UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Corridor Redesign of Chancellor Boulevard - Team 15

Gregg Gillis, Jackson Hamersley, Quinn Hardie, Damon Houston, Erica Mason,

Sina Naseri, Sarah Power

University of British Columbia

CIVL 445

Themes: Transportation, Community, Land

April 9th, 2018

CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Team 15

Empire Engineering CIVL 446

Krista Falkner and David Gill
UBC Campus and Community Planning
2210 East Mall
Vancouver, BC V6T 1Z4

April 9, 2018

Dear Krista Falkner and David Gill,

Empire Engineering presents this final detailed design report to UBC SEEDS for the redesign of the Chancellor Boulevard roadway corridor, as outlined in the *Corridor Redesign of Chancellor Boulevard Project Brief.*

The Corridor Redesign of Chancellor Boulevard Project is a complex multi-disciplinary project. Our engineering team was retained by UBC SEEDS after submitting a proposal late September of 2017. A summary design report and presentation was delivered to the client on March 5th, 2018.

Empire Engineering brings a unique and varied design experience to the redesign of this project, with experience and interest in structural, geotechnical, hydrological, and transportation engineering, as well as urban planning and project management. We have put an emphasis on stakeholder engagement, public safety, and environmental stewardship as these aspects of the project are vitally important.

Please do not hesitate to contact Empire Engineering consultants for any questions regarding this report. We look forward to working with you as the project advances to the construction phase.

Sincerely,

Empire Engineering

Executive Summary

Empire Engineering has prepared a design report for the redesign of Chancellor Boulevard from Drummond Drive to Acadia Road. Several key issues have been identified that have been addressed in the redesign. Due to insufficient traffic calming measures and the current road configuration, typical vehicle speeds in the project area exceed the posted speed limit of 60 km/h. The poor condition of the existing multi-purpose path and absence of safe pedestrian crossings limits pedestrian and cyclist accessibility and has resulted in these users taking alternative routes to access the University of British Columbia. Furthermore, the road is located near salmon-bearing creeks and sensitive ecological areas within Pacific Spirit Regional Park. Stakeholders have been considered throughout the project through consultation discussed in the Preliminary Design Report.

The new road design includes one vehicle travel lane of a reduced width and designated bicycle lane in each direction, separated by rumble strips. This "road diet" approach will reduce travel speeds and also decrease the total impervious surface within the project area. To address additional forms of safe passage across the corridor, a precast concrete tunnel at the Spanish Trail head will be installed that provides space for both pedestrian and cyclists. This underpass will be equipped with accessible ramps, stairs, and lighting. Additionally, a marked crosswalk at the Pioneer Trail head will be added and equipped with a semi-actuated pedestrian crossing light. Pedestrians will also be able to access an improved and repaved multi-purpose trail along Chancellor Boulevard. Through the process of an Environmental Assessment, plans have been made to mitigate potential environmental issues that may arise during construction and operation. As such, a detailed Stormwater Management Plan has been implemented to increase the infiltration of stormwater into the natural groundwater.

Empire Engineering estimates a cost of $6,146,000 for the remainder of the design and construction of this project. Construction is expected to be completed in 13 weeks, starting May 2018.

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1. Introduction

Empire Engineering has prepared the following detailed design report for the SEEDS (Social Ecological Economical Development Studies) Sustainability Program of the University of British Columbia (UBC) regarding the Corridor Redesign of Chancellor Boulevard. This design report provides the information required to carry the project forward to the tendering and construction phases.

1.1 Project Description and Objectives

The Chancellor Boulevard Corridor (project area) includes the area along Chancellor Boulevard from Drummond Drive to just west of Acadia Road (Figure 1). This roadway provides one of four connections to/from the UBC campus and Vancouver, via connection to West 4th Avenue.

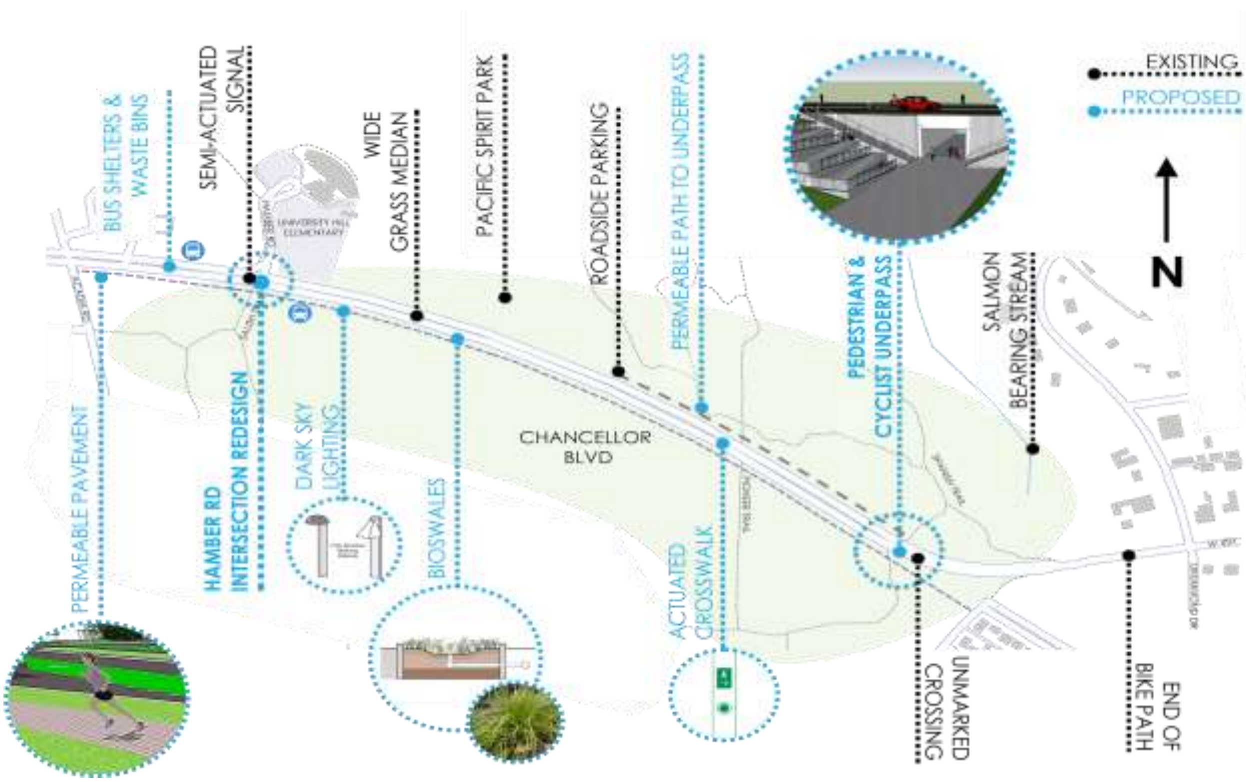

Figure 1. Aerial view of the project area and significant locations.

Several safety and accessibility issues have been identified with the existing roadway and addressed in this final design report. Specifically, the following objectives have been included in the design solution.

- Accommodation of future transportation demands for all transportation modes and addressal of safety concerns for all road users
- Construction of a pedestrian/cyclist underpass to offer safe passage across the roadway at a location that optimizes usage
- Minimization of environmental and societal construction effects
- Enhancing of the natural ecosystem, such as the salmon-bearing streams
- Minimization of construction cost and cost-of-ownership to UBC

1.2 Project Scope

The scope of work included in the project includes all engineering design considerations (i.e. transportation, geotechnical, structural, environmental, etc.) associated with the redesign of Chancellor Boulevard within the project area. The following items were included in the scope of work:

- Acquisition and review of relevant information to determine future traffic demands
- Computer-modelling of lane and intersection configurations for future traffic volumes
- Conduction of a turning-movement study at Hamber and Acadia intersections
- Safety analysis, including speed, visibility, and cyclist/pedestrian safety
- Incorporation of a cyclist/pedestrian underpass at an optimal location
- Preparation of a stakeholder engagement plan
- Preparation of a Class B cost estimate and construction schedule
- Issued for Tender Drawings

1.3 Key Issues and Design Criteria

The corridor's redesign is intended to improve the safety, accessibility, and serviceability of the corridor for all modes of transportation, with priority given to buses, cyclists, and pedestrians. The following key issues have been identified with the current configuration and conditions of Chancellor Boulevard:

Poor condition & drainage
Improve the existing multi-use path & road drainage

Excessive vehicle speeds
Implement speed reduction measures for a safe cycling environment

Site contains sensitive ecosystems
Protect & enhance the natural environment

Lack of crossings for vulnerable users
Provide safe crossings for pedestrians & cyclists

- Typical travel speeds exceed the posted speed limit of 60 km/h, and few speed management systems are in effect, posing safety concerns for all users
- With the exception of one pedestrian-activated light at the Hamber Road intersection, designated cyclist facilities and pedestrian/cyclist crossings are insufficient
- The paved multi-use path on the south side of the road is in poor condition and seldom used
- Cyclists typically divert to other routes due to safety hazards and accessibility issues

The final design was selected to best-solve these design issues alongside the following additional project objective criteria:

- Traffic calming principals have improved safety and attractiveness for pedestrians and cyclists by reducing motor vehicle travel speeds to 50 km/h;
- Alternative travel modes have been encouraged through the implementation of various non-automobile facilities, in accordance with UBC's Transportation Plan;
- The University's social, economic, and environmental sustainability standards have been met, in accordance with UBC's Official Community Plan; and

1.4 Governing Policies and Documents

Chancellor Boulevard falls under the jurisdiction of the British Columbia Ministry of Transportation and Infrastructure (MoTI), and as such, is subject to the design provisions and criteria outlined in the Geometric Design Guidelines for BC Roads. In British Columbia, two core documents are utilized:

- Geometric Design Guide for Canadian Roads (TAC)
- A Policy on the Geometric Design of Highways and Streets (AASHTO)

Additionally, as the redesign includes the design of an underpass, the following governing documents are relevant to the geotechnical and structural designs:

- National Building Code of Canada
- CSA A23.3 (Design of Concrete Structures)

Hydrotechnical design is covered across several of these documents. However, the City of Surrey's Design Criteria Manual was utilized for the design of bioswales and other natural drainage features.

Finally, two UBC core documents were utilized:

1. UEL Official Community Plan (2005)

   The 2005 University Endowment Lands Official Community Plan (OCP) outlines the planning and land use objectives to meet the community's vision. As one of the UEL's arterial roads, Chancellor Boulevard's redesign should follow the directions of the OCP. This includes the implementation of speed reduction measures and direction of non-local traffic to main arterial roads. The OCP also encourages the MoTI to install an on-road bicycle lane on Chancellor Boulevard between Acadia Road and the 8th Avenue (University Endowment Lands).

2. UBC Transportation Plan (2014)

   The UBC Transportation Plan has established UBC's targets for managing travel demands, promoting sustainable travel modes, and decreasing the single occupancy vehicle trips by 20% from 1997 levels. Some of the initiatives implemented have included new bicycle facilities, reducing parking supply and the U-Pass program. UBC has also collaborated with Translink to improve the Community Shuttle service on campus. The plan also outlines the need for improved safety at road crossings through raised crosswalks, lighting, as well as audible and tactile indicators (UBC Campus and Community Planning).

1.5 Limitations

This final design document was developed for exclusive use by UBC SEEDS and the UBC community. This report and its contents are not to be used for construction until comments have been received and reviewed by the Consultant from both UBC SEEDS and by the contractor after the tendering phase has been completed.

1.6 Team Contributions

Table 1 indicates each member's contributions to the technical and developmental aspects of this report. It should be noted that although tasks have been divided, the design process is an integrative approach that involves knowledge and competence of all aspects by all team members.

Table 1. Team Contributions

Contributor	Responsibilities	Reviewed By
Damon Houston	Road Design, Geometric Design	Erica Mason
Erica Mason	Road Design, Traffic Analysis	Sina Naseri
Gregg Gillis	Environmental Assessment, Stormwater Management	Sarah Power
Jackson Hamersley	Underpass, Geotechnical, and Structural	Quinn Hardie
Sarah Power	Environmental Assessment, Stormwater Management	Gregg Gillis
Sina Naseri	Construction Schedule, Cost Estimate, Stakeholder Management	Damon Houston
Quinn Hardie	Underpass, Geotechnical, and Structural	Jackson Hamersley

2. Reconnaissance and Existing Site Conditions

The redesign of Chancellor Boulevard involved extensive information gathering from available studies and surveys previously conducted at or near the project area, including screenline traffic volumes, hydrogeological data, and utilities and infrastructure data. Additionally, the project team conducted several site-visits to perform traffic counts, observe faults with the corridor layout as it exists today, and discuss perceived issues with local stakeholders and road users. This section presents a summary of the findings of this preliminary study.

2.1 Corridor Layout and Transportation Infrastructure

Chancellor Boulevard is a four-lane arterial road that serves as a connection between the northern section of the UBC campus and Vancouver through Pacific Spirit Regional Park. The road features two wide travel lanes of variable widths per travel direction, separated by a 5.5 m wide grass median. Parking is restricted on both sides of the road, with the exception of a pullout near the entrance to the Pioneer Trail on the north side of the road that extends approximately 200 m (STA 00+00 to STN 11+48.29). Key destinations in the project area include University Hill Elementary School, the University Endowment Lands Works Yard, and entrances to park trails. There is one signalized intersection at Hamber Road that provides direct access to University Hill Elementary School (STN 48+50.00). In addition, there are several unmarked intersections with Pacific Spirit Regional Park trails along the roadway. A list of all intersections within the project area and along the boundaries and the traffic controls in place at each location, as it exists today, are listed in Table 2.

Table 2. Intersections along Chancellor Boulevard

Intersection	Control	Pedestrian Crossing
Drummond Drive	Stop Control on Drummond Drive	Unmarked
Spanish Trail	None	Unmarked
Pioneer Trail	None	Unmarked
Hamber Road	Semi-Actuated	Crosswalk on West Approach
Acadia Circlet	Stop Control on Acadia Circlet	Unmarked
Acadia Road	Stop Control on Acadia Road	Unmarked

2.2 Accommodated Travel Modes

Chancellor Boulevard is one of four major access routes to the UBC campus and, as such, sees high volumes of traffic flow. Chancellor Boulevard is also a designated truck and transit route. The location within Pacific Spirit Regional Park also attracts cyclists, and other recreationalists to the area.

2.2.1 Walking

There is a paved multi-use path that runs along the south side of the road; however, it is in poor condition and seldom used. There are also several multi-use trails that cross Chancellor Boulevard; however, there are no marked crosswalks across the corridor for pedestrians and cyclists between these trails. The morning activity around the elementary school generates the highest pedestrian traffic and many students use the marked crosswalk at the west approach at Hamber Road. A pedestrian-actuated traffic signal controls this intersection to increase pedestrian safety.

2.2.2 Cycling

Although the corridor is a designated bike route, designated bike lanes terminate at the boundaries of the project area (at Drummond Drive and Acadia Road), leaving cyclists to share the road with vehicles or make use of the separated multi-use path along the corridor length. The lack of designated cyclist facilities along the roadway has discouraged cyclists from travelling along the corridor, and it has been observed that these users will typically deviate to other routes to access the UBC campus.

2.2.3 Transit

There are two bus stops located at Hamber Road that serve the #44 and #84 express bus routes. These transit stops only feature a bus stop ID sign and do not provide standard amenities such as a covered bus shelter or waste receptacles. Bus stops are located in pullouts that do not block the normal flow of traffic.

2.3 Traffic Conditions and Future Demand

UBC produces an annual transportation status report that compiles the results of the annual traffic data collection programs at each campus, including speed counts, screenline counts, and intersection traffic counts (UBC Campus and Community Planning, 2016). Key findings from the Fall 2016 report are as follows:

- The daytime population at UBC has increased from 42,300 in 1997 to 66,850 in 2016.
- Chancellor Boulevard had an average daily traffic volume (ADT) of 10,320, an 11.5% decrease from 1997. This is 17% of the traffic to and from UBC.
- The average 85th percentile traffic speeds along Chancellor Boulevard in the westbound and eastbound directions are 60.1 km/hr and 58.7 km/hr respectively. The westbound traffic speed has decreased from 71.2 km/hr in 2013.
- Transit has the greatest mode share of all trips to and from UBC.
- Bicycle and pedestrian trips decreased significantly after the implementation of the student U-Pass program and are not a significant mode share. These have, however, increased in comparison to the three-year rolling average.
- Since 1997, SOV trips have increased by 11.5% and HOV trips have decreased by 68%.

Figure 2. Summary of Trip Distribution Data To/From UBC - Fall 2016

2.3.1 Screenline Volume Data

A screenline is located at Chancellor Boulevard east of Western Parkway. Although this is located outside of the project area, it was assumed that the traffic at Allison road had negligible impact and thus, the speed and traffic count data at Western Parkway would be representative of the intersection at Acadia

Road. Count information for pedestrians and cyclists were not available. Empire Engineering also conducted a traffic count on October 5th to get a preliminary estimate for traffic movements at Hamber Road, Acadia Road, and Acadia Circle., as detailed in Appendix C.

2.3.2 Vehicle Trips from University Hill Elementary School

The highest activity for all travel modes takes place at the Hamber Road during the AM Peak. In addition to the available traffic data, traffic movements were estimated from the current student enrollment, 360, and staff members, 32, at the elementary school (Vancouver School District). The expected peak hours of the school are 8:15 am to 9:15 am and 2:45 pm to 3:45 pm. Although pick-up/drop-off activity occurs in the roundabout in front of the school, vehicle queues can occur along Chancellor Boulevard. The traffic survey observed that 140 students used public transit or walked to school. The majority were driven to the school. The survey also found that 60% of vehicles turning onto Hamber Road came from eastbound direction and 67% of vehicles leaving turned towards UBC.

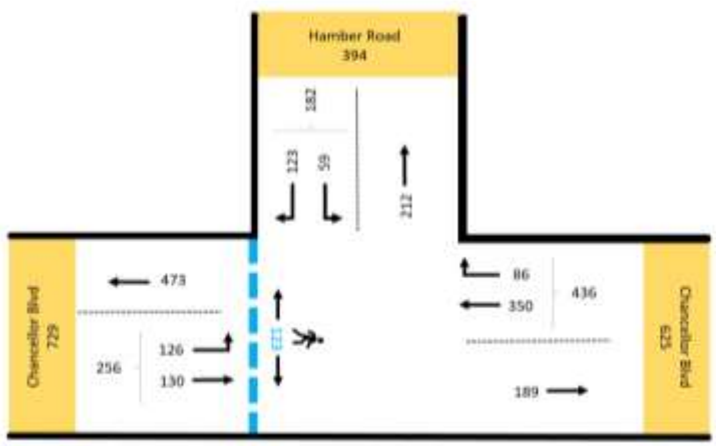

Figure 3. Traffic Volumes at Hamber Intersection during AM Peak

2.3.3 Traffic Model

Traffic operations of the project area's existing conditions were evaluated using Trafficware's Synchro 6.0 software. The model was used to test the Volume to Capacity ratio (V/C), Intersection Capacity Utilization (ICU) and the delay-based Level of Service (LOS) of each intersection. Although this was useful for evaluating the effects of the proposed redesign, Synchro 6 is unable to properly assess pedestrian-actuated crosswalks. As an alternative, two different control types can be used in the model:

- Fully actuated signal - this would assume pedestrian actuation for each cycle
- Stop-controlled - this would assume no actuation

The high levels of activity for all modes occur at the Hamber and Acadia intersections during the AM Peak Hour, and thus, the traffic conditions were modelled for this time period. To build the traffic model, traffic volumes were approximated using the average AM Peak volume from the 2016 data at Western Parkway. Assuming that this volume was not affected by Allison Road (no added or lost vehicles), this provided an expected volume for Acadia Road. The volumes at the following intersections were calculated by incorporating the survey data collected by Empire Engineering. The peak hour factor was estimated to be 0.83 based on the screenline survey data. This data is summarized graphically in Figure 4 and was provided in the Preliminary Design Report.

Figure 4. Existing AM Peak Hour Traffic Volumes

These results indicate that although the Level of Service is high, there is excess volume capacity and thus, the potential to reduce the number of lanes.

2.4 Environment and Surrounding Ecosystem

The environment surrounding Chancellor Boulevard is part of Pacific Spirit Regional Park, which is home to a diverse ecosystem susceptible to human activity and sensitive to minor changes induced by construction and the addition of new infrastructure. There are multiple fish-bearing streams on the north side of the road within Pacific Spirit Regional Park where surrounding groundwater penetrates into the streams.

2.5 Existing Utilities

The University Endowment Lands (UEL) has provided water, sanitary and storm drawings that indicate the existing utilities along the corridor. Most of the infrastructure lies in the subsurface beneath the median that extends the length of the project area. The features at the intersection include water valves, sanitary, storm, and water mains and utility access holes, fire hydrants, and a storm outfall. The storm mains continue down Chancellor in 200, 250, and 300 mm diameter pipes, assumed to be 1 m underground. Some catch basins are located outside of the proposed road area, and thus will have to be relocated. This is discussed in more detail in **Section 5.** For the electric utilities, BC One Call will be informed of the construction. The current signal operates, and street lighting will be added to this circuit. The utility box is located on the North-East side corner of the Hamber Road intersection. No additional changes will be needed.

3. Roadway Design

This section presents a detailed outline of the proposed roadway redesign including the roadway layout, cross-sectional slopes, designated pedestrian and cyclist facilities, design details with the intersection with Hamber Road, and traffic modelling results of the redesign.

3.1 Roadway Layout

Conventional highway design typically uses the road's operating speed to determine horizontal dimensions; however, by using the target speed of 50 km/hr, geometric decisions will proactively increase safety for pedestrians and cyclists alike. The roadway layout was chosen to improve accessibility and safety to all road users while optimizing benefit-cost ratios.

3.1.1 Typical Horizontal Layout

The roadway redesign maintains the existing grass median and reduces the current four-lane orientation to two vehicle travel lanes, with the addition of two designated bicycle lanes of a 2.5 m width located on the outsides of the roadway. Each vehicle lane width is reduced from the current range of 4.0 - 4.5 m to a width of 3.3 m. Rumble strips and reflective raised pavement markers are installed within a buffer space between the vehicle and bicycle lanes that measures 0.5 m in width. This typical cross section is illustrated in Figure 5. Details drawings are provided in Appendix G.2.

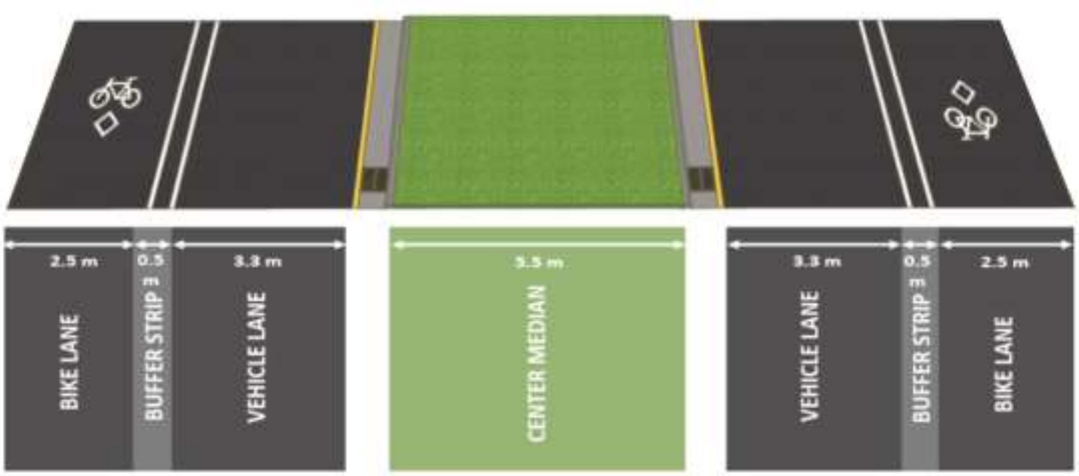

Figure 5. Typical Road Cross-Section and Dimensions

3.1.1.1 Reduced Travel Lane Width

The reduction of the vehicle travel lane widths, also known as a "road diet" approach, will promote safer driver behaviour by encouraging drivers to travel at the target design speed of 50 km/hr, as higher speeds become more uncomfortable in narrower travel lanes. The reduced travel lane widths also contribute to the reduction of the total impervious area along the roadway.

3.1.1.2 Rumble Strips

The rumble strips act as a physical barrier between the vehicle travel lanes and cyclist lanes by preventing vehicles from overtaking the bicycle lane, but still allow for vehicles to yield to emergency vehicles or move off the travel lane in the event of a stall. Rumble strips are also more cost-effective than the installation of a physical barrier, and offer very similar traffic-calming effects. The continuous rumble strips are installed within the buffer strips located between the vehicle and bicycle lanes. The rumble strips measure 140 mm wide and are placed 100 mm from the leftmost painted white line, according to design standards.

