UBC Botanical Garden Stormwater Management System

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EXECUTIVE SUMMARY

For the UBC Botanical Garden Revitalization Project, Renew Engineering Solutions will focus on a water distribution system improvement to reduce the Garden's reliance on potable water irrigation, and minimize erosion due to excessive storm water runoff. The goal of the design is to provide a sustainable and cost effective water distribution system for UBC Botanical Gardens. The design will consist of three civil engineering sub-disciplines; Environmental, Geotechnical, and primary discipline Hydrotechnical Engineering.

In order to reduce costs, a prefabricated underground modular tank system will be used to store stormwater. The size of the storage tank is 3000 m^3, which is enough to provide an average of one-month's irrigation supply in the dry summer period.

A sump tank will be installed at the south-west corner of the stormwater storage tank where water will be allowed to collect in order to prime the pump. A single multi-stage pump will be installed to provide sufficient pressure to the existing sprinkler system.

A flow control device will be installed to allow the storage tank to fill completely prior to bypassing any excess water. The system will allow the bypass of large volumes of water such as those that occur during 1 in 50 year storm events. The overflow system will ensure that any water that is discharged is done so at a reasonable flow rate and velocity to minimize adverse effects downstream such as sediment deposition and bank erosion.

The current cattail system will be dredged and expanded to allow for a larger storage volume of 7800 m^3. By increasing the wetted perimeter of the pond, infiltration will be increased. The cattail pond will provide the two treatment processes of gravity separation and filtration before the water is stored in the subsurface tank and distributed for irrigation.

Several outfall protection strategies will be explored in addition to underground stormwater storage tank development to ensure further bank erosion is mitigated during heavy rainfall events.

Sustainable development is a key component in the design of the entire system. The supplier of the underground stormwater storage tank, StormTrap, have several LEED contributions to reduce potential environmental impacts.

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1 INTRODUCTION AND PROJECT OVERVIEW

The upgrade initiatives proposed by Renew Engineering Solutions, henceforth referred to as "Renew," can be summarized as a general overhaul of the existing water distribution system inside the Gardens. At present, the entire plant collection in the Gardens receives water from the municipal supply provided by the Greater Vancouver Regional District. As such, the plants receive water that has been treated by several different methods including the use of chlorine. While such treatment is necessary for safe consumption by humans, it is not entirely necessary for water that is distributed to a plant collection. Renew's designs will feature storm water capture, treatment, and reuse to irrigate the entire collection at the UBC Botanical Gardens.

FIGURE 1 AN OVERVIEW MAP OF THE PROPOSED UPGRADES TO THE WATER TREATMENT AND DISTRIBUTION SYSTEM

The first upgrade will involve the efficient collection of stormwater that falls into the Trail 7 Catchment Area. Once collected, the stormwater will pass through a flow diversion device which will either send water into the Cattail Pond for treatment, or if the Cattail Pond is full, convey water into the existing stormwater sewers. The storm sewer will convey excess water to the improved outfall.

Water that enters the Cattail Pond will be subject to two low-cost treatment measures, gravity separation and filtration. From here, the treated water will travel with the no-cost use of gravitational head into the storage tank.

The storage tank is set to be composed of precast concrete modular segments that will be assembled on-site. The segments, provided by supplier StormTrap, will be joined together during a short construction period to achieve a full volume of 3000 m^3. As planned, the Tank will be located underneath the current maintenance Yard in the Gardens to minimize its footprint.

After residing in the storage tank the treated water will be distributed to all regions of the Gardens via an underground pipe network. A sump pump adjacent to the tank will be required to deliver pressurized water to the irrigation system.

With the proposed improvements mentioned above, it is the aim of Renew to lessen the Garden's operating costs and shrink its dependence on the municipal water supply. A detailed discussion of each proposed development follows in Section 2.

1.1 Engineering Disciplines

The following detailed designs for the storage tank and general stormwater management improvements consist of three sub-disciplines which relate to the broader definition of Civil Engineering. These three sub-disciplines are: Hydrotechnical, Environmental, and Geotechnical Engineering, with the lead engineering discipline being Hydrotechnical Engineering. The components of the design which are related to each sub-discipline are as follows:

- Hydrotechnical: The detailed design is focused on this area, which encompasses analysis of hydrological data to determine average flows, storage capacities, flood plans, and sizing of the various distribution systems such as pumps and orifices.
- Environmental: This area of engineering is very important in the detailed design and includes details relating to the removal of contaminants during the retention in the newly designed cattail pond.
- Geotechnical: A geotechnical assessment of the area surrounding the storage tank is included in this report to ensure suitable bearing capacity, settlement, and other geotechnical areas that are of concern. Also, erosion control measures are addressed in this report for the outfalls along the bank by Old Marine Drive.

2 WATER DISTRIBUTION NETWORK

2.1 BACKGROUND

The current water use plan at the UBC Botanical Gardens utilizes potable water for all applications. In order to reduce the reliance on potable water, a distribution network will be installed to better utilize storm water to meet the UBC Botanical Gardens' irrigation needs. Prefabricated parts will be utilized to reduce engineering costs and lead times.

2.2 WATER SOURCE

The proposed stormwater management system will be entirely fed from the Trail 7 Catchment Area (T7C), with a future possibility of tying into the 16th Avenue Catchment should water supplies from the T7C begin to diminish as further stormwater best management practices are implemented on campus. Figure 7 on Page 13 shows the stormwater catchment areas and the locations of current outfalls. Renew will disconnect the Trail 7 outfall and redirect the water towards the stormwater management system located in the north-east corner of the UBC Botanical Gardens.

2.3 WATER NETWORK PLAN

The designed stormwater management system will utilize multiple stages to divert, treat, store and pump the stormwater to where it is required. Below in Figure 2, all of the stages can be seen. The entire system utilizes gravimetric potential to move water between stages up until the pump station, where the water is pressurized for irrigation use. Each stage of the system is described below in further detail.

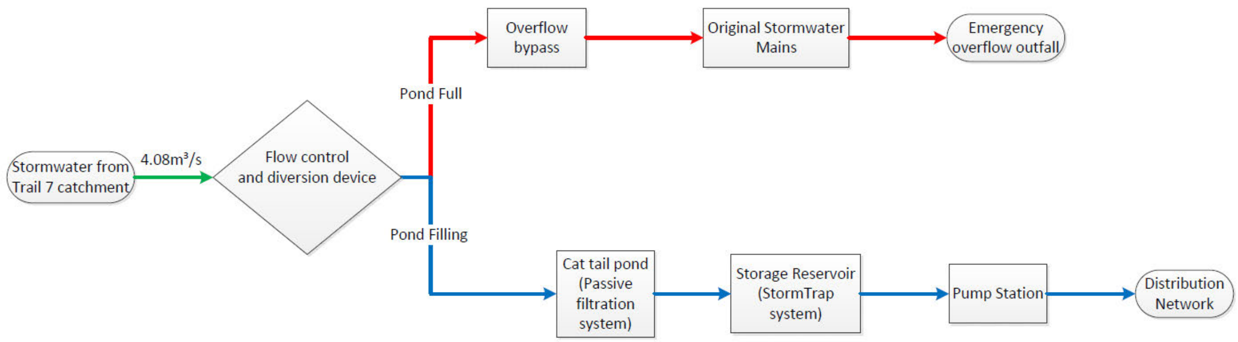

FIGURE 2 STORMWATER MANAGEMENT SYSTEM DESIGN

2.3.1 *FLOW CONTROL DEVICE*

The flow control device will be intercepted by the current stormwater main at the roundabout at Stadium Rd. and West Mall. The flow device will have two main routes, one utilized while the cattail pond is filling and another utilized once the cattail pond is full. Initially, all water is channeled into the cattail pond and once the pond is full, water backs up into the flow control device and flows over the weir into the overflow bypass. The height of the weir is adjustable to allow the level within the cattail pond to be managed. An image of the flow control device is included to the right in Figure 3.

FIGURE 3 - STORMGATE™ FLOW MANAGEMENT CONTROL DEVICE WITH ADJUSTABLE WEIR (CONTECH ENGINEERED SOLUTIONS, 2014)

2.3.2 *PUMPING STATION*

In order to provide water to the irrigation system at the UBC Botanical Gardens, the water stored in the tank will have to be pressurized prior to being delivered to the sprinkler mains. To accomplish the system pressurization a sump tank will be installed at the south-west corner of the stormwater storage tank where water will be allowed to collect in order to prime the pump. A single multi-stage pump will be installed to provide the required head to the sprinkler system at the downstream end of the sprinkler distribution mains. The multi-stage pump can be seen on the right in Figure 4. The pump selection process can be seen in Appendix D, and the final pump specifications are shown below in Table 1.

