University of British Columbia

Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

# East Mall Redesign

Prepared by: Francis Hsu, Lane Isaac, Ryan Keefe, Joshua Rea, Steve Sun, Evan Zenke

Prepared for:

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University of British Columbia

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# Executive Summary

A comprehensive, detailed design has been prepared for review in response to the University of British Columbia's request for a complete redesign of the East Mall corridor. The section of East Mall under consideration is located between West 16th Avenue and Agronomy Road on the south side of campus. With guidance from the client, UBC SEEDS, the detailed design looks to revamp the corridor into a new and effective design with sustainability and functionality as core design principles. Furthering the concept of sustainability, a holistic approach of incorporating a bioswale, recycled road material, and environmental planning is used. To address the functionality and concerns raised by UBC SEEDS, designers incorporated the use of road geometry, traffic calming, bus stops, drop-off zones, traffic analysis, pavement, signage, and canopy designs. Through these design elements, designers look to promote sustainable modes of traffic such as foot traffic, public transit, and cycling by making the corridor more livable for users.

To ensure that the detailed design is logistically feasible, designers considered the impact on the community, the environmental management, maintenance over the life cycle, construction methodology/schedule, and cost. The ultimate result of the detailed design is a construction start date of May 1st, 2021 and a completion date of October 6th, 2021, which will be broken down into different construction phases. The project's total estimated cost is expected to be $9,102,000+tax, which includes all design and support costs.

The design team is excited to present the detailed design of the East Mall redesign project. It is with the utmost pride to have been selected and afforded the opportunity to contribute to the University of British Columbia's community. The team looks forward to assisting with the project as it moves towards the construction phase to ensure this project comes to fruition.

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# 1.0 Introduction

The East Mall road is located in the southwestern part of the University of British Columbia (UBC) Vancouver Campus. It is a major arterial route that brings students, athletes, staff, and visitors onto campus. East Mall has multiple purposes, such as street parking for students, a pick-up and drop-off spot for athletes, the main cycling route to get onto campus, and a major walking path for the people that live beside East Mall. It is a multimodal traffic route that the team has redesigned to achieve all the client's requests and convert it into modern, green infrastructure.

## 1.1 Background

East Mall has shown that it is out of date and in need of upgrades. According to traffic data, vehicles frequently exceed the speed limit along the road, which needs to be addressed. If the users and people living in the area do not feel safe on East Mall, people will be less likely to use it. Secondly, with the sports fields on the northwest side of East Mall, it becomes very congested during peak pick-up and drop-off times. Vehicles have resorted to stopping in the bicycle lane to perform quick drop-offs. This is not a safe method for pick-ups and drop-offs, as the driving lane and cycling lane get squeezed into a single lane from the double-wide parked vehicles. This is also inefficient because cars parked closest to the curb can get trapped from parked vehicles between them and the driving lane, spending more time in the pick-up and drop-off area than needed. Additionally, cyclists lack a barrier between themselves and vehicular traffic, resulting in a reduced level of service (LOS) for cyclists. The cycling lane is in the middle of the driving lane and parking spots; this leaves little room to make sudden adjustments if something out of the ordinary were to happen. Furthermore, East Mall lacks green infrastructure. It may be subjectively nice to drive down because of the trees and sports fields, but the abundance of paved/impervious surfaces has resulted in too much stormwater run-off. East Mall comes with its challenges, but the team is confident the design addresses those concerns.

## 1.2 Scope

To help the team overcome the challenges outlined in the previous section, the challenges were compartmentalized to areas in which the team's engineers could use their expertise to efficiently resolve the issues. The major design components considered for the project are the road alignment, traffic calming features, bus stops, intersection design, pavement design, a bioswale, and a canopy structure on Agronomy Road.

# 2.0 Project Design Considerations

The team began the project by forming a clear understanding of the client's requests to develop the project design criteria.

## 2.1 Factors of Influence

Working with the client, the team was able to identify and categorize the most significant issues for East Mall. In this method, the team created a design that meets all the client's requests. The requests from the client are as follows:

- Incorporate green infrastructure on East Mall
- Reduce vehicular traffic speed and density
- Increase the corridor liveability
- Improved pick-up and drop-off areas
- Increase the active transportation that travels along East Mall
- Reduce stormwater run-off
- Provide a canopy structure along Agronomy Road

Additionally, the client requested this project be as sustainable as possible and promote environmental stewardship. The team believes these requests from the client are the most influential for creating the project's design and the team used extreme attention to detail to achieve these requests.

## 2.2 Community Impact

Community impact was a primary consideration through all stages of the design process. Since the project will have a significant impact on the local community, it was important for the design team to ensure public opinion was adequately incorporated. Based primarily on the site location, the following stakeholders comprise the parties most affected by the project:

- UBC SEEDS
- UBC Campus and Community Planning
- UBC Community
- UBC Plant Operations
- UBC Endowment Lands
- UBC Residence and Housing
- BC Ministry of Transportation and Infrastructure
- TransLink
- Musqueam

The list above includes, but is not limited to, significant stakeholders. Each stakeholder provides unique perspectives with respect to their concerns; thus, the final design is one that all parties are satisfied with. The team understands the importance of addressing the appropriate stakeholders' concerns in the final design; however, not all concerns can be incorporated. The design team developed a stakeholder interest matrix to quantify the level of influence each party has.

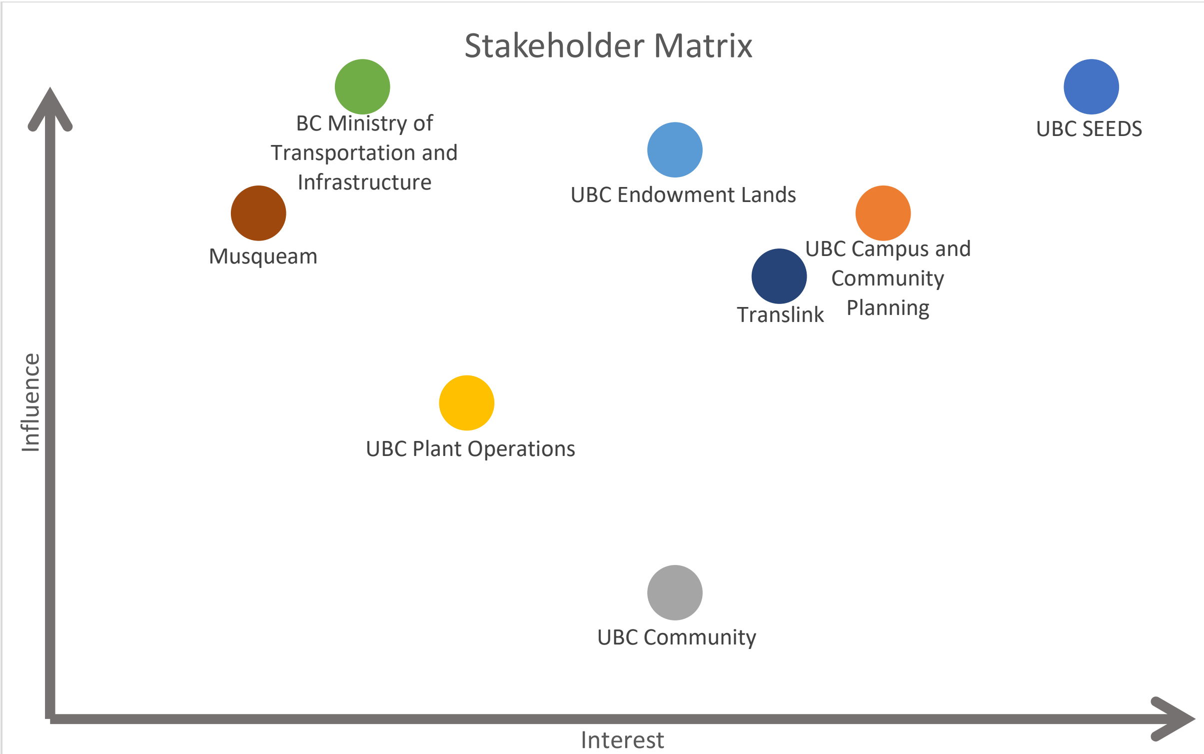


*Figure 1: Stakeholder Matrix*

## 2.3 Design Criteria

To achieve the requests outlined in the previous section, multiple design standards, guidelines, models, and software were used to accomplish the requests. The codes and manuals from various governing bodies formed the relevant design criteria for each phase of the East Mall Redesign. The following table outlines each phase of the project and relevant guidelines that were used during the design.

*Table 1: Codes and Guidelines Summary*

| **Design Phase** | **Relevant Manuals/Guidelines** |
|---|---|
| **Road geometry** | • Transportation Association of Canada Geometric Design Guide for Canadian Roads<br>• UBC Vancouver Transportation Plan (2014)<br>• BC Transit Infrastructure Design Guidelines |
| **Intersection design** | • Manual on Uniform Traffic Control Devices |
| **Pavement design** | • AASHTO Guide for Design of Pavement Structures (1993) |

| | |
|---|---|
| **Sidewalks & Cyclist lane** | • Ministry of Transportation & Infrastructure Active Transportation Design Guide |
| **Bioswale** | • Stormwater Source Control Design Guidelines (2012) |
| **Canopy structure** | • National Building Code of Canada (2015)<br>• CISC Handbook of Steel Construction (2017)<br>• CSA Engineering Design in Wood Manual (2019)<br>• API Pile Design Manual (2007) |
| **All design phases** | • City of Vancouver Engineering Design Manual<br>• City of Vancouver Standard Detail Drawing Standard |

## 2.4 Limitations

Several limitations within the design stem from the lack of available information and the design team's inability to view the existing site conditions due to the COVID-19 travel restrictions. The first limitation was the lack of underground service data along the East Mall corridor as SEEDS could not produce drawing documents for the design team. This led to several assumptions regarding the depth of existing services and determining all the underground infrastructure's exact locations. The lack of topographic survey data also created issues with determining precise utility locations, existing road slopes, and general flow paths of water for the bioswale design. The team had to utilize Light Detection And Ranging (LiDAR) data from the UBC geodetic database. Still, the contour elevation accuracy provided a 25cm discrepancy with the calculated road elevations for the design. Existing core data was also unavailable, making it difficult to estimate the existing asphalt lift and subbase thickness for the road's milling and pulverization. Finally, the team could not visit East Mall in person to view the existing site conditions. This made it difficult to perceive where existing signages, paint lines and key utility lines are located. The team could only utilize the most recent Google Maps street view platform to view the site. Therefore, an assumption was made that no significant changes have occurred within portions of East Mall between the time the photo was taken and the present day.

# 3.0 Detailed Design

The redesign of East Mall consisted of an upgraded road corridor, a new overhead canopy located at Agronomy Road, and stormwater management systems. The upgraded corridor includes new road cross-sections, bus stops, signalized intersections, traffic calming measures, and a tie-in to UBC's Stadium corridor. A summary plan of the components of the detailed design is shown below:

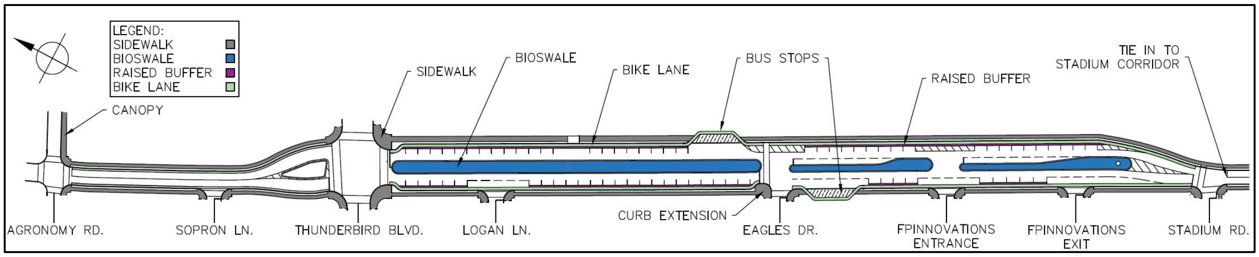


*Figure 2: Project Plan*

## 3.1 Road Geometry

All road features were designed according to the Transportation Association of Canada (TAC) Geometric Design Guideline provided by UBC and the City of Vancouver's Engineering Design Manual. The new corridor's main geometrical changes compared to the existing road is the re-ordering of various road lanes to improve cyclist safety (see Figure 3).

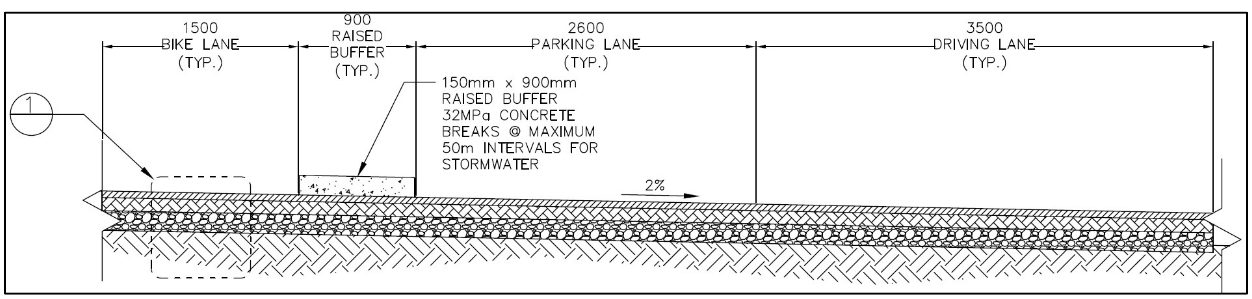


*Figure 3: Typical Road Section*

The bike lane was moved from between the driving and parking lane to the outermost edge of the road pavement. An additional raised buffer was added between the bike lane and parking lane. The parking lane acts as the primary line of protection from driving vehicles, while the raised buffer protects cyclists from cars parking and vehicle doors opening. All road pavement from FPInnovations to Thunderbird Boulevard is sloped towards the center of the corridor to allow for stormwater drainage into the bioswale located in the 6-meter wide center median (Figure 4).

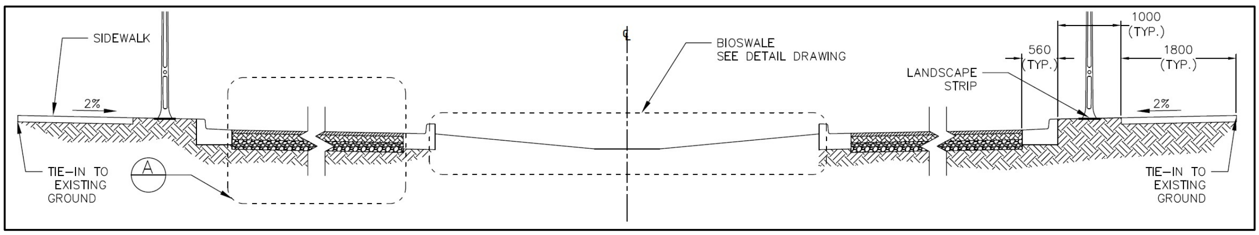


*Figure 4: Road with Bioswale Cross Section*

Because the parking lane was moved closer towards the driving lane, the intersection at Eagles Drive was adjusted slightly to ensure pedestrian safety. On top of new signalization, a curb extension was added at the northwest corner of the intersection to increase site distances for pedestrians and drivers (Figure 5).

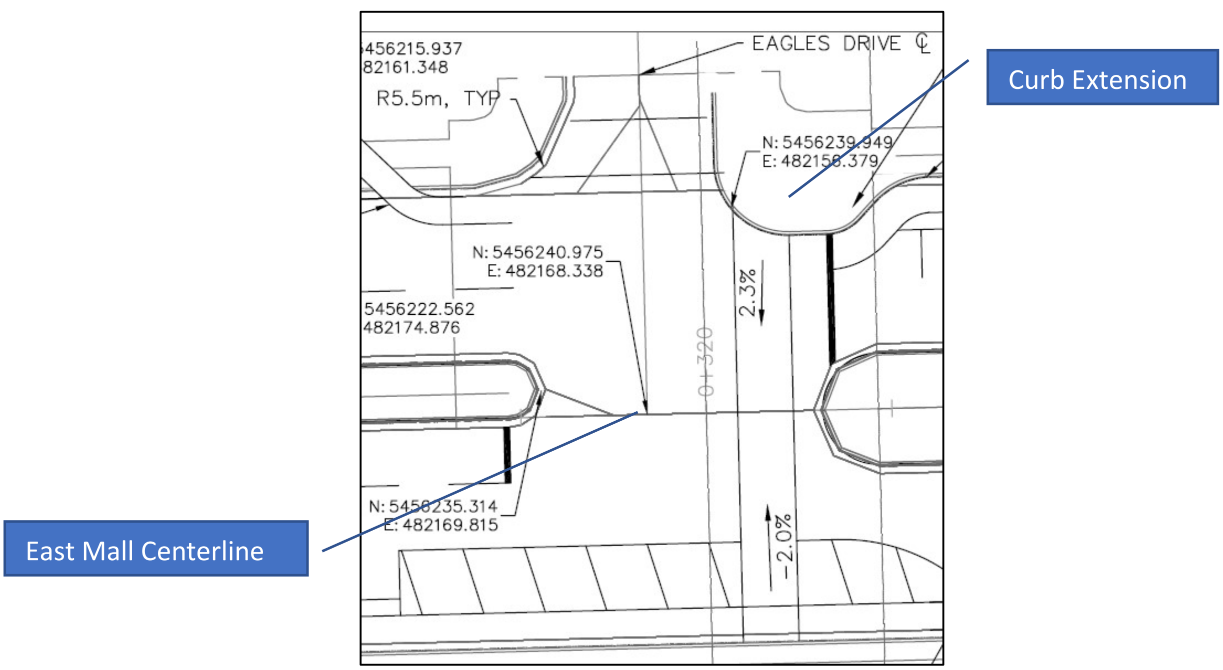


*Figure 5: Eagles Drive Intersection*

Upgrading infrastructure for pedestrians and cyclists not only improves their safety but also contributes to the team's goal of increasing corridor livability and encouraging multimodal transportation. All other areas of the corridor without a center median will maintain a typical road crown with 2% slopes away from the road centerline, as shown in the figure below.

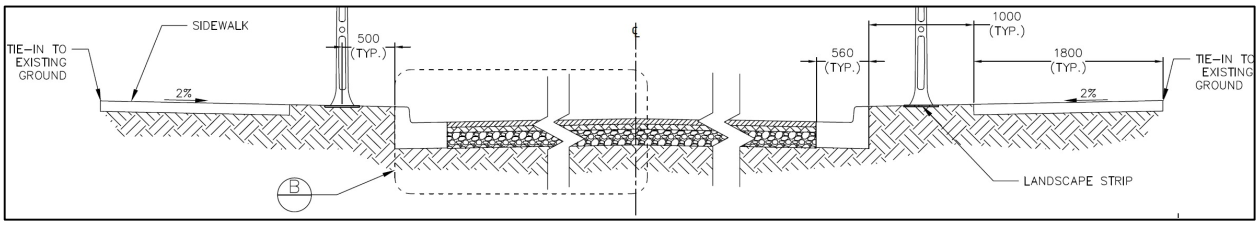


*Figure 6: Typical Road Cross Section*

The new redesign of the road between Stadium Road and Thunderbird Boulevard resulted in a reduction of overall pavement width from an average of 29m to 25m, which resulted in a 13.5% decrease in asphalt surface area.

## 3.2 Traffic Calming

Several traffic calming features were added to the design to address the lack of pedestrians and cyclist's safety along the East Mall Road. The first traffic calming feature implemented was the change of buffer region between the cyclist lane and parking lane. The buffer region will now prioritize the safety of cyclists as the parking stalls will now be placed alongside the East Mall traffic lane. This will effectively narrow the driving lane and reduce the overall speed of vehicles along the East Mall road as the drivers must account for the reduced maneuverability within the road.

Another traffic calming feature includes the addition of pedestrian curb extensions along the Eagles Drive intersection. This is shown in drawing C02-08 of the drawing package in Appendix A. These curb extensions will provide adequate room for pedestrian safety and reduce overall traffic speed for vehicles entering the intersection.

Traffic lights will also be installed at both the Eagles Drive and Stadium Road intersections to reduce overall travel speed along the East Mall corridor. Speed limit enforcement techniques such as speed cameras or vehicle-activated speed signs will be implemented if speeding continues to persist within the proposed East Mall design.

## 3.3 Bus Stop

To further encourage multimodal transportation and improve cyclist safety, the two existing bus stops located near the Eagles Drive intersection were redesigned. The two existing bus stop locations are shown in Figure 7.

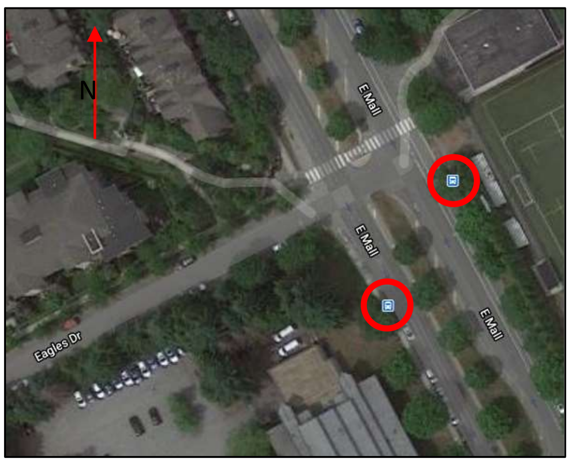


*Figure 7: Existing Bus Stops*

The bus stops were redesigned to assist with encouraging multimodal transportation and providing adequate safety for cyclists. The existing infrastructure requires buses to impede the bike lane when entering the stops, which results in cyclists having to wait or pass around the left side of the bus. Passing around the left side of the bus exposes cyclists to buses exiting the stops and vehicles in the driving lane. To help mitigate these issues, a new bus stop is to be implemented with the main feature being the rerouting of the bike lane behind the bus stop, as shown in Figure 8.

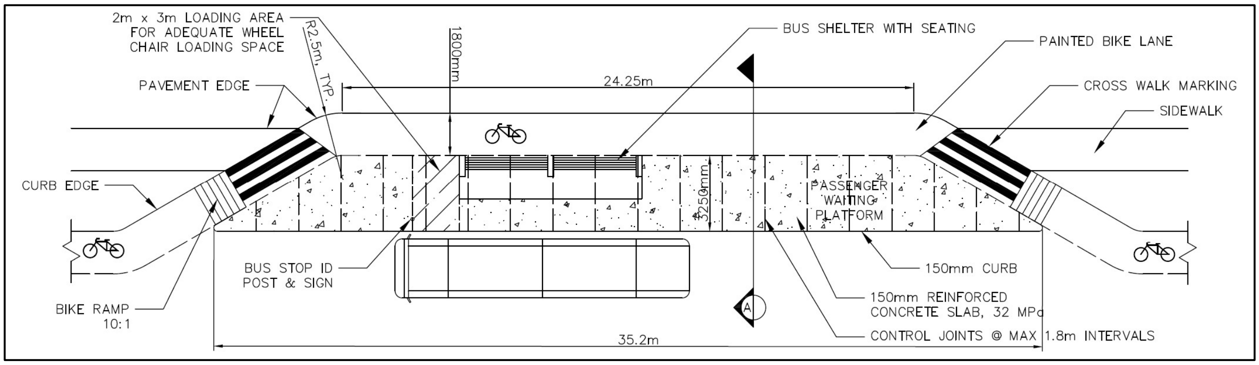


*Figure 8: Typical Bus Stop Plan*

The new bus stop design was designed according to the 2010 BC Transit Infrastructure Design Guidelines and the 2018 BC Transit Infrastructure Design Summary. A bus shelter and a waiting platform were also added to improve rider comfort, encouraging multimodal transportation (Figure 9).

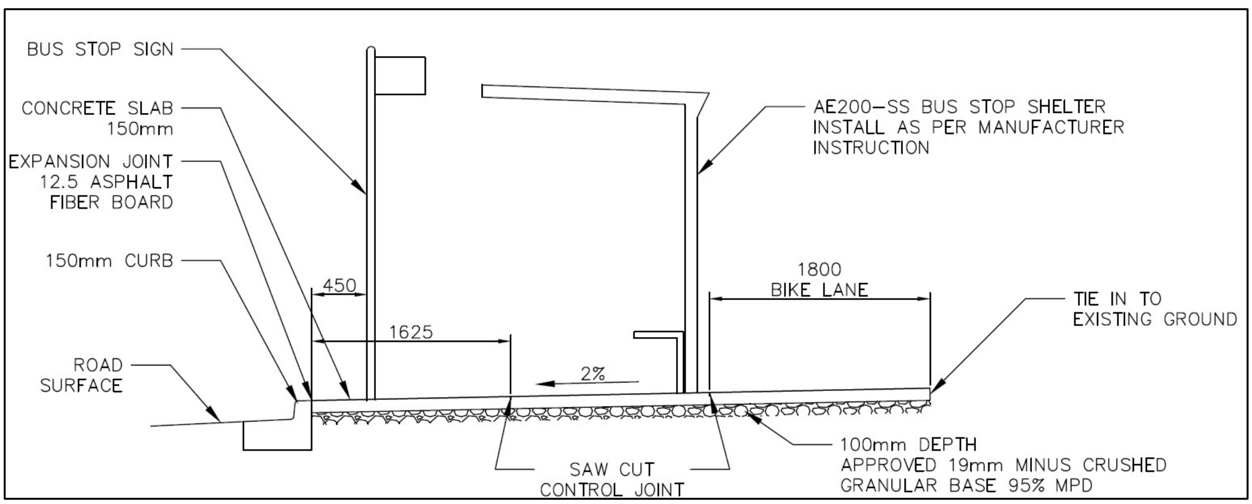


*Figure 9: Bus Stop Elevation View*

## 3.4 Drop-off Zone

At periodic times in the year, pick-up and drop-off at the sports field reaches its capacity and causes logistical issues with traffic. During these peaks in capacity, vehicles monopolize the available parking spots and do not allow other vehicles to safely stop to pick up/drop off as needed. In some scenarios, vehicles will double park in the existing bike lane, which creates a hazard for cyclists and motorists. To remedy the situation, pick up and drop off signage will be posted along the highlighted area in Figure 10.

The signage will limit parking in the designated areas, allowing vehicles to remain for no longer than 15 minutes in a given stall. This will help ensure sufficient turnover in the allocated spots to the field while curbing potential hazards.

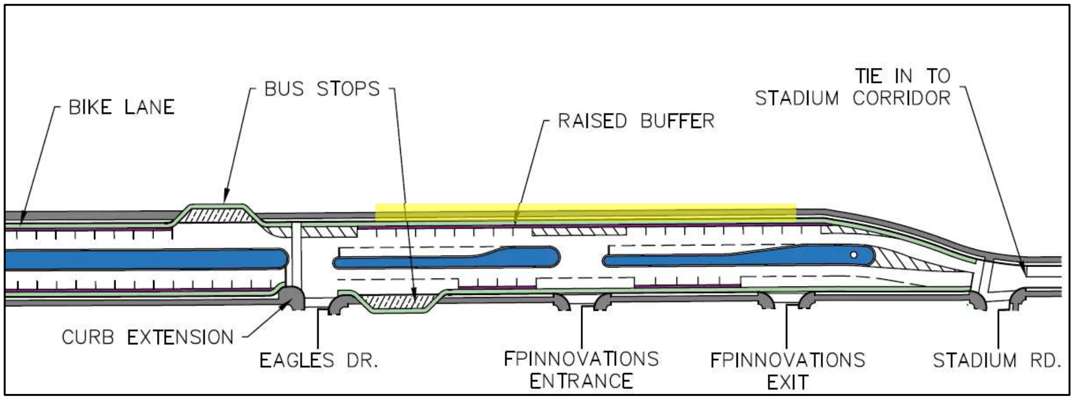


*Figure 10: Pick up & drop off zone*

## 3.5 Traffic Analysis

A detailed traffic analysis was conducted utilizing traffic volume data obtained from Creative Transportation Solutions (CTS) in October 2019 through the Synchro 6 traffic analysis program. The Level of Service (LOS) data obtained from Synchro will be based on the 2010 Highway Capacity Manual (HCM) LOS for each intersection along the East Mall road [1].

### 3.5.1 Existing Traffic Analysis

In Table 2, a traffic data summary for each existing intersection is provided. It is shown that the existing Stadium Road intersection is currently at an LOS rating of F, indicating a long delay for traffic to enter the East Mall corridor. This issue is also prevalent for Eagles Drive and Stadium Road intersections during peak hours in the PM timeframe as the LOS dips from an A to C rating for both intersections. For the Agronomy Road and Thunderbird Boulevard intersections, the design would retain both existing intersection controls as they are within acceptable LOS standards.

*Table 2: Existing Intersection Data*

| EXISTING EAST MALL ROAD INTERSECTION DATA | | | | |
|---|---|---|---|---|
| Intersecting Road | Agronomy Road | Thunderbird Blvd | Eagles Drive | Stadium Road |
| Control Type: | Unsignalized | Signalized-Pretimed | Unsignalized | Unsignalized |
| | **East Mall Intersections - AM Traffic Volume** | | | |
| LOS: | A | B | A | F |
| Average Control Delay (s): | 10.7 | 12.4 | 13.4 | 51.6 |
| Intersection Capacity Utilization: | 46.8% | 67.8% | 43.5% | 60.1% |
| | **East Mall Intersections - MD Traffic Volume** | | | |
| LOS: | A | A | A | A |
| Average Control Delay (s): | 8.4 | 9.1 | 8.6 | 9.3 |
| Intersection Capacity Utilization: | 37.0% | 35.5% | 31.6% | 39.6% |
| | **East Mall Intersections - PM Traffic Volume** | | | |
| LOS: | A | B | C | C |
| Average Control Delay (s): | 11.4 | 12.3 | 16.0 | 19.0 |
| Intersection Capacity Utilization: | 44.0% | 68.4% | 59.0% | 62.7% |

### 3.5.2 Future Traffic Analysis

To account for the future influx of vehicular traffic along the East Mall road, a growth factor of 1% per year through a 25-year timeframe was used as suggested by UBC SEEDS [2]. Under the projected 2045 traffic data, implementation of 2 new semi-actuated signalized traffic lights have been placed along both Stadium Road and Eagles Drive intersections as a means to address the existing LOS issues. These traffic lights will act as a traffic calming feature for East Mall road as it will reduce overall vehicular speeding while also providing safer pedestrian crossing options. In Table 3, a traffic data summary for each future intersection is provided.

*Table 3: New Design Intersection Data*

| FUTURE EAST MALL ROAD INTERSECTION DATA | | | | |
|---|---|---|---|---|
| Intersecting Road | Agronomy Road | Thunderbird Blvd | Eagles Drive | Stadium Road |
| Control Type: | Unsignalized | Signalized Pretimed | Signalized Semi-Actuated | Signalized Semi-Actuated |
| | **East Mall Intersections - AM Traffic Volume** | | | |
| LOS: | A | B | A | A |
| Average Control Delay (s): | 10.7 | 12.4 | **5.6** | **6.4** |
| Intersection Capacity Utilization: | 46.8% | 67.8% | 43.5% | 60.1% |
| | **East Mall Intersections - MD Traffic Volume** | | | |
| LOS: | A | A | A | A |
| Average Control Delay (s): | 8.4 | 9.1 | **4.3** | **4.1** |
| Intersection Capacity Utilization: | 37.0% | 35.5% | 31.6% | 39.6% |
| | **East Mall Intersections - PM Traffic Volume** | | | |
| LOS: | A | B | A | A |
| Average Control Delay (s): | 11.4 | 12.3 | **3.5** | **6.1** |
| Intersection Capacity Utilization: | 44.0% | 68.4% | 59.0% | 62.7% |

### 3.5.3 Phasing

With the introduction of the two new traffic lights working in tandem with the Thunderbird Intersection lights, further optimization was done towards the phasing time to prioritizes the through movement of traffic along the East Mall road. The final design of the phasing times will also incorporate a dedicated semi permissible left turn light for the Thunderbird intersection. The results of each phasing time throughout the day are shown in Appendix B, with a maximum phasing cycle of 69 seconds in length during peak rush in the AM. In Figure 11, the average traffic delays during peak hours in the AM for the entire East Mall corridor are shown with respect to the new phasing cycles implemented for the design.


*Figure 11: Traffic Delays*

This shows that the maximum delay along the entire East Mall will be roughly 15 - 25 seconds, therefore making it a maximum LOS rating of B during peak traffic flow under standard traffic volume conditions.

## 3.6 Pavement Design

From the traffic data collected by CTS, it was possible to develop a pavement structure design that will service motorists for years to come. The American Association of State Highway and Transportation Officials (AASHTO) was used as the principal design guide to formulate the road structure design. With a service life of 25 years in mind for the pavement structure, the designers found the appropriate traffic load in Equivalent Single Axels (ESAL) that the road would be subjected to. Once the traffic loading conditions were found, attention was shifted to the type of structure the designers wanted to use.

As part of the sustainability initiative within the East Mall Redesign, the engineers wanted to reuse as much of the existing material as possible in the new design. To reduce waste, the engineers optioned for a pulverize-stabilize approach. Pulverizing is the process of taking the existing road and breaking down the asphalt, and mixing it in with the underlying base. By taking this approach, it introduces variability into the base material that demanded consideration. To account for this variability, the material must be stabilized with type-10 portland cement to promote cohesion between the variable material.

With the type of desired methodology identified, the engineers referred to the AASHTO design guide and the State of Connecticut design practices to develop a comprehensive structure. From the design load in ESAL and site supporting parameters, the engineers were able to find the minimum required structural number that is demanded to ensure the road is sufficient. To meet the required structural number, designers used layer coefficients, depths, and drainage coefficients. The ultimate result is two separate pavement designs shown in the following figure, while calculations are shown in Appendix C.

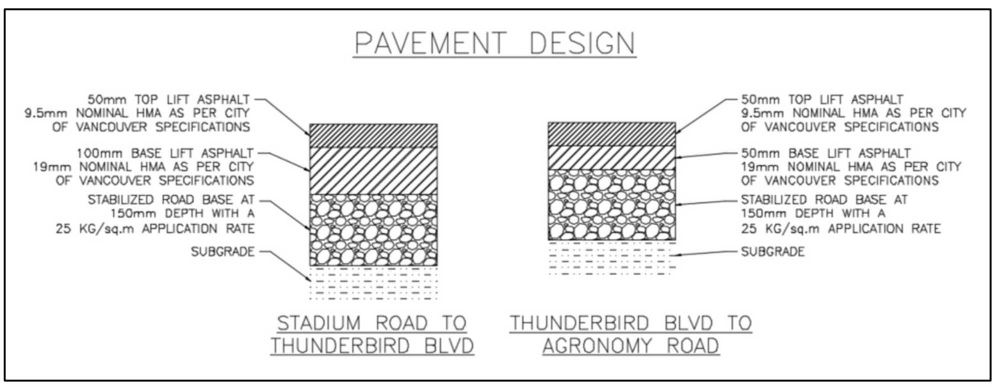


*Figure 12: Pavement Design*

When formulating the stratified layers that would comprise the road structure, the designers were cognizant of the idea of cost, constructability, and functionality. To help reduce material costs, designers split East Mall into two separate sections. The first section is between Agronomy Road and Thunderbird Blvd, while the other is between Stadium Road and Thunderbird Blvd. The rationale behind this is there is less traffic on the first section than the latter. To help mitigate cost, designers opted to use a thinner base-lift asphalt depth to save material costs. To make the constructability of the road structure viable, designers selected typical depths that can be transferred to imperial units easily for crews on site. Compounding the idea of using typical industry standards, engineers referenced typical Hot Mix Asphalt (HMA) designs from the City of Vancouver. Working in sequential order, the road base will comprise of reused road base stabilized with 25 kg/m2 portland cement at 150 mm depth. Paved on top of the base will be a 19 mm nominal HMA base-lift and subsequently a 9.5 mm nominal HMA top-lift of asphalt. The depths between the two different designs vary slightly, but the material selection is uniform to simplify the paving operations' constructability. When shifting to the functionality of the structure, designers wanted to use a thinner top lift of asphalt with a smaller nominal aggregate to allow for improved rideability. In addition, having the thinner top lift of asphalt lends itself to future rehabilitations better as it allows for the option of milling the road surface and replacing the top lift of asphalt.

