UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Corridor Redesign of Chancellor Boulevard - Team 17

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University of British Columbia

CIVL 445

Themes: Transportation, Community, Land

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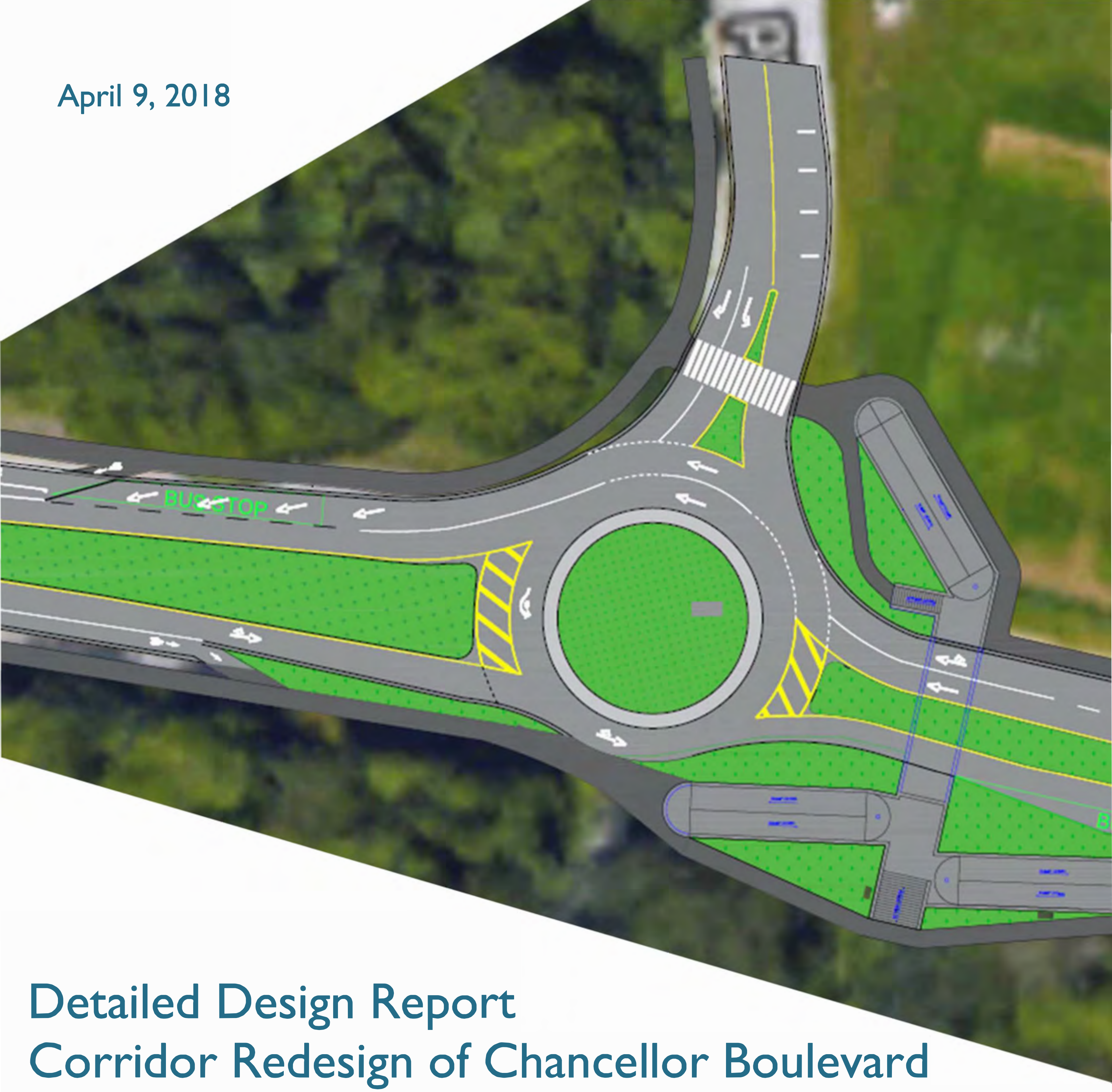

Detailed Design Report
Corridor Redesign of Chancellor Boulevard

Submitted by: Team 17

Client:

THE UNIVERSITY OF BRITISH COLUMBIA

SEEDS Sustainability Program

Consultant:

DTS Engineering

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Date: April 9, 2018

To: University of British Columbia

Campus and Community Planning

UBC SEEDS Sustainability Program

RE: Corridor Redesign of Chancellor Boulevard – Detailed Design Report

At the request of the University of British Columbia – Campus and Community Planning, Dynamic Transportation Solutions (DTS) Engineering is pleased to submit the detailed design report for the Corridor Redesign of Chancellor Boulevard.

This report outlines the detailed design of all the key features including roadway design, underpass design, drainage, and lighting. We have also included a construction schedule, along with phasing diagrams, which is anticipated to commence in May of 2018. Lastly, an economic analysis was completed, and the project costs were estimated to be approximately $6.58M to construct. In addition to the report, sample calculations can be found in the Appendices. Detailed drawings and design and construction specifications are included as well.

We look forward to the continued partnership with the University of British Columbia on this project. As a leading roadway and intersection design engineering firm, we believe that this report will help provide a better understanding of the proposed solution for the redesign of the corridor. If there are any questions or concerns that require clarification, please feel free to contact us at (604) 822-2637.

Sincerely,

Dynamic Transportation Solutions (DTS) Engineering – Team 17

DTS Engineering

Executive Summary

Currently, Chancellor Boulevard is heavily favoured for motorized vehicle use. So, the corridor space is redesigned to improve travelling conditions for sustainable methods of travel: by bike, by foot, and by transit. Ultimately, the main focus of this design is to improve the safety for all the users of the road and to reduce the number and the severity of collisions.

A roundabout will replace the signalized intersection at Hamber Road and Chancellor Boulevard. Bike lanes will replace the outer lanes in each direction. There will a painted median between the vehicle lanes and the bike lanes to provide a buffer for the cyclists. Numerous other were designed as well, including bus stops, sidewalks, and a pedestrian underpass. The pedestrian underpass structure will span from the north to the south end of Chancellor Boulevard, on the east side of the Hamber Road intersection. The underpass will be shared between the pedestrians and cyclists. Signage along the corridor is to be added as per the detailed drawings attached to the report.

The stormwater management system has also been redesigned to convey minor and major storm events that are expected to occur. Additional catch basins will be added to prevent ponding and the pipe network will also require upsizing. The drainage in the underpass tunnel has also been designed to prevent flooding from occurring.

Lighting has been designed to be installed all along the corridor to help promote safety for all users of the road. 9.14m Davit luminaire poles will be used to mount the 71W ATBS LED head fixtures by American Electric Lighting Addition for roadway and roundabout lighting. New Westminster Series NWS 16” will be used for pedestrian sidewalk lighting. The tunnel will have 70W HPS lights installed at 1.8m intervals.

The total cost of construction of this project is estimated to be $6.58M. These costs were calculated based on a start date of May 2018 and an anticipated completion date in March 2019.

For further detail, please refer to the body of the report. Attached to the report are appendices for sample calculations, detailed drawings, and specifications used for this project.

Table 0. Contribution of Individual Team Members

Team Member	**Contribution**
Jaime Abella	- Drawing package - Structural design of pedestrian underpass
Aldin Agustin	- Schedule and construction phasing - Drawing package
Zoe Athans	- Roadway design and signage - Drawing Package - Specification Package
Kelvin Chen	- Cost estimate/Maintenance plan - Drawing package
Matthew Cheung	- Cover letter, executive summary, compilation and formatting - Introduction and project overview - Lighting
Anson Lau	- Stormwater drainage and analysis - Lighting

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1.0 Project Overview

Chancellor Boulevard is one of five major access routes that leads to UBC Campus, as well as to homes, hiking trails, and to University Hill Elementary School. Currently, the corridor is optimized for motorized vehicles, making it difficult or even dangerous for pedestrians and cyclists to travel in this corridor. Therefore, DTS Engineering has redesigned the corridor changing the road configuration and intersection, installing a pedestrian underpass, and upgrading the stormwater management system.

Figure 1. Location of Project

Utilizing the research and data that has been collected, the primary users and their purpose of using the road has been understood. In addition, various stakeholders have been surveyed and their opinions were used to help derive the three design options. All the options prioritize safety with no exceptions. To align the environmental space of Chancellor Boulevard to the goals of the UBC Transportation Plan and Campus plan, the corridor was designed to meet future traffic demands and prioritize active transportation modes over motor vehicle travel. Other variable which were also taken into consideration include: cost, storm water management, and overall aesthetics.

2.0 Site Overview

The location of the project is along Chancellor Boulevard from west of Acadia Road to west of Drummond Drive, as highlighted in Figure 1. In current state, Chancellor Boulevard consists of two lanes of traffic in each direction, heading eastbound and westbound, separated by a center median. The lanes converge into single lane traffic in both directions at Acadia Road and Drummond Drive.

Chancellor Boulevard intersects with Hamber Road which provides access to students and staff of University Hill elementary School. The intersection currently has pedestrian-controlled traffic lights crossing in the north and south direction on the west side of the intersection. Vehicles exit the school through a single lane which diverges into right turn and left turn lanes. The right turn lane enters a merging lane to merge into westbound traffic while the vehicles turning left onto Chancellor Boulevard have a stop sign.

There are currently two bus stops on Chancellor Boulevard in the span of the project: one in the westbound direction and one in the eastbound direction, both of which are by the intersection of Hamber Road. There exists a multi-use pathway for pedestrians and cyclists travelling in both directions located on the south end of the road. Lastly, Chancellor Boulevard bisects numerous hiking trails of the Pacific Spirit Regional Park. There is a section along the north side of Chancellor Road for vehicle parking by the East Canyon, the Chancellor, and the Pioneer Trails.

3.0 Key Issues

The following are three main issues that were identified for the current corridor:

1. The corridor is prioritized to favor motorized vehicles,

2. High vehicle speeds increase the risk for accidents along the corridor,

3. The corridor is not optimized for the current traffic volumes.

Currently, the capacity of the corridor greatly outweighs the demand in both eastbound and westbound directions. In addition, it is common to find cars travelling beyond the posted speed limit of 60km/hr, forcing cyclists, travelling in both directions, to share the pathway with pedestrians located on the south side of the boulevard. In addition, there is insufficient lighting during the evening to promote a safe environment for cyclists and pedestrians. Overall, these issues promote users of this corridor to travel by vehicle, and as a result, hinders UBC to reach its goal of sustainable travel as outlined in their Transportation Plan.

4.0 Project Objectives

Based on the client's RFP document and presentation, nine primary objectives have been identified. These objectives will be achieved under the British Columbia (BC) Ministry of Transportation and Infrastructure's (MoTI) engineering design guidelines and the interest of stakeholders/public. The nine identified primary objectives are:

1. Determine Current Traffic Conditions – Collect more reliable data for all modes of transportation

2. Accommodate for Future Demands – Ensure corridor meets the needs for future demands

3. Prioritize transit, cyclist and pedestrians – As required, give priority to active transportation modes over vehicles

4. Maximize Efficiency for All Modes – Redesign corridor to provide more efficient use of space to accommodate vehicles as well as pedestrians, cyclists, and transit routes

5. Improve Safety – Control speeds of vehicles, improve facilities for all modes of transportation

6. Enhance Aesthetics of Corridor – Enhance the look of the surrounding environment and design to align with the UBC – Vancouver Campus Plan

7. Improve Drainage – Redesign current drainage system to resolve drainage issues along the corridor

8. Minimize Costs – Explore different options to provide the most cost-effective design to meet the goals

9. Promote Sustainability & Energy Efficiency – Explore different construction methods and design options to provide sustainable and energy efficient solutions

5.0 Consultation & Stakeholder Engagement

Stakeholders for the Chancellor Boulevard Corridor Redesign project include any individuals, groups or organization that are likely to be impacted by or have an investment or interest in the project's outcomes. Stakeholder consultation was a key component in developing the final preliminary design. However, due to limited budget and time, direct stakeholder engagement and consultation could not be completed. Instead, all stakeholder groups were identified (as shown in Table 1), and their concerns, priorities and polices were understood through online research. This information was incorporated into the design and stakeholder's concerns.

Table 1. Project Stakeholders

Stakeholder Group	Relationship to the Project
UBC Campus and Community Planning	• Will provide funding and approval for the project
British Columbia Ministry of Transportation and Infrastructure	• Governs the University Endowment Lands • Operates and maintains Chancellor Boulevard and the adjacent local roads • Will provide funding and approval for the project
UBC Staff and Students	• Use Chancellor Boulevard to commute to/from UBC
University Hill Elementary School	• The school is located at the Hamber Road and Chancellor Boulevard intersection • Students, staff and parents use Chancellor Boulevard to commute to/from school
Metro Vancouver	• Governs, operates and maintains Pacific Spirt Park. The park boarders either side of Chancellor Boulevard
Pacific Spirt Park Society	• Acts as public stewards and a community portal for various stakeholders in Pacific Spirt Park
City of Vancouver	• Chancellor Boulevard connects to West 4th Avenue which is governed by the city
University Endowment Lands & Homeowners	• Chancellor Boulevard is within the University Endowment Lands • Homeowners within the University Endowment Lands travel on Chancellor Boulevard
Aboriginal Groups	The following groups were identified as potential stakeholders from the Government of British Columbia's Consultative Areas Database: • Soowahlie First Nation, Seabird Island Band, Shxw'ow'hamel First Nation, Skawahlook First Nation, Sto:lo Tribal Council, Sto:lo Nation, Cowichan Tribes, Lake Cowichan First Nation, Lyackson First Nation, Penelakut Tribe, Halalt First Nation, Stz'uminus First Nation, Squamish Nation, Musqueam Nation, Tsleil-Waututh Nation

6.0 Key Features of Roadway Design

During the preliminary stage of the design, a traffic analysis of the Chancellor Boulevard corridor was completed using Synchro 6 traffic analysis software. The analysis was completed to develop the lane configuration along the corridor and the intersection configuration at the Hamber Road intersection. Please see Team 17's *Preliminary Design Report: Corridor Redesign of Chancellor Boulevard* for detailed information regarding the traffic analysis and for justification/technical considerations concerning the key features of the roadway design.