3.1.1.3 Reflective Raised Pavement Markers

In lieu of street lighting, reflective raised pavement markers (RRPM's) are installed to provide a visual aid for drivers to stay within the travel lane when there is limited natural light available. The RRPM's reflect light provided by headlights, and are also effective during adverse weather conditions.

3.1.1.4 Bus Stop Shelters

Two bus stops are located within the project area, and are regularly used due to the proximity to the elementary school. Bus stop shelters and waste collection bins will be added to ensure a positive experience for transit users along the corridor.

3.1.1.5 "Living Lab": Inductive Loop Bicycle Counters

As part of the Transportation 2040 Plan, inductive loop bicycle counters have been implemented around the city. This simple piece of infrastructure works as a reasonably inexpensive data collection system. A counter will be installed on the north side of Chancellor Boulevard, between the Spanish Trail head and the Pioneer Trail head, and on the south side of the Boulevard, east of the Hamber Road intersection, just past the bus stop. These locations will get the most exposure in both travel directions, as pedestrians are cyclists frequently occupy these areas.

3.1.2 Cross-Sectional Slopes

The roadway is superelevated with a 2% grade with the crown located along the buffer strips; a typical cross-slope is shown for the eastbound direction in Figure 6**.** Stormwater drains inwards from the vehicle lanes and is collected and conveyed along the drainage curbs located against the median, and drains through the catch basins. The bike lanes drain stormwater outwards to grass swales - located between the bicycle lane and pedestrian footpath - that are discussed in more detail in **Section 5**. More detailed layout and cross-sectional drawings are included in Appendix G.3.

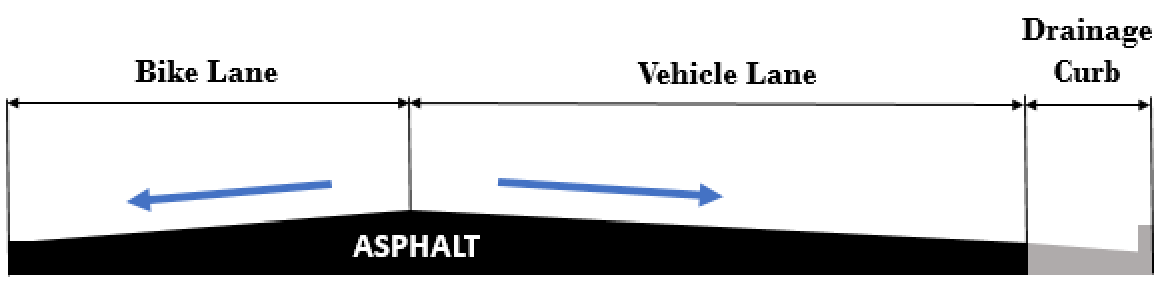

Figure 6. Typical Eastbound Cross-Slope

3.2 Pedestrian and Cyclist Facilities

The redesign includes several designated pedestrian and cyclist features and facilities to improve the accessibility and safety of the roadway in order to promote pedestrian and cyclist usage.

3.2.1 Designated Cyclist Lanes

The addition of two designated cyclist lanes will provide safe and accessible facilities for bicyclists using the roadway to access UBC and to the trails within Pacific Spirit Regional Park. The City of Vancouver promotes the design of cyclist facilities that cater to all levels of rider skill, and recommends a lane width of 2.5 m for a unidirectional path to provide a comfortable clearance space for cyclists who wish to pass another user (City of Vancouver, 2017). As the roadway includes many University Hill Elementary School students who cycle to and from school, this design recommendation was considered to be mandatory so younger riders would be provided ample space among more experienced cycling road users. The designated cyclist lanes include standard painted diamond-and-bicycle symbols to indicate cyclist designation, and solid green paint in areas where turning lanes or intersections allow for vehicle encroachment over the bike lanes. Finally, the orientation of the designated bike lanes in the redesign allows for a simple transition to the bike lane orientations at each end of the project area (west of Acadia Road and east of Drummond Drive).

3.2.2 Designated Pedestrian Pathways

An improved pedestrian pathway on the south side of Chancellor Boulevard is included in the redesign and features a permeable paver called Uni Eco-Stone. This pervious stone material is pedestrian and cyclist friendly, and contributes to the overall aesthetics of the roadway and impervious area reduction. An additional pedestrian pathway composed of a medium grade gravel is also included in the redesign, and is located on the north side of Chancellor Boulevard between Spanish Trail and Pioneer Trail, where high volumes of hikers and mountain bikers were observed navigating between the two respective trailheads. Currently, no features exist in this region. The existing and redesigned roadway cross-sections, including the improved and additional pedestrian facilities, are shown in Figures 7 and 8, respectively.

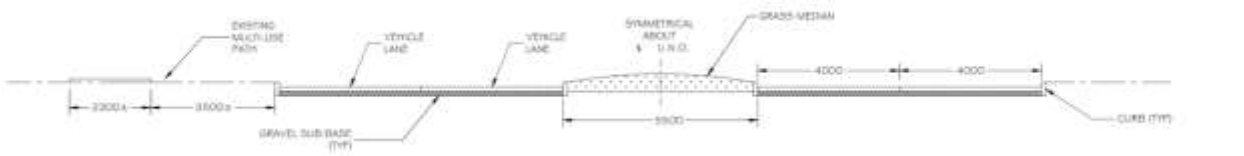

Figure 7. Existing Roadway Cross-Section

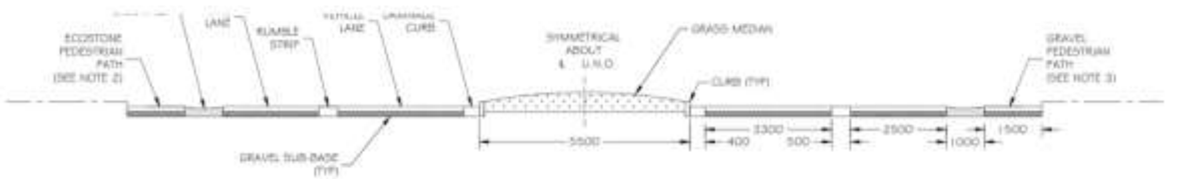

Figure 8. Redesigned Roadway Cross-Section

3.2.3 Designated Safe-Crossing Facilities

In addition to the pedestrian-activated crosswalk at Hamber Road and the pedestrian underpass, an additional actuated pedestrian crosswalk is included in the redesign located along the Pioneer Trail to connect the north and south sides of the trail. The sight distance for drivers in this region is significant enough that crosswalk signs and a painted crosswalk are an adequate designation of the crossway. A calculation for the required sight distance, based on the stopping sight distance calculated to be 65 m, can be found in Appendix B.1.

3.2.4 Lighting

In order to preserve the natural aesthetics of the corridor, no roadway lighting is provided for vehicles. Instead, rumble strips and reflective raised pavement markers are installed as additional safety measures, as described earlier. However, lighting is provided for pedestrians and cyclists in attempt to make the corridor more accessible when there is minimal natural light. "Dark Sky Friendly" lighting was selected as the best lighting option that minimizes effects on the natural environment. The "Dark Sky Friendly" certification is discussed in more detail in **Section 6**.

Fully shielded walkway bollard lighting will be installed every 100 meters and at important road and path intersections. There is a total of 36 lights along both the bike paths and the south pedestrian path, costing approximately $300 each. The wiring for the lights will be kept in PVC conduit underneath the grass section separating the bike lane and the repaved pedestrian path. The power will come from the intersection at Hamber Road.

3.3 Intersection with Hamber Road

The intersection at Hamber Road introduces additional complexities to the typical roadway cross-section. The existing intersection includes two bus stops, located on the northwest and southeast corners of the intersection, and the only currently-existing designated pedestrian crosswalk, controlled via a pedestrian-activated traffic signal. The crosswalk is highly utilized by elementary school students. Several congestion issues were observed with the roadway during the peak hours of 8:30-9:30 am and 2:30-3:30 pm, particularly with turning to and from Hamber Road from Chancellor Boulevard.

The intersection redesign maintains the currently-existing designated left-hand turning lane on Chancellor Boulevard to Hamber Road, and introduces a secondary designated turning lane for right-hand turns onto Hamber Road for vehicles travelling westbound on Chancellor Boulevard. To facilitate the extra roadway width required, the central grass median is reduced locally. Rumble strips are temporarily suspended through the intersection, and the cyclist lanes are painted solid green to increase visibility.

The channelized right-hand turning lane from Hamber Road to Chancellor Boulevard is removed to provide full protection of pedestrians at the intersection. The additional space is utilized in the redesign for a bus pullout. A pullout is also provided for the stop at the southeast corner of the intersection to allow for the passing of vehicles during a pickup. The redesign does not require the relocation of any of the existing infrastructure or lighting systems.

3.4 Roadway Redesign Traffic Analysis

The roadway redesign was modelled and compared to the existing conditions using Synchro 6.0. This analysis demonstrated that the road diet will not affect the Level of Service. Reducing four-lane roads to two lanes do not affect the future traffic capacity, as road network capacity is primarily determined by intersection layouts and traffic light phasing. Current and future traffic volumes were found to be less than the capacity of the proposed two-lane road. A single traffic lane can accommodate up to 2,000 vehicles per hour, whereas the maximum forecast traffic volume in the future is 900 vehicles per hour per lane.

4.2.2 Intersection Performance

The road's redesign was modelled and compared to the existing conditions, Figure 9. This analysis found that the road diet successful in that it increased the V/C of each intersection, the level of service did not change. The pedestrian crossing at the Pioneer Trail was modelled as a stop-controlled intersection and was found to have an adequate Level of Service.

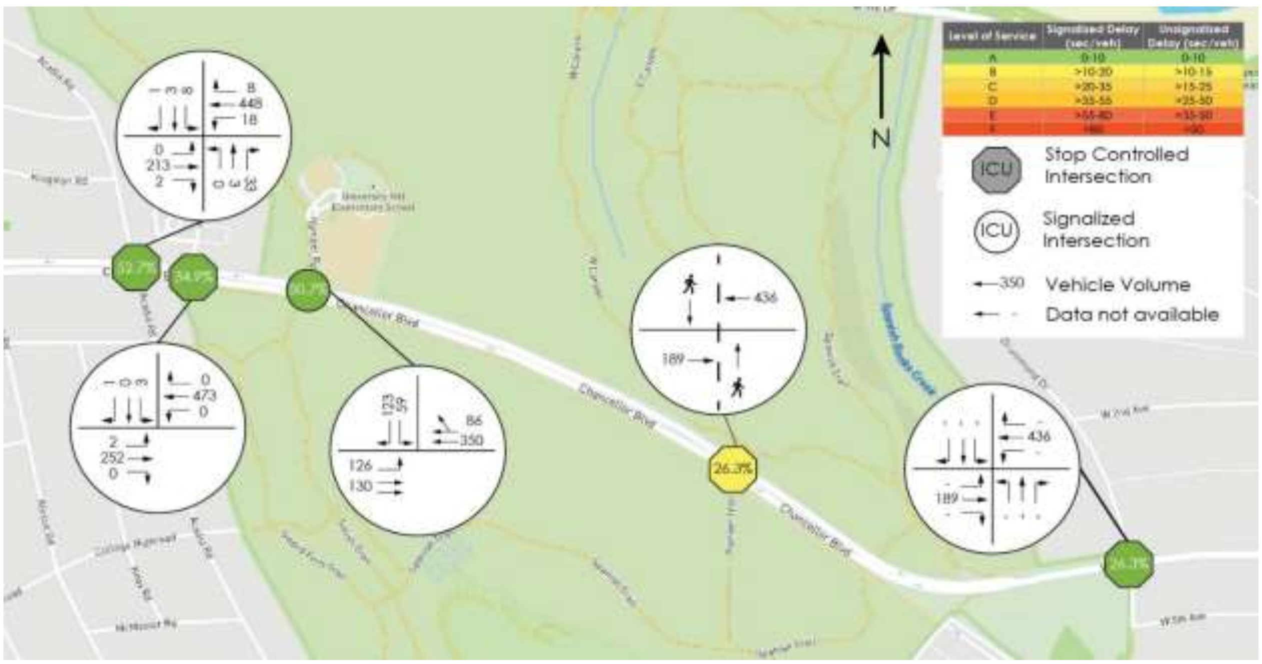

Figure 9. AM Peak Hour Traffic Volumes and Level of Service after Redesign

4. Underpass Design

The pedestrian and cyclist underpass will be located at the Spanish Trail, Station 4+60 in Drawing CB-002, to provide a safe crossing for pedestrians using the park trails, as well as cyclists using the bike route between West 4th and UBC. This is the highest elevation point along the road, which will simplify construction and improve drainage. The tunnel will be added to join the Northern and Southern halves of the Spanish trail, crossing underneath Chancellor Boulevard. It will be accessible to cyclists, pedestrians and wheelchairs, and will have both natural and artificial lighting to provide a feeling of safety regardless of time or weather conditions. The location also provides sufficient space for the ramp and stair system. Design loads for the underpass structure are provided in Appendix A.

- The tunnel will be constructed out of precast, reinforced, concrete box culverts. These will be constructed in two 10 m sections and lowered into the excavation by a mobile crane.
- It will have two retaining walls, a wheelchair/cyclist ramp, and two sets of stairs at each end. These will be connected to the existing cyclist and pedestrian paths.
- A ground infiltration stormwater drainage system will be connected to the tunnel. Collection gutters will feed underground "soakaway" tanks and allow water to drain into the surrounding soil.

4.1 Geotechnical Evaluation

The geotechnical model was developed from the Piteau Associates Geotechnical and Hydrogeological Assessment of the UBC Area (2002). This study used Sonic Drilling and Mud Rotary drilling, as well as visual mapping of the exposed cliff faces and groundwater monitoring to develop a comprehensive geotechnical site profile. From this study, it was determined that up to 65 meters below ground surface (BGS) of the project area is composed mainly of Podzolic sands with isolated silt lenses. Typical soil parameters for these soils have been obtained, and are used to obtain soil pressures and settlements for the tunnel design, shown in Table 3.

Table 3. Soil Parameters used for Tunnel Design

Ultimate Bearing Resistance (kPa)	Factored Bearing Resistance (kPa)	Soil Elastic Modulus (kPa)	Soil Angle of Friction (o)	Soil Unit Weight (kN/m³)
180	90	14,000	28	19

4.2 Underpass Design

Due to the desired short construction period and the simple nature of the tunnel, a reinforced, precast concrete tunnel design is used in the design. Detailed dimensions and drawings of this design can be found in drawings CB-004 and CB-005 in Appendix G.1. This tunnel was designed to minimize weight differential on the soil, therefore not causing consolidation settlements and causing elastic settlements of under 1 cm upwards (Calculations in Appendix B.4). The tunnel will have a 5 m wide by 3.5 m tall opening, per the specifications for a pedestrian/cyclists underpass. The tunnel will have both a cyclist and pedestrian lane in each of the north and south directions. To shorten the construction process, these tunnel sections will be precast off-site and then installed in a pre-excavated hole on the project site. Specifications call for a 30 MPa concrete using recycled concrete aggregate (RCA) to minimize environmental impacts of this tunnel construction.

4.3 Entrances to the Tunnel

At either end of the tunnel, there will be a paved entrance way, details of which can be found on drawings CB-004 and CB-005 in Appendix G.1. Leading into these entrances, there will be stairs with accompanying bike channels and wheelchair ramps. In accordance with the BC Building code (2012), the stairs will have a slope of 67% and will have a landing at the midpoint of the stairs, as the stairs exceed 3.6 m in height. Details for these stairs can be found on drawings CB-004 and CB-005. The maximum slope of the wheelchair ramp will be a 5% grade. To provide this grade to the depth of the tunnel entrances, these ramps will include several landings as resting points for users. These access points will have steel railings on either side. The remaining sloped area surrounding the tunnel entrances will be covered with grass, with a grade of 2:1, which will improve slope stability and stormwater management.

Next to the staircases, there will be a precast concrete soil retaining wall. These will be fully embedded reinforced concrete walls that are 0.3 m thick, with two rows of soil anchors installed at a spacing of 1 per meter. These walls were designed by both hand calculations and using the WallAPP computer program. More details of the retaining walls can be found on drawing CB-006. Per NBCC 2010, these retaining walls were designed to withstand an earthquake with a 2475-year return period, with a peak ground acceleration of 0.46 g, as well as supporting a fully loaded city bus (the maximum vertical load).

4.4 Construction Process

While exact construction methodology is to be left up to the contractor, a recommended construction sequence is shown below. Key items for construction engineering are:

- In order to prevent cracking in the permanent pavement, 2 weeks should be allowed after tunnel placement for upwards elastic soil rebound to occur.
- Temporary slopes will have slopes of 50% or less, or will be engineered with support structures installed.

Table 4. Construction sequencing for Tunnel Construction

Activity	Notes
Trench Excavation	Unsupported slopes to be at a 2:1 temporary side slope or have engineered temporary support.
Structure Placement	Place tunnel and drainage structures, install retaining walls at end.
Backfill	Backfill and soil leveling over permanent structures.
Installation of Soil Anchors	Installation and tensioning of permanent soil anchors in support of the retaining walls.
Allowance for upwards settlement	Allowance for elastic rebound of tunnel, occurs during installation of soil anchors. Paving can occur after this stage.
End Platforms and Staircases	Construction and installation of: Permanent side slopes, end platforms, staircases, wheelchair ramps and drainage connections.
Final commissioning	Installation of lighting, wall facings, drainage accessories, guardrails, vegetation.

5. Stormwater Management

A stormwater management plan for Chancellor Boulevard will be required to provide adequate drainage for safe vehicle travel and to avoid flooding of the roadway and pedestrian/cyclist tunnel.

5.1 Existing Facilities

A stormwater main runs along the corridor beneath the center grass median. Catch basins are located at intervals along the roadway that are tied into the stormwater main. To facilitate the new road cross-section and cross-slopes, some catch basins that are currently located along the southernmost section of the roadway will have to be relocated towards the center median. The existing tie-ins can be reused.

5.2 Roadside Stormwater Drainage

Empire Engineering will aim to reduce the amount of water flowing into the storm main. The overarching goal for stormwater improvements will be natural infiltration to return the stormwater back into the groundwater supply. As such, the cross-slopes of the corridor will allow stormwater to drain inwards from the vehicle lanes and outwards from the bicycle lanes. Stormwater on the vehicle lanes will be directed towards drainage curbs that are located along the median, which will convey stormwater to drainage basins where it is collected. On the outside of the bicycle lanes, grass swales will convey and collect water to be absorbed. These bioswales will be built between the bike lane and pedestrian path to increase water filtration and create a barrier between the pathways. Additionally, pooling of water has been observed along the roadway, particularly at the lowest point of elevation on the road, between Hamber Road and Pioneer Trail. These pooling areas pose a safety concern to drivers. To reduce the impact of this pooling, a bioswale will be constructed in the grass median space.

The design of both of these features follows the Simplified Rainfall Capture Method. The Surrey Design Guidelines were considered, as these standards are the most up-to-date and accurate standards in the lower mainland for Infiltration Trench Design. The Impervious to Pervious Ratio for a collector road should be 20:1, which is important to consider during design. The soil profile is based on the Canadian Geological Survey, which suggests that the soil along Chancellor Blvd is a Vashon Drift and Capilano Sediment, meaning there are interbeds of sand and gravel. The soil properties were found using the waterbalance.ca calculator tools. The rainfall intensity was found on the UBC Technical Guidelines, and using a IDF curve and the volumetric reduction criteria of 72% of the 2-year, 24-hour storm, an approximate 41.4 mm of rainfall was used to design the volumes needed. Both of the swales will have a 150 mm diameter, vertical, perforated pipe every 15m along the length in order to monitor the rain drainage. The bioswales will use naturally occurring vegetation that has been approved by the City of Vancouver and will increase groundwater quality through water filtration.

The large bioswale at the low point will have a horizontal perforated pipe connected to the main storm drain in case of overflow. Both swales meet the requirements outlined by the 2016 Surrey Guidelines, such as the 1.2 to 2 m depth and a 1 m width. A geotextile non-woven material will line the rain garden, the trench will then be filled with gravel with diameters ranging from 25 to 75 mm, then topped with a growing medium layer to support the vegetation in place. There will be three curb inlets in each direction to spread water throughout the swale.

The outside swales are continuous along the side of the road and are therefore designed to have a tributary area of 1 m of roadway, by 2.5 m width of the bicycle lane. The input volume is therefore 0.104 m^3. The captural volume, which is a combination of the evaporation, growing medium, rock layer and infiltration capacities, based on a 1m swale is 0.126 m^3. The depth of the growing medium would be 0.15 m and rock layer would be 0.2 m. This capture volume exceeds the required input amount and is acceptable. For the large bioswale at the low point in the road, a tributary area of 8m width by 100 m of road is used, so a total of 33.18 m^3 of rainfall is input to this area. The swale has dimensions of 5.5m width and 20m length, with a 0.4 m thick growing medium and a 0.6 m rock layer, has capacity to capture 34.28 m^3 of rainfall. Therefore, this is also acceptable for rainfall capture based on the input calculations. Appendix F will show sample calculations of how these values were derived.

Figure 10. Example Bioswale Rendering

5.3 Tunnel Stormwater Drainage

The floor slab of the tunnel will be sloped outward such that any water that enters the tunnel will be transported to narrow ditches that run along the walls inside the tunnel. The ditches will be grated so that large debris (leaves, rock, etc) cannot enter. The ditches will be connected to PVC piping at the south end of the tunnel, that will drain into structural plastic crates called "soakaway" tanks. These tanks will be wrapped in a permeable geotextile that will allow the collected stormwater to slowly drain into the surrounding soil. These soakaway tanks can be seen in drawings CB-201 & CB-206.

Data from a nearby soil core sample (Nazhat) shows that the type of soil at the elevation the tanks will be at is silt. Due to silts low permeability, 8.64 mm/day (Nazhat), the tanks had to be designed large enough for there to be adequate time for the water to release into the surrounding soil, without flooding in ditches. On each side of the tunnel, there will be a soakaway tank of 20 m in length, and a volume of 10.39 m^3.

6. Environmental Assessment

Empire Engineering has put together a summary of the Environmental Assessment (EA) that was completed after the conceptual design phase of the Chancellor Boulevard Redesign. The EA has considered the stakeholders in the area and addressed the requests and concerned brought up in consultation. This summary will explain the issues and potential mitigation techniques for each environmental concern.

6.1 Construction Practices

Empire Engineering will make significant effort to mitigate the impact of construction on the environment. The construction industry contributes a significant amount to the production of greenhouse gases (GHG). Cement production itself contributes 5% of global GHG emissions. The choice of material, its transportation, and eventual disposal, collectively referred to as material flow, all contribute to the release of these gases into the atmosphere.

There are several methods in each aspect of construction that can reduce GHG emissions. First, recycled material will be used wherever possible, such as the asphalt for the road, wood for the road forms, and aggregate for the tunnel. The asphalt will include rubber from recycled tires, the form wood will be previously used and demolition waste will be ground to use as aggregate. The precast concrete for the tunnel construction will reduce the likelihood of spills in Pacific Spirit Regional Park and reduces the amount of waste needed to be transported away from the site. The materials will also be sourced locally, to reduce the cost and emissions of transportation. Finally, all the construction and demolition waste will be taken to local recyclers, such as Urban Recyclers.

6.2 Noise Containment

Empire Engineering realizes the effects of construction noise and vibrations on the surrounding environments, including the local community and the wildlife in Pacific Spirit Regional Park. The operational noise will include vehicles and motorcycle engine noise, constantly passing through the park on the road. The noise and reverberations will interfere with the quality of life for the humans in the nearby neighbourhoods off Drummond Drive. University Hill Elementary School is also along the corridor, with school hours being between weekdays 9:00 am and 3:00 pm, September until June. The primary concern for wildlife is the impact on daily routines and communication. Vibrations are known to force small mammals and amphibians out of their burrows during hibernation times. Birds communicating through calls can be interrupted by the noise, if above a certain decibel.

Empire Engineering will implement a number of mitigation measures to ensure the wellbeing of the community and wildlife. Mufflers will be used on loud equipment and anti-noise screens will be installed for particularly loud activities, such as milling the existing asphalt. The work will be completed during the daytime to reduce distractions to human and animal populations. Furthermore, by completing construction during the summer months, this project will not disrupt the elementary school or wildlife hibernation.

