University of British Columbia

Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

UBC Groundwater Emergency Water Supply - Final Design Report

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Executive Summary

The University of British Columbia - Social Ecological Economic Development Studies (SEEDS) Sustainability Program has identified a need for an emergency water supply for the UBC Vancouver Point Grey Campus (Campus) to address water demands during a potential seismic event or major service disruption. This report presents the team's detailed design for an emergency water supply system using groundwater wells.

Due to the extensive scope of a full groundwater system, the scope for detailed design was narrowed to focus on the following design components: well design, distribution from wells to reservoir, construction sequencing and scheduling, and cost estimating. The codes and standards used include the UBC Technical Guidelines, the City of Surrey Design Manual and corresponding Master Municipal Construction Documents Supplement, the BC Design Guidelines for Rural Residential Community Water Systems, and the Canadian Concrete Code (CSA-A23.3). The key regulations and acts referenced are the BC Drinking Water Protection Act and Regulation, Groundwater Protection Act, and the Water Sustainability Act.

The design features a phased construction approach with seven groundwater wells constructed during Phase 1 and four wells in Phase 2 to meet the anticipated 2050 water demand of 70 L/s for a supply service length of one week. Each well will be fitted with a 250 mm steel casing, 150 mm Grundfos SP-30-14 submersible groundwater intake pump, 250 mm shutter style well intake screen, 150 mm ductile iron drop pipe to connect the pump to the effluent well check valve, pitless adapter, two 25 mm PVC sounding tubes for observation, and watertight well cap. Adjacent to the well cap will be an above-ground well controls and maintenance house. Electrical and automation controls of the well operations will be designed by an electrical sub-consultant.

The distribution mains on East Mall which feeds the flows from the wells to the reservoir are 6" Kubota Earthquake Resistant Ductile Iron GENEX piping to meet required flow and pressure design criteria. Piping from the wells to this feeder main are 8" Kubota GENEX ductile iron piping.

A 2700m^3 underground reinforced concrete cast-in place concrete reservoir will be located under the pavement space adjacent to the UBC Life Building, with the structural design to be completed by a sub-consultant. To meet potable water quality standards, a treatment and controls building will be designed for filtration, removal of iron and manganese, and chlorine disinfection by a process and mechanical sub-consultant.

A Class A cost estimate was completed for the preliminary design and prices the project at $15.8M with a 5% contingency.

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1.0 Introduction

The UBC SEEDS Sustainability Program is seeking to design an emergency water distribution system for the UBC Point Grey Campus (the Campus) using groundwater as the water supply resource. The emergency water supply would be required should an interruption to service occur. An interruption to service could result from a seismic event, power failure, or contamination, any of which could strain or deplete the Campus' water supply.

This report presents the team's detailed design for the project and acts as the final deliverable for the project. Included in this report are an outline of the design criteria and standards; detailed design outputs for all design components; construction specifications; a Class A cost estimate; a draft construction plan and schedule; and detailed design drawings.

2.0 Project Overview

2.1 Context

Metro Vancouver currently provides the Campus with potable water from the Sasamat Reservoir which is conveyed through the University Endowment Lands (UEL). The campus receives water through two separate water mains: one along University Boulevard and another along West 16th Avenue from the reservoir. By sourcing the same water supply through the two mains, the water system is at risk of unscheduled interruptions, such as contaminated supply or major damage during a large-scale natural disaster. If the primary water supply is interrupted for an extended period of time, the Campus would struggle to continually service the inhabitants with adequate potable water.

The UBC SEEDS program has identified the current system shortfalls and is looking to assess the feasibility of using groundwater as a viable water source during a service interruption. The campus resides on glacial till with geological studies showing a Quadra sand layer which contains an aquifer of safe drinking water. Designing an emergency water supply to deliver treated potable water would enable the Campus to maintain its essential operations during temporary service interruptions.

In October 2020, a temporary water outage occurred at the UEL which resulted from issues with the water main supplying water to the campus. While no water shortage occurred, the water system experienced low-pressure resulting in some discoloration and turbidity. This incident further emphasized the importance of improving the resilience of the Campus' water system by adding redundancy.

2.2 Objectives

The key project design objectives outlined by the client are as follows:

- Determine the feasibility of using groundwater wells as an emergency water source for the UBC Point Grey Campus; and
- Design infrastructure to extract, treat, store and distribute the emergency water supply to the Campus.

2.3 Scope of Work

The revised scope of work for the detailed design includes the following:

- Groundwater well design to meet the water demands including wellhead and pump design; and
- The distribution pipe network system from groundwater wells to the underground reservoir.

The scope of work for detailed design to be completed by sub-consultants includes the structural design of the pump house, the structural design of the water reservoir, the structural and civil design of the water treatment system, any electrical and mechanical designs, and the civil design for the distribution system from reservoir to service points.

The preliminary design for the reservoir, distribution system from the reservoir to service points, and water treatment system have been provided in this report to guide the sub-consultants on the detailed design requirements.

2.4 Site Layout

The project is located at the UBC Point Grey Campus in Vancouver, B.C. Figure 1 presents an aerial view of the site. The urban density, surrounding trees and vegetation, and underground structures are important to note as design constraints in the site layout.

Figure 1: Aerial Imagery of Site

The geological investigation of the site was informed by the 'Hydrogeological and Geotechnical Assessment of Northwest Area UBC Campus, Vancouver' 2002 report by Piteau Associates (Piteau Hydrogeological Report). As stated in the report, the campus resides on primarily glacial till with a Quadra sand layer which contains an aquifer of safe drinking water. The perched upper aquifer flows westwards, and the lower aquifer flows south west. Groundwater was seen to flow much easier in the lower aquifer than the upper. Well yields ranged from 50-100 US GPM with the highest flows being 100 US GPM (6.6 L/s) from the lower aquifer in the northeast region of the Campus. Due to high yield rates in the northeast region, the team's design will focus on well locations in this portion of the Campus.

3.0 Design Criteria and Standards

3.1 Design Criteria

The unknown parameters that were first defined to size the system were the water demand, maximum length of emergency service, potential aquifer yields, and water quality from the quadra sand layers. Our team conducted research and calculations informed by guidelines from the WHO, BC and Canadian governments, EPA, and case studies from other cities in similar climates to define these parameters.

Defined below are the unknown parameters which are used to size and design each element of the detailed design.

Emergency Water Demand

The 2020 water demand was calculated to be 40 L/sec, growing to 70 L/sec by 2050 based on UBC water usage data, MMCD and WHO guidelines. A breakdown of the methodology in calculating the demand is included in Appendix B. The following assumptions were used to determine the water demand:

- To reduce the water demand needed for toilet flushing, it was assumed that 60% of the sewer system would fail in the event of a large natural disaster (only the large sewer pipes would remain operational); thus only requiring 60% of the total toilet flushing demand.
- The growth rate of water usage is 2% per year (based on UBC Water Management Plan: Normal Water Usage 2017 and 2019 data).
- Only water usage for domestic, UBC Hospital, toilet flushing and associated handwashing and water leaks were included in the water demand calculation. Research and other academic/institutional water usages are deemed non-essential during large natural disasters.
- Domestic water usage was set at 15 L/capita/day for drinking, food and basic hygienic practices. This was based off the upper limit of the WHO guidelines. As Canadian water usage is significantly higher than in areas where this document is used normally for emergency planning an additional allowance was included for toilet flushing and associated handwashing (16.8 L/capita/day). This results in a water usage of 40 L/capita/day, which is significantly above the emergency water usage planning recommendations.

Length of Service Interruption

A 1-week length of service interruption was chosen based on a variety of external literature for comparable communities facing large natural disasters (i.e. earthquakes). It is assumed that after 1 week, the large water mains will be repaired and 70% of the service connections will be restored.

Well Locations

The chosen well locations were based on Piteau Associates' 2002 report, Hydrogeological and Geotechnical Assessment of the Northwest UBC Campus. Yields were mapped from existing wells with historical data. It is assumed that these existing wells and their historical yield rates are representative of yield rates in 2020 in the proximal areas surrounding the well.

Well Yields

A maximum yield of 100 GPM (6.6 L/s) occurs on the northeastern side of campus drawing from the lower aquifer.

Water Quality

It is assumed that the aquifer contains negligible traces of Arsenic, Nitrate and Ammonia. Manganese and Iron may also be present in the water as identified by the client. The distributed water shall be treated to follow the 4-3-2-1-0 policy in the Canadian Drinking Water Guidelines and further meet all the requirements of the provincial Drinking Water Protection Act and the Drinking Water Protection Regulation.

Based on the key design criteria identified the following non-negotiable design criteria were identified regarding the design objective:

- All infrastructure shall meet applicable standards and regulatory requirements;
- All placement of infrastructure shall conform to the UBC Land Use Plan;
- Water demand during emergencies includes UBC students, faculty and staff who do not live on campus as per UBC's Emergency Response Plan;
- Designs shall prioritize protection of life, incident stabilization, property and environmental preservation and mission continuity/resumption;
- Design complies with Environmental Protection Policy, including, but not limited to, providing adequate training for staff and including monitoring systems and procedures for handling and reporting accidents for all activities and areas of concern;
- Design is mindful of the local environment and stakeholder interests in maintaining the local environment and the wilderness aesthetic that currently exists; and
- Water quality meets BC Drinking Water Protection Act and BC Drinking Water Regulation.

3.2 Standards and Codes

The following regulatory requirements and permits were identified for the scope of this project. It is important to note that due to the scale and scope of the project consultation with various government bodies is recommended to verify permitting requirements.

Standards and Codes:

- Water Sustainability Act (2021)
- Groundwater Protection Regulation Under Water Sustainability Act for regulation of water supply well (2021)
- BC Drinking Water Protection Act (2021)
- BC Drinking Water Protection Regulation (2021)
- Canadian Drinking Water Guideline (2020)
- Canadian Concrete Design Code (2014)
- BC Plumbing Code (2018)
- The City of Surrey Design Criteria Manual (2020)
- The City of Surrey Supplementary Master Municipal Construction Documents (2020)
- University of British Columbia's Technical Guidelines for Water Utilities (2020)
- British Columbia's Design Guidelines for Rural Residential Community Water Systems (2012)

Permits:

- BC Water License
- City of Vancouver Water Systems Operating Permit
- Development Permit (applicability will depend on if the zoning of the identified well locations changes before submission to the regulatory body with phased approach)
- City of Vancouver Plumbing Permit
- City of Vancouver Mechanical Permit
- City of Vancouver Building Permit for the treatment/controls building, reservoir and distribution system

3.3 Software

The following modelling software was used to complete the design and analysis for the groundwater wells and distribution system:

- Civil 3D
- AutoCAD
- EPANET
- Microsoft Excel

3.4 Technical Considerations

The following technical considerations were identified specific to the groundwater well design:

- The well location must be fully accessible at all times via statutory right of ways and not be subject to flooding with the site grading directing any surface runoff away from the wellhead.
- For contamination protection the casing extends a minimum of 300mm above finished grade for contamination protection, the top of casing must be a minimum of 600mm above the 100 year flood construction level and a minimum 50mm thick bentonite grout surface seal is included at all entry and exit points of the well house.
- The well casing must be continuous and watertight.
- The annular space between the borehole and production casing should be sealed to a minimum depth of 5.0m.
- A sampling spigot and flow meter are located on the discharge piping to meet well testing requirements
- Two 25mm sounding tubes installed in each well for periodic measurements of water levels.
- Freeze protection was provided through the use of a pitless adaptor and underground piping.
- Ease of maintenance was considered by placing all well valves, flow meter, sampling spigot and mechanical and electrical components in the well house above ground. Additionally, a pitless adaptor allows for the pump to be removed from well for maintenance.
- The well is located separate from the pump house and other enclosures to allow access in the case of future rehabilitation or re-development.
- The discharge well piping should include one check valve, an isolation valve, pressure gauge, flow meter and a sampling spigot.

The following technical considerations were identified specific to the distribution network design:

- Minimum and maximum velocity of 0.8 m/s and 2 m/s respectively.
- Minimum and maximum pressure of 40psi and 150psi respectively.
- Minimum clearance of 750mm from other utilities with a minimum 3 m clearance from sanitary infrastructure.
- Minimum grade of 0.1%.
- Minimum cover of 1m to finished grade for freeze protection.
- Protective coating included in the recommended pipe material, Kubota's GENEX ductile iron pipe, will provide sufficient corrosion protection, as polyethylene encasement is insufficient.

3.5 Design Issues Outlined and Addressed

The critical design issues that were identified are mainly related to the lack of site investigation that occurred prior to the commencing of preliminary and detailed design. Described below are the design issues and the steps required prior to construction to address the uncertainties.

- The *Piteau Hydrogeological Report* was used to inform the well yields and drawdown rates for the groundwater wells. Since the report was focused only on the northwest portion of campus data was inferred for the other areas. Prior to construction in-situ and laboratory testing should be completed to confirm local ground conditions at each well location.
- Several requirements must be met either before or after construction to fulfill standards and regulations, and to meet best practices for a groundwater supply system. Comprehensive in-situ and lab testing must be completed for each well location prior to drilling, as required by the BC Groundwater Protection Act, including pumping yield rate measurements, consolidation and permeability tests, and gradation characterization of local ground conditions. This will include a pilot program.
- The seismic and ground movement potential were not evaluated prior to commencement of the detailed design. A site investigation should occur prior to construction to document any potential damage to existing infrastructure.
- A standard road cross-section was supplied to inform the detailed design of the distribution network. Prior to construction, the detailed design should be compared against GIS data and as-built information for all existing utilities and road alignments.
- Well locations were chosen based on aerial photos and a site visit. Prior to construction, the well locations should be compared against GIS data and as-built information for all existing utilities, road alignments and buildings in the surrounding areas to ensure no conflicts or impacts to the surrounding infrastructure. If a potential conflict or near conflict is identified, a professional engineer shall be required to comment on the design.
- An environmental assessment has not been completed for any conflicting vegetation (including large trees on the proposed reservoir site). Prior to construction an arborist should be contacted to determine any impacts to the proposed tree removals.
- Groundwater wells are not commonly used throughout the Lower Mainland, except for the City of White Rock, resulting in a lack of precedent design and construction experience. Not having reliable precedents will create difficulties for the construction team.
- Even though construction is scheduled to start on a favorable date (May 1st, 2021) after the end of winter (March 20th, 2021), weather is never certain. Unexpected weather may impact

construction productivity and delay the project. A buffer has been established in the schedule to account for such events, however, if this buffer is exceeded, working hours may have to be adjusted to bring the project back on track.

- Canada has been relatively slow to roll-out vaccines to its population and British Columbia is currently experiencing a rapidly increasing third wave of COVID-19. As the construction start date of Phase 1 is within a month away, there is uncertainty associated with how this rise in cases will affect the province in the short-term. Furthermore, site management restrictions such as social distancing and the requirement of masks may generate construction delays. For example, additional measures such as staggering the work of various trades may need to be imposed to prevent different construction teams from coming into close contact with one another.

After the construction it is important that additional testing and work are completed. This includes but is not limited to:

- Field testing of distribution system per the identified standards in Section 8.0.
- Well disinfection per the British Columbia's Design Guidelines for Rural Residential Community Water Systems Section 4.3.10 to remove any bacteriological contamination prior to connection to the potable water system.
- Continuous monitoring of aquifer levels and recharge rates to ensure the wells are functioning as design and pumping rates do not need to be adjusted.
- Updating the UBC Emergency Response Plan to incorporate the emergency system.

4.0 Detailed Design Components

4.1 Design Overview

The design uses a phased build-out approach with 7 wells constructed in Phase 1 and four more wells constructed in Phase 2. This construction method was chosen to avoid overbuilding for current demand and to reduce the initial capital investment.

The detailed designs for the following components are further described in this section:

- **Groundwater Wells:** Construct 7 wells in Phase 1, 4 wells in Phase 2, fitted with a submersible pump assembly and motor drawing from the lower aquifer.
- **Distribution to From Wells to Reservoir:** Watermains using seismically resilient GENEX ductile iron piping to provide distribution from the wells and the reservoir

Detailed design drawings for each of these components are provided in the Detailed Design Drawing Set found in Appendix A.

4.1.1 Well Supply and Locations

The *Piteau Hydrogeological Report* was used to approximate the yield based on the extrapolation of point data. The report outlined a well yield of 100 US GPM (6.5 L/s) from the lower aquifer in the northeast region of the UBC Campus. This yield rate was used to determine the number of wells required to meet the calculated water demand of 40L/s in 2020 and 70L/s in 2050. To prevent overbuilding of infrastructure and reduce initial capital costs, a phased approach will be used to reach the full build-out for 2050. Phase 1 will include 7 wells which will yield a rate of 45.5L/s, and Phase 2 will use an additional 4 wells reaching a total yield from both phases of 71.5L/s. Table 2 summarizes the demand and supply for the chosen well quantities and Figure 2 provides the locations for the chosen well locations.

Table 2: Well Yield and Water Demands

Building Phase	Water Demand	Number of Wells	Total Well Yield
Phase 1: 2020	40 L/s	7	45.5 L/s
Phase 2: 2050	70 L/s	4 additional wells (Totaling 11 wells)	71.5 L/s

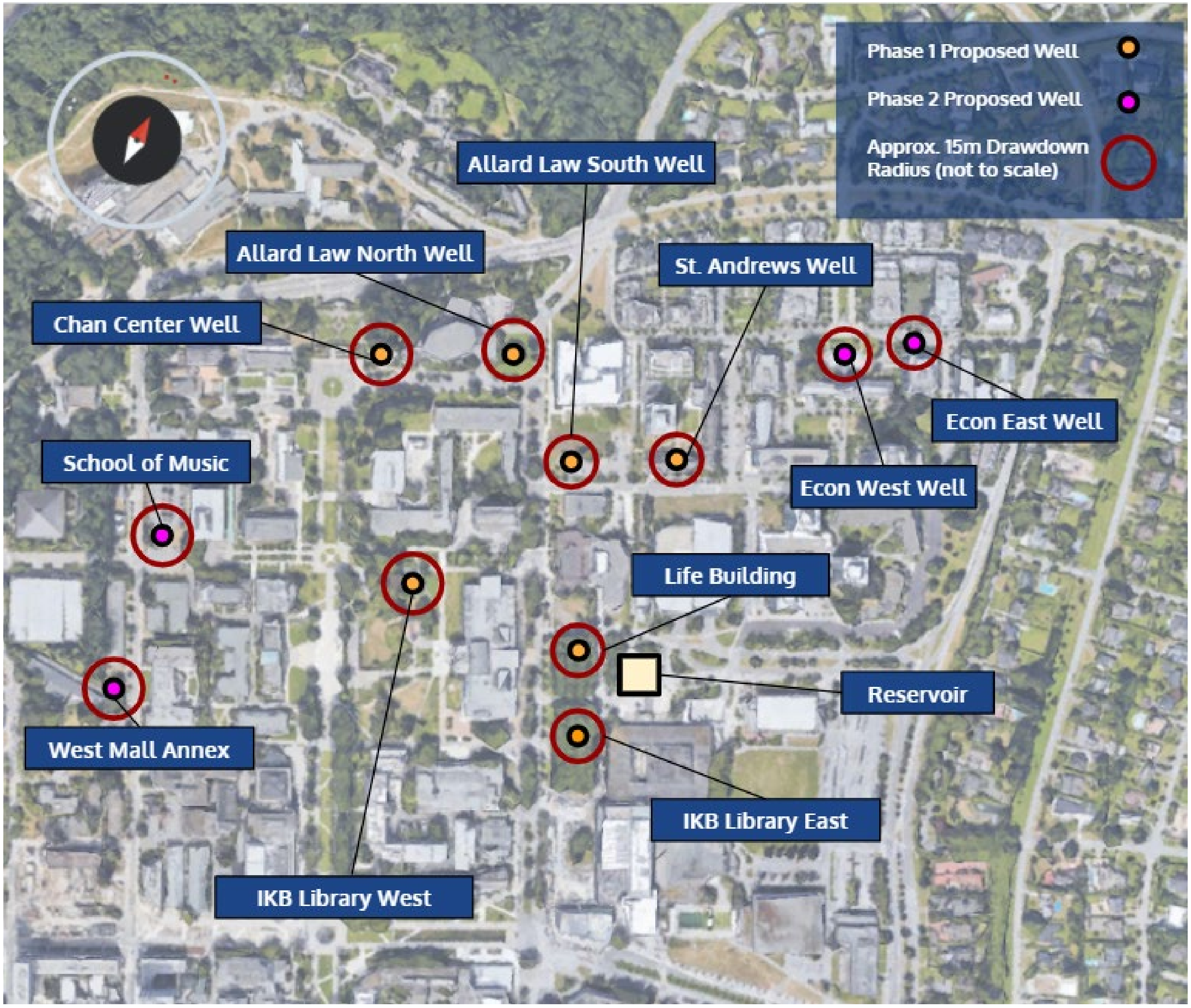

Figure 2: Well Locations and Phasing

4.1.2 Well Design

The quadra sand layer for the lower aquifer is at depths ranging from 60-70m below the surface elevation. As such, deep groundwater wells have been designed to access the aquifer. The groundwater wells include the following key elements: pumps, motors, casing, screens, pipes and valves/fittings. Detailed design drawings for the various elements of the groundwater wells are provided in drawings C101-C107 in Appendix A.

Table 3 summarizes the surface elevation, assumed water table elevation, total well depth and required well head for each well. A visual profile of the well elevations and water table depth is provided in Drawing C102-C103 in Appendix A.

Table 3: Well System Head

Well Location	Elevation [m-ASL]	Water Table [m-ASL]	Well Depth [m-ASL]	Total Well-Head [m]
Chan Centre	77	7	-0.5	115.1
Allard Law North	73	7	-0.5	114.9
Allard Law South	84	7	-0.5	114.9
St Andrews	80.8	7	-0.5	115.0
IKB West	87.5	7	-0.5	114.0
IKB East	85.4	7.5	-0.5	114.8
Life Building	84.2	7.5	-0.5	114.6
School of Music	79.5	4	-0.5	115.2
West Mall Annex	77.5	4.5	-0.5	114.4
Econ West	77.6	4.5	-0.5	114.4
Econ East	78.2	4.5	-0.5	115.5

4.1.3 Well Components

The following components were chosen for the well and wellhead design based on the pump specifications and relevant design guidelines. Due to the lack of precedent well design within the area, assumptions were made based on the limited precedent wells available.

Table 4: Well and Wellhead Components

Component	Description and Design Rationale
Pump	Grundfos SP-30-14 6" submersible pump and motor assembly. See Section 4.2.2 for sizing details. Submersible pumps have been chosen because they require less energy and are more efficient than jet pumps at large depths.
Well Casing	**Material:** Steel, chosen for its durability, high weldability and ease of installation. A protective oxide coating will prolong the longevity of the material under mildly corrosive conditions. Steel is ductile and resistant to lateral ground movement. **Thickness:** Minimum 8.2mm wall thickness (British Columbia's Design Guidelines for Rural Residential Community Water Systems) **Diameter:** 250mm casing that will house 150mm submersible pump, 2-25mm sounding tubes and electrical cables.
Intake Screen	**Material:** Steel as per same rational as well casing. **Type:** Shutter-style screen that is commercially fabricated with a keystone wire-wound 304 grade stainless steel (British Columbia's Design Guidelines for Rural Residential Community Water Systems). A wire-wound design allows for easy installation, affordability, maximum open area and low possibility of clogging **Length:** Should not be extended within 0.5m of the aquifer top and bottom. **Surrounding Material:** Intake screens are to be located within a gravel pack surrounding the well casing with a grout seal emplaced above any artificial filter pack.

	The artificial filter pack will be the primary filter for the groundwater and should be composed of a formation of sand then a well graded gravel. A geotechnical engineer will be required to comment on the effectiveness of the native material or if an artificial material will be required.
Drop Pipe	**Material:** Kubota Earthquake Resistant Ductile Iron Pipe (GENEX) **Diameter:** 150mm diameter to ensure adequate velocities within the pipe at the desired flow rates. **Length:** The drop pipe will extend from the intake screen to the pitless adaptor, exact length will vary depending on the well location.
Adaptor	**Type:** Pitless adaptor as it eliminates the need for a well pit and protects the pipes from freezing. Allows the well piping, foot valves and submersible pump to be removed from the casing for operation and maintenance tasks.
Cap	**Type:** 150 mm Cast Iron watertight well cap to prevent contamination. Shall be installed so easily removable for maintenance purposes.
Electrical Cables	**Specification:** Shall be properly strapped to the drop pipe, to be designed by electrical sub-consultant.
Well Monitoring	Two 25mm diameter PVC sounding tubes installed within the well casing for redundancy and dedicated use.
Surface Seal	**Location:** The surface seal should be located between the borehole and production casing to a minimum depth of 5.0m **Thickness:** Minimum thickness of 50mm of Bentonite Grout mixed to 30% solids by weight (British Columbia's Design Guidelines for Rural Residential Community Water Systems).

4.1.4 Pump House

The following describes the components selected to be housed in and around the pump house. Detailed Design drawings for the pump house can be found in the Drawing Set in Appendix A.

Table 5: Pump House Components

Component	Description and Design Rationale
Valves/Fixtures	**Check Valve:** 6" 80DIX Check Valve or similar. Selected due to high strength epoxy coated ductile iron body featuring a double-guided ductile iron poppet. Designed for vertical and horizontal applications up to a maximum pressure of 400PSI. **Gate Valve:** 6" AWWA C515 Gate Valve 115MJ or similar. Mechanical joint made with a ductile iron resilient wedge gate valves which meet AWWA C515 standard, with stainless steel stem, class 150, MJ flange. **Pressure Gage:** 2.5" dial pressure gauge with ¼" NPT bottom connection, unleaded or similar. Sized for 0-400PSI pressure to align with check valve pressure range. **Flow Meter:** 6" WM-PT Series Paddle Wheel Flow Meter or similar. Accommodates flows up to 1800gpm with an accuracy of +/- 1.5%.

	Sampling Spigot: Located within the pump house for easy access.
Generator	**Generator:** Diesel generator that will provide back-up power to the pump house in case of emergency. **Location:** Generator will be located within the pump house to ensure adequate protection from the elements. Sub-consultants to complete the exhaust system and structural design of foundation underneath generator.
Other	The structural, foundation, electrical and HVAC design of the pump houses is to be completed by sub-consultants.
Fire Hydrant	The fire hydrant was provided to provide continued access to the aquifer and its water supply should the distribution mains to the reservoir fail during a major emergency. See Drawing C107 for sizing specifications of the fire hydrant.

4.2 Distribution: Wells to Reservoir

4.2.1 Routing

Plan and profile drawings for the designed distribution system from the wells to the reservoir are provided in the drawing set in Appendix A. Watermains are primarily located in the northeast portion of the campus with the largest watermains running on East Mall directing flows to the reservoir.

In the absence of reliable profile information and only the provision of plan drawing for existing utilities, assumptions were made in the routing of the proposed distribution pipes. These assumptions are outlined below, which also reference the UBC Technical Guidelines:

- Electrical, communications, natural gas lines, and other third-party utilities are buried with 0.6m of cover with an average duck bank width of 0.4m. Gas lines are 50mm to 100mm in diameter.
- Sanitary sewers are buried with 1.5m to 3.0m average cover, certain locations are deeper. Sanitary sewers are 200mm to 450mm in diameter.
- Storm sewers are buried with 1.5m to 3.0m average cover, certain locations are deeper or shallower. Storm sewers are 300mm to 900mm in diameter. Larger diameters are installed along East Mall, north of University Blvd. and south of TRIUMF.
- Minimum clear separation from storm and sanitary of 3m must be met if mains run parallel, small separation requires approval from UBC Energy & Water Services.
- Minimum clearance of 750mm from all other utilities.

Note that the utility trench for distribution north of the reservoir towards Chan Centre along East Mall is to be shared with the well supply main from the wells to the reservoir. Typical cross sections are provided in the drawing set in Appendix A. Prior to construction, a utility locates subcontractor shall be hired to complete a full subsurface investigation to confirm that the pipe alignment design is feasible.

Coordination with UBC Energy & Water Services and third-party utility companies must also be completed regarding utility routing and servicing prior to final construction drawings.

Prior to commissioning, water pressure tests must be completed and passed per the UBC Technical Guidelines in the presence of a UBC Energy & Water Services representative. Repairs and adjustments must be made if tests are not passed before the system is fully operational. Complete disinfection of the pipes must also be completed before servicing to remove contaminants that have entered the system during construction. Further commissioning details are provided in 0400 - Watermain Installation specifications in Appendix D.

4.2.2 Well Distribution Piping and Pump Sizing

Each groundwater well is fitted with a Grundfos 13.6 kW SP 30-14 6" submersible groundwater intake pump with an average maximum efficiency of 76%. The pumps were modelled at each well within the existing and future EPANET well system models to confirm hydraulic performance. Each pump will meet the required 6.6 L/s well discharge rate. Figure 3 presents the pump curve with calculations shown in Appendix C. Note that for various wells the flow rate is constant with operating total dynamic head (TDH) varying. A flow control valve is included at each well at its connection to the larger distribution system to control flow from the well to the reservoir.

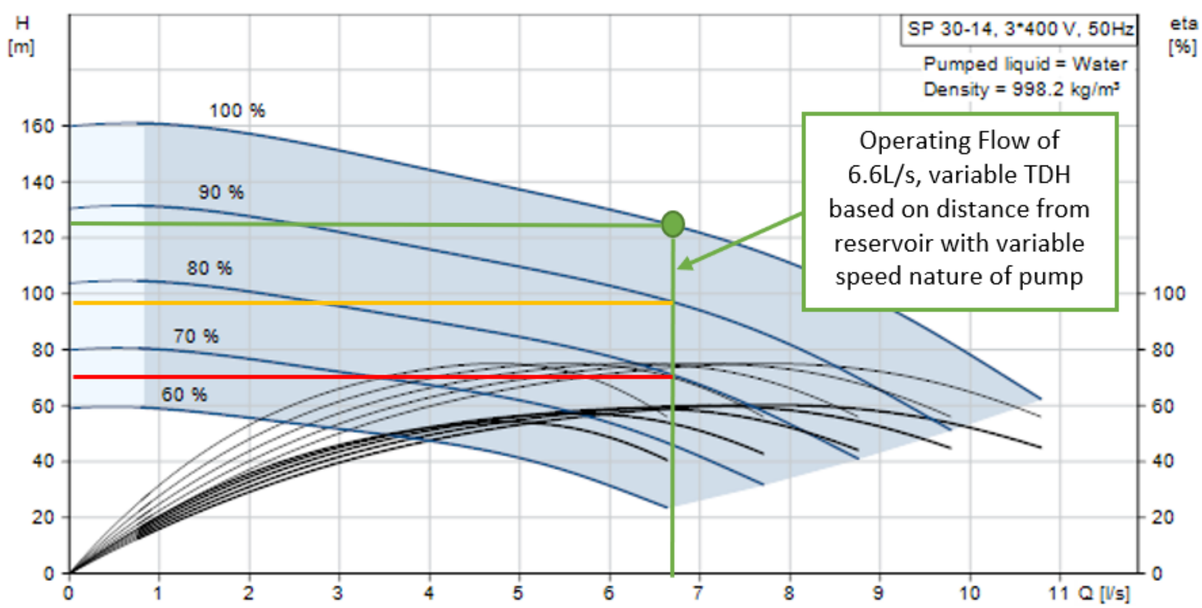

Figure 3: Well Pump Curve

The well-to-reservoir distribution system conveys untreated water from each groundwater well to the water reservoir through the construction of new watermains. Pipe sizing was completed within the Phase

1 and 2 EPANET well system models, which confirmed adequate required pressure and velocity per UBC Technical Guidelines.

The distribution main on East Mall was sized to 8” Kubota Earthquake Resistant Ductile Iron Pipe GENEX. The well connections which feed the key distribution main were sized to 6” Kubota Earthquake Resistant Ductile Iron Pipe GENEX. The pipe material was selected for its compliance with UBC Water Utilities Technical Guidelines and its seismic resiliency. At each tee and connection to the key distribution main will be AWWA C509 ductile iron gate valves for flow isolation. The key distribution mains, valve connections, and tees will be restrained with lock ring couplings from Kubota, which will not be supported by thrust blocks due to its potential to dislodge from the ground and damage adjacent piping during a seismic event.

4.2.3 Seismic Considerations

As verbally noted by the client, the likely failure of distribution systems during major seismic activity is due to join pull-out. To increase the distribution resiliency, restraint couplings from Kubota’s GENEX series are used to mitigate issues of joint pull-out. The chosen pipe material from Kubota is also resistant against excessive ground movements due to its high ductility. In the unlikely event that a seismic event disrupts the designed pipe distribution system, fire hydrants have been provided at each well for emergency distribution.

4.2.4 Freezing and Corrosion Considerations

To prevent freezing of pipes, a minimum cover of 1m will be required from the outer diameter of the distribution mains as outlined by the UBC Technical Guidelines. Corrosion of the pipes due to the environment will likely occur for ductile iron, so corrosion protection must be implemented to extend the service life of the pipes. To address potential corrosion of ductile iron, the all ductile iron watermains will be thermally-sprayed with a zinc-alloy corrosion protection layer as an integral part of the product. Due to the incorporated corrosion protection, additional active corrosion protection, such as active cathodic protection electrical systems, will not be required.

5.0 Detailed Design Specifications for Sub-Consultant

5.1 Sub-Consultant Design Overview

The following components are to be designed by a sub-consultant:

- **Distribution from Reservoir to Service Points**: Direct connections to emergency assembly building using seismically resilient GENEX ductile iron piping with parallel pumps at the reservoir and booster station by the Cunningham Building.
- **Reservoir**: 2700m^3 Reinforced Concrete Cast-in-Place concrete reservoir.
- **Water Treatment:** Provide potable water quality standards using gravity filtration and chlorine disinfection.

Preliminary design details and specifications are included in this report to guide the sub-consultant in the detailed design. Preliminary design drawings for each of these components as a reference for the sub-consultants are provided in the Detailed Design Drawing Set found in Appendix A.

5.2 Reservoir

5.2.1 Water Storage Volume and Location

A reinforced cast-in place reservoir has been designed to store 2700$m^3$of water and is located underground beneath the concrete plaza and proposed greenspace adjacent to the UBC Life Building. The proposed location is shown on Figure 4. The reservoir shape will be a rectangular box spanning roughly 30.5 m in length, 30.5 m in width and 3m in height. For excavation, the reservoir must be located at least 1m under the ground surface. According to the *Piteau Report*, only sand, till, and silt are present within a depth of about 5m.

Figure 4: Proposed Reservoir Location - Plan View (Left), Street View (Right)

The reservoir was sized to support UBC's 2050 water demands. Its size is equated to the sum of fire, equalization, and emergency storage. The equation used is from the Design Guidelines for Rural Residential Water Systems and exact calculations are provided in Appendix B.

5.2.2 Structure

The six main structural components of the reservoir include the top slab, beams, columns, retaining walls, slab on grade, and footings. The top slab is the cover of the reservoir and is designed as a two-way system. The gravity loads are transferred in the following order: top slab → beams → columns → footings → soil. As per the National Building Code of Canada and British Columbia's Building Code, the reservoir is designed for the following loads:

- Dead loads: Reinforced concrete self-weight, soil cover weight and soil lateral loads
- Live Loads: Surface occupancy, water and snow loads
- Seismic Loads: Ground acceleration

The structural design of each of the components of the reservoir structure will be performed by the subconsultant in accordance with the National Building Code of Canada and British Columbia's Building Code. Table 6 provides preliminary unfactored loads of the reservoir components. Note that not every design load has been included on the table. Loads for footings, beams, and some other items will be accounted for during the reservoir's detailed design. If full, the highest load in the reservoir will be the water, followed by the soil backfill, and slabs.

Table 6: Unfactored Design Loads

Load Type	Unfactored Load (kN)
Water	42875
Soil Backfill	23250
Top Slab	12749
Slab on Grade	18213
Single Column	11
Retaining Walls	2627
Live Load	7440

For a limit states design, the load combinations that need to be applied to the unfactored loads are found on table 4.1.3.2.A of BCBC 2018. The final dimensions of the structural elements and reinforcement specification are to be finalized by a structural consultant. Our team oversees designing additional components such as the reservoir's overflow pipe, drain and atmospheric vent.