## 3.7 Signage

Whenever there is a new project, public safety is considered with the utmost importance. To ensure that the public is safe, it is vital that line painting, signage, and lights are designed according to relevant documents and specifications. As a primary source to create the signage, traffic lighting, and line painting plan for the East Mall Redesign, the City of Vancouver specifications were referred to. However, the City of Vancouver did not provide all relevant information to formulate the detailed plan but provided excellent local guidance. To fill the void of absent information, the City of Vancouver recommended designers refer to the Manual of Uniform Traffic Control Devices (MUTCD) guide for streets and highways.

## 3.8 Bioswale

To reduce the surface run-off from the site and incorporate green infrastructure, a bioswale was designed in three of the meridian sections of East Mall. Bioswales are effective, natural filtration spots that allow rainwater and run-off to infiltrate back into the surrounding soil. Bioswales also act as temporary storage of rainwater in the event of a large storm. Bioswales allow for rainwater to be retained before the rainwater needs to be directed to a storm sewer. When rainwater is “cut off” and flows into the bioswale, it reduces the volume and flows that the storm sewer will experience; consequently increasing the storm sewer's lifespan and reducing maintenance costs. Whereas the bioswale is much easier to maintain, fixing the bioswale is mostly plant replacement and vegetation control. Furthermore, bioswales can be designed to be aesthetically pleasing – making them effective for storm mitigation and incorporating green infrastructure.

### 3.8.1 Design Considerations

When designing the bioswale, multiple factors must be considered. These factors include the intensity of the storm, the volume of water that the storage requires, the type of material used, and existing infrastructure. The stormwater design manual that the team used to design the bioswale is the Stormwater Source Control Design Guidelines 2012 for Metro Vancouver. The design manual considers storm intensity and average yearly rainfall, the impervious areas that flow to the bioswale, and the pervious areas of existing soil to infiltrate the run-off. As shown from the calculations in Appendix D, the bioswale will be approximately 2.8 meters deep from the top of the curb, split into three layers. As shown in Figure 13 is the typical cross-section of the bioswale. Also shown in the drawing is the use of filter fabric; the fabric adds a small amount of rigidity to the material to be held in place.

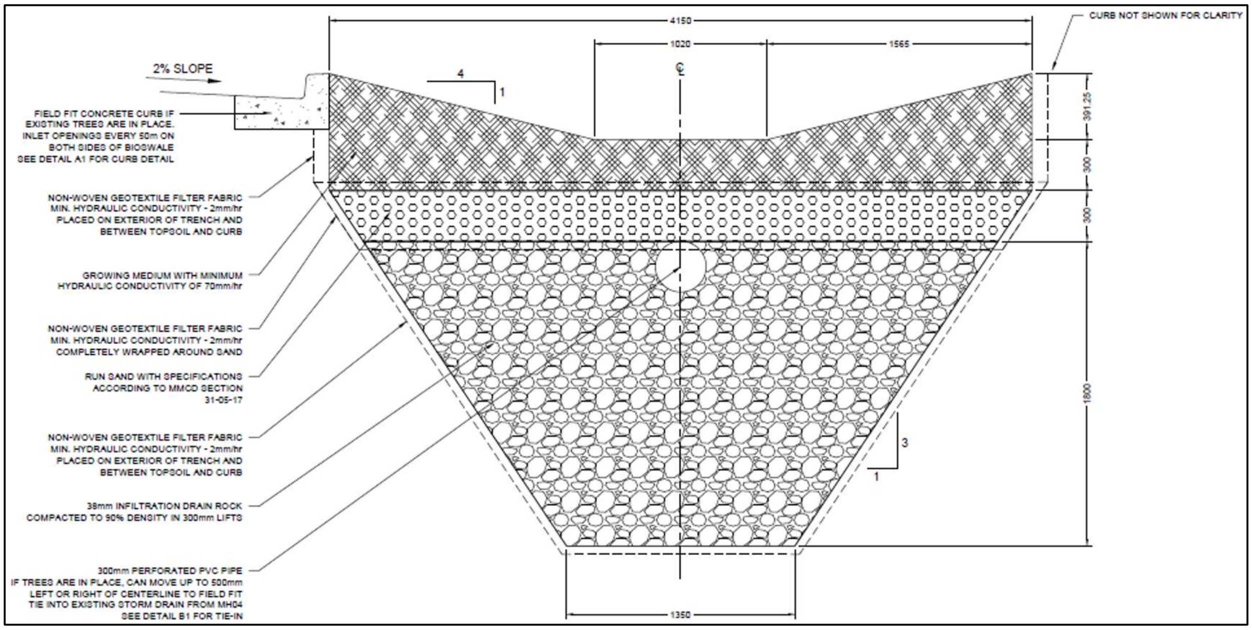


*Figure 13: Bioswale Cross-Section*

Also, the fabric acts as a permeable layer where water can freely flow through it, but the material wrapped in the fabric is prevented from displacement. Filter fabric prevents unwanted materials, like sand and silt, from entering the drain rock of the bioswale.

Another consideration of the bioswale is the use of highly permeable material. Rainwater needs to flow through the top two layers with little resistance to flow into the drain rock. Therefore, the use of sandy loam is suggested for the top layer. This material is suitable for supporting plant life and permeable enough to satisfy the design guidelines. Secondly, the sand layer needs to be compacted to 95% of maximum proctored density. As sand is a highly permeable material, water will have no issue flowing through to the drain rock. Finally, the infiltration of rainwater into the existing soil occurs when the water is in the drain rock storage.

At the top of the drain rock is a perforated pipe. This pipe is in place so that if there is a severe storm to fill the storage of the drain rock, the pipe can continuously transfer water between meridian sections of the bioswale. Moreover, the last bioswale section will be connected to the existing storm sewer adjacent to the southern-most meridian. The perforated pipe will be a solid pipe between meridians where it will be covered by asphalt. This allows for the continuous flow of water into the next bioswale section and adjacent manhole during a severe storm event. It also prevents the loss of water below the asphalt surface, reducing the chance for water damage to occur to the subgrade of the road. The perforated pipe is a safety measure to prevent overflowing; however, since the existing storm drains surrounding East Mall will still be active, and the area where precipitation flows into the bioswale is small, the chances of overflowing are minimal.

Furthermore, existing infrastructure needs to be examined. The existing storm and sanitary lines are in line with the bioswale, but they are 3 meters below grade and will not be affected. On the other hand, the water main is aligned with the bioswale and is expected to be 1.5 meters below the existing grade – approximately 0.5 meters below grade of the bioswale's perforated pipe. However, the team believes that the bioswale drain rock will be compacted enough and more than deep enough to be suitable for the pipe bedding of the water main. Therefore, the water main will not have to be relocated out of the bioswale, and services will remain in place throughout the duration of construction. Contractors are to take care to fully support the water main when excavating the bioswale until the drain rock has been placed and use thrust blocks as required.

Finally, the perforated pipe network needs manhole installation to provide maintenance of the pipe. These are only for clean-out purposes as the system is small. Therefore, the depth of the manholes can extend to the bottom of the bioswale excavation for ease of installation. The pipe network will begin at station 0+515 with no manhole, so water does not sit stagnantly inside the manhole. As per the City of Vancouver's design standard for storm sewers, the maximum spacing between manholes is 183 meters. With this spacing, the team designed to put manholes at stations 0+340, 0+220, and 0+135. From station 0+135, there will be a solid pipe connection to the adjacent existing storm manhole, allowing for gravity drainage. The minimum slope of the perforated pipe is 0.5%; however, the slope of the pipe will follow the grade as proposed in the new profile of East Mall. Contractors are to consult with bioswale consultants for the installation of the bioswale and perforated pipe network.

## 3.9 Canopy

The canopy structure is included in the design with the purpose of providing the project area with an architecturally pleasing structural component. The structure is to be located on the northeast side of the intersection of East Mall and Agronomy Road, adjacent to the Gerald McGavin Building. In addition to the architectural beauty, the structure will also serve a practical use. The canopy will provide protection from adverse weather conditions for pedestrian traffic travelling along Agronomy Road. The following figure shows an elevation view of the canopy.

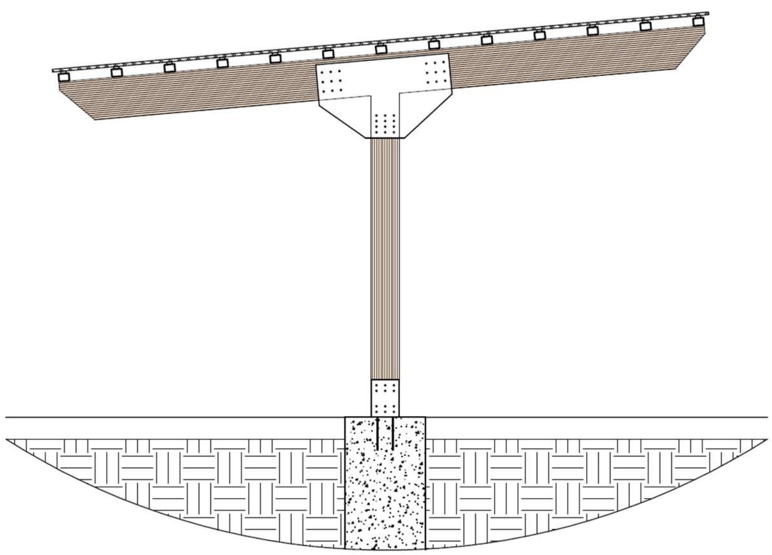

*Figure 14: Canopy Side View*

### 3.9.1 Design Considerations

There are many structural constraints included in the design of the canopy to ensure it functions as it was designed. Firstly, the sustainability initiative for the project as a whole was the overarching constraint for all canopy components. This initiative is shown through various aspects of the design. Firstly, timber was chosen as the primary structural component as it provides a more environmentally friendly option than other materials such as steel or aluminum. This is primarily due to the lower carbon emissions in timber production compared to other material manufacturing processes. Wood also acts as a carbon sink which further increases the canopy's sustainability. In addition, the structure also must align with the architectural style of the existing landscape. The surrounding area consists of multiple existing glass-roof canopies and an abundance of vegetation in the form of shrubs and trees along Agronomy Road. Furthermore, a robust design in terms of materials and sizing was desired as the team targeted a prominent final design. Detailed drawings are available at the end of the drawing package in Appendix A.

There are also various considerations relating to structural issues and possible failure mechanisms investigated during the structural design. A summary of the primary issues and likely failure mechanisms is outlined in the following table.

*Table 4: Structural Design Considerations*

| Issue/ Failure Mechanism | Description | Mitigation |
| --- | --- | --- |
| **Utility conflict** | Pile location may interfere with existing electrical utility lines | Hydrovac pile excavations to avoid destructive interference |
| **Unique material** | Glass surface structural design procedure is unknown | Ensure glass manufacturer approves glass portion of design |
| **Exposure** | Structural components exposed | Apply appropriate modification factors during design procedure |
| **Long-term deterioration** | Possible structural deterioration over the project life | Monitor structural integrity at appropriate intervals to ensure structurally sound |
| **Unexpected loading** | Possible accidental loads due to structure being outside | |

### 3.9.2 Structural Design

The design of the primary structural components of the canopy includes various assumptions based on project characteristics. While all assumptions influence the design process, only a select few are directly applied to the calculations as resistance factors. Additional assumptions made were stated throughout the design calculations, as shown in Appendix E. A brief overview of the notable considerations is as follows:

- Site dimensions were obtained via Google Earth due to the inability to access the site physically. The assumption is that the obtained measurements provide a sufficient degree of accuracy.
- For purposes of wind/snow loads, values were obtained based on data for a 1/50 year storm located at Granville and 41$^{st}$ Avenue.
- For timber design calculations, wet-service conditions were assumed considering the main structural components are exposed to adverse weather elements.
- Additional reduction factors are applied in various other aspects where required.

Computer program RISA2D was also used to aid in the structural design. The application was used to determine extreme values for each member; various models were analyzed throughout the design process, leading to a simple determination of maximum shear, bending and axial force values.

#### *3.9.2.1 Loads*

Design loads acting on the canopy structure were obtained in accordance with the 2015 National Building Code of Canada (NBCC 2015) [3]. Snow and wind load calculations were completed in detail and are based on various structural characteristics such as the snow accumulation factor. Load Case 3 provided the largest factored loading combination, according to the following load equation

$$W_f := 1.25 \cdot D + 1.5 \cdot S + 1.0 \cdot L$$

#### *3.9.2.2 Steel Design*

The purlin design was completed according to the procedure outlined in the Handbook of Steel Construction [4]. Based on the RISA2D shear and bending moment diagrams, the governing moment and shear design values were compared against the chosen Hollow Structural Steel (HSS) section resistance to ensure capacity was met. It should also be noted that the final purlin sectional properties are significantly over-designed for the given capacity to allow for freedom in the roof surface design.

#### *3.9.2.3 Timber Design*

All timber components were designed according to the 2019 Wood Design Manual (CSA086:19) [5]. RISA2D was used to obtain the design values for the top beams and supporting columns. For all glulam members, exposure to positive and negative bending moments was assumed. As a result, Douglas Fir-Larch 20f-EX and 24f-EX stress grades were chosen for the beams and columns, respectively.

#### *3.9.2.4 Foundation Design*

The foundation was designed in accordance with the procedure outlined in the American Petroleum Institute 2007 manual [6]. Each of the columns will transfer the canopy load to the underlying soil via friction piles. To meet the project's sustainability initiative, recycled aggregate is to be used in the concrete piles to help minimize the carbon demand.

# 4.0 Environmental Management Plan

An Environmental Management Plan (EMP) will be implemented for the East Mall redesign to comply with the project's designated environmental protection permits and approvals. The EMP will form the basis of an Environmental Assessment (EA) to be conducted before the construction process to determine any at-risk areas that could be affected by the redesign or construction process. The EA will catalogue the different types of species that are affected by the redesign. Secondly, a soil investigation shall be completed to determine any ground contaminants/pollutants within the surrounding area. All hazardous waste found shall be disposed of accordingly with compliance to the BC Ministry of Environment site remediation guidelines. Another feature of the EMP is restoration through Low Impact Development (LID). LID refers to the use of natural processes that result in infiltration, evapotranspiration, or stormwater management to protect water quality discharge in the neighbouring environment. LID is achieved through the redesign's integrated bioswale as it will act as a designated source control for any rainfall that has collected pollutants from the road.

Furthermore, a Construction Environmental Plan (CEP) shall be created for the duration of construction. The CEP shall include vehicle pre-site inspections, recording all equipment models and their engine types, and their respective engine efficiencies for all equipment used on site. This shall be done to monitor and control the total amount of environmental pollutants created by on site-personnel. An Emergency Spill Response Plan shall be introduced with the CEP to address any oil, gas, or unwanted fluid spilled on site. Additionally, a Storm and Wastewater Management Plan and a Sediment and Erosion Control Plan shall be implemented to control the large amount of dust and dirt that settles within the construction area. Silt traps will be installed and inspected regularly in manholes/storm drains to prevent any silt/dirt/dust/debris from entering the systems.

# 5.0 Methodology

The construction schedule is considered paramount to the success of the East Mall Redesign. Being cognizant of the project's impact on the various stakeholders, the project was discretized into three separate phases. This was done to minimize the project's duration and impact on the neighbouring communities while promoting an efficient means of construction.

## 5.1 Site Setup

The location for the site laydown area shall be at the southeast corner of the parking lot boarding Thunderbird Blvd and Health Sciences Mall. At this centralized location, the contractor should establish their site office as it has adequate space for temporary storage for materials and equipment throughout the project. Figure 15 illustrates the site setup.

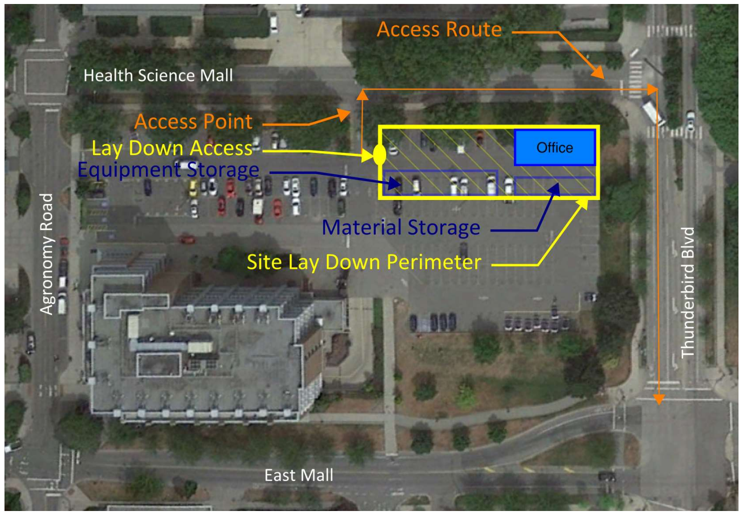


*Figure 15: Site Setup*

The rationale behind selecting the specified location is to keep operations localized throughout construction. The site setup should be fenced off to ensure the general population's safety while protecting equipment and materials from vandalism. In addition, it aids in keeping the site logistics localized to a single area. Within the confines of the site laydown, site lavatory facilities may be placed for onsite personal. To facilitate the access, the north entry should be used to ensure that equipment does not damage the adjacent vehicles in the parking lot. Also, following the designated route keeps disruption to the surrounding traffic and facilities to a minimum.

While the centralized project location is being set up, a team of surveyors shall be mobilized to the site. The surveyors will establish control points and conduct the preliminary field survey to create grades necessary for concrete work. Survey stakes and hubs will be placed on even stationing's to specify the cuts and fills for their respective chainage and shall be given to the contractor as a field reference to the design drawings.

## 5.2 Phase 1

Phase 1 of the East Mall Redesign will take place between Stadium Road and Eagles Drive. Due to the nature of East Mall being an arterial road, the designers wanted to maintain the flow of traffic throughout the duration of the project with intermittent closures. To maintain the safety of workers and motorists, construction will follow the flow of traffic. This will allow for a one-way flagger operation to stop traffic intermittently to allow for short-term work accommodations. The chronological order of work will follow a prescribed path that is mirrored in later phases. To illustrate the flow of construction, Figure 16 identifies the sequential order of operations.

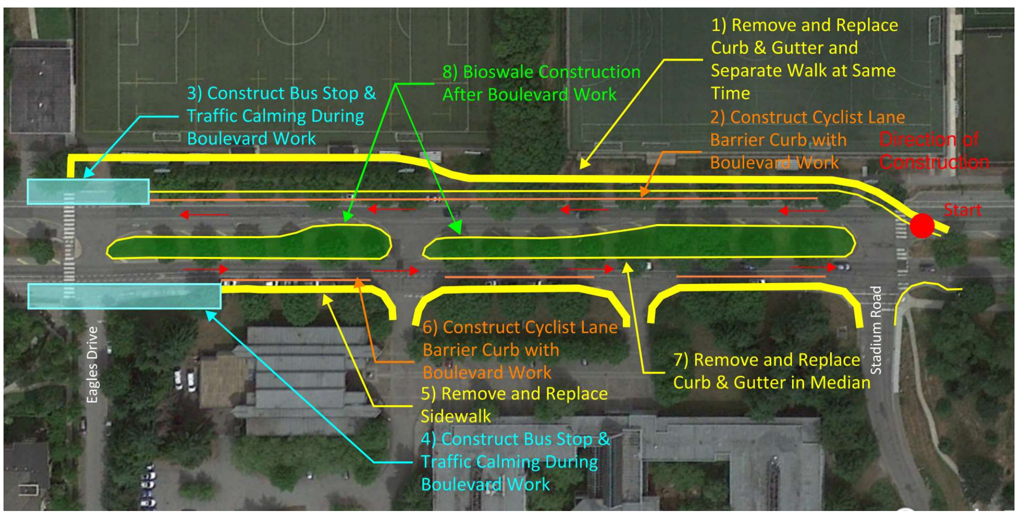


*Figure 16: Construction Phase 1*

Construction will start at the southeast corner of the phase and move northwards alongside the controlled traffic flow. The workers will be removing and replacing key items such as the separate walk, curb & gutter, and cyclist lane barrier curb as the construction crew moves towards the Eagles Drive intersection. Once the construction reaches Eagles Drive, the bus stops and traffic calming features will be built. After the construction of the bus stops and traffic calming features, construction will switch to the opposite side of the road and complete the boulevard work specified. While the initial construction crew is working on the west side of the road, a secondary crew will start median work on the east side of Phase 1. Taking this approach reduces the impact on traffic while allowing the flagger operations to divert traffic accordingly. The bioswale will have to be dug and installed up to the compacted sand layer in the median. It is important that a representative is contacted to inspect and make recommendations to ensure the existing trees are maintained within the bioswale at this stage of construction. Once the bioswale is up to grade, the workers may cast the concrete curb and gutter on the perimeter of the bioswale. Once all the concrete work is placed, survey crews shall be sent out to check coordinates and elevation against the Civil 3D master plan.

Upon verifying the adherence of the boulevard structure to the design drawings, road operations may commence. To start the road construction, the existing structure shall be pulverized using a mixer. After the road is pulverized to the limits of Phase 1, excess swell material shall be bulked out. 160 mm of depth shall be removed to account for the addition of portland cement and the future asphalt structure. Once excess material is removed, a 25 $kg/m^2$ application rate of cement shall be applied with water to the road structure with a mixing depth of 150 mm. Immediately after mixing, the road surface shall be graded and compacted thoroughly. Following the road base preparation, a 100 mm base lift of 19 mm nominal hot mix asphalt shall be placed. Note that the top lift will not immediately follow the base lift as it will be done when every phase of construction has completed the initial base lift accordingly. This ensures a more uniform driving surface and achieves proper compaction across each phase for the final lift of asphalt.

## 5.3 Phase 2

Phase 2 will occur between Thunderbird Blvd and Eagles Drive and shall follow a similar methodology as Phase 1 for construction. The critical steps within Phase 2 are identified and shown in Figure 17.

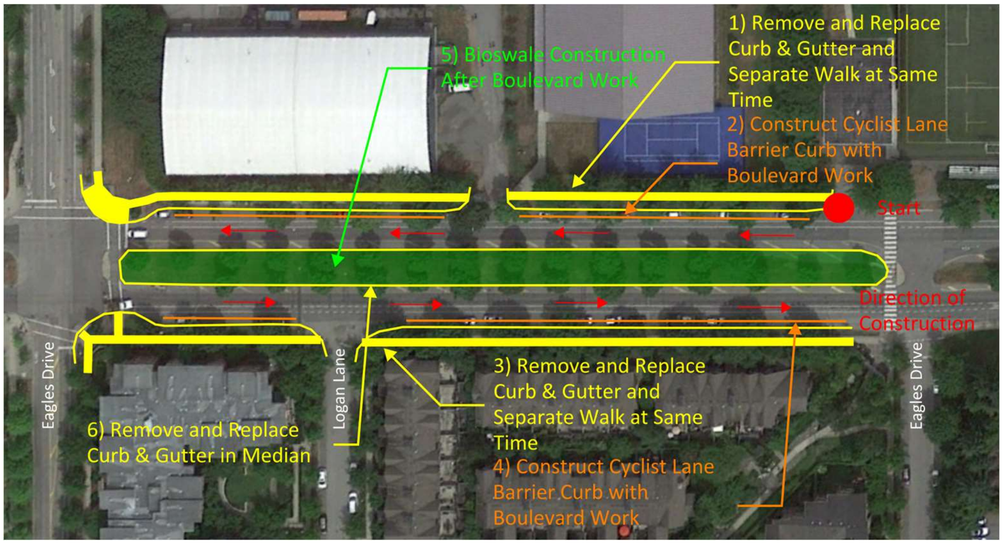


*Figure 17: Construction Phase 2*

Construction shall start on the east side of the intersection of Eagles Drive. Working in a counter-clockwise manner, the separate walk, curb & gutter, and cyclist barrier curb shall be removed and replaced. Once the crews reach Thunderbird Blvd, work shall switch to the opposite side of the road. Working southward, similar elements shall be replaced. Soon after the key work has been completed on the road's exterior sides, attention may be transitioned to the center median. The center median shall be excavated to the specification layout in the bioswale design indicated in Appendix A. and constructed accordingly. Once the bioswale reaches the installation of the sandy layer, the curb and gutter around the permitter of the bioswale shall be installed. Much like Phase 1, the bioswale must be inspected by a specified representative to ensure the preservation of existing trees.

Once the boulevard and median work are completed, the pavement work follows the same procedure in Phase 1. Designers wanted to maintain consistency to ensure that work procedures are familiar to workers onsite and minimize deviation due to miscommunications.

## 5.4 Phase 3

Phase 3 diverges from the first two phases. The Phase 3 footprint shall be established between Agronomy Road to Thunderbird Blvd. Within the confines of the phase plan, the curb & gutter and separate walk shall be removed and replaced as per Appendix A.

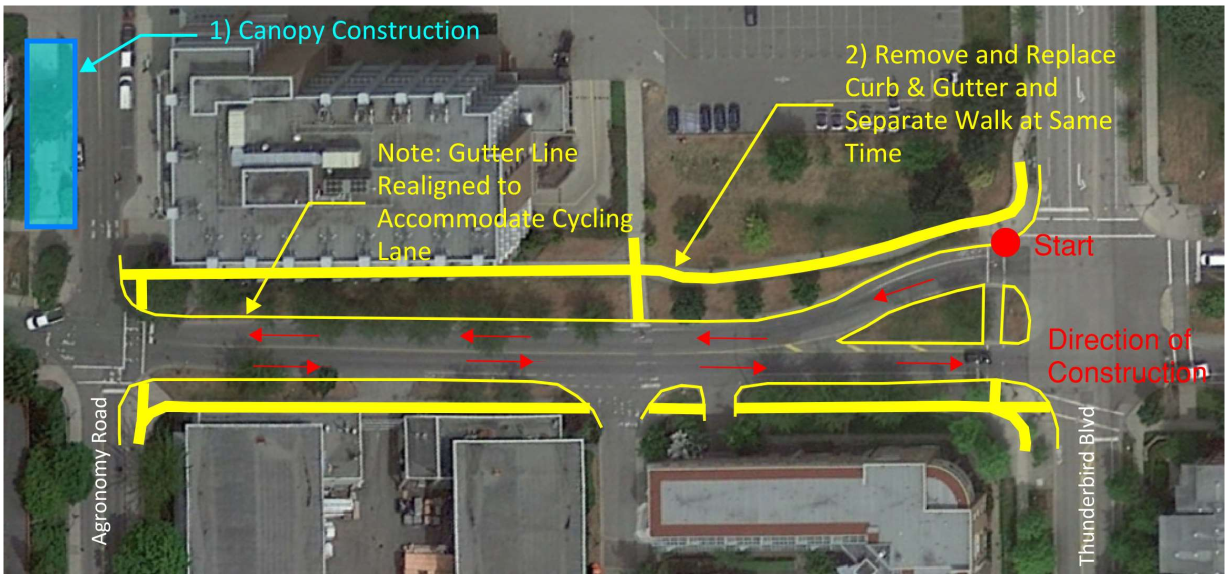


*Figure 18: Construction Phase 3*

From Figure 18, Phase 3 shall be initiated with the construction of the pedestrian canopy, which is to comply with Appendix A. The canopy construction will begin with the drilling and pouring for the cast-in-place concrete foundation piles. Once the foundation is poured, prefabricated columns and beams shall be installed. To finish the pedestrian canopy, glass sheeting shall be installed and fastened to the HSS steel purlins that bear on the beams. While the pedestrian canopy is being constructed, the road work of Phase 3 may commence. Starting on the southeast point of Phase 3, the separate walk and curb & gutter shall be removed and replaced working in a counter-clockwise manner. Once the exterior concrete work is completed, the curb and gutter shall be replaced around the island near Thunderbird Blvd. While the concrete work in Phase 3 is occurring, landscapers may place topsoil and install vegetation on the entirety of the project. It is at this point that the bioswale will be landscaped. Following the removal and replacement of the concrete work, the asphalt work shall follow the same steps prescribed for Phase 1. Once the base lift of Phase 3 is installed, it is possible to begin applying the 50mm top lift of 9.5mm nominal asphalt. The top lift of asphalt shall be paved at the same time to get the most uniform driving surface possible. Upon completion of the top lift of asphalt throughout the entirety of the site, it is possible to install the traffic accommodations set out in Appendix A, including line painting, lights, and signage installation. Once the traffic accommodation measure has been put in place, the entirety of the site shall be cleaned to client satisfaction and the physical construction of the project may conclude and shift into the maintenance stage.

# 6.0 Maintenance Plan

When looking to the project's future, there are required maintenance and operation practices that need to be taken to ensure the project reaches the full design life. To create this check and balance, it is recommended that the project is subject to a Construction Completion Certification (CCC) and a Final Acceptance Certification (FAC). To hold the contractor accountable for East Mall Redesign's construction, a CCC should be completed immediately after construction to ensure that the project is built to the specified standards. This allows the contractor to rectify any incomplete or defective work. Two years from when the CCC is issued, an FAC should be conducted to identify any further defective project elements. Taking this approach allows the project to carry out its service while identifying weak links that would not meet the design life's entirety. To ensure that the contractor is culpable for the product that is delivered, it is recommended that the client withhold 10% of invoiced payables throughout the construction. Maintaining these holdbacks places a fiscal responsibility on the contractor to incentivize quality work and adherence to CCC and FAC protocols.

After the FAC is issued, the responsibility of road maintenance shifts to UBC. UBC will be accountable for ensuring that the facilities designed and constructed in the East Mall Redesign are serviced regularly. To set the stage for a Maintenance Plan, it is recommended that East Mall is inspected on a semi-annual basis. By conducting routine inspections, hazards and defects may be identified. Primary defects that are anticipated to arise over time are:

- Pavement surface cracking/crack sealing
- Intermittent cracks in the concrete walk, curb and gutters/crack sealing
- Faded pavement lines & line painting
- Loss of abrasion on the paved surface
- Drainage issues due to settlement
- Bioswale cleaning
- Landscape upkeep

Once identified, defects and issues may be categorized on a spectrum of importance to ensure that each defect is addressed accordingly. From the identification, the defects may be prioritized and integrated into UBC's operations plan to be fixed accordingly within an appropriate time.

# 7.0 Schedule

To simulate the specified construction process of the various phases, RSMeans productivity data was retrieved from the online database. Utilizing the quantities generated from detailed takeoffs extracted from the Civil 3D model, the respective RSMeans productivity was applied to determine each activity's duration. The durations were compiled in the prescribed order and then placed in Gantt Projects to formulate the phase schedule shown in Appendix F. The simulation result is a Phase 1 start date of May 1, 2021, and a phase wrap up of July 2, 2021. At the transition point from the end of Phase 1, Phase 2 will start immediately after. Phase 2 will take two months to finish and wrap up on September 2, 2021, before pivoting to Phase 3, which is set to end on October 12, 2021, marking the completion of the construction.

# 8.0 Cost

A Class A estimate was conducted for this project utilizing the Government of Alberta 2019 Unit Price Report as the primary data set for standard construction costs. Adjustments and correction factors were done to convert the associated unit prices to the expected 2021 prices within the Vancouver area industry standards. The project's expected total cost will be $9,102,200, which is the sum of the construction cost, corrections, and construction consideration for the project, as shown in Table 5.

*Table 5: Project Cost Summary*

| Project Cost Summary | | |
|---|---|---|
| **Item #** | **Description** | **Total** |
| 1 | Cost of Construction | $ 5,056,778.10 |
| 2 | Corrections | $ 960,787.84 |
| 3 | Construction Considerations | $ 3,084,634.64 |

## 8.1 Construction Considerations

Construction considerations listed in Appendix H include the project management, preliminary and detailed design cost, project maintenance/operations cost, and the project's contingency fee. Each of these costs will be taken as a percentage of the total construction cost for the job.

## 8.2 Contingency

The contingency fee shall be 10% of the total construction cost, which is valued to be $505,677. Contingency cost will account for the following conditions:

1) Unforeseen Circumstances
    a) Unsuitable soil conditions not accounted for within the original scope of the excavation
    b) Unknown underground utilities while excavating
    c) Takeoff errors resulting from inconsistent surveyor's data between client provided data and as-built data collected on the site
    d) Equipment breakdown and construction material incompatibility

2) Project Modification

   a) Client-Requested modifications

   b) Consultant-Requested modifications

## 8.3 Maintenance Cost

The project's annual maintenance and operations cost has been estimated to be $20227/year as per UBC building operations rates and wages. This will include the landscaping, road, bioswale, canopy maintenance cost, and other general upkeep costs.

## 8.4 Permits

As per the UBC building permit application checklist and the City of Vancouver's development regulations and permits, the total cost of permitting will be approximately $101,135. The construction of the East Mall redesign will be subjected to the following permits and regulations:

- Excavation/Ground Disturbance Permits
- Foundation/Structural Permits
- Building Permits
- Electrical
- Signage
- Noise Regulation
- Tree Removal

## 8.5 Consultation and Project Management

Based on a 50-hour workweek, the consulting and design fees of the project will be approximately $1,011,355 throughout the pre and post-construction phase of the project. This cost shall include the detailed design carried out by the engineers and CAD technicians, onsite surveying, geotechnical works, site inspections, contractor management and project consultation.

## 8.6 Cost of Construction

The cost of construction will be split into six items, as shown in **Error! Reference source not found.**. The total cost of construction was estimated to be $5,056,778, with further detail of each schedule cost located in Appendix H.

*Table 6: Cost of Construction*

| Cost of Construction | | |
|---|---|---|
| **Item #** | **Description** | **Total** |
| A | Schedule A - Pre-Construction Cost | $ 32,633.32 |
| B | Schedule B - Concrete Work | $ 1,443,999.18 |
| C | Schedule C - Bioswale | $ 653,414.98 |
| D | Schedule D - Roadway Work | $ 2,624,070.90 |
| E | Schedule E - Traffic Control | $ 58,405.72 |
| F | Schedule F - Pedestrian Canopy | $ 244,254.00 |
| | **Cost of Construction** | $ 5,056,778.10 |

### 8.6.1 Schedule A – Pre-Construction Cost

Schedule A is comprised of all pre-construction costs. This includes mobilization of equipment, site creation of site office and muster zones, construction traffic accommodation and project information signages for the project. Construction traffic management will also account for temporary signage and road flaggers during construction. The estimated cost for Schedule A is $32,633.32.

### 8.6.2 Schedule B – Concrete Work

Schedule B is composed of the concrete works associated with the project. Concrete work shall start with the initial removal and disposal of existing concrete structures such as sidewalks, para-ramps, curb, and gutter. Adjustments of nearby exiting water valves and catch basin manholes shall be implemented within schedule B as the type of work required similar onsite equipment. Placement of new monolithic concrete structures shall follow suit according to the new roadway alignment. Schedule B finally concludes with the replacement of existing topsoil and landscaping that was initially removed alongside the existing concrete structure. The estimated cost of Schedule B will be a total of $1,443,999.

### 8.6.3 Schedule C – Bioswale

Schedule C shall consist of the bioswale construction cost associated with the excavation, placement, and landscaping along the East Mall corridor. Tree removal shall be done initially, followed by trenching and excavation. The bulk cost of schedule C shall come from installing the bioswale and introducing new vegetation as required by the Stormwater Source Control Design Guidelines 2012 for Metro Vancouver. The total cost of Schedule C shall amount to $653,414.

### 8.6.4 Schedule D – Roadway Construction

Schedule D will focus on the roadway work through the East Mall road. This section shall include the cost associated with the milling of the existing road, base reconstruction, cement stabilization, ACP material cost, and disposal of deleterious material. Adjustment of existing sanitary manholes and water valves along the road shall also be accounted for within the Schedule D cost. The total cost shall be $2,624,070 for the roadway construction along East Mall.

### 8.6.5 Schedule E – Traffic Control

Schedule E is the overall traffic control cost along the East Mall corridor. The costs within this schedule account for traffic sign removal and replacement, line painting, and light standard installation. Stop bars and pedestrian crossing painting along each intersection will also be accounted for within this schedule. The total cost for Schedule E will be $58,405.

### 8.6.5 Schedule F – Pedestrian Canopy

Schedule F is the total cost incurred with the installation of the pedestrian canopy. This will include the cost for the pile installation, column installation and placement, beam erection, and glass panelling for the canopy roofing system. The total cost for Schedule F shall be $244,254.