6.3 Lighting

Empire Engineering has also considered the lighting along the corridor. The challenge with this small, but important feature of the road redesign is the conflicting effects of human versus animal movement. Lighting along pathways is necessary to provide a safe environment for cyclists and pedestrians in the early morning and at night. This ensures good visibility and a more comfortable ride. However, lighting is one known road feature that interrupts animal migratory paths and separates habitats. Nocturnal animals are significantly affected by artificial light during their awake time, altering their hunting practices. As well, migratory birds rely on lighting to guide the way, so with the increased lighting in cities, birds end up off track, missing the ideal season for nesting, mating, and foraging.

Currently, there is no lighting along the corridor until the Hamber Intersection; however, vehicle headlights along the road can create light pollution. During construction, all work will be done during the day, so there will be minimal effect on lighting. At night, all material will be stored appropriately and lights will be shut off. For the lifetime of the redesign after completion of the construction, Empire Engineering will install Dark Sky lighting, that meets the Vancouver Campus Plan design guidelines, intermittently along the bike lanes and pedestrian path. A project goal is to increase green modes of transportation, so this lighting is required to create a safe environment for cyclists and pedestrians in the early morning and at night. Dark sky lighting emits minimal light while still illuminating the way. The lighting will be emitted from fully shielded walkway bollards, pictured in the bottom right of Figure 12. The light is all focused downward and does not emit the blue wavelength, therefore reducing light pollution and glare. The lights will only be on during darkness and direct the light only where it needs to go, the impact on the wildlife will be limited, while providing the safety and security for the cyclists and pedestrians using the pathways.

Figure 12. Examples of Dark Sky Lighting (Dark Sky)

6.4 Soil, Sediment, and Groundwater

The soil and groundwater will be affected by the constant toxic chemicals and other contaminants from the road users. The runoff of rainwater off the road, deicing in the winter, excavation of the tunnel and other construction practices all contribute to the risk of contaminating the soil and groundwater. Eventually, this water feeds into the streams in Pacific Spirit Regional Park and well as into the roots of the surrounding trees. Additionally, erosion could be a concern with respect to the tunnel. Therefore, there is an increased number of suspended solids and chemicals that need to be removed from the road surface. The current solution is the use of storm drains, emptying the collected runoff into pipes and rerouting it directly to nearby streams and water sources. This has a huge negative effect on the stream habitat and results in dying species and poisoning of native species.

The project site currently has a typical stormwater catch basin system; however, Empire Engineering will need to reduce the amount of water and contaminants flowing into these basins. During construction, all excavated material will be removed and recycled off-site, or protected from the natural environment until it is moved. In order to mitigate operational runoff into the park, which houses a number of streams, including a salmon-bearing stream, Empire Engineering will implement swales, vegetated buffers and permeable pavement. At the lowest part of the road, between the Pioneer Trail and Hamber Road, a small inlet will allow water to run into the median where porous soil, natural plants, and rocks will filter the runoff, removing heavy pollutants from the stormwater. The same will be found along the outside of the bike lane, on a smaller scale. Finally, the new pedestrian path will be repaved using permeable pavement, such as Unilock, Uni Eco-Stone, as detailed in Appendix D. Each of these changes will increase the water infiltration through the soil which is the best solution to deter toxins from reaching the groundwater and making its way into the water cycle. The overall decrease of impervious surface area, with the narrowing of the road width, will also contribute to this infiltration.

6.5 Vegetation and Wildlife

The redesign of Chancellor Boulevard will have an effect on the vegetation and wildlife, even though the road exists in a fairly similar condition. The Canadians Fisheries and Oceans Act, as well as the BC Fisheries Act, will be used to meet all requirements. The construction and continued use of vehicles will have a negative impact on the habitat. The project, in the worst case scenario, could have a dramatic amount of deterioration and disruption, as fish habitats are incredibly sensitive. This could be due to increased suspended solids in the runoff, or disruption from construction activity and vibration. A similar issue is present for terrestrial animals. Disruption from construction and loss of habitat for implementation of the tunnel will impact the population in Pacific Spirit Regional Park. During operation, the increased usage of the road by all modes will change the animal behaviour as there will be a greater human presence in and around the park.

To mitigate of the effects of this project on the vegetation and wildlife, Empire Engineering will install a variety of features and follow best practice during construction. Tree removal will be needed for the tunnel construction. To compensate for this, trees will be planted elsewhere in the park. The material waste will be disposed of to maintain a natural decomposition cycle and the work will be done by a professional arborist. Tree protection fencing will be in place, which will decrease the damage to the remaining trees and will also temporarily discourage animals entering the construction zone. The streams will be monitored before, during and after construction and left in a state similar to how it was found. All waste will be disposed of properly as to not end up in the surrounding environment. After construction is completed, all areas will be restored to an improved original state. As well, in partnership with regional park board, signage informing the pedestrian and cyclist traffic to not interfere with the wildlife will be installed along the pedestrian walkway and a waste receptacle will be placed at each park entrance. A wildlife crossing was considered for the project, however, since the road is existing, no additional measures than the pedestrian underpass will be taken to provide this feature.

7. Stakeholder Management

7.1 Engagement Methodology

In collaboration with UBC Campus & Community Planning, University Neighbourhood Association, and University Endowment Lands, Empire Engineering has engaged and consulted multiple stakeholders throughout the process of developing the preliminary design and will continue to do so in each project phase. In the initial stages of this project, our team identified the different stakeholders and their respective concerns and interests. Based on this information our stakeholder management team determined the most effective engagement methods for each group and created a plan for different stages of engagement to ensure adequate two-way communication.

Our engineering team has evaluated the feedback received from all the interest groups and has used this information to adjust the design to best satisfy the concerns and needs of all members of the community. During this process, our team has maintained an open communication format with the stakeholders to ensure that all different perspectives are heard and assure the stakeholders that their input is beneficial and critical to the success of this project.

7.2 Stakeholders & Engagement Timeline

Table 5 lists the key stakeholders of this project and the communication channel used to engage with each group.

Table 5. Stakeholders and Communication Channel

Stakeholder Group	Communication Channel
University of British Columbia (SEEDs)	Meetings, Reports, Email
Ministry of Transportation and Infrastructure	Meetings, Reports, Codes, Permitting
University Hill Elementary	Open House, Online Survey, Presentation
University Endowment Lands (Residents)	Open House, Online Survey, Presentation
Translink	Reports, Meetings, Email
UBC Faculty, Students, and Staff	Open House, Online Survey
Fisheries and Oceans Canada	Reports, Meetings, Permitting
Musqueam First Nations	Meetings, Email

The timeline of the major public consultation events since the beginning of the design process is shown in Figure 13.

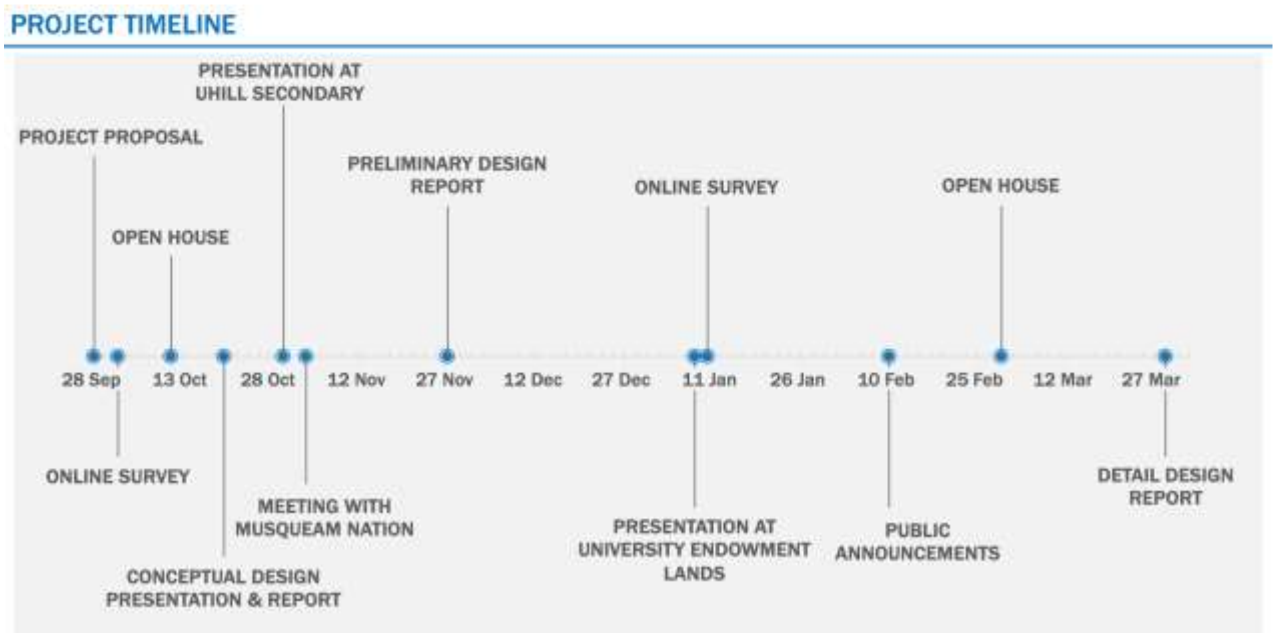

Figure 13. Stakeholder Engagement Timeline

Online surveys have been an effective tool to identify the community's needs and receive feedback on proposed design features. Empire Engineering has used utilized this tool in different stages of the project.

Open houses were an opportunity for our team to present the design and plans to the members of the community and receive feedback immediately and answer any questions that arise. Specific presentations to the residents of the University Endowment Lands and the student and staff at University Hill Elementary School were conducted; since this project has a direct impact on their daily activities.

Public announcement strategies including flyers, advertisements in local newsletters, emails, and road signs will be utilized prior to the construction of the project to inform all stakeholders of the changes to the traffic patterns and construction schedule.

8. Construction Specifications

The construction of this project is expected to begin in May 2018 and is estimated to last until July 28, 2018. Due to the tunnel construction method and the low volume of traffic to UBC during the summer months, Chancellor Boulevard is expected to be closed for the majority of the construction period allowing for a shorter construction time. There will be limited vehicle access allowed to University Hill Elementary School from the west side of the project, as well as limited pedestrian access to Pacific Spirit Regional Park. To reduce construction time and minimize disturbance to community members, excavation for the underpass on the East side of the project will begin simultaneously with improvements to the road on the West end of the project. By the time the repaving crew reaches underpass location the road surface will be ready for paving. To prepare a detail construction schedule, productivity rates from *RSMeans Heavy Construction Cost Data* were used for each task to estimate the task's duration. For certain tasks number of crews were increased to reach the desired production rate.

A Gantt chart of the construction schedule alongside with the detail productivity rates and crews required for each task can be found in Appendix H. Figure 11 illustrates the anticipated number of workers on site throughout the duration of project.

Figure 11. Number of Workers on Sight

The decline in number of workers observed in the second week of June, is due to the two week upward settlement allowance required for the underpass construction. This requirement delays some tasks on the critical path of the project. Activities not related to the upward settlement will continue during this period.

9. Cost Estimate

This section is to be read in conjunction with Appendix I: Cost Estimate.

9.1 Estimate Methodology

The cost estimating rationale and methods used for this project are in compliance with Ministry of Transportation and Infrastructure's *Project Cost Estimating Guidelines*. The cost of this project was estimated by identifying and quantifying all the necessary tasks to complete the project. The final design drawings were used to complete quantity takeoffs, and unit rates for these tasks were adapted from *RSMeans Heavy Construction Cost Data, 20th edition*. These values include the material, labour, and equipment cost for each task, as well as overhead and profit for the contractors. Unit rates used from this source were converted from United State's national average to Vancouver's cost using the appropriate conversion ratio depending on the activity. Table 6 summarizes theses cost indices. The ratios include the US to Canadian dollar conversion rates as noted by the publisher. A multiplier of 1.33 was then used to convert the unit rates from 2006 dollars to 2018 dollars based on RSMeans historical cost index.

Table 6. Vancouver Cost Indices

Division	Vancouver's Cost Index	Ratio to US National Average
02-Site Construction	110.3	1.103
03-Concrete	116.8	1.168
16-Electrical	107.5	1.075
01590-Equipment Rental	111.3	1.113

A contingency ranging from 10 to 20% of the estimated cost of major tasks of the project is included in this cost estimate. The contingency percentage is dependent on the risk and uncertainty associated with these tasks. The contingency does not include costs due to changes in the design or scope of the project. There is also an allowance for engineering and construction management, traffic management, and mobilization in the cost estimate.

9.2 Construction Cost Estimate

The total estimated cost of this project is $6,146,000 (not including taxes). The cost breakdown for the major tasks of this project are detailed in Table 7 below.

Table 7. Cost Breakdown

Item	Cost
Road Improvements	$1,440,000
Underpass	$908,000
Pedestrian Path Improvements	$352,100
Pedestrian Crossing Signal	$123,600
Environmental Protection	$493,600
Lighting	$917,500
Landscaping	$167,500
Traffic Management	$440,500
Mobilization	$484,500
Design and Construction Engineering	$799,000
Permitting	$20,000
Total	**$6,146,000**

9.3 Annual Operating and Maintenance Costs

The asphalt pavement used for resurfacing the road has a life expectancy of 20+ years; minimizing the need for repairs and maintenance cost to the owner. The estimated operation and maintenance cost is **$36,000** annually and it includes landscaping, snow and ice removal, lighting maintenance, and inspections and repairs to the the underpass. The details of this estimate can be found in Appendix I.

10. Conclusion

Appended are the detailed design drawings required to advance to the tendering and ultimately construction phase of the Corridor Redesign of Chancellor Boulevard project. Please do not hesitate to contact Empire Engineering at *info@empireengineering.com* with any questions or comments regarding the contents of this report or the project.

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Appendix A Design Loads

A.1. Top Slab Factored Moment and Shear Forces

- Calculations based on a three-axle bus with GVWR of 30290 kg, which gives a Live point load of 49.52 kN per wheel.
- Uniformly distributed dead load of 31.26 kN/m was applied to account for the self-weight of the slab and the soil on top.
- Load combination of 1.25DL + 1.5LL
- Max Factored Moment of 288 kNm at the midpoint of the slab
- Max Factored Shear Load of 155 kN at the supporting wall.
- Sample calculations for Moment and Shear resistance for 0.5 m thick concrete beam in **Appendix B**.

A.2. Side (Vertical) Slab Factored Moment and Shear Forces

- Soil Properties as follows: $\gamma = 18\ \frac{kN}{m^3}, phi = 28^o$
- Calculations based on a three-axle bus with GVWR of 30290 kg, which gives a live point load of 49.52 kN per wheel.
- Horizontal Earth Pressures with a At Rest Coefficient of $K_o = 0.5305$
- Load Combination of 1.25DL + 1.5LL
- Max Factored Moment of 350 kNm 3.2 meters below the ground surface
- Max Factored Shear Load of 266 kN at the base of the tunnel wall

Appendix B Sample Calculations

B.1. Stopping Sight Distance and Required Sight Distance

$$stopping\ sight\ distance\ (SSD) = break\ reaction\ time \times velocity\ + braking\ distance$$

Where:
brake reaction time = 2.5 s (AASHTO, 2001)
deceleration rate = 3.4 m/s^2 (AASHTO, 2001)

$$break\ reaction\ time = 2.5\ s\ \times 50\ km/h\ \times 1\ m/s\ /\ 3.6\ km/h\ = 34.8\ m$$

$$braking\ distance = 0.039 \cdot V^2/a = 0.039 \cdot (50\ km/h)^2\ /\ 3.4\ m/s^2 = 28.68\ m$$

$$SSD = 34.8\ m + 28.68\ m = 63.5m \approx 65\ m$$

B.2. Pedestrian Underpass Concrete Slab Design:

Calculations for Moment resistance of 0.5 m deep concrete slab, to be used for the top slab of pedestrian underpass.

$$M_r = T_r * \left(d - \frac{a}{2}\right) \qquad T_r = \varphi_s * A_s * f_y$$

<u>Where:</u>
φ_s = 0.85 (Constant for steel)
A_s = 3500 mm^2 (Area of Steel in tension)
f_y = 400 MPa (Yield strength of steel)
d = 437.5 mm (Effective steel depth)
a = 91.54 mm (Depth of compression block)

M_r = 466 KN*m > M_f = 275 KN*m
Where M_f is the maximum factored load for the slab

Equations were applied to an Excel spreadsheet in order to test a variety of slab depths and steel reinforcement.
Similar calculations were done for the bottom slab

Shear resistance of the Concrete slab was calculated first assuming that No shear reinforcement was used.

$$V_C = \varphi c \times \lambda \times \beta \times \sqrt{f'c} \times bw \times dv$$

Where:
φc=0.65
λ=1

β= 0.165
$f'c$= 25 MPa
bw=1000 mm
dv= 393.75 mm

Vc = 211 kN > Vf = 155 kN
Therefore, no additional shear reinforcement is required in the top and bottom slabs.

B.3. Pedestrian Underpass Concrete Wall Design:

Shear resistance of the Concrete walls was calculated first assuming that No shear reinforcement was used.

$$V_C = \varphi c \times \lambda \times \beta \times \sqrt{f'c} \times bw \times dv$$

Where:
φc=0.65
λ=1
β= 0.165
$f'c$= 25 MPa
bw=1000 mm
dv= 393.75 mm

Vc = 211 kN > Vf = 155 kN, therefore must add stirrups for shear reinforcement

Shear resistance for Concrete walls was re-calculated assuming Minimum shear reinforcement would be provided.

$$V_C = \varphi c \times \lambda \times \beta \times \sqrt{f'c} \times bw \times dv$$

Where:
φc=0.65
λ=1
β= 0.18
$f'c$= 25 MPa
bw=1000 mm
dv= 393.75 mm

Vc= 230.3 KN < Vf=266 KN

Vs ≥ Vf - Vc = 35.66 KN

$$Vs = \varphi s \times fy \times Av \times l/S$$

Where:
φs=0.85
fy=400 MPa
Av=200 mm^2 (for 10M stirrups)
l = dv×Cotθ =393.75mm×Cot(35˚)= 563.1 mm
S=Spacing for stirrups (to be determined)

For Vs>35.66 KN, S<1073.8 mm
Set S=250 mm

Vs=153.15 KN
Vr = Vs+Vc = 153.15+230.3 = 383.15 KN

Vr=383.15 KN > Vf=266 KN, sufficient shear reinforcement.

For vertical reinforcement, please see moment resistance calculations for Concrete slabs.

For Horizontal reinforcement, assume minimum requirement from CSA A23.3.

$$A_{hmin} = 0.002A_g$$

Where:
$A_g = 500\,mm \times 1000\,mm = 500{,}000\,mm^2$
$A_{hmin} = 1000\,\frac{mm^2}{m}$

Select 15M bars, $A_b = 200\,mm^2, n = 5\,bars/m$

$$S \leq A_b \times \frac{1000}{A_s} = 200\,mm$$

Axial load resistance for the wall section was determined for a 1m long section.

$$Pr = \frac{2}{3} \times \alpha \times \phi c \times f'c \times Ag \times (1 - (\frac{K \times h_u}{32 \times t})^2)$$

Where:

α=0.8

$$\phi c = 0.65$$
$$f'c = 25\ MPa$$
$$Ag = 500mm \times 1000mm = 500{,}000\ mm^2$$
$$K = 1\ (for\ simply\ supported\ Walls)$$
$$h_u = 3500\ mm$$
$$t = 500\ mm$$

$$Pr = 4125977\ N/m = 4126\ KN/m > Pf = 155\ KN/m$$

B.4. Forces on the Tunnel Walls:

B.4.1 Force Due to Horizontal Soil Pressure

$P(d) = K_0\gamma(d - D)$

K_0 = Coefficient of at rest horizontal Soil Pressure
γ= Unit Weight of Soil
D = Total Wall Depth
P(d) = Pressure at depth d

B.4.2 Force Due to Overlaying Soil Pressure

$$P(d) = K_0\gamma h$$

h = Height of overburden Soil Layer

B.4.3 Force Due to Bus (Line Load)

$$P(d) = \frac{F}{D}\frac{0.203b}{(0.16 + b^2)^2}$$

F = Line Load Due to Bus
b = (d/D)

B.5. Tunnel Settlements

<u>Excavated Soil Weight</u>

$\gamma_s = 19\ kN/m^3$ $D_f = 5.5m$

$H = 4.5\ m$ $B = 6\ m$

$$q = D_f * \gamma_s = 104.5\ kPa$$
$$W_{es} = \gamma_s * D_f * B = 627\ kN/m\ Depth$$

<u>Tunnel Weight</u>

$$\gamma_c = 23\ kN/m^3$$
$$A_t = 9.5m^2$$
$$W_t = \gamma_c * A_t = 220\ kN/m\ Depth$$

Soil Cover Weight

$$\gamma_s = 19\ kN/m^3$$
$$B = 6\ m$$
$$H_{AV} = 1m$$
$$W_{sc} = \gamma_s * H_{Av} * B = 114\ kN/m\ Depth$$

Weight Differential

$$W_{Tot} = W_{sc} + W_t - W_{es} = -294\ kN/m\ Depth$$
$$\Delta q = W_{tot}/B = -48.83\ kPa$$

Elastic Settlement (adjusted to exclude creep)

Scmertmann Data for B=6, L/B=3.33333

Zone	$\Delta z\ (m)$	I_z	$E_s\ (kPa)$	$\frac{Iz\Delta z}{Es}$
1	4.11	0.204	14000	5.99*10^-5
2	12.33	0.272	14000	2.40*10^-4

$$C = 1 - 0.5(\frac{q}{\Delta q}) = 1 - 0.5\left(\frac{104.5kPa}{48.83kPa}\right) < 0 --> \ assume\ = 0.5$$

$$S_e = C\Delta q \sum \frac{Iz\Delta z}{Es} = 0.5 * -48.33kn/m3 * 3.00 * 10^{-4} = 7.25\ mm < 1\ cm\ (Negligible)$$

Appendix C Traffic Volume and Synchro Data

C.1. Summary of Traffic Count Data

	Source	Mode	NORTH Approach LT	NORTH Approach T	NORTH Approach RT	SOUTH Approach LT	SOUTH Approach T	SOUTH Approach RT	WEST Approach LT	WEST Approach T	WEST Approach RT	EAST Approach LT	EAST Approach T	EAST Approach RT
Hamber	Empire Engineering collected traffic count data on Thursday October 5th from 8:30am-9:00am	Veh (observed)	25		50				78	130			350	52
		Bus												
		Pedestrian					4			123				
		Bike			21		5			1			7	
		Veh/Bus Total	25	0	50	0	0	0	78	130	0	0	350	52
Acadia Cir	Empire Engineering collected traffic count data on Monday October 2nd from 2:45pm-3:15pm	Veh (observed)	3		1				2	128		2	350	
		Bus											9	
		Pedestrian												
		Bike											14	
		Veh/Bus Total	3	0	1	0	0	0	2	128	0	2	359	0
Acadia Rd	Empire Engineering collected traffic count data on Thursday October 5th from 8:30am-9:00am	Veh (observed)	8	3	1		1	32	0	110	1	15	364	7
		Bus						1		8			9	
		Pedestrian				2		10		11			2	
		Bike				2		24		7		3	14	
		Veh/Bus Total	8	3	1	0	1	33	0	118	1	15	373	7
Allison Road	Assumed Negligible	Veh/Bus Total	0	0	0	0	0	0	0	215	0	0	567	0
Western Parkway	Fall 2016 7-Day Tube Count	Veh/Bus Total	0	0	0	0	0	0	0	215	0	0	567	0

C.2. Traffic Volume Approximation for Hamber Road Intersection, AM Peak

	AM Peak Traffic for School		Source
Population	Student Population	360	UHill Plan
	Staff Population	32	UHill Website
	Total	**392**	
Staff assumptions	Cyclists	2	Based on cyclists crossing intersection
	Drivers	30	Estimate
	Total	**32**	UHill Website
Student assumptions	Transit commuters	139	Oct 5th Survey - pedestrians crossing road + walking EB
	Dropped off	221	
	Children/Vehicle	1.2	Estimate
	Number of Vehicles	**184**	

	Volume Estimates for AM Peak School Traffic		Notes
Volume of Vehicles Leaving School (Hamber Rd) Based on Oct 5th Survey Data	Cars In - EBLT	78	60%
	Cars In - WBRT	52	40%
	Total Cars In	130	
Volume of Vehicles Leaving School (Hamber Rd) Based on Oct 5th Survey Data	Cars Parked (Staff)	30	Estimated cars that park at school
	Cars Out (observed)	75	Observed vehicles leaving school
	Cars Out (assumed)	25	Estimated vehicles still in Hamber Roundabout
	Total Cars Out	**100**	
Estimate of Vehicles Missing from Survey	Students dropped off (observed)	120	Assuming 1.2 children for each car that entered/left Hamber Rd
	Students remaining	240	Estimated from Student Population
	Vehicles Remaining	84	**These could have arrived between 8:00-8:30 or after 9:00**