This section provides a brief overview of the key features of the roadway design.

6.1 Lane Configuration

The design includes a reduction in vehicle lanes, from two-lanes to one-lane in both east and westbound directions along Chancellor Boulevard. The lane width is reduced from 4.0 m to 3.3 m.

6.2 Paint Separated Bike Lanes

The existing outer vehicle lanes, in both east and westbound directions, are replaced with 3.0 m wide paint separated bike lanes. A 1.5 m painted median separates the vehicle lane from the bike lane. The painted median is installed to provide a buffer between cyclists and motorists.

6.3 Hamber Road Intersection

Figure 2. Hamber Road Intersection

As shown in Figure 2, the existing pedestrian-controlled T-intersection is replaced with a three-way roundabout at the Hamber Road intersection.

The key components of the roundabout include:

- Two entry lanes on the westbound approach – one through lane and one right-turn/through lane.
- Two entry lanes on the southbound approach – one left-turn lane and one right-turn lane.
- One entry lane on the eastbound approach – one through/left-turn lane.

- One exit lane at the north and east sides and two exit lanes at the west side.
- Geometric curvature and deflections to reduce travel speeds.
- Yield at entry – traffic entering the roundabout must yield to traffic within the roundabout.
- Shared pedestrian and cyclist pathway connecting to sidewalk and bike lanes at the west and east sides of the intersection. The pathway is included to separate cyclists from motorist.

In addition, an underpass tunnel is installed across the westbound side of the roundabout and a crosswalk is installed across the southbound side. The pedestrian and cyclist underpass and crosswalk are included to provide access to University Hill Elementary School and Pacific Spirt Park. The underpass tunnel is discussed in more detail in Section 8. For safety and visibility, the crosswalk includes school crossing signage and adjacent street lights.

6.4 Roadway Surface

The existing road surface at the Hamber Road intersection is completely removed to facilitate construction of the underpass tunnel and new roundabout. Concrete curbs are installed, and concrete pathways are installed on the north and south side of the roundabout. Asphalt is installed on the road surface at the intersection. Along the corridor, the road surface is milled and filled.

6.5 Crosswalks

Figure 3. Crosswalks

As shown in Figure 3, two new special crosswalks with zebra pavement markings are installed mid-block between Drummond Drive and Hamber Road. For safety and visibility, the crosswalk design includes pedestrian controlled overhead amber flashing lights, pedestrian crossing signage and adjacent street lights. The crosswalks are located where unmarked crosswalks are currently located. The crosswalks will allow pedestrians and cyclists to access trails within Pacific Spirt Park.

6.6 Pedestrian Pathway

Figure 4. Pedestrian Pathway

The existing pedestrian pathway which spans the southside of Chancellor Boulevard is reused. The existing asphalt is to be stripped and replaced to remove tree root distortion and pedestrian tripping hazards. The existing pathway does not connect to the sidewalk on the south side of West 4th Avenue (which begins at Drummond Drive). The design includes a new asphalt pedestrian pathway which connects the existing pathway to the sidewalk, as shown in Figure 4. This new link is installed to improve walking accessibility and to improve safety for pedestrians.

6.7 Pacific Spirt Park Parking

Figure 5. Parking

As shown in Figure 5, the existing parking mid-block on the northside of corridor is reused. Parking is included for access to Pacific Spirt Park.

6.8 Bus Stops

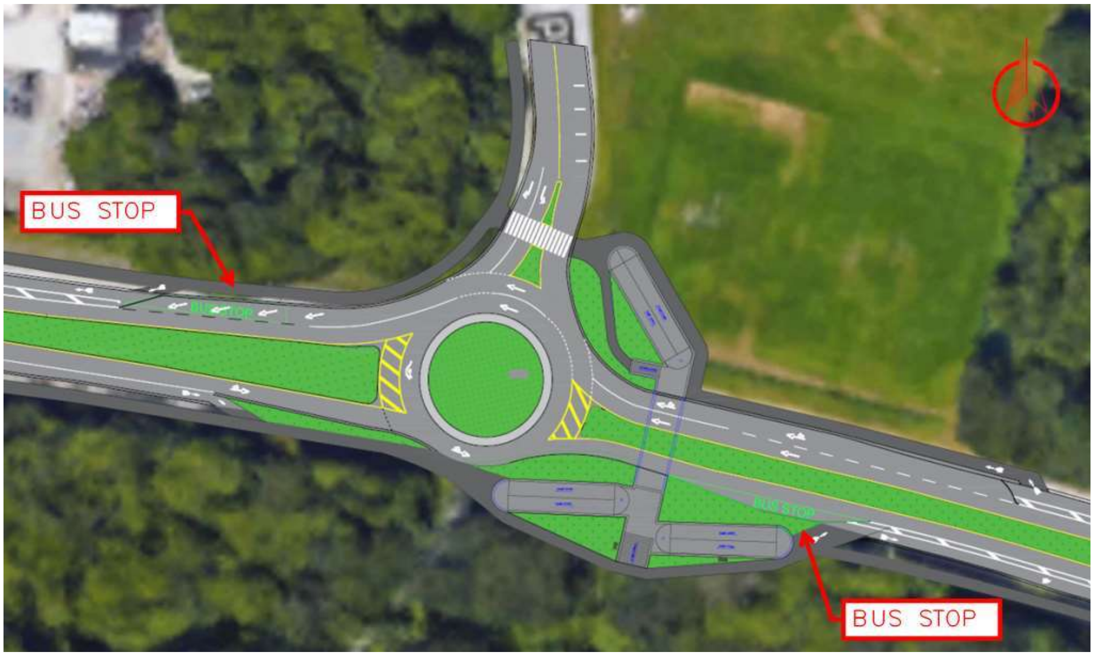


Figure 6. Bus Stops

As shown in Figure 6, two bus stops are installed at the Hamber Road intersection. One bus stop serves the eastbound direction and the other serves the westbound direction. The bus stops are installed in approximately the same location as the existing bus stops. In addition, improvements and amenities will be added to make the bus stops more accessible and comfortable for the transit users, as per Translink's Universally Accessible Bus Stop Design Guidelines, which can be found in the Specifications.

At each bus stop, seating will be installed along with overhead structures to shelter the waiting users from harsh climate conditions. The shelter will be designed to fit and to be accessible to persons in wheelchairs. Adjacent street lighting will also be installed to help improve visibility of the users for the bus drivers, but also to help promote safety and to help deter criminal activities at the bus stops. Tactile strips will be installed adjacent to the ID pole to assist the visually impaired and to prevent slippage. Lastly, wheelchair landing pads will be installed to ensure easy accessibility for users with disabilities. A bus bay will be installed for the eastbound bus stop.

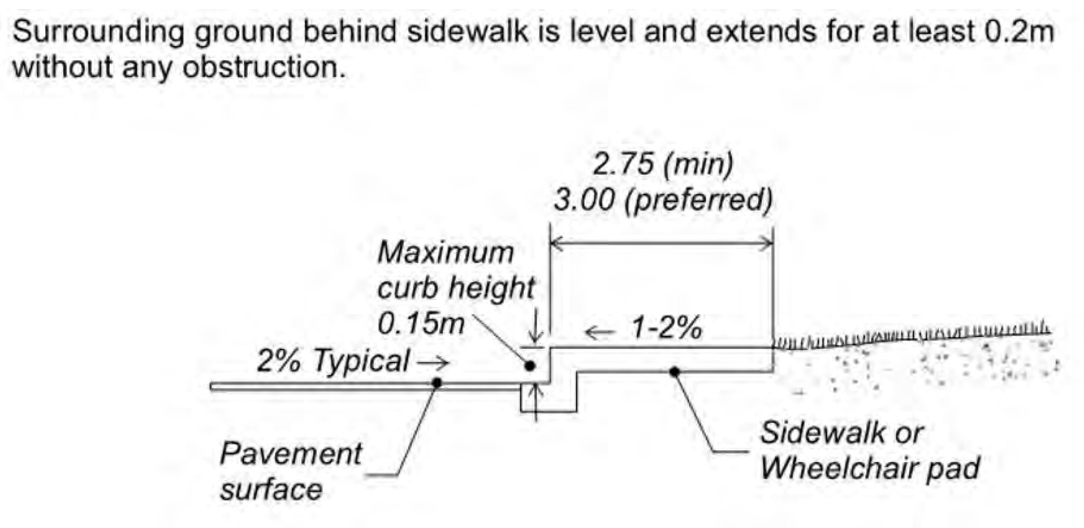


Figure 7. Wheelchair Landing Pad for Bus Stops

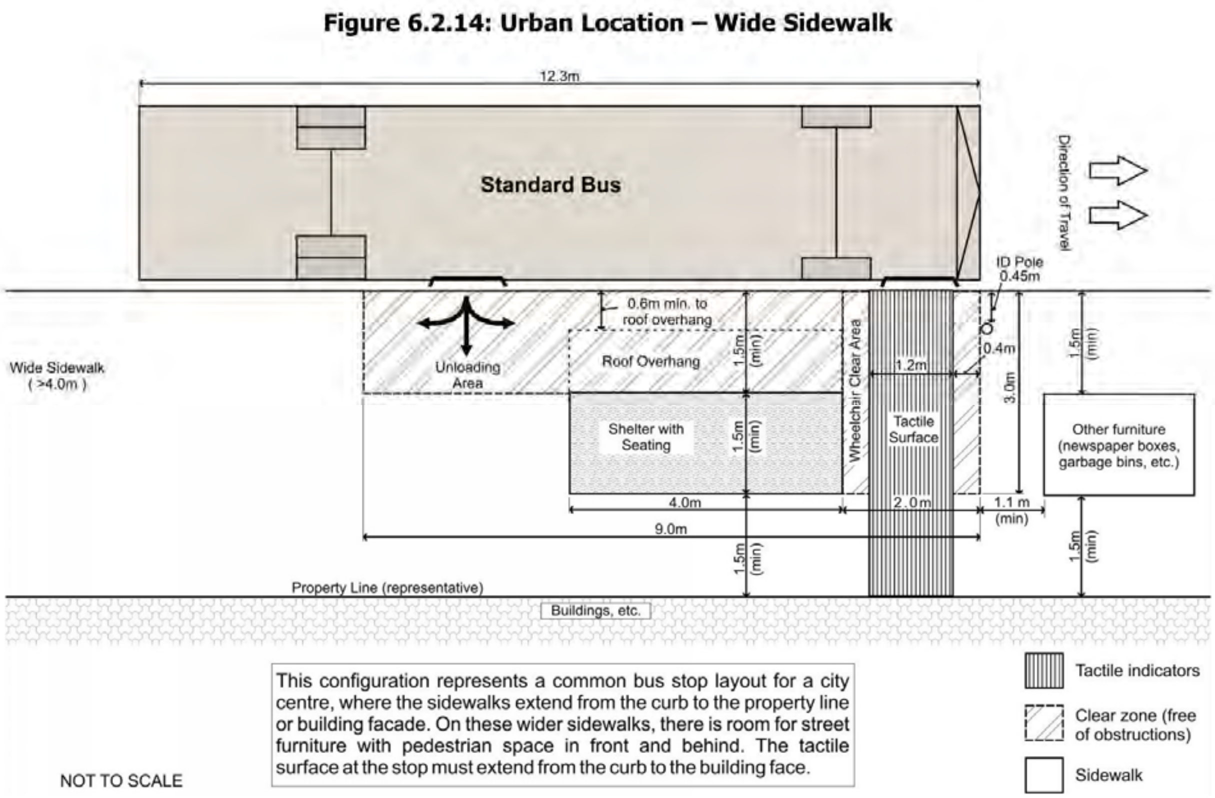


Figure 8. Configuration of Westbound Bus Stop

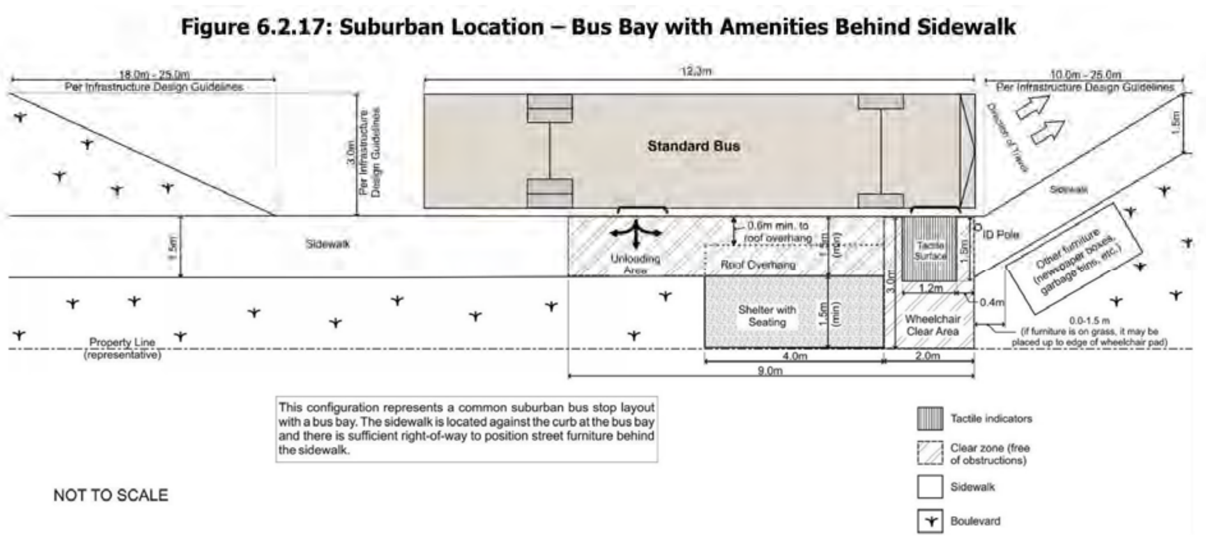


Figure 9. Configuration of Eastbound Bus Stop

7.0 Detailed Roadway Design

This section provides additional information related to the detailed roadway design including design criteria, standards and software used in the design.