# 9.0 Conclusion

The design team has developed a redesign for the East Mall roadway located on the UBC campus in Vancouver. Stages in the design process included conceptual, preliminary, and detailed phases, culminating with a final product that provides an upgrade to the existing landscape. Prior to the commencement of the design process, the team developed a list of objectives for the redesign, as follows:

- Incorporation of green infrastructure
- Reduce vehicular traffic speed and density
- Increase corridor liveability
- Improved pick-up and drop-off areas
- Increase the active transportation that travels along East Mall
- Reduce stormwater run-off
- Incorporate a canopy structure along Agronomy Road

The design team believes that these goals are met by the redesign. Each objective is addressed through the incorporation of specific project components such as the traffic calming features to reduce speeding within the corridor. Other important aspects of the design include adjusting the existing right-of-way cross-section to promote non-vehicular traffic modes by increasing the level of service and analyzing traffic data to determine optimal intersection designs. Sustainability was also a major consideration throughout all phases of the redesign. Certain aspects of the design noticeably promote sustainability goals, such as reusing the existing asphalt during the resurfacing to minimize waste material from the project and using timber and RCA concrete for the canopy structure. In addition, a bioswale was designed to provide stormwater storage within the center median and acts as a natural filtration system to improve the run-off quality. In the end, the redesign incorporates the client's requests and considers relevant design criteria, making it an effective design option for East Mall. The design team is extremely excited to continue working alongside UBC SEEDS as construction moves forward, to see this project come to life.

# 10.0 References


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# Appendix A – Drawing Package

# EAST MALL REDESIGN

UNIVERSITY OF BRITISH COLUMBIA

ROAD CORRIDOR DESIGN FOR EAST MALL
FROM STADIUM ROAD TO AGRONOMY ROAD
CITY OF VANCOUVER
APRIL, 2021

BY:

GROUP 13
EVAN ZENKE
LANE ISAAC
STEVE SUN
JOSHUA REA
FRANCIS HSU

# CONTENTS

# GENERAL NOTES

GENERAL

1. ALL WORK SHALL BE COMPLETED IN ACCORDANCE WITH THE CURRENT CITY OF VANCOUVER AND THE UNIVERSITY OF BRITISH COLUMBIA'S CONSTRUCTION STANDARDS.

2. A SITE VISIT WILL HAVE TAKEN PLACE PRIOR TO BEGINNING CONSTRUCTION IN ORDER TO BECOME FAMILIAR WITH THE SITE CONDITIONS.

3. AT THE END OF THE WORK AND PRIOR TO FINAL ACCEPTANCE, ALL OF THE SCAFFOLDS, WASTE AND TEMPORARY STRUCTURES WILL BE REMOVED FROM THE SITE AND THE SITE WILL BE CLEANED TO THE OWNER'S SATISFACTION.

4. FOR ANY WORK THAT MAY DISTURB THE NORMAL ACTIVITIES TAKING PLACE NEAR THE CONSTRUCTION SITE, THE CONTRACTOR WILL PROVIDE THE OWNER WITH A WRITTEN REQUEST TO PROCEED, WHICH WILL INCLUDE THE NATURE OF TECH WORK TO BE EXECUTED.

5. THE LOCATIONS AND/OR DEPTHS OF UNDERGROUND UTILITIES SHOWN HAVE BEEN TAKEN FROM OFFICE RECORD INFORMATION FROM THE UNIVERSITY OF BRITISH COLUMBIA AND MUST BE TAKEN AS APPROXIMATE.

6. EXISTING INFRASTRUCTURE WITHIN THE CONSTRUCTION BOUNDARY IS TO BE INSPECTED PRIOR TO CONSTRUCTION. ANY EXISTING DAMAGE OR DEFICIENCIES SHALL BE DOCUMENTED AND REPORTED TO THE ENGINEER PRIOR TO STARTING CONSTRUCTION.

6. CONTRACTOR IS RESPONSIBLE FOR LOCATING AND PROTECTING ALL EXISTING UTILITIES.

7. ALL MEASUREMENTS ARE IN mm UNLESS SPECIFIED OTHERWISE.

8. THE CONTRACTOR SHALL BE AWARE THAT THERE ARE MANHOLES AND VALVES WITHIN THE RESURFACING LIMITS. CARE SHALL BE TAKEN IN THESE LOCATIONS DURING MILLING OPERATIONS.

9. THE CONTRACTOR SHALL VERIFY ALL DIMENSIONS AND CONDITIONS IN THE FIELD PRIOR TO CONSTRUCTION AND ORDERING OF MATERIALS. THE CONTRACTOR WILL ALSO NOTIFY THE ENGINEER OF ANY DISCREPANCY.

10. THE CONTRACTOR WILL REVIEW AND BECOME FAMILIAR WITH THE UNIVERSITY OF BRITISH COLUMBIA'S CONTRACTORS SAFETY ORIENTATION MANUAL.

11. APPROPRIATE SAFETY MEASURES SUCH AS BARRICADES AND SIGNAGE WILL BE TO THE CITY OF VANCOUVER STANDARDS.

12. FLAGMEN SHALL BE PRESENT DURING ALL ROAD CLOSURE HOURS, INCLUDING LUNCH HOUR.

13. ALL EXCAVATION ADJACENT TO THE EDGE OF PAVEMENT SHALL BE PROTECTED WITH EXTENDED LEG BARRICADES AND APPROPRIATE LIGHTS.

14. THE CONTRACTOR SHALL PROVIDE ACCESS TO ABUTTING PROPERTY, UTILITIES, PEDESTRIANS, AND VEHICULAR TRAFFIC DURING CONSTRUCTION. INTERRUPTIONS OF SERVICES REQUIRE A WRITTEN AUTHORIZATION FROM THE OWNER OF SERVICE.

15. WHEN EXCAVATION IS COMPLETE, ALL BANKS MUST BE STABILIZED DURING CONSTRUCTION.

16. APPROPRIATE SIGNAGE SHALL BE CONSTRUCTED IN ACCORDANCE WITH THE CITY OF VANCOUVER STANDARDS.

ENVIRONMENTAL PROTECTION

12. THE MANAGEMENT AND DISPOSAL OF WASTE WILL BE CONDUCTED IN ACCORDANCE WITH SECTION 01 57 01 OF THE CITY OF VANCOUVER CONSTRUCTION SPECIFICATIONS AND ANY OTHER RELEVANT REGULATIONS.

13. THE CONTRACTOR SHALL TAKE ALL NECESSARY PRECAUTIONS FOR THE PROTECTION OF STORMWATER INFILTRATION AREAS IN ACCORDANCE WITH SECTION 01 57 01 OF THE CITY OF VANCOUVER CONSTRUCTION SPECIFICATIONS.

14. IN EVERY CASE OF ENVIRONMENTAL EMERGENCIES, EMERGENCY INTERVENTION TEAMS WILL BE NOTIFIED.

15. ALL OF THE PERMITS REQUIRED FOR OPERATION AND THROUGH CONTRACTUAL OBLIGATION WILL BE OBTAINED.

16. SHOULD CONTAMINATED SOILS BE DISCOVERED AT THE WORK SITE, WORK WILL BE STOPPED IMMEDIATELY AND THE ENGINEER WILL BE NOTIFIED WITHOUT DELAY SO THAT HE/SHE MAY PROVIDE THE GENERAL CONTRACTOR WITH A PROCEDURE FOR THE MANAGEMENT OF THESE SOILS, IN ACCORDANCE WITH ANY SOIL PROTECTION AND CONTAMINATED LAND REHABILITATION POLICIES.

17. THE CONTRACTOR SHALL TAKE ALL NECESSARY PRECAUTIONS FOR THE PROTECTION OF EXISTING PLANT MATERIAL FOR WHICH THE CONTRACT DOES NOT PROVIDE REMOVAL. THE PROTECTION OF EXISTING PLANT MATERIAL SHALL BE DONE IN ACCORDANCE WITH ANY RELEVANT REGULATIONS.

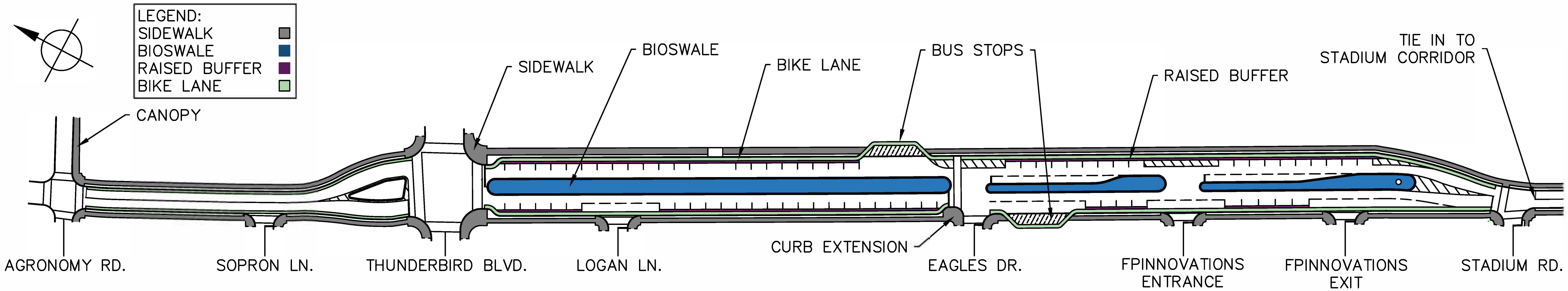
18. AT ALL TIMES, THE GENERAL CONTRACTOR WILL HAVE AT HAND AN EMERGENCY KIT FOR THE RECOVERY OF PETROLEUM PRODUCTS, WHICH WILL INCLUDE CONFINEMENT SAUSAGES, ABSORBENT ROLLS, SPHAGNUM MOSS, AS WELL AS CONTAINERS AND RELATED ACCESSORIES ESSENTIAL TO ADDRESS SMALL SCALE ACCIDENTAL SPILLS AND TO ENSURE RECUPERATION AND STORAGE OF SOILED MATERIAL AND THE MANAGEMENT OF CONTAMINATED SOIL AND MATERIALS.

19. FIRES AND THE BURNING OF WASTE IS STRICTLY PROHIBITED AT THE CONSTRUCTION SITE.

DEMOLITION

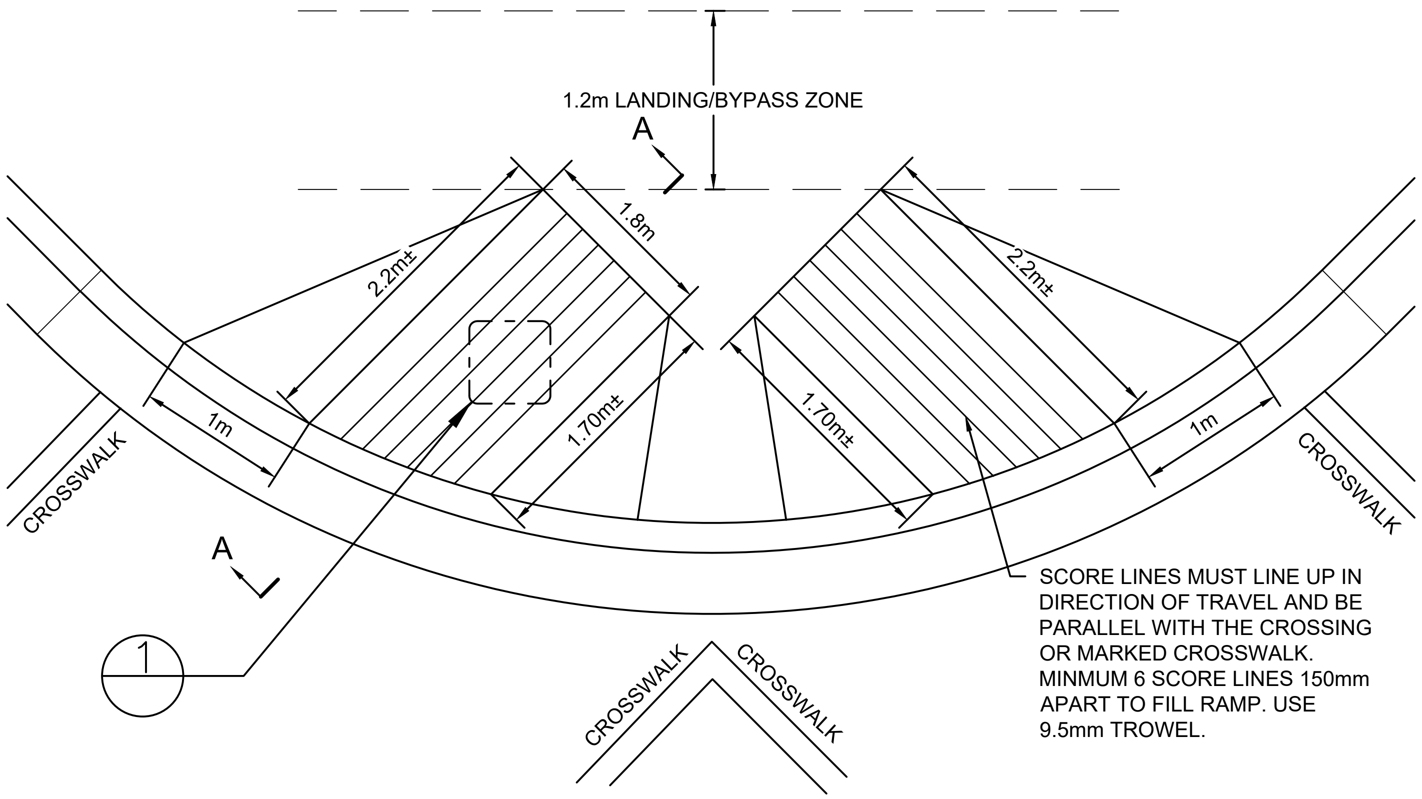
20. REMOVED EQUIPMENT AND ACCESSORIES THAT WILL NOT BE REUSED WILL BE PRESENTED TO THE OWNER. SHOULD THE LATTER DECIDE NOT TO KEEP THEM, THEY WILL BECOME THE PROPERTY OF THE GENERAL CONTRACTOR, WHO WILL REMOVE THEM FROM THE SITE AND DISPOSE OF THEM IN APPROPRIATE LOCATIONS. IF THEY CAN BE REUSED BUT THE OWNER DOES NOT WISH TO USE THEM, THEY WILL BE CONSIDERED AS WASTE AND WILL BE ELIMINATED.

21. THE GENERAL CONTRACTOR WILL TAKE RESPONSIBILITY FOR DAMAGES RESULTING FROM DEMOLITION WORK DUE TO WEATHER, NEGLIGENCE, AND/OR LACK OF COORDINATION OR PRECAUTIONS.

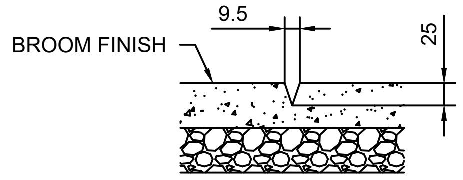



EAST MALL REDESIGN – OVERALL PLAN
SCALE 1: 1750

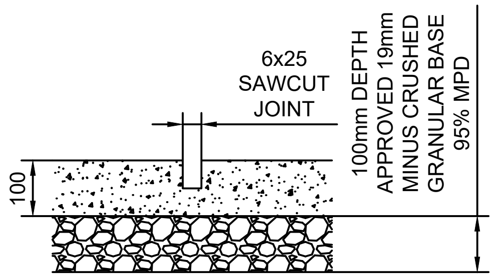
| UNIVERSITY OF BRITISH COLUMBIA | | |
|---|---|---|
| CLASS: | GENERAL NOTES AND OVERALL PLAN | COURSE: |
| DWN: | | DWG NO.:C02-01 |
| DATE: 02/03/2021 | | PAGE: 2 OF 19 |
| SCALE: AS SHOWN | | |



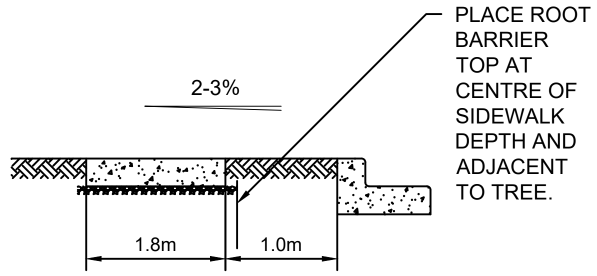

PEDESTRIAN CURB RAMP DETAIL
SCALE: NTS



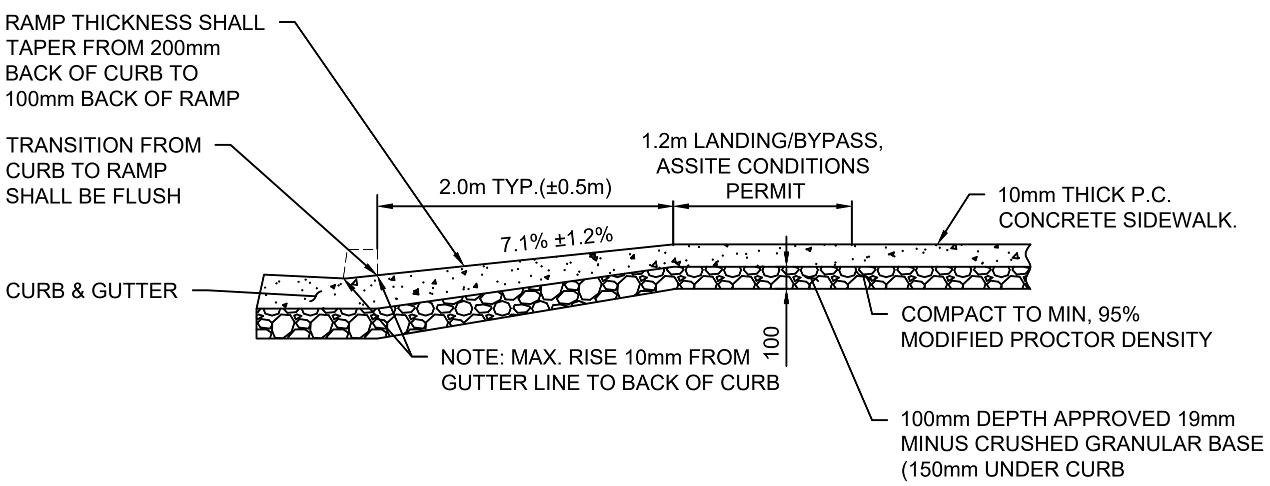

1 TYP. TROWEL SCORE MARK
SCALE: NTS



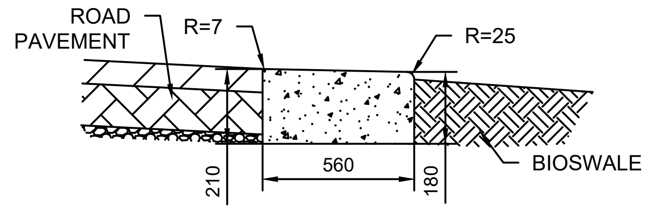

STANDARD CONTROL JOINT
SCALE: NTS




SEPARATE WALK
SCALE: NTS




A CURB RAMP SECTION
SCALE: NTS

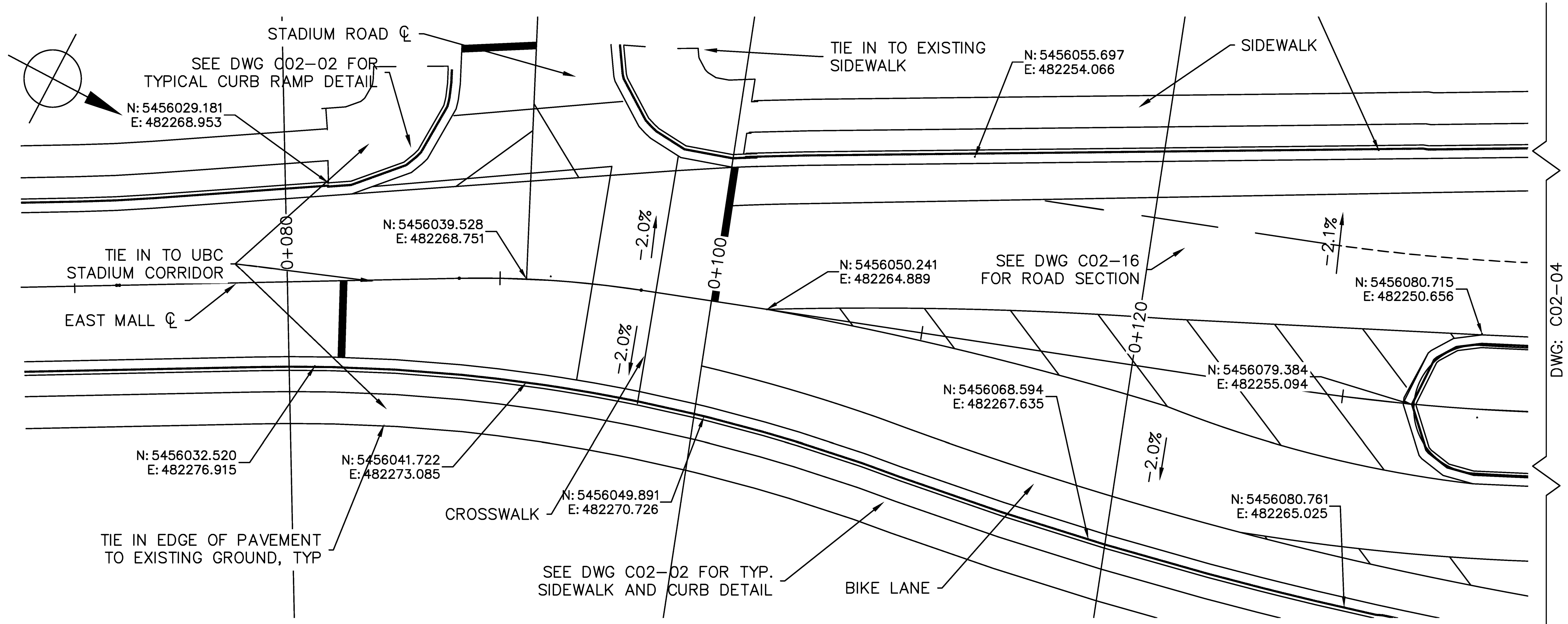



BIOSWALE FLUSH CURB
SCALE: NTS

NOTES:

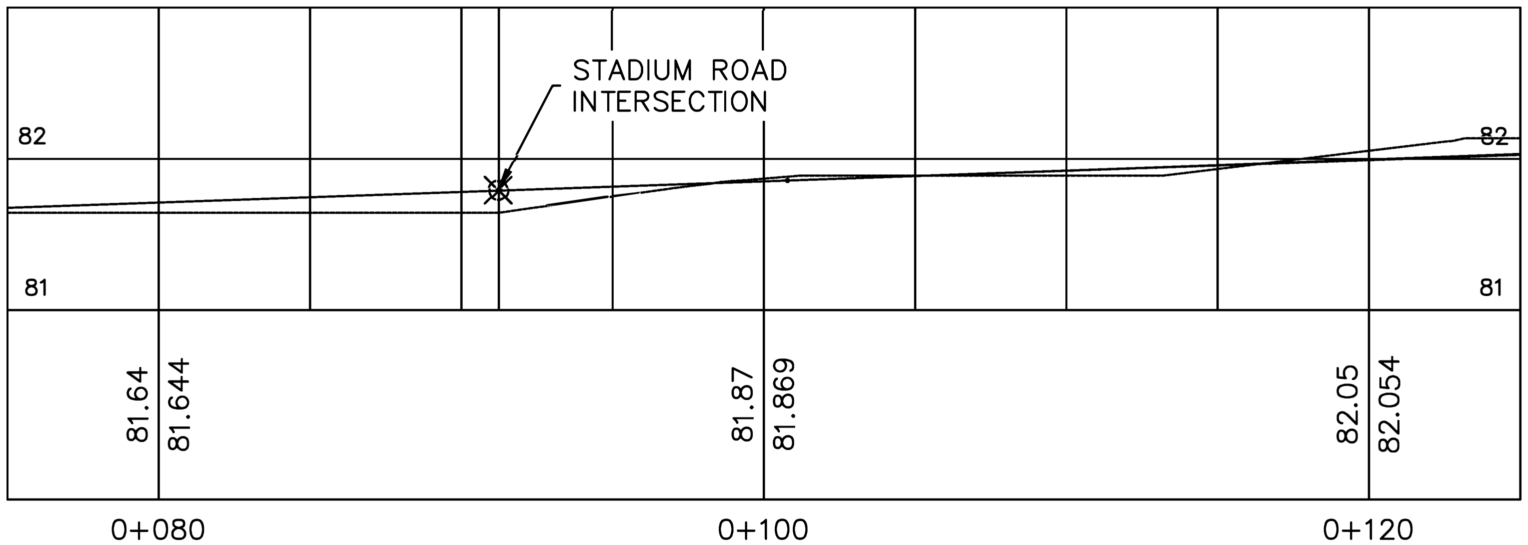
- DETAILS OBTAINED FROM THE CITY OF VANCOUVER'S STANDARD DETAIL DRAWING GUIDE (2018).

| | | |
|---|---|---|
| GROUP #: | TYPICAL DETAILS | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02–02 |
| DATE:03/18/2021 | | DWG. NO.: 02 of 23 |
| SCALE:AS SHOWN | | |




EAST MALL PLAN 0+080 TO 0+120

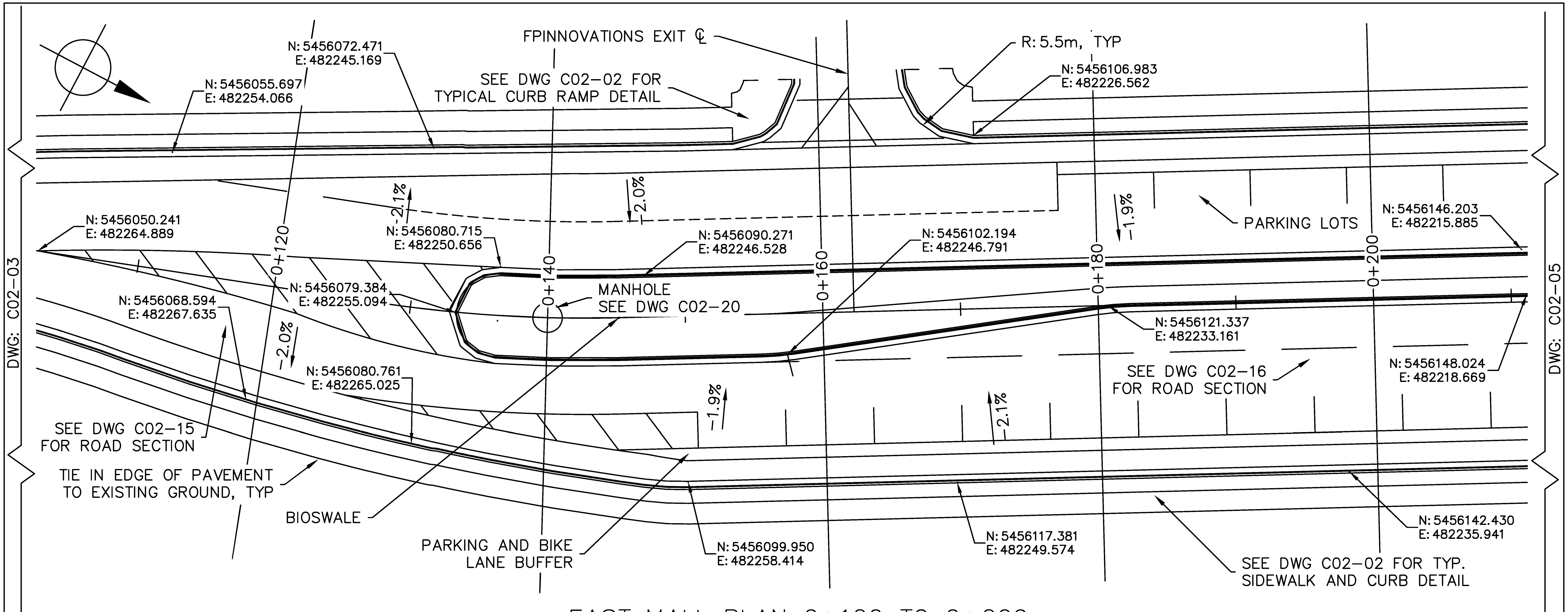
SCALE: 1:200




EAST MALL PROFILE 0+080 TO 0+120

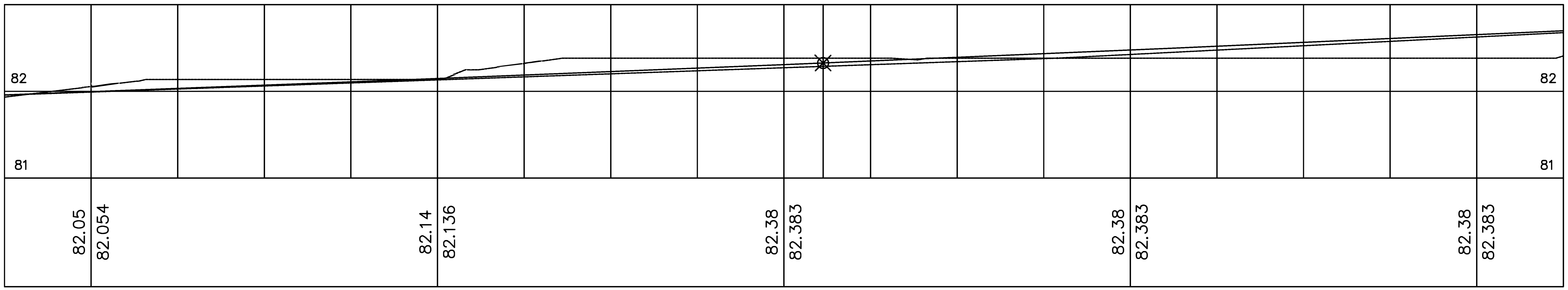
SCALE: 1:250

| | | |
|---|---|---|
| GROUP #: | CORRIDOR PLAN/PROFILE<br>0+080–0+120 | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02–03 |
| DATE:03/18/2021 | | DWG. NO.: |
| SCALE:AS SHOWN | | 3 OF 23 |




EAST MALL PLAN 0+120 TO 0+200

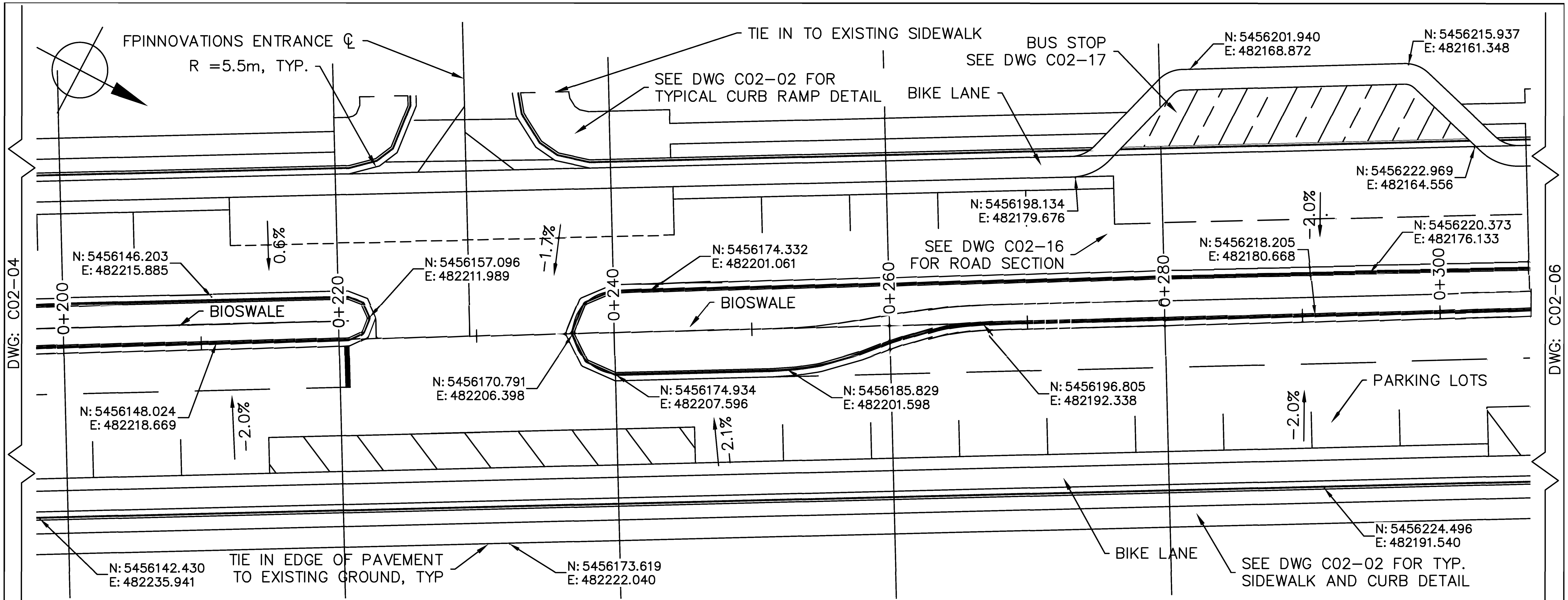
SCALE: 1:300




EAST MALL PROFILE 0+120 TO 0+200

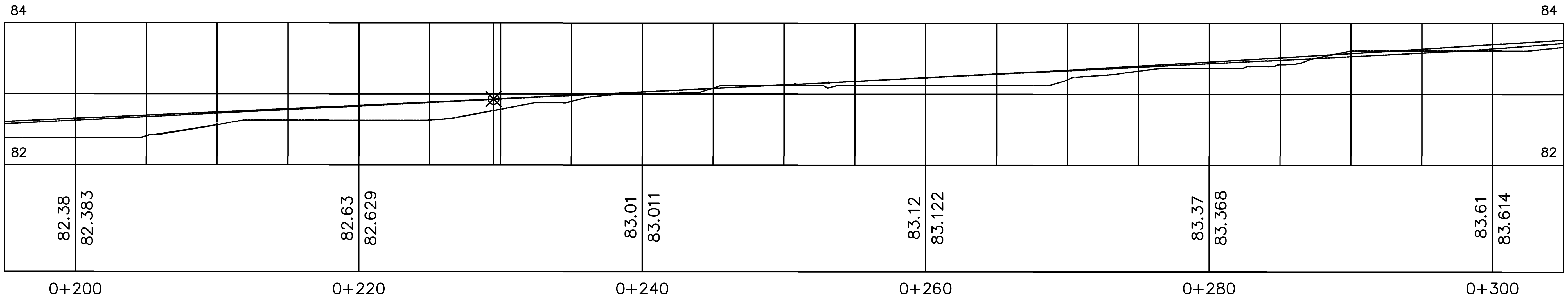
SCALE: 1:250

| | | |
|---|---|---|
| GROUP #: | CORRIDOR PLAN/PROFILE<br>0+120-0+200 | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02-04 |
| DATE:03/18/2021 | | DWG. NO.: |
| SCALE:AS SHOWN | | 4 OF 23 |




