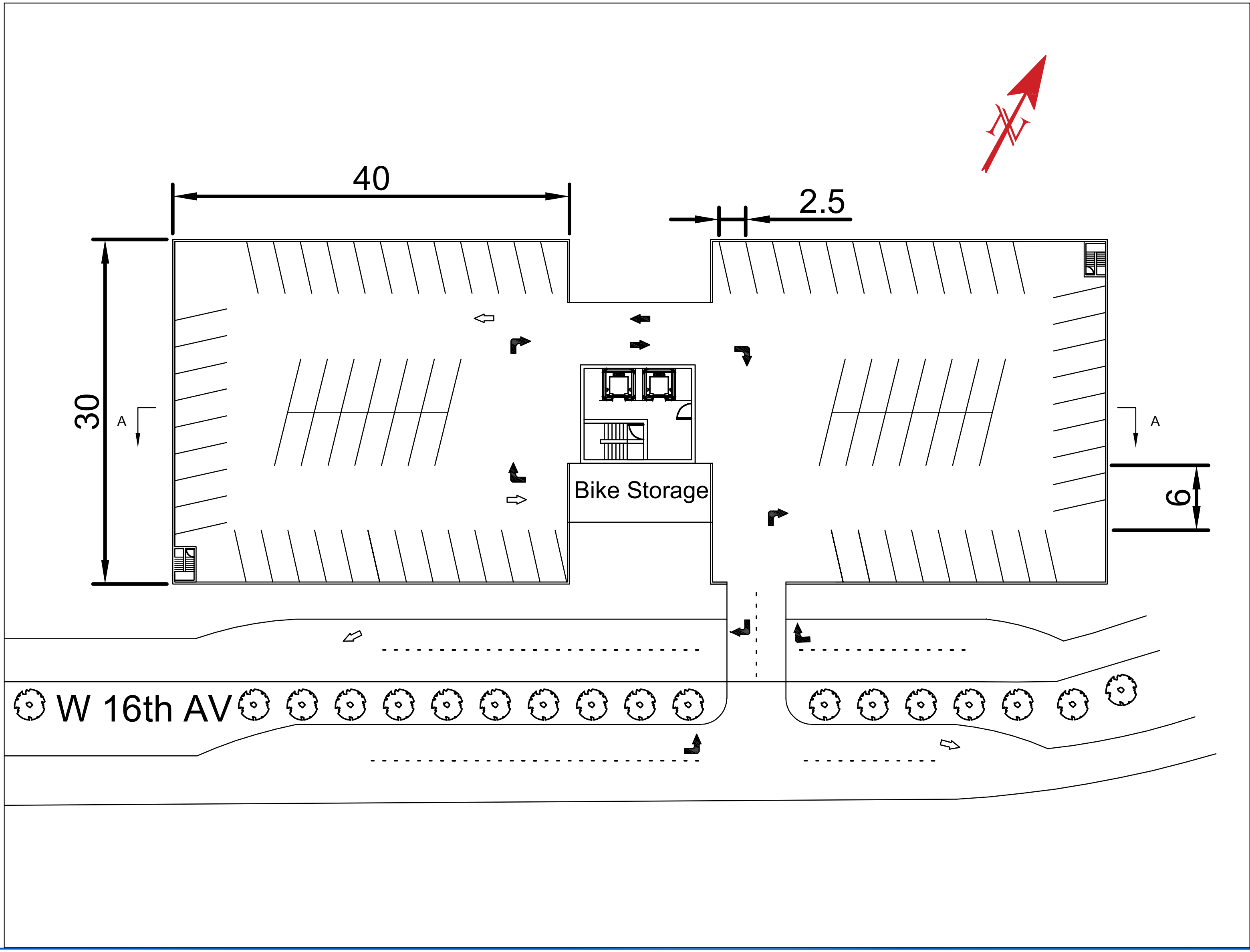

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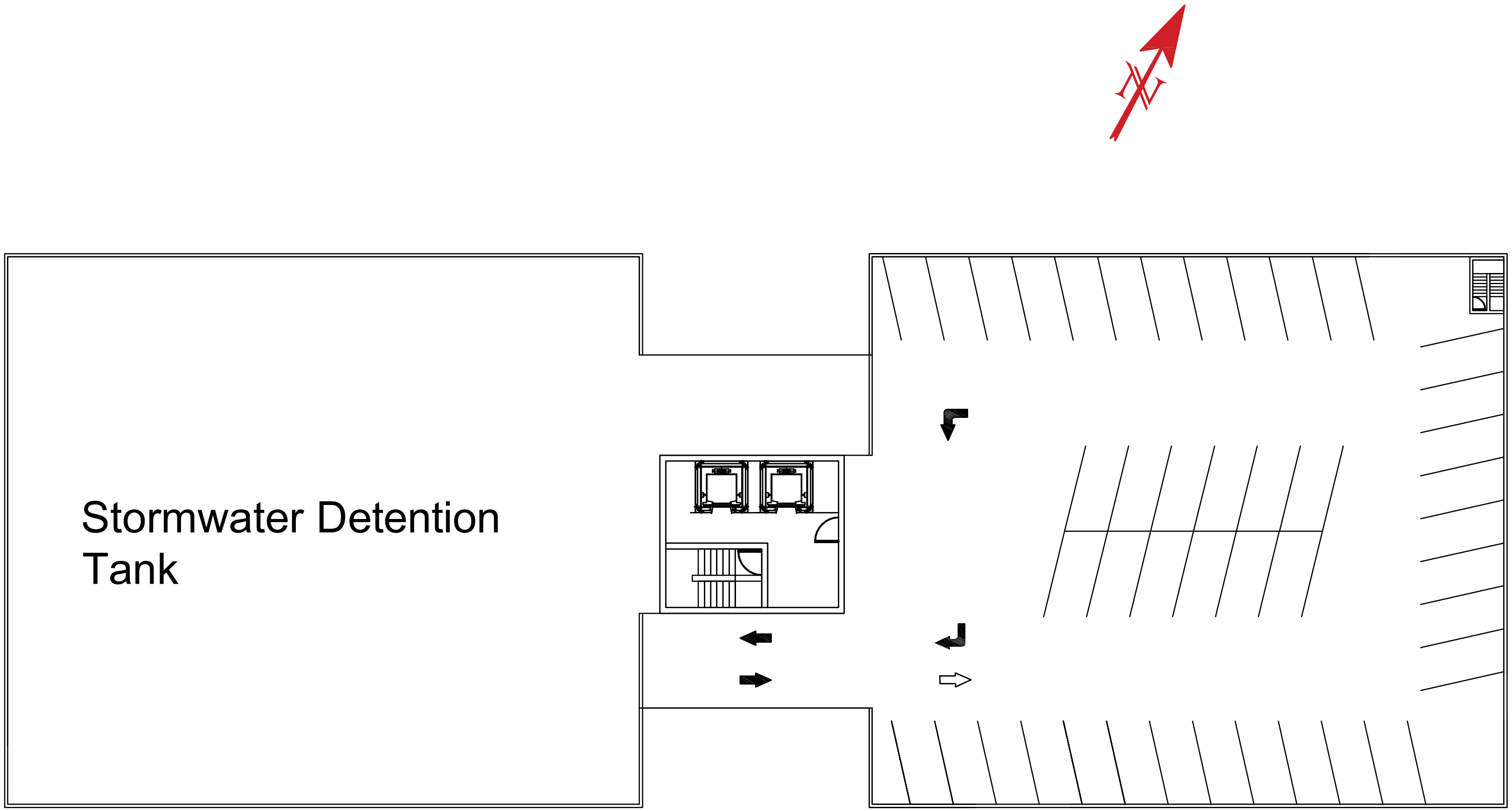
TITLE: Parkade Cross-Section AA	NTS SCALE AT A4	JD DRAWN.	DL CHECKED.	2 REVISION

SHEARWATER DESIGNS

Shearwater Engineering
2335 Engineering Road



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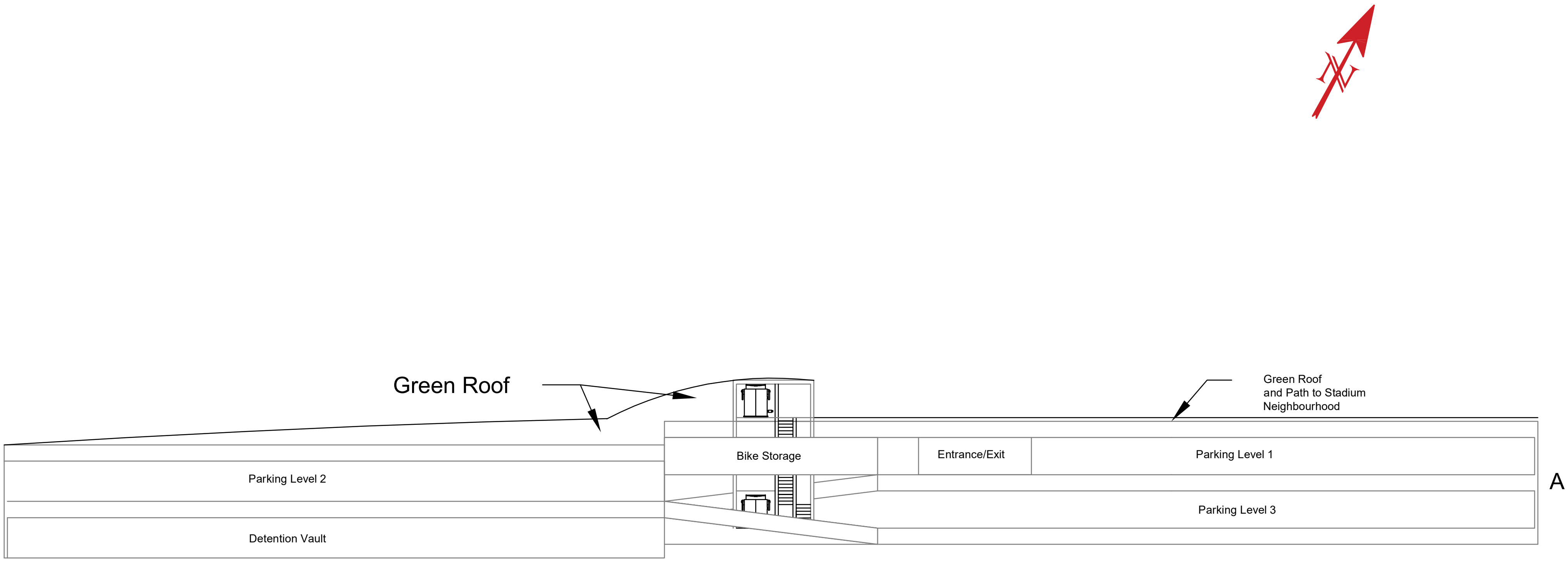
SHEARWATER DESIGNS