Please refer to the Detailed Drawings and the Specifications attached to this report for further details.

7.1 Geometric Design

The geometric design of the corridor was designed in accordance with TAC's Geometric Design Guide for Canadian Roads and BC MOTI's BC Supplement to TAC Geometric Design Guide.

The roadway geometry was designed to meet the following design criteria:

- Design speed of 70 km/hr,
- Reduce posted speed limit from 60 km/hr to 50 km/hr,
- Provide sufficient stopping sight distance along the corridor,
- Capacity to meet traffic demands with minimal delays,
- Design life of 20-years assuming appropriate maintenance is performed over the design life,
- Reduce vehicle lanes from two-lanes to one-lane in east and westbound directions,
- Convert existing outer vehicle lanes to paint-separated bike lanes.

7.2 Signage and Pavement Markings

Road signage and pavement markings were designed in accordance with BC MOTI's Manual of Standard Traffic Signs & Pavement Markings and the Manual on Uniform Traffic Control Devices (MUTCD).

Information signage specific to UBC was designed in accordance with the UBC Wayfinding Exterior Signage Standards and Guidelines.

7.3 Cyclist and Pedestrian Design Features

The paint separated buffered bike lanes and special cyclist pavement markings were designed using NACTO's Urban Street Design Guide.

The two new special crosswalks with pedestrian controlled push buttons and overhead flashers were designed in accordance with the Pedestrian Crossing Control Manual for British Columbia.

7.4 Roundabout Design

The design of the Hamber Road intersection roundabout including the geometric design, pavement markings and signage were designed in accordance with the above noted standards as well as the following additional standards:

- Kansas Roundabout Guide (as recommended in BC MOTI's BC Supplement to TAC Geometric Design Guide)
- BC MOTI's Technical Bulletin - Lane Use Signs and Pavement Markings at Multi-Lane Roundabouts

The roundabout was designed to meet the following design criteria:

- Design speed of 30 km/hr,
- WB-15 truck design vehicle,
- Pedestrian and cyclists to be completely protected from motorists.

To meet the above criteria, the following components were included in the roundabout design:

- Deflections and entry/exit curvature used to reduce vehicle speeds
- 2.0 m wide truck apron in central island to accommodated WB-15 design vehicle
- Shared pedestrian and cyclist pathways on the south and north side of the roundabout to protect pedestrians and cyclists from motorists
- 15.0 m central island radius to meet design speed, lane configuration and design vehicle.

7.5 Software

The following software was used to develop the roadway design:

- **Synchro 6** – used for traffic analysis of the preliminary roundabout design
- **AutoCAD 2018** – used to develop the detailed design drawings

8.0 Structural Design of Underpass Pedestrian Tunnel and Ramps

8.1 Underpass Pedestrian Tunnel Overview

An underpass tunnel for pedestrians and cyclists is one of the non-negotiable component of the Redesign of Chancellor Boulevard Project. DTS Engineering recommends constructing the underpass tunnel just East of Hamber Road and Chancellor Boulevard intersection. This location was chosen because this is where most pedestrians and cyclists activities have been observed. The tunnel spans 21m across Chancellor Boulevard. The underpass tunnel will provide an easy and safe access to users crossing the

Chancellor Boulevard which includes Pacific Spirit Park trail users, UBC cyclists, University Hill Elementary School students and staff. The design offers accessibility for pedestrians, cyclists and pedestrian with disabilities (PWDs). As shown in Figure 10, ramps and stairs on both north and south side of Chancellor Boulevard are provided for access to the pedestrian underpass tunnel.

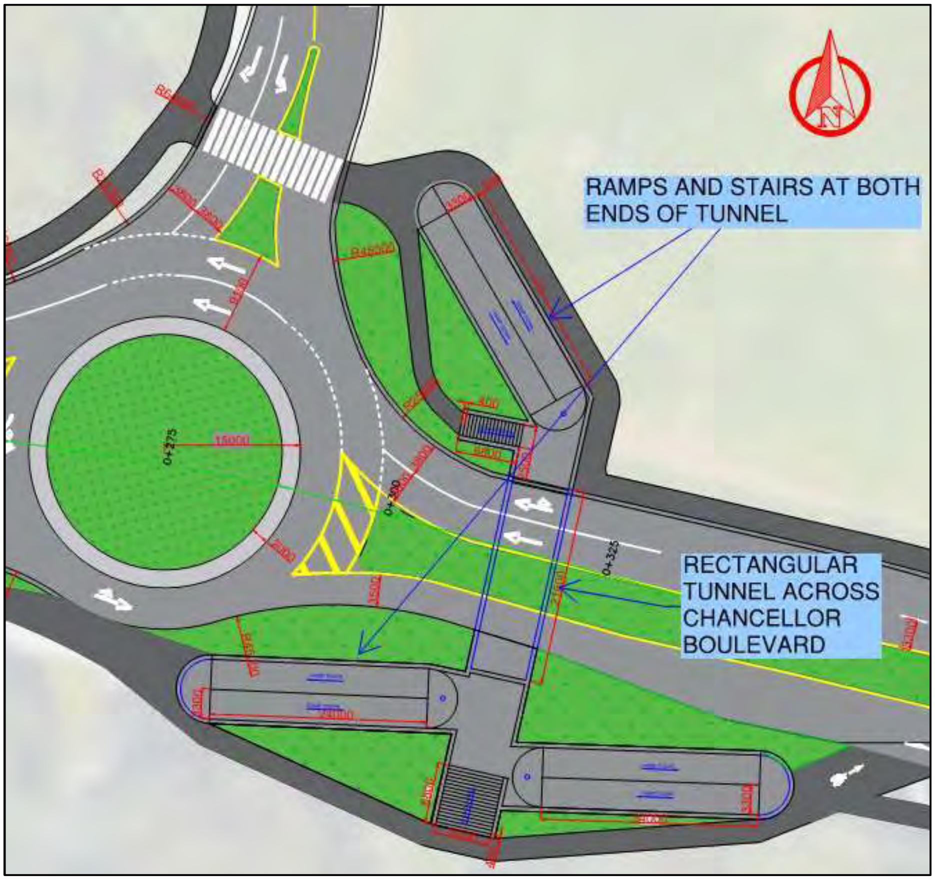


Figure 10: Underpass Pedestrian Tunnel Overview

8.2 Design Codes and Standards

A combination of various design codes and standards were used to complete the detailed design of the structural components of the underpass pedestrian tunnel and ramps (See Table 2). These standards were used to ensure that the dimensions, design loads, and amount of reinforcements are adequate to maintain the structural integrity of the underpass.

Table 2. Design Standards and Guidelines Used

Design Code/Standard/Reference
Canadian Highway Bridge Design Code 2017 (CSA S6-14)
Design of Concrete Structures (CSA 23.3)
BC Supplement to TAC Geometric Design Guideline 2007 Edition
BCBC 2012
NBCC 2010
Reinforced Concrete Design - A Practical Approach 2009

8.3 Structural Analysis and Design Software

The structural analysis and design of the underground pedestrian bridge was conducted through hand calculations and use of computer programs. The software used were SAP2000 and S-FRAME. These programs were used to identify the design loads and verify whether the dimensions and amount of reinforcement determined from hand calculations are in accordance to current CSA design codes. SAP2000 was primarily used to determine the design loads while S-FRAME was used to ensure that member dimensions and sizes conform with CSA design codes.

8.4 Design Criteria and Considerations

The structural material for the tunnel and ramps is reinforced concrete. The underpass tunnel and ramps are designed to have a design life of 75 years as specified by Canadian Highway Bridge Design Code. Various design criteria and considerations were identified throughout the design process. The underpass tunnel spans across Chancellor Blvd; therefore, the structure must be designed to support live vehicle traffic loads, road pavement dead loads, and lateral earth pressure loads (See Figure 11). In addition, the ramps and stairs providing access to the underpass tunnel are exposed to the exterior environment; therefore, these components must be designed to support live pedestrian traffic loads, snow load, and lateral earth pressure loads (See Figure 12). The foundation for both the tunnel and ramp structures are shallow foundations including strip cantilevered wall foundations and spread foundations. These components are designed to not exceed the factored soil bearing capacity (100kPa) recommended by the geotechnical reports. Table 3 highlights the design loads and design considerations reviewed for each component of the tunnel, ramps, and on-grade structures. These design considerations were accounted for in determining the member sizes and amount of reinforcement of the proposed underpass pedestrian tunnel (See Appendix B for calculations and Detailed Drawings for details).