FIGURE 4 - MULTI-STAGE PUMP (GOULDS WATER TECHNOLOGY, 2014)

TABLE 1 PUMP SELECTION DETAILS FOR DESIGN SPECIFICATIONS

Pump Selection Details	
Manufacturer:	Goulds Water Technology
Division:	Commercial Water
Pump Model No. :	5SV 2900 RPM - 50Hz
Pump Type:	Non-self-priming vertical multi-stage
Motor :	2900 RPM 3PH, 2 pole: 208-230V, 50Hz
No. of stages:	11
Max. Efficiency:	68%
Total HP:	2.31 HP

2.3.3 Distribution Mains

In order to convey the water from the pumping station to the irrigation system two distribution mains will be installed. The details of these mains can be found in Appendix D. All of the pipes in the system are made from high-density polyethylene (HDPE) due to its resistance to impact, freeze-thaw cycles and low coefficient of friction. The pipes are also available from a local supplier and have a very short lead-time.

3 Cattail Pond

Once stormwater has passed the flow diversion device it will be directed into the south end of the Cattail Pond. From here the stormwater will use gravitational head to flow towards the north end of the pond where the exit orifice is located. While stored in the Cattail Pond the stormwater will be subject to gravity separation and filtration, which are expected to remove a large proportion of primary contaminants within the stormwater. A detailed discussion of the Cattail Pond's layout, followed by the expected contaminants removal plan, and cost summary are presented below.

3.1 Layout

The Cattail Pond is planned as a constructed wetland – that is, it will be designed as a detention system with wetland vegetation. Water will be kept permanently inside the system to sustain the vegetation, while the design exit flow rate will be such that the minimum volume of water will be sustained constantly.

With approximate dimensions of 90 m by 30 m, the oval-shaped pond has been designed to attain a surface area of 2600 m^2 upon reaching its maximum storage volume (see Figure 5 below). The average depth of the pond at maximum capacity will be 3.0 m, which effectively gives the pond a maximum storage capacity of 7800 m^3. In an emergency scenario it is planned that excess water in other locations of the campus can be diverted into the pond if required. Thus, the pond will be maintained at an operating depth of 2.0 m, which grants an operating storage volume of 5200 m^3.

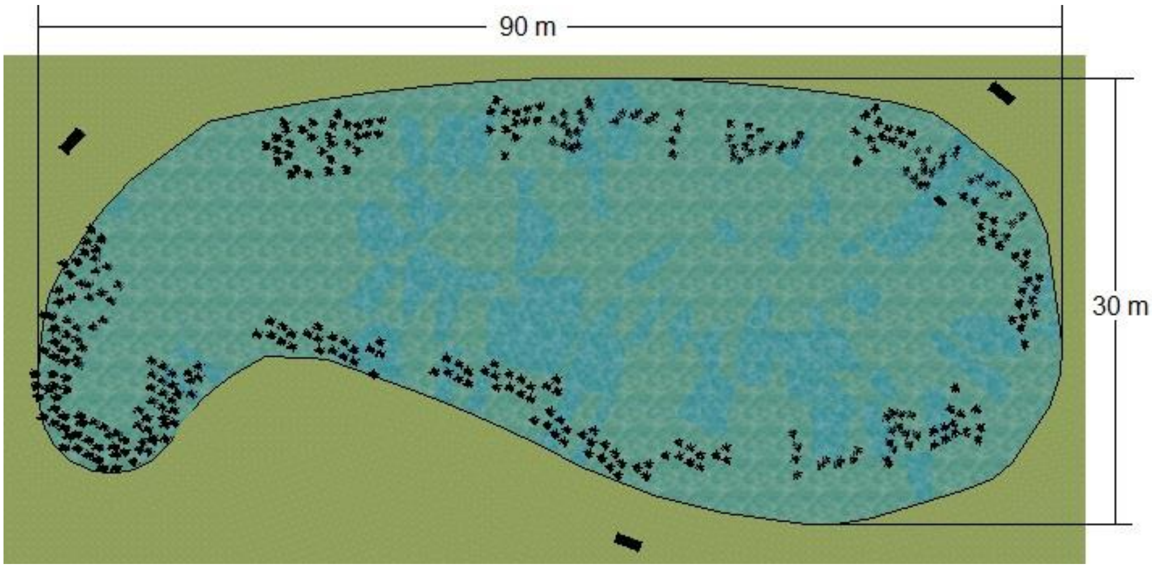

FIGURE 5 AN OVERHEAD VIEW OF THE UPGRADED CATTAIL POND AT MAXIMUM CAPACITY

Renew plans to install the upgraded Cattail Pond in precisely the same location where the existing pond is currently. This location has been chosen for two reasons, the first being that the space is already used as a cattail pond. Thus, modifications of the area will be kept to a minimum. The second reason this area has been chosen is because of its relatively higher elevation compared to the rest of the Gardens. Hence, gravitational head will be used to move water from the pond into the storage tank.

The length of the new pond is to be about the same as the current pond, while the width will be expanded by a factor of two. In this section of the Gardens, called the Great Lawn, it has been observed that the space to the east of the pond contains a large grassy field. In order to make room for the expanded Pond, approximately 20% of this grassy space will be annexed by the Cattail Pond. It is anticipated that the Garden's collection will not be reduced in any way, as all (if any) plants that are removed to make space for the pond will be restored in another location.

3.2 Contaminant Removal Plan

The Cattail Pond has been designed to remove a large fraction of primary contaminants through the process of gravity separation. In addition to this, contaminants are expected to be removed through the process of filtration provided by wetland vegetation inside the pond. Together, these two processes will remove a high proportion of total suspended solids, nutrients, and metals.

From two different sources, the first being Weiss, Gulliver, and Erickson (2007, p. 226), and the second from Comings, Booth, and Horn (2000, p. 327), removal rates for several contaminants found empirically are shown in Table 2 below.

Table 2 Removal rates of primary contaminants in the Cattail Pond

Contaminant	Removal Efficiency (%)
Total Suspended Solids	93*
Total Phosphorus	68*
Zinc	72**
Cadmium	52**
Copper	47**
Lead	76**

Sources: * (Weiss, Gulliver, and Erickson, 2007, Table 4)
** (Comings, Booth, and Horn, 2000, Figure 6)

Using the removal efficiencies shown in Table 2, it is possible to estimate the quantities of each contaminant that will be retained each year. This estimate is achieved using the equation below, which describes how much of each contaminant will build up in the water shed area per year.

$$L=0.10*A*R_f*R_v*C$$

where L = annual pollutant load (kg), A = area (ha), R_f = average annual rainfall, R_v = ratio of runoff to rainfall in the watershed, and C = contaminant concentration (mg/L) (Weiss et al, 2007, p. 225)

With an annual rainfall of 1457 mm across the Vancouver region (Environment Canada), water shed area of 52.6 hectares, and an estimated 80% of the watershed that is permeable, it is possible to calculate the quantity of each contaminant that will be filtered per year. Relevant figures are shown in Table 3.

TABLE 3 ESTIMATED CONTAMINANT REMOVAL

Pollutants	Average Annual Concentration (mg/L)	Annual Pollutant Load (kg)	Annual Removal load (kg)
Total Suspended Solids	131	30119	28010
Total Phosphorus	0.55	126	86.0
Zinc	0.083	19.1	13.7
Cadmium	0.00031	0.071	0.037
Copper	0.0039	0.90	0.42
Lead	0.0047	1.08	0.82

Reducing the total suspended solids concentration will have the effect of reducing turbidity, which will in effect encourage more plant growth. Meanwhile, a reduction in total phosphorus will have the effect of limiting algae growth inside the pond. With the removal rates as shown, it is evident that the Cattail Pond will provide a significant enhancement to the quality of water before it is stored in the storage tank.

3.3 COST

According to Weiss, Gulliver, and Erickson (2007, Figure 3), who provide an educated estimated cost of constructing a wetland pond, it will be approximately $23.60 CAD per cubic meter of stored water for a pond of this size. With a maximum storage volume of 7800 m^3, the total construction cost works out to be approximately $184,000. Note that this figure includes estimates of excavating soil to install the pond.