Adjusted Volumes		Notes
Total Number of Vehicles	214	Staff vehicles + drop-off vehicles
Total Number of Vehicles In/Out	184	Drop-off vehicles that turn into Hamber Rd and exit
Cars In - EBLT	129	Observed volume + vehicles missing from survey x 60%
Cars In - WBRT	86	Observed volume + vehicles missing from survey x 40%
Total Cars In	215	**Total Cars In - Assuming same distribution**
Cars Out - RT WB	124	Observed volume + vehicles missing from survey x 67%
Cars Out - LT EB	61	Observed volume + vehicles missing from survey x 33%
Total Cars Out	185	**Total Cars Out - Assuming same distribution**

C.3. Sample Synchro Output of Existing Conditions Acadia Rd & Chancellor Blvd

Volume
1: Chancellor Boulevard & Acadia Road 2017-11-27

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		✥		↰	↑	↱		✥			✥	
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (m)	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Grade (%)		0%			0%			0%			0%	
Storage Length (m)	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0
Storage Lanes	0		0	1		1	0		0	0		0
Turning Speed (k/h)	25		15	25		15	25		15	25		15
Satd. Flow (prot)	0	1902	0	1809	1904	1619	0	1653	0	0	1827	0
Flt Permitted				0.950							0.968	
Satd. Flow (perm)	0	1902	0	1809	1904	1619	0	1653	0	0	1827	0
Link Speed (k/h)		60			60			30			30	
Link Distance (m)		227.4			44.6			429.1			132.8	
Travel Time (s)		13.6			2.7			51.5			15.9	
Volume (vph)	0	213	2	18	450	7	0	1	33	8	3	1
Lane Group Flow (vph)	0	259	0	22	542	8	0	41	0	0	15	0
Sign Control		Free			Free			Stop			Stop	

Intersection Summary
Area Type: Other
Control Type: Unsignalized
Intersection Capacity Utilization 37.7% ICU Level of Service A
Analysis Period (min) 15

C.4. Sample Synchro Output – Redesign Conditions for Acadia Rd & Chancellor Blvd

Volume
1: Chancellor Boulevard & Acadia Road 2017-11-27

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations		✥			✥			✥			✥	
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900
Lane Width (m)	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Grade (%)		0%			0%			0%			0%	
Storage Length (m)	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0
Storage Lanes	0		0	0		0	0		0	0		0
Turning Speed (k/h)	25		15	25		15	25		15	25		15
Satd. Flow (prot)	0	1902	0	0	1897	0	0	1653	0	0	1827	0
Flt Permitted					0.998						0.968	
Satd. Flow (perm)	0	1902	0	0	1897	0	0	1653	0	0	1827	0
Link Speed (k/h)		60			60			30			30	
Link Distance (m)		228.3			84.9			429.1			132.8	
Travel Time (s)		13.7			5.1			51.5			15.9	
Volume (vph)	0	213	2	18	450	7	0	1	33	8	3	1
Lane Group Flow (vph)	0	259	0	0	572	0	0	41	0	0	15	0
Sign Control		Free			Free			Stop			Stop	

Intersection Summary
Area Type: Other
Control Type: Unsignalized
Intersection Capacity Utilization 52.7% ICU Level of Service A
Analysis Period (min) 15

Appendix D Uni Eco-Stone Specification Sheet

UNI ECO-STONE® - AVAILABLE IN VANCOUVER, BRITISH COLUMBIA

Special Order Colors

STANDARD FINISH

WASHED FINISH

BRUSHED FINISH

Minimum quantities and special pricing may apply. Contact us for more details.

With so many different options for customization we ask that you contact your local Unilock Representative for more information about customizing this product.

Minimum quantities will apply.

Special Order Shapes & Sizes

STANDARD (SPECIAL ORDER)
23 CM X 11.5 CM X 8 CM
9" X 4.5" X 3.125"

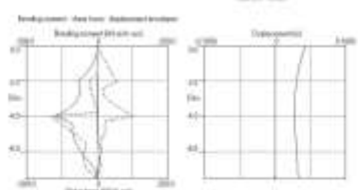
Minimum quantities and special pricing may apply. Contact us for more details.

	Unit Thickness	Sq. Ft. Bndl.	Sq. Ft. Layer	Sq. Ft. Stone	Layers Bndl.	Ln Ft Sec. Soldier	Ln Ft Bndl. Soldier	Sq Ft Ln Ft Soldier	Ln Ft Sec. Sailor	Ln Ft Bndl. Sailor	Sq Ft Ln Ft Sailor	Units Sq. Ft.	Lbs Bndl.	Lbs Sec.	Units Bndl.

Special order from standard colors. Sold in full bundles only. 40-50 bundle minimum order required. This product is optimized for mechanical installation.

No records found.

Appendix E WallAPP output for Soil Retaining Wall:



Appendix F Bioswale Details

F.1. Rainfall & Soil Data for Bioswale

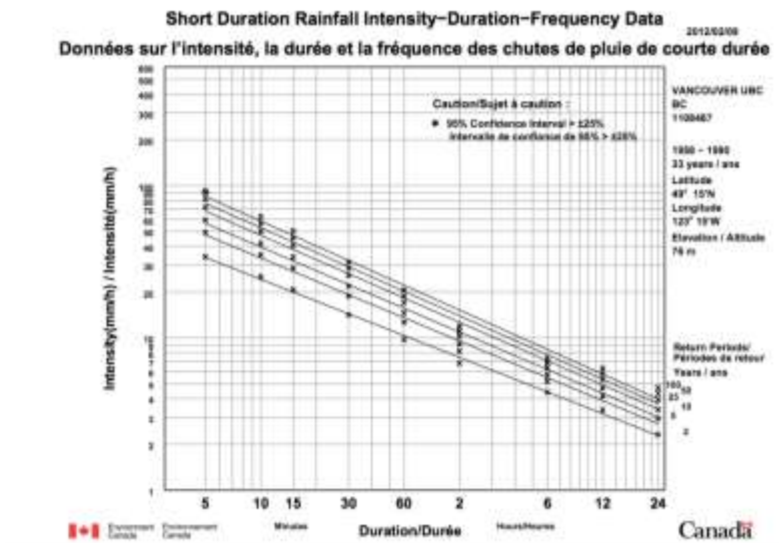


Figure 12. IDF Curve from the UBC Technical Guidelines

Table 7. IDF Data, based on above Graph

Vancouver - UBC		
2 year, 24 hour rainfall	57.6	mm
72%	41.472	mm
2 year Intensity	2.4	mm/hr
72% DFO	1.728	mm/hr
72% 24 hour Rainfall	41.472	mm

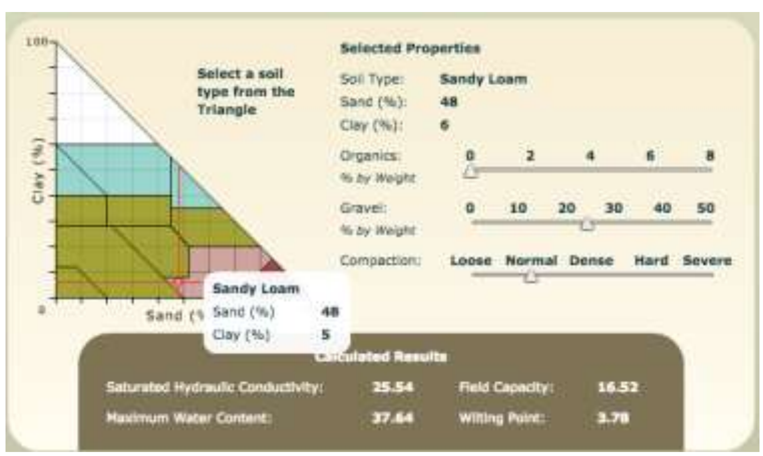


Figure 13. Soil Parameters

F.2. Low Point Bioswale

Tributary Area	800 m^2
Input Volume	33.178 m^3

Capture Capacity Low Point Bioswale

Swale Surface Area	110 m^2
24 Hour Evaporation Rate	0.7 mm/day
Evaporation Capacity	0.077 m^3
Growing Medium Thickness	0.4 m
Growing Medium Volume	44 m^3
Growing Medium Capacity	5.61 m^3
Field Capacity	16.52%
Wilting Point	3.78%
Rock Porosity	35%
Rock Layer Volume	66 m^3
Rock Layer Capacity	24.82 m^3
24 Hour Infiltration Rate	36 mm/day
Infiltration Capacity	3.96 m^3
Total Capacity	34.28 m^3

F.3. Sample Calculations for Bioswale Capacity

$$Evaporation\ Capacity = 24\ hr\ Evap\ Rate * Surface\ Area$$

Evap Capacity = 0.7 mm/day/1000 * 110 m^2 = 0.007 m^3/ day

$$Growing\ Medium\ Capacity = Growing\ Medium\ Volume * (Field\ Capacity - Wilting\ Point)$$

Growing Medium Capacity = 110m^2 * 0.4 m * (16.52% - 3.78%) = 5.61m^3

$$Rock\ Layer\ Capacity = Volume\ of\ Rock\ Layer * Porosity$$

Rock Layer Capacity = 110 m^2 * 0.6m * 35% = 24.64 m^3

$$Infiltration\ Capacity = 24\ hr\ Infiltration\ Rate * Surface\ Area$$

Infiltration Capacity = 36 mm/day / 1000 * 110 m^2 = 3.96 m^3

Rainfall Capture Capacity = Capacity of (Evap + Growing Medium + Rock Layer + Infiltration)

F.4. Roadside Swales

Tributary Area	2.5 m^2
Input Volume	0.103 m^3

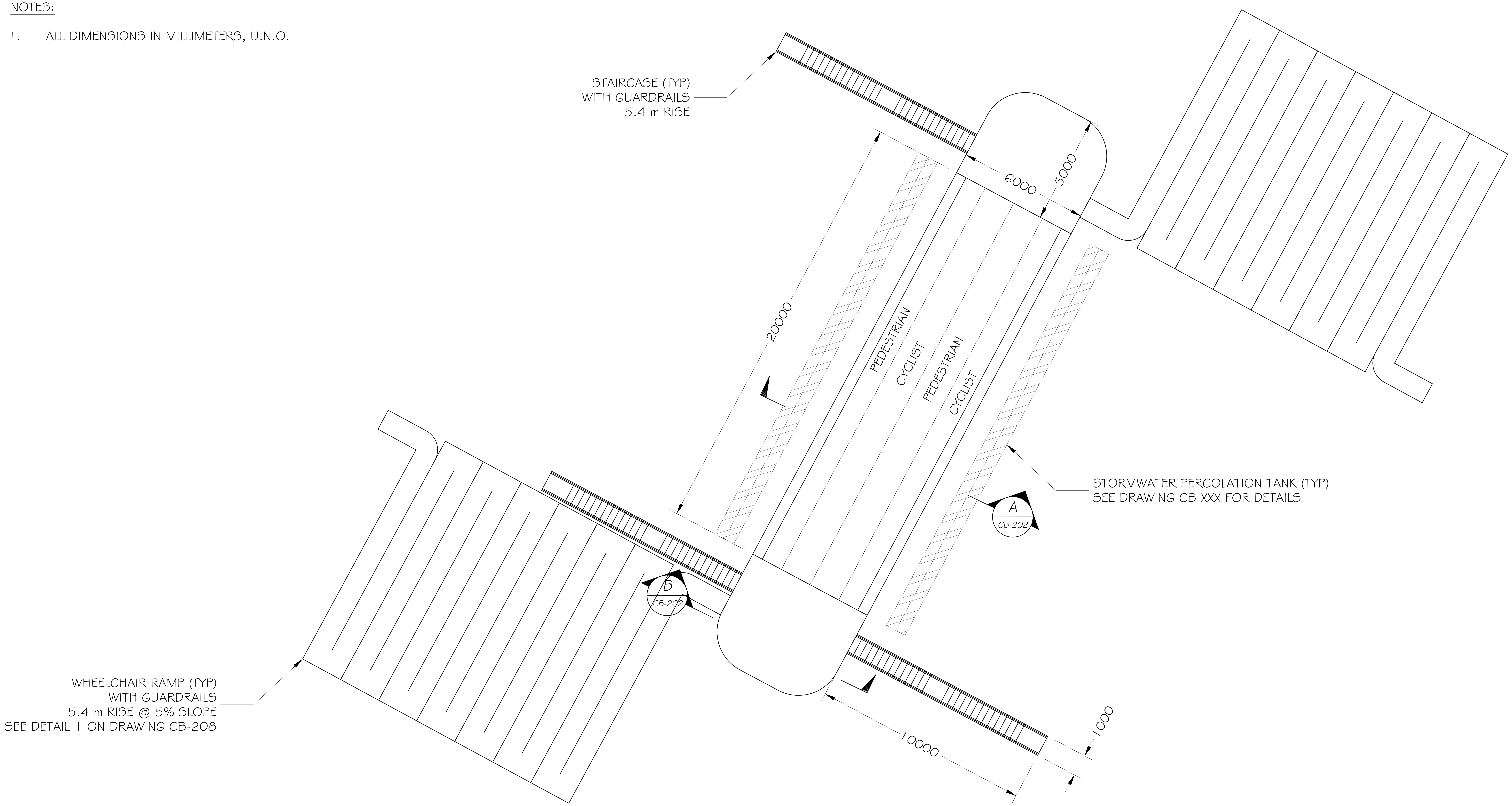
Capture Capacity for Roadside Swales

Swale Surface Area	1 m^2
24 Hour Evaporation Rate	0.7 mm/day
Evaporation Capacity	0.0007 m^3
Growing Medium Thickness	0.15 m
Growing Medium Volume	0.15 m^3
Growing Medium Capacity	0.019 m^3
Field Capacity	16.52%
Wilting Point	3.78%
Rock Porosity	35%
Rock Layer Volume	0.2 m^3
Rock Layer Capacity	0.07 m^3
24 Hour Infiltration Rate	36 mm/day
Infiltration Capacity	0.036 m^3
Total Capacity	0.126 m^3

Same calculations as above.

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS, U.N.O.



DETAIL 1 (CB-002)

TUNNEL AT SPANISH TRAIL

FOR TENDER

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	Drawn	Date	Check	Date	Description
Revisions					

CHANCELLOR BOULEVARD
ROADWAY CORRIDOR DESIGN

VANCOUVER	BRITISH COLUMBIA	CANADA

Office: UBC

Design By: EE

Drawn: JH | Checked: JF

Date: 17/11/22 | Date: 17/11/27

CHANCELLOR BOULEVARD
PEDESTRIAN TUNNEL
GENERAL ARRANGEMENT
APPENDIX G2

In Charge Of: JOE FLACCO

EMPIRE ENGINEERING

District: TRANSPORTATION

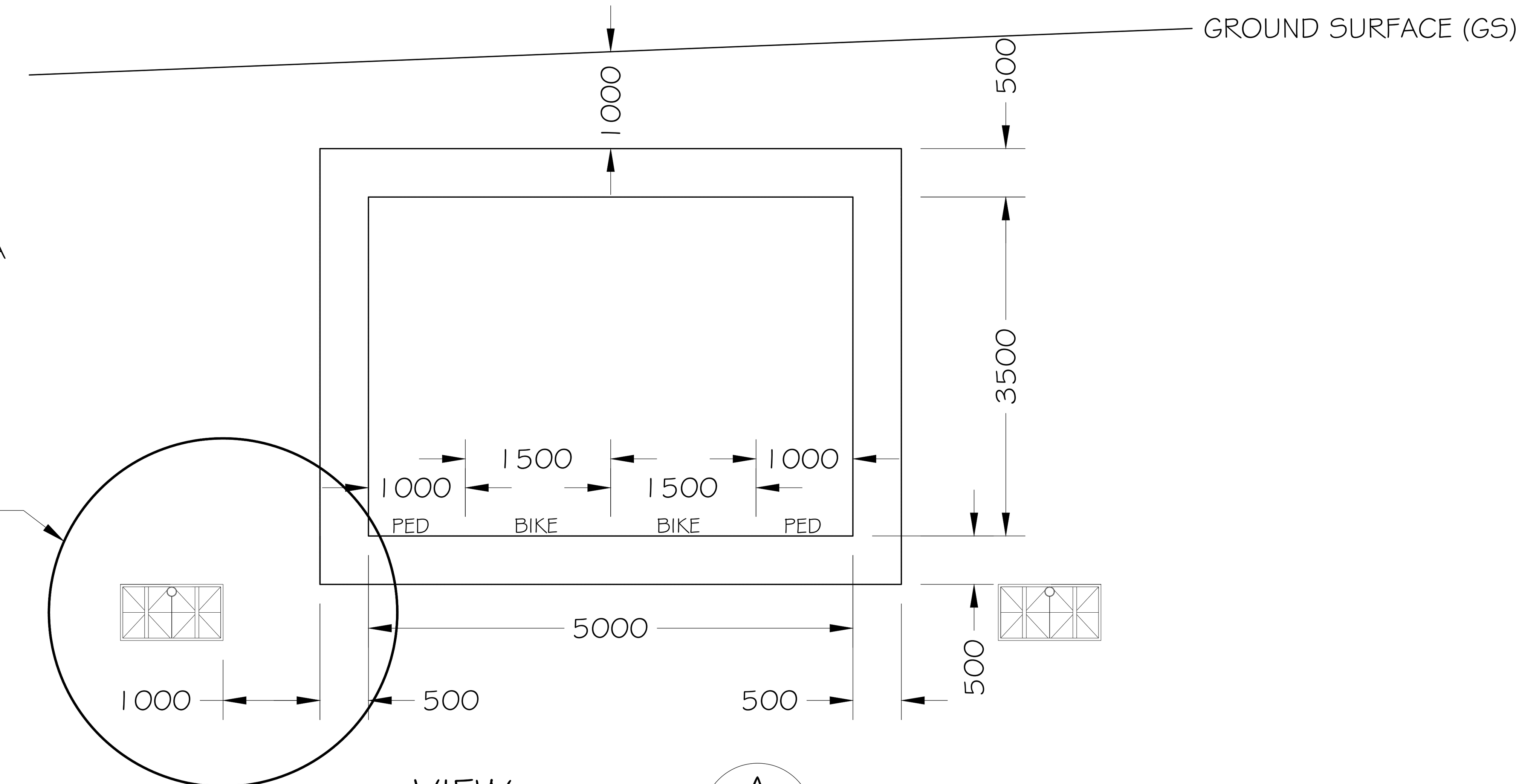
Job Number: 720 | Rev: 0

Sheet Number: CB-201

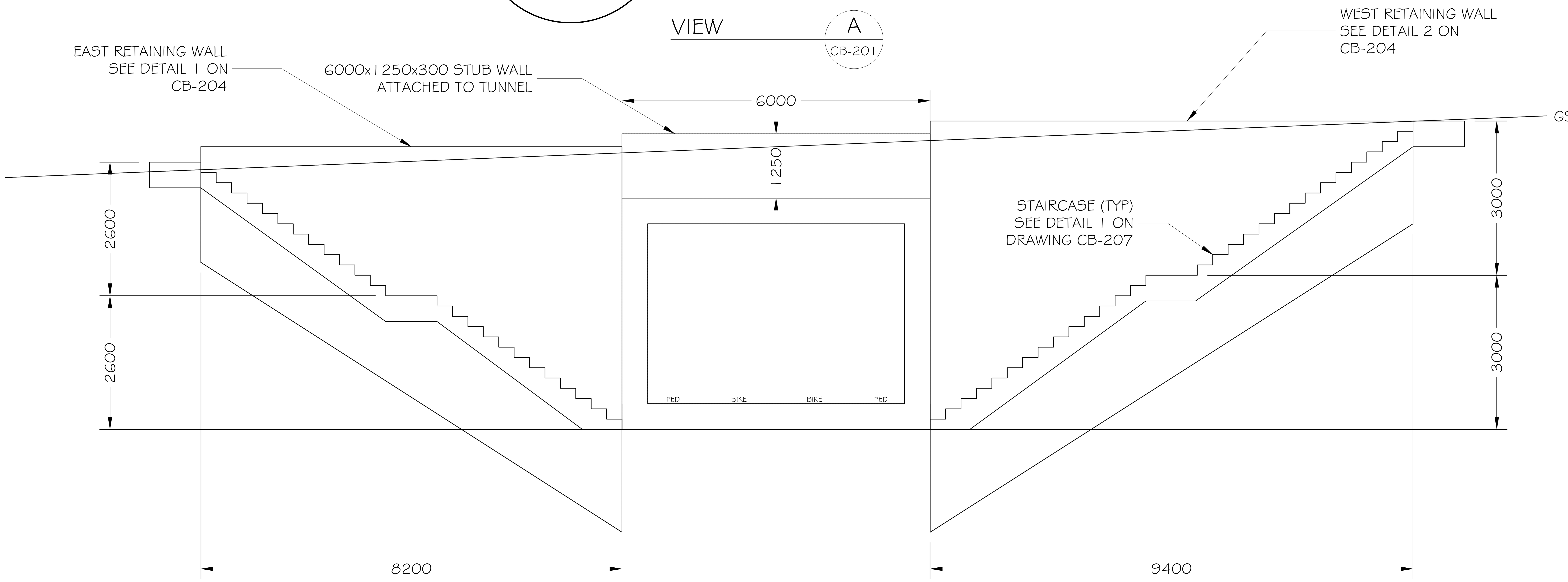
Apr 08, 2018 - 6:27pm C:\Users\ja...CB.dwg

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS U.N.O.
2. SOUTH TUNNEL END SHOWN, NORTH END SIMILAR
3. TUNNEL DESIGNED IN ACCORDANCE WITH NBCC 2010 AND CSA-S6-14
4. TUNNEL AND STUB WALL TO BE MADE OF 30 MPa CONCRETE USING RCA
5. FOR REINFORCEMENT DETAILS SEE DRAWING
   - 5.1. TUNNEL: CB-203
   - 5.2. RETAINING WALL: CB-205



VIEW A CB-201



VIEW B CB-201

TUNNEL END VIEW

FOR TENDER

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CHANCELLOR BOULEVARD ROADWAY CORRIDOR DESIGN

VANCOUVER | BRITISH COLUMBIA | CANADA

Office: UBC

Design By: EE

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Date: 17/11/23 | Date: 17/11/27

