University of British Columbia

Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

East Mall Redesign - Final Detailed Design Report

Prepared by: Benny Orr, Davis Su, Hamed Barkh, Colleen Qiu, Shota Inoda, Melissa Luo

Prepared for:

Course Code: CIVL 446

University of British Columbia

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SEEDS Sustainability Program

UBC sustainability

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EXECUTIVE SUMMARY

The following report contains a detailed design summary report for the UBC East Mall Redesign from Stadium Road to Agronomy Road with tie ins into the planned Stadium Neighbourhood. The project's objectives are to: (1) maximize safety, (2) minimize cost, (3) increase active mode share, (4) calm traffic, (5) increase green space to improve stormwater retention, (6) tie-in with the proposed Stadium Neighbourhood alignment, and (7) accommodate the sports field's high pick-up / drop-off (PUDO) demand.

The following document is a summary of the detailed design including a design overview, issue-for-construction drawings, cost estimate, schedule, life cycle analysis, and maintenance.

The selected design includes raised bike lanes, parking lane changes, rain gardens, curb extensions, and crosswalk upgrades along East Mall and a cantilevered steel walkway along Agronomy Road. The key considerations for the design have remained the same throughout the duration of the project, namely: client objectives, design feasibility, and stakeholder feedback. To arrive at the detailed design the following analyses were conducted: traffic analyses to inform the geometric design, a structural analysis for the walkway, stormwater analysis for rain gardens, and a life cycle analysis for determining the optimal service-life maintenance plan.

The detailed design has a Class A cost estimate of $3,578,000 and the project is on track to be constructed between May 10th and is expected to be completed by February 1st 2022 with a median time to completion of 186 work days excluding weekends and holidays. The project's next steps include tendering the project and obtaining relevant permits and approvals.

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1.0 INTRODUCTION

1.1 Project Background

UBC SEEDS is currently developing a detailed design for the East Mall Redesign Project. A preliminary design was developed in December 2021 which included the addition of protected bike lanes and rain gardens along East Mall, and a steel cantilevered walkway along Agronomy Rd. For the detailed design stage, a design was developed that addresses the client objectives of: (1) maximizing safety, (2) minimizing cost, (3) increasing active mode share, (4) calming traffic, (5) increasing green space to improve stormwater retention, (6) tying in with the proposed Stadium Neighbourhood alignment, and (7) accommodating the sports field's high PUDO demand.

The existing East Mall corridor from W16th Ave to Agronomy Rd (**Figure 1.1**) consists of a right-of-way (ROW) ranging from 25 m to 38 m. Each direction has a 50 km/h speed limit; is separated by a median / yellow paint markings; and consists of unidirectional vehicle and bike lanes, parking facilities / PUDO areas, sidewalks, and planting strips. The northbound direction incorporates left-turn bays at Stadium Rd and Eagles Dr.

Figure 1.1: Project Study Area

1.2 Team Member Contribution

Below is a table describing contributions by individual team members for the development of the preliminary design. In the event questions arise, it is best to contact the party responsible for that aspect of the design.

Table 1.1: Team Member Contribution

Team Member	Design Responsibilities	Report Preparation
Benny Orr	• Prepare roadway design technical specifications per codes / standards • Research roadway layers • Build Civil 3D corridor model and prepare production drawings • Generate quantity reports pertaining to roadway design	• Edited Section 2.0
Colleen Qiu	• Prepare roadway design technical specifications as per codes and standards • Research roadway layers • Build Civil 3D corridor model and prepare production drawings (Plan, Profile, Section)	• Drafted Section 2.1, 2.2, 2.3, and 2.5 • Reviewed Section 3.0
Davis Su	• Cost Estimate • Construction Plan and Sequencing • Walkway Connection Design and Drawings • AutoTurn analysis	• Drafted Section 2.4, 4.6, 5.1, 5.2, 6.0 • Reviewed Section 4.0
Hamed Barkh	• Roadway Life Cycle Analysis • Roadway Maintenance Schedule • Walkway, Rain Garden, Maintenance Plans • Schedule • Overland flow modelling	• Drafted Executive Summary, Section 5.3, 5.4 • Reviewed Section 2.0
Melissa Luo	• Pedestrian walkway design and analysis • Walkway detailed drawings • Walkway technical specifications • Walkway 3D modelling	• Drafted Section 4.0 • Reviewed Section 6.0
Shota Inoda	• Stormwater design and analysis • Stormwater detailed drawings • Pipeline system layout and design • PCSWMM stormwater model	• Drafted Section 3.0 • Reviewed Section 5.0

2.0 ROADWAY DESIGN

2.1 Standards and Software Used

Throughout the roadway design process, guidelines in various categories were referenced for both parametric and qualitative considerations as shown in **Table 2.1** and **2.2**.

Table 2.1: Standards and Guidelines Referenced in Roadway Design

Guideline / Standard	Version / Year
Geometric Design Guidelines	
TAC Geometric Design Guide for Canadian Roads (Chapter 2-6, 9)	June 2017
BC Supplement to TAC Geometric Design Guide for Canadian Roads	April 2019
BC Active Transportation Design Guide (“ATDG”)	2019
Pavement Design Guidelines	
AASHTO Guide for Design of Pavement Structures	1993
BC MoTI Pavement Structure Design Guidelines	2015
Toronto Transportation Services - Pavement Design and Rehabilitation Guideline	2019
Other Guidelines for General Reference	
City of Vancouver Engineering Design Manual	V1 (2019)
City of Vancouver Construction Specifications	V1(2019)
City of Vancouver Standard Detail Drawings - Roadworks	Sep 2018
City of Surrey Supplementary Master Municipal Construction Documents	April 2020
UBC Vancouver Campus Plan - Part 3 Design Guidelines	Oct 2020

Table 2.2: Software in Roadway Design

Software	Project Application
Synchro 6	The study area was modelling to determine link and node LOS, delay, and V/C. Modelling results informed our left-turn bay design decisions.
AutoCAD 2020	AutoCAD was used to create preliminary plan drawings of the roadway and to add markups to the detailed design drawings.
Autodesk Civil 3D 2021	Civil 3D was used for corridor modelling and IFC drawing production.
AutoTurn 11 Demo	A swept path analysis using AutoTurn was conducted on the roadway to verify turning movements, vehicle path feasibility, and parking.
Pave-Save (Shani et al. 2021)	Various pavement designs were input into the LCA model to determine the optimal asphalt thickness.

2.2 Design Criteria

Based on the guidelines and standards listed in **Section 2.1** and the client's objectives, the key design criteria below were identified for each design component as shown in **Table 2.3**. The bolded criteria are design input determined by our engineering team after discussion with the client. For the full technical specification table, please see **Appendix A**.

Table 2.3: Key Design Criteria in Roadway Design

Design Component	Key Design Criteria
Travel Lane	● **Design vehicle: WB-20** ● **Design speed: 50 km/h** ● Minimum horizontal radius = 100 m (per TAC) for 50 km/h roads with 2% superelevation ● Minimum K factor = 7 and Maximum grade = 6% (per TAC) ● Minimum width = 3.3 m to 3.7 m for rural roadways with buses and larger trucks (per TAC) ● Synchro: Projected volumes meet Level of Service > D and V/C Ratio < 1
Parking Lane	● Typical width = 2.4 m (per TAC) ● Relieve parking stress
Bicycle Through Zone	● **Design cyclist speed = 30 to 35 km/h** ● Minimum horizontal radius = 24 to 33 m (per TAC) for 30-35 km/h with 2% superelevation ● Desired width = 2.0 m for uni-directional bike lanes with <150 bikes/hr (per ATDG) - available counts at Thunderbird Blvd shows <40 bikes/hr (CTS counts from client) ● Desirable concrete buffer width = 0.6 m (per ATDG) ● Maximum superelevation = 2% for universal accessibility (per TAC & ATDG)
Landscape Zone	● Minimum width = 1.5 m for furnishing zones with larger trees (per ATDG) ● Recommended width = 2.0 m for basic furnishing zones (per ATDG)
Pedestrian Through Zone	● Desired width = 2.4 m for a collector road next to multi-family residential land use (per ATDG)
Safety Components	● Recommended setback distance from road edge = 4.4 m (per TAC) ● For 50 km/h design speeds, stopping sight distance = 65 m (per TAC) ● Curb extension: Transition curve radius between the main and extended curb shall contain a 3-5 m radius for street cleaning vehicles to maneuver properly
Pavement Structure	● Typical Pavement Structure Type C: Low Volume & Subdivision Roads (20 yr Design ESAL < 100,000): 50 - 75 mm AP, 225 mm of 25mm CBC, 300 mm min. of SGSB on Fine Grained Soil per BCMoTI Pavement Structure Design Guidelines ○ ESAL calculated based on CTS traffic counts provided by client ○ AP thickness selected based on life cycle analysis considering

	road and pavement layer parameters ● Typical bike lane pavement thickness: 50 mm AP and 150mm Granular Base (per CoV) ● Smooth concrete finishes on sidewalk pavement (per UBC)

2.3 Technical Considerations and Design Rationale

2.3.1 Plan Drawing Components

Intersections: When designing the horizontal alignment of the road, we paid special attention to the stopping-sight-distance (SSD) at intersections to ensure safety of road users. SSD is the distance required for vehicles to react, brake, and come to a stop, which is typically taken as 65 m for a 50 km/hr design speed. The placement of parking zones and curb extensions was decided based on sightline checks per the Transportation Association of Canada (TAC) *Geometric Design Guide, 2017* as shown in **Figure 2.1**. Landscaping and parked vehicles that can obstruct driver view should be avoided in the "clear sight triangles" as shown in **Figure 2.1**.

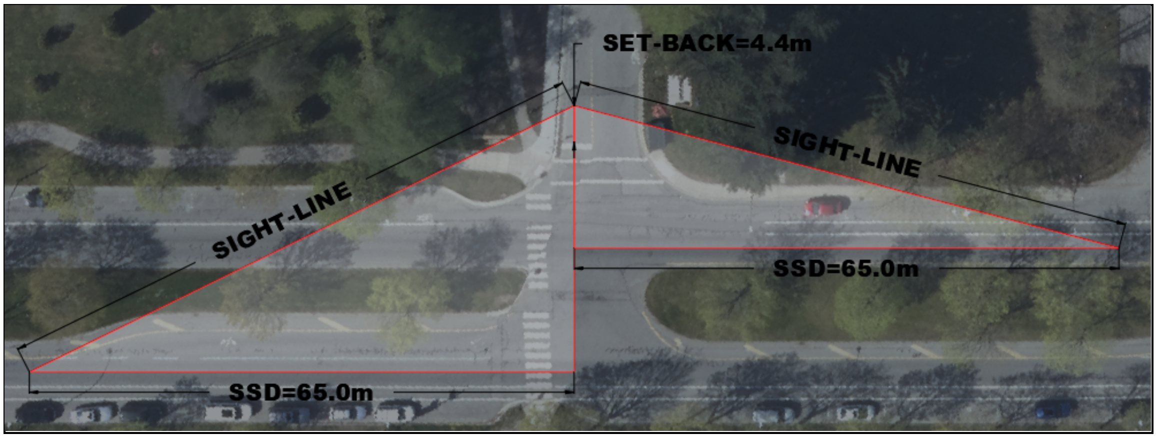


Figure 2.1: Intersection Sightline Check Example

Curb Extensions: Curb extensions of 5 m radius were placed to mark parking termination points, narrow pedestrian crossing widths to reduce probability of collisions, and allow for smooth maintenance vehicle maneuvers during periodic roadway cleaning.

Stadium Road Transition: When transitioning from a 25.5 m right-of-way (ROW) to a 35.0 m one, the lanes have been curved at a radius of 100 m at Stadium Road as a speed control measure as shown in **Figure 2.2**.

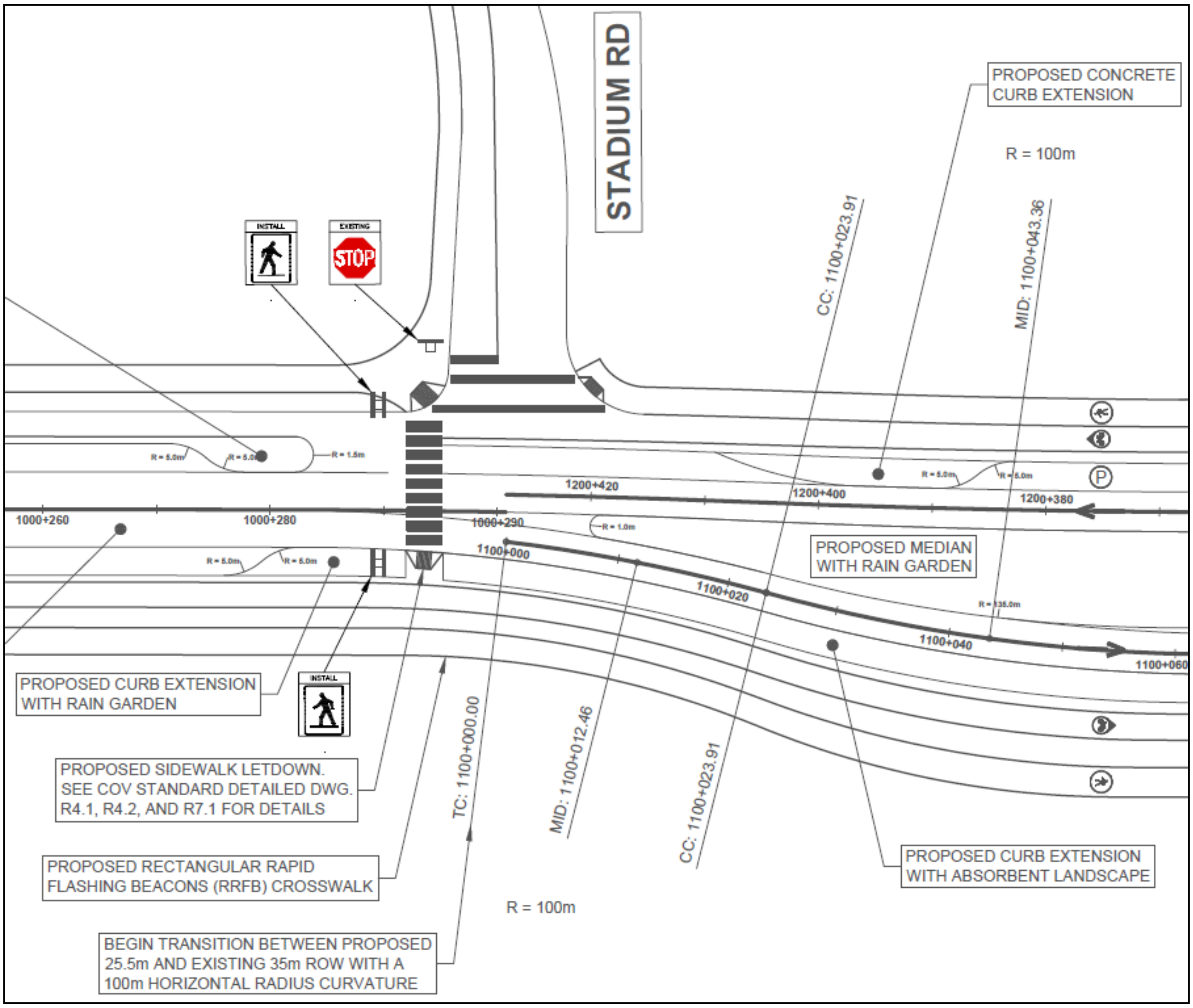


Figure 2.2: Proposed Roadway Transition at Stadium Road

Bicycle Lane Transition and Bypass at Transit Stops: Two design speeds and horizontal alignment curvature radius were considered for the bike lane design due to the roadway grade (uphill / downhill). The northbound direction going uphill from W16th Ave to Thunder Blvd along East Mall features a 24 m horizontal radius curvature at a 30 km/h design speed. The southbound direction going downhill from Thunderbird Blvd to W16th Ave features a 30-33 m horizontal radius curvature at a 35 km/h design speed. The wider horizontal radius curvature allows cyclists to perform safer turning maneuvers at transition points / bicycle bypasses while travelling at greater downhill speeds.

The existing community shuttle bus stops at Eagles Drive will also be upgraded to incorporate a bicycle bypass (outlined in TAC *Geometric Design Guide, 2017* Section 5.7.4) as shown in **Figure 2.3**. This is based on the consideration of potential conflicts between embarking/disembarking bus passengers with cyclists when busses stop adjacent to the protected bike lane without a transit island. Hence, a transit island with a 2.3 m width is added to address this conflict. Crossings with clear markings, pavement treatment, and signages will mitigate the conflict between the cyclists and the pedestrians crossing to the island by enhancing crosswalk visibility.

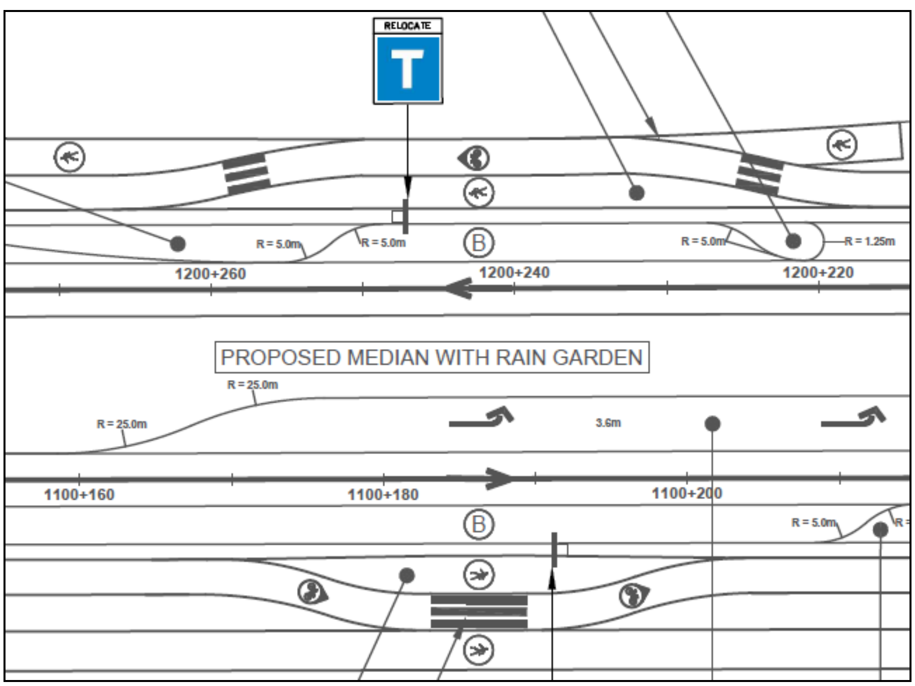


Figure 2.3: Transit Stop Bicycle Bypasses

Left-Turn Bays: The existing left-turn bay is removed at Stadium Road to make room for the Stadium Neighbourhood developments. All other existing left-turn bays have been maintained along East Mall. A capacity analysis was conducted for left-turn bay requirements along the corridor and is further discussed in **Section 2.4**.

Turning Radius and Swept Path Analysis: A swept path analysis was conducted using AutoTurn, a software that allows 2D simulation of vehicle movement paths. The analysis was used to verify the feasibility of turning movements, vehicle paths, and parking maneuvers on the road designs. Analysis is typically done using representative design vehicles developed by TAC. However, due to trial software limitations, only the DEMO vehicle was available. The vehicle was rescaled to approximately match the TAC design vehicles (example shown in **Figure 2.4**). Design vehicles used are listed in **Table 2.4**. A minimum 0.5m vehicle clearance can be maintained for all necessary vehicle movements.

Table 2.4: Design Vehicles

Vehicle	Description
TAC WB-20	Largest design vehicle. **Note:** *As East Mall is not a truck route, curb radii and left-turn bays were not designed for WB-20 maneuvers. In locations where WB-20 maneuvers are necessary, standard large truck maneuvers (e.g. using adjacent lanes for turns, oversteer turns, driving on lane lines) were considered acceptable.*
TAC P	Passenger vehicles used to verify turning movements, vehicles paths, and parking.
TAC MSU	Medium trucks used to verify turning movements, vehicle paths, and parking.

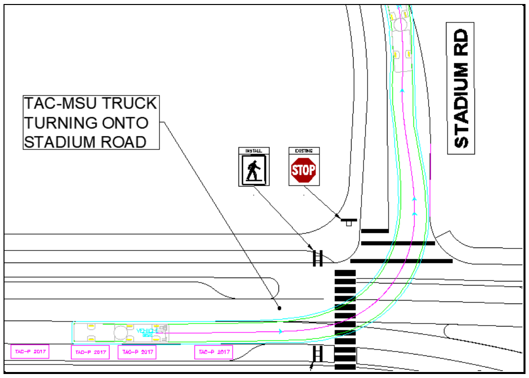


Figure 2.4: Swept Path Example - Stadium Road

2.3.2 Profile Drawing Components

Since the elevation change along East Mall is relatively small, maximum grade is not a concern for automobiles or bicycles. Since a 2% cross slope is adopted, a minimum longitudinal grade is not mandatory for drainage. Crest curves have to be flat enough to provide sufficient sight distances, and these sight distance considerations are accounted for in the K-value limits. Since the road base is in good condition, the existing road profile has been maintained as much as possible to reduce costs.

2.3.3 Section Drawing Components

Drainage and integration with stormwater infrastructure are the main considerations in section design. A cross slope (or superelevation) of 2% has been implemented in all the sections as shown in **Figure 2.5**. When a centre rain garden is present, both sides of the roadway are slanted towards the rain garden. From West 16th Ave to Stadium Road where there is no rain garden, the roadway is sloped towards the curb and gutter by the elevated bike lane. Pavement layer materials and thickness are determined based on 20-year design Equivalent Single Axle Load (ESAL) (see **Table 2.3**), industry standards, and a life cycle analysis (see **Section 5.4.1**). The Contractor is responsible for the asphalt concrete mix design.

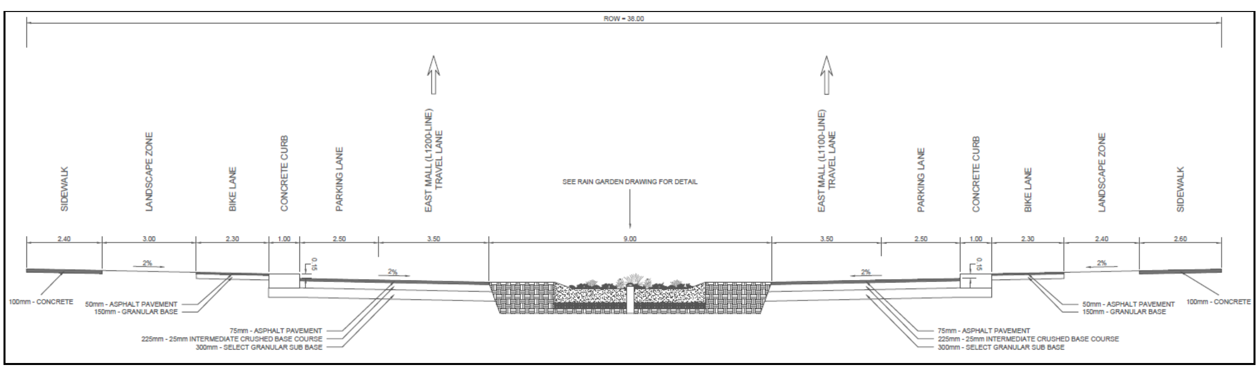


Figure 2.5: Eagles Drive to Thunderbird Blvd Cross Section

2.4 Traffic Analysis

To evaluate the proposed roadway design, traffic analysis was conducted using Synchro 6, a software that analyzes road capacity, vehicle delay, and queue lengths to analyze 2040 traffic growth. 2040 AM and PM peak vehicle Level of Service (LOS), delay, and volume-capacity (V/C) ratio were found for the five intersections along East Mall as shown in **Table 2.5** and in greater detail in **Appendix C**. Traffic volumes used were from Bunt's *Stadium Neighbourhood Planning Traffic Analysis (2020)* report as well as data provided by the client from Creative Transportation Solutions. All intersections were found to operate overall at LOS C or better.

Table 2.5: 2040 Synchro Results Summary

Intersection	2040 AM			2040 PM		
	LOS	Total Delay (s)	Max V/C	LOS	Total Delay (s)	Max V/C
Agronomy Rd	B	10.7	0.42	B	12.1	0.53
Thunderbird Blvd	C	25	**0.91**	C	20.6	0.79
Logan Ln	A	0.1	0.41	A	0.1	0.37
Eagle Dr	A	0.2	0.4	A	0.2	0.37
Stadium Rd	A	4.9	0.62	A	6.3	0.53

There are potential capacity issues at Thunderbird Blvd, with a 0.91 V/C in the northbound through movement. The analysis assumes moderate vehicle growth into 2040. Given UBC's travel mode strategy, vehicle growth will likely be lower than modelled, meaning active transportation oriented policies may be a viable strategy as opposed to roadway expansions.

Left Turn-Bay Analysis: A capacity analysis of left-turn movements along the corridor was conducted in Synchro. A major consideration was the 95th percentile queue length, a value that represents the highest queue reasonably expected with a 1/20 chance of occurrence. Additionally, per the *Highway Capacity Manual 2000*, left-turn bays are typically considered when turning vehicles approach 100 vehicles and should be verified with a capacity analysis. A summary of findings is provided below, with analysis results shown in **Table 2.6**:

- Longer queues are expected for the northbound AM and southbound PM movements at Thunderbird Boulevard where there are no left-turn bays. However, the low peak hour left turn volumes do not justify a left turn bay (36 NB AM and 6 SB PM vehicles).
- Although Stadium road is expected to have left-turn volumes greater than 100 during the 2040 AM and PM peaks, minimal disruptions to traffic queues and LOS are expected, meaning a left-turn bay removal is acceptable.

Table 2.6: Left-Turn Lane Analysis - 2040 Weekday Peaks

Intersection Left Turn Approach	2040 AM				2040 PM			
	Left Turn Volume	LOS	95th Perc. Queue (m)	Existing Storage (m)	Left Turn Volume	LOS	95th Perc. Queue (m)	Existing Storage (m)
Thunderbird Blvd NB	36	C	#146.9**	N/A	20	B	24.4**	N/A
Thunderbird Blvd SB	42	B	15.1**	N/A	6	C	#81.2**	N/A
Thunderbird Blvd EB	4	B	21.4**	N/A	15	A	18.5	N/A
Thunderbird Blvd WB	190	B	#46.4	50	57	B	#62.0**	50
Eagle Dr NB	7	A	0.1	40	9	B	0.2	40
Stadium Rd NB	111	A	4	40*	223	A	10.3	40*

*Stadium road northbound left-turn bay to be removed for new neighbourhood alignment. Due to the limitations of Synchro, the delay and LOS results were not found to change

**For intersections without left-turn bays, queue lengths are for the combined left-through movement.

2.5 Key Components Description

Key dimensions of lane widths, horizontal radius, superelevation, longitudinal gradient, K-values of vertical curves as well as pavement layers are specified in **Table 2.7**. Note that existing curb and sidewalk letdown placements and dimensions are maintained where possible. For detailing of other roadway components such as signages and lightings, please refer to municipal design standards. Detailed plan, profile, and section drawings as well as references to relevant roadway component standard detail drawings from municipalities are included in **Appendix B**.

Table 2.7: Roadway Design Specifications Table

**Note: Notations such as “L1000-Line” refer to horizontal alignment lines in accordance with the design drawings (see Appendix B).*

<table>
<tr><th>Location (S to N)</th><th>Pedestrian Through Zone</th><th>Bicycle Through Zone</th><th>Parking Lane</th><th>Vehicle Lane</th><th>Median</th><th>Landscape Zone</th></tr>
<tr><td>W16th Ave</td><td colspan="6">Proposed design to tie-in with the existing intersection (roundabout controlled) as per the client’s scope</td></tr>
<tr><td rowspan="3">L1000-Line

W16th Ave - Stadium Road

ROW = 25.5 m</td><td colspan="6">Designed as per the schematic cross section layout provided by the client</td></tr>
<tr><td>➢ Width: 2.35 m (East Side - E) and 2.4 m (West Side - W)
➢ Separated from bike lane with landscape zone
➢ 2% superelevation towards curb</td><td>➢ Width: 2.2 m
➢ Unidirectional and elevated (height = 0.15 m)
➢ Separated from sidewalk and parking lane with landscape zone and concrete buffer, respectively
➢ Concrete buffer width: 0.6 m
➢ 2% superelevation towards curb</td><td>➢ Width: 2.5 m
➢ 6 paid parking stalls converted to 5-minute pick-up / drop-off spots
➢ 2% superelevation towards curb</td><td>➢ Width: 3.3 m
➢ 2% superelevation towards curb</td><td>➢ Removed to accommodate narrow 25.5 m ROW</td><td>➢ Width: 1.8 m (E) and 1.75 m (W)
➢ 2% superelevation towards curb
➢ Street lights placed on E at 45 m interval and 0.5 m from edge near road</td></tr>
<tr><td colspan="6">➢ K-value of crest/sag curves: ranges from 16.20 to 118.75 (identical profiles in both directions)
➢ Longitudinal gradient: ranges from 0.74% to 1.47% (identical profiles in both directions)</td></tr>
<tr><td>Stadium Road</td><td colspan="6">➢ Control Type: Stop
➢ Transition from 25.5 m to 35 m ROW: Vehicle lane horizontal radius = 100 m (NB)
➢ LT bay removed as supported by synchro analysis (see Section 2.3 - Traffic Analysis in Synchro: Left Turn-Bay Analysis)
➢ Curb extension (radius = 5 m) with rain garden (E) and concrete (W) used to narrow crossing distance
➢ Crosswalk with Rectangular Flash Beacon (RRFB) and paint-markings to improve safety
➢ Proposed sidewalk letdown on east side (see CoV Standard Detailed Drawings R4.1, R4.2, and R7.1 for details)</td></tr>
<tr><td rowspan="2">L1100/1200-Line

Stadium Road - Parking Lot Entrance (W)- Eagles Drive

ROW = 35 m</td><td>➢ Width: 2.6 m (E) and 2.4 m (W)
➢ W side is adjacent to bike lane
➢ E side is separated from bike lane with landscape zone
➢ 2% superelevation towards rain garden (road center)</td><td>➢ Width: 2.3 m
➢ Unidirectional and elevated (height = 0.15 m)
➢ Separated from parking lane with concrete buffer
➢ Concrete buffer width: 1.0 m
➢ 2% superelevation towards rain garden (road centre)</td><td>➢ Width: 2.5 m
➢ 2% superelevation towards rain garden (road centre)</td><td>➢ Width: 3.5 m
➢ 2% superelevation towards rain garden (road centre)</td><td>➢ Width: 9 m
➢ Median converted to rain garden</td><td>➢ Width: 2.4 m (E only) to preserve existing ROW (existing condition do not have landscape zone on W side)</td></tr>
<tr><td colspan="6">➢ K-value of crest/sag curves: ranges from 225.28 to 299.21 from south to north and 29.48 to 71.38 from north to south
➢ Longitudinal gradient: ranges from 0.75% to 1.41% from south to north and -0.59% to -1.64% from north to south</td></tr>
<tr><td>Parking Lot Entrance (W)</td><td colspan="6">➢ Control Type: Stop and curb extension radius: 5 m
➢ LT bay storage length and width to be maintained, but shifted towards the median to minimize project cost and allow for future volume growth from new developments
➢ No crosswalk provided (same as existing conditions)</td></tr>
<tr><td>Eagles Drive</td><td colspan="6">➢ Control Type: Stop
➢ LT bay storage length and width to be maintained, but shifted towards the median to minimize project cost and allow for future volume growth from new developments
➢ Curb extension (radius = 5 m) with absorbent landscape (E) and concrete (W) used to narrow crossing distance
➢ Crosswalk with Rectangular Flash Beacon (RRFB) and paint-markings to improve safety
➢ Proposed sidewalk letdown on east side (see CoV Standard Detailed Drawings R4.1, R4.2, and R7.1 for details)
➢ The existing community shuttle bus stop locations (NB and SB) are maintained, but will be modified to incorporate a bicycle bypass configuration (“scissors transit stop”)
○ East side bicycle bypass horizontal radius: 24 m
○ West side bicycle bypass horizontal radius: 30 m</td></tr>
<tr><td rowspan="2">L1100/1200-Line

Eagles Drive - Logan Lane - Thunderbird Blvd

ROW = 38 m</td><td>➢ Width: 2.6 m (E) and 2.4 m (W)
➢ Separated from bike lane with landscape zone
➢ 2% superelevation towards rain garden (road centre)</td><td>➢ Width: 2.3 m
➢ Unidirectional and elevated (height = 0.15 m)
➢ Separated from sidewalk and parking lane with landscape zone and concrete buffer, respectively
➢ Concrete buffer width: 1 m
➢ 2% superelevation towards rain garden (road centre)</td><td>➢ Width: 2.5 m
➢ 2% superelevation towards rain garden (road centre)</td><td>➢ Width: 3.5 m
➢ 2% superelevation towards rain garden (road centre)</td><td>➢ Width: 9 m
➢ Median converted to rain garden</td><td>➢ Width: 2.4 m (E) and 3 m (W)
➢ 2% superelevation towards rain garden (road centre)</td></tr>
<tr><td colspan="6">➢ K-value of crest/sag curves: ranges from 155.32 to 299.21 from south to north and 161.16 to 493.49 from north to south
➢ Longitudinal gradient: ranges from 0.61% to 1.16% from south to north and -1.04% to -0.47% from north to south</td></tr>
</table>

Logan Lane	➢ Control Type: **Stop** ➢ Maintain existing right-in / right-out movements from East Mall to Logan Ln and vice versa ➢ No crosswalk provided as blocked by median (same as existing conditions) ➢ Parking stalls removed for the westside of East Mall between Logan Ln and Thunderbird Blvd to provide bike lane transition that is at-grade with the vehicle lane					
Thunderbird Boulevard	➢ Control Type: **Signalized** ➢ Maintain existing overhead traffic signals on all corners ➢ Transition from the proposed to existing alignment: ○ Vehicle lane horizontal radius = **550 m** (SB) ○ Bike lane horizontal radius = **24 m** (NB) and **33 m** (SB) ➢ No NB LT bay provided because existing wide medians on both the north and south sides of the intersection are sufficient to accommodate vehicles waiting to turn left ➢ Curb extension (radius = **5 m**), next to which elevated bike lane drops off into separated bike lane with paint-markings for NB direction and vice versa for SB direction ➢ Maintain crosswalk on all approaches (same as existing conditions)					
L1300 to 1600-Line	The existing road configuration is preserved. However, paint-markings and median need to be modified to tie in with the modified configuration before Thunderbird Blvd.					
Thunderbird Blvd - Agronomy Road **ROW = 24 m**	➢ Width: **2.9 m** (E) and **2.0 m** (W) ➢ Separated from bike lane with landscape zone	➢ Width: **1.6 m** ➢ Unidirectional and at road grade ➢ Separated from vehicle lane with paint-marking only	➢ None	➢ Width: **3.5 m**	➢ None except immediately after Thunderbird Blvd intersection	➢ Width: **2.4 m** (W) and **6.5 m** (E)
	➢ K-value of crest/sag curves: maintains existing ➢ Longitudinal gradient: maintains existing					
Agronomy Road	The existing intersection configuration is maintained					
Pavement Structure	➢ **100 mm** Concrete Pavement with light broom finish	➢ **50 mm** Asphalt Pavement (AP) and **150 mm** Granular Base (GB)	➢ **75 mm** AP ➢ Existing CBC and SGSB maintained where possible	➢ **75 mm** AP ➢ Existing CBC and SGSB maintained where possible	➢ Sandy loam as top soil for vegetation	➢ Sandy loam as top soil for vegetation

3.0 STORMWATER INFRASTRUCTURE

As the population of UBC grows, the trend of densification has resulted in loss of greenery. Combined with the effects of climate change, this can result in increased flooding, habitat depletion, and pollution in the water system. UBC's Integrated Stormwater Management Plan has indicated concerns for East Mall between Thunderbird Blvd and West 16th Ave, stating "continued source-point controls will be important for any new development". By implementing **Green Stormwater Infrastructure (GSI)**, peak runoffs may be reduced by absorbing excess water, and runoff water quality may be improved by filtering stormwater. This section provides a description of the Green Stormwater Infrastructure design implemented in our design.