Weiss et al (2007, Figure 9) also include quotes for the annual operations and maintenance (O/M) costs for a constructed wetland. It was found that for a pond of the designated volume, the O/M annual costs will be in the order of $3700. This figure takes into account the costs of removing accumulated sediment once per year, and routinely maintaining a free-flowing orifice. In addition, this annual cost accounts for removing floating trash and invasive plant species, and mowing the perimeter of the pond.

4 WATER STORAGE SYSTEM

4.1 STORAGE CAPACITY

In order to store enough stormwater to meet the monthly peak water consumption of the botanical garden, an underground stormwater storage tank with a capacity of 3000 m^3 will be built in the Garden's service area.

4.1.1 Water Consumption

The chart in Figure 6 shows the potable water consumption of the garden over the last three summers. Based on the chart, the weekly water consumption in summer has increased from 568 m^3 to 790 m^3 in the span of three years. In August, the water consumption reached the peak, which is approximately 4000 m^3 per month, or 1000 m^3 per week.

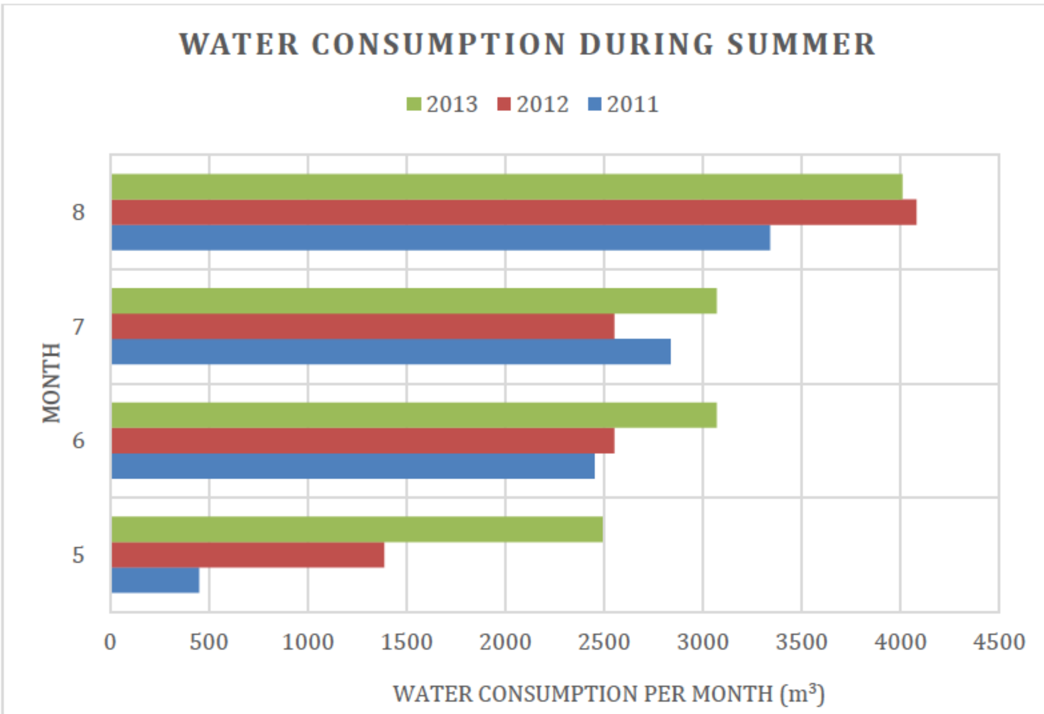

Figure 6 Potable water consumption for the last three years (Justice, 2014)

Based on the proposed water conservation measures, the monthly peak water consumption will decrease from 4000 m^3 to 3000 m^3 in the future. This is because the current irrigation system will be replaced by a micro-irrigation system. The efficiency of a drip system is 20% to 40% higher than the efficiency of the current sprinkler system (C. Wilson and M. Bauer, 2011).

4.1.2 *STORMWATER SUPPLY*

Refer to Section 2.2 for details of the stormwater supply source. See Figure 7 below for details of Trail 7 Catchment and Outfall.

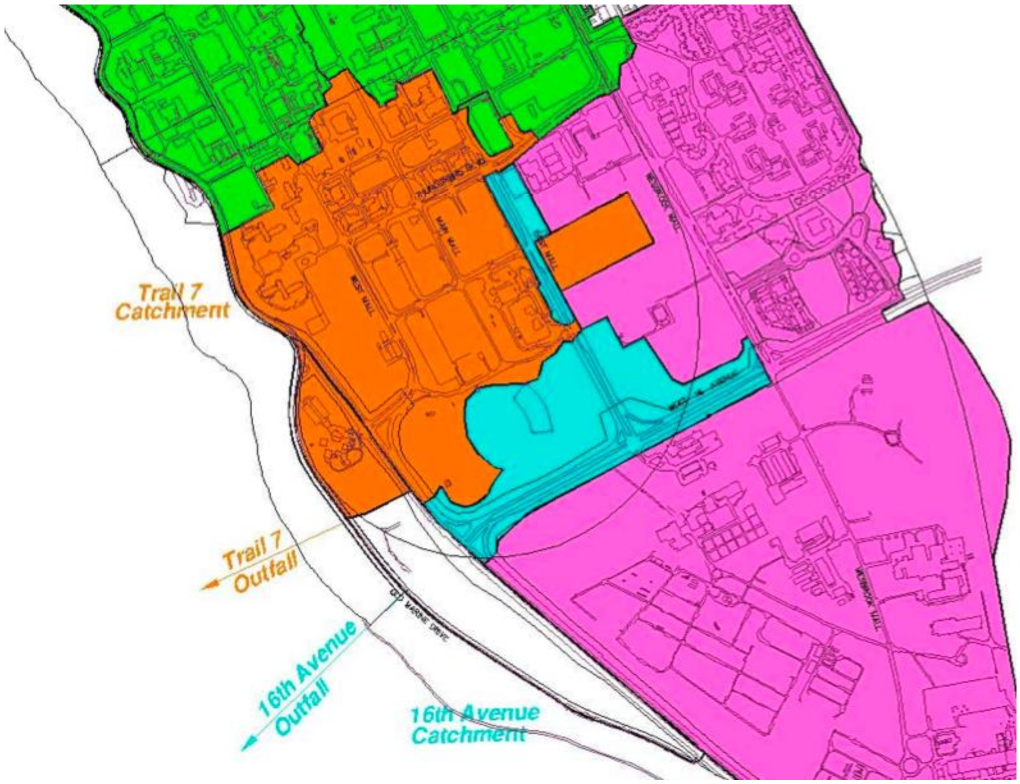

FIGURE 7 CATCHMENT AREA FOR TRAIL 7 (APLIN & MARTIN CONSULTANTS LTD. & HOLLAND BARRS PLANNING GROUP, 2005)

Figure 8 below provides the climactic data utilized to calculate the rainfall volume expected during the summer months. The rational method was utilized to calculate the overall flow into the tank and the detailed calculations can be found in Appendix D.

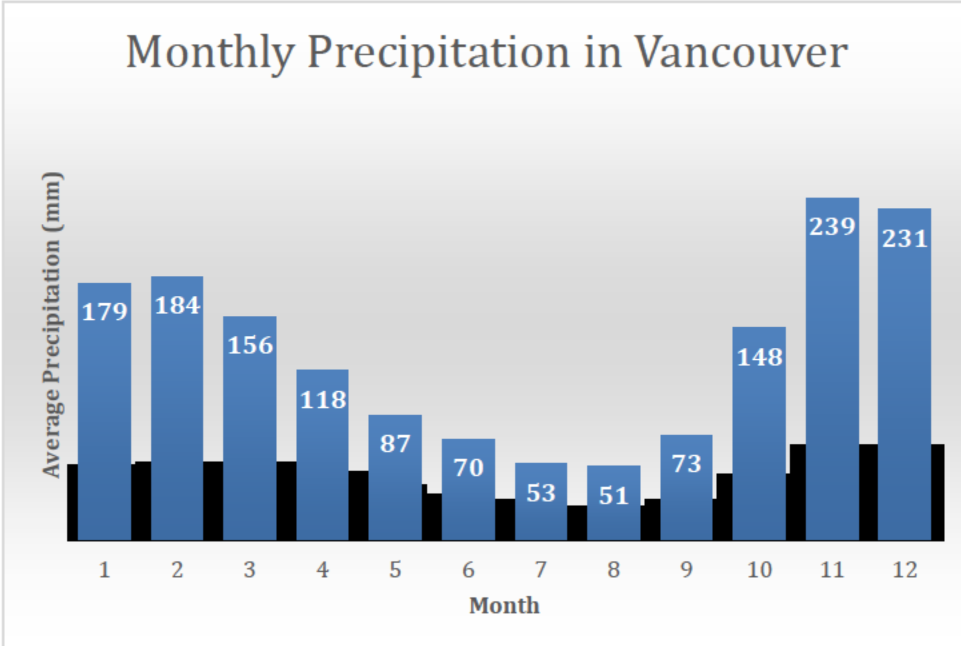

Figure 8 Average monthly precipitation over the last 30 years in Vancouver (Government of Canada, 2014)

The system has been designed to retain a 1 in 25 year storm flow rate which yields a rainfall intensity of 52 mm/hr. Climactic data suggests that a storm duration of 15 minutes should be utilized as the design value. Climate change has also been taken into consideration through reviews of statistical weather analysis. For increased accuracy, a weighted average of runoff coefficients (Listed in Table 4) was utilized to calculate the design flows for the system.