CHANCELLOR BOULEVARD
PEDESTRIAN TUNNEL
CROSS SECTIONS
APPENDIX G2

In Charge Of: JOE FLACCO

EMPIRE ENGINEERING

District: TRANSPORTATION

Job Number: 720 | Rev: 0

Sheet Number: CB-202

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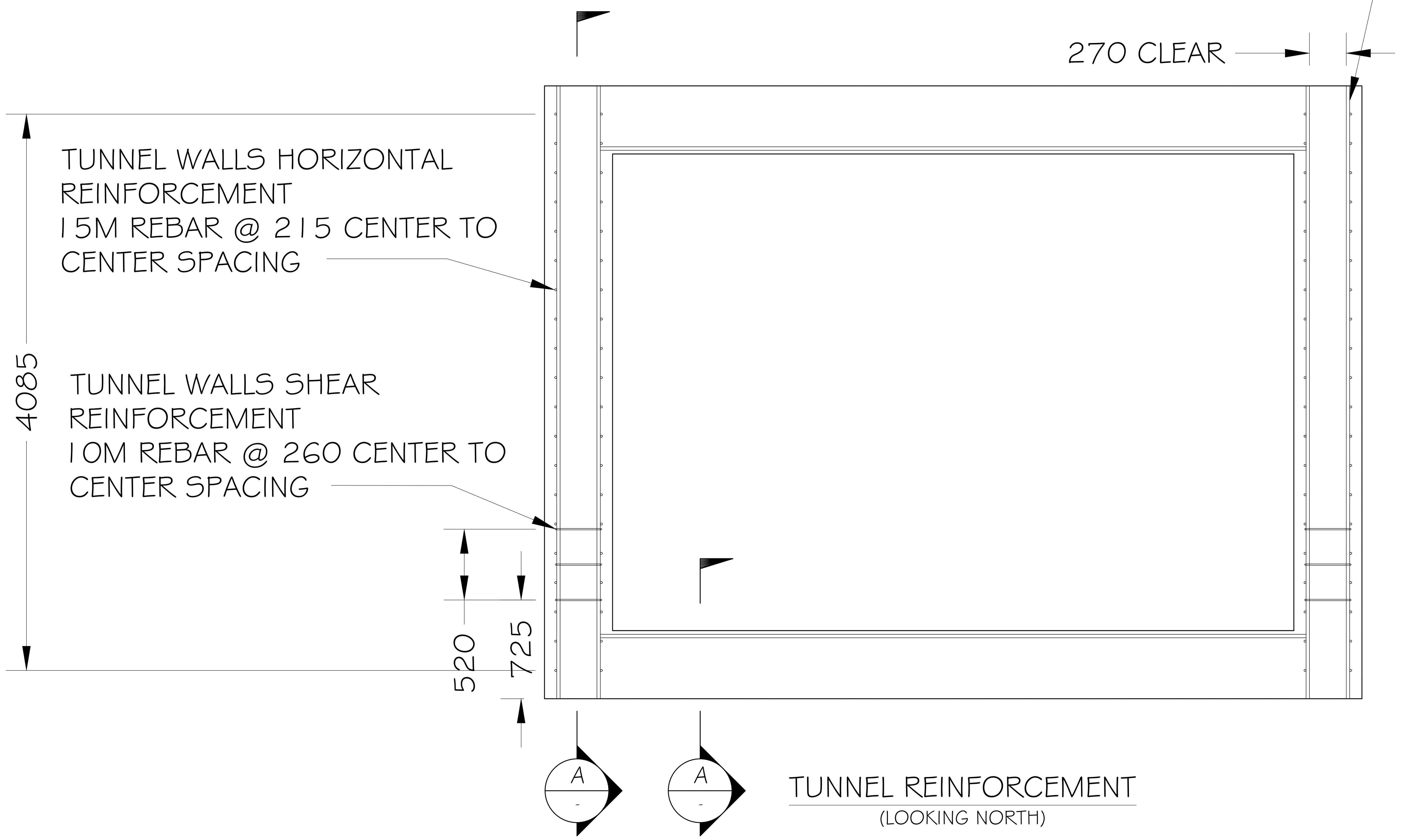
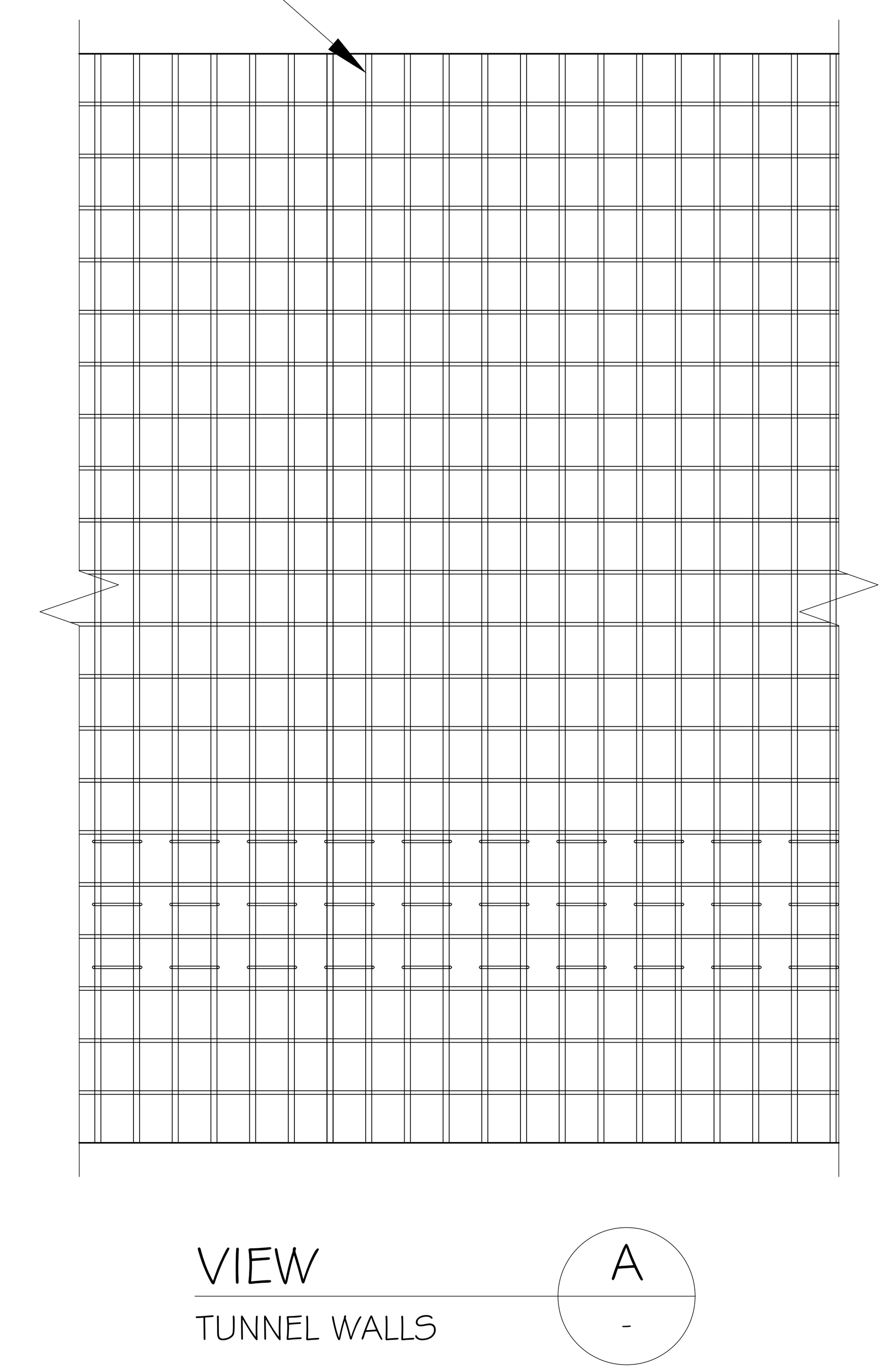
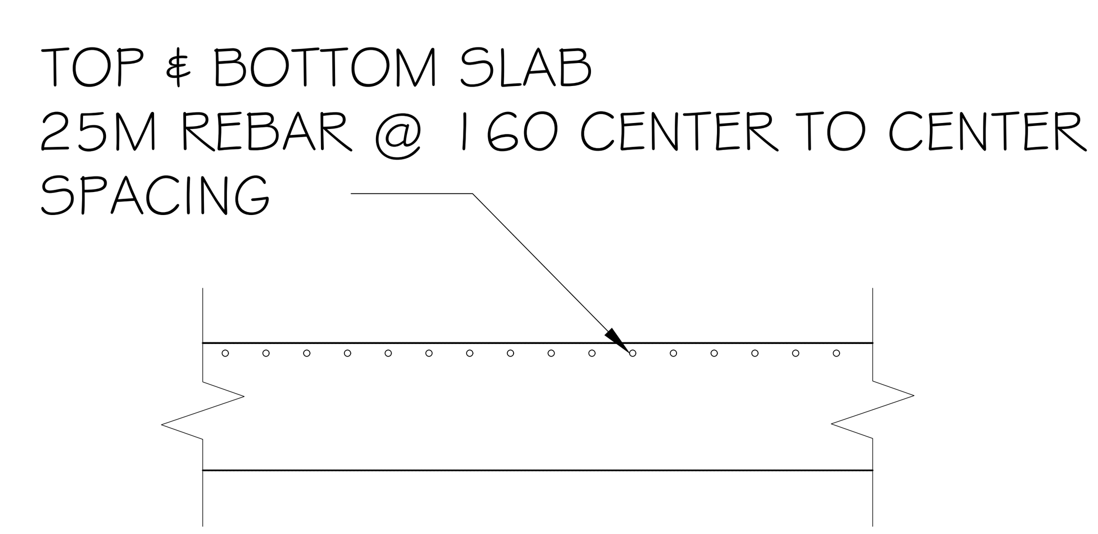


TUNNEL REINFORCEMENT
(LOOKING NORTH)



VIEW A
TUNNEL WALLS



VIEW B
BOTTOM SLAB SHOWN, TOP SLAB SIMILAR

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS U.N.O.
2. DESIGNED TO REQUIREMENTS OF NBCC 2010
3. TUNNEL TO BE MADE FROM 30 MPa CONCRETE, USING RCA
4. REINFORCING STEEL = CSA GRADE 350

FOR TENDER

CHANCELLOR BOULEVARD
ROADWAY CORRIDOR DESIGN
VANCOUVER | BRITISH COLUMBIA | CANADA

	Drawn	Date	Check	Date	Description
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Revisions

Office: UBC
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Drawn: JH
Checked: JF
Date: 17/11/21
Date: 17/11/27

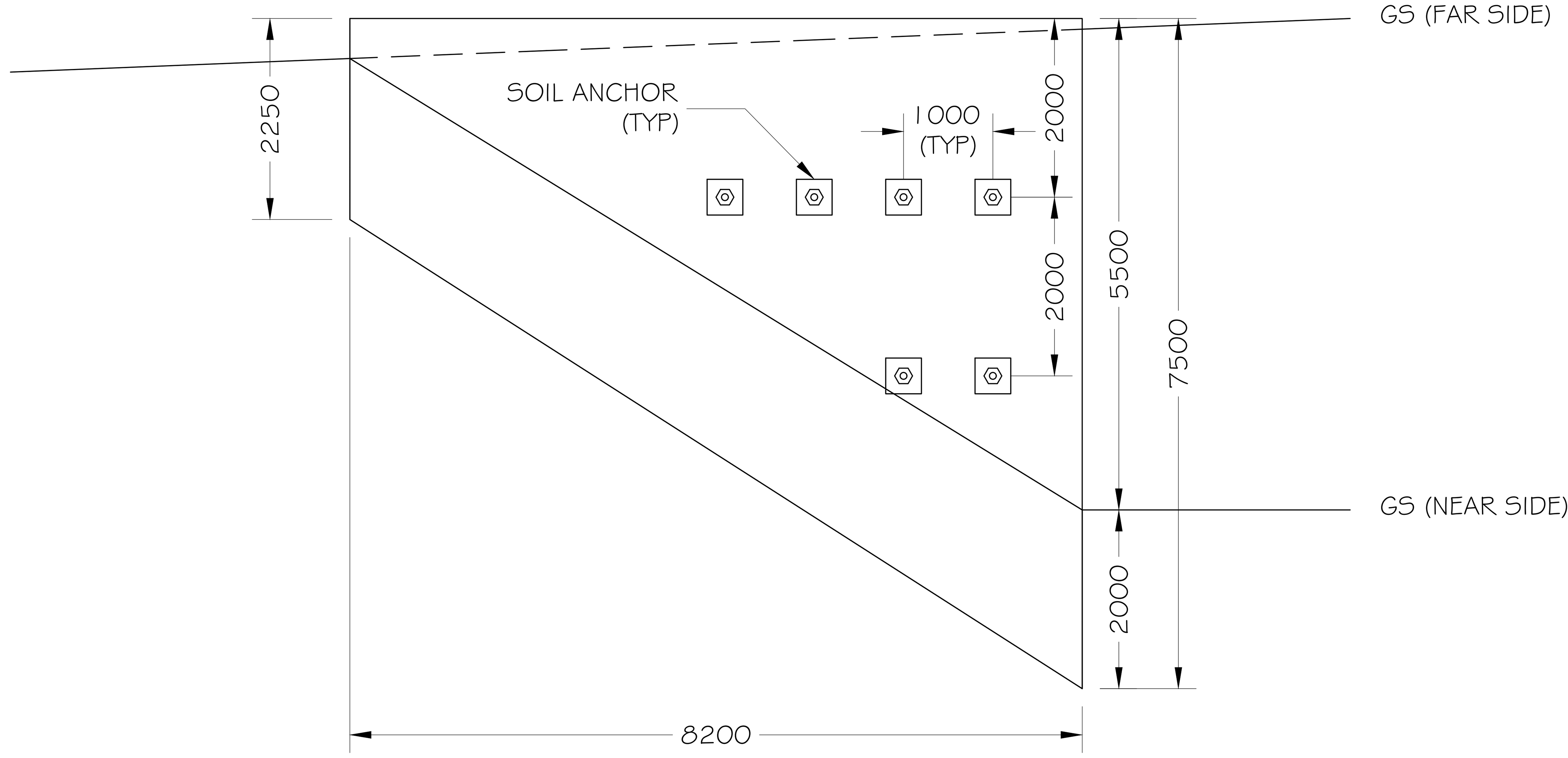
CHANCELLOR BOULEVARD
PEDESTRIAN TUNNEL
REINFORCEMENT DETAILS
APPENDIX G2

In Charge Of: JOE FLACCO

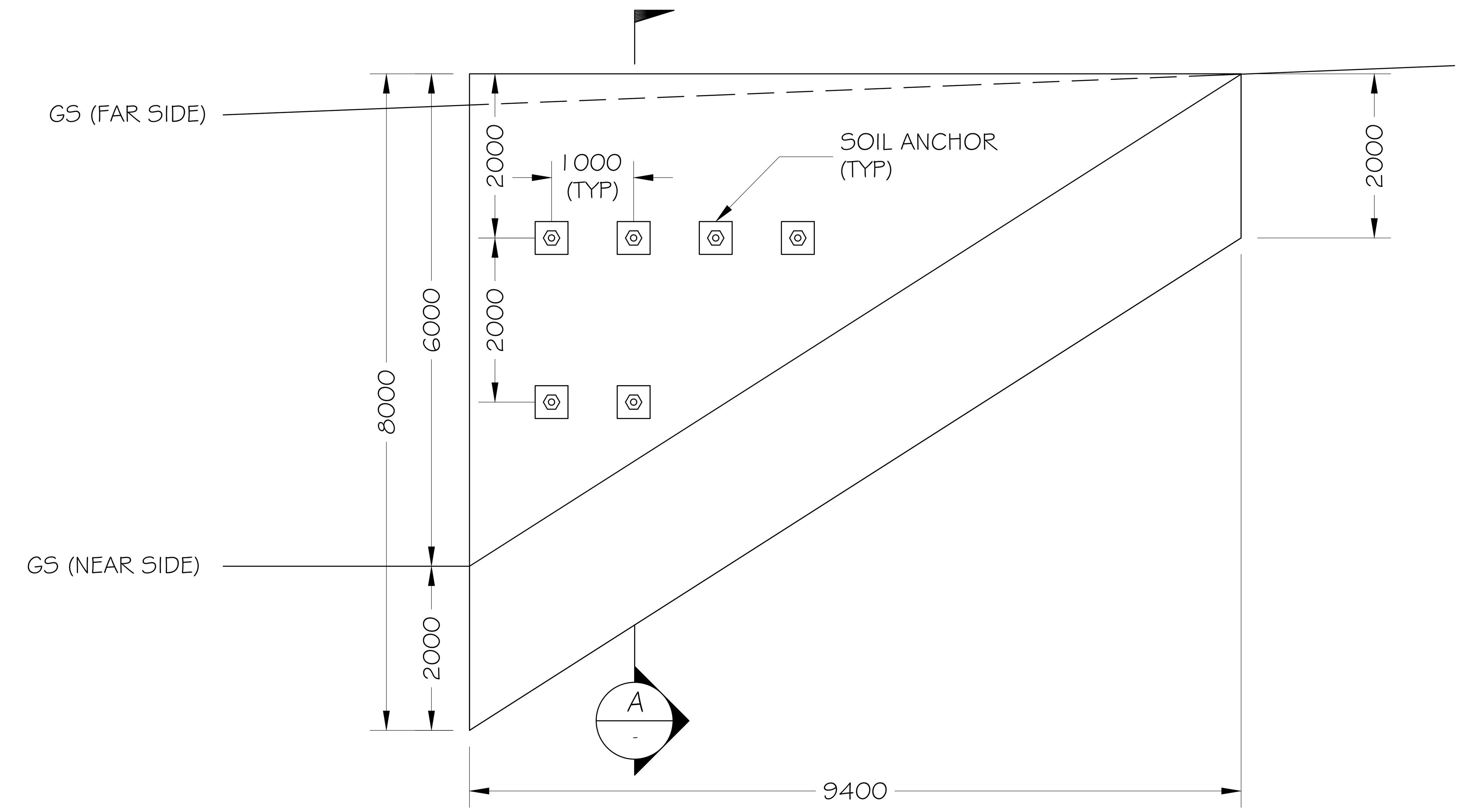
EMPIRE ENGINEERING

District: TRANSPORTATION

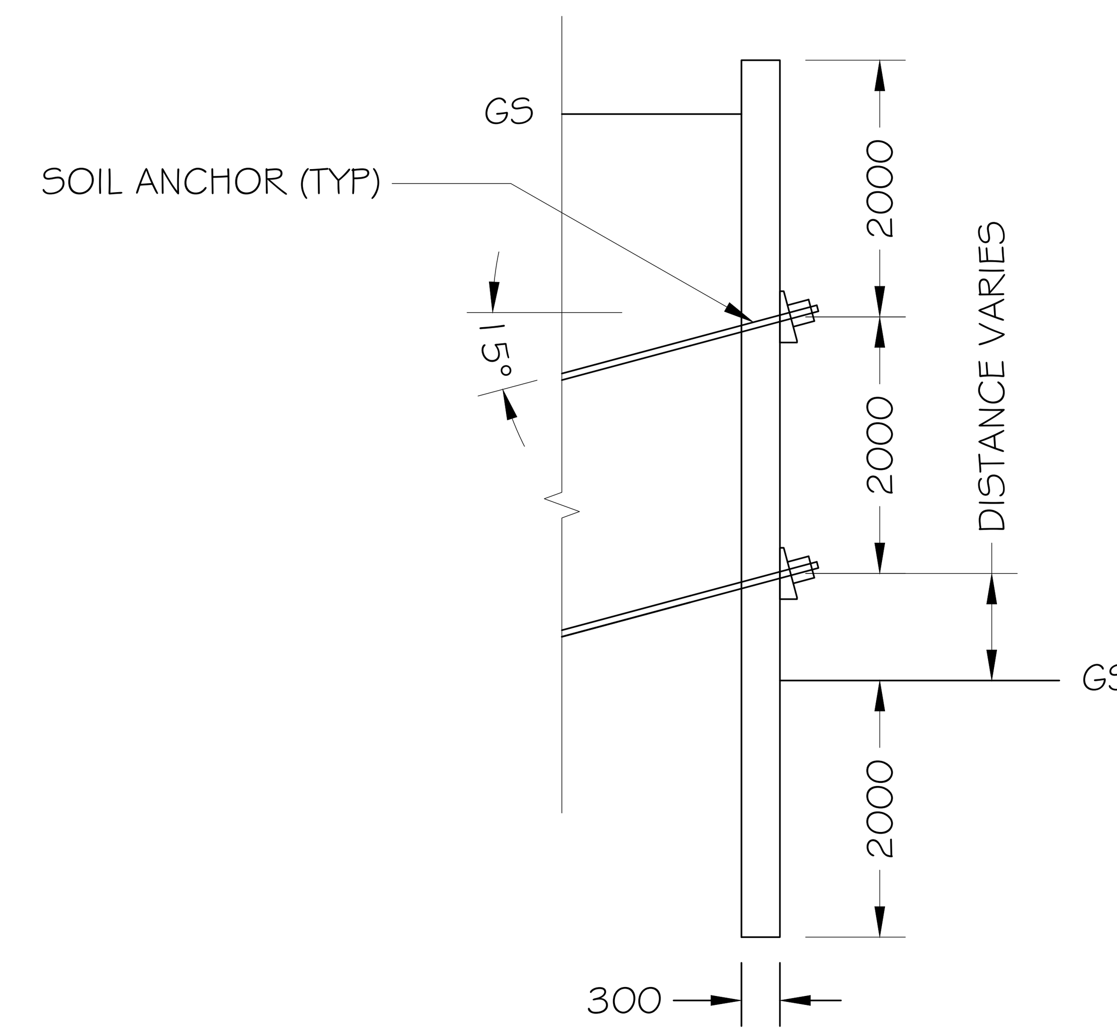
Job Number: 720
Rev: 0
Sheet Number: CB-203



DETAIL 1 (CB-202)
EAST RETAINING WALL



DETAIL 2 (CB-202)
WEST RETAINING WALL



VIEW A (-)
SOIL ANCHORS

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS U.N.O.
2. DESIGNED TO REQUIREMENTS OF NBCC 2010
3. RETAINING WALL TO BE MADE FROM 30 MPa CONCRETE, USING RCA
4. SOIL ANCHORS ARE TO BE 51 mm Ø, AND ABLE TO WITHSTAND A FACTORED LOAD OF 300 kN
4.1. FREE LENGTH = 2 METERS
4.2. BONDED LENGTH = 6.5 METERS
4.3. BOND STRENGTH = 300 kPa
4.4. STEEL = CSA GR. 350
5. RETAINING WALL DESIGNED TO WITHSTAND $\frac{1}{2475}$ YEAR EARTHQUAKE WITH A pga OD 0.46g
6. FOR REINFORCEMENT DETAILS SEE DRAWING CB-205

FOR TENDER

CHANCELLOR BOULEVARD
ROADWAY CORRIDOR DESIGN

VANCOUVER	BRITISH COLUMBIA	CANADA

	Drawn	Date	Check	Date	Description
6					
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Revisions

Office: UBC	
Design By: EE	
Drawn: JH	Checked: JF
Date: 17/11/21	Date: 17/11/27

CHANCELLOR BOULEVARD
PEDESTRIAN TUNNEL
RETAINING WALLS
APPENDIX G2

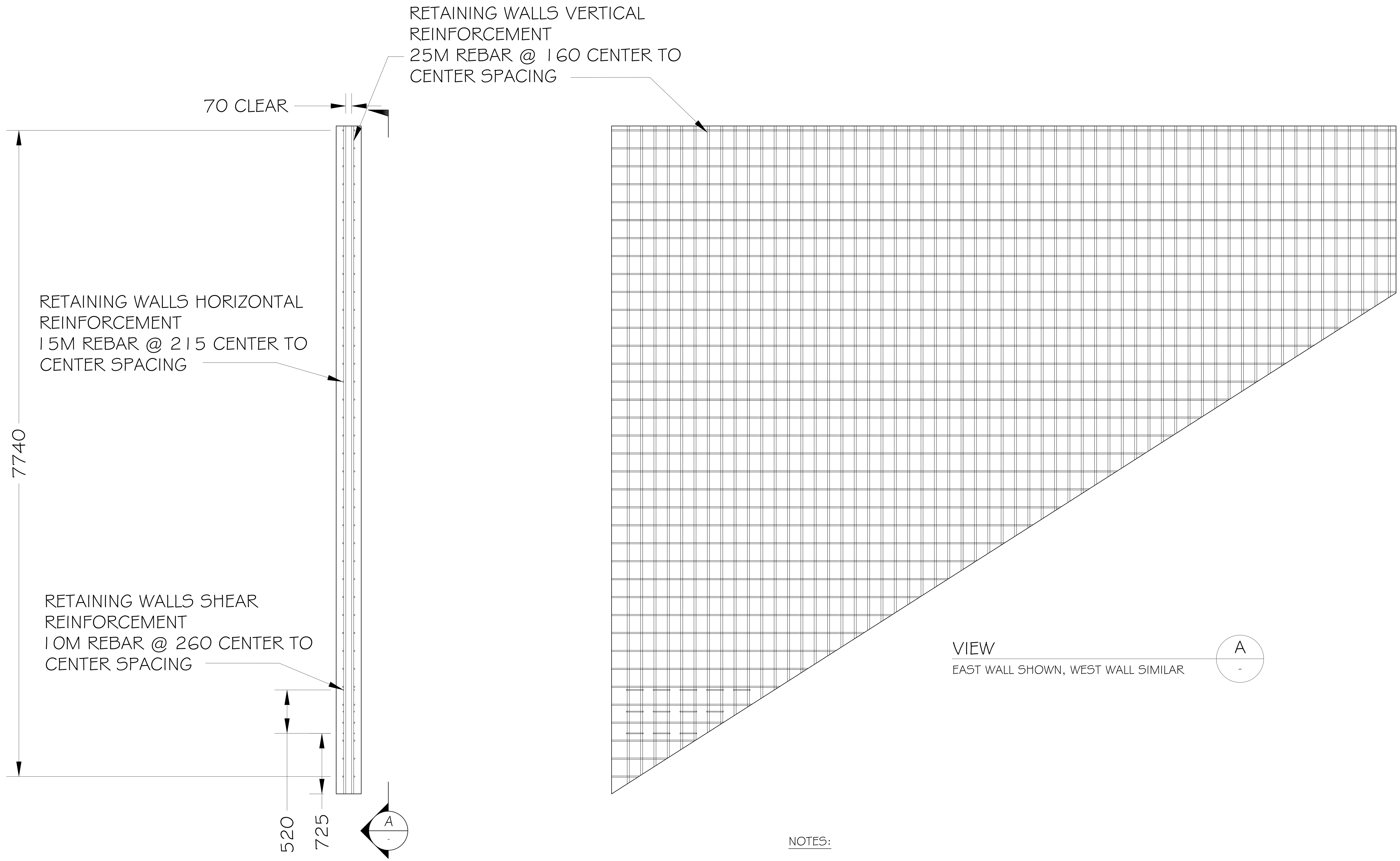
In Charge Of: JOE FLACCO

EMPIRE ENGINEERING

District: TRANSPORTATION

Job Number	Rev
720	0

Sheet Number: CB-204



RETAINING WALL REINFORCEMENT

(LOOKING WEST)