5.2.3 Operation and Maintenance

Underground reservoirs are an efficient and cost-effective way to store water with routine maintenance. To maintain a high level of service, the reservoir will be regularly cleaned and inspected to reduce replacement costs and keep the emergency groundwater supply in service.

Protection methods to prevent contamination of the water in the reservoir include:

- An aeration pipe with a screen through the reinforced concrete roof to allow the circulation of fresh air through the tank;
- An inlet pipe placed above the water level of the tank to prevent back-flow and allow water to be heard entering the tank (hearing the rush of water entering the tank reduces frequency of hatch openings for inspection); and
- A manhole in the roof of the reservoir would allow for easy access to the tank for cleaning, inspection, and repairs.

5.2.4 Environmental Considerations

The proposed reservoir location currently has a green landscape with 5 mature trees. The potential impacts to the local environment have been analyzed and the suggested preservation method is transplantation, with confirmation from a licensed arborist prior to construction. Despite the higher costs associated with transplantation, the preservation of the environment was a key design criterion to mitigating environmental impacts. The root pruning technique needs to be completed prior to construction in the presence of a licensed arborist to ensure the trees have a higher chance of living when they are transplanted in May.

After completing the reservoir, a new and more vibrant green environment will be built. Apart from the trees, the current landscape is mainly composed of concrete. Therefore, when landscaping the new area, concrete pathways will be limited to sufficiently satisfy accessibility requirements and an emphasis will be given to xeriscaping, which is the approach of growing native vegetation that does not require irrigation to reduce maintenance. Only trees and shrubs with smaller root zones will be used above or closely adjacent to the reservoir to prevent damages to the top slab of the reservoir.

5.3 Distribution: Reservoir to Service Points

5.3.1 Distribution Network

After treatment of extracted groundwater, the system distribution network will safely and efficiently convey potable water to five direct assembly area connections: one servicing the UBC Hospital and four servicing assembly areas. This design was chosen for its relatively easy operation and low estimated initial and operational costs. The assembly areas chosen to service both the north and south campus populations are the AMS Nest, the Doug Mitchell Sports Centre, the Forestry Building, and the Chan Centre. These buildings will be appended to the UBC Emergency Response Plan as facilities with uninterrupted potable water service. During a major emergency, if large sections of the existing water system are compromised, the original water supply connection is throttled closed. Then, the connection to the treated groundwater is gradually increased in flow and pressure. Preliminary distribution drawings with an overall plan and details are included in Appendix A.

A hydraulic analysis was performed to determine the pipe sizing, pressure rating, pump sizing, and service flows and pressures at direct connections in EPANET 2.2. For pipe sizing, the peak hourly demand (PHD) for future conditions in 2050 was used to determine the maximum allowable flow through the distribution pipes. Table 7 presents a summary of the demand flows and pressures for each connection.

Table 7: Distribution Requirements

Parameter	Value	Notes
Flow Criteria		
Total System PHD (2050)	147 L/s	Determined from 2030 ADD, adjusted for 2% population growth
Assembly Connection PHD (2050)	33 L/s	PHD = 2.1*ADD, flow for each connection, peaking factor from CoV
Hospital PHD (2050)	15 L/s	PHD = 2.1*ADD, peaking factor for CoV
Pressure Criteria		
Minimum PHD Pressure	275 kPa	Sourced from CoV
Maximum Service Pressure	1035 kPa	Sourced from CoV
Velocity Criteria		
Maximum PHD Flow Velocity	2.0 m/s	Sourced from CoV

Through analysis on EPANET, all nodes received excess of the required flows and within the allowable pressure and velocity requirements. Direction connections are supplied with backup preventers and pressure reducing valves to protect the connection from excessive pressures in the event of a water hammer from rapid valve closure.

Three pumps in parallel were selected for the initial reservoir distribution from the reservoir. A set of parallel booster pumps were added midway in front of the Cunningham Building between Doug Mitchell and the reservoir to increase the delivery pressure. An operating speed of 80% was noted by the manufacturer to be the most efficient speed, which also managed to remain within the pressure limits and below the maximum velocity criterion. Each location will also have an extra standby pump for additional distribution resiliency. The pumps are 75HP and require electrical connections that support 460V and three phase capabilities. Figure 5 shows the pump curve and operating point for each pump, respective of their location in the overall system.

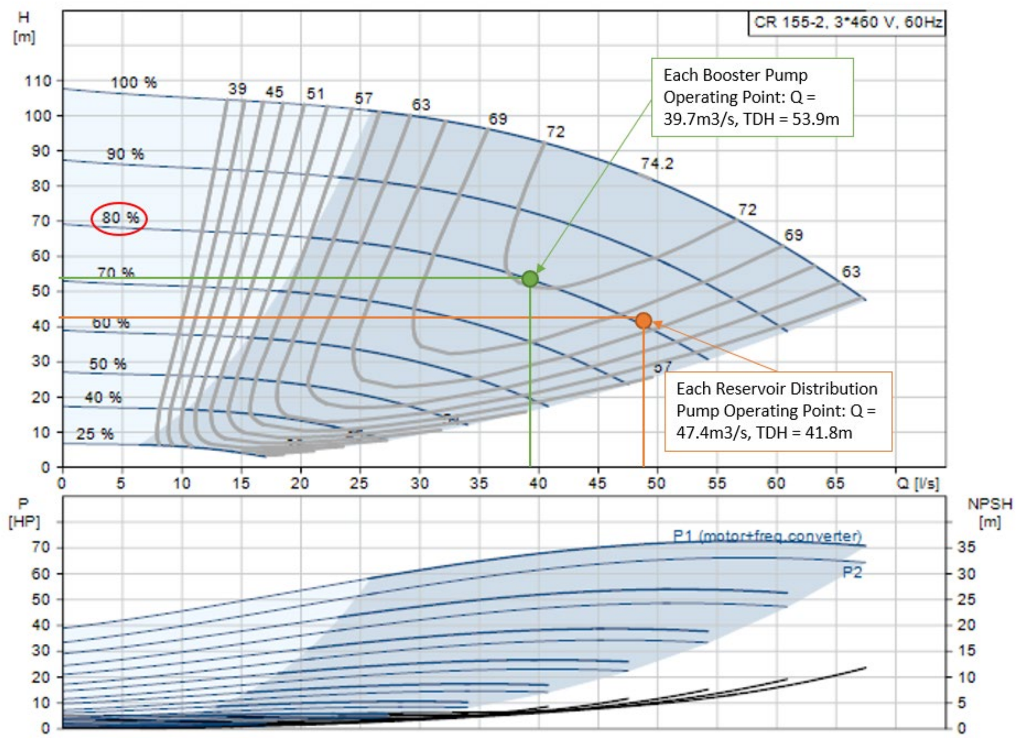

Figure 5: Distribution and Booster Pump Curves and Operating Points

A summary of system distribution components is provided in Table 8. These specifications are to be given to the sub-consultant to complete the detailed design.

Table 8: Distribution System Feature Summary

Design Feature	Specification
Reservoir Effluent Pipe	300mm (12") GENEX Ductile Iron Pipe, from reservoir to tee connection near Agricultural Road and East Mall intersection to 200mm DI distribution main
Distribution Main and Direct Connections	200mm (8") GENEX Ductile Iron Pipe, from tee to each assembly connection, 8" manual valves for easy operation by service operators in case connection needs to be isolated, restraint coupling at every joint, backflow preventer and pressure-reducing valves to reduce pressure at connections to reduce water hammer damage

Reservoir Distribution Pumps	Grundfos CR 155-2 (75HP) in reservoir housing, 4 pumps in parallel (3 on duty, 1 as backup for resiliency) operating at 80% full speed to meet required flows and pressures
Booster Pump	Grundfos CR 155-2 (75HP) in underground housing in front of the Cunningham building, 3 in parallel (2 duty, 1 backup), designed to deliver required pressures to south campus as per EPANET analysis, operating at 80% full speed to meet required flows and pressures

5.4 Water Treatment

A reliable and safe treatment system is necessary to ensure the best possible water quality is provided to the UBC population during both emergency and non-emergency operations. A mechanical and water treatment subconsultant will be hired to conduct the water treatment design scope of the work following the recommendations and details outlined in this section.

In British Columbia, all community water systems must meet the requirements of the provincial Drinking Water Protection Act and the Drinking Water Protection Regulation. In addition, potable water quality is required to meet the guidelines for the Canadian Drinking Water Quality.

According to the Canadian Drinking Water Quality's Groundwater Guidelines (CDWQG) and Health Canada, water systems must meet the 4-3-2-1-0 policy as follows:

- Log 4 (99.99%) removal and/or inactivation of enteric viruses.
- Log 3 (99.9%) removal and/or inactivation of protozoa
- 2 treatment processes for all surface water sources for multi-barrier protection
- 1 nephelometric turbidity unit (NTU) or less of water turbidity
- 0 E. Coli or fecal coliform bacteria, known more commonly as "zero total coliforms"

To ensure that the distributed water meets the required guidelines, the water supply will undergo four treatment stages prior to entering the reservoir for storage:

1. Screening to ensure common ground minerals and pathogens attached to particles are removed for potable consumption
2. Aeration to remove iron and manganese, minerals that were confirmed by the client to exceed the CDWQG's maximum acceptable concentration (MAC)
3. Sedimentation and gravity filtration to settle out the precipitated iron and manganese particles
4. Chlorine disinfection to remove remaining pathogens and continually disinfect the supply while in the storage reservoir

A schematic diagram of the water treatment system is provided in Drawing M001 in Appendix A.

To further meet the CDWQG's guidelines, the water leaving the treatment plant is monitored to ensure no detection of total coliforms (I.e. feces naturally occurring in the water). The filtration system is designed and operated to achieve a treated water turbidity target from individual filters of less than 0.1 NTU. Aeration of the water is completed to ensure a MAC level of 0.12 is achieved. Free chlorine concentrations in the drinking water after chlorination should range from 0.04 to 2.0 mg/L.

To ensure the water quality leaving the reservoir after storage has been maintained, testing of water is to be completed at the reservoir outlet pipes. Chlorine injection at the outlet of the reservoir may be required if these tests indicate that a higher level of disinfection must be met prior to distribution.

5.5 Additional Scope of Work

Below is a summary of additional scope of work that is integral to this groundwater system that will be completed by sub-consultants. Note that the tasks listed are not exhaustive and extensive scope discussions will be made with sub-consultants prior to the completion of detailed design.

Table 9: Additional Scope Tasks

Sub-Consultant Discipline/Work Scope	Scope Tasks
Process/Mechanical Design for Water Treatment	Detailed design of treatment system: – Specify equipment and tank sizing – Specify chemical concentrations setpoints – Outline sampling program in accordance with CDWQG and UBC's Water License – Outline operations and protocol for operating treatment system
Structural Design	Detailed design of reinforced concrete reservoir, treatment and well house: – Reinforcement design, baffle sizing – Produce detailed IFT drawings and calculations with senior QA/QC review in accordance with BC Building Code
Electrical Design	Detailed design of well and distribution controls: – Specify instrumentation and electrical equipment in accordance with CSA Electrical Code for well house, reservoir, treatment system, and overall systems distribution control – Include detailed design of SCADA system for remote control of well and distribution pumps and valves

6.0 Construction Specifications

Below are the general requirement specifications for construction works. Other specifications are included in Appendix D and are as follows:

- 0200 - Well Installation
- 0300 - Treatment
- 0400 - Waterworks
- 0500 - Concrete Works
- 0600 - Earthworks and Roadworks

0100 - General Requirements Specifications

<u>0101 - Project Record Documents</u>

In compliance with the EGBC Quality Management Program, proper quality control and assurance must be undertaken. This includes the preparation and organization of project record documents. These documents include but are not limited to: contract drawings, specifications, field memos, addenda, change orders, reviewed shop drawings and manufacturer's data, field test records, and inspection certificates. Site conditions may also be recorded, including record of construction progress through field reports, record of field changes, and surveying of installed underground utilities and appurtenances. Further details can be referenced through the MMCD specification 01 33 01 Project Record Documents.

<u>0102 - Reference Specifications</u>

Contractors may refer to MMCD specification 01 42 00 Reference Specifications for standard codes and specifications mentioned within this set of specifications.

<u>0103 - Temporary Facilities and Utilities</u>

Prior to the start of construction, temporary facilities and utilities must be prepared, including a first aid facilities, a security scheme, sanitary facilities, and storage and staging locations. As the groundwater system is a new system, temporary utilities (sanitary, storm) will not be required, except for temporary lighting and communications for on-site communication and field work, as well as temporary water for sanitary purposes. Refer to MMCD specification 01 53 01 Temporary Facilities for further details.

<u>0104 - Traffic Control and Vehicle Access</u>

A traffic management plan for all construction works must be approved by UBC Energy & Water Services and Department of Campus and Community Planning representatives. Temporary access roads, parking areas, and general traffic control must be included in the plan. Traffic control must be designed in accordance with the BC MOTI's "Traffic Control Manual for Work on Roadways". When working on a travelled road, ensure equipment placement does not interfere or is hazardous to travelling public and do not leave equipment on travelled areas overnight. The plan must also include required lane closures, traffic control informational and warning devices, and the use of flaggers and designated areas. Note that special attention must be taken to diverting vehicle flow around the UBC Hospital and adjacent emergency services during construction. Refer to MMCD specification 01 55 00 Traffic Control, Vehicle Access and Parking for further details.

0105 - Environmental Protection

Temporary erosion and sediment control (ESC), environmental protection, and temporary stormwater pollution control measures must be completed prior to construction. ESC design must include temporary drainage and pumping to ensure proper drainage, protection measures to prevent discharge into adjacent watercourses, and specifications of ESC products to be installed. Further details related to ESC silt fence specifications, quantities, installation, and maintenance can be found in MMCD specification 01 57 01 Environmental Protection. For general environmental protection, ensure that fires are not allowed to burn and must be immediately extinguished, site clearing and plant protection are designed for and include approval from a certified arborist, and that emissions are controlled within the work site and especially in temporary enclosures. Sandblasting is strongly discouraged. Employ dust control measures, such as wetting dry surfaces, where and when required on temporary roads. Silt accumulations must be removed offsite at the end of construction.

0106 - Site Safety

The prime contractor on site must have an approved safety program that is in accordance with WorkSafe BC as site safety is the sole responsibility of the prime contractor. The prime contractor and any site workers must also be registered with WorkSafe BC. At a minimum, the prime contractor must abide by WorkSafe BC's Occupational Health and Safety Regulations, the BC Building Code, and the BC Fire Code. The prime contractor must prepare a project safety plan with necessary site rules, guidelines, hazard identification and risk assessment, safety manual and related safety materials, safety orientation plan, and further details included in the full UBC Contractor Safety Orientation Manual. The prime contractor is also responsible for notifying the Owner's representative about site incidents or near misses, results of any accident investigations, minutes for safety committee meetings, safety inspections performed, and any issues with UBC's maintenance forces with regards to lock-outs, tie-ins, or power line contact control. As backfilling and excavation will occur near gas lines and electrical systems, permits must be obtained from the BC Safety Authority and UBC Regulatory Services. In light of the recent COVID-19 pandemic, the prime contractor must also have a health and safety plan in accordance with the Provincial Health Authority and Vancouver Coastal Health that protects workers from contracting COVID. This plan includes, but is not limited to, personal protective equipment that limits transmission, social distancing measures, and procedures to respond to COVID infections within the work crew.

7.0 Draft Plan of Construction Work

This section details the project's construction sequence. As previously discussed, the construction of this project is to be subdivided in two phases. The first phase is expected to begin construction on May 1, 2021, the second phase is expected to begin construction on May 1, 2050.

Phase 1 involves the construction of the reservoir, water treatment building, pump station, 7 wells, and 4 segments of water distribution mains. Figure 6 illustrates the construction sequence of Phase 1. Phase 1 construction, beginning on May 1st, 2021 will have the following construction sequence:

1. Components highlighted in blue: reservoir, water treatment building, pump station, Life Building Well, IKB Library East Well, and East Mall Main
2. Components in green: IKB Library West Well, Allard Law South Well, and Memorial Road Main
3. Components in yellow: St. Andrew Well and Walter Gage Road Main
4. Components in pink: Chan Center Well, Allard Law North Well, and Crescent Road Main

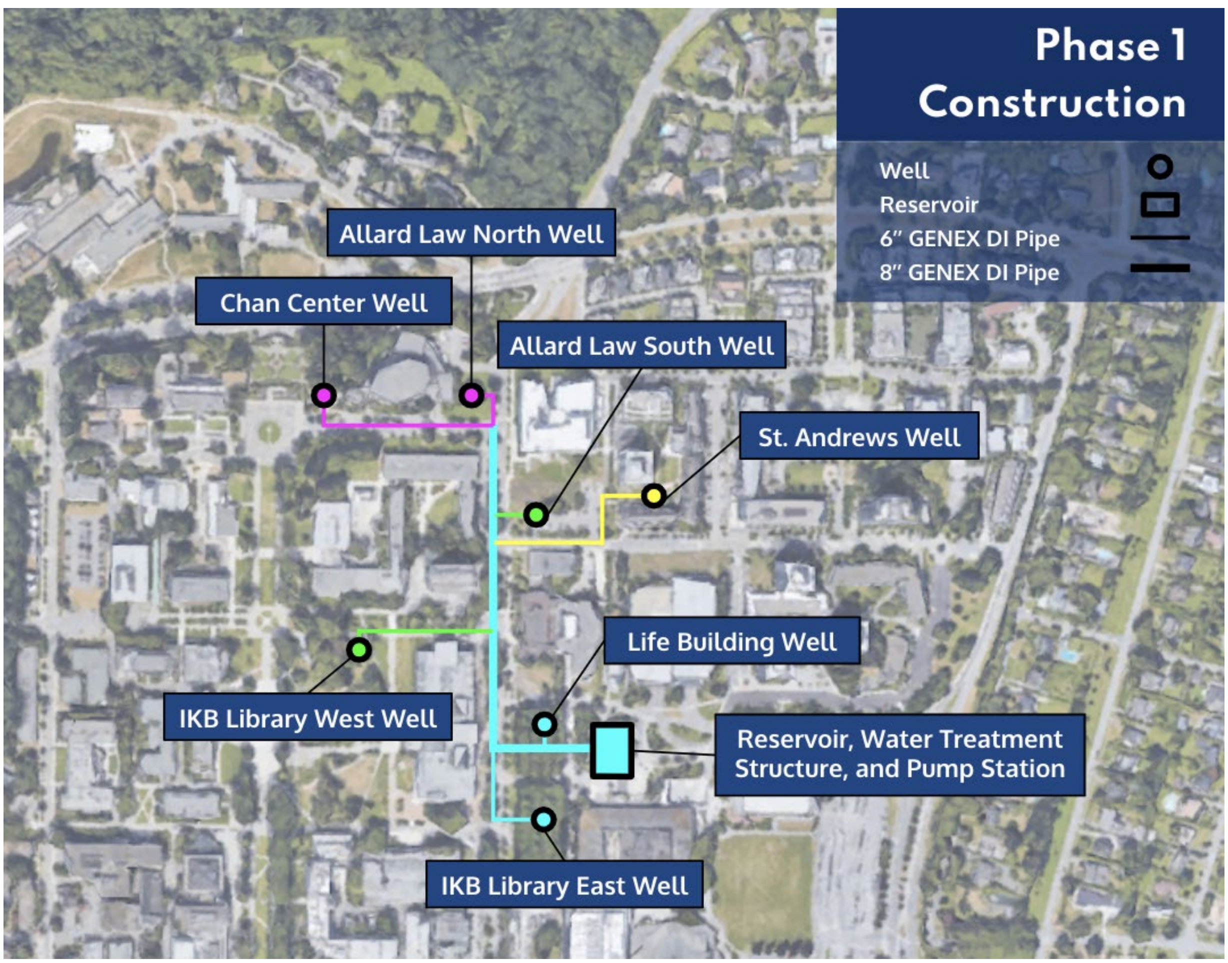

Figure 6: Phase 1 Construction Sequence

Phase 2 involves the construction of four additional wells to increase the system's yield to sustain future demands. Figure 7 illustrates the construction sequence of Phase 2. Note that the components in purple were all completed during Phase 1. Phase 2 construction, beginning on May 1st, 2050 will have the following construction sequence:

1. Components highlighted in green: Econ East Well, Econ West Well, and the expansion of the Walter Gage Road Main to Iona Drive
2. Components in blue: School of Music Well, and West Mall Annex Well
3. Components in yellow: Memorial Road Main
4. Components in pink: West Mall Main

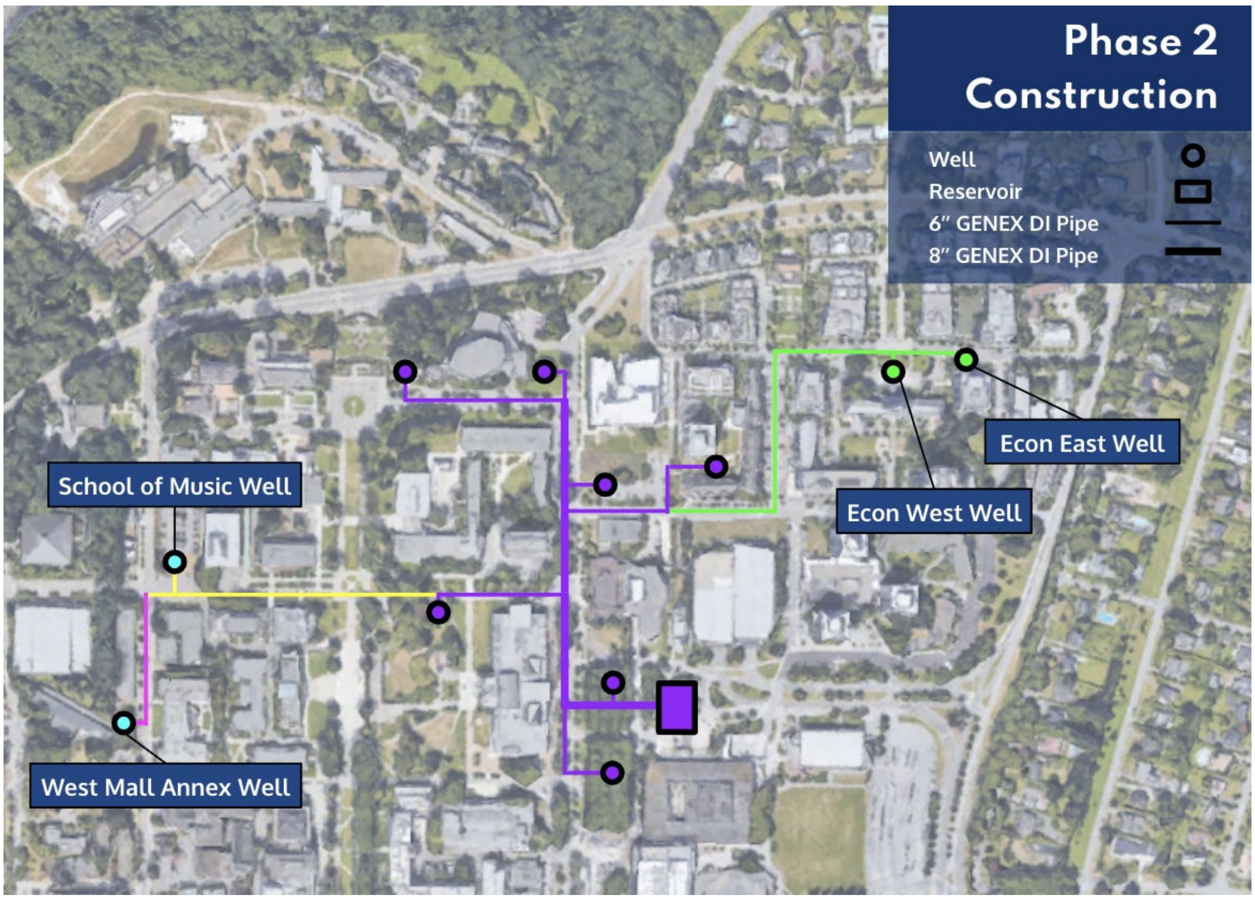

Figure 7: Phase 2 Construction Sequence

The components of the system were separated into four major activities: groundwater wells, reservoir, distribution system, and the water treatment & controls building. The general work breakdown of each one of the four major activities is shown on Figure 8, including permitting, site preparation, excavation, piping, concrete works, and commissioning. For detailed scheduling and the full construction work sequence and its respective dates, refer to the project schedule provided in Appendix E.

Figure 8: Draft Plan of Construction Work

8.0 Service-Life Maintenance Plan

Regular maintenance of the new emergency water system is pertinent for resiliency and emergency preparedness. All components of the groundwater emergency supply system require different forms of maintenance; however, all components benefit equally from good recordkeeping. Records will include equipment test results, maintenance checks, and equipment repairs. Note that O&M recommendations from manufacturers shall be followed and take precedence over information detailed below.

8.1 Groundwater Well

Groundwater wells should be maintained to prevent foreign objects from intrusion through the well head or an annular space. Annual inspections are required to check for adequate wellhead protection, conduct water quality analyses, document any changes in aesthetic properties of water, and to record well water level and drawdown rates. The well casing will be checked for cracks and holes that could potentially allow contaminants into the well.

Ground conditions surrounding the well shall be monitored to ensure an intact surface seal. During well monitoring and sampling, all equipment must be disinfected before insertion. The well must be disinfected after the removal of any temporarily installed equipment. The water will be sampled and well equipment will be visually inspected monthly. Well cleaning is recommended every 10 years, alternating between the brush and bail method and acid treatment to remove any build up of mineral or bacterial debris on the well casing or screen.

8.2 Distribution Watermains

Water will be sampled weekly to ensure that water quality adheres to the Canadian Drinking Water Guidelines. Hydrants and valves will undergo annual inspections to verify components are working as intended and no abnormalities are present. Pipe flushing will be conducted on a regular basis to remove sediment buildup especially in pipes with low velocities. Watermains will be actively monitored for leakage by accelerometers and leak noise loggers. Pressure throughout the water system will be monitored as to never exceed the rated operation pressure.

Pumps for distribution from the reservoir to the service points shall be replaced every 10 years and follow maintenance routines as per the manufacturer's recommendation. Pumps should be field tested periodically to check that they are still operating on its original pump curve. If the resulting field pump curve deviates from the original curve, further investigation is required.

8.3 Reservoir

Before initial use, the completed reservoir structure must be cleaned and disinfected to avoid contamination of the water at first entry. This includes taking two or more successive samples at 24-hour intervals to ensure that the water meets microbiological standards before general operation. The main operations of the reservoir consist of opening and closing the inlet and outlet valves every two months to prevent them from sticking, checking the screened vents, and managing the chlorinator used to disinfect the water. Due to the porous nature of concrete, it can become a breeding ground for algae, E.coli, and other microbial forms. Regular disinfection and cleaning are recommended to prevent water contamination. The reservoir should be drained, de-silted, cleaned with a brush, and disinfected with chlorine once a year or when contamination is detected. Weekly inspections will be done to check security, water meters, pumps. Furthermore, weekly water samples should be conducted at the reservoir outlet.

Other potential issues include cracks, leaks, and structural damage within the concrete. Detecting and repairing these issues is the most cost-effective way to conserve the water in the reservoir. These leaks and structural repairs, once noticed, take priority and must be repaired on an emergency basis as they could cause contamination or collapse under strenuous conditions.

8.4 Water Treatment

Treated water will be sampled monthly to confirm the water quality meets potable standards. The following sections list specific maintenance practices for each treatment component.

8.4.1 Screen

A monthly visual inspection of the screen is required to ensure problems are addressed promptly. The main concerns for the well screen are clog and corrosion prevention. The following best management practices should be followed during monthly inspections:

- Ensure all bearings are greased and the drive motor and gear reducers does not leak fluids
- No corrosion or loose wires are present on control equipment
- Perform motor tests then record and compare results against previous records
- Check timers, sensors and other programs to ensure proper function
- Replace screen components as needed over time
- Clear the screen of debris buildup.

8.4.2 Aeration System

Maintaining the aeration system blowers are the focus for servicing an aeration system. Blower engines must be lubricated periodically, air filters must be changed as needed, and regular checks must be performed to ensure adequate ventilation is present. The system must be cleaned regularly to remove build up from precipitated materials. The storage tank should be flushed every six months.

8.4.3 Sedimentation and Gravity Filtration

Filter maintenance includes examining media when the filter is drained, performing surface sweeps, conducting regular backwashing, and measuring media bed depth. Annual media inspections should be performed to look for abnormalities such as mud balls, craters, cracks, mounding, and media pulling away from filter walls. Other indicators to look for include fouling, scaling, or loss of bed depth. Surface sweeps should be inspected regularly to ensure free rotation and proper media and sweep elevation. Rubber caps on the surface sweeps shall be replaced every two years. Regular backwashing approximately every 96 hours is required to prevent spikes in water turbidity and prevent the formation of permanent clumps which decrease filter capacity.

8.4.4 Chlorination

The chlorination system will be inspected monthly for a cylinder change and will undergo a bi-monthly valve and diaphragm cleaning. Every six months the meters and floats will be disassembled and cleaned. Chlorination equipment components will be replaced as necessary.

9.0 Schedule

The project schedule for Phase 1 of the project is included in Figure 9. Construction is scheduled to occur over 220 workdays, from May 1, 2021 to March 14, 2022. The critical path identified for this phase relies on the construction of the building that houses distribution pumps and water treatment facilities. The earliest completion date for this milestone is estimated to be January 3, 2022.

Figure 10. This phase is expected to be much shorter due to the significantly reduced scope of construction. The time required to build four additional wells and their respective distribution mains is estimated to be 80 workdays. Construction is anticipated to occur between May 1 and August 19, 2050.

Table 10 summarizes project milestones for Phase 1 and Phase 2 of the project. Float calculations for the following figures and tables are included in Appendix E.

Table 10: Summary of Project Milestones

Milestone	Earliest Completion Date
Phase 1	
Project Start	May 1, 2021
Groundwater Well Construction	July 27, 2021
Reservoir Construction	November 5, 2021
Building for Pump Station & Water Treatment	January 3, 2022
Distribution System to Reservoir	January 3, 2021
Distribution System From Reservoir	January 3, 2021
Project Close Out	March 14, 2022
Phase 2	
Project Start	May 1, 2050
Groundwater Well Construction	June 10, 2050
Distribution Main Construction	July 15, 2050
Project Close Out	August 19, 2050

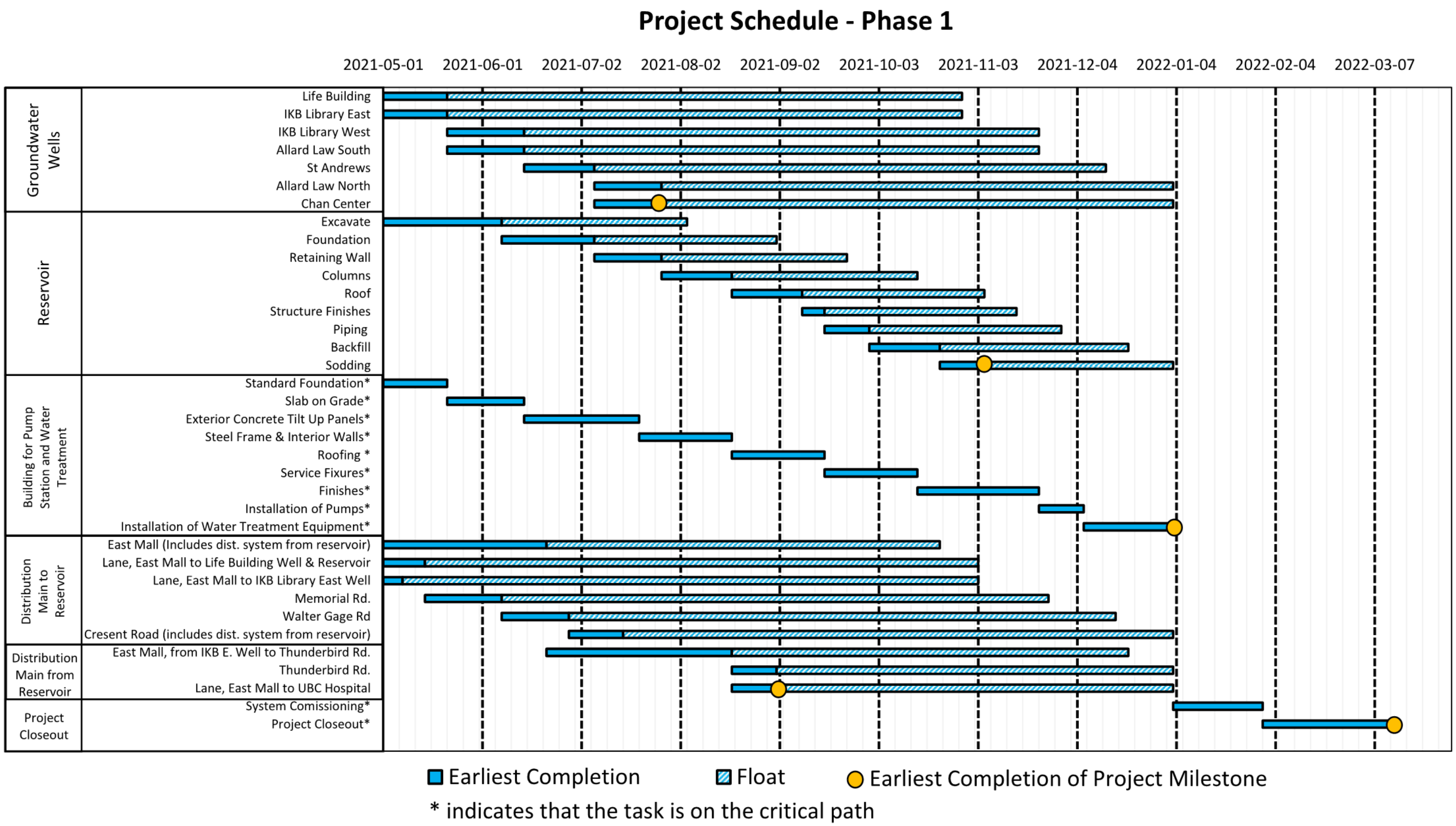

Figure 9: Phase 1 Construction Schedule

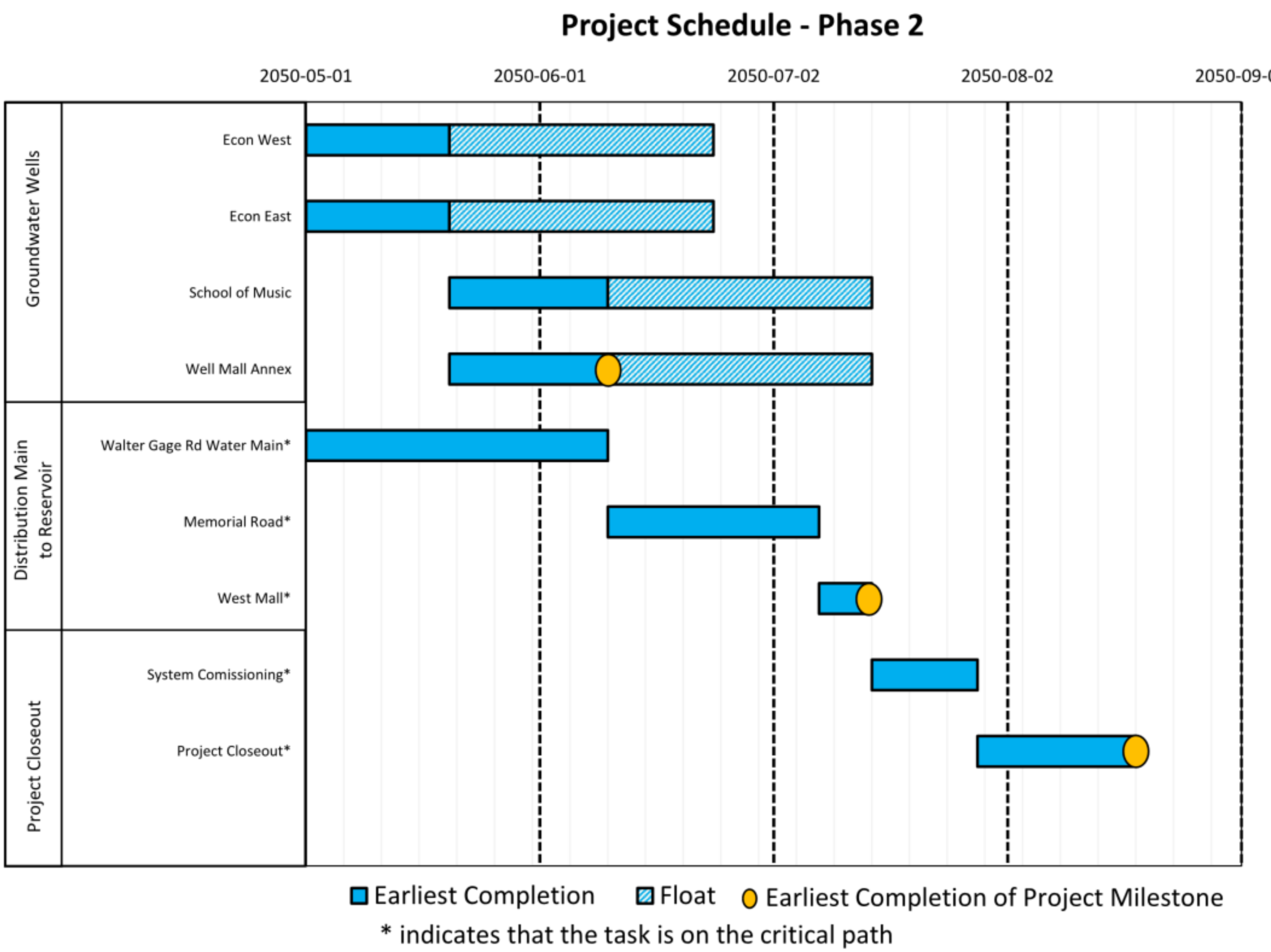

Figure 10: Phase 2 Construction Schedule

10.0 Cost Estimate

A Class A cost estimate was conducted for the project's detailed design including components within our team's scope of work and the scope to be completed by sub-consultants. The total groundwater system upgrade is expected to cost approximately $15.8M with Phase 1 costing $12.4M. and Phase 2 costing $3.4M. Costs of major project components are summarized below in Table 11. A detailed itemized breakdown of the costs is provided in Appendix F.