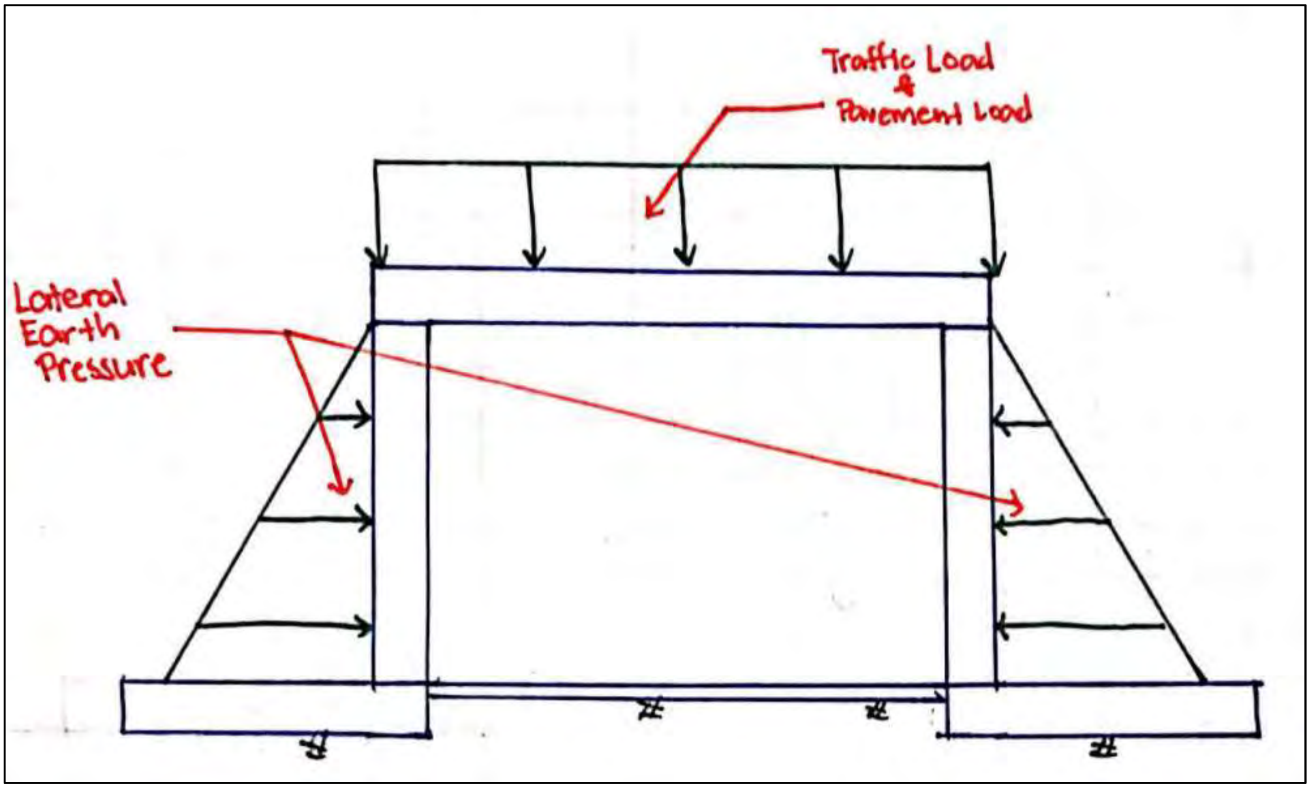


Figure 11: Tunnel Design Loads

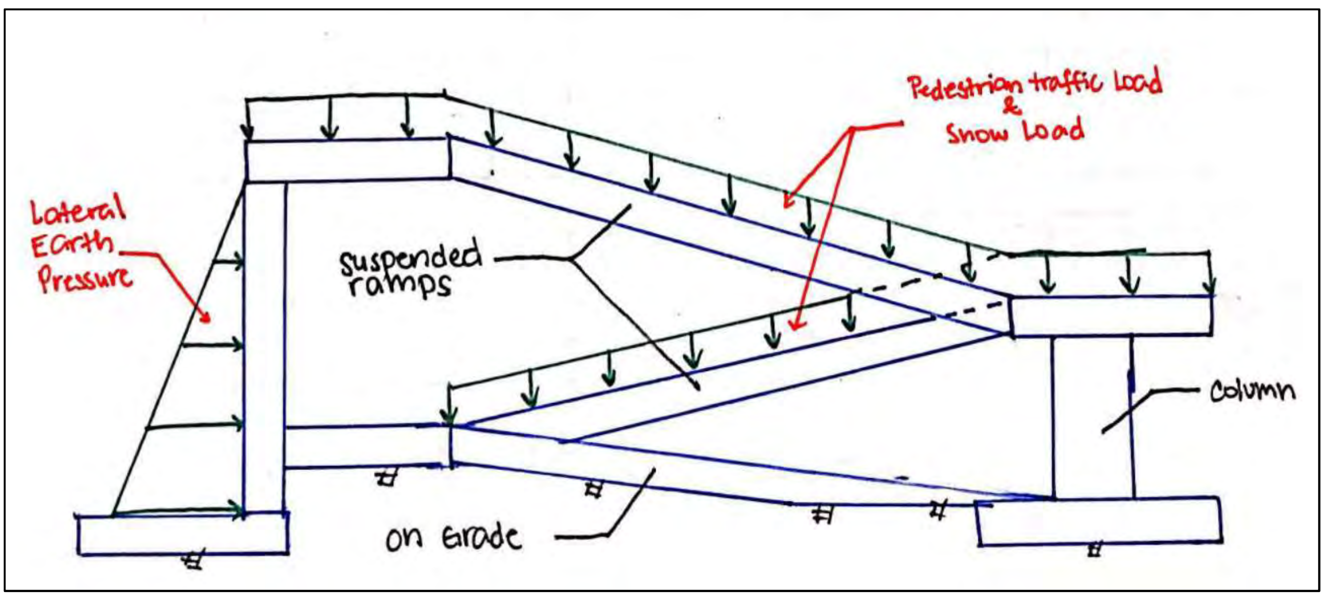


Figure 12: Ramp Design Loads

Table 3: Design Loads and Considerations

Component	Design Load and Consideration
Tunnel Structure	
Suspended Roof Slab	• Live traffic load • Road pavement and backfill dead loads
Cantilevered Retaining Walls	• Lateral earth pressures
Wall Strip Foundation	• Design to not exceed existing soil bearing capacity
Ramps	
Suspended Ramp and Landings	• Live pedestrian traffic load • Snow load
Supporting Column	• Transferred loads from suspended ramp and landings
Cantilevered Retaining Walls	• Lateral earth pressures
Wall Strip Foundation	• Design to not exceed existing soil bearing capacity
Column Footing/Spread Foundation	• Design to not exceed existing soil bearing capacity
On-Grade Structures	
Slab-On-Grade and Ramp-On-Grade	• Shrinkage and temperature loads • Flexure loads from external factors (eg: differential settlement)
Stair-On-Grade	• Shrinkage and temperature loads • Flexure loads from external factors (eg: differential settlement)

8.5 General Dimensions

Table 4 shows the general dimensions of the proposed underground pedestrian bridge. These dimensions were determined from detailed hand calculations (See Appendix B), structural analysis software results and design standard references. The complete detailed drawings including steel reinforcement layout are available in Detailed Drawings Section for reference.

Table 4: Underpass Pedestrian Bridge General Dimensions

Component	Dimension
Tunnel	
Vertical Clearance	3.1m
Horizontal Clearance	6.2m
Span	21m
Bike Lane	2m per direction
Pedestrian Lane	2m
Ramp	
Slope	7%
Ramp Width	3.3m

Stair	
Rise	200mm
Run	400mm

8.6 Tunnel Lighting

Sustainable lighting will be provided in the underpass both day and night to promote safety and comfortability. Energy sufficient and smart lightings are to be used to minimize light pollution and wildlife disturbance near Pacific Spirit Park. In addition, specifications for the lighting in the tunnel will also follow UBC Vancouver's Campus Plan to ensure that the design will align with UBC's sustainability goals. Refer to Section 10 for the detailed light specification and design that will be installed throughout the tunnel structure.

8.7 Tunnel Drainage System

The tunnel design must incorporate adequate drainage system to protect the structural integrity and service life of the infrastructure. Since the tunnel ramps are uncovered, rainwater from the ramps will flow into the tunnel. To prevent flooding and ponding within the tunnel, gutter drains and subgrade piping that leads to the main stormwater system are to be constructed. Refer to Section 9 for details and specifications of drainage system to be installed.

8.8 Underpass Pedestrian Tunnel Construction Specifications

Chancellor Boulevard is an arterial roadway governed by BC MOTI. Therefore, the construction of the underpass pedestrian tunnel shall conform with the construction specifications provided by the ministry. The contractor/s and subcontractor/s who will provide services for this project are expected to perform work in accordance to BC MOTI's 2016 Standard Specifications for Highway Construction. Excerpts of related sections are available in the Specifications Package. The following are the sections within the construction specifications document that directly relates to the construction of the underpass pedestrian tunnel:

- **Section 215** – *Bridge*
- **Section 211** – *Portland Cement Concrete*
- **Section 407** – *Foundation Excavation*
- **Section 412** – *Concrete Reinforcement*

9.0 Stormwater Drainage and Management

This section describes the design measures used to address stormwater drainage along the corridor. The scope of this section is to minimize costs by reusing existing infrastructure, while checking the existing infrastructure to see if it can successfully convey the 10 to 25-year storm, and provide upsizing where necessary. Additionally, the redesign must incorporate the tunnel underpass into the new drainage system to prevent flooding of the tunnel. Resizing of other utilities such as sanitary and water main pipes is beyond the scope of this design.

9.1 Drainage Redesign Study Area

The extent of the stormwater pipe redesign is the intersection drainage area, or between stations 0+225 to 0+475. The other drainage area, from 0+475 to 1+300, is not considered for sewer pipe redesign. Since only the road surface is being repaved, and the road geometry and alignment is not changing by much, this means that the existing infrastructure can remain unchanged to reduce costs. The two drainage areas are shown below:

1. The intersection of Hamber Road and Chancellor Boulevard, between stations 0+225 and 0+475,
2. And the remainder of the corridor east of the intersection, between stations 0+475 and 1+300.

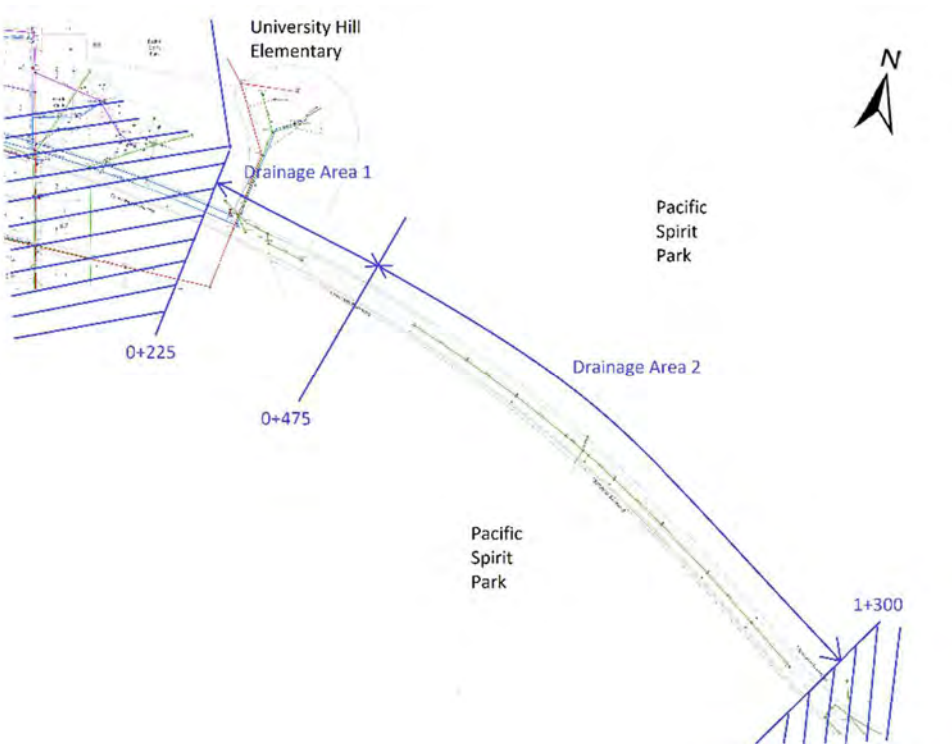


Figure 13. The Two Drainage Areas and Notable Landmarks

The BC Ministry of Transportation and Infrastructure (BCMOTI) Supplement to the TAC Geometric Design Guidelines (TAC Supplement) will be the primary reference document for specifications, and it will be used alongside the Surrey Design Criteria to design manhole and catchbasin spacing, the sewer pipe sizes, and to check the design against specifications in the TAC Supplement. Additional technical sources were consulted for values Manning's coefficient for different surfaces[1], as well as for rain IDF curves[2] that account for climate change for rain stations in Vancouver.

9.2 Catchbasin and Grate Spacing

The terms catchbasins and grates are to be used interchangeably in this section to refer to drain coverings and the basins used to divert overland stormwater flow into the pipe system below ground. The existing drains on Chancellor Boulevard are currently spaced 65m on the EB side, and 85m on the WB side. The existing spacing was checked using the 'spreadsheet method' outlined in the BCMOTI TAC Supplement §1050.06. Since this road is an arterial road in an urban area that connects the UBC Campus and Vancouver with the intent to service bicycle users, the Depressed Bicycle Safe Grate will be used as per TAC Supplement §1050.06. More details on tables and calculations with this method can be found in the Appendix.

The overall results showed that the initial grate spacing must be at most 107m away from the second grate, and consecutive grates should be spaced at most 96m from each other. This means the existing spacing is more than sufficient.

9.3 Roundabout Drainage Redesign

This drainage area contains the redesigned roundabout intersection with an underpass, whose purpose is to cross Chancellor Boulevard on the east side of the intersection. Stormwater is collected from University Hill Elementary north of the intersection, as well as from the University Golf Course south of the intersection, and from a ravine the west of Hamber Road to the Spanish Banks as the figure below shows. Therefore, the stormwater sewer pipes need to work around the tunnel underpass.

[1] Nebraska Department of Roads Drainage and Erosion Control Manual 2006, Appendix B

[2] Metro Vancouver Climate Change (2050) Adjusted IDF Curves: Metro Vancouver Climate Stations

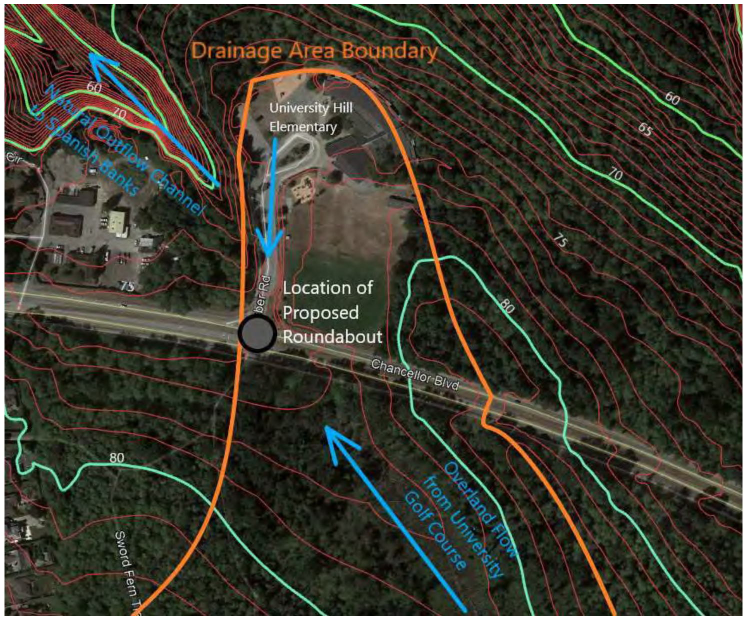


Figure 14. The Study Area and Drainage Area Boundary (Contour elevations are given in meters)

This could be done by placing the sewer pipe above, through, or below the tunnel. Placing the pipe above the tunnel would lead to lower lateral and vertical soil loads as it is higher in the ground, but it is not within the recommended depth of stormwater pipes in the Surrey Design Criteria (between 1.5-3.0 m) and would be subject to approval by the project engineer. Placing the pipe through the tunnel would compromise the structural integrity of the tunnel, and would require a separate pipe to convey tunnel drainage to the main pipe network.