Shearwater Engineering
2335 Engineering Road



SITE: STADIUM NEIGHBOUHOOD SWM

TITLE: Parkade Cross-Section AA

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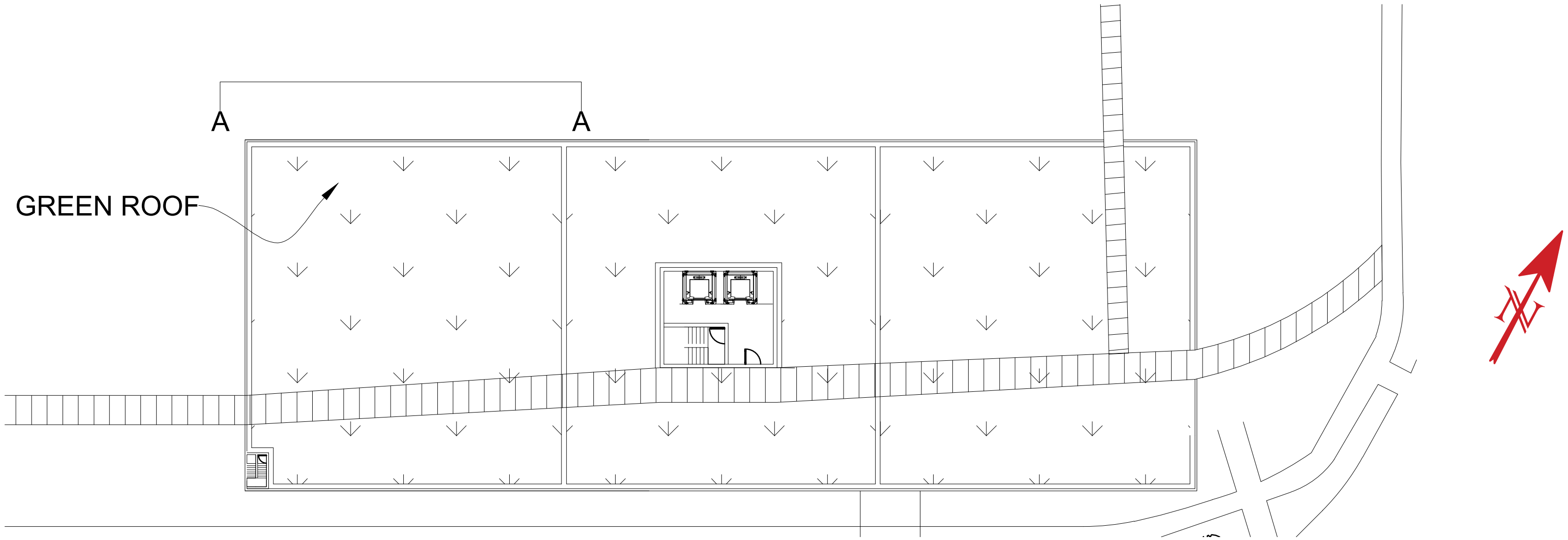
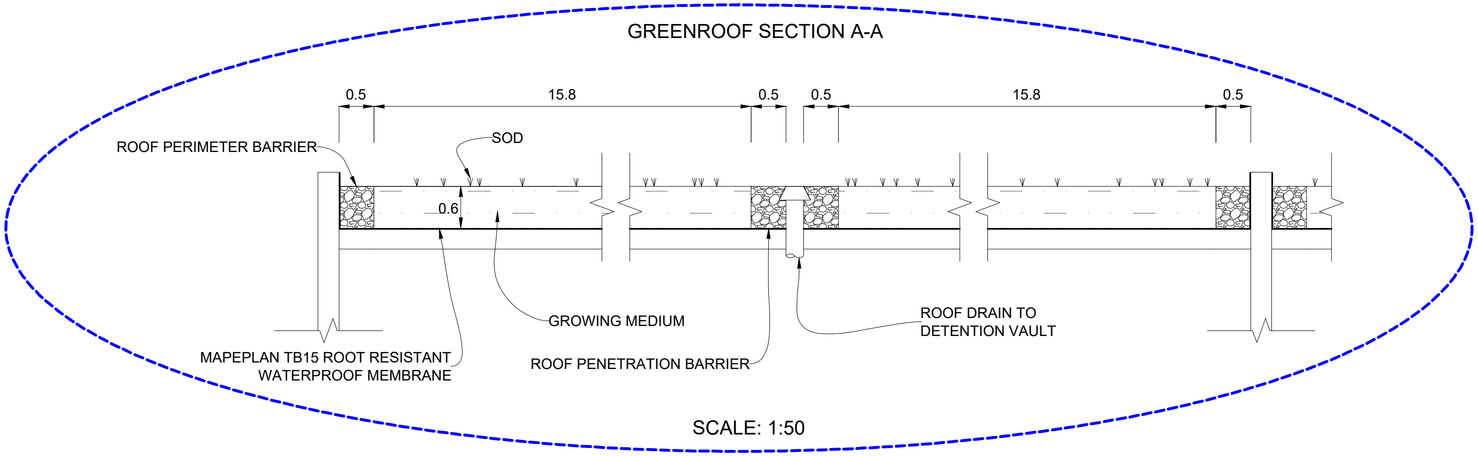
SCALE AT A4. NTS	DRAWN. JD	CHECKED. DL	REVISION. 2

SHEARWATER DESIGNS

Shearwater Engineering
2335 Engineering Road





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TITLE: GREEN ROOF	1:500 SCALE AT A4.	DL DRAWN.	DL CHECKED. 0 REVISION.	

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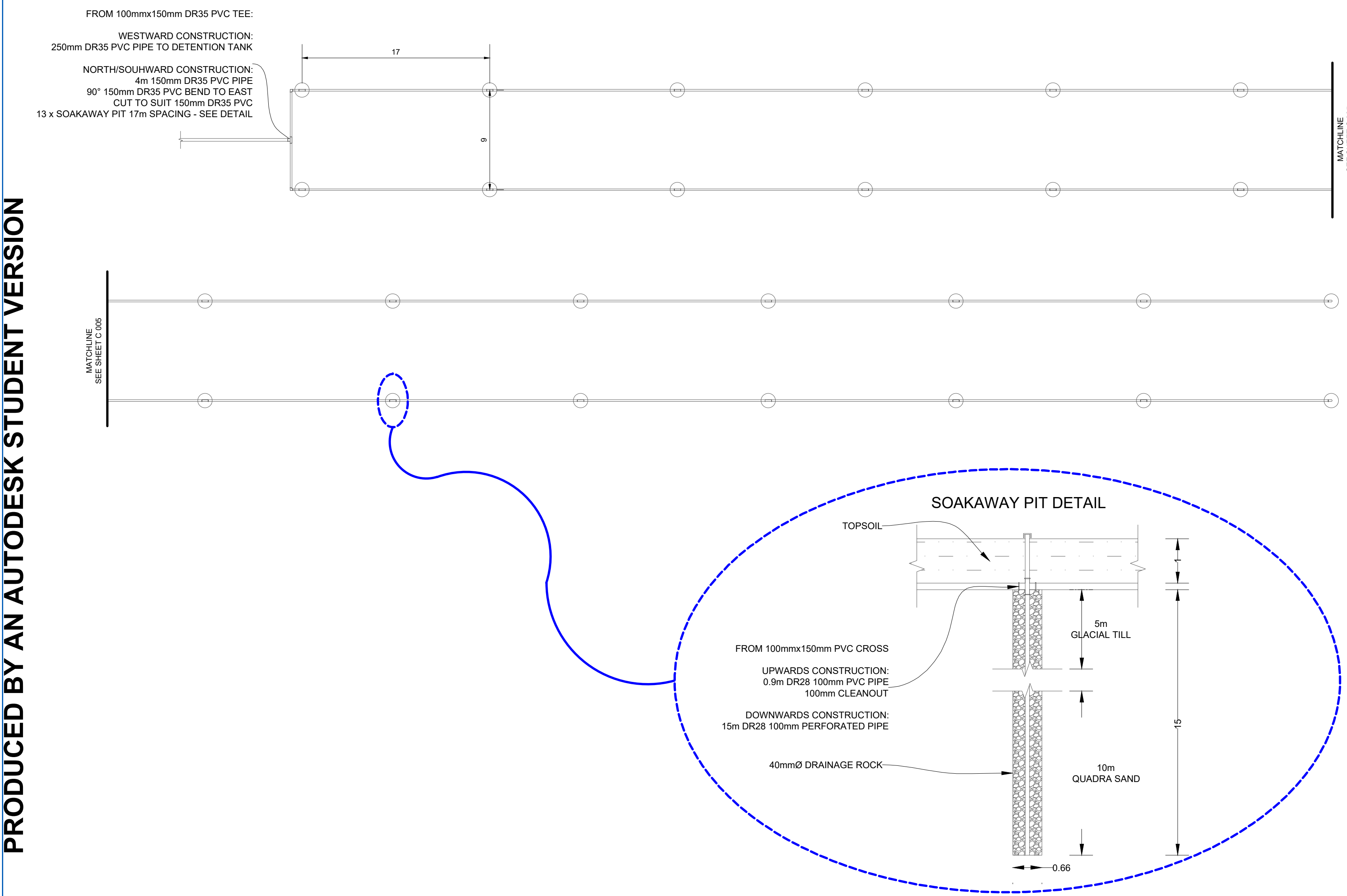

SCALE: 1:50

SITE: STADIUM NEIGHBOUHOOD SWM	C 005 DRAWING NO.		01/04/19 IFC DATE.	Shearwater Engineering 2335 Engineering Road
TITLE: SOAKAWAY PIT	1:500 SCALE AT A4.	DL DRAWN.	DL CHECKED. 2 REVISION.	