Table 4 Runoff reduction coefficients and the corresponding catchment areas

Area No.	Area (ha)	C	Type of catchment area
1	9.29	0.15	Rolling woodlands and forests
2	2.86	0.9	Flat turf
3	40.45	0.6	Buildings and grasses areas

The minimum amount of stormwater supply per month during summer can be estimated by the following equation:

$$Mass = \Sigma\,(C_i * A_i * R)$$

Where R = rainfall per month

As a result, the design flow is 4.08 m^3 and the total amount of stormwater supply in August is 1.44 million m^3.Based on the analysis above, the tank will receive enough stormwater to meet the monthly peak water consumption of the garden during summer.

4.2 Stormwater Storage Tank

By comparing the overall price, design, and serviceability among all the producers of stormwater harvesting facilities, the supplier "StormTrap", was selected.

The supplier provides concrete storage tanks that are made of precast concrete components known as "Double Trap," as shown in Figure 9.

Figure 9 Double Trap System (StormTrap, 2011)

Because of the prefabrication and modular design, the layout of the tank can be custom made to meet any area constrains. It will maximize the storage volume while minimizing the footprint. In addition, the modular construction will largely reduce the construction time and installation cost. Also, the whole tank is underground and each component has sound structural design, so garden workers will still be able to park their cars and store equipment in the area above. The design will minimize impacts on both workers in the Gardens and collections.

4.2.1 Detailed Design

The storage capacity of this stormwater tank is 3000 m^3. It will be built in the service area of the botanical garden. This is because the elevation of this area is higher than the rest of the garden, so the irrigation system can be mainly gravity fed. The footprint of the tank is 36 m by 30.5 m and the height of each modular component is 3.0 m. The tank is made of five different precast modular components, which are shown in Figure 10.

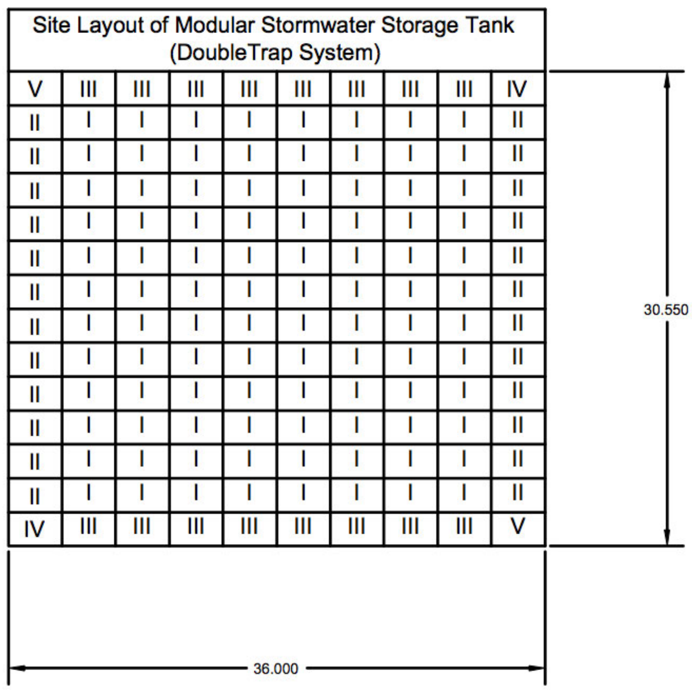

Figure 10 Storage Tank layout

The design of Type I "Double Trap" is shown in Figure 11. All types of the "Double Trap" are 200 mm thick to resist truck loadings. Detailed structural calculations were done by StormTrap. Please refer to Appendix C for the detailed design of the other types of modular components, maintenance access and inlet/outlet.

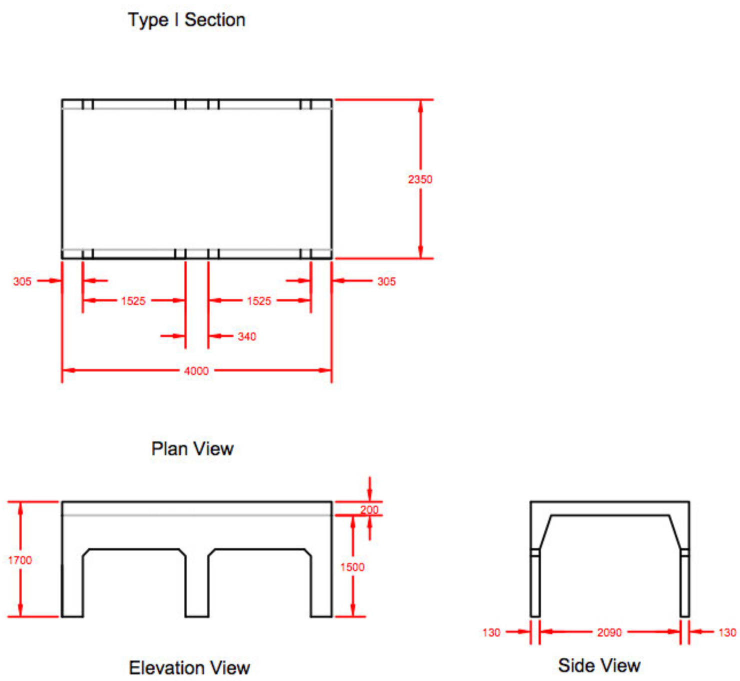

FIGURE 11 DESIGN OF TOP HALF OF TYPE I DOUBLE TRAP SYSTEM

4.2.2 CONCRETE SEALING AND WATERPROOFING

Concrete tanks used for stormwater are not naturally waterproof, so a waterproof liner and internal chemical resistant sprayed coatings will be used. Connections between different modular components will be sealed by using a waterproof liner. The waterproof liner will cover the whole bottom and side surface of the tank. It will also be used on the top surface to seal the void between modular components. This is shown in Figure 12.

FIGURE 12 USING WATERPROOF LINER TO SEAL THE TANK (MATT KAMENICK, 2014)

In order to protect the concrete segments from any soluble substrate in stormwater, a waterproof liner and internal chemical resistant sprayed coatings will be used on the internal surface of the tank. It will also help the liner to seal the tank. Since workers can easily get into the tank through the maintenance access, the sprayed coatings are very easy to be repaired.

4.3 GEOTECHNICAL ASSESSMENT

A geotechnical assessment was carried out on the foundation soil for the water storage tank installation. This was to determine the bearing capacity of the soil, to find the likelihood of any total or differential settlement, and to quantify any risk of liquefaction. Several geotechnical investigations have been previously carried out on UBC campus providing the necessary data to carry out geotechnical calculations. The area is characterized by a very thick layer of dense sand and till with thin inter-layers of silt (Piteau Associates, 2002). This layer varies in thickness from 30 to 45 m and the water table is at a depth of 45 m (Piteau Associates, 2002). Table 5 shows the soil parameters used in the geotechnical analysis.