To reduce the risk of flooding, reduce untreated stormwater discharge, and increase greenspace, a center median rain garden is proposed along East Mall from 16th Ave to Thunderbird Blvd. The design retrofits the pre-existing large center median on East Mall with a rain garden.

3.1 Standards and Software

Throughout the GSI design process, guidelines in various categories were referenced for both parametric and qualitative considerations as shown in **Table 3.1**.

Table 3.1: Standards and Guidelines Referenced in Stormwater Design

Guideline / Standard	Year of Release
GSI Design Guidelines	
Fisheries and Oceans Canada Guidelines	2001
City of Vancouver's Rainwater Infrastructure Guideline	2018
Metro Vancouver Stormwater Source Control Design Guidelines	2012
Vancouver Campus Plan Design Guidelines Part 3	2010
Pipeline Design Guidelines	
UBC Technical Guidelines Section 33 49 00	2020

Table 3.2 presents the various softwares used for the stormwater design.

Table 3.2: Software in Stormwater Design

Software	Project Application
PCSWMM	The study area was modelling using PCSWMM to analyze the run-off and infiltration rates.
AutoCAD 2020	AutoCAD was used to create detailed plan drawings of the rain garden and to add markups to the detailed design drawings.
QGIS	Overland flow was modeled using QGIS to determine the degree of overland water accumulation

3.2 Design Targets

Below are the design objectives set for our project following the Fisheries and Oceans Canada Guidelines and City of Vancouver's Rainwater Infrastructure Guidelines.

1. Collect and treat the volume of the 6-month/24-hour precipitation event equalling 90% of the total rainfall from impervious areas with suitable Best Management Practices (BMPs).
2. Reduce post-development flows to pre-development levels for the 6-month/24- hour, 2-year/24-hour, and 5-year/24-hour precipitation events.
3. Remove 80% of total suspended solids from the first 24 mm of rainfall from all previous and impervious surfaces.

3.3 Rainfall Analysis

To analyze the effectiveness of the GSI design implemented in the East Mall Redesign Project, 3 rainfall scenarios with different durations were used. A summary of the rainfall events are shown on **Table 3.3**. The following points were considered when obtaining our 3 rainfall scenarios:

- IDF (Intensity-Duration-Frequency) curves were obtained from IDF_CC Tool 4.0 by Western University. The curves represent a climate model with a time period ranging from 2006 to 2100. This accounts for the effects climate change on future rainfall events.
- SCS Type 1A curve with a time interval of 6 mins was used to replicate a typical rainfall distribution. The SCS Type 1A was developed by the Soil Conservation Service. Type 1A storms represent pacific climates with wet winters and dry summers.
- A 6-month/24-hour precipitation event was assumed to be 72% of the 2-year, 24-hour event volume.

The distribution of rainfall for each scenario is summarized in **Table 3.3**. Climate change was considered for all IDF curves to accurately model future scenarios. The 3 IDF curves were chosen to depict practical scenarios which East Mall will commonly experience.

Table 3.3: Summary of the Three Rainfall Scenarios

Scenario	Model	Intensity-Duration-Frequency	Time (h)	Total rainfall (mm)
1	SCS Type 1A	6-month 24-hour (under climate change)	24	41.0
2	SCS Type 1A	2-year 24-hour (under climate change)	24	56.9
3	SCS Type 1A	5-year 24-hour (under climate change)	24	72.19

3.3 Evapotranspiration Analysis

Daily evapotranspiration (ET) data provided by Environment and Climate Change Canada at the Vancouver Airport station was chosen for evapotranspiration analysis because of its proximity to UBC. The effects of climate change were ignored during the analysis. While climate change will likely increase air temperature, the effects of higher humidity and CO_2 concentrations are expected to counteract the effects due to rise in temperature (Snyder et al., 2011). For our model, the annual average evapotranspiration of 1.9 mm/day was used. Monthly ET values are provided in **Appendix B**.

3.4 Groundwater Analysis

The water table at UBC was indicated to be typically greater than 45 m below ground level (Piteau Associates Engineering., 2002). Due to the deep water table, the water table is assumed to have negligible impact on the infiltration of surface runoff during the analysis. However, due to a layer of low permeability till just below the topsoil, there is potential for water to pool over this layer during heavy rainfall events. The increasing number of impermeable surfaces such as roads and parking lots have further aggravated the problem by causing more demand for water infiltration in permeable areas.

The thickness of the till layer varies along East Mall. There are concerns that the till layer may be thicker than anticipated below the rain garden which may cause lower infiltration rates than anticipated. It is recommended that the contractor conducts boreholes tests to a depth of up to 15m to assess if excavating a portion of the till is necessary.

3.5 Plants and Soil

Green stormwater infrastructures such as rain gardens can remove pollutants from runoff flows. Plants rooted into the soil slow the flow of runoff, allowing the pollutant particles to settle, which are then incorporated into the soil where it is immobilized and/or decomposed. Deeper topsoil helps with plant resiliency and water retention due to the roots reaching further down into the soil. A soil depth of 450 mm is assumed to meet the 80% TSS removal target set for this project and therefore is the recommended soil depth for the rain garden and absorbent landscape. We also recommend a minimum of 10% organic matter to increase the water carrying capacity and promote healthier plants that are more resilient to pests. **Table 3.4** identifies the growing medium properties for the rain garden.

Table 3.4: Growing Medium Specifications

Particle Size	Percent of dry weight
Gravel	0%
Sand	45-60%
Silt	20-30%
Clay	15-30%
Organic Content	10-15%

50 mm of mulch is recommended to cover the exposed soil in the rain garden to reduce erosion and prevent weeding. The mulch must be medium-size to ensure it is not too large that it floats or too small that it reduces infiltration. Mulch shall be replaced a minimum of once a year to prolong the life expectancy of the rain garden. The gravel storage below the growing medium must have a void ratio of 0.75 and contain only materials in the range of 9mm to 20mm. The detailed drawing of the rain garden profile is provided in **Appendix B**.

Flood tolerant, tall growing plants such as red-osier dogwood, Labrador tea, and Spiraea douglasii are recommended for the rain garden. The rain garden should have a mixture of different colours to improve the aesthetics and attract wildlife. For information on maintenance strategies refer to **Section 5.4.3**.

3.6 Overland Flow

Overland flow was modelled using the kinematic wave D8 algorithm in QGIS (Johnson, D. L., & Miller, A. C. 1997) to determine the accumulation of stormwater on East Mall. The model used 8,802,667 lines of x, y, z data from Abacus (University of British Columbia. Campus and Community Planning. 2015) to interpolate a digital elevation model of UBC Vancouver campus. A homogeneous rainfall over the entire region was analyzed for a 24 hour period with 6 minute time steps. Results indicated that there was some accumulation at the bottom of East Mall near 16th Ave. However, major overland flow accumulation was not a concern. A figure showing the flow accumulation on East Mall is presented in **Appendix D**.

3.7 Design Description

3.7.1 Design Layout

Rain gardens and absorbent landscapes are the two GSIs implemented on East Mall (descriptions in **Table 3.5**).

Table 3.5: Summary of GSI

GSI	Description
Absorbent Landscape Area: 9955m^2	● 450mm deep topsoil which is assumed to remove over 80% of total suspended solids (TSS) ● American sweet gum trees planted along absorbent landscape ● Podzol soil underneath the topsoil
Rain Garden Area: 1789m^2	● 450 mm deep growing and infiltrating medium (sandy loam) which is assumed to remove over 80% of total suspended solids (TSS). ● A 200 mm deep gravel layer beneath the soil and a 190mm diameter PVC pipe connecting the rain garden to the main storm sewer. ● The side slopes are 200 mm high to allow water to pool before flooding over to the road. Maximum slope of 20% ● Plants used: Red osier dogwood, labrador tea, sweet gale, douglas spirea, lyngby's sedge, slough sedge, beaked sedge, small-flowered bulrush ● Maximum overflow structures spacing of 10m ● At the widest cross-section between eagles and Thunderbird the rain garden is 4.8m wide with 2.1m absorbent landscape buffer zones between the rain garden and the paved road

A section view of the GSI is presented below in **Figure 3.1** and in further detail in **Appendix B**.

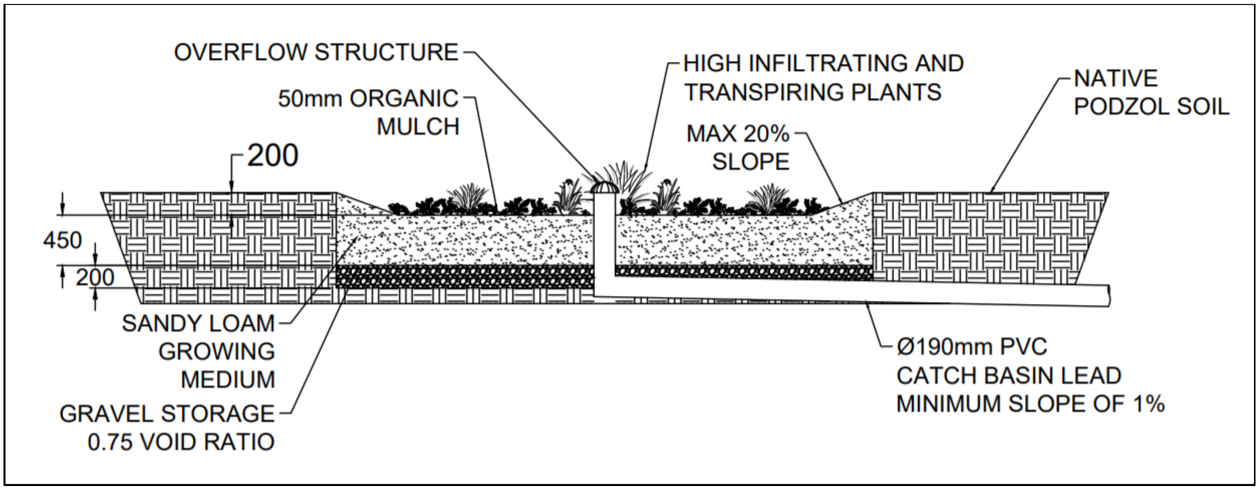


Figure 3.1: Typical Cross-section of Rain Garden

Based on UBC's ISMP and **Section 3.6,** the primary concern for stormwater was between 16th Ave and Thunderbird Blvd. North of Thunderbird Blvd was determined to be "well drained and only presents minor flooding" by UBC's ISMP. The layout which was designed to effectively capture stormwater is presented in **Appendix B**.

3.7.2 Pipeline System

The storm sewer design followed UBC Technical Guidelines. Overflow structures connect the rain garden to the main stormwater drainage system, conveying any overflow the rain garden is not able to infiltrate. Manholes are placed throughout the system to enable inspections and maintenance operations. The original stormwater system was kept and only portions near the rain gardens were modified to connect the overflow structure to the main pipeline. **Table 3.6** describes various components of the stormwater system. The locations of the pipeline components along East Mall are presented in **Appendix B**.

Table 3.6: Summary of Pipeline Components

Component	Description
Pipeline Length: 920m	• 450mm Diameter PVC piping • 1.5m below ground level • Flows only by gravity with a minimum velocity of 0.6m/s when flowing full to half full • Minimum slope of 0.2% • 750 mm horizontal clearance with sanitary sewer
Manhole	• Maximum spacing of 100m • Located at every bend in the pipeline
Catch Basin/overflow structure	• Services a maximum area of 500m^{2} to • Minimum slope of 1% catch basin leads • 0.5m pipeline offset from bottom of catch basin to catch debris and mitigate clogging in pipeline • At rain gardens: An overflow structure which conveys extreme rainfall volumes to the stormwater system eliminating the need for a regular catch basin

3.8 Stormwater Model

Our proposed rain garden was modelled to verify that our design meets the stormwater criteria set in **Section 3.2**. All stormwater modelling was completed in PCSWMM Professional 2D because of its capabilities in analyzing complex conditions which considers rainfall, soil parameters, catchment characteristics, and pipe systems. Further breakdown of the stormwater model including elevation graphs of pipeline, layout of East Mall, detailed rainfall distributions, runoff and infiltration rates for different models/scenarios are included in **Appendix D**.

3.7.1 Design Model Input and Parameters

A summary of the model input and parameters are listed below. A more detailed breakdown of all parameters are included in **Appendix D**:

- The topsoil at UBC was assumed to be loam with the soil characteristics outlined in the SWMM 5.1 Manual.
- The rain garden's soil was assumed to be sandy loam with dense vegetation growth

- The maximum overland flow distance for each sub catchment was assumed to be half the ROW.
- Fixed evapotranspiration potential of 1.89mm/day was used for the 24 hour rainfall events.
- Snowfall effects were negligible and assumed to have no effect on the model (Snow catch factor of 1).
- Horton's infiltration method was used to analyze the absorbent landscape
- Model used 5 subcatchments: West 16th Ave to Stadium Road, Stadium Road to Eagle Drive, Thunderbird Boulevard Intersection, and Eagle Drive to Thunderbird Boulevard, and Thunderbird Boulevard to Agronomy Road.

3.7.2 PCSWMM Results

All design targets identified in **Section 3.2** were achieved based on guidelines mentioned in **Section 3.1** and our PC SWMM model. A detailed breakdown of the results are shown in **Appendix D**.

4.0 PEDESTRIAN WALKWAY

4.1 Design Standards and Criteria

The design criteria such as codes and standards followed are discussed for each of the components below.

Steel Members Sizing: Wind load, snow load, and earthquake loads have been calculated according to the NBCC 2015 to ensure gravity load and lateral stability. Dead load was obtained by computing the member's self weight referencing the steel sections catalogue. The calculated load demands were then inputted into SAP2000 structural analysis software to determine the internal load demand taken by each member. The capacities of each member were determined according to the CSA S16-2019 Design of Steel Structures. The design was verified by ensuring the demand is less than the capacity using ultimate limit state design.

Second Order Analysis: Beam-column action and the P-delta effect was further analyzed due to bending moment and axial force acting simultaneous on the columns. The three limit states: cross sectional strength, overall member strength, and lateral-torsional buckling strength were computed according to CSA S16-19 to ensure capacity is greater than the demand.

Connection Strength: Bolts and weld connection capacities were determined using CSA S16-19 and compared with the load demands calculated previously to ensure the structure would not undergo connection failure.

Footing Stability: Reinforced concrete footing capacity was calculated according to CSA A23.3 Design of Concrete Structures. Reinforcement, anchors, and lateral ties configurations were designed to standard. The capacity was compared to the load demand calculated previously to ensure it’s sufficient.

4.2 Site Location

The pedestrian covered walkway consists of a single row of columns supporting a cantilever canopy. It is planned to be installed on Agronomy Road between East Mall and Health Sciences Mall. The driveway separates the canopy into two sections to allow vehicles to pass through. Each section spans 36 m and 32 m, respectively. The width of the canopy is 2.5 m, covering the entire sidewalk width to provide pedestrian weather protection. The plan view of the walkway is illustrated in **Figure 4.1.**

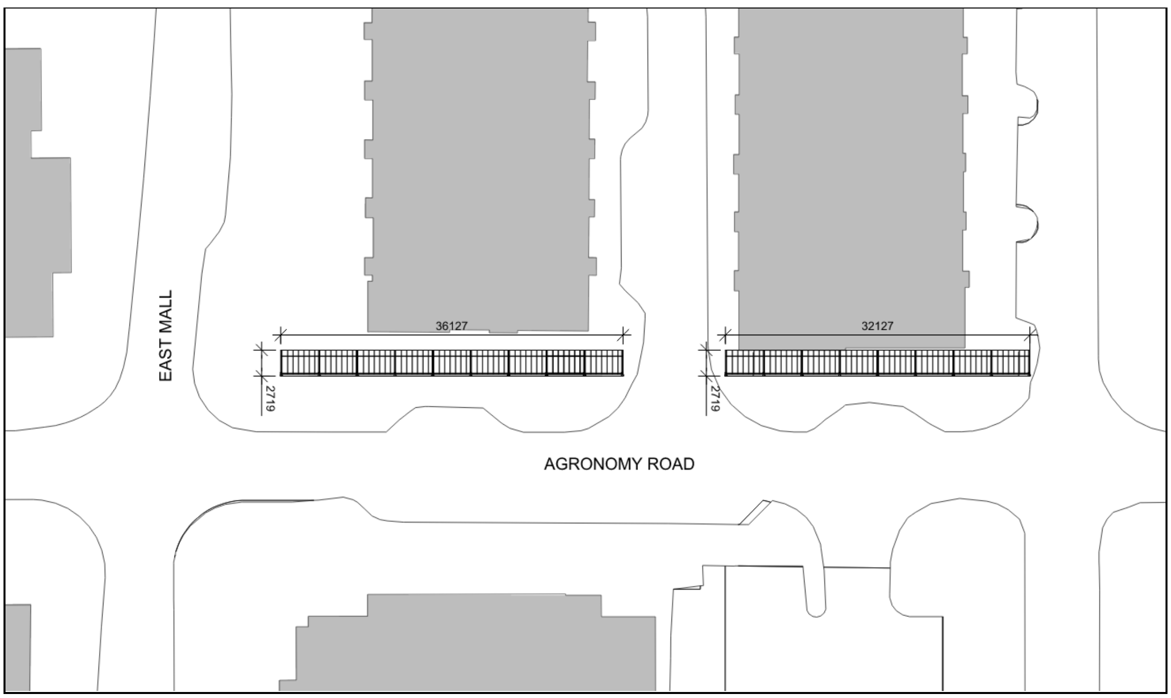


Figure 4.1: Plan View of Pedestrian Walkway

4.3 Key Component Description

A description of key walkway components is provided in **Table 4.1**. The full drawing set for the walkway is attached in **Appendix B** which illustrates all these design components in detail. A rendering of the walkway is provided in **Figure 4.2**.

Table 4.1: Key Walkway Component Description

Design Component	Description
Main Steel Structure	• 3.5m tall round HS 219x9.5 columns spaced @ 4m • Tapered cantilever beam HS 178x127x9.5 extends 2.5m horizontally • 2 HS 102x51x9.5 structural beams spans 4m along the entire walkway • Joists HS 76x51x3.2 spaced @ 570mm with slot to insert glass panel • HSS Light beam (non load carrying) supported by columns allowing space for electrical wires
Footing	• 400 mm deep 1200x1200 footing with 7-15M bars top and bottom • 75 concrete cover • 150 deep 350x350 concrete pedestal with 10M vertical and lateral ties • 320x320 base plate welded to column
Connections	• Structural beam to cantilever beam connection: Two L51x51x6.4 angles with bolts • Column to cantilever connection: 8mm thick custom HSS sleeve (male) slot in cantilever inner wall with four 16mm diameter blind bolts • Column to cantilever connection: Weld gusset plate to cantilever and bolted to column • Beam splice connection: custom slot joint with 16mm diameter bolts
Glass Panels	• 14mm thick tempered laminated glass panel • Sloped at 11 degrees with gap at the end to avoid water accumulation
Fabrication	• Blind bolt and sleeve connections are implemented to increase ease of installation • Fillet and bevel welds could be completed in the shop to reduce field fabrication • All connections are designed so that only bolting is required on-site to accelerate the construction schedule

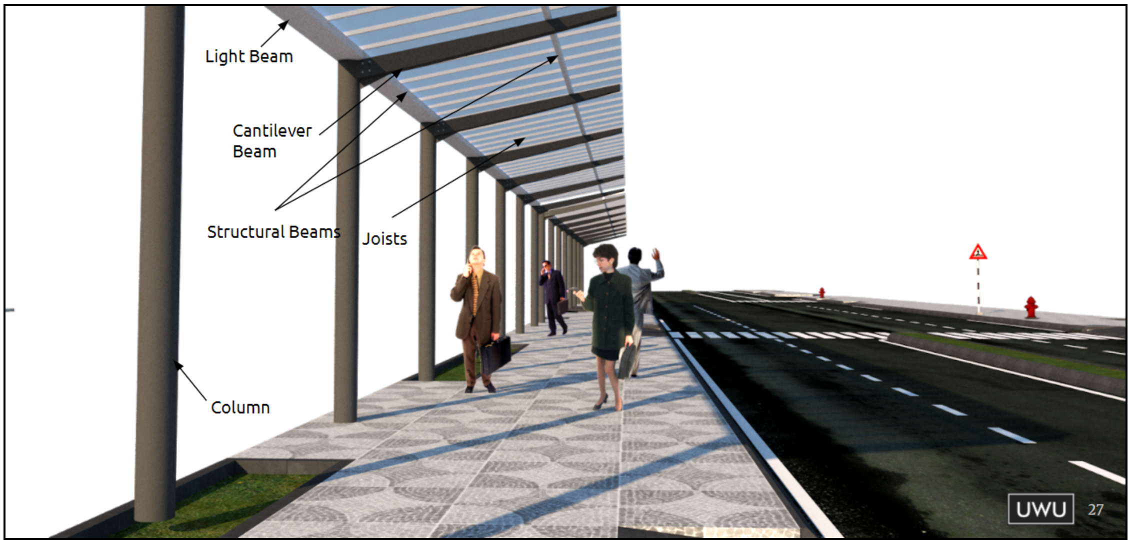


Figure 4.2: Rendering of the Pedestrian Walkway

4.4 Structural Analysis and Design Checks

Various design checks were carried out for each component to ensure structural failure does not occur. The governing capacity and Demand/Capacity ratios (D/C) using factored loads and capacities are outlined in **Table 4.2**. Detailed calculations and design checks can be found **Appendix E**.

Table 4.2: Demand and Capacity Summary

Components	Demand	Capacity	D/C	Comments
Cantilever Beam	287 MPa (conservative approach)	315 MPa	91%	Governed by bending stress
Structural Beam	288 MPa (conservative approach)	315 MPa	92%	Governed by bending stress
Column	227.7 MPa	315 MPa	72%	Governed by bending stress
P-Delta Analysis	N/A	N/A Limit State 2 and 3 governs	54%	Limit State 2 and 3 has equal values
Structural Beam-Cantilever Angle Connection	2.5 kN	70 kN	3.6%	Bolt Shear Capacity governs. This connection is provided for lateral stability

				only
Beam Splice Connection	12 kN (Shear)	82 kN (Shear)	15%	Bolt bearing stress governs. No Axial force is expected.
Column-Cantilever Bolt Connection	205 kN	296 kN	69%	Shear resistance of column determining
Column-Cantilever Weld Connection	205 kN (Orient 1) 150 kN (Orient 2)	622 kN (kN) 492 kN (kN)	65%	Multi-orientation force on weld. Combined D/C taken.
Footing	57.5 kN	500 kPa (assumed soil bearing capacity)	11.5%	The design is governed by reinforcement development length
Base Plate	57.5 kN	690 kN	8.3%	The base plate size is governed by the column section size

4.5 Construction Specifications

Full detailed technical specification regarding fabrication, materials, and welded construction can be found in **Appendix B**.

4.6 Special Fabrication Requirements

Note that while most walkway components consist of readily available sections and components, certain components of the walkway require specialized steel fabrication which will require early discussion on the contractor's end. This includes:

- Tapered cantilever beams composing custom HSS sections as shown in **Figure 4.3**
- Sleeve connections for the cantilever and beams (see **Figure 4.4**). While the outer female sleeves consist of readily available sections, to allow for a flush sleeve connection, the inner male sleeves must be custom fabricated as no standard section is readily available.

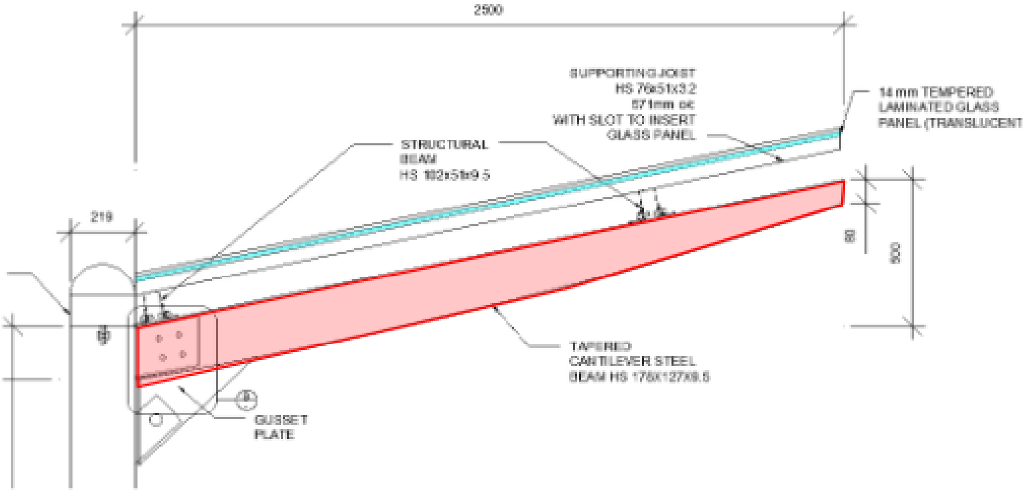


Figure 4.3: Tapered Cantilever Beam

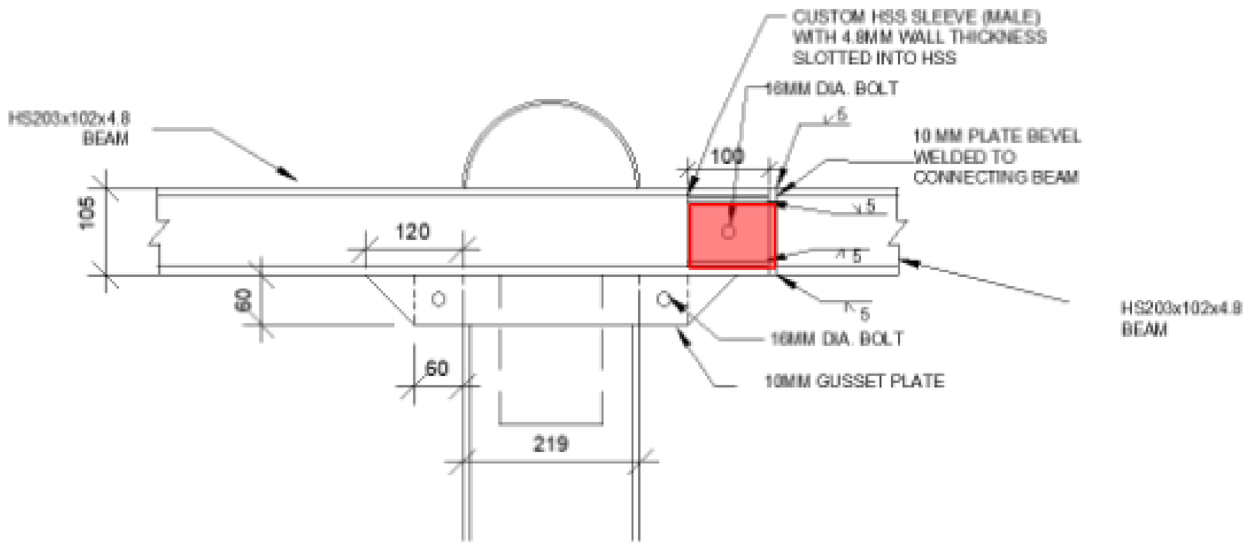


Figure 4.4: Beam Sleeve Connection

5.0 PROJECT MANAGEMENT

5.1 Site Plan and Anticipated Issues

5.1.1 East Mall Construction

East Mall is a collector road which services over 7000 veh/day and numerous pedestrians, cyclists, and buses during the pre-Covid school years. To minimize traffic disruptions, a phased construction process which maintains two way traffic at all times is expected to be feasible. The East Mall roadway design can be split into three sub-phases (see **Figure 5.1**):

- Phase A1 - W16th Avenue to Stadium Road
- Phase A2 - Stadium Road to Eagles Drive
- Phase A3 - Eagles Drive to Thunderbird Boulevard

To maintain continuous two-way traffic, each sub-phase can be further split into two subphases for west side construction and east side construction. As shown in **Figure 5.2**, parking and bike lanes can be temporarily converted to through lanes and be demarcated through tubular markers. Upon the completion of construction on one side, the opposite side may be constructed, with two-way traffic being diverted to the finished side. Additional construction issues as well as mitigation measures are summarized in **Table 5.1**.

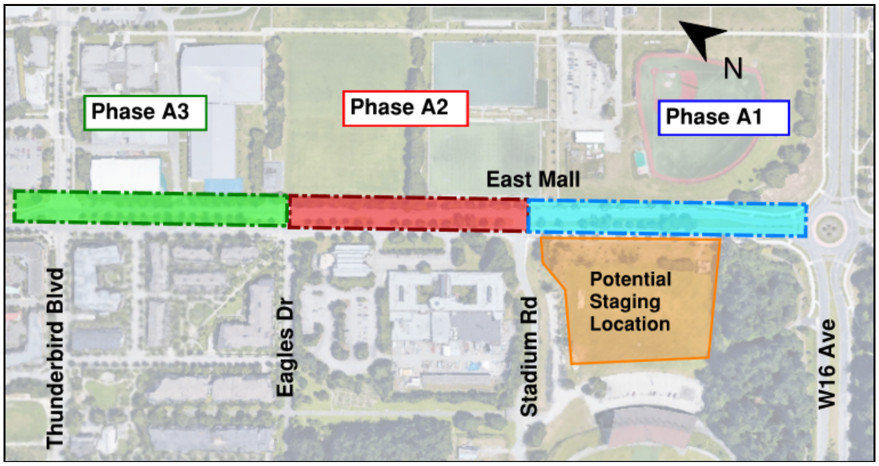


Figure 5.1: East Mall Phasing

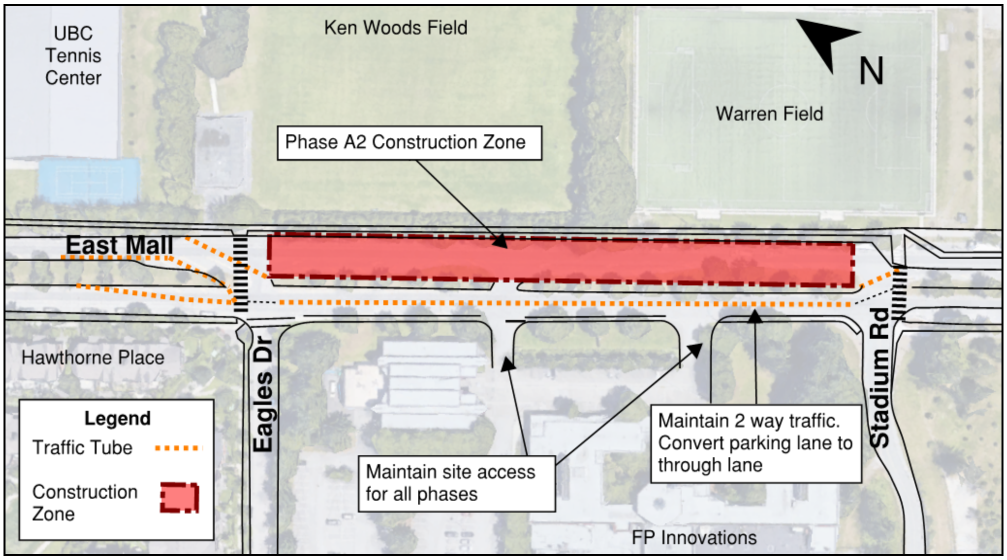


Figure 5.2: Sample SIte Layout - Phase A.2.2 East Side Construction

Table 5.1: East Mall Construction Issues and Mitigation Issues

Issues	Mitigation Measures
Full and Partial Road Closures	● No full road closures expected to be necessary along East Mall ● If the contractor chooses a staging option that requires full road closures, it should be done between May and August 2021 (UBC's online summer term) to minimize traffic disruptions. Appropriate detour routes to be identified by contractor.
Maintaining 2-Way Traffic Operations	● 2 way traffic can be maintained by temporarily converting existing parking and bike lanes to vehicle lanes with markers ● Some temporary curb changes required in Phase A.1
Business, Institutional, Residential Accesses (Phase A.2, A.3)	● Traffic control person to facilitate site access when construction conflicts with accesses ● Some temporary curb changes required in Phase A.1 ● Public information plan to account for stakeholders
Trench Excavations for Installation of pipes	● OHS regulations to be followed for trench excavation and shoring
Pipe and Soil Uncertainties	● Borehole excavation prior to construction to verify utilities and soil structure
Staging Requirements	● Sufficient ROW for on-road staging while maintaining traffic ● Storage available south of Stadium Road (see **Figure 5.1**)
Parking Closure	● Parking expected to be sufficient even with stall closures
Bike Lane Closure	● Traffic control plan to account for cyclist rerouting and signage

5.1.2 Pedestrian Walkway Construction

The covered walkway is to be constructed along the north side of Agronomy Road between East Mall and Health Science Lane. Key construction considerations are discussed in **Table 5.2** and proposed walkway staging is shown in **Figure 5.3**.