EAST MALL PLAN 0+200 TO 0+300

SCALE: 1:300




EAST MALL PROFILE 0+200 TO 0+300

SCALE: 1:250

| | | |
|---|---|---|
| GROUP #: | CORRIDOR PLAN/PROFILE<br>0+200-0+300 | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02-05 |
| DATE:03/18/2021 | | DWG. NO.: |
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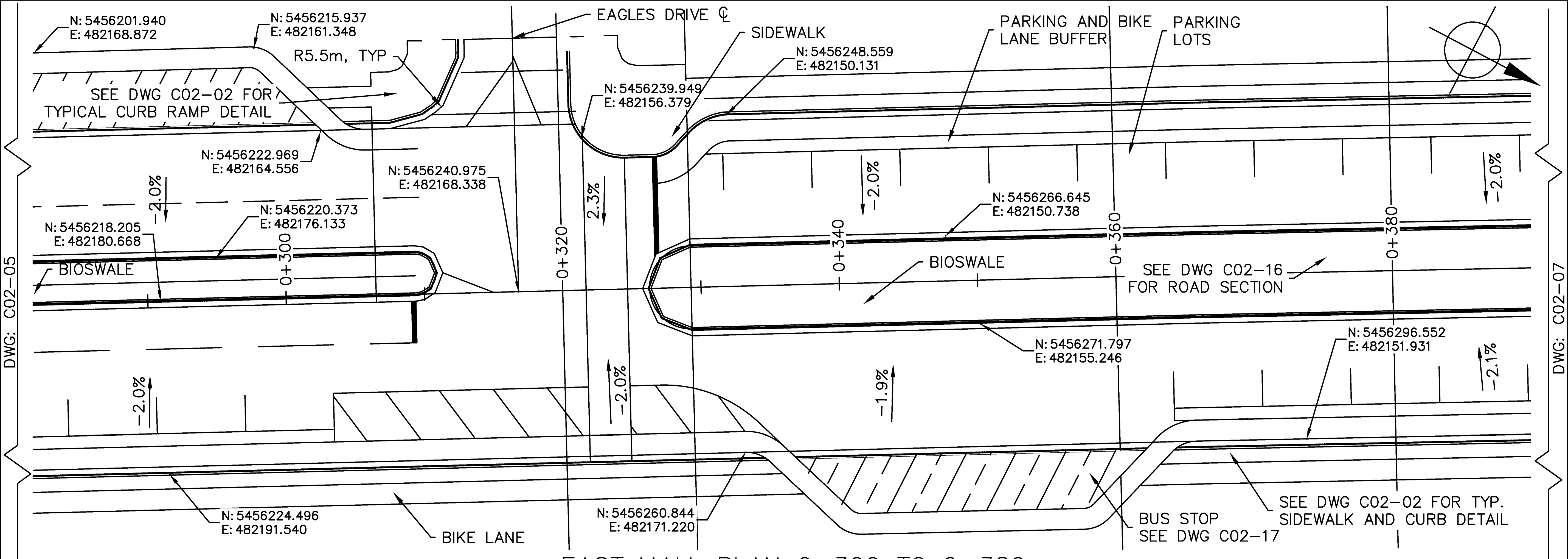
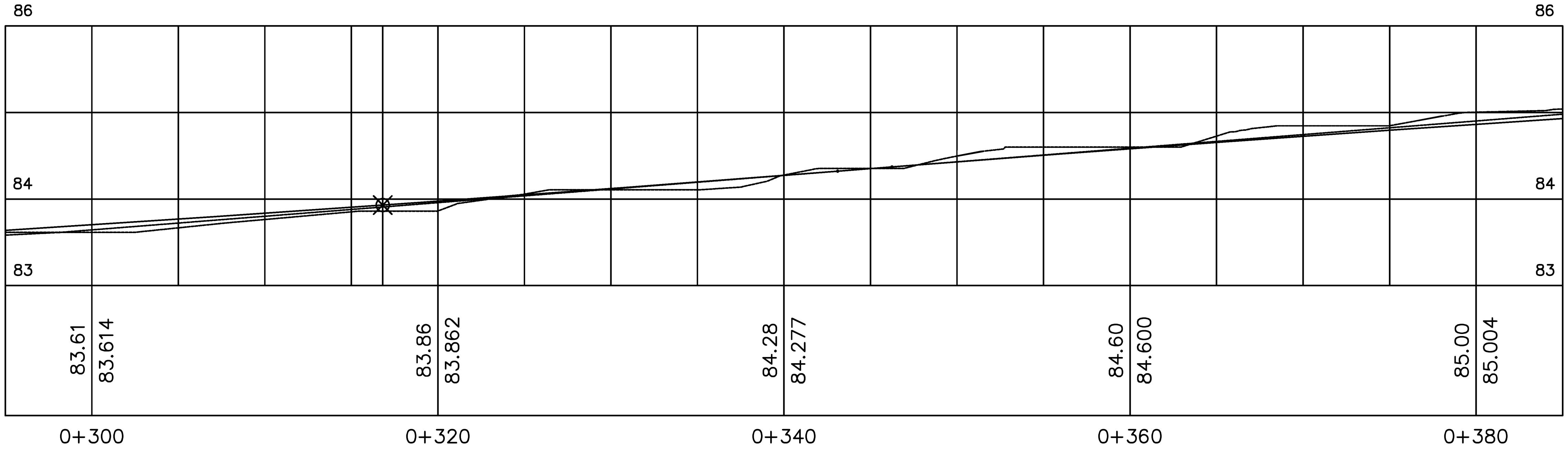
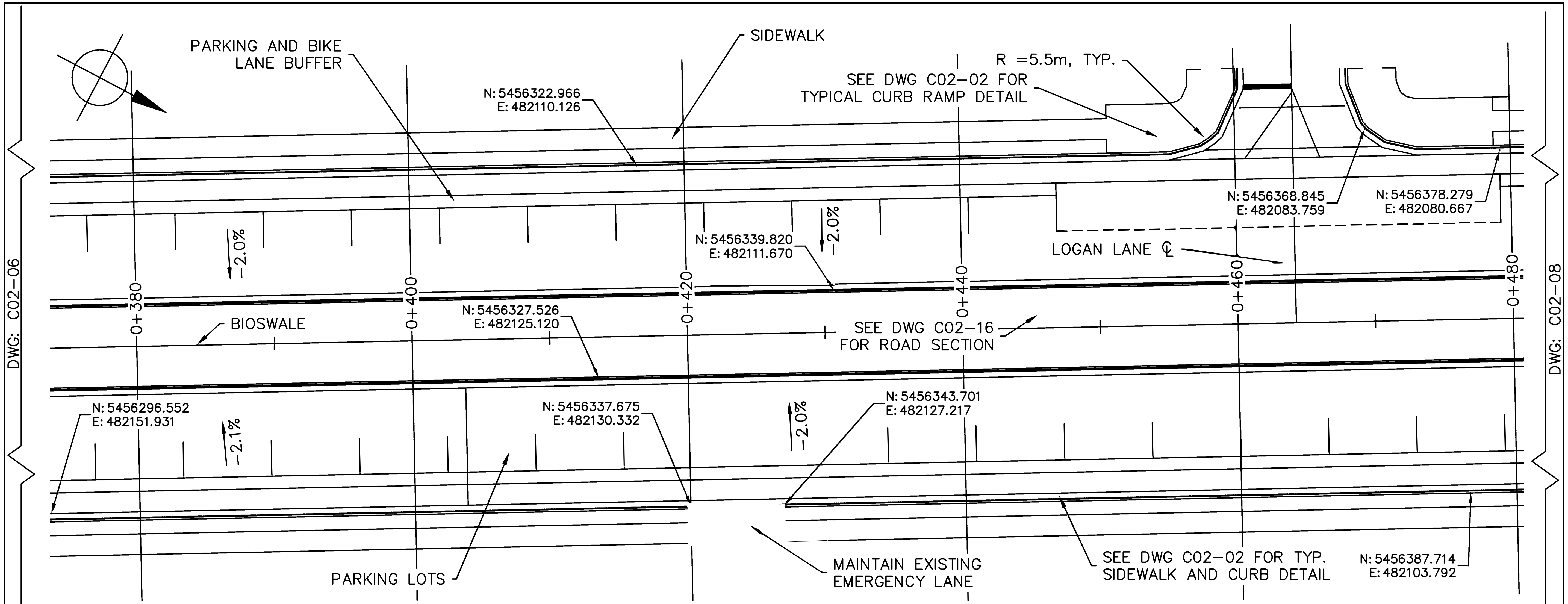



EAST MALL PLAN 0+300 TO 0+380
SCALE: 1:300



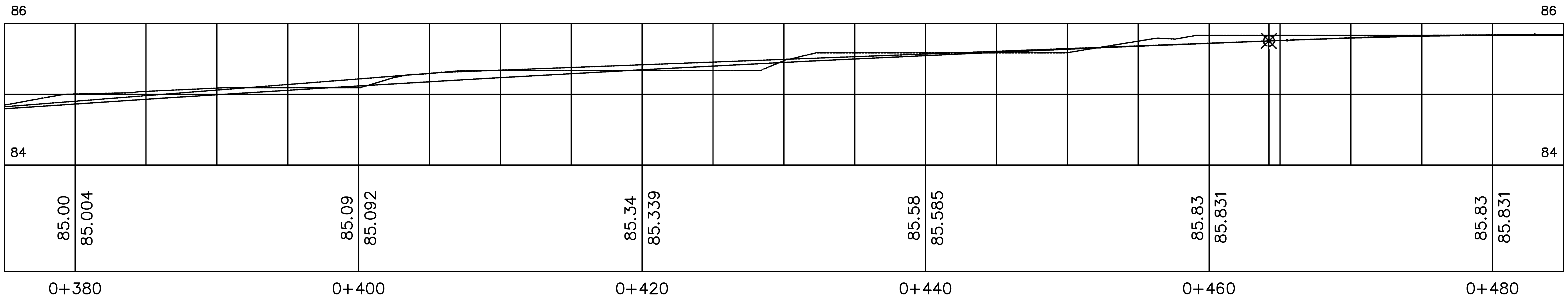

EAST MALL PROFILE 0+300 TO 0+380
SCALE: 1:300

| | | |
|---|---|---|
| GROUP #: | CORRIDOR PLAN/PROFILE<br>0+300-0+380 | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02-06 |
| DATE:03/18/2021 | | DWG. NO.:<br>6 OF 23 |
| SCALE:AS SHOWN | | |




EAST MALL PLAN 0+380 TO 0+480

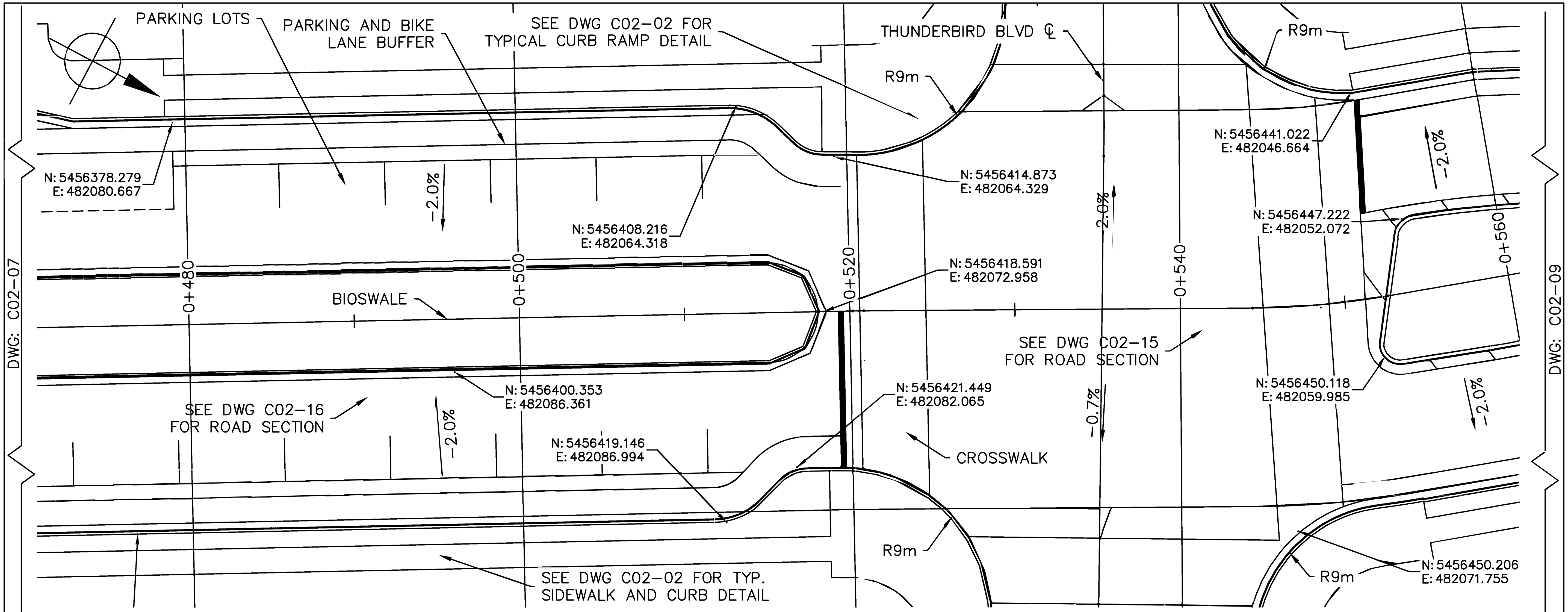
SCALE: 1:300




EAST MALL PROFILE 0+380 TO 0+480

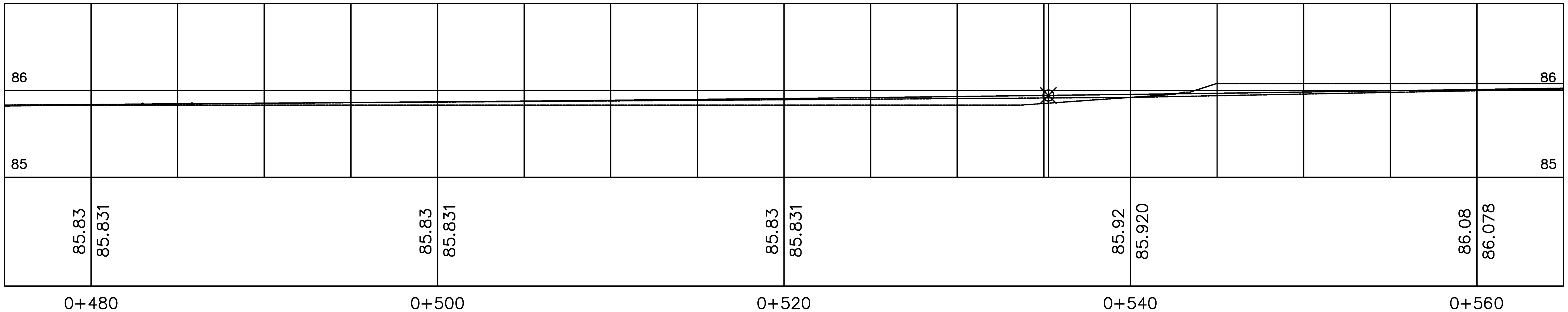
SCALE: 1:300

| | | |
|---|---|---|
| GROUP #: | CORRIDOR PLAN/PROFILE<br>0+380–0+480 | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02–07 |
| DATE:03/18/2021 | | DWG. NO.: 7 OF 23 |
| SCALE:AS SHOWN | | |




EAST MALL PLAN 0+480 TO 0+560

SCALE: 1:250




EAST MALL PROFILE 0+480 TO 0+560

SCALE: 1:250

| | | |
|---|---|---|
| GROUP #: | CORRIDOR PLAN/PROFILE 0+480-0+560 | COURSE: CIVL 446 |
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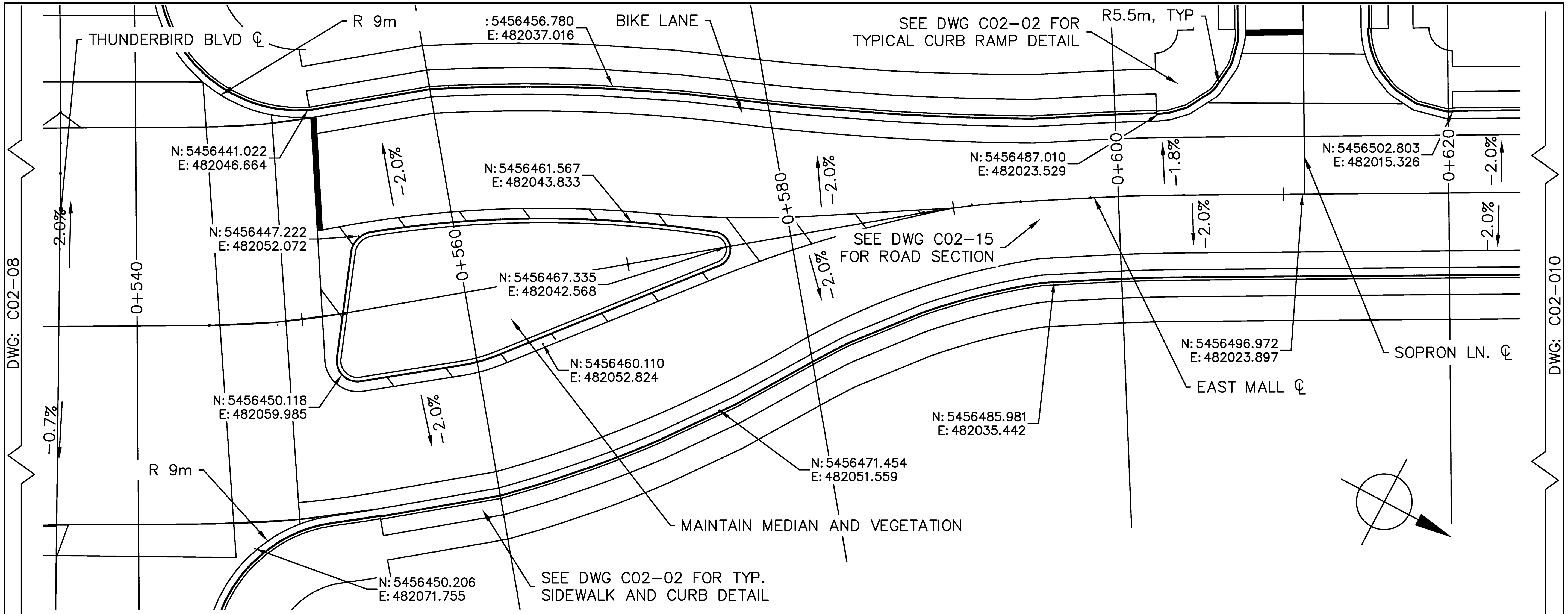
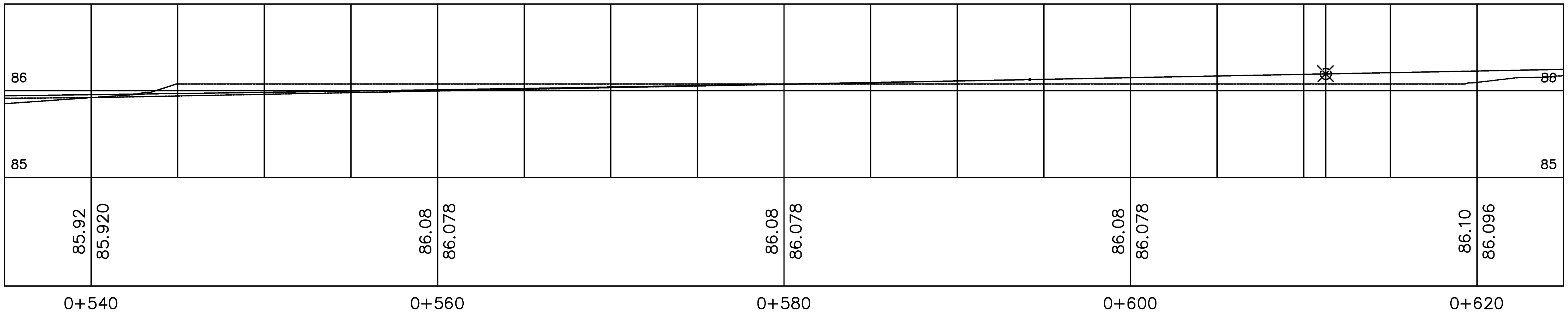
| DATE:03/18/2021 | | DWG. NO.: |
| SCALE:AS SHOWN | | 8 OF 23 |




EAST MALL PLAN 0+540 TO 0+620

SCALE: 1:250




EAST MALL PROFILE 0+540 TO 0+620

SCALE: 1:250

| | | |
|---|---|---|
| GROUP #: | CORRIDOR PLAN/PROFILE<br>0+540-0+620 | COURSE: CIVL 446 |
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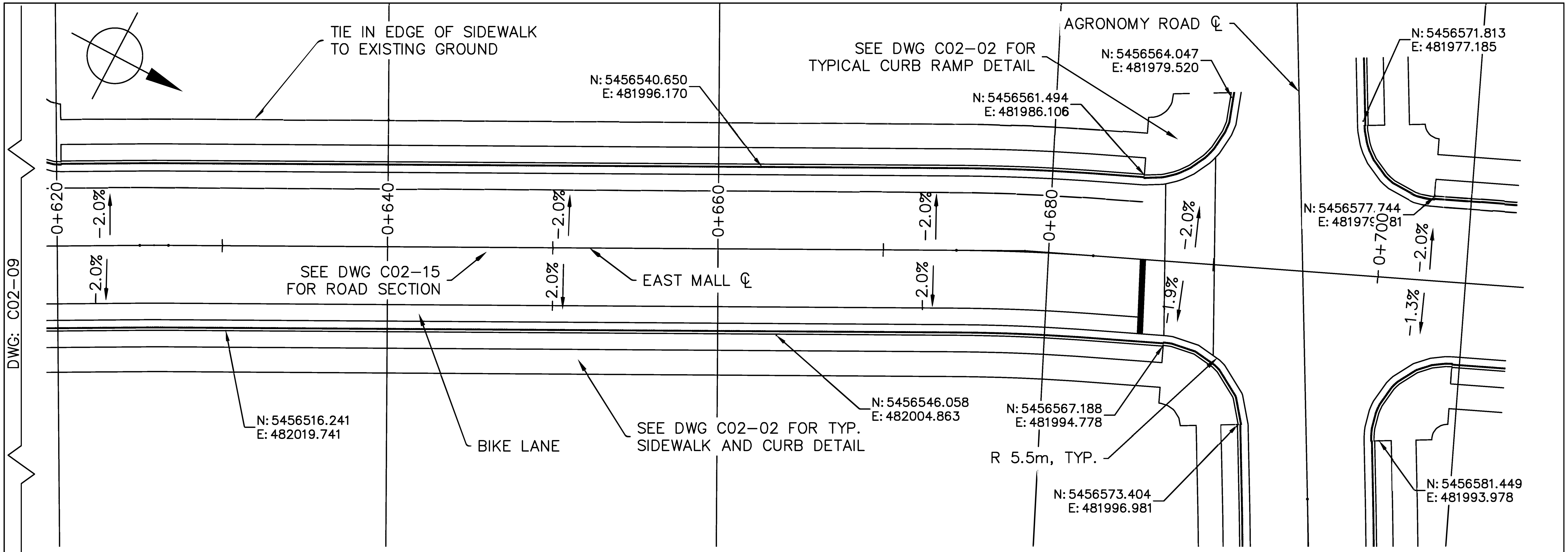
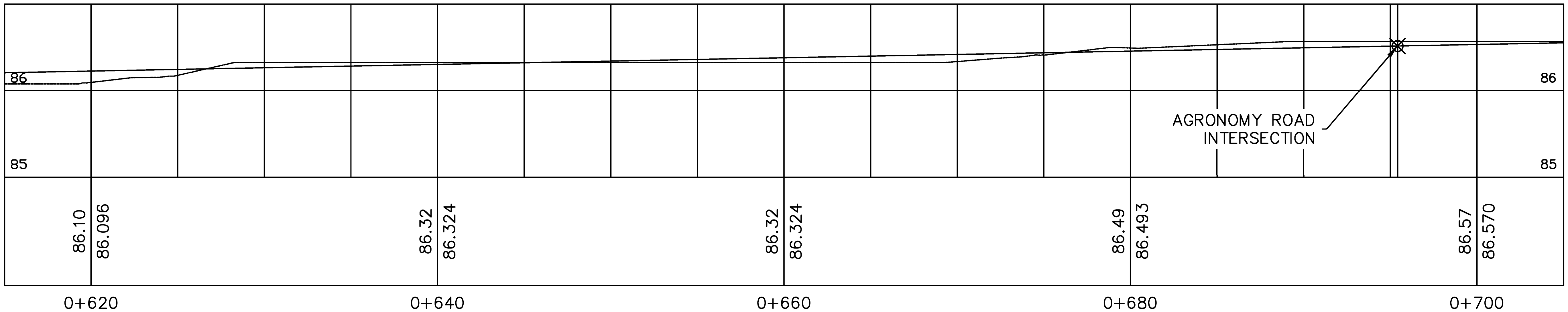
| DATE:03/18/2021 | | DWG. NO.: 9 OF 23 |
| SCALE:AS SHOWN | | |




EAST MALL PLAN 0+620 TO 0+700

SCALE: 1:250




EAST MALL PROFILE 0+620 TO 0+700

SCALE: 1:250

| | | |
|---|---|---|
| GROUP #: | CORRIDOR PLAN/PROFILE<br>0+620-0+700 | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02-10 |
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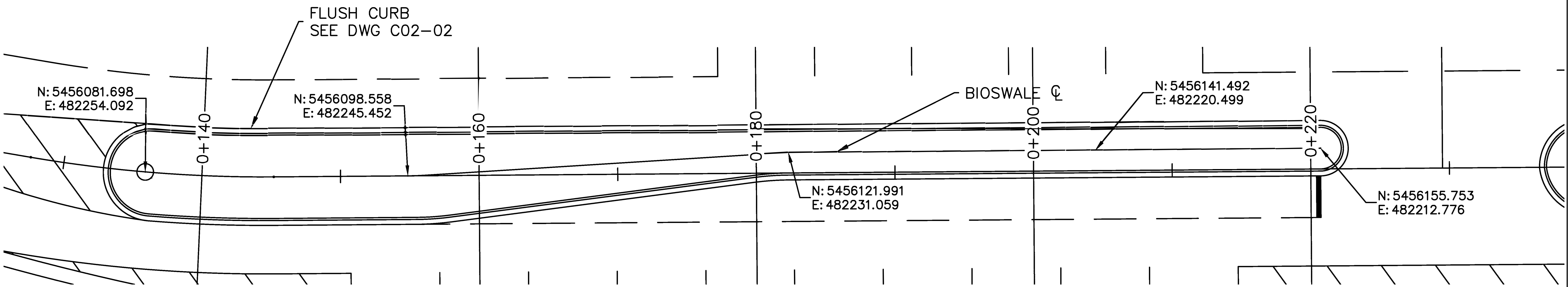
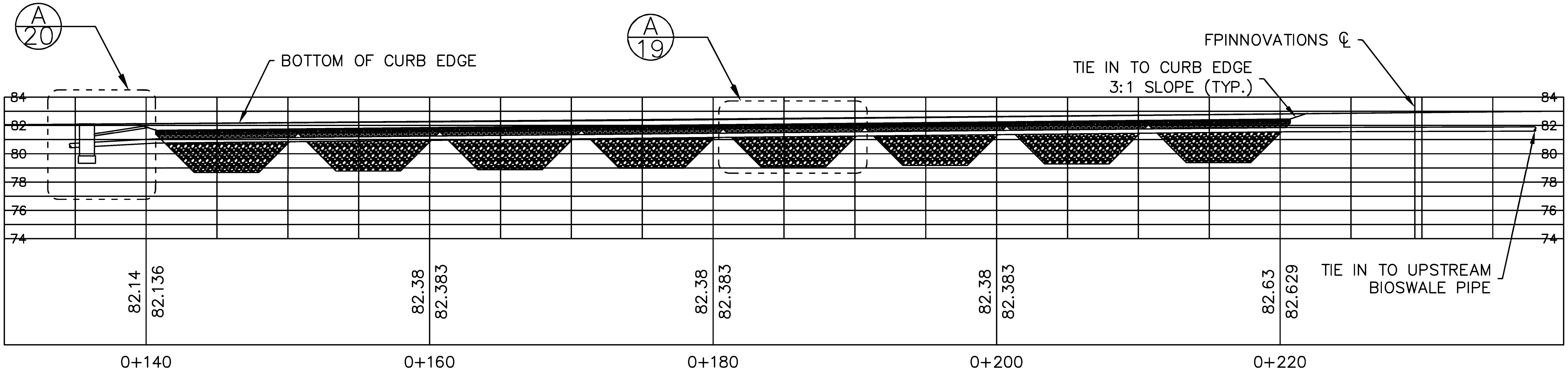
| SCALE:AS SHOWN | | 10 OF 23 |

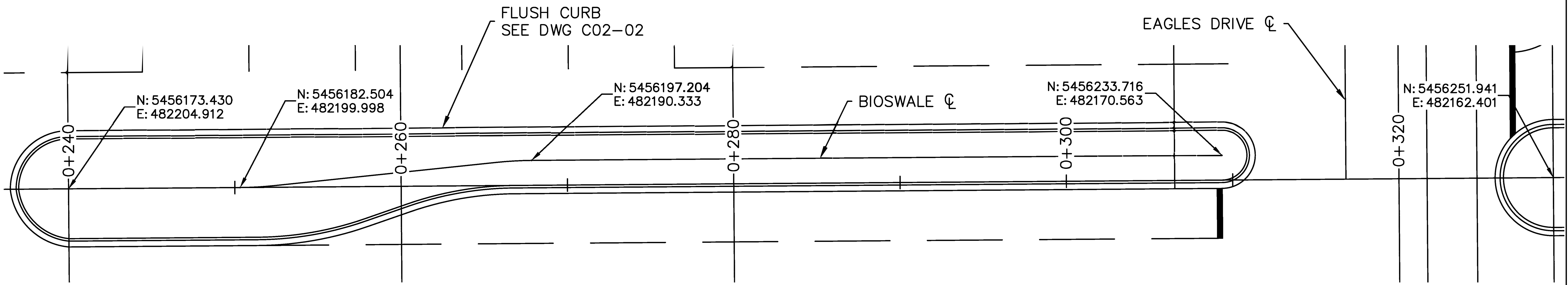



BIOSWALE PROFILE – 0+133.6 TO 0+237
SCALE 1:300

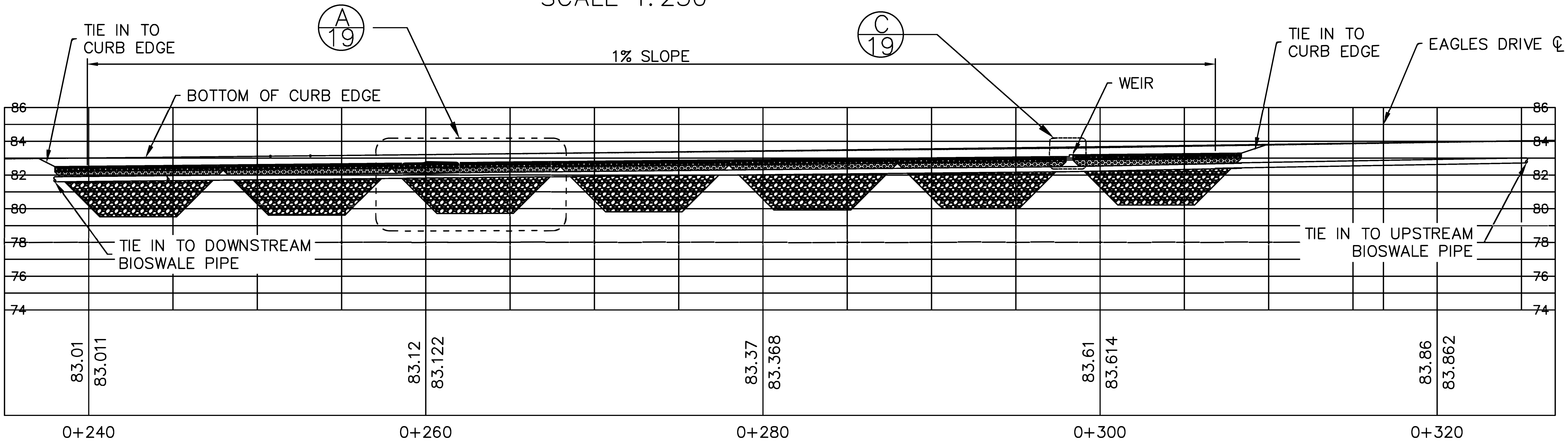



BIOSWALE PROFILE – 0+133.6 TO 0+237
SCALE 1:300

| | | |
|---|---|---|
| GROUP #: | BIOSWALE PLAN AND PROFILE<br>0+133.6 – 0+237 | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02–11 |
| DATE:03/15/2021 | | DWG. NO.: |
| SCALE:AS SHOWN | | 11 OF 23 |

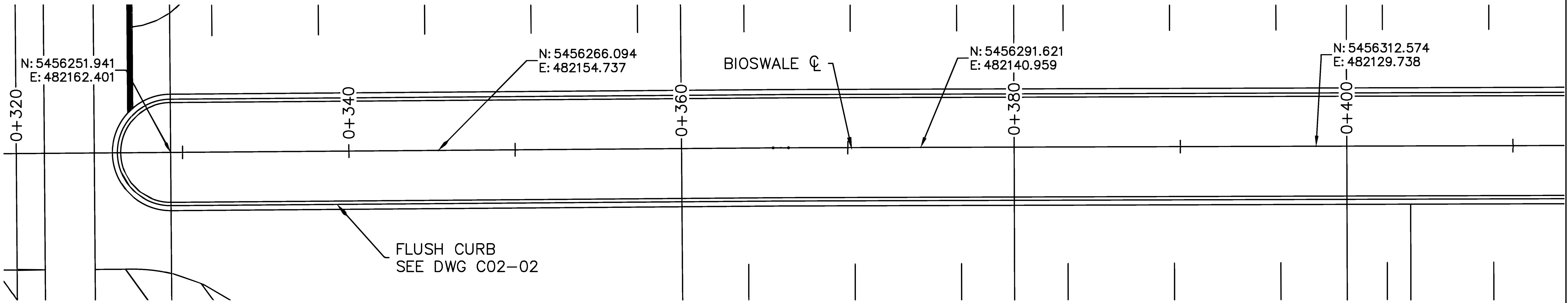



BIOSWALE PLAN – 0+237 TO 0+310.8
SCALE 1:250

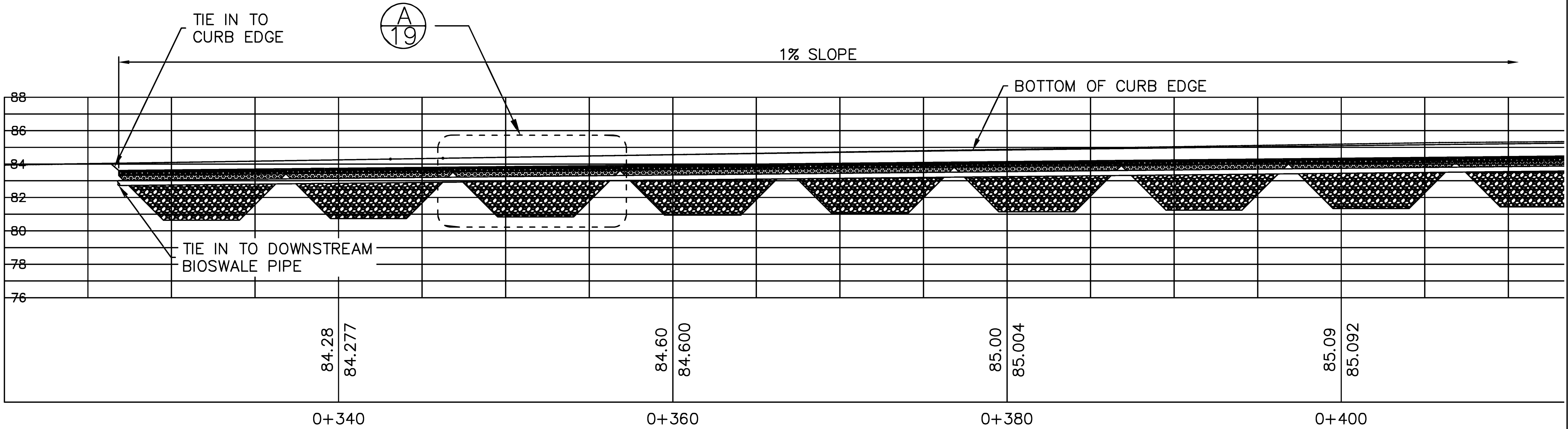



BIOSWALE PROFILE – 0+237 TO 0+310.8
SCALE 1:250

| | | |
|---|---|---|
| GROUP #: | BIOSWALE PLAN AND PROFILE<br>0+237 – 0+310.8 | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02–12 |
| DATE:03/15/2021 | | DWG. NO.:<br>12 OF 23 |
| SCALE:AS SHOWN | | |