TABLE 5 SOIL PROPERTIES USED IN ANALYSIS (PITEAU ASSOCIATES, 2002)

Description	Density (kg/m^3)	Friction Angle (deg.)	Shear Modulus (MPa)
Very Dense Sand	2000	38	200

4.3.1 BEARING CAPACITY

The bearing capacity of the soil in the area is a very important consideration. The installation of the water storage tank will disturb the soil in the area and change the bearing pressure on the tank footprint. The bearing capacity of the soil was determined using the equation below (Budhu, 2008). The tank was modeled as a large shallow footing type foundation for simplicity.

$$ESA: q_u = \gamma D_f (N_q - 1) s_q d_q r_q w_q + 0.5 \gamma B N_\gamma s_\gamma d_\gamma r_\gamma w_\gamma$$

An effective stress approach was used since the soil is mostly sand and will not consolidate. The bearing capacity of the soil was found to be 21,000 kPa, which is more than sufficient to carry the load of the full tank and concrete slab, which together apply a maximum bearing pressure of approximately 50 kPa.

4.3.2 SETTLEMENT

Total and differential settlement of the tank is not a concern since the combined weight of the full tank and slab is less than that of the excavated soil. In other words, installation of the underground water storage tank will decrease the overall bearing pressure on the soil. Soil dilation is not a concern since the soil is non-cohesive and the water table is very deep.

4.3.3 *LIQUEFACTION*

The UBC Botanical Garden is in a location with a very low risk of liquefaction due to the very thick layer of dense sand and the low water table.

5 OUTFALL PROTECTION

5.1 TRAIL 7 OUTFALL

Currently the rainwater collected by the stormwater system for the Trail 7 catchment drains from an outfall just southwest of Old Marine Drive. The area is very badly eroded as the bank has little protection from the water that pours from the outfall during rain events. The outfall location can be seen in Figure 7 and a current photo of the eroded outfall can be seen adjacent in Figure 13.

FIGURE 13 TRAIL 7 OUTFALL

The proposed stormwater management system will greatly reduce the volume of water flowing through the Trail 7 outfall, slowing the erosion in the area. However, during large rain events, the retention system will fill to capacity causing some of the water draining from the Trail 7 catchment to flow through the existing drainage system to the outfall. Consequently, mitigation measures must be taken in order to protect the bank from further erosion that could potentially undermine the integrity of the foundation of Old Marine Drive.

5.1.1 *Outfall Protection Strategy*

There are several different methods available for protecting outfalls from erosion. Multiple methods were considered; however, for this particular application backfill and riprap protection would be the most effective and aesthetic. Using a riprap outfall provides a much more natural appearance and is relatively simple to construct. Old Marine Drive provides good access to the area but may need to be partially closed to make room for equipment during construction. Figure 14 shows an example of a simple riprap outfall.

Figure 14 Riprap Outfall

6 Implementation Plan

The implementation and construction of the Sub Surface Storage Reservoir (SSSR) will consist of various construction activities. The following section provides a detailed analysis of the construction plan as well important information regarding the anticipated schedule and cost of the project. The scope of this implementation plan includes a detailed plan for the SSSR, as well as a conceptual plan for the bypass system, Cattail pond rehabilitation and outfall upgrades.

6.1 CONSTRUCTION ACTIVITIES

The construction of the storage tank and other features can be split up into the following activities.

6.1.1 PRELIMINARY SURVEY AND INVESTIGATION

A preliminary site survey and investigation is required before any construction or disturbance occurs. The purpose of the survey and investigation is to confirm anticipated ground conditions as well as locate any underground utilities that will require relocating or decommissioning. No subsurface utilities are anticipated in the proposed storage tank location, however if the site investigation determines there is underground services the necessary arrangements with the owner of the utility will need to be made to either relocate or decommission and remove the utility.

6.1.2 INITIAL EXCAVATION FOR THE STORAGE TANK

As previously mentioned in Section 0, the anticipated ground conditions for the excavation is characterized by a very thick layer of dense sand and glacial till with thin inter-layers of silt as determined by several site investigations previously carried out in locations near the proposed site of the storage tank (Piteau Associates, 2002). If these conditions are confirmed in the site investigation then the following 4V:3H (Case 1) excavation profile may be used according to Worksafe BC which is shown in Figure 15.

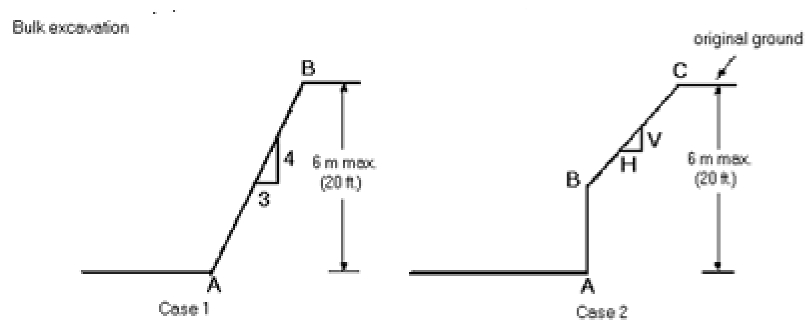

FIGURE 15 BULK EXCAVATION SLOPING IN LIEU OF SHORING (WORK SAFE BC, 2009)

If ground conditions are determined by the site investigation to be worse than anticipated, shoring will need to be used to ensure excavation slope stability.

6.1.3 STORAGE TANK INSTALLATION

The SSSR will consist of a concrete base slab, modular panels and all necessary inlet and outlet connections. As detailed in the plans, the base slab will be poured over the entire footprint of the modular panels by use of a concrete pump to ensure a water-tight reservoir. The modular concrete panels will be installed according to StormTrap's suggested installation procedures by use of a 75 ton RT crane which will ensure lifting capacity of the furthest pick. The initial inlet connection from the cattail pond and outlet from the sump will be prepared as per plans at this stage as well. Final connections will be made during following activities. The construction of the sump and pumping station will occur at this stage as well.

6.1.4 CONNECTION OF PUMPING STATION TO DISTRIBUTION SYSTEM AND HYDROSTATIC TESTING

The connection will be trenched by the use of a 300 mm minimum deep trench and HDPE pipe to the closest existing distribution main as determined by the initial site survey. Once this outlet connection is made, the distribution system will be tested to ensure there are no leaks and there is adequate pressure provided by the pump.

6.1.5 Backfilling of the Storage Tank

Once the Distribution system has passed the hydrostatic testing, it may then be backfilled to original ground levels according to the plans. Backfilling will be conducted in 300mm lifts equally on both sides, compacting each lift to 100% SPDD according to the directions advised by StormTrap.

6.1.6 Cattail Pond Rehabilitation

The Cattail pond will be excavated and redesigned at the same time as the other construction activities. The pond will need to be drained before any excavation occurs. This will be done by natural infiltration into the soil, or by means of pumping. Inlet and drainage controls will then be installed in preparation of connection to the storage tank in the next activity.

6.1.7 Connection of Cattail Pond to Storage Tank

Once the cattail pond rehabilitation is completed, the outlet of the pond can then be connected to the storage tank. Using a 300 mm minimum deep trench and HDPE pipe, the outlet of the cattail pond will be connected to the prepared inlet of the storage tank.

6.1.8 *Connection of System to UBC Stormwater Main*

The installation of the flow diversion device can be done concurrently with the activities associated with the storage tank and cattail pond. As described previously, the flow diversion device will be situated in the roundabout at Stadium Drive. The stormwater in the main will need to be diverted during this operation. The pipe will be blocked at the closest upstream manhole, and the water will then be pumped to the closest downstream manhole. This portion of the construction should preferably be done in the summer during low flows to avoid the use of large pumps and flood control measures. The stormwater main will then be excavated and uncovered enough to install the inlet flow diversion device. Once the device is installed, it will be backfilled and the pipe will be trenched and laid to the inlet of the cattail pond. All pipe will then be backfilled and landscaped to original ground conditions.

6.2 Construction Schedule

The complete anticipated construction schedule is attached in Appendix A. To avoid the rainy season in Vancouver, construction will begin in May. This is so that construction activities such as redesigning the cattail pond will be primarily done in dry conditions. The total length of construction is planned to be minimized at five weeks partly due to the rapid installation methods associated with the modular design of the storage tank, effectively diminishing potential visitorship losses during the construction period. Construction activities will occur simultaneously to also reduce the overall length of the construction period.