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS U.N.O.
2. DESIGNED TO REQUIREMENTS OF NBCC 2010
3. TUNNEL TO BE MADE FROM 30 MPa CONCRETE, USING RCA
4. REINFORCING STEEL = CSA GRADE 350

FOR TENDER

Drawn	Date	Check	Date	Description
6				
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Revisions

CHANCELLOR BOULEVARD ROADWAY CORRIDOR DESIGN

VANCOUVER | BRITISH COLUMBIA | CANADA

Office: UBC

Design By: EE

Drawn: JH | Checked: JF

Date: 17/11/21 | Date: 17/11/27

CHANCELLOR BOULEVARD PEDESTRIAN TUNNEL RET. WALL REINFORCEMENT DETAILS APPENDIX G2

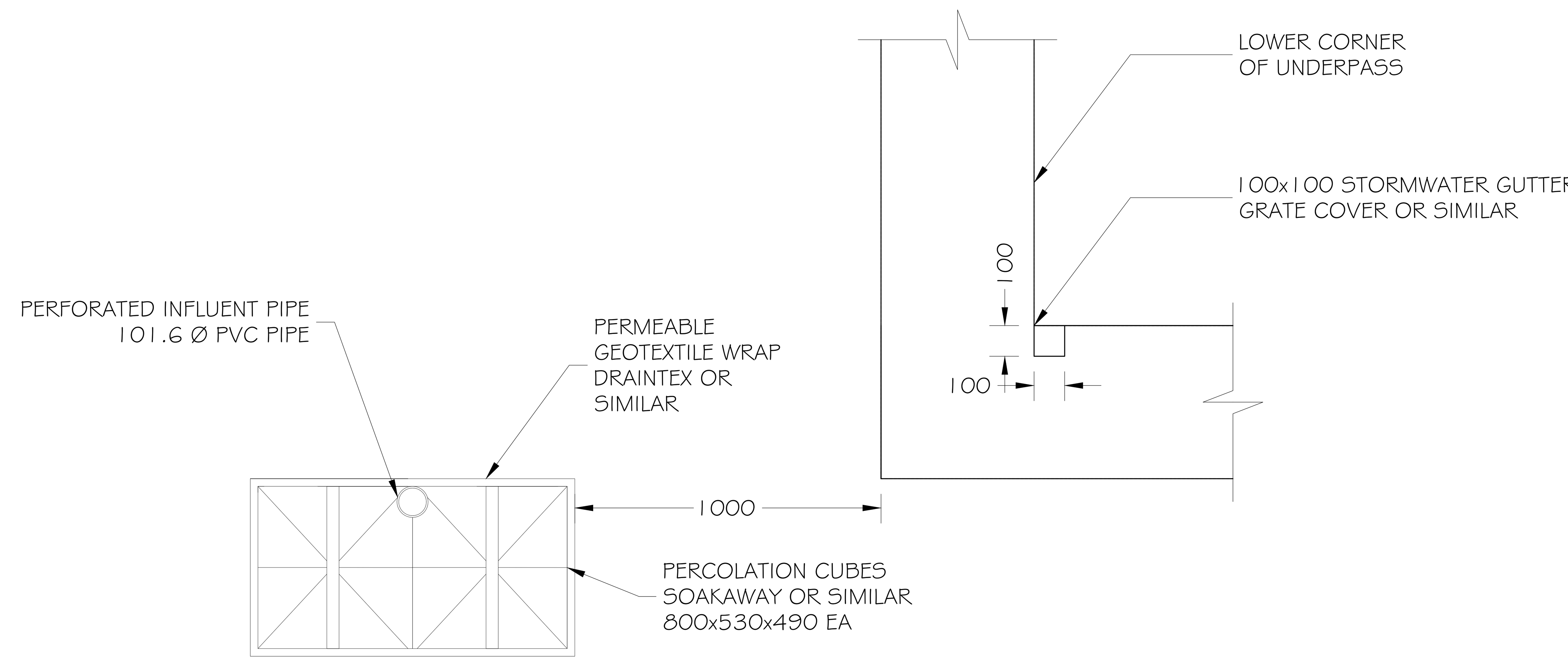
In Charge Of: JOE FLACCO

EMPIRE ENGINEERING

District: TRANSPORTATION

Job Number: 720 | Rev: 0

Sheet Number: CB-205



DETAIL
STORMWATER PERCOLATION TANKS
1
CB-202

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS U.N.O.
2. STORMWATER DRAINAGE DESIGNED FOR 25mm/24hr

FOR TENDER

CHANCELLOR BOULEVARD
ROADWAY CORRIDOR DESIGN

VANCOUVER	BRITISH COLUMBIA	CANADA

	Drawn	Date	Check	Date	Description
6					
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Revisions

Office: UBC
Design By: EE
Drawn: JH
Checked: JF
Date: 17/11/21
Date: 17/11/27

CHANCELLOR BOULEVARD
PEDESTRIAN TUNNEL
STORMWATER PERCOLATION TANKS
APPENDIX G2

In Charge Of: JOE FLACCO

EMPIRE ENGINEERING

District: TRANSPORTATION

Job Number: 720
Rev: 0
Sheet Number: CB-206

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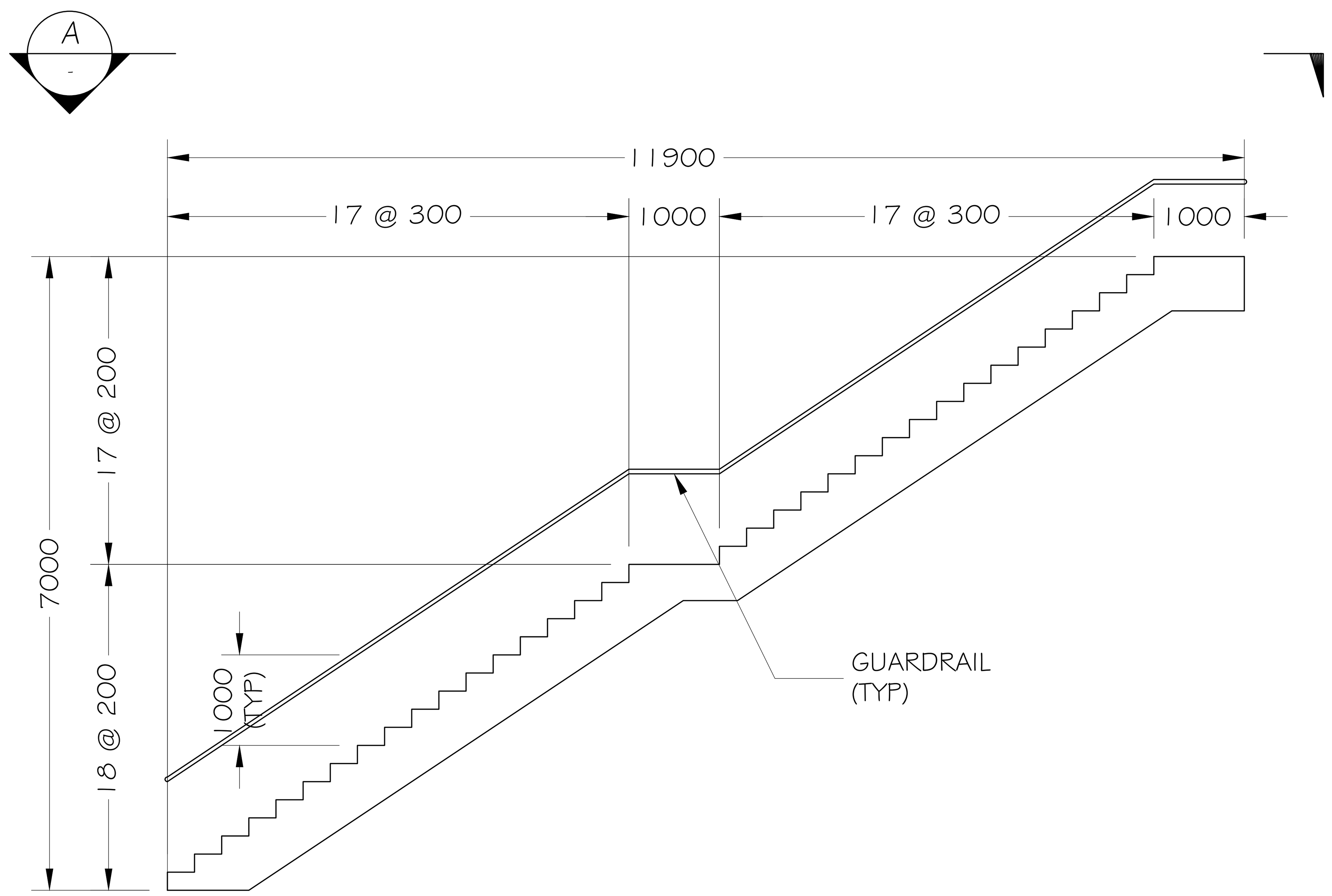
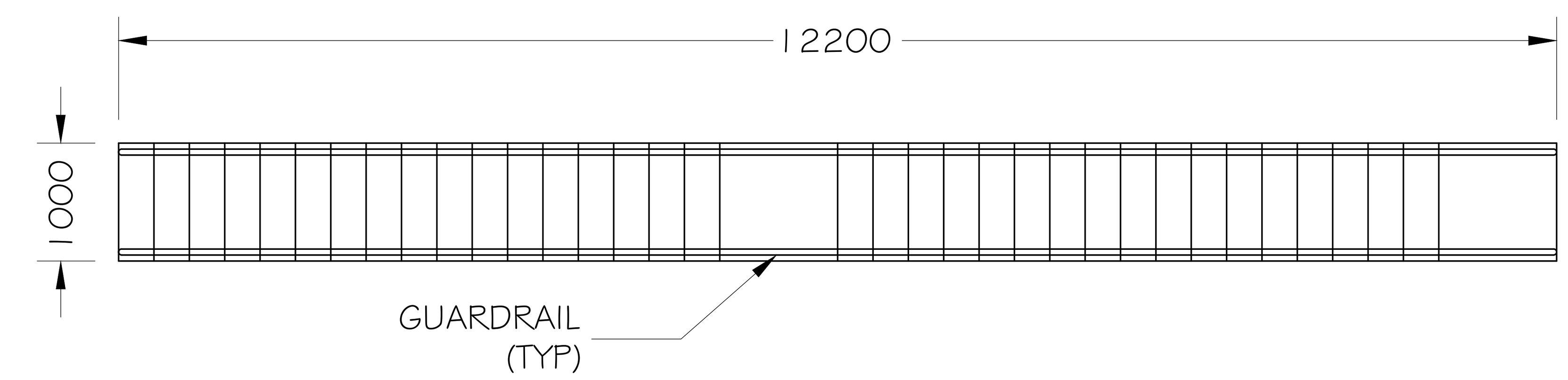


DETAIL 1 CB-202
STAIRS, EAST SHOWN, WEST SIMILAR



VIEW A

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS U.N.O.
2. DESIGNED TO REQUIREMENTS OF NBCC 2010
3. STAIRS TO BE MADE FROM 30 MPa CONCRETE, USING RCA
4. GUARDRAILS TO BE IN ACCORDANCE WITH NBCC 2010, SPECIFICALLY
4.1. 1 METER CLEARANCE ABOVE STAIRS
4.2. ABLE TO WITHSTAND A LINE LOAD OF 0.5 kN/m OR A POINT LOAD OF 1.0 kN
4.3. ON BOTH SIDES OF STAIRCASE

FOR TENDER

CHANCELLOR BOULEVARD
ROADWAY CORRIDOR DESIGN

VANCOUVER	BRITISH COLUMBIA	CANADA

	Drawn	Date	Check	Date	Description
6					
5					
4					
3					
2					
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Revisions

Office: UBC	
Design By: EE	
Drawn: JH	Checked: JF
Date: 17/11/21	Date: 17/11/27

CHANCELLOR BOULEVARD
PEDESTRIAN TUNNEL
STAIR DESIGN
APPENDIX G2

In Charge Of: JOE FLACCO

EMPIRE ENGINEERING

District: TRANSPORTATION

Job Number	Rev
720	0

Sheet Number: CB-207

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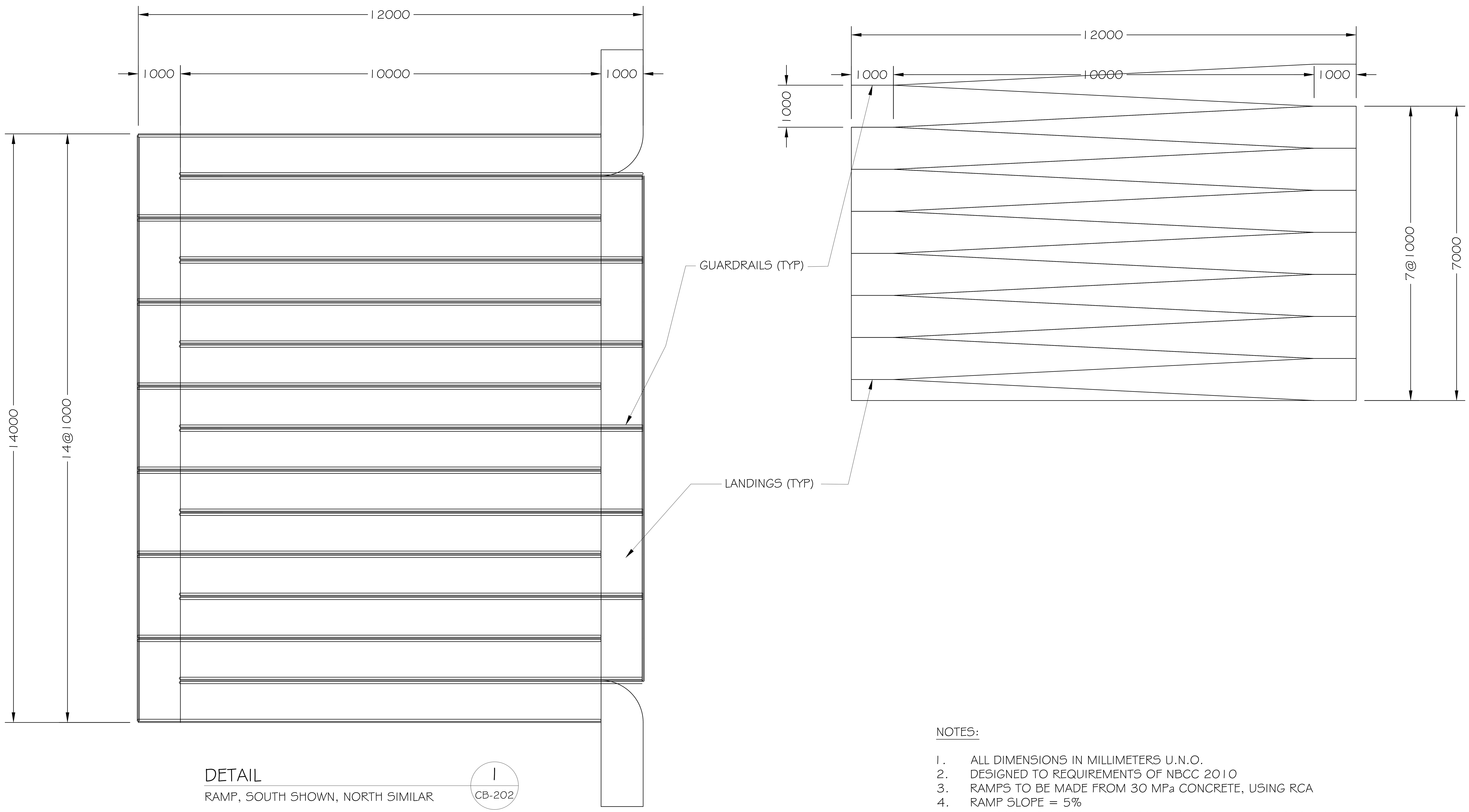

DETAIL 1 CB-202
RAMP, SOUTH SHOWN, NORTH SIMILAR

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS U.N.O.
2. DESIGNED TO REQUIREMENTS OF NBCC 2010
3. RAMPS TO BE MADE FROM 30 MPa CONCRETE, USING RCA
4. RAMP SLOPE = 5%
5. GUARDRAILS TO BE IN ACCORDANCE WITH NBCC 2010, SPECIFICALLY
5.1. 1 METER CLEARANCE ABOVE STAIRS
5.2. ABLE TO WITHSTAND A LINE LOAD OF 0.5 kN/m OR A POINT LOAD OF 1.0 kN
5.3. ON BOTH SIDES OF STAIRCASE

FOR TENDER

CHANCELLOR BOULEVARD
ROADWAY CORRIDOR DESIGN

VANCOUVER	BRITISH COLUMBIA	CANADA

	Drawn	Date	Check	Date	Description
6					
5					
4					
3					
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Revisions

Office: UBC
Design By: EE
Drawn: JH
Checked: JF
Date: 17/11/21
Date: 17/11/27

CHANCELLOR BOULEVARD
PEDESTRIAN TUNNEL
WHEELCHAIR RAMP DESIGN
APPENDIX G2

In Charge Of: JOE FLACCO

EMPIRE ENGINEERING

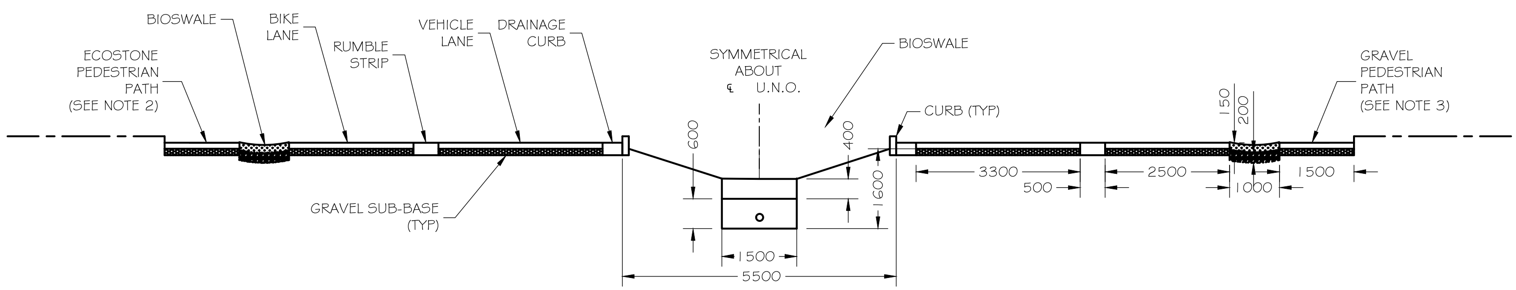
District: TRANSPORTATION

Job Number: 720
Rev: 0
Sheet Number: CB-208

Apr 08, 2018 - 6:28pm C:\Users\ja...CB.dwg

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS, U.N.O
2. UNILOCK UNI ECOSTONE OR APPROVED SIMILAR PERMEABLE PAVEMENT
3. GRAVEL PEDESTRIAN PATH ON NORTH SIDE OF RAOD RUNS ONLY FROM SPANISH TO PIONEER TRAILS



VIEW C (CB-002)
BIOSWALE CROSS-SECTION

Rev.	Drawn	Date	Check	Date	Description
6					
5					
4					
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Revisions

CHANCELLOR BOULEVARD
ROADWAY CORRIDOR DESIGN
VANCOUVER | BRITISH COLUMBIA | CANADA

Office: UBC	
Design By: EE	
Drawn: SP	Checked: JF
Date: 17/11/06	Date: 17/11/27

CHANCELLOR BOULEVARD
STORMWATER DRAINAGE
BIOSWALE CROSS SECTION
APPENDIX G3

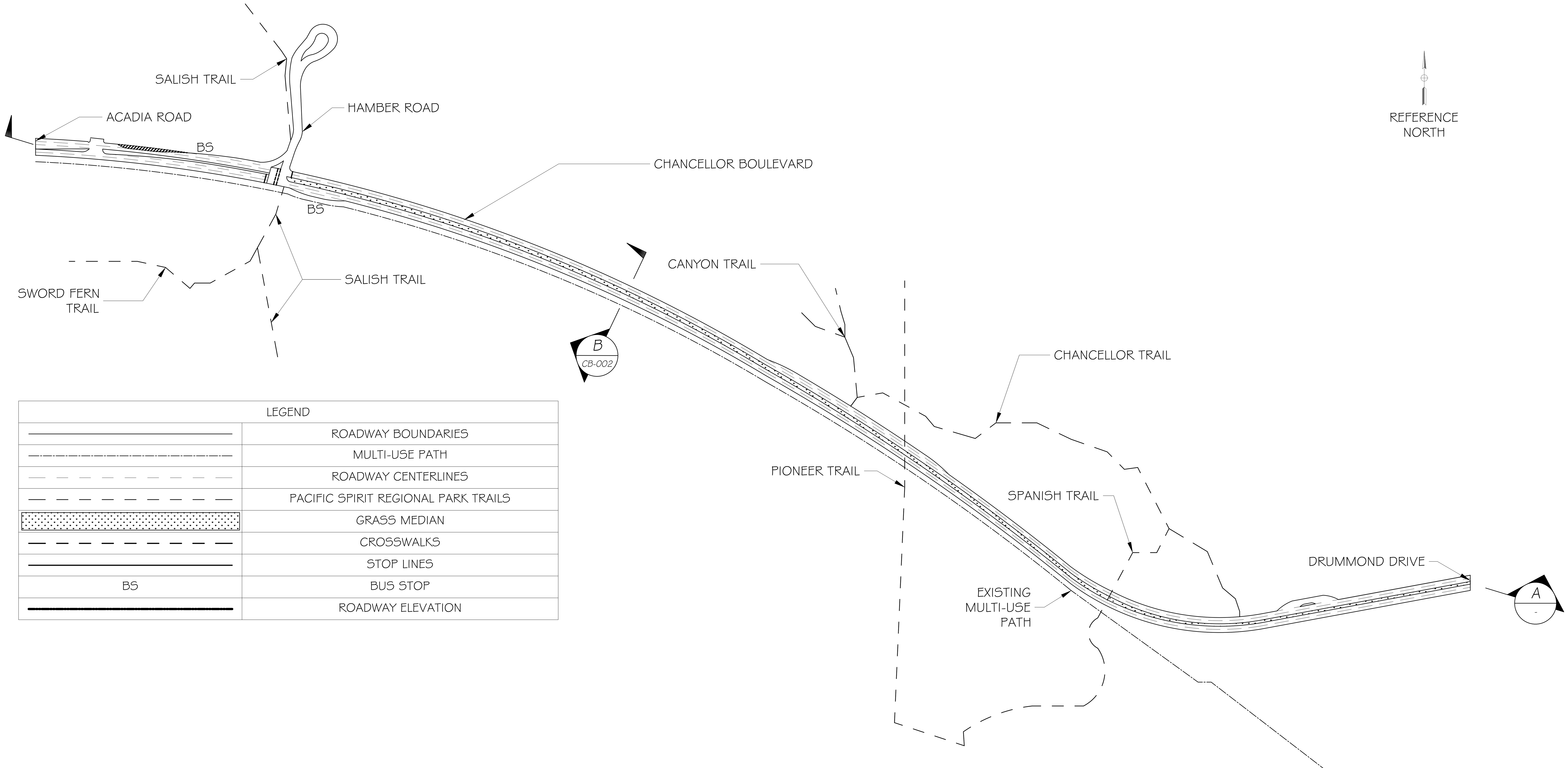
In Charge Of: JOE FLACCO

Windows OLE Object

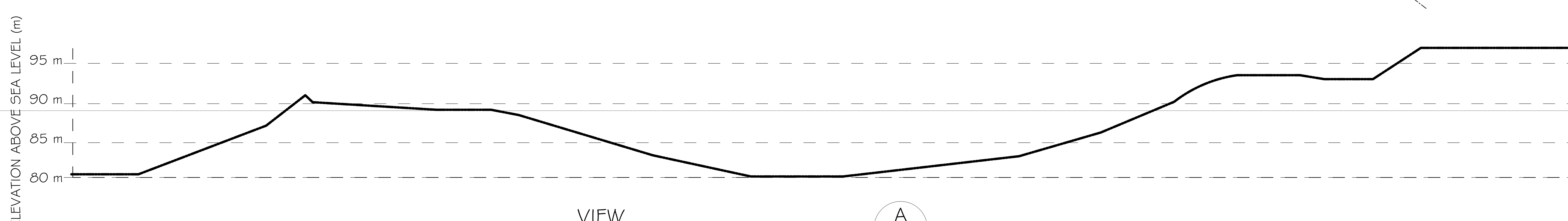
District: TRANSPORTATION

Job Number	Rev
720	0

Sheet Number: CB-300



LEGEND	
	ROADWAY BOUNDARIES
	MULTI-USE PATH
	ROADWAY CENTERLINES
	PACIFIC SPIRIT REGIONAL PARK TRAILS
	GRASS MEDIAN
	CROSSWALKS
	STOP LINES
BS	BUS STOP
	ROADWAY ELEVATION