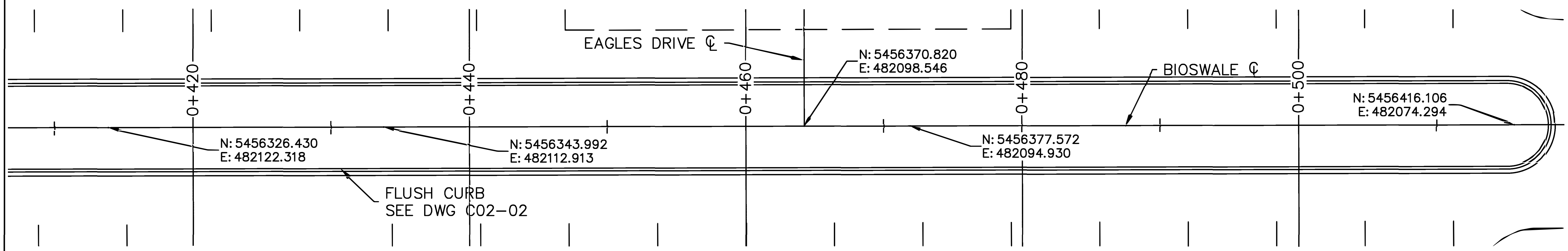



BIOSWALE PLAN – 0+326.4 TO 0+410
SCALE 1:250

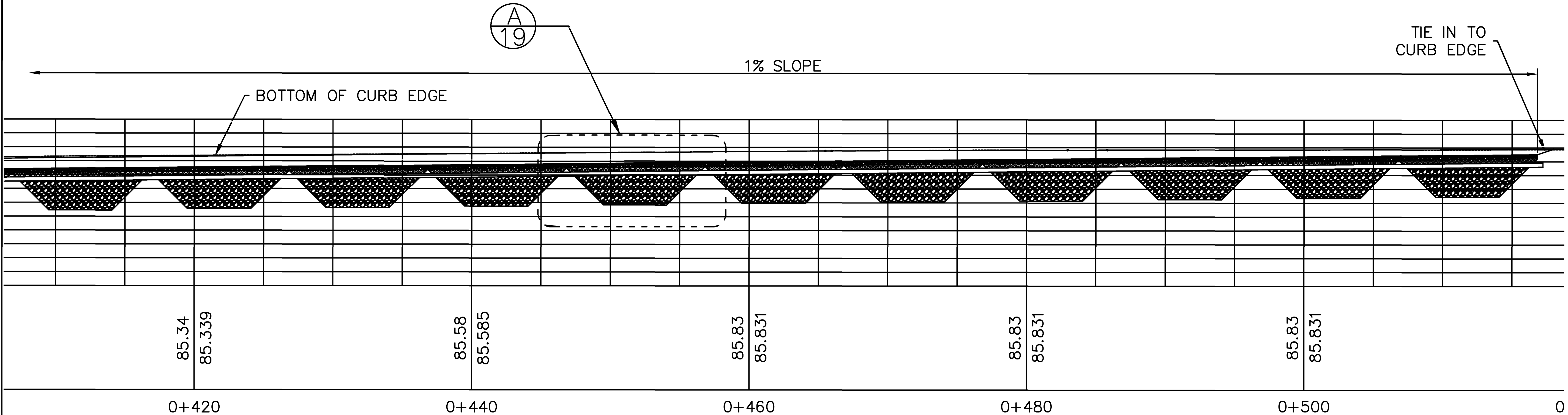



BIOSWALE PROFILE – 0+326.4 TO 0+410
SCALE 1:250

| | | |
|---|---|---|
| GROUP #: | BIOSWALE PLAN AND PROFILE<br>0+326.4 – 0+410 | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02–13 |
| DATE:03/15/2021 | | DWG. NO.:<br>13 OF 23 |
| SCALE:AS SHOWN | | |




BIOSWALE PLAN – 0+410 TO 0+518
SCALE 1: 300




BIOSWALE PROFILE – 0+410 TO 0+518
SCALE 1: 300

| | | |
|---|---|---|
| GROUP #: | BIOSWALE PLAN AND PROFILE<br>0+410 – 0+518 | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02–14 |
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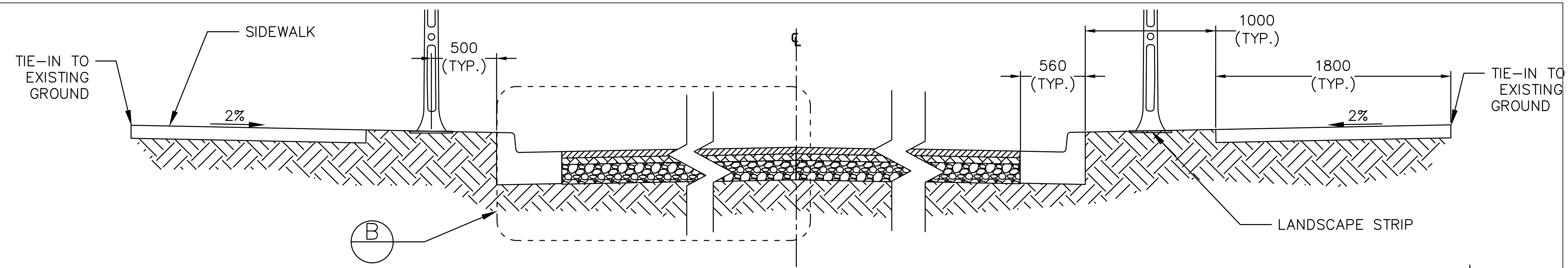
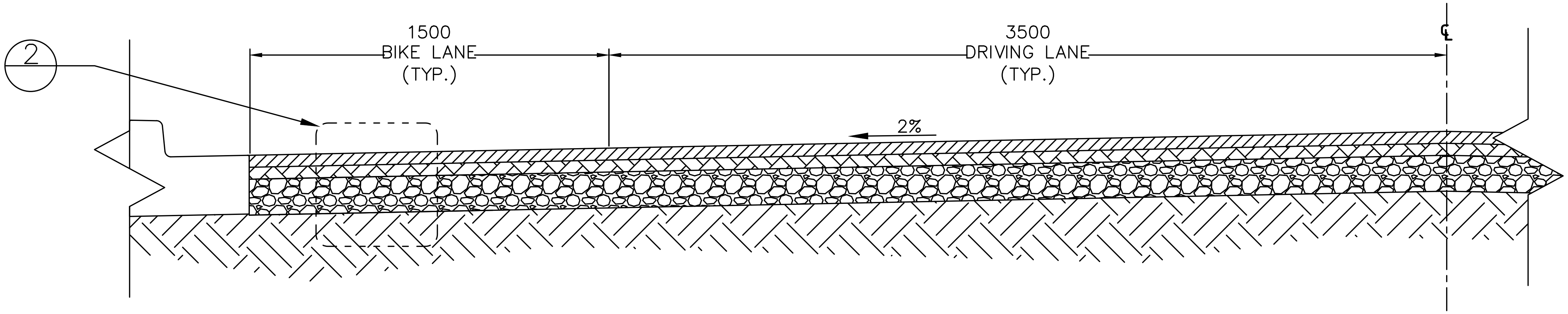
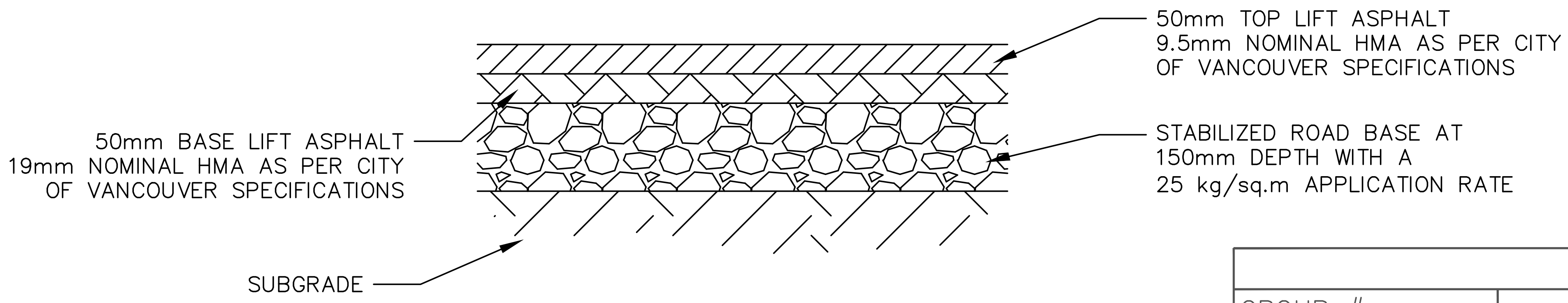



FULL ROAD SECTION
SCALE 1:30

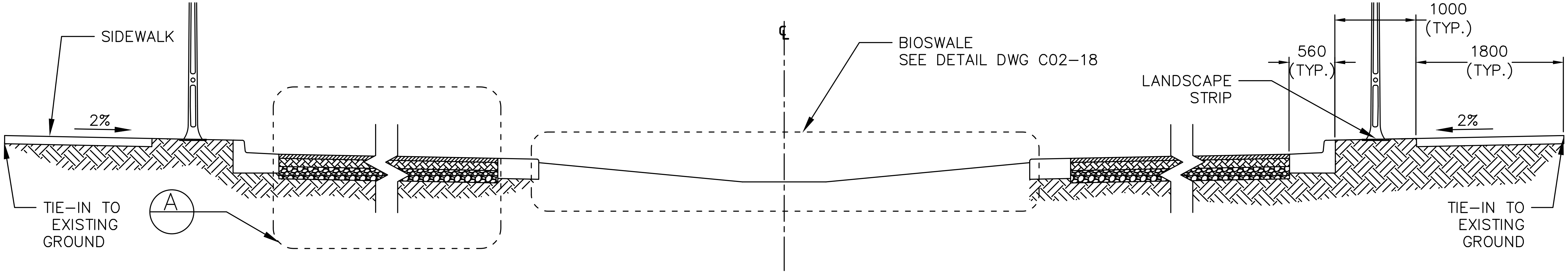



B ROAD PAVEMENT CLOSE–UP
SCALE 1:20

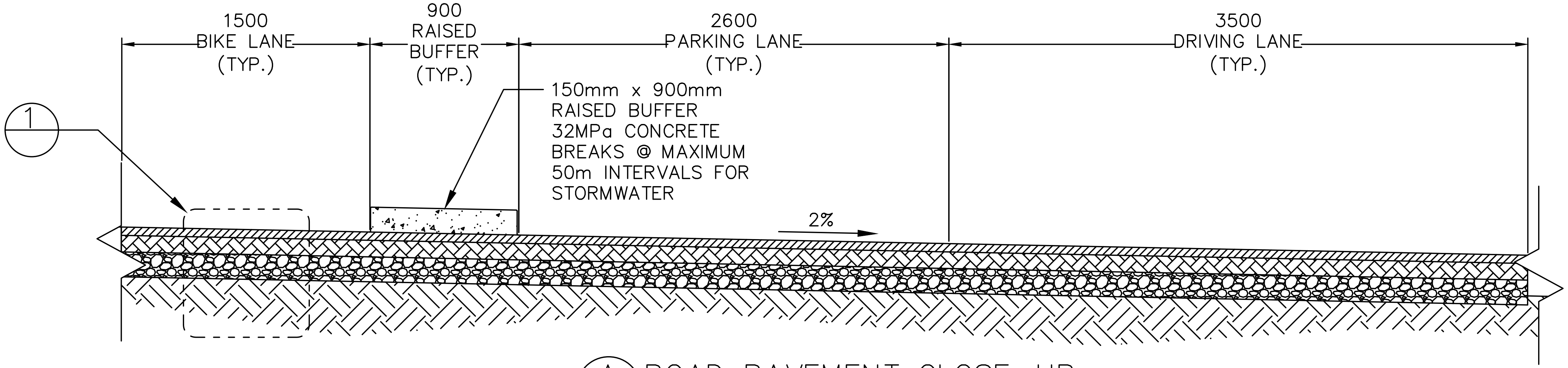



2 ROAD PAVEMENT CLOSE–UP
SCALE 1:10

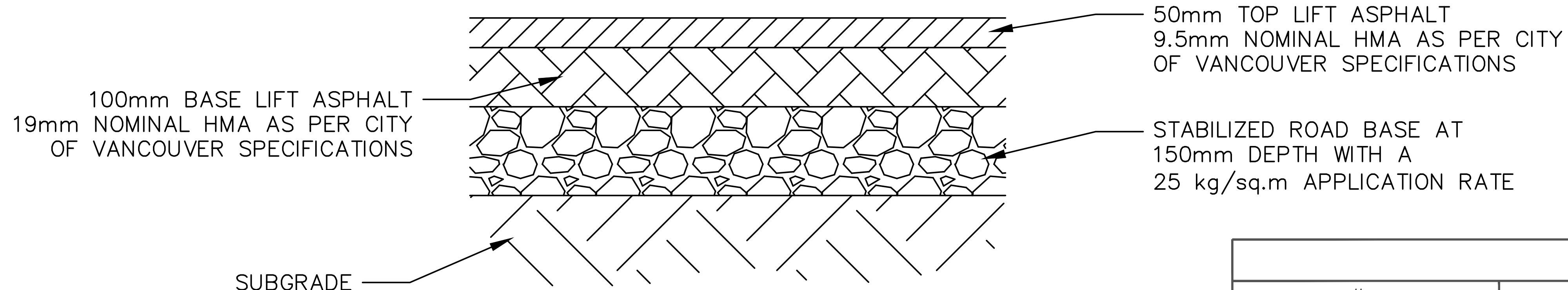
| | | |
|---|---|---|
| GROUP #: | TYPICAL ROAD DETAIL | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02–15 |
| DATE:03/20/2021 | | DWG. NO.: 15 OF 23 |
| SCALE:AS SHOWN | | |




FULL ROAD SECTION WITH MEDIAN
SCALE 1:50




A ROAD PAVEMENT CLOSE–UP
SCALE 1:30




1 ROAD PAVEMENT CLOSE–UP
SCALE 1:10

| | | |
|---|---|---|
| GROUP #: | TYPICAL ROAD WITH MEDIAN DETAIL | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02–16 |
| DATE:03/20/2021 | | DWG. NO.: 16 OF 23 |
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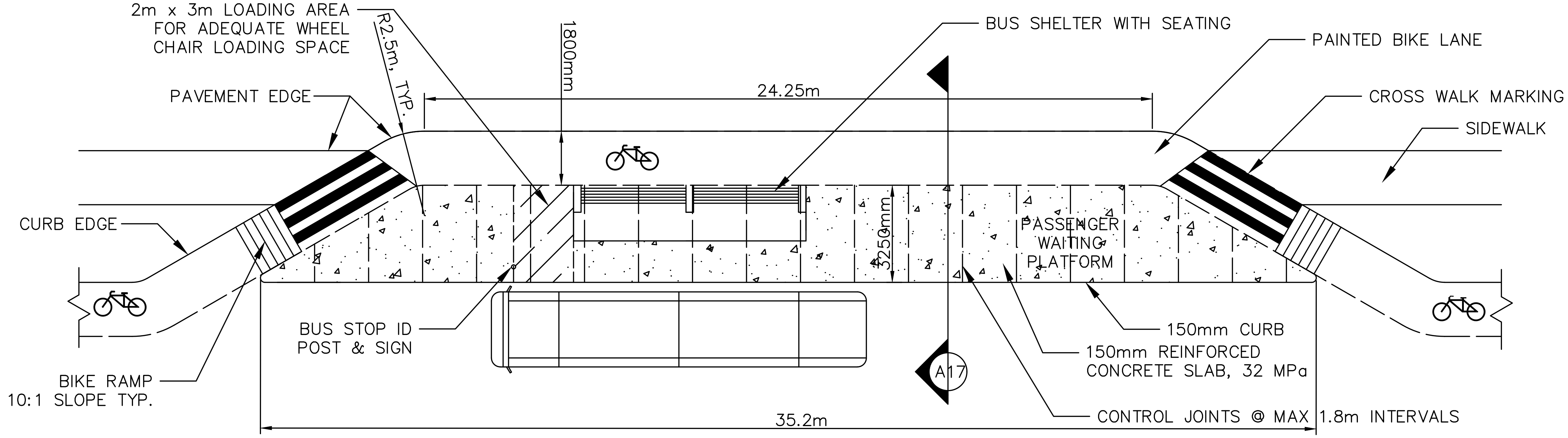
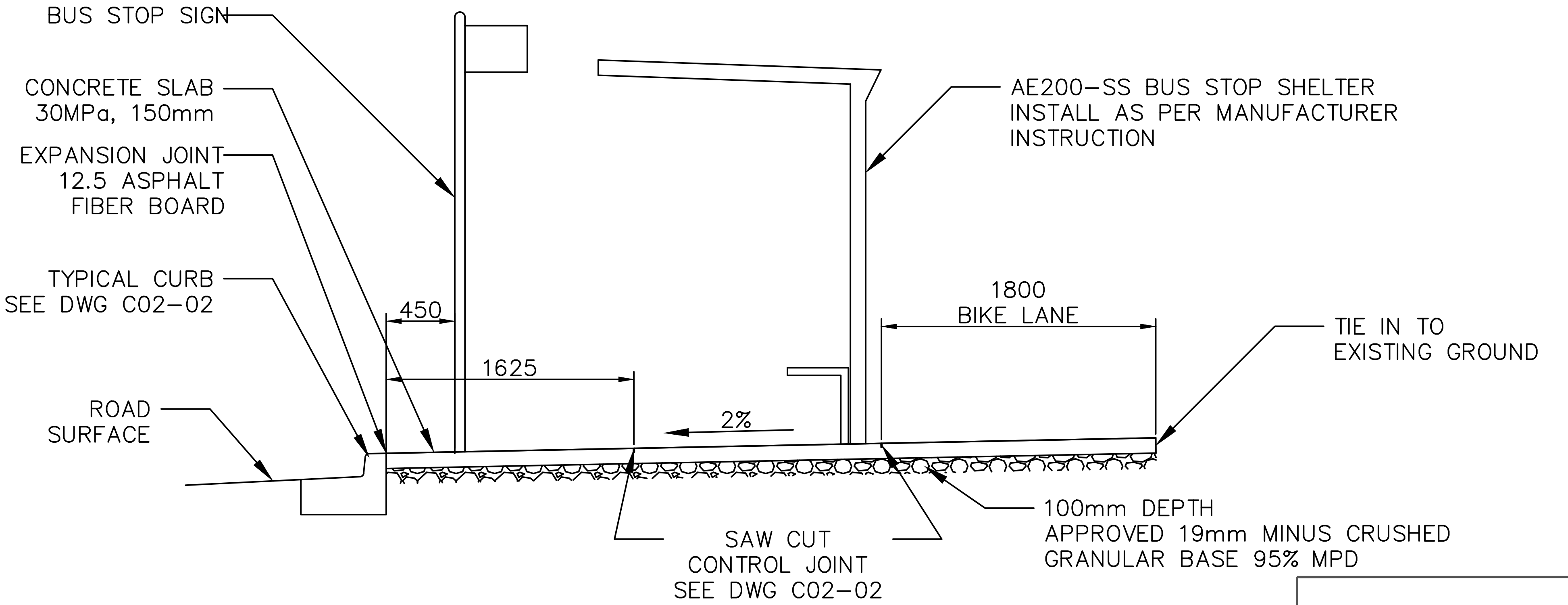



EAST MALL TYPICAL BUS STOP PLAN
SCALE 1:150

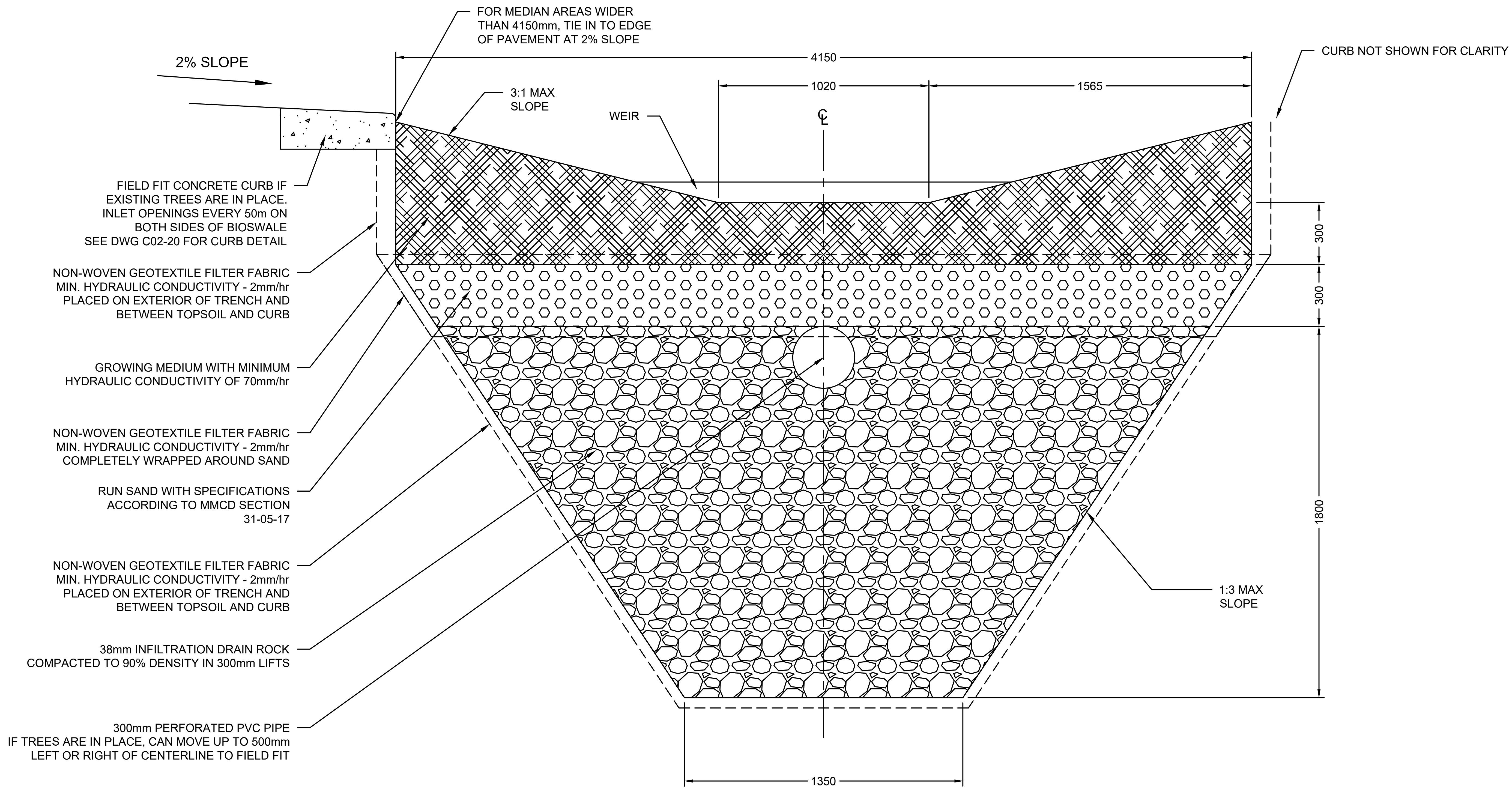



A BUS STOP SECTION
SCALE 1:40

NOTES:

- NON-SPECIFIED MATERIALS MUST BE PROCURED AND CONSTRUCTED/INSTALLED ACCORDING TO VANCOUVER CONSTRUCTION STANDARDS.
- CONTRACTOR RESPONSIBILITY TO INSTALL APPROPRIATE SIGNAGE ACCORDING TO CITY OF VANCOUVER STANDARDS.

| | | |
|---|---|---|
| GROUP #: | EAST MALL TYPICAL BUS STOP DETAIL | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02-17 |
| DATE:3/13/2021 | | DWG. NO.: 17 of 23 |
| SCALE:AS SHOWN | | |




| | | |
|---|---|---|
| GROUP #: | BIOSWALE SECTION DETAIL | COURSE: CIVL 446 |
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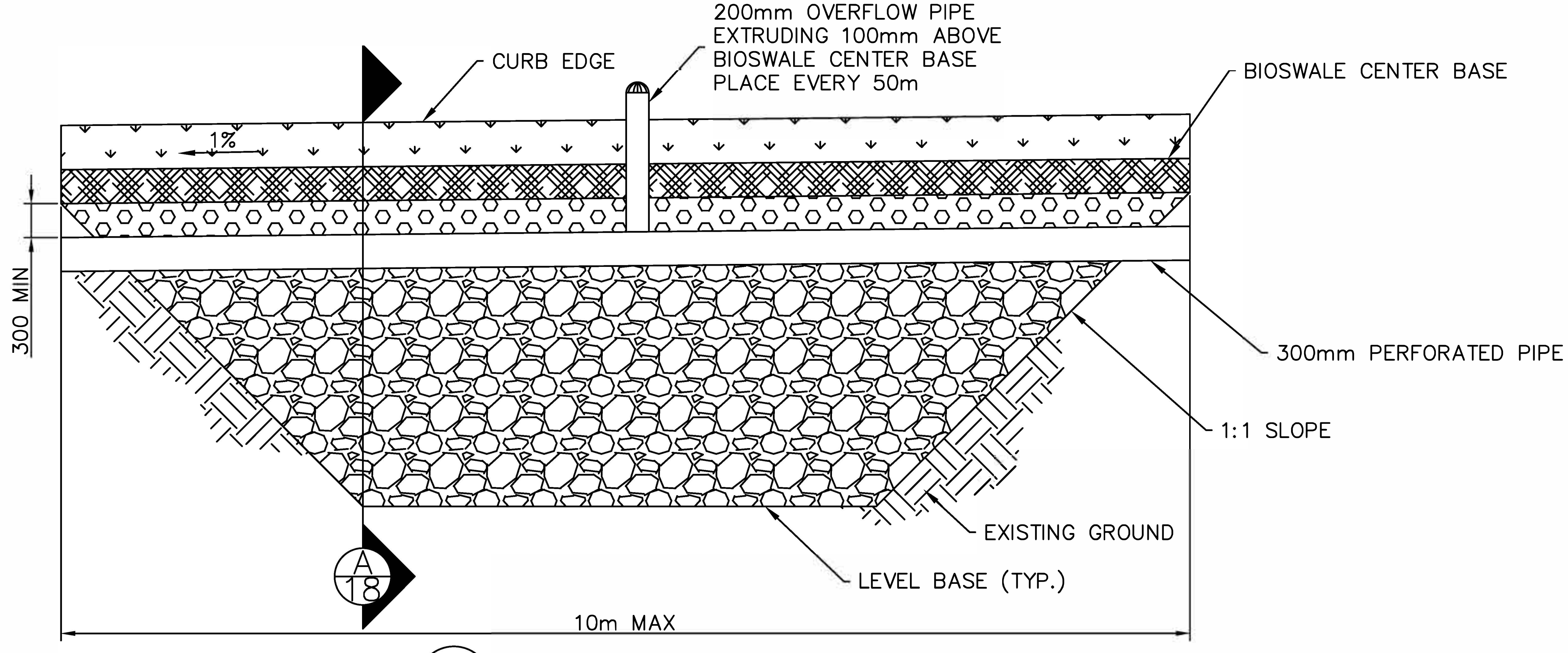
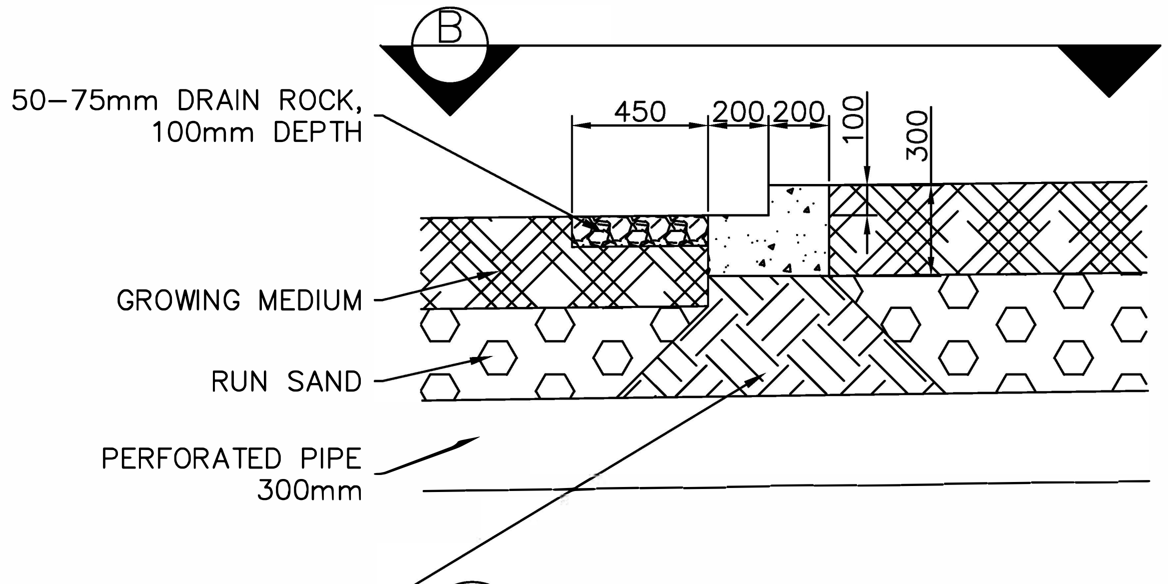
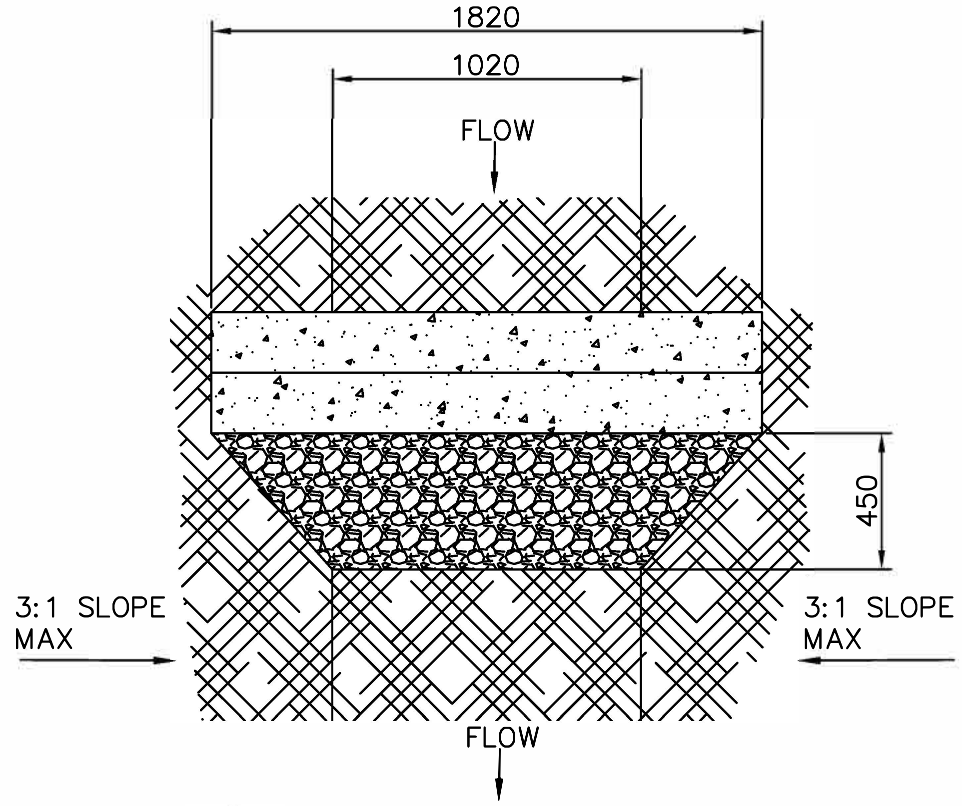
| SCALE:1:20 | | |




A BIOSWALE SECTION
SCALE 1:50




C BIOSWALE WEIR DETAIL
SCALE 1:25

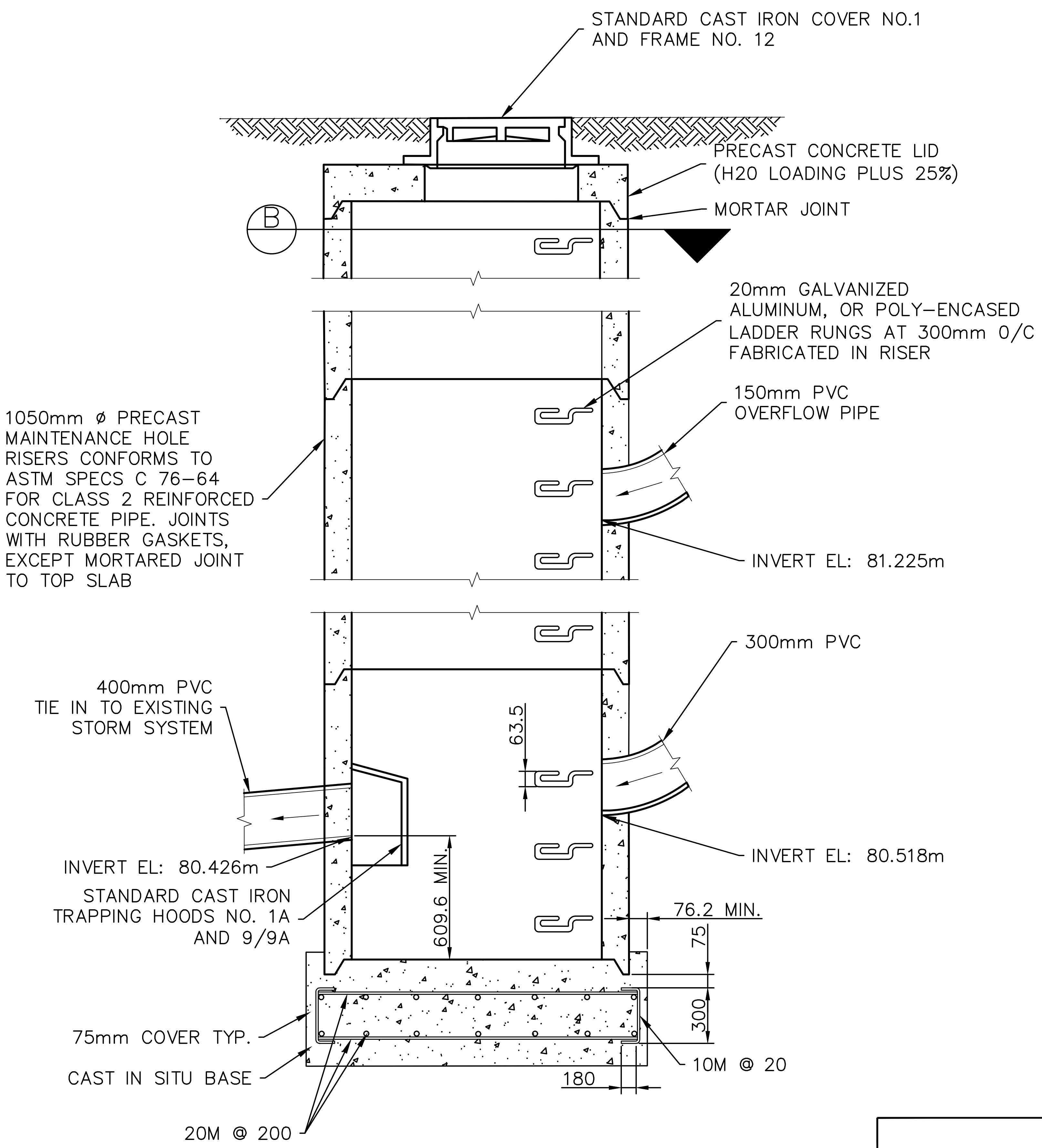



B BIOSWALE WEIR PLAN
SCALE 1:25

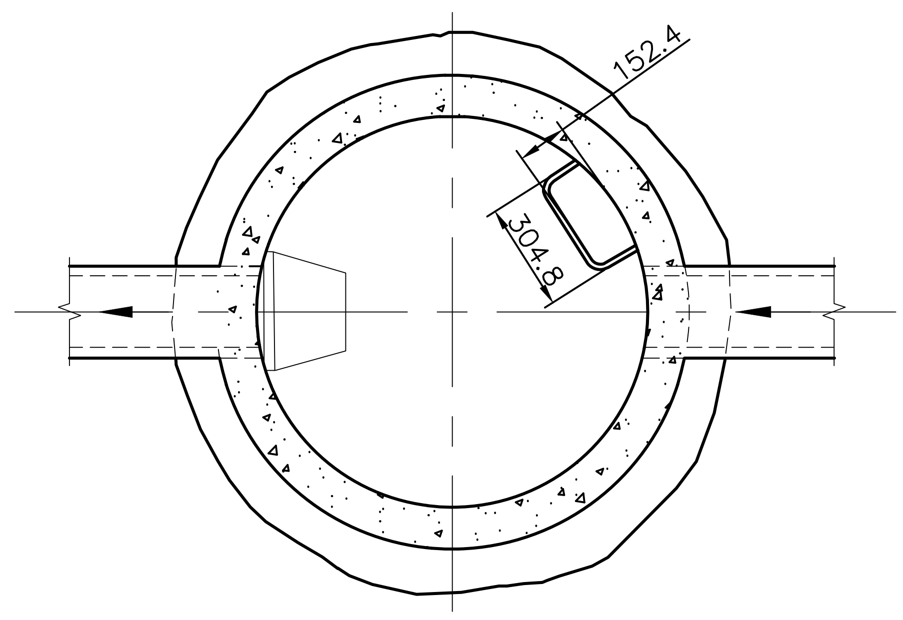
NOTES:

ISOLATE THE SWALE SITE FROM SEDIMENTATION DURING CONSTRUCTION, EITHER BY USE OF EFFECTIVE EROSION AND SEDIMENT CONTROL MEASURES UPSTREAM, OR BY DELAYING THE EXCAVATION OF 300mm OF MATERIAL OVER THE FINAL SUBGRADE OF THE SWALE UNTIL AFTER ALL SEDIMENT-PRODUCING CONSTRUCTION IN THE DRAINAGE AREA HAS BEEN COMPLETED (MARYLAND DEPT. ENVIRONMENTAL RESOURCE PROGRAMS, 2001).

| | | |
|---|---|---|
| GROUP #: | BIOSWALE PROFILE AND WEIR DETAIL | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02-19 |
| DATE:03/15/2021 | | DWG. NO.: 19 OF 23 |
| SCALE:AS SHOWN | | |




MAINTENANCE HOLE
SCALE: NTS

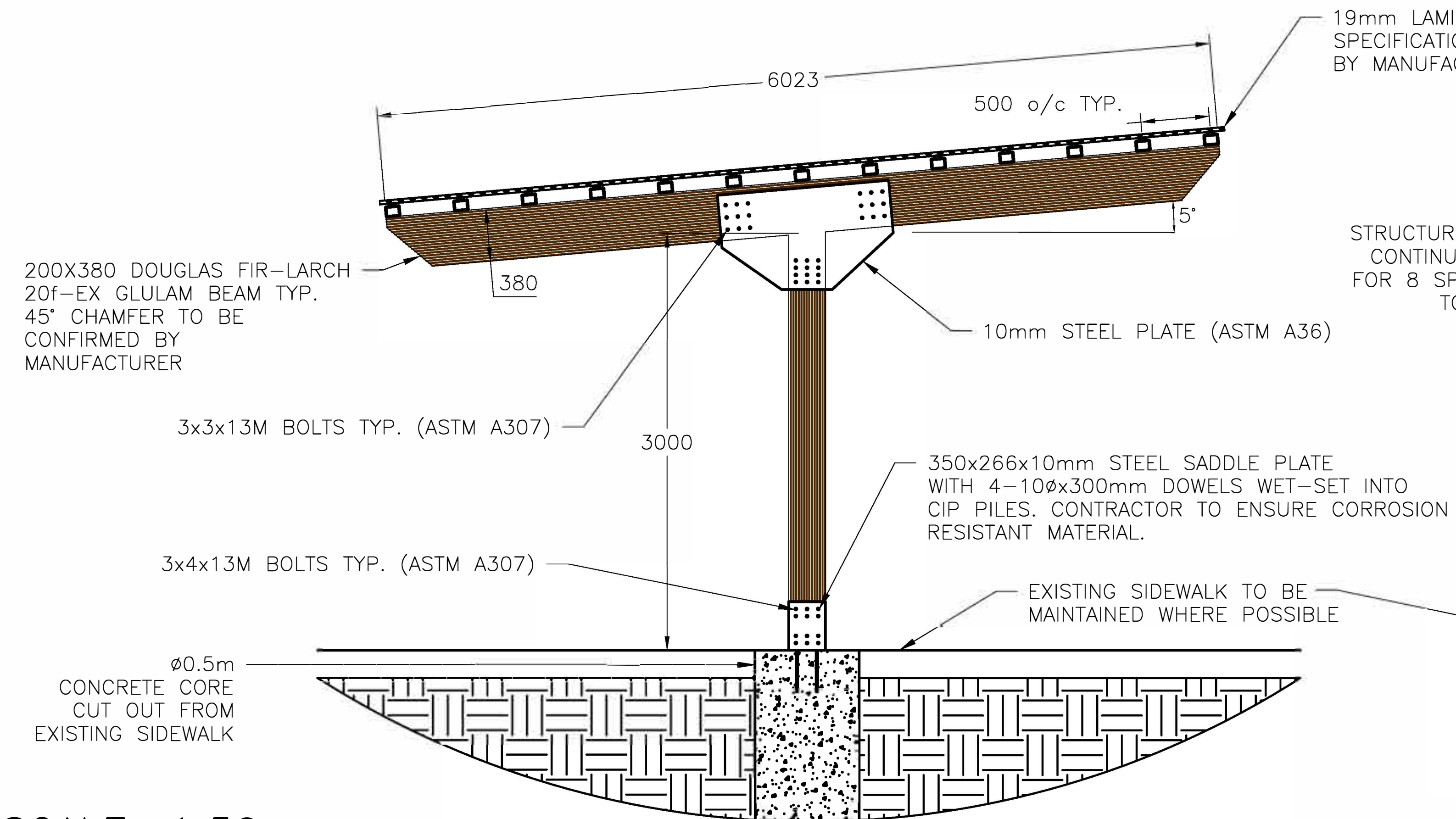



B MAINTENANCE HOLE SECTION
SCALE: NTS

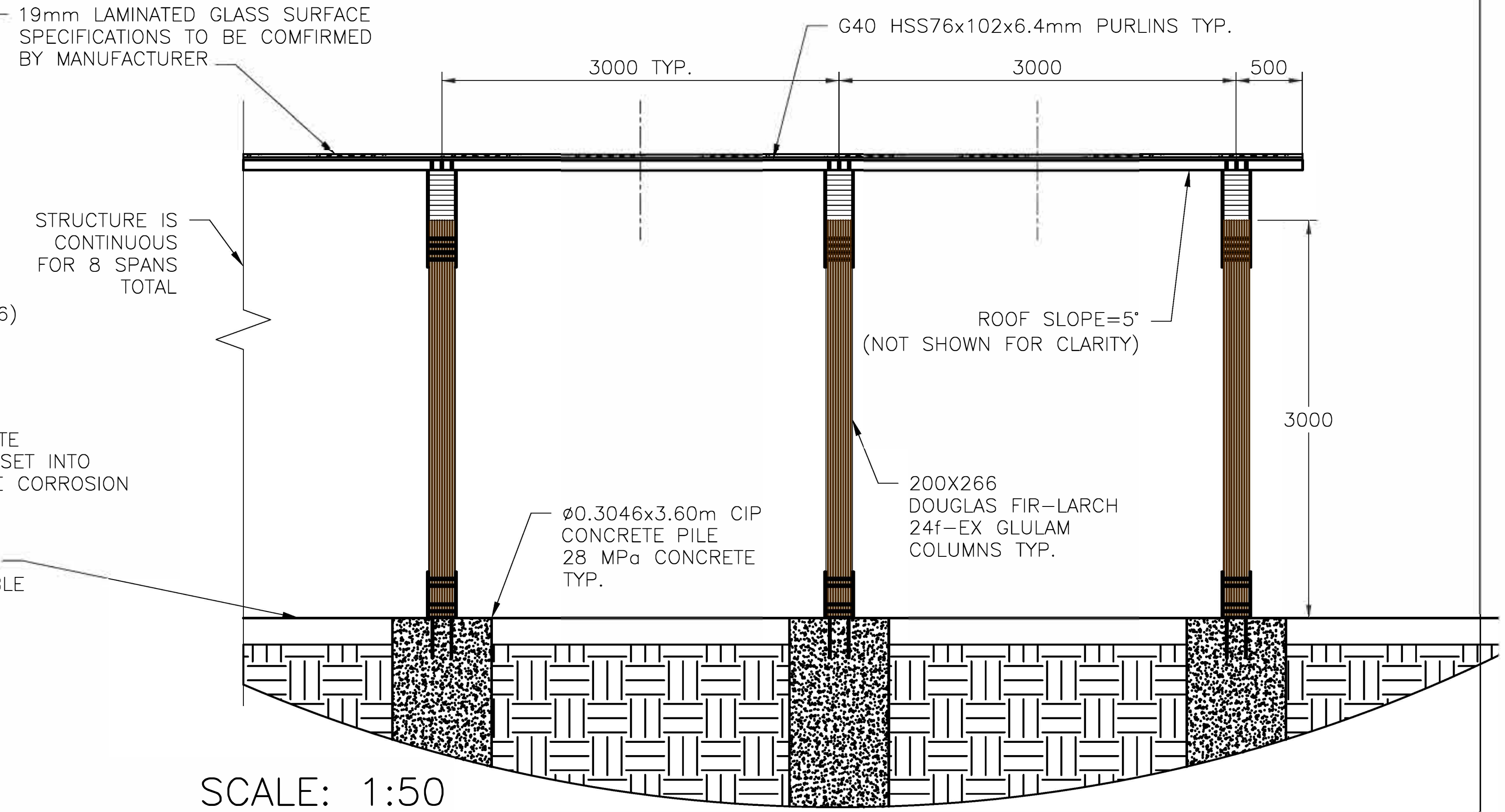
NOTES:

- SITE CAST CONCRETE SHALL HAVE A MINIMUM STRENGTH COMPRESSIVE STRENGTH OF 28MPa AT 28 DAYS.
- MAXIMUM DEPTH TO FIRST RUNG IS 500mm. WHEN HAND HOLD IS INSTALLED BETWEEN TOP AND FIRST RUNG AS PER MMCD, MAXIMUM DEPTH MAY BE INCREASED TO 660mm.
- NO RUNGS ARE PERMITTED IN OR ABOVE THE PRECAST LID.
- MAINTENANCE HOLE LID & FRAME MUST BE PURCHASED FROM THE CITY OF VANCOUVER.
- REINFORCING STEEL SHALL CONFORM TO G30.18, GRADE 400W.
- ALL DIMENSIONS IN mm UNLESS STATED OTHERWISE.

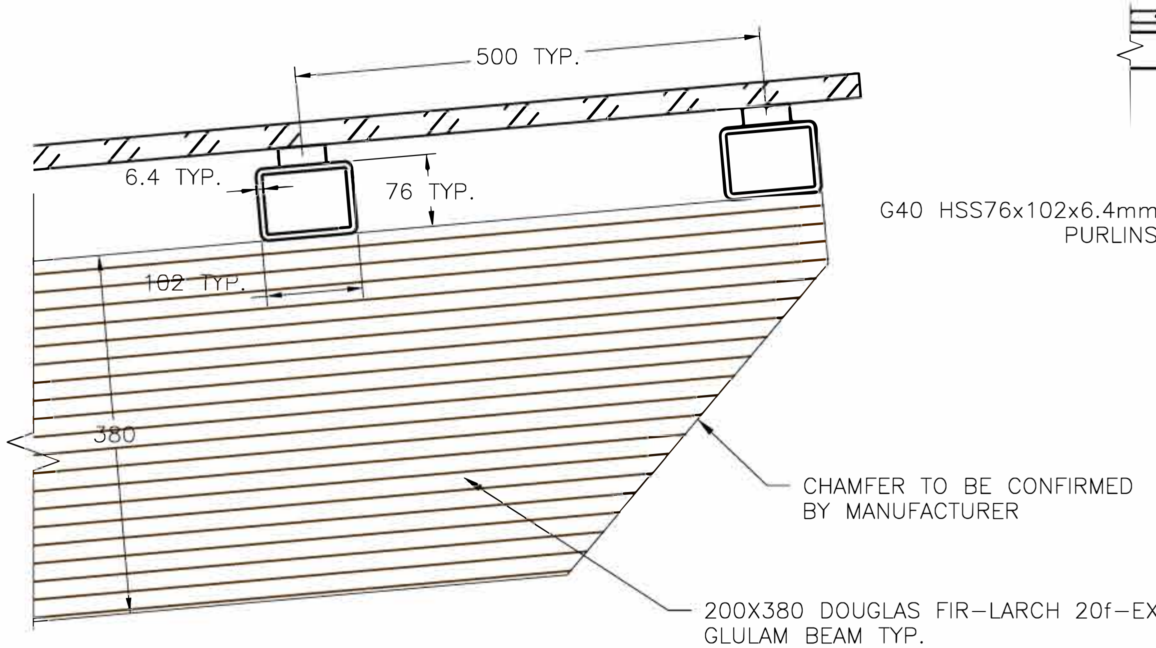
| | | |
|---|---|---|
| GROUP #: | MAINTENANCE HOLE DETAIL | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02-20 |
| DATE:03/15/2021 | | DWG. NO.: 20 OF 23 |
| SCALE:AS SHOWN | | |




SCALE: 1:50

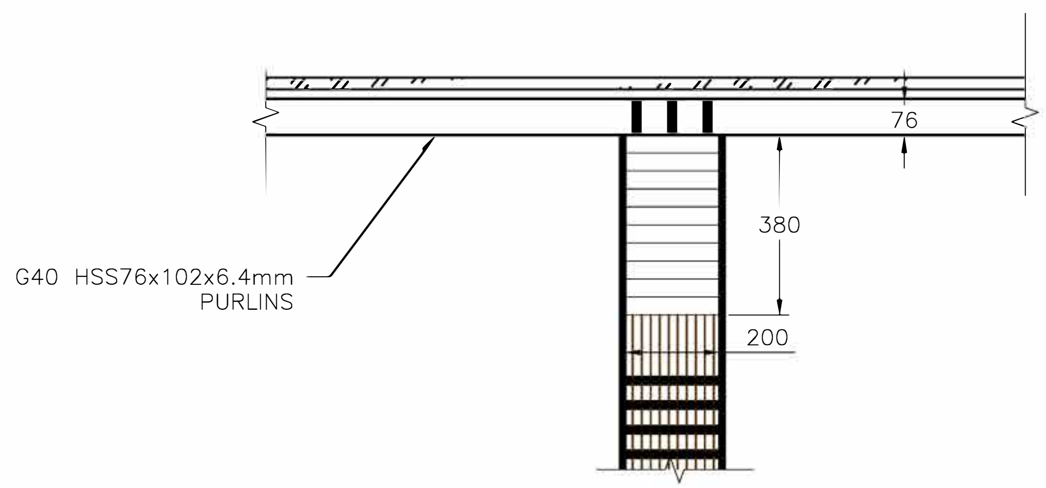



SCALE: 1:50



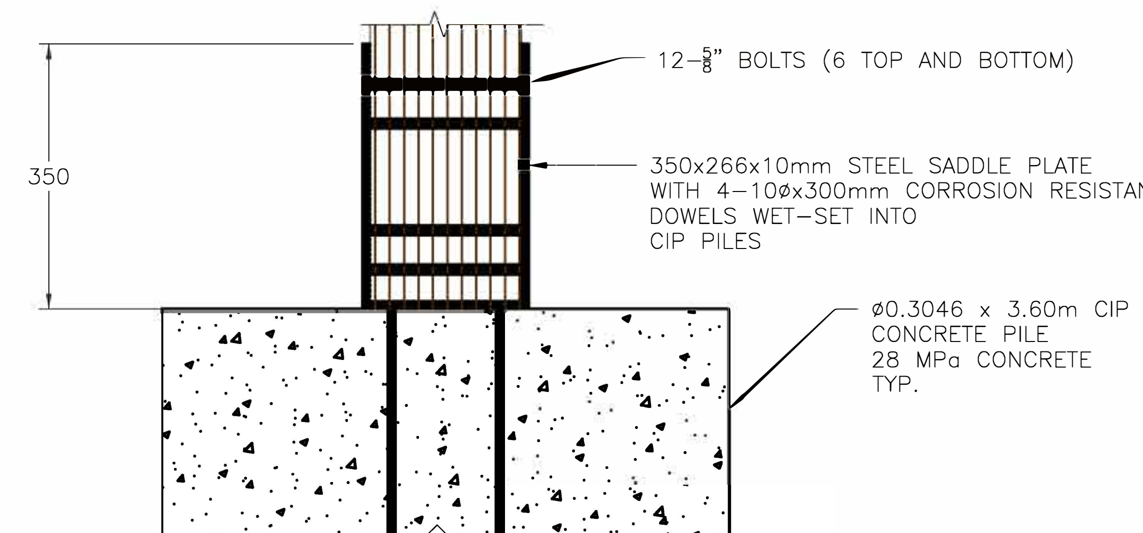

CANTILEVER DETAIL

SCALE: 1:8




COLUMN CONNECTION DETAIL

SCALE: 1:16

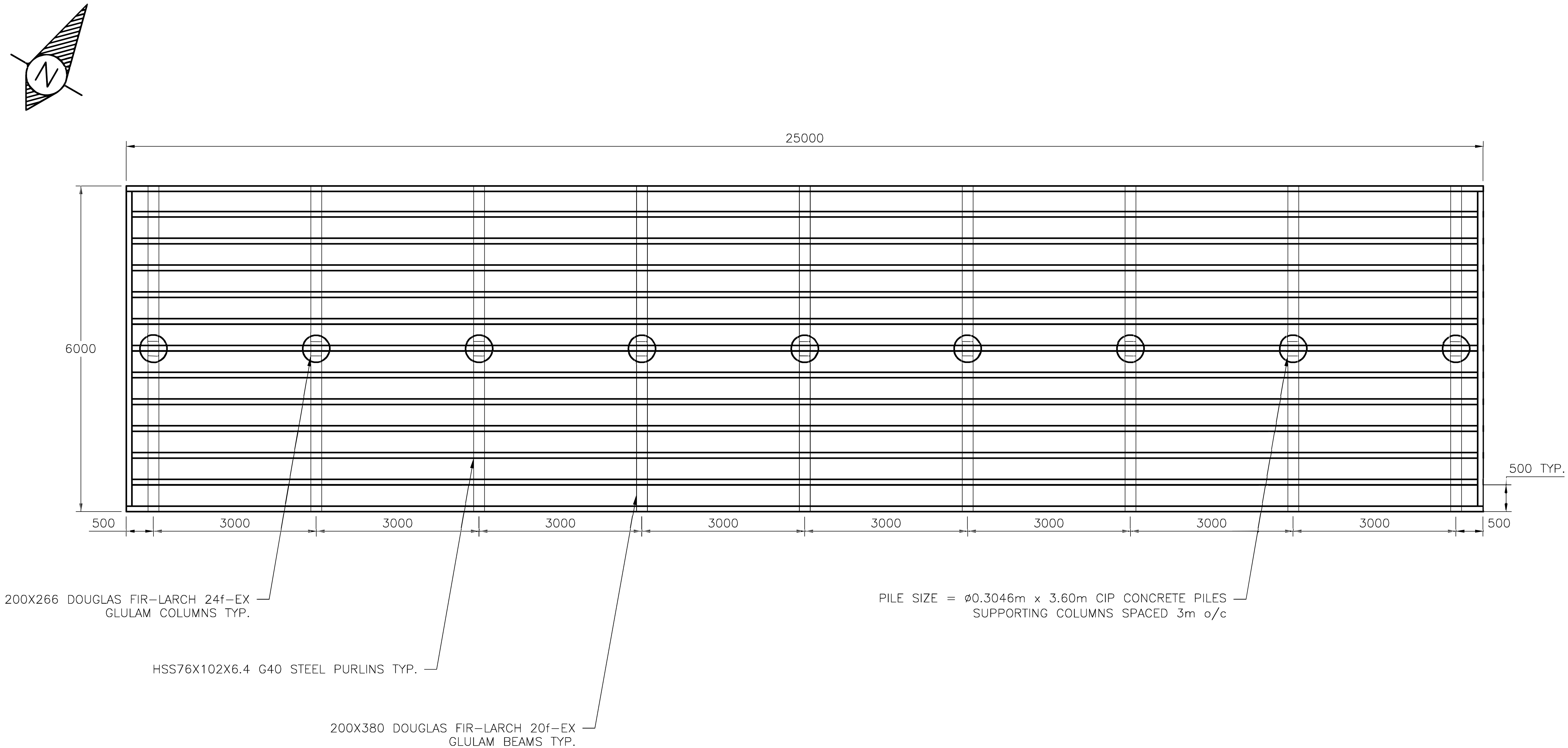



COLUMN CONNECTION DETAIL

SCALE = 1:10

NOTES:
- ALL DIMENSIONS ARE IN MILLIMETERS
- DRAWING MUST BE PRINTED IN 17"X11" PAPER

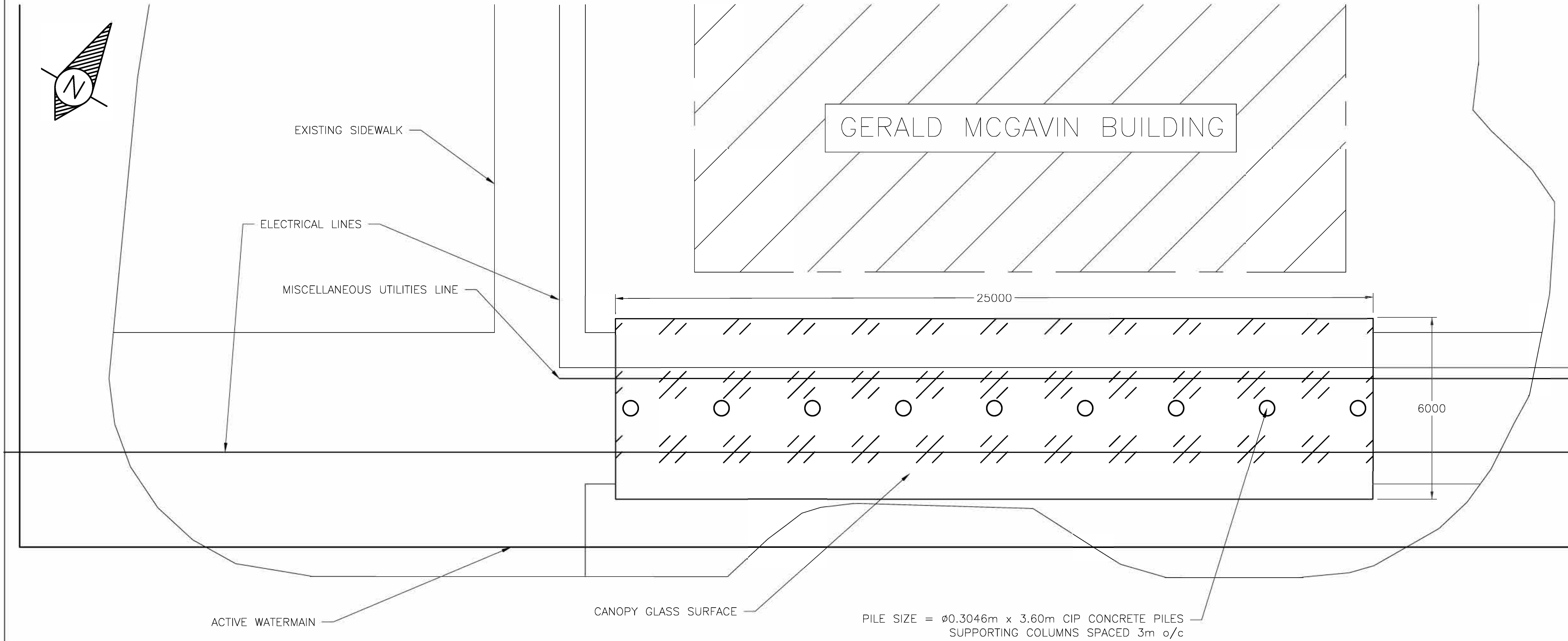
| | | |
|---|---|---|
| GROUP #: | CANOPY – CROSS SECTION AND ELEVATION VIEW | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02-21 |
| DATE:03/27/2021 | | DWG. NO.: 21 OF 23 |
| SCALE:AS SHOWN | | |




NOTES:

- ALL DIMENSIONS ARE IN MILLIMETERS
- DRAWING MUST BE PRINTED IN 17"X11" PAPER
- ROAD IS LOCATED ON THE SOUTH SIDE OF CANOPY
- CANOPY SLOPED DOWN AT 5° TOWARDS SOUTH SIDE OF ROAD

| | | |
|---|---|---|
| GROUP #: | CANOPY – PLAN VIEW | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02–22 |
| DATE:03/27/2021 | | DWG. NO.: 22 OF 23 |
| SCALE:AS SHOWN | | |




UTILITY NOTE:
- AS SEEN IN DRAWING, THERE IS POSSIBLE CONFLICT BETWEEN UTILITY LINES AND PILE LAYOUT. ENSURE PROPER MEASURES ARE TAKEN TO MITIGATE RISK OF CONTACT.

STRUCTURE SITE LAYOUT
SCALE: N.T.S.

NOTES:
- ALL DIMENSIONS ARE IN MILLIMETERS
- DRAWING MUST BE PRINTED IN 17"X11" PAPER

| | | |
|---|---|---|
| GROUP #: | CANOPY – PLAN VIEW & SURROUNDING STRUCTURES | COURSE: CIVL 446 |
| DWN: | | DWG. NAME: C02–23 |
| DATE:03/27/2021 | | DWG. NO.: 23 OF 23 |
| SCALE:AS SHOWN | | |

# Appendix B – Synchro 6 Thunderbird Intersection Phasing

## East Mall – Thunderbird Intersection Phasing AM

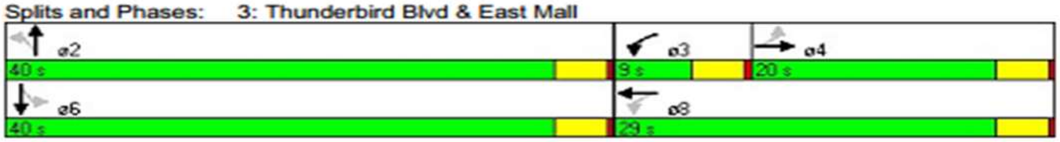
**Timings**
**3: Thunderbird Blvd & East Mall** 2021-02-27

| Lane Group | EBL | EBT | EBR | WBL | WBT | WBR | NBL | NBT | NBR | SBL | SBT | SBR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | | | | | |
| Total Lost Time (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| Satd. Flow (prot) | 0 | 1674 | 0 | 1805 | 1834 | 0 | 0 | 1724 | 0 | 0 | 1781 | 0 |
| Flt Permitted | | 0.978 | | 0.423 | | | | 0.980 | | | 0.823 | |
| Satd. Flow (perm) | 0 | 1633 | 0 | 651 | 1834 | 0 | 0 | 1685 | 0 | 0 | 1479 | 0 |
| Satd. Flow (RTOR) | | 20 | | | 11 | | | 72 | | | 19 | |
| Volume (vph) | 5 | 87 | 36 | 59 | 94 | 19 | 32 | 296 | 187 | 28 | 68 | 11 |
| Lane Group Flow (vph) | 0 | 196 | 0 | 68 | 201 | 0 | 0 | 612 | 0 | 0 | 136 | 0 |
| Turn Type | Perm | | | pm+pt | | | Perm | | | Perm | | |
| Protected Phases | | 4 | | 3 | 8 | | | 2 | | | 6 | |
| Permitted Phases | 4 | | | 8 | | | 2 | | | 6 | | |
| Total Split (s) | 20.0 | 20.0 | 0.0 | 9.0 | 29.0 | 0.0 | 40.0 | 40.0 | 0.0 | 40.0 | 40.0 | 0.0 |
| Act Effct Green (s) | | 16.0 | | 25.0 | 25.0 | | | 36.0 | | | 36.0 | |
| Actuated g/C Ratio | | 0.23 | | 0.36 | 0.36 | | | 0.52 | | | 0.52 | |
| v/c Ratio | | 0.50 | | 0.21 | 0.30 | | | 0.67 | | | 0.17 | |
| Control Delay | | 25.7 | | 16.4 | 16.4 | | | 15.0 | | | 8.1 | |
| Queue Delay | | 0.0 | | 0.0 | 0.0 | | | 0.0 | | | 0.0 | |
| Total Delay | | 25.7 | | 16.4 | 16.4 | | | 15.0 | | | 8.1 | |
| LOS | | C | | B | B | | | B | | | A | |
| Approach Delay | | 25.7 | | | 16.4 | | | 15.0 | | | 8.1 | |
| Approach LOS | | C | | | B | | | B | | | A | |
| 90th %ile Green (s) | 16.0 | 16.0 | | 5.0 | 25.0 | | 36.0 | 36.0 | | 36.0 | 36.0 | |
| 90th %ile Term Code | MaxR | MaxR | | MaxR | MaxR | | Coord | Coord | | Coord | Coord | |
| 70th %ile Green (s) | 16.0 | 16.0 | | 5.0 | 25.0 | | 36.0 | 36.0 | | 36.0 | 36.0 | |
| 70th %ile Term Code | MaxR | MaxR | | MaxR | MaxR | | Coord | Coord | | Coord | Coord | |
| 50th %ile Green (s) | 16.0 | 16.0 | | 5.0 | 25.0 | | 36.0 | 36.0 | | 36.0 | 36.0 | |
| 50th %ile Term Code | MaxR | MaxR | | MaxR | MaxR | | Coord | Coord | | Coord | Coord | |
| 30th %ile Green (s) | 16.0 | 16.0 | | 5.0 | 25.0 | | 36.0 | 36.0 | | 36.0 | 36.0 | |
| 30th %ile Term Code | MaxR | MaxR | | MaxR | MaxR | | Coord | Coord | | Coord | Coord | |
| 10th %ile Green (s) | 16.0 | 16.0 | | 5.0 | 25.0 | | 36.0 | 36.0 | | 36.0 | 36.0 | |
| 10th %ile Term Code | MaxR | MaxR | | MaxR | MaxR | | Coord | Coord | | Coord | Coord | |

**Intersection Summary**

Cycle Length: 69
Actuated Cycle Length: 69
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Green
Control Type: Pretimed
Maximum v/c Ratio: 0.67
Intersection Signal Delay: 16.3 Intersection LOS: B
Intersection Capacity Utilization 67.8% ICU Level of Service C
Analysis Period (min) 15

Splits and Phases: 3: Thunderbird Blvd & East Mall




2020-11-27 Baseline
University of British Columbia

Synchro 6 Report
Page 1

## East Mall – Thunderbird Intersection Phasing MD

**Timings**
**3: Thunderbird Blvd & East Road** 2021-02-27

| Lane Group | EBL | EBT | WBL | WBT | NBL | NBT | SBL | SBT |
|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | |
| Volume (vph) | 2 | 56 | 74 | 60 | 37 | 105 | 33 | 106 |
| Turn Type | Perm | | pm+pt | | Perm | | Perm | |
| Protected Phases | | 4 | 3 | 8 | | 2 | | 6 |
| Permitted Phases | 4 | | 8 | | 2 | | 6 | |
| Detector Phases | 4 | 4 | 3 | 8 | 2 | 2 | 6 | 6 |
| Minimum Initial (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| Minimum Split (s) | 20.0 | 20.0 | 8.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| Total Split (s) | 20.0 | 20.0 | 8.0 | 28.0 | 21.0 | 21.0 | 21.0 | 21.0 |
| Total Split (%) | 40.8% | 40.8% | 16.3% | 57.1% | 42.9% | 42.9% | 42.9% | 42.9% |
| Yellow Time (s) | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| All-Red Time (s) | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Lead/Lag | Lag | Lag | Lead | | | | | |
| Lead-Lag Optimize? | Yes | Yes | Yes | | | | | |
| Recall Mode | Max | Max | Max | Max | Max | Max | Max | Max |
| Act Effct Green (s) | | 16.0 | 24.0 | 24.0 | | 17.0 | | 17.0 |
| Actuated g/C Ratio | | 0.33 | 0.49 | 0.49 | | 0.35 | | 0.35 |
| v/c Ratio | | 0.21 | 0.13 | 0.11 | | 0.48 | | 0.35 |
| Control Delay | | 9.3 | 7.3 | 5.6 | | 13.2 | | 13.5 |
| Queue Delay | | 0.0 | 0.0 | 0.0 | | 0.0 | | 0.0 |
| Total Delay | | 9.3 | 7.3 | 5.6 | | 13.2 | | 13.5 |
| LOS | | A | A | A | | B | | B |
| Approach Delay | | 9.3 | | 6.4 | | 13.2 | | 13.5 |
| Approach LOS | | A | | A | | B | | B |

**Intersection Summary**
Cycle Length: 49
Actuated Cycle Length: 49
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Green, Master Intersection
Natural Cycle: 50
Control Type: Pretimed
Maximum v/c Ratio: 0.48
Intersection Signal Delay: 11.1 Intersection LOS: B
Intersection Capacity Utilization 35.5% ICU Level of Service A
Analysis Period (min) 15

Splits and Phases: 3: Thunderbird Blvd & East Road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University of British Columbia

Synchro 6 Report
Page 1

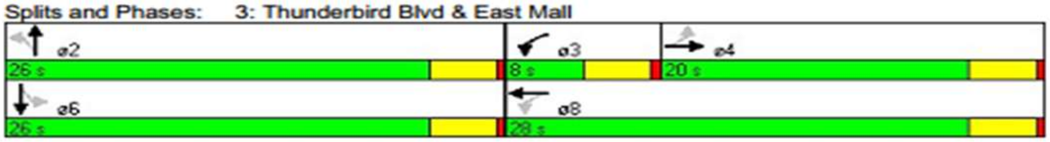
## East Mall – Thunderbird Intersection Phasing PM

**Timings**
**3: Thunderbird Blvd & East Mall** 2021-02-27

| Lane Group | EBL | EBT | WBL | WBT | NBL | NBT | SBL | SBT |
|---|---|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | | | |
| Volume (vph) | 6 | 83 | 213 | 78 | 37 | 76 | 115 | 260 |
| Turn Type | Perm | | pm+pt | | Perm | | Perm | |
| Protected Phases | | 4 | 3 | 8 | | 2 | | 6 |
| Permitted Phases | 4 | | 8 | | 2 | | 6 | |
| Detector Phases | 4 | 4 | 3 | 8 | 2 | 2 | 6 | 6 |
| Minimum Initial (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| Minimum Split (s) | 20.0 | 20.0 | 8.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| Total Split (s) | 20.0 | 20.0 | 8.0 | 28.0 | 26.0 | 26.0 | 26.0 | 26.0 |
| Total Split (%) | 37.0% | 37.0% | 14.8% | 51.9% | 48.1% | 48.1% | 48.1% | 48.1% |
| Yellow Time (s) | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| All-Red Time (s) | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Lead/Lag | Lag | Lag | Lead | | | | | |
| Lead-Lag Optimize? | Yes | Yes | Yes | | | | | |
| Recall Mode | Max | Max | Max | Max | Max | Max | Max | Max |
| Act Effct Green (s) | | 16.0 | 24.0 | 24.0 | | 22.0 | | 22.0 |
| Actuated g/C Ratio | | 0.30 | 0.44 | 0.44 | | 0.41 | | 0.41 |
| v/c Ratio | | 0.33 | 0.58 | 0.15 | | 0.38 | | 0.67 |
| Control Delay | | 12.1 | 16.3 | 8.0 | | 11.1 | | 19.4 |
| Queue Delay | | 0.0 | 0.0 | 0.0 | | 0.0 | | 0.0 |
| Total Delay | | 12.1 | 16.3 | 8.0 | | 11.1 | | 19.4 |
| LOS | | B | B | A | | B | | B |
| Approach Delay | | 12.1 | | 13.6 | | 11.1 | | 19.4 |
| Approach LOS | | B | | B | | B | | B |

**Intersection Summary**
Cycle Length: 54
Actuated Cycle Length: 54
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Green, Master Intersection
Natural Cycle: 60
Control Type: Pretimed
Maximum v/c Ratio: 0.67
Intersection Signal Delay: 15.0 Intersection LOS: B
Intersection Capacity Utilization 68.4% ICU Level of Service C
Analysis Period (min) 15

Splits and Phases: 3: Thunderbird Blvd & East Mall




5:00 pm Baseline
University of British Columbia

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# Appendix C – Pavement

## Pavement Design
### Stadium Road - Thunderbird Blvd

| Vehicle Classification | Base Year AADT | Flexibile ESAL Factor | Base Year ADL | Growth Factor | Design Year AADT | Design ADL |
|---|---|---|---|---|---|---|
| Cars and Pickups | 5246 | 0.0007 | 3.6722 | 1.1 | 56839 | 40 |
| 3+ axle SU | 21 | 0.58 | 12.18 | 1.1 | 228 | 132 |
| Buses | 28 | 0.57 | 15.96 | 1.1 | 303 | 173 |
| | | | 31.8122 | | 57370 | 345 |

| | | |
|---|---|---|
| ESALs | 865,734 | |
| $Z_r$ | -1.28 | ZR |
| Standard Deviation | 0.45 | S |
| Delta PSI | 3.00 | DPSI |
| Subgrade $M_r$ | 10000 | psi |

| | Surface mix | Base mix | Stab. Base | subbase |
|---|---|---|---|---|
| $a_i$ | 0.44 | 0.34 | 0.14 | 0.00 |
| D[i], inches | 2.00 | 4.00 | 6.00 | 0.00 |
| $m_i$ | | 1.00 | 1.00 | 1.00 |

| | | |
|---|---|---|
| Reliability, % | 90 | R |
| Initial and terminal serviceability | Po | Pt |
| Delta PSI | 5.00 | 2.00 |
| Design SN | 3.08 | |
| Required SN (Solver will fill in) | 2.84 | |
| log10(W18) = | 5.94 | |
| | 5.94 | |
| target cell | 0.00 | |

| Asphalt Structure | |
|---|---|
| Top Lift Asphalt | 2.00 |
| Base Lift Asphalt | 4.00 |
| Cement Stabilized Base | 6.00 |

## Pavement Design
### Thunderbird Blvd - Agronomy Road

| Vehicle Classification | Base Year AADT | Flexibile ESAL Factor | Base Year ADL | Growth Factor | Design Year AADT | Design ADL |
|---|---|---|---|---|---|---|
| Cars and Pickups | 4215 | 0.0007 | 2.9505 | 1.1 | 45668 | 32 |
| Buses | 7 | 0.57 | 3.99 | 1.1 | 76 | 43 |
| | | | 6.9405 | | 45744 | 75 |

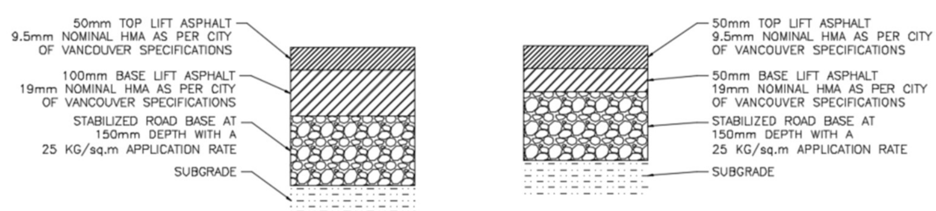
| | | |
|---|---|---|
| ESALs | 188,878 | |
| $Z_r$ | -1.28 | ZR |
| Standard Deviation | 0.45 | S |
| Delta PSI | 3.00 | DPSI |
| Subgrade $M_r$ | 10000 | psi |

| | Surface mix | Base mix | Stab. Base | subbase |
|---|---|---|---|---|
| $a_i$ | 0.44 | 0.34 | 0.14 | 0.00 |
| D[i], inches | 2.00 | 2.00 | 6.00 | 0.00 |
| $m_i$ | | 1.00 | 1.00 | 1.00 |

| | | |
|---|---|---|
| Reliability, % | 90 | R |
| Initial and terminal serviceability | Po | Pt |
| Delta PSI | 5.00 | 2.00 |
| Design SN | 2.40 | |
| Required SN (Solver will fill in) | 2.28 | |
| log10(W18) = | 5.28 | |
| | 5.28 | |
| target cell | 0.00 | |

| Asphalt Structure | |
|---|---|
| Top Lift Asphalt | 2.00 |
| Base Lift Asphalt | 2.00 |
| Cement Stabilized Base | 6.00 |

PAVEMENT DESIGN




STADIUM ROAD TO THUNDERBIRD BLVD

THUNDERBIRD BLVD TO AGRONOMY ROAD

# Appendix D – Bioswale Calculations

| | | |
|---|---|---|
| **Project:** East Mall Redesign<br>**Designer:**<br>**Reviewer:** | **Page:** 1 of 2<br>**Updated:** 28/11/2020<br>**Reviewed:** 29/11/2020 | |

**Design Bioswale for East Mall Center Boulevard from Stadium Road to Eagles Drive**

**Design calculations were conducted accordint to Metro Vancouver's Stormwater Source Control Design Guidelines 2012.*

Slope breaking mechanism:

Assume swale longitudinal slope is within 1-2% which means weirs or terraces are not required.

