University of British Columbia

Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

# Wesbrook Mall Redesign – Phase 4

Prepared by: Vasilii Bogdan, Tai Phan, Aaron Przy, Tan Vuong, Mitchell Zazulak, Lisi Zhang

Prepared for:

Course Code: CIVL 446

University of British Columbia

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## Executive Summary

The Wesbrook Mall Redesign project is a UBC roadway rehabilitation plan that has been proceeding over several years that is nearing completion. This report contains a detailed design for the fourth and final phase of the project developed by our consulting team. There is an extensive amount of information regarding the redesign of this final phase and its components outlined throughout the report. Details that can be found include roadway alignments, water retention plans, construction strategies, scheduling, as well as a Class A cost estimation for the project.

Team 14 has developed a design that contains many benefits to improve this portion of Wesbrook Mall on the University grounds. Key features that our design implements include:

- Enhancing sustainable transportation infrastructure
- Implementing rain water retention strategies
- Considering environmental concerns and impacts
- Increasing safety for all corridor users
- Maximizing on-street parking available

The noted elements above are further outlined in the body of this report. Our team focused primarily on enhancing infrastructure for sustainable modes of transportation. The established design emphasizes infrastructure enhancements in hopes of enabling users to shift away from personal vehicle use. The City of Vancouver has implemented a goal for 2040 for transit, cycling, and walking to be two-thirds of all trips taken in the city. Our team has taken a similar approach by creating a safer and more accessible framework for users of all ages and abilities. Primary components of the project that emphasize safety include clearly marked and designated cycling lanes, additional drive lanes to reduce transit disruption, widened sidewalks, and a newly constructed overpass for pedestrians to cross Wesbrook Mall.

The design our team has developed has a tentative timeline starting in May 2022 and taking approximately 25 weeks to complete. Our tentative schedule is limited to weather constraints and recent infrastructure damages in British Columbia that may cause delays due to material shortages.

A detailed cost estimate is enclosed in the report highlighting action items and unit rates for the complete construction of the project. We expect the total cost of construction to be roughly $3,840,000 with $27,000 of annual operating and maintenance costs. A slightly higher contingency of 15% was used to account for the current shortage of construction materials, as well as other unforeseen events that may occur.

To view a 3D rendering that our team developed of the Wesbrook Mall Redesign – Phase 4 corridor, please visit the following link: https://www.youtube.com/watch?v=G51U1FlnjDU.

## 1.0 Stakeholders

Our consulting team researched the area of the University of British Columbia and established all stakeholders that the project will likely have impact on. The list of stakeholders and their primary interests and concerns are summarized in Table 1 below.

*Table 1 Key Stakeholders and their interests*

| **Stakeholder** | **Primary Interests** |
|---|---|
| **BC Ministry of Transportation and Infrastructure** | - Design complies with BC Engineering Standards & Guidelines<br>- Satisfy projected future traffic demand<br>- Ensure safety to all corridor users |
| **University of British Columbia** | - Maximize on-street parking space available<br>- Limit tree removals along Wesbrook Mall<br>- Mitigate traffic congestion during current and projected future peak hours |
| **UBC Staff, Students, and Residents** | - Ensure efficient transit commuting and effective scheduling<br>- Increase safety to all users, including pedestrians, cyclists, vehicle drivers, and transit users |
| **TransLink** | - Ensure the design does not interrupt bus schedule and bus routes<br>- Plan an alternate route or relocation of bus stop during construction |
| **UBC SEEDS Sustainability Program** | - Prioritize sustainable modes of transportation over personal vehicle use<br>- Minimize impacts to surrounding eco-system |
| **Musqueam First Nations** | - Consider heritage site, and ensure archaeology artifacts are well-preserved |

| | |
|---|---|
| **Residents living on or near UBC** | - Minimize construction disturbance<br>- Provide consistent flow of traffic with minimal congestion |
| **University Endowment Lands (residents)** | - Ensure construction does not affect livelihood<br>- Minimize ecological disturbances and provide safe measures regarding habitats |

# 2.0 Introduction

## 2.1 Project Overview

### 2.1.1 Background Information

Our team was contracted to develop a design plan of the Wesbrook Mall corridor from Thunderbird Boulevard to 16th Avenue. This section of roadway is part of an ongoing multi-year project to refurbish the entire corridor extending from 16th Avenue to Chancellor Boulevard. Main objectives of the project were to tie-in to the already completed stages of construction and create a seamless transition between phases. Moreover, the goal was to emphasize priority placed on greener modes of transportation rather than personal vehicles use; this includes taking public transit, cycling, and walking all while maximizing safety, comfort, and convenience for all users. We aimed to achieve this while keeping the budget to a reasonable construction value. One of the main components to the design was to incorporate either an overpass or tunnel for pedestrians to safely cross Wesbrook Mall, to gain access to the Thunderbird Arena. In addition, integrating green space and infrastructure that will aid in retaining rainwater in this phase.

### 2.1.2 Purpose of Redesign

The key criteria that were involved in this phase of the project include providing an adequate solution to the increasing demand of sustainable modes of transportation, public safety, and maintaining the functionality of the existing roadway.

Increasing demand of sustainable modes of transportation including public transit, cycling, and walking has resulted in more shared roadways being used than ever before. Making sure that all types of transportation methods were accommodated is important when redesigning existing right of ways. This ensures that there is sufficient space available to provide safe and convenient passages for all users to enjoy.

Public safety is a major concern for all projects of any nature. Since this roadway accommodates a large volume of users due to being located on the University grounds, this makes public safety a key concern for the project. Ensuring that all users feel safe and comfortable was a top priority for determining the new design of this phase of the corridor. To achieve this, clear guidance and separation among travel modes must be established to reduce unforeseen incidents.

Maintaining the functionality of this roadway is extremely important as this corridor is a primary passage for UBC staff and students, as well as local residents and visitors. Within this phase of the corridor there is a recreational facility, the Doug Mitchell Thunderbird Sports Centre. Having a facility of this nature will involve dense traffic volumes during sporting events. Therefore, ensuring the functionality of the roadway is adequate will allow for the most efficient and effective travel along Wesbrook Mall.

## 3.0 Issues and Criteria

During the planning and construction phases of the project, our team found some notable issues that will be discussed in the section of the report. Each of the issues has either already been resolved during design stages or have strategizes in place to mitigate and/or eliminate the potential concerns.

## 3.1 Design Issues

Issues that were caught during the design stages of the project have been listed in the following sections and were considered during the progression towards our final detailed design.

### 3.1.1 Road Alignment

Throughout the design of the project, our team found some critical alignment issues that needed to be addressed in order for the design to function optimally. As the design progressed, critical issues found included:

- Adjusting horizontal road alignments due to the additional/widening of drive lane(s) resulting in curb line shifting
- Ensuring continuity across the corridor for all travel mode infrastructure, as well as continuity with surrounding infrastructure around Wesbrook Mall
- Providing on-street parking space near the Fire Hall to accommodate firetrucks, sporting buses, and other large visiting vehicles

### 3.1.2 Overpass Design

When designing the overpass for pedestrians near the Doug Mitchell Thunderbird Sports Centre, few challenges were acknowledged and resolved which include the following:

- Creating a comprehensive bridge design that would include a roof glazing system to provide weather protection for pedestrians
- Configuring the overpass access stairs that will not be disruptive to cyclists or pedestrians while considering the limited space available

### 3.1.3 Tress Removal

As requested by the client, minimizing tree removals was emphasized goal that our team strived to attain. The trees along the roadsides did not pose as an issue for the design, with the exception of a few trees with the placement of our pedestrian overpass. However, the trees in the medians were planted in a way such that they were staggered along the East and West curb lines. Due to the trees being staggered and the East curb of the median needing to be shifted, the trees on that curb line became an issue leading to the majority of tree removals required.

## 3.2 Construction Issues

With the noted construction issues our team discovered throughout the duration of the planning stages of the project, we have created a table outlining each. Table 2 below identifies the concerns, places a likelihood of occurrence, impact of magnitude, and lastly a brief plan to address each risk. In Section 8.0 of the report, we have created and outline mitigation strategies for the construction issues predicted to potentially occur.

*Table 2 Risk Matrix*

| Category | Risks | Likelihood (1-5) | Impact (1-5) | Address Plan |
|---|---|---|---|---|
| Road Access | Public Transit | 5 | 1 | Detour bus route and schedule |
| | Personal Vehicle | 2 | 1 | Local traffic only |
| | Emergency Vehicles | 5 | 5 | Provide temporary access with steels platforms |
| Surrounding Disruptions | Construction Noise | 5 | 4 | Inevitable, construction during typical bylaw hours |
| | Site Vibration | 1 | 2 | Shallow foundation used; reduced potential for vibration |
| | Dust and/or Debris | 5 | 2 | Water control and proper mitigation/cleanup |
| 1 – Very Low | 2 - Low | 3 – Moderate | 4 – High | 5 – Very High |

# 4.0 Road Design

## 4.1 Road Alignment Overview

Our design team broke down the corridor from Thunderbird Boulevard to 16th Avenue into 4 segments for the easement of design as shown in Figure 1 and Table 3 below. Additionally, this done to reduce the amount of information presented in each section and ensure clarity of significant elements. The following sections cover highlighted features that are found in each of the four segments to better understand the design our team has developed.

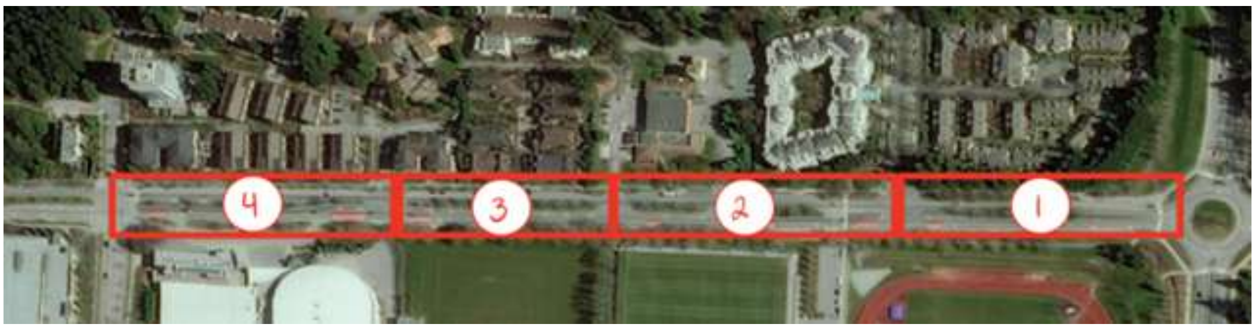


*Figure 1 Wesbrook Mall Corridor*

*Table 3 Project Sections*

| Segment # | South end | North end | Length (m) |
|---|---|---|---|
| 1 | 16th Ave | Hampton Place | 253 |
| 2 | Hampton Place | RCMP Station | 160 |
| 3 | RCMP Station | Panhellenic House | 160 |
| 4 | Panhellenic | Thunderbird Blvd. | 175 |

The newly designed corridor includes two directional drive lanes, new 2m (minimum) sidewalks and an elevated Northbound bike lane. An overpass pedestrian bridge was also implemented which will be discussed further in Section 7.0.

### 4.1.1 Segment 1 (16th Avenue to Hampton Place)

The first segment starts at the South end of the corridor and runs between the roundabout at 16th Ave to Hampton Place. Entering the corridor off of the roundabout, we have included an additional drive lane in the Northbound direction as it would allow for 2 exiting lanes from the traffic circle. This lane will run through the entire length to Thunderbird Blvd to allow for reduced potential for public transit congestion during peak hours. Additionally, the sidewalks at the roundabout, on the East side of Wesbrook Mall were altered, as shown in Figure 2, to allow for better access for pedestrians to enter the traffic circle directly off of the corridor.

*Figure 2 Segment 1 Sidewalk Configuration*

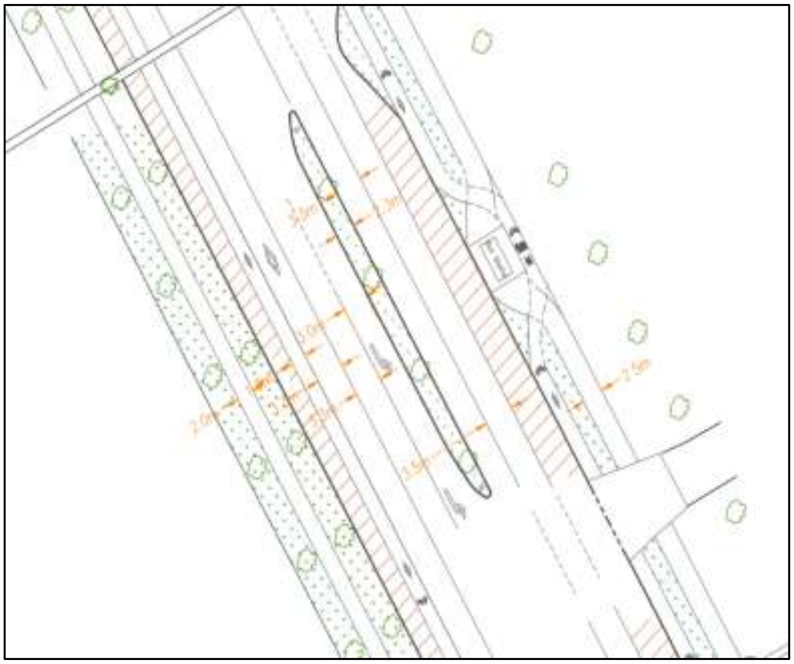

Figure 3 Plan View of Segment 2

### 4.1.2 Segment 2 (Hampton Place to RCMP Station)

4.1.2.1 Road Continuity

Segment 2 starts at Hampton Place and ends at the RCMP station as seen in Figure 3. The road design was shifted 2m to the West to ensure seamless continuity with Segment 1 and Segment 3. The outer East curb line was shifted 2m West which increased the green space between the Northbound sidewalk and bike lane. Medians were also trimmed to ensure minimum road width were achieved and complied with industry standards.

4.1.2.2 Bus Stop

The additional 2m on the East curb provided adequate space for the existing bus stop loading zone illustrated in Figure 4. The bus stop area was increased to 5m x 5.7m with a 9sq.m bus shelter. A 1.5m path was provided for pedestrians to cross the bus area without conflicting with individuals waiting for their bus; and a 1.4m wide area was included to ensure accessibility that can be seen in Figure 5.


Figure 4 Bus Stop Configuration

*Figure 5 3D Rendering of Bus Stop*

### 4.1.3 Segment 3 (RCMP Station to Panhellenic House)

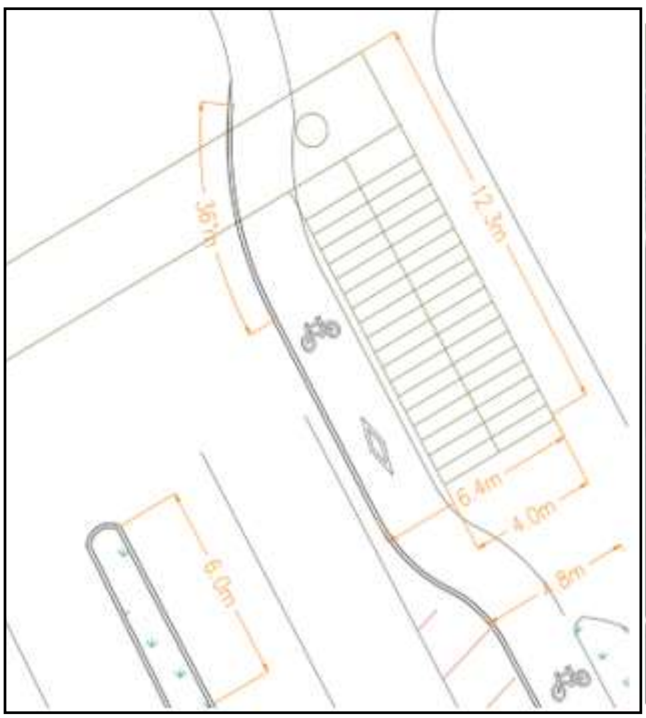


*Figure 6 Rendering of Pedestrian Crossing*

In this segment of the corridor, we have our newly implemented pedestrian overpass. The bridge spanning across Wesbrook Mall has been included in the redesign as per request and allows for an increase in safety for pedestrians while crossing the roadway. The East side curb was configured as shown in Figure 6 to fit the bridge foundation. The bike lane and sidewalk were designed to pass the bridge stair area without creating conflicting points with the differing users. This design will cause a 6m reduction (approximately 2 parking stalls) from the existing parking zone, which was deemed necessary to ensure user safety. The green space on the West side of Wesbrook Mall provides sufficient space for the bridge stairs and column foundations; thus, no curb or sidewalk changes were required.

### 4.1.4 Segment 4 (Panhellenic House to Thunderbird Boulevard)

Two full-length lanes with a left-turn lane are in both North and Southbound directions, illustrated in Figure 7. The left turn lanes provide access to Thunderbird Blvd for Northbound traffic and the Panhellenic House for Southbound traffic. The Northbound parking lane introduced in Segment 3 continues until the Thunderbird Blvd intersection. An additional 2.5m wide lane is implemented for buses to diverge from the main drive lanes as passengers can easily load without disturbing traffic flow; this is also illustrated in Figure 7 below.

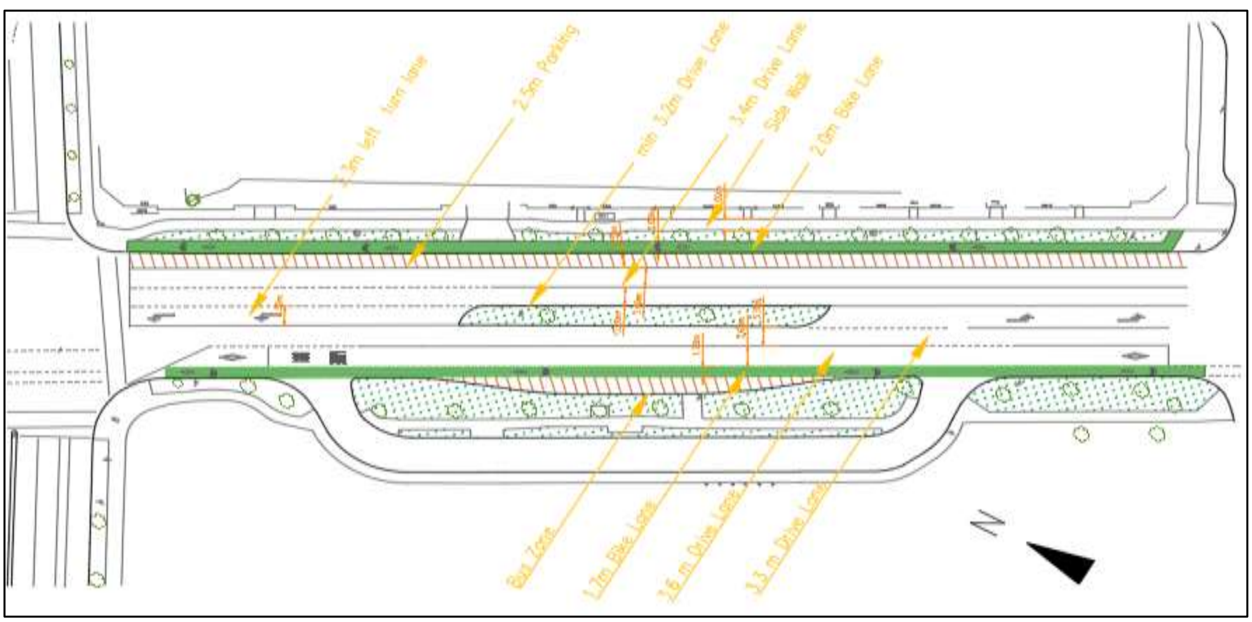


*Figure 7 Plan View of Segment 4*

### 4.1.5 Traffic Data Analysis

The designed road alignment was analyzed using SIDRA with projected 2050 peak hour traffic demands. Table 4 below shows the degree of saturation and the level of service at the Thunderbird Blvd and Wesbrook Mall intersection. Based on our data analysis, this new design decreases the degree of saturation by 30%. With the addition of another Northbound drive lane, both the degree of saturation and the level of service are sufficient and under the industry requirements of 1.0 and LOS E respectively.

*Table 4 Degree of Saturation at Thunderbird Intersection*

| Lane Use and Performance | | | | | | | |
|---|---|---|---|---|---|---|---|
| | DEMAND FLOWS [ Total veh/h | HV ] % | Cap. veh/h | Deg. Satn v/c | Lane Util. % | Aver. Delay sec | Level of Service |
| South: RoadName | | | | | | | |
| Lane 1 | 257 | 0.9 | 383 | 0.671 | 80[5] | 37.4 | LOS D |
| Lane 2 | 222 | 24.1 | 265 | 0.836 | 100 | 79.6 | LOS E |
| Lane 3 | 318 | 5.0 | 381 | 0.836 | 100 | 56.0 | LOS E |
| Lane 4 | 53 | 0.0 | 1029 | 0.052 | 100 | 42.6 | LOS D |
| Approach | 850 | 8.4 | | 0.836 | | 55.7 | LOS E |

## 4.2 Pavement Structure Design

Pavement structure design is one of the most important aspects for achieving a reasonable and acceptable service life under loading conditions. By choosing pavement structures than can support the loading applied throughout the service life, maintenance and rehabilitation costs can be reduced and/or eliminated in the near future. Our team has provided different pavement types, structure designs, and rationale for each of the varying pavements that can be seen along this corridor of Wesbrook Mall in the following sections.

### 4.2.1 Roadway Pavement Structure

As the roadway will be serving several different vehicle types, varying between personal vehicles, public transit, and commercial trucks, the structure of the pavement must be able to support these vehicle loads. Team 14 has classified the Wesbrook Mall corridor to be "Type B" in the Ministry of Transportation and Infrastructure's "Pavement Structure Design Guidelines"[1]. This Type B classification of pavement structure is suitable for medium to high traffic volume with infrequent heavy commercial vehicles to satisfy the required needs based on our Average Annual Daily Traffic analysis performed. Thus, the roadway pavement structure has been design as shown in Figure 8 below.