VIEW A
ELEVATION PROFILE OF CHANCELLOR BLVD

FOR TENDER

	Drawn	Date	Check	Date	Description
6					
5					
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Revisions

CHANCELLOR BOULEVARD
ROADWAY CORRIDOR DESIGN

VANCOUVER | BRITISH COLUMBIA | CANADA

Office: UBC
Design By: OTHERS
Drawn: JH | Checked: JF
Date: 17/11/01 | Date: 17/11/27

CHANCELLOR BOULEVARD
EXISTING CONDITION
GENERAL ARRANGEMENT
APPENDIX G3-1

In Charge Of: JOE FLACCO

EMPIRE ENGINEERING

District: TRANSPORTATION

Job Number: 720 | Rev: 0
Sheet Number: CB-001

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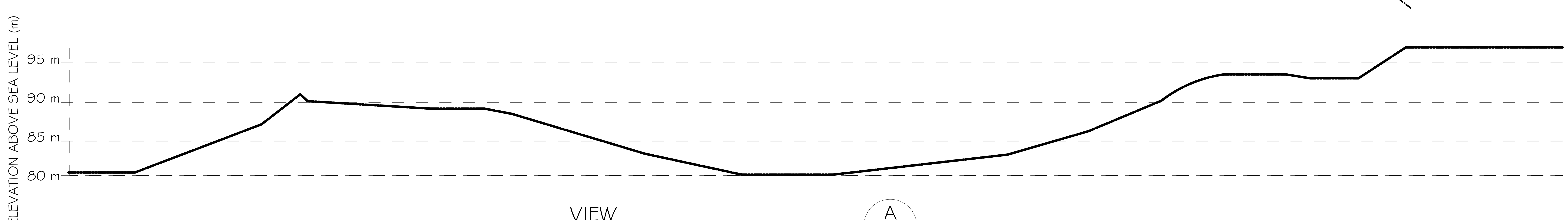

VIEW A

ELEVATION PROFILE OF CHANCELLOR BLVD

FOR TENDER

CHANCELLOR BOULEVARD
ROADWAY CORRIDOR DESIGN

VANCOUVER	BRITISH COLUMBIA	CANADA

	Drawn	Date	Check	Date	Description
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Revisions

Office: UBC

Design By: EE

Drawn: JH | Checked: JF

Date: 17/11/01 | Date: 17/11/27

CHANCELLOR BOULEVARD
NEW ROADWAY CONFIGURATION
GENERAL ARRANGEMENT
APPENDIX G3-2

In Charge Of: JOE FLACCO

EMPIRE ENGINEERING

District: TRANSPORTATION

Job Number: 720 | Rev: 0

Sheet Number: CB-002

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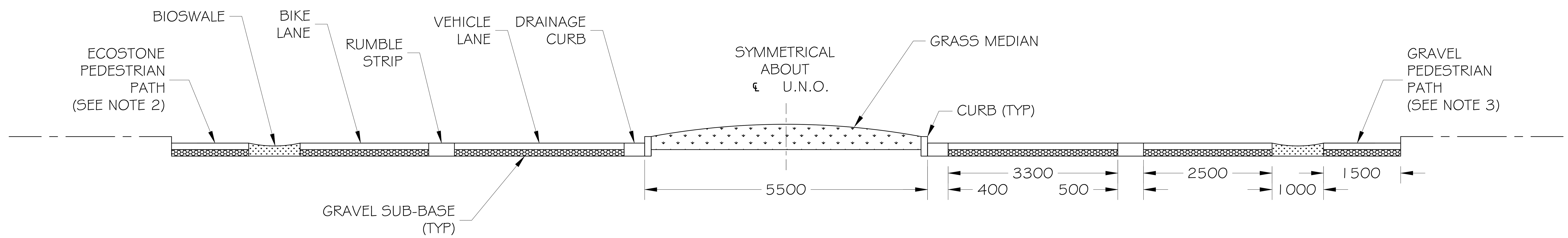
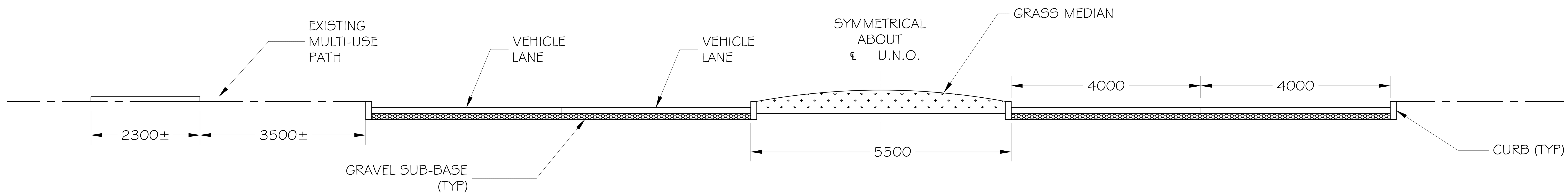
NOTES:

1. ALL DIMENSIONS IN MILLIMETERS, U.N.O
2. UNILOCK UNI ECOSTONE OR APPROVED SIMILAR PERMEABLE PAVEMENT
3. GRAVEL PEDESTRIAN PATH ON NORTH SIDE OF RAOD RUNS ONLY FROM SPANISH TO PIONEER TRAILS

REFERENCE NORTH



VIEW C (CB-002)
NEW ROADWAY CROSS-SECTION



VIEW B (CB-001)
EXISTING ROADWAY CROSS-SECTION

FOR TENDER

CHANCELLOR BOULEVARD
ROADWAY CORRIDOR DESIGN

VANCOUVER	BRITISH COLUMBIA	CANADA

	Drawn	Date	Check	Date	Description
6					
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Revisions

Office: UBC
Design By: EE
Drawn: JH | Checked: JF
Date: 17/11/06 | Date: 17/11/27

CHANCELLOR BOULEVARD
EXISTING CONDITION
TYPICAL CROSS SECTION
APPENDIX G3-3

In Charge Of: JOE FLACCO

EMPIRE ENGINEERING

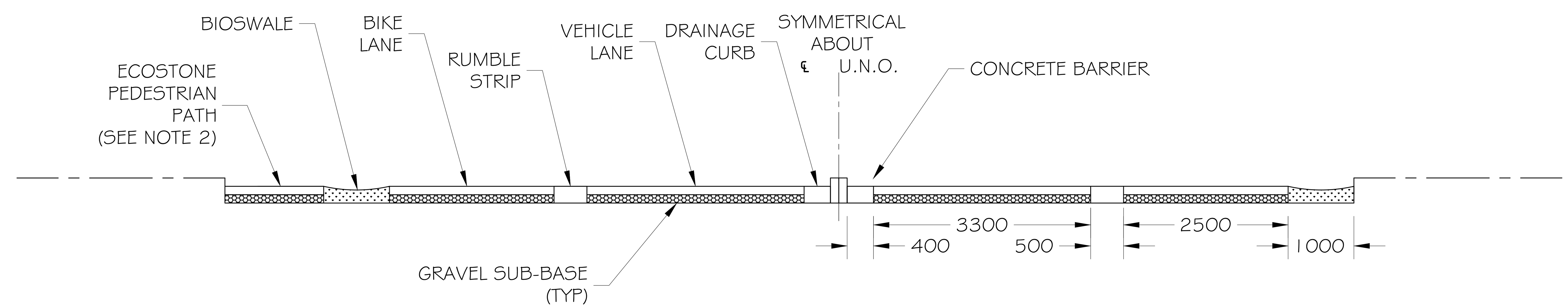
District: TRANSPORTATION

Job Number: 720 | Rev: 0
Sheet Number: CB-003

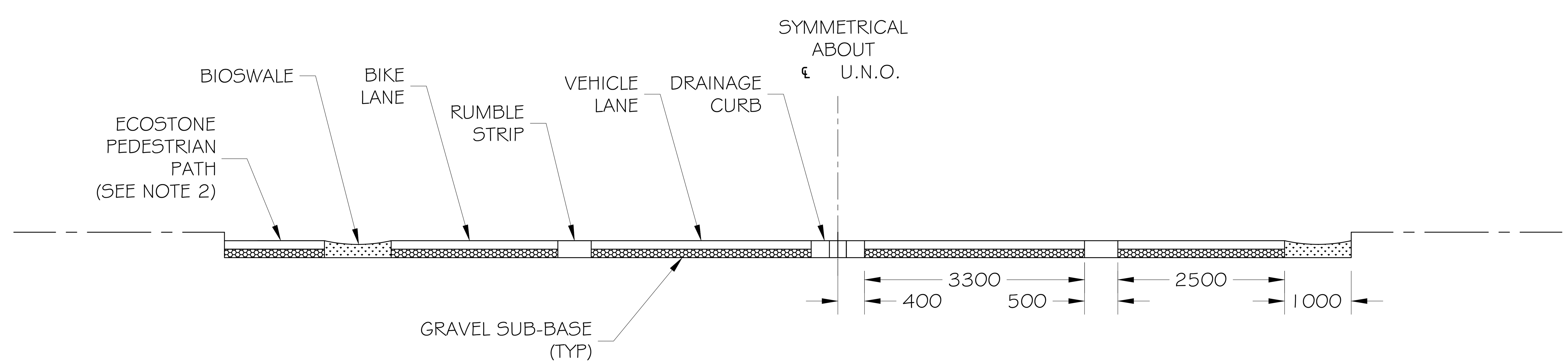
NOTES:

1. ALL DIMENSIONS IN MILLIMETERS, U.N.O
2. UNILOCK UNI ECOSTONE OR APPROVED SIMILAR PERMEABLE PAVEMENT
3. GRAVEL PEDESTRIAN PATH ON NORTH SIDE OF RAOD RUNS ONLY FROM SPANISH TO PIONEER TRAILS

REFERENCE NORTH



VIEW E (CB-002)
NEW ROADWAY CROSS-SECTION



VIEW D (CB-002)
NEW ROADWAY CROSS-SECTION

FOR TENDER

CHANCELLOR BOULEVARD
ROADWAY CORRIDOR DESIGN

VANCOUVER	BRITISH COLUMBIA	CANADA

Rev	Drawn	Date	Check	Date	Description
6					
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Revisions

Office: UBC	
Design By: EE	
Drawn: EM	Checked: JF
Date: 18/04/01	Date: 18/04/03

CHANCELLOR BOULEVARD
DETAILED DESIGN
TYPICAL CROSS SECTION
APPENDIX G3-4

In Charge Of: JOE FLACCO

EMPIRE ENGINEERING

District: TRANSPORTATION

Job Number	Rev
720	0

Sheet Number: CB-004

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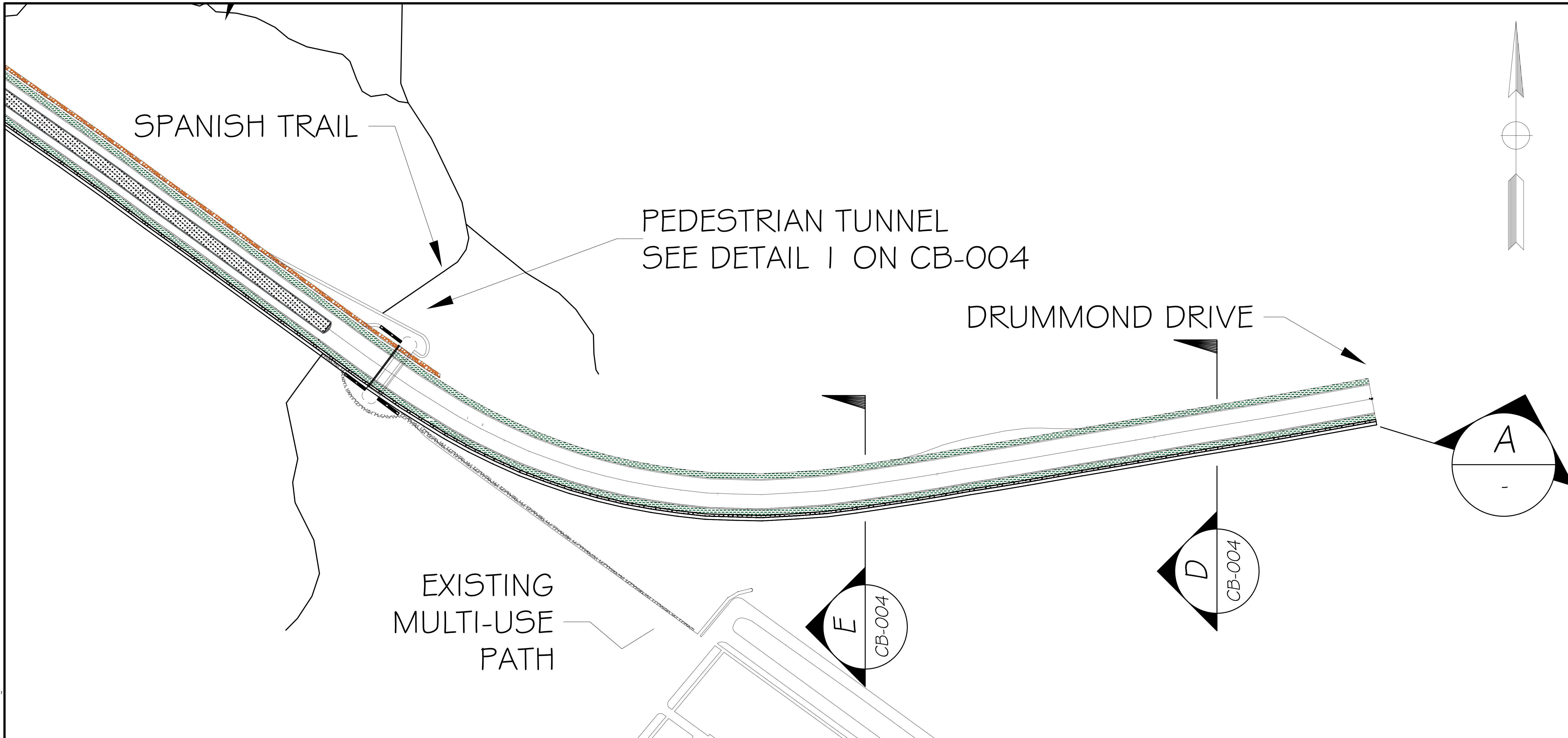

CHANCELLOR BOULEVARD
ROADWAY CORRIDOR DESIGN

VANCOUVER	BRITISH COLUMBIA	CANADA

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Revisions

Office: UBC
Design By: EE
Drawn: EM
Checked: DH
Date: 18/04/01
Date: 18/04/01

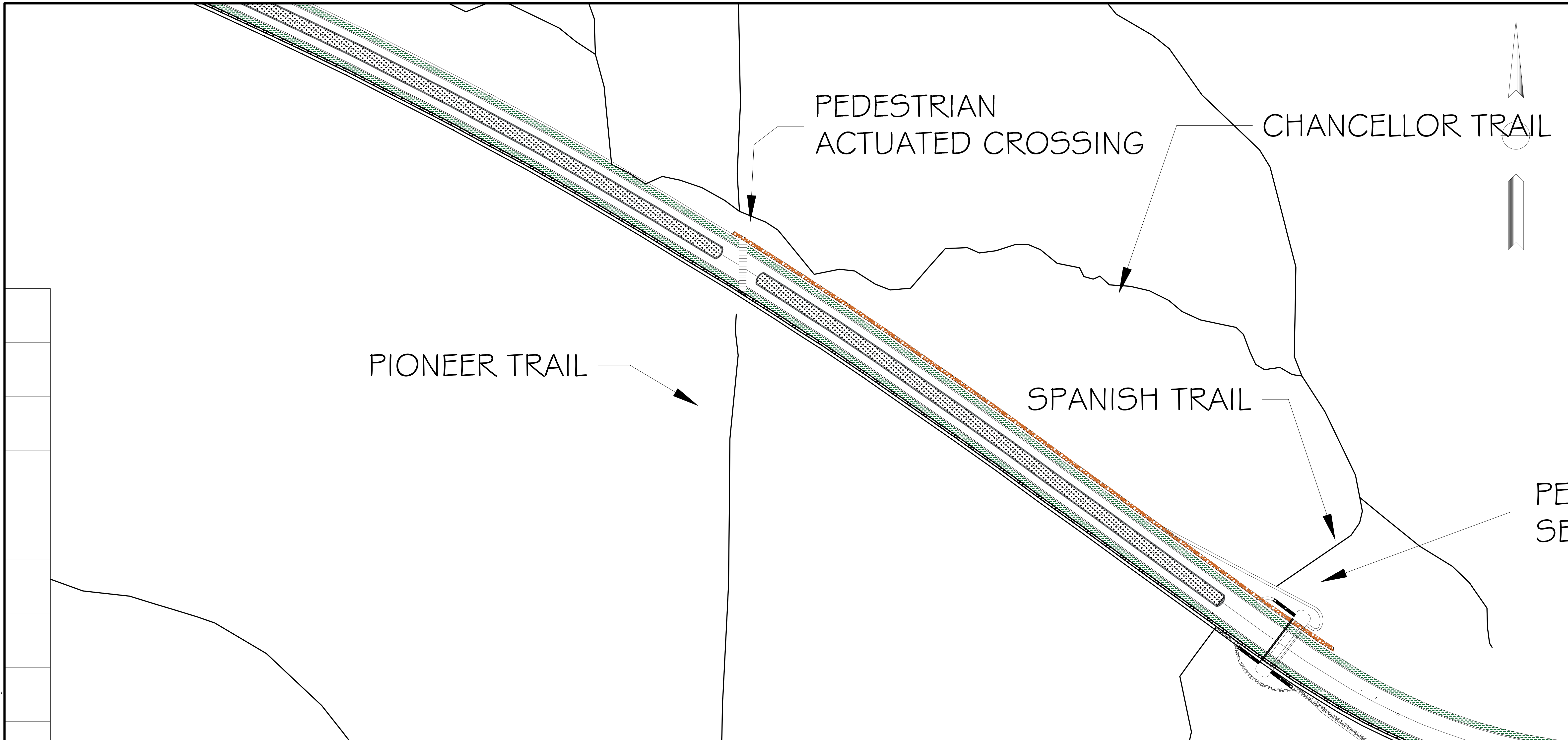
CHANCELLOR BOULEVARD
PLAN VIEW DETAIL
SECTION 1
APPENDIX H2-5

In Charge Of: JOE FLACCO

EMPIRE ENGINEERING

District: TRANSPORTATION

Job Number: 720
Rev: 0
Sheet Number: CB-005



CHANCELLOR BOULEVARD
ROADWAY CORRIDOR DESIGN

VANCOUVER	BRITISH COLUMBIA	CANADA

	Drawn	Date	Check	Date	Description
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Revisions

Office: UBC
Design By: EE
Drawn: EM
Checked: DH
Date: 18/04/01
Date: 18/04/01

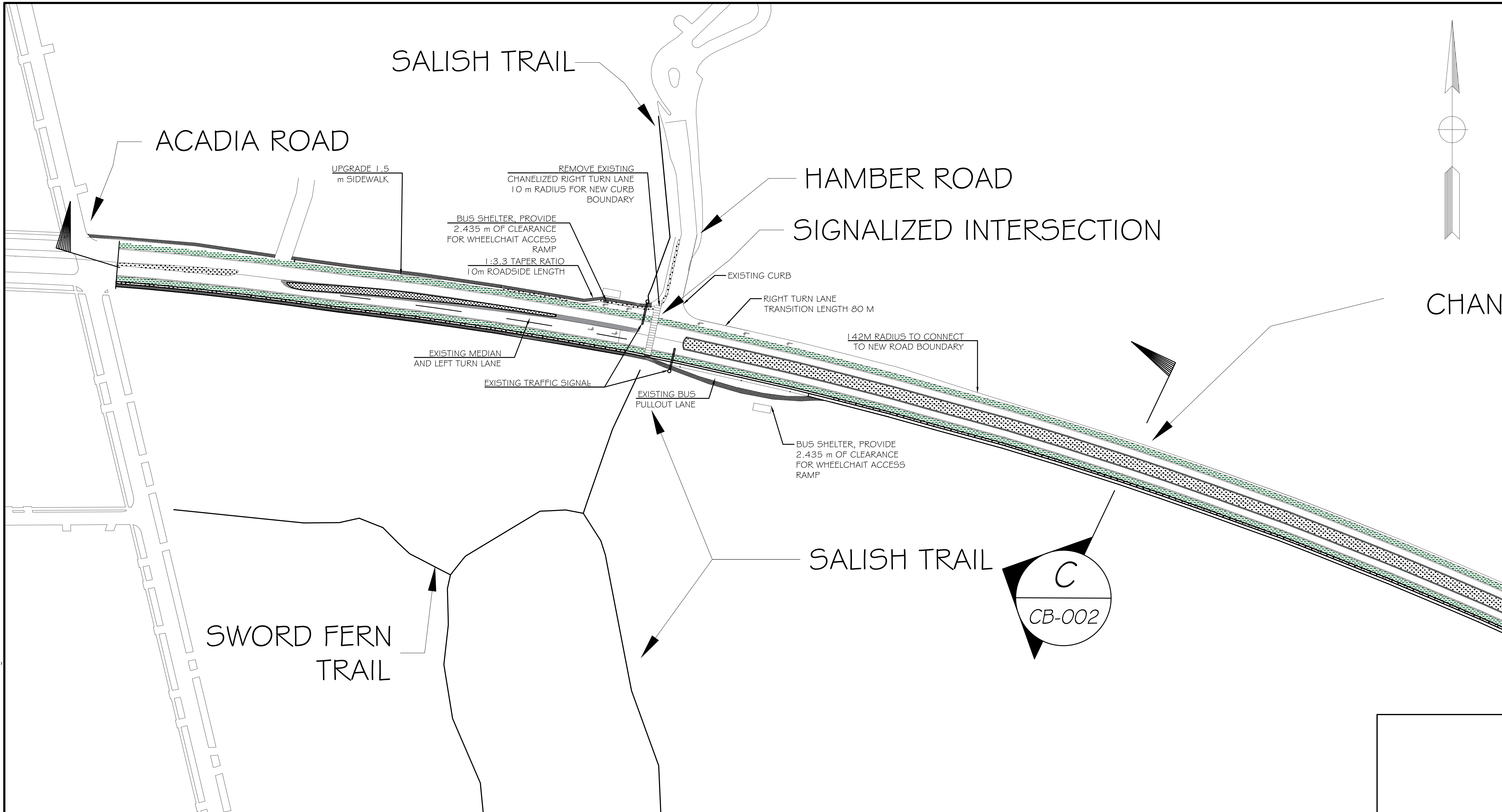
CHANCELLOR BOULEVARD
PLAN VIEW DETAIL
SECTION-2
APPENDIX H2-6

In Charge Of: JOE FLACCO

EMPIRE ENGINEERING

District: TRANSPORTATION

Job Number: 720
Rev: 0
Sheet Number: CB-006



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	Drawn	Date	Check	Date	Description