7 ENVIRONMENTAL IMPACT ASSESSMENT

The environmental objective for this project is to provide a sustainable and cost-effective stormwater management system. A significant reduction or elimination of the following environmental issues are expected after the redevelopment of water distribution system within UBC Botanical Garden:

- Erosion and periodic flooding within the UBC Botanical Garden.
- Erosion on cliff and subsequent damage to outfall (Fraser River estuary)
- Potable water irrigation

7.1 EROSION

Excessive amount of water runoff is one of the major causes for erosion, and stormwater erosion is generated when precipitation flows over land and does not percolate into ground. Erosion could cause environmental impacts to UBC Botanical Garden and its surrounding area. One of major concern is erosion could cause soil quality reduction, and the plants within the garden reliant on the nutrient – rich topsoil, which is most vulnerable to erosion. Also, soil's water retention capacities could be greatly reduced due to long-term erosion. In addition, if erosion continues and conditions are getting worse, the periodic flooding could cause serious damage to the stream bank and cliffs. Furthermore, pollutants such as pesticides, metals, toxins, oil, phosphate, and excessive amount of sediments may be transported to the Fraser River and cause algal blooms, effectively reducing the amount of dissolved oxygen in the water and diminishing water quality and aquatic habitats.

7.2 Potable Water Irrigation

Currently, UBC Botanical Gardens has been using potable water as the source for irrigation. This is a wasteful and unsustainable method for irrigation that could be improved by using a storage tank in the garden to collect and store the stormwater for irrigation use at all times during the year.

7.3 Potential Environmental Impact During Construction

Land left exposed or undergoing construction is vulnerable to an increased rate of erosion. The plants or grass – natural version of vegetated buffer for erosion, will be removed during construction and leave the ground exposed. As stormwater flows over the construction site it can pick up pollutants like sediments, debris, chemicals from paints, concrete washout, and be transferred by runoff, causing potential damage to the garden plants, sewer systems and river. The following steps should be followed during the construction practice to reduce pollution damage:

- Preventing concrete wash-water exposure to stormwater system.
- Plan and implement waste water control measures before starting jobs.
- Plan for emergency spills such as diluting the wastewater to reduce the damage.
- Always contain wash-water and slurry.
- Clear the site and properly dispose of any waste after construction is completed.

7.4 Post System Upgrade

A cattail pond will be used as a primary filtration system to treat the stormwater before it enters the water storage tank. Gravitational separation will be used predominantly to settle the containments from runoff. The tank will capture stormwater runoff and store it to provide a convenient source of irrigation and to reduce the amount of potable water required for irrigation. In addition, the impact due to erosion would be mitigated downstream. A proper maintenance plan is required for the cattail pond and storage tank to minimize the potential environmental impacts during operation.

7.4.1.1 Water Storage Tank:

- Follow confined entry procedure when entering vaults.
- Inspect annually at a minimum, remove floating debris and oil etc.
- Remove sediments when depth reaches 150mm. (Ideally during dry-periods in summer)

7.4.1.2 Cattail Pond:

- Monitor sediment depth annually, and remove accumulated sediment from forebays once every 5 to 10 years.
- Monthly inspection maintain a free-flowing orifice.
- Clean away floating trash and debris bi-weekly to remain aesthetics of cattail pond.
- Remove vegetation along the dam face once a year if needed.
- Remove invasive plant species annually.
- Mow the perimeter of wet ponds depends on design aesthetics.
- Control pests, such as muskrats and beavers.

8 COST

THE TOTAL ESTIMATED COSTS FOR THIS PROJECT ARE SUMMARIZED IN

Table 6. A detailed cost break down is included in Appendix E.

TABLE 6 SYSTEM COMPONENT COST SUMMARY

Component	Capital Cost
Water Storage Tank	$2,287,118
Cattail Pond Construction	$184,000
Pumping Station	$6000
Total	**$2,477,118**

Table 6 is inclusive of all aspects of the project except for the outfall protection. The outfall protection was excluded from the overall cost because it was highly variable due to the accessibility issues with the location of the current outfall. Moreover, it was determined to be under the park's department responsibilities and therefore outside of the scope for this project as it is not something the Botanical Gardens or UBC would be responsible for funding. However, please refer to Section 5 which gives conceptual information that can be utilized by the parks department.

The total maintenance costs are estimated in Table 7.

TABLE 7 SYSTEM OPERATIONS AND MAINTENANCE COST SUMMARY

Annual Operation & Maintenance	Annual Cost
Tank Cleaning	$1800
Pump Maintenance	$100
Cattail Pond Maintenance	$3700
Total Annual Cost	**$5,600**

The annual cost is expected to be quite minimal as it is expected that cleaning out the storage tank is expected to occur only every 5 years due to most contaminants settling out in the cattail pond before the water enters the storage tank. Therefore, most of the maintenance cost is associated with the cattail pond which is cheaper to maintain than the storage tank.

9 Conclusion

The UBC Botanical Garden is a role model of sustainable practices at UBC as well as Vancouver as a whole. Renew Engineering Solutions strives to reinforce the Garden's commitment to sustainable practices by implementing the stormwater management system described above. The system will greatly reduce the Garden's reliance on the potable water supply which is currently being used for irrigation. Renew recognizes the need for low maintenance solutions, thus, each component of the system is designed to be constructed with minimum disturbance and with very low operating costs. The cattail pond utilizes natural water treatment mechanisms while also providing an aesthetic water feature and waterfowl habitat. Overall, the system provides a cost effective, long-term solution to the Garden's water supply problem.