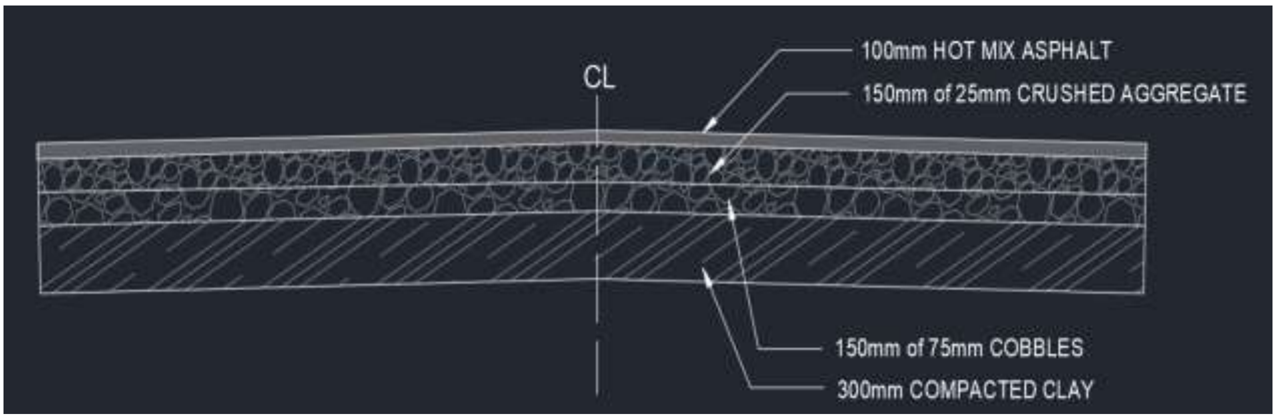


*Figure 8 Typical Road Section*

### 4.2.2 Sidewalk Pavement Structure

As all sidewalks along the Wesbrook Mall Phase 4 corridor are to be removed and replaced, a new pavement structure has been designed. The concrete and base structure follows the City of Vancouver's Construction Specifications[2] for commercial and residential concrete sidewalks. Concrete pavement will be used to provide adequate strength and ensure a long-lasting service life with minimal maintenance required. All sidewalks will be 2m minimum throughout the corridor, supplying space for pedestrians to move around one another without needing to leave the concrete surface. In addition, the concrete pavement will be broom finished with 6mm wide and 25mm deep saw-cut joints with a spacing of 2m to control concrete cracking. A detailed cross section of the new sidewalk pavement is illustrated in Figure 9 below.

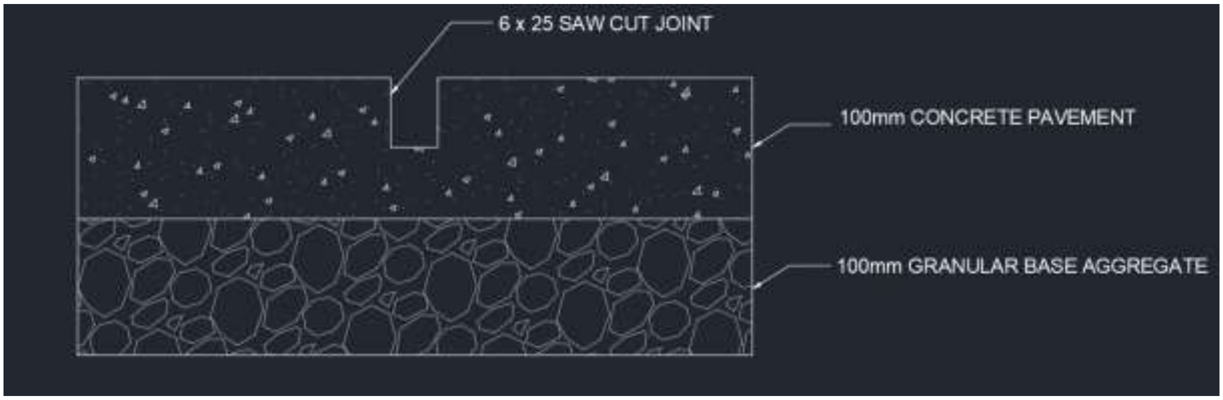


*Figure 9 Typical Sidewalk Section*

### 4.2.3 Bicycle Lane Pavement Structure

In our design we have created similar bike lanes in each direction to accommodate cyclists traveling through the corridor. Due to the difference in space availability, we have placed each bike lane in different areas with consideration to the drive lanes, and sidewalks. Therefore, slight adjustments were required in the pavement structures to ensure the loading resistance would be adequate, consequently reducing the need for frequent repairs. The following sections cover how the structures have been altered for the differing bike lane directions.

#### 4.2.3.1 Northbound Elevated Bicycle Lane

Our team has decided to implement the use of permeable concrete to be used for the bike lanes throughout the corridor. Using permeable concrete pavement will allow for rain water to seep through the surface and drain into the rain water retention system (See Section 6.3) installed below. 100mm thick permeable concrete at 40MPa strength will be used in the Northbound bike lane and will provide sufficient strength to handle the bearing capacity from commuting cyclists[3]. The base required for this structure includes 600mm of open-graded base course to provide strength and protection for the ACO StormBrixx® retention system below. Additionally, the entire length of retention system shall be wrapped with a layer of filter fabric geotextile to prevent debris from entering the system. Within the structure, the open-graded base course consists of lower sand content which will increase drainage of surface water to enter into the catchment apparatus[4].

4.2.3.2 Southbound At-Grade Bicycle Lane

Given that the at-grade bike lane extending across the corridor in the Southbound direction will lead to passenger vehicles crossing over the bike lane while parking; the structure required a slight modification. While passenger vehicles apply larger loads than cycling traffic, increasing the permeable concrete pavement layer to 150mm was vital to provide a reasonable service life[3]. The 600mm base layer previously discussed, can supply ample resistance that can sufficiently handle the load applied by passenger vehicles crossing over, therefore no modifications were required to the base.

Bike lane pavement structures have been drawn and outlined in Figure 10 below, to clarify installation of material depths for above and around the ACO StormBrixx® retention system in both North and Southbound directions.

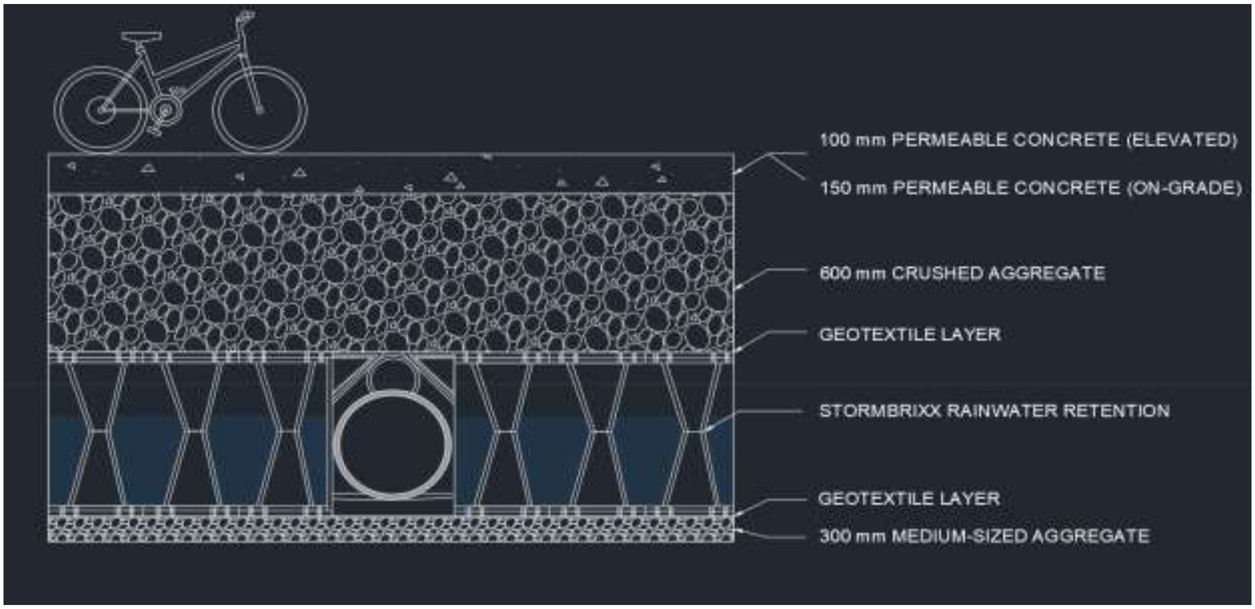


*Figure 10 Typical Bike Lane section*

### 4.2.4 Pavement Maintenance Plan

Several potential pavement failures may occur after years of service which depend on the vehicular loading and weather conditions. Thus, roadway inspections shall be carried out every 6 months to evaluate surface conditions and initiate repairs as soon as acknowledged. The most common type of failures and remedies are summarized in Table 5 below[5].

*Table 5 Maintenance Plan*

| Failure Type | Cause | Remediation |
|---|---|---|
| Shoving – wave in the pavement along the direction of travel | Abrupt movement of heavy loading, especially in the bus and parking lane | Grinding pavement level and replace it with full depth patching |
| Parallel Cracking – longitudinal wheel path cracking and joint cracking | Caused by freezing and thawing effects and heavy traffic loading | Crack treatment and spray patching |
| Surface potholes | Weather conditions, improper mixture of asphalt design, failed base layers | Applying cold mix for temporary repair; otherwise, use pothole patch |

## 5.0 Tree Removal Strategy

As requested by the client, our team has tried to reduce tree removals during the designing phases of the project. Keeping all existing trees in place is inevitable as curb lines were required to be adjusted. The existing trees in the area range widely in age and size; therefore, an evaluation was taken to determine the impacts of moving the trees.

Due to the timeline and season of which the project will be commenced, transplanting of trees is not a feasible option. The best time to move trees is in the late spring or early fall, before budding occurs. Moving trees in summer months applies excess stresses on the tree that typically results in low survival rates[6]. Our team strives to preserve the ecological footprint on every project. Therefore, we have implemented a strict policy that a minimum 1:1 tree removal to tree replant ratio is to be achieved within our landscaping plan.

There is a total of 25 trees required to be removed and several areas where new vegetation can be planted. Our team recommends using the green space along the corridor for new self-sustaining trees, shrubs, and flowers to both aid in rain water retention, and also increase the visual appeal. The detailed drawings that can be found in Appendix A outline which trees along the corridor will need to be removed in order for the project to begin. Appendix B also outlines our landscaping plan including new and existing trees, rain gardens and softscape along the corridor.

# 6.0 Water Retention Strategy

## 6.1 Rain Gardens

### 6.1.1 Overview

Rain gardens are to be located in all five medians along the designed corridor. The primary purpose of a rain garden is to collect, absorb, and filter rain water and stormwater in order to accommodate temporary flooding.

The benefits of providing rain gardens include the following:

- Enhance the landscape appearance at the University of British Columbia boundary
- Provide habitat for beneficial insects and birds

- Filter oil, grease, and other pollutants from the road before they reach groundwater, or the storm drain that leads them to the ocean
- Reduce potential flooding that would result in overflow to the new design
- Increase the amount of water that soaks into the ground aquifer

The design ponding depth is 6in measured from the top of the rain garden soil mix that is covered by a mulch layer. The ponding depth was determined based on the Rain Garden Sizing Chart as shown in the Table 6 below. Regardless of a soil drainage rate and given 146cm (Region 4) annual rainfall in Vancouver, the resultant 6in of ponding depth was considered as most suitable.

*Table 6 Rain Garden Sizing Chart*

| | Rainfall Region | Ponding Depth | SOIL DRAINAGE RATES 0.10 - 0.24* Inches/Hour | 0.25 - 0.49 Inches/Hour | 0.50 - 0.99 Inches/Hour | 1.00 - 2.49 Inches/Hour | 2.50 + Inches/Hour |
|---|---|---|---|---|---|---|---|
| | Recommended Sizing Factor: Size the top surface of the ponding area for your rain garden by multiplying the contributing area by this percentage. | | | | | | |
| GOOD (80%) | REGION 1 | 6" to 12" | 8% | 7% | 7% | 6% | 6% |
| | REGION 2 | 6" to 12" | 14% | 10% | 8% | 6% | 6% |
| | REGION 3 | 6" to 12" | 16% | 11% | 8% | 7% | 6% |
| | REGION 4 | 6" to 12" | 19% | 12% | 10% | 7% | 6% |
| | REGION 5 | 6" to 12" | 23% | 15% | 11% | 9% | 6% |
| | REGION 6 | 6" to 12" | 28% | 18% | 13% | 10% | 7% |
| BETTER (95%) | REGION 1 | 6" to 12" | 9% | 9% | 8% | 8% | 7% |
| | REGION 2 | 6" to 12" | 20% | 14% | 11% | 9% | 7% |
| | REGION 3 | 6" to 12" | 22% | 15% | 12% | 10% | 7% |
| | REGION 4 | 6" to 12" | 29% | 18% | 14% | 11% | 8% |
| | REGION 5 | 6" to 12" | 34% | 22% | 16% | 13% | 9% |
| | REGION 6 | 6" to 12" | 42% | 27% | 19% | 15% | 10% |
| BEST (Most All the Water) | REGION 1 | 6" | 13% | 10% | 9% | 9% | 8% |
| | | 12" | N/A* | 10% | 9% | 8% | 8% |
| | REGION 2 | 6" | 39% | 32% | 26% | 21% | 15% |
| | | 12" | N/A* | 27% | 23% | 20% | 15% |
| | REGION 3 | 6" | 45% | 36% | 30% | 25% | 17% |
| | | 12" | N/A* | 31% | 26% | 22% | 17% |
| | REGION 4 | 6" | 54% | 43% | 34% | 27% | 18% |
| | | 12" | N/A* | 36% | 31% | 25% | 17% |
| | REGION 5 | 6" | 75% | 47% | 35% | 26% | 17% |
| | | 12" | N/A* | 45% | 31% | 25% | 17% |
| | REGION 6 | 6" | 72% | 56% | 42% | 30% | 19% |
| | | 12" | N/A* | 48% | 39% | 29% | 19% |

SIZING FACTORS

For City of Vancouver, the prime time to work on the soil is from May – August and planting from September – November. The reason behind building the rain garden during summer months is that the soil is moist, but not saturated. This eliminates the risk of over compaction of the wet soil by machinery. On the other hand, it is recommended to plant rain gardens during fall so that trees can establish themselves during rainy winter months. A typical cross section of the proposed rain garden trench is shown in Figure 11 below.

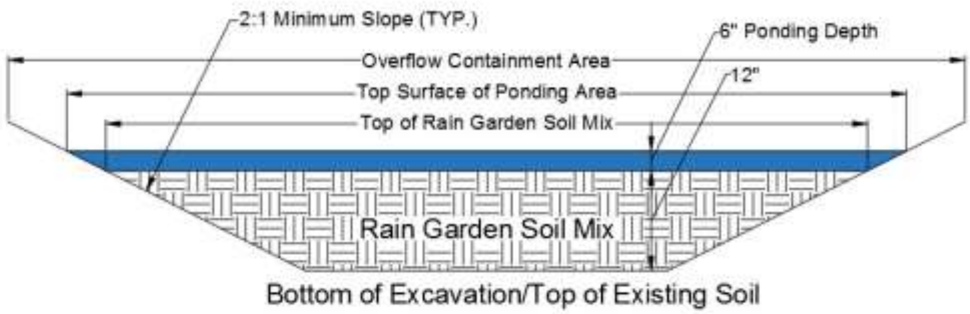


*Figure 11 Typical Section of Rain Garden*

### 6.1.2 Construction

For building the rain gardens, our team considered three different options:

- Excavate and Replace Soil – used when the soil quality is bad – mostly clay
- Excavate and Amend Soil for Reuse – used when the soil quality is moderate – some clay content
- Amend Soil in Place – used when the soil quality is good – no clay content

Once excavation is complete, the soil mix will be placed to a desired depth of 18in as presented above. The soil mix should be placed about 6in at a time and lightly tamped by walking over each layer. The soil will be filled up to a level that meets the designed ponding depth (6in) overflow containment area (6in above the overflow minimum). It is important to ensure that the bottom of the rain gardens is flat and level.

After the previous step is completed, the rain gardens are prepared for landscaping. In general, it is important to improve aesthetics as this will a diversity of plants, including small trees, shrubs, herbs, emergent (sedges, rushes), and grasses for year-round color that include a variety of height and texture. Larger plants will require more care throughout the year while evergreens will reduce weed content and reduce overall maintenance.

For plants with direct moisture contact (the bottom of the trench), the following can be used:

- Emergents: slough sedge (*carex obnupta*) and small-fruited bulrush (*scirpus microcarpus*)
- Ferns: lady fern (*athyrium filix-femina*) and deer fern (*blechnum spicant*)
- Deciduous shrubs: dwarf red-twig dogwood (*cornus sericea 'Kelseyi'*) and black twinberry (l*onicera involucrate*)

For plants on a side-slope, the following suggested:

- Ferns: sword fern (*polystichum munitum*) and lady fern (*athyrium filix-femina*)
- Deciduous shrubs: snowberry (s*ymphoricarpos albus*)
- Evergreen shrubs: salal (*gaultheria shallon*) and boxwood honeysuckle (*lonicera pileata*)

### 6.1.3 Maintenance

The following activities are recommended for routine maintenance as shown on Table 7 below.

*Table 7 Maintenance Schedule*

| ***Rain Garden Location*** | ***Condition*** | ***Maintenance Activity*** |
|---|---|---|
| **Rain Garden Bottom Area** | Visible sediment that reduces drainage | Remove sediment accumulation |
| | Matted accumulation of leaves compromising drainage | Remove leaves |
| **Ponded Water** | Ponded water remains in the basin for more than 3 days after the end of storm | Remove debris sediments; check water inputs; determine if soil is clogged by sediment or if soil is over compacted |

| | | |
|---|---|---|
| **Weeds** | Problem with growing weeds | Remove weeds especially in spring when the soil is moist, and weeds are small; apply mulch after weeding |
| **Vegetation** | Dying, dead, or unhealthy plants | Maintain a healthy cover of plants; remove any diseased plants; re-stake trees if they require more support |
| | Vegetation reduces sight distance and sidewalks | Plant low-growing species where sight lines are required (the south tip of the rain garden) |
| | Yellowing, poor growth, poor flowering, spotting or curled leaves, weak roots or stems | Identify specific nutrient deficiencies; consult with a professional for garden care advice; do not use synthetic fertilizers |
| **Mulch** | Bare spots are present of mulch depth is less than 2 inches | Supplement mulch with hand tools to a depth of 2 to 3 inches; keep all mulch away from woody stems |

## 6.2 Softscape

Where hardscaping features such as the rain gardens are not possible and/or feasible, softscape elements will be implemented throughout the corridor. By planting vegetation from the listed species in Section 6.1.3, extra rain water retention can be achieved through absorption and consumption by the spread of greenery. Additionally, softscape that spreads along the roadsides and within the median space will provide an increased visual appeal for users and pollinators that travel through this phase of Wesbrook Mall to enjoy.

## 6.3 Underground Retention System

### 6.3.1 Overview

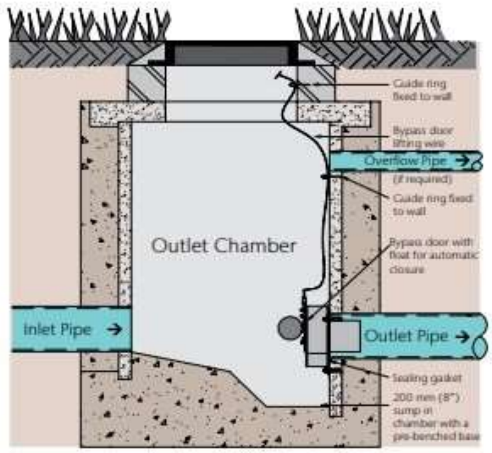


*Figure 12 Water Retention*

Our team has decided to contract manufacturer ACO Systems Ltd for its StormBrixx® underground rainwater retention and infiltration system, which will be implemented underneath the bike lanes in both North and Southbound directions. This technology is widely and successfully used in 46 countries[4]. The UBC rainwater retention system is designed for 1:50 year storm events. As shown in Figure 12, the system connects to the existing stormwater piping network to spread the peak flow event over a long period, release the runoff water slowly and mitigate the downstream surge effect.

The rainwater storage tank will use two layers of the StormBrixx® HD units, with a total depth of 1.2m and a width of 0.6m. According to the manufacturer, a gravel cover of 0.6m is required to carry the bike lane loading. Two pipes are needed to connect the storage tank to the catch basins[4]. The upper pipe is intended to increase the discharge during heavy flood events, and the lower pipe is to slow down the flow by gradually discharging.

Our decision to implement the ACO StormBrixx® retention system was based on the following:

- Recognized product by BC Ministry of Transportation and Infrastructure
- High structural design capacity
- Easy construction and maintenance

### 6.3.2 Feasibility

The ACO StormBrixx® HD has a design life of 60 years and is easy to maintain[4]. The open structure of StormBrixx® allows inspection cameras and maintenance devices to have free passage through the system. This product has a high void ratio of 95% of the total volume available for storage; therefore, approximately 1000m$^3$ rainfall can be stored during a heavy storm event.

According to the soil capacity calculations, the soil bearing capacity is over 600kPa at approximately 1.8m in-depth, with a safety factor of 3 applied. This resistance is adequate for holding the system at full capacity during extreme rainfall events. Also, the lateral soil pressure at 1.8m depth is estimated as 7.6kPa, where the lateral strength of ACO StormBrixx® HD is 90kPa[4], thus serving full potential without risks of lateral failure. The detailed calculation for these strength values is included in Appendix C.

During a regular rainfall event, water on the sidewalk flows to the surrounding greenery using a 2% slope. After the surrounding soil is saturated, water will be collected into the retention system and slowly discharged to the stormwater pipe system. The runoff water on the road will be discharged from the catch basins. During a peak flow event, when the rainfall water pipe is overcapacity, water will produce a backflow to the storage tank and discharge gradually after the flooding.

A filter fabric will be installed to cover the system along with the gravel cover layer. The purpose is to ensure extra water filtration to reduce potential clogging from larger particles coming through. An oil level monitor can also be added to track the amount of oil flowing in from the road surface. Having this oil monitor installed will allow for proper monitoring and ensure the quality of water entering the system is acceptable.