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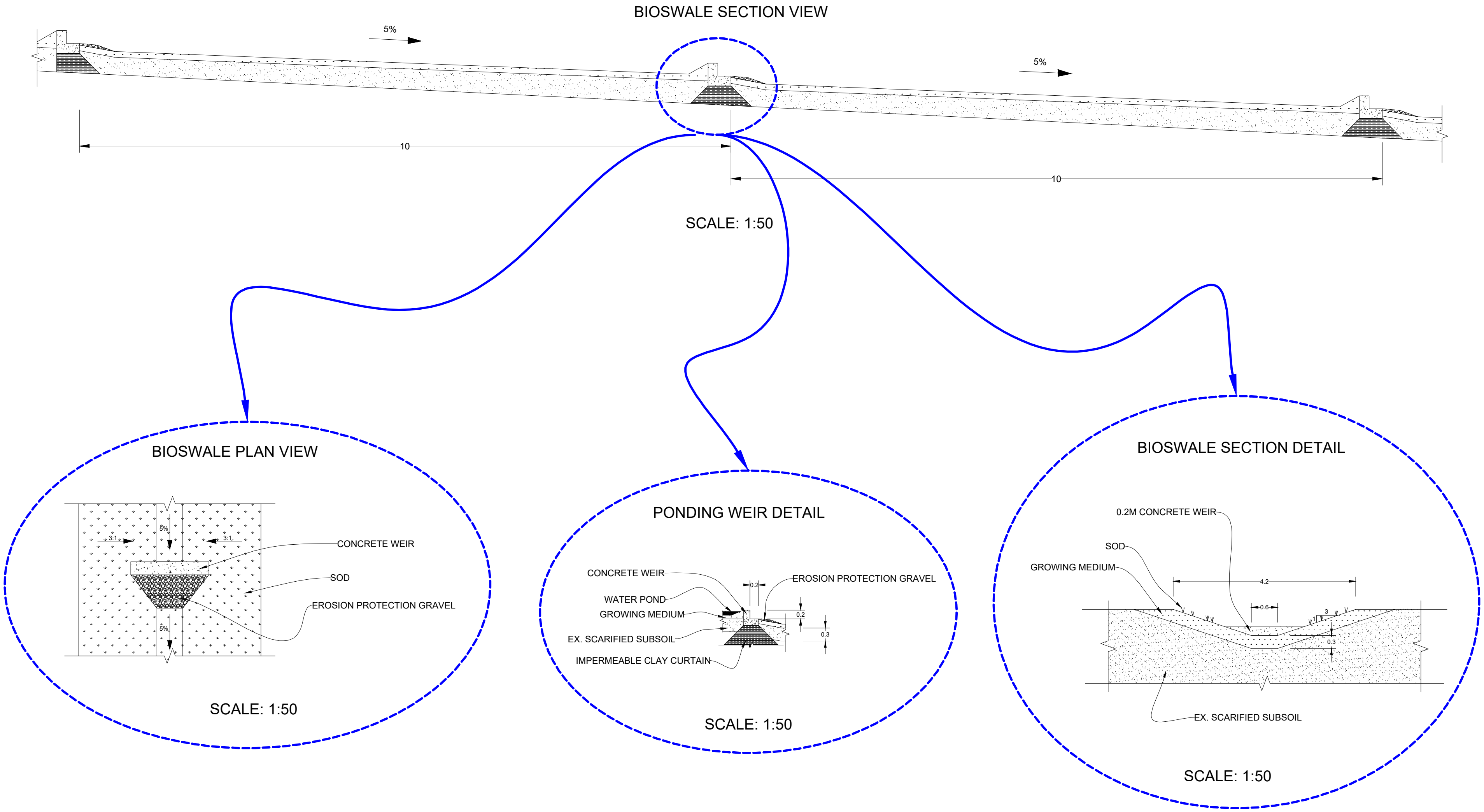

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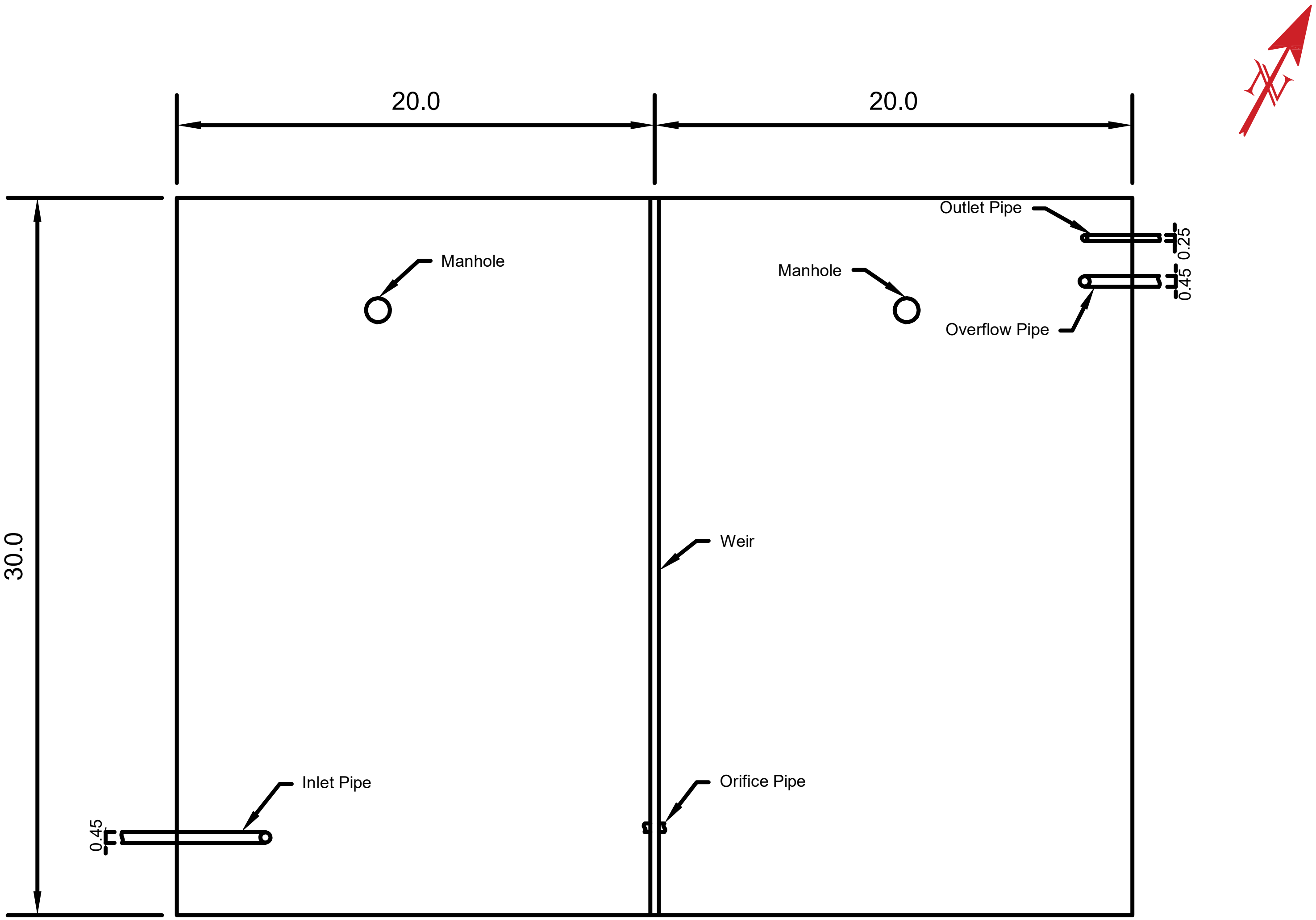

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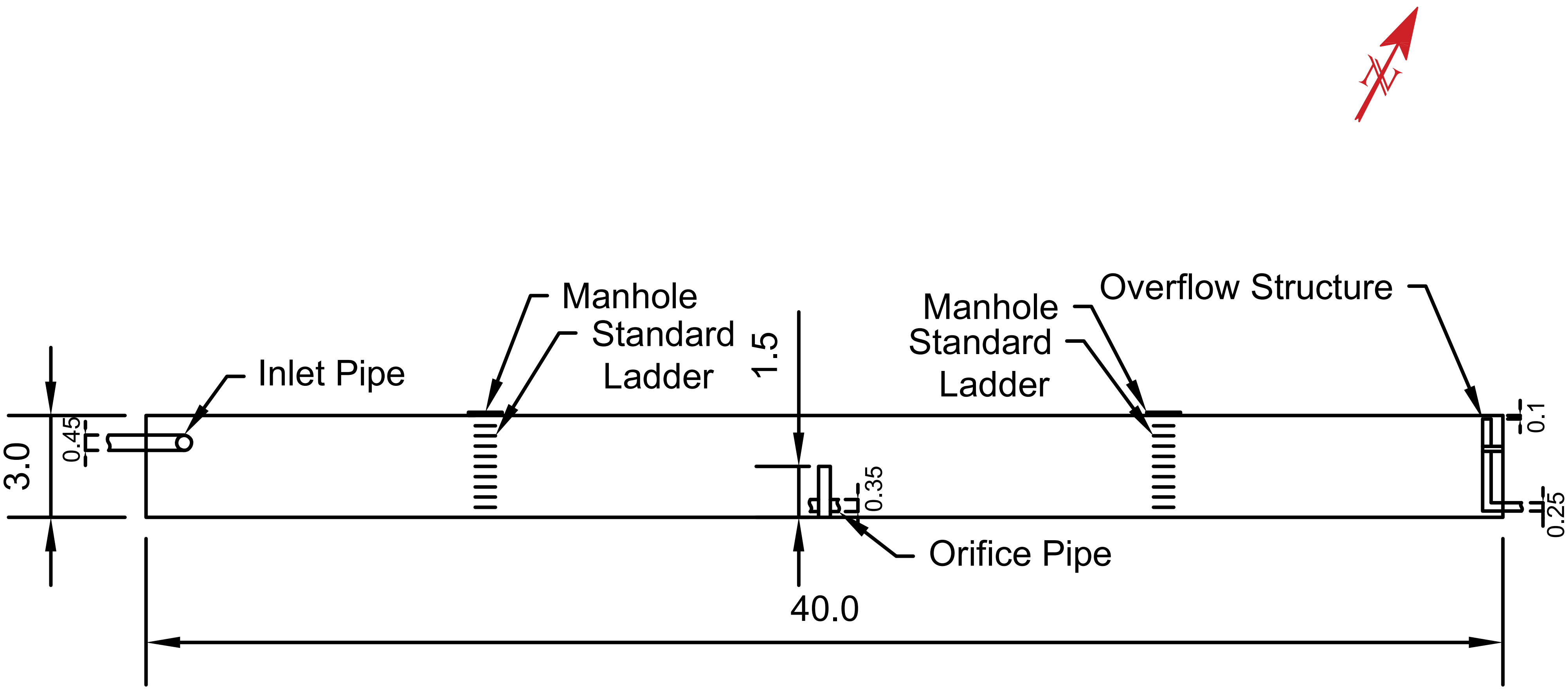