General construction costs include mobilization, demobilization, traffic management, superintendent fees, project manager fees, and insurance. Permitting fees summarize the costs to apply for Development, Building, Plumbing, Electrical, and Operating Permits.

Common to Phase 1 and Phase 2, groundwater wells and distribution main construction are major elements of the design. The well components are priced to include major activities such as drilling and pump testing, in addition to well components such as pumps, piping, and valves. The cost of a pump house structure and fire hydrant are also notable inclusions in this category. Distribution piping costs include costs for excavation, laying pipe, paving, and miscellaneous utility relocation.

In Phase 1, an underground reservoir and a building for water treatment and pumping will be constructed. Costing of the reservoir summarizes excavation, pouring, and finishing. A large building will be constructed adjacent to the reservoir which houses four distribution pumps and a water treatment system. The water treatment processes are scaled based on unit-size costs from Sharma's 2010 study "Development of A Preliminary Cost Estimation Method for Water Treatment Plants".

Table 11: Summary of Total Design Life Costs

Item	Total Capital Costs (2020 CAD)	Total O&M (2020 CAD)
Phase 1 – 28 years	$12,385,100	$16,820,000
Phase 2 – 47 years	$3,380,000	$35,630,000
Total 75 year design life	$15,765,100	$52,450,000
	Total Project Design Life Costs	**$68,215,100**

Table 12: Summary of Construction Costs

Item	Phase 1 Costs (CAD)	Phase 2 Costs (CAD)
General Construction	$748,000	$280,000
Groundwater Wells	$3,301,000	$1,226,000
Reservoir	$558,000	N/A
Distribution	$1,182,000	$1,231,000
Backup Energy Source	$1,362,000	N/A
Water Treatment	$1,910,000	N/A
Structures for Pumping	$889,000	N/A
Permitting	$114,000	$49,000
Phase Subtotal	**$10,064,000**	**$2,786,000**
5% contingency	$503,200	$140,000
Phase Total Cost (2011 CAD$)	$10,567,200	$2,930,000
Phase Total Cost (2021 CAD$)	**$12,385,100**	**$3,380,000**

The design expectancy for our project is based on the life expectancy of the Phase 1 wells – 75 years. During this time, operation and maintenance (O&M) costs must be maintained to operate the emergency groundwater system. The system is expected to be in operation by 2022. Phase 1 of the system (7 wells in operation) is expected to last 28 years with Phase 2 of the system (11 wells in operation) beginning in 2050 and being sustained for 47 years.

A total O&M cost and an annual unit cost associate with each task for Phase 1 and Phase 2 is included in Table 13. A breakdown of each phase is shown in Appendix F. Highest costs are associated with operating the groundwater wells as well as the water treatment system. The higher flows requiring water treatment places more strain on the equipment and requires more resources to maintain and operate the processes. Due to this, O&M costs associated with Phase 2 of the project are significantly higher than Phase 1. Over the entire 75 year design life, the average annual O&M costs is expected to be $701,413.

Table 13: Summary of Annual Operation and Maintenance Costs

Item	Years	O&M Cost/Year (2020 CAD)	Total Phase O&M (2020 CAD)
Phase 1	28	$602,400	$16,820,000
Phase 2	47	$760,400	$35,630,000
Total Life Expectancy	**75**	**$701,413**	**$52,450,000**

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Appendix A

Detailed Design Drawings

CLIENT UBC SEEDS SUSTAINABILITY PROGRAM

PROJECT

UBC GROUNDWATER EMERGENCY WATER SUPPLY

DESCRIPTION IFC DRAWING SET

DRAWING LIST

PROJECT SITE – UBC POINT GREY CAMPUS
NTS

WARNING
THE SIZE, DEPTH AND LOCATION OF THE EXISTING OVERHEAD AND UNDERGROUND UTILITIES AND RESPECTIVE STRUCTURES SHOWN ARE APPROXIMATE AND ARE FOR GUIDANCE ONLY. THE COMPLETENESS OR ACCURACY OF THIS INFORMATION IS NOT GUARANTEED. IT SHALL BE THE CONTRACTOR'S SOLE RESPONSIBILITY TO VERIFY THE LOCATION OF THE FACILITIES PRIOR TO COMMENCING WORK, AND TO ADVISE THE CONSULTANT OF ANY POTENTIAL CONFLICT.

#	Date	Issue / Revision	Appr.
0	12/20	PRELIMINARY DESIGN	
1	04/21	DETAILED DESIGN IFC	

Owner: UBC Sustainability

Prime Consultant

Sub-Consultant

Scale: AS SHOWN

Drawn by	GM	04/12/21
Designed by	GM	04/12/21
Checked by		
Approved by		

UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

COVER

Drawing Number: C000 Revision: 1

GENERAL NOTES

1. THE UNIVERSITY OF BRITISH COLUMBIA SHALL BE REFERRED TO AS THE CITY .
2. CONSTRUCTION IS TO BE IN ACCORDANCE WITH THE UBC TECHNICAL GUIDELINES SECTION 33 10 00 WATER UTILITIES, AND THE APPLICABLE MUNICIPAL MASTER SPECIFICATIONS AND STANDARD DETAIL DRAWINGS, CITY OF SURREY STANDARD CONSTRUCTION DOCUMENTS, SUPPLEMENTARY SPECIFICATIONS & STANDARD DRAWINGS AND CITY DESIGN CRITERIA.
3. THE DEVELOPER SHALL BE RESPONSIBLE FOR OBTAINING ALL CITY PERMITS FOR WORK WITHIN THE CITY ROAD ALLOWANCE.
4. WHERE UTILITY OR SERVICE CROSSINGS ARE REQUIRED ACROSS EXISTING PAVEMENTS, AN UNDERGROUND METHOD OF INSTALLATION IS REQUIRED UNLESS SPECIAL APPROVAL IS GIVEN FROM THE CITY FOR AN OPEN CUT OPERATION. ALL EXISTING PAVEMENTS, BOULEVARDS, DRIVEWAYS, ETC., ARE TO BE REINSTATED TO ORIGINAL OR BETTER CONDITION AND IN ACCORDANCE WITH CITY SPECIFICATIONS AND THE PAVEMENT CUT POLICY.
5. ALL STREET, TRAFFIC, AND ADVISORY SIGNS, PAVEMENT MARKINGS AND NO-POST GUARDRAILS REQUIRED BUT NOT NECESSARILY SHOWN ON THE DRAWINGS, SHALL BE INSTALLED BY THE CITY AT THE DEVELOPER'S COST.
6. WHERE INFILLING OF EXISTING DITCHES IS REQUIRED OR WHERE SERVICES ARE CONSTRUCTED IN A FILL SECTION, FILL MATERIAL IS TO BE IN ACCORDANCE WITH CITY SPECIFICATIONS AND IS TO BE COMPACTED TO 95 % OF MODIFIED PROCTOR DENSITY.
7. RESIDENTS DIRECTLY AFFECTED BY CONSTRUCTION OF THIS PROJECT MUST BE GIVEN 48 HOURS WRITTEN NOTICE OF THE PROPOSED START OF CONSTRUCTION.
8. THE DEVELOPER WILL REQUIRE WRITTEN AUTHORIZATION FROM A PRIVATE PROPERTY OWNER, WITH A COPY TO THE CITY, PRIOR TO ANY ENTRY ONTO PRIVATE PROPERTY AND A WRITTEN RELEASE, FROM THE PROPERTY OWNER, WHEN COMPLETED.
9. WHEN NATIVE SITE GRANULAR BACKFILL IS PROPOSED FOR USE IN TRENCHES THE DEVELOPER SHALL EMPLOY A PROFESSIONAL ENGINEER WITH EXPERIENCE IN GEOTECHNICAL ENGINEERING FOR PERFORMANCE OF IN PLACE DENSITY AND SIEVE TESTING. SELECTION OF THE PROFESSIONAL ENGINEER AND USE OF THE SITE MATERIAL IS TO BE APPROVED BY THE CITY. THE SITE MATERIAL MUST FALL WITHIN ONE OF THE GRANULAR BACKFILL MATERIAL SPECIFICATIONS. RIVER SAND IS NOT ACCEPTABLE AS TRENCH BACKFILL MATERIAL.
10. THE DEVELOPER SHALL FACILITATE AND SUPPLY ALL NECESSARY SAFETY EQUIPMENT REQUIRED UNDER THE WCB REGULATIONS FOR THE CITY OR ITS REPRESENTATIVES OR THE ENGINEER OF RECORD TO INSPECT THE SANITARY SEWER AND STORM SEWER SYSTEMS. THE EQUIPMENT SHALL BE SUPPLIED UNTIL SUCH TIME AS A CERTIFICATE OF COMPLETION IS ISSUED BY THE CITY.
11. DEVELOPER IS TO VERIFY THE LOCATION AND ELEVATION OF ALL PIPES, OR OTHER UTILITY CROSSINGS, PRIOR TO CONSTRUCTION AND SHALL NOTIFY THE ENGINEER OF RECORD OF ANY CONFLICTS.
12. THE DEVELOPER SHALL EMPLOY A PROFESSIONAL ENGINEER TO DESIGN A SEDIMENT AND EROSION CONTROL SYSTEM IN THE DEVELOPMENT IN ORDER TO PREVENT SILT DISCHARGES TO THE STORM DRAINAGE SYSTEM AND WATERCOURSES.

CITY ROAD WORK NOTES

1. THE DEVELOPER SHALL EMPLOY A PROFESSIONAL ENGINEER WITH EXPERIENCE IN GEOTECHNICAL ENGINEERING FOR PERFORMANCE OF IN PLACE TESTING DURING THE PREPARATION OF THE SUB-GRADE AND CONSTRUCTION OF THE ROAD STRUCTURE TO VERIFY THE ADEQUACY OF THE PROPOSED AND EXISTING ROAD STRUCTURE AND SUB-GRADE. SELECTION OF THE PROFESSIONAL ENGINEER IS TO BE APPROVED BY THE CITY.
2. EXISTING VALVE BOXES, MANHOLES, ETC. WITHIN THE ROAD ALLOWANCE MUST BE ADJUSTED TO SUIT THE PROPOSED FINISHED GRADE.
3. ALL LOOSE, ORGANIC, OTHERWISE DELETERIOUS MATERIALS OR SOFT SPOT(S) ARE TO BE EXCAVATED AND REMOVED FROM THE ROADWAY AND UTILITY TRENCHES IN THE ROADWAY AS PER THE GEOTECHNICAL CONSULTANT'S REPORT OR AS DIRECTED BY THE CITY.

CITY WATER WORKS NOTES

1. THE DEVELOPER SHALL SUPPLY ALL MATERIALS AND FITTINGS REQUIRED FOR THE TIE-IN OF THE NEW WATER MAINS BY THE CITY.
2. ALL NEW WATER MAINS, AT TIE-IN POINTS, ARE TO BE CAPPED 1.5 M FROM THE EXISTING WATER MAIN. THE PROPOSED WATER MAIN IS TO BE SET AT THE LINE AND GRADE TO MEET THE EXISTING WATER MAIN.
3. TIE-INS TO EXISTING WATER MAINS AND FINAL TESTING AND CHLORINATION OF NEW MAINS IS TO BE PERFORMED BY THE CITY AT THE DEVELOPER'S COST.
4. UTILITY SEPARATION: A MINIMUM 3 M HORIZONTAL CLEARANCE IS REQUIRED FROM EITHER SANITARY SEWER OR STORM SEWER PIPING, WHEN THEY RUN PARALLEL TO WATER MAIN. WHEN CROSSING SANITARY SEWERS AT 90° ANGLE, THE WATER PIPE SHALL BE ENCASED WITH 20 MPA CONCRETE OF MINIMUM THICKNESS 150 MM. IF CONCRETE IS NOT DESIRABLE, JOINTS OF THE WATER MAIN CAN BE WRAPPED WITH HEAT SHRINK PLASTIC OR PACKED WITH COMPOUND AND WRAPPED WITH PETROLEUM TAPE IN ACCORDANCE WITH THE LATEST VERSION OF THE AWWA STANDARDS C217, AND C214 OR C209. .
5. MINIMUM 750 MM CLEARANCE IS REQUIRED FROM ALL OTHER SERVICES.
6. MINIMUM 3 M. CLEARANCE TO BUILDING FOOTING OR PER MMCD GENERAL DESIGN GUIDELINES CLAUSE 1.3. .3 WHEN CROSSING ELECTRIC DUCT BANK (CROSSING SHALL BE DONE AT 90°), RUN PIPE WITH MINIMUM VERTICAL CLEARANCE 150 MM FROM THE BOTTOM OF ELECTRIC DUCT BANK. IF CROSSING OF ELECTRICAL DUCTBANK CANNOT BE DONE IN THIS MANNER, THEN ENCASE WATER PIPE IN ONE LARGER PLASTIC PIPE PROJECTING MINIMUM 500 MM FROM EITHER SIDE OF ELECTRIC DUCTBANK.
7. TEST AND/OR BLEED POINTS CONSISTING OF CORPORATION COCKS, SIZED TO ACHIEVE MINIMUM FLUSHING VELOCITY OF 0.8 M/S IN ACCORDANCE WITH AWW C651, TO BE PROVIDED WHERE SHOWN ON CONTRACT DRAWINGS OR AS REQUIRED BY UTILITIES MECHANICAL ENGINEER FOR PRESSURE TESTING AND FLUSHING.

WARNING
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#	Date	Issue / Revision	Appr.
0	12/20	PRELIMINARY DESIGN	
1	04/21	DETAILED DESIGN IFC	

Owner

Prime Consultant

Sub-Consultant

Scale AS SHOWN

Drawn by	GM	04/12/21
Designed by	GM	04/12/21
Checked by		
Approved by		

UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

NOTES

Drawing Number C001

Revision 1

LEGEND

EXISTING

WATER MAIN	W
SANITARY SEWER MAIN	S
SANITARY SEWER FORCEMAIN	FM
STORM SEWER MAIN	D
STORM DITCH	
TELECOMMMUNICATIONS	TEL
DISTRICT ENERGY	DES
ELECTRICAL	UE
GAS MAIN	G

NOTES
1. ALL UTILITY LOCATIONS ARE TAKEN FROM THE UTILITYMASTERMAP2019.PDF DOCUMENT PROVIDED BY THE CLIENT.
2. UTILITY LOCATIONS ARE FOR REFERENCE ONLY AND EXACT LOCATIONS SHOULD BE DETERMINED PRIOR TO CONSTRUCTION.
3. TOPOGRAPHIC CONTOURS WERE TAKEN FROM THE CAMPUS CONTOURS.DWG FILE FOUND ON THE UBC WEBSITE.

EXISTING SITE PLAN
1:5000

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WARNING
THE SIZE, DEPTH AND LOCATION OF THE EXISTING OVERHEAD AND UNDERGROUND UTILITIES AND RESPECTIVE STRUCTURES SHOWN ARE APPROXIMATE AND ARE FOR GUIDANCE ONLY. THE COMPLETENESS OR ACCURACY OF THIS INFORMATION IS NOT GUARANTEED. IT SHALL BE THE CONTRACTOR'S SOLE RESPONSIBILITY TO VERIFY THE LOCATION OF THE FACILITIES PRIOR TO COMMENCING WORK, AND TO ADVISE THE CONSULTANT OF ANY POTENTIAL CONFLICT.

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UBC Sustainability

Prime Consultant

Sub-Consultant

Scale 1:5000

Drawn by	GM	12/03/20
Designed by	GM	04/12/21
Checked by		
Approved by		

UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

SITE PLAN

Drawing Number C100

Revision 1

LEGEND

PROPOSED

PROPOSED WELL – PH1
PROPOSED WELL – PH2

EXISTING

WATER MAIN	W
SANITARY SEWER MAIN	S
SANITARY SEWER FORCEMAIN	FM
STORM SEWER MAIN	D
STORM DITCH	
TELECOMMMUNICATIONS	TEL
DISTRICT ENERGY	DES
ELECTRICAL	UE
GAS MAIN	G

NOTES

1. WATER WELLS ARE SPACED A MINIMUM OF 15m APART FROM OTHER WELLS.
2. IT IS ASSUMED THAT THE DRAWING OF WATER FROM EACH WELL IS INDEPENDENT FROM THE OTHER WELLS.

WELL NETWORK PLAN

1:2000

WARNING
THE SIZE, DEPTH AND LOCATION OF THE EXISTING OVERHEAD AND UNDERGROUND UTILITIES AND RESPECTIVE STRUCTURES SHOWN ARE APPROXIMATE AND ARE FOR GUIDANCE ONLY. THE COMPLETENESS OR ACCURACY OF THIS INFORMATION IS NOT GUARANTEED. IT SHALL BE THE CONTRACTOR'S SOLE RESPONSIBILITY TO VERIFY THE LOCATION OF THE FACILITIES PRIOR TO COMMENCING WORK, AND TO ADVISE THE CONSULTANT OF ANY POTENTIAL CONFLICT.

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Sub-Consultant

Scale 1:2000

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Designed by	GM	04/12/21
Checked by		
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UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

WELL NETWORK PLAN

Drawing Number: C101
Revision: 1

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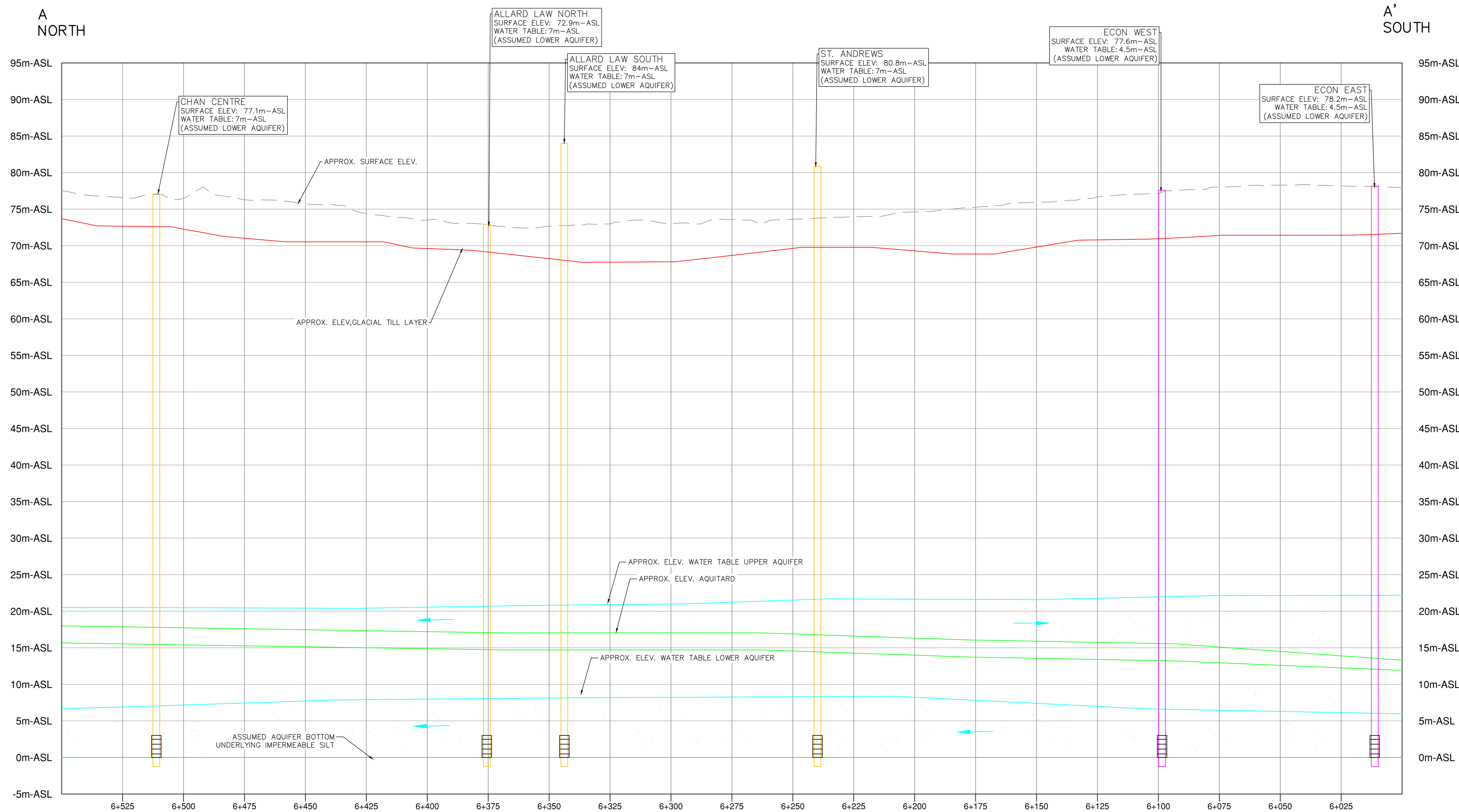

LEGEND

- PHASE 1 WELL
- PHASE 2 WELL
- AQUIFER (QUADRA SAND WITH TRACE GRAVEL)
- GROUNDWATER FLOW DIRECTION
- WELL SCREEN

GROUNDWATER NOTES

1. WATER DEPTHS AND SOIL TYPES ARE ASSUMED BASE ON THE "HYDROGEOLOGICAL AND GEOTECHNICAL ASSESSMENT OF NORTH WATER AREA UBC CAMPUS, VANCOUVER" (2002) – PITEAU ASSOCIATES.
2. FURTHER GEOTECHNICAL ASSESSMENT SHOULD BE COMPLETED BY THE CONTRACTOR TO DETERMINE ACTUAL WATER LEVEL AND SOIL LEVELS AT EACH OF THE PROPOSED WELL LOCATIONS.
3. THE BOTTOM OF THE LOWER AQUIFER IS ASSUMED TO BE 0m ABOVE SEA LEVEL.
4. WATER QUALITY INFORMATION WAS REFERENCED FROM PITEAU HYDROGEOLOGICAL STUDY (2002) AND CONFIRMED VERBALLY BY THE CLIENT. FURTHER INFORMATION ENCLOSED IN WATERSPRITE ENGINEERING'S PRELIMINARY DESIGN REPORT (2020).
5. GROUNDWATER WILL BE DRAWN FROM THE LOWER AQUIFER AS IT PROVIDES MORE STABLE YIELDS.

SECTION A-A' - WELL NETWORK PROFILE

H 1:1000
V 1:250

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WARNING
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Owner: UBC Sustainability

Prime Consultant

Sub-Consultant

Scale: AS SHOWN

Drawn by	GM	04/12/21
Designed by	GM	04/12/21
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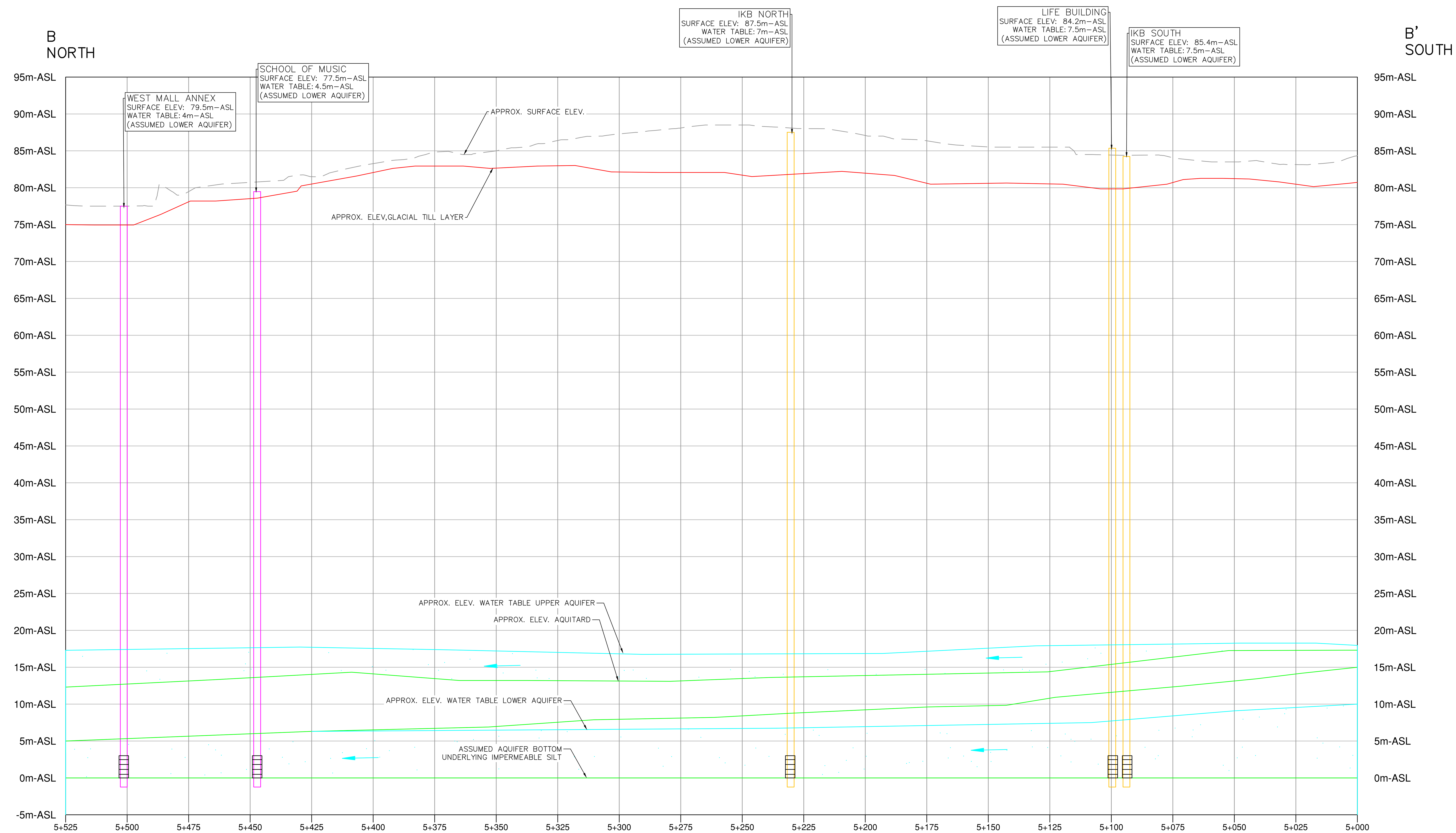
UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

WELL NETWORK PROFILE - SECTION A-A'

Drawing Number: C102
Revision: 1



LEGEND

- PHASE 1 WELL
- PHASE 2 WELL
- AQUIFER (QUADRA SAND WITH TRACE GRAVEL)
- GROUNDWATER FLOW DIRECTION
- WELL SCREEN

GROUNDWATER NOTES

1. WATER DEPTHS AND SOIL TYPES ARE ASSUMED BASE ON THE "HYDROGEOLOGICAL AND GEOTECHNICAL ASSESSMENT OF NORTH WATER AREA UBC CAMPUS, VANCOUVER" (2002) – PITEAU ASSOCIATES.
2. FURTHER GEOTECHNICAL ASSESSMENT SHOULD BE COMPLETED BY THE CONTRACTOR TO DETERMINE ACTUAL WATER LEVEL AND SOIL LEVELS AT EACH OF THE PROPOSED WELL LOCATIONS.
3. THE BOTTOM OF THE LOWER AQUIFER IS ASSUMED TO BE 0m ABOVE SEA LEVEL.
4. WATER QUALITY INFORMATION WAS REFERENCED FROM PITEAU HYDROGEOLOGICAL STUDY (2002) AND CONFIRMED VERBALLY BY THE CLIENT. FURTHER INFORMATION ENCLOSED IN WATERSPRITE ENGINEERING'S PRELIMINARY DESIGN REPORT (2020).
5. GROUNDWATER WILL BE DRAWN FROM THE LOWER AQUIFER AS IT PROVIDES MORE STABLE YIELDS.

SECTION B-B' - WELL NETWORK PROFILE

H 1:1000
V 1:250

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WARNING
THE SIZE, DEPTH AND LOCATION OF THE EXISTING OVERHEAD AND UNDERGROUND UTILITIES AND RESPECTIVE STRUCTURES SHOWN ARE APPROXIMATE AND ARE FOR GUIDANCE ONLY. THE COMPLETENESS OR ACCURACY OF THIS INFORMATION IS NOT GUARANTEED. IT SHALL BE THE CONTRACTOR'S SOLE RESPONSIBILITY TO VERIFY THE LOCATION OF THE FACILITIES PRIOR TO COMMENCING WORK, AND TO ADVISE THE CONSULTANT OF ANY POTENTIAL CONFLICT.

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Prime Consultant

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Designed by	GM	04/12/21
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UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

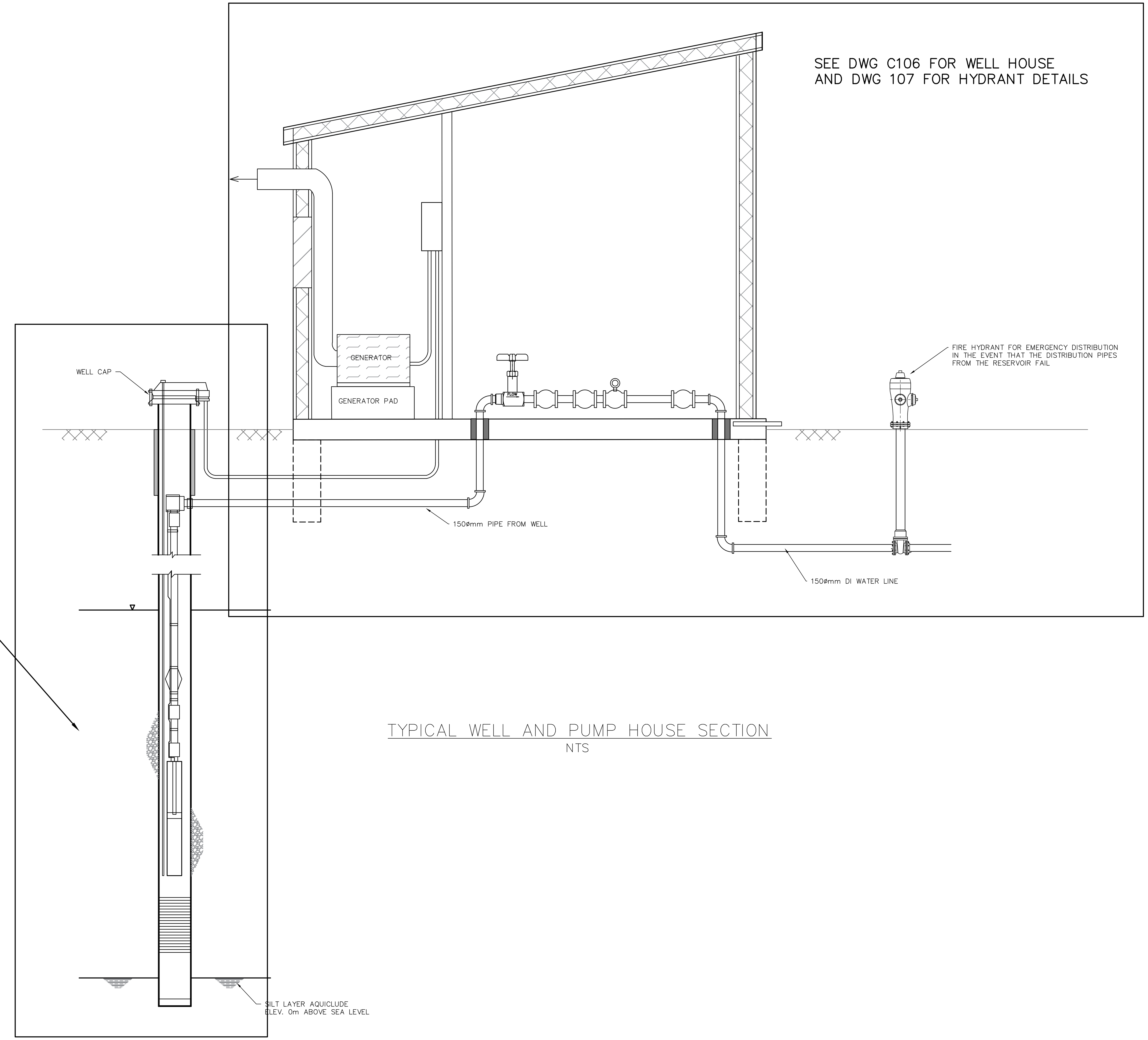
UBC POINT GREY CAMPUS

WELL NETWORK PROFILE - SECTION B-B'

Drawing Number: C103
Revision: 1

NOTES:

1. WELL CAP OUTSIDE PUMP HOUSE TO ALLOW FOR FUTURE EXPANSION/REHABILITATION.
2. DISTRIBUTION PIPE TO PUMP HOUSE SHALL BE PLACED BELOW THE FROST LINE.
3. STRUCTURAL DESIGN OF PUMP HOUSE TO BE COMPLETED BY SUBCONSULTANTS.
4. ELECTRICAL AND MECHANICAL DESIGN TO BE COMPLETED BY SUBCONSULTANTS.
5. GROUT SEAL SHALL BE EMPLACED ABOVE ANY ARTIFICIAL FILTER PACK
6. IT IS IMPORTANT TO NOTE THAT IN A GRAVEL ENVELOPE, THE GRAVEL IS THE PRIMARY FILTER FOR THE GROUNDWATER AND THE SCREEN IS REQUIRED TO HOLD THE GRAVEL PACK IN PLACE
7. SHUTTER–STYLE SCREEN: COMMERCIALLY FABRICATED KEYSTONE WIRE–WOUND 304 GRADE STAINLESS STEEL (PER RURAL DESIGN GUIDELINES)
8. SURFACE SEAL SHALL BE BENTONITE GROUT MIXED TO 30% SOLIDS BY WEIGHT



TYPICAL WELL AND PUMP HOUSE SECTION
NTS

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WARNING
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Owner

Prime Consultant

Sub-Consultant

Scale AS SHOWN

Drawn by	KO	12/04/2021
Designed by	KO	12/04/2021
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Approved by		

UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

WELL DESIGN SECTION

Drawing Number C104

Revision 1

NOTES:
1. WELL CAP OUTSIDE PUMP HOUSE TO ALLOW FOR FUTURE EXPANSION/REHABILITATION.
2. DISTRIBUTION PIPE TO PUMP HOUSE SHALL BE PLACED BELOW THE FROST LINE.
3. ELECTRICAL AND MECHANICAL DESIGN TO BE COMPLETED BY SUBCONSULTANTS.
4. GROUT SEAL SHALL BE EMPLACED ABOVE ANY ARTIFICIAL FILTER PACK
5. IT IS IMPORTANT TO NOTE THAT IN A GRAVEL ENVELOPE, THE GRAVEL IS THE PRIMARY FILTER FOR THE GROUNDWATER AND THE SCREEN IS REQUIRED TO HOLD THE GRAVEL PACK IN PLACE
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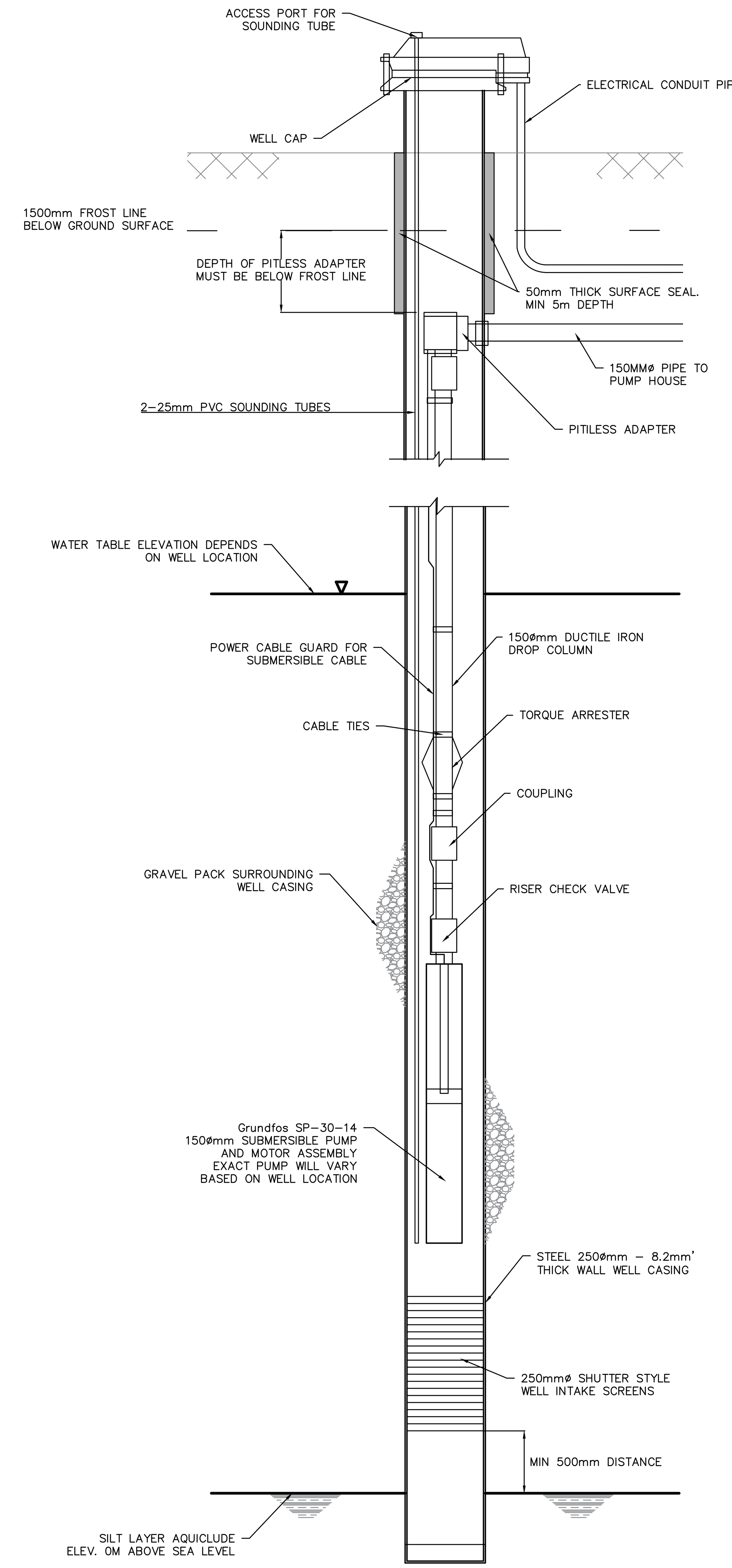
7. SURFACE SEAL SHALL BE BENTONITE GROUT MIXED TO 30% SOLIDS BY WEIGHT



TYPICAL WELL DETAIL

NTS

#	Date	Issue / Revision	Appr.
0	12/20	PRELIMINARY DESIGN	
1	04/21	DETAILED DESIGN IFC	

Owner: UBC Sustainability

Prime Consultant

Sub-Consultant

Scale: AS SHOWN

Drawn by	KO	04/04/2021
Designed by	KO	02/22/2021
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UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

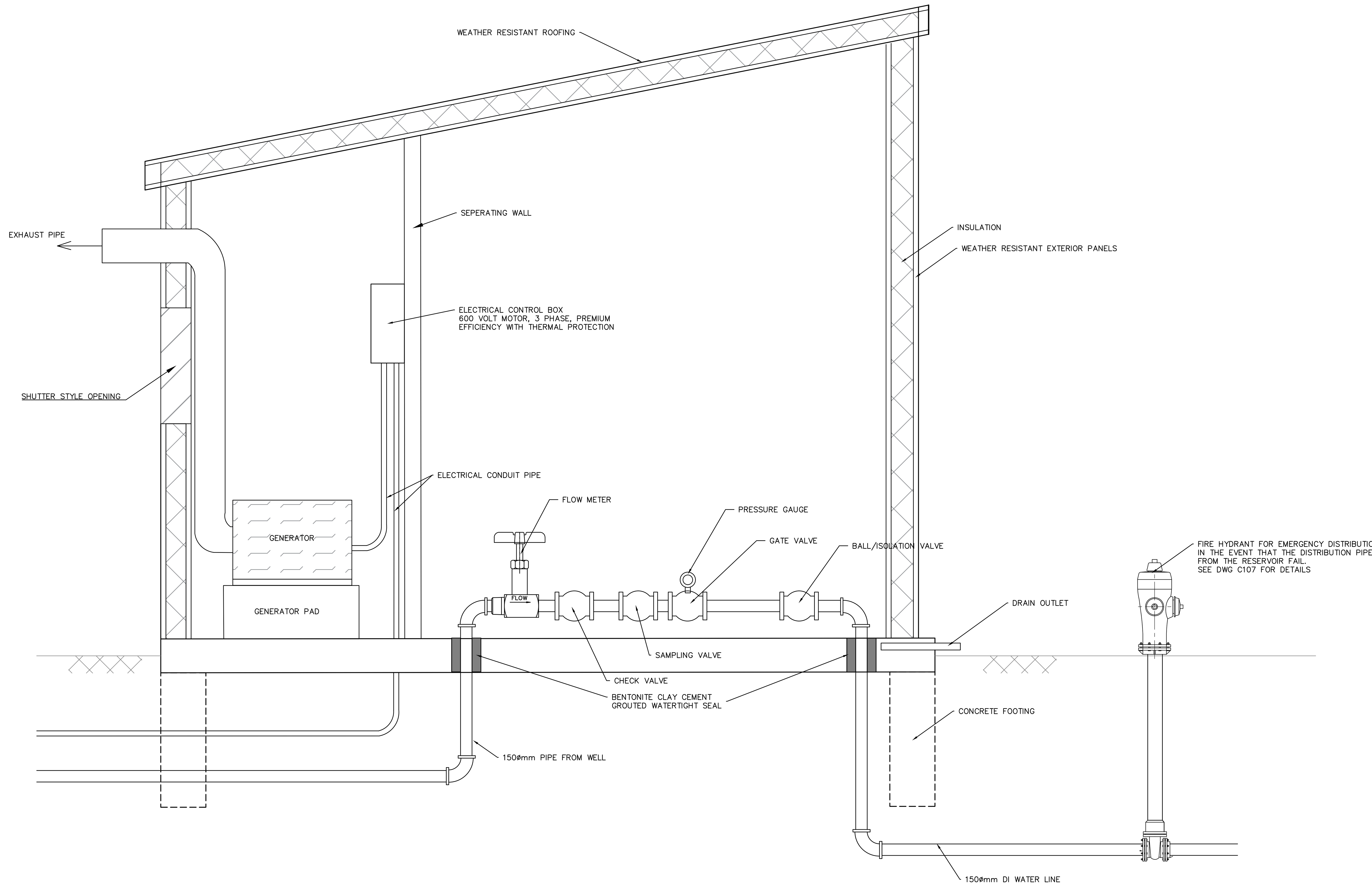
UBC POINT GREY CAMPUS

TYPICAL WELL DETAIL

Drawing Number: C105

Revision: 1

NOTES:
1. STRUCTURAL DESIGN OF PUMP HOUSE TO BE COMPLETED BY SUBCONSULTANTS.
2. ELECTRICAL AND MECHANICAL DESIGN TO BE COMPLETED BY SUBCONSULTANTS.



TYPICAL WELL HOUSE DETAIL

NTS

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WARNING
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#	Date	Issue / Revision	Appr.
0	12/20	PRELIMINARY DESIGN	
1	04/21	DETAILED DESIGN IFC	

Owner

UBC Sustainability

Prime Consultant

Sub-Consultant

Scale AS SHOWN

Drawn by	KO	04/04/2021
Designed by	KO	02/22/2021
Checked by		
Approved by		

UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

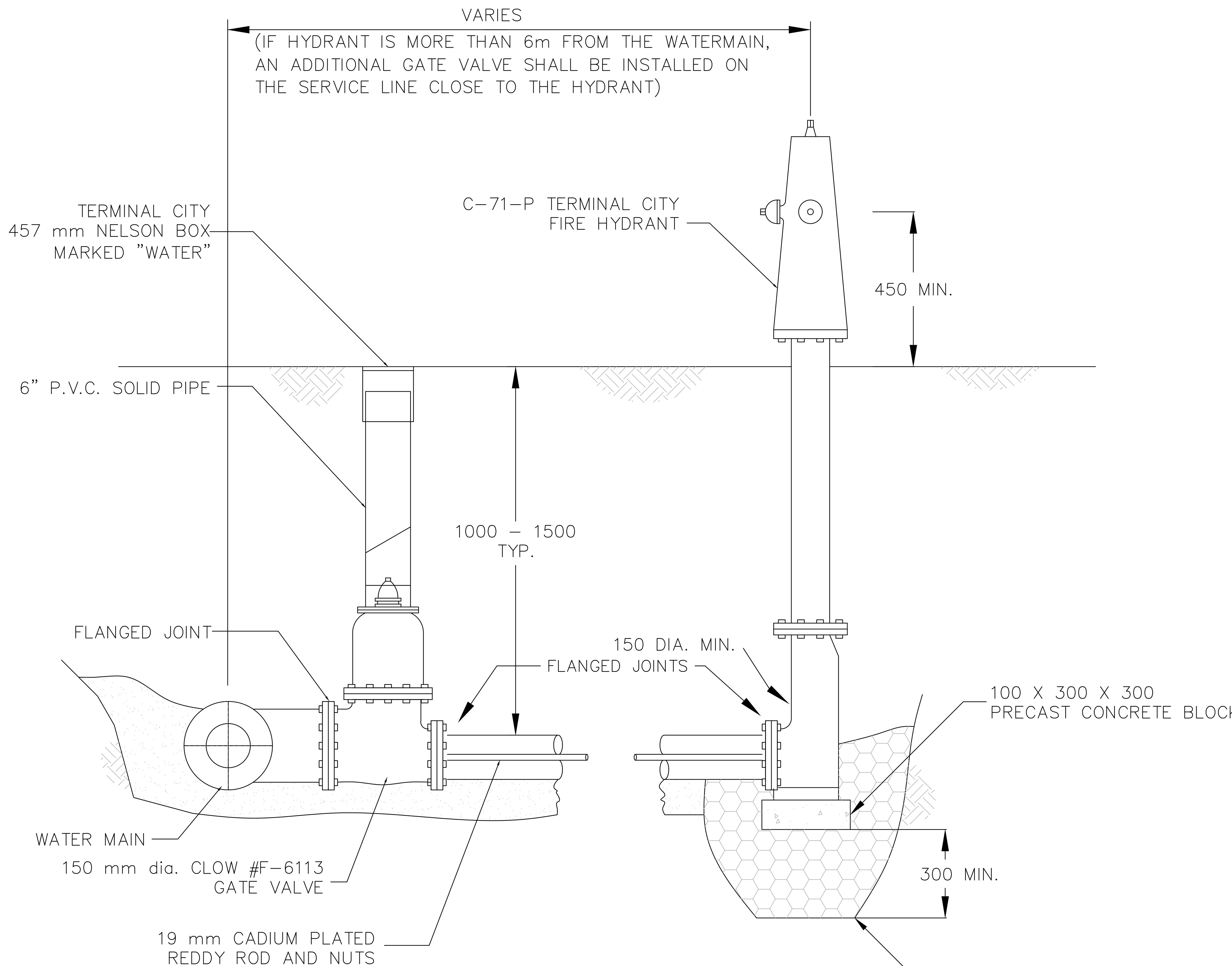
UBC POINT GREY CAMPUS

TYPICAL WELL HOUSE DETAIL

Drawing Number C106

Revision 1

NOTES:
1. DETAIL IS GOTTEN FROM AND MUST MEET UBC DESIGN STANDARDS
2. A HUB X FLANGE ISOLATION VALVE SHALL BE INSTALLED DIRECTLY AT THE WATER MAIN TAKE-OFF.
3. IN CASES WHERE THE FIRE HYDRANT LOCATION EXCEEDS 6m FROM THE WATER MAIN, A SECOND VALVE SHALL BE INSTALLED DIRECTLY AT THE HYDRANT.



TYPICAL FIRE HYDRANT DETAIL
NTS

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Owner
UBC Sustainability

Prime Consultant

Sub-Consultant

Scale
AS SHOWN

Drawn by	KO	04/04/2021
Designed by	KO	02/22/2021
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Approved by		

UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

TYPICAL FIRE HYDRANT DETAIL

Drawing Number
C107

Revision
1

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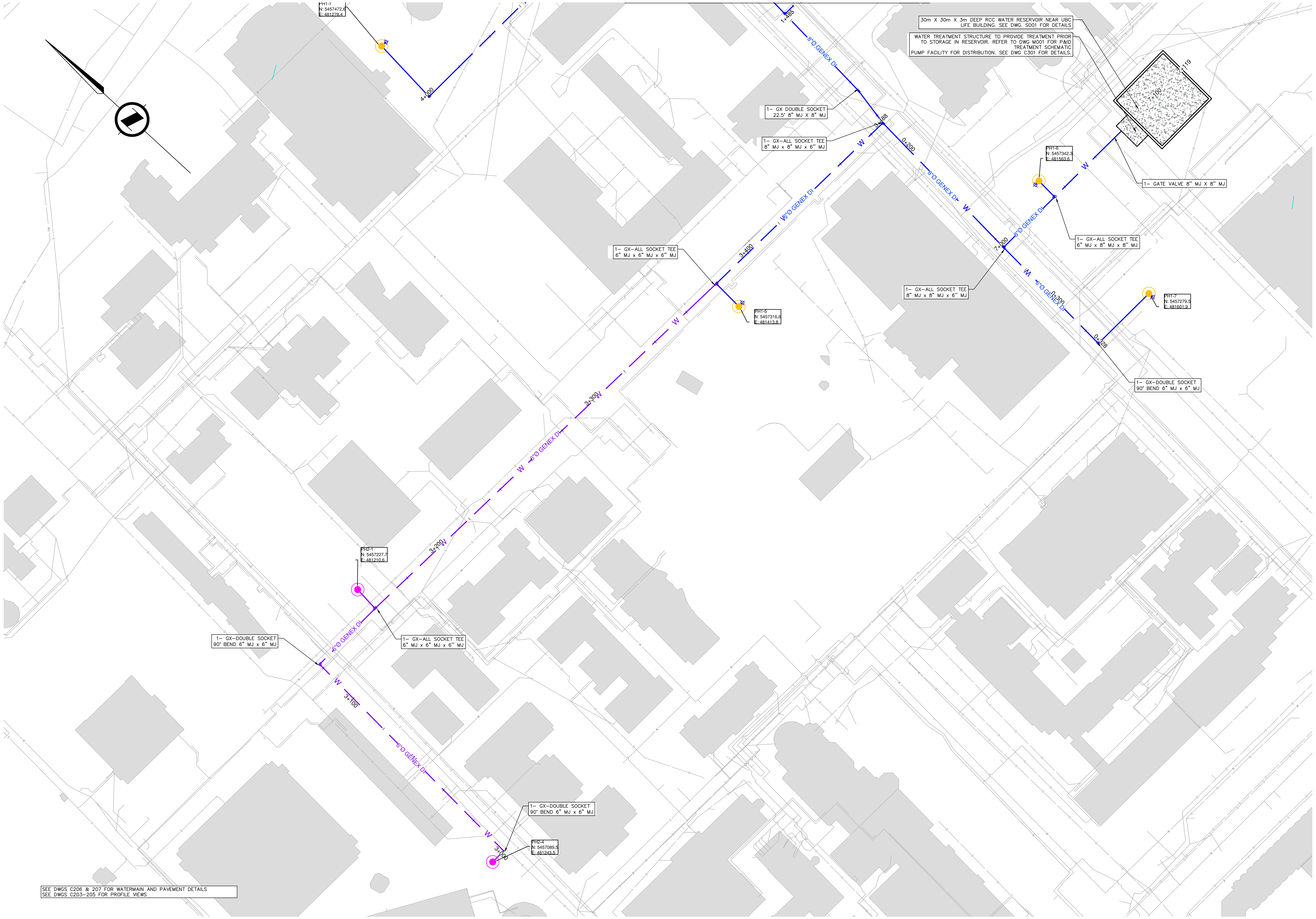
MATCH DWG C202



DISTRIBUTION NETWORK PLAN - SOUTH

1:2000

LEGEND

PROPOSED

- WATERMAIN TO RESERVOIR – PH1 — W —
- WATERMAIN TO RESERVOIR – PH1 — W —
- WATER PIPE FROM RESERVOIR — W —
- WATER VALVE
- WATER HYDRANT
- PROPOSED WELL – PH1
- PROPOSED WELL – PH2

EXISTING

- WATER MAIN — W —
- SANITARY SEWER MAIN — S —
- SANITARY SEWER FORCEMAIN — FM —
- STORM SEWER MAIN — D —
- STORM DITCH
- TELECOMMUNICATIONS — TEL —
- DISTRICT ENERGY — DES —
- ELECTRICAL — UE —
- GAS MAIN — G —

GROUNDWATER DISTRIBUTION NOTES:

1. PRIMARY RESTRAINT METHODS INDICATED IN PLAN ARE REFERENCED FROM KUBOTA'S GENEX PIPING CATALOGUE, WHICH ARE DESIGNED SPECIFICALLY FOR GENEX DUCTILE IRON PIPING.
2. EACH SOCKET IS FITTED WITH A LINER WITH THE MATCHING DIAMETER TO CONVERT JOINT INTO RESTRAINT–TYPE JOINTS FOR THRUST PROTECTION OF FITTINGS.
3. EACH SOCKET IS TO BE FITTED KUBOTA'S RUBBER GASKETS (PROVIDED WITH EACH JOINT) WITH THE MATCHING DIAMETER.
4. SHOULD CUT PIPES BE USED, KUBOTA'S G–LINK SHOULD BE USED FOR PROPER FITTING CONNECTION.
5. REFER TO KUBOTA EARTHQUAKE RESISTANT DUCTILE IRON PIPE (GENEX) FOR ALL DIMENSIONS OF PIPES, FITTINGS AND ACCESSORIES.

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Owner: UBC Sustainability

Prime Consultant

Sub-Consultant

Scale: 1:1000

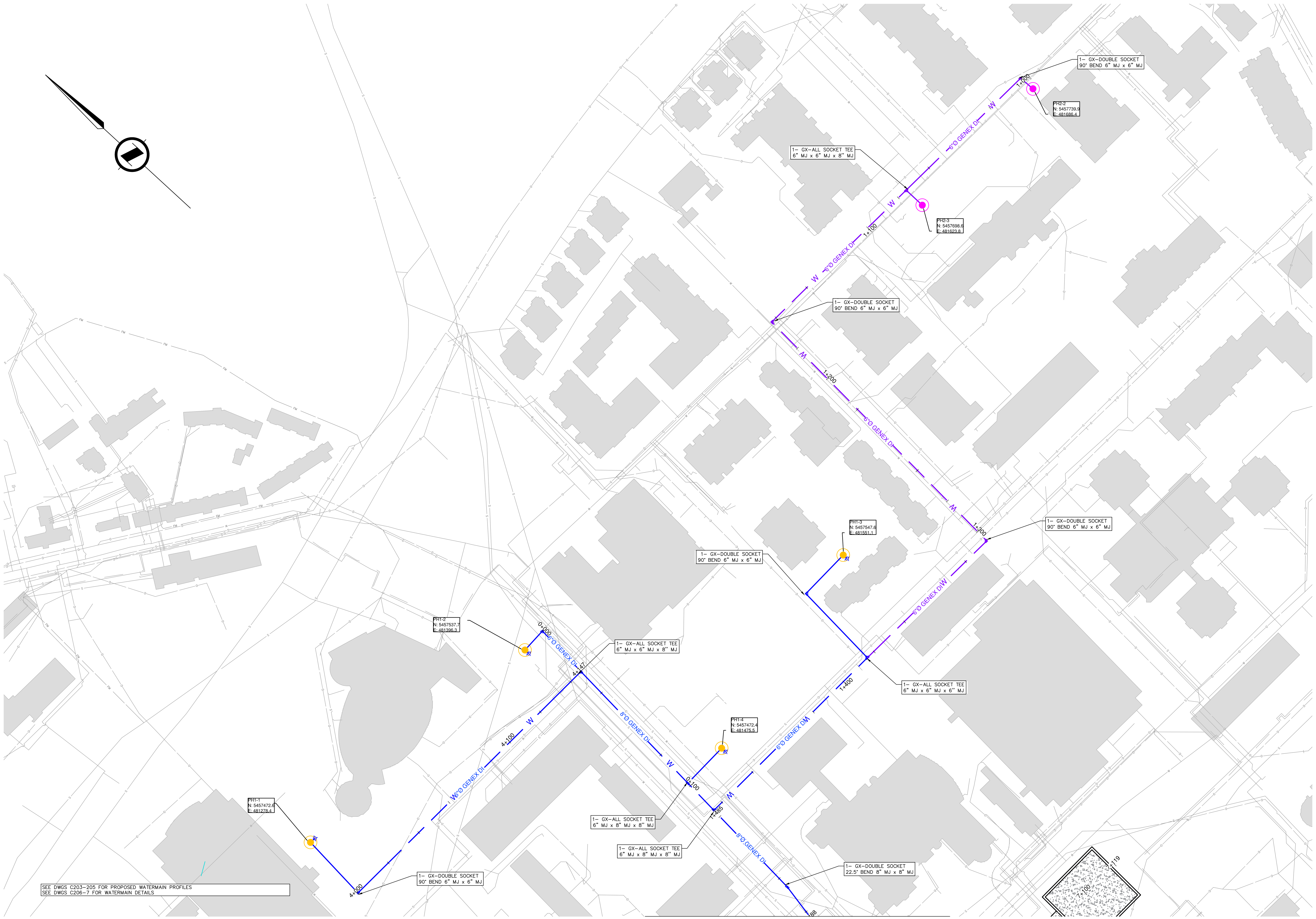
Drawn by	GM	04/12/12
Designed by	GM	04/12/21
Checked by		
Approved by		

UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

DISTRIBUTION NETWORK PLAN - SOUTH

Drawing Number: C201
Revision: 1



LEGEND

PROPOSED

WATERMAIN TO RESERVOIR – PH1	— — W — —
WATERMAIN TO RESERVOIR – PH1	— — W — —
WATER PIPE FROM RESERVOIR	— — W — —
WATER VALVE	
WATER HYDRANT	
PROPOSED WELL – PH1	
PROPOSED WELL – PH2	

EXISTING

WATER MAIN	W
SANITARY SEWER MAIN	S
SANITARY SEWER FORCEMAIN	FM
STORM SEWER MAIN	D
STORM DITCH	
TELECOMMUNICATIONS	TEL
DISTRICT ENERGY	DES
ELECTRICAL	UE
GAS MAIN	G

GROUNDWATER DISTRIBUTION NOTES:

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DISTRIBUTION NETWORK PLAN
1:1000

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Owner

UBC Sustainability

Prime Consultant

Sub-Consultant

Scale	1:1000	
Drawn by	GM	04/12/21
Designed by	GM	04/12/21
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Approved by		

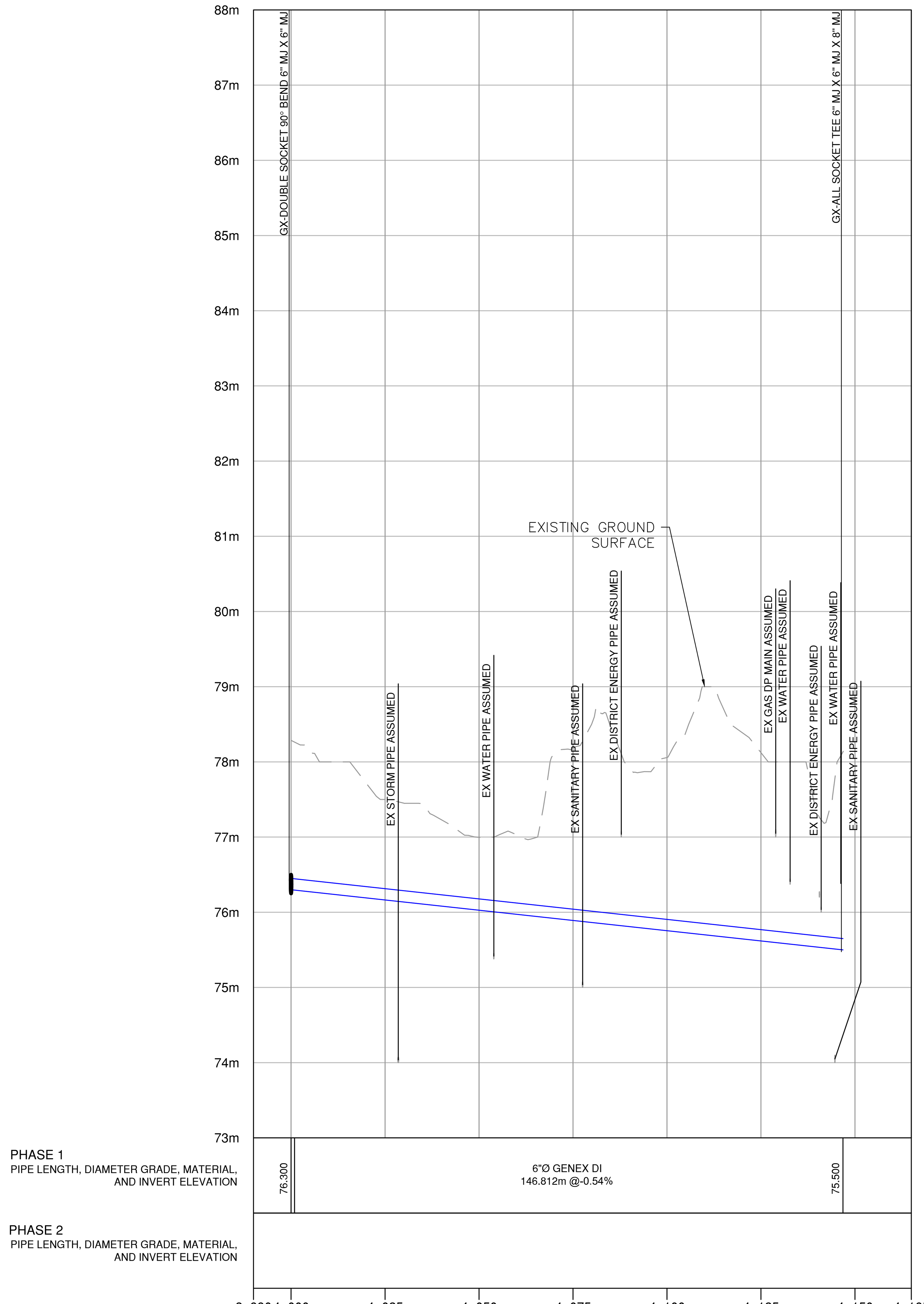
UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

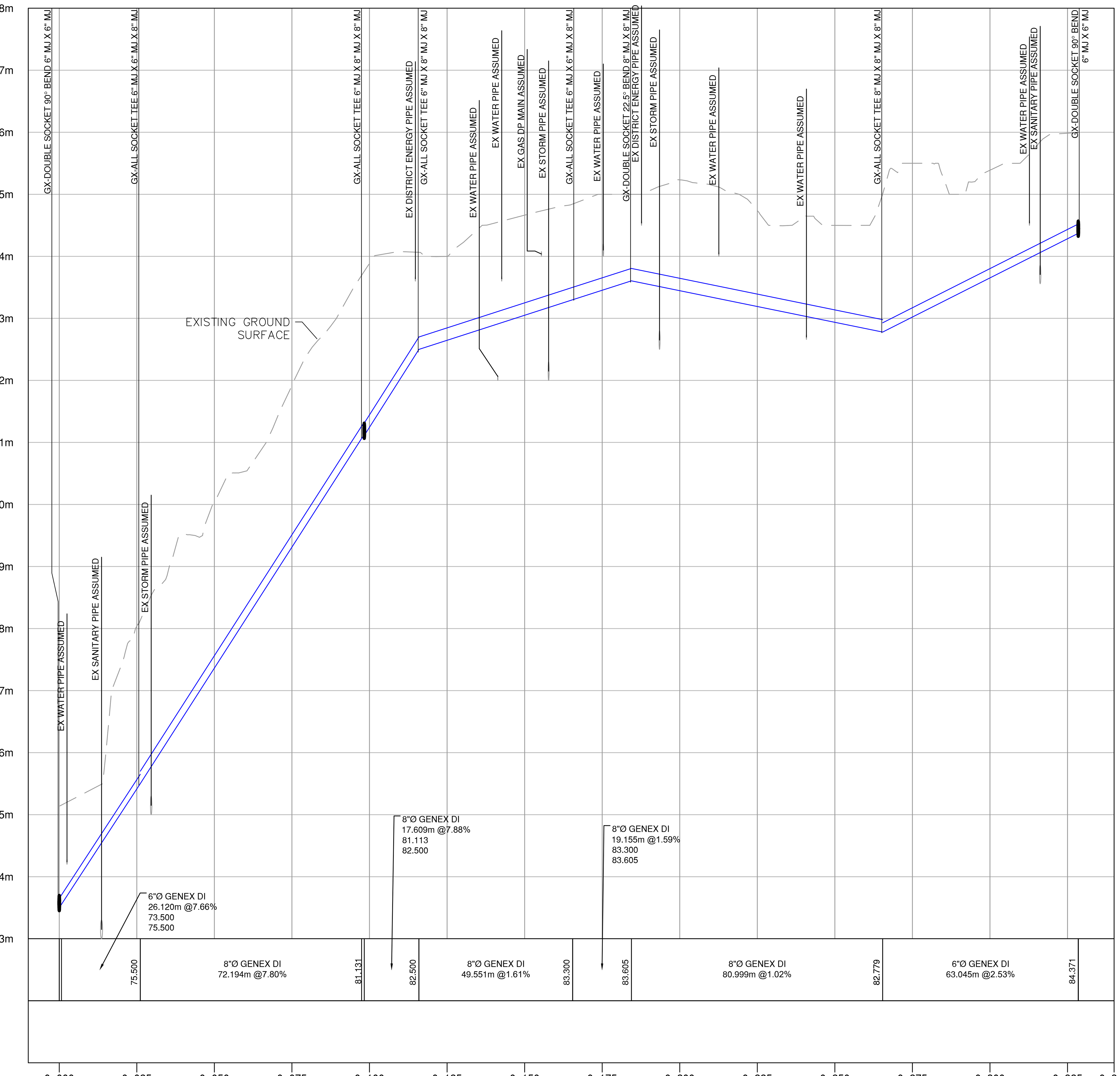
DISTRIBUTION NETWORK PLAN - NORTH

Drawing Number: C202

Revision: 1



EAST MALL PROFILE
STA 4+000 - 4+150
H: 1:2000
V: 1:200



EAST MALL PROFILE
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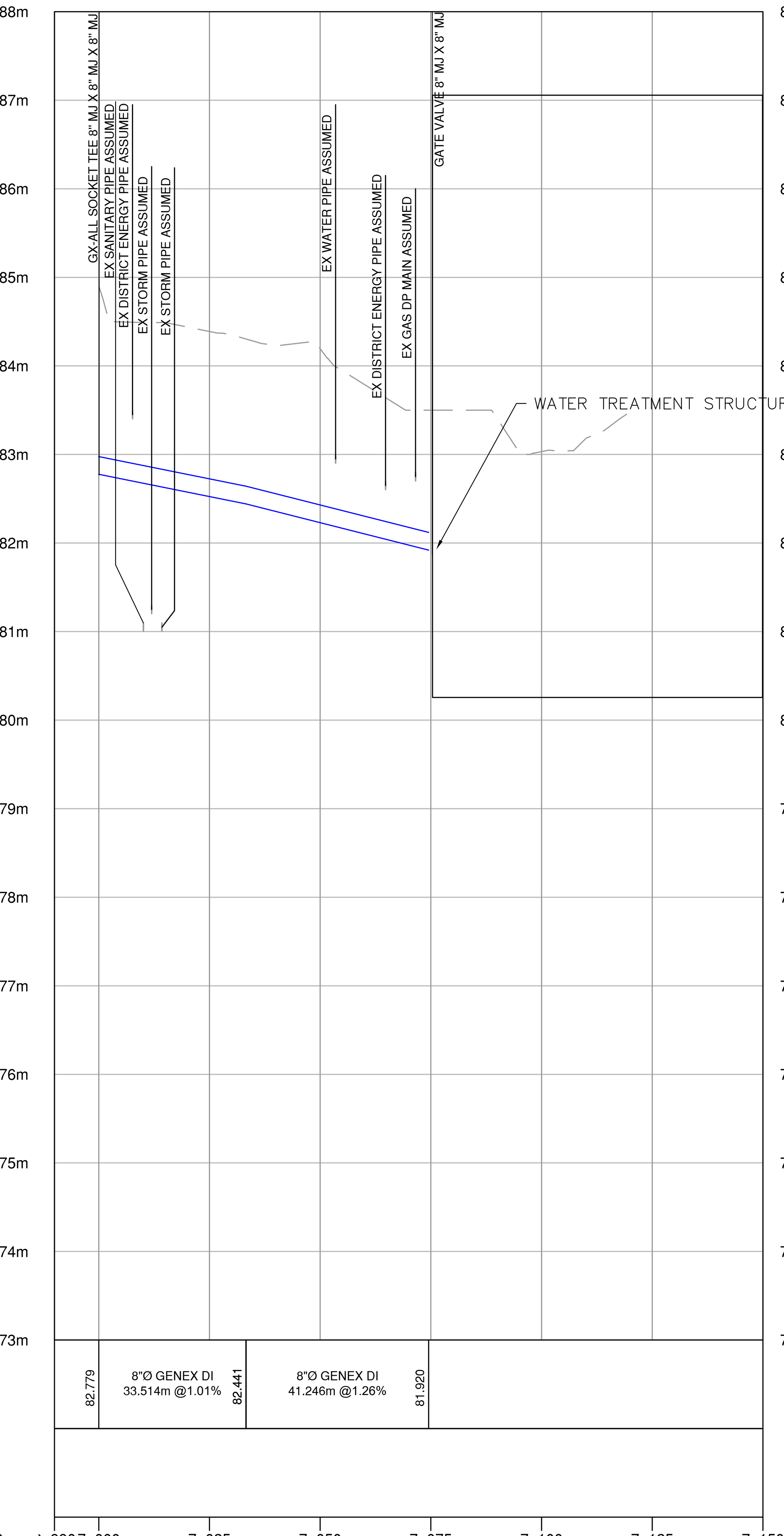
V: 1:200