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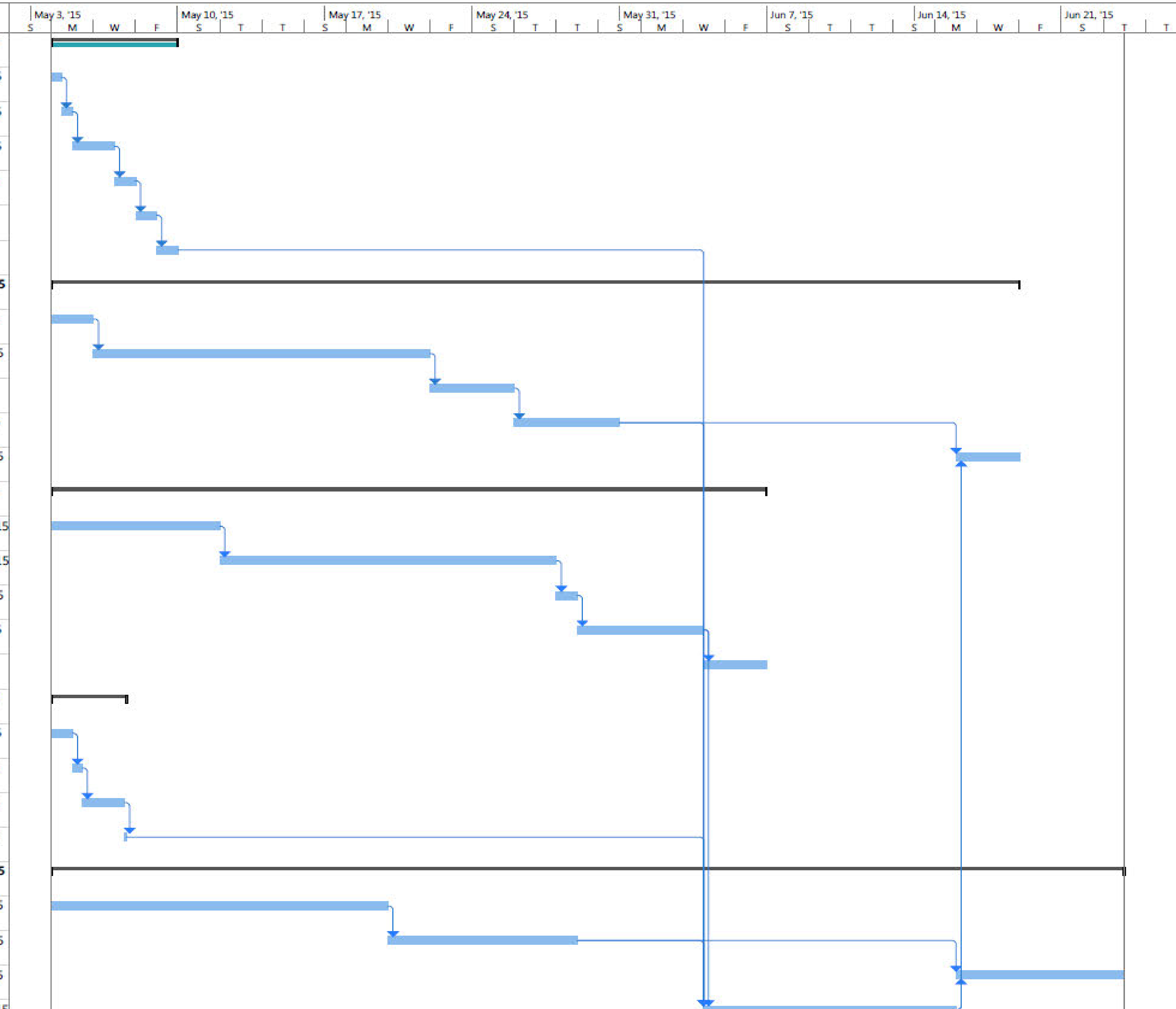
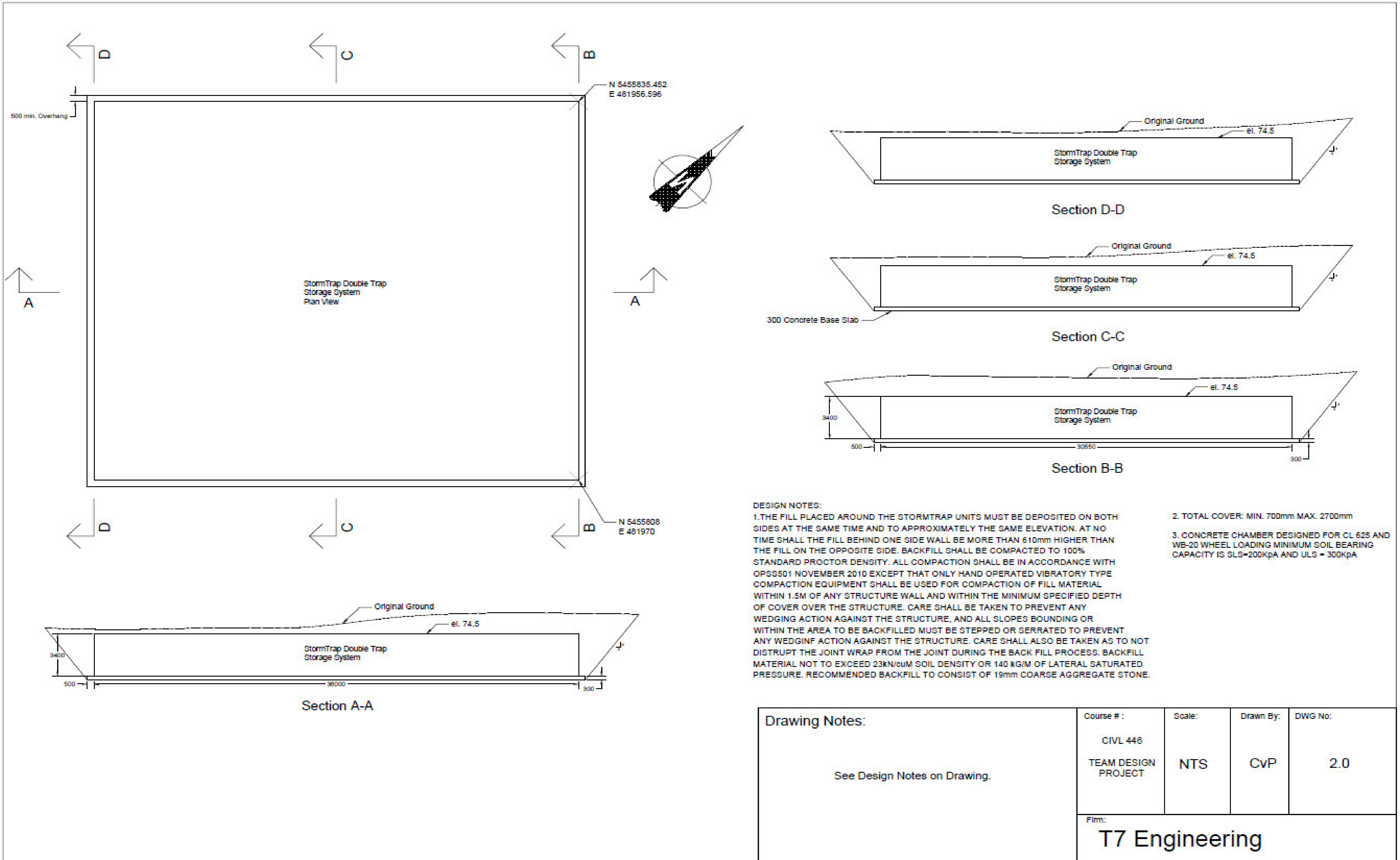
11 Appendix A - Project Schedule

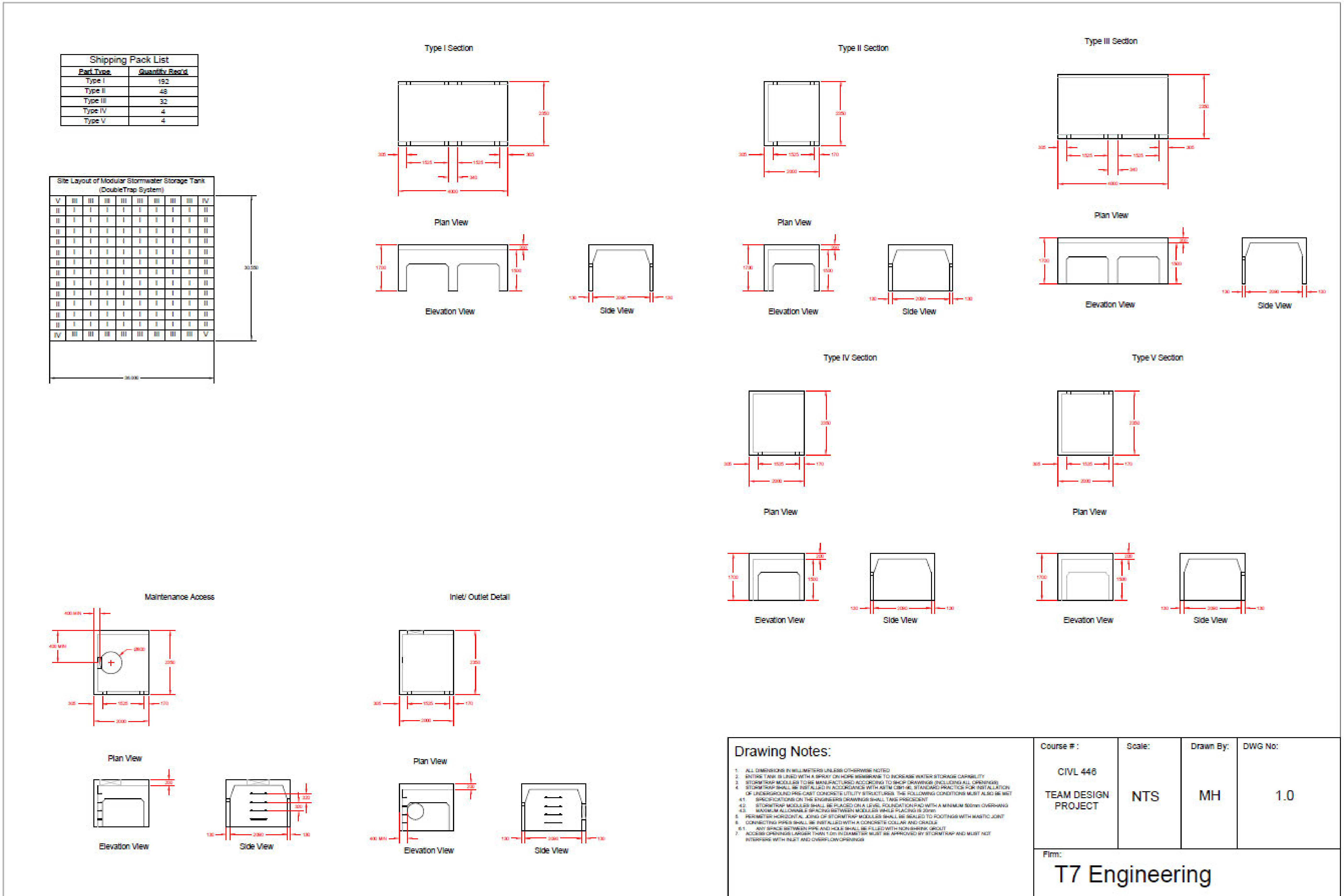
ID	Task Name	Duration	Start	Finish
1	**Flow Control Device**	**6 days**	**Mon 5/4/15**	**Sat 5/9/15**
2	Cut Asphalt & Sidewalks	0.5 days	Mon 5/4/15	Mon 5/4/15
3	Excavate to Stormwater Main	0.5 days	Mon 5/4/15	Mon 5/4/15
4	Install Dewatering System in Main	2 days	Tue 5/5/15	Wed 5/6/15
5	Install Flow Control Device	1 day	Thu 5/7/15	Thu 5/7/15
6	Remove Dewatering System	1 day	Fri 5/8/15	Fri 5/8/15
7	Backfill and Patch Pavement	1 day	Sat 5/9/15	Sat 5/9/15
8	**Cattail Pond**	**40 days**	**Mon 5/4/15**	**Thu 6/18/15**
9	Dewater Existing Cattail Pond	2 days	Mon 5/4/15	Tue 5/5/15
10	Excavate New Cattail Pond	14 days	Wed 5/6/15	Thu 5/21/15
11	Install Inlet &Drainage Control Structures	3 days	Fri 5/22/15	Mon 5/25/15
12	Install Geo-membranes and Vegetation	5 days	Tue 5/26/15	Sat 5/30/15
13	Fill Cattail Pond	3 days	Tue 6/16/15	Thu 6/18/15
14	**Stormwater Storage**	**30 days**	**Mon 5/4/15**	**Sat 6/6/15**
15	Clear Excavation Area	7 days	Mon 5/4/15	Mon 5/11/15
16	Excavate Tank Area	14 days	Tue 5/12/15	Wed 5/27/15
17	Stage Tank Pieces	1 day	Thu 5/28/15	Thu 5/28/15
18	Install Storage Tank	5 days	Fri 5/29/15	Wed 6/3/15
19	Backfill Excavated Area	3 days	Thu 6/4/15	Sat 6/6/15
20	**Pump Station**	**3.75 days**	**Mon 5/4/15**	**Thu 5/7/15**
21	Excavate	1 day	Mon 5/4/15	Mon 5/4/15
22	Install Pre-Fab Sump	0.5 days	Tue 5/5/15	Tue 5/5/15
23	Install & Test Pump	2 days	Tue 5/5/15	Thu 5/7/15
24	Backfill Excavated Area	0.25 days	Thu 5/7/15	Thu 5/7/15
25	**Distribution Network**	**44 days**	**Mon 5/4/15**	**Tue 6/23/15**
26	Excavate Entire Trench (1 & 2)	14 days	Mon 5/4/15	Tue 5/19/15
27	Install Pipe	8 days	Wed 5/20/15	Thu 5/28/15
28	Backfill Excavated Area	7 days	Tue 6/16/15	Tue 6/23/15
29	**System Testing & Commissioning**	10 days	Thu 6/4/15	Mon 6/15/15