Table 5.2: Walkway Construction Issues and Mitigation Issues

Issues	Mitigation Measures
Construction interference with pedestrian, traffic, and building operations	• Construction recommended from May to August 2021 during UBC online summer term to minimize distributions. • Public information and traffic control plan
Sidewalk Closures and Pedestrian Safety	• The construction zone along Agronomy Road should be closed and fenced off from pedestrians
Lane Closures	• Single lane alternating traffic may be necessary along Agronomy Road using traffic control persons
Gerald McGavin and Donald Rix buildings awning removal and entrance closure	• Early notification and discussion with building managers • Early building permitting and approval • Information plan for alternative building access
Material deliver, staging and storage	• Proposed staging yard in parking lot by Technology Enterprise Building (See **Figure 5.3**) • Early notification and discussion with the building manager and arrangements for alternative parking and access locations.
Custom fabricated components	• Early discussion with fabricators on feasibility, timeline, and delivery (See **Section 4.6** for specific components to be considered)

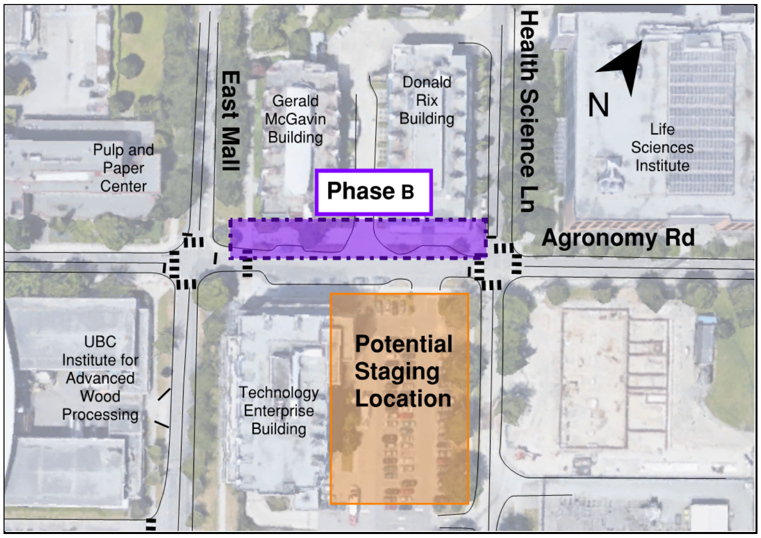


Figure 5.3: Phase B - Covered Walkway Staging

5.1.3 Traffic Management Plan

The contractor is to develop a traffic management plan for the East Mall construction and walkway construction along Agronomy Road per the BC MoTI's *Traffic Manual for Work on Roadways* 2020. The plan is to include a traffic control plan, incident management plan, public information plan, and implementation plan which addresses all issues mentioned in **Section 5.1**. The final phasing and construction sequence is to be verified by the contractor.

5.2 Cost Estimate and Quantity Take-Off

5.2.1 Capital Costs

A Class A cost estimate was developed for the detailed design and serves as an approximate expected bid cost. The project is expected to cost $3,578,000 in 2021 CAD and is broken down in **Table 5.3** and is shown in greater detail in **Appendix F**. Quantities used in the cost-estimate were estimated from the final design drawings and are shown in **Appendix F**. The cost estimate covers construction capital costs following bid acceptance up until construction completion. This value includes an additional 10% contingency cost to represent unaccounted for items and variations in bid prices as well as a 8% fee for construction management. An additional 5% of costs was added for bonding and insurance costs. The cost estimate was based on historical item bid costs from sources including:

- Alberta Transportation Department Unit Prices, 2016
- BC MoTI Construction and Rehabilitation Cost Guide - November 2013
- RS Means
- UNC Highway Safety Research Center - Costs for Pedestrian and Bicyclist Infrastructure Improvements (Bushell et al, 2013)

- Cost Analysis of Bicycle Facilities: Cases from cities in the Portland, OR region (Weigand et al, 2013)

All costs were scaled to 2021 CAD using the *BC Highway Construction Cost Indexes* which are indexes developed by the BC Ministry of Transportation to adjust historical bid costs to the current year. Additionally, adjustments were made for sources outside of BC to Vancouver costs by comparing local taxes and currency values.

Table 5.3: Cost Estimate

Item	Cost (2021 CAD)
Site Clearing	$115,000
Roadwork	$1,142,000
Bike Lane Along Corridor + SIdewalk Re-construction (~20% of Corridor)	$484,000
Traffic Installations (Road Markings, Signage, Crossings)	$89,000
Walkway (Agronomy Road)	$371,000
Stormwater (GSI, Utilities, Landscaping)	$665,000
Management Fee + Permitting (8% + 0.5%)	$244,000
Bonding and Insurance (5%)	$143,000
Contingency (10%)	$325,000
Total	**$3,578,000**

A variety of factors may affect the actual bid price. Major assumptions in the cost estimate as well as the effects of potential scope of work changes are identified in **Table 5.4**.

Table 5.4: Potential Factors Affecting Final Cost

Factor	Discussion
Asphalt Resurfacing	● The top 75mm asphalt layer replacement has been assumed for East Mall from W16 Ave to Thunderbird Blvd ● Should the client decide not to replace the asphalt from Stadium Road to Thunderbird Blvd, up to $170,000 may be saved
Road Subgrade Installation	● Asphalt resurfacing without changes to existing subgrades assumed (except the new road area from W16th Ave to Stadium Rd) ● Should major subgrade concerns be discovered in testing, up to an additional $530,000 may be required

Stadium Neighbourhood	● The previously proposed road upgrades in preparation for the Stadium Neighbourhood Developments along East Mall from W16 Ave to Stadium Road have been included in the cost estimate.
Engineering	● The majority of engineering required has been assumed to be complete and was not directly considered. Additional engineering costs are only covered by the contingency and management fee.
Traffic Management	● Traffic management was assumed to be included in the historical bid costs in each item and was not considered separately. Specific measures (e.g. consultant fees for temporary timing plans, temporary curb removals, temporary road installations,etc), were not explicitly accounted for and are only captured in the contingency.

5.2.2 Life Cycle Costs and Present Worth

Operation and maintenance (O&M) costs for the roadway, stormwater, and walkway project annually as well as over 50-year life cycle were assessed and are shown in **Table 5.5**. There is an expected annual cost of approximately $46,100 and an overall project present worth of $6,186,000 2021 CAD over a 50-year life cycle. Only cost items shown in **Table 5.5** were considered, meaning costs that were not included were not considered in the estimate. It was found that most cost items (road and bike lane maintenance) are existing costs which also apply to a “Do-Nothing” option. Costs that are unique to the proposed design designated “New” in **Table 5.5** and costs that overlap with existing costs labelled “Existing”. Factoring out existing O&M costs, the project is only expected to add $8,500 annually or $425,000 over a 50-year life cycle. The additional cost is primarily from the O&M costs of the new crosswalk RRFBs, Rain Garden, and Walkway. For further discussion on service life and maintenance, see **Section 5.4**.

Table 5.5: Life Cycle Costs

Item	Frequency	New or Existing	Cost
East Mall			
Road Rehabilitation	37 Years	Existing	$303,000
Road O&M	Annually	Existing	$22,000
Bike Lane O&M	Annually	Existing	$1,900
Sidewalk O&M	Annually	Existing	$2,300
RRFB O&M	Annually	**New**	$600
Traffic Signal O&M	Annually	Existing	$5,700
Lighting O&M	Annually	Existing	$5,700
Rain Garden O&M	Annually	**New**	$1,400
Sub-Total (Annual Costs Only)			**$39,600**
Agronomy Road Covered Walkway			
Walkway Lighting O&M	Annually	**New**	$1,600.00
Walkway Maintenance O&M	Annually	**New**	$4,900.00
Sub-Total			**$6,500.00**
Overall			
Annual Total			$46,100
50-Year Cost (Present Worth)			$2,608,000
Capital Costs (From **Table 5.3**)			$3,578,000
Total Present Worth (50-Year Cost + Capital Cost)			**$6,186,000**

5.3 Schedule

The schedule was developed by using a critical path analysis (CPA) algorithm that used a list of 40 tasks, their sequencings, and expected durations to determine the earliest a task may start and finish, thereby allowing us to calculate float times for tasks that are not on the critical path. A monte carlo simulation was superimposed atop the CPA algorithm to account for variation in productivity rates under the assumption that task durations follow triangular distributions. The final stage of the project is expected to begin May 2nd 2021 and last until February 1st 2021 with an expected duration of 186 work days excluding weekends and holidays. The high level schedule may be seen in **Figure 5.4** in which each repeating “A” subphase consists of roadway demolitions, utility relocations, stormwater system installs, pavement overlays, and curb repairs. Phase B refers to the walkway and consists of demolitions, footing installation, and installation of prefabricated components. The detailed schedule breakdown, critical path analysis, and expected task completions may be seen in **Appendix G.**

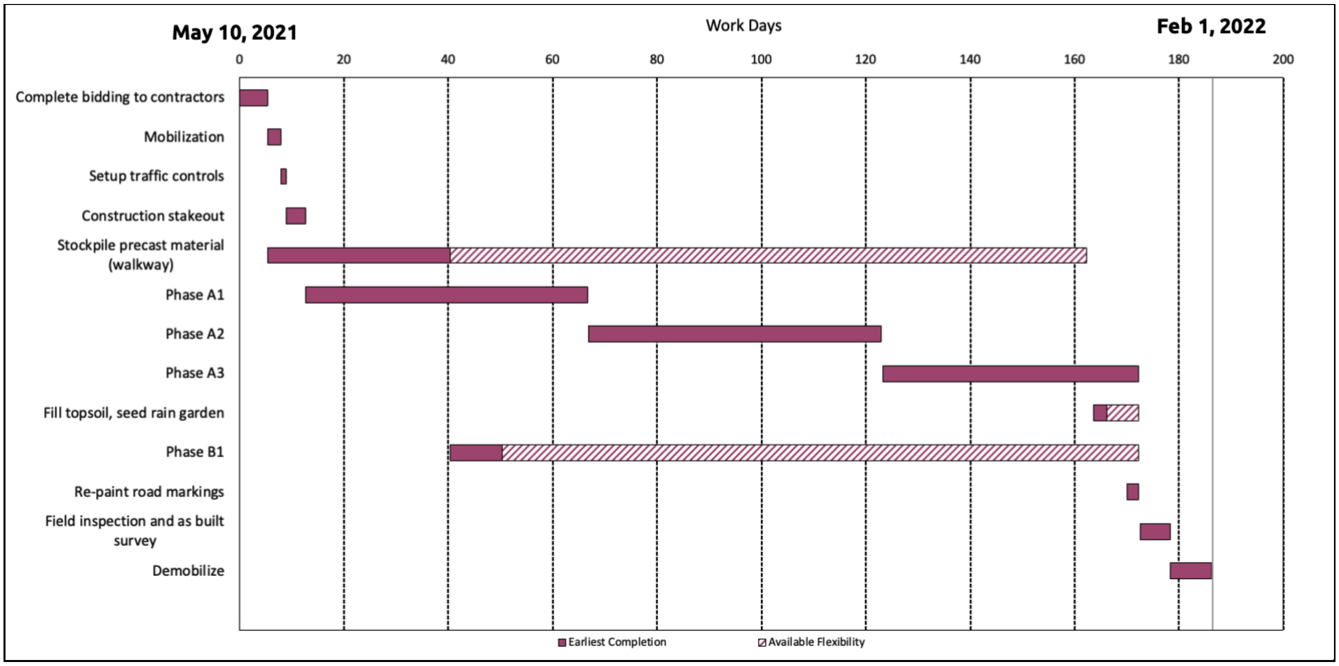


Figure 5.4: Schedule

5.4 Service-life and Maintenance Plan

5.4.1 Roadway

The service life and maintenance plan for the roadway were conducted in two steps: (1) determining the optimal asphalt thickness, and maintenance trigger value for the lowest global warming potential and costs over a 50 year period, and (2) back calculating the years to first service based on the optimal maintenance trigger value determined in step 1.

Step 1: In order to determine the optimal maintenance trigger value, the ideal asphalt thickness was first discovered, since the thickness of the asphalt affects not only the deterioration rate, but the use phase and end of life global warming potential as well. The software package "Pave-Save" (Shani et al. 2021) was used with a set of 26 general inputs and 7 inputs for each pavement design being considered to conduct a probabilistic LCA in order to determine the efficient frontiers for various designs as a function of IRI trigger values for maintenance (**Figure 5.5**). The model quantified the global warming potential through the embodied impacts, pavement-vehicle interactions, albedo, and work-zone congestion and cost impacts through the consideration of current construction and rehabilitation costs, a price index, and salvage values. A full list of the inputs used for the LCA model may be found in **Appendix H.**

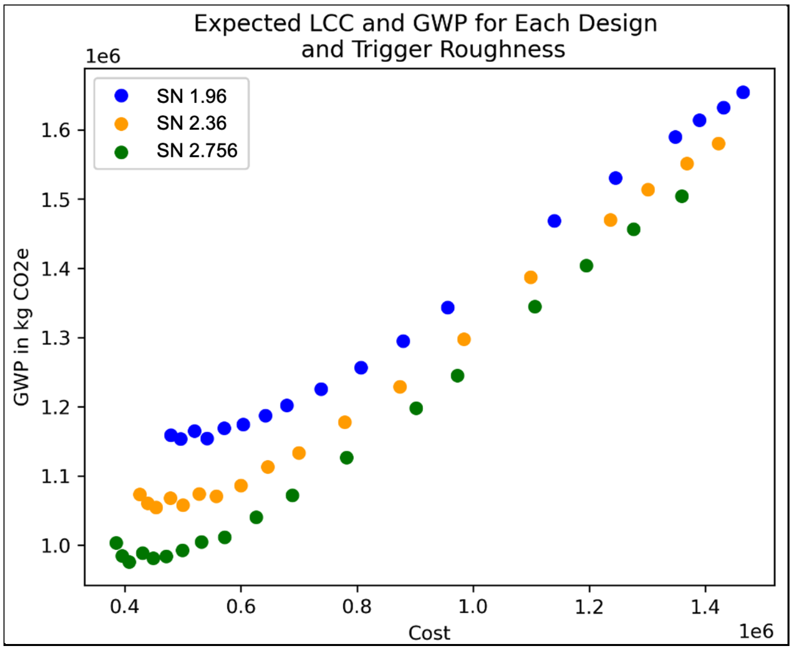


Figure 5.5: Design Pareto Frontiers

We found that a thickness of 2.756in (green dots) gave us the lowest GWP and Cost at every IRI trigger value. Since costs decline monotonically the less often maintenance is conducted, costs are minimized by minimizing maintenance frequency. However, as maintenance is carried out less often, the increase from road roughness leads to an increase in GHG due to the increasing use phase impacts (**Figure 5.6**). Maintaining too often on the other hand, leads to large emissions from construction, in addition to higher costs. Therefore, the minimum GWP was attained at an IRI trigger value between 3.16-3.56m/km. Given that this is a local, low volume road, the results are intuitive, as the main driver of GWP is from construction rather than the use phase. Therefore maintaining every time the road hits an IRI value of between 3.16-3.56m/km will result in the lowest global warming potential. However, should the client choose, they can postpone maintenance to lower the life cycle costs, but potentially at the expense of increasing GWP.

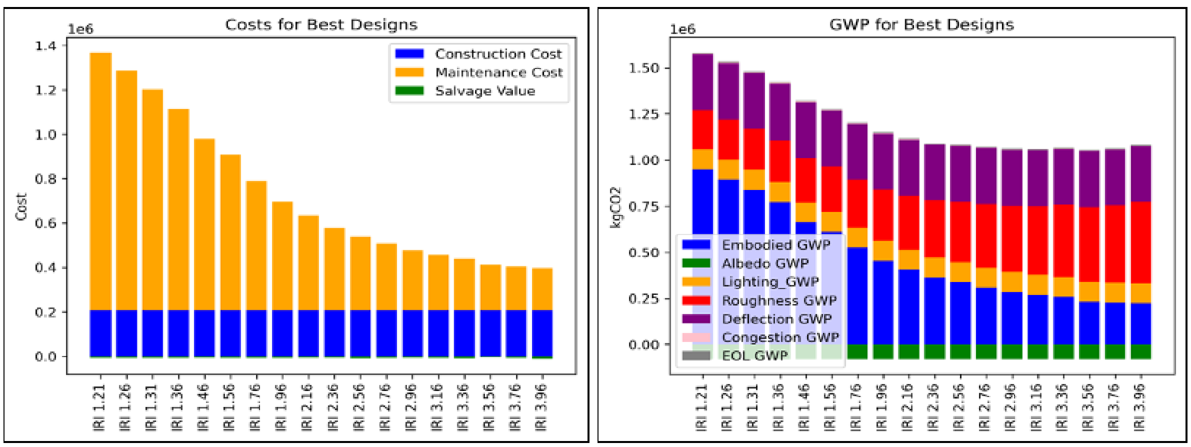


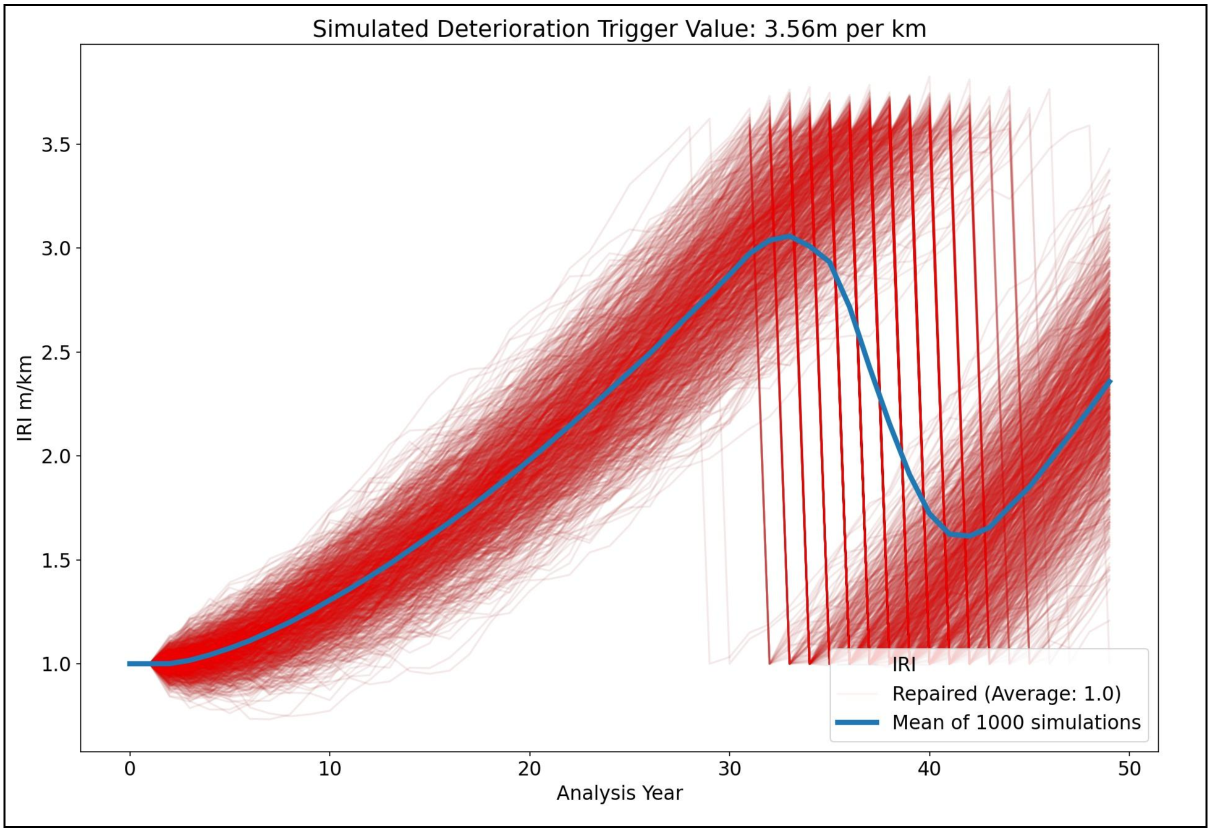
Figure 5.6: Cost and GWP for Best Design

Step 2: The maintenance schedule was calculated based on the assumption that an IRI value of 3.16, 3.36, or 3.56 m/km is chosen as the maintenance trigger. The time to first maintenance is estimated by computing the cumulative density function from the output of 1000 simulations of pavement degradation according to **Equation 1**. The equation describes deterioration as a function of pavement age, aadtt, and structural number at each time step for hot mix asphalts. The model is assumed to follow a difference stationary process a.k.a random walk with drift according to the following specification (Swei et al. 2018) :

$$\Delta D_{i,t} = \alpha Age^{\beta_1}_{i,t-1} AADTT^{\beta_2}_{i,t-1} SN^{\beta_3}_{i,t-1} + \varepsilon_{i,t}$$ **[Equation 1]**

where $\alpha = 0.08$, $\beta_1 = ln(Age)$, $\beta_2 = ln(AADTT)$, $\beta_3 = -2.5$, $\varepsilon \sim N(0, 2.59 \times 10^{-3})$

An output of the deterioration processes with an IRI Trigger Value of 3.56m/km is presented in **Figure 5.7** below using the Age, AADTT, SN, and AADTT growth rates for our East Mall design. A Red Line indicates a simulation which underwent at least one repair, and gray lines indicated no repairs. In **Figure 5.7** each simulation required a repair, indicated by the sharp drop in IRI, and therefore every line is red. Figures for comparisons to lower and higher trigger values are presented in **Appendix H**.



**Equation 1. is the same model that underlies Pave-Save's deterioration module, however it is run independently from the LCA software in order to derive more granular insights into the service life of this road.*

Figure 5.7: 1000 Deterioration Simulations for Selected Design (SN 2.76)

The time to first maintenance for a range of trigger values is then back calculated to produce **Figure 5.8 and Table 5.6**.

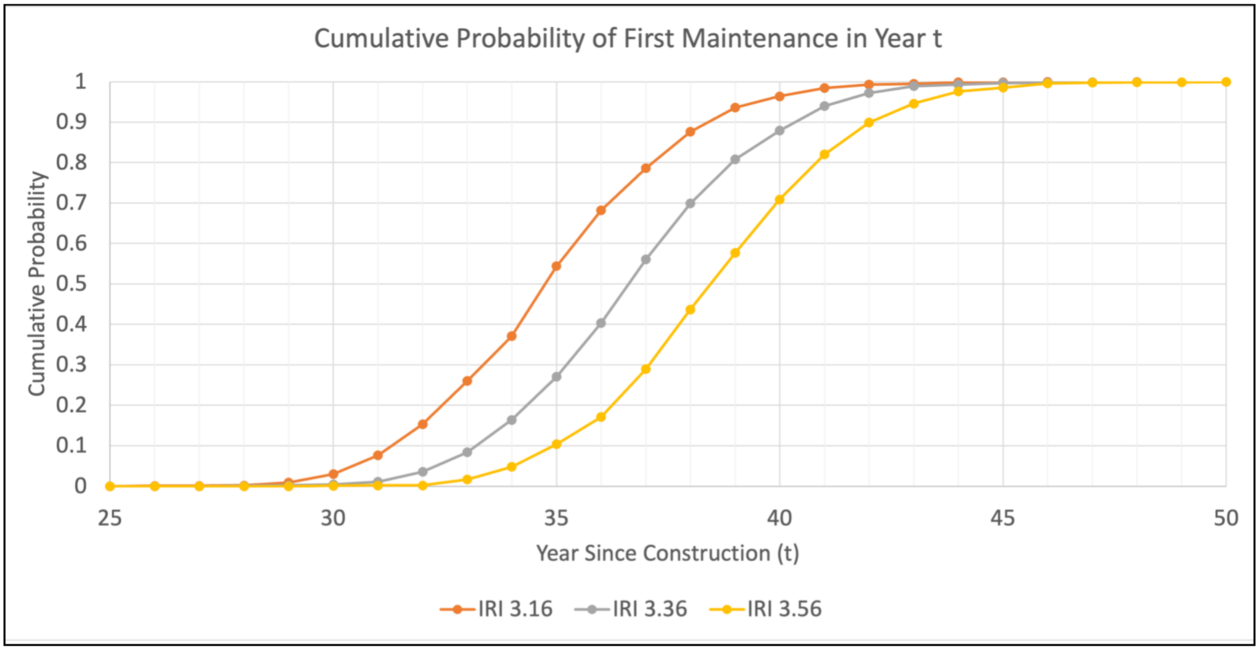


Figure 5.8: Cumulative Probability of First Maintenance

Table 5.6: Predicted Maintenance Schedule

IRI Trigger Value(m/km)	Years to First Maintenance*	Average Number of Maintenance over 50 Years
3.16	35	1.06
3.36	37	1.01
3.56	39	1.00

**Rounded to nearest year*

Our results suggest that with any of the three IRI trigger values, only one maintenance will be needed throughout the 50 year lifetime of the roadway. The choice to maintain at 3.16, 3.36, or 3.56 trade off costs and GWP, but all three remain on the Pareto efficient frontier. Therefore it is at the operator's discretion to select a maintenance value according to GWP or cost preferences. By comparison, our estimates of time to first maintenance align well with

Infrastructure Canada estimates of average expected life of new publicly owned roads suggests the expected useful life of this road will be approximately 34 years (Statistics Canada. (n.d.))

5.4.2 Rain Garden

The rain garden is designed to be low maintenance by using a combination of resilient, low or no deciduous trees to prevent leaves from clogging the drainage mechanisms. The rain gardens exact maintenance plan will be provided by the manufacturer of the rain garden bed. Below is a table of typical maintenance activities and frequencies collected from three manufacturers specifications. **Table 5.7** contains our tabulation of common maintenance schedules according to guidelines published by two engineering consultancies (Kerr Wood Leidal Consulting Engineers. (n.d.), Blue Water Baltimore (n.d)).

Table 5.7: Rain Garden Typical Maintenance

Maintenance Activity	Frequency
Water to promote plants during dry periods Replace eroded vegetation	As needed
Prune and weed swale Remove trash and debris	Monthly
Remove accumulated sediment Replace sediment and mulch that has been eroded as needed	Annually
Remove and replace mulch Test planting bed for pH	2-3 Years

5.4.3 Walkway

The walkway, being built to design snow and rain loads for British Columbia with corrosion resistant material does not require a specific maintenance plan. Rather, the system should be inspected by building operations according to the shorter of either annually or along with building structural inspections.

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Summary

The East Mall redesign project is ready with Issue-For-Construction (IFC) drawings complete for the roadway, stormwater, and walkway designs aspects of the project including:

- Roadway construction consists of new elevated bike lanes, pavement markings, RRFB installations, curb extensions, and road resurfacing. Road narrowing is proposed along East Mall from W16-Avenue to Stadium Road to require new sub-base and asphalt.
- Proposed stormwater retention system includes 1789 m^2 of rain garden in the East Mall median and proposed green curb extensions and 9555 m^2 of absorbent landscape area.
- 3.5 m tall covered pedestrian walkway designed along Agronomy Road between East Mall and Health Science Mall with 2.5 m canopy width.

The project is expected to cost $3,578,000 CAD in 2021 capital costs and a project present worth of $6,186,000 2021 CAD for a 50-year service life. Construction is expected to begin on May 2nd, 2021 and last until February 1st 2022 with an expected duration of 186 work days.

6.2 Recommendations and Next Steps

The following recommendations have been made for project implementation:

- UBC SEEDS to tender project and awarding bid to suitable contractor
- Contractor to obtain / develop relevant permits, approvals, and traffic management plan
- For the rain garden construction, additional site soil conditions may be required and should be obtained by the contractor (E.g. through borehole drilling)
- Early consultation with fabricators and suppliers as well as relevant building managers is recommended for the walkway construction along Agronomy Road

7.0 REFERENCES

Blue Water Baltimore. (n.d.). *Routine Maintenance Activities for Rain Gardens*. Retrieved May 4, 2021 from https://bluewaterbalto.wpengine.com//wp-content/uploads/BWBRainGardenRoutineMaintenance.pdf

Bushell, Max A., Bryan W. Poole, Charles V. Zegeer, and Daniel A. Rodriguez. “Costs for Pedestrian and Bicyclist Infrastructure Improvements.” *University of North Carolina Highway Safety Research Center, University of North Carolina, Chapel Hill* 45 (2013)

Johnson, D. L., & Miller, A. C. (1997). A spatially distributed hydrologic model utilizing raster data structures. *Computers & Geosciences*, *23*(3), 267–272. https://doi.org/10.1016/S0098-3004(96)00084-2

Ministry of Transportation and Infrastructure. “Construction and Rehabilitation Cost Guide.” Ministry of Transportation and Infrastructure, November 2013. https://www2.gov.bc.ca/assets/gov/driving-and-transportation/transportation-infrastructure/contracting-with-the-province/documents/costguide-2013.pdf.

Rain Gardens: Design, Implementation, and Maintenance Considerations. (n.d.). Kerr Wood Leidal Consulting Engineers. Retrieved March 7, 2021, from https://www.kwl.ca/wp-content/uploads/2019/07/8-1a.pdf

Shani, P., Chau, S., & Swei, O. (2021). The economic cost (and savings) to reduce the global warming impact of transport infrastructure: A study of U.S. roadways. *Resources, Conservation & Recycling*, *In Press*.