Thus, running the pipe underneath the tunnel is the best option as it does not require a separate pipe leading form the tunnel to the main network. This does result in higher vertical and lateral loads on the pipe, and should be checked against the pipe's load capacity.

The design flow for each pipe is calculated using the Rational Method, which according to both the TAC Supplement (§1020.06) and Surrey Design Criteria (§5.3.1) is best suited for small catchment areas, although the maximum drainage area sizes that are suitable for the rational method are different (1000 ha and 20 ha respectively). Since the TAC Supplement is considered the primary reference document, the Supplement requires that the minor pipe system be capable of conveying the 10 to 25 year storm.

The flow for each tributary area is given by:

$$Q = RAIN$$

Where Q is the flow, in m^3/s;

R is the runoff coefficient, which is unitless;

A is the tributary drainage area, in hectares;

I is the rainfall intensity, in mm/hr; and

N is the conversion factor, equal to $\frac{1}{360} = 0.00277$

9.3.1 Runoff Coefficient

The runoff coefficient is calculated using an area weighted average of the drainage area. Sub-areas with different surface covers and slopes were tabulated, and their corresponding runoff coefficients were found from Table 1020.A from the TAC Supplement, which provides conservative estimates of the runoff coefficient and is shown below. The equation to calculate the runoff coefficient for a tributary area with *n* sub-areas is as follows:

$$R = \frac{A_1R_1 + A_2R_2 + \cdots + A_nR_n}{A_1 + A_2 + \cdots + A_n}$$

Table 1020.A Maximum Runoff Coefficient Values For Coastal Type Basins

Surface Cover Physiography	Impermeable	Forested	Agricultural	Rural	Urban
mountain (>30%)	1.00	0.90	-	-	-
steep slope (20-30%)	0.95	0.80	-	-	-
moderate slope (10-20%)	0.90	0.65	0.50	0.75	0.85
rolling terrain (5-10%)	0.85	0.50	0.40	0.65	0.80
flat (<5%)	0.80	0.40	0.30	0.55	0.75
return period 10-25 years	+0.05	+0.02	+0.07	+0.05	+0.05
return period > 25 years	+0.10	+0.05	+0.15	+0.10	+0.10
snowmelt	+0.10	+0.10	+0.10	+0.10	+0.10

9.3.2 Tributary Areas

Elevation contours from the City of Vancouver database were used in conjunction with the manholes placed to determine the tributary areas for each pipe section between manholes. The sub-areas containing different types of surfaces was noted for a weighted calculation of the runoff coefficient (R) by area, as shown above. Areas were measured approximately in Google Earth perpendicular to the contour lines. Advanced hydraulics software packages can be used to produce more accurate estimates of drainage areas.

When a pipe connects into another pipe, the cumulative $R \times A$ for both the upstream pipes is to be added together at the junction and any pipes downstream of the junction.

9.3.3 Rainfall Intensity

The rainfall intensity is calculated from IDF curves given in the Metro Vancouver Climate Change Adjusted IDF Curves. The nearest rain station to the project location was used, namely VA01 – Kitsilano High School. The intensity is dependent on the time of concentration, which is calculated by adding the time of overland flow and the travel time in the pipe between each manhole. A copy of the IDF curves and rainfall data from rain gauge VA01 is provided in the Appendix.

9.3.4 Overland Flow

The overland flow T_O for the uppermost lot is calculated using the dynamic wave equation shown below, with the following steps:

$$T_O = \frac{6.92L^{0.6}n^{0.6}}{i^{0.4}S^{0.3}}$$

Where L is the longest length of flow over the uppermost lot in the tributary area;
n is Manning's coefficient for overland flow, which was found by consulting literature;
i is the rainfall intensity; and
S is the slope of overland flow.

1. The overland flow length is measured directly from Google Earth or a similar GIS software for the uppermost lot, perpendicular to the contours.
2. Manning's coefficient is calculated similarly to the runoff coefficient by performing a weighted average of Manning's coefficient for various surface types. The various lengths of overland flow over a unique surface is multiplied by Manning's coefficient for that surface and then added together, then divided by the total overland length. Coefficients were consulted from the Nebraska Department of Roads Drainage and Erosion Control Manual.
3. The intensity is calculated from the IDF equation from the VA01 rain station, assuming an initial time of concentration t_c' of 5 minutes.
4. The slope is calculated by taking the difference in elevation between the two points used to calculate the length in step 1 and dividing by that length.

9.3.5 Travel Time

The travel time is calculated simply by assuming a full pipe and applying Manning's Equation to determine the full pipe velocity, and then dividing the length of pipe by the velocity to determine the travel time.

$$T_t = \frac{V_{Manning}}{L_{pipe}} = \frac{R^{\frac{2}{3}} S^{0.5}}{n L_{pipe}} = \frac{\left(\frac{D}{4}\right)^{0.67} S^{0.5}}{0.013 L_{pipe}}$$

9.3.6 Time of Concentration

Once the overland flow time and travel time are found, the time of concentration is simply the two times added together. The intensity is then calculated using the time of concentration and the IDF equations given for rain gauge VA01. Each consecutive pipe has the time of concentration from all upstream pipes added to its own. Once the time of concentrations are solved, the design flows for the 10, 25, and 100-year events can then be calculated with the rational method, and the pipes can be sized.

9.3.7 Sizing the Pipe Network

There are a number of criteria to determine the specifications of the pipe network. The pipe network must have a ratio of $Q_5/Q_{capacity}$ less than 1, and must meet minimum slope and velocity requirements outlined in §5.4.2.5 and §5.4.2.6 respectively. The Rational Method Spreadsheet in Table 5.3.14 of the Surrey Design Criteria was used to evaluate the current pipe sizes along the corridor.

It was found that the current system is currently sufficiently designed, and is capable of conveying the 10 and 25-year storm, and nearly capable of handling the 100-year storm, with the exception of Pipe A-1 (see the appendix for a list of pipes and locations). As such, it is recommended that the new pipe system should be slightly downsized to reduce costs during construction.

The design process follows the following steps:

1. Place manhole inverts initially at a constant depth of 1.5m below grade. This is an arbitrary value as the depths of the utilities are unknown at this stage. The actual depths of the utilities at the intersection should be confirmed before beginning construction.
2. Connect manholes with pipes of the smallest diameter available, 250mm.
3. Calculate the slope and length of pipe from the manhole UTM coordinates and elevation.
4. The pipe flow and velocity at capacity is calculated using Manning's equation, assuming a Manning's coefficient of 0.013.

5. Starting with the pipe section at the highest elevation, check that the flow ratios $Q_{10}/Q_{capacity}$ and $Q_{25}/Q_{capacity}$ does not exceed 1.
    a. If either exceeds 1, increase the pipe diameter to the next highest available size and repeat steps 4 and 5.
    b. If it is less than 1, proceed to the next downstream pipe.
6. If no more pipes remain in this section, then move to the next section. If no more sections remain in the network, then the network pipe sizing is complete.
7. Since the TAC Supplement does not explicitly mention a minimum sewer pipe slope, the Surrey Design Criteria has been used as a design check for this step. Check the minimum slope of each pipe against Table 5.4.1 of the Surrey Design Criteria, which changes depending on the diameter of the pipe.
    a. If it is not steep enough, change the manhole inverts to adjust the slopes.
    b. If the slope exceeds 15%, an anchoring system must be approved by the project engineer to account for potential scouring and pipe damage. Once sufficient, proceed to the next step.
8. As per the TAC Supplement, check that the full pipe velocity is between 0.6 and 5 m/s.
    a. The Surrey Design Criteria recommends that pipe velocities (not full pipe velocities) should be between 1 and 3 m/s.
        i. If it is below 1 m/s, check if the full pipe velocity exceeds 0.6 m/s (§ 5.4.2.6).
        ii. If it exceeds 3 m/s, special provisions must protect the pipe from sewer displacement.

Detailed sample calculations and a pipe summary table are shown in the Appendix. A plan view of the intersection with the storm drainage pipes and some properties are shown in the Appendix.

9.4 Tunnel Drainage

As mentioned earlier, the sewer pipes will run beneath the tunnel underpass so that the stormwater main can service the tunnel, and therefore a second stormwater main will not need to be constructed. The tunnel should be superelevated at a slope of at least 2%, allowing water that seeps into or ends up in the tunnel to flow into perforated drain pipes with a diameter of 100mm on the sides of the tunnel. These drain pipes will convey flow towards one of two catchbasins (marked TUN-DR-1 and TUN-DR-2 in Drawing F01) on either entrance of the tunnel, at the base of the stair landings. Water entering the two tunnel drains mentioned earlier will then flow through a standard 200mm PVC lead pipe to the main network, at a minimum slope of 0.5% as per §1050.07. Measures should be taken to prevent stormwater from flowing into the covered tunnel, such as sloping all surfaces away from the tunnel, and installing a curb along the side of the ramps.

10.0 Lighting

Improving accessibility for alternative transportation modes such as pedestrians and cyclists is one of the primary goals of this project. Improving safety at night for pedestrians and cyclists is a goal that UBC also shares, as mentioned in page 12 of the UBC Vancouver Campus Plan: “Enhanced night lighting will improve personal safety and wayfinding”. A key problem with the corridor along Chancellor Boulevard is that it is very dark after dusk and does not contribute to a safe walking or cycling environment.

As such, improving lighting to the shared pathway on Chancellor Boulevard is one way our project addresses this issue. The selection of lighting is important, as there are many considerations to be made before choosing the type and spacing of the lighting, such as energy efficiency, reduction of light pollution, and general aesthetics. Additionally, since the upgrades to the corridor will be funded primarily by UBC and MoTI, the lighting design should follow MoTI and UBC design guidelines, the TAC Guide for the Design of Roadway Lighting (the Code) and UBC Vancouver Campus Plan respectively. The Code typically defers to the Illuminating Engineering Society North America’s (IESNA) Lighting Handbook when it comes to design specifications, which was used for the lighting design.

10.1 Roadway Lighting

To create a safe and comfortable travelling environment for vehicles and cyclists, street lighting will be installed along the corridor. Davit luminaire poles of 9.14m will be used to mount the 71W ATBS LED head fixtures by American Electric Lighting supplied by EECOL Electric Corporation, one of vendors recommended by the Government of British Columbia. EECOL is a local supplier from Langley, meaning low transportation times and costs and ultimately helping to reduce the project’s environmental footprint. Vertical clearance of large vehicles was a design limitation. According to BC Law, the height of heavy vehicles must not exceed 4.15m, which will clear the street light poles without an issue.

Low Emission Diodes (LED) have been chosen over conventional incandescent bulbs or high intensity discharge (HID) lamps due to their relatively low electricity consumption while being able to emit the required amount of light as per the Guide for the Design of Roadway Lighting (2006) provided by the Transportation Association of Canada (Figure 15 below). LED’s also have lower maintenance costs due their expected life span of greater than 100,000 running hours. Each street light fixture is anticipated to save approximately 40% of used electricity when compared to the use of HID light fixtures.

Roadway Classification	Average Maintained Illuminance at Pavement by Pedestrian Conflict (lux)			Average-to-Minimum Uniformity Ratio
	High	Medium	Low	
Arterial/Arterial	34.0	26.0	18.0	≦ 3.0
Arterial/Collector	29.0	22.0	15.0	≦ 3.0
Arterial/Local	26.0	20.0	13.0	≦ 3.0
Expressway-Highway/Arterial	31.0	25.0	18.0	≦ 3.0
Expressway-Highway/ Expressway-Highway/	28.0	24.0	18.0	≦ 3.0
Expressway-Highway/Collector	26.0	21.0	15.0	≦ 3.0
Expressway-Highway/Local	23.0	19.0	13.0	≦ 3.0
Collector/Collector	24.0	18.0	12.0	≦ 4.0
Collector/Local	21.0	16.0	10.0	≦ 4.0
Local/Local	18.0	14.0	8.0	≦ 6.0

Figure 15. Average Maintained Illuminance Levels (taken from Guide of Roadway Lighting (2006))

Based on the table above, the LED fixtures will need to provide an average maintained illuminance of 22.0 lux. The 71W ATBS LED head fixtures is rated to output 6300Lm of light per fixture. At a height of 9.14m and using a wide-angle fixture with beam angle of 120˚, the calculated illuminance of each LED fixture is 23.8 lux. The calculated light spread for each fixture is 31.7m; hence, the luminaire poles will be spaced at intervals of approximately 30m to maintain the average-to-minimum uniformity ratio of less than 3.0. The following are the calculations for the illuminance and the light spread:

$$Illuminance = \frac{lumen\ per\ pole}{road\ width * pole\ spacing} * utilization\ factor = \frac{6300\ lumens}{7.5m * 30m} * 0.85 = 23.8\ lux$$

$$Light\ Spread = \tan\left(\frac{beam\ angle}{2}\right) * Height = \tan\left(\frac{120^\circ}{2}\right) * 9.12m = 31.7m\ diameter$$

The lights will be staggered along the north and south side of the corridor at a spacing of approximately 30m between adjacent lights. Please refer to the Detailed Drawings for the proposed placement of the street lights.