### 6.3.3 Economic and Environmental Impacts

*Figure 13 Stacked Stormbrixx units*

The ACO StormBrixx® underground rainwater retention and infiltration system are manufactured from recyclable polypropylene. The stackable design of StormBrixx®, where the base units nest together, meaning fewer vehicles are needed for transport compared to other retention products. The side panels and other accessories nest together as well. $CO_2$ emissions are reduced due to the minimal truck loads required during transportation. This technology can also save on-site storage space required due to the stacking capability shown in Figure 13 and reduces the material handling labor.

### 6.3.4 Maintenance

One major issue that could potentially occur with the StormBrixx® system is sediment build up potentially causing failure to the system, including a reduction in capacity and outflow. Additionally, sediments may carry effluent substances that could affect river quality during the stormwater discharge. A flushing device[4] is necessary to break apart and dispose the build up by the contained effluent. The frequency of inspection and maintenance should be carried out in consistent intervals (every 4-6 months). However, it is dependent on the storm events throughout the year as more inspections are necessary if events are occurring at higher frequencies.

## 6.4 Permeable Concrete

Through the use of permeable concrete, the rainwater that falls directly on and/or is directed to the bike lanes will easily flow through the pavement and into the retention systems installed below.

Permeable concrete pavements typically contain a large void ratio due to the reduced use of smaller aggregates in the mix design. Void ratios that are typical to permeable concrete range from roughly 15-35%[7]; therefore, allowing easement of flow through the material, especially if the fluid has low viscosity as the rainwater. Precipitation that flows from another area and directs itself onto the pavement may be carrying some other effluents and/or dust and debris which could lead to clogging of the pores.

### 6.4.1 Maintenance

The maintenance of permeable pavements is a quite simple process. High pressured water can be used through pressure washing devices to help push the materials clogged in the voids either through or out of the pavement. Additionally, other methods of maintaining the permeable concrete pavement include using sweepers and vacuums to get the materials out of the voids and remove the clogged/congested issues[8]. The main difference between the two maintenance methods would be the effluents being wet versus dry. Removing more viscous liquids (i.e., oils from the asphalt pavement) that have coated the aggregate and reduce the void sizes would more effectively be removed through pressure washing. On the other hand, small rocks or debris caught in the voids would more effectively be removed by sweeper or vacuuming methods.

# 7.0 Pedestrian Overpass

## 7.1 Location and Design

The location of the pedestrian bridge was proposed to be at the intersection that is South of the Doug Mitchell Thunderbird Sports Centre. This location provides access to the sports center, as well as grants reliable crossing accessibility between 16$^{th}$ Ave and Thunderbird Blvd. The main purpose of the construction of an overpass was to create a safe crossing for individuals to cross Wesbrook Mall. By providing a physical separation between foot and vehicular traffic, there is not only safety granted for the pedestrians, but also a reduction in traffic flow disruption from pedestrians crossing at ground level. The proposed structure with the altered road design is shown on Figure 14 below. The overpass will be extremely beneficial when there is an event taking place at the sports centre, while heavy foot traffic can be expected.

*Figure 14 Overpass at Doug Mitchell Sports Centre*

## 7.2 Design Overview and Parameters

The pedestrian overpass has been designed in CSI Bridge software. Figure 15 below represents the full-scale model.

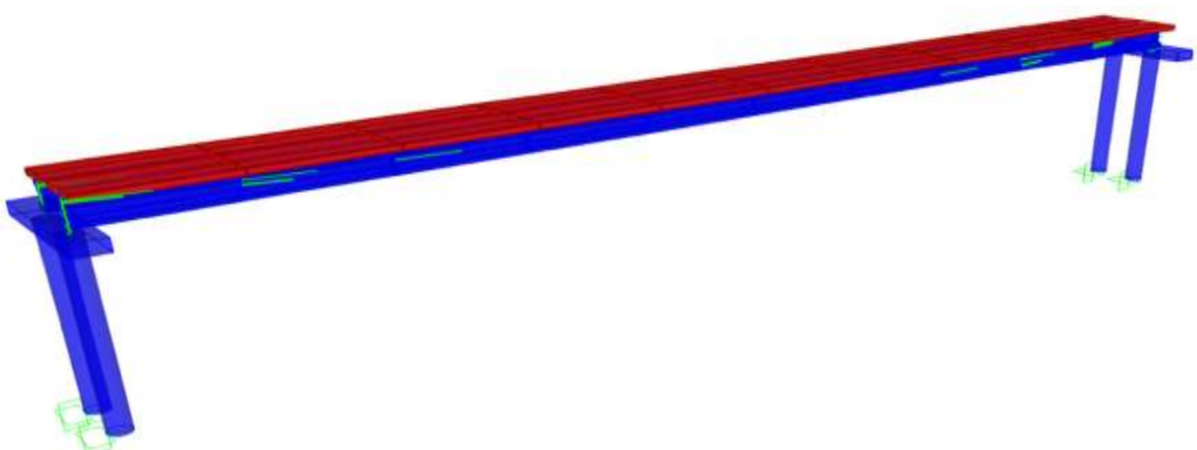

*Figure 15 CSI Bridge Modelling*

For this model, the bridge consists of a glazing roof system (not shown, but considered in the analysis), slab, girders, elastomeric pads, bent caps, columns, and footings. Our team decided to implement precast stairs to access the bridge on both sides. All concrete is 30MPa as the typical specified yield strength for this overpass. In addition, the following information pertains to concrete properties:

*Table 8 Material Properties*

| | |
|---|---|
| Weight per Unit Volume | 23.5kN |
| Modulus of Elasticity, E | 24,855,578Pa or ~ 25GPa |
| Poisson Ratio, U | 0.2 |
| Coefficient of Thermal Expansion, *a* | $9.9^{-6}$ C |
| Shear Modulus, G | 10356491Pa or ~ 10.3GPa |

Reinforcing steel including main reinforcement and ties (excluding tendons) has the following properties:

| | |
|---|---|
| Weight per Unit Volume | 76kN |
| Modulus of Elasticity, E | 200GPa |
| Poisson Ratio, U | 0.3 |
| Coefficient of Thermal Expansion, *a* | $1.1^{-5}$ C |
| Shear Modulus, G | 76,900MPa |
| Minimum Yield Stress, Fy | 400MPa |
| Minimum Tensile Stress, Fu | 620MPa |
| Expected Yield Stress, Fy | 455MPa |
| Expected Tensile Stress, Fu | 682MPa |

As shown above, the expected yield and tensile stresses are larger than the nominal values. This is in fact normal since the manufacturer in general wants to be on the safe side by reporting lower values than actual under the laboratory testing.

The following table represents prestressed post-tension tendon properties:

*Table 9 Post-Tension Tendon Properties*

| | |
|---|---|
| Weight per Unit Volume | 76kN |
| Modulus of Elasticity, E | 200GPa |
| Coefficient of Thermal Expansion, *a* | $1.1^{-5}$ C |

| | |
|---|---|
| Shear Modulus, G | 98,250MPa |
| Minimum Yield Stress, Fy | 1690MPa |
| Minimum Tensile Stress, Fu | 1860MPa |

As expected, shear modulus and specified yield and tensile stresses are larger than for the regular reinforcement.

## 7.3 Design Elements

### 7.3.1 Deck Slab

A flat slab using cast-in-place concrete was selected with the thickness of 200mm and a total width of 2.5m. The length of the slab corresponds to the overall bridge span of 30m.

### 7.3.2 Girders

There are two girders having identical properties required for this project. Girders were selected of precast concrete with the overall height of 0.85m and the length of 30m. For full detailed dimensions refer to Appendix D.

Prestressed post-tension tendons of harped type are incorporated within the precast girders along the entire length. Harped type tendon layout is shown graphically in Tendons Layout Data found in Appendix D. ‘Post-tension’ means that tendons are prestressed after concrete has hardened. Prestressed tendons are vital part of the bridge reinforcement since it allows to compensate for tensile forces that would otherwise occur due to dead and live loads. These tensile forces would cause excessive deflections at the midspan that would initiate cracks which in turn would trigger concrete delamination and eventually spalling. Figure 16 below demonstrates the effect achieved due to tendons being embedded within the girders. For this project, the selected tendons are lowrelaxation, seven-wire uncoated steel strands for prestressed concrete with the nominal diameter of a single strand of 9.53mm. For the tendon layout data refer to Appendix D.

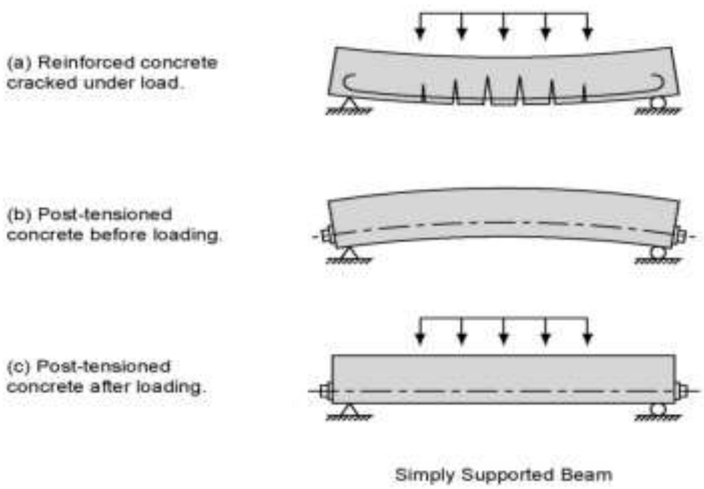


*Figure 16 Post Tensioned Concrete*

### 7.3.3 Bent Cap

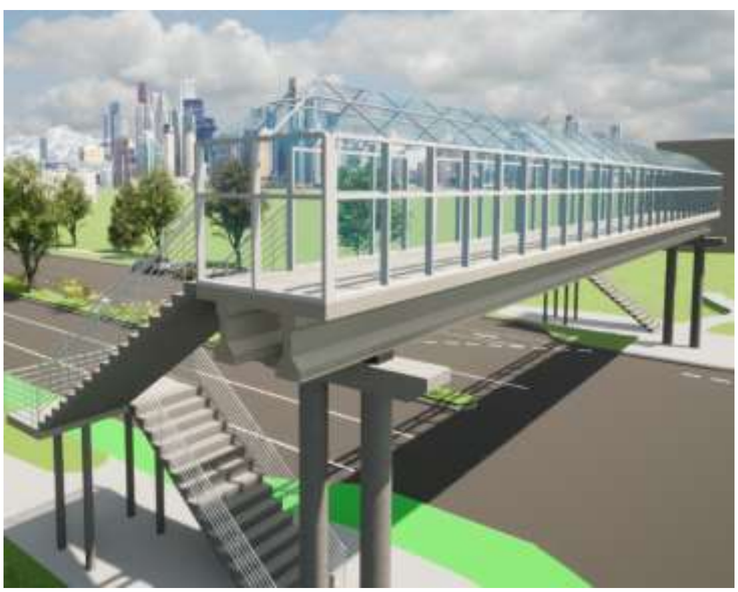

*Figure 17 Bent Cap and Integrated Concrete Columns*

The primary purpose of the bent cap is for load distribution as well as support of girders that are placed on top. As a result, they are located at each end of the bridge, directly integrated in the supporting columns while having 1m o/c offset from the end of the girder. Figure 17 shows the proposed column-cap arrangement. Each bent cap was determined to be 400mm deep and 700mm wide with integrated 20M reinforcement held by rectangular ties. Longitudinal and confinement bars (ties) were selected A615-60 of American grade which corresponds to 20M of CSA equivalence[7] with the nominal area of 300mm$^2$. Clear cover was designed to be 40mm since the concrete will be exposed to freeze-thaw cycles as well as sulphates. For details on bent cap reinforcement refer to Appendix D.

### 7.3.4 Columns

A total of 4 columns of 6m in height will support the vertical loads and transfer them to the combined concrete footing. Columns are circular with 500mm outside diameter reinforced with 8 vertical rebars spaced equally in a circle pattern and confined by spiral ties. Both ties and main reinforcements are 20M. Concrete cover was determined to be also 40mm for the same reason as outlined in Section 7.3.3. For details regarding concrete columns reinforcement refer to Appendix D.

### 7.3.5 Footings

There are 2 combined footings at each end of the overpass supporting 2 columns each. Since the frost depth in Vancouver is 0.45m, soil cover was designed to be 0.5m. Total width of the combined footing is 4m, thickness is 1m and length is 5.3m.

### 7.3.6 Precast Stairs

Sanderson Concrete is the leading firm in precast concrete stairs in Western Canada. The company is providing a wide range of solutions available to choose from for pedestrian stairs. The reason to choose precast concrete stairs are the following:

- Construction time can be substantially shortened
- Lighter overall structure as opposed to cast-in-place concrete, since precast concrete stairs are hollow inside
- Labor cost is considerably lower since pre-built stairs can be moved and installed quickly

- Can be mounted year-round as opposed to cast-in-place steps which require additional effort during colder months

### 7.3.7 Glazing System

Hammerglass AB provides a wide range of custom-made solutions for glazing systems, where we utilized their curtain walls and roofing products. The advantages of this glazing system include the following:

- Noise protection
- Falling protection
- Aesthetics
- Maintain interior temperature
- Cover from precipitation

## 7.4 Overpass Load Cases

During the comprehensive analysis by CSI Bridge, the overpass was determined to be stable, full analysis completed, with no errors identified.

The following forces were considered for this project, as per NBCC 2015 and AASHTO:

- Dead load case produces the maximum moment of 167.8kNm at the midspan as well as the axial load of 80kN under FEA (finite element analysis). This load primarily consists of the self-weight of the glazing system as well as associated structural components as listed above. For detailed loading deflection and values obtained refer to Pedestrian Overpass Analysis found in the Appendix.
- Live load results in the axial forces of 16.6kN. Only live load due to pedestrians was considered for this project with no maintenance vehicle access.

- Wind load results in the maximum vertical shear of 317kN obtained by CSIBridge. However, manual calculations based on NBCC yield somewhat different result. The formula was used for static procedure as follows $p = I_w q C_e C_t C_g C_p$, where $I_w = 1$ for normal importance, $q = 0.48$ according to climatic data, $C_e = 0.902$ based on height of the structure ratio, $C_t = 1$ since structure located on flat open terrain, $C_g = 2$ as gust coefficient and $C_p = 1$ was taken as the worst case. Multiplying by the total effective area yields force of 107kN. Despite the higher magnitude of the resultant wind load produced by the software, the structure determined to be statically stable.
- Snow load was calculated manually as per NBCC: $S = I_s[S_s(C_b C_w C_s C_a + S_r)]$, where $I_s = 1$ for normal category structure, $S_s = 2.4$kPa and $S_r = 0.2$kPa as per climatic data for Vancouver, $C_a = 1$ for uniform snow load case, $C_w = 1$, $C_b = 0.8$ since $I_c$ is less than $70/C_w^2$ and $C_s = 1$ since roof slope is less than $30^o$. With the pressure under snow load of 2.4kPa, the following combination yields the load on the glazing top of 180kN.

## 8.0 Construction Strategies

While construction commences, our team has established some strategies to reduce disturbance to the surrounding environment and/or individuals during the duration of the project.

### 8.1 Phase Breakdown

For construction of this design, we divided the construction into two phases. Phase 1 consisted of Segment 1 and Segment 3, while Phase 2 consisted of Segment 2 and Segment 4. Our team has determined that staggering the construction of the 4 segments would decrease traffic delays and minimize the need to implement temporary bus stops and/or routes.

## 8.2 Disruption Mitigation Plan

As the duration of construction will take several months, outlined in detail in Section 9.0, a construction plan was established by our team to express the actions to be taken throughout the construction stages of this project. Providing the surrounding individuals and environment a safe and minimally disruptive work zone is a goal our team aims to achieve.

### 8.2.1 Pedestrians and Residents

During construction, all primary entrances to apartment buildings along the corridor will be maintained and prioritized as much as possible. One sidewalk along Wesbrook Mall will remain open, except when temporary detours are required during particular construction activities. The construction crews will display sufficient instructions, proper signage and fencing for all sidewalk users to ensure well-managed safety and clarity.

### 8.2.2 Vehicular and Transit Access

A single lane for both directions of Wesbrook Mall will remain open during peak hour times. Bike lanes will be temporarily closed, and bus stops will be temporarily moved to accommodate and ensure the safety of transit users where required. Traffic will be reduced to a single lane during some construction periods in either direction[10]. Road detours will also be put in place as required. The construction crews will ensure that proper detour signage and trained traffic directors will be used to minimize confusion between road users.

### 8.2.3 Parking

Vehicle parking along Wesbrook Mall will be restricted to accommodate construction space. Limited parking will be prioritized for residents, emergency vehicles, and construction vehicles during the construction phases of the project.

### 8.2.4 Dust and Debris

In order to control dust and debris that will be produced during construction phases of the project, our team suggests periodically watering down granular surfaces to maintain airborne dust. Daily site clean-up duties will be required by contractors to reduce unnecessary materials left throughout the construction zones.

### 8.2.5 Noise and Vibration

During construction, residents and traffic users may experience noise and vibration disturbance during construction stages. All efforts will be made to limit the amount of excess noise and vibration created within working by-laws hours where possible.

## 8.3 Closing Items

### 8.3.1 Final Action Items

Once the construction phases wrap up for the project, several items will need to be completed before the roadway can be safely opened to the public for full use. Construction crews will have excess and scrap materials on-site until the completion of a final clean-up. Final construction items to be completed following a site clean-up which include:

- Line painting and roadway markings
    - Bike lane and pedestrian crosswalks
- Installation of traffic signage
- Installation of replacement bus shelters along the corridor in existing locations
- Testing of all electrical components to ensure proper functionality

### 8.3.2 Signage & Pavement Markings

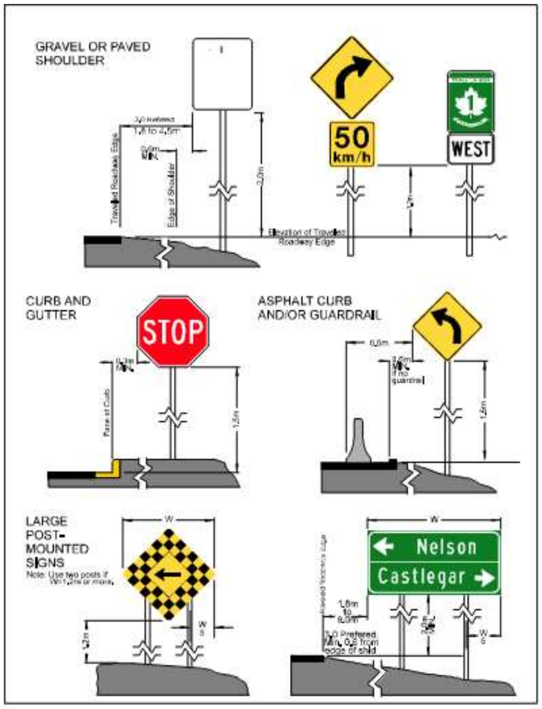


*Figure 18 Typical Sign Design*

Road Signage and markings must follow the BC Ministry of Transportation and Highways Manual of Standard Traffic Signs and Pavement Markings.

- All signs must be mounted on either a sheet of aluminum, plywood, or extruded aluminum
- The placement of signs must be within the driver's field of vision
- Driver travelling at speed limit must have enough time to read and comprehend
- Signs should not block sight lines for traffic entering or leaving roadway

All signs will be provided by the Provincial Sign Shop to ensure uniformity across to province.

### 8.3.3 Bus Shelter Upgrade

Additionally, before the corridor will be fully finalized and open to the public, the existing bus shelters will be replaced with new greener infrastructure in the same locations that routes previously travelled. BC Transit recently implemented a project that replaced a large number of bus shelters with innovative alternatives that include solar panels and green roofs increasing the appearance and functionality[11]. For this section of the corridor, new shelters will be installed with green roof systems that will additionally aid in minimal retention of rain water while increasing the appeal of the roadsides. The shelters to be used can be seen in Figure 19 below.

*Figure 19 Green Bus Stop Infrastructure*

## 9.0 Construction Schedule

After further development of the detailed design, our team has made a few minor adjustments to the initial schedule proposed in the preliminary design. As mentioned in Section 8.2, construction for the design has been divided into two phases. Construction for Phase 1 will begin in May 2022 and is scheduled to be completed early August 2022. Construction for Phase 2 will start immediately following the completion of Phase 1 and will be completed in late October 2022. The total duration for the construction of the complete Wesbrook Mall Phase 4 Redesign is tentatively 25 weeks. The full detailed schedule with outlined tasks, dates, and durations is displayed in Appendix F.

## 10.0 Class A Cost Estimation

The class A cost estimate was completed based off the detailed drawings and specifications. Quantities were measured using AutoCAD and unit of measure pricing was obtained through Gordian's RS Means database. Pricing that was unavailable from the database was obtained through contacting suppliers and research on local pricing. The **total cost** is determined to be \$3,838,723.52 with an annual operation and maintenance fee at \$27,000 per year. For a full breakdown of our Class A cost estimate please refer to Appendix F. The detailed cost estimate may vary from 5-10% on actual project cost.