Statistics Canada. (n.d.). *Table 34-10-0072-01 Average expected useful life of new publicly owned road assets, Infrastructure Canada*. Retrieved April 10, 2021, from https://doi.org/10.25318/3410007201-eng

Swei, O., Gregory, J., & Kirchain, R. (2018). Does pavement degradation follow a random walk with drift? Evidence from variance ratio tests for pavement roughness. *Journal of Infrastructure Systems*, *24*(4), 04018027. https://doi.org/10.1061/(ASCE)IS.1943-555X.0000450

University of British Columbia. Campus and Community Planning. (2015). *[University of British Columbia Point Grey Campus Digital Elevation Model (DEM), 2015]* (University of British Columbia. Campus and Community Planning, Ed.; V1 ed.). Abacus Data Network. https://hdl.handle.net/11272.1/AB2/2FKBA6

Weigand, L., McNeil, N., Dill, J. (2013). *Cost Analysis of Bicycle Facilities: Cases from cities in the Portland, OR region*. Retrieved April 12, 2021, from Dill_Bicycle_Facility_Cost_June2013.pdf (activelivingresearch.org)

Appendix A - Roadway Technical Design Criteria Table

Appendix A - Roadway Design Technical Criteria Table

Design Element	Present Conditions	MoTI / TAC Guidelines Criteria	Proposed Criteria	Comments / Notes
1.0 - Roadway				
Functional Classification	Minor	Minor	Minor	
Design Classification	UCD	UCD	UCD	UCD = Urban-Collector-Divided.
Posted Speed	50 km/h	50 km/h	50 km/h	
Design Speed	50 km/h	50 km/h	50 km/h	
Basic # of Lanes	1 per Direction	1 per Direction	1 per Direction	Not including left-turn bays or transition lanes.
Minimum Horizontal Radius	100 m	100 m	100 m	For urban designs.
Minimum K Factor (Sag V.C.)	Unknown	5-6	6	For urban designs / K Factors to provide Stopping Sight Distance.
Minimum K Factor (Crest V.C.)	Unknown	7	7	K Factors to provide Stopping Sight Distance.
Maximum Grade	Unknown	6%	6%	Based on rolling topography.
Maximum Superlevation	Unknown	6%	2%	Typical maximum superelevation is 4%, but 6% is allowed.
Minimum Stopping Sight Distance	Unknown	65 m	65 m	For a design speed of 50 km/h
Minimum Intersection Sight Distance	Unknown	RFS/LFS: 95 m/105 m	RFS/LFS: 95 m/105 m	RFS = Right-turn From Stop / LFS = Left-turn From Stop.
Minimum Sight-Line Setback Distance	Unknown	4.4 m	4.4 m	Point from the major road edge to the driver's eye-line.
Minimum Corner / Curb Radius	Varies	5-10 m	Existing	Circular curve used. Min.value desired to ensure sufficient turning radius, reduced turning speeds, and provide pedestrian crossing comfort.
Minimum Curb Extension Radius	5 m	3-5 m	5 m	Ensure street cleaning vehicles can maneuver properly along the edges of the curb.
Minimum Curb Extension Offset Distance	2.2 m	1.5-2.2 m	2.5 m	Distance may be extended to accomodate available parking space.
Through Lane Width	3.5 m	3.0-3.7 m	3.3-3.5 m	Minimum through lane width = 3.3 m for roads servicing bus / larger trucks.
Right-Turn Lane Width	3.5-4.0 m	3.0-3.7 m	3.3-3.5 m	Can be reduced by 0.2-0.25 m from the through lane dim. / Upper limit = 4.0 m.
Left-Turn Lane Width	3.2-3.5 m	3.0-3.7 m	3.6 m	Can be reduced by 0.2-0.25 m from the through lane dim. / Upper limit = 4.0 m.
Parking Lane Width	2.4 m	2.4 m	2.5 m	Can be increased to accomodate for larger vehicles.
Median Width	9 m	1-35 m	9 m	
Concrete Buffer Width	N/A	0.3-1.0 m	0.6-1 m	Minimum concrete buffer width = 0.6 m if parking lane adjacent to bike lane to accomodate for door openings.
Annual Average Daily Traffic (AADT)	6231	N/A	6550	
Level of Service (to Year 2040)	C or better	C or better	C or better	Based on Intersection LOS from Synchro assuming 0.5% growth rate to year 2030.
Design Vehicle	WB-20	WB-20	WB-20	Based on roadway classification and counts.
2.0 - Bike Lane				
2.1 - General				
Design Speed	Unknown	20-30 km/h	30 km/h (NB) and 35 km/h (SB)	
Actual Road Grade	2%/-2%	2%/-2%	2%/-2%	
Stopping Sight Distance (SSD)	Unknown	34 m (30 km/h) / 36 m (35 km/h)	34 m (NB) / 36 m (SB)	Depends on speed and grade
Minimum Horizontal Clearance from Obstruction	Unknown	0.2 m	0.2 m	0.2 m to obstruction between 100mm and 650mm high and 0.5 m to obstruction greater than 750 mm high
Minimum Vertical Clearance	Unknown	3.6m	N/A	
Bicycle Bypass at Transit Stop	Unknown	2.5 m min. psg loading zone	2.5 m	
Mininum Raised Median Width	Unknown	0.6 m	0.6 - 0.9 m	Parking stops should be spaced with longitudinal gaps of 2.0 m or less
2.2 - Horizontal Alignment				
Basic # of Lanes	1	1	1 per direction	
Minimum Horizontal Radius	Unknown	24 m	24 m	A function of bicycle speed, superelevation, and coeficient of friction
Lateral Clearance on Vertical Curve	Unknown	5.9 m / 6.6 m	5.9 m / 6.6 m	Depends on stopping sight distance (34m / 36m) and horizontal radius (24m). Linear interpolation applied to Table 5.5.3 values.
Minimum Bike Lane Width	1.5 m	1.8 m	2.2 m	Desired width = 2.0 m for uni-directional bike lanes with <150 bikes/hr - available counts at Thunderbird Blvd shows <40 bikes/hr
2.3 - Vertical Alignment				
Recommended Minimum Longitudinal Gradient (Grade)	N/A	0.6%	N/A	Not a hard requirement, for drainage only. Can be reduced to 0% if thjere is adequat cross-slope and lateral slope
Minimum Crest Curve Length	Unknown	at least min SSD	34 m / 36 m	
Minimum Sag Curve (K)		2.3 / 3.1	4	Depends on design speed. K = (V^2)/390.
Maximum Superlevation (If Crowned)	%	%	2%	
Cross-slope	N/A	2%-4%	3%	
3.0 - Roadside (Furnishing + Pedestrian Through Zones)				
Minimum Pedestrian Through Zone Width	1.8 m	1.5 m for 2 people and 2.25 m for 3	2.35 m	
Minimum Furnishing Zone Width	2 m	1.5 m	1.75 m	1.2 m is the absolute minimum for small/mid trees and 1.5 mn is required for larger trees
4.0 - Pavement				
4.1 - Vehicle and Parking Lane				
Minimum Pavement Thickness	Unknown	50mm AC Surface Course 90mm AC Lower Course 150mm Granular Base 300mm Granular Subbase	Not Used	For Higher Zoned Collector / Residential Streets
		50 - 75 mm AP 225 mm of 25mm CBC 300 mm min. of SGSB on Fine Grained Soil	75 mm AP 225 mm of 25mm CBC 300 mm min. of SGSB on Fine Grained Soil	Typical Pavement Structure Type C: Low Volume & Subdivision Roads; 20 yr Design ESAL < 100,000
Standard Asphaltic Concrete Mixes and Corresponding Asphalt Cement (Surface Course)	Unknown	SP 12.5; PG 64-28	SP 12.5; PG 64-28	Surface course mic for resurfacing and reconstruction work on local and collector roads; traffic category B (0.3-3 millions ESAL)
		SP 19.0; PG 58-28	Not Used	Binder course mix for all non-roadway areas including interim repair and utility cut repair work
Hot Mix Asphalt (HMA) Layer Thickness	Unknown	40-50 mm	Mnimum 40 mm	Surface Course Mix typical compact layer thickness for Superpave 12.5 Type HMA; lower value is for finer graded mixes and the upper minimum value is fopr coarses graded mixes
4.2 - Protected Bike Lane				
Minimum Pavement Thickness	Unknown	50mm MMCD Upper Course #2/9.5mm 150mm Granular Base	50mm MMCD Upper Course #2/9.5mm 150mm Granular Base	
4.3 - Sidewalk				
Minimum Pavement Thickness	Unknown	100 mm Concrete	100 mm Concrete	
5.0 - Intersection Design				
5.1 - Intersection Horizontal Alignment				
Intersecting Angle	Unknown	70-110 degrees	70-110 degrees	
Tangent Length	Unknown	20 m	20 m	
Maximum Deflection Angle across Intersection	Unknown	3° to 5°	3° to 5°	
5.2 - Intersection Vertical Alignment				
Minimum Cross Slope of Both Roadways	Unknown	0.5 %	0.5 %	
Change in Rate of Superelvation	Unknown	0.020 /m/10m length	0.020 /m/10m length	For a design speed of 50 km/h
Maximum grade change in intersection	Unknown	3-4%	3-4%	
Minimum grade along curb returns	Unknown	0.5 %	0.5 %	
Grade at vehicle stops	Unknown	0.5 % - 3%	0.5 % - 3%	
5.3 - Tapers and Auxillary Lanes				
RT Taper Ratio (w/o Auxilliary Lane)	Unknown	15:1	15:1	For a design speed of 50 km/h
RT Taper Length (w/o Auxilliary Lane)	Unknown	53 m	53 m	For a design speed of 50 km/h and lane width = 3.5m
RT Taper Horizontal Radius((w/o Auxilliary Lane)	Unknown	500 m	500 m	For a design speed of 50 km/h
RT Taper Ratio Range (w/ Auxilliary Lane)	Unknown	11:1 - 17:1	11:1 - 17:1	For a design speed of 50 km/h
RT Parallel Lane Length (w/ Auxilliary Lane)	Unknown	35-75 m	35-75 m	For a design speed of 50 km/h
RT Taper Reverse Curve Radius(w/ Auxilliary Lane)	Unknown	90-150 m	90-150 m	For a design speed of 50 km/h
LT Lanes Minimum Storage Length	Unknown	15 m	15 m	
LT Lane Transition Horizontal Radius	Unknown	500 m	500 m	For a design speed of 50 km/h
LT Taper Ratio Range	Unknown	8:1 - 30:1	8:1 - 30:1	For a design speed of 50 km/h
LT Bay Taper Ratio (Transition into Median)	Unknown	10:1	10:1	For a design speed of 50 km/h
LT Bay Taper Radius for Symmetrical Reverse Curve	Unknown	90-150 m	90-150 m	For a design speed of 50 km/h

Appendix B - Detailed Design Drawings

THE UNIVERSITY OF BRITISH COLUMBIA

UWU

PROJECT NO. 00000-00001

EAST MALL REDESIGN (W16TH AVE TO AGRONOMY ROAD)

UBCV SOUTH CAMPUS

ISSUED FOR CONSTRUCTION APRIL 14, 2021

(FOR CIVL 446 EDUCATIONAL PURPOSES ONLY)

REV	DATE
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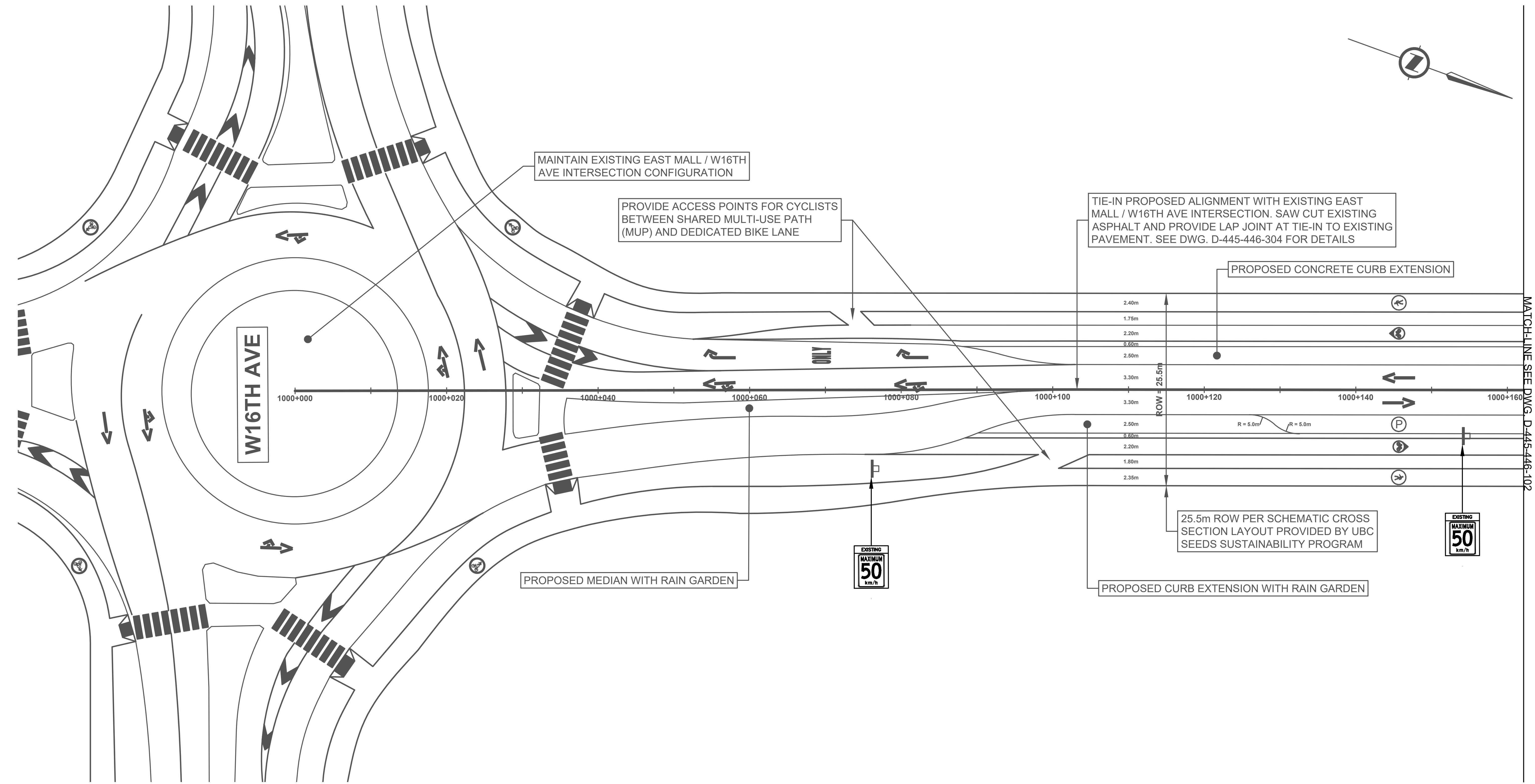
B	APR 14, 2021



NOTES:
1. FOR ROADWAY PROFILE, SEE DWG. D-445-446-201 TO 205 FOR DETAILS.
2. FOR ROADWAY CROSS SECTION, SEE DWG. D-445-446-301 TO 304 FOR DETAILS.
3. FOR GREEN STORM WATER INFRASTRUCTURE (GSI), SEE DWG. D-401 TO 403 FOR DETAILS.
4. FOR PEDESTRIAN COVERED WALKWAY, SEE DWG. D-501 TO 503 FOR DETAILS.
5. FOR STANDARD DETAIL DRAWINGS:
   - 5.1. STREET LIGHTS - SEE SURREY MMCD DWG. SSD-R.E.1 TO R.E.4 (PROPOSED STREET LIGHTS TO BE PLACED ON THE EAST SIDE OF EAST MALL FROM W16TH AVE TO STADIUM ROAD AT 45 m INTERVAL AND 0.5 m FROM THE ABSORBENT LANDSCAPE EDGE NEAREST TO ROADWAY).
   - 5.2. RECTANGULAR FLASHING BEACON - SEE SURREY MMCD DWG. CCSD-14d.
   - 5.3. CURBS - SEE CITY OF VANCOUVER STANDARD DETAIL DWG. C4.1 AND C19.1.
   - 5.4. SIDEWALK LETDOWN - SEE CITY OF VANCOUVER STANDARD DETAIL DWG. R4.1, R4.2, AND R7.1.
   - 5.5. SIGN POSTS + SIGNS - SEE CITY OF VANCOUVER STANDARD DETAIL DWG. R8.1 TO 8.16 AND C19.2 TO 19.3.
   - 5.6. PARKING METER LAYOUT - SEE CITY OF VANCOUVER STANDARD DETAIL DWG. R9.1.

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DATE 2021-04-14

REV	DATE	REVISIONS	SIGNATURE
A	21/03/05	Submission for Design Summary Report	
B	21/04/14	Submission for Final Design Report	

UBC
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SUSTAINABILITY PROGRAM
MUNICIPAL ENGINEERING
SOUTHERN CAMPUS

PLAN
EAST MALL
W16TH AVE TO AGRONOMY RD

SENIOR DESIGNER
DATE 2021-04-14

DESIGNED	C.Q.	DATE	2021-04-14
QUALITY CONTROL	B.Q.	DATE	2021-04-14
QUALITY ASSURANCE	B.Q.	DATE	2021-04-14
DRAWN	C.Q.	DATE	2021-04-14

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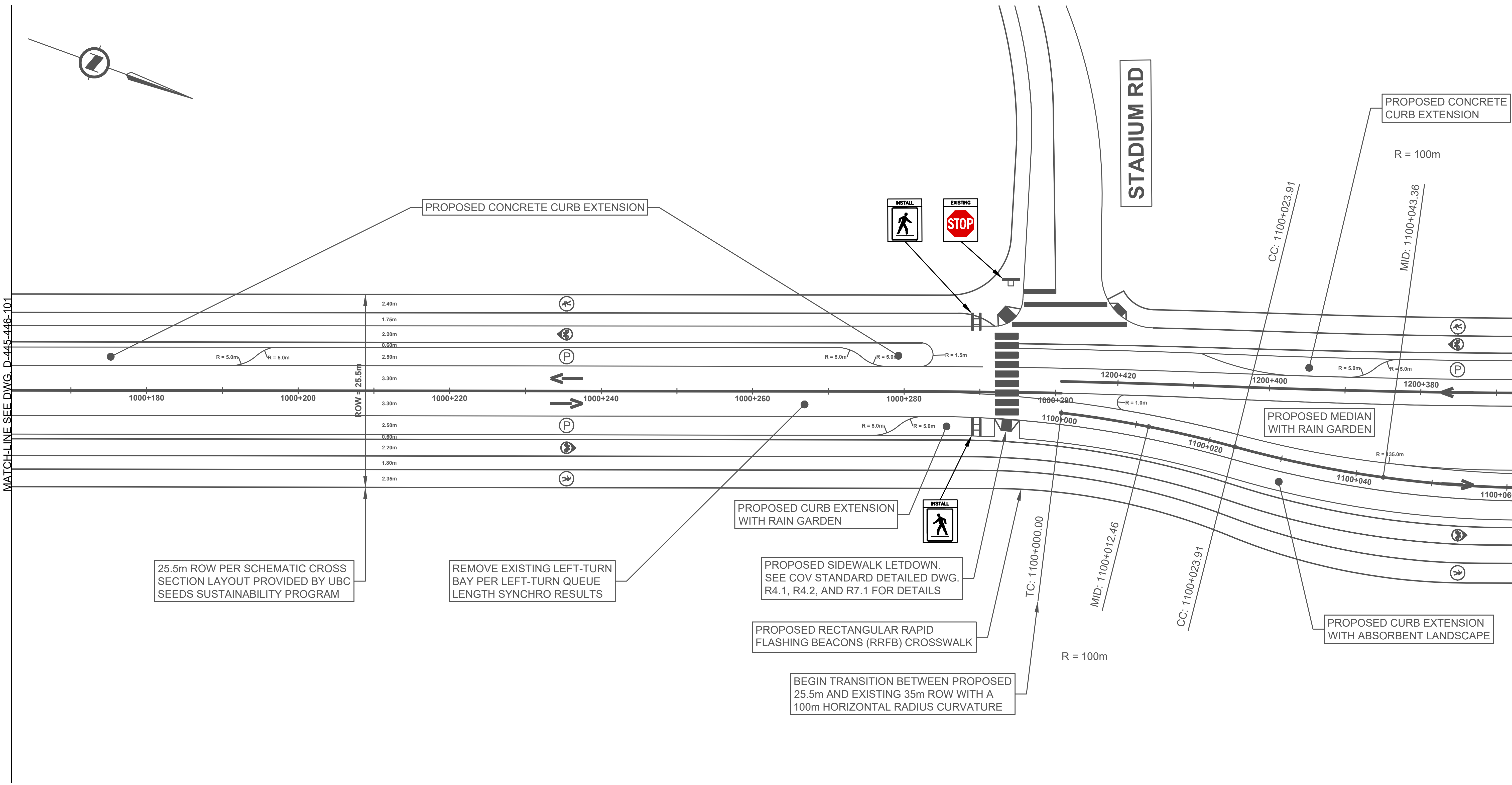

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CAD FILENAME 100PL_CIVL-445-446 - EAST MALL
DATE 2021-04-14

REV	DATE	REVISIONS	SIGNATURE
A	21/03/05	Submission for Design Summary Report	
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PLAN
EAST MALL
W16TH AVE TO AGRONOMY RD

SENIOR DESIGNER
DATE 2021-04-14

DESIGNED C.Q. DATE 2021-04-14
QUALITY CONTROL B.O. DATE 2021-04-14
QUALITY ASSURANCE B.O. DATE 2021-04-14
DRAWN C.Q. DATE 2021-04-14

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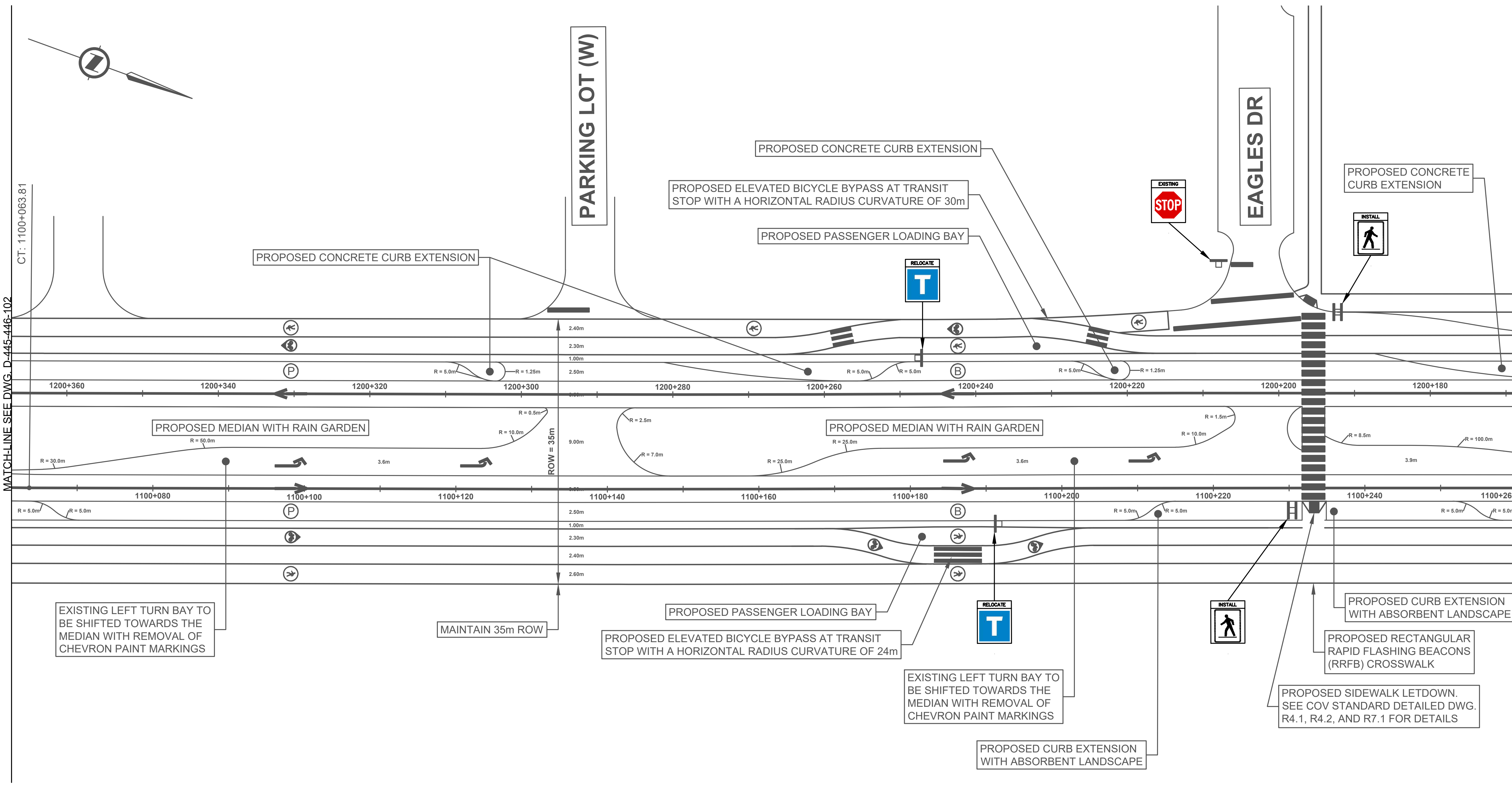

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SCALE 1:500 (0, 5, 25m)

CAD FILENAME: 100PL_CIVL-445-446 - EAST MALL
DATE: 2021-04-14

REV	DATE	REVISIONS	SIGNATURE
A	21/03/05	Submission for Design Summary Report	
B	21/04/14	Submission for Final Design Report	

PLAN
EAST MALL
W16TH AVE TO AGRONOMY RD

DESIGNED	C.Q.	DATE	2021-04-14
QUALITY CONTROL	B.O.	DATE	2021-04-14
QUALITY ASSURANCE	B.O.	DATE	2021-04-14
DRAWN	C.Q.	DATE	2021-04-14

SENIOR DESIGNER
DATE 2021-04-14

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
20-0001	00000-00001	R	D-445-445-103	B

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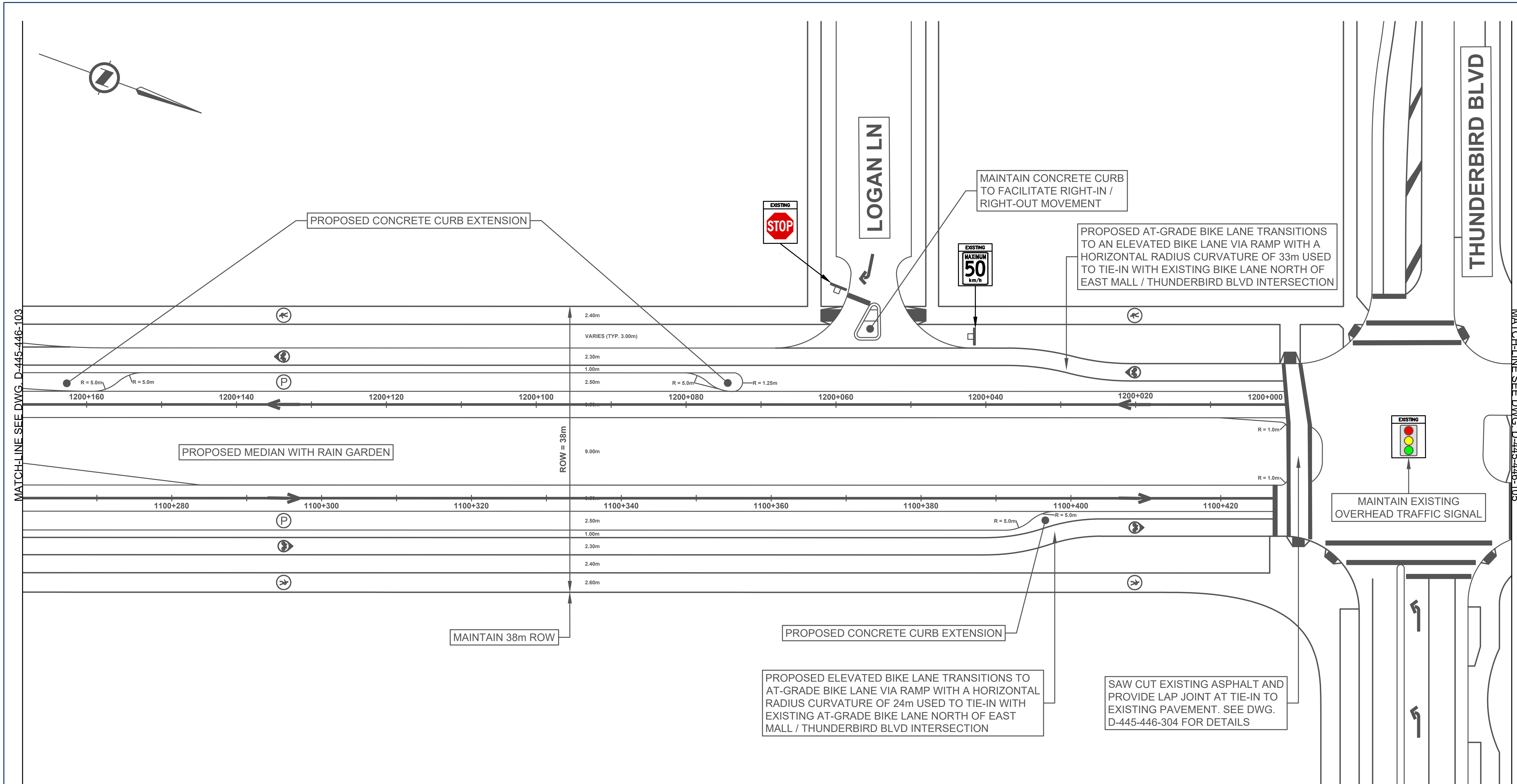

NOTES:

1. FOR ROADWAY PROFILE, SEE DWG. D-445-446-201 TO 205 FOR DETAILS.
2. FOR ROADWAY CROSS SECTION, SEE DWG. D-445-446-301 TO 304 FOR DETAILS.
3. FOR GREEN STORM WATER INFRASTRUCTURE (GSI), SEE DWG. D-401 TO 403 FOR DETAILS.
4. FOR PEDESTRIAN COVERED WALKWAY, SEE DWG. D-501 TO 503 FOR DETAILS.
5. FOR STANDARD DETAIL DRAWINGS:
   - 5.1. STREET LIGHTS - SEE SURREY MMCD DWG. SSD-R.E.1 TO R.E.4 (PROPOSED STREET LIGHTS TO BE PLACED ON THE EAST SIDE OF EAST MALL FROM W16TH AVE TO STADIUM ROAD AT 45 m INTERVAL AND 0.5 m FROM THE ABSORBENT LANDSCAPE EDGE NEAREST TO ROADWAY).
   - 5.2. RECTANGULAR FLASHING BEACON - SEE SURREY MMCD DWG. CCSD-14d.
   - 5.3. CURBS - SEE CITY OF VANCOUVER STANDARD DETAIL DWG. C4.1 AND C19.1.
   - 5.4. SIDEWALK LETDOWN - SEE CITY OF VANCOUVER STANDARD DETAIL DWG. R4.1, R4.2, AND R7.1.
   - 5.5. SIGN POSTS + SIGNS - SEE CITY OF VANCOUVER STANDARD DETAIL DWG. R8.1 TO 8.16 AND C19.2 TO 19.3.
   - 5.6. PARKING METER LAYOUT - SEE CITY OF VANCOUVER STANDARD DETAIL DWG. R9.1.

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SCALE 0 5 1:500 25m

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UBC SEEDS SUSTAINABILITY PROGRAM
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SOUTHERN CAMPUS

PLAN
EAST MALL
W16TH AVE TO AGRONOMY RD

SENIOR DESIGNER
DATE 2021-04-14

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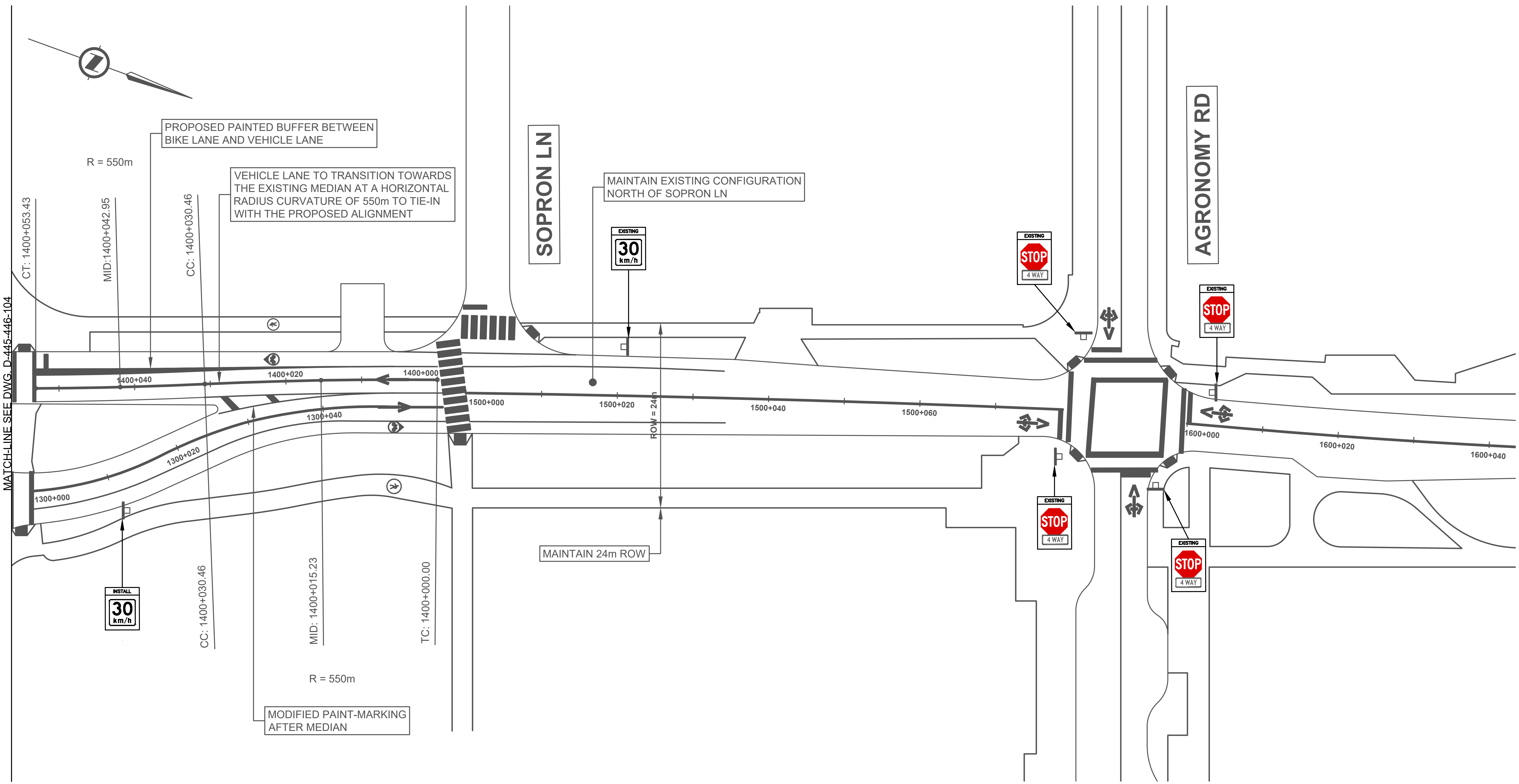
FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
20-0001	00000-00001	R	D-445-445-104	B



NOTES:

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MUNICIPAL ENGINEERING
SOUTHERN CAMPUS

PLAN
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W16TH AVE TO AGRONOMY RD

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FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
20-0001	00000-00001	R	D-445-445-105	B