10.2 Roundabout Lighting

Lighting will be placed around the perimeter of the roundabout to help road users and pedestrians to identify the geometry of the intersection. Illumination is important at this intersection, especially at critical conflict points, to help prevent incidents from happening and to keep everyone safe. High potential conflict areas in roundabouts are shown in Figure 16 below. The LED lights used for the roundabout will be the same ones used for the corridor, attached to 9.14m Davit luminaire poles as discussed in the previous section. The lighting poles will be installed on the exterior perimeter of the roundabout, at a spacing of approximately 30m as previously discussed. The illuminance on the pavement will be a minimum of 22.0 lux. For a schematic of the lighting for the roundabout, see Figure 17 below or refer to the Detailed Drawings.

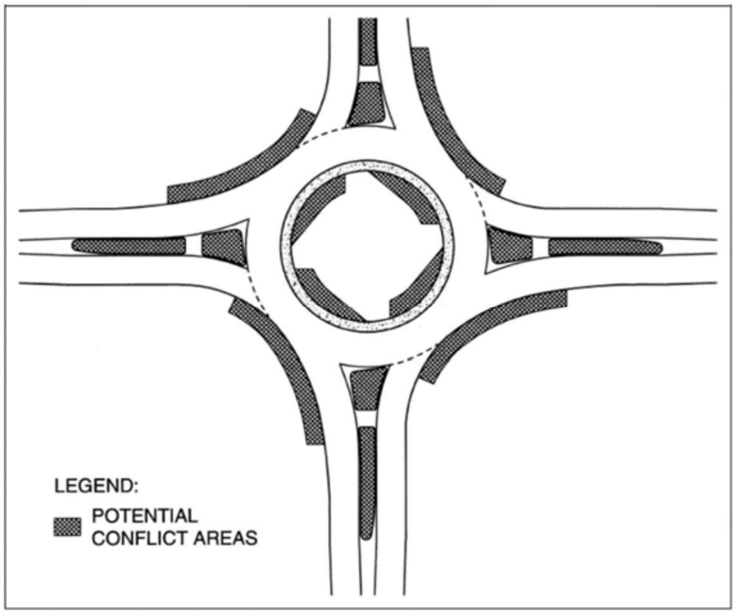


Figure 16. Potential Conflict Areas for Roundabouts (Kansas DOT)

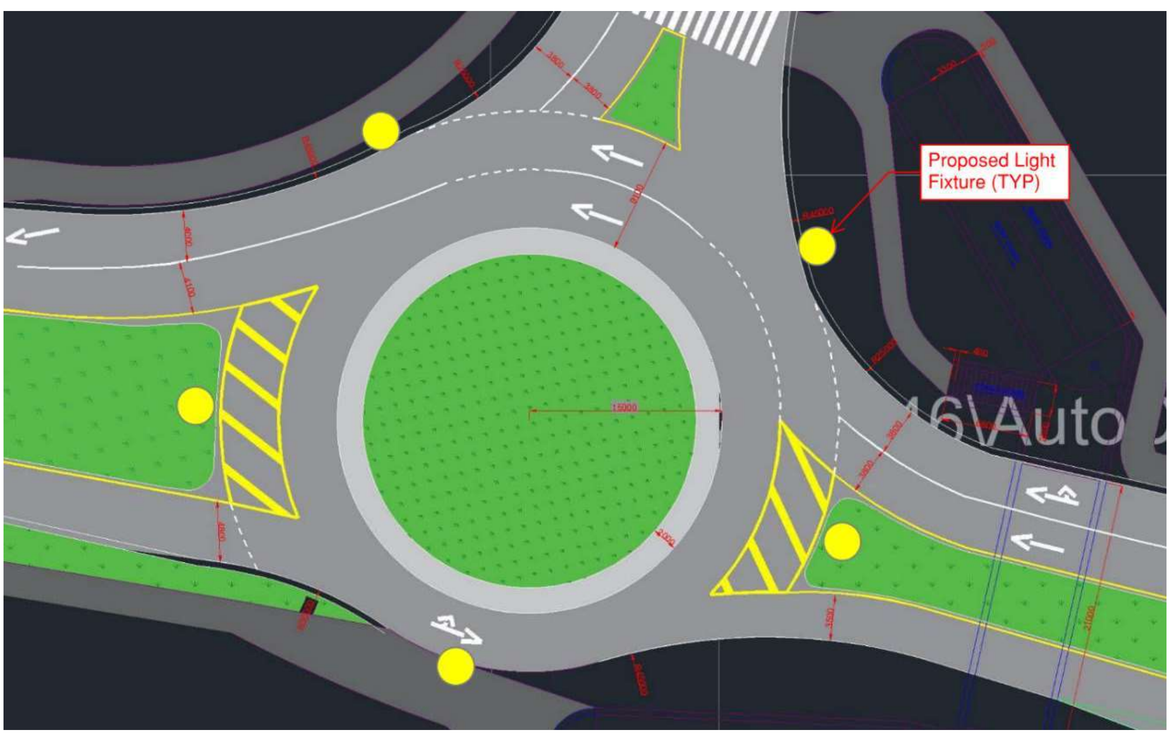


Figure 17. Proposed Placement of Street Lights at Roundabout

10.3 Pedestrian Lighting

Dedicated pedestrian walkway lighting is only warranted in the circumstances where there are the following scenarios, as per Section 303.3.9 of the Code:

1. Ramps to pedestrian overpasses
2. Stairs of more than 2 risers high or other similar hazards
3. Walkways in high security areas as determined by the Ministry Electrical Representative

However, as UBC is a major stakeholder and funder of the project, UBC may wish to include dedicated pedestrian lighting on the walkway to improve walkability of the corridor. Currently, UBC uses the Philips New Westminster Globe Series Roadway NW201 20” for roadway lighting, and the New Westminster Series NWS 16” for pedestrian sidewalk lighting. Table 4 in the Code recommends a pole height of 11m to 13.5m and a wattage of 250W to 400W for a 4 lane road. The pedestrian lights will be spaced at intervals of approximately 20m, similar to the current configuration on the UBC Campus.

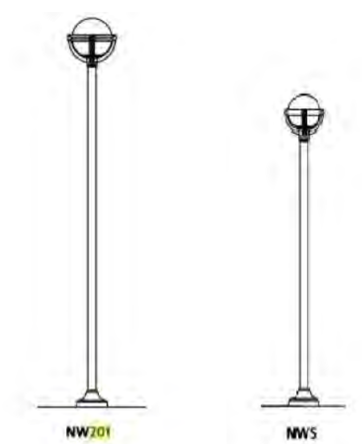


Figure 18. Two Lighting Used for Roadways and Sidewalks Respectively

10.4 Midsection Crosswalk Lighting

The Pedestrian Crossing Control Manual for British Columbia recommends that overhead signs with downlighting for the crossing should be installed indicating the location of a crosswalk, along with a flashing 20cm lens pedestrian activated yellow beacon.

There are two crosswalks in our design, located on the eastern part of the corridor. The map below shows the two locations, with red rectangles around them. Both of these crosswalks should have overhead signs with lighting and flashing beacons.

10.5 Tunnel Lighting

Daytime lighting in tunnels is to counteract the darkness of the tunnel during daytime and improve vision at nighttime. However, tunnel lighting is warranted only for sufficiently long tunnels, or tunnels with poor wall reflectivity and or poor daylight exposure. A warrant for tunnel lighting is to be determined according to IESNA RP-22.

According to Section 308 for Tunnel and Under/Overpass Lighting of the BC Supplement to the TAC Geometric Design Guide, typically pedestrian and bicycle tunnels are illuminated with 70W High Pressure Sodium (HPS) Lights that are on the Ministry Recognized Product List (Clause 308.1.2.1). Therefore, the 70W HPS will be used. The luminaries will be spaced no further than 1.8m apart to provide sufficient visibility for the users and to promote a sense of safety through the underpass.

10.6 Environmental Considerations

Light pollution is an important factor to consider when designing a lighting system. Light pollution is excess light that is directed or reflected onto areas not needing lighting (light trespass), including areas beyond the warrant, the sky, or light that causes glare. According to the International Dark-Sky Association, light pollution results in wasted energy, as well as negative effects on wildlife, such as affecting nocturnal animal's hunting and sleep patterns, or bird migration.

To reduce light pollution, a few measures can be taken:

- Avoid light trespass into that are not important or beyond the lighting warranted area;
- Reduce emitting light into the sky by using internal caps or full cutoffs;
- Performing a photometry assessment

Lowering the light to the ground through the use of light bollards can also reduce the light pollution, however the UBC Campus Plan advises against the use of these. The Campus Plan however does not give reasoning as to why they are discouraged.

11.0 Schedule and Construction Phasing

The preliminary schedule outlines the sequencing of work from initial design development to the completion of construction. Preconstruction is projected to start on January 1, 2018 and construction is to start on May 1, 2018 and end on March 6, 2019. Construction is broken down into three phases to maintain ongoing traffic conditions and keep negative construction effects to a minimum. Refer to Appendix D for the detailed schedule.

11.1 Phase 1

During Phase 1 of construction (during summer), Chancellor Boulevard will be completely closed off in order to accelerate the excavation process for the new tunnel underpass and the new roundabout intersection as shown on Figure 19. At this stage, underground utility lines are to be relocated and the tunnel underpass will be constructed (See Figure 20). The north lanes of the roundabout intersection are filled, paved and finished in preparation for phase 2 as shown on Figure 21.