*Table 10 Cost Overview*

| | | |
|---|---|---|
| Total Construction | $ | 3,838,723.52 |
| Annual | $ | 26,961.55 |
| | | |
| | | |
| Permits | $ | 205,325.00 |
| Site Assesement & Management | $ | 197,638.63 |
| Road Works - Phase 1 | $ | 1,301,083.25 |
| Road Works - Phase 2 | $ | 1,325,884.93 |
| OverPass | $ | 808,791.70 |
| Annual Maintance | $ | 20,961.55 |
| Operating Costs | $ | 6,000.00 |

## References


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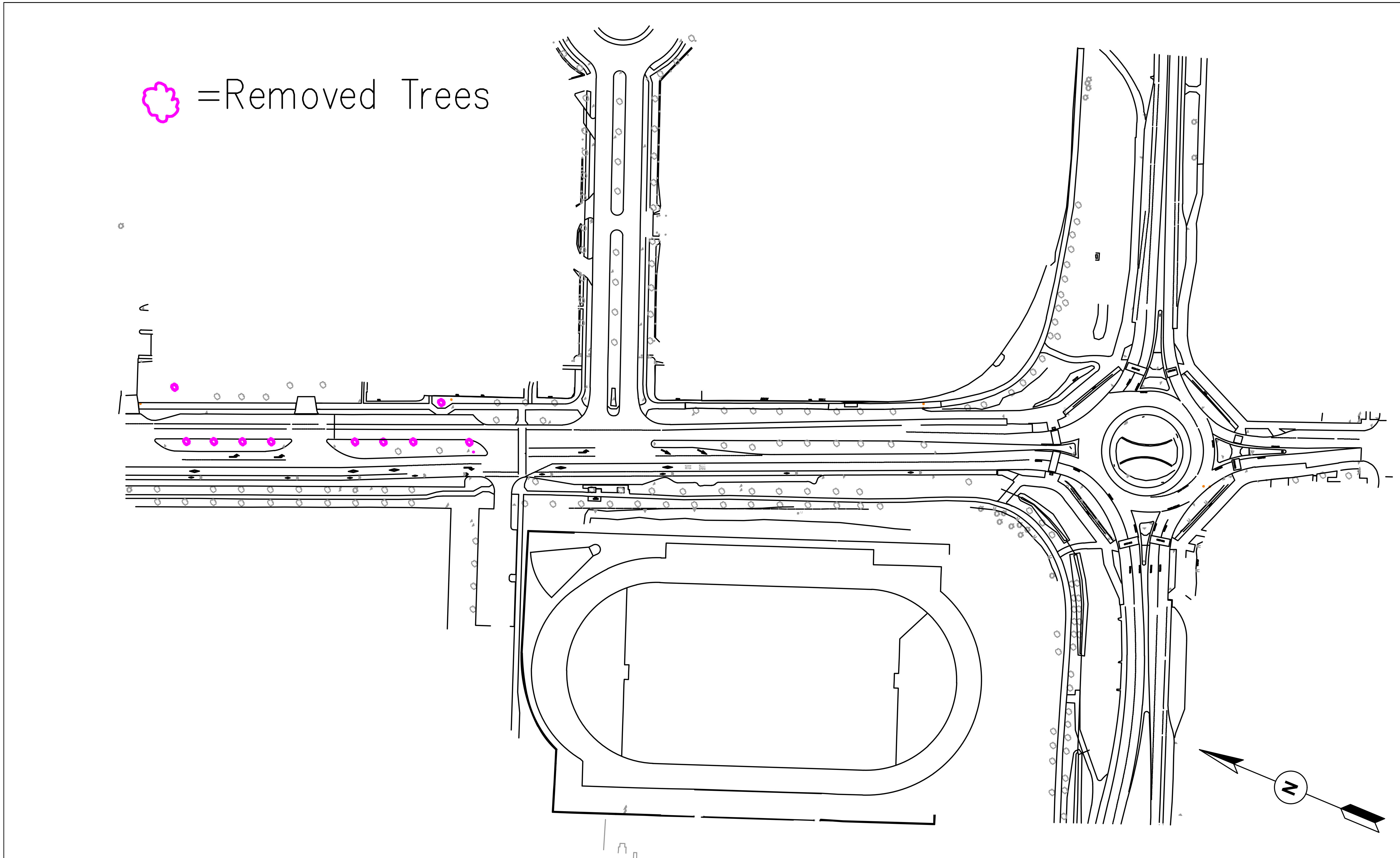
[10] City of Vancouver. *Road Closure and Construction Projects.* Retrieve September 19$^{th}$, 2021, from
https://vancouver.ca/streets-transportation/roadwork.aspx.

[11] Kenneth Chan, Daily Hive. *$5 Millions to Spend on 150 New Transit Bus Shelter Across the Province.***.** Retrieve April 5$^{th}$, 2022, from
https://dailyhive.com/vancouver/bc-transit-bus-shelter-funding

## Appendix A – Tree Removal Plan




| SEGMENT 1 and 2 | | DESIGNED & DRAWN BY:- | NOTE:- | REVISION | DATE:- | CONTENT:- | CLIENT: |
|---|---|---|---|---|---|---|---|
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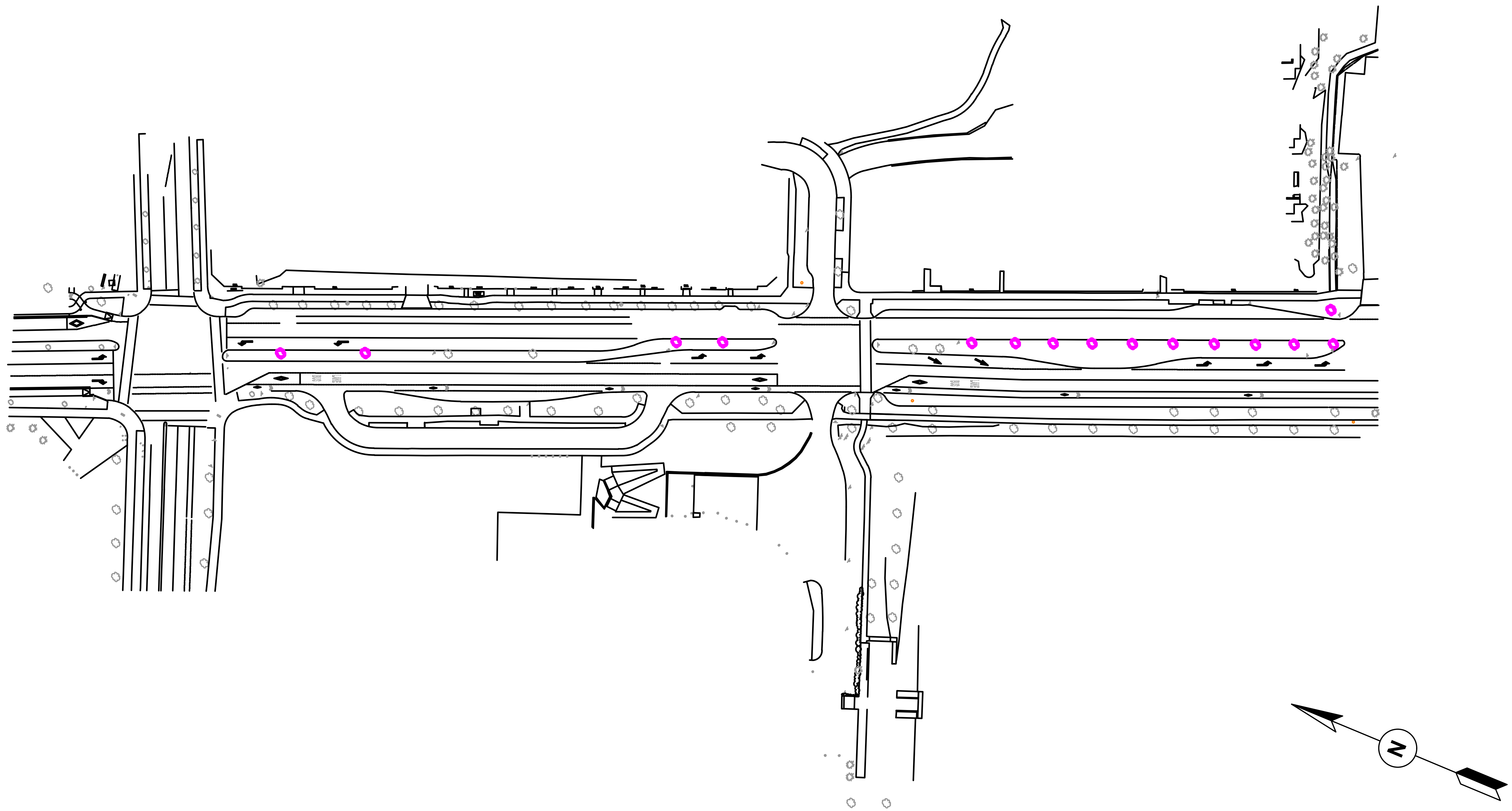
| SCALE: AS NOTED | DRAWING NO: 2 | | | | | | |
| DATE: April, 2022 | | | | | | | |

=Removed Trees



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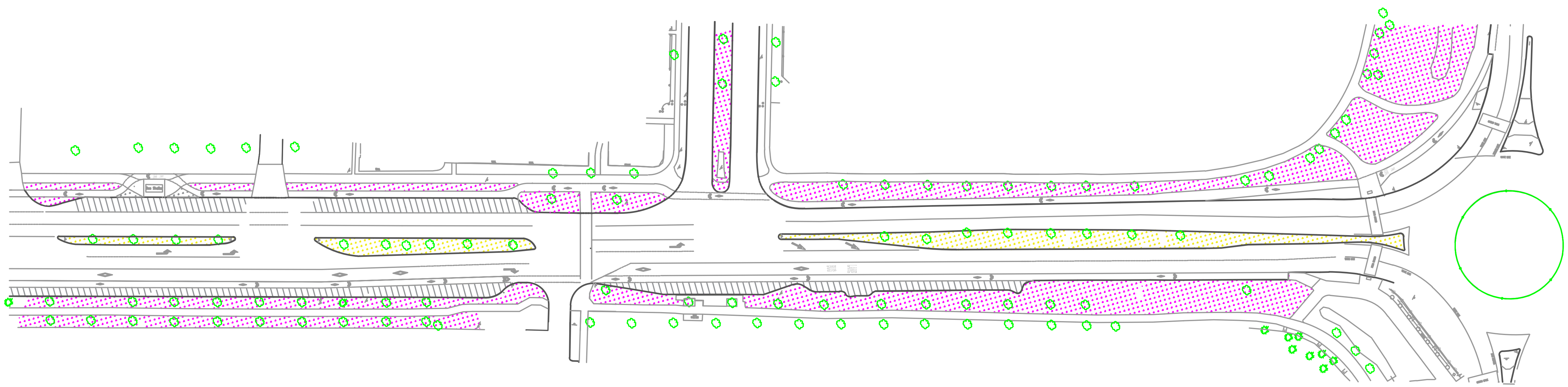
| SCALE: AS NOTED | DRAWING NO: 1 | | | | | | |
| DATE: April, 2022 | | | | | | | |

**Appendix B – Landscaping Plan**



=Softscape/Vegetation
=Raingarden
=Trees

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SEGMENT 1 and 2 | | DESIGNED & DRAWN BY:- | NOTE:- | REVISION | DATE:- | CONTENT:- | CLIENT: |
| NAME OF THE DRAWING: | AS MENTIONED | TEAM 14 | -ALL DIMENSIONS IN METERS.<br>-DO NOT MEASURE FROM THIS DRAWING.<br>-REPORT ANY DISCREPANCIES TO THE DESIGNER. | | | | UBC |
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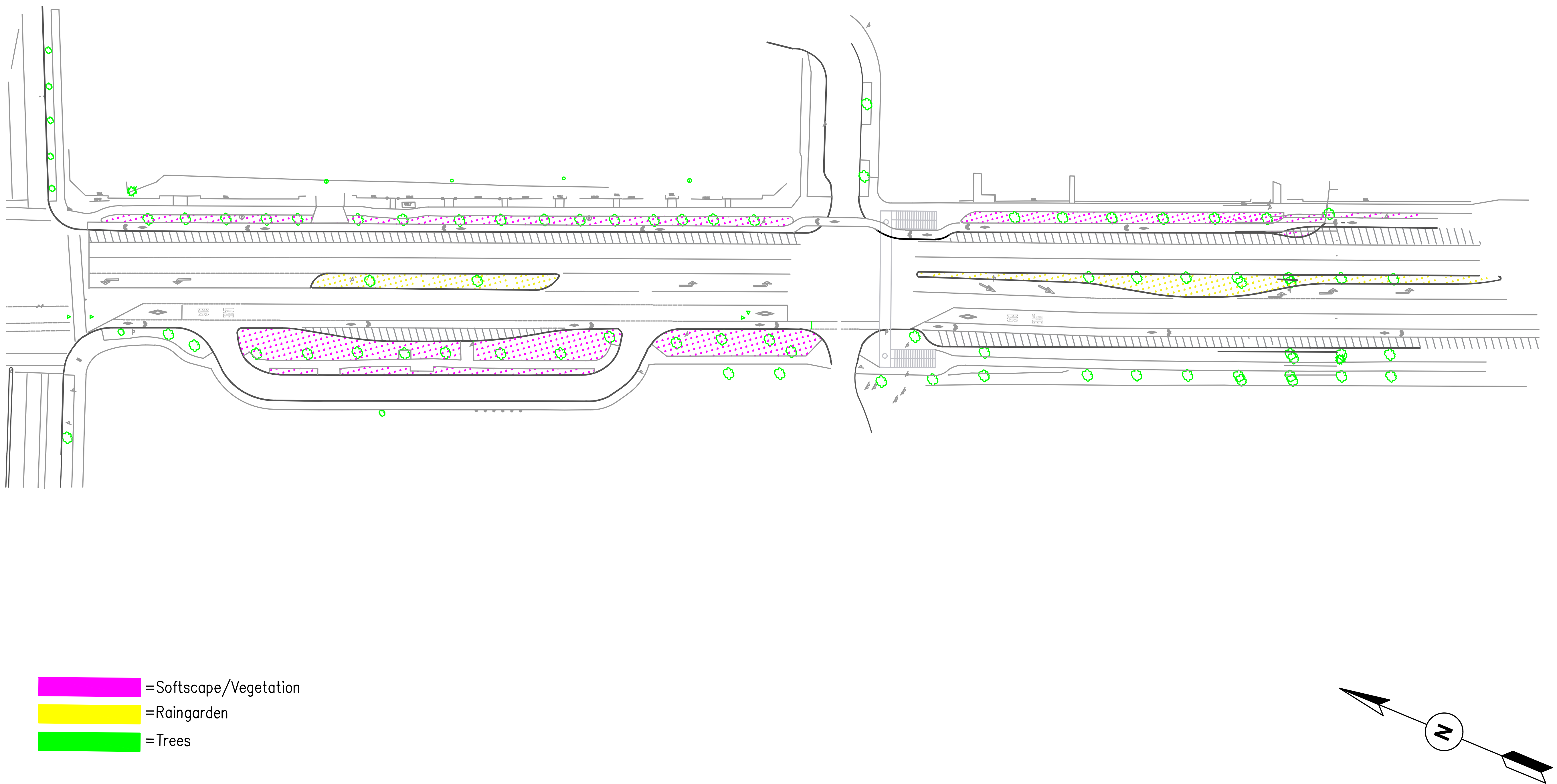
| DATE: April, 2022 | | | | | | | |




| SEGMENT 3 and 4 | | | DESIGNED & DRAWN BY:- |
|---|---|---|---|
| NAME OF THE DRAWING: | AS MENTIONED | | TEAM 14 |
| SCALE: | AS NOTED | DRAWING NO: 1 | |
| DATE: | April, 2022 | | |

NOTE:-

-ALL DIMENSIONS IN METERS.
-DO NOT MEASURE FROM THIS DRAWING.
-REPORT ANY DISCREPANCIES TO THE DESIGNER.

| REVISION | DATE:- | CONTENT:- |
|---|---|---|
| | | |
| | | |
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| | | |
| | | |
| | | |

CLIENT:

UBC

## Appendix C – StormBrixx® HD Bearing Capacity

Total water Capacity.

Assume. 97 % of total volume can store water.

Height of tank: 1.2 m

Width of tank: 0.6 m

Total length 700 m

$\Rightarrow$ Estimated volume : $1.2 \cdot 0.6 \cdot 700 = \boxed{488.88 \text{ m}^3}$

Soil Bearing Capacity.

$\phi = 30^\circ$ $N_c = 37.2$ $N_q = 22.5$ $N_\gamma = 20.1$

Assume $\gamma = 19 \text{ KN/m}^3$.

$\sigma_D = 1.2 \times 19 = 228 \text{ kPa}$

$q_{ult} = (22.8)(22.5) + 0.5(19)(0.6)(20.1)$

$= \boxed{627.57 \text{ kPa}}$

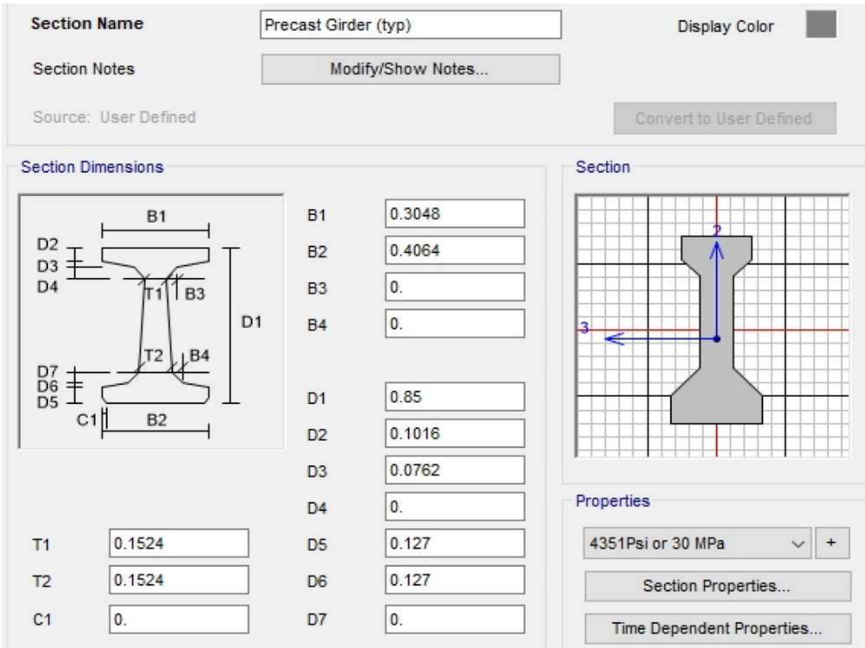
Lateral Soil Strength

$$k_a = \frac{1 - \sin 30^\circ}{1 + \sin 30^\circ}$$

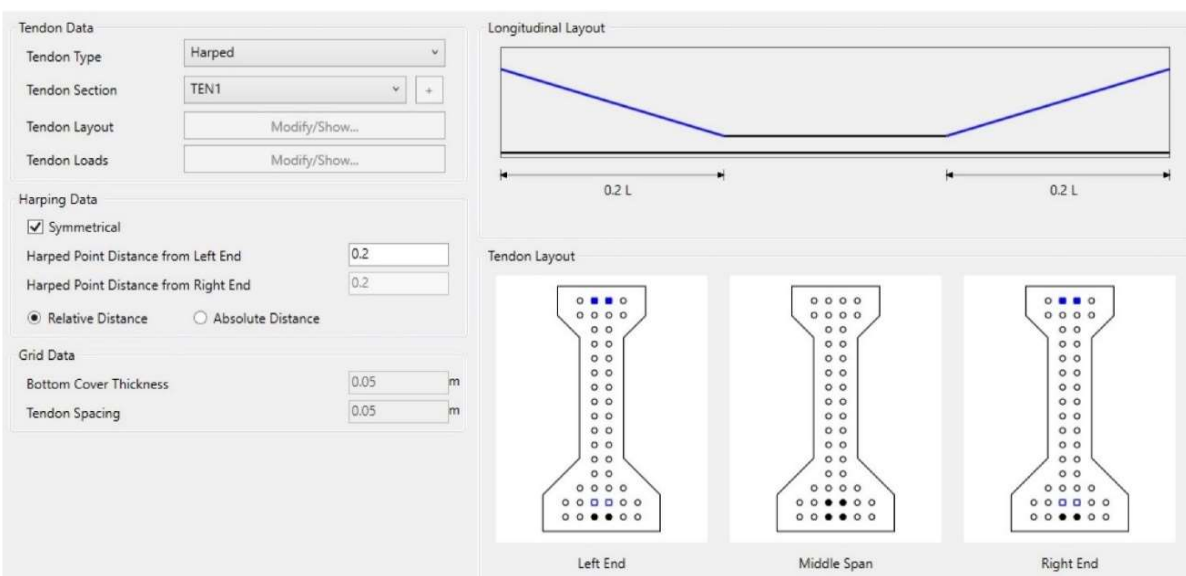
$V = k_a (1.2)(19) = \boxed{7.6 \text{ kPa}}$

# Appendix D – Overpass Analysis

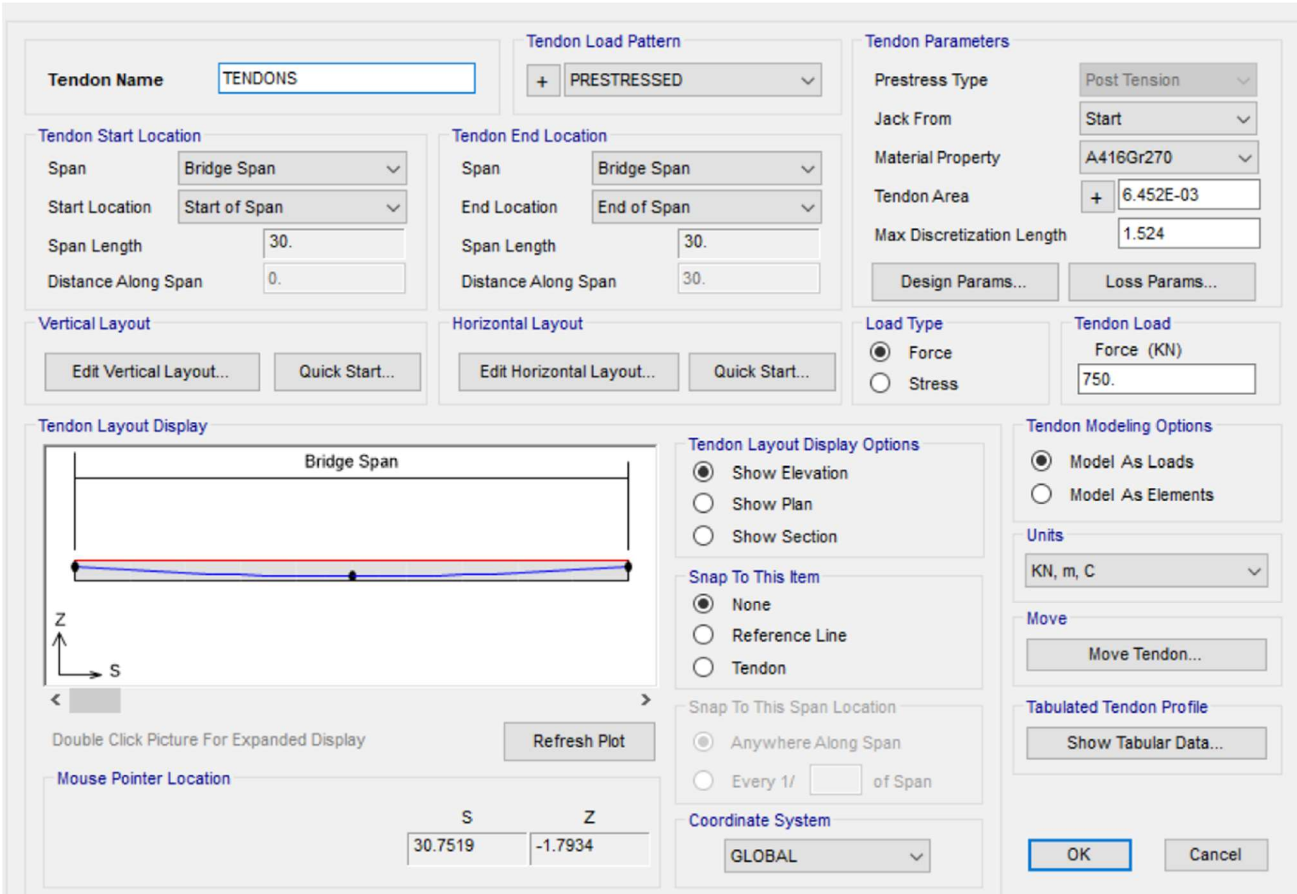
***Precast Concrete Girder Dimensions***