12 Appendix B – Excavation Plans



13 Appendix C – StormTrap^{TM} Tank Design



Shipping Pack List	
Part Type	Quantity Req'd
Type I	192
Type II	48
Type III	32
Type IV	4
Type V	4

Drawing Notes:

1. ALL DIMENSIONS IN MILLIMETERS UNLESS OTHERWISE NOTED
2. ENTIRE TANK IS LINED WITH A SPRAY ON HDPE MEMBRANE TO INCREASE WATER STORAGE CAPABILITY
3. STORMTRAP MODULES TO BE MANUFACTURED ACCORDING TO SHOP DRAWINGS (INCLUDING ALL OPENINGS)
4. STORMTRAP SHALL BE INSTALLED IN ACCORDANCE WITH ASTM C891-90, STANDARD PRACTICE FOR INSTALLATION OF UNDERGROUND PRE-CAST CONCRETE UTILITY STRUCTURES. THE FOLLOWING CONDITIONS MUST ALSO BE MET
   - 4.1. SPECIFICATIONS ON THE ENGINEERS DRAWINGS SHALL TAKE PRECEDENT
   - 4.2. STORMTRAP MODULES SHALL BE PLACED ON A LEVEL FOUNDATION PAD WITH A MINIMUM 500mm OVERHANG
   - 4.3. MAXIMUM ALLOWABLE SPACING BETWEEN MODULES WHILE PLACING IS 20mm
5. PERIMETER HORIZONTAL JOINS OF STORMTRAP MODULES SHALL BE SEALED TO FOOTINGS WITH MASTIC JOINT
6. CONNECTING PIPES SHALL BE INSTALLED WITH A CONCRETE COLLAR AND CRADLE
   - 6.1. ANY SPACE BETWEEN PIPE AND HOLE SHALL BE FILLED WITH NON-SHRINK GROUT
7. ACCESS OPENINGS LARGER THAN 1.0m IN DIAMETER MUST BE APPROVED BY STORMTRAP AND MUST NOT INTERFERE WITH INLET AND OVERFLOW OPENINGS

Course #:	Scale:	Drawn By:	DWG No:
CIVL 446 TEAM DESIGN PROJECT	NTS	MH	1.0

Firm: T7 Engineering

14 Appendix D – Hydrotechnical calculations

Rational Method

Rational Method

$$Q \quad C * i * A$$

Rainfall Intensity

Comments: Assumed 1 in 25 year storm with a duration of 15 minutes as a design storm for detention pond design. Climate change was taken into consideration through reviews of statistical weather analysis

i= 52 mm/hr

Composite Runoff Coefficient Calculation

Area No.	Area (ha)	C	Comments
1	9.29	0.15	Rolling woodlands & forests
2	2.86	0.9	Flat turf
3	40.45	0.6	buildings and grasses areas
∑	52.6		
Composite C		0.536835	

Design Flow Rate

Q = 4.07875 m³/s

Pumping Station Design

Flowpath	Manhole		Pressure Line Design: Max. Flow Rate	Pipe Dia.	Length	Hazen-Williams Coeff. "C"	Friction Headloss (H.W.)	Head Reqd. @ DS End	Total Head Reqd.	Pump Head Reqd.	Pump Station Design Requirements
	From(US)	To(DS)	(L/s)	(mm)	(m)		(m)	(m)	(m)	(m)	
Path 1	Tank	NE GDNS	1.096	100	60	140	0.0169	71	70.2469	71	Reqd. Head: 71m (232ft) Reqd. Flow Rate: 1.096 L/s (17.4GPM)
Path 2	Tank	SW GDNS	1.096	100	200	140	0.0562	71	70.2862	71	

15 Appendix E – Detailed Cost Breakdown

Water Storage Tank Capital Cost:

Materials and Freight	$	1,083,765.00
Excavation	$	38,404.00
Installation	$	446,370.00
Backfill	$	10,799.00
Misc.	$	50,000.00
Engineering	$	570,268.30
Tax (12%)	$	263,952.76
Total	**$**	**2,463,559.06**

Source: Matt Kamenick, E. (2014, March 7). StormTrap Waterproofing Options. Morris, IL, USA.

Water Storage Tank Maintenance Cost:

Total cleaning cost every five years	$9,000
Annual Tank Cleaning	**$1,800**

Maintenance costs obtained from local best management practices: Gibb, A., Kelly, H., Schueler, T., Horner, R., Simmler, J., & Knutson, J. Best Management Practices Guide for Stormwater. Greater Vancouver Sewerage and Drainage District, Vancouver.

Water Storage Tank Operating Cost:

Cattail Pond Cost:

Cattail Pond Construction Cost:

Surface area of pond		2600	m^2
Average depth of pond		3.0	m
Water Quality Volume (ie total volume)		7800	m^3
Unit construction cost	$	23.60	$\$/m^3$
Total construction cost (TCC) (CAD)	**$**	**184,044.94**	

Cattail numbers are derived from case study report: Weiss, P. T., Gulliver, J. S., & Erickson, A. J. (2007). Cost and pollutant removal of storm-water treatment practices. Journal of Water Resources Planning and Management(133), 218-229.

Cattail Pond Maintenance Cost:

Annual O/M cost (% of TCC)	2.0%
Annual O/M cost (CAD)	**$ 3,680.90**

Maintenance costs obtained from local best management practices: Gibb, A., Kelly, H., Schueler, T., Horner, R., Simmler, J., & Knutson, J. Best Management Practices Guide for Stormwater. Greater Vancouver Sewerage and Drainage District, Vancouver.

Pumping Station:

Capital Cost:

Pump Cost	**$**	**6,000.00**

Maintenance Cost:	**$**	**100.00**

Source: Goulds Water Technology. (2014, March 24). Goulds Pumps. Retrieved March 24, 2014, from Direct Industry: http://img.directindustry.com/images_di/photo-g/stainless-steel-multi-stage-vertical-centrifugal-pumps-14176-2277143.jpg