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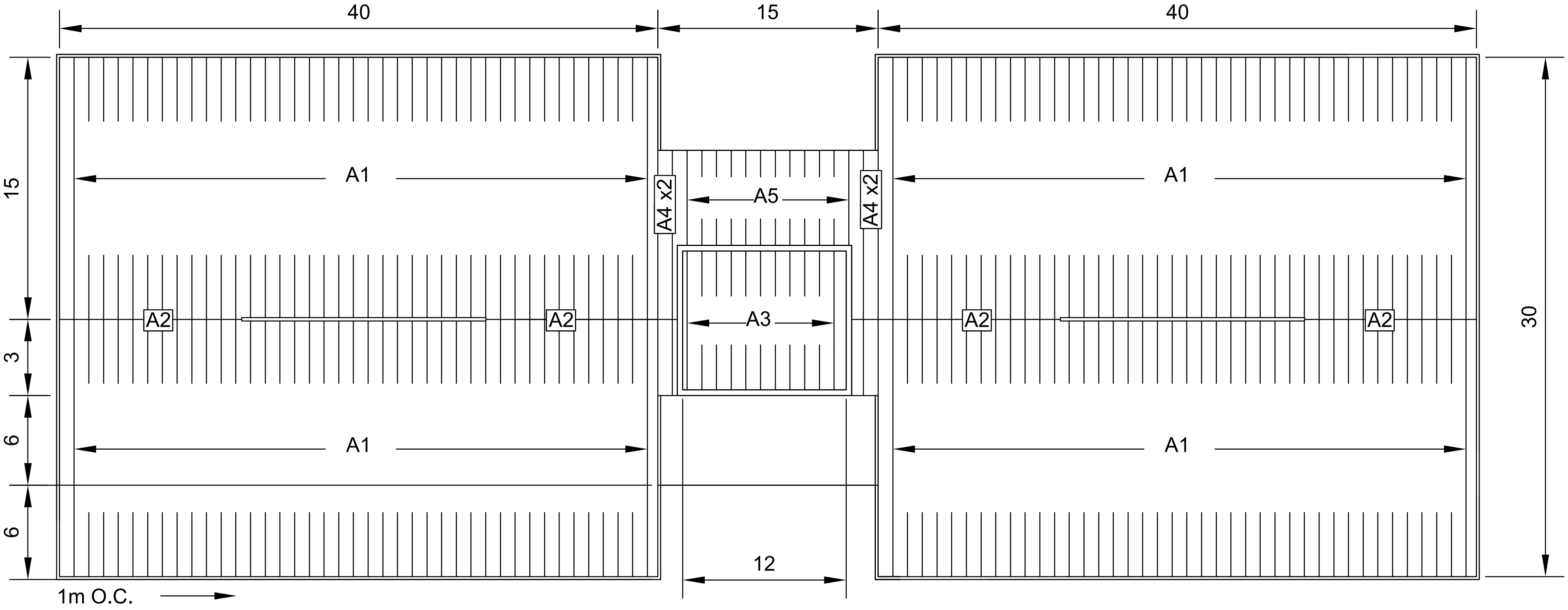
Shearwater Engineering
2335 Engineering Road



Beam Schedule

Beam Type	Depth x Width	Length	Rebar
A1	0.8 x 0.25	15	Tension: 1 row of 2 55M bars Shear: 2 legs of 10M Stirrups at 600 mm
A2	0.8 x 0.25	12.5	Tension: 1 row of 2 55M bars Shear: 2 legs of 10M Stirrups at 600 mm
A3	0.8 x 0.25	10	Tension: 1 row of 2 55M bars Shear: 2 legs of 10M Stirrups at 600 mm
A4	0.8 x 0.25	12	Tension: 1 row of 2 55M bars Shear: 2 legs of 10M Stirrups at 600 mm
A5	0.8 x 0.25	6	Tension: 1 row of 2 55M bars Shear: 2 legs of 10M Stirrups at 600 mm

SITE: STADIUM NEIGHBOUHOOD SWM

C 009
DRAWING NO.

31/03/19
IFC DATE.

SHEARWATER DESIGNS

Shearwater Engineering
2335 Engineering Road

TITLE: Parkade Cross-Section AA

NTS
SCALE AT A4

JD
DRAWN

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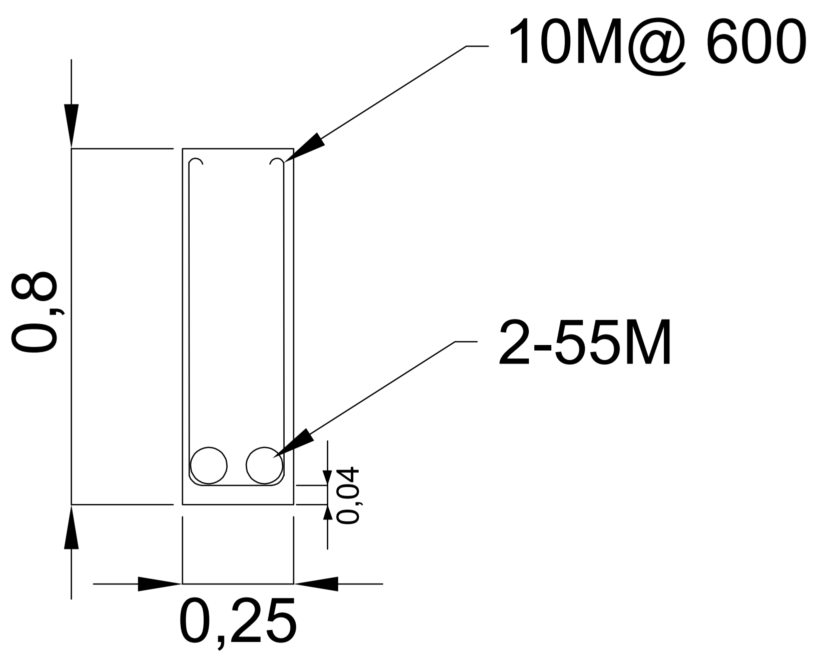
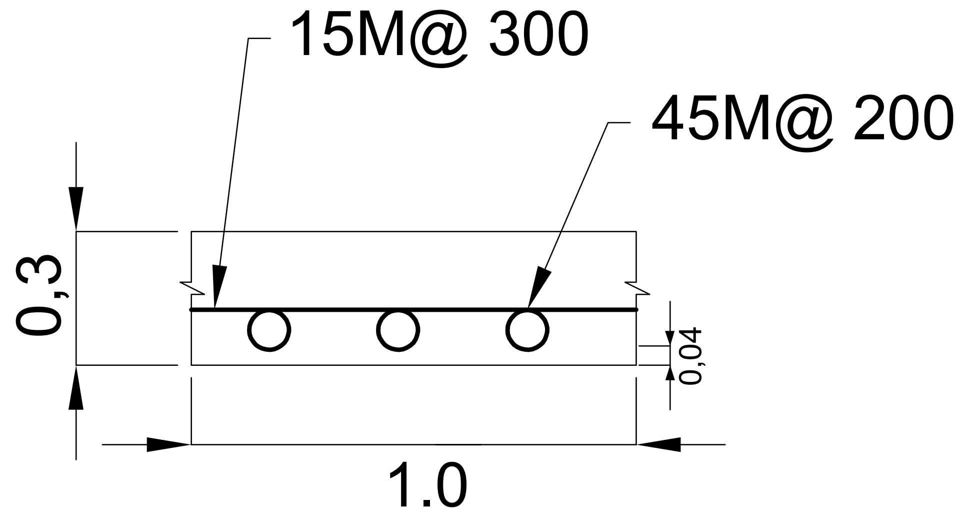
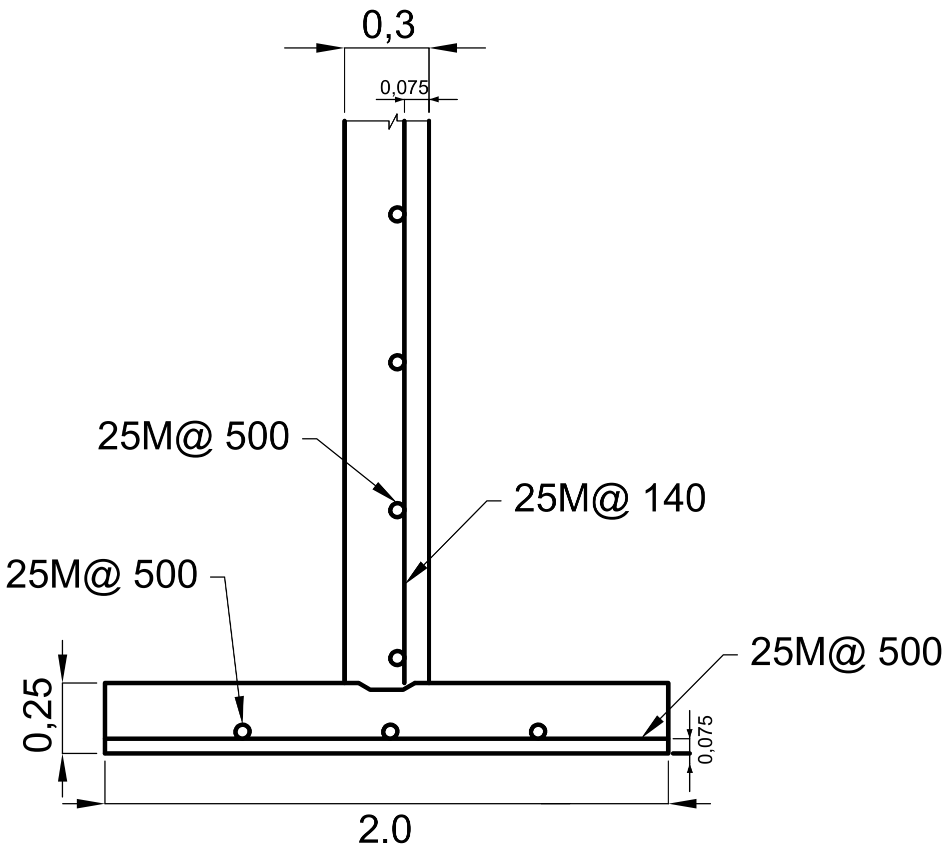