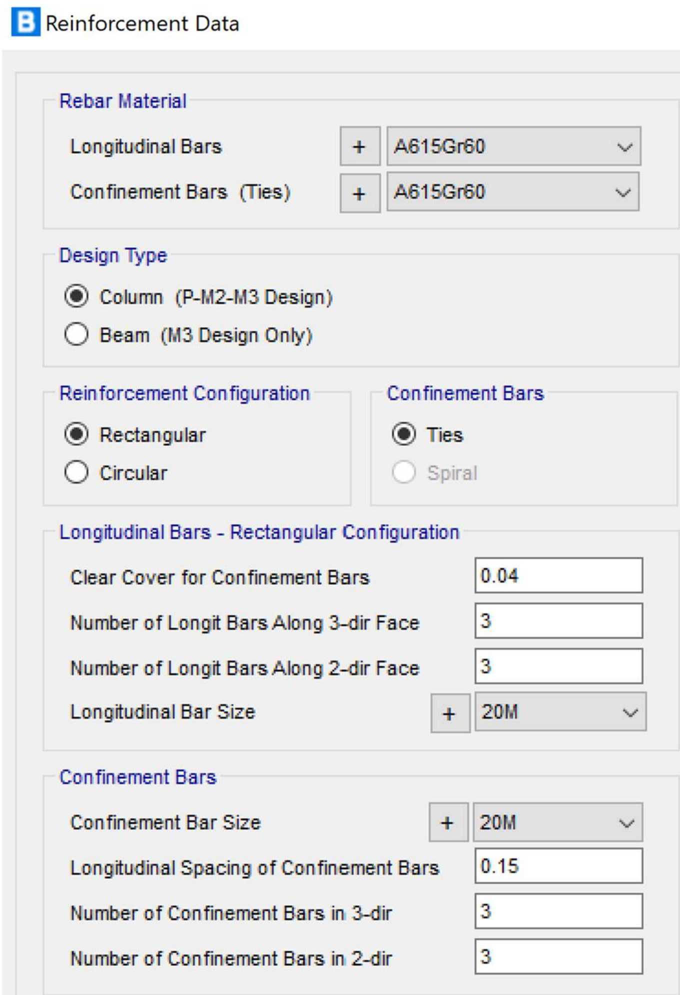

***Tendons Layout Data***



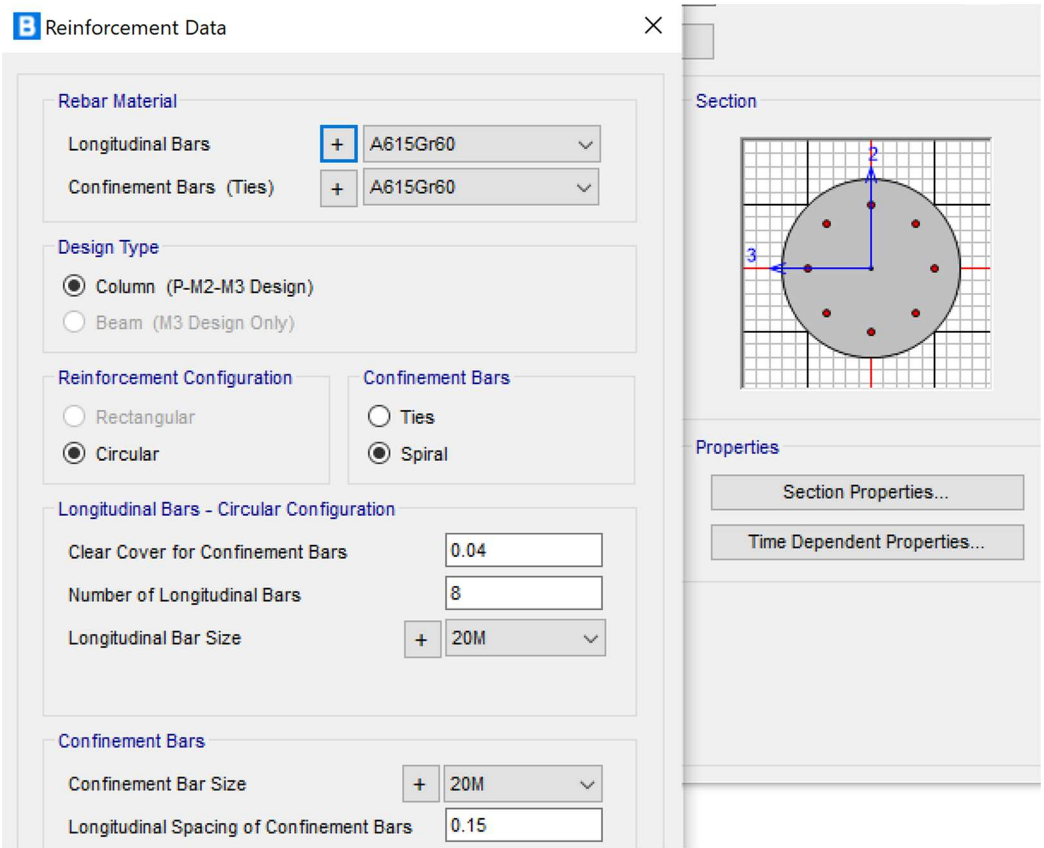
*Tendons Layout Data cnt'd*



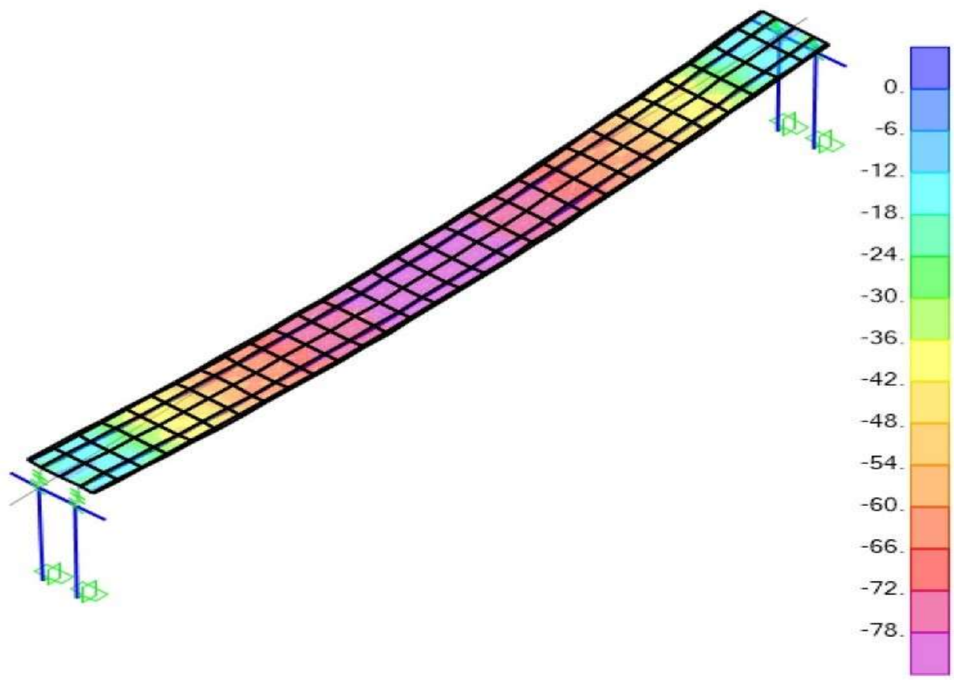
*Bent Cap Reinforcement Details*



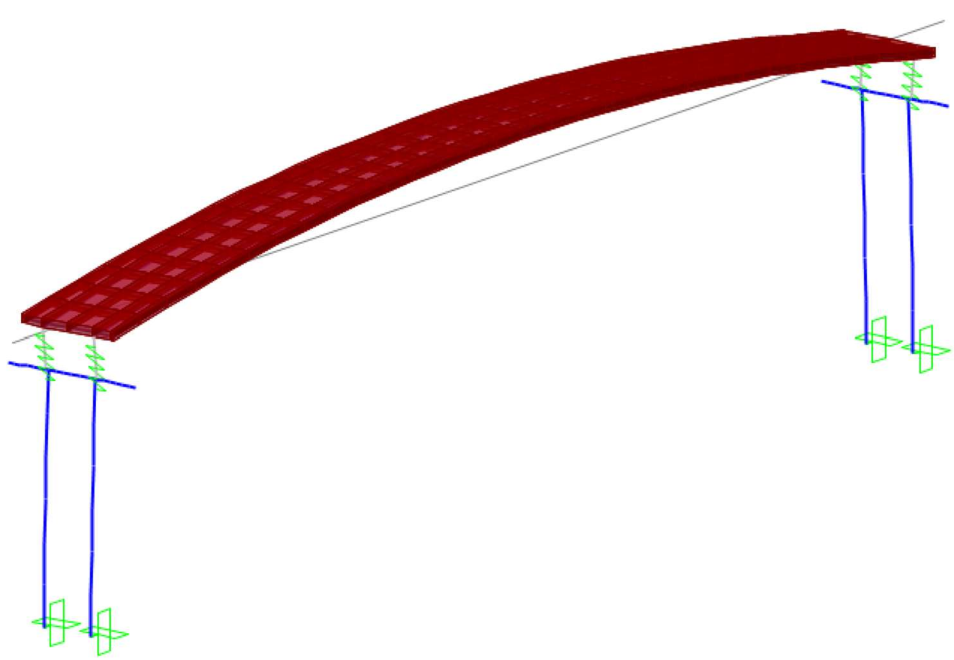
### *Column Reinforcement Details*



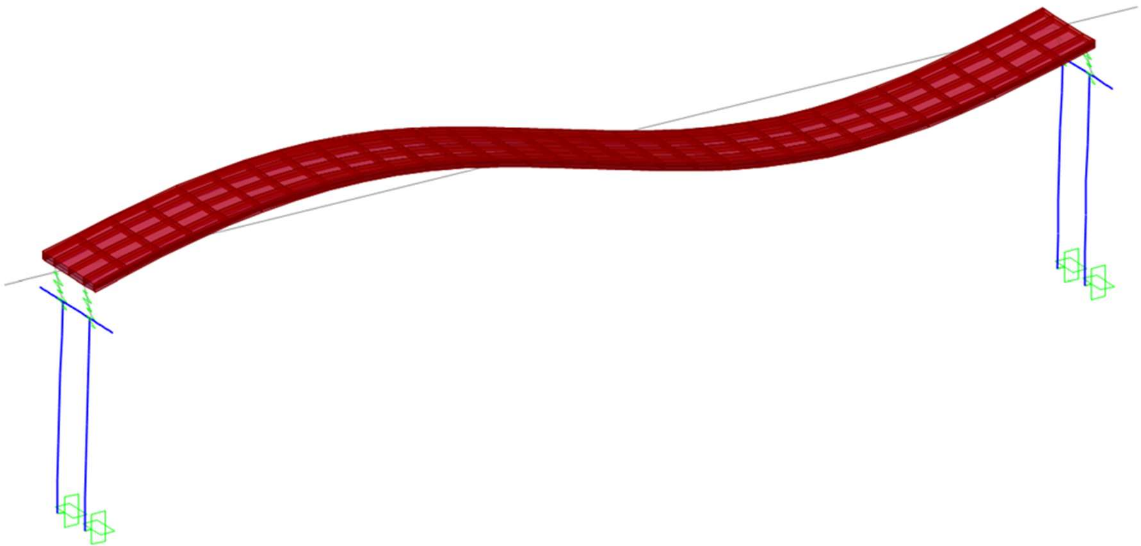
***Dead Load Case - Finite Element Analysis***




***Prestressed Load Deformed Shape***

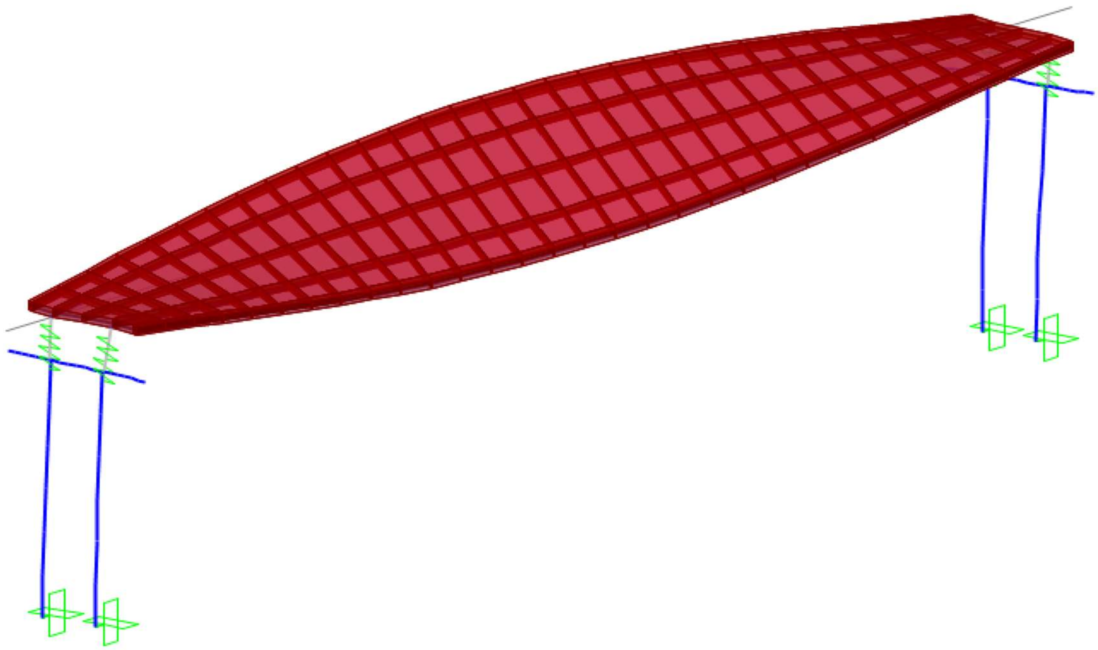


*The Most Critical 6th Modal Shape Under RSA Analysis*

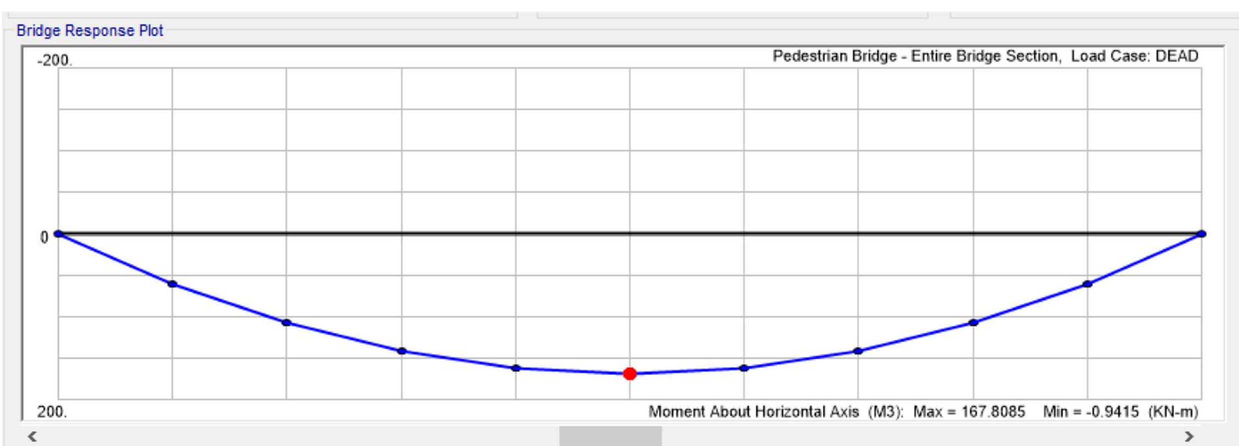


*The Second Largest Moment Produced in 2nd Modal Shape under RSA Analysis*

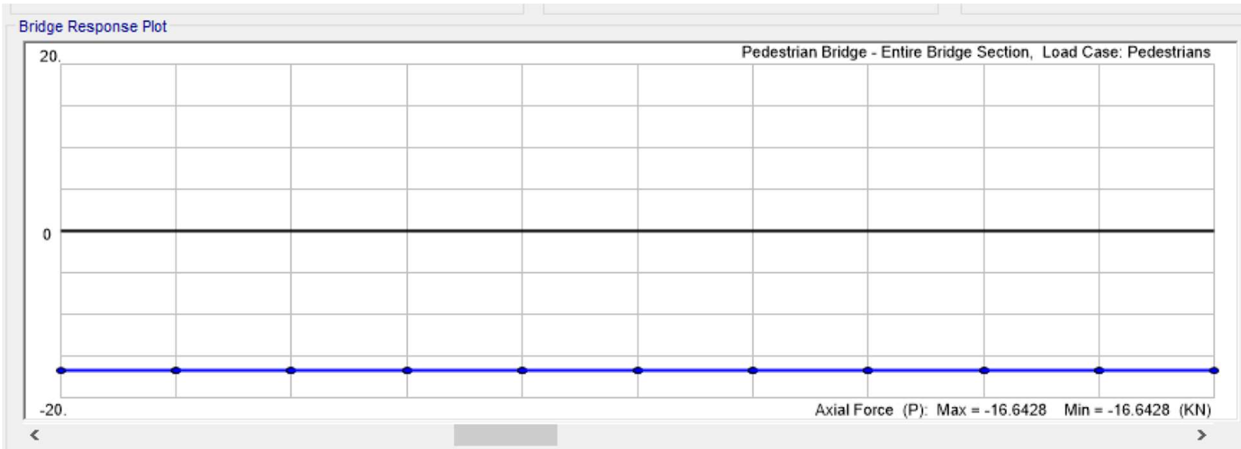
***Torsional Force as a Result of 5th Modal Shape under RSA Analysis***