EAST MALL PROFILE
STA 7+000 - 7+150
H: 1:2000
V: 1:200

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Owner: UBC Sustainability

Prime Consultant

Sub-Consultant

Scale: AS SHOWN

Drawn by	GM	04/12/21
Designed by	GM	04/12/21
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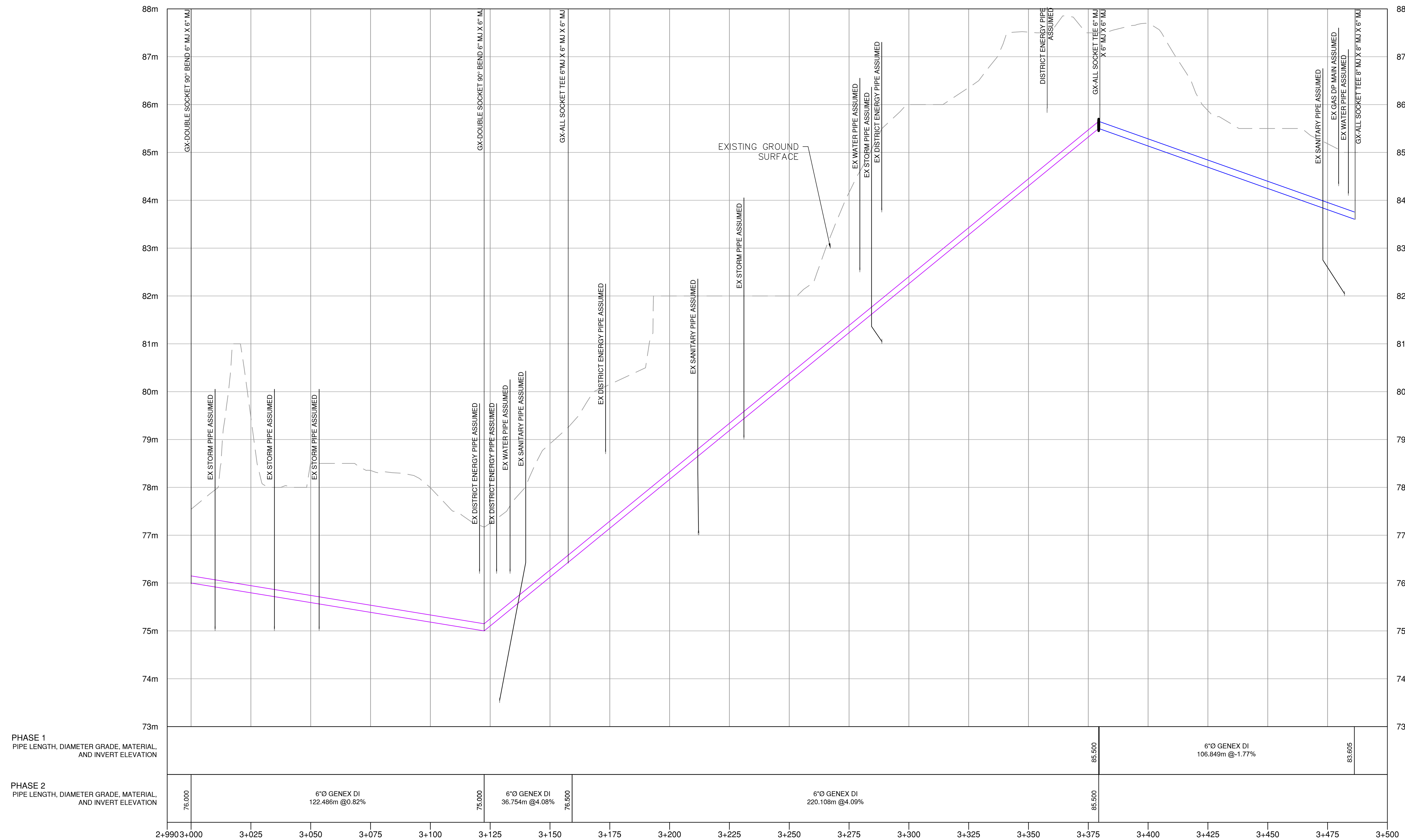
UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

DISTRIBUTION NETWORK PROFILE - EAST MALL

Drawing Number: C203
Revision: 1



AGRICULTRAL RD PROFILE
STA 3+000 - 3+500
H: 1:2000
V: 1:200

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Owner

UBC Sustainability

Prime Consultant

Sub-Consultant

Scale AS SHOWN

Drawn by	GM	04/12/21
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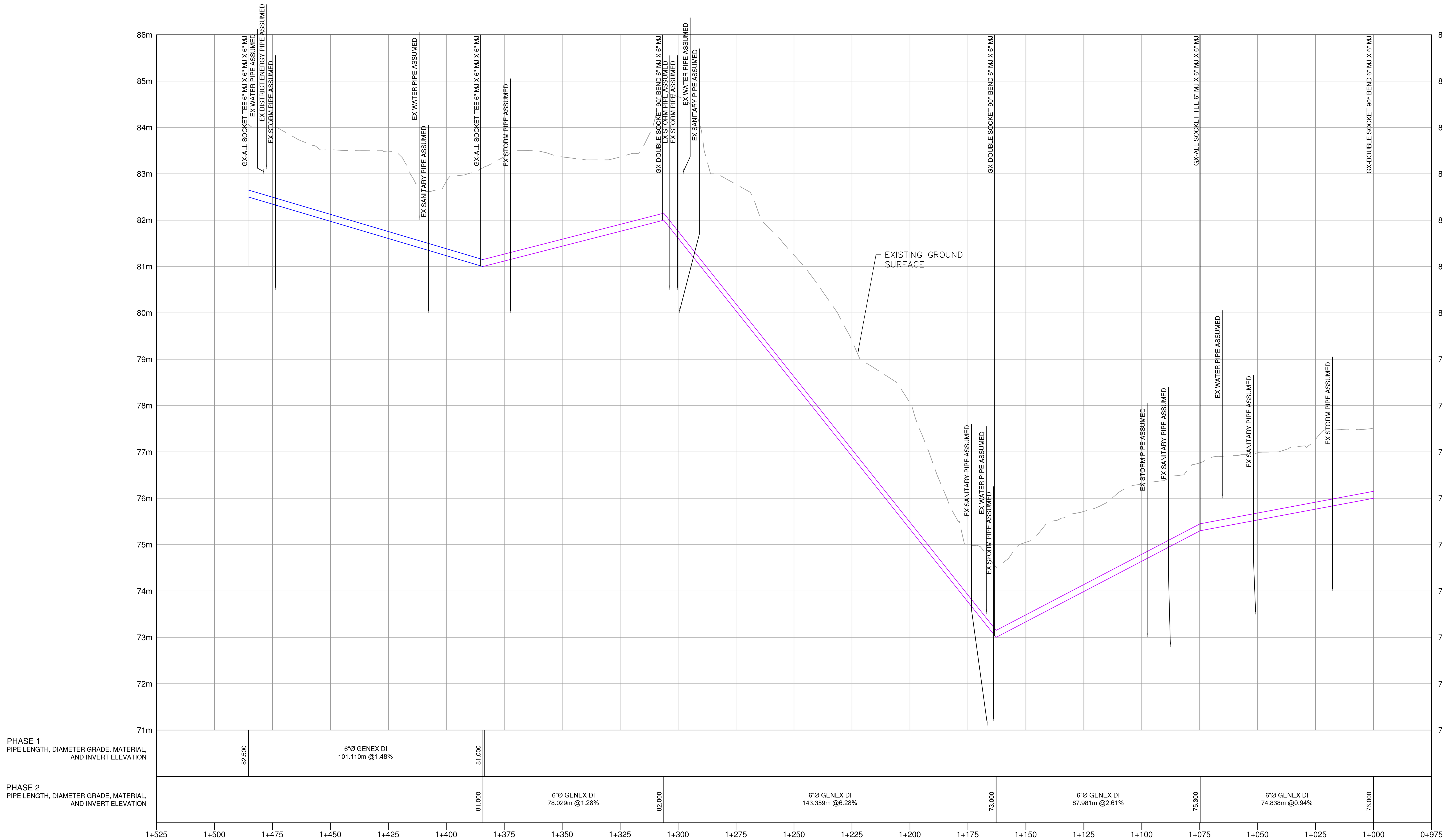
UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

DISTRIBUTION NETWORK PROFILE - AGRICULTURAL RD

Drawing Number C204

Revision 1



GAGE/IONA DR PROFILE
STA 1+000 - 1+500
H: 1:2000
V: 1:200

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Owner

UBC Sustainability

Prime Consultant

Sub-Consultant

Scale: AS SHOWN

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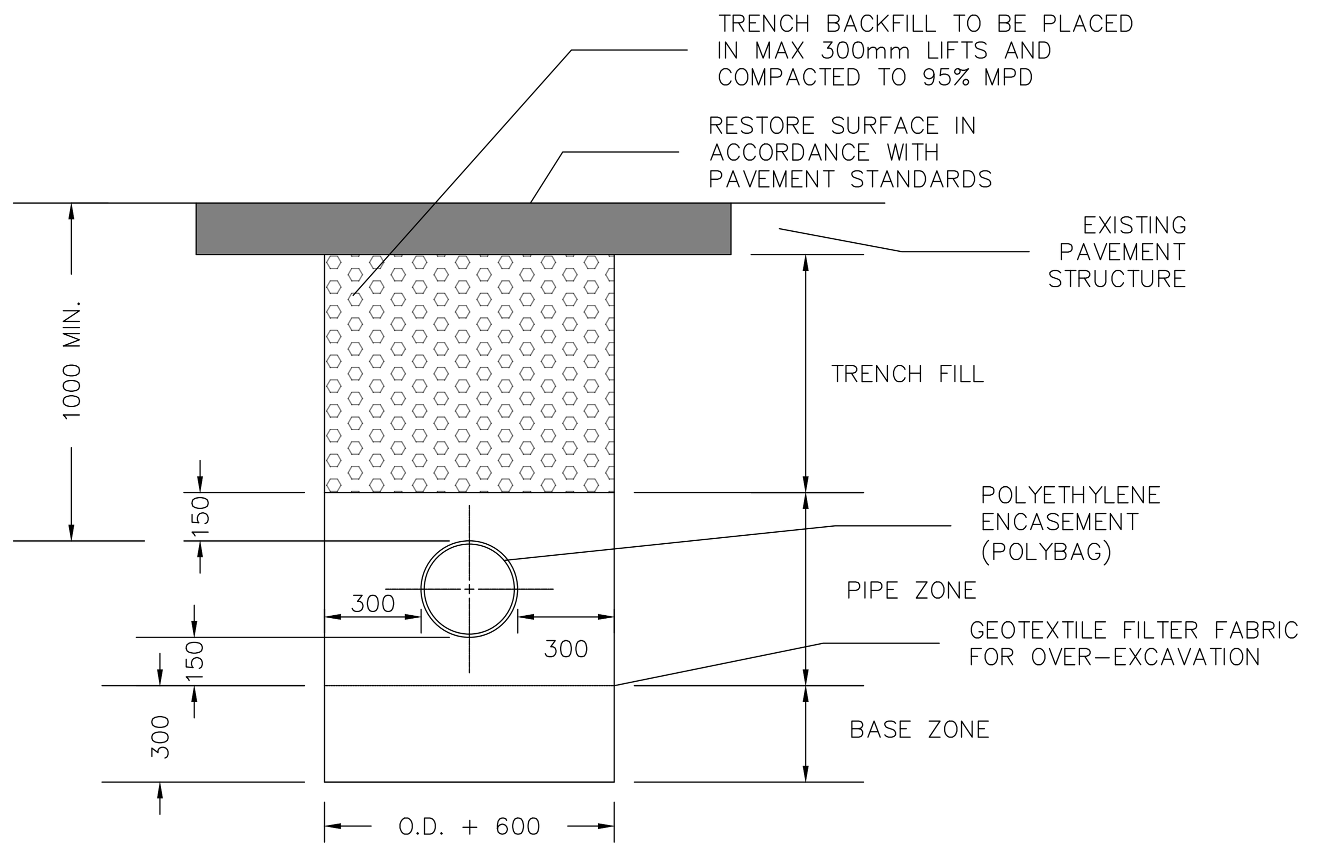
UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

DISTRIBUTION NETWORK PROFILE - GAGE/IONA DR

Drawing Number: C205

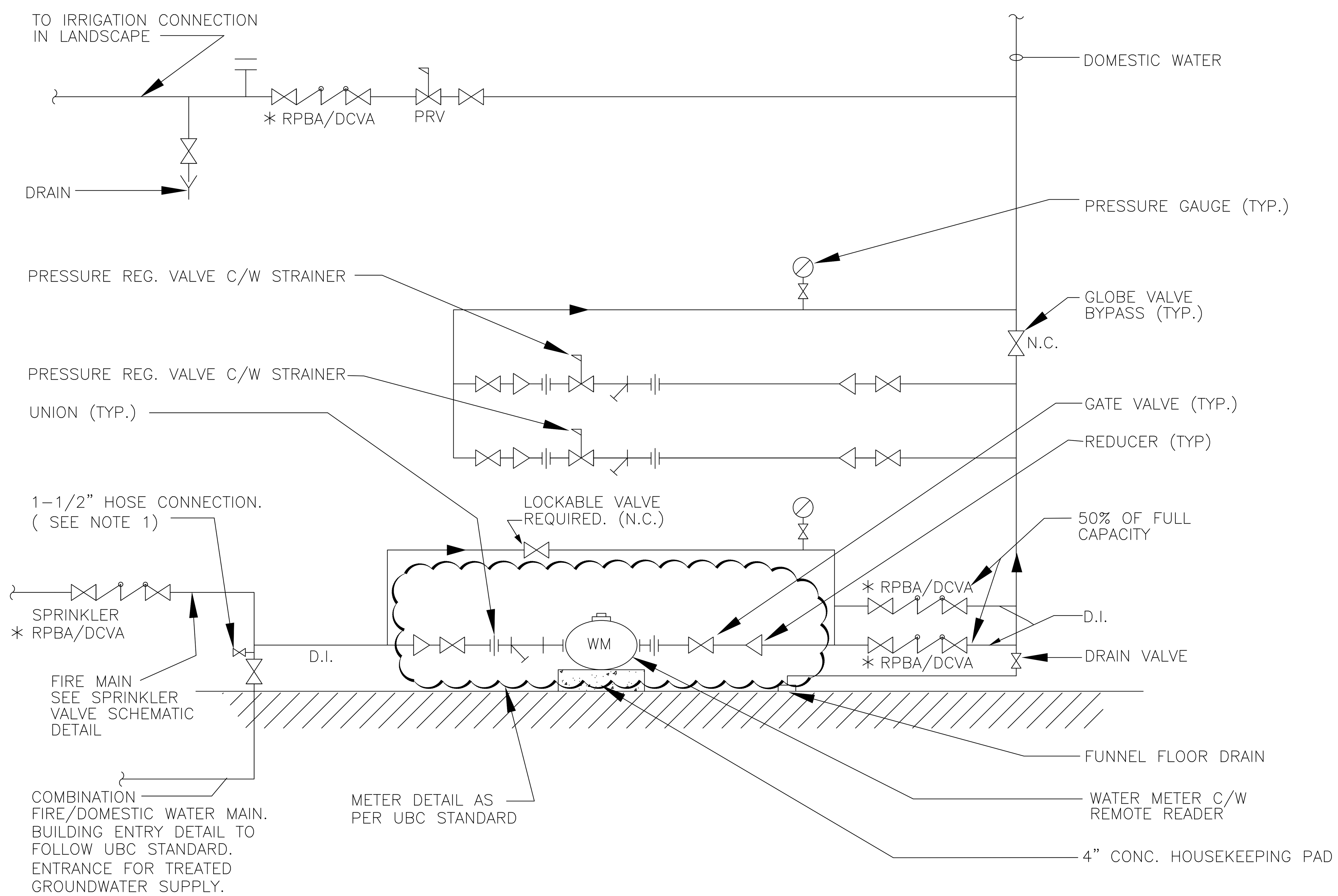
Revision: 1



TYPICAL UTILITY TRENCH FOR WATERMAIN AND WELL SUPPLY PIPE
N.T.S

UTILITY TRENCH NOTES:

1. TRENCH FILL: NATIVE BACKFILL OR APPROVED BACKFILL BY UBC ENERGY & WATER SERVICES.
2. PIPE ZONE: PLACE CLEAN GRAULAR PIPE BEDDING, GRADED GRAVEL, 19mm MINUS, MMS TYPE 1. COMPACTED TO 95% MODIFIED PROCTOR.
3. BASE ZONE: PLACE GRANULAR BEDDING (SAND) IN UNIFORM 100mm LAYERS.
4. GEOTEXTILE FABRIC LAYER: PLACE ABOVE BOTTOM OF TRENCH, NILEX 4551 OR SIMILAR.
5. PROTRUDING ROCK, BOULDER, LARGE STONES, FOREIGN MATERIAL AND SHORING MUST BE REMOVED TO MAINTAIN A MINIMUM CLEARANCE OF 150mm AROUND ALL PIPES, VALVES AND FITTINGS BEFORE COMPACTION.
6. ALL DIMENSIONS IN MILLIMETERS UNLESS STATED OTHERWISE.
7. DETAIL REFERENCED FROM CITY OF VANCOUVER DETAIL G4.2 (2018) AND ADJUSTED PER UBC TECHNICAL GUIDELINES FROM UBC ENERGY & WATER SERVICES.
8. TYPICAL TRENCH DETAIL TO BE APPLICABLE FOR DISTRIBUTION MAIN FROM RESERVOIR TO SYSTEM AND FOR WELL SUPPLY TO RESERVOIR.



TYPICAL CONNECTION SCHEMATIC WITH BUILDING POTABLE WATER SYSTEM IN MECHANICAL ROOM
N.T.S

WATER STN. SCHEMATIC NOTES:

1. 2" HOSE CONNECTION: BALL VALVE WITH THREADED FITTINGS – LOCKABLE VALVE REQUIRED (N.C.).
2. TWO BACKFLOW PREVENTION ASSEMBLIES PIPED IN PARALLEL ARE REQUIRED AT THE WATER SERVICE ENTRY TO ALL BUILDINGS, TO ALLOW FOR SERVICING WITHOUT HAVING TO COMPLETE ISOLATE THE WATER SUPPLY TO THE BUILDING.
3. STAINER TO BE INSTALLED BEFORE BACKFLOW DEVICES.
4. CROSS CONNECTION PROTECTION TO FOLLOW CSA STANDARDS.
5. DETAIL FROM UBC TECHNICAL GUIDELINES NO. 1140–UT–01–WaterStnSchematic.dwg

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Owner: UBC Sustainability

Prime Consultant

Sub-Consultant

Scale: AS SHOWN

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Designed by	LL	04/12/21
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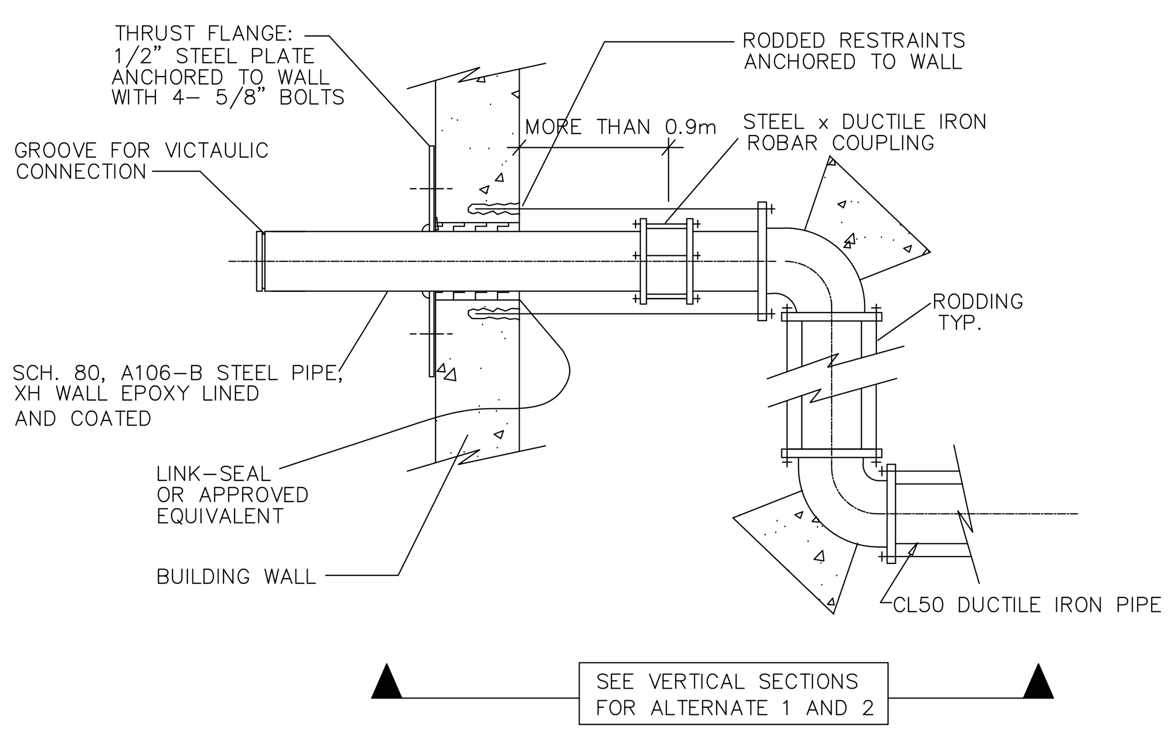
UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

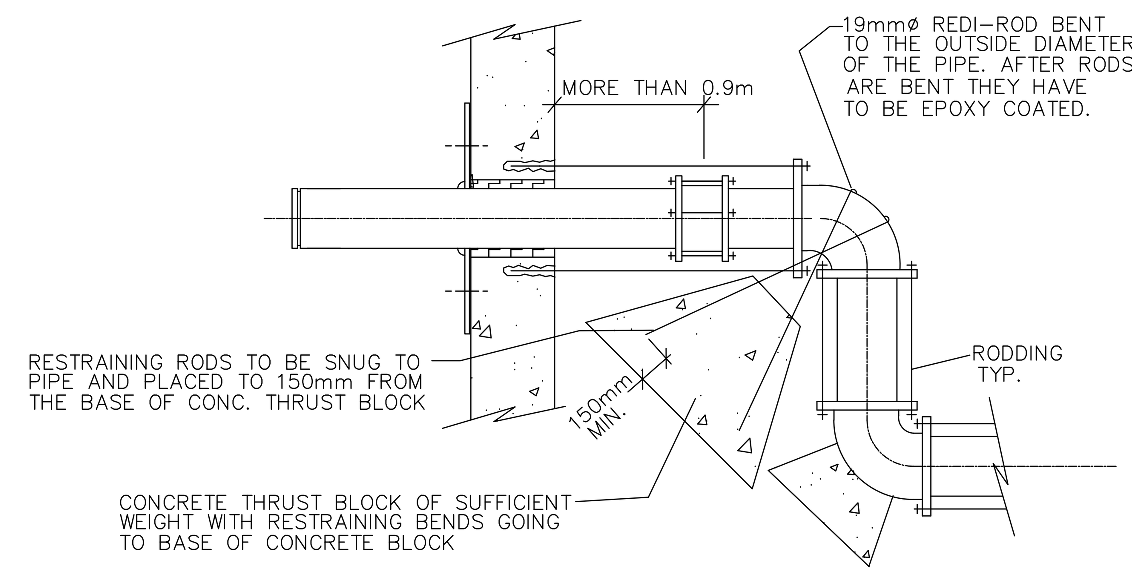
WATERMAIN DETAILS 1

Drawing Number: C206

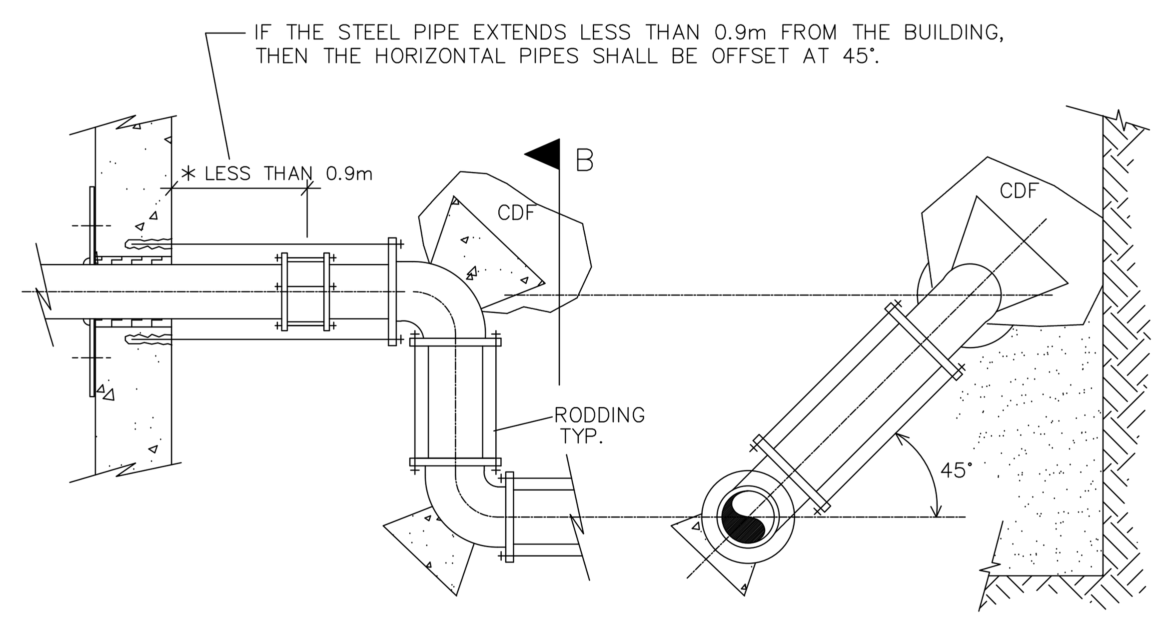
Revision: 1



PLAN VIEW (TYPICAL)



VERTICAL SECTION - ALTERNATE 1



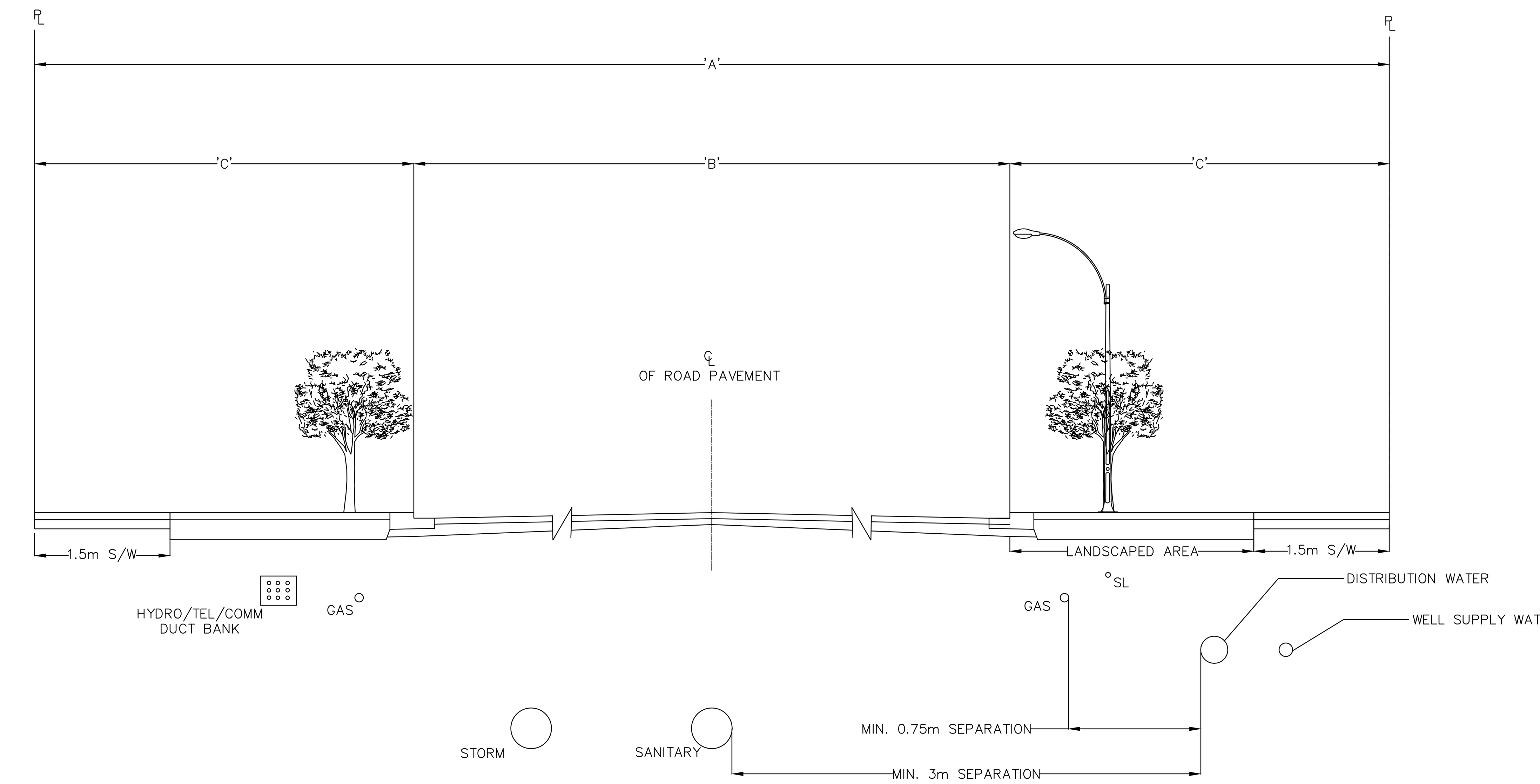
VERTICAL SECTION - ALTERNATE 2

SECTION B

WATERMAIN BUILDING PENETRATION NOTES:

1. ALL MATERIAL TO BE SUPPLIED AND INSTALLED BY CONTRACTOR UNLESS OTHERWISE SPECIFIED.
2. THRUST BLOCKS
- PLACE 6 mil POLYETHYLENE ON INTERFACE BETWEEN CONCRETE AND FITTING.
- PLACE 20 MPa CONCRETE AGAINST UNDISTURBED GROUND; KEEP CONCRETE CLEAR OF FITTING JOINTS.
- IF THRUST BLOCKS CANNOT BE PLACED AGAINST UNDISTURBED SOIL, THE SPACE BETWEEN THRUST BLOCK AND UNDISTURBED SOIL SHALL BE FILLED WITH CONTROL DENSITY FILL (CDF).
3. THRUST FLANGE
- 1/2" STEEL PLATE WELDED TO SCH. 80 A106-B STEEL PIPE XH WALL
- EPOXY LINED AND COATED
4. DETAIL FROM UBC TECHNICAL GUIDELINES NO. 1140-UT-03-WaterEntry.dwg

TYPICAL WATERMAIN BUILDING PENETRATION DETAIL
N.T.S



TYPICAL ROAD SECTION WITH UTILITIES
N.T.S

TYPICAL SECTION NOTES:

1. 'A' WIDTH TO RANGE FROM 15.1m TO 20.0m; 'B' WIDTH TO VARY FROM 6.6m TO 11.0m; 'C' WIDTH TO VARY FROM 4.45m TO 4.50m. REFER TO CITY OF SURREY DETAIL SSD-R.3 FOR FURTHER INFORMATION.
2. UTILITY TRENCH FOR BOTH THE DISTRIBUTION AND WELL SUPPLY WATER PIPES TO FOLLOW PROVIDED DETAIL.
3. ANY DEVIATION FROM MINIMUM SEPARATION TO BE APPROVED BY UBC ENERGY & WATER SERVICES PRIOR TO INSTALLATION.
4. DETAIL REFERENCED FROM CITY OF SURREY SUPPLEMENTARY STANDARD DRAWING SSD-R.3 (2020) WITH MODIFICATIONS.