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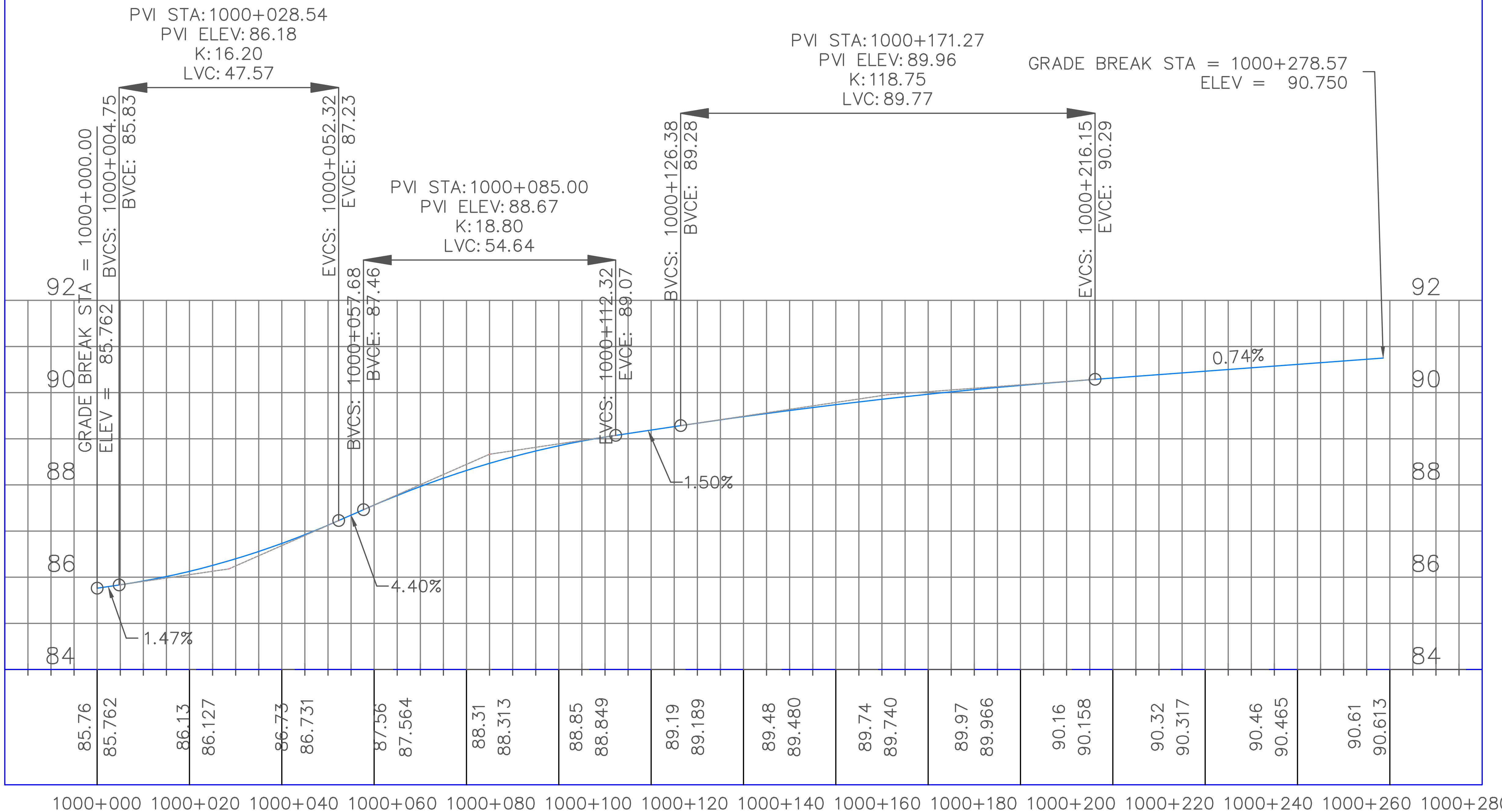
L1000-LINE PROFILE (W16TH AVE TO STADIUM RD)



NOTES:

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MUNICIPAL ENGINEERING
SOUTHERN CAMPUS

PROFILE
EAST MALL
W16TH AVE TO AGRONOMY RD

SENIOR DESIGNER
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FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
20-0001	00000-00001	R	D-445-446-201	B

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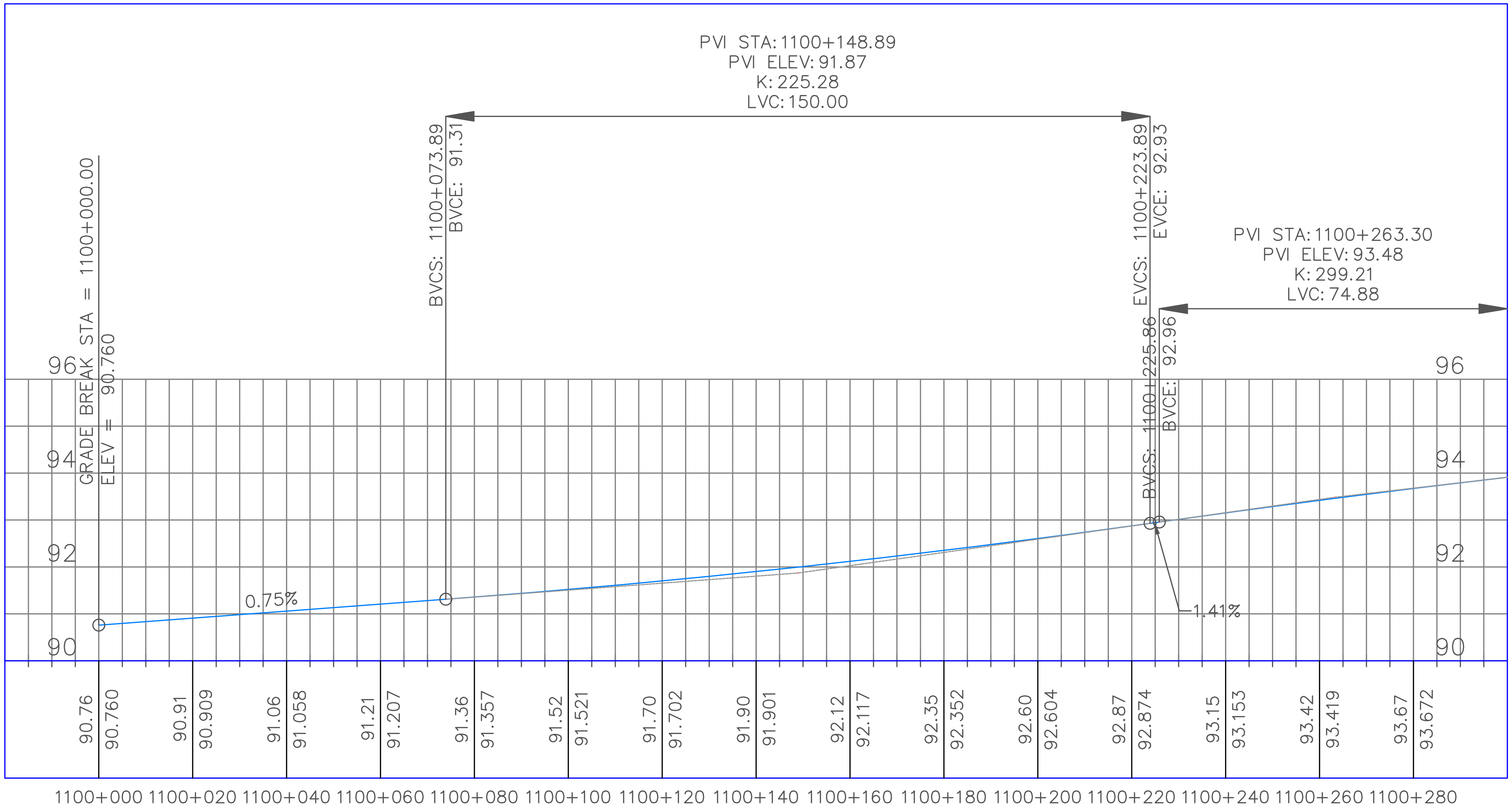
L1100-LINE PROFILE (STADIUM RD TO EAGLES DR)



NOTES:
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2. FOR ROADWAY CROSS SECTION, SEE DWG. D-445-446-301 TO 304 FOR DETAILS.
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MUNICIPAL ENGINEERING
SOUTHERN CAMPUS

PROFILE
EAST MALL
W16TH AVE TO AGRONOMY RD

SENIOR DESIGNER
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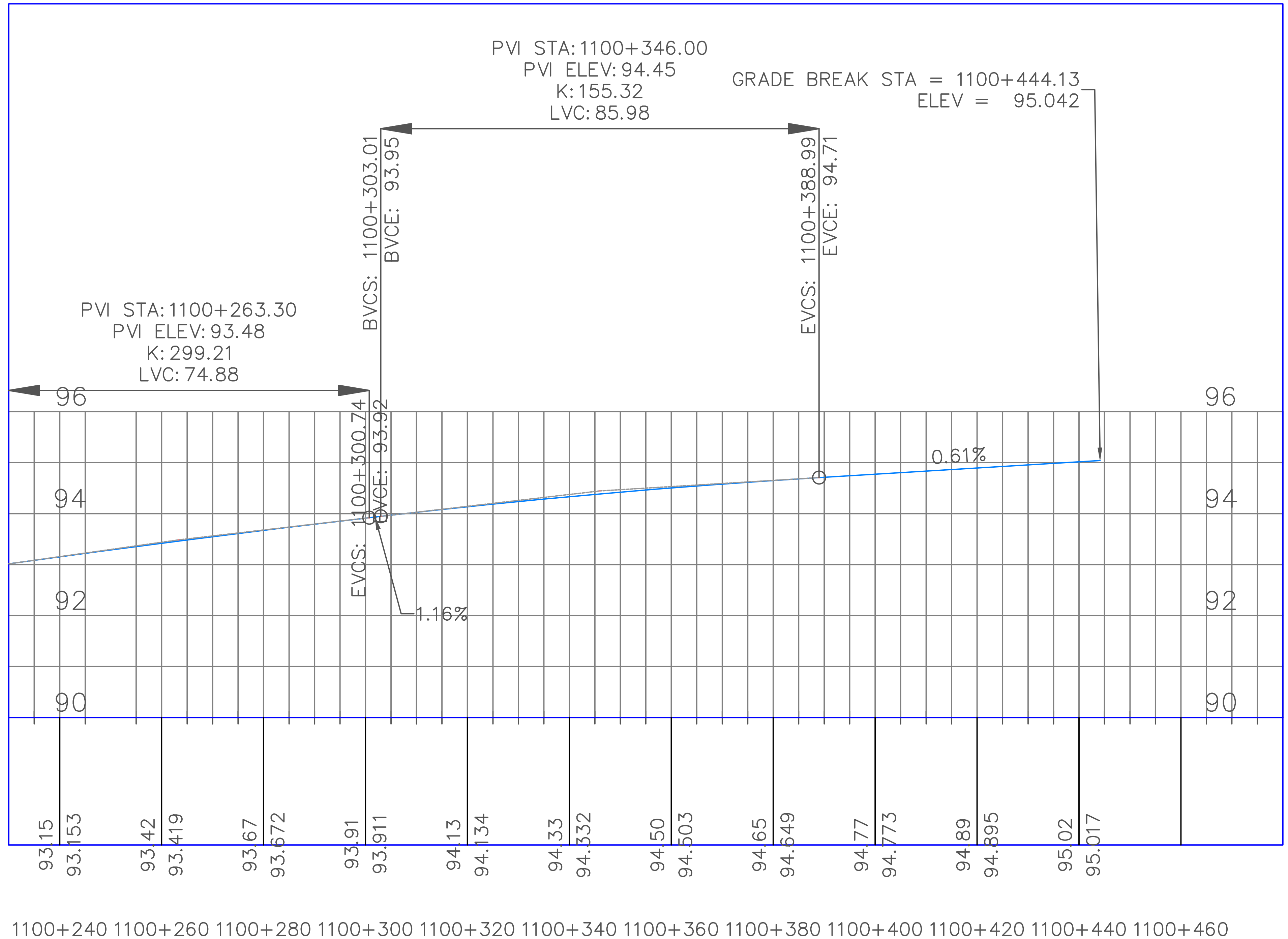
FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
20-0001	00000-00001	R	D-445-446-202	B

L1100-LINE PROFILE (EAGLES DR TO THUNDERBIRD BLVD)



NOTES:

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UBC SEEDS
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MUNICIPAL ENGINEERING
SOUTHERN CAMPUS

PROFILE
EAST MALL
W16TH AVE TO AGRONOMY RD

SENIOR DESIGNER
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FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
20-0001	00000-00001	R	D-445-446-203	B

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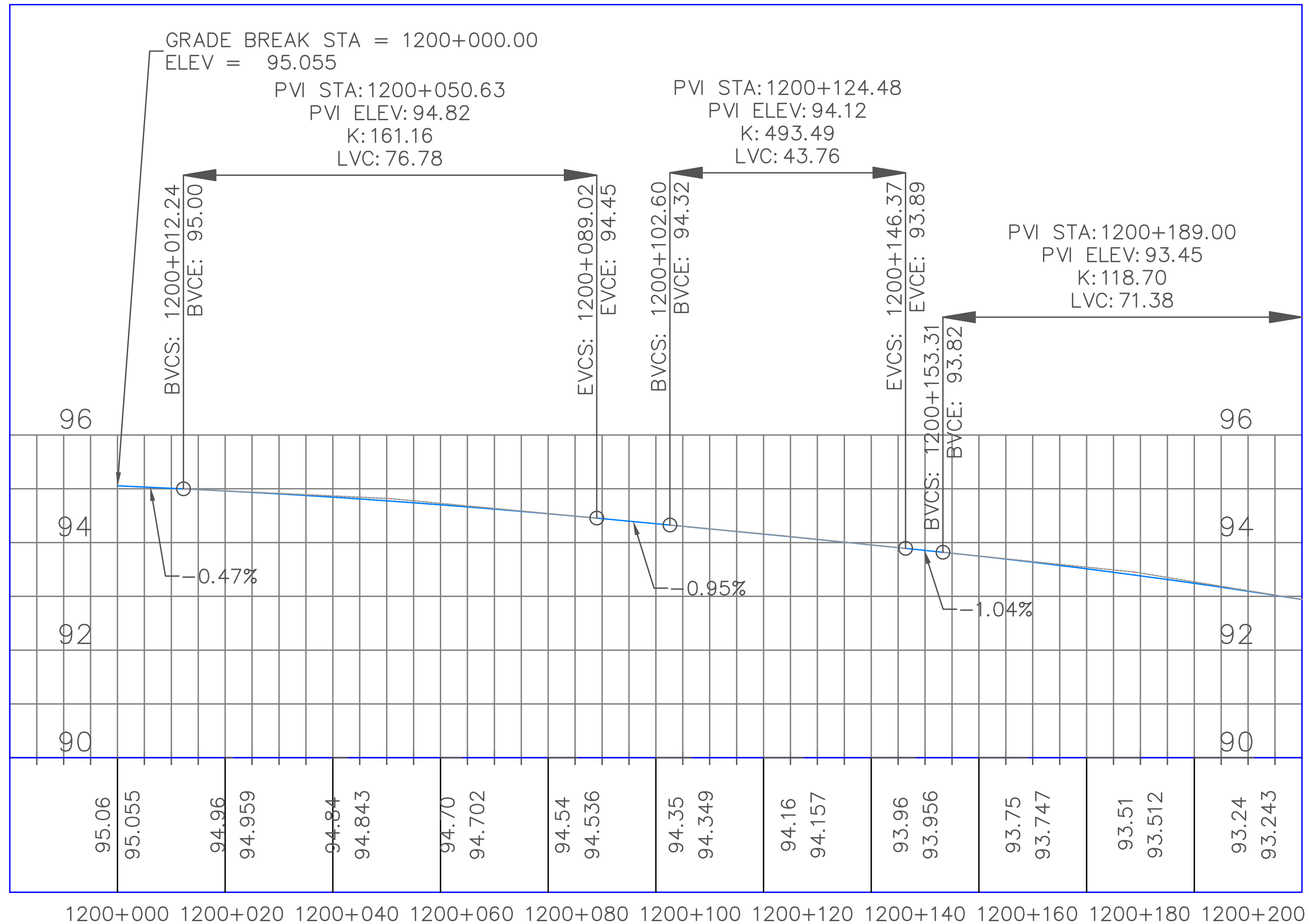
L1200-LINE PROFILE (THUNDERBIRD BLVD TO EAGLES DR)



NOTES:
1. FOR ROADWAY PLAN, SEE DWG. D-445-446-101 TO 105 FOR DETAILS.
2. FOR ROADWAY CROSS SECTION, SEE DWG. D-445-446-301 TO 304 FOR DETAILS.
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MUNICIPAL ENGINEERING
SOUTHERN CAMPUS

PROFILE
EAST MALL
W16TH AVE TO AGRONOMY RD

SENIOR DESIGNER
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FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
20-0001	00000-00001	R	D-445-446-204	B

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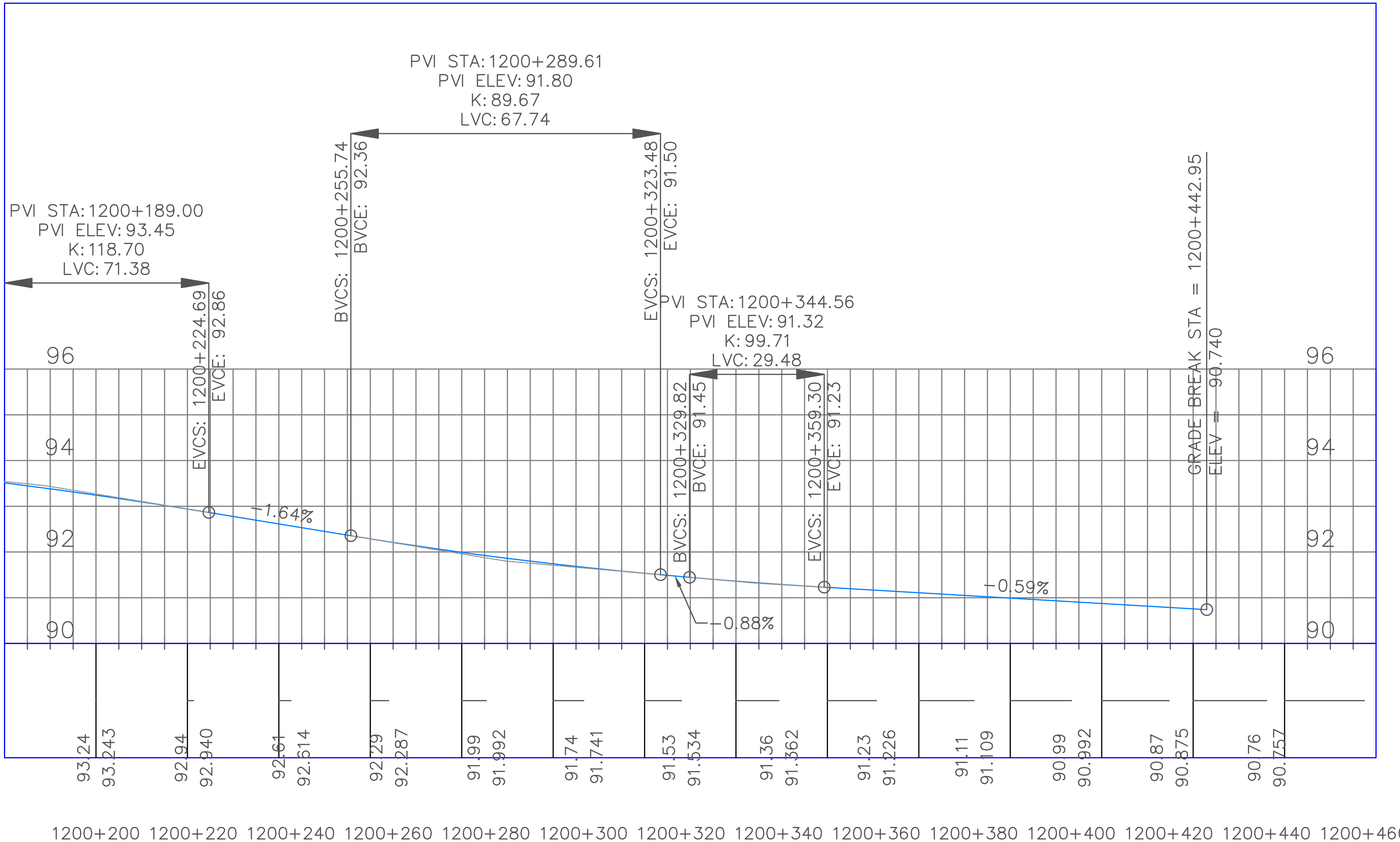
L1200-LINE PROFILE (EAGLES DR TO STADIUM RD)



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PROFILE
EAST MALL
W16TH AVE TO AGRONOMY RD

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20-0001	00000-00001	R	D-445-446-205	B

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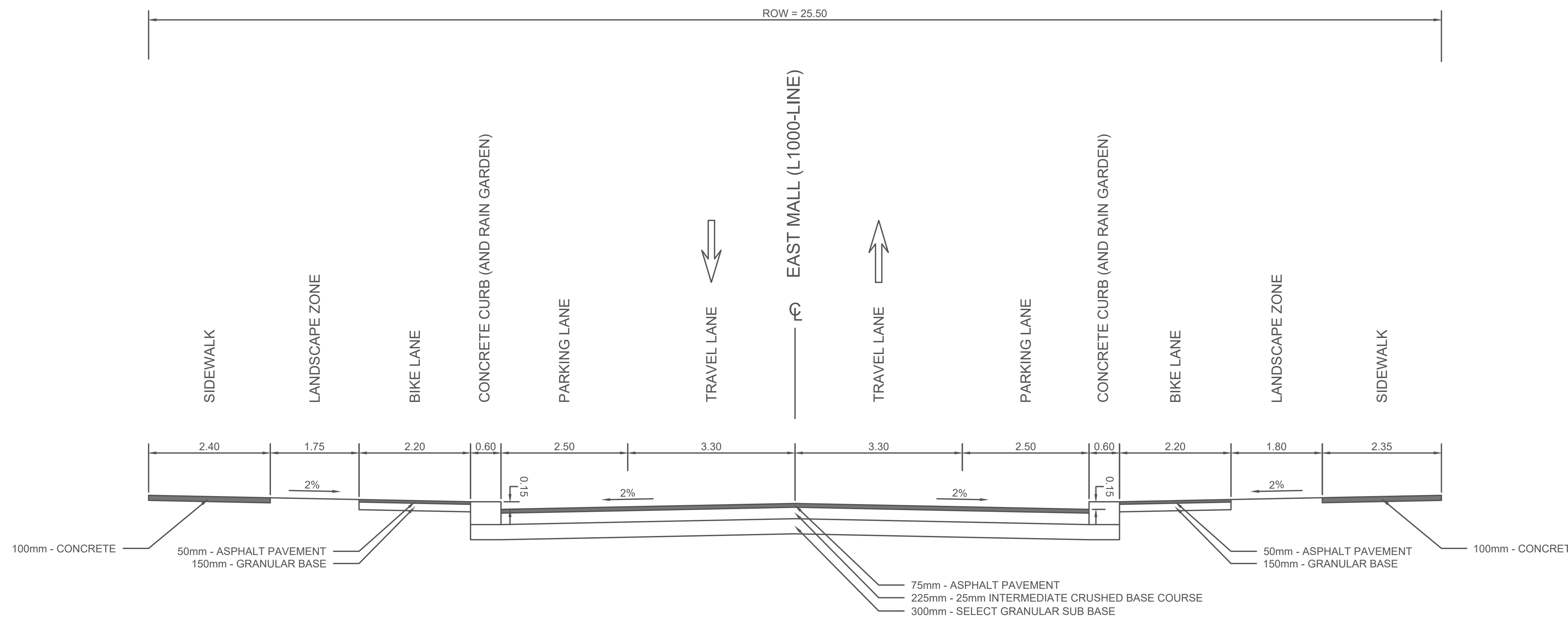

L1000-LINE
W16TH AVE TO STADIUM RD
CROSS SECTION

NOTES:
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SOUTHERN CAMPUS

SCALE 0 1 1:100 5m

CAD FILENAME 300CS_CIVL-445-446 - EAST MALL
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CROSS SECTION
EAST MALL
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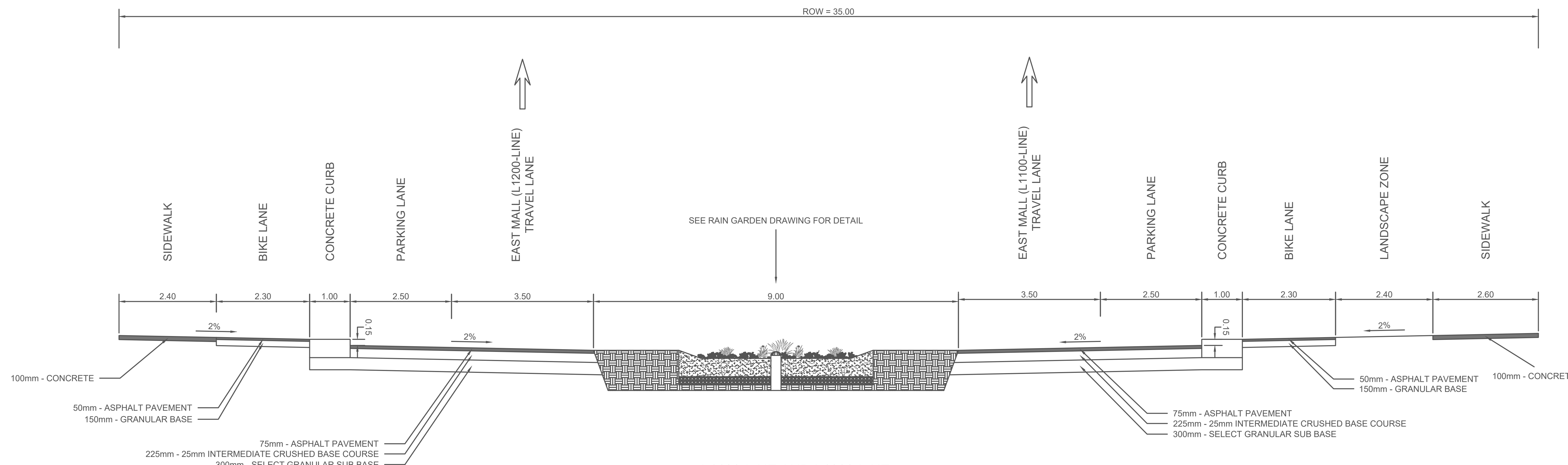

L1100-LINE AND L1200-LINE
STADIUM RD TO EAGLES DR
CROSS SECTION

NOTES:

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   - 5.1. STREET LIGHTS - SEE SURREY MMCD DWG. SSD-R.E.1 TO R.E.4 (PROPOSED STREET LIGHTS TO BE PLACED ON THE EAST SIDE OF EAST MALL FROM W16TH AVE TO STADIUM ROAD AT 45 m INTERVAL AND 0.5 m FROM THE ABSORBENT LANDSCAPE EDGE NEAREST TO ROADWAY).
   - 5.2. RECTANGULAR FLASHING BEACON - SEE SURREY MMCD DWG. CCSD-14d.
   - 5.3. CURBS - SEE CITY OF VANCOUVER STANDARD DETAIL DWG. C4.1 AND C19.1.
   - 5.4. SIDEWALK LETDOWN - SEE CITY OF VANCOUVER STANDARD DETAIL DWG. R4.1, R4.2, AND R7.1.
   - 5.5. SIGN POSTS + SIGNS - SEE CITY OF VANCOUVER STANDARD DETAIL DWG. R8.1 TO 8.16 AND C19.2 TO 19.3.
   - 5.6. PARKING METER LAYOUT - SEE CITY OF VANCOUVER STANDARD DETAIL DWG. R9.1.

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SCALE 0 1 1:100 5m

CAD FILENAME 300CS_CIVL-445-446 - EAST MALL
DATE 2021-04-14

REV	DATE	REVISIONS	SIGNATURE
A	21/03/05	Submission for Design Summary Report	
B	21/04/14	Submission for Final Design Report	

CROSS SECTION
EAST MALL
W16TH AVE TO AGRONOMY RD

SENIOR DESIGNER
DATE 2021-04-14

DESIGNED C.Q. DATE 2021-04-14
QUALITY CONTROL B.O. DATE 2021-04-14
QUALITY ASSURANCE B.O. DATE 2021-04-14
DRAWN C.Q. DATE 2021-04-14

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
20-0001	00000-00001	R	D-445-446-302	B

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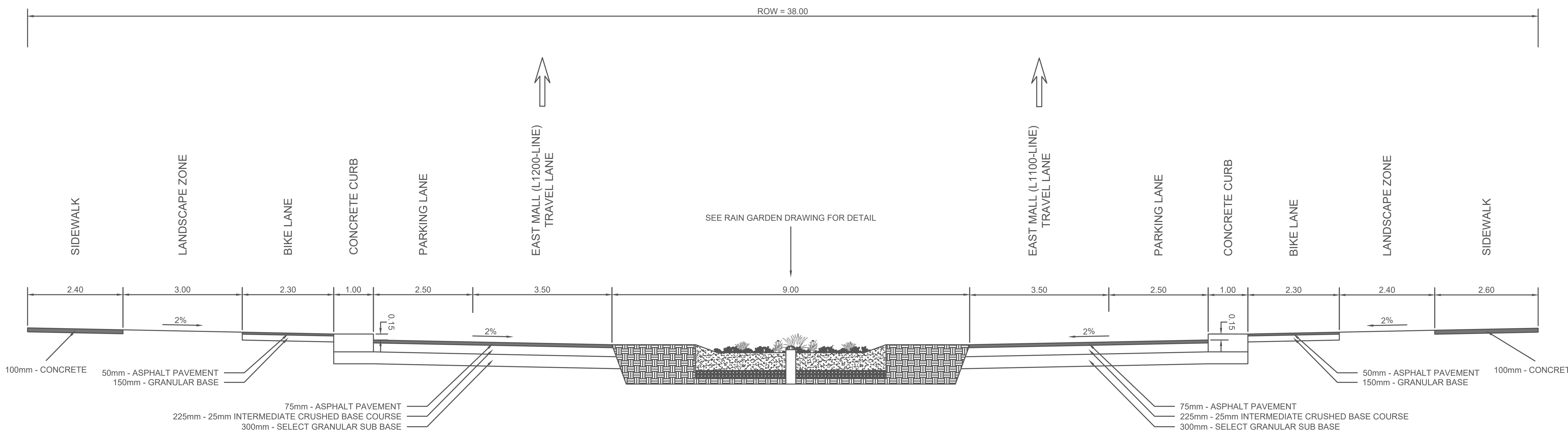

L1100-LINE AND L1200-LINE
EAGLES DR TO THUNDERBIRD BLVD
CROSS SECTION

NOTES:

1. FOR ROADWAY PLAN, SEE DWG. D-445-446-101 TO 105 FOR DETAILS.
2. FOR ROADWAY PROFILE, SEE DWG. D-445-446-201 TO 205 FOR DETAILS.
3. FOR GREEN STORM WATER INFRASTRUCTURE (GSI), SEE DWG. D-401 TO 403 FOR DETAILS.
4. FOR PEDESTRIAN COVERED WALKWAY, SEE DWG. D-501 TO 503 FOR DETAILS.
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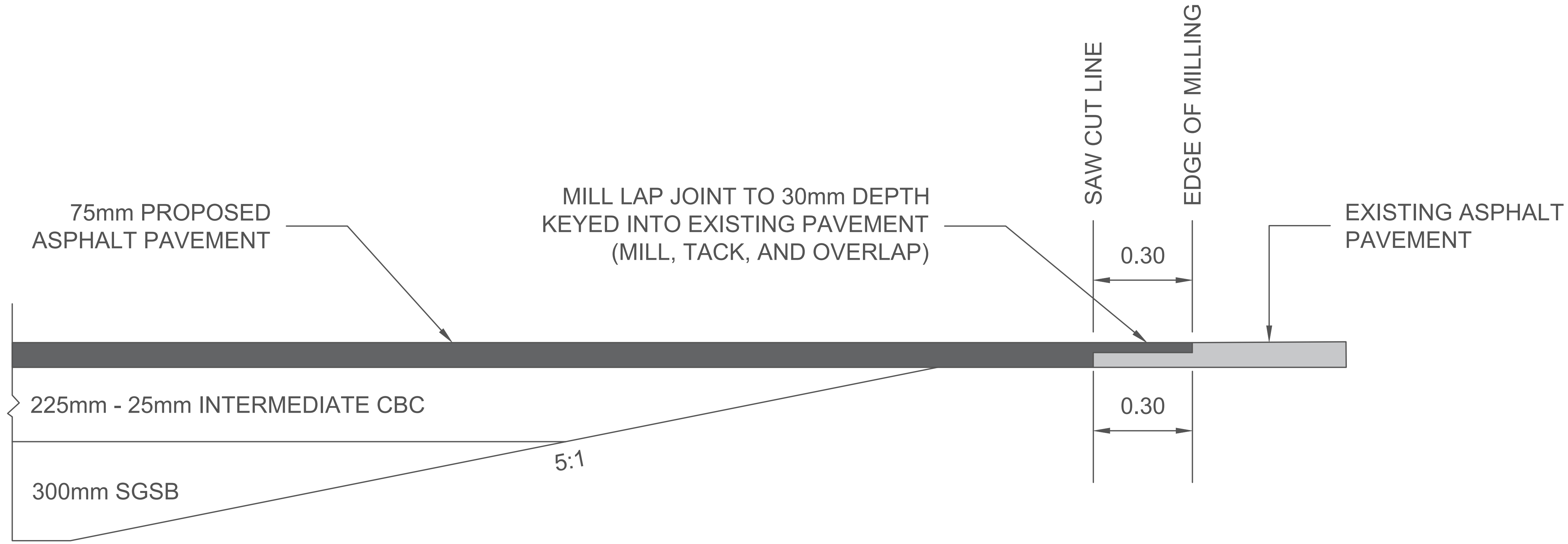
20-0001	00000-00001	R	D-445-446-303	B



PAVEMENT SAW CUT AND LAP JOINT DETAIL
(SEE PLANS FOR LOCATIONS)

NOTES:
1. FOR ROADWAY PLAN, SEE DWG. D-445-446-101 TO 105 FOR DETAILS.
2. FOR ROADWAY PROFILE, SEE DWG. D-445-446-201 TO 205 FOR DETAILS.
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CROSS SECTION
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DATE 2021-04-14