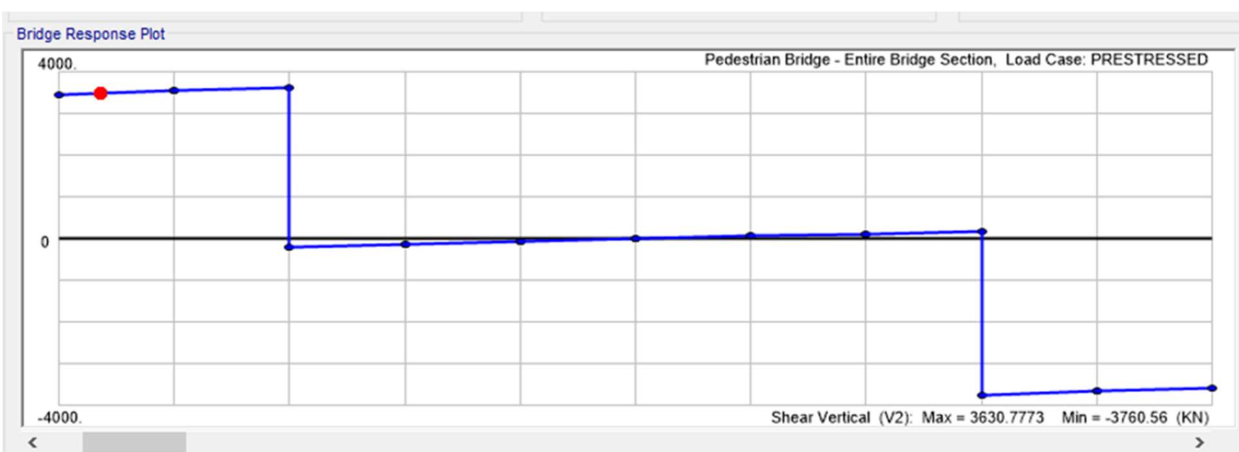
***Dead Load – Moment Diagram***



*Live Load – Axial Force Diagram*




*Prestressed Load – Shear Force Diagram*



### *6th Most Critical Modal Shape – Moment Diagram*

# Appendix E – Detailed Class A Cost Estimate

| | | | | | |
|---|---|---|---|---|---|
| Class A Estimate | | | | Date | 29-Mar-22 |
| Project Name : Wesbrook Redesign Phase 4 | *Westbrook Mall Re-Design Phase 4* | | | Start Date | 02-May |
| Client Name: UBC SEEDs | *UBC SEEDS* | | | End Date | 24-Oct |

| Phase | Task | U/M | Quantity | Unit Price | Total |
|---|---|---|---|---|---|
| **Permits** | | | | | |
| | Tree Removal | EA | 25 | $ 1,500.00 | $ **37,500.00** |
| | Road Closure (per lane per day per block) | EA | 168 | $ 974.00 | $ **163,632.00** |
| | Construction Permit | EA | 1 | $ 3,000.00 | $ **3,000.00** |
| | Inspections | EA | 4 | $ 250.00 | $ **1,000.00** |
| | Crane Permit for overpass (per Day) | EA | 1 | $ 193.00 | $ **193.00** |
| | | | | **Total** | $ **205,325.00** |
| | | | | | |
| **Project Site Costs** | | | | | $ - |
| | Geotechnical Investigation | EA | 1 | $ 10,200.00 | $ **10,200.00** |
| | Site Surveying | ACRE | 8.5 | $ 546.15 | $ **4,642.28** |
| | Construction Management | 1 | 1 | $ 182,796.36 | $ **182,796.36** |
| | | | | **Total** | $ **197,638.63** |
| | | | | | |
| **Phase 1** | | | | | $ - |
| | Contingency | 15% | 1 | $ 162,533.90 | $ **162,533.90** |
| | Site Clearing | SM | 12562.85 | $ 8.20 | $ **103,015.39** |
| | Tree Removal | EA | 10 | $ 1,260.00 | $ **12,600.00** |
| | Road Demolition | SM | 9080 | $ 10.56 | $ **95,884.80** |
| | Disposal of Material | EA | 5 | $ 1,450.00 | $ **7,250.00** |
| | General Excavation | BCY | 18000 | $ 10.55 | $ **189,900.00** |
| | Hydrovac | Day | 20 | $ 260.35 | $ **5,207.00** |
| | Grading (subgrade for base course) | SM | 9080 | $ 7.90 | $ **71,732.00** |
| | Site Survey | EA | 1 | $ 1,546.15 | $ **1,546.15** |
| | Water Retention System | FT3 | 4080 | $ 12.50 | $ **51,000.00** |
| | Install Water Retention System | EA | 1 | $ 9,999.00 | $ **9,999.00** |
| | Pourous Concrete (bike lane) | SF | 1700 | $ 17.55 | $ **29,835.00** |
| | Install New Storm Drains | EA | 2 | $ 2,950.00 | $ **5,900.00** |
| | Base Course Drainage Layer | SM | 6325 | $ 28.97 | $ **183,215.51** |
| | Road Pavement | SM | 6325 | $ 37.97 | $ **240,151.04** |
| | Sidewalk Pavemnent | SM | 1400 | $ 35.63 | $ **49,879.96** |
| | Painting Road Lines | LF | 3050 | $ 2.35 | $ **7,167.50** |
| | Bike Lane Painting | SM | 1700 | $ 0.83 | $ **1,411.00** |
| | Re-plant trees | EA | 10 | $ 1,260.00 | $ **12,600.00** |
| | Sodding, 1" deep on level ground | SM | 2700 | $ 1.95 | $ **5,265.00** |
| | Rain Garden | SM | 2700 | $ 4.65 | $ **12,555.00** |
| | Bus Shelter:T3 Seriers with Green Roof | EA | 1 | $ 32,845.00 | $ **32,845.00** |
| | Bench | EA | 1 | $ 5,590.00 | $ **5,590.00** |
| | Garbage Bin | EA | 1 | $ 4,000.00 | $ **4,000.00** |
| | | | | **Total** | $ **1,301,083.25** |

| | | | | | |
|---|---|---|---|---|---|
| **Phase 2** | | | | | $ - |
| | Contingency | 15% | 1 | $ 172,183.36 | **$ 172,183.36** |
| | Site Clearing | SM | 10800 | $ 8.20 | **$ 88,560.00** |
| | Tree Removal | EA | 15 | $ 1,260.00 | **$ 18,900.00** |
| | Road Demolition | SM | 9800 | $ 10.56 | **$ 103,488.00** |
| | Disposal of Material | EA | 6 | $ 1,450.00 | **$ 8,700.00** |
| | General Excavation | BCY | 18000 | $ 10.55 | **$ 189,900.00** |
| | Hydrovac | Day | 20 | $ 260.35 | **$ 5,207.00** |
| | Grading (subgrade for base course) | SM | 1500 | $ 7.90 | **$ 11,850.00** |
| | Site Survey | EA | 1 | $ 1,546.15 | **$ 1,546.15** |
| | Water Retention System | FT3 | 4080 | $ 12.50 | **$ 51,000.00** |
| | Install Water Retention System | EA | 1 | $ 9,999.00 | **$ 9,999.00** |
| | Pourous Concrete (bike lane) | SF | 1300 | $ 17.55 | **$ 22,815.00** |
| | Install New Storm Drains | EA | 2 | $ 2,950.00 | **$ 5,900.00** |
| | Base Course Drainage Layer | SM | 7300 | $ 28.97 | **$ 211,458.22** |
| | Road Pavement | SM | 7300 | $ 37.97 | **$ 277,170.37** |
| | Sidewalk Pavemnent | SM | 3200 | $ 35.63 | **$ 114,011.34** |
| | Painting Road Lines | LF | 2650 | $ 2.35 | **$ 6,227.50** |
| | Bike Lane Painting | SM | 1300 | $ 0.83 | **$ 1,079.00** |
| | Re-plant trees | EA | 14 | $ 1,260.00 | **$ 17,640.00** |
| | Sodding, 1" deep on level ground | SM | 1250 | $ 1.95 | **$ 2,437.50** |
| | Rain Garden | SM | 1250 | $ 4.65 | **$ 5,812.50** |
| | | | | **Total** | **$ 1,325,884.93** |

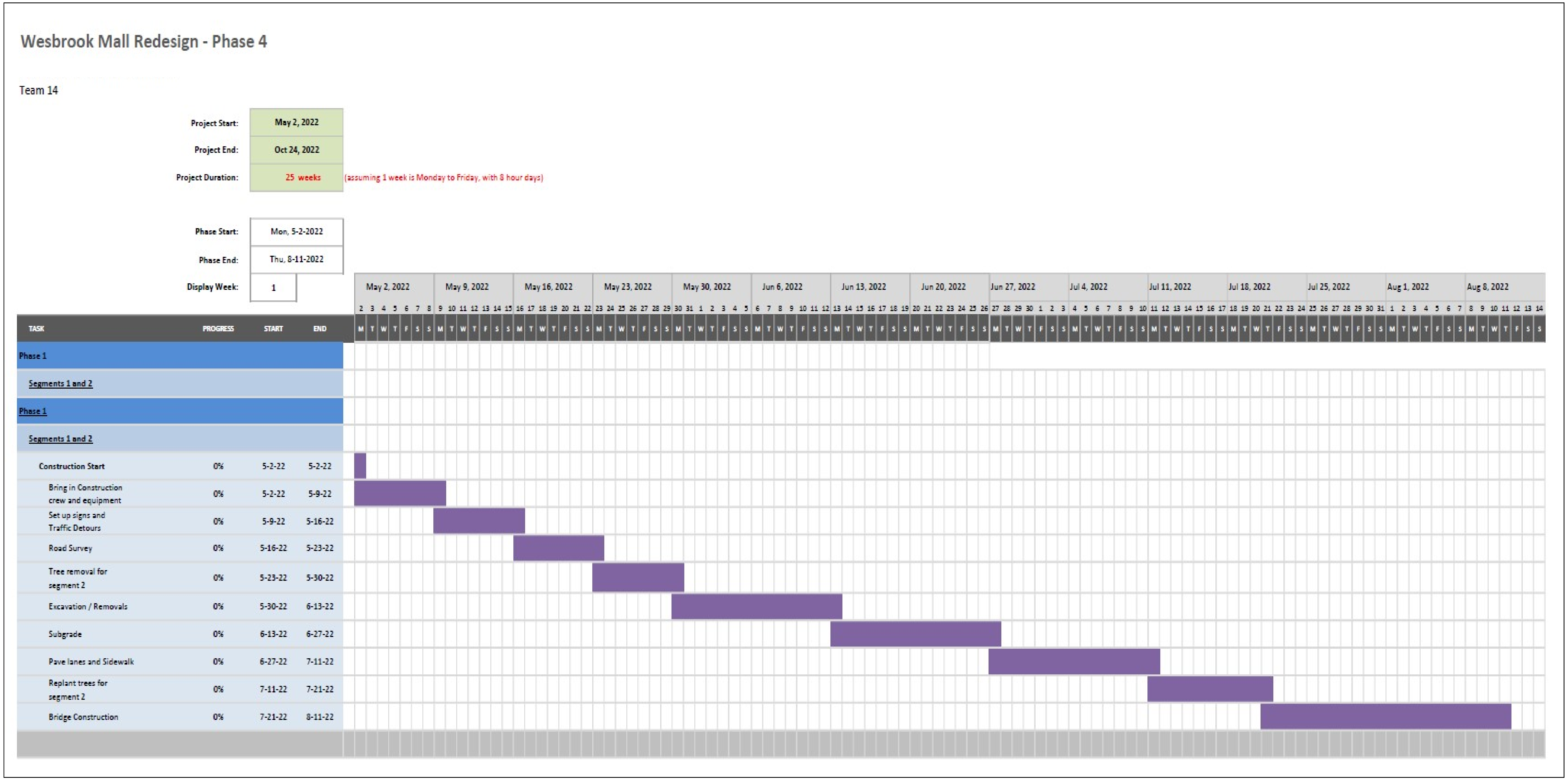
| | | | | | |
|---|---|---|---|---|---|
| **OverPass** | | | | | |
| | Contingency | 15% | 1 | $ 105,494.57 | **$ 105,494.57** |
| | Concrete Columns | EA | 4 | $ 1,990.30 | **$ 7,961.20** |
| | Elastomeric Pads | EA | 4 | $ 1,750.00 | **$ 7,000.00** |
| | 10" Slab | SM | 90 | $ 83.67 | **$ 7,530.30** |
| | Precast PreTensioned Beams | EA | 2 | $ 220,000.00 | **$ 440,000.00** |
| | Precast Stairs (per riser) | EA | 76 | $ 872.61 | **$ 66,318.36** |
| | Glazing + Alumnium Frame | SM | 227 | $ 747.80 | **$ 169,750.60** |
| | Crane (100 ton, truck mounted) | DAY | 1 | $ 4,736.67 | **$ 4,736.67** |
| | Aluminum Railing | Riser | 76 | $ 105.00 | **$ 7,980.00** |
| | Installation Labour | EA | 1 | $ 276,217.26 | **$ 276,217.26** |
| | | | | **Total** | **$ 808,791.70** |

| | | | | | |
|---|---|---|---|---|---|
| **Annual Maintance** | | | | | |
| | Signal Light Maintainance | EA | 2 | $ 7,000.00 | **$ 14,000.00** |
| | Upkeep of greenery (mowing, watering) | EA | 1 | $ 2,750.00 | **$ 2,750.00** |
| | Retention System Flush | EA | 1 | $ 2,200.00 | **$ 2,200.00** |
| | Upkeep of sidewwalk and bike lane | EA | 1 | $ 1,500.00 | **$ 1,500.00** |
| | Repair of Pavement (10-25SF) | EA | 5 | $ 102.31 | **$ 511.55** |
| | | | | **Total** | **$ 20,961.55** |

| | | | | | |
|---|---|---|---|---|---|
| **Operating Costs** | | | | | $ - |
| | Electricity per light | EA | 4 | $ 1,500.00 | **$ 6,000.00** |
| | | | | | $ - |
| | | | | **Total** | **$ 6,000.00** |

## Appendix F - Construction Schedule

Phase 1 Construction Schedule



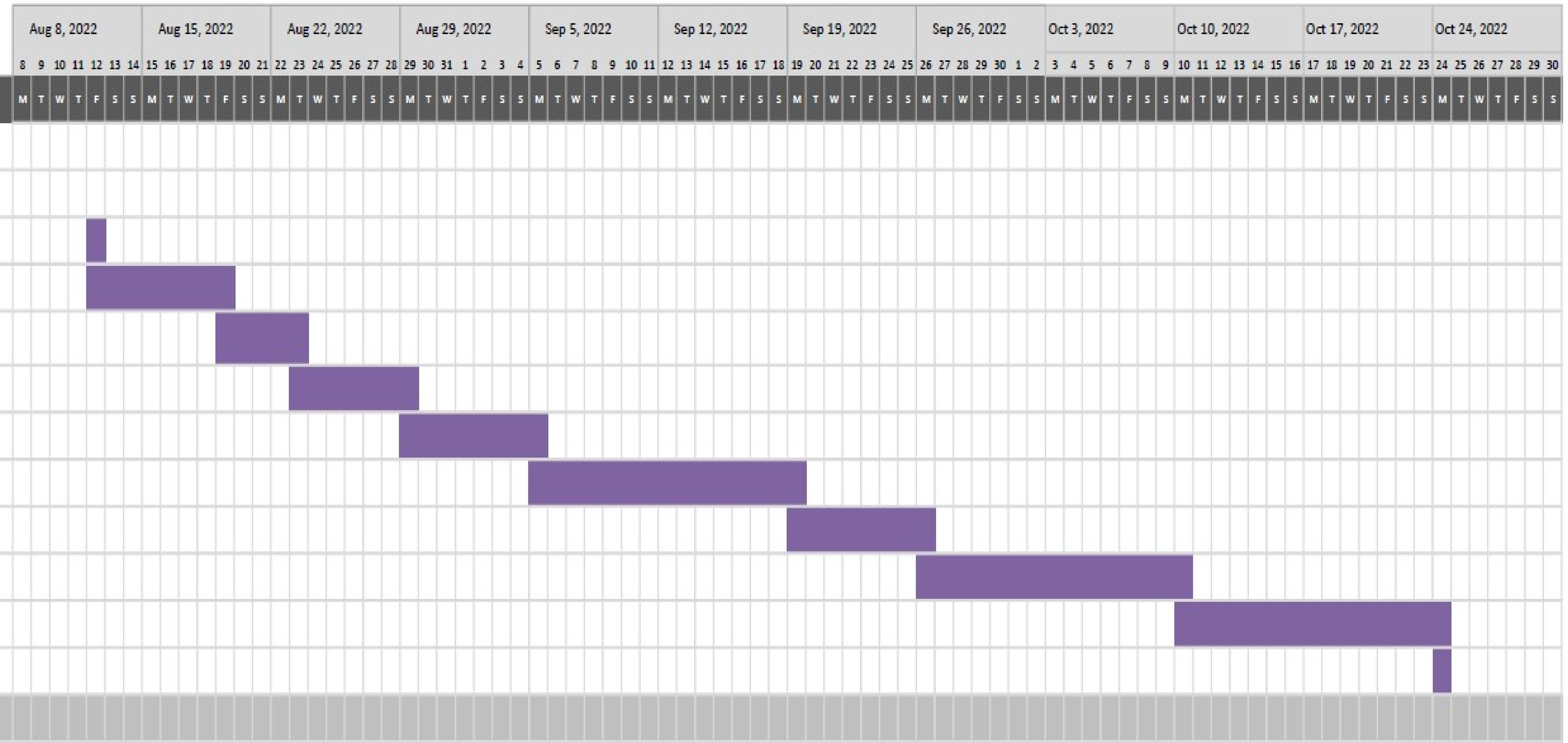
Phase 2 Construction Schedule

## Wesbrook Mall Redesign - Phase 4

Team 14

| | |
|---|---|
| Phase Start: | Fri, 8-12-2022 |
| Phase End: | Mon, 10-24-2022 |
| Display Week: | 1 |

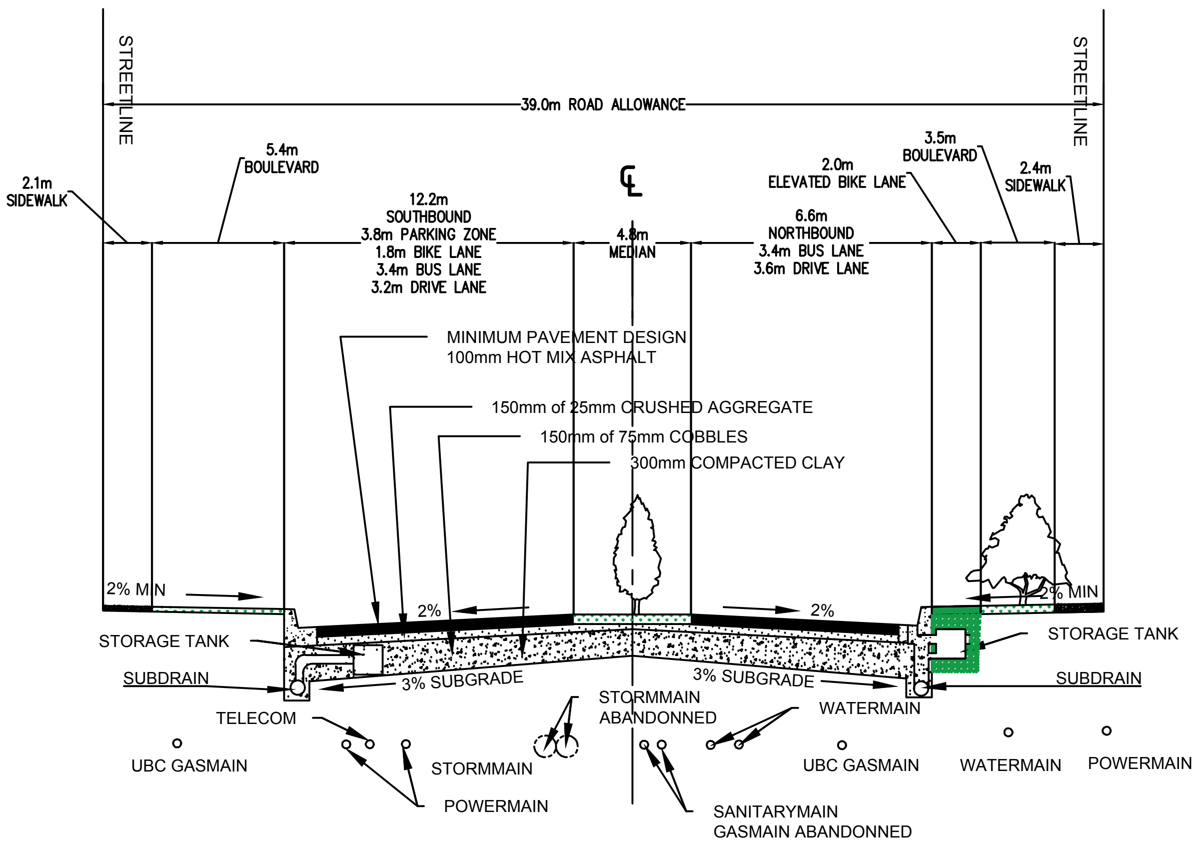
| TASK | PROGRESS | START | END |
|---|---|---|---|
| Phase 2 | | | |
| Segments 3 and 4 | | | |
| Construction Start | 0% | 8-12-22 | 8-12-22 |
| Relocate Construction crew and equipment | 0% | 8-12-22 | 8-19-22 |
| Moves signs and establish new road detours | 0% | 8-19-22 | 8-23-22 |
| Road Survey | 0% | 8-23-22 | 8-29-22 |
| Tree removal for segment 3 | 0% | 8-29-22 | 9-5-22 |
| Excavation / Removals | 0% | 9-5-22 | 9-19-22 |
| Subgrade | 0% | 9-19-22 | 9-26-22 |
| Pavement of Southbound Sidewalk | 0% | 9-26-22 | 10-10-22 |
| Pavement of Northbound lanes and sidewalk | 0% | 10-10-22 | 10-24-22 |
| Construction Complete | 0% | 10-24-22 | 10-24-22 |