A. Beam Cross-Section



B. Slab Cross-Section

SITE: STADIUM NEIGHBOUHOOD SWM	C 010 DRAWING NO.		31/03/19 IFC DATE.	SHEARWATER DESIGNS Shearwater Engineering 2335 Engineering Road
TITLE: Parkade Cross-Section AA	NTS SCALE AT A4.	JD DRAWN.	DL CHECKED. 0 REVISION.	



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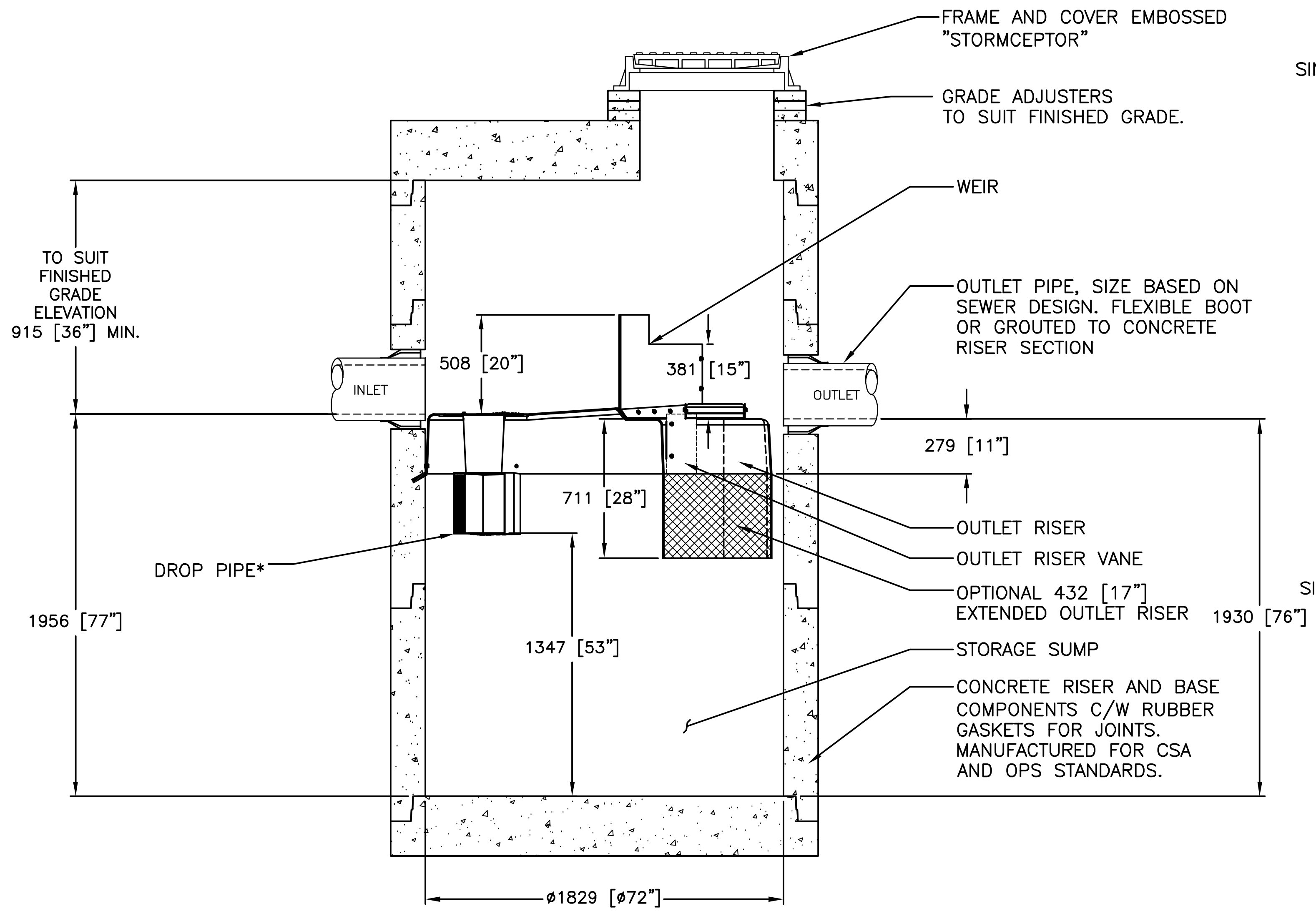
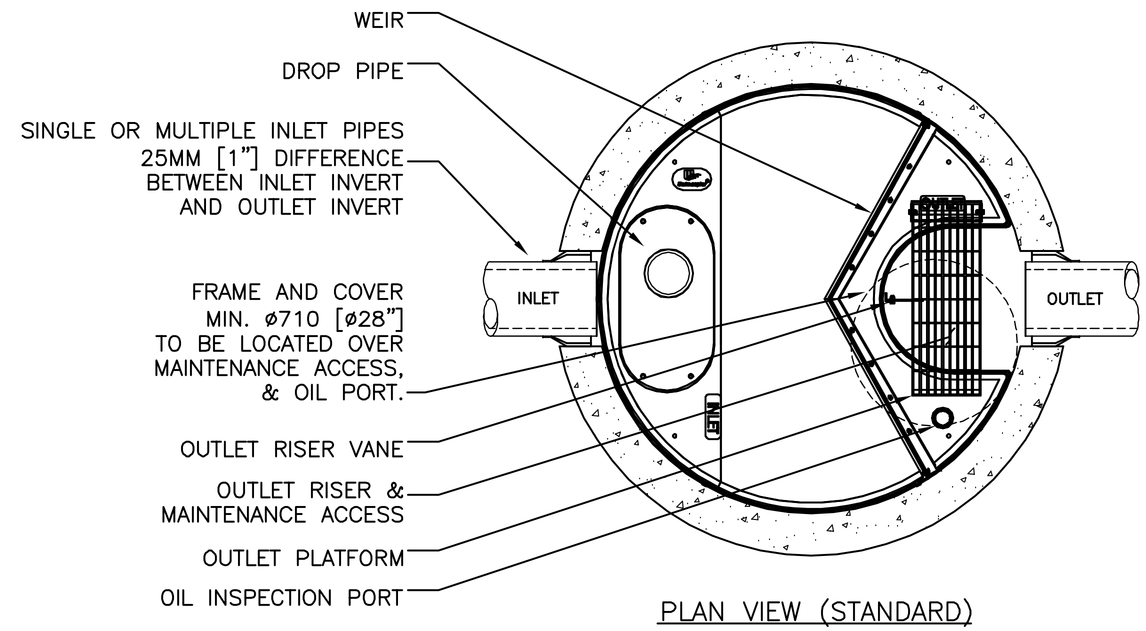
TITLE: Parkade Cross-Section AA	NTS SCALE AT A4.	JD DRAWN.	DL CHECKED. 0 REVISION.	

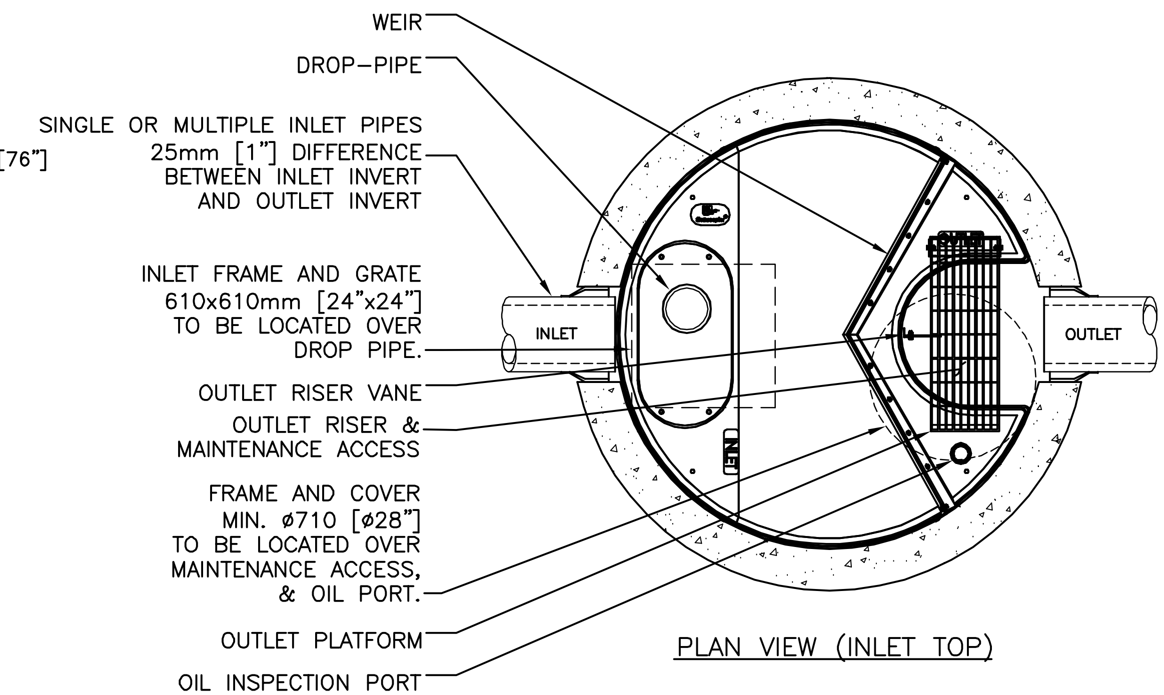
DRAWING NOT TO BE USED FOR CONSTRUCTION



SECTION VIEW



PLAN VIEW (STANDARD)



PLAN VIEW (INLET TOP)

GENERAL NOTES:

* MAXIMUM SURFACE LOADING RATE (SLR) INTO LOWER CHAMBER THROUGH DROP PIPE IS 1135 L/min/m^2 (27.9 gpm/ft^2) FOR STORMCEPTOR EF6 AND 535 L/min/m^2 (13.1 gpm/ft^2) FOR STORMCEPTOR EFO6 (OIL CAPTURE CONFIGURATION).