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DRAWN C.Q. DATE 2021-04-14

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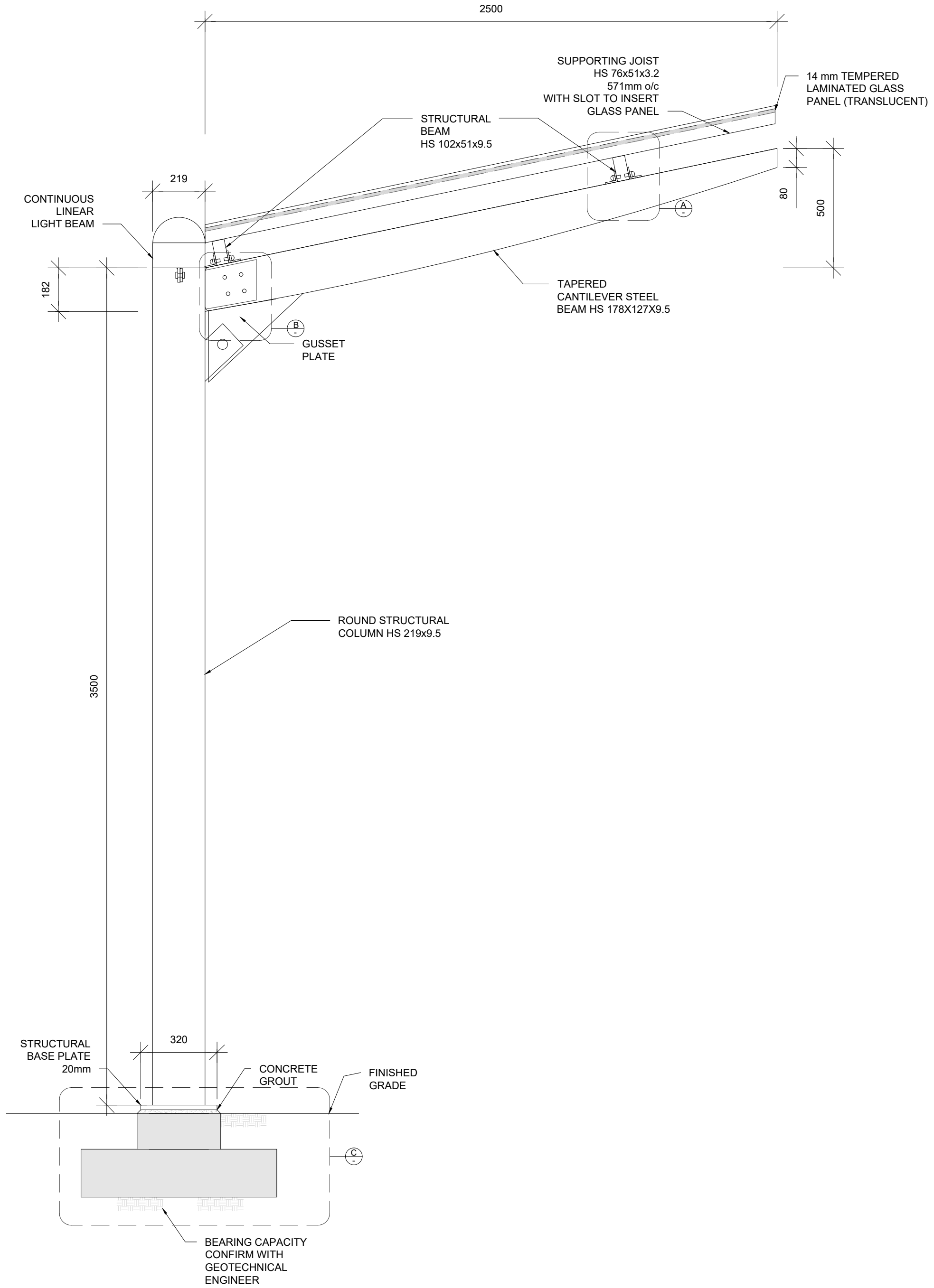
PRODUCED BY AN AUTODESK STUDENT VERSION
PRODUCED BY AN AUTODESK STUDENT VERSION



CANOPY ELEVATION VIEW
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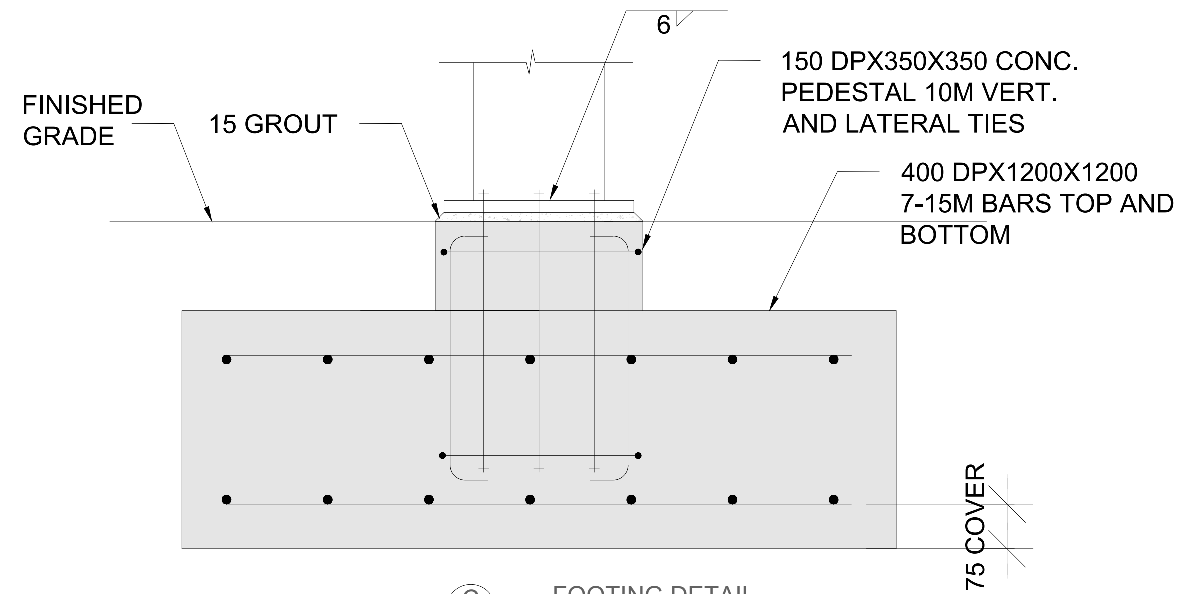
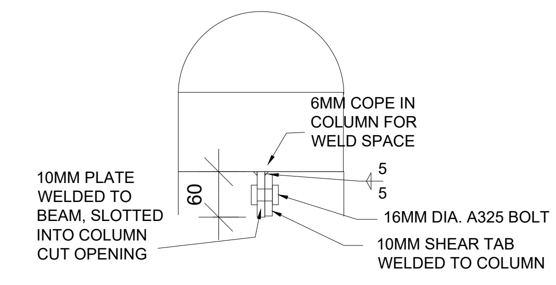
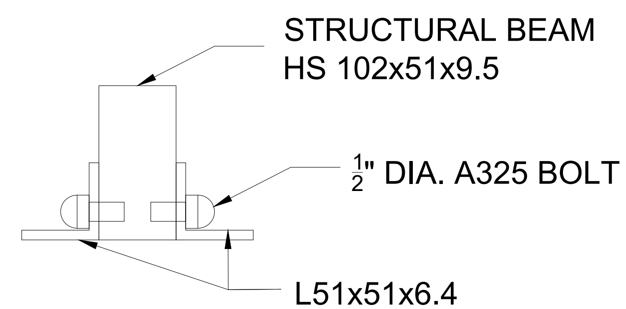


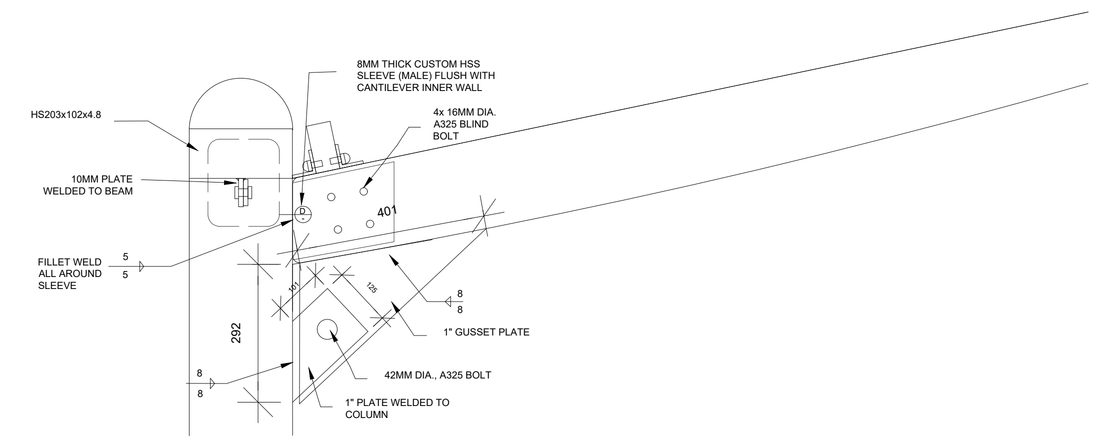
C FOOTING DETAIL
SCALE: 1:20



D BEAM SLOT DETAIL
SCALE: 1:10



A CONNECTION DETAIL
SCALE: 1:5



B CANTILEVER-COLUMN CONNECTION
SCALE: 1:16

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CAD FILENAME 500WW_CIVL-445-446 - EAST MALL
DATE 2021-04-11

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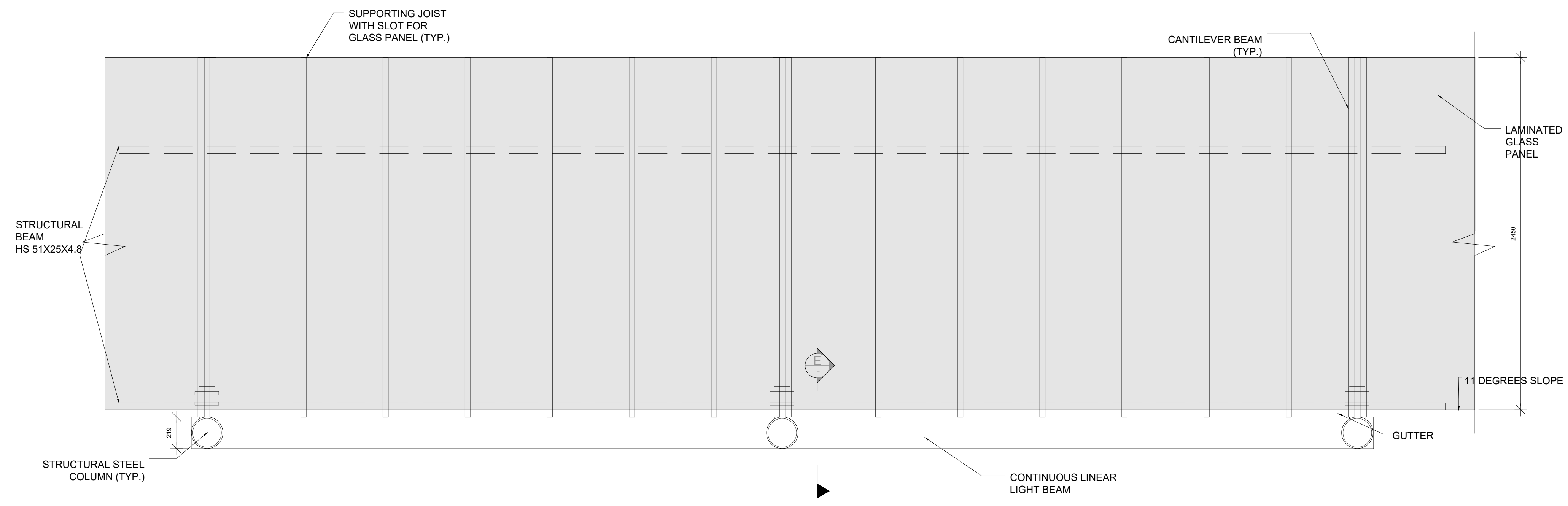
WALKWAY
EAST MALL
W16TH AVE TO AGRONOMY RD

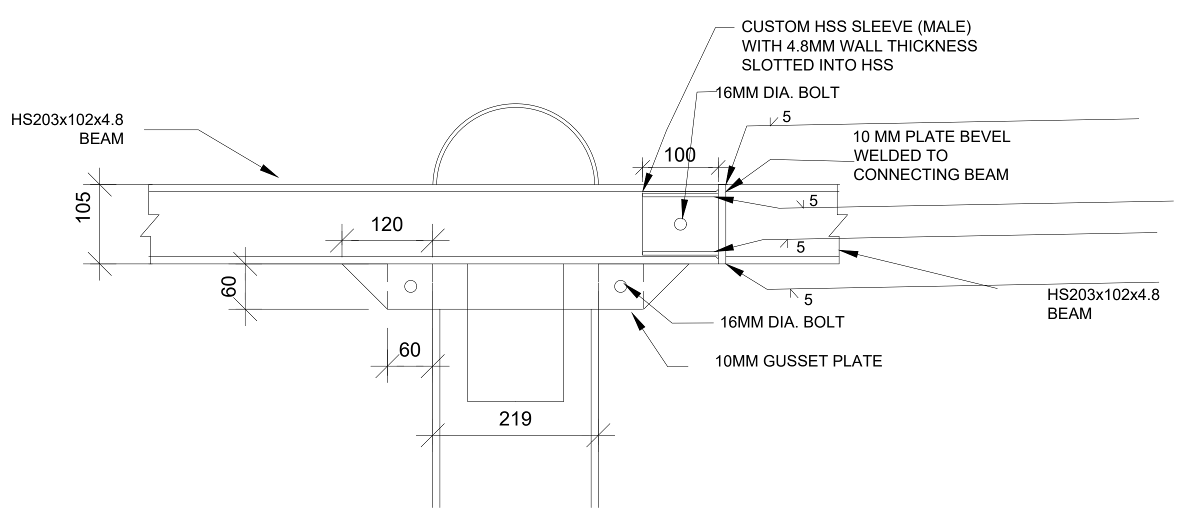
DESIGNED	M.L.	DATE	2020-12-03
QUALITY CONTROL	B.O.	DATE	2021-04-11
QUALITY ASSURANCE	B.O.	DATE	2021-04-11
DRAWN	M.L.	DATE	2021-03-11

SENIOR DESIGNER
DATE 2021-04-11

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
20-0001	00000-00001	R	D-445-445-501	-



CANOPY PLAN VIEW
SCALE: 1:40



E
-
BEAM SPLICE DETAIL
SCALE: 1:10

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CAD FILENAME 500WW_CIVL-445-446 - EAST MALL
DATE 2020-12-03

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WALKWAY
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W16TH AVE TO AGRONOMY RD

SENIOR DESIGNER
DATE 2020-12-03

DESIGNED M.L. DATE 2020-12-03
QUALITY CONTROL B.O. DATE 2020-12-03
QUALITY ASSURANCE B.O. DATE 2020-12-03
DRAWN M.L. DATE 2020-12-03

FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
20-0001	00000-00001	R	D-445-445-502	-

1.0 Fabrication

Fabrication shall be performed in an enclosed area that is adequately heated.
Prior to fabrication, the welders' and welding operators' qualifications, shop drawings, welding procedures, mill certificates, and welding consumable certificates shall be submitted for the Owner's review.

In advance of fabrication, the Owner will convene a prefabrication meeting with the Contractor, the Designer to review issues such as, quality control, welding procedures, mill certificates and heat numbers, splices, coatings, shop trial assembly, and schedule.

The Contractor shall provide a schedule of fabrication to the Owner in the form of a Gantt Chart updated on no less than a monthly basis.

1.1 Shop Drawings

Shop drawings for the walkway shall be developed from a 3D model. The model shall include each element and assembled product. Before the geometry is finalized, as-built geometry and elevations of the structure shall be confirmed by the Contractor. Discrepancies shall be submitted to the Owner for review and accepted by the Engineer.

Shop drawings shall show all information and details needed for the fabrication including member shapes, dimensions, connection details, material, arraignment of member locations, faster details, weld details and symbols, and coating details.

1.2 Bolt Holes

Clause 11.4.8 in Division II of AASHTO shall apply except that all bolt holes in load carrying segments of main members and any material welded to main members shall be drilled full size or subpunched and reamed to full size. All holes in member splices shall be circular and perpendicular to the member and shall be deburred to ensure a proper faying surface.
Standard holes for high strength bolts shall be of a diameter not more than 2 mm in excess of the nominal bolt diameter, except that the following bolt/hole combinations will be permitted:

a) either 3/4 inch or M20 bolts in 22 mm holes;
b) either 7/8 inch or M22 bolts in 24 mm holes;
c) either 1 inch or M24 bolts in 27 mm holes;
d) either 1-1/8 inch or M30 bolts in 32 mm holes.

Punched holes shall be clean cut, without torn or ragged edges. The diameter of the die shall not exceed the diameter of the punch by more than 2 mm. If a punched hole must be enlarged to admit a high strength bolt, it shall be reamed.

1.3 Shop Trial Assembly

The structure shall be progressively assembled in accordance with the following requirements:
Before trial assembly starts, the Contractor shall submit to the Owner's representative for review by the Engineer a detailed plan showing the proposed trial assembly arrangement and procedures.
Field connections shall be pre-assembled prior to erection to verify the geometry of the completed structure.
Holes for splices shall be drilled during trial assembly in the shop, or sub-drilled and then reamed to full size while assembled.

1.4 Surface Finishes

All steel components shall be blast cleaned after fabrication. Shop painting shall conform with the BC MOTI Specifications, Painting.

1.5 Fabrication Tolerances

Dimensions shown on the Plans are at a reference temperature of 0 °C. The Contractor shall make the necessary dimensional adjustments for actual temperatures at the time and place of fabrication. Normal tolerance for structural steel fabrication and fitting between hole groups will be ± 3 mm unless specified otherwise. Dimensional tolerances for structural members shall comply with the appropriate tolerances as specified in AWS D1.5, Section 3.5, and CAN/CSA-S6-00, Section 10.24.7

2.0 Materials

2.1 Welding Consumables

All electrodes shall match the base metal specified in accordance with CSA W59, Table 12.1. The deposited weld metal shall provide strength, ductility, impact toughness, and corrosion resistance equivalent to the base metal.

Welding consumables for all processes shall be certified by the Canadian Welding Bureau (CWB) as complying with the requirements of CSA W48.

2.2 High Strength Bolts

Unless otherwise specified on the Plans, uncoated high strength bolts shall conform to the requirements of ASTM A490, Type 3 (or ASTM A490M Type 3 of equivalent size), weathering steel, with compatible nuts and hardened washers. All bolts and compatible washers and nuts shall be either metric or imperial.

Certified mill test reports for the fastener material shall be provided. The supplier shall provide a lot number appearing on the shipping package and a certification noting when and where all testing was done, including rotational capacity tests.

2.3 Structural Steel

Structural material, either plain or fabricated, shall be stored above the ground in an upright and shored position upon platforms, skids, or other supports. It shall be kept free from dirt and other foreign matter, and shall be protected as far as practical from corrosion. Long members shall be supported on skids placed near enough together to prevent overstress from deflection.

3.0 Welded Construction

The quality and details of welds shall be in accordance with AWS D1.5.

Welding procedures shall be in accordance with the requirements of CSA W47.1 and this specification. Prequalified joint geometry and parameters shall be accepted as specified by CSA Standard W59-03.

Welding procedures shall be submitted for each type of weld used in the structure. The procedures shall bear the approval of the CWB and shall be accompanied by documentary proof that the procedures have been qualified by the CWB at the plant where the Work is to be carried out. Welding procedures shall be reviewed by the Owner's Representative prior to use on the structure.

The procedures shall include the following information: joint type, surface preparation, welding process, welding position, base metal specification, welding consumable specification and size, preheat requirements, amperage and voltage requirements, speed, polarity, and welding equipment. Additional information, as described in CSA W47.1-03, Appendix C, shall also be included in the procedures.

Tack welds, where permitted, shall be done by qualified welders using the smallest size weld required to hold the components of the assembly together. Tack welds and temporary welds shall be subject to the requirements of AWS D1.5 Clauses 3.3.7, 3.3.8 and 12.13.

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SCALE 1:40
CAD FILENAME 500WW_CIVL-445-446 - EAST MALL
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FILE NUMBER	PROJECT NUMBER	REG	DRAWING NUMBER	REV
20-0001	00000-00001	R	D-445-445-503	-

Appendix C - Synchro Analysis Results Table

Synchro Analysis Results - 2040

AM

Intersections	Measure	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Agronomy	V/C	0.16	0.16	0.16	0.06	0.06	0.06	0.42	0.42	0.42	0.42	0.42	0.42
	LOS	A	A	A	A	A	A	B	B	B	B	B	B
	95th Percentile Queue	0.16	0.16	0.16	0.06	0.06	0.06	0.42	0.42	0.42	0.42	0.42	0.42
Thunderbird	V/C		0.33		0.66	0.24			0.91			0.2	
	LOS		B		C	B			C			A	
	95th Percentile Queue		21.4		#46.4	14.1			#146.9			15.1	
Logan Lane	V/C			0.02					0.41			0.17	0.17
	LOS			A					A			A	A
	95th Percentile Queue			0.4					0			0	0
Eagles Dr	V/C	0.03		0.03				0.01	0.4			0.18	0.18
	LOS	B		B				A	A			A	A
	95th Percentile Queue	0.6		0.6				0.1	0			0	0
Stadium	V/C	0.62		0.62				0.15	0.5			0.26	0.26
	LOS	D		D				A	A			A	A
	95th Percentile Queue	31.3		31.3				4	0			0	0

PM

Intersection	Measure	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Agronomy	V/C	0.23	0.23	0.23	0.33	0.33	0.33	0.27	0.27	0.27	0.53	0.53	0.53
	LOS	B	B	B	B	B	B	B	B	B	B	B	B
	95th Percentile Queue	-	-	-	-	-	-	-	-	-	-	-	-
Thunderbird	V/C		0.24		0.77	0.17			0.7			0.79	
	LOS		A		C	A			B			C	
	95th Percentile Queue		18.5		#62.0	13.6			24.4			#81.2	
Logan Lane	V/C			0.01					0.24			0.37	0.37
	LOS			B					A			A	A
	95th Percentile Queue			0.3					0			0	0
Eagles Dr	V/C	0.02		0.02				0.01	0.24			0.37	0.37
	LOS	B		B				A	A			A	A
	95th Percentile Queue	0.4		0.4				0.2	0			0	0
Stadium	V/C	0.53		0.53				0.32	0.32			0.43	0.43
	LOS	D		D				A	A			A	A
	95th Percentile Queue	22.2		22.2				10.3	10.3			0	0

Appendix D - PC SWMM / QGIS Inputs and Results

Evapotranspiration Parameters

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ET (mm/d)	0.5	0.8	1.3	2.3	3.3	3.5	3.7	3.2	2.2	1	0.5	0.4

Rain Garden Parameters

Rain Garden Parameters				
Layer	Parameter	Value	Source	Notes
Surface	Berm height (mm)	203.2	Rain Gardens - A How to Manual [3]	Typical Value
	Vegetation Volume (fraction)	0.1	SWMM User's Manual Version 5.1 Appendix C.13 [4]	dense vegetation growth
	Surface roughness (Manning's n)	0.24	SWMM User's Manual Version 5.1 Appendix A.6 [4]	dense grass
	Surface slope (percent)	2	Default value in SWMM	Typical Value
Soil	Thickness (mm)	450	SWMM User's Manual Version 5.1 Appendix C.13	Typical Value
	Porosity (volume fraction)	0.453	SWMM User's Manual Version 5.1 Appendix A.2 [4]	Sandy Loam
	Field capacity (volume fraction)	0.19	SWMM User's Manual Version 5.1 Appendix A.2	Sandy Loam
	Wilting point (volume fraction)	0.085	SWMM User's Manual Version 5.1 Appendix A.2	Sandy Loam
	Conductivity (mm/hr)	11	SWMM User's Manual Version 5.1 Appendix A.2	Sandy Loam
	Conductivity slope	27	SWMM User's Manual Version 5.1 Appendix C.13	0.48(%Sand) + 0.85(%Clay).
	Suction head (mm)	110	SWMM User's Manual Version 5.1 Appendix A.2	Sandy Loam
Storage	Thickness (mm)	200	SWMM User's Manual Version 5.1 Appendix C.13	Typical Value
	Void ratio (voids/solids)	0.75	Default value in SWMM	Typical Value
	rate (mm/hr)	10.922	SWMM User's Manual Version 5.1 Appendix A.2	Minimum infiltration rate of surrounding soil
	Clogging factor	0	-	-

Absorbent Landscape Parameters

Horton Infiltration Parameters			
Parameter	Value	Source	Notes
Maximum Infiltration Rate (mm/hr)	25.4	SWMM User's Manual Version 5.1 Appendix C.8 [4]	Moist Loam soil
Minimum Infiltration Rate (mm/hr)	10.9	SWMM User's Manual Version 5.1 Appendix A.2	Saturated hydraulic conductivity of Loam
Decay Constant	4	Default value in SWMM	Typical Value
Dry Time (days)	7	Default value in SWMM	Typical Value

Subcatchment Parameters

Subcatchments Parameters								
Roadway	**Total Area (m2)**	**Rain Garden (m2)**	**Absorbent Landscape (m2)**	**Outlet**	**Width (m)**	**Flow Length (m)**	**Slope (%)**	**Imperv. Area Treated (%)**
West 16th Ave to Stadium Rd (S1)	6756	249	1132	J6	504.8	13.384	2	100
Stadium Rd to Eagle Dr (S2)	4797	420	817	J5	286.8	16.726	2	100
Eagles Dr to Thunderbird Blvd (S3)	3536	300	463	S2	194.6	18.119	2	100
Thunderbird Blvd Intersection (S4)	9477	820	3131	S3	425.4	22.278	2	100
Thunderbird Blvd to Agronomy Rd (S5)	7663	0	4412	J2	302.8	25.307	2	100

Junction Inputs

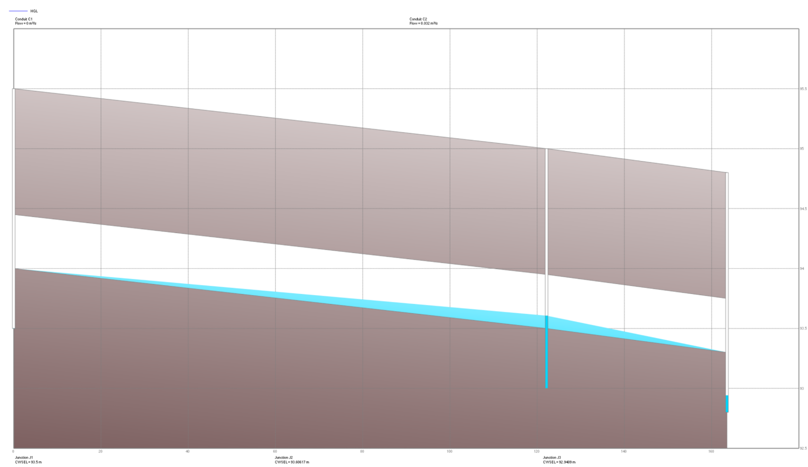
Name	Invert Elev. (m)	Rim Elev. (m)	Depth (m)
J1	93.5	95.5	2
J2	93	95	2
J3	92.8	94.8	2
J4	93	95	2
J5	90.5	92.5	2
J6	89.7	91.7	2
J7	87	89	2
J8	84	86	2

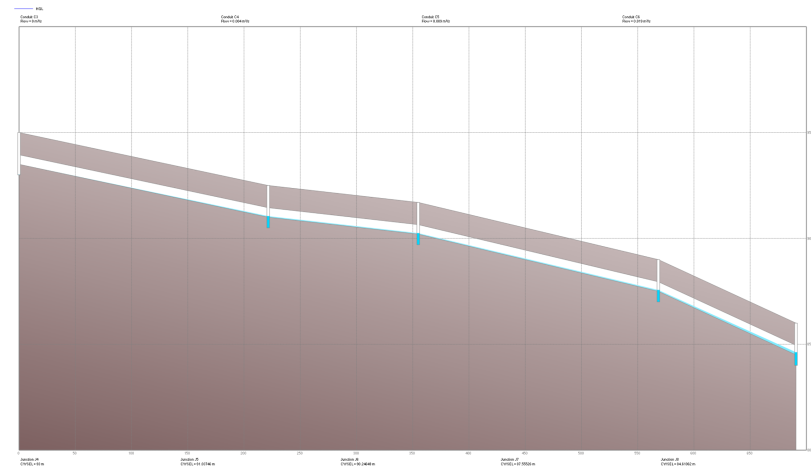
Conduit Inputs

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Inlet Offset (m)	Outlet Offset (m)	Cross-Section	Diameter (m)	Slope (%)
C1	J1	J2	122.155	0.01	0.5	0.5	CIRCULAR	0.45	0.23
C2	J2	J3	41.358	0.01	0.5	0.5	CIRCULAR	0.45	0.28
C3	J4	J5	221.519	0.01	0.5	0.5	CIRCULAR	0.45	0.65
C4	J5	J6	133.361	0.01	0.5	0.5	CIRCULAR	0.45	0.34
C5	J6	J7	213.463	0.01	0.5	0.5	CIRCULAR	0.45	0.72
C6	J7	J8	122.388	0.01	0.5	0.5	CIRCULAR	0.45	1.40

PCSWMM Results

	Area (m2)	Precip. (mm)	Runon (mm)	Evap. (mm)	Infiltration (mm)	Imperv Runoff (mm)	Perv Runoff (mm)	Runoff Depth (mm)	Runoff Volume (ML)	GSI?	Precip. (m3)	Runoff (m3)	Total Collected	Pre-Dev. Peak Runoff (m^3/s)	Peak Runoff (m^3/s)	Post-Dev. Levels Improved?
6-month/24-hour precipitation event																
S1	6756	43.6	0	0.79	19.61	33.98	27.36	10.43	0.07	YES	294.5	70.46508	90.24%	0.02	0.02	YES
S2	4797	43.6	0	0.77	25.13	31.99	25.55	0	0	YES	209.1	0		0.01	0	YES
S3	3536	43.6	0	0.78	21.93	33.91	29.04	0	0	YES	154.1	0		0.01	0	YES
S4	9477	43.6	0	0.67	30.82	25.01	14.27	0	0	YES	413.1	0		0.03	0	YES
S5	7663	43.6	0	0.47	34.38	18.11	8.7	8.7	0.07	NO	334.1	66.66		0.02	0.02	YES
2-year/24-hour precipitation event																
S1	6756	56.9	0	0.79	20.1	44.56	40.02	23.01	0.16	YES	384.4	155.4	84.15%	0.02	0.02	YES
S2	4797	56.9	0	0.78	26.56	41.95	37.54	0.12	0	YES	272.9	0.57		0.02	0	YES
S3	3536	56.9	0	0.78	23.17	44.47	41.1	3.63	0.01	YES	201.1	12.83		0.01	0	YES
S4	9477	56.9	0	0.75	37.93	32.79	24.89	0	0	YES	539.2	0		0.03	0	YES
S5	7663	56.9	0	0.56	40.38	23.75	15.9	15.9	0.12	NO	436.0	121.84		0.02	0.02	YES
5-year/24-hour precipitation event																
S1	6756	72.19	0	0.79	20.47	56.73	54.61	37.9	0.26	YES	487.7	256.05	73.13%	0.03	0.03	YES
S2	4797	72.19	0	0.78	27.58	53.41	51.35	13.27	0.06	YES	346.2	63.65		0.02	0.01	YES
S3	3536	72.19	0	0.79	24.01	56.61	54.99	17.57	0.06	YES	255.26	62.12		0.02	0.01	YES
S4	9477	72.19	0	0.77	39.58	41.74	38.33	3.71	0.04	YES	684.1	35.15		0.04	0	YES
S5	7663	72.19	0	0.67	44.28	30.23	27.18	27.18	0.21	NO	553.1	208.2		0.03	0.03	YES





Junction 1 to 3 During 5-year 24-hour precipitation (Left)
Junction 4 to 8 During 5-year 24-hour precipitation (Right)

QGIS Flow accumulation model of UBC Campus (Opacity of Whitelines = Density of Flow)

Appendix E - Pedestrian Walkway Calculations

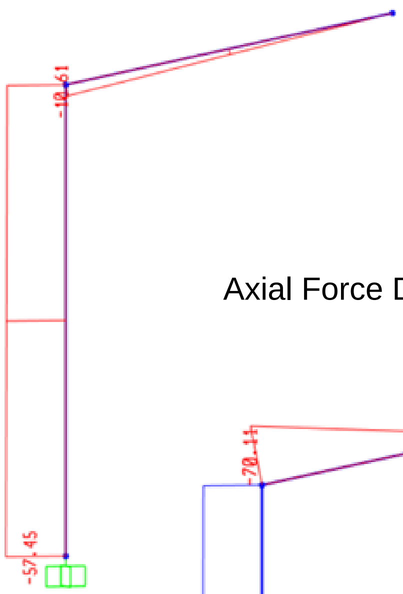
Cantilever Structure Load Demand

Unfactored Dead Load			
Column Weight	**=**	**1.6927155**	**kN**
Section used	=	**HS219x9.5**	
linear weight of section	=	49.3	kg/m
height	=	3.5	m
Cantilever Weight	**=**	**1.0229373**	**kN**
Section Used	=	**HS178x127x9.5**	
linear weight of section	=	40.9	kg/m
cantilever horizontal length	=	2.5	m
cantilever height	=	0.5	m
cantilever length	=	2.5495098	m
Beam Weight (2 beams)	**=**	**0.3562992**	**kN**
beam span	=	4	m
Section Used	=	HS51x25x4.8	
linear weight of section	=	4.54	kg/m
Joists Weight (per span)	=	**0.1187664**	**kN**
joist spacing	=	0.6	m
number of joists	=	8	
approx. weight of 1 joist	=	1.5133333	kg/m
Load applied to 1 cantilever	=	0.2375328	kN
distributed load	=	0.093168	kN/m
include 25% for glass panels	**=**	**0.11646**	**kN/m**

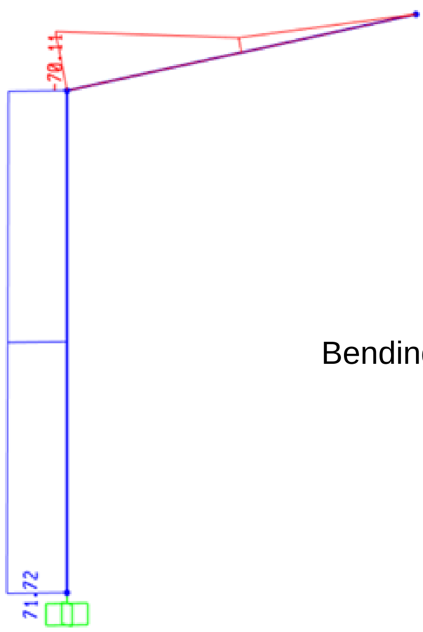
Wind Load (S6-19 Table A3.1.1)			
Hourly mean wind pressure, (10 yr return)	=	360	Pa
Hourly mean wind pressure, (25 yr return)	=	430	Pa
Hourly mean wind pressure, (50 yr return)	=	480	Pa
Hourly mean wind pressure, (100 yr return)	=	530	Pa
wind load on glass > transferred to cant.	=	1920	N/m
column width/diameter	=	0.219	m
wind load on column	**=**	**105.12**	**N/m**