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UBC Sustainability

Prime Consultant

Sub-Consultant

Scale: AS SHOWN

Drawn by	LL	04/12/21
Designed by	LL	04/12/21
Checked by		
Approved by		

UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

WATERMAIN DETAILS 2

Drawing Number: C207

Revision: 1

SEE DWG C206-207 FOR WATERMAIN DETAILS

LEGEND

PROPOSED

WATERMAIN TO RESERVOIR – PH1	— W —
WATERMAIN TO RESERVOIR – PH1	— W —
WATER PIPE FROM RESERVOIR	— W —
WATER VALVE	⋈
WATER HYDRANT	⌖
PROPOSED WELL – PH1	●
PROPOSED WELL – PH2	●

EXISTING

WATER MAIN	— W —
SANITARY SEWER MAIN	— S —
SANITARY SEWER FORCEMAIN	— FM —
STORM SEWER MAIN	— D —
STORM DITCH	——
TELECOMMMUNICATIONS	— TEL —
DISTRICT ENERGY	— DES —
ELECTRICAL	— UE —
GAS MAIN	— G —

WATER DISTRIBUTION NOTES

1. DETAILED DESIGN TO BE COMPLETED BY SUB-CONSULTANT.
2. HYDRAULIC ANALYSIS WAS COMPLETED IN EPANET 2.2.

DISTRIBUTION NETWORK TO SERVICE POINTS PLAN

1:2500

NOT FOR CONSTRUCTION

April 7, 2021

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Owner: UBC Sustainability

Prime Consultant

Sub-Consultant

Scale: 1:2500

Drawn by	GM	04/12/21
Designed by	GM	04/12/21
Checked by		
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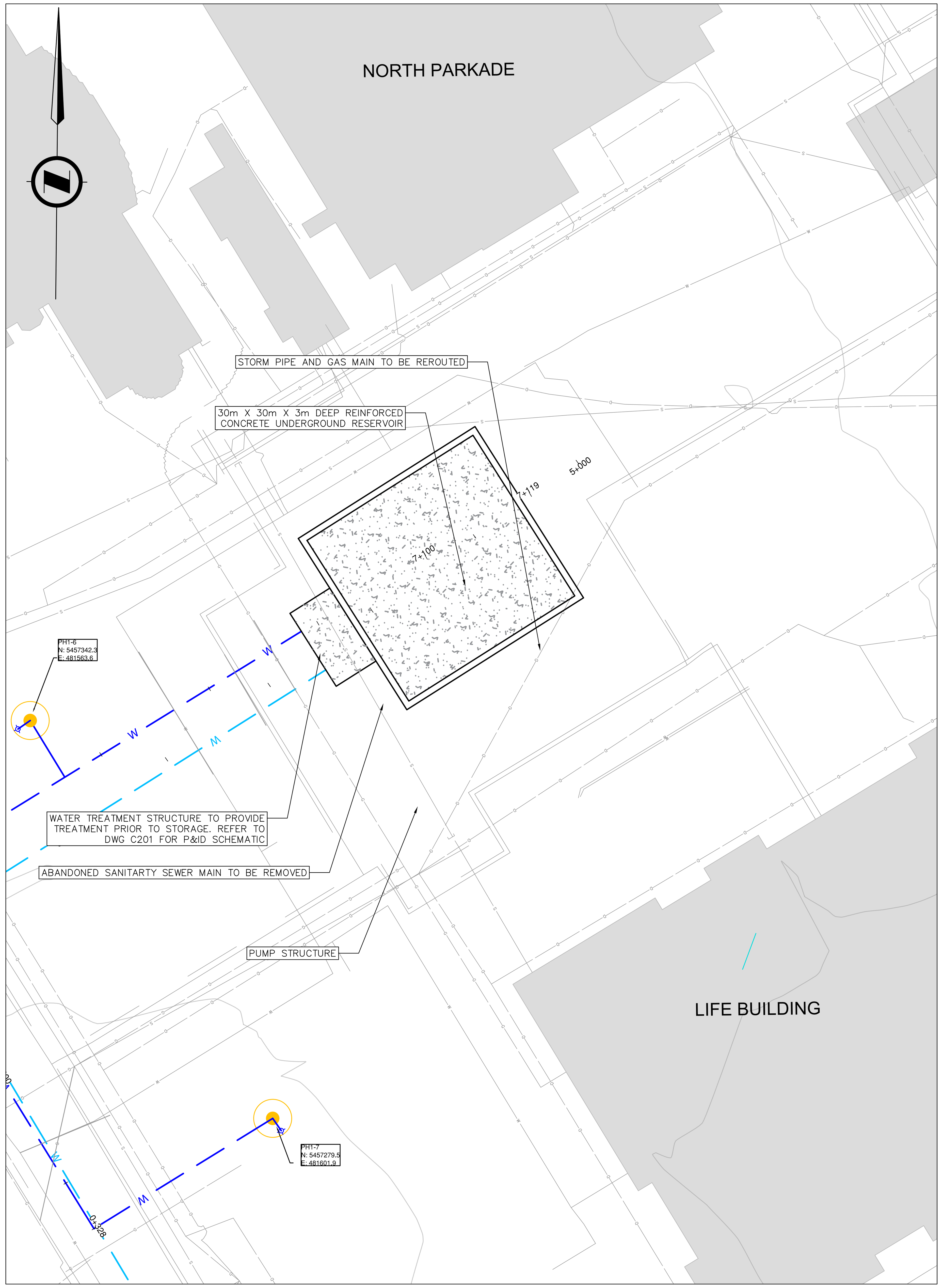
UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

DISTRIBUTION NETWORK TO SERVICE POINTS PLAN

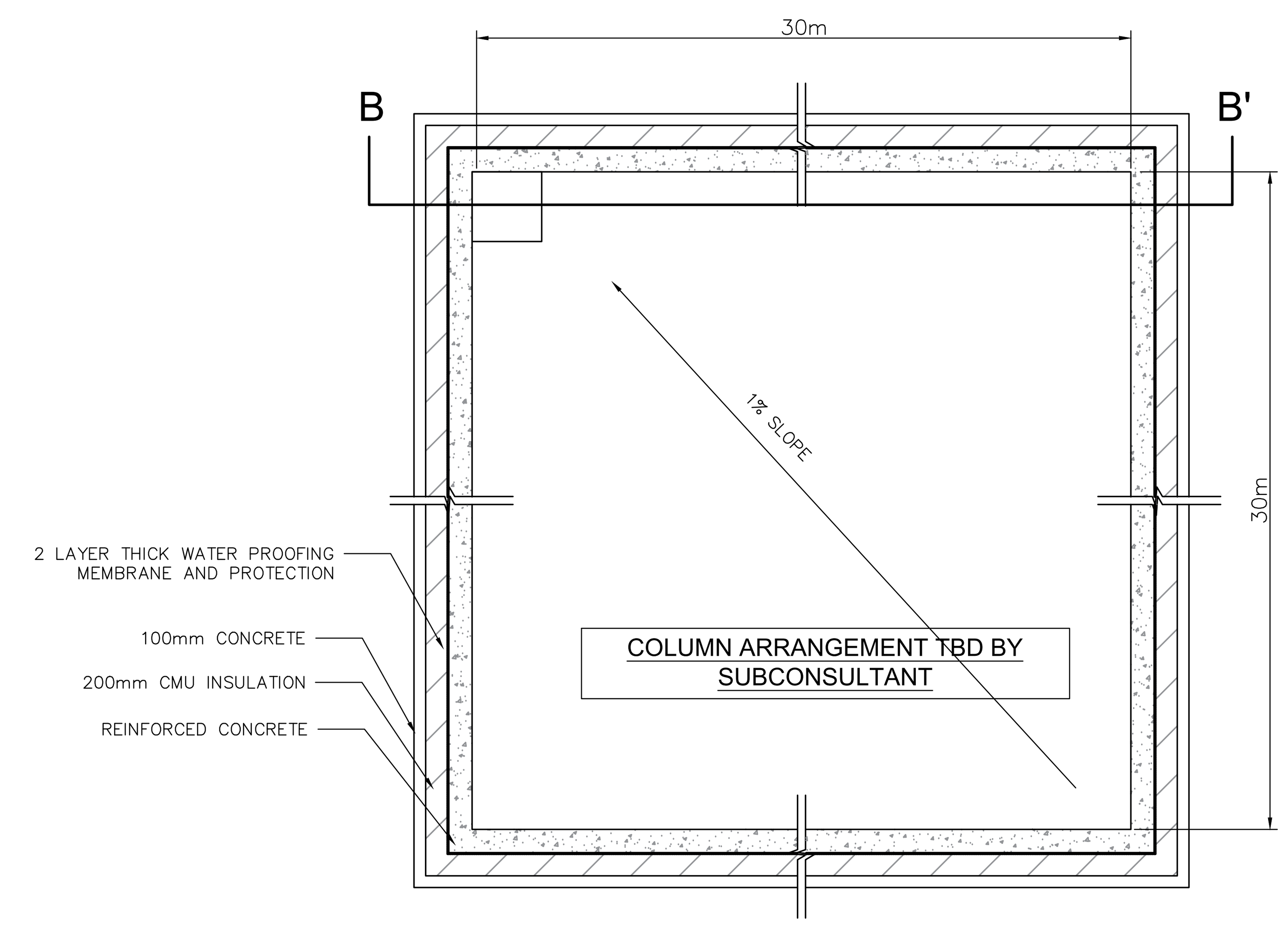
Drawing Number: C301

Revision: 1



SITE PLAN OF RESERVOIR

1:500

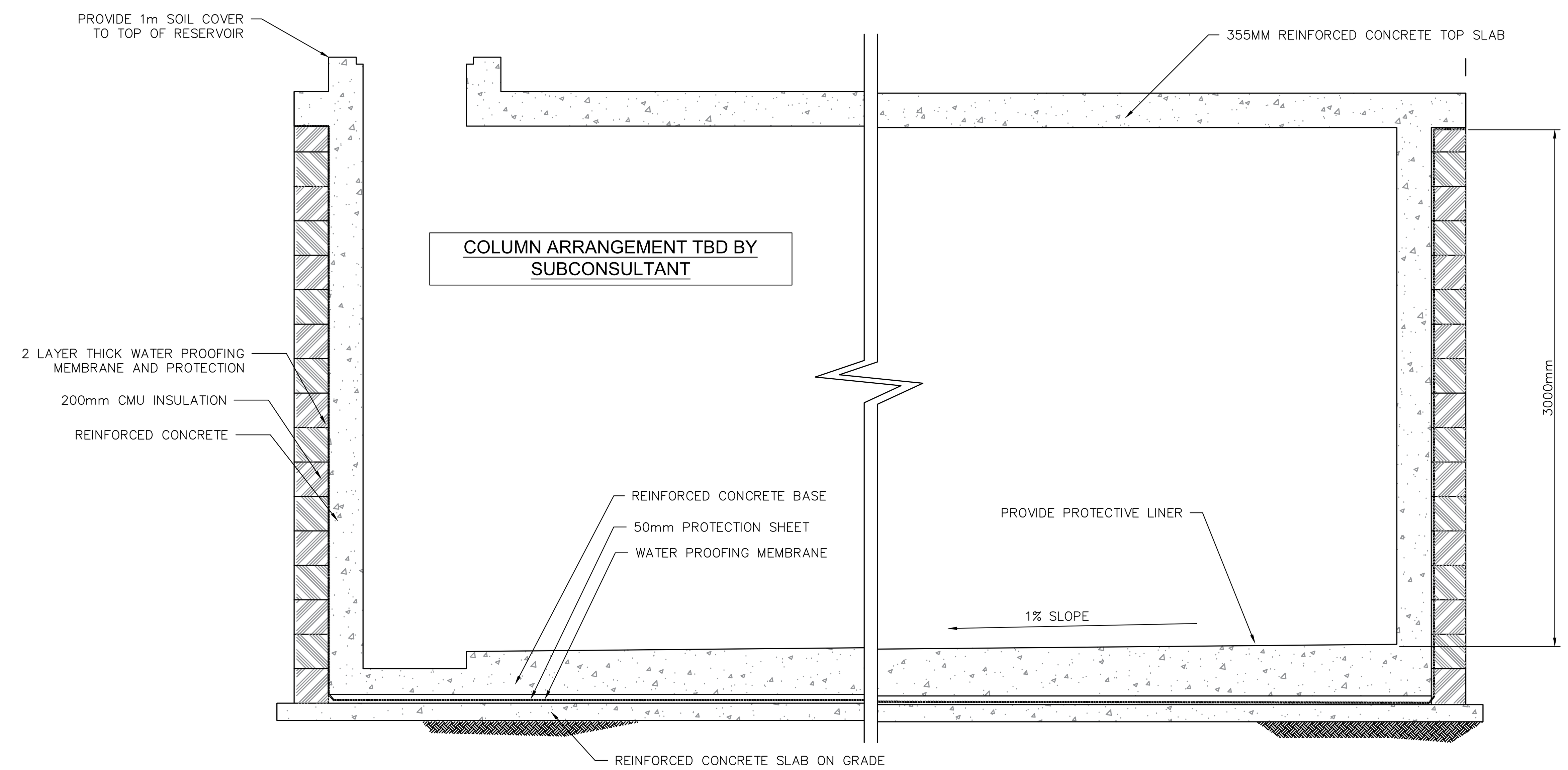


PLAN

NTS

RESERVOIR NOTES

1. DETAILED DESIGN TO BE COMPLETED BY SUB-CONSULTANT.



CROSS SECTION B-B'

NTS

NOT FOR CONSTRUCTION

April 7, 2021

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Owner

UBC Sustainability

Prime Consultant

Sub-Consultant

Scale: AS SHOWN

Drawn by	GM	04/12/21
Designed by	GM	04/12/21
Checked by		
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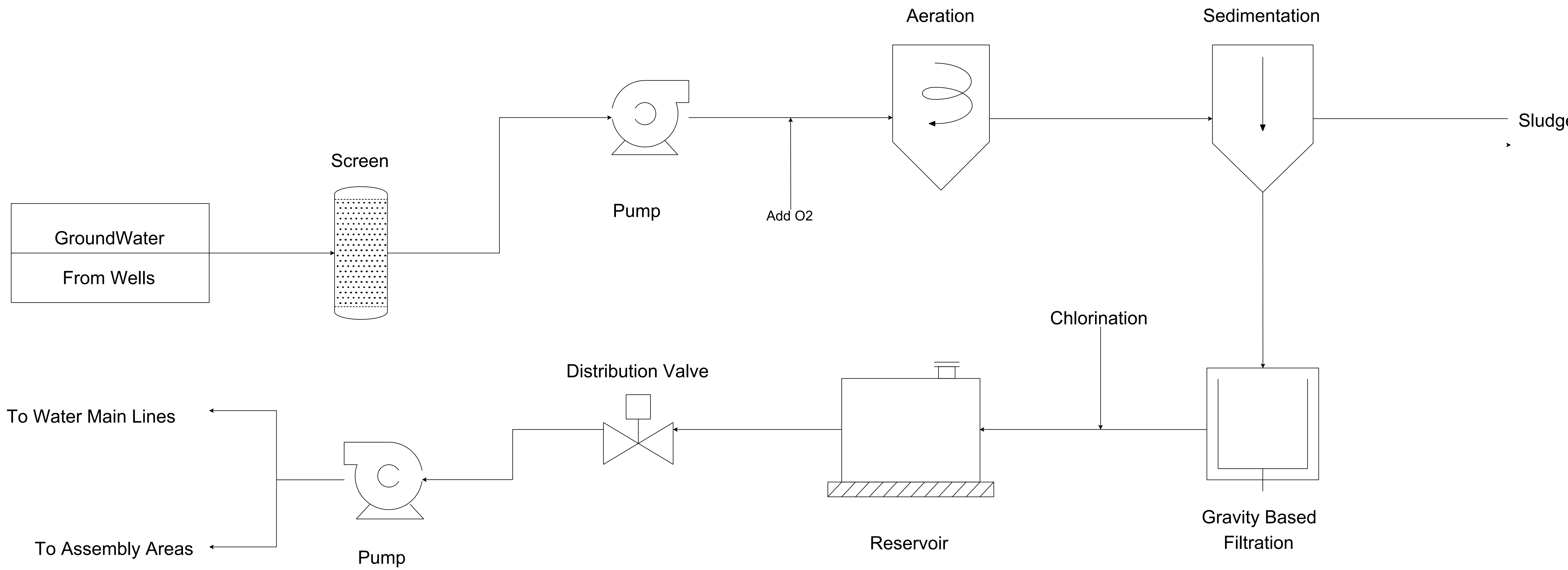
UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

RESERVOIR DESIGN

Drawing Number: S001

Revision: 1



WATER TREATMENT PROCESS

NOTES:
1. THIS DRAWING IS PRELIMINARY AND SIMPLIFIED, IT IS JUST MEANT TO HIGHLIGHT THE MAJOR TREATMENT STEPS.
2. THE TREATMENT BUILDING WILL BE LOCATED RIGHT NEXT TO THE RESERVOIR AND THE WATER FROM ALL THE WELLS WILL BE PIPED TO THE BUILDING
3. PIPING USED WILL BE THE SAME AS THAT INDICATED IN THE DISTRIBUTION SYSTEM CAD DRAWING. THE SAME SPECIFICATIONS WILL BE MAINTAINED.
4. TREATMENT OF POTABLE WATER IS DONE IN ACCORDANCE TO THE CANADIAN DRINKING WATER GUIDELINES.
5. CHLORINE LEVEL OF THE WATER EXITING THE RESERVOIR WILL BE CHECKED AT THE DISTRIBUTION VALVE.
6. WATER TREATMENT DETAILED DESIGN TO BE DESIGNED BY A SUB-CONSULTANT

WARNING
THE SIZE, DEPTH AND LOCATION OF THE EXISTING OVERHEAD AND UNDERGROUND UTILITIES AND RESPECTIVE STRUCTURES SHOWN ARE APPROXIMATE AND ARE FOR GUIDANCE ONLY. THE COMPLETENESS OR ACCURACY OF THIS INFORMATION IS NOT GUARANTEED. IT SHALL BE THE CONTRACTOR'S SOLE RESPONSIBILITY TO VERIFY THE LOCATION OF THE FACILITIES PRIOR TO COMMENCING WORK, AND TO ADVISE THE CONSULTANT OF ANY POTENTIAL CONFLICT.

#	Date	Issue / Revision	Appr.
0	12/20	PRELIMINARY DESIGN	
1	04/21	DETAILED DESIGN IFC	

Owner

Prime Consultant

Sub-Consultant

Scale: NTS

Drawn by	KO	04/12/21
Designed by	KO	04/12/21
Checked by		
Approved by		

UBC GROUNDWATER EMERGENCY SUPPLY PROJECT

UBC POINT GREY CAMPUS

WATER TREATMENT DIAGRAM

Drawing Number: M001

Revision: 1

Appendix B

Water Demand Calculations

Water Demand Calcuation

Water Demand Activities	11000	permanent residents
	9000	seasonal residents (september to april)
	35000	daytime residents --> assume that daytime residents would stay on campus
	34490	residents within walking distance (west point gray + dunbar-southlands population within a 1 hour walking distance)
		Academic water use
		UBC Agriculture use
	332	UBC Hospital in-patient beds
	55990	Students
	16447	Faculty and Staff

Minimum Water Demand for Major Emergency

Type	Unit	ADD (L/unit/day)	Value	ADD (L/day)	ADD (L/s)	Source	Notes		
Population (Domestic Use)	person	**15**	89490	1342350	15.53646	Table 9.1 WHO Technical notes on drinking-water, sanitation and hygiene in emergencies	Water use needed for drinking and food, basic hygiene practices and basic cooking needs (7.5lpd to 15lpd). Higher end chosen due to populations limited practice conserving water.		
UBC Hospital	Bed	**1000**	332	332000	3.84259	"Hospital" MMCD 2004 Figure 2.1 page 13	MMCD value was selected since it was only a 20% reduced water usage demand (3.84L/s compared to normal 4.82 L/s water usage)		
Washroom Facilities (toilets)	person	**16**	89490	1431840	16.57222	Table 9.2 WHO Technical notes on drinking-water, sanitation and hygiene in emergencies	Flushing Toilets: 20-40 liters/user/day. Assume 60% failure of sewer system		
Washroom Facilities (hand-washing)	person	**0.8**	89490	71592	0.82861	Table 9.2 WHO Technical notes on drinking-water, sanitation and hygiene in emergencies	Public Toilets: 1-2 liters/user/day. Assume 60% failure of sewer system.		
Water Leaks	Percentage of UBC 2017 total water usage	5% of total water usage		158889	1.83899	UBC Water Management Plan: Normal Water Usage based on 2017 and 2019 data	5% of the total water transmitted through the system.		
			2020 Demand	**3336671**	**38.61888**		assume MDD = 1.6xADD	**5338674**	**2020 L/day**
			2050 Demand	**6043918**	**69.95275**		assume MDD = 1.6xADD	**9670269**	**2020 L/sec**
							assume MDD = 1.6xADD	**0**	**2050 L/day**
							assume MDD = 1.6xADD	**0**	**2050 L/sec**

Reservoir Storage Tank Calculations

Required to meet fire flow, and to offset instantaneous demand

Components	A	Fire Flow	From Surrey, institutional 120L/s for 1.5hr; high rise residential 200 L/s
	B	Equilization Storage	PHD for 150 minutes
	C	Emergency	0.25 (A+B)

	A (FF)	B (Equalization)	C (Emergency)	Total (L)		Total (m3)
2020 Volume	1080000	597514	419379	2096893		**2097**
2050 Volume	1080000	1082314	540579	2702893		**2700**
	V = Qt	V = (PHD)150min	V = (A+B)0.25			

Appendix C

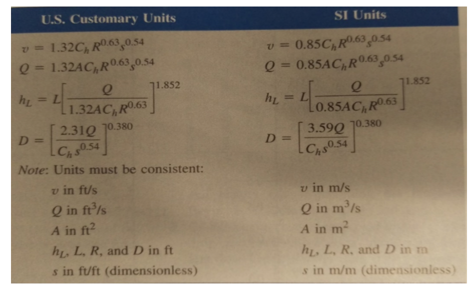
Pump and System Curve Calculations

Dsitribution from Wells to Reservoir

Watermain System Curve - Initial Estimates for Pump Curve (not final system curve)

System Parameters	Material	H-W C Factor	I.D	Length	
East Mall Feeder Main	DI	120	**200.00**	**369**	m
Connection to Feeder Main	DI	120	**150.00**	**366**	m
					m
			TOTAL	**735**	

*** assume pressure constant sustained thorughout of 40psi at discharge and distribution locations**


U.S. Customary Units

$v = 1.32 C_h R^{0.63} s^{0.54}$

$Q = 1.32 A C_h R^{0.63} s^{0.54}$

$h_L = L\left[\frac{Q}{1.32 A C_h R^{0.63}}\right]^{1.852}$

$D = \left[\frac{2.31 Q}{C_h s^{0.54}}\right]^{0.380}$

Note: Units must be consistent:

v in ft/s

Q in ft^3/s

A in ft^2

h_L, L, R, and D in ft

s in ft/ft (dimensionless)

SI Units

$v = 0.85 C_h R^{0.63} s^{0.54}$

$Q = 0.85 A C_h R^{0.63} s^{0.54}$

$h_L = L\left[\frac{Q}{0.85 A C_h R^{0.63}}\right]^{1.852}$

$D = \left[\frac{3.59 Q}{C_h s^{0.54}}\right]^{0.380}$

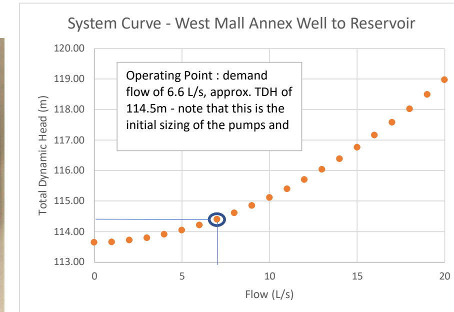
v in m/s

Q in m^3/s

A in m^2

h_L, L, R, and D in m

s in m/m (dimensionless)



Well Base Elevation	**-0.5**	**m ASL**
Discharge Elevation	85.0	m ASL
Required Pressure	28.1	m water column
Discharge Elevation at Reservoir	**113.1**	**m**

	200mm FM			**150mm FM**		
Fittings k Factors (FM):	**k-factor**	**Quantity**	**Tot. k**	**k-factor**	**Quantity**	**Tot. k**
Discharge Cnnx	**0.3**	**0**	**0.0**	**0.3**	**1**	**0.3**
Elbows	**0.2**	**1**	**0.2**	**0.2**	**2**	**0.4**
Inlet	**1**	**0**	**0.0**	**1**	**0**	**0.0**
Non-return valves	**0.9**	**0**	**0.0**	**0.9**	**1**	**0.9**
Tee	**0.4**	**7**	**2.8**	**0.4**	**0**	**0.0**
Valve	**0.3**	**13**	**3.9**	**0.3**	**1**	**0.3**
		sum	6.9		**sum**	1.9

H vs. Q

FLOW RATE	v	HGL at	200mm FM		150mm FM		Disch.	Suction	TDH	Flow	Head
(l/s)	(m/s)	Discharge	Pipe	Fitting	Pipe	Fitting	HGL	HGL	m	USGPM	ft
0	0.000	113.142	0.000	0.000	0.000	0.000	113.14	-0.50	113.64	0.00	372.75
1	0.032	113.142	0.004	0.000	0.016	0.000	113.16	-0.50	113.66	15.85	372.81
2	0.064	113.142	0.014	0.001	0.057	0.001	113.22	-0.50	113.72	31.70	372.99
3	0.095	113.142	0.030	0.003	0.121	0.003	113.30	-0.50	113.80	47.55	373.26
4	0.127	113.142	0.051	0.006	0.206	0.005	113.41	-0.50	113.91	63.40	373.62
5	0.159	113.142	0.077	0.009	0.311	0.008	113.55	-0.50	114.05	79.25	374.07
6	0.191	113.142	0.108	0.013	0.436	0.011	113.71	-0.50	114.21	95.10	374.61
7	0.223	113.142	0.144	0.017	0.580	0.015	113.90	-0.50	114.40	110.95	375.23
8	0.255	113.142	0.185	0.023	0.743	0.020	114.11	-0.50	114.61	126.80	375.93
9	0.286	113.142	0.230	0.029	0.924	0.025	114.35	-0.50	114.85	142.65	376.71
10	0.318	113.142	0.279	0.036	1.123	0.031	114.61	-0.50	115.11	158.50	377.56
11	0.350	113.142	0.333	0.043	1.340	0.038	114.90	-0.50	115.40	174.35	378.50
12	0.382	113.142	0.391	0.051	1.575	0.045	115.20	-0.50	115.70	190.20	379.51
13	0.414	113.142	0.453	0.060	1.826	0.052	115.53	-0.50	116.03	206.05	380.59
14	0.446	113.142	0.520	0.070	2.095	0.061	115.89	-0.50	116.39	221.91	381.75
15	0.477	113.142	0.591	0.080	2.380	0.070	116.26	-0.50	116.76	237.76	382.98
16	0.509	113.142	0.666	0.091	2.682	0.079	116.66	-0.50	117.16	253.61	384.29
17	0.541	113.142	0.745	0.103	3.001	0.090	117.08	-0.50	117.58	269.46	385.67
18	0.573	113.142	0.828	0.115	3.336	0.100	117.52	-0.50	118.02	285.31	387.11
19	0.605	113.142	0.916	0.129	3.687	0.112	117.99	-0.50	118.49	301.16	388.63
20	0.637	113.142	1.007	0.143	4.055	0.124	118.47	-0.50	118.97	317.01	390.22

Well Head Calculations - Detailed Design

Well Pipe	
Pipe Material	Steel
Friction	140
Distribution Pipe	
Pipe Material	Ductile Iron
Friction	140

Flow Rate in each well	**0.0066 m^3/s**
Reservoir Elevation	85 m-ASL
Required Pressure	40 PSI
	92.4 ft of head
	28.16 m of head

SI units [edit]

When used to calculate the head loss with the International System of Units, the equation becomes:[12]

$$S = \frac{h_f}{L} = \frac{10.67\, Q^{1.852}}{C^{1.852}\, d^{4.8704}}$$

where:

- S = Hydraulic slope
- h_f = head loss in meters (water) over the length of pipe
- L = length of pipe in meters
- Q = volumetric flow rate, m^3/s (cubic meters per second)
- C = pipe roughness coefficient
- d = inside pipe diameter, m (meters)

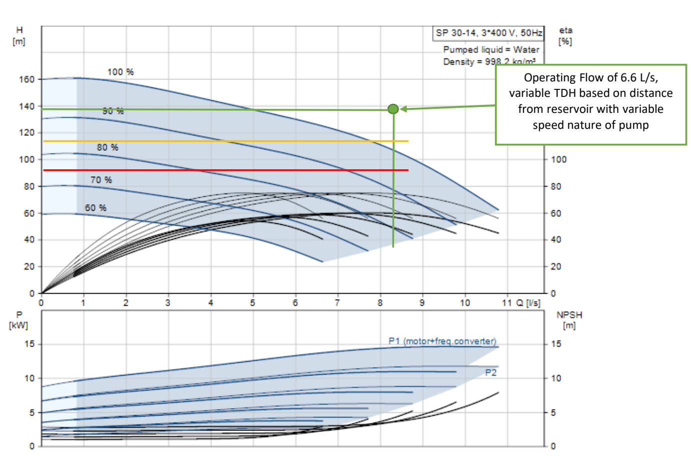
Note: pressure drop can be computed from head loss as h_f × the unit weight of water (e.g., 9810 N/m^3 at 4 deg C)

Calculations by: Gabriella Monagan
Updated by: Lauren Lee
Updated date: 2021-04-06

Phase 1 Wells | Phase 2 Wells

Well Information						Well				Well Dept	Distribution				Final Head Calculations	
Well Location	Elevation	Water Table	Well Depth	Elevation Head	Pressure Head	Flow	Pipe Diameter	Well Pipe Length	Friction Head	Total Head ([m]	Flow	Pipe Diameter	Dist. Pipe Length	Friction Head	Total Friction Head	Total Well Head
	[m-ASL]	[m-ASL]	[m-ASL]	[m]	[m]	[m^3/s]	[mm]	[m]	[m]	[m]	[m^3/s]	[mm]	[m]	[m]	[m]	[m]
Chan Centre	77	7	-0.5	85.5	28.16	0.0066	100	77.5	0.5957	114.2592	0.0066	150	505	0.5387	1.134	114.798
Allard Law North	73	7	-0.5	85.5	28.16	0.0066	100	73.5	0.5650	114.2285	0.0066	150	384	0.4097	0.975	114.638
Allard Law South	84	7	-0.5	85.5	28.16	0.0066	100	84.5	0.6495	114.3130	0.0066	150	274	0.2923	0.942	114.605
St Andrews	80.8	7	-0.5	85.5	28.16	0.0066	100	81.3	0.6249	114.2884	0.0066	150	405	0.4321	1.057	114.721
IKB North	87.5	7	-0.5	85.5	28.16	0.0066	100	88	0.6764	114.3399	0.0066	150	290	0.3094	0.986	114.649
IKB South	85.4	7.5	-0.5	85.5	28.16	0.0066	100	85.9	0.6603	114.3238	0.0066	150	181	0.1931	0.853	114.517
Life Building	84.2	7.5	-0.5	85.5	28.16	0.0066	100	84.7	0.6510	114.3146	0.0066	150	52	0.0555	0.707	114.370
School of Music	79.5	4	-0.5	85.5	28.16	0.0066	100	80	0.6149	114.2784	0.0066	150	506.55	0.5404	1.155	114.819
West Mall Annex	77.5	4.5	-0.5	85.5	28.16	0.0066	100	78	0.5995	114.2631	0.0066	150	661	0.7052	1.305	114.968
Econ West	77.6	4.5	-0.5	85.5	28.16	0.0066	100	78.1	0.6003	114.2638	0.0066	150	650	0.6934	1.294	114.957
Econ East	78.2	4.5	-0.5	85.5	28.16	0.0066	100	78.7	0.6049	114.2685	0.0066	150	735.3	0.7844	1.389	115.053

Selected Pump:	Grundfos SP 30-14



Reservoir to Distribution Points - Initial Hydraulic Analysis Using EPANET

Analysis Date: 2020-11-29 8:07:44 PM

EPANET
Hydraulic And Water Quality
Analysis for Pipe Networks

Version: 2.2
Input File: Capstone 1.net

Completed by: Lauren Lee

Flow Demands	
Nodes	**PHD (L/s)**
Total PHD (2050)	147
Hospital Node	15
All Other Handwashing/Res Nodes	132
Node Count	4
Per Node Split	33
AMS Nest	33
Doug Mitchell	33
Forestry	33
Chan Centre	33

Pressure Demands	
Min Pressure (kPa)	275
Min Pressure (m)	28
Max Pressure (kPa)	1035
Max Pressure (m)	106

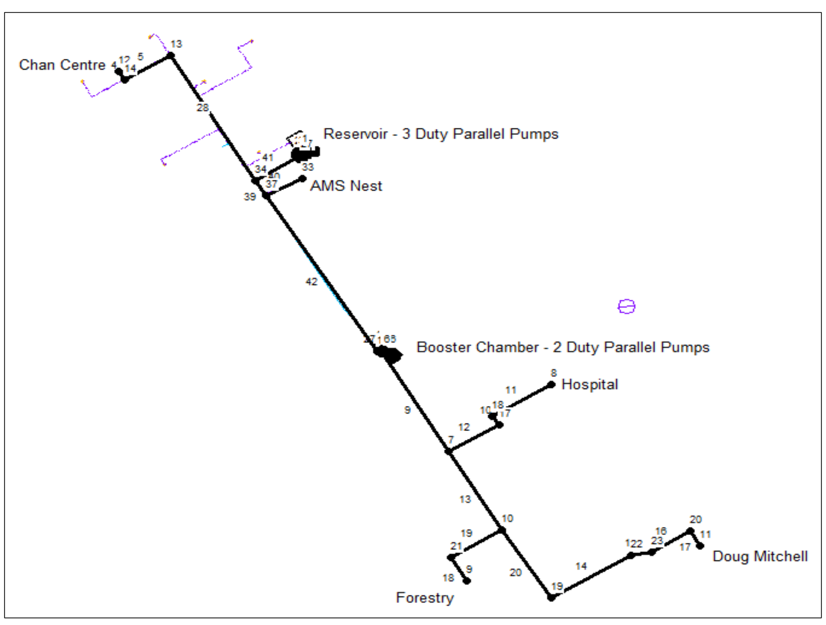
Velocity Demands	
Max Velocity Under PHD (m/s)	3.5

Final Pump Curve		
ID	**Flow (LPS)**	**Head (m)**
Curve1	0	108
Curve1	10	105
Curve1	20	103
Curve1	30	100
Curve1	40	92
Curve1	50	81
Curve1	60	64
Curve1	65	54

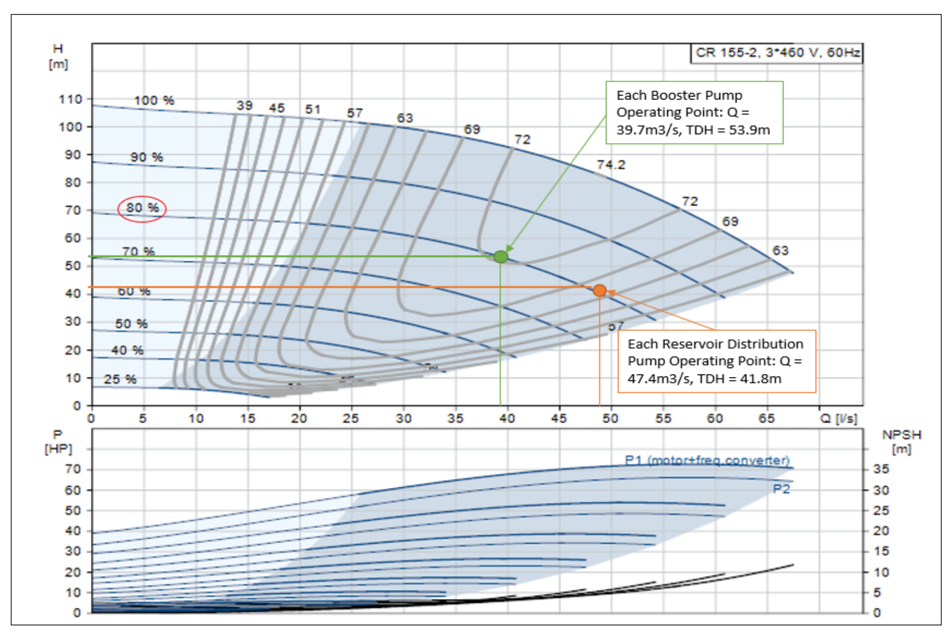
Link Attributes											
Type	**Link**	**Start**	**End**	**Length**	**Diameter**	**Flow**	**Velocity**	**Below Max V?**	**Headloss**	**Status**	**Notes**
	ID	Node	Node	m	mm	LPS	m/s		m/km		
Pipe	4	14	12	59.4	300	32	0.45	YES	0.78	Open	
Pipe	5	13	14	281.55	300	32	0.45	YES	0.78	Open	
Pipe	9	16	7	680.68	300	79.4	1.12	YES	4.19	Open	
Pipe	10	17	18	59.2	200	15.4	0.49	YES	1.45	Open	
Pipe	11	18	8	359	200	15.4	0.49	YES	1.45	Open	
Pipe	12	7	17	304.21	200	15.4	0.49	YES	1.45	Open	
Pipe	13	7	10	540.72	200	64	2.04	YES	20.26	Open	
Pipe	14	19	22	486.94	200	32	1.02	YES	5.61	Open	
Pipe	15	22	23	107.47	200	32	1.02	YES	5.61	Open	
Pipe	16	23	20	234.7	200	32	1.02	YES	5.61	Open	
Pipe	17	20	11	101.05	200	32	1.02	YES	5.61	Open	
Pipe	18	21	9	163.3	200	32	1.02	YES	5.61	Open	
Pipe	19	10	21	310.02	200	32	1.02	YES	5.61	Open	
Pipe	20	10	19	478.55	200	32	1.02	YES	5.61	Open	
Pipe	21	1	31	2.3	300	143.4	2.03	YES	12.53	Open	
Pipe	22	31	29	1.63	300	143.4	2.03	YES	12.53	Open	
Pipe	28	34	13	861.99	300	32	0.45	YES	0.78	Open	
Pipe	8	29	4	0.33	300	47.35	0.67	YES	1.61	Open	
Pipe	23	25	5	0.34	300	-47.35	0.67	YES	1.61	Open	
Pipe	2	27	29	0.55	300	-48.69	0.69	YES	1.69	Open	
Pipe	6	3	25	0.55	300	48.69	0.69	YES	1.69	Open	
Pipe	27	15	35	31.1	300	79.4	1.12	YES	4.19	Open	
Pipe	38	36	16	19.87	300	79.4	1.12	YES	4.19	Open	
Pipe	39	34	37	109.5	300	111.4	1.58	YES	7.85	Open	
Pipe	40	37	33	218.61	200	32	1.02	YES	5.61	Open	
Pipe	41	25	34	283.25	300	143.4	2.03	YES	12.53	Open	
Pipe	42	37	15	1088.18	300	79.4	1.12	YES	4.19	Open	
Pipe	7	35	2	1	300	39.7	0.56	YES	1.16	Open	
Pipe	25	6	36	1	300	39.7	0.56	YES	1.15	Open	
Pump	29	29	25	#N/A	#N/A	47.35	0	N/A	-41.84	Open	Pump, Speed 80%
Pump	24	4	5	#N/A	#N/A	47.35	0	N/A	-41.84	Open	Pump, Speed 80%
Pump	3	27	3	#N/A	#N/A	48.69	0	N/A	-41.84	Open	Pump, Speed 80%
Pump	37	35	36	#N/A	#N/A	39.7	0	N/A	-53.86	Open	Pump, Speed 80%
Pump	1	2	6	#N/A	#N/A	39.7	0	N/A	-53.86	Open	Pump, Speed 80%