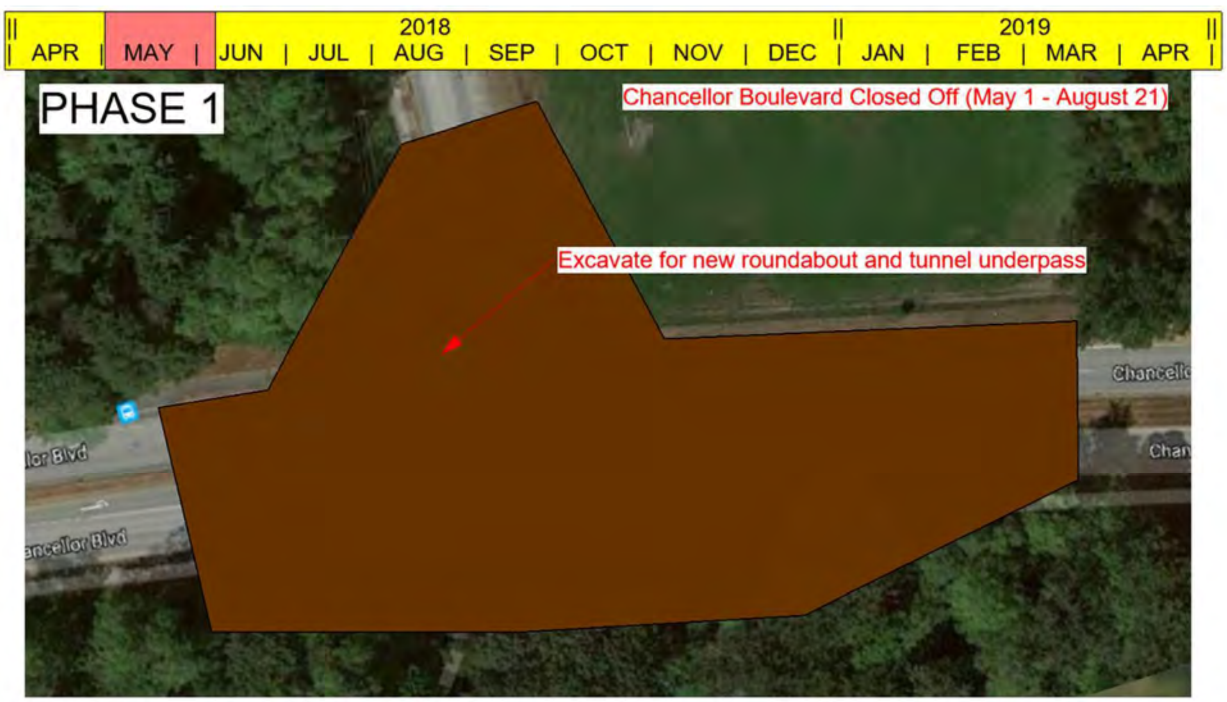


Figure 19. Phase 1 - Excavation

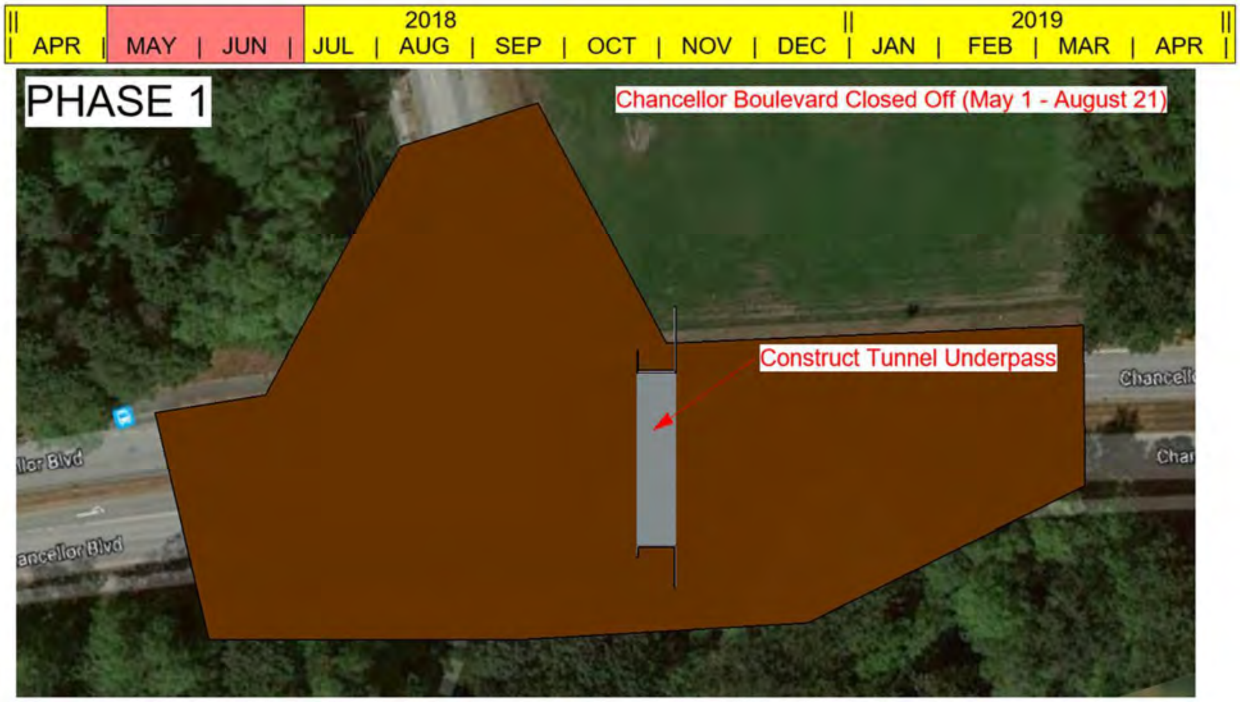


Figure 20. Phase 1 – Tunnel Underpass

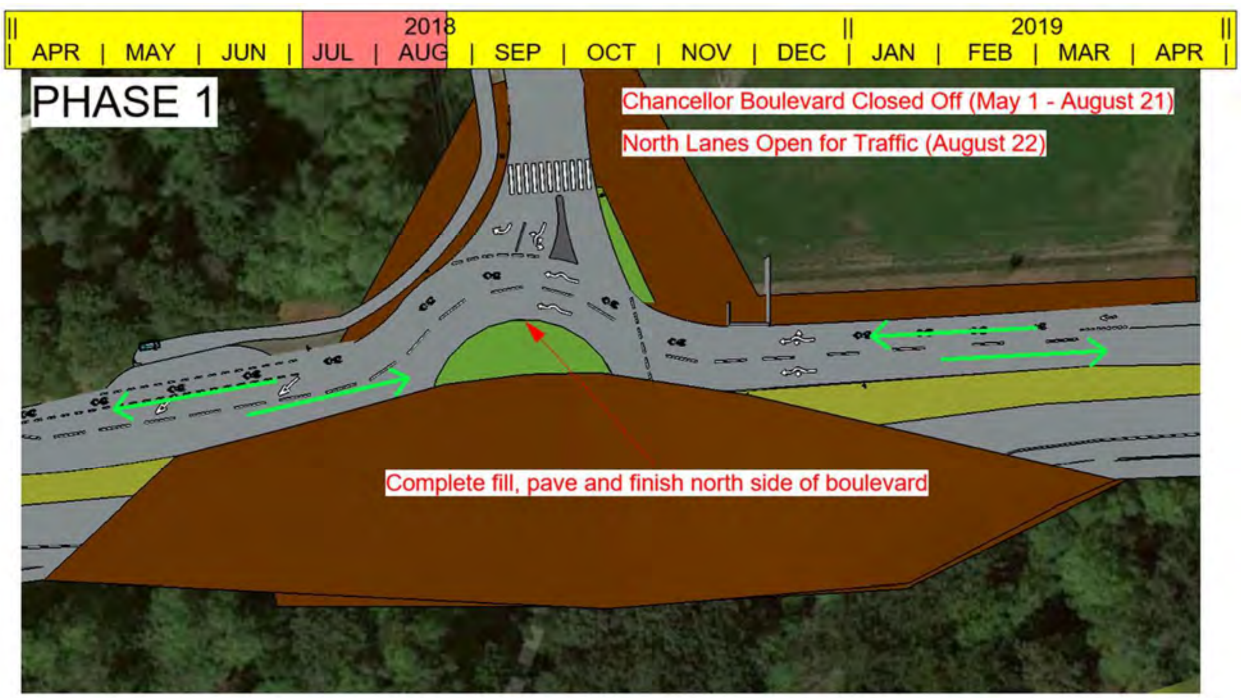


Figure 21. Phase 1 – North Side Paving

11.2 Phase 2

In Phase 2, the north side of the corridor will be in use while the south intersection lanes are filled, paved and finished as shown on Figure 22. Both north and south sides of the corridor will be open as soon as the south intersection lanes are completed. The tunnel ramps and stairs are expected to be completed at the end of phase 2 as shown on Figure 23.

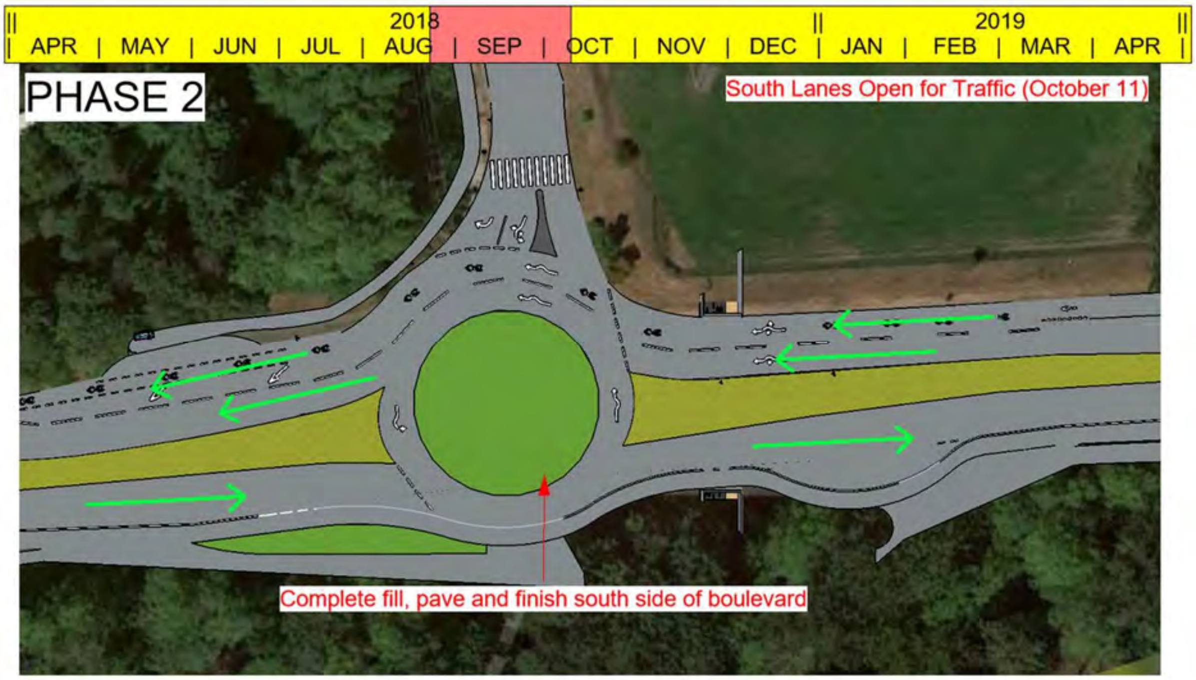


Figure 22. Phase 2 – South Side Paving

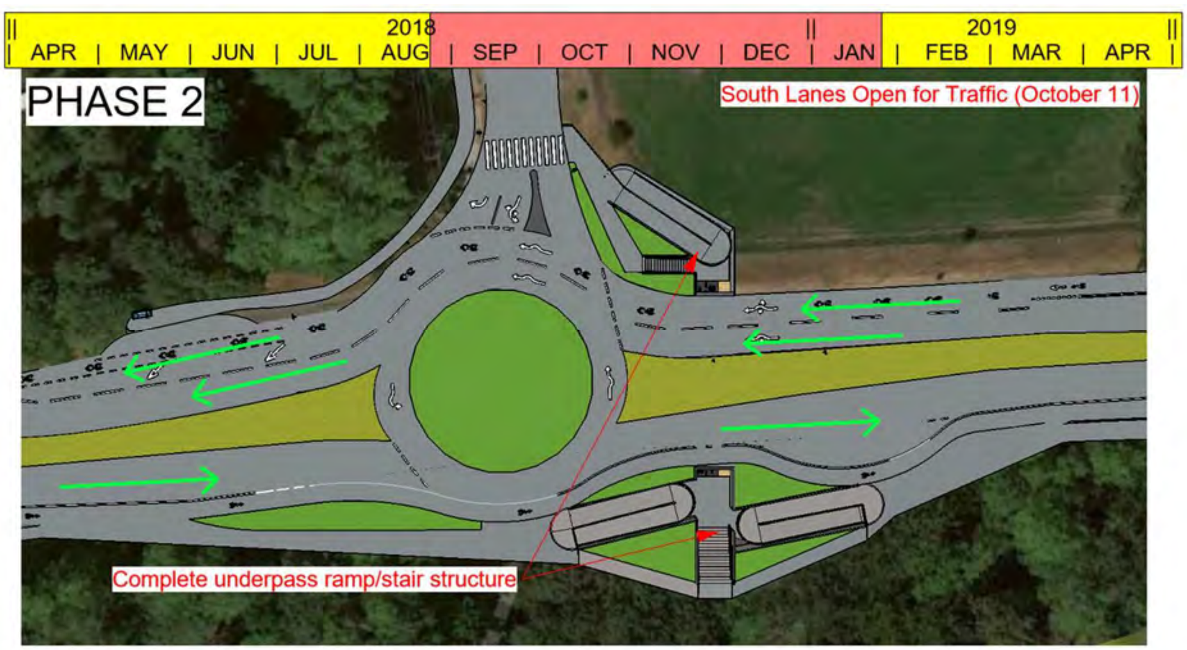


Figure 23. Phase 2 – Underpass Ramp/Stair Structure

11.3 Phase 3

Phase 3 focuses on the final finishing details along the entire corridor. Existing roads are milled and filled, painted medians are applied, and street lights are installed all throughout the corridor. Pedestrian crosswalks with amber lights and integrated systems are also completed in this phase. These are shown on Figure 24.

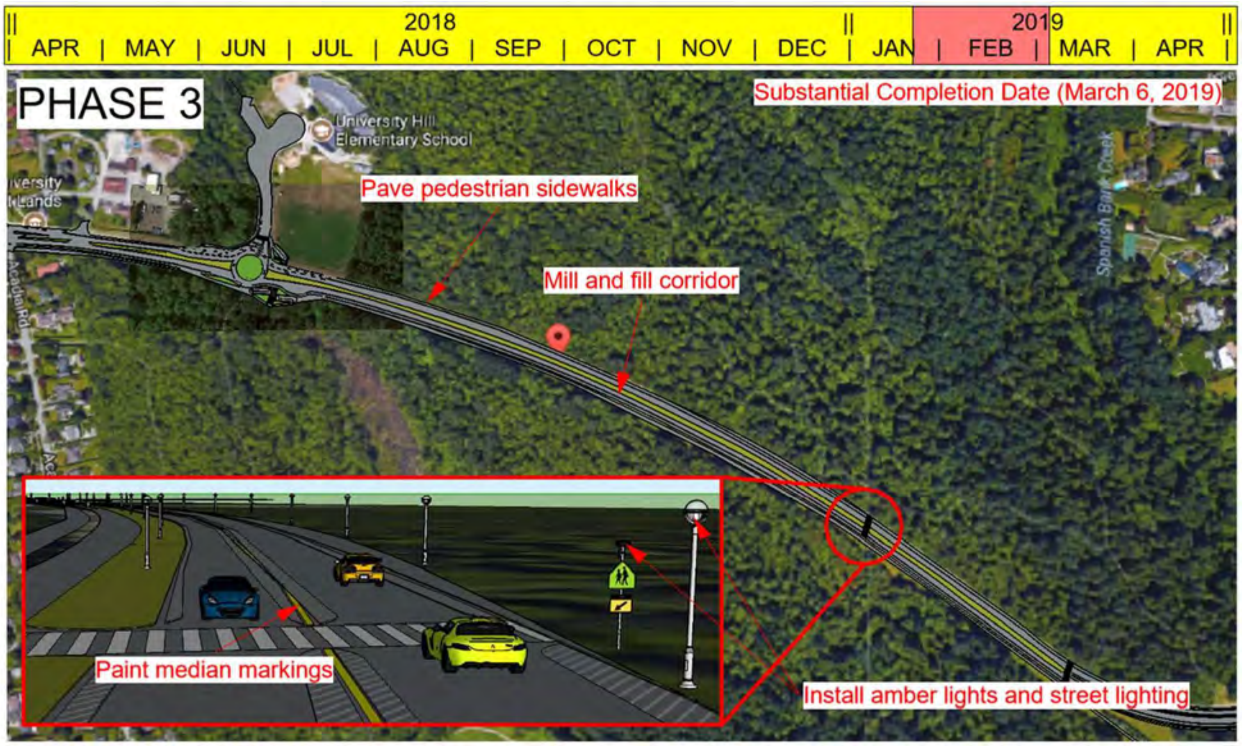


Figure 24. Phase 3 – Corridor Upgrades

Anticipated Site Condition Issues

Since the site is located outside, there are construction site issues related to weather conditions. A heavy storm might cause site problems as there is limited space for an erosion/sedimentation control area. Due to limited information on utility lines, there might be issues during excavation. The actual location of existing utility lines is not fully known as as-built utility drawings are outdated. In addition, possible drainage during the relocation/construction of utility lines is possible during a heavy storm event. Foundation placement of the stair and ramps for the underpass might have to be revised if geological site conditions are not met. Other site condition issues that could arise may include dust and/or noise that might be problematic for the public.