Snow Load (NBCC 2015, 4.1.6)				
Ground Snow Load	S_s	=	2.5	kPa
Associated Rain Load	S_r	=	0.3	kPa
Importance Factor	I_s	=	0.8	(low)
Wind exposure factor	C_w	=	1	
Basic Roof Snow Load Factor	C_b	=	1.6	
Slope Factor	C_s	=	1	(for angle < 15)
Specific Weight of Snow	γ	=	3.275	kN/m^3
Accumulation Factor	C_a	=	1	
Specified Snow Load	**S**	**=**	**3.44**	**kPa**
distributed load on cantilever		**=**	**13.76**	**kN/m**

SAP2000 RESULTS FOR LOAD DEMAND				
LOAD CASE 1: 1.4D				
Column Axial	N	=	3.25	kN
Cant. Axial	N	=	0.32	kN
Max. Column Cant Mome	M	=	2.05	kNm
LOAD CASE 3: 1.25D + 1.5S + 0.4W (governing)				
Column Axial	N	=	57.45	kN
Cant. Axial	N	=	10.61	kN
Max. Column Moment	M	=	71.72	kNm
Max. Cant Moment	M	=	70.11	kNm
LOAD CASE 4: 1.25D + 1.4W + 0.5S				
Column Axial	N	=	27.17	kN
Cant. Axial	N	=	3.73	kN
Max. Column Moment	M	=	38.14	kNm
Max. Cant Moment	M	=	32.49	kNm



Axial Force Diagram



Bending Moment Diagram

Beam Load Demand

Unfactored Dead Load			
Column Weight	**=**	**1.6927155**	**kN**
Section used	=	HS219x9.5	
linear weight of section	=	49.3	kg/m
height	=	3.5	m
Cantilever Weight	**=**	**1.0229373**	**kN**
Section Used	=	HS178x127x9.5	
linear weight of section	=	40.9	kg/m
cantilever horizontal length	=	2.5	m
cantilever height	=	0.5	m
cantilever length	=	2.5495098	m
Beam Weight (2 beams)	**=**	**0.3562992**	**kN**
beam span	=	4	m
Section Used	=	HS51x25x4.8	
linear weight of section	=	4.54	kg/m
Joists Weight (per span)	=	**0.1187664**	**kN**
joist spacing	=	0.6	m
number of joists	=	8	
approx. weight of 1 joist	=	1.5133333	kg/m
Deadload applied to 1 beam	**=**	**0.0593832**	**kN/m**

DISTRIBUTED LOAD ON BEAM				
LOAD CASE 1: 1.4D				
		=	0.08313648	kN/m
LOAD CASE 3: 1.25D + 1.5S + 0.4W (governing)				
		=	6.764229	kN/m
LOAD CASE 4: 1.25D + 1.4W + 0.5S				
		=	3.064229	kN/m
Max moment	**M**	**=**	**13.528458**	**kNm**

Wind Load (S6-19 Table A3.1.1)			
Hourly mean wind pressure, (10 yr return)	=	360	Pa
Hourly mean wind pressure, (25 yr return)	=	430	Pa
Hourly mean wind pressure, (50 yr return)	=	480	Pa
Hourly mean wind pressure, (100 yr return)	=	530	Pa
wind load on glass > transferred to cant.	**=**	**1920**	**N/m**
column width/diameter	=	0.219	m
wind load on column	**=**	**105.12**	**N/m**
Wind load applied to 1 beam	=	**0.6**	**kN/m**

Snow Load (NBCC 2015, 4.1.6)				
Ground Snow Load	S_s	=	2.5	kPa
Associated Rain Load	S_r	=	0.3	kPa
Importance Factor	I_s	=	0.8	(low)
Wind exposure factor	C_w	=	1	
Basic Roof Snow Load Factor	C_b	=	1.6	
Slope Factor	C_s	=	1	(for angle < 15)
Specific Weight of Snow	γ	=	3.275	kN/m^3
Accumulation Factor	C_a	=	1	
Specified Snow Load	**S**	**=**	**3.44**	**kPa**
distributed load on cantilever		=	**13.76**	**kN/m**
Snow load applied to 1 beam		**=**	**4.3**	**kN/m**

Steel Section Checks

Column	**HS219x9.5**
Cantilever	**HS178x127x9.5**

yield strength	F_y	=	350	MPa	
Column Check					
moment stress in column, σ	My/I	=	**227.737**	**MPa**	
capacity		=	**315**	**MPa**	
	D/C	=	0.722975		**OK**
axial force in column	**N**	**=**	**57.45**	**kN**	
compression capacity	C_r	**=**	**1635.543**	**kN**	
	ϕ	=	0.9		
	λ	=	0.628107		
	D/C	=	0.035126		**OK**

Cantilever Check					
moment stress in colun	My/I	=	**287.2248387**	**MPa**	
capacity		=	**315**	**MPa**	
	D/C	=	0.911824885		**OK**

Bearing Capacity					
	ϕ_c	=	0.65		$B_r = 0.85\varphi_c f'_c A_1$
	f'_c	=	20	MPa	
bearing area required	A_1	=	5199.095	mm^2	[SMALLER THAN HSS SECTION]
Plate Chosen	**PL**	**=**	**250mm x 250mm x 15mm**		

Beam	**HS102x51x9.5**

yield strength	F_y	=	350	MPa	
Beam Check					
moment stress in column, σ	My/I	=	**287.5505**	**MPa**	
capacity		=	**315**	**MPa**	
	D/C	=	0.912859		**OK**
LTB moment capacity	M_r	**=**	**25.528**	**kNm**	**OK**
	D/C	=	0.529946		

Beam Column (P-Delta Effects) Check

Limit State 1 - Cross Sectional Strength				
Compressional resistance	C_r	=	1975.05	kN
	ϕ	=	0.9	
Moment resistance in x	M_{rx}	=	131.985	kNm
	ϕ	=	0.9	
	CLASS	=	1	[1, 2, 3]
Moment resistance in y	M_{ry}	=	131.985	kNm
	ϕ	=	0.9	
	CLASS	=	1	[1, 2, 3]
amplification factor	U_{1x}	=	1	must be >= 1
curvature (ratio of smaller/la	κ	=	1	[- for single curvature, + for double]
no transverse loads	ω_1	=	0.4	
distributed loads/close space	ω_1	=	1	
concentrated loads	ω_1	=	0.85	
final ω1	ω_1	=	0.4	[choose from above 3]
	C_f	=	57.45	kN
	C_e	=	5559.2057	
	β	=	0.6	
	λ_y	=	0	
$\frac{C_f}{C_r}+\frac{0.85U_{1x}M_{fx}}{M_{rx}}+\frac{\beta U_{1y}M_{fy}}{M_{ry}}\le 1.0$	Left Side	=	0.4909737	(Class 1,2 OK
		=	0.572483	(Class 3) OK
$\frac{M_{fx}}{M_{rx}}+\frac{M_{fy}}{M_{ry}}\le 1.0$	Left Side	=	0.5433951	OK

Limit State 2 - Overall Member Strength				
Compressional resistance	C_r	=	1635.54	kN
	ϕ	=	0.9	
	n	=	1.34	[1.34 for rolled, 2.24 for built up]
	λ_x	=	0.62811	
	λ_y	=	0.62811	
final λ	λ	=	0.62811	[choose max of 2 above, if uniaxial bending then buckling about bending axis]
Moment resistance in x	M_{rx}	=	131.985	kNm
Moment resistance in y	M_{ry}	=	131.985	kNm
amplification factor	U_{1x}	=	0.40418	[for braced, 1 for unbraced]
amplification factor	U_{1y}	=	0.40418	[for braced, 1 for unbraced]
	β	=	0.85	
$\frac{C_f}{C_r}+\frac{0.85U_{1x}M_{fx}}{M_{rx}}+\frac{\beta U_{1y}M_{fy}}{M_{ry}}\le 1.0$	Left Side	=	0.22181	(class 1,2) OK
		=	0.25475	(class 3) OK
$\frac{M_{fx}}{M_{rx}}+\frac{M_{fy}}{M_{ry}}\le 1.0$	Left Side	=	0.5434	OK

Limit State 3 - LTB Strength					
Compressional resistanc	C_r	=	1635.54	kN	
	λ	=	0.62811		
Moment resistance in x	M_{rx}	=	131.985	kNm	
	CLASS	=	1	[1, 2, 3]	
warping constant	C_w	=	3.1E+12	mm^6	
	κ	=	1	[enter which k to be used]	
	w_2	=	2.5	[for end moments only]	
unbraced length	L	=	3000	mm	[CHANGE]
	ϕ	=	0.9		
	M_u	=	16847.3	kNm	
If Class 1 or 2					
	M_p	=	146.65	kNm	
	$0.67M_p$	=	98.2555	kNm	
	M_r	=	131.985	kNm	
If Class 3					
	M_y	=	110.25	kNm	
	$0.67M_y$	=	73.8675	kNm	
	M_r	=	99.225	kNm	
Moment resistance in y	M_{ry}	=	131.985	kNm	
amplification factor	U_{1x}	=	0.40418	[not less than 1 for braced, 1 fo	
amplification factor	U_{1y}	=	0.40418	[for braced, 1 for unbraced]	
$\frac{C_f}{C_r}+\frac{0.85U_{1x}M_{fx}}{M_{rx}}+\frac{\beta U_{1y}M_{fy}}{M_{ry}}\le 1.0$	Left Side	=	0.22181	(Class 1,2	OK
		=	0.25475	(Class 3)	OK
$\frac{M_{fx}}{M_{rx}}+\frac{M_{fy}}{M_{ry}}\le 1.0$	Left Side	=	0.5434		OK

Seismic Lateral Force Calculation

2%/50 years (0.000404 per annum) probability

Distance	Latitude	Longitude	Sa (0.05)	Sa (0.1)	Sa (0.2)	Sa (0.3)	Sa (0.5)	Sa (1.0)	Sa (2.0)	Sa (5.0)	Sa (10.0)	PGA (g)	PGV (m/s)
0.000	49.261	-123.247	0.467	0.711	0.879	0.886	0.785	0.441	0.266	0.083	0.030	0.382	0.575

FIND BASE SHEAR					
height of the building	h_n	=	3.5	m	
fundamental period (moment frames)	T_a	=	0.217505	s	
fundamental period (braced frames)	T_a	=	0.0875	s	
spectral acc.	S_a	=	0.88	g	[from NRCAN]
amplification factor	$F(T_a)$	=	1		
design spectral acc.	S(T)	=	0.88		
	S(0.2)	=	0.879		[from NRCAN]
	S(0.5)	=	0.785		[from NRCAN]
	S(1.0)	=	0.441		[from NRCAN]
	S(2)	=	0.266		[from NRCAN]
seismic weight	W	=	7.5	kN	[calculate this]
	M_v	=	1		
importance factor	I_E	=	1		
	R_d	=	3.5		[assume moderately d
	R_o	=	1.5		
design base shear (lateral eq. force)	V	=	1.257143	kN	
	V_{min}	=	0.38	kN	
	V_{max}	=	1.121429	kN	
final design base shear	**V**	**=**	**1.121429**	**kN**	

Connections Calculation - Angles

Demands				
Distributed gravity loads on beam		=	6.787539	kN/m
Total gravity loads on beam		=	27.15016	kN
Lateral Load from Gravity Load		=	1.357508	kN
Seismic Lateral Load		=	1.12	kN
Design lateral load	**L**	**=**	**2.477508**	**kN**

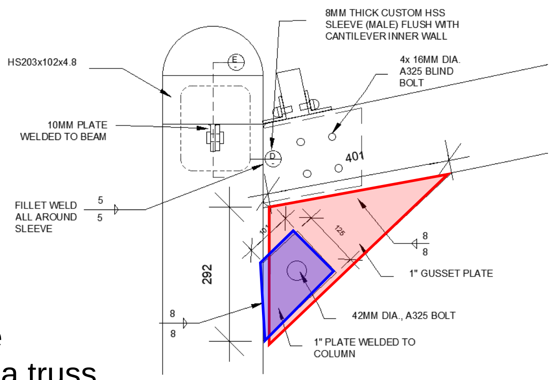
[assume 5% of gravity load] (Lateral Load from Gravity Load)

[see seismic lateral load next page] (Seismic Lateral Load)

Angle section chosen	**L51x51x6.4**				
thickness of angle	t	=	6.4	mm	
Bolt tensile strength	F_{ub}	=	825	MPa	
bolt diameter	d_b	=	12.7	mm	[1/2" bolt]
nominal bolt area	A_b	=	126.6769	mm^2	
steel part tensile strength	F_u	=	450	MPa	
steel part yield strength	F_y	=	350	MPa	

BOLT CAPACITY						
Threads not in shear plane						
	V_r	**=**	**100.3281**	kN		
	ϕ_b	=	0.8			
# of shear planes	m	=	1			
# of bolts in connection	n	=	2			[1 bolt on each side of beam]
Threads in shear plane						
	V_r	**=**	**70.22966**	**kN**	**OK**	[assuming worst case - threads in shear plane]
*if L >=760 mm, L being length between ends bolts, then 0.6 is now 0.5						
Threads not in shear plane	**V_r**	**=**	83.60673	kN		
Threads in shear plane	V_r	=	58.52471	kN		
Bearing capacity						
	B_r	**=**	**175.5648**	**kN**	**OK**	
	ϕ_{br}	=	0.8			
thickness of material	t	=	6.4	mm		[angle thickness governs, beam thickness = 9.5mm]
bolt diameter	d	=	12.7	mm		

Gusset Plate



B CONNECTION DETAIL

Note: Gusset plate assumed to act as a truss

Summary of D/C	D/C
Bearing Resistance	26%
Bolt Shear Restance (Axial)	78%
Bolt Shear Resistance (Combined)	61%
Combined Compression and Shear	62%
Compression	46%
Column Bearing	20%
Column Punching Shear	45%
Beam Punching Shear	45%
Weld Strength (Weld Material) (Axial)	84%
Weld Strength (Fuse) (Axial)	64%

Bearing Resistance		
Br = 3*alpha_br*n*t*d*Fu		
alpha_br	0.8	
n	1	
t	25.4	mm
d	42	mm
Br	1152.144	kN
Axial Demand	300	kN
Shear Demand	0	kN
Axial D/C	26%	
Shear D/C	0%	
Combine D/C	26%	

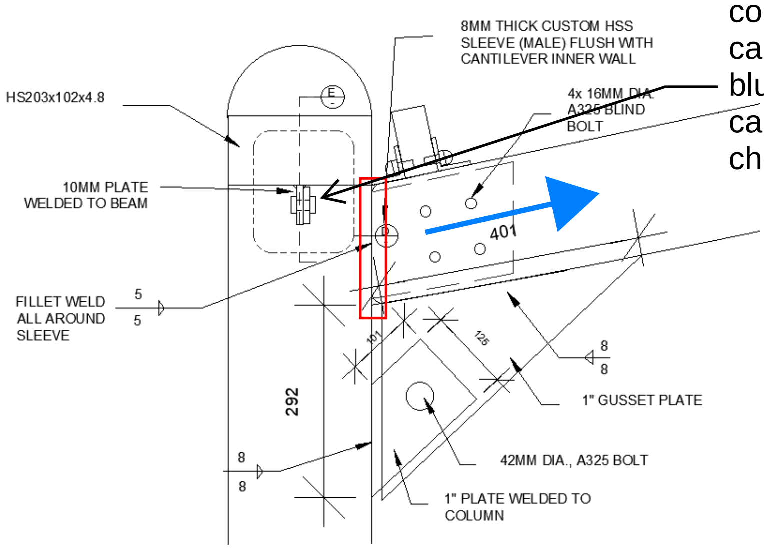
Bolt Resistance (Same for Both Inner and Outer Sleeve)		
Vr = 0.6*alpha_b*n*m*Ab*Fub*0.7		
alpha_b	0.8	
n	1	
m	1	
d	42	mm
Ab	1385.44236	mm^2
Fub	825	Mpa
Vr	384.0446223	kN
Axial Demand	300	kN
Shear Demand	0	kN
Axial D/C	78%	
Shear D/C	0%	
Combine D/C	61%	

Compression		
Slenderness Check		
kL/r		
k	1	
L	500	mm
rx	36.08439182	mm
ry	7.332348419	mm
kL/rx	13.85640646	
kL/Ry	68.19097668	
Slenderness <= 200?	**PASS**	
Compressive Resistance		
Cr = alpha*A*Fy*(1 + lamda^2n)^(-1/n)		
alpha	0.9	
n	1.34	
lamda = kL/r*sqrt(Fy/(pi()^2*E)	0.908021355	
(1 + lamda^2n)^(-1/n)	0.652459045	
Cr	652.5406026	kN
Compression Demand	300	kN
Capacity	46%	
Column / Beam Bearing Resistance		
Br = 1.5*alpha*Fy*A		
alpha	0.9	
Fy	350	Mpa
A	3175	mm^2
Br	1500.1875	kN
Demand (Max Tension,Compression)	300	kN
Capacity	20%	

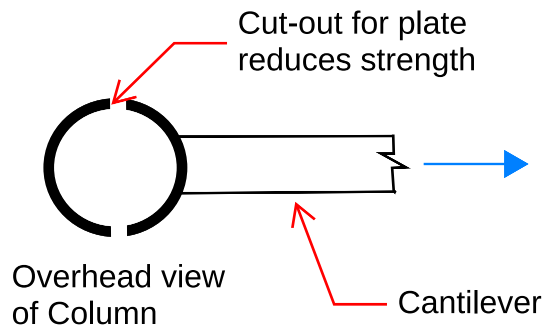
Shear Failure		
Vr	alpha*Aw*Fs	
alpha	0.9	
h	125	mm
w	25.4	mm
Aw = ht	3175	mm^2
Aw (minus bolt holes)	3091	mm^2
h/w	4.921259843	
kv	5.34	
sqrt(Kv/Fy)	0.123519808	
Fs	231	Mpa
Vr	642.6189	kN
Shear Demand	0	kN
Capacity	0%	

Weld Calculations		
Weld - Axial Strength		
Vr = 0.67*alphaw*Aw*Xu*(1+0.5*sin(theta)^1.5)*Mw		
alpha_w	0.67	
Throat	5.656854249	mm
Perimeter	250	mm
Aw	1414.213562	mm^2
Xu	490	Mpa
Theta	0	degrees
Theta	0	radians
Mw	1	
Vr	311.0718294	kN
Axial Force	300	kN
Assumed Angle	60	degrees
Shear Componenet of Axial	259.8076211	
D/C	84%	

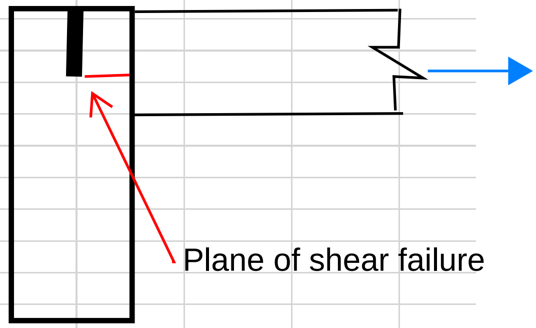
Base Metal Strength		
Vr = 0.67*alphaw*Am*Fu		
alpha_w	0.67	
Perimeter	250	mm
Am	2000	mm^2
Vr	404.01	kN
Axial Demand	259.8076211	kN
Axial D/C	64%	



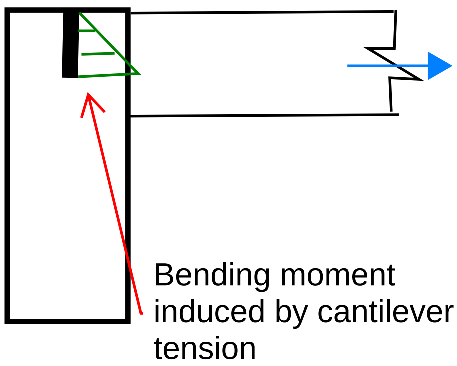
Beam slot connection reduces column strength against cantilever tension (shown in blue). Column ability to resist cantilever tension is the main check here.



Shear Resistance (Axial Resistance)	Refer to AISC Manual for Shear Design - *Specification for the Design of Hollow Structural Sections*	
V = alpha*Vn		
alpha	0.9	
Vn = 0.3*Fy*Ag	329.175	kN
V	296.2575	kN
a/D	0.04349612	
3.2*(E/Fy)^2/(D/t)^(2.5)	412.2875198	
D/t	22.99055614	
lamda_r = 0.114*E/Fy	65.14285714	
Check: D/t <= lamda_R	PASS	
Axial Demand	205	
D/C	69%	



Moment Resistance			
Moment Demand			
Axial Force	205	kN	
Moment Arm	40.00	mm	= Depth of Cantilever / 2
Moment Demand	8.20	kN*m	(Simplifying Assumption Made to be Conservative)
Moment Resistance (Half Circle)			
Mr = alpha*S*Fy			
Alpha	0.9		
S	49,143.14		
Mr	15.48	kN*m	
D/C	53%		
Combined Moment and Shear Resistance			
D/C	76%		



Compression (From Compressive Force)		
Slenderness Check		
kL/r		
k	1	
L	158.74	mm
rx	32.34833574	mm
kL/rx	4.91	
Slenderness <= 200?	**PASS**	
Compressive Resistance (From Axial Force)		
Cr = alpha*A*Fy*(1 + lamda^2n)^(-1/n)		
alpha	0.9	
n	1.34	
lamda = kL/r*sqrt(Fy/(pi()^2*E)	0.07	
(1 + lamda^2n)^(-1/n)	0.999501818	
Cr	987.0330333	kN
Compression Demand	150	kN
Capacity	15%	

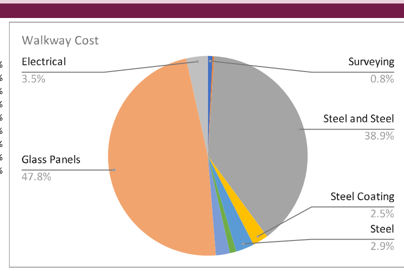
Appendix F - Quantity Takeoff and Cost Estimate

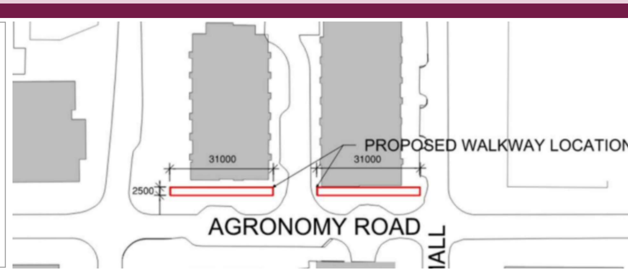
	Item Description	Quantity	Units	Unit Cost	Total Price	Subtotal
Site Preparation	Construction photographs and aerial photos - add for traffic control area	1.00	Ea	$561	$561	$115,207
	Surveying	1.58	ha	2,885.56	$4,544.75	
	Clearing	0.68	ha	$6,547	$4,419	
	Cold Milling Asphalt Pavement (W16 Ave - Thunderbird)	574.00	m3	$40	$22,926	
	Subgrade Excavation (W16 Ave - Stadium)	1,011.00	m3	$18	$17,700	
	Common Excavation (W16-Ave - Stadium)	1,140.00	m3	$5	$6,104	
	Removing Curb and Gutter	1,500.00	m	$35	$52,129	
	Removal and Disposal of Existing Signs 1 Post	10.00	units	$111	$1,114	
	Asphalt Surface (Removal and Dispose) - Asphalt Sidewalk	31.00	m3	$36	$1,109	
	Remove Concrete Surface (concrete sidewalk)	125.00	m2	$37	$4,600	
Road Construction	Curb and Gutter All Heights	1,500.00	m	$148	$221,823	$1,626,021
	Solid Concrete Median (assume for bike buffer from road)	1,360.00	m2	$148	$201,120	
	Raised Cycle Track (one way)	1,360.00	m	$292	$397,414	
	Concrete Sidewalk	318.00	m	$249	$79,034	
	Curb Ramps	8.00	Each	$920	$7,363	
	Bus Stop Curb Extentions (Standard Curb Extention)	1.00	Each	$23,498	$23,498	
	Standard Curb Extention	3.00	Each	$23,498	$70,493	
	Green Curb Extension	7.00	Each	$42,774	$299,415	
	Asphalt Concrete Pavement - EPS Mix Type H1 (PG58-34)	1,436.00	tonne	$139	$199,313	
	Granular Fill Pit Run (Des 6)	1,011.00	m3	$119	$120,572	
	Preparing Subgrade Surface (First Layer)	1,927.00	m2	$1	$2,712	
	Preparing Subgrade Surface (Second Layer)	1,927.00	m2	$2	$3,263	
Traffic Installations	Intersection Lines - Supplying Paint and Painting	2.00	Each	Each Int.	$621	$88,859
	Roadway Lines - Supplying Paint and Painting (Directional Dividing and 2 Edge	1.50	km	$820	$1,230	
	Parking Stall Lines	1,360.00	m	$3	$3,526	
	High Visibility Crosswalk	4.00	Each	$3,029	$12,117	
	RRFB	2.00	Each	$31,514	$63,029	
	Left Turn Arrow	8.00	Each	$228	$1,825	
	Bus Stop Sign Installation	2.00	Each	$137	$273	
	Cycling Wayfinding Signs	8.00	Each	$301	$2,410	
	Sign Installations (misc)	28.00	Each	$137	$3,828	
Walkway Insallation	Walkway Installation* (See walkway cost estimates for breakdown)	62.00	m	$5,988	$371,281	$371,281
Utilities, GSI, and Landscaping	Utility structures and utility vaults precast concrete - 6' x 12' x 6' high, I.D., 6"	1.00	Each	$15,088	$15,087.70	$664,530
	Utility line signs, markers, and flags	25.00	CLF	$14	$355.19	
	Rain garden (median)	19,257.00	sqft	$22	$429,268.84	
	Topsoil Supply and Place	5,602.00	m2	$25	$141,235.09	
	Adjust Catch Basin	26.00	Units	$1,292	$33,581.21	
	Adjust Manholes	12.00	Units	$940	$11,279.94	
	Trenching and Backfilling	950.00	sqft	$19	$17,764.96	
	Tree transplanting, tree removal, trees - deciduous / shade (8'-10' high / dig &	170.00	each	$69	$11,679.63	
	Sodding, bent grass sod, on sloped ground - over 6 M.S.F.	60.00	MSF	$71	$4,277.78	
	Total					$2,865,899
	Permitting (0.5%)					$14,329
	Bonding and Insurance Fee (5%)					$143,295
	With Management Fee (8%)					$229,272
	Contingency (10%)					$325,279
	With Contingency (10% Contingency)					**$3,578,074**

Walkway Price Estimate

Component									Equivalent	Source	Category	Assumptions	Unit Cost	Quantity	Units	Quanitity (Converted)	Price (O&P)
Surveying		Area (m^2)	Area (acres)														
	Surveying	352	0.0869995056						Topographical surveying, conventional, minimum	RSMeans	Topographical Surveying	Average cost between maximum and minimum. If area is less t	$2,226	0.08699950568	Acre		$2,226
																Subtotal	$2,226
Site Work and Demolition		Area Per Section (r	Number	Area (m2	Area (yd2)												
	Concrete Removal	1.44	16	23.04	27.55584				Concrete to 6" thick, hydraulic hammer, mesh reinforced	RSMeans	Demolish, Remove Pavement and Curbs		$14	27.55584	S.Y.		$389
		Length (m)	Length (L.F.)														
	Awning Removal	26	85.30183727						Deconcstruction of wood components: Porch Roof Framing	RSMeans	Deconstruction of Buidling Co	No value from RSMeans, similar category for wood framing usε	$2	$162	L.F.		307.9396325
																Subtotal	$696
Steel and Steel Fabrication		Section	Cross Section /	kg/m	Length Per	Number	Total Length	Weight (lb)									
									Total Material Cost, Shop Fabricated, Primed, Delivered	RSMeans	Structural Steel Projects		$2,475	11.30976	tonnes		$27,992
Steel Structural Sections																	
	Cantilever	HS178x127x9.5	5210	40.9	2.5	18	45	4049.1	Structural Tubing, rect. 5" to 6" wide, light Section	RSMeans	Columns, Structural		$1.66	4049.1	lb		$6,721.51
	Light Beam	HS203x102x4.8	2760	21.7	4	16	64	3055.36	Structural Tubing, rect. 5" x 3" x 1/4" x 12'-0"	RSMeans	Columns, Structural		$566	16	EA		$9,056
	Column	HS219x9.5	6270	49.3	3.5	18	63	6832.98	Interpolation of 8"-diameter x 14'-0" and 10"-diameter x 14	RSMeans	Columns, Structural	Interpolate between pipe prices for HSS section. Linear interpo	$793.11	18	EA		$14,276.06
	Structural Beam	HS102x51x9.5	2310	18.1	4	32	128	5096.96	Estimation: Structural Tubing, sq, 4"x4"x1/4"x12'-0"	RSMeans	Columns, Structural	Next smallest size (section not provided in RSMeans)	$312.50	18	EA		$5,625.00
	Supporting Joist	HS76x51x3.2	741	5.82	2.5	112	280	3585.12	Estimation: Structural Tubing, sq, 4"x4"x1/4"x12'-0"	RSMeans	Columns, Structural	Next smallest size (section not provided in RSMeans)	$312.50	32			$10,000.00
	Base Plate		Weight per sec	16.5		18		297	Column Base Plate, Light, Up to 150 lb	RSMeans	Structural Steel Projects		$2.05	297	lb		$608.85
	Weight Increase Factor (see table below)									RSMeans	Structural Steel Properties	Increase Based on Weight Factor	50.00%				$37,140
	Weight Factor	**Max weight (tons)**	**Weight Increase**		Total (tons)	11.30976											
0	Less than 2 tons	0	100.00%		Increase Fac	50.00%											
	2 to 9 tons	2	75.00%														
	10 to 24 tons	9	50.00%														
	25 to 49 tons	24	30.00%														
	50 to 74 tons	49	20.00%														
	75 to 99 tons	74	10.00%														
																Subtotal	$111,419
Steel Coatings and Finishes		Section	Perimeter (mr	Length	Surface Are	Surface Area (S.F.)											
	Cantilever	HS178x127x9.5	0.61	45	27.45	590.9386819			Non sacrificial, permanent non-stick coating, clear, on meta	RSMeans	Graffiti Resistant Coatings		**$2.49**	**590.9386819**	**S.F.**		**$1,471.44**
	Light Beam	HS203x102x4.8	0.612	64	39.168	843.2016864			Non sacrificial, permanent non-stick coating, clear, on meta	RSMeans	Graffiti Resistant Coatings		**$2.49**	**843.2016864**	**S.F.**		**$2,099.57**
	Column	HS219x9.5	0.6880087911	63	43.3445538	933.1137892			Non sacrificial, permanent non-stick coating, clear, on meta	RSMeans	Graffiti Resistant Coatings		**$2.49**	**933.1137892**	**S.F.**		**$2,323.45**
	Cantilever	HS178x127x9.5	0.61	45	27.45	590.9386819			Cold Galvanizing, brush in field	RSMeans	Exterior Steel Coatings		$0.57	**590.9386819**	**S.F.**		**$336.84**
	Light Beam	HS203x102x4.8	0.612	64	39.168	843.2016864			Cold Galvanizing, brush in field	RSMeans	Exterior Steel Coatings		$0.57	**843.2016864**	**S.F.**		**$480.62**
	Column	HS219x9.5	0.6880087911	63	43.3445538	933.1137892			Cold Galvanizing, brush in field	RSMeans	Exterior Steel Coatings		$0.57	**933.1137892**	**S.F.**		**$531.87**
																Subtotal	$7,243.80
Steel Connections																	
Steel Fasteners		Bolts Per Column	Number of Co	Total Bolts													
	Anchor Bolts	6	18	108					Single Bolt Installed in Fresh Concrete, Hooked w/ nut and v	RSMeans	Anchor Bolts		**$5.49**	**108**	**E.A.**		**$592.92**
	High Strengh Bolts	**16**	**18**	**288**					**A325 Type 1, structural steel, bolt-nut-washer set**	**RSMeans**	**High Strength Bolts**	**Assume all are 5/8" diameter (various types, assumed to be s**	**$7.60**	**288**	**E.A.**		**$2,188.80**
	Drilling Steel	**16**	**18**	**288**					**Drilling and layout for steel, up to 1/4" deep, no anchor**	**RSMeans**	**Drilling Steel**	**Assume all ar 5/8" diameter**	**$7.93**	**288**	**E.A.**		**$2,283.84**
Welding		Length Per Segme	Segements	Total W	Total Weld Length (ft)												
	Weld	**2.8**	**18**	**50.4**	**165.354330**				**Continuous fillet, stick welding, incl. equipment**	**RSMeans**	**Welding Steel**	**Assume fillet welds, 3/16" - 1/4", ignore bevel welds**	**$20.15**	**165.3543307**	**E.A.**		**$3,331.06**
																Subtotal	$8,396.62
Concrete			Volume (m^3)	Volume	Number	Total Volume (cu.yd)											
	Footings	818x819x400	0.2683044	0.35303	22	7.766706316			Footings (3000 psi), spread under 1 C.Y.	RSMeans	0330 Cast in Place Concrete		$369.60	7.766706316	C.Y.		$2,870.57
		349x349x150	0.01827015	0.02403	22	0.528872763			Footings (3000 psi), spread under 1 C.Y.	RSMeans	0330 Cast in Place Concrete		$369.60	0.5288727632	C.Y.		$195.47
																Subtotal	$3,066.05
Gutters and Drainage		Length (m)	Length (l.f.)														
	Gutter	62	203.4120735						Copper gutters, half round, 16 ounce, stock units, 6" wide	RSMeans			$16.10	203.4120735	L.F.		$3,274.93
	Downspout	63	206.6929134						Copper downspouts, round, stock, 16 ounce, 4" diameter	RSMeans			$15.51	206.6929134	L.F.		$3,205.81
																Subtotal	$6,480.74
Glass Panels		Width (m)	Length (m)	Area (sq	Area (sq.ft)												
	Glass Panel	2.5	62	155	1668.40611				Glass, full vision window system, 3/4" inch glass mullions, 1	RSMeans		Assumed window installation cost same as glass panel installat	$82	1668.406115	S.F.		$136,809
																Subtotal	$136,809
Electrical		Number															
	Lighting	10							Roadway Area Luminaire, Low Pressure Sodium, 135 Watt	RSMeans	Roadway Area Luminaire	Assumed roadway luminaire equivalent of walkway lighting	$1,008	10	Ea.		$10,080
																Subtotal	$10,080
																Total	$286,417