Swale side slopes:

Use 4:1 side slopes recommended by Metro Vancouver to allow for convenience during maintenance.

Treatment soil depth:

Use treatment soil depth of 300mm (Typical value according to Metro Vancouver design guideline).

Rock reservoir size:

T = 4 days

**Use max allowable according to design manual*

Ks = 2.3 mm/hr

**Soil classification is clay loam according to hydrogeo assessment conducted by Piteau Associates (2002). Ks value obtained from Table 1-4.*

Table 1-4: Typical Literature Infiltration Rates

| USDA Soil Class | Saturated hydraulic conductivity (mm/hr) |
|---|---|
| Sand | 210 |
| Loamy sand | 61* |
| Sandy loam | 26* |
| Loam | 13 |
| Silt loam | 6.8 |
| Sandy clay loam | 4.3 |
| Clay loam | 2.3 |
| Silty clay loam | 1.5 |
| Sandy clay | 1.2 |
| Silty clay | 0.9 |
| Clay | 0.6 |

n = 0.35

**Use typical value according to design guide*

$$D_R = \frac{Ks \times T \times 24}{n}$$

Dr = 631 mm (Rock Trench Depth)

300mm < 631mm < 2000mm OK

Round Dr to nearest 50mm to allow for constructability:

Dr = 650 mm

| Project: East Mall Redesign | Page: 2 of 2 | |
|---|---|---|
| Designer: | Updated: 28/11/2020 | |
| Reviewer: | Reviewed: 29/11/2020 | |

Swale base width:

| | | |
|---|---|---|
| Total Area = | 12723 | m^2 |
| Pervious Area = | 2961 | m^2 |
| Swale Length = | 393 | m |
| Impervious Area = | 9762 | m^2 |

$$I/P = \frac{24 \times Ks + D_R \times n + 0.2 \times D_S}{R} - 1$$

| | | | |
|---|---|---|---|
| Ks = | 2.3 | mm/hr | |
| Dr = | 2000 | mm | Use max allowable |
| n = | 0.35 | | |
| Ds = | 300 | mm | |
| R = | 81 | mm | Table 1-7 |

**R = Rainfall Capture Depth (Obtained from Table 1-7 of guideline).*

I/P = 9.1 < 20 OK (Table 3-1)

| | | |
|---|---|---|
| Swale Base Area = | 1077 | m^2 |
| Swale Base Width = | 2.74 | m |

2.74 > 2.4m (recommended max base width)
Need to add perforated pipe and orifice for to increase outflow and reduce base width requirement.

West Vancouver average rainfall is approximately 1300mm according to West Vancouver climate-

Only 1100mm and 1600mm charts available, so use 1600mm chart to be conservative.

Using a capture of 75% recommended by design guide, I/P value is 19 with a Dr = 1.8m (see graph).

New base width = 1.35 m
**Rounded to nearest 50mm*

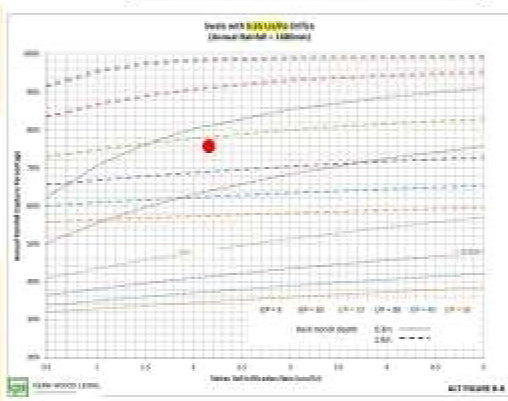
Assume perforated pipe diameter to be 200mm. Assumed pipe is slightly higher than minimum required diameter of 150mm to be conservative.

Table 3-1: Rain Garden Maximum I/P Ratios by Surface Type

| Surface Type | Max. I/P Ratio |
|---|---|
| General/Industrial Storage/Loading Areas | 20:1 |
| Divided or Undivided Major Road (Expressway or Highway) | 20:1 |
| Collector Road | 20:1 |
| Parking >1 car/day/parking space | 20:1 |
| Local Road | 30:1 |
| Parking <1 car/day/parking space | 40:1 |
| Low traffic areas, no parking | 50:1 |
| Single Family Residential, Lot and Roof | 50:1 |

Table 1-7: Typical Rainfall Capture Targets

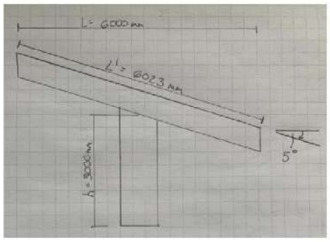
| 6-Month, 24-Hour Rainfall Capture Targets | |
|---|---|
| Climate Station | Rainfall Capture Target* |
| North Vancouver Lynn Creek (upper elevations) | 86 mm |
| North Vancouver Municipal Hall (lower elevations) | 58 mm |
| West Vancouver CS (upper elevations) | 81 mm |
| West Vancouver Municipal Hall (lower elevations) | 56 mm |
| Maple Ridge Reservoir | 65 mm |
| Langley Lochiel | 46 mm |
| Surrey Kwantlen Park | 39 mm |
| White Rock STP | 37 mm |
| Vancouver Airport | 36 mm |



# Appendix E – Canopy

Project: East Mall Redesign - Canopy Structure
Client: Universtiy of British Columbia - UBC SEEDS

# Load Calculations




Roof Dimensions (Plan View):

$L_{plan} := 6000\ mm$

$W_{plan} := 25000\ mm$

$H_{column} := 3000\ mm$

$L' := 6023\ mm$

$\theta := 5\ °$

**Determine Snow Load** $S = I_s [S_s (C_b C_w C_s C_a) + S_r]$ (NBCC 2015, 4.1.6.2 (1))

$S_s := 1.9\ kPa$ (NBCC 2015, Table C-2)

$S_r := 0.3\ kPa$ -Vancouver (Granville & 41 Ave)

$I_s := 1$ -Normal importance category (NBCC 2015, Table 4.1.6.2-A)

$C_w := 1$ -No wind exposure adjustment (NBCC 2015, 4.1.6.2 (3))

$I_c := 2\ L_{plan} - \dfrac{L_{plan}^{\ 2}}{W_{plan}} = 10.56\ m$

$\dfrac{70}{C_w^{\ 2}} = 70$ >Ic, case i) applies $C_b := 0.8$ (NBCC 2015, 4.1.6.2 (2))

$C_s := 1$ -Unobstructed slippery roof (NBCC 2015, 4.1.6.2 (6))

Since this could be considered a multi-level roof, Ca must be determined taking into account the upper roof.
Note that due to the configuration of the roof, only case I applies. (NBCC 2015, Figure 4.1.6.5-B)

$H_{bldg} := 15\ m$

$h := H_{bldg} - H_{column} = 12\ m$

$\gamma_{snow} := 0.43\ m^{-1} \cdot S_s + 2.2\ \dfrac{kN}{m^3} = 3.017\ \dfrac{kN}{m^3}$ < 4kn/m^3 (NBCC 2015, 4.1.6.13)

$h' := h - \dfrac{C_b \cdot C_w \cdot S_s}{\gamma_{snow}} = 11.496\ m$ (NBCC 2015, Figure 4.1.6.5-A)

$x := 10\ h' = 114.962\ m$

$w_{upper} := 23\ m$ $l_{upper} := 53\ m$

$I_{cs} := 2\ w_{upper} - \dfrac{w_{upper}^{\ 2}}{l_{upper}} = 36.019\ m$

$h_p := 300\ mm$

$h'_p := h_p - \left(\dfrac{0.8\ S_s}{\gamma_{snow}}\right) = -0.204\ m$ 0 < h'p < (Ics/5)

$\beta := 1$ -Case I

$F := 0.35\ \beta \cdot \sqrt[2]{\dfrac{\gamma_{snow} \cdot (I_{cs} - 5\ h'_p)}{S_s}} + C_b = 3.484$ < 5 OK

$C_{a0\_1} := \beta \cdot \dfrac{\gamma_{snow} \cdot h}{C_b \cdot S_s} = 23.818$ $C_{a0\_2} := \dfrac{F}{C_b} = 4.355$

$C_{a0} := min(C_{a0\_1}, C_{a0\_2}) = 4.355$ (NBCC 2015, 4.1.6.5 (3))

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$x_d := 5 \cdot \frac{C_b \cdot S_s}{\gamma_{snow}} \cdot (C_{a0} - 1) = 8.452\ \boldsymbol{m}$ (NBCC 2015, 4.1.6.5 (2))

$C_a := 1$ For x>xd (NBCC 2015, 4.1.6.5 (1))

$W_s := I_s \cdot (S_s \cdot (C_b \cdot C_w \cdot C_s \cdot C_a) + S_r) = 1.82\ \boldsymbol{kPa}$ -Note that this load is acting in the vertical direction

$W_s := W_s \cdot \frac{L'}{L_{plan}} = 1.827\ \boldsymbol{kPa}$ -Load acting perpendicular to roof surface

**Determine Wind Load** $\mathrm{p = I_W q C_e C_t C_g C_p}$ (NBCC 2015, 4.1.7.3 (1))

$q := 0.45\ \boldsymbol{kPa}$ -1/50 yr for Vancouver (Granville & 41 Ave) (NBCC 2015, Table C-2)
$I_w := 1$ -Normal importance category (NBCC 2015, Table 4.1.7.3)
$C_t := 1$ (NBCC 2015, Table C-2) (NBCC 2015, 4.1.7.4)
$C_{e\_1} := 0.9$

$h := H_{column} + L_{plan} \cdot \tan(\theta)$ -Midheight of member
$h = 3.525\ \boldsymbol{m}$ (NBCC 2015, 4.1.7.4 (6))

$C_{e\_2} := \left(\frac{h}{10}\right)^{0.2}$

$C_e := \max(C_{e\_1}, C_{e\_2}) = 0.9$ -Assuming open terrain (NBCC 2015, 4.1.7.4 (5))

$A_{trib} := L_{plan} \cdot W_{plan} = 150\ \boldsymbol{m}^2$ > 100 m^2 OK

$C_pC_{g\_1} := -2.5$ $C_pC_{g\_2} := 0.3$ (NBCC 2015, Figure 4.1.7.6-C)

$C_{pi} := 0$

$W_{p\_1} := I_w \cdot (q \cdot C_e \cdot C_t \cdot C_pC_{g\_1}) = -1.013\ \boldsymbol{kPa}$ $W_{p\_2} := I_w \cdot (q \cdot C_e \cdot C_t \cdot C_pC_{g\_2}) = 0.122\ \boldsymbol{kPa}$

**Determine maximum factored load combination**

$SP_{purlins} := 500\ \boldsymbol{mm}$ -Purlins to be HSS and spaced at 500mm o/c

$D := 0.5\ \frac{\boldsymbol{kN}}{\boldsymbol{m}}$ -Roof assembly self weight

$L := 0.5 \cdot \frac{\boldsymbol{kN}}{\boldsymbol{m}}$ -Minimum specified live load (NBCC 2015, Table 4.1.5.3)

$S := W_s \cdot SP_{purlins} = 0.913\ \frac{\boldsymbol{kN}}{\boldsymbol{m}}$

$W_1 := W_{p\_1} \cdot SP_{purlins} = -0.506\ \frac{\boldsymbol{kN}}{\boldsymbol{m}}$

$W_2 := W_{p\_2} \cdot SP_{purlins} = 0.061\ \frac{\boldsymbol{kN}}{\boldsymbol{m}}$

Based on load combinations in NBCC 2015, case 3 governs

$W_f := 1.25 \cdot D + 1.5 \cdot S + 1.0 \cdot L$
$W_f = 2.50\ \frac{\boldsymbol{kN}}{\boldsymbol{m}}$ -Governing load case acting on purlins
-Assume this load is uniform for all purlin sections

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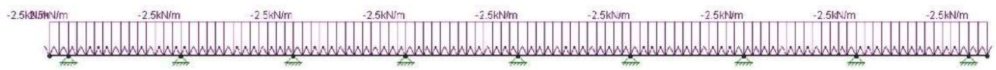
# Purlin Design

-Purlins to be constructed using HSS G40.20
-Design factored load acting on purlins is uniform with magnitude 2.5 kN/m
-Assume purlins are laterally supported by the surface material on compression flange
-Conservative self weight has already been accounted for in the load calculations

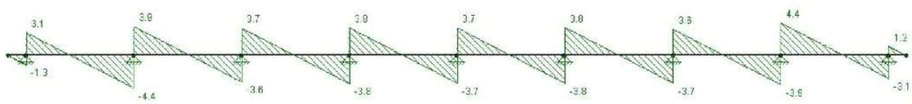
The following RISA 2D model was used to design the purlins:



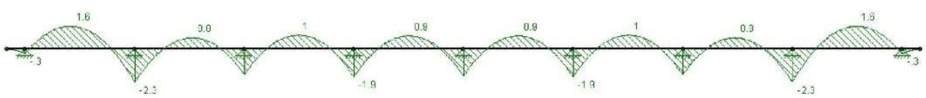

Note: In the loading model above, the load is assumed to be uniform for the entire length of the structure, although in reality, it will likely vary throughout. This provides conservative design values at the critical locations. Also note that the pinned supports represent the column supports, spaced 3m apart.

Shear and Bending Moment Diagrams:

VFD:




BMD:




$SP_{purlin} := 500\ mm$

$SP_{column} := 3000\ mm$

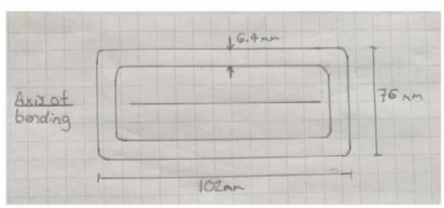
$F_y := 350\ MPa$

$V_{max} := 4.41\ kN$

$M_{max} := 2.30\ kN \cdot m$

For HSS 76x102x6.4mm oriented as shown:

$b := 102\ mm$
$h := 76\ mm$
$t := 6.4\ mm$




$Z := 54000\ mm^3$ -About major axis

$I := 1710000\ mm^4$ -About major axis (CSA S16-14, Part 6)

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**Check flexural resistance**

$b_{el} := b - 4 \cdot t = 76.4\ \boldsymbol{mm}$ (CSA S16-14, 11.3.2)

$\dfrac{b_{el}}{t} = 11.938$

$Class_1 := \dfrac{420}{\sqrt[2]{F_y}}$ (CSA S16-14, Table 4-6)

$Class_1 = 22.45$ >bel/t Therefore, section is class I

$\phi := 0.9$

$M_r := \phi \cdot Z \cdot F_y = 17.01\ \boldsymbol{kN \cdot m}$ (CSA S16-14, 13.5 (a))

$M_{max} = 2.3\ \boldsymbol{kN \cdot m}$ Mmax<Mr, OK for bending resistance

**Check shear resistance**

$h := h - 2 \cdot t = 63.2\ \boldsymbol{mm}$ -Clear depth of purlin web

$w := 2 \cdot t = 12.8\ \boldsymbol{mm}$

$k_v := 5.34$

$A_w := 2 \cdot h \cdot t = 808.96\ \boldsymbol{mm}^2$ -Shear area

For the Fs calculation, HSS is assumed to have a stiffened web

$\dfrac{h}{w} = 4.938$

$Case_1 := \dfrac{1014}{\sqrt[2]{F_y}}$

$Case_1 = 54.201$ > h/w Therefore, web case i) applies

$F_s := 0.66 \cdot F_y = 231\ \boldsymbol{MPa}$

$V_r := \phi \cdot A_w \cdot F_s = 168.183\ \boldsymbol{kN}$ (CSA S16-14, 13.4.1.1)

$V_{max} = 4.41\ \boldsymbol{kN}$ Vmax<Vr, OK for shear resistance

Use G40 HSS 76x102x6.4 for all purlins

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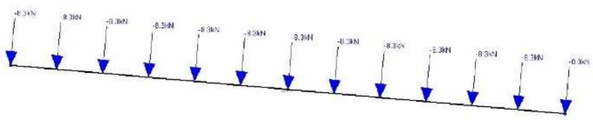
# Beam Design

-Beams to be constructed using Douglas Fir-Larch 20f-EX due to the exposure to positive and negative bending moments resulting from the wind loading
-Assume wet service conditions

The following RISA 2D model was used to model the members:




$V_{max} := 58.1\ \boldsymbol{kN}$
$M_{max} := 87.7\ \boldsymbol{kN \cdot m}$

$SP_{purlin} := 500\ \boldsymbol{mm}$
$SP_{column} := 3000\ \boldsymbol{mm}$

$L_{plan} := 6000\ \boldsymbol{mm}$
$\theta := 5\ °$ -Roof slope in degrees

$$L := \frac{L_{plan}}{\cos(\theta)} = 6023\ \boldsymbol{mm}$$

**For 200x380mm DFL 20f-EX:**

$b := 200\ \boldsymbol{mm}$ -This must be the same as column dimension
$d := 380\ \boldsymbol{mm}$ -This should be a multiple of 38 mm (lamination depth)

$$S := \frac{b \cdot d^2}{6} = \left(4.813 \cdot 10^6\right)\ \boldsymbol{mm}^3$$

**Check flexural resistance**

Moment resistance is the lesser of the following:

$M_{r1} = \phi\ F_b\ SK_x\ K_{Zbg}$

$M_{r2} = \phi\ F_b\ SK_x\ K_L$ (CSA 086, 7.5.6.5.1)

$\phi := 0.9$

$F_b = f_b\ (K_D\ K_H\ K_{Sb}\ K_T)$

| | | |
|---|---|---|
| $f_b := 25.6\ \boldsymbol{MPa}$ | | (CSA 086, Table 7.2) |
| $K_D := 1$ | -Standard term load duration | (CSA 086, Table 5.1) |
| $K_H := 1$ | -Glulam, spaced reasonably far apart | (CSA 086, 7.4.4) |
| $K_{Sb} := 0.8$ | -Wet-service conditions | (CSA 086, Table 7.3) |
| $K_T := 1$ | -Standard treatment | (CSA 086, 7.4.3.1) |

$F_b := f_b \cdot (K_D \cdot K_H \cdot K_{Sb} \cdot K_T) = 20.48\ \boldsymbol{MPa}$ (CSA 086, 7.5.6.5.1)

$K_x := 1$ -Uniform cross section, no curvature (CSA 086 7.5.6.5.2)

$$K_{Zbg} := \left(\frac{130}{b}\right)^{0.1} \cdot \left(\frac{610}{d}\right)^{0.1} \cdot \left(\frac{9100}{L}\right)^{0.1}$$

$K_{Zbg} = 1.047$ < 1.3 (CSA 086, 7.5.6.5.1)

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$L_u := \frac{L}{2} = 3011\ mm$ (CSA 086 7.5.6.4.1)

$L_e := 1.92 \cdot L_u = (5.782 \cdot 10^3)\ mm$ -Cantilever, no intermediate supports (CSA 086 Table 7.4)

$C_B := \sqrt[2]{\frac{L_e \cdot d}{b^2}} = 7.411$ < 50 OK (CSA 086 7.5.6.4.3)

$K_L := 1$ -Since Cb<10 (CSA 086 7.5.6.4.4 (a))

$M_{r\_1} := \phi \cdot F_b \cdot S \cdot K_x \cdot K_{Zbg} = 92.851\ kN \cdot m$

$M_{r\_2} := \phi \cdot F_b \cdot S \cdot K_x \cdot K_L = 88.719\ kN \cdot m$

$M_r := min(M_{r\_1}, M_{r\_2}) = 88.719\ kN \cdot m$

$M_{max} = 87.7\ kN \cdot m$ Mmax<Mr OK for bending resistance

**Check shear resistance**

$Vol := b \cdot d \cdot L = 0.458\ m \cdot m^2$ <2m^3, equation b) can be used (CSA 086 7.5.7.3(a))

$V_r = \phi F_v \frac{2A_g}{3}$ (CSA 086 7.5.7.3(b))

$\phi := 0.9$

$F_v = f_v (K_D K_H K_{Sv} K_T)$

| | | |
|---|---|---|
| $f_v := 2\ MPa$ | | (CSA 086, Table 7.2) |
| $K_D = 1$ | -Standard term load duration | (CSA 086, Table 5.1) |
| $K_H = 1$ | -Glulam, spaced reasonably far apart | (CSA 086, 7.4.4) |
| $K_{Sv} := 0.87$ | -Wet-service conditions | (CSA 086, Table 7.3) |
| $K_T = 1$ | -Standard treatment | (CSA 086, 7.4.3.1) |

$F_v := f_v \cdot (K_D \cdot K_H \cdot K_{Sv} \cdot K_T) = 1.74\ MPa$

(CSA 086 7.5.7.3)

$A_g := b \cdot d = 76000\ mm^2$

$V_r := \frac{2}{3} \cdot \phi \cdot F_v \cdot A_g = 79.344\ kN$

$V_{max} = 58.1\ kN$ Vmax<Vr OK for shear resistance

Use 200x380mm Douglas Fir-Larch 20f-EX for all top beam members

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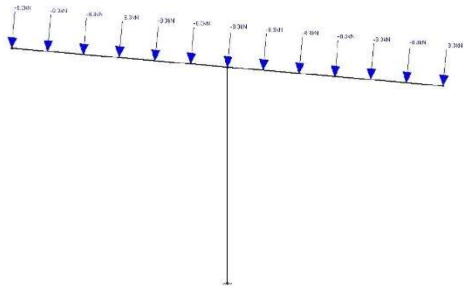
# Column Design

-Columns to be constructed using Douglas Fir-Larch 24f-EX due to the exposure to positive and negative bending moments resulting from the wind loading
-Assume wet service condition
-We must also check the flexural/shear resistance of this member as it will be subject to both shear and bending

The following RISA 2D model was used to model the columns. Each point load corresponds to the purlin reaction, equal to 8.3 kN acting downwards



$SP_{purlin} := 500\ mm$
$SP_{column} := 3000\ mm$
$L := 3000\ mm$
$\theta := 5\ °$ -Roof slope in degrees

$P_{max} := 107.9\ kN$
$V_{max} := 9.39\ kN$
$M_{max} := 28.64\ kN \cdot m$

**For 200x266mm DFL 24f-EX:**

$b := 200\ mm$ -This must be the same as beam dimension
$d := 266\ mm$ -This should be a multiple of 38 mm (lamination depth)
$A_g := b \cdot d = 53200\ mm^2$

$$S := \frac{b \cdot d^2}{6} = \left(2.359 \cdot 10^6\right)\ mm^3$$

$$I := \frac{b \cdot d^3}{12} = \left(3.137 \cdot 10^8\right)\ mm^4$$

**Check flexural resistance**

Moment resistance is the lesser of the following:
$M_{r1} = \phi\ F_b\ SK_x\ K_{Zbg}$
$M_{r2} = \phi\ F_b\ SK_x\ K_L$ (CSA 086, 7.5.6.5.1)
$\phi := 0.9$

$F_b = f_b\ (K_D\ K_H\ K_{Sb}\ K_T)$

| | | |
|---|---|---|
| $f_b := 30.6\ MPa$ | | (CSA 086, Table 7.2) |
| $K_D := 1$ | -Standard term load duration | (CSA 086, Table 5.1) |
| $K_H := 1$ | -Glulam, spaced reasonably far apart | (CSA 086, 7.4.4) |
| $K_{Sb} := 0.8$ | -Wet-service conditions | (CSA 086, Table 7.3) |
| $K_T := 1$ | -Standard treatment | (CSA 086, 7.4.3.1) |

$F_b := f_b \cdot \left(K_D \cdot K_H \cdot K_{Sb} \cdot K_T\right) = 24.48\ MPa$

(CSA 086, 7.5.6.5.1)
$K_x := 1$ -Uniform cross section, no curvature (CSA 086 7.5.6.5.2)

$$K_{Zbg} := \left(\frac{130}{b}\right)^{0.1} \cdot \left(\frac{610}{d}\right)^{0.1} \cdot \left(\frac{9100}{L}\right)^{0.1}$$

$K_{Zbg} = 1.163$ < 1.3 (CSA 086, 7.5.6.5.1)

$L_u := L = 3000\ mm$ (CSA 086 7.5.6.4.1)
$L_e := 1.69 \cdot L_u = \left(5.07 \cdot 10^3\right)\ mm$ -Cantilever, concentrated moment at free end (CSA 086 Table 7.4)

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$C_B := \sqrt[2]{\frac{L_e \cdot d}{b^2}} = 5.807$ < 50 OK (CSA 086 7.5.6.4.3)

$K_L := 1$ -Since Cb<10 (CSA 086 7.5.6.4.4 (a))

$M_{r\_1} := \phi \cdot F_b \cdot S \cdot K_x \cdot K_{Zbg} = 60.426\ \boldsymbol{kN \cdot m}$ $M_{r\_2} := \phi \cdot F_b \cdot S \cdot K_x \cdot K_L = 51.963\ \boldsymbol{kN \cdot m}$

$M_r := min\left(M_{r\_1}, M_{r\_2}\right) = 51.963\ \boldsymbol{kN \cdot m}$

$M_{max} = 28.64\ \boldsymbol{kN \cdot m}$ Mmax<Mr OK for bending resistance

**Check shear resistance**

$Vol := b \cdot d \cdot L = 0.16\ \boldsymbol{m \cdot m^2}$ <2m^3, equation b) can be used (CSA 086 7.5.7.3(a))

$V_r = \phi F_v \frac{2A_g}{3}$ (CSA 086 7.5.7.3(b))

$\phi := 0.9$

$F_v = f_v\ (K_D\ K_H\ K_{Sv}\ K_T)$

| | | |
|---|---|---|
| $f_v := 2\ \boldsymbol{MPa}$ | | (CSA 086, Table 7.2) |
| $K_D = 1$ | -Standard term load duration | (CSA 086, Table 5.1) |
| $K_H = 1$ | -Glulam, spaced reasonably far apart | (CSA 086, 7.4.4) |
| $K_{Sv} := 0.87$ | -Wet-service conditions | (CSA 086, Table 7.3) |
| $K_T = 1$ | -Standard treatment | (CSA 086, 7.4.3.1) |

$F_v := f_v \cdot \left(K_D \cdot K_H \cdot K_{Sv} \cdot K_T\right) = 1.74\ \boldsymbol{MPa}$ (CSA 086 7.5.7.3)

$V_r := \frac{2}{3} \cdot \phi \cdot F_v \cdot A_g = 55.541\ \boldsymbol{kN}$

$V_{max} = 9.39\ \boldsymbol{kN}$ Vmax<Vr OK for shear resistance

**Check compressive resistance** $P_r = \phi\ F_c\ A\ K_{Zcg}\ K_C$ (CSA 086 7.5.8.5)

$\phi := 0.8$

$F_c = f_c\ (K_D\ K_H\ K_{Sc}\ K_T)$

| | | |
|---|---|---|
| $f_c := 30.2\ \boldsymbol{MPa}$ | | (CSA 086, Table 7.2) |
| $K_D = 1$ | -Standard term load duration | (CSA 086, Table 5.1) |
| $K_H = 1$ | -Glulam, spaced reasonably far apart | (CSA 086, 7.4.4) |
| $K_{Sc} := 0.75$ | -Wet-service conditions | (CSA 086, Table 7.3) |
| $K_T = 1$ | -Standard treatment | (CSA 086, 7.4.3.1) |

$F_c := f_c \cdot \left(K_D \cdot K_H \cdot K_{Sc} \cdot K_T\right) = 22.65\ \boldsymbol{MPa}$ (CSA, 086 7.5.8.5)

$Z := b \cdot d \cdot L = 0.16\ \boldsymbol{m^3}$

$K_{Zcg} := 0.68 \cdot (Z)^{-0.13}$

$K_{Zcg} = 0.863$ <1 (CSA 086, 7.5.8.5)

$E := 12800\ \boldsymbol{MPa}$ (CSA 086, Table 7.2)

$E_{05} := 0.87 \cdot E = 11136\ \boldsymbol{MPa}$

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$K_e := 2$ -Not restrained at one end (CSA 086, Table A.4)

$L_e := K_e \cdot L = 6\ m$ (CSA 086, 7.5.8.1)

$C_{c\_width} := \frac{L_e}{b}$ $C_{c\_depth} := \frac{L_e}{d}$

$C_c := \max\left(C_{c\_width}, C_{c\_depth}\right) = 30$ <50 OK (CSA 086, 7.5.8.2)

$K_{SE} := 0.9$ -Wet-service conditions (CSA 086, Table 7.3)

$$K_c := \left(1 + \frac{F_c \cdot K_{Zcg} \cdot C_c^{\,3}}{35 \cdot E_{05} \cdot K_{SE} \cdot K_T}\right)^{-1} = 0.399$$ (CSA 086, 7.5.8.6)

$P_r := \phi \cdot F_c \cdot A_g \cdot K_{Zcg} \cdot K_c = 332.196\ kN$

$P_{max} = 107.9\ kN$ Pmax<Pr OK for axial compression

**Check beam bearing resistance** $Q_r = \phi\ F_{cp}\ A_b\ K_B\ K_{Zcp}$ (CSA 086 7.5.9.2)

$\phi := 0.8$

$F_{cp} = f_{cp}\ (K_D\ K_{Scp}\ K_T)$

$f_{cp} := 7\ MPa$ (CSA 086, Table 7.2)

$K_D = 1$ -Standard term load duration (CSA 086, Table 5.1)

$K_{Scp} := 0.67$ -Wet-service conditions (CSA 086, Table 7.3)

$K_T = 1$ -Standard treatment (CSA 086, 7.4.3.1)

$F_{cp} := f_{cp} \cdot \left(K_D \cdot K_{Scp} \cdot K_T\right) = 4.69\ MPa$ (CSA 086, 7.5.7.3)

$K_B := 1$ -Bearing length greater than 150mm (CSA 086, Table 6.16)

$\frac{b}{38 \cdot mm} = 5.263$ -Ratio of member width to member depth where member depth is lamination dimension

$K_{Zcp} := 1.15$ (CSA 086, Table 6.15)

$Q_r := \phi \cdot F_{cp} \cdot A_g \cdot K_B \cdot K_{Zcp} = 229.547\ kN$

$P_{max} = 107.9\ kN$ Pmax<Qr OK for bearing

**Check combined axial and bending resistance**

$$\left(\frac{P_f}{P_r}\right)^2 + \frac{M_f}{M_r}\left[\frac{1}{1 - \frac{P_f}{P_E}}\right] \le 1$$ (CSA 086, 7.5.12)

$$P_E := \frac{\pi^2 \cdot E_{05} \cdot K_{SE} \cdot K_T \cdot I}{L_e^{\,2}} = \left(8.619 \cdot 10^5\right)\ N$$ (CSA 086, 7.5.12)

$$\left(\frac{P_{max}}{P_r}\right)^2 + \frac{M_{max}}{M_r}\left(\frac{1}{1 - \frac{P_{max}}{P_E}}\right) = 0.736$$ <1 OK for combined bending