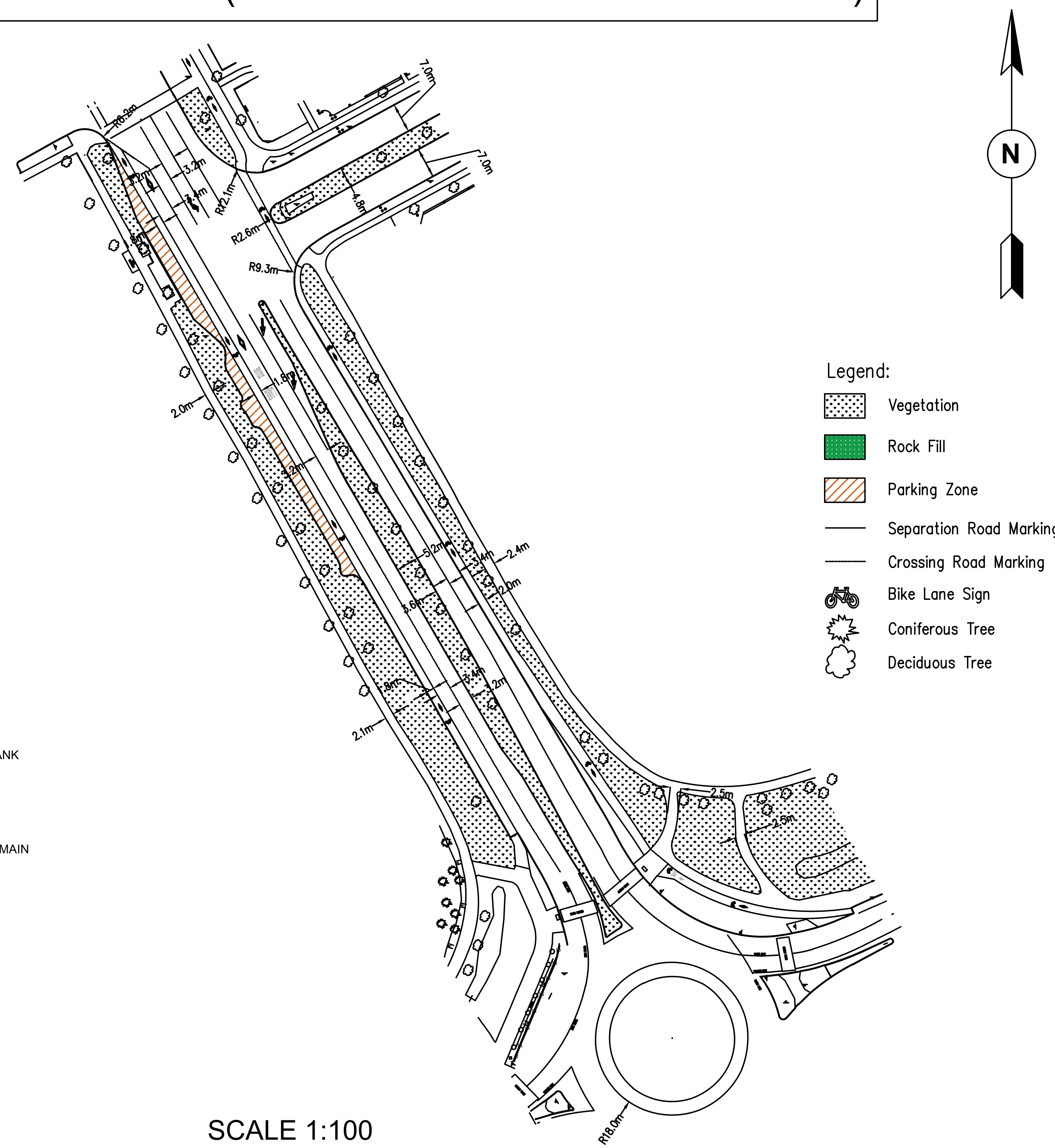
**Detailed Road Design Drawings**

# SEGMENT 1 (16th AVENUE - HAMPTON PLACE)

## TYPICAL CROSS-SECTION



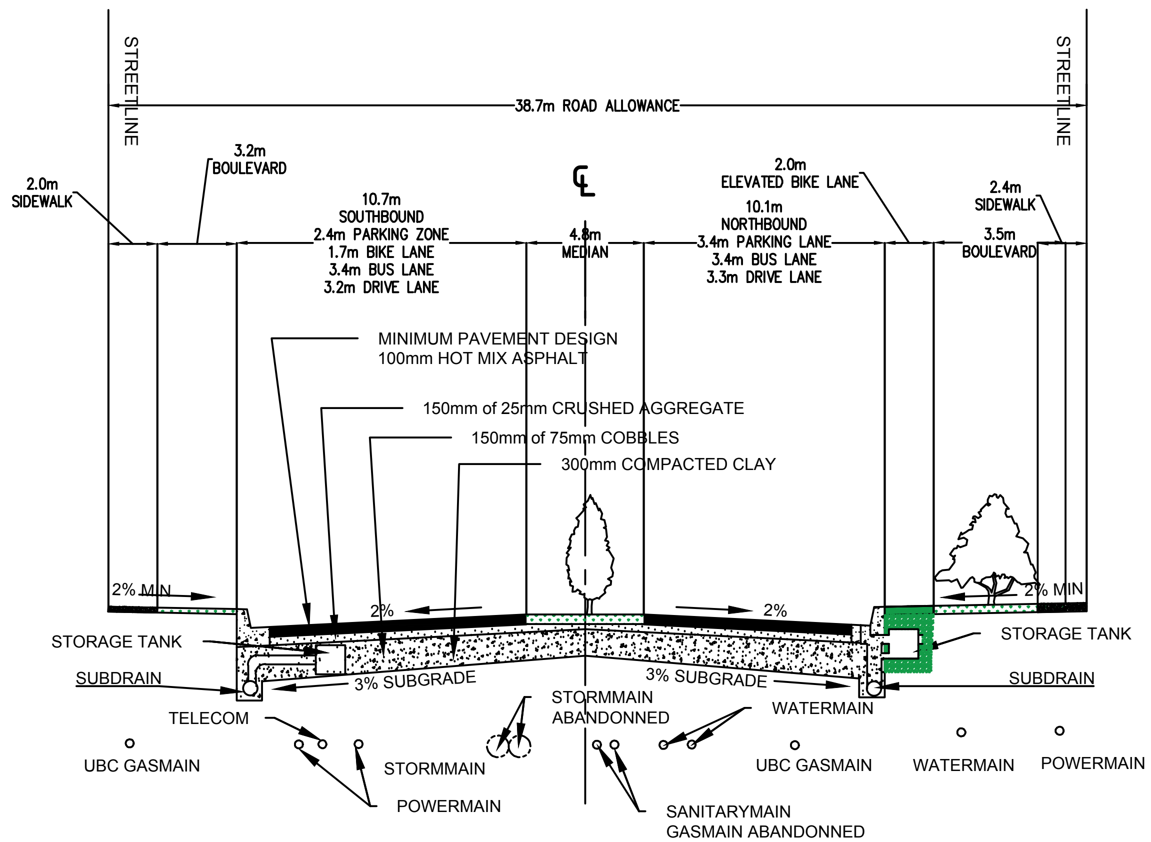

NTS




| SEGMENT 1 | | DESIGNED & DRAWN BY:- | NOTE:- | REVISION | DATE:- | CONTENT:- | CLIENT: |
|---|---|---|---|---|---|---|---|
| NAME OF THE DRAWING: | AS MENTIONED | TEAM 14 | -ALL DIMENSIONS IN METERS.<br>-DO NOT MEASURE FROM THIS DRAWING.<br>-REPORT ANY DISCREPANCIES TO THE DESIGNER. | | | | UBC |
| SCALE: AS NOTED | DRAWING NO: 1 | | | | | | |
| DATE: April, 2022 | | | | | | | |

# SEGMENT 2 (HAMPTON PLACE TO RCMP)

## TYPICAL CROSS-SECTION

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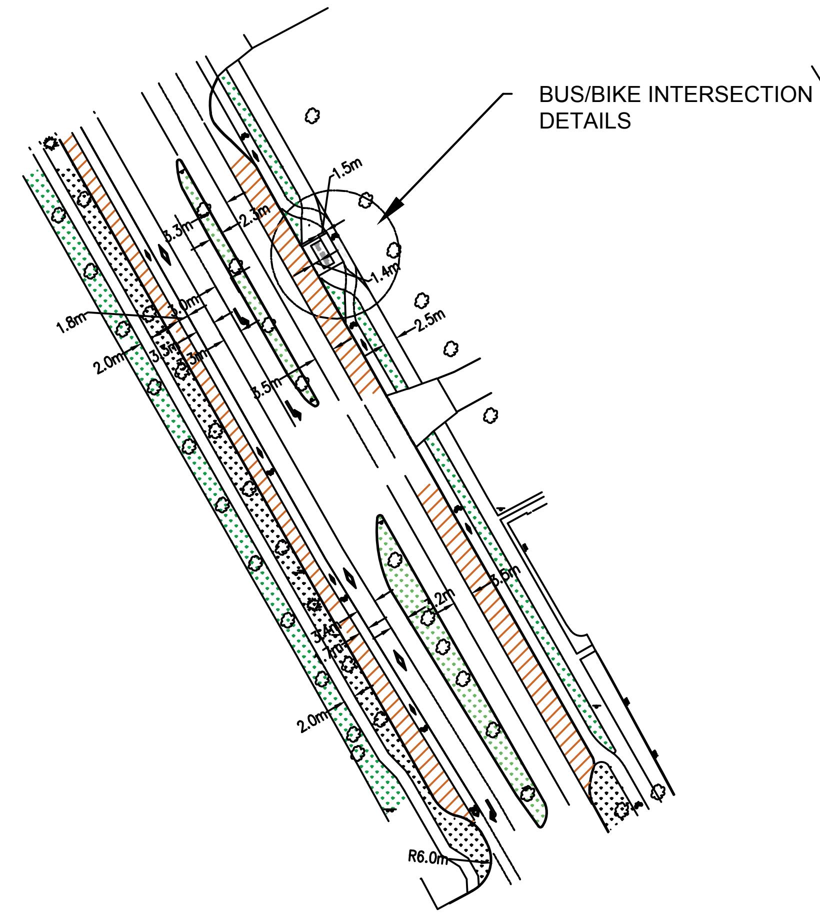
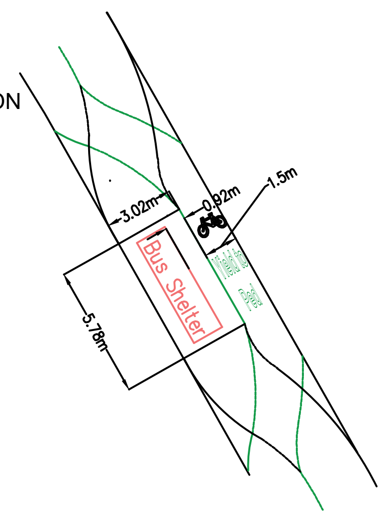



SCALE 1:100

Legend:

- Vegetation
- Rock Fill
- Parking Zone
- Separation Road Marking
- Crossing Road Marking
- Bike Lane Sign
- Coniferous Tree
- Deciduous Tree

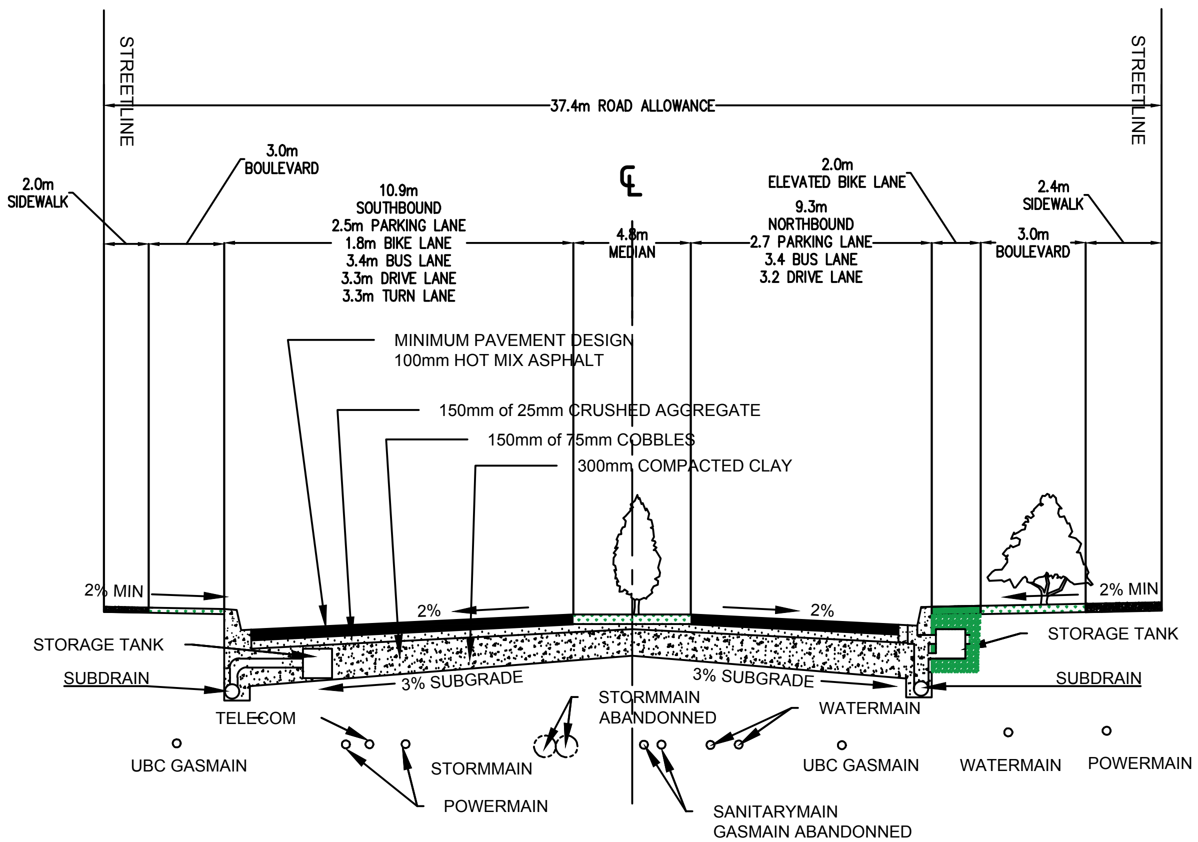
| | | | | |
|---|---|---|---|---|
| SEGMENT 2 | | DESIGNED & DRAWN BY:- | NOTE:- | CLIENT: |
| NAME OF THE DRAWING: | AS MENTIONED | TEAM 14 | -ALL DIMENSIONS IN METERS.<br>-DO NOT MEASURE FROM THIS DRAWING.<br>-REPORT ANY DISCREPANCIES TO THE DESIGNER. | UBC |
| SCALE: AS NOTED | DRAWING NO: 2 | | | |
| DATE: April, 2022 | | | | |

| REVISION | DATE:- | CONTENT:- |
|---|---|---|
| | | |

XX

# SEGMENT 3 (RCMP TO PANHELLENIC HOUSE)

## TYPICAL CROSS-SECTION

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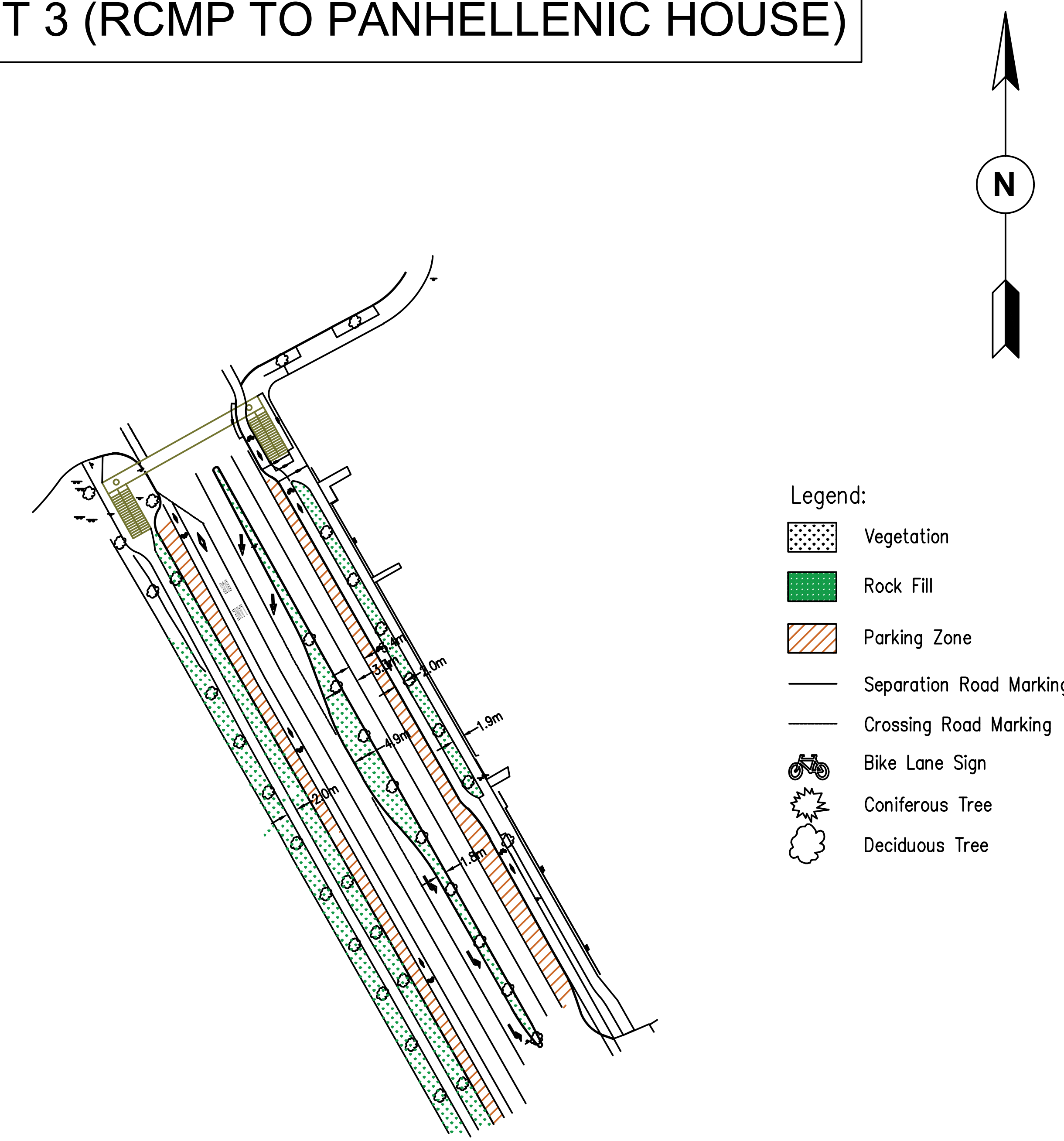


SCALE 1:100

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
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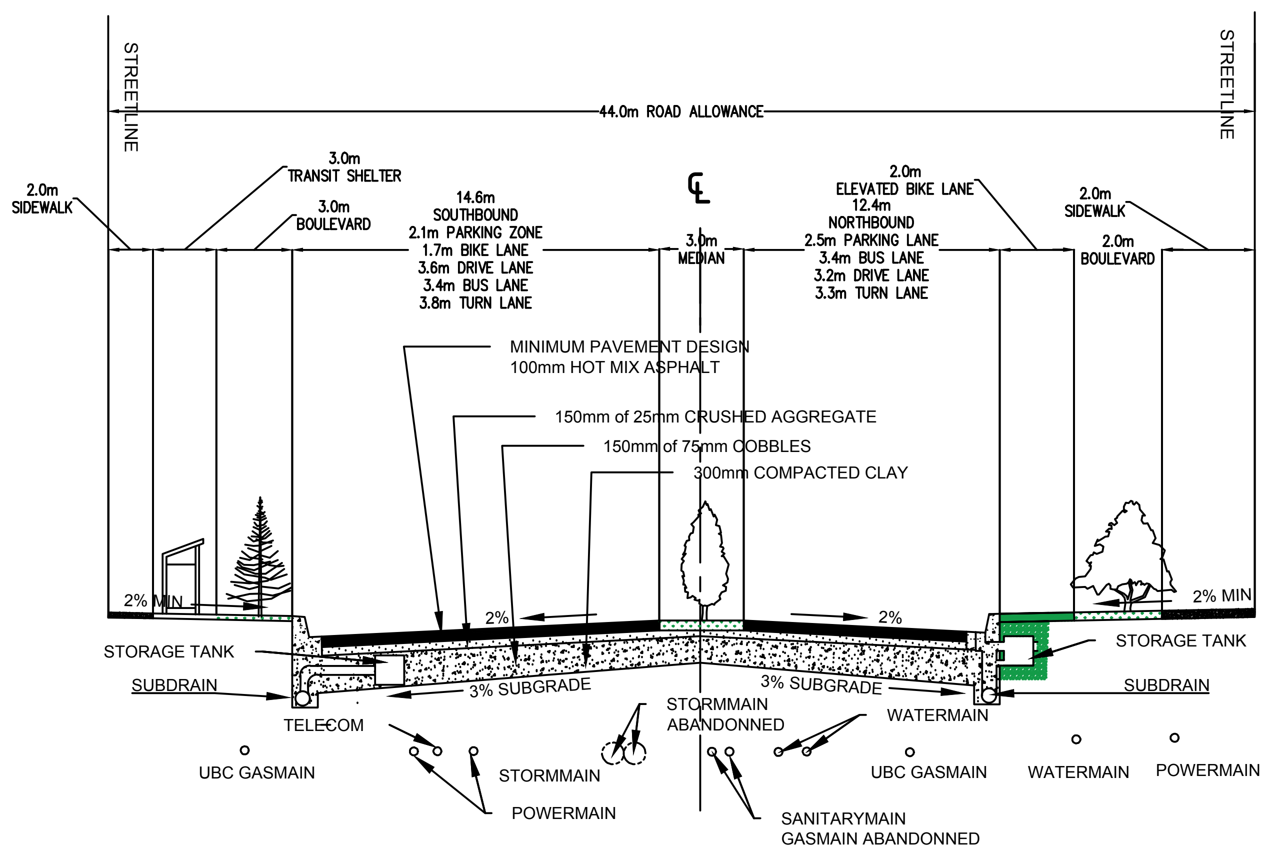
| NAME OF THE DRAWING: | AS MENTIONED | TEAM 14 | -ALL DIMENSIONS IN METERS.<br>-DO NOT MEASURE FROM THIS DRAWING.<br>-REPORT ANY DISCREPANCIES TO THE DESIGNER. | | | | | |
| SCALE: AS NOTED | DRAWING NO: 3 | | | | | | | |
| DATE: April, 2022 | | | | | | | UBC | |

# SEGMENT 4 (PANHELLENIC HOUSE TO THUNDERBIRD BLVD)

## TYPICAL CROSS-SECTION

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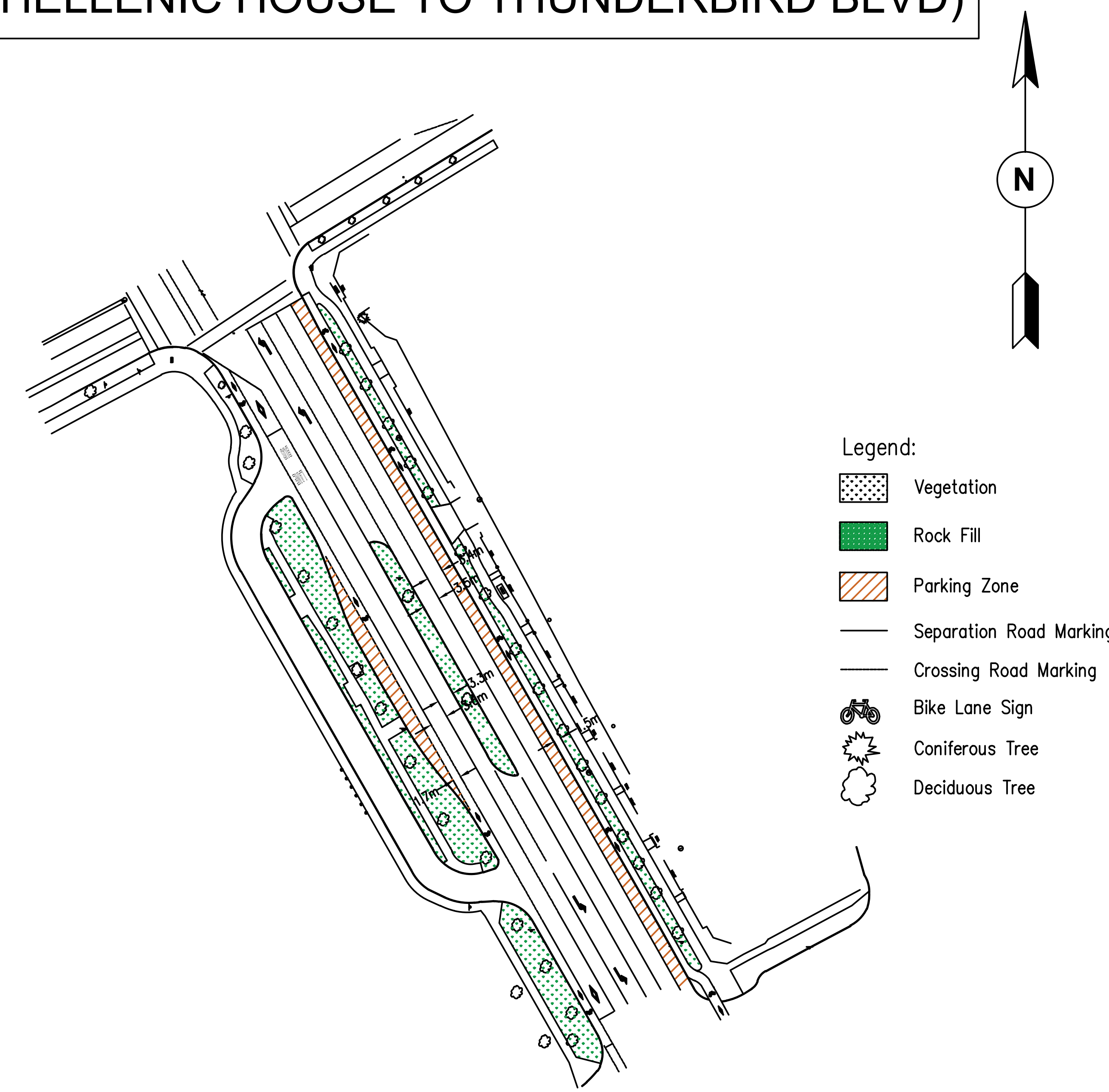