Cost Breakdown Cost		Percentage
Surveying	$2,226	0.78%
Site Preparation	$696	0.24%
Steel and Steel Fa	$111,419	38.90%
Steel Coating and	$7,243.80	2.53%
Steel Connection	$8,396.62	2.93%
Concrete	$3,066.05	1.07%
Gutters and Drai	$6,480.74	2.26%
Glass Panels	$136,809	47.77%
Electrical	$10,080	3.52%
Total	$286,417	





Appendix G - Detailed Construction Schedule

Inputs
Intermediate Calculations
Outputs

Project Start Date	Monday, May 10, 2021
Total Number of Work Days	185
Done Before...	Monday, January 31, 2022

Task ID	Task Name	Min (Days)	Max (Days)	Most Likely Duration (Days)	Simulated Days
0	Start	0	0	0	0
1	Complete bidding to contractors	1	10	7	8
2	Mobilization	2	4	3	4
3	Setup traffic controls	1	1	1	1
4	Construction stakeout	2	4	3	2
5	Stockpile precast material (walkway)	21	42	35	31
6	A1 Northbound Demolitions	5	10	8	5
7	A1 Utility Relocations	7	14	12	12
8	A1 Install Stormwater Systems	2	4	3	3
9	A1 Pavement Overlay	5	8	7	5
10	A1 Curb Repair	2	5	4	4
11	A1 Southbound Demolitions	5	10	8	8
12	A1 Install Stormwater Systems	2	4	3	3
13	A1 Pavement Overlay	5	8	7	7
14	A1 Curb Repair	2	5	4	4
15	A2 Northbound Demolitions	5	10	8	8
16	A2 Utility Relocations	7	14	12	10
17	A2 Install Stormwater Systems	2	4	3	3
18	A2 Pavement Overlay	5	8	7	6
19	A2 Curb Repair	2	5	4	4
20	A2 Southbound Demolitions	5	10	8	7
21	A2 Install Stormwater Systems	2	4	3	2
22	A2 Pavement Overlay	5	8	7	7
23	A2 Curb Repair	2	5	4	3
24	A3 Northbound Demolitions	5	10	8	9
25	A3 Utility Relocations	7	14	12	11
26	A3 Install Stormwater Systems	2	4	3	3
27	A3 Pavement Overlay	5	8	7	6
28	A3 Curb Repair	2	5	4	4
29	A3 Southbound Demolitions	5	10	8	8
30	A3 Install Stormwater Systems	2	4	3	3
31	A3 Pavement Overlay	5	8	7	6
32	A3 Curb Repair	2	5	4	3
33	Fill topsoil, seed rain garden	2	4	3	3
34	B1 Demolish curb for walkway footings	2	4	3	4
35	B1 Install walkway footing + columns	5	9	8	9
36	B1 Install walkway roof	1	3	2	1
37	Re-paint road markings	2	3	3	2
38	Field inspection and as built survey	3	7	6	5
39	Demobilize	7	10	9	8
40	Finish	0	0	0	0

Task ID	Immediate Predecssor						EF of Predecessor						ES	EF
0	0						0	0	0	0	0	0	0	0
1	0						0	0	0	0	0	0	0	8
2	1						8.35	0	0	0	0	0	8.35	12
3	2						11.9	0	0	0	0	0	11.9	13
4	3						12.9	0	0	0	0	0	12.9	15
5	1						8.35	0	0	0	0	0	8.35	39
6	4						15	0	0	0	0	0	15	20
7	6						20.3	0	0	0	0	0	20.3	32
8	7						32.1	0	0	0	0	0	32.1	36
9	8						35.5	0	0	0	0	0	35.5	41
10	9						40.9	0	0	0	0	0	40.9	45
11	10						45.1	0	0	0	0	0	45.1	53
12	11						53.2	0	0	0	0	0	53.2	56
13	12						56.2	0	0	0	0	0	56.2	63
14	13						63.4	0	0	0	0	0	63.4	68
15	14						67.6	0	0	0	0	0	67.6	76
16	15						75.8	0	0	0	0	0	75.8	86
17	16						85.9	0	0	0	0	0	85.9	89
18	17						88.7	0	0	0	0	0	88.7	95
19	18						95.1	0	0	0	0	0	95.1	99
20	19						99.2	0	0	0	0	0	99.2	107
21	20						107	0	0	0	0	0	107	109
22	21						109	0	0	0	0	0	109	116
23	22						116	0	0	0	0	0	116	119
24	23						119	0	0	0	0	0	119	128
25	24						128	0	0	0	0	0	128	139
26	25						139	0	0	0	0	0	139	142
27	26						142	0	0	0	0	0	142	148
28	27						148	0	0	0	0	0	148	152
29	28						152	0	0	0	0	0	152	160
30	29						160	0	0	0	0	0	160	163
31	30						163	0	0	0	0	0	163	169
32	31						169	0	0	0	0	0	169	172
33	30						163	0	0	0	0	0	163	166
34	5						39.4	0	0	0	0	0	39.4	43
35	34						43	0	0	0	0	0	43	52
36	35						51.8	0	0	0	0	0	51.8	53
37	31						169	0	0	0	0	0	169	171
38	32	33	36	37			172	166	52.9	171	0	0	172	177
39	38						177	0	0	0	0	0	177	185
40	39						185	0	0	0	0	0	185	185

Task ID	Immediate Successor						LS of Successor						LS	LF	TF	Critical?
0	1						0.0						0	0	0	
1	2	5					8.3	127.5					0	8	0	Critical
2	3						11.9						8	12	0	Critical
3	4						12.9						12	13	0	Critical
4	6						15.0						13	15	0	Critical
5	34						158.6						128	159	119	
6	7						20.3						15	20	0	Critical
7	8						32.1						20	32	0	Critical
8	9						35.5						32	36	0	Critical
9	10						40.9						36	41	0	Critical
10	11						45.1						41	45	0	Critical
11	12						53.2						45	53	0	Critical
12	13						56.2						53	56	0	Critical
13	14						63.4						56	63	0	Critical
14	15						67.6						63	68	0	Critical
15	16						75.8						68	76	0	Critical
16	17						85.9						76	86	0	Critical
17	18						88.7						86	89	0	Critical
18	19						95.1						89	95	0	Critical
19	20						99.2						95	99	0	Critical
20	21						106.6						99	107	0	Critical
21	22						109.0						107	109	0	Critical
22	23						116.0						109	116	0	Critical
23	24						119.3						116	119	0	Critical
24	25						127.9						119	128	0	Critical
25	26						139.0						128	139	0	Critical
26	27						142.1						139	142	0	Critical
27	28						148.2						142	148	0	Critical
28	29						152.3						148	152	0	Critical
29	30						160.0						152	160	0	Critical
30	31	33					162.6	168.8					160	163	0	Critical
31	32	37					168.6	170.0					163	169	0	Critical
32	38						172.1						169	172	0	Critical
33	38						172.1						169	172	6	
34	35						162.2						159	162	119	
35	36						171.0						162	171	119	
36	38						172.1						171	172	119	
37	38						172.1						170	172	1	
38	39						177.1						172	177	0	Critical
39	40						184.9						177	185	0	Critical
40													185	185	0	Critical

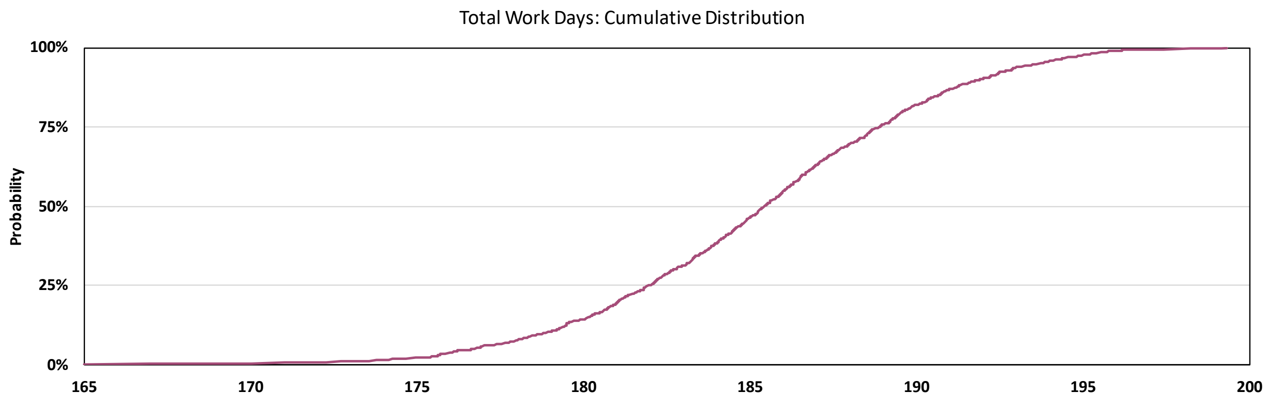
Values for Calendar Calculations

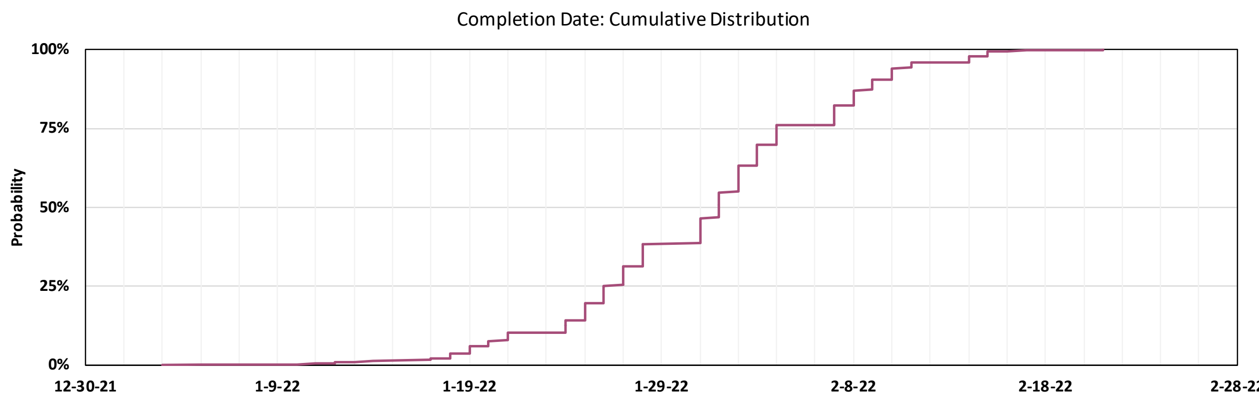
Task ID	Labels	ES	Earliest Done by...	Latest Date Done by...	Early Duration (Inc. Time Off)	Float (Inc. Time Off)
0						
1	Complete bidding to contractors*	2021-05-10	2021-05-20	2021-05-20	10	0
2	Mobilization*	2021-05-20	2021-05-26	2021-05-26	6	0
3	Setup traffic controls*	2021-05-26	2021-05-27	2021-05-27	1	0
4	Construction stakeout*	2021-05-27	2021-06-01	2021-06-01	5	0
5	Stockpile precast material (walkway)	2021-05-20	2021-07-06	2021-12-24	47	171
6	A1 Northbound Demolitions*	2021-06-01	2021-06-08	2021-06-08	7	0
7	A1 Utility Relocations*	2021-06-08	2021-06-24	2021-06-24	16	0
8	A1 Install Stormwater Systems*	2021-06-24	2021-06-29	2021-06-29	5	0
9	A1 Pavement Overlay*	2021-06-29	2021-07-07	2021-07-07	8	0
10	A1 Curb Repair*	2021-07-07	2021-07-14	2021-07-14	7	0
11	A1 Southbound Demolitions*	2021-07-14	2021-07-26	2021-07-26	12	0
12	A1 Install Stormwater Systems*	2021-07-26	2021-07-29	2021-07-29	3	0
13	A1 Pavement Overlay*	2021-07-29	2021-08-10	2021-08-10	12	0
14	A1 Curb Repair*	2021-08-10	2021-08-16	2021-08-16	6	0
15	A2 Northbound Demolitions*	2021-08-16	2021-08-26	2021-08-26	10	0
16	A2 Utility Relocations*	2021-08-26	2021-09-10	2021-09-10	15	0
17	A2 Install Stormwater Systems*	2021-09-10	2021-09-15	2021-09-15	5	0
18	A2 Pavement Overlay*	2021-09-15	2021-09-24	2021-09-24	9	0
19	A2 Curb Repair*	2021-09-24	2021-09-30	2021-09-30	6	0
20	A2 Southbound Demolitions*	2021-09-30	2021-10-12	2021-10-12	12	0
21	A2 Install Stormwater Systems*	2021-10-12	2021-10-15	2021-10-15	3	0
22	A2 Pavement Overlay*	2021-10-15	2021-10-25	2021-10-25	10	0
23	A2 Curb Repair*	2021-10-25	2021-10-29	2021-10-29	4	0
24	A3 Northbound Demolitions*	2021-10-29	2021-11-10	2021-11-10	12	0
25	A3 Utility Relocations*	2021-11-10	2021-11-26	2021-11-26	16	0
26	A3 Install Stormwater Systems*	2021-11-26	2021-12-02	2021-12-02	6	0
27	A3 Pavement Overlay*	2021-12-02	2021-12-10	2021-12-10	8	0
28	A3 Curb Repair*	2021-12-10	2021-12-16	2021-12-16	6	0
29	A3 Southbound Demolitions*	2021-12-16	2021-12-28	2021-12-28	12	0
30	A3 Install Stormwater Systems*	2021-12-28	2021-12-30	2021-12-30	2	0
31	A3 Pavement Overlay*	2021-12-30	2022-01-07	2022-01-07	8	0
32	A3 Curb Repair*	2022-01-07	2022-01-13	2022-01-13	6	0
33	Fill topsoil, seed rain garden	2021-12-30	2022-01-04	2022-01-13	5	9
34	B1 Demolish curb for walkway footin	2021-07-06	2021-07-12	2021-12-30	6	171
35	B1 Install walkway footing + columns	2021-07-12	2021-07-22	2022-01-12	10	174
36	B1 Install walkway roof	2021-07-22	2021-07-23	2022-01-13	1	174
37	Re-paint road markings	2022-01-07	2022-01-11	2022-01-13	4	2
38	Field inspection and as built survey*	2022-01-13	2022-01-20	2022-01-20	7	0
39	Demobilize*	2022-01-20	2022-01-31	2022-01-31	11	0
40						

Holidays in BC	
New Year's	2021-01-01
Family Day	2021-02-15
Good Friday	2021-04-02
Victoria Day	2021-05-24
Canada Day	2021-07-01
BC Day	2021-08-02
Labour Day	2021-09-06
Thanksgiving Day	2021-10-11
Remembrance Day	2021-11-11
Christmas Day	2021-12-25

Axis Bounds in Number

2021-05-10	44326.00
2022-01-31	44592.00





Statistic	Work Days...	Done by...
Average	186	2022-01-31
5% probability project is done by...	177	2022-01-19
50% probability project is done by...	186	2022-02-01
95% probability project is done by...	193	2022-02-11

Appendix H - Roadway Life Cycle Analysis

PAVEMENT LCA SUMMARY

General Inputs

Analysis Period	50
Number of LCA Simulations	1000

Roadway Inputs

Dimensions

Road Length (mi)	0.56
Lane Width (ft)	11.3
Number of Lanes	2
Shoulder Width (ft)	0
Number of Shoulders	0

Condition

Base Aggregate Bulk Density (kg/m^3)	1500
Percent Bitumen by Mass (%)	6.00%
Contructed IRI (m/km)	1
Maximum IRI (m/km)	1.21, 1.26, 1.31, 1.36, 1.46, 1.56, 1.76, 1.96, 2.16, 2.36, 2.56, 2.76, 2.96, 3.16, 3.36, 3.56, 3.76, 3.96

Design Inputs

Design 1

Asphalt Thickness (in)	1.96
Asphalt Structural-Layer Coefficient	0.4
Asphalt Drainage Coefficient	1
Aggregate Thickness (in)	6
Aggregate Structural-Layer Coefficient	0.1
Aggregate Drainage Coefficient	1
SN1	1.38

Design 2

Asphalt Thickness (in)	2.36
Asphalt Structural-Layer Coefficient	0.4
Asphalt Drainage Coefficient	1
Aggregate Thickness (in)	6
Aggregate Structural-Layer Coefficient	0.1
Aggregate Drainage Coefficient	1.00
SN2	1.54

Design 3 (Selected Design)

Asphalt Thickness (in)	2.756
Asphalt Structural-Layer Coefficient	0.4
Asphalt Drainage Coefficient	1
Aggregate Thickness (in)	6
Aggregate Structural-Layer Coefficient	0.1
Aggregate Drainage Coefficient	1
SN3	1.70

Traffic Inputs

Speed Limit (mph)	30

Average Annual Daily Traffic (AADT)

Initial AADT	6231
Initial Percent of Small Trucks	0.00%
Initial Percent of Medium Trucks	1.00%
Initial Percent of Large Trucks	0.00%

Congestion Inputs

Duration

Construction Duration	43
Maintenance Duration	14

Traffic Impacts

Percent of Passenger Cars Impacted	16.70%
Percent of Trucks Impacted	16.70%

Fuel Economy

Initial Gallon per Mile for Light Duty Vehicles (LDVs)	2.86E-02
Initial Gallon per Mile for Heavy Duty Vehicles (HDVs)	0.139832

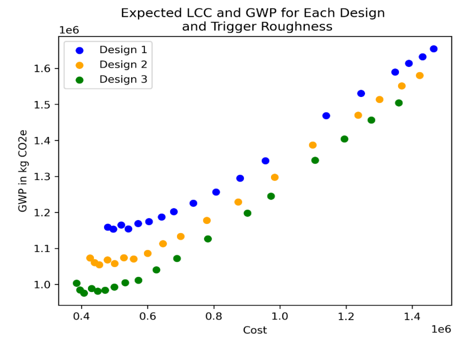
GWP Inputs

Geographic Location	Proxy for Vancouver:	Seattle
Current Albedo		0.12
Embodied Impacts Input File Name		Input_Processes.xls
Embodied Impacts Input File Path		ads\Pave-Save\Input_Processes.xls

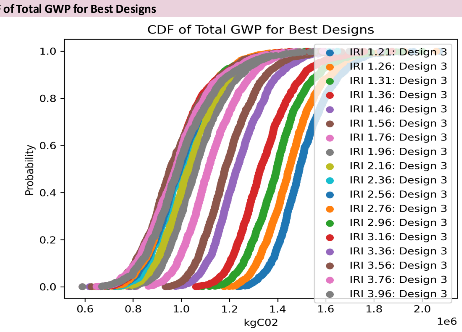
Cost Inputs

Discount Rate	1.70%
Use Price Index	TRUE

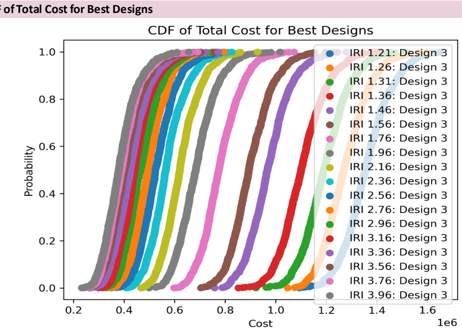
Expected LCC and GWP for Each Design and Trigger Roughness



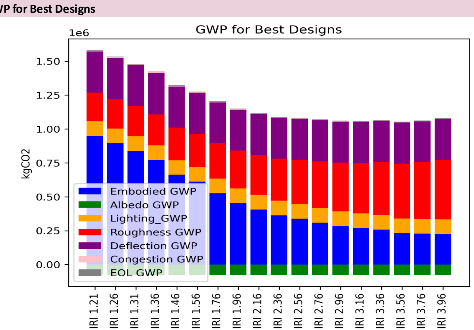
CDF of Total GWP for Best Designs



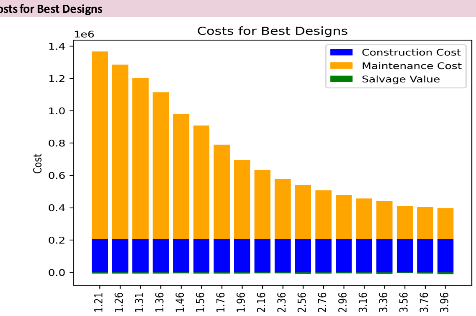
CDF of Total Cost for Best Designs



GWP for Best Designs



Costs for Best Designs



Sample Global Warming Potential (kg $CO2_e$) & Costs for Select IRI Trigger Values

Poor Maintenance Triggers (1.21,2.96,3.96)

Only some values shown as sample. Charts display all analysis trigger values

Optimal Maintenance Range (3.16-3.56)

IRI 1.21

	Avg Des. 1	% Des. 1	Avg Des. 2	% Des. 2	Avg Des. 3	% Des. 3
Embodied GWP	1003684.55	60.67	984241.199	62.28	949276.775	63.1
Albedo GWP	-77846.5314	-4.71	-77846.5314	-4.93	-77846.5314	-5.17
Lighting_GWP	108360.135	6.55	108360.135	6.86	108360.135	7.2
Roughness GWP	229879.012	13.89	218488.929	13.83	211896.878	14.09
Deflection GWP	379797.173	22.96	336459.311	21.29	302059.197	20.08
Congestion GWP	6014.15147	0.36	5906.7863	0.37	5714.21572	0.38
EOL GWP	4566.98779	0.28	4745.90994	0.3	4923.04286	0.33
Total GWP	1654455.48	100	1580355.74	100	1504383.71	100
Construction Cost	186240.54	12.71	196731.666	13.83	206959.144	15.22
Maintenance Cost	1285330.63	87.73	1233660.25	86.72	1160578.6	85.37
Salvage Value	-6550.58594	-0.45	-7893.96664	-0.55	-8058.72281	-0.59
Total Cost	1465020.59	100	1422497.95	100	1359479.02	100

IRI 2.96

	Avg Des. 1	% Des. 1	Avg Des. 2	% Des. 2	Avg Des. 3	% Des. 3
Embodied GWP	388010.432	33.04	336974.413	31.36	283543.701	28.82
Albedo GWP	-77846.5314	-6.63	-77846.5314	-7.25	-77846.5314	-7.91
Lighting_GWP	108360.135	9.23	108360.135	10.09	108360.135	11.01
Roughness GWP	371511.834	31.64	365489.659	34.02	360343.731	36.63
Deflection GWP	377376.855	32.14	334737.093	31.15	302906.577	30.79
Congestion GWP	2366.70028	0.2	2005.02635	0.19	1573.36481	0.16
EOL GWP	4566.98779	0.39	4745.90994	0.44	4923.04286	0.5
Total GWP	1174346.41	100	1074465.7	100	983,804.02	100
Construction Cost	186240.54	30.84	196731.666	37.25	206959.144	43.88
Maintenance Cost	424060.681	70.23	341948.229	64.75	271203.329	57.5
Salvage Value	-6471.87683	-1.07	-10584.4067	-2	-6541.79679	-1.39
Total Cost	603829.344	100	528095.488	100	471620.676	100

IRI 3.96

	Avg Des. 1	% Des. 1	Avg Des. 2	% Des. 2	Avg Des. 3	% Des. 3
Embodied GWP	293428.719	25.31	255504.224	23.8	225155.149	22.44
Albedo GWP	-77846.5314	-6.71	-77846.5314	-7.25	-77846.5314	-7.76
Lighting_GWP	108360.135	9.35	108360.135	10.1	108360.135	10.8
Roughness GWP	452469.376	39.03	446647.355	41.61	439460.232	43.79
Deflection GWP	376596.127	32.48	334441.188	31.16	302285.732	30.12
Congestion GWP	1746.64221	0.15	1472.21309	0.14	1221.99972	0.12
EOL GWP	4566.98779	0.39	4745.90994	0.44	4923.04286	0.49
Total GWP	1159321.46	100	1073324.49	100	1003559.76	100
Construction Cost	186240.54	38.85	196731.666	46.2	206959.144	53.77
Maintenance Cost	301780.223	62.96	240533.383	56.49	189907.081	49.34
Salvage Value	-8682.73124	-1.81	-11466.9806	-2.69	-11943.1479	-3.1
Total Cost	479338.032	100	425798.069	100	384923.077	100

IRI 3.16

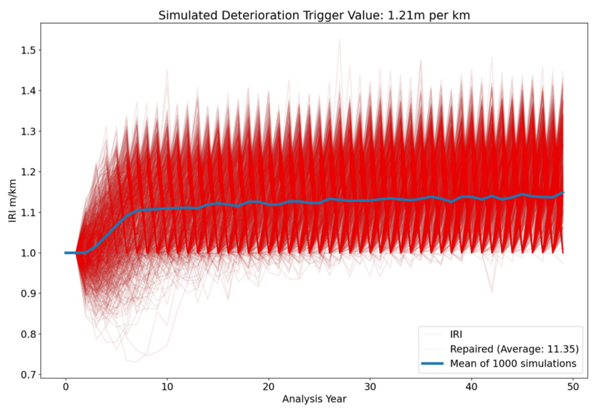
	Avg Des. 1	% Des. 1	Avg Des. 2	% Des. 2	Avg Des. 3	% Des. 3
Embodied GWP	367010.633	31.39	304571.828	28.79	268884.077	27.41
Albedo GWP	-77846.5314	-6.66	-77846.5314	-7.36	-77846.5314	-7.93
Lighting_GWP	108360.135	9.27	108360.135	10.24	108360.135	11.04
Roughness GWP	389468.789	33.31	380172.191	35.94	373019.6	38.02
Deflection GWP	375492.06	32.11	336079.127	31.77	302276.719	30.81
Congestion GWP	2242.74672	0.19	1751.9043	0.17	1465.80063	0.15
EOL GWP	4566.98779	0.39	4745.90994	0.45	4923.04286	0.5
Total GWP	1169294.82	100	1057834.56	100		100
Construction Cost	186240.54	32.59	196731.666	39.35	206,959.14	46.13
Maintenance Cost	394834.414	69.09	308917.049	61.79	249908.311	55.7
Salvage Value	-9610.83583	-1.68	-5670.74949	-1.13	-8206.09651	-1.83
	571464.118	100	499977.965	100		100

IRI 3.36

	Avg Des. 1	% Des. 1	Avg Des. 2	% Des. 2	Avg Des. 3	% Des. 3
Embodied GWP	337604.539	29.25	296739.168	27.78	257565.265	26.05
Albedo GWP	-77846.5314	-6.75	-77846.5314	-7.29	-77846.5314	-7.87
Lighting_GWP	108360.135	9.39	108360.135	10.14	108360.135	10.96
Roughness GWP	403537.544	34.97	398919.539	37.34	392623.775	39.71
Deflection GWP	375794.993	32.56	335682.071	31.42	301663.002	30.51
Congestion GWP	1995.50483	0.17	1749.04436	0.16	1428.70209	0.14
EOL GWP	4566.98779	0.4	4745.90994	0.44	4923.04286	0.5
Total GWP	1154013.17	100	1068349.34	100	988,717.39	100
Construction Cost	186240.54	34.4	196731.666	41.12	206959.144	48.09
Maintenance Cost	361182.536	66.72	292483.606	61.13	233563.751	54.27
Salvage Value	-6093.46985	-1.13	-10734.6028	-2.24	-10171.2027	-2.36
Total Cost	541329.606	100	478480.669	100	430351.692	100

IRI 3.56

	Avg Des. 1	% Des. 1	Avg Des. 2	% Des. 2	Avg Des. 3	% Des. 3
Embodied GWP	331550.775	28.46	268015.726	25.42	232180.467	23.79
Albedo GWP	-77846.5314	-6.68	-77846.5314	-7.38	-77846.5314	-7.97
Lighting_GWP	108360.135	9.3	108360.135	10.28	108360.135	11.1
Roughness GWP	421451.086	36.17	413477.779	39.21	405102.255	41.5
Deflection GWP	375027.588	32.19	336139.082	31.88	302240.449	30.96
Congestion GWP	2021.20548	0.17	1500.79504	0.14	1192.42159	0.12
EOL GWP	4566.98779	0.39	4745.90994	0.45	4923.04286	0.5
Total GWP	1165131.24	100	1054392.9	100	976152.24	100
Construction Cost	186240.54	35.8	196731.666	43.33	206959.144	50.79
Maintenance Cost	345202.354	66.35	261914.445	57.69	205201.749	50.36
Salvage Value	-11172.0846	-2.15	-4655.43857	-1.03	-4696.46884	-1.15
Total Cost	520270.809	100	453990.672	100	407464.424	100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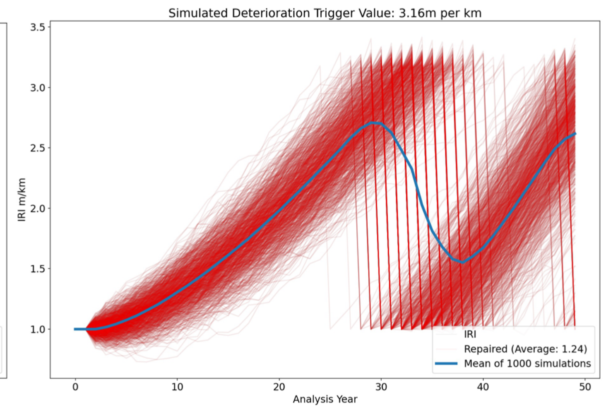
IRI m/km
Analysis Year
IRI
Repaired (Average: 11.35)
Mean of 1000 simulations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IRI m/km
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IRI
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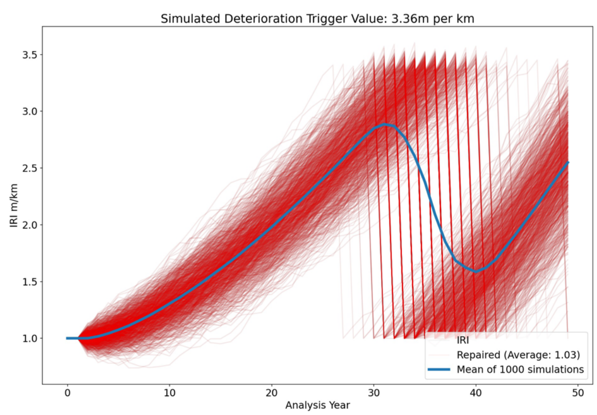
Mean of 1000 simulations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IRI m/km
Analysis Year
IRI
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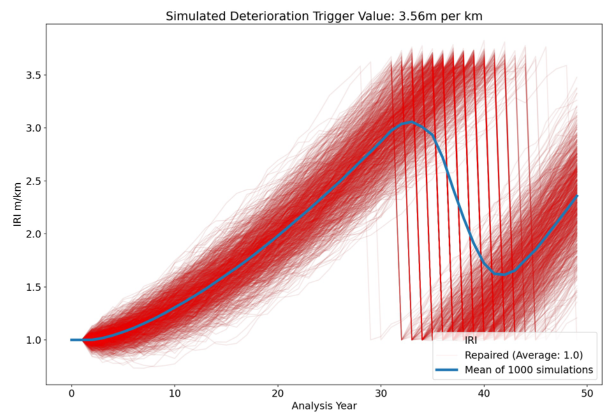
Mean of 1000 simulations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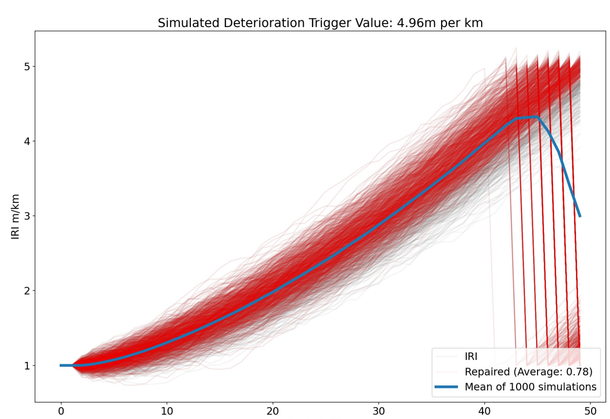
IRI m/km
Analysis Year
IRI
Repaired (Average: 1.0)
Mean of 1000 simulations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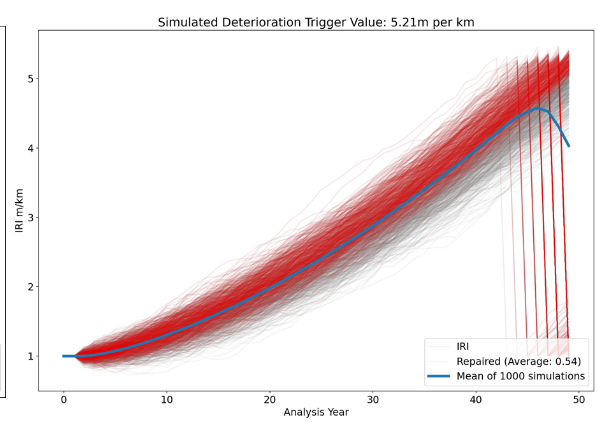
IRI m/km
Analysis Year
IRI
Repaired (Average: 0.78)
Mean of 1000 simulations


Simulated Deterioration Trigger Value: 5.21m per km
IRI m/km
Analysis Year
IRI
Repaired (Average: 0.54)
Mean of 1000 simulations