Use 200x380mm Douglas Fir-Larch 24f-EX for all columns

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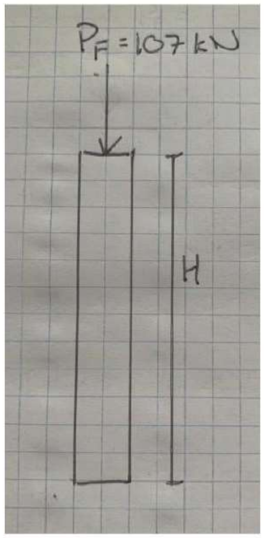
# Pile Design




$\beta := 0.5$

$D_{pile} := 16\ \boldsymbol{in}$

$H_{pile} := 3.6\ \boldsymbol{m}$

$A_f := 5\ \boldsymbol{m}^2$

$\rho_{soil} := 2000\ \dfrac{\boldsymbol{kg}}{\boldsymbol{m}^3}$

$g := 9.81\ \dfrac{\boldsymbol{m}}{\boldsymbol{s}^2}$

$\phi := 1.5$

$P_F := 107.9\ \boldsymbol{kN}$

$P_{F\_Ult} := \phi \cdot P_F = 161.85\ \boldsymbol{kN}$

**Determine ultimate friction resistance**

$A_s := \pi \cdot D_{pile} \cdot H_{pile} = 4.596\ \boldsymbol{m}^2$

$\gamma_{soil} := \rho_{soil} \cdot g = 19.62\ \dfrac{\boldsymbol{kN}}{\boldsymbol{m}^3}$

$\sigma'_z := \gamma_{soil} \cdot H_{pile} = 70.632\ \boldsymbol{kPa}$

$f_s := \beta \cdot \sigma'_z = 35.316\ \boldsymbol{kPa}$

$Q_{ult} := f_s \cdot A_s = 162.322\ \boldsymbol{kN}$ >Pf_Ult

*Pile Meets Capacity*

Notes:
-Recycled concrete aggregate to be used in piles
-Reference to API RP 2A-WSD 2007 section 6.4.3 Shaft Friction and End Bearing in Cohesionless Soils for procedure

Page 1 of 1

# Appendix F – Construction Schedule

Project: East Mall Redesign
Client: University of British Columbia - UBC SEEDS
File No: CIVL 446-0003-2021

# Schedule: Productivities

**RSMeans**

Date: 03/05/2021

| | Road Base Work | Units | Daily output |
|---|---|---|---|
| 1.1 | Cement soil stabilization, 12% mix by volume, 12" depth, includes scarifying and compaction | sq.m | 803 |
| 1.2 | In place pulverizing at 8" depth | sq.m | 1672 |
| 1.3 | Bulk out and remove swell | cu.m | 350 |
| 1.4 | Contingency (10% of work duration) | each | |

| | Asphalt Work | Units | Daily output |
|---|---|---|---|
| 2.1 | Asphalt surface treatment, tack coat, emulsion, 0.10 gallons per S.Y | sq.m | 8361 |
| 2.2 | Asphalt Paving, 1" to 3" Top lift | sq.m | 5017 |
| 2.3 | Asphalt Paving, 1" to 3" Base Lift | sq.m | 5017 |
| 2.4 | Contingency (10% of work duration) | each | |

| | Boulevard Work | Units | Daily output |
|---|---|---|---|
| 3.1 | 2" asphalt side walks excl base | sq.m | 67 |
| 3.2 | Gravel fill 4", excl surfacing | sq.m | 598 |
| 3.3 | 4" concrete side walks excl base | sq.m | 232 |
| 3.4 | Gravel fill 4", excl surfacing | sq.m | 598 |
| 3.5 | Cast-in place concrete curbs and gutters, machine formed, concrete included | lm | 609.6 |
| 3.6 | Sodding, bluegrass sod, on level ground, 1" deep | sq.m | 2044 |
| 3.7 | Concrete curb and gutter removal | lm | 109.728 |
| 3.8 | Demolish, remove sidewalk pavement | sq.m | 71 |
| 3.9 | Cast-in place concrete medians | lm | 121.92 |
| 3.11 | Concrete slab work | sq.m | 44 |
| 3.12 | Gravel fill 4", excl surfacing | sq.m | 598 |
| 3.13 | Gutter fill | lm | 2000 |
| 3.14 | Contingency (10% of work duration) | each | |

| | Traffic Accommodation | Units | Daily output |
|---|---|---|---|
| 4.1 | Traffic Signals, add for protective/permissive turns, including all labour, material and equipment | each | 1.00 |
| 4.2 | Signs, roadway delineators and reference marker | each | 500.00 |
| 4.3 | Roadway line painting and markers | lm | 243.84 |
| 4.4 | Contingency (10% of work duration) | each | |

Project: East Mall Redesign
Client: University of British Columbia - UBC SEEDS
File No: CIVL 446-0003-2021

# Schedule: Productivities

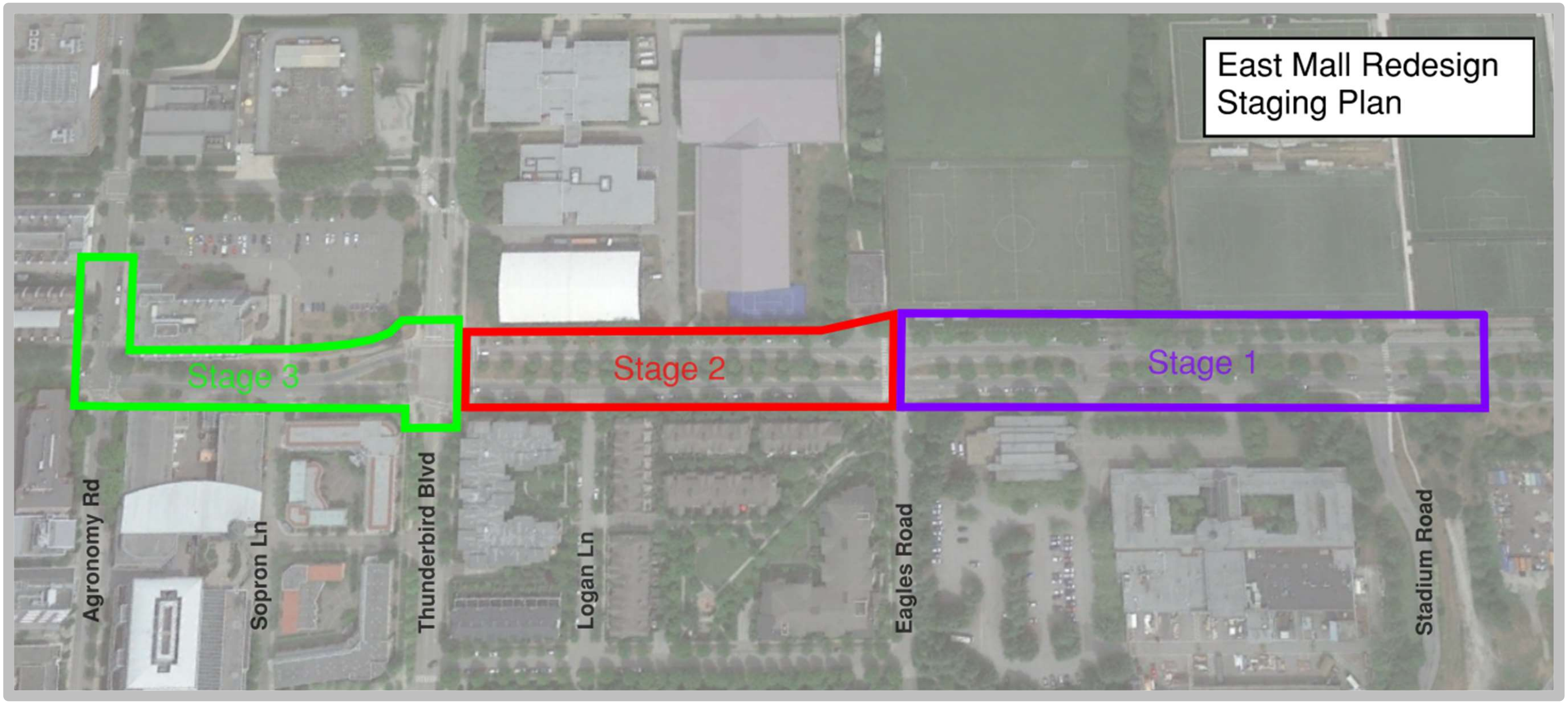
**RSMeans**

Date: 03/05/2021

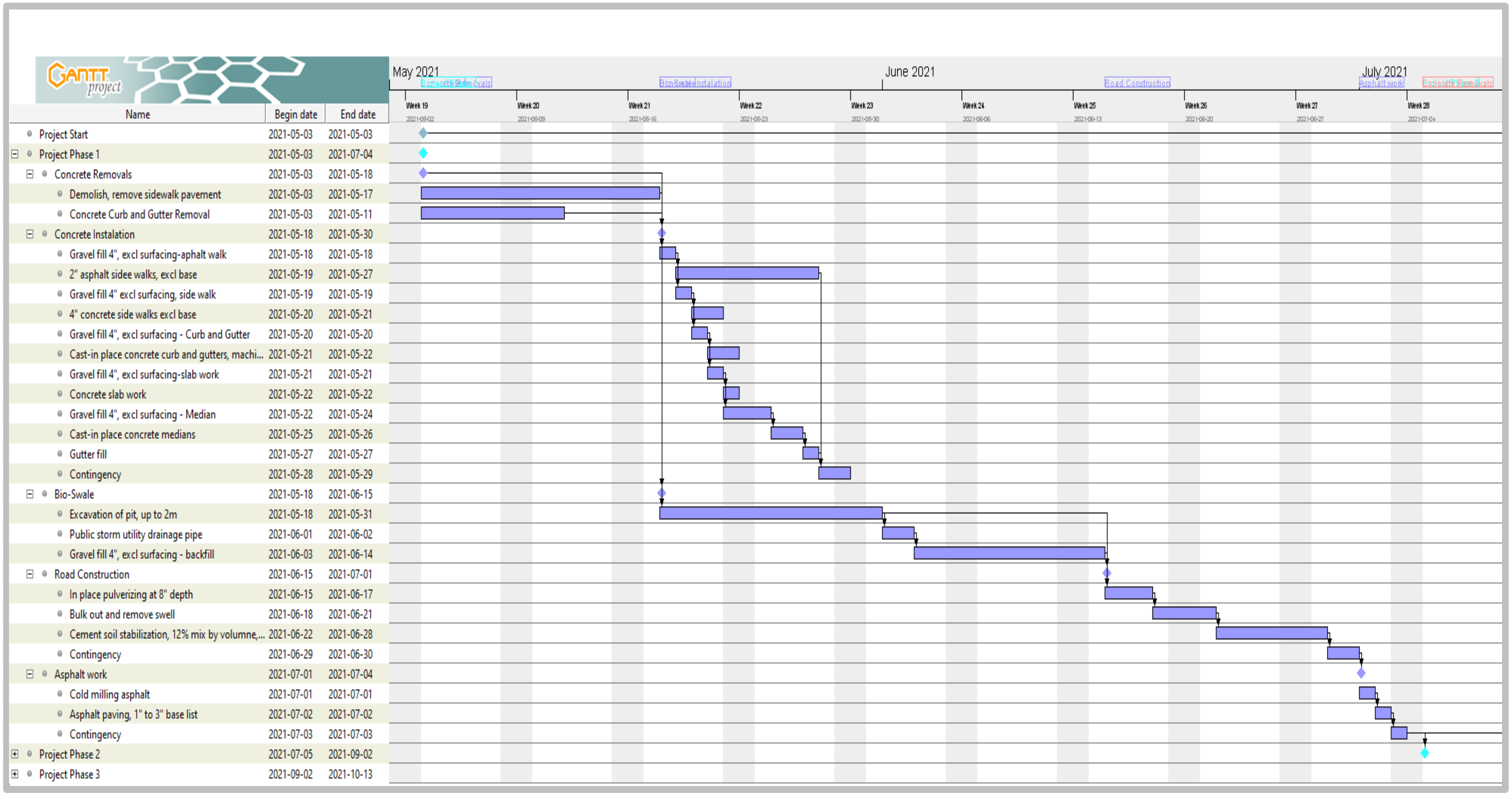
| | Canopy | Units | Daily output |
|---|---|---|---|
| 5.1 | Piles installation and placement | each | 5.50 |
| 5.2 | Column erection and placement | lm | 213.36 |
| 5.3 | Beam erection and placement | lm | 121.92 |
| 5.4 | Glass roofing system placement and installation | sq.m | 20 |
| 5.5 | Contingency (10% of work duration) | each | |

| | Bio-Swale | Units | Daily output |
|---|---|---|---|
| 6.1 | Gravel fill 4", excl surfacing | sq.m | 598 |
| 6.2 | Sand fill 12" sand placement and leveling | sq.m | 502 |
| 6.3 | Soils for earth work, topsoil borrow, weed free | cu.m | 458.733 |
| 6.4 | Planting, trees, shrubs and ground cover, light topsoil | each | 101.00 |
| 6.5 | Public storm utility drainage piping | lm | 100.584 |
| 6.6 | Excavation of pit, up to 2m | cu.m | 150 |
| 6.7 | Contingency (10% of work duration) | each | |

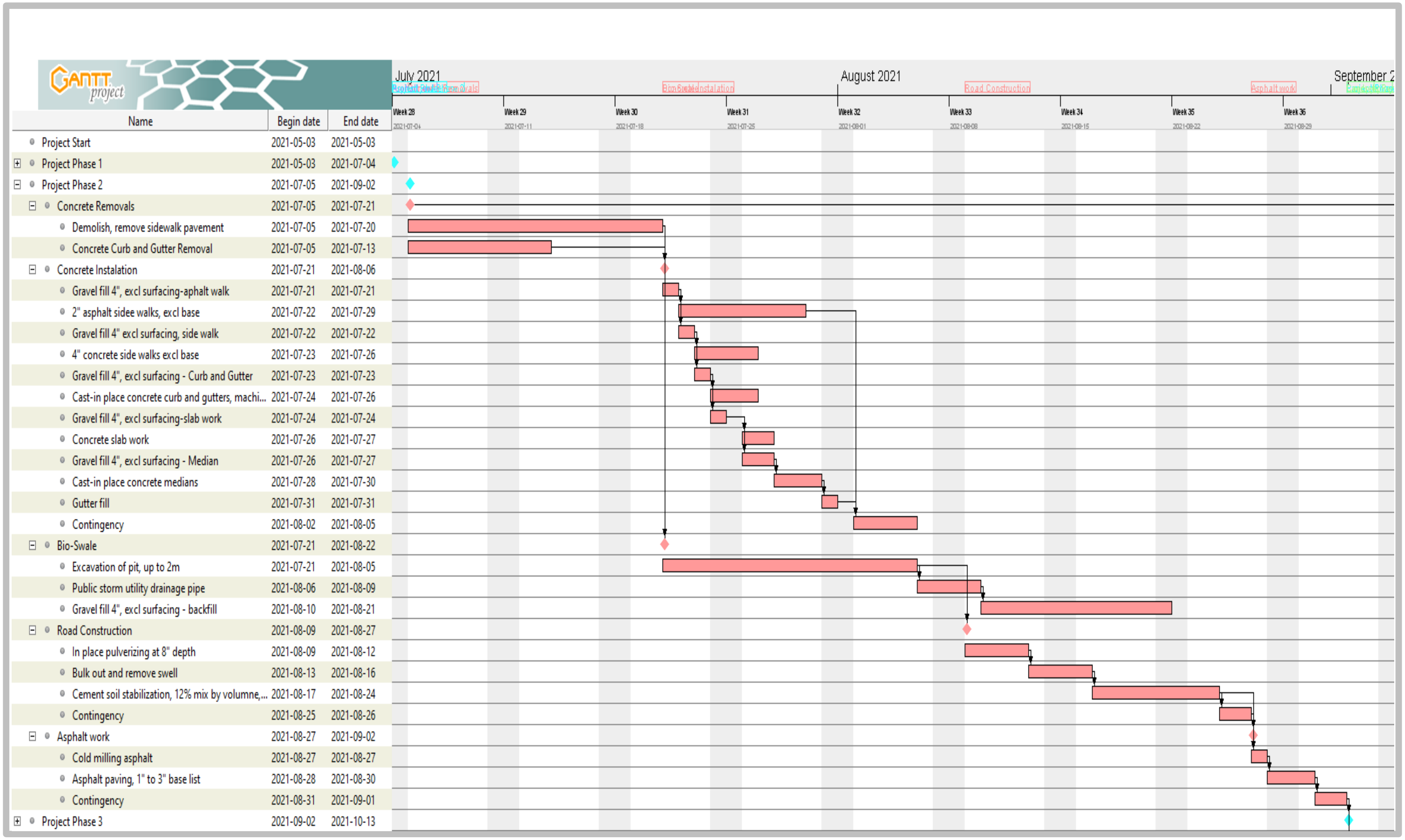
Staging Plan



Phase 1 – Stadium Road to Eagles Drive

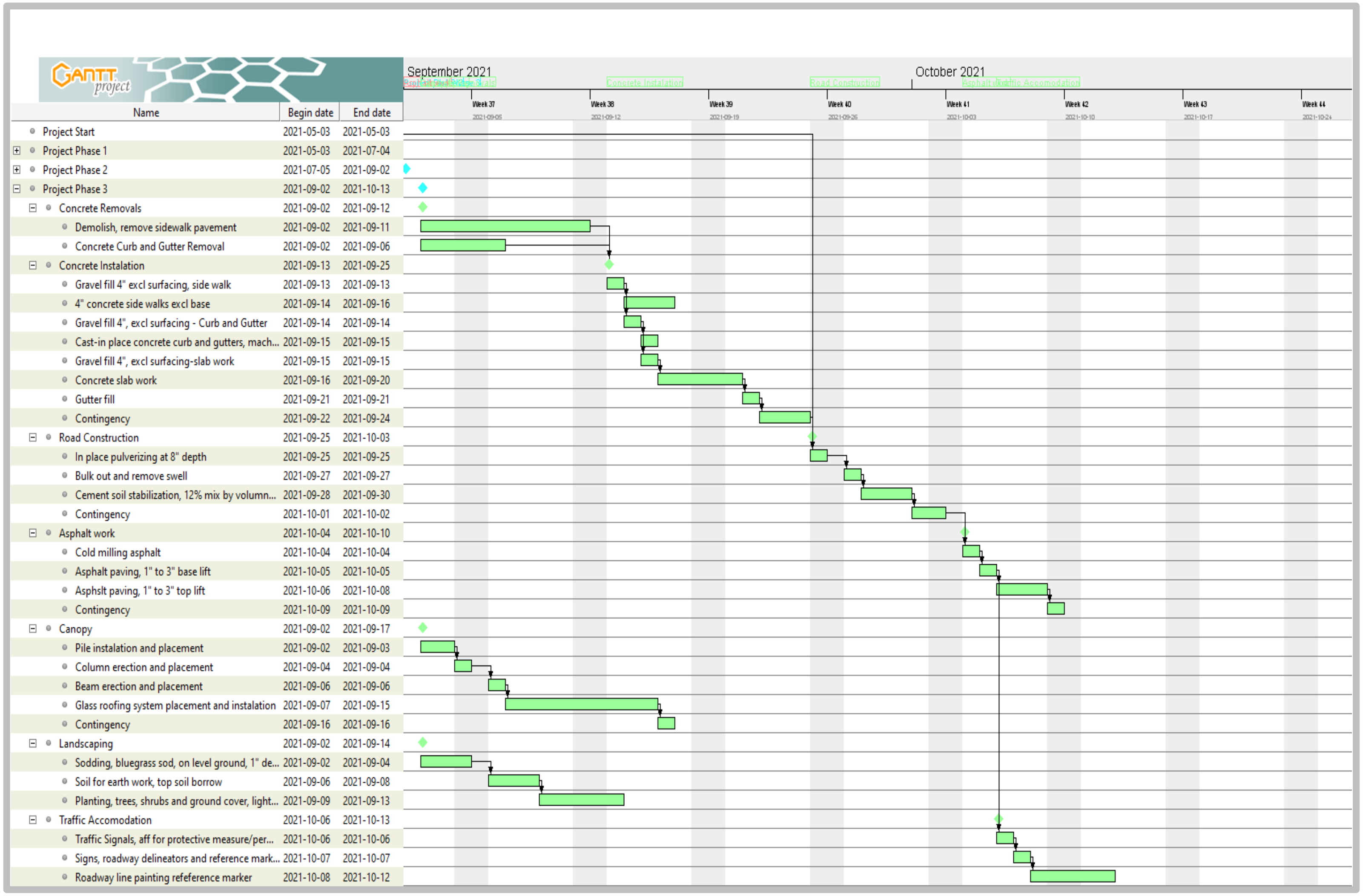


Phase 2 – Eagles Drive to Thunderbird Blvd



| Name | Begin date | End date |
|---|---|---|
| Project Start | 2021-05-03 | 2021-05-03 |
| Project Phase 1 | 2021-05-03 | 2021-07-04 |
| Project Phase 2 | 2021-07-05 | 2021-09-02 |
| Concrete Removals | 2021-07-05 | 2021-07-21 |
| Demolish, remove sidewalk pavement | 2021-07-05 | 2021-07-20 |
| Concrete Curb and Gutter Removal | 2021-07-05 | 2021-07-13 |
| Concrete Instalation | 2021-07-21 | 2021-08-06 |
| Gravel fill 4", excl surfacing-aphalt walk | 2021-07-21 | 2021-07-21 |
| 2" asphalt sidee walks, excl base | 2021-07-22 | 2021-07-29 |
| Gravel fill 4" excl surfacing, side walk | 2021-07-22 | 2021-07-22 |
| 4" concrete side walks excl base | 2021-07-23 | 2021-07-26 |
| Gravel fill 4", excl surfacing - Curb and Gutter | 2021-07-23 | 2021-07-23 |
| Cast-in place concrete curb and gutters, machi... | 2021-07-24 | 2021-07-26 |
| Gravel fill 4", excl surfacing-slab work | 2021-07-24 | 2021-07-24 |
| Concrete slab work | 2021-07-26 | 2021-07-27 |
| Gravel fill 4", excl surfacing - Median | 2021-07-26 | 2021-07-27 |
| Cast-in place concrete medians | 2021-07-28 | 2021-07-30 |
| Gutter fill | 2021-07-31 | 2021-07-31 |
| Contingency | 2021-08-02 | 2021-08-05 |
| Bio-Swale | 2021-07-21 | 2021-08-22 |
| Excavation of pit, up to 2m | 2021-07-21 | 2021-08-05 |
| Public storm utility drainage pipe | 2021-08-06 | 2021-08-09 |
| Gravel fill 4", excl surfacing - backfill | 2021-08-10 | 2021-08-21 |
| Road Construction | 2021-08-09 | 2021-08-27 |
| In place pulverizing at 8" depth | 2021-08-09 | 2021-08-12 |
| Bulk out and remove swell | 2021-08-13 | 2021-08-16 |
| Cement soil stabilization, 12% mix by volumne,... | 2021-08-17 | 2021-08-24 |
| Contingency | 2021-08-25 | 2021-08-26 |
| Asphalt work | 2021-08-27 | 2021-09-02 |
| Cold milling asphalt | 2021-08-27 | 2021-08-27 |
| Asphalt paving, 1" to 3" base list | 2021-08-28 | 2021-08-30 |
| Contingency | 2021-08-31 | 2021-09-01 |
| Project Phase 3 | 2021-09-02 | 2021-10-13 |

Phase 3 – Thunderbird Blvd to Agronomy Road




| Name | Begin date | End date |
|---|---|---|
| Project Start | 2021-05-03 | 2021-05-03 |
| Project Phase 1 | 2021-05-03 | 2021-07-04 |
| Project Phase 2 | 2021-07-05 | 2021-09-02 |
| Project Phase 3 | 2021-09-02 | 2021-10-13 |
| Concrete Removals | 2021-09-02 | 2021-09-12 |
| Demolish, remove sidewalk pavement | 2021-09-02 | 2021-09-11 |
| Concrete Curb and Gutter Removal | 2021-09-02 | 2021-09-06 |
| Concrete Instalation | 2021-09-13 | 2021-09-25 |
| Gravel fill 4" excl surfacing, side walk | 2021-09-13 | 2021-09-13 |
| 4" concrete side walks excl base | 2021-09-14 | 2021-09-16 |
| Gravel fill 4", excl surfacing - Curb and Gutter | 2021-09-14 | 2021-09-14 |
| Cast-in place concrete curb and gutters, mach... | 2021-09-15 | 2021-09-15 |
| Gravel fill 4", excl surfacing-slab work | 2021-09-15 | 2021-09-15 |
| Concrete slab work | 2021-09-16 | 2021-09-20 |
| Gutter fill | 2021-09-21 | 2021-09-21 |
| Contingency | 2021-09-22 | 2021-09-24 |
| Road Construction | 2021-09-25 | 2021-10-03 |
| In place pulverizing at 8" depth | 2021-09-25 | 2021-09-25 |
| Bulk out and remove swell | 2021-09-27 | 2021-09-27 |
| Cement soil stabilization, 12% mix by volumn... | 2021-09-28 | 2021-09-30 |
| Contingency | 2021-10-01 | 2021-10-02 |
| Asphalt work | 2021-10-04 | 2021-10-10 |
| Cold milling asphalt | 2021-10-04 | 2021-10-04 |
| Asphalt paving, 1" to 3" base lift | 2021-10-05 | 2021-10-05 |
| Asphslt paving, 1" to 3" top lift | 2021-10-06 | 2021-10-08 |
| Contingency | 2021-10-09 | 2021-10-09 |
| Canopy | 2021-09-02 | 2021-09-17 |
| Pile instalation and placement | 2021-09-02 | 2021-09-03 |
| Column erection and placement | 2021-09-04 | 2021-09-04 |
| Beam erection and placement | 2021-09-06 | 2021-09-06 |
| Glass roofing system placement and instalation | 2021-09-07 | 2021-09-15 |
| Contingency | 2021-09-16 | 2021-09-16 |
| Landscaping | 2021-09-02 | 2021-09-14 |
| Sodding, bluegrass sod, on level ground, 1" de... | 2021-09-02 | 2021-09-04 |
| Soil for earth work, top soil borrow | 2021-09-06 | 2021-09-08 |
| Planting, trees, shrubs and ground cover, light... | 2021-09-09 | 2021-09-13 |
| Traffic Accomodation | 2021-10-06 | 2021-10-13 |
| Traffic Signals, aff for protective measure/per... | 2021-10-06 | 2021-10-06 |
| Signs, roadway delineators and reference mark... | 2021-10-07 | 2021-10-07 |
| Roadway line painting refeference marker | 2021-10-08 | 2021-10-12 |

# Appendix G – Construction Cost

Project: East Mall Redesign
Client: University of British Columbia - UBC SEEDS
File No: CIVL446-002-2021

Date: 03/05/2021

# Class A Construction Cost Estimate

| Project Cost Summary | | |
|---|---|---|
| **Item #** | **Description** | **Total** |
| 1 | Cost of Construction | $ 5,056,778.10 |
| 2 | Corrections | $ 960,787.84 |
| 3 | Construction Considerations | $ 3,084,634.64 |

**Total Cost of Construction** **$ 9,102,200.57**

## Notes:

**Source of Cost Data**

The spreadsheet utilizes the Unit Price Average Report Create by the Government of Alberta. The data set was the most complete within a reasonable geographic location. It enabled the designers to analyze multiple elements of the project to help hone the precision of the estimate. In the corrections section of the estimate, a location modifier was utilized to convert between Alberta to British Columbia conditions. In addition, the data was sourced from 2019 values. To make adjustments, a correction factor was used to convert to the expected 2021 conditions when the project is planned to start.

**Assumptions**

Designers used typical values of percent increase for corrections and construction considerations found from BC Transportation. In the absences of data from the BC Transportation, designers used past values from experience.

Project: East Mall Redesign
Client: University of British Columbia - UBC SEEDS
File No: CIVL446-002-2021

Date: 03/05/2021

# Class A Construction Cost Estimate

## Project Cost Summary

| Cost of Construction | | |
|---|---|---|
| **Item #** | **Description** | **Total** |
| A | Schedule A - Pre-Construction Cost | $ 32,633.32 |
| B | Schedule B - Concrete Work | $ 1,443,999.18 |
| C | Schedule C - Bioswale | $ 653,414.98 |
| D | Schedule D - Roadway Work | $ 2,624,070.90 |
| E | Schedule E - Traffic Control | $ 58,405.72 |
| F | Schedule F - Pedestrian Canopy | $ 244,254.00 |
| | **Cost of Construction** | **$ 5,056,778.10** |

| Corrections | | | | |
|---|---|---|---|---|
| **Item #** | **Description** | | | **Total** |
| 1 | Location Factor | 2% | Construction Cost | $ 101,135.56 |
| 2 | Time Factor (Convert from 2017 data to 2021) | 2% | Construction Cost | $ 101,135.56 |
| 3 | Federal Wage Factors (Wage Increases) | 3% | Construction Cost | $ 151,703.34 |
| 4 | Taxation | 12% | Construction Cost | $ 606,813.37 |
| | | | Cost of Correction Factor | $ 960,787.84 |

| Construction Considerations | | | | |
|---|---|---|---|---|
| **Item #** | **Description** | | | **Total** |
| 1 | Project Management | 5% | Construction Cost | $ 252,838.90 |
| 2 | Preliminary Design | 5% | Construction Cost | $ 252,838.90 |
| 3 | Detailed Design | 10% | Construction Cost | $ 505,677.81 |
| 5 | Environmental Investigation | 1% | Construction Cost | $ 50,567.78 |
| 6 | Project Profits | 15% | Construction Cost | $ 758,516.71 |
| 7 | Bond and Permitting | 2% | Construction Cost | $ 101,135.56 |
| 8 | Project Maintaince & Operations | 10% | Construction Cost | $ 505,677.81 |
| 9 | Overheads | 3% | Construction Cost | $ 151,703.34 |
| 10 | Project Contingency | 10% | Construction Cost | $ 505,677.81 |
| | | | Costs of Considerations | $ 3,084,634.64 |

Project: East Mall Redesign
Client: University of British Columbia - UBC SEEDS
File No: CIVL446-002-2021

Date: 03/05/2021

# Class A Construction Cost Estimate

## Line Item Cost Summary

| Schedule A - Pre-Construction Cost | | | | | |
|---|---|---|---|---|---|
| **Item #** | **Description** | **Quantity** | **Unit** | **Cost/Unit** | **Total Cost** |
| X103 | Pre-Construction Advertising Sign | 1 | sign | $ 2,633.32 | $ 2,633.32 |
| | Construction Traffic Accomodation | 1 | each | $ 20,000.00 | $ 20,000.00 |
| | Site Mobilization | 1 | each | $ 10,000.00 | $ 10,000.00 |
| | | | | **Subtotal** | $ 32,633.32 |

| Schedule B - Concrete Work | | | | | |
|---|---|---|---|---|---|
| **Item #** | **Description** | **Quantity** | **Unit** | **Cost/Unit** | **Total Cost** |
| S284 | Concrete Base - Remove and Dispose | 477.2 | bases | $ 311.31 | $ 148,557.13 |
| X215 | Concrete Curb and Gutter - Remove and Dispose | 2034 | metre | $ 48.12 | $ 97,876.08 |
| | Remove Side Walk | 1364 | meter | $ 40.00 | $ 54,560.00 |
| | Remove Para Ramp | 27 | each | $ 145.00 | $ 3,915.00 |
| | Remove Commercial Crossing | 126.8 | square meter | $ 28.00 | $ 3,550.40 |
| D734 | Adjust Water Valve | 20 | unit | $ 710.00 | $ 14,200.00 |
| D732 | Adjust Manhole | 20 | unit | $ 680.00 | $ 13,600.00 |
| X320 | Concrete Curb | 2034 | metre | $ 126.00 | $ 256,284.00 |
| X310 | Monolithic Sidewalk, Curb and Gutter | 1191.4 | metre | $ 411.67 | $ 490,463.64 |
| | Flate work up to 200mm in depth | 954.4 | square meter | $ 284.00 | $ 271,049.60 |
| | Construct Para ramp | 27 | each | $ 997.65 | $ 26,936.55 |
| | Construct Commercial Crossing | 126.8 | square meter | $ 175.00 | $ 22,190.00 |
| G320 | Topsoil - Supply and Place (Landscaping) | 2038.8 | square meter | $ 20.02 | $ 40,816.78 |
| | | | | Subtotal | $ 1,443,999.18 |

| Schedule C - Bioswale | | | | | |
|---|---|---|---|---|---|
| **Item #** | **Description** | **Quantity** | **Unit** | **Cost/Unit** | **Total Cost** |
| X415 | Granular Fill for Medians | 789 | tonne | $ 98.82 | $ 77,968.98 |
| | Vegetation Installation and Landscaping | 3146 | square meter | $ 85.00 | $ 267,410.00 |
| | Tree Removal | 15 | each | $ 860.00 | $ 12,900.00 |
| | Underground Work | 401 | meter | $ 736.00 | $ 295,136.00 |
| | | | | **Subtotal** | $ 653,414.98 |

Project: East Mall Redesign
Client: University of British Columbia - UBC SEEDS
File No: CIVL446-002-2021

Date: 03/05/2021

## Class A Construction Cost Estimate

| Schedule D - Roadway Work | | | | | |
|---|---|---|---|---|---|
| Item # | Description | Quantity | Unit | Cost/Unit | Total Cost |
| | Base Reconstruction - mixed in place cement | 11420 | square meter | $ 12.00 | $ 137,040.00 |
| | Disposal of Waste Material | 2512.4 | cubic meter | $ 27.00 | $ 67,834.80 |
| | Cement Stabilization by Weight | 228400 | kg/square meter | $ 5.00 | $ 1,142,000.00 |
| F980 | Asphalt Concrete Pavement | 4008.4 | tonne | $ 317.48 | $ 1,272,593.18 |
| Q554 | Cold Milling Asphalt Pavement | 132 | square meter | $ 13.81 | $ 1,822.92 |
| D734 | Adjust Water Valve | 2 | unit | $ 710.00 | $ 1,420.00 |
| D732 | Adjust Manhole | 2 | unit | $ 680.00 | $ 1,360.00 |
| | | | | **Subtotal** | $ 2,624,070.90 |

| Schedule E - Traffic Control | | | | | |
|---|---|---|---|---|---|
| Item # | Description | Quantity | Unit | Cost/Unit | Total Cost |
| S272 | Supply of Signs, Aluminum | 46 | square meter | $ 180.64 | $ 8,309.44 |
| S288 | Install Sign - Less than 1 m2 | 46 | sign | $ 65.45 | $ 3,010.70 |
| S342 | Durable Pavement Message - Stop Bar | 8 | message | $ 592.22 | $ 4,737.76 |
| S346 | Durable Pavement Message - Pedestrian Crossing | 3 | message | $ 1,295.00 | $ 3,885.00 |
| S351 | Roadway Lines - Supplying Paint and Painting (Lane Dividing and 2 Edge Lines) | 0.65 | kilometre | $ 1,044.83 | $ 679.14 |
| S360 | Intersection Lines - Supplying Paint and Painting | 3 | intersection | $ 292.84 | $ 878.52 |
| U125 | Street Light Standard - Supply and Install | 6 | unit | $ 3,587.65 | $ 21,525.90 |
| U122 | Pre-Cast Concrete Street Light Base - Supply and Install | 6 | unit | $ 2,257.95 | $ 13,547.70 |
| U115 | Removal and Disposal of Existing Light Fixtures | 6 | unit | $ 305.26 | $ 1,831.56 |
| | | | | **Subtotal** | $ 58,405.72 |

| Schedule F - Pedestrian Canopy | | | | | |
|---|---|---|---|---|---|
| Item # | Description | Quantity | Unit | Cost/Unit | Total Cost |
| | Pile instalation and placement | 6 | each | $ 5,320.00 | $ 31,920.00 |
| | Column instaltalation and erection, including material | 27 | ft | $ 1,216.00 | $ 32,832.00 |
| | Beam erection and placement, including material | 54 | ft | $ 1,538.00 | $ 83,052.00 |
| | Glass roofing system placement and installation | 150 | square meter | $ 643.00 | $ 96,450.00 |
| | | | | **Subtotal** | $ 244,254.00 |