12.0 Economic Analysis

12.1 Cost Estimate

DTS Engineering has conducted a cost analysis of the redevelopment of Chancellor Blvd. The goal of this cost estimate is to produce the best cost estimate corresponding to the level of project development which shall take into account of contingencies reflective to the project risks and project phase. Roundabouts are typically more expensive than stop controlled and cost about the same as signalized intersections. However, in this project, since the roundabout is undergoing complete redevelopment, the cost to construct a roundabout may be more cost effective than a signalized intersection.

This complete cost estimate will include the following cost: Project Management, Planning, Design, Property Acquisition, Roadway Construction, Underpass Construction, Active Transportation Facilities, Electrical, Landscaping, QC/QA and Operation and Maintenance. The total project cost is projected at 6.58 million dollars. The estimate was completed by referring to the Ministry of Transportation and Infrastructure 2013 cost guide as well as price per linear meter industry standards. The table below summarizes the cost of key items in project. The following table is a summary of the cost estimate for the project.

Summary Cost Estimate			
Item	**Base Cost**	**Contingency (20%)**	**Total Cost**
Roundabout	602,070	120,414	722,484
Roadway	1,140,164	228,033	1,368,196
Underpass	1,322,422	264,484	1,586,907
Active Transportation	411,632	82,326	493,958
Electrical	712,800	142,560	855,360
Landscaping	6,364	1,273	7,637
Design Cost			443,669
Property Acquisition			0
Project Management			155,284
Planning			44,367
Construction QA/QC			443,669
Annual Operation and Maintenance			221,835
Inflation Cost (2013 to 2018)			241,238
Total Project Cost			**6,584,604**

12.2 Methodology:

1. Determine the required unit price based on 2013 MoTi's cost guide
2. Estimate the required construction quantities from our project scope
3. Estimate the construction cost of each infrastructure/section
4. Estimate the inflation from 2013-2018
5. Due to unknown factors and stage of the project, apply 20% contingency (unless construction unit price is included in cost guide)

12.3 Assumptions:

Project Management	• Assume 3.5% of total construction cost
Planning	• Assume 1% of construction base estimate
Design	• Preliminary Design - 2% of construction base estimate • Detailed Design Services – 8% of construction base estimate
Property Acquisition	• Pacific Spirit Regional Park is owned by Metro Vancouver and Chancellor Blvd is owned by MoTi and UBC. • Tunnel and Roundabout will require right of way from Pacific Spirit Regional Park as existing roadway is not large enough to accommodate for extra infrastructure • Assume government entities agree on shared ownership of tunnels or roundabout and therefore **no property acquisition is required** • Allocate cost for tree cutting
Environmental	• Assume no environmental compensation cost
Construction	
Roadway	• Mill and Fill existing roadway except for roundabout area • Grading construction cost include construction, materials supplied by MOT, miscellaneous and utility relocation, but does not include engineering design or property acquisition • Paint markings for roadways as a separate cost • Signage as a separate cost • No detectors or intersection lighting • Assume Roundabout area is all new roadway construction
Utilities	• Assume 50m spacing between lighting on both sides • Only require super elevation to provide drainage on main road • Roundabout and tunnel to install new drainage to existing storm system • Allocate $30,000 for ITS system
Active Transportation	• Rehabilitate sidewalk by assuming using a hot in place asphalt with add mix and rejuvenating agent @ 50mm depth • Includes centre line marking, geotechnical evaluations, construction cost, labour, equipment and materials • Bicycle lanes only require paint marking

Underpass	• Split cost into subsections:
	  o Excavation
	  o Tunnel concrete

	○ Ramp concrete ○ Finishing • Assume tree cutting only for area due to roundabout and ramp right of way • All construction quantities taken from AutoCAD • Cost of tunnel lighting is $1000/unit, spaced 1 every 3 meters • All unit cost taken from average of cost unit price list from: http://www.transportation.alberta.ca/Content/docType257/Production/UnitPriceList.pdf
Landscaping	• 1248667859mm^2 of landscaping. Quantity determined from AutoCAD
Property Acquisition	• Pacific Spirit Regional Park is owned by Metro Vancouver and Chancellor Blvd is owned by MoTi and UBC. • Tunnel and Roundabout will require right of way from Pacific Spirit Regional Park as existing roadway is not large enough to accommodate for extra infrastructure • Assume government entities agree on shared ownership of tunnels or roundabout and therefore **no property acquisition is required** • Allocate cost for tree cutting
Construction QA/QC	• Assume 5% of base construction estimate
Operational and Maintenance	• Assume maintained by MoTI • Assume 5% of total estimate • Operation and Maintenance detail located in service life maintenance plan

13.0 Service Life Maintenance Plan

In evaluating our project, a service life maintenance plan was conducted in order to optimize and extend the life of the components in this project. The annual operation and maintenance cost is noted in the project cost section. The following section will analyze the service life maintenance plans for key components in our project site which includes: Roadway and sidewalk pavement, ramps, tunnel, and the roundabout.

13.1 Roadway and Sidewalk Asphalt Pavement

Service maintenance methods for roadways range depending on the type of maintenance needed, severity of damage, and cause of damage. Routine maintenance of road such as road sweeping, and cleaning must be conducted under a regular basis to avoid drainage from being clogged and to keep our streets clean and vibrant. Roadway repaving is required and is essential to ensure the safety of roadway vehicles. Mill and Fill is expected to last between 15 to 25 years. Maintenance is required to mitigate large asphalt repairs which will cost more in the long run. According to MoTi, lane edge lines and dividing lines on lower volumes roads are repainted every two years. Sidewalk pavement markings are done every five years.

13.2 Ramps

Routine maintenance of the ramps is essential to the safety and maintenance of the structures. The ramps must be periodically cleaned to avoid build up of debris. Snow removal is also essential to ensure good traction. Drain hole must be unclogged to drain the storm water effectively. Periodic checks of the ramps, railings, and fasteners are essential to determine any cracks or damages that may occur.

13.3 Pedestrian Tunnel/Underpass

About 70 – 80% of all operational and maintenance activities are performed as preventative maintenance in order to prevent replacement of capital infrastructure. The tunnel must periodically be tested and measured to ensure that no significant movement has occurred. Sealing or repair of concrete may be needed due to freezing. Tunnels need to be periodically washed as part of a preventative maintenance program. Groundwater infiltration can cause corrosion in the inside of the tunnel and significantly decrease the useful life of the tunnel. Debris must be removed from the tunnel drainages systems on a periodic basis. If flooding is anticipated, a pump system must be available and capable of pumping out flood water. Illumination in the tunnel should utilize high efficiency LED lighting and should be monitored periodically. Electrically systems such as fire detection and cameras must be monitored and tested.

13.4 Roundabout

Compared to a signalized intersection, a roundabout will not require additional constant power or detection maintenance specifically during a power outage situation. Illumination maintenance is about the same as a signalized intersection. Compared to a signalized intersection, a roundabout will require more landscaping maintenance in the center island, splitter islands, and perimeters. Choosing specific landscaping that requires less maintenance will reduce the cost for maintenance. DTS Engineering recommends providing an inset in the roundabout to provide maintenance access to the central island. However, an inset may not be required if landscaping maintenance inside the roundabout is conducted during low vehicle volume hours. In addition, snow removal is essential to maintaining the roundabout. Snow removal may be easier in a roundabout as it is easier to turn around snowplows. However, snow removal in a roundabout may require more caution as to not damage the raised curbs and side aprons. Common snow removal techniques suggest that the inner most section of the roundabout is plowed first and removed in a circulatory fashion towards the outside edge of the roundabout. Afterwards, a second snow plow is utilized to clear the entries and exits of the roundabout. Snow storage must not obstruct the drivers approaching or circulating the roundabout. Pedestrian access must also not be obstructed. Under large snowfall, knocking down the height of the snow piles may be necessary to prevent obstruction to sight.

Appendix

rjc Creative Thinking Practical Results

Project Traffic Safety Analysis
Date RJC No.
Designer Zoe Athans

From AASHTO Geometric Design Guide Exh. 3-1 Stopping Sight Distance

Design Speed	Design Stopping Sight
40 km/hr	56 m
50 km/hr	65 m
60 km/hr	85 m
70 km/hr	105 m

Posted Speed Limit = 50km/hr, Design Speed = 70km/hr

Crosswalk #1 (for Eastside)

Horizontal curve:

$$M = R\left[1 - \cos\frac{28.65S}{R}\right]$$

$M \approx 10m$
$R \approx 260m$

$$10 = 260\left[1 - \cos\frac{28.65S}{260}\right]$$

S = 145m → V = 80km/hr > Design Speed ✓ ok
S = sight distance

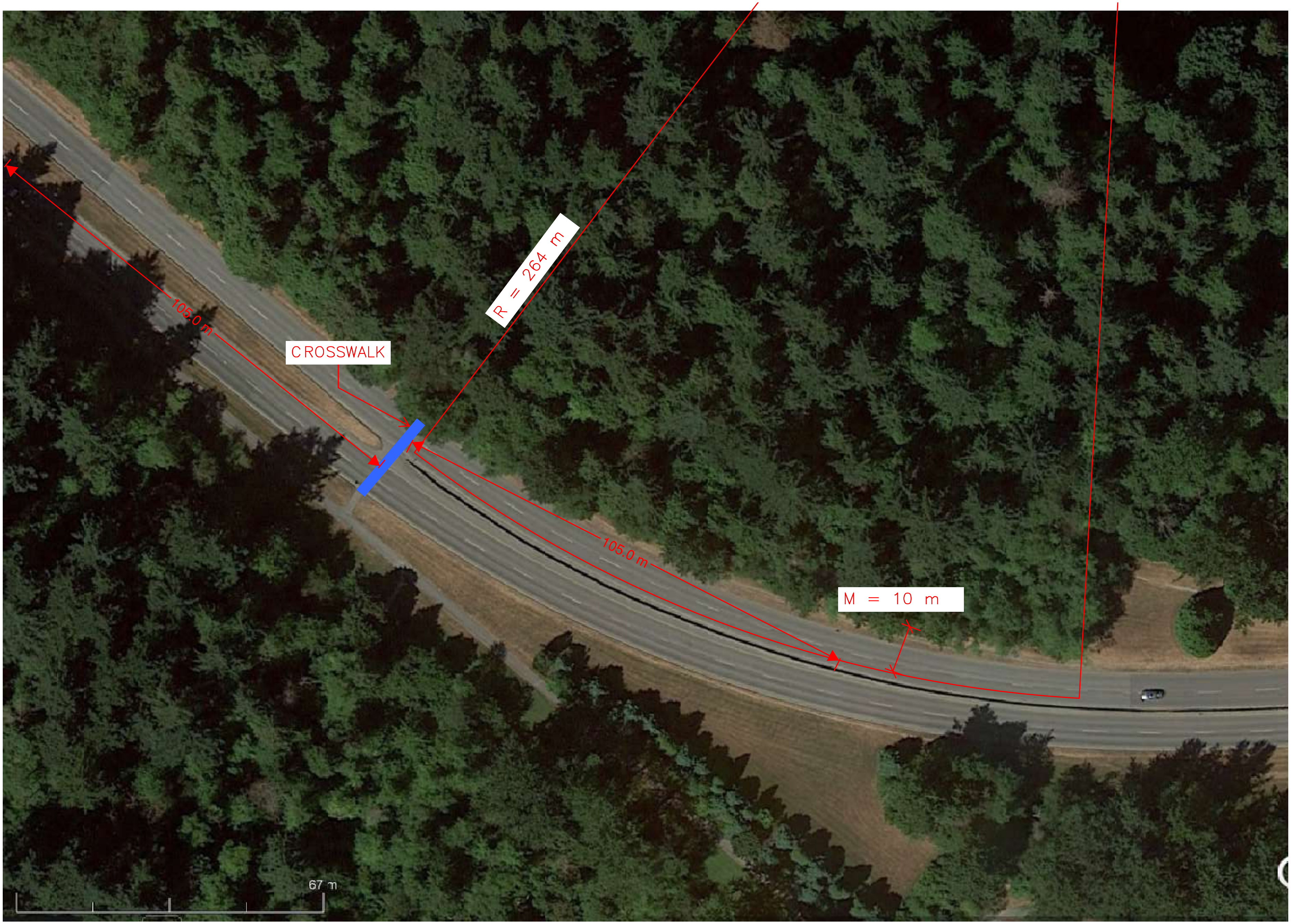
Stopping Sight = 105m < 145m ✓

Crosswalk #2