Node Results										
Type	**Node**	**Elevation**	**Demand**	**Flow Met?**	**Head**	**Pressure**	**Descrip.**	**Meet Min Pres?**	**Below Max Pres?**	**Notes**
	ID	m	LPS		m	m				
Junction	7	92	0	N/A	170.71	78.71		YES	YES	
Junction	8	89.7	15.4	Yes	169.66	79.96	;Hospital	YES	YES	
Junction	9	93	32	Yes	157.09	64.09	;Forestry	YES	YES	
Junction	10	94.5	0	N/A	159.75	65.25	;	YES	YES	
Junction	11	96	32	Yes	151.84	55.84	;DougM	YES	YES	
Junction	12	76.8	32	Yes	124.4	47.6	;Chan	YES	YES	
Junction	13	78.2	0	N/A	124.67	46.47		YES	YES	
Junction	14	77	0	N/A	124.45	47.45		YES	YES	
Junction	15	87.3	0	N/A	119.92	32.62		YES	YES	
Junction	16	87.3	0	N/A	173.56	86.26		YES	YES	
Junction	17	91.8	0	N/A	170.27	78.47		YES	YES	
Junction	18	91.3	0	N/A	170.18	78.88		YES	YES	
Junction	19	95.5	0	N/A	157.06	61.56		YES	YES	
Junction	20	95.5	0	N/A	152.41	56.91		YES	YES	
Junction	21	95	0	N/A	158.01	63.01		YES	YES	
Junction	22	96.5	0	N/A	154.33	57.83		YES	YES	
Junction	23	96.5	0	N/A	153.73	57.23		YES	YES	
Junction	25	84.3	0	N/A	128.89	44.59		YES	YES	
Junction	29	84.3	0	N/A	87.05	2.75		N/A	YES	Low pressure at pump effl., disregard model assumption
Junction	31	84.3	0	N/A	87.07	2.77		N/A	YES	Low pressure at pump effl., disregard model assumption
Junction	33	84.5	32	Yes	123.25	38.75	;Nest	YES	YES	
Junction	34	85.1	0	N/A	125.34	40.24		YES	YES	
Junction	4	84.3	0	N/A	87.05	2.75		N/A	YES	Low pressure at pump effl., disregard model assumption
Junction	5	84.3	0	N/A	128.89	44.59		YES	YES	
Junction	3	84.3	0	N/A	128.89	44.59		YES	YES	
Junction	27	84.3	0	N/A	87.05	2.75		N/A	YES	Low pressure at pump effl., disregard model assumption
Junction	35	87.3	0	N/A	119.79	32.49		YES	YES	
Junction	36	87.3	0	N/A	173.65	86.35		YES	YES	
Junction	37	86.1	0	N/A	124.48	38.38		YES	YES	
Junction	2	87.3	0	N/A	119.79	32.49		YES	YES	
Junction	6	83	0	N/A	173.65	90.65		YES	YES	
Reservoir	1	87.1	-143.4	N/A	87.1	0		N/A	N/A	

EPANET Model Map



Grundfos Pump Curve



Watermain System Curve - Initial Estimates for Pump Curve (not final system curve)

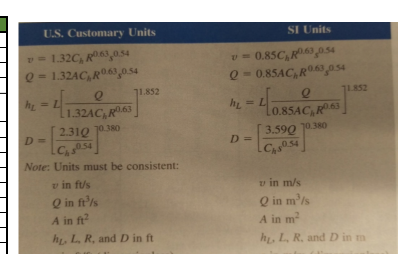
System Parameters	Material	I.D	Length	
Watermain to Farthest T	DI	200.00	1274.7	m
				m
	TOTAL		1274.7	

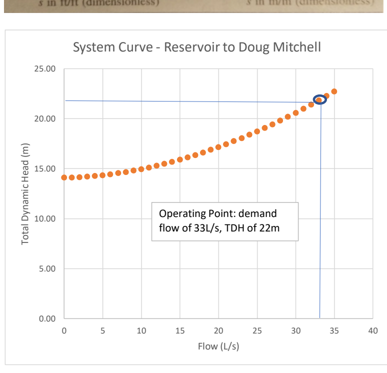
*** assume pressure constant sustained thorughout of 275kPa at discharge and distribution locations**

Surface Elevation of Reservoir	**84**	m
Net Reservoir Cover	**3**	m
Pump Elevation	**81**	m
Surface Elevation of Distribution Location	**96**	m
Net Pipe Cover	**0.9**	m
Discharge Elevation	**95.1**	m
Hazen-Williams C Factor	**130**	

Fittings k Factors (FM):	**k-factor**	**Quantity**	**Tot. k**
Discharge Cnnx	0.3	0	0.0
Elbows	0.2	3	0.6
Inlet	1	0	0.0
Non-return valves	0.9	0	0.0
Tee	0.4	0	0.0
Valve	0.3	6	1.8
		sum	2.4

H vs. Q									
FLOW RATE	**v**	**HGL at**	**FM**		**Disch.**	**Suction**	**TDH**	**Flow**	**Head**
(l/s)	**(m/s)**	**Discharge**	**Pipe**	**Fitting**	**HGL**	**HGL**	**m**	**USGPM**	**ft**
0	0.000	95.1	0.000	0.000	95.10	81.00	14.10	0.00	46.25
1	0.032	95.1	0.012	0.000	95.11	81.00	14.11	15.85	46.29
2	0.064	95.1	0.042	0.000	95.14	81.00	14.14	31.70	46.39
3	0.095	95.1	0.089	0.001	95.19	81.00	14.19	47.55	46.54
4	0.127	95.1	0.152	0.002	95.25	81.00	14.25	63.40	46.75
5	0.159	95.1	0.230	0.003	95.33	81.00	14.33	79.25	47.01
6	0.191	95.1	0.323	0.004	95.43	81.00	14.43	95.10	47.32
7	0.223	95.1	0.429	0.006	95.54	81.00	14.54	110.95	47.68
8	0.255	95.1	0.550	0.008	95.66	81.00	14.66	126.80	48.08
9	0.286	95.1	0.684	0.010	95.79	81.00	14.79	142.65	48.52
10	0.318	95.1	0.831	0.012	95.94	81.00	14.94	158.50	49.01
11	0.350	95.1	0.991	0.015	96.11	81.00	15.11	174.35	49.55
12	0.382	95.1	1.165	0.018	96.28	81.00	15.28	190.20	50.13
13	0.414	95.1	1.351	0.021	96.47	81.00	15.47	206.05	50.75
14	0.446	95.1	1.549	0.024	96.67	81.00	15.67	221.91	51.41
15	0.477	95.1	1.761	0.028	96.89	81.00	15.89	237.76	52.11
16	0.509	95.1	1.984	0.032	97.12	81.00	16.12	253.61	52.86
17	0.541	95.1	2.220	0.036	97.36	81.00	16.36	269.46	53.65
18	0.573	95.1	2.468	0.040	97.61	81.00	16.61	285.31	54.47
19	0.605	95.1	2.728	0.045	97.87	81.00	16.87	301.16	55.34
20	0.637	95.1	2.999	0.050	98.15	81.00	17.15	317.01	56.25
21	0.668	95.1	3.283	0.055	98.44	81.00	17.44	332.86	57.20
22	0.700	95.1	3.578	0.060	98.74	81.00	17.74	348.71	58.18
23	0.732	95.1	3.885	0.066	99.05	81.00	18.05	364.56	59.21
24	0.764	95.1	4.204	0.071	99.38	81.00	18.38	380.41	60.27
25	0.796	95.1	4.534	0.077	99.71	81.00	18.71	396.26	61.37
26	0.828	95.1	4.876	0.084	100.06	81.00	19.06	412.11	62.52
27	0.859	95.1	5.229	0.090	100.42	81.00	19.42	427.96	63.69
28	0.891	95.1	5.593	0.097	100.79	81.00	19.79	443.81	64.91
29	0.923	95.1	5.968	0.104	101.17	81.00	20.17	459.66	66.17
30	0.955	95.1	6.355	0.112	101.57	81.00	20.57	475.51	67.46
31	0.987	95.1	6.753	0.119	101.97	81.00	20.97	491.36	68.79
32	1.019	95.1	7.162	0.127	102.39	81.00	21.39	507.21	70.16
33	1.050	95.1	7.582	0.135	102.82	81.00	21.82	523.06	71.56
34	1.082	95.1	8.013	0.143	103.26	81.00	22.26	538.91	73.00
35	1.114	95.1	8.455	0.152	103.71	81.00	22.71	554.76	74.48





Water Demand for Major Emergency								
Type	Unit	D (L/unit/d	Value	ADD (L/s)	PHD 2020 (L/s)	HD 2050 (L/	Source	Notes
ion (Dome	person	15	89490	15.5	32.6	59.1	Table 9.1 WHO Technical notes on	Water use needed for drinking and food, basic hygiene practices and basic
BC Hospita	Bed	1000	332	3.8	8.1	14.6	"Hospital" MMCD 2004 Figure 2.1 page	MMCD value was selected since it was only a 20% reduced water usage
m Facilitie	person	16	89490	16.6	34.8	63.0	Table 9.2 WHO Technical notes on	Flushing Toilets: 20-40 liters/user/day. Assume 60% failure of sewer
acilities (ha	person	0.8	89490	0.8	1.7	3.2	Table 9.2 WHO Technical notes on	Public Toilets: 1-2 liters/user/day. Assume 60% failure of sewer system.
Water Leak	%	5% of total water usage		1.8	3.9	7.0	UBC Water Management Plan: Normal	5% of the total water transmitted through the system.
			Total	**38.6**	**81.1**	**146.9**		assume MDD = 1.6xADD, PHD = 2.1xADD from CoV

Appendix D

Construction Specifications

CONSTRUCTION SPECIFICATIONS FOR EMERGENCY WATER SUPPLY PROJECT

0200 - Well Installation

The following specifications are based on section 4.3 of the BC Design Guidelines for Rural Residential Community Water Systems

0201 - Well Location

Production wells must be fully accessible at all times via statutory rights of ways written in favour of the utility. Well sites must not be subjected to flooding and site grading must direct surface runoff away from the wellhead. Wells should be located separate from pump houses or other enclosures to facilitate access for future well redevelopment and rehabilitation. Electrical equipment, water treatment and disinfection can be incorporated into an adjacent (or centralized) enclosure. Kiosks in lieu of pump houses are an acceptable alternative in many areas. All wells, pump houses and kiosks must be located within a secure fenced compound to prevent vandalism and unauthorized access.

0202 - Well Drilling

Well drilling must be completed by (or under the direct supervision of) a Qualified Well Driller (QWD) registered in British Columbia. The QWD will work in conjunction with the engineering company in charge. Drill cuttings should be collected at regular intervals to determine the depth, thickness and characteristics of aquifers and aquitards (confining layers). It is recommended to take water samples during the drilling process and analyze the samples for water quality parameters in a lab. If those preliminary water samples suggest unsuitable water quality of the aquifer, then it may be more economical to drill in a new location rather than completing the well.

The well should be drilled using air-rotary rigs, but cable tool rigs can be used if needed. Care must be taken when constructing production wells using a different drilling method than were used to advance test wells.

0203 - Well Casing

Permanent well casings must be continuous and watertight. Production wells shall have a minimum casing diameter of 200 mm to allow installation of a nominal 100 mm diameter pump assembly. A minimum 8.2 mm wall thickness is required for 200 mm well casings.

The manufacturing standard for single-ply carbon steel well casing shall be as follows: ANSI/AWWA C200, ASTM A53 Grade B, ASTM A139 Grade B and ASTM A778. For larger diameter casings and/or site-specific structural requirements refer to AWWA A100-06

The casing must extend a minimum distance of 300 mm above finished grade. Top of the casing (not including the vented cap) for the wells must be at least 600 mm above the 100-year flood level of record.

0204 - Well Screens and Gravel Packs

Well screens should be commercially fabricated keystone wire-wound 304 or higher-grade stainless steel.

The well screen interval is dictated by the depth and thickness of water-bearing zones. Screen length should consider the total thickness of the aquifer and the increased efficiency which results from a longer screen. Public wells will require high-efficiency designs to maximize production and minimize long-term operating (including power) costs.

Care must be taken to locate the screen interval within the main portion of the formation to prevent the migration of fines into the screen during development. It is recommended to not extend the screen within 0.5 m of the aquifer top and bottom. Telescopic screen designs shall allow for at least 1.0 m of overlap and will be sealed against the production casing with an elastomeric seal (neoprene K-packer). A grout seal shall be emplaced above any artificial filter pack (other than pre-packed telescopic screens). The bottom plate and or sump must be constructed of the same material as the screen.

A nearby monitoring well is highly recommended to confirm the aquifer is not being depressurized or dewatered during testing and regular operation. Operating well levels within the screen elevations should only occur during peak demand times and not on a regular basis.

0205 - Surface Seal

In addition to section 4.3 of the BC Design Guidelines for Rural Residential Community Water Systems, the surface seal should follow the minimum sealing requirements laid by the BC Groundwater Protection Regulations. All annular space between the borehole and production casing should be sealed with an appropriate sealant to a minimum depth of 5.0 m. This includes any surface and telescopic casings left in place for various reasons (such as artesian pressure control). The seal must prevent surface water and or contamination from entering the annulus via the surface. The seal should have a minimum 50 mm thickness and must be suitable for the application and the environment. Typically, a Bentonite Grout mixed to 30% solids (by weight) is recommended.

Under certain circumstances and upon approval by the engineer or geoscientist, the following materials can be utilized for surface seals:

1) Neat cement as per AWWA A100-06.
2) Neat cement and bentonite mixtures (used with caution as these two compounds compete for hydration).

The grout/sealant must be placed into the annulus from the base of the desired interval to the ground surface. The grout shall be mixed at surface and pumped continuously or as a series of batches. Grout should be pumped until it discharges from the surface at the same solids content as pumped to minimize the potential for washout.

Single-string screen completions require considerable thought and care to properly seal undesired zones which may impact water quality.

Where pitless adaptors are installed or other well excavations occur after the surface seal is placed, the surface seal must be properly repaired during backfilling or the surface seal must extend sufficiently beneath the excavation to achieve the minimum required surface seal depth.

0206 - Well Pump and Discharge Piping

The well pumps used should be the 13.6 kW Grundfos SP-30-14 - 150 mm submersible pump and the motor assembly will vary based on the well location. The pumps shall run at an average maximum efficiency of 76% and should be able to meet the required maximum flow of 6.6 L/s. Both requirements shall be confirmed after pump installation.

The discharge piping should incorporate at least one check valve, an isolation valve, pressure gauge, flow meter (totalizing) and a sampling spigot.

A combination air valve may be required upstream from the check valve with exhaust/relief piping terminating above floor elevation in a downward position with a corrosion resistant screen.

Discharge piping should be configured to allow testing of each installed pump with provisions to discharge to waste. The proponent is responsible for ensuring that discharge to waste is authorized by regulatory agencies. The majority of these piping components should be accessible via an above ground pump station building or within an underground valve chamber. If pitless adaptors or units are utilized, at least one check valve should be located within the well casing upstream of the pitless adaptors or units.

0207 - Pitless Adaptors

The pitless adapters or units should be installed below the, 1.5 m, local frost penetration depth. Pitless adapters are to be made of materials compatible with the well casing and discharge piping to prevent corrosion. They should be dependable and provide access to the pump for maintenance or repair.

Pitless units are to be fabricated and installed from the point of connection with the well casing and should include a suitable well cap. Pitless units are to be welded or threaded to the original casing below the maximum anticipated frost depth. They should provide an inside diameter suitable to access/remove the pump for maintenance or repair, and to accommodate cables, sounding tubes and other well appurtenances. Pitless units should be of materials compatible with the casing and discharge piping to prevent corrosion.

0208 - Sounding Tubes

For periodic measurements of water levels in completed wells. Two 25 mm diameter PVC sounding tubes should be installed into each well for redundancy and dedicated use. PVC material should be of ANSI/AWWA C605 or ASTM D2241 standard.

0209 - Well Cap

The well cap shall be a 150 mm watertight cast iron cap with screened air vents. To all for easy access to the well without interfering with seal to casing or conduit and wiring.

0210 - Well Disinfection

Upon construction and before connection to a potable water system, the well must be disinfected to remove any bacteriological contamination. A well must also be disinfected after detection of bacteriological contamination. Steps for a standard well disinfection process are outlined below. Procedures for shock disinfection or hard to disinfect wells can be found on the website of the B.C. Ministry of Environment/Water Stewardship Division or in ANSI/AWWA C654.

The standard well disinfection requires a chlorine concentration of 50 to 200 mg/L throughout the water column. Based on the well casing diameter and water depth, the required amount of commercial bleach is calculated and mixed with a suitable volume of water. This concentrated solution is then added to well and should be maintained for at least 12, preferably 24 hours. After this period, the exhausted chlorine solution must be pumped to waste in an environmentally sensitive manner (authorities typically require de-chlorination before discharge). It shall not be pumped into the distribution system. Chlorination of the distribution system should be completed as a separate step as per AWWA C651-05.

0211 - Valve Specification

As per Section 33 10 00 of the UBC Technical Guidelines, Gate Valves shall be manufactured to AWWA C509, ductile iron body, resilient seated, non-rising steam, hub or flanged ends. Maximum distance between isolating distribution valves to be 100 m. Maximum depth of valve knuckles to be 600 mm.

0212 - Well Protection Plan

The well protection plans as outlined by the Province of British Columbia, Environment Canada and the British Columbia Ground Water Association Well Protection Toolkit shall be followed.

In addition to a well protection plan, there are a number of other measures a well designer and/or well owner should consider for keeping a well and aquifer safe. These measures are not limited to the following:

i. Ensure the wellhead is graded so that surface water drains away from the well.
ii. Protect the casing protrusion from physical damage.
iii. Operate the well in a manner that prevents the intrusion of saltwater of contaminated water into the well or aquifer.
iv. Do not disturb the wellhead or surface seal or when disturbed repair properly.
v. Ensure the pump house is in good repair and kept free of chemicals and other contaminants such as pesticides, fertilizers or gasoline.
vi. Regularly sample the water quality of the well and disinfect the well if needed.
vii. Consider intrusion alarm systems on well caps or well enclosures.

0213 - Flowing Artesian Wells

The provincial regulatory requirements for controlling flowing artesian wells are outlined in Section 77 of the Water Act. If artesian conditions are encountered when constructing or supervising construction of a well, the qualified well driller or qualified professional must ensure the artesian flow is controlled and advise the well owner (and the landowner, if applicable) of the steps taken to do so. If the flow cannot be controlled, the person responsible for drilling the well should advise the B.C. Ministry of Environment’s regional hydrogeologist and must comply with any directions given.

0214 - Fire Hydrant Installation

As per Section 33 10 00 of the UBC Technical Guidelines, fire hydrants should be 150 mm diameter Terminal City type C-71-P hydrants subjected to hydrostatic pressure test of 2070 kPa in compliance with AWWA C502. With a maximum lineal spacing distance of 100 m between hydrants. Minimum size of pipe connection 150 mm. Each hydrant should have an isolating valve not more than 6 m in front of it. Hydrants not in service should have an orange painted sign, 30 cm x 30 cm, lettered “Not in Service" on the main port. Only remove when the water main is accepted by the Mechanical Utilities Engineer. Install hydrants per AWWA M17 and manufacturer’s instruction.

0300 - Water Treatment

The design engineer should contact the local Health Authority for the project specific water treatment requirements. As a minimum and as part of the multi-barrier approach, all community water systems should provide chlorination for maintaining a minimum residual free chlorine concentration of 0.2 mg/L.

For the aeration system, ensure the system is installed and operated according to the manufacturer’s instructions. After installation, retest both the raw water (prior to treatment) and the treated water at a state certified laboratory to ensure the system is working properly and removing the contaminants. Continue to test the quality of both the raw and treated water annually or more frequently (quarterly or semi-annually) if high levels of contaminants are present in the raw water. Frequent testing will help determine how well the treatment system is working and whether maintenance or replacement of components may be necessary.

For the gravity filtration system, since it operates downflow. The filter medium should be a 15-30 in. deep bed of sand or anthracite. Single or multiple grades of sand or anthracite may be used. A large particle bed that supports the filter media to prevent fine sand or anthracite from escaping into the underdrain system. The support bed also serves to distribute backwash water. Typical support beds consist of 1 8-1 in. gravel or anthracite in graded layers to a depth of 12-16 in. The size and shape of the filter media affect the efficiency of the solid’s removal. Sharp, angular media form large voids and remove less fine material than rounded media of equivalent size. The media must be coarse enough to allow solids to penetrate the bed for 2-4 in.

0301 - Sampling Parameters and Frequency

Per the University of British Columbia's drinking water quality guidelines, drinking water should be tested a minimum of two times per year, with weekly testing for total coliforms, E. coli, HPCs, free chlorine residual, turbidity, temperature, pH and conductivity. Water quality should be tested at taps and/or at drinking water fountains in buildings on campus. The sampling locations should vary to cover a large cross-section of campus buildings—different geographical locations, various occupancy (research, operations, student housing, etc.), old buildings, high traffic, and buildings for which there have been special water testing requests. Buildings are tested for at least one calendar year through two test periods.

Samples collected in each target building should be measured for standard parameters contained in the Guidelines for Canadian Drinking Water Quality. These measurements include microbiological parameters (i.e., total coliforms, E. coli, turbidity), chemicals (i.e., arsenic, copper, lead, iron, zinc etc.) and physical parameters (i.e., pH, temperature, odour, etc.).

In general, the highest-priority guidelines are those dealing with microbiological contaminants. Guidelines for chemical and physical parameters are:

i. Health-based and listed as maximum acceptable concentrations (MAC)
ii. Based on aesthetic considerations and listed as aesthetic objectives (AO)
iii. Established based on operational considerations and listed as operational guidance values (OG).

0400 - Waterworks

The following specifications apply to both well-to-reservoir and reservoir-to-distribution-points distribution systems.

Water Distribution Design Standards & Policies

The latest revisions of the following standards shall apply to water distribution at UBC.

1. UBC Land Use, Permitting and Sustainability Policy - UBC Policy UP12 https://planning.ubc.ca/planning-development/policies-and-plans/campus-land-useplanning/land-use-permitting-and-sustainability-policy-ubc-policy
2. B.C. Master Municipal Construction Documents (MMCD).
3. B.C. Water & Waste Association (BCWWA).
4. American Water Works Association.
5. CSA Standards (as applicable).

Material Specifications

0401 - Pipes

Per UBC Technical Guidelines, watermain pipe material shall be Class 50 ductile iron pipe manufactured to AWWA C151. The recommended pipe selection is Kubota's GENEX seismically resilient ductile iron pipe, which meets AWWA C151/C153.

0402 - Fittings/Joints/Couplings/Tees

Per UBC Technical Guidelines, joints shall be single rubber gasket for push-on bell and spigot type joints to AWWA C111 or approved equal. Flanged joints shall be AWWA C110; flat faced conforming to ANSI B16.1, Class 125; refer to GENEX catalogue for flanged socket joints. Fittings shall be ductile to AWWA C110 suitable for pressure rating of 2,415 kPa. Bolts shall be medium carbon steel or Martensitic steel, ASTM A325 heavy hex finished, hot dip galvanized to ASTM A153, with sizing to AWWA 110. Nuts shall be heavy steel hex carbon steel to ASTM A563 Grade C hot dip galvanized to ASTM A153. Tee shall be GX-All Socket Tees from Kubota's GENEX ductile iron piping catalogue.

0403 - Valves and Valve boxes

Per UBC Technical Guidelines - Water Utilities Specifications, gate valves shall be manufactured to AWWA C509, ductile iron body, resilient seated, non-rising steam, hub or flanged ends. Maximum distance between isolating distribution valves to be 100 m. Maximum depth of valve knuckles to be 600 mm. Valve boxes for distribution system valves shall be Nelson-type as manufactured by Terminal City or Dobney Foundry. Valve box riser pipe to be 150 mm diameter PVC DR35.

0404 - Backflow Prevention

In accordance with the UBC Technical Guidelines - Water Utilities, backflow preventers shall be in accordance with the recommendations contained in the latest edition of the BC Plumbing Code.

Installation Specifications

0405 - Trenching

Trench alignment and depth to match detailed design drawings and in accordance with WorkSafe BC trench shoring and excavation support guidelines. Removal all vegetation and debris, then cut pavement along limits of proposed excavation and strip topsoil, disposing any waste material properly. Remove any disturbed or softened material from trench material before placing bedding material. Ensure trench is properly drained during placement of bedding, pipe, and backfill to ensure proper compaction of granular material. Where native backfill is approved for re-use, transport approved material to other staging locations and protect material from contamination, segregation, and weather.

0406 - Granular Bedding

Granular bedding must have a minimum cover of 1.0 m. For pipe bedding use clean granular pipe bedding, graded gravel, 19 mm (-), MMS type 1. Bottom thickness shall be 300 mm. Top shall be minimum 300 mm thick. Sides shall be minimum 225 mm to maximum 300 mm thick. Place granular bedding (sand) material across the full width of trench bottom in uniform layers of 100 mm depth. Compact to 95% Modified Proctor Density using vibration plate compactor.

0407 - Pipe Install

Inspect pipe before placing it into the trench for any defects. Lay and join ductile iron pipes to AWWA C600. Lay pipes on prepared bedding per line and grade. For joints, install gaskets as recommended by the manufacturer. Ensure completed joints are restrained by compacting bedding material alongside and over installed pipes. Minimum 3m horizontal clearance of pipe from storm or sanitary piping with minimum 750mm clearance from all other services. When crossing electric duct banks, trunk pipe with minimum vertical clearance 150 mm from bottom of duct per UBC Technical Guidelines. Complete building service connection penetrations per detailed design drawings. For all fittings and new pipes, polybag all new watermain components to protect from debris.

0408 - Valve Installation

Install valves to manufacturer's recommendations at locations in detailed design drawings. At every valve and fitting, install up to 3 m length of tie rods on each side when pipe couplings are used. Valves to be installed with actuating stem plumb.

0409 - Backfill and Compaction

As per UBC Technical Guidelines - Water Utilities, native backfill material may be used for trench backfill in boulevard and easement areas if free of rocks greater than 25 mm. Approval from UBC Energy & Water Services is required. Use imported bedding only when proposed work is installed under through paved areas, UBC Mechanical Utilities Engineer deems native material is unsuitable for backfill, or the trench has been excavated in rock. Compacts backfill to 95% Modified Proctor Density.

0410 - Disinfection and Testing

All testing and flushing to be performed in the presence of the approving UBC Mechanical Utilities Engineer. Water in new piping must be maintained at a minimum of 25 mg/L for a minimum of 24 hours for disinfection. A sample must be taken every 350 m of new piping and tested for zero total coliform and E. coli bacteria. Should the sample fail the "bug test", the main should be disinfected and re-tested until acceptance. Pressure and leakage tests should be performed to AWWA C600 and AWWA M41 for ductile iron piping.

0411 - Shutoff and Isolation Procedures

System shutdown must be requested in writing and adhering to UBC's shutdown request form per UBC Technical Guidelines - Water Utilities. Valve operation and isolation may only be performed by UBC Energy & Water Services and any activity requires the notification of the UBC Mechanical Utilities Engineer and Head Plumber. Hot tapping is generally not accepted and should not be required for the installation of the new groundwater system.

0500 - Concrete Works

The following specifications are based on The University of British Columbia's Technical Specifications for Architects and Engineers, BC Design Guidelines for Rural Residential Community Water Systems, and The Master Municipal Construction Documents. As per UBC's Structural Standards, the following specifications are required for Structural Concrete in UBC projects and facilities:

1. Reinforcing steel that is part of the seismic load-resisting system shall conform to CAN/CSA G30.18W.
2. No calcium chloride, in any form, is permitted in any concrete mix.
3. All exterior concrete to be air-entrained in accordance with CSA/CAN - A23.½
4. Post tensioned floor systems are not preferred by UBC and require pre-approval and acceptance before being used for projects.
5. Unless pre-approved by UBC, exposed concrete elements are to be treated as follows:
   - Bottom edges of exposed slabs and beams, and exposed column and wall edges are to be beveled 20mm x 20mm.
   - All top edges of exposed slabs, upstands, stairs, and other concrete

6. Slabs-on-grade are to be 150 mm minimum thickness, reinforced and provided with control joints. Reinforcing shall meet or exceed Code temperature requirements. Control joints shall be provided in each direction in an approximately square pattern, joint spacing not to exceed 4000 mm oc. Poly sheet to be placed below all interior slabs-on-grade.

0501 - Pump Station

As per BC Design Guidelines, the water pump station building structure should be durable under damp conditions, fire resistant, weather resistant, and constructed with outward-opening exit doors. The pump station should preferably be built of concrete blocks and be located above ground. The concrete floor slab should be sloped in order to enhance drainage during emergency leakage situations. Exterior concrete walls below grade must be watertight by means of suitable coatings and membranes, and provisions should be made to prevent water from coming in contact with the walls. The structure must be in compliance with the B.C. Building Code, and the Workers Compensation Board requirements. Consult a structural engineer and a materials consultant for concrete specifications and steel reinforcing arrangement.

0502 - Reservoir

As per BC Design Guidelines, reservoirs should preferably be built of reinforced concrete, and be located underground. The reservoir's structural design must include seismic considerations and an associated geotechnical report must be submitted with the application for a Certificate of Public Convenience and Necessity. Reservoir roofs must be watertight and sloped in order to prevent pooling of rain waters that may contaminate the structure. In regard to openings, it must also include a vent to circulate clean air, and an accessible hatch entrance for inspection, cleaning and maintenance. Consult a structural engineer for structure specifications, a materials consultant for concrete mix design, and a geotechnical engineer for ground load capacity evaluation.

0503 - Underground Chambers

As per BC Design Guidelines, underground chamber structures that accommodate valves, pumps or flow meters must meet B.C. Building Code requirements. Underground chambers should be located outside vehicular traffic areas and should be constructed of watertight reinforced concrete. All exterior concrete walls exposed to soil should be applied with at least two layers of brush-on tar coating or one layer of a watertight torch-on membrane. In addition, a dimpled membrane should be installed between the sealed wall and the backfill material. The foundation and the concrete floor slab should be protected by a perimeter drain system and a base material. The interior concrete walls of all chambers should be painted with a durable, white sealer.

0504 - Thrust Blocks

As per Section 33 10 00 of UBC's Technical Specifications, concrete thrust blocks shall be placed between valves, tees, wyes, plugs, caps, bends and undisturbed ground as shown on the Contract Drawings or as directed by Mechanical Utilities Engineer. Thrust blocks to undisturbed soil shall be provided, complete with bearing area and block volume. Consult a geotechnical and structural engineer for additional site considerations and concrete mix design.

0600 - Earthworks and Roadworks

The following specifications are based on The University of British Columbia's Technical Specifications for Architects and Engineers, and The Master Municipal Construction Documents.

0601 - Excavation Permit

As per UBC's Contractor Safety Manual, excavation permits from UBC Regulatory Services are required for: Any machine excavation, no matter how deep; Any excavation deeper than 500mm; Any penetration of earth with drill, piles, augers, spikes etc, and; Any penetration of concrete deeper than 50mm.

0602 - Clearing

Verify limits of clearing with Contract Administrator to determine site restrictions and environmental preservation features. Preserve vegetation designated for replanting at another location. Clear only vegetation (i.e. trees, shrubs, stumps) and debris not designated to remain in the area in order to leave the ground surface in suitable conditions for excavation. Dispose of cleared material as work progresses to prevent accumulation on site. Site fires for the purpose of burning are not permitted without the approval of the Contract Administrator.

0603 - Dust Control

Control dust at all times during the duration of the Contract. The MMCD recommends the application of flake calcium chloride at a rate of 1.00 kg/m^2, and of aqueous solutions at the following rates:

- Calcium chloride (25%) at 2.4 L/m^2 on roads not previously treated and 3.0 L/m^2 for road stabilization.

- Calcium chloride (35%) or magnesium chloride (30%) at 1.6 L/m^2 on roads not previously treated and 2.0 L/m^2 for road stabilization.

0604 - Excavation & Trenching

Prepare site by cutting pavement or sidewalk along the limits of the proposed excavation. If the excavation passes through a lawn, cut the sod and save it for replanting once backfilling is complete. In regard to worker and public safety, the work performed should comply with MMCD General Conditions, Clause 4.2, Safety and MMCD General Conditions, Clause 4.3, Protection of Work, Property, and the Public. If excavating trenches, design and install shoring as per WorkSafe BC regulations.

0605 - Surface Restoration

Restore disturbed surfaces to condition at least equal to what existed prior to construction. Any damage to adjacent lands should also be resolved and written releases from landowners must be obtained after final restoration. Gardens and lawns should be restored with approved topsoil to match pre-construction conditions.

0606 - Asphalt Restoration

As per Section 32 10 00 and 32 14 00, any utility upgrades or other projects that disturb and damage existing paving shall reinstate paving to original condition in compliance with relevant guidelines. All standard municipal roadways should conform to MMCD and the Transportation Association of Canada's, Geometric Design Guide for Canadian Roads, current editions. Furthermore, all road repair, remediation and rehabilitation shall be compliant with MMCD, current edition.

As per the MMCD, permanent pavement should be restored within 30 days of temporary patch work. The base must be compacted to a minimum 95% Modified Proctor density, and a compact hot-mix asphalt pavement material must be placed with a minimum thickness as specified on MMCD Standard Detail Drawing G5. Ensure that the final pavement surface is smooth and matches with the grade of adjacent pavement. See MMCD Section 32 12 16 for further details on hot-mix pavement.