1. ALL DIMENSIONS INDICATED ARE IN MILLIMETERS (INCHES) UNLESS OTHERWISE SPECIFIED.
2. STORMCEPTOR STRUCTURE INLET AND OUTLET PIPE SIZE AND ORIENTATION SHOWN FOR INFORMATIONAL PURPOSES ONLY.
3. UNLESS OTHERWISE NOTED, BYPASS INFRASTRUCTURE, SUCH AS ALL UPSTREAM DIVERSION STRUCTURES, CONNECTING STRUCTURES, OR PIPE CONDUITS CONNECTING TO COMPLETE THE STORMCEPTOR SYSTEM SHALL BE PROVIDED AND ADDRESSED SEPARATELY.
4. DRAWING FOR INFORMATION PURPOSES ONLY. REFER TO ENGINEER'S SITE/UTILITY PLAN FOR STRUCTURE ORIENTATION.
5. NO PRODUCT SUBSTITUTIONS SHALL BE ACCEPTED UNLESS SUBMITTED 10 DAYS PRIOR TO PROJECT BID DATE, OR AS DIRECTED BY THE ENGINEER OF RECORD.

FOR SITE SPECIFIC DRAWINGS PLEASE CONTACT YOUR LOCAL STORMCEPTOR 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. ELEVATIONS SHOULD BE MAINTAINED EXCEPT WHERE NOTED ON BYPASS STRUCTURE (IF REQUIRED).

INSTALLATION NOTES

A. ANY SUB-BASE, BACKFILL DEPTH, AND/OR ANTI-FLOTATION PROVISIONS ARE SITE-SPECIFIC DESIGN CONSIDERATIONS AND SHALL BE SPECIFIED BY ENGINEER OF RECORD.
B. CONTRACTOR TO PROVIDE EQUIPMENT WITH SUFFICIENT LIFTING AND REACH CAPACITY TO LIFT AND SET THE STRUCTURE (LIFTING CLUTCHES PROVIDED)
C. CONTRACTOR WILL INSTALL AND LEVEL THE STRUCTURE, SEALING THE JOINTS, LINE ENTRY AND EXIT POINTS (NON-SHRINK GROUT WITH APPROVED WATERSTOP OR FLEXIBLE BOOT)
D. CONTRACTOR TO TAKE APPROPRIATE MEASURES TO PROTECT THE DEVICE FROM CONSTRUCTION-RELATED EROSION RUNOFF.
E. DEVICE ACTIVATION, BY CONTRACTOR, SHALL OCCUR ONLY AFTER SITE HAS BEEN STABILIZED AND THE STORMCEPTOR UNIT IS CLEAN AND FREE OF DEBRIS.

STANDARD DETAIL
NOT FOR CONSTRUCTION

SITE SPECIFIC DATA REQUIREMENTS

STORMCEPTOR MODEL	EFO6				
STRUCTURE ID					*
HYDROCARBON STORAGE REQ'D (L)					*
WATER QUALITY FLOW RATE (L/s)					*
PEAK FLOW RATE (L/s)					*
RETURN PERIOD OF PEAK FLOW (yrs)					*
DRAINAGE AREA (HA)					*
DRAINAGE AREA IMPERVIOUSNESS (%)					*
PIPE DATA:	I.E.	MAT'L	DIA	SLOPE %	HGL
INLET #1	*	*	*	*	*
INLET #2	*	*	*	*	*
OUTLET	*	*	*	*	*

* PER ENGINEER OF RECORD

MARK	DATE	REVISION DESCRIPTION	BY
1	6/8/18	OUTLET PLATFORM	JSK
0	05/26/17	INITIAL RELEASE	JSK

Stormceptor® EF

imbrium®

SCALE = NTS

DATE: 10/13/2017
DESIGNED: JSK | DRAWN: JSK
CHECKED: BSF | APPROVED: SP
PROJECT No.: EFO6 | SEQUENCE No.: *
SHEET: 1 OF 1

STANDARD SPECIFICATION FOR "OIL GRIT SEPARATOR" (OGS) STORMWATER QUALITY TREAMENT DEVICE WITH THIRD-PARTY VERIFIED LIGHT LIQUID RE-ENTRAINMENT SIMULATION PERFORMANCE TESTING RESULTS

PART 1 – GENERAL

1.1 WORK INCLUDED

This section specifies requirements for selecting, sizing, designing, maintaining, and constructing an underground Oil Grit Separator (OGS) device for stormwater quality treatment, **specifically an OGS device that has been third-party tested for oil and fuel retention capability using a protocol for light liquid re-entrainment simulation testing, with t testing results and a Statement of Verification in accordance with all the provisions of ISO 14034 Environmental Management – Environmental Technology Verification (ETV)**. Work includes supply and installation of concrete bases, precast sections, and the appropriate precast section with OGS internal components correctly installed within the system, watertight sealed to the precast concrete prior to arrival to the project site.

1.2 REFERENCE STANDARDS

1.2.1 For Canadian projects only, the following reference standards apply:

CAN/CSA-A257.4-14: Joints for Circular Concrete Sewer and Culvert Pipe, Manhole Sections, and Fittings Using Rubber Gaskets
CAN/CSA-A257.4-14: Precast Reinforced Circular Concrete Manhole Sections, Catch Basins, and Fittings
CAN/CSA-S6-00: Canadian Highway Bridge Design Code

1.2.2 For ALL projects, the following reference standards apply:

ASTM D-4097:	Contact Molded Glass Fiber Reinforced Chemical Resistant Tanks
ASTM C 478:	Specification for Precast Reinforced Concrete Manhole Sections
ASTM C 443:	Specification for Joints for Concrete Pipe and Manholes, Using Rubber Gaskets
ASTM C 891:	Standard Practice for Installation of Underground Precast Concrete Utility Structures
ASTM D2563:	Standard Practice for Classification of Visual Defects in Reinforced Plastics

1.3 SHOP DRAWINGS

1.3.1 Shop drawings shall be submitted upon request with each order to the contractor then forwarded to the Engineer of Record for review and acceptance. Shop drawings shall detail the precast concrete components and OGS internal components prior to shipment, including the sequence for installation.

1.3.2 Unless directed otherwise by the Engineer of Record, OGS stormwater quality treatment product substitutions or alternatives submitted within ten days prior to project bid shall not be accepted. All alternatives or substitutions submitted shall be based on the exact same criteria detailed in Section 3, in entirety, subject to review and approval by the Engineer of Record. Any and all changes to project cost estimates, bonding amounts, plan check fees for revision of approved documents, or design impacts due to regulatory requirements as a result of a product substitution shall be coordinated by the Contractor with the Engineer of Record.

1.4 HANDLING AND STORAGE

Prevent damage to materials during storage and handling.

1.4.1 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.

1.4.2 Follow all instructions including the sequence for installation in the shop drawings during installation.

PART 2 – PRODUCTS

2.1 GENERAL

2.1.1 The OGS vessel shall be cylindrical and constructed from precast concrete riser and slab components.

2.1.2 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.

2.1.3 The OGS shall be allowed to be specified and have the ability to function as a 240-degree bend structure in the stormwater drainage system, or as a junction structure.

2.1.4 The OGS to be specified shall have the capability to accept influent flow from an inlet grate and an inlet pipe.

2.2 PRECAST CONCRETE SECTIONS

All precast concrete components shall be designed and manufactured to meet highway loading conditions per State/Provincial or local requirements.

2.3 GASKETS

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.

2.4 JOINTS

The concrete joints shall be watertight and meet the design criteria according to ASTM C-990. For projects where joints require gaskets, the concrete joints shall be watertight and oil resistant and meet the design criteria according to ASTM C-443. Mastic sealants or butyl tape/rope alone are not an acceptable alternative.

2.5 FRAMES AND COVERS

Frames and covers shall be manufactured in accordance with State/Provincial or local requirements for inspection and maintenance access purposes. A minimum of one cover, at least 22-inch (560 mm) in diameter, shall be clearly embossed with the OGS manufacturer's product name to properly identify this asset's purpose is for stormwater quality treatment.

2.6 PRECAST CONCRETE

All precast concrete components shall conform to the appropriate CSA or ASTM specifications.

2.7 FIBERGLASS

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.

2.8 OGS POLLUTANT STORAGE

The OGS device shall include a sump for sediment storage, and a fiberglass insert for the capture and storage of petroleum hydrocarbons and buoyant gross pollutants. The total sediment storage capacity shall be a minimum 40 ft^3 (1.1 m^3). The total petroleum hydrocarbon storage capacity shall be a minimum 50 gallons (189 liters). The access opening to the sump of the OGS device for periodic inspection and maintenance purposes shall be a minimum 16 inches (406 mm) in diameter.