SCALE 1:100

| | | | | | | | | |
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| SEGMENT 4 | | DESIGNED & DRAWN BY:- | NOTE:- | REVISION | DATE:- | CONTENT:- | CLIENT: | |
| NAME OF THE DRAWING: | AS MENTIONED | TEAM 14 | -ALL DIMENSIONS IN METERS.<br>-DO NOT MEASURE FROM THIS DRAWING.<br>-REPORT ANY DISCREPANCIES TO THE DESIGNER. | | | | | |
| SCALE: AS NOTED | DRAWING NO: 4 | | | | | | | |
| DATE: April, 2022 | | | | | | | UBC | |

# Detailed Overpass Design Drawings

1 Rendering Lookign South
1 : 1

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rendering (Looking South) | | DESIGNED & DRAWN BY: | NOTE: | REVISION | DATE: | CONTENT | CLIENT: | |
| NAME OF THE DRAWING: | AS MENTIONED | TEAM 14 | - ALL DIMENSIONS IN METERS.<br>- DO NOT MEASURE FROM THIS DRAWING<br>- REPORT ANY DISCREPANCIES TO THE DESIGNER | | | | | |
| SCALE: | AS NOTED | | | | | | | |
| DATE: | April, 2022 | | | | | | UBC | |

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1 Rendering Looking North
1 : 1

| Rendering (Looking North) | | DESIGNED & DRAWN BY: | NOTE: |
|---|---|---|---|
| NAME OF THE DRAWING: | AS MENTIONED | TEAM 14 | - ALL DIMENSIONS IN METERS.<br>- DO NOT MEASURE FROM THIS DRAWING<br>- REPORT ANY DISCREPANCIES TO THE DESIGNER |
| SCALE: | AS NOTED | | |
| DATE: | April, 2022 | | |

| REVISION | DATE: | CONTENT | CLIENT: |
|---|---|---|---|
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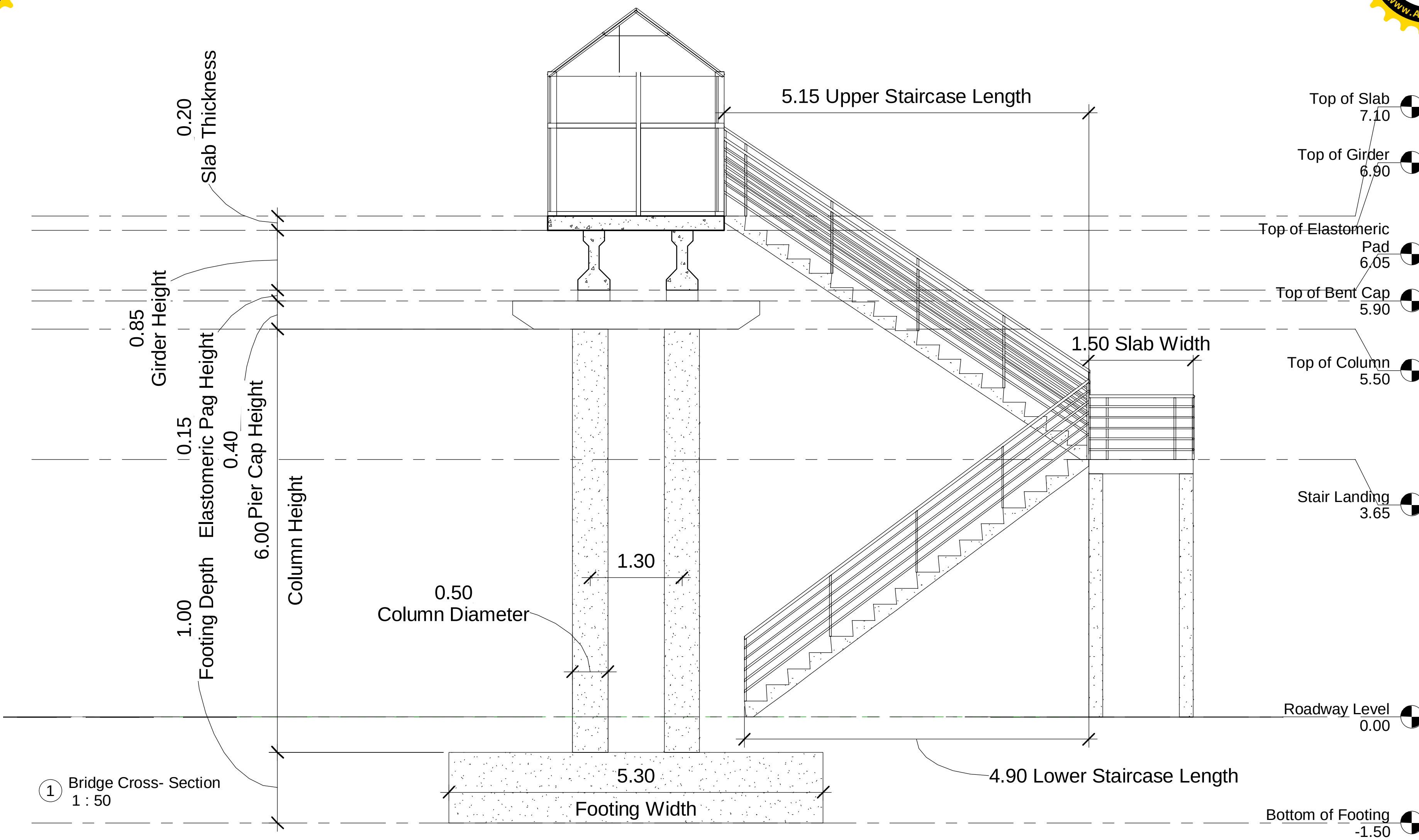
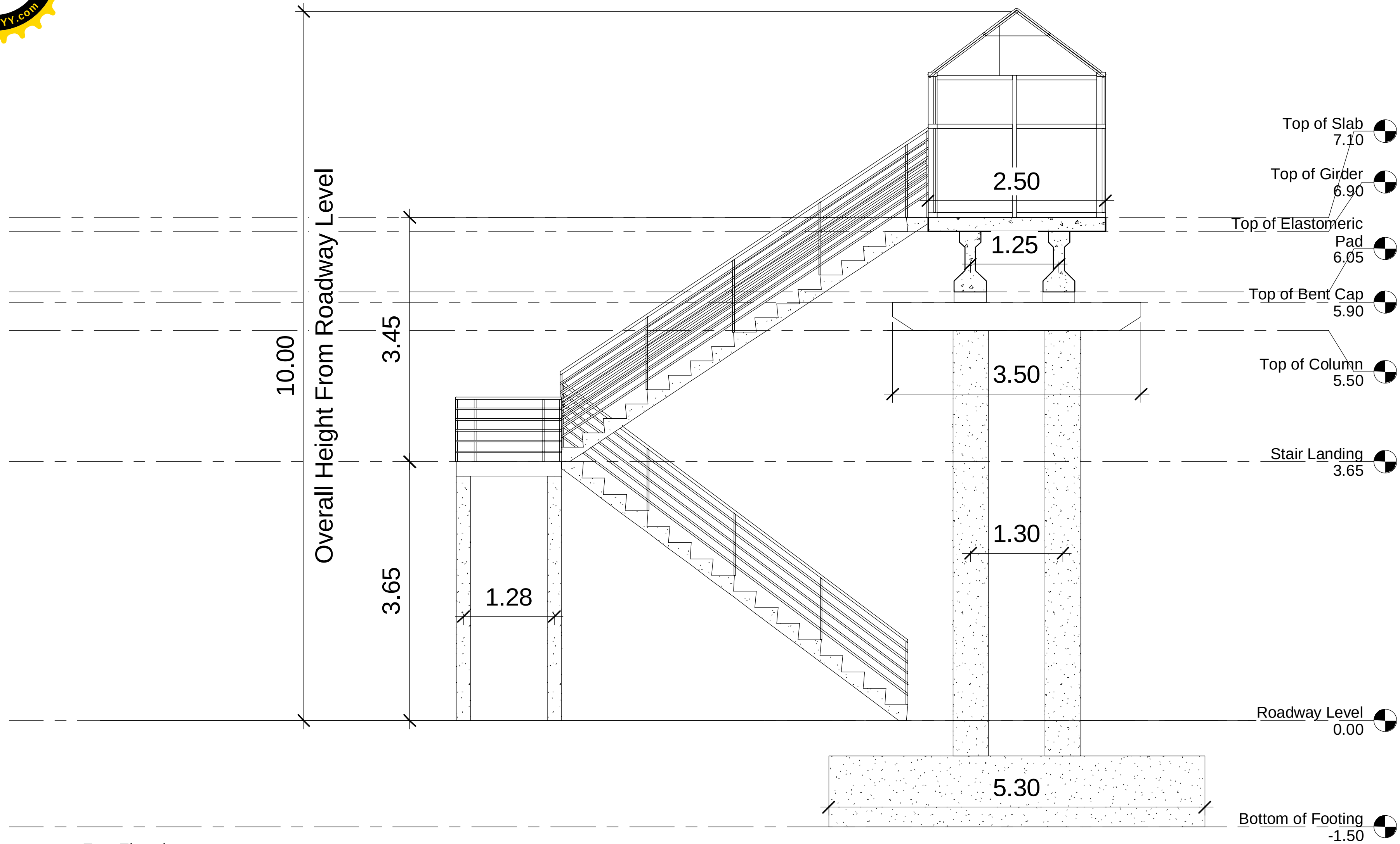
| | | | UBC |

UBC



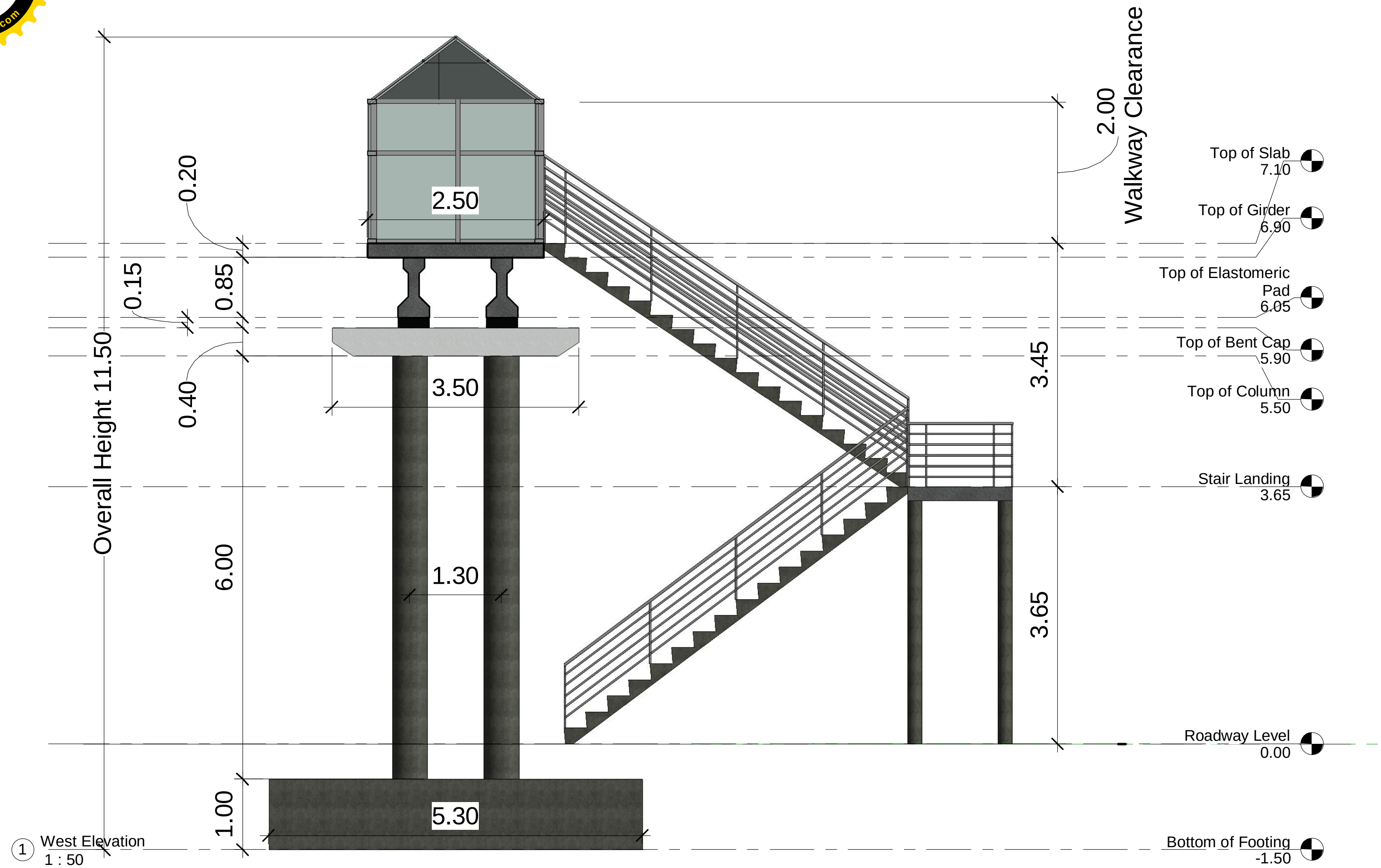

1 Bridge Cross- Section
1 : 50

| Cross-Section | | DESIGNED & DRAWN BY: | NOTE: | REVISION | DATE: | CONTENT | CLIENT: |
|---|---|---|---|---|---|---|---|
| NAME OF THE DRAWING: | AS MENTIONED | TEAM 14 | - ALL DIMENSIONS IN METERS.<br>- DO NOT MEASURE FROM THIS DRAWING<br>- REPORT ANY DISCREPANCIES TO THE DESIGNER | | | | |
| SCALE: | AS NOTED | | | | | | |
| DATE: | April, 2022 | | | | | | UBC |




1 East Elevation
1 : 50

| East Elevation | | DESIGNED & DRAWN BY: | NOTE: | REVISION | DATE: | CONTENT | CLIENT: |
|---|---|---|---|---|---|---|---|
| NAME OF THE DRAWING: | AS MENTIONED | TEAM 14 | - ALL DIMENSIONS IN METERS.<br>- DO NOT MEASURE FROM THIS DRAWING<br>- REPORT ANY DISCREPANCIES TO THE DESIGNER | | | | UBC |
| SCALE: AS NOTED | | | | | | | |
| DATE: April, 2022 | | | | | | | |




| West Elevation | | DESIGNED & DRAWN BY: | NOTE: | REVISION | DATE: | CONTENT | CLIENT: |
|---|---|---|---|---|---|---|---|
| NAME OF THE DRAWING: | AS MENTIONED | TEAM 14 | - ALL DIMENSIONS IN METERS.<br>- DO NOT MEASURE FROM THIS DRAWING<br>- REPORT ANY DISCREPANCIES TO THE DESIGNER | | | | UBC |
| SCALE: | AS NOTED | | | | | | |
| DATE: | April, 2022 | | | | | | |

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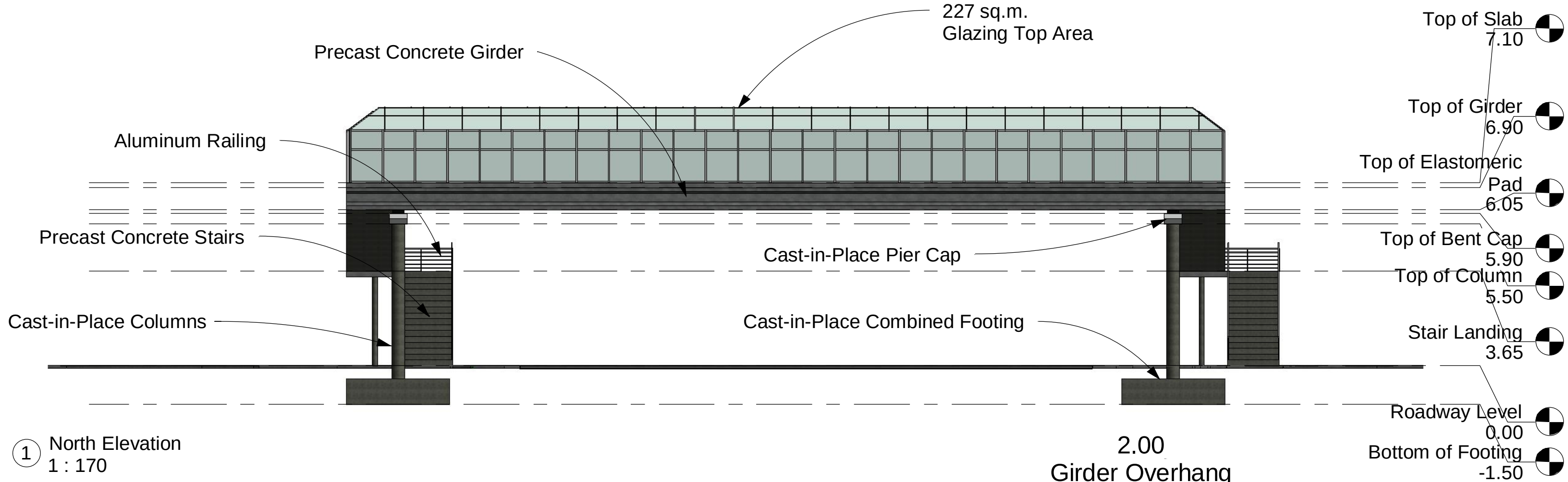
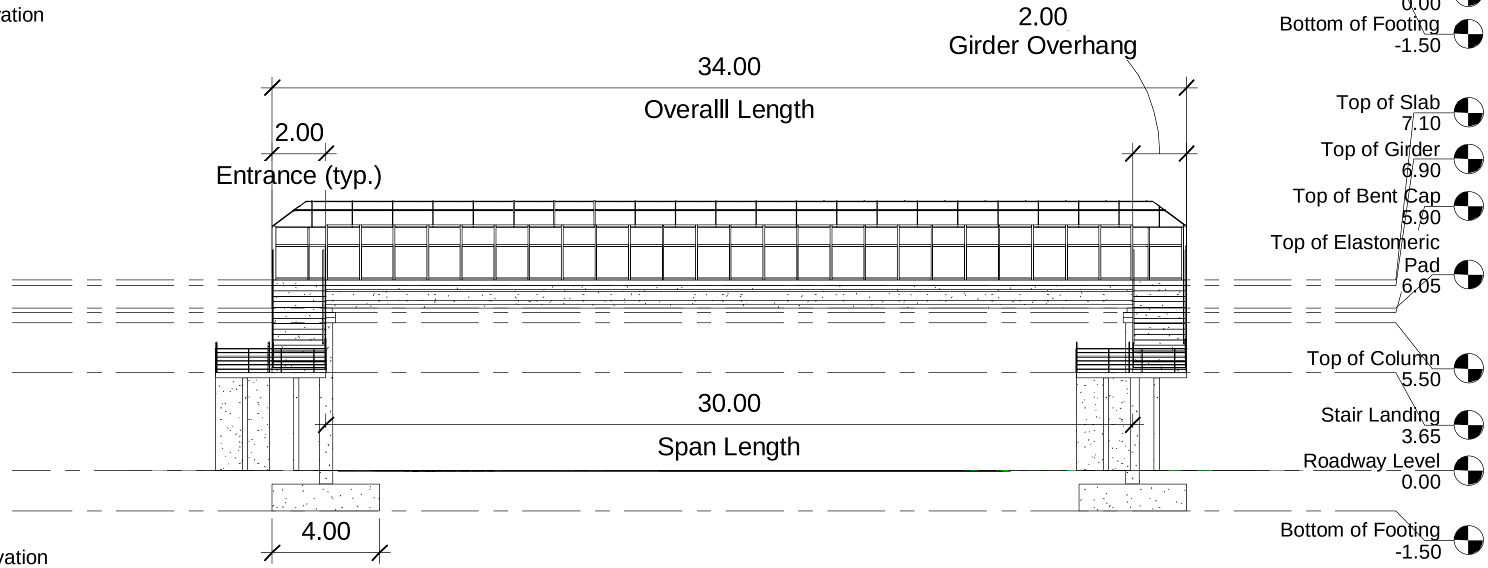



1 North Elevation
1 : 170




2 South Elevation
1 : 170

| North & South Elevation | | DESIGNED & DRAWN BY: | NOTE: | REVISION | DATE: | CONTENT | CLIENT: |
|---|---|---|---|---|---|---|---|
| NAME OF THE DRAWING: | AS MENTIONED | TEAM 14 | - ALL DIMENSIONS IN METERS.<br>- DO NOT MEASURE FROM THIS DRAWING<br>- REPORT ANY DISCREPANCIES TO THE DESIGNER | | | | |
| SCALE: | AS NOTED | | | | | | |
| DATE: | April, 2022 | | | | | | UBC |

**3D Renderings**


TEAM 14


4 m