Appendix E

Construction Schedule

Scheduling Module - Phase 1

Project Begin Date	2021-05-01
Total Number of Work Days	220
Project Completion Date	2022-03-14

Activity Category	Task ID	Task Name	Duration (Days)	Pr						
	0	Start	0	0						
Groundwater Well Construction	1	Life Building	15	0						
	2	IKB Library East	15	0						
	3	IKB Library West	15	1	2					
	4	Allard Law South	15	1	2					
	5	St Andrews	15	3	4					
	6	Allard Law North	15	5						
	7	Chan Center	15	5	5					
Reservoir Construction	8	Excavate	25	0						
	9	Foundation	20	8						
	10	Retaining Wall	15	9						
	11	Columns	15	10						
	12	Roof	15	11						
	13	Structure Finishes	5	12						
	14	Piping	10	13						
	15	Backfill	15	14						
	16	Sodding	10	15						
Building for Pump Station & Water Treatment	17	Standard Foundation	15	0						
	18	Slab on Grade	15	17						
	19	Exterior Concrete Tilt Up Panels	25	18						
	20	Steel Frame & Interior Walls	20	19						
	21	Roofing	20	20						
	22	Service Fixures	20	21						
	23	Finishes	25	22						
	24	Installation of Pumps	10	23						
	25	Installation of Water Treatment Equipment	20	24						
Distribution System To Reservoir	26	East Mall (Includes dist. system from reservoir)	35	0						
	27	Lane, East Mall to Life Building Well & Reservoir	10	0						
	28	Lane, East Mall to IKB Library East Well	5	0						
	29	Memorial Rd.	15	27	28					
	30	Walter Gage Rd	15	29						
	31	Cresent Road (includes dist. system from reservoir)	12	30						
Distribution System From Reservoir	32	East Mall, from IKB E. Well to Thunderbird Rd.	40	26						
	33	Thunderbird Rd.	10	32						
	34	Lane, East Mall to UBC Hospital	10	32						
Project Close Out	35	System Comissioning	20	6	7	16	25	31	34	33
	36	Project Closeout	30	35						
	37	Finish	0	36						

Task ID	Fol							EF						
0	1	2	8	17	26	26	27	0	0	0	0	0	0	0
1	3	4						0	0	0	0	0	0	0
2	3	4						0	0	0	0	0	0	0
3	5							15	15	0	0	0	0	0
4	5							15	15	0	0	0	0	0
5	6		7					30	30	0	0	0	0	0
6	35							45	0	0	0	0	0	0
7	35							45	45	0	0	0	0	0
8	9							0	0	0	0	0	0	0
9	10							25	0	0	0	0	0	0
10	11							45	0	0	0	0	0	0
11	12							60	0	0	0	0	0	0
12	13							75	0	0	0	0	0	0
13	14							90	0	0	0	0	0	0
14	15							95	0	0	0	0	0	0
15	16							105	0	0	0	0	0	0
16	35							120	0	0	0	0	0	0
17	18							0	0	0	0	0	0	0
18	19							15	0	0	0	0	0	0
19	20							30	0	0	0	0	0	0
20	21							55	0	0	0	0	0	0
21	22							75	0	0	0	0	0	0
22	23							95	0	0	0	0	0	0
23	24							115	0	0	0	0	0	0
24	25							140	0	0	0	0	0	0
25	35							150	0	0	0	0	0	0
26	32							0	0	0	0	0	0	0
27	29							0	0	0	0	0	0	0
28	29							0	0	0	0	0	0	0
29	30							10	5	0	0	0	0	0
30	31							25	0	0	0	0	0	0
31	35							40	0	0	0	0	0	0
32	33	34						35	0	0	0	0	0	0
33	35							75	0	0	0	0	0	0
34	35							75	0	0	0	0	0	0
35	36							60	60	130	170	52	85	85
36	37							190	0	0	0	0	0	0
37								220	0	0	0	0	0	0

Task ID	LS							ES	EF	LS	LF	TF	Critical?
0	110	110	40	0	85	85	118	0	0	0	0	0	Critical
1	125	125						0	15	110	125	110	
2	125	125						0	15	110	125	110	
3	140							15	30	125	140	110	
4	140							15	30	125	140	110	
5	155		155					30	45	140	155	110	
6	170							45	60	155	170	110	
7	170							45	60	155	170	110	
8	65							0	25	40	65	40	
9	85							25	45	65	85	40	
10	100							45	60	85	100	40	
11	115							60	75	100	115	40	
12	130							75	90	115	130	40	
13	135							90	95	130	135	40	
14	145							95	105	135	145	40	
15	160							105	120	145	160	40	
16	170							120	130	160	170	40	
17	15							0	15	0	15	0	Critical
18	30							15	30	15	30	0	Critical
19	55							30	55	30	55	0	Critical
20	75							55	75	55	75	0	Critical
21	95							75	95	75	95	0	Critical
22	115							95	115	95	115	0	Critical
23	140							115	140	115	140	0	Critical
24	150							140	150	140	150	0	Critical
25	170							150	170	150	170	0	Critical
26	120							0	35	85	120	85	
27	128							0	10	118	128	118	
28	128							0	5	123	128	123	
29	143							10	25	128	143	118	
30	158							25	40	143	158	118	
31	170							40	52	158	170	118	
32	160	160						35	75	120	160	85	
33	170							75	85	160	170	85	
34	170							75	85	160	170	85	
35	190							170	190	170	190	0	Critical
36	220							190	220	190	220	0	Critical
37								220	220	220	220	0	Critical

Task ID	ES	EF	LF	EF Days (Inc. Time Off)	Float Days (Inc. Time Off)	Labels
0	2021-05-01	2021-05-01	2021-05-01	0	0	Start*
1	2021-05-01	2021-05-21	2021-10-29	20	161	Life Building
2	2021-05-01	2021-05-21	2021-10-29	20	161	IKB Library East
3	2021-05-21	2021-06-14	2021-11-22	24	161	IKB Library West
4	2021-05-21	2021-06-14	2021-11-22	24	161	Allard Law South
5	2021-06-14	2021-07-06	2021-12-13	22	160	St Andrews
6	2021-07-06	2021-07-27	2022-01-03	21	160	Allard Law North
7	2021-07-06	2021-07-27	2022-01-03	21	160	Chan Center
8	2021-05-01	2021-06-07	2021-08-04	37	58	Excavate
9	2021-06-07	2021-07-06	2021-09-01	29	57	Foundation
10	2021-07-06	2021-07-27	2021-09-23	21	58	Retaining Wall
11	2021-07-27	2021-08-18	2021-10-15	22	58	Columns
12	2021-08-18	2021-09-09	2021-11-05	22	57	Roof
13	2021-09-09	2021-09-16	2021-11-15	7	60	Structure Finishes
14	2021-09-16	2021-09-30	2021-11-29	14	60	Piping
15	2021-09-30	2021-10-22	2021-12-20	22	59	Backfill
16	2021-10-22	2021-11-05	2022-01-03	14	59	Sodding
17	2021-05-01	2021-05-21	2021-05-21	20	0	Standard Foundation*
18	2021-05-21	2021-06-14	2021-06-14	24	0	Slab on Grade*
19	2021-06-14	2021-07-20	2021-07-20	36	0	Exterior Concrete Tilt Up Panels*
20	2021-07-20	2021-08-18	2021-08-18	29	0	Steel Frame & Interior Walls*
21	2021-08-18	2021-09-16	2021-09-16	29	0	Roofing *
22	2021-09-16	2021-10-15	2021-10-15	29	0	Service Fixures*
23	2021-10-15	2021-11-22	2021-11-22	38	0	Finishes*
24	2021-11-22	2021-12-06	2021-12-06	14	0	Installation of Pumps*
25	2021-12-06	2022-01-03	2022-01-03	28	0	Installation of Water Treatment Equipment*
26	2021-05-01	2021-06-21	2021-10-22	51	123	East Mall (Includes dist. system from reservoir)
27	2021-05-01	2021-05-14	2021-11-03	13	173	Lane, East Mall to Life Building Well & Reservoir
28	2021-05-01	2021-05-07	2021-11-03	6	180	Lane, East Mall to IKB Library East Well
29	2021-05-14	2021-06-07	2021-11-25	24	171	Memorial Rd.
30	2021-06-07	2021-06-28	2021-12-16	21	171	Walter Gage Rd
31	2021-06-28	2021-07-15	2022-01-03	17	172	Cresent Road (includes dist. system from reservoir)
32	2021-06-21	2021-08-18	2021-12-20	58	124	East Mall, from IKB E. Well to Thunderbird Rd.
33	2021-08-18	2021-09-01	2022-01-03	14	124	Thunderbird Rd.
34	2021-08-18	2021-09-01	2022-01-03	14	124	Lane, East Mall to UBC Hospital
35	2022-01-03	2022-01-31	2022-01-31	28	0	System Comissioning*
36	2022-01-31	2022-03-14	2022-03-14	42	0	Project Closeout*
37	2022-03-14	2022-03-14	2022-03-14	0	0	Finish*

Scheduling Module - Phase 2

Project Begin Date	2050-05-01
Total Number of Work Days	80
Project Completion Date	2050-08-19

Activity Category	Task ID	Task Name	Duration (Days)	Precedent Activities						Following Activities					
	0	Start	0	0						1	2	5			
Groundwater Well Construction	1	Econ West	15	0						3	4				
	2	Econ East	15	0						3	4				
	3	School of Music	15	1	2					8					
	4	Well Mall Annex	15	1	2					8					
Distribution Main to Reservoir	5	Walter Gage Rd Water Main	30	0						6					
	6	Memorial Road	20	5						7					
	7	West Mall	5	6						8					
Project Close Out	8	System Comissioning	10	3	4	7				9					
	9	Project Closeout	15	8						10					
	10	Finish	0	9											

Task ID	EF of Precedent Activities						LS of Upcoming Activity					
0	0	0	0	0	0	0	25	25	0			
1	0	0	0	0	0	0	40	40				
2	0	0	0	0	0	0	40	40				
3	15	15	0	0	0	0	55					
4	15	15	0	0	0	0	55					
5	0	0	0	0	0	0	30					
6	30	0	0	0	0	0	50					
7	50	0	0	0	0	0	55					
8	30	30	55	0	0	0	65					
9	65	0	0	0	0	0	80					
10	80	0	0	0	0	0						

Task ID	ES	EF	LS	LF	TF	Critical?	ES	EF	LF	EF Days (Inc. Time Off)	Float Days (Inc. Time Off)	Labels
0	0	0	0	0	0	Critical	2050-05-01	2050-05-01	2050-05-01	0	0	Start*
1	0	15	25	40	25		2050-05-01	2050-05-20	2050-06-24	19	35	Econ West
2	0	15	25	40	25		2050-05-01	2050-05-20	2050-06-24	19	35	Econ East
3	15	30	40	55	25		2050-05-20	2050-06-10	2050-07-15	21	35	School of Music
4	15	30	40	55	25		2050-05-20	2050-06-10	2050-07-15	21	35	Well Mall Annex
5	0	30	0	30	0	Critical	2050-05-01	2050-06-10	2050-06-10	40	0	Walter Gage Rd Water Main*
6	30	50	30	50	0	Critical	2050-06-10	2050-07-08	2050-07-08	28	0	Memorial Road*
7	50	55	50	55	0	Critical	2050-07-08	2050-07-15	2050-07-15	7	0	West Mall*
8	55	65	55	65	0	Critical	2050-07-15	2050-07-29	2050-07-29	14	0	System Comissioning*
9	65	80	65	80	0	Critical	2050-07-29	2050-08-19	2050-08-19	21	0	Project Closeout*
10	80	80	80	80	0	Critical	2050-08-19	2050-08-19	2050-08-19	0	0	Finish*

Appendix F
Class A Cost Estimate

		Imperial		Metric		Unit Rates Based on Imperial Quantities			Costs			Total Costs
Bid Item No.	**Bid Item Description**	**Unit**	**Quantity**	**Unit**	**Quantity**	**Material**	**Labour**	**Equipment**	**Material**	**Labour**	**Equipment**	**Estimated Cost**
						PHASE 1						
Bid Item: 1	**General Construction Costs**											**$574,900**
	Mobilization (2% of total project cost)											$141,600
	Demobilzation (2% of total project cost)											$129,700
	Traffic Management (1% of total construction costs)											$64,900
015213201100	Portable office 8' x 12'	S.F	96.00	S.m.	8.92	$95.00	$4.59	$0.00	$9,120.00	$440.64	$0.00	$9,600
015433406420	Portable toilet	Week	44.00	Week	44.00	$0.00	$0.00	$76.60	$0.00	$0.00	$3,370.40	$3,400
013113200280	Superintendent	Week	44.00	Week	44.00	$0.00	$2,200.00	$0.00	$0.00	$96,800.00	$0.00	$96,800
013113200220	Project Manager	Week	44.00	Week	44.00	$0.00	$2,375.00	$0.00	$0.00	$104,500.00	$0.00	$104,500
011050	Surveyor	hr.	168.00	hr.	168.00	$0.00	$145.00	$0.00	$0.00	$24,360.00	$0.00	$24,400
013113300050	Builder's Risk Insurance (0.4% of total job cost)	Job	1.00	Job	1.00							$28,400
Bid Item: 2	**Groundwater Well & Pumphouse x7**		**7.00**									**$2,539,000**
332113100200	10" Well Drilling	L.F.	2635.50	L.m.	803.30	$0.00	$14.60	$28.50	$0.00	$38,478.28	$75,111.71	$113,600
332113103100	Grundfos SP-30-14 6" Submersible Pump and Motor Assembly	Ea.	7.00	Ea.	7.00	$8,425.00	$1,050.00	$900.00	$58,975.00	$7,350.00	$6,300.00	$72,700
332113108590	Distribution Pump Installation and Testing	Ea.	7.00	Ea.	7.00	$0.00	$1,400.00	$2,700.00	$0.00	$9,800.00	$18,900.00	$28,700
332113108170	10" Well Screen	L.F.	3689.70	L.m.	1124.62	$340.00	$12.70	$35.50	$1,254,497.38	$46,859.17	$130,984.28	$1,432,400
332113108580	Surface Seal Well, Concrete Filled	Ea.	7.00	Ea.	7.00	$785.00	$930.00	$2,600.00	$5,495.00	$6,510.00	$18,200.00	$30,300
332113108410	Gravel Pack & 10" Steel Casing	L.F.	2635.50	L.m.	803.30	$5.95	$12.45	$38.50	$15,681.22	$32,811.96	$101,466.70	$150,000
	Pitless Adaptor	Ea.	7.00	Ea.	7.00	$0.00	$0.00	$2,000.00	$0.00	$0.00	$14,000.00	$14,000
331113253980	1" PVC Sounding Tube	L.F.	33207.28	L.m.	10121.58	$0.22	$0.60	$0.00	$7,305.60	$19,924.37	$0.00	$27,300
331113152040	6" DI pipe	L.F.	17522.28	L.m.	5340.79	$14.60	$10.70	$2.72	$255,825.24	$187,488.36	$47,660.59	$491,000
	6" 80DIX Check Valve	Ea.	28.00	Ea.	28.00	$1,165.00	$400.00	$0.00	$32,620.00	$11,200.00	$0.00	$43,900
221113479270	6" Coupling	Ea.	7.00	Ea.	7.00	$143.00	$50.00	$0.00	$1,001.00	$350.00	$0.00	$1,400
	Torque Arrester	Ea.	7.00	Ea.	7.00	$200.00	$0.00	$0.00	$1,400.00	$0.00	$0.00	$1,400
	2.5" Dial Pressure Gauge	Ea.	7.00	Ea.	7.00	$25.00	$27.00	$0.00	$175.00	$189.00	$0.00	$400
	6" WM-PT Series Paddle Wheel Flow Meter	Ea.	7.00	Ea.	7.00	$380.00	$122.00	$0.00	$2,660.00	$854.00	$0.00	$3,600
331113158220	6" Tee	Ea.	7.00	Ea.	7.00	$530.00	$157.00	$0.00	$3,710.00	$1,099.00	$0.00	$4,900
331113158020	6" 90 degree Bend	Ea.	28.00	Ea.	28.00	$370.00	$105.00	$0.00	$10,360.00	$2,940.00	$0.00	$13,300
	6" AWWA C515 Gate Valve 115MJ	Ea.	7.00	Ea.	7.00	$1,329.00	$400.00	$0.00	$9,303.00	$2,800.00	$0.00	$12,200
230523805570	6" Ball Valve	Ea.	7.00	Ea.	7.00	$1,750.00	$400.00	$0.00	$12,250.00	$2,800.00	$0.00	$15,100
332113108550	Pump Testing	hr.	112.00	hr.	112.00	$0.00	$116.00	$360.00	$0.00	$12,992.00	$40,320.00	$53,400
133423300300	Pump House Structure (6'x6')	S.F.	252.00	S.m.	23.41	$47.00	$14.35	$0.00	$11,844.00	$3,616.20	$0.00	$15,500
221113741960	6" PVC Pipe	L.F.	34.45	L.m.	10.50	$24.50	$19.80	$0.00	$844.00	$682.09	$0.00	$1,600
034113500020	4" Precast Concrete Block	S.F.	6.78	S.m.	0.63	$5.55	$1.43	$0.79	$37.64	$9.70	$5.36	$100
331219101170	Fire Hydrant	Ea.	7.00	Ea.	7.00	$1,600.00	$123.00	$14.30	$11,200.00	$861.00	$100.10	$12,200
Bid Item: 3	**Reservoir 2700m3**											**$429,000**
312316465220	Excavation (Dozer)	B.C.Y	6066.54	B.C.m.	4638.21	$0.00	$0.63	$2.01	$0.00	$3,821.92	$12,193.75	$16,100.00
033053404050	Foundation Concrete (includes forms, reincorcing steel, placing, and finishing)	C.Y.	616.36	C.m.	471.24	$169.00	$82.00	$0.42	$104,164.98	$50,541.59	$258.87	$155,000.00
033053406250	Reinforcing Walls (includes forms, reincorcing steel, placing, and finishing)	C.Y.	109.28	C.m.	83.55	$129.00	$68.50	$203.60	$14,097.06	$7,485.65	$22,249.31	$43,900.00
033053401040	Columns (includes forms, reincorcing steel, placing, and finishing)	C.Y.	22.58	C.m.	17.26	$580.00	$485.00	$43.00	$13,093.75	$10,949.09	$970.74	$25,100.00
033053402150	Top Slab (includes forms, reincorcing steel, placing, and finishing)	C.Y.	431.45	C.m.	329.87	$227.00	$181.00	$15.40	$97,939.73	$78,092.91	$6,644.37	$182,700.00
0312323131600	Backfill, bulk, 6" to 12" lifts, dozer backfilling	E.C.Y.	1091.98	E.C.m.	834.88	$0.63	$0.63	$1.81	$687.95	$687.95	$1,976.48	$3,400.00
329223100200	Sodding, bluegrass sod, on level ground, 1" deep, 4 M.S.F.	M.S.F	2.50	M.S.m.	0.23	$275.00	$85.00	$8.95	$686.47	$212.18	$22.34	$1,000.00
331219101170	Fire Hydrant	Ea.	1.00	Ea.	1.00	$1,600.00	$123.00	$14.30	$1,600.00	$123.00	$14.30	$1,800.00

		Imperial		Metric		Unit Rates Based on Imperial Quantities			Costs			Total Costs
Bid Item No.	**Bid Item Description**	**Unit**	**Quantity**	**Unit**	**Quantity**	**Material**	**Labour**	**Equipment**	**Material**	**Labour**	**Equipment**	**Estimated Cost**
Bid Item: 4	**Distribution Main to the Reservoir**											**$908,900**
312316130062	Excavation	B.C.Y	1666.50	B.C.m.	1274.13	$0.00	$2.40	$2.37	$0.00	$3,999.60	$3,949.60	$8,000.00
	Piping - 150 DI Class 52 (Kubota GENEX) c/w Imported Backfill Depth	L.F.	1883.20	L.m.	574.00	$769.23	$0.00	$0.00	$441,538.46	$0.00	$0.00	$441,600.00
	Piping - 200 DI Class 52 (Kubota GENEX) c/w Imported Backfill Depth	L.F.	1040.03	L.m.	317.00	$1,000.00	$0.00	$0.00	$317,000.00	$0.00	$0.00	$317,000.00
220719300168	Polyethelene Protective Pipe Jacketing 6" ID	L.F.	1883.20	L.m.	574.00	$0.88	$3.75	$0.00	$1,657.22	$7,062.01	$0.00	$8,800.00
220719300176	Polyethelene Protective Pipe Jacketing 8" ID	L.F.	1040.03	L.m.	317.00	$1.18	$4.19	$0.00	$1,227.23	$4,357.71	$0.00	$5,600.00
331113158020	GX Double Socket 90 degree bend 6" MJ x 6" MJ	Ea.	3.00	Ea.	3.00	$370.00	$105.00	$0.00	$1,110.00	$315.00	$0.00	$1,500.00
	GX Double Socket 22.5 degree bend 8" MJ x 8" MJ	Ea.	1.00	Ea.	1.00	$709.00	$0.00	$0.00	$709.00	$0.00	$0.00	$800.00
331113158220	GX All Socket Tee 6" MJ x 6" MJ x 6" MJ	Ea.	2.00	Ea.	2.00	$530.00	$157.00	$0.00	$1,060.00	$314.00	$0.00	$1,400.00
331113158240	GX All Socket Tee 8" MJ x 8" MJ x 8" MJ	Ea.	5.00	Ea.	5.00	$785.00	$188.00	$0.00	$3,925.00	$940.00	$0.00	$4,900.00
	GX All Socket Tee 8" MJ x 6" MJ x 6" MJ	Ea.	1.00	Ea.	1.00	$875.00	$0.00	$0.00	$875.00	$0.00	$0.00	$900.00
312323131600	Backfill, bulk, 6" to 12" lifts, dozer backfilling	E.C.Y.	805.30	E.C.m.	615.70	$0.63	$0.63	$1.81	$507.34	$507.34	$1,457.60	$2,500.00
329223100200	Sodding, bluegrass sod, on level ground, 1" deep, 4 M.S.F.	M.S.F	2.11	M.S.m.	0.20	$275.00	$85.00	$8.95	$580.23	$179.35	$18.88	$800.00
321126130560	Paving	S.Y.	1172.19	S.m.	108.90	$28.00	$1.10	$0.83	$32,821.32	$1,289.41	$972.92	$35,100.00
	Utility Relocation	Allowance	1.00	Allowance	1.00	$0.00	$80,000.00	$0.00	$0.00	$80,000.00	$0.00	$80,000.00
Bid Item: 5	**Backup Energy Source**											**$1,047,300**
263213133220	Diesel Generator	Ea.	7.00	Ea.	7.00	$143,000.00	$5,850.00	$760.00	$1,001,000.00	$40,950.00	$5,320.00	$1,047,300
Bid Item: 6	**Water Treatment**											**$1,469,000**
	Tilt Up Concrete Panel Building	S.F.	2250.00	S.m.	209.03	$95.00	$25.00	$10.00	$213,750.00	$56,250.00	$22,500.00	$292,500.00
	Screen	Ea.	1.00	Ea.	1.00	$15,000.00	$0.00	$0.00	$15,000.00	$0.00	$0.00	$15,000.00
	Aeration Tower	Ea.	1.00	Ea.	1.00	$182,786.91	$0.00	$0.00	$182,786.91	$0.00	$0.00	$182,800.00
	Rectangular Clarifier	Ea.	1.00	Ea.	1.00	$260,597.00	$0.00	$0.00	$260,597.00	$0.00	$0.00	$260,600.00
	Gravity Filtration Structures	Ea.	1.00	Ea.	1.00	$512,009.40	$0.00	$0.00	$512,009.40	$0.00	$0.00	$512,100.00
	Chlorine Dioxide Generating and Feed	Ea.	1.00	Ea.	1.00	$206,000.00	$0.00	$0.00	$206,000.00	$0.00	$0.00	$206,000.00
Bid Item: 6	**Structures for Pumping**											**$683,600**
	Building for Water Treatment and Pump Station	S.F.	2250.00	S.m.	209.03	$95.00	$25.00	$10.00	$213,750.00	$56,250.00	$22,500.00	$292,500
	Grundfos CR 155-2 A-G-A-E-HQQE Pump	Ea.	7.00	Ea.	7.00	$20,790.00	$0.00	$0.00	$145,530.00	$0.00	$145,530.00	$291,100.00
	Underground Pump Chamber	Allowance	1.00			$50,000.00	$0.00	$0.00	$50,000.00	$0.00	$50,000.00	$100,000
Bid Item: 7	**Permitting**											**$87,200**
	Development Permit - Water Treatment and Pump Station Building											$11,900
	Development Permit - Reservoir											$8,900
	Building Permit - Water Treatment and Pump Station Building											$2,000
	Building Permit - Reservoir											$5,200
	Plumbing Permit											$900
	Electrical Permit											$57,300
	Operating Permit											$1,000
											Phase 1 Subtotal	**$7,738,900**
											Contingency (5%)	**$387,000**
											Phase 1 Total Cost (2011 USD)	**$8,125,900**
											Phase 1 Total Cost (2021 CAD)	**$12,380,900**

		Imperial		Metric		Unit Rates Based on Imperial Quantities			Costs			Total Costs
Bid Item No.	**Bid Item Description**	**Unit**	**Quantity**	**Unit**	**Quantity**	**Material**	**Labour**	**Equipment**	**Material**	**Labour**	**Equipment**	**Estimated Cost**
						PHASE 2						
Bid Item: 9	**General Construction Costs**											**$215,256**
	Mobilization (2% of total project cost)											$37,800
	Demobilzation (2% of total project cost)											$37,800
	Traffic Management (1% of total construction costs)											$18,900
015213201100	Portable office 8' x 12'	S.F	96.00	S.m.	8.92	$95.00	$4.59	$0.00	$9,120.00	$440.64	$0.00	$9,600
015433406420	Portable toilet	Week	17.00	Week	17.00	$0.00	$0.00	$76.60	$0.00	$0.00	$1,302.20	$1,400
013113200280	Superintendent	Week	17.00	Week	17.00	$0.00	$2,200.00	$0.00	$0.00	$37,400.00	$0.00	$37,400
013113200220	Project Manager	Week	17.00	Week	17.00	$0.00	$2,375.00	$0.00	$0.00	$40,375.00	$0.00	$40,400
011050	Surveyor	hr.	168.00	hr.	168.00	$0.00	$145.00	$0.00	$0.00	$24,360.00	$0.00	$24,400
013113300050	Builder's Risk Insurance (0.4% of total job cost)	Job	1.00	Job	1.00							$7,556
Bid Item: 10	**Groundwater Well & Pumphouse x4**		**4.00**									**$942,800**
332113100200	10" Well Drilling	L.F.	1507.55	L.m.	459.50	$0.00	$14.60	$28.50	$0.00	$22,010.17	$42,965.06	$65,000
332113103100	Grundfos SP-30-14 6" Submersible Pump and Motor Assembly	Ea.	4.00	Ea.	4.00	$8,425.00	$1,050.00	$900.00	$33,700.00	$4,200.00	$3,600.00	$41,500
332113108590	Distribution Pump Installation and Testing	Ea.	4.00	Ea.	4.00	$0.00	$1,400.00	$2,700.00	$0.00	$5,600.00	$10,800.00	$16,400
332113108170	10" Well Screen	L.F.	1206.04	L.m.	367.60	$340.00	$9.40	$26.50	$410,052.49	$11,336.75	$31,959.97	$453,400
332113108580	Surface Seal Well, Concrete Filled	Ea.	4.00	Ea.	4.00	$785.00	$930.00	$2,600.00	$3,140.00	$3,720.00	$10,400.00	$17,300
332113108410	Gravel Pack & 10" Steel Casing	L.F.	1507.55	L.m.	459.50	$5.95	$8.35	$26.00	$8,969.90	$12,588.01	$39,196.19	$60,800
	Pitless Adaptor	Ea.	4.00	Ea.	4.00	$0.00	$0.00	$2,000.00	$0.00	$0.00	$8,000.00	$8,000
331113253980	1" PVC Sounding Tube	L.F.	10854.33	L.m.	3308.40	$0.22	$0.80	$0.00	$2,387.95	$8,683.46	$0.00	$11,100
331113152040	6" DI pipe	L.F.	5952.10	L.m.	1814.20	$14.60	$10.70	$2.72	$86,900.66	$63,687.47	$16,189.71	$166,800
230523801470	6" 80DIX Check Valve	Ea.	16.00	Ea.	16.00	$1,165.00	$400.00	$0.00	$18,640.00	$6,400.00	$0.00	$25,100
221113479270	6" Coupling	Ea.	4.00	Ea.	4.00	$143.00	$50.00	$0.00	$572.00	$200.00	$0.00	$800
	Torque Arrester	Ea.	4.00	Ea.	4.00	$200.00	$0.00	$0.00	$800.00	$0.00	$0.00	$800
230953103014	2.5" Dial Pressure Gauge	Ea.	4.00	Ea.	4.00	$25.00	$27.00	$0.00	$100.00	$108.00	$0.00	$300
232120220220	6" WM-PT Series Paddle Wheel Flow Meter	Ea.	4.00	Ea.	4.00	$380.00	$122.00	$0.00	$1,520.00	$488.00	$0.00	$2,100
331113158220	6" Tee	Ea.	4.00	Ea.	4.00	$530.00	$157.00	$0.00	$2,120.00	$628.00	$0.00	$2,800
331113158020	6" 90 degree Bend	Ea.	16.00	Ea.	16.00	$370.00	$105.00	$0.00	$5,920.00	$1,680.00	$0.00	$7,600
230523802070	6" AWWA C515 Gate Valve 115MJ	Ea.	4.00	Ea.	4.00	$1,329.00	$400.00	$0.00	$5,316.00	$1,600.00	$0.00	$7,000
230523805570	6" Ball Valve	Ea.	4.00	Ea.	4.00	$1,750.00	$400.00	$0.00	$7,000.00	$1,600.00	$0.00	$8,600
332113108550	Pump Testing	hr.	64.00	hr.	64.00	$0.00	$116.00	$360.00	$0.00	$7,424.00	$23,040.00	$30,500
133423300300	Pump House Structure (6'x6')	S.F.	144.00	S.m.	13.38	$47.00	$14.35	$0.00	$6,768.00	$2,066.40	$0.00	$8,900
221113741960	6" PVC Pipe	L.F.	19.69	L.m.	6.00	$24.50	$19.80	$0.00	$482.28	$389.76	$0.00	$900
034113500020	4" Precast Concrete Block	S.F.	3.88	S.m.	0.36	$5.55	$1.43	$0.79	$21.51	$5.54	$3.06	$100
331219101170	Fire Hydrant	Ea.	4.00	Ea.	4.00	$1,600.00	$123.00	$14.30	$6,400.00	$492.00	$57.20	$7,000
Bid Item: 11	**Distribution**											**$946,200**
312316130062	Excavation	B.C.Y	1145.43	B.C.m.	875.74	$0.00	$2.40	$2.37	$0.00	$2,749.03	$2,714.67	$5,500
	Piping - 150 DI Class 52 (Kubota GENEX) c/w Imported Backfill Depth	L.m.	775.00	L.m.	775.00	$798.00	$0.00	$0.00	$618,450.00	$0.00	$0.00	$618,500
220719300168	Polyethelene Protective Pipe Jacketing 6" ID	L.F.	1145.43	L.m.	349.13	$0.88	$3.75	$0.00	$1,007.98	$4,295.36	$0.00	$5,400
	GX Double Socket 90 degree bend 6" MJ x 6" MJ	Ea.	5.00	Ea.	5.00	$370.00	$105.00	$0.00	$1,850.00	$525.00	$0.00	$2,400
331113158220	GX All Socket Tee 6" MJ x 6" MJ x 6" MJ	Ea.	2.00	Ea.	2.00	$530.00	$157.00	$0.00	$1,060.00	$314.00	$0.00	$1,400
312323131600	Backfill, bulk, 6" to 12" lifts, dozer backfilling	E.C.Y.	1088.81	E.C.m.	832.46	$0.63	$0.63	$1.81	$685.95	$685.95	$1,970.75	$3,400
329223100200	Sodding, bluegrass sod, on level ground, 1" deep, 4 M.S.F.	M.S.F	1.90	M.S.m.	0.18	$275.00	$85.00	$8.95	$521.62	$161.23	$16.98	$700
321126130560	Paving	S.Y.	9484.08	S.m.	881.10	$28.00	$1.10	$0.83	$265,554.28	$10,432.49	$7,871.79	$283,900
	Utility Relocation	Allowance	1.00	Allowance	1.00	$25,000.00	$0.00	$0.00	$25,000.00	$0.00	$0.00	$25,000
Bid Item: 8	**Permitting**											**$37,200**
	Plumbing Permit											$500
	Electrical Permit											$36,200
	Operating Permit											$500
											Phase 2 Subtotal	**$2,141,500**
											Contingency (5%)	**$107,100**
											Phase 2 Total Cost (2011 USD)	**$2,248,600**
											Phase 2 Total Cost (2021 CAD)	**$3,372,100**
											Phase 1 + 2 Total Cost (2021 CAD)	**$15,753,000**

O&M - PHASE 1						
Element	**Item Description**	**Quantity Required in 28 years**	**Unit**	**Rate/Unit**	**28 Year Total**	**O&M Cost/Year**
Groundwater Wells x7					**$11,522,700.00**	**$413,000.00**
Groundwater Well x1 - expected life expectancy is 75 years					$1,646,100.00	$59,000.00
	Annual O&M (monthly water sampling, equipment inspection, well water level and drawdown rates)	28	ea	$36,000.00	$1,008,000.00	$36,000.00
	Well Cleaning - Brush and Bail method	3	ea	$40,000.00	$120,000.00	$4,300.00
	Well Cleaning - acid treatment involving chemical application, neutralization, disposal, pump removal and reinstallation	3	ea	$100,000.00	$300,000.00	$10,800.00
	Replace well pump and motor every 10 years	2	ea	$10,500.00	$21,000.00	$800.00
	Energy required assuming $0.0958/kwh	245280	hr	$0.02	$4,200.00	$200.00
	Hydrant inspection, flushing, and cleaning	3136	hr	$61.50	$192,900.00	$6,900.00
Water Treatment					**$2,835,400.00**	**$101,500.00**
	Screen O&M (electricity, labour, maintenance)	28	ea	$2,000.00	$56,000.00	$2,000.00
	Aeration Tower O&M (electricity, labour, maintenance)	28	ea	$4,773.90	$133,700.00	$4,800.00
	Rectangular Clarifier O&M (electricity, labour, maintenance)	28	ea	$12,803.00	$358,500.00	$12,900.00
	Gravity Filtration Structures O&M (electricity, labour, maintenance)	28	ea	$49,237.19	$1,378,700.00	$49,300.00
	Chlorine Dioxide Generating and Feed O&M (electricity, labour, maintenance)	28	ea	$32,444.41	$908,500.00	$32,500.00
Distribution (eg. pipes and valves etc.)					**$424,900.00**	**$15,200.00**
	Inspection of valves, pipe leak repairs, labour	28	ea	$15,172.00	$424,900.00	$15,200.00
Distribution Pump Stations					**$364,700.00**	**$13,100.00**
	Replace 7 pumps every 10 years	7	ea	$20,790.00	$145,600.00	$5,200.00
	Annual O&M (inspect structure and equipment)	28	ea	$7,822.00	$219,100.00	$7,900.00
Reservoir					**$147,800.00**	**$5,300.00**
	Inspections and Maintenance of Structure	28	ea	$4,290.00	$120,200.00	$4,300.00
	Hydrant inspection, flushing, and cleaning	448	hr	$61.50	$27,600.00	$1,000.00
Diesel Generator					**$1,517,700.00**	**$54,300.00**
	Replace 7 generators every 25 years	1	ea.	$1,047,300.00	$1,047,300.00	$37,500.00
	Annual Diesel Consumption	5.6	years	$54,000.00	$302,400.00	$10,800.00
	Annual equipment cleaning and maintenance	28	ea	$6,000.00	$168,000.00	$6,000.00
				Total Costs	**$16,813,200.00**	**$602,400.00**

O&M - PHASE 2						
Element	**Item Description**	**Quantity Required in 47 years**	**Unit**	**Rate/Unit**	**47 Year Total**	**O&M Cost/Year**
Groundwater Wells x11					**$27,360,300.00**	**$584,100.00**
Groundwater Well x1 - expected life expectancy is 75 years					$2,487,300.00	$53,100.00
	Annual O&M (monthly water sampling, equipment inspection, well water level and drawdown rates)	47	year	$36,000.00	$1,692,000.00	$36,000.00
	Well Cleaning - Brush and Bail method (every 10 years)	5	ea	$40,000.00	$200,000.00	$4,300.00
	Well Cleaning - acid treatment involving chemical application, neutralization, disposal, pump removal and reinstallation (1 once per well lifetime)	5	ea	$100,000.00	$500,000.00	$10,700.00
	Replace well pump and motor every 10 years	4	ea	$10,500.00	$42,000.00	$900.00
	Energy required assuming $0.0958/kwh	411720	hr	$0.02	$7,000.00	$200.00
	Hydrant inspection, flushing, and cleaning	752	hr	$61.50	$46,300.00	$1,000.00
Water Treatment					**$4,829,300.00**	**$103,000.00**
	Screen O&M (electricity, labour, maintenance)	47	ea	$2,000.00	$94,000.00	$2,000.00
	Aeration Tower O&M (electricity, labour, maintenance)	47	ea	$4,773.90	$224,400.00	$4,800.00
	Rectangular Clarifier O&M (electricity, labour, maintenance)	47	ea	$12,803.00	$601,800.00	$12,900.00
	Gravity Filtration Structures O&M (electricity, labour, maintenance)	47	ea	$50,722.43	$2,384,000.00	$50,800.00
	Chlorine Dioxide Generating and Feed O&M (electricity, labour, maintenance)	47	ea	$32,446.96	$1,525,100.00	$32,500.00
Distribution (eg. pipes and valves etc.)					**$1,294,500.00**	**$27,600.00**
	Inspection of valves, pipe leak repairs, labour	47	ea	$27,542.00	$1,294,500.00	$27,600.00
Distribution Pump Stations					**$804,300.00**	**$17,200.00**
	Replace 7 pumps every 10 years	21	ea	$20,790.00	$436,600.00	$9,300.00
	Annual O&M (inspect structure and equipment)	47	ea	$7,822.00	$367,700.00	$7,900.00
Reservoir					**$248,000.00**	**$5,300.00**
	Inspections and Maintenance of Structure	47	yr	$4,290.00	$201,700.00	$4,300.00
	Hydrant inspection, flushing, and cleaning	752	hr	$61.50	$46,300.00	$1,000.00
Diesel Generator					**$1,089,600.00**	**$23,200.00**
	Replace generator every 25 years	2	ea.	$150,000.00	$300,000.00	$6,400.00
	Diesel Consumption	9.4	years	$54,000.00	$507,600.00	$10,800.00
	Equipment cleaning and maintenance	47	ea	$6,000.00	$282,000.00	$6,000.00
				Total Costs	**$35,626,000.00**	**$760,400.00**