2.9 LADDERS

Ladder rungs shall be provided upon request or to comply with State/Provincial or local requirements.

2.10 INSPECTION

All precast concrete sections shall be level and inspected to ensure dimensions, appearance, integrity of internal components, and quality of the product meets State/Provincial or local specifications and associated standards.

PART 3 – PERFORMANCE & DESIGN

3.1 GENERAL

The OGS stormwater quality treatment device shall be verified in accordance with ISO 14034:2016 Environmental management – Environmental technology verification (ETV). The OGS stormwater quality treatment device shall remove oil, sediment and gross pollutants from stormwater runoff during frequent wet weather events, and retain these pollutants during less frequent high flow wet weather events below the insert within the OGS for later removal during maintenance. The Manufacturer shall have at least ten (10) years of local experience, history and success in engineering design, manufacturing and production and supply of OGS stormwater quality treatment device systems, acceptable to the Engineer of Record.

3.2 HYDROLOGY AND RUNOFF VOLUME

The OGS device shall be engineered, designed and sized to treat a minimum of 90 percent of the average annual runoff volume, unless otherwise stated by the Engineer of Record, using historical rainfall data. Rainfall data sets should be comprised of a minimum 15-years of rainfall data or a longer continuous period if available for a given location, but in all cases a minimum 5-year period of rainfall data.

3.3 ANNUAL (TSS) SEDIMIMENT LOAD AND STORAGE CAPACITY

The OGS device shall be capable of removing and have sufficient storage capacity for the calculated annual total suspended solids (TSS) mass load and volume without scouring previously captured pollutants prior to maintenance being required. The annual (TSS) sediment load and volume transported from the drainage area should be calculated and compared to the OGS device's available storage capacity by the specifying Engineer to ensure adequate capacity between maintenance cycles. Sediment loadings shall be determined by land use and defined as a minimum of 450 kg (992 lb) of sediment (TSS) per impervious hectare of drainage area per year, or greater based on land use, as noted in Table 1 below.

Annual sediment volume calculations shall be performed using the projected average annual treated runoff volume, a typical sediment bulk density of 1602 kg/m^3 (100 lbs/ft^3) and an assumed Event Mean

Concentration (EMC) of 125 mg/L TSS in the runoff, or as otherwise determined by the Engineer of Record.

Example calculation for a 1.3-hectares parking lot site:

- 1.28 meters of rainfall depth, per year
- 1.3 hectares of 100% impervious drainage area
- EMC of 125 mg/L TSS in runoff
- Treatment of 90% of the average annual runoff volume
- Target average annual TSS removal rate of 60% by OGS

Annual Runoff Volume:

- 1.28 m rain depth x 1.3 ha x 10,000 m^2/ha= 16,640 m^3 of runoff volume
- 16,640 m^3 x 1000 L/m^3 = 16,640,000 L of runoff volume
- 16,640,000 L x 0.90 = 14,976,000 L to be treated by OGS unit

Annual Sediment Mass and Sediment Volume Load Calculation:

- 14,976,000 L x 125 mg/L x kg/1,000,000 mg = 1,872 kg annual sediment mass
- 1,872 kg x m^3/1602 kg = 1.17 m^3 annual sediment volume
- 1.17 m^3 x 60% TSS removal rate by OGS = 0.70 m^3 minimum expected annual storage requirement in OGS

As a guideline, the U.S. EPA has determined typical annual sediment loads per drainage area for various sites by land use (see Table 1). Certain States, Provinces and local jurisdictions have also established such guidelines.

Table 1 – Annual Mass Sediment Loading by Land Use

	Commercial	Parking Lot	Residential			Highways	Industrial	Shopping Center
			High	Med.	Low			
(lbs/acre/yr)	1,000	400	420	250	10	880	500	440
(kg/hectare/yr)	1,124	450	472	281	11	989	562	494

Source: U.S. EPA Stormwater Best Management Practice Design Guide Volume 1, Appendix D, Table D-1, Burton and Pitt 2002

3.4 SIZING METHODOLOGY

The OGS device shall be engineered, designed and sized to provide stormwater quality treatment based on treating a minimum of 90 percent of the average annual runoff volume and a minimum removal of an annual average 60% of the sediment (TSS) load based on the Particle Size Distribution (PSD) specified in Table 2, Section 3.5, and based on third-party performance testing conducted in accordance with the Canadian Environmental Technology Verification (ETV) Program's **Procedure for Laboratory Testing of Oil-Grit Separators.** Sizing shall be determined using historical rainfall data (as specified in Section 3.2) and a sediment removal performance curve derived from the actual third-party verified laboratory testing data. The OGS device shall also have sufficient annual sediment storage capacity as specified and calculated in Section 3.3.

3.4.1 The Peclet Number is not an approved method or model for calculating TSS removal, sizing, or scaling OGS devices.

3.4.2 If an alternate OGS device is proposed, supporting documentation shall be submitted that demonstrates:

- Canadian ETV or ISO 14034 ETV Verification Statement which verifies third-party performance testing conducted in accordance with the **Procedure for Laboratory Testing of Oil-Grit Separators,** including the Light Liquid Re-entrainment Simulation Testing.
- Equal or better sediment (TSS) removal of the PSD specified in Table 2 at equivalent surface loading rates, as compared to the OGS device specified herein.
- Equal or better Light Liquid Re-entrainment Simulation Test results (using low-density polyethylene beads as a surrogate for light liquids such as oil and fuel) at equivalent

surface loading rates, as compared to the OGS device specified herein. However, an alternative OGS device shall not be allowed as a substitute if the Light Liquid Re-entrainment Simulation Test was performed with screening components within the OGS device that are effective at retaining the low-density polyethylene beads, but would not be expected to retain light liquids such as oil and fuel.

- Equal or greater sediment storage capacity, as compared to the OGS device specified herein.
- Supporting documentation shall be signed and sealed by a local registered Professional Engineer. All costs associated with preparing and certifying this documentation shall be born solely by the Contractor.

3.5 PARTICLE SIZE DISTRIBUTION (PSD) FOR SIZING

The OGS device shall be sized to achieve the Engineer-specified average annual percent sediment (TSS) removal based solely on the test sediment used in the Canadian ETV Program's **Procedure for Laboratory Testing of Oil-Grit Separators.** This test sediment is comprised of inorganic ground silica with a specific gravity of 2.65, uniformly mixed, and containing a broad range of particle sizes as specified in Table 2. No alternative PSDs or deviations from Table 2 shall be accepted.

Table 2
Canadian ETV Program Procedure for Laboratory Testing of Oil-Grit Separators
Particle Size Distribution (PSD) of Test Sediment

Particle Diameter (Microns)	% by Mass of All Particles	Specific Gravity
1000	5%	2.65
500	5%	2.65
250	15%	2.65
150	15%	2.65
100	10%	2.65
75	5%	2.65
50	10%	2.65
20	15%	2.65
8	10%	2.65
5	5%	2.65
2	5%	2.65

3.6 CANADIAN ETV or ISO 14034 ETV VERIFICATION OF SCOUR TESTING

The OGS device shall have Canadian ETV or ISO 14034 ETV Verification of completed third-party scour testing conducted and have in accordance with the Canadian ETV Program's **Procedure for Laboratory Testing of Oil-Grit Separators**. This scour testing is conducted with the device pre-loaded with test sediment comprised of the particle size distribution (PSD) illustrated in Table 2.

3.6.1 To be acceptable for on-line installation, the OGS device must demonstrate an average scour test effluent concentration less than 10 mg/L at each surface loading rate tested, up to and including 2600 L/min/m^2.

Data generated from laboratory scour testing performed with an OGS device pre-loaded with a coarser PSD than in Table 2 (i.e. the coarser PSD has no particles in the 1-micron to 50-micron size range, or the D_{50} of the test sediment exceeds 75 microns) shall not be acceptable for the determination of the device's suitability for on-line installation.

3.7 DESIGN ACCOUNTING FOR BYPASS

3.7.1 The OGS device shall be specified to achieve the TSS removal performance and water quality objectives without washout of previously captured pollutants. The OGS device shall also have sufficient hydraulic conveyance capacity to convey the peak storm event, in accordance with hydraulic conditions per the Engineer of Record. To ensure this is achieved, there are two design options with associated requirements:

3.7.1.1 The OGS device shall be placed **off-line** with an upstream diversion structure (typically in an upstream manhole) that only allows the water quality volume to be diverted to the OGS device, and excessive flows diverted downstream around the OGS device to prevent high flow washout of pollutants previously captured. This design typically incorporates a triangular layout including an upstream bypass manhole with an appropriately engineered weir wall, the OGS device, and a downstream junction manhole, which is connected to both the OGS device and bypass structure. In this case with an external bypass required, the OGS device manufacturer must provide calculations and designs for all structures, piping and any other required material applicable to the proper functioning of the system, stamped by a Professional Engineer.

3.7.1.2 Alternatively, OGS devices in compliance with Section 3.6 shall be acceptable for an **on-line** design configuration, thereby eliminating the requirement for an upstream bypass manhole and downstream junction manhole.

3.7.2 The OGS device shall also have sufficient hydraulic conveyance capacity to convey the peak storm event, in accordance with hydraulic conditions per the Engineer of Record. If an alternate OGS device is proposed, supporting documentation shall be submitted that demonstrates equal or better hydraulic conveyance capacity as compared to the OGS device specified herein. This documentation shall be signed and sealed by a local registered Professional Engineer. All costs associated with preparing and certifying this documentation shall be born solely by the Contractor.

3.8 <u>LIGHT LIQUID RE-ENTRAINMENT SIMULATION TESTING</u>

The OGS device shall have Canadian ETV or ISO 14034 ETV Verification of completed third-party Light Liquid Re-entrainment Simulation Testing in accordance with the Canadian ETV Program's **Procedure for Laboratory Testing of Oil-Grit Separators**, with results reported within the Canadian ETV or ISO 14034 ETV verification. This re-entrainment testing is conducted with the device pre-loaded with low density polyethylene (LDPE) plastic beads as a surrogate for light liquids such as oil and fuel. Testing is conducted on the same OGS unit tested for sediment removal to assess whether light liquids captured after a spill are effectively retained at high flow rates.