Revisions

CHANCELLOR BOULEVARD
ROADWAY CORRIDOR DESIGN

VANCOUVER	BRITISH COLUMBIA	CANADA

Office: UBC

Design By: EE

Drawn: EM | Checked: DH

Date: 18/04/01 | Date: 18/04/01

CHANCELLOR BOULEVARD
PLAN VIEW DETAIL
SECTION 3
APPENDIX H2-7

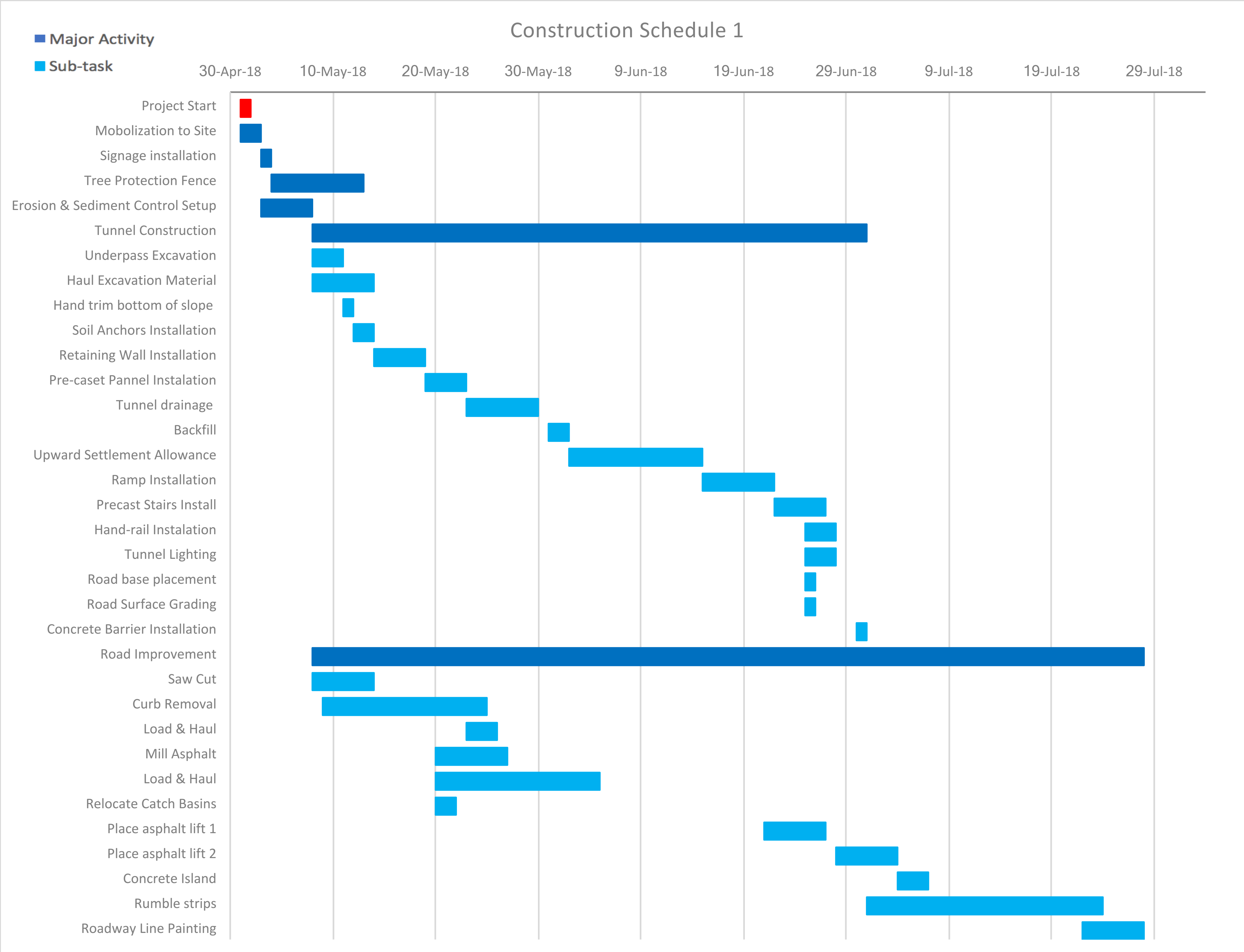
In Charge Of: JOE FLACCO

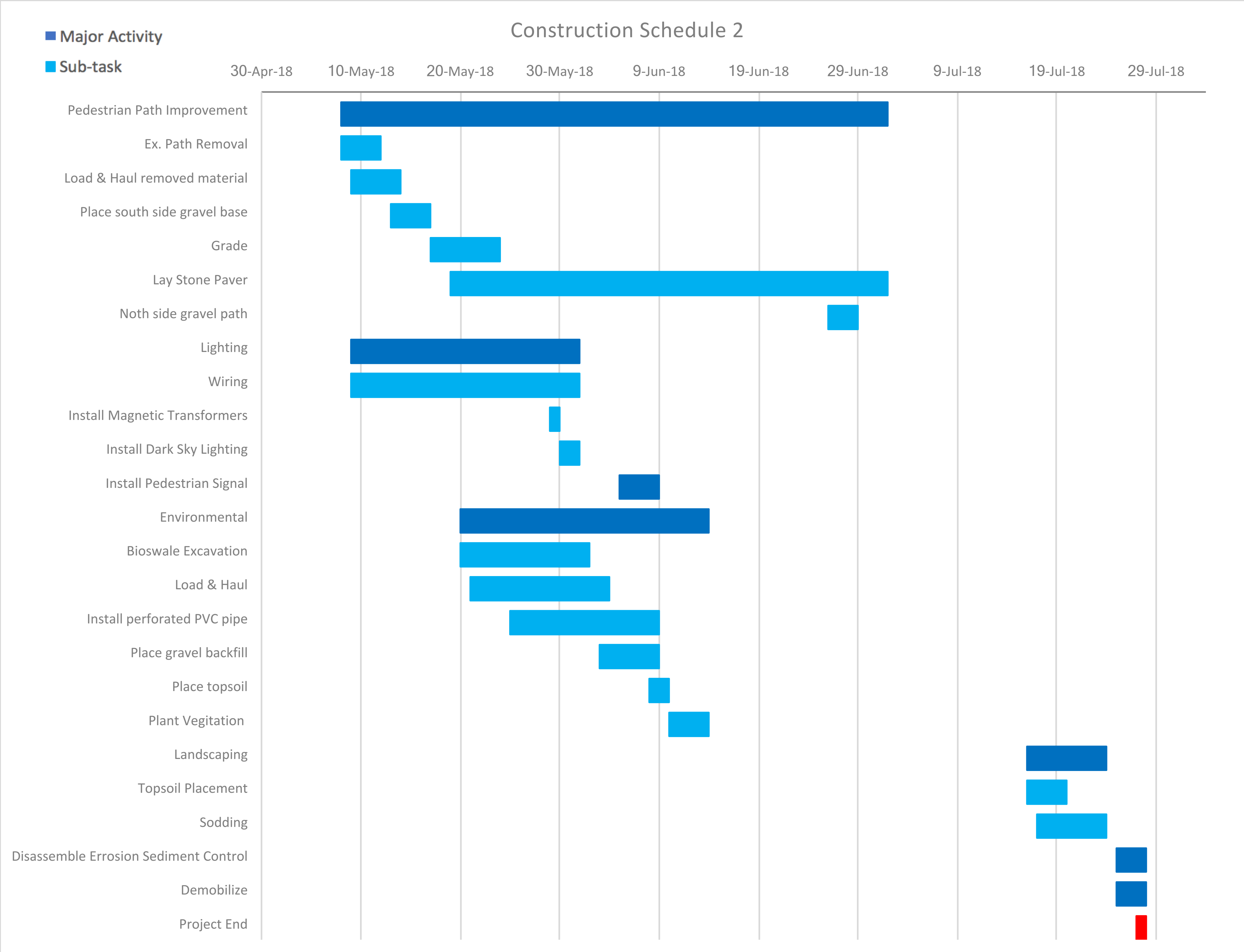
EMPIRE ENGINEERING

District: TRANSPORTATION

Job Number: 720 | Rev: 0

Sheet Number: CB-007


Construction Schedule 1
Major Activity
Sub-task
30-Apr-18
10-May-18
20-May-18
30-May-18
9-Jun-18
19-Jun-18
29-Jun-18
9-Jul-18
19-Jul-18
29-Jul-18
Project Start
Mobolization to Site
Signage installation
Tree Protection Fence
Erosion & Sediment Control Setup
Tunnel Construction
Underpass Excavation
Haul Excavation Material
Hand trim bottom of slope
Soil Anchors Installation
Retaining Wall Installation
Pre-caset Pannel Instalation
Tunnel drainage
Backfill
Upward Settlement Allowance
Ramp Installation
Precast Stairs Install
Hand-rail Instalation
Tunnel Lighting
Road base placement
Road Surface Grading
Concrete Barrier Installation
Road Improvement
Saw Cut
Curb Removal
Load & Haul
Mill Asphalt
Load & Haul
Relocate Catch Basins
Place asphalt lift 1
Place asphalt lift 2
Concrete Island
Rumble strips
Roadway Line Painting


Construction Schedule 2
Major Activity
Sub-task
30-Apr-18
10-May-18
20-May-18
30-May-18
9-Jun-18
19-Jun-18
29-Jun-18
9-Jul-18
19-Jul-18
29-Jul-18
Pedestrian Path Improvement
Ex. Path Removal
Load & Haul removed material
Place south side gravel base
Grade
Lay Stone Paver
Noth side gravel path
Lighting
Wiring
Install Magnetic Transformers
Install Dark Sky Lighting
Install Pedestrian Signal
Environmental
Bioswale Excavation
Load & Haul
Install perforated PVC pipe
Place gravel backfill
Place topsoil
Plant Vegitation
Landscaping
Topsoil Placement
Sodding
Disassemble Errosion Sediment Control
Demobilize
Project End

Line #	Item Description	Unit	EST QTY	Crew	# of Crews	Daily output / Crew	Days to complete
Civil							
02200-02220-360-0010	Saw Cut	LM	3500	B-89	2	320.04	5.5
02000-02220-250-6000	Concrete curb removal	LM	3500	B-6	2	109.73	15.9
02200-02220-350-3080	Load Truck	CM	210	B-17	1	91.75	2.3
02200-02220-350-5100	Haul	CM	210	B-34B	1	1185.13	0.2
02950-02960-100-5280	Mill Asphalt	SM	21720	B-71	1	3344.40	6.5
02200-02220-350-3080	Load truck	CM	4344	B-17	3	91.75	15.8
02200-02220-350-5100	Haul	CM	4344	B-34B	1	1185.13	3.7
02200-02220-240-0040	Relocate Catch Basin	EA	12	B-6	1	7.00	1.7
02700-02740-310-0120	3" thick asphaltic concrete, supply and place Lift 1	SM	21720	B-25	1	4101.07	5.3
02700-02740-310-0120	3" thick asphaltic concrete, supply and place Lift 2	SM	21720	B-25	1	4101.07	5.3
02300-02315-640-0050	Road base for tunnel location	CM	114	B-6	1	114.69	1.0
02300-02310-100-0010	Grading	SM	380	B-11L	1	334.44	1.1
02700-02750-300-0110	Concrete Island. Plain 8" cement pavement. Small area	SM	200	B-26	1	1149.64	0.2
02300-02315-640-0050	base supply and place	SM	60	B-6	1	114.69	0.5
02700-02770-300-0300	Concrete Curb and Gutter	LM	25	C-2A	1	152.40	0.2
02800-02840-910-0510	Rumble stripss, polycarbonate 24" x 3-1/2" x 1/2" high	EA	5741	2 Clab	5	50.00	23.0
02700-02760-300-0020	Roadway Line (Supply and Paint)	LM	14000	B-78	1	6096.00	2.3
02700-02760-300-0620	Arrow or Gore Painting	LM	300	B-78	1	701.04	0.4
02700-02760-500-1200	Pavement Messages (Paint)	EA	20	2 Pord	1	40.00	0.5
00000-00000-000-0000	Green Bike Lane Paint	SM	200	B-78	1	80.00	2.5
Pedestrian Path Upgrade							
02200-02220-250-5050	Asphalt Removal and Disposal	SM	2300	B-38	1	576.91	4.0
02200-02220-350-3080	Load truck	CM	920	B-17	2	91.75	5.0
02200-02220-350-5100	Haul	CM	920	B-34B	1	1185.13	0.8
02700-02775-275-1000	North Side Gravel Path (supply and place)	SM	500	2 Clab	1	157.93	3.2
02300-02315-640-0050	Southside Path Gravel Base	CM	460	B-6	1	114.69	4.0
02300-02310-100-0010	Grading	SM	2300	B-11L	1	334.44	6.9
02700-02780-600-1100	UniStone or Approved Permeable Pavement	SM	2300	D-1	7	7.52	43.7
Tunnel							
02300-02315-424-0300	Excavation backhoe hydraulic 3 C.Y capacity	B.C.M	3000	B-12D	1	978.69	3.1
02300-02315-490-0560	Haul	L.C.M	3690	B-34B	20	29.82	6.2
02300-02315-462-1000	Hand trimming bottom slopes and side of excavation	SM	400	B-2	2	222.96	0.9
00220-00260-730-0320	Soil anchors (Supply and Install)	EA	24	B-47G	1	13.70	1.8
00000-00000-000-0000	Concrete Pannel Instalation	EA	15	X-10	1	4.00	3.8
02800-02830-100-3700	Pre-cast Concrete Retaining Walls 12' tall open face	SM	187	B-13	2	19.51	4.8
00000-00000-000-0000	Soakaway Cubes	EA	160	X-4	1	30.00	5.3
02600-02620-300-0100	Geotecxtile Wrap supply and place	SM	150	2 Clab	1	2006.64	0.1
02600-02620-630-2110	150mm perforated PVC pipe supply and install	LM	60	B-14	1	91.44	0.7
00000-23002-315-2000	Structural Backfill Place	M3	1400	B-10L	1	841.06	1.7
02700-02750-300-0110	Cast in place concrete ramp	SM	360	B-26	1	1149.64	0.3
00000-00000-000-0000	Pre-cast Concrete Stairs	EA	5	X-4	1	1.00	5.0
02800-02840-200-0010	Stair Railings Supply and install	LM	390	B-80	1	259.08	1.5
03300-03350-300-2400	Accessible ramp Surfacing	SM	360	1 Cefi	1	60.39	6.0
02800-02840-200-0010	Accessible Ramp Railing supply and install	LM	340	B-80	1	259.08	1.3
02800-02840-200-2000	Concrete Traffic Barrier	LM	60	B-29	1	115.82	0.5
00000-00000-000-0000	Lighting Allowance	EA	1	2-elec	1		3
Environmental							
01500-01560-250-0350	Tree Protection fence ($38/100ft)	LM	3500	A-4	4	100.00	8.75
00000-00000-000-0000	Awareness Signage	EA	8	A-4	1	10.00	0.8
00000-00000-000-0000	Tree Protection Signage	EA	8	A-4	1	20.00	0.4
00000-00000-000-0000	Erosion & Sediment Control Allowance	Total	1	X-8	1	0.20	5.0
02300-02315-462-6040	Bioswale Excavation	BCM	1016	B-12A	1	82.58	12.3
02300-02315-490-0560	Haul	LCM	1250	B-34B	3	29.82	14.0
02300-02315-640-0050	Suply and place gravel (23 to 75 mm)	LCM	671.58	B-6	1	114.69	5.9
02600-02620-630-2110	150mm perforated PVC pipe supply and install	LM	2580	B-14	2	91.44	14.1
02900-02910-710-3850	Topsoil Supply and Placement 300HP dozer	SM	2693	B-10M	1	2508.30	1.1
Traffic and Pedestrian Signals							
02800-02890-300-0200	Ped cross walk signal with pushbuttopn and mast arm	Total	1	R-11	1	0.30	3.3
Lighting							
16100-16132-240-1400	Wiring for lighting (4 full lengths)	LM	1700	2-elec	4	18.29	23.2
00000-00000-000-0000	Magnetic Transformer (300V to 12V)	EA	4	2-elec	2	2.00	1.0
00000-00000-000-0000	Dark Sky Lighting for bike and ped paths	EA	36	2-elec	2	10.00	1.8
Landscaping							
02900-02910-710-3850	Topsoil Supply and Placement	SM	9000	B-10M	1	2508.30	3.6
02900-02920-400-0300	Sodding 1" thick	SM	9000	B-63	1	1254.15	7.2

Line #	Item Description	Unit	EST QTY	UNIT COST	TOTAL COST
Civil					
02000-02220-250-6000	Concrete curb removal	LM	3500	$18.17	$63,581.39
02200-02220-350-3080	Load Truck	CM	210	$32.94	$6,918.07
02200-02220-350-5100	Haul	CM	210	$1.08	$225.90
00000-00000-000-0000	Dispose	CM	210	$20.00	$4,200.00
02950-02960-100-5280	Mill Asphalt	SM	21720	$2.53	$54,941.39
02200-02220-350-3080	Load truck	CM	4344	$32.94	$143,105.14
02200-02220-350-5100	Haul	CM	4344	$1.08	$4,672.82
00000-00000-000-0000	Dispose	CM	4344	$31.00	$134,664.00
02200-02220-360-0010	Saw Cut	LM	3500	$6.51	$22,767.87
02700-02740-310-0120	3" thick asphaltic concrete, supply and place x 2lifts	SM	43440	$13.35	$579,936.92
02300-02315-640-0050	Road base for tunnel location	CM	114	$60.51	$6,897.90
02300-02310-100-0010	Grading	SM	380	$5.66	$2,149.40
02700-02770-300-0300	Concrete Curb and Gutter	LM	25	$39.75	$993.84
02800-02840-910-0510	Rumble stripss, polycarbonate 24" x 3-1/2" x 1/2" high	EA	5741	$30.11	$172,853.02
02200-02220-240-0040	Relocate Catch Basin	EA	12	$284.93	$3,419.15
02700-02760-300-0020	Roadway Line (Supply and Paint)	LM	14000	$1.49	$20,912.71
02700-02760-300-0620	Arrow or Gore Painting	LM	300	$8.63	$2,587.59
02700-02760-500-1200	Pavement Messages (Paint)	EA	20	$71.97	$1,439.33
00000-00000-000-0000	Green Bike Lane Paint	SM	200	$45.00	$9,000.00
02700-02750-300-0110	Concrete Island. Plain 8" cement pavement. Small area	SM	200	$65.87	$13,174.64
02300-02315-640-0050	base supply and place	SM	60	$60.51	$3,630.47
			Contingency at	15%	$187,810.73
			Roadway Improvement Total		$1,439,882.28
Pedestrian Path Upgrade					
02200-02220-250-5050	Asphalt Removal and Disposal	SM	2300	$7.22	$16,605.31
02200-02220-350-3080	Load truck	CM	920	$32.94	$30,307.72
02200-02220-350-5100	Haul	CM	920	$1.08	$989.64
00000-00000-000-0000	Dispose	CM	920	$31.00	$28,520.00
00000-00000-000-0000	UniStone or Approved Permeable Pavement	SM	2300	$80.00	$184,000.00
02700-02775-275-1000	North Side Gravel Path (supply and place)	SM	500	$9.80	$4,900.96
02300-02315-640-0050	Southside Path Gravel Base	CM	460	$60.51	$27,833.62
02300-02310-100-0010	Grading		2300	$5.66	$13,009.51
			Contingency at	15%	$45,925.01
			Pedestrian Path Improvement Total		$352,091.78
			Total Civil		$1,791,974.05
Tunnel					
02300-02315-424-0300	Excavation backhoe hydraulic 3 C.Y capacity	B.C.M	3000	$4.55	$13,657.49
02300-02315-490-0560	Haul	L.C.M	3690	$43.22	$159,481.45
02300-02315-462-1000	Hand trimming bottom slopes and side of excavation	SM	400	$11.38	$4,553.15
00000-00000-000-0000	Pre-cast Concrete	M3	190	$250.00	$47,500.00
00000-00000-000-0000	Concrete Pannel Instalation	EA	15	$500.00	$7,500.00
02300-02315-210-5000	Structural backfill supply	CM	1400	$19.21	$26,892.38
00000-23002-315-2000	Structural Backfill Place	M3	1400	$1.69	$2,366.53
02800-02830-100-3700	Pre-cast Concrete Retaining Walls 12' tall open face	SM	187	$250.00	$46,750.00
00220-00260-730-0320	Soil anchors 9m long grade 75 (Supply and Install)	EA	24	$609.51	$14,628.34
02700-02750-300-0110	Cast in place concrete ramp	SM	360	$65.87	$23,714.34
00000-00000-000-0000	Pre-cast Concrete Stairs	M3	20	$250.00	$5,000.00
02800-02840-200-0010	Stair Railings Supply and install	LM	390	$98.78	$38,524.68
02800-02840-200-2000	Concrete Traffic Barrier	LM	60	$252.98	$15,178.58
00000-00000-000-0000	Transfer Precast Concrete to Site Allowance	EA	1	$200,000.00	$200,000.00
03300-03350-300-2400	Accessible ramp Surfacing	SM	360	$16.50	$5,939.64
02800-02840-200-0010	Accessible Ramp Railing supply and install	LM	340	$98.78	$33,585.62
00000-00000-000-0000	Soakaway Cubes	EA	160	$50.00	$8,000.00

Line #	Item Description	Unit	EST QTY	UNIT COST	TOTAL COST
02600-02620-300-0100	Geotecxtile Wrap supply and place	SM	150	$3.16	$474.29
02600-02620-630-2110	150mm perforated PVC pipe supply and install	LM	60	$46.74	$2,804.42
00000-00000-000-0000	Lighting Allowance	EA	1	$100,000.00	$100,000.00
			Contingency at	20%	$151,310.18
				Tunnel Construction Total	$907,861.10
Environmental					
00000-00000-000-0000	Tree Protection fence ($38/100ft)	LM	3500	$1.25	$4,375.00
00000-00000-000-0000	Tree Protection stakes (every 2.5 meters)	EA	1400	$3.00	$4,200.00
00000-00000-000-0000	Tree Protection Signage	EA	8	$200.00	$1,600.00
02300-02315-462-6040	Bioswale Excavation	BCM	1016	$25.16	$25,566.21
02300-02315-490-0560	Haul	LCM	1250	$43.22	$54,011.05
00000-00000-000-0000	Erosion & Sediment Control Allowance	Total	1	$150,000.00	$150,000.00
02900-02910-710-3850	Topsoil Supply and Placement 300HP dozer	SM	2693	$9.88	$26,612.76
02300-02315-640-0050	Suply and place gravel (23 to 75 mm)	LCM	671.58	$60.51	$40,635.87
02600-02620-630-2110	150mm perforated PVC pipe supply and install	LM	2580	$46.74	$120,590.21
00000-00000-000-0000	Awareness Signage	EA	8	$200.00	$1,600.00
			Contingency at	15%	$64,378.67
				Environmental Total	$493,569.77
Traffic and Pedestrian Signals					
02800-02890-300-0200	Ped cross walk signal with pushbuttopn and mast arm	Total	1	$112,356.19	$112,356.19
			Contingency at	10%	$11,235.62
				Traffic and Pedestrian Signal Total	$123,591.81
Lighting					
00000-00000-000-0000	Dark Sky Lighting for bike and ped paths	EA	36	$300.00	$10,800.00
16100-16132-240-1400	Wiring for lighting	LM	1700	$483.72	$822,317.84
00000-00000-000-0000	Magnetic Transformer (300V to 12V)	EA	4	$200.00	$800.00
				10%	$83,391.78
				Lighting Total	$917,309.62
Landscaping					
02900-02920-400-0300	Sodding 1" thick	SM	9000	$7.04	$63,317.30
02900-02910-710-3850	Topsoil Supply and Placement	SM	9000	$9.88	$88,928.79
			Contingency at	10%	$15,224.61
				Landscaping Total	$167,470.70

			Subtotal	$4,401,777.06
Traffic Control	10%			$440,177.71
			Subtotal 2	$4,841,954.76
Mobilization (including traffic Control)	10%			$484,195.48
			Subtotal 3	$5,326,150.24
Final Design and Construction Management	15%			$798,922.54
			Subtotal 4	$6,125,072.77
Permitting	LS			$20,000.00
			Subtotal 4	$6,145,072.77
		Rounding		$927.23
			Grand Total	**$6,146,000.00**

Annual Maintenance Cost

Line #	Description	Unit	EST QTY	Unit cost	Cost Per time	Times per year	Yearly Cost
02950-02985-700-1590	Clear Brush with dozer, ball chain medium clearing	SM	9000	$ 1.02	$ 9,169.55	2	$ 18,339.09
02950-02985-700-3060	Aerate lawn 72" width	SM	9000	$ 0.01	$ 60.87	1	$ 60.87
02950-02985-700-4500	rake leaves . Powere raker	SM	9000	$ 0.13	$ 1,159.63	2	$ 2,319.26
02950-02985-700-6110	De-icing road and sidewalks with rotary spreador	SM	24020	$ 0.12	$ 2,848.09	3	$ 8,544.28
00000-00000-000-0000	Lighting Maintenance	Total	1	$ 2,000.00	$ 2,000.00	1	$ 2,000.00
00000-00000-000-0000	Inspection and repairs to underpass	Total	1	$ 5,000.00	$ 5,000.00	1	$ 5,000.00
						Total	**$ 36,263.50**