3.8.1 For an OGS device to be an acceptable stormwater treatment device on a site where vehicular traffic occurs and the potential for an oil or fuel spill exists, the OGS device must have reported verified performance results of greater than 99% cumulative retention of LDPE plastic beads for the five specified surface loading rates (ranging 200 L/min/m^2 to 2600 L/min/m^2) in accordance with the Light Liquid Re-entrainment Simulation Testing within the Canadian ETV Program's **Procedure for Laboratory Testing of Oil-Grit Separators**. However, an OGS device shall not be allowed if the Light Liquid Re-entrainment Simulation Testing was performed with screening components within the OGS device that are effective at retaining the LDPE plastic beads, but would not be expected to retain light liquids such as oil and fuel.

3.9 <u>PETROLEUM HYDROCARBONS AND FLOATABLES STORAGE CAPACITY</u>

Petroleum hydrocarbons and floatables storage capacity in the OGS device shall be a minimum 50 gallons (189 Liters), or more as specified.

3.9.1 The OGS device shall have gasketed precast concrete joints that are watertight, and oil resistant and meet the design criteria according to ASTM C-443 to provide safe oil and other hydrocarbon materials storage and ground water protection. Mastic sealants or butyl tape/rope alone are not an acceptable alternative.

3.10 <u>SURFACE LOADING RATE SCALING OF DIFFERENT MODEL SIZES</u>

The reference device for scaling shall be an OGS device that has been third-party tested in accordance with the Canadian ETV Program's **Procedure for Laboratory Testing of Oil-Grit Separators**. Other model sizes of the tested device shall only be scaled such that the claimed TSS removal efficiency of the scaled device shall be no greater than the TSS removal efficiency of the tested device at identical **surface loading rates** (flow rate divided by settling surface area). The depth of other model sizes of the tested device shall be scaled in accordance with the depth scaling provisions within Section 6.0 of the Canadian ETV Program's **Procedure for Laboratory Testing of Oil-Grit Separators**.

3.10.1 The Peclet Number and volumetric scaling are not approved methods for scaling OGS devices.

PART 4 – INSPECTION & MAINTENANCE

The OGS manufacturer shall provide an Owner's Manual upon request.

4.1 A Quality Assurance Plan that provides inspection and maintenance for a minimum of 5 years shall be included with the OGS stormwater quality device, and written into the Environmental Compliance Approval (ECA) or the appropriate State/Provincial or local approval document.

4.2 OGS device inspection shall include determination of sediment depth and presence of petroleum hydrocarbons and floatables below the insert. Inspection shall be easily conducted from finished grade through a Frame and Cover of at least 22 inch (560 mm) in diameter.

4.3 Inspection and pollutant removal from below the OGS's insert shall be conducted as a periodic maintenance practice using a standard maintenance truck and vacuum apparatus, and shall be easily conducted from finished grade through a Frame and Cover of at least 22-inches (560 mm) in diameter, and through an access opening to the OGS device's sump with a minimum 16-inches diameter (406 mm).

4.4 No confined space for sediment removal or inspection of internal components shall be required for normal operation, annual inspection or maintenance activity.

PART 5 – EXECUTION

5.1 <u>PRECAST CONCRETE INSTALLATION</u>

The installation of the precast concrete OGS stormwater quality treatment device shall conform to ASTM C 891, ASTM C 478, ASTM C 443, CAN/CSA-A257.4-14, CAN/CSA-A257.4-14, CAN/CSA-S6-00 and all highway, State/Provincial, or local specifications for the construction of manholes. Selected sections of a general specification that are applicable are summarized below. 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.

5.2 <u>EXCAVATION</u>

5.2.1 Excavation for the installation of the OGS stormwater quality treatment device shall conform to highway, State/Provincial or local specifications. Topsoil that is removed during the excavation for the OGS stormwater quality treatment device shall be stockpiled in designated areas and not be mixed with subsoil or other materials. Topsoil stockpiles and the general site preparation for the installation of the OGS stormwater quality device shall conform to highway, State/Provincial or local specifications.

5.2.2 The OGS device shall not be installed on frozen ground. Excavation shall extend a minimum of 12 inch (300 mm) from the precast concrete surfaces plus an allowance for shoring and bracing where required. If the bottom of the excavation provides an unsuitable foundation additional excavation may be required.

5.2.3 In areas with a high water table, continuous dewatering shall be provided to ensure that the excavation is stable and free of water.

5.3 BACKFILLING

Backfill material shall conform to highway, State/Provincial or local specifications. Backfill material shall be placed in uniform layers not exceeding 12 inches (300 mm) in depth and compacted to highway, State/Provincial or local specifications.

5.4 OGS WATER QUALITY DEVICE CONSTRUCTION SEQUENCE

5.4.1 The precast concrete OGS stormwater quality treatment device is installed and leveled in sections in the following sequence:

- aggregate base
- base slab, or base
- riser section(s) (if required)
- riser section w/ pre-installed fiberglass insert
- upper riser section(s)
- internal OGS device components
- connect inlet and outlet pipes
- riser section, top slab and/or transition (if required)
- frame and access cover

5.4.2 The precast concrete base shall be placed level at the specified grade. The entire base shall be in contact with the underlying compacted granular material. Subsequent sections, complete with oil resistant, watertight joint seals, shall be installed in accordance with the precast concrete manufacturer's recommendations.

5.4.3 Adjustment of the OGS stormwater quality treatment device can be performed by lifting the upper sections free of the excavated area, re-leveling the base, and re-installing the sections. Damaged sections and gaskets shall be repaired or replaced as necessary. Once the OGS stormwater quality treatment device has been constructed, any lift holes must be plugged with mortar.

5.5 DROP PIPE AND OIL INSPECTION PIPE

Once the upper precast concrete riser has been attached to the lower precast concrete riser section, the OGS device Drop Pipe and Oil Inspection Pipe must be attached, and watertight sealed to the fiberglass insert using Sikaflex 1a. Installation instructions and required materials shall be provided by the OGS manufacturer.

5.6 INLET AND OUTLET PIPES

Inlet and outlet pipes shall be securely set using grout or approved pipe seals (flexible boot connections, where applicable) so that the structure is watertight. Non-secure inlets and outlets will result in improper performance.

5.7 FRAME AND COVER OR FRAME AND GRATE INSTALLATION

Precast concrete adjustment units shall be installed to set the frame and cover/grate at the required elevation. The adjustment units shall be laid in a full bed of mortar with successive units being joined using sealant recommended by the manufacturer. Frames for the cover/grate should be set in a full bed of mortar at the elevation specified.

5.7.1 A minimum of one cover, at least 22-inch (560 mm) in diameter, shall be clearly embossed with the OGS device brand or product name to properly identify this asset's purpose is for stormwater quality treatment.

APPENDIX F: SCHEDULE AND WORK BREAKDOWN STRUCTURE

STADIUM NEIGHBORHOOD UNDERGROUND PARKADE AND WATER STORAGE PROJECT

Shearwater Designs

Mon, 5-28-2018

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Code	TASK	Duration (days)	START	END
	Project Start up	**30**	5-28-18	6-27-18
01-001	Stakeholder Engagement	**3**	5-28-18	5-31-18
01-002	Tendar & award to prime contractor	**2**	5-31-18	6-2-18
01-003	Documentation, permitting	**25**	6-2-18	6-27-18
01-004	Kick-Off Meeting	**0**	6-27-18	6-27-18
	Engineering	**7**	6-27-18	7-4-18
02-001	Site Assesment	1	6-28-18	6-29-18
02-002	Full budget analysis	3	6-28-18	7-1-18
02-003	Shop Drawings Approval	7	6-28-18	7-5-18
02-004	QA/QC Plan deveoped	6	6-28-18	7-4-18
02-005	**Site Mobiization + Preperation**	**48**	7-5-18	8-22-18
02-006	Stripping, Grubbing, Clearing	14	7-5-18	7-19-18
02-007	Fencing and Signs	0	7-20-18	7-20-18
02-008	Storage Area Creation for Materials/Equipment	6	7-25-18	7-31-18
02-009	Surveying and Grading	16	8-1-18	8-17-18
02-010	Tree removal	20	7-5-18	7-25-18
02-011	16th avenue Concrete Path Removal	5	8-17-18	8-22-18
02-012	Bulk Excavation	12	7-25-18	8-6-18
	Parkade + Detention Tank Superstructure Construction	**50**	8-6-18	9-25-18
03-001	Dewatering	1	8-6-18	8-7-18
03-002	Trenching and Pipe Connections	5	8-16-18	8-21-18
03-003	Lateral Earth Support installation	2	8-21-18	8-23-18
03-004	Formwork and reinforcement cages	10	8-23-18	9-2-18
03-005	Site Inspection	0	9-2-18	9-2-18
03-006	Base Level Pad & Strip Foundations Installation	3	9-2-18	9-5-18
03-007	Cast In Place Dry Detention Vault Installation	3	9-5-18	9-8-18
03-008	Second Floor and Ramp Form Construction	5	9-5-18	9-10-18
03-009	Second Floor Concrete Pours	6	9-10-18	9-16-18
03-010	Grade level Foor and Ramp Form Construction	5	9-5-18	9-10-18
03-011	Grade Level Concrete Pours	6	9-10-18	9-16-18
03-012	Steel Reinforcement	10	9-5-18	9-15-18
03-013	Floor + Wall Finishes	3	9-15-18	9-18-18
03-014	Green Roof	7	9-18-18	9-25-18
03-015	Electrical Services Installation	3	9-18-18	9-21-18
03-016	Mechanichal Services Installation	4	9-21-18	9-25-18
	Soakaway Pits and Natural Systems	**7**	6-27-18	7-4-18
04-001			6-28-18	7-5-18
	Closeout	**48**	7-5-18	8-22-18
05-001	Backfill	5	7-5-18	7-19-18
05-002	Landscaping	14	7-20-18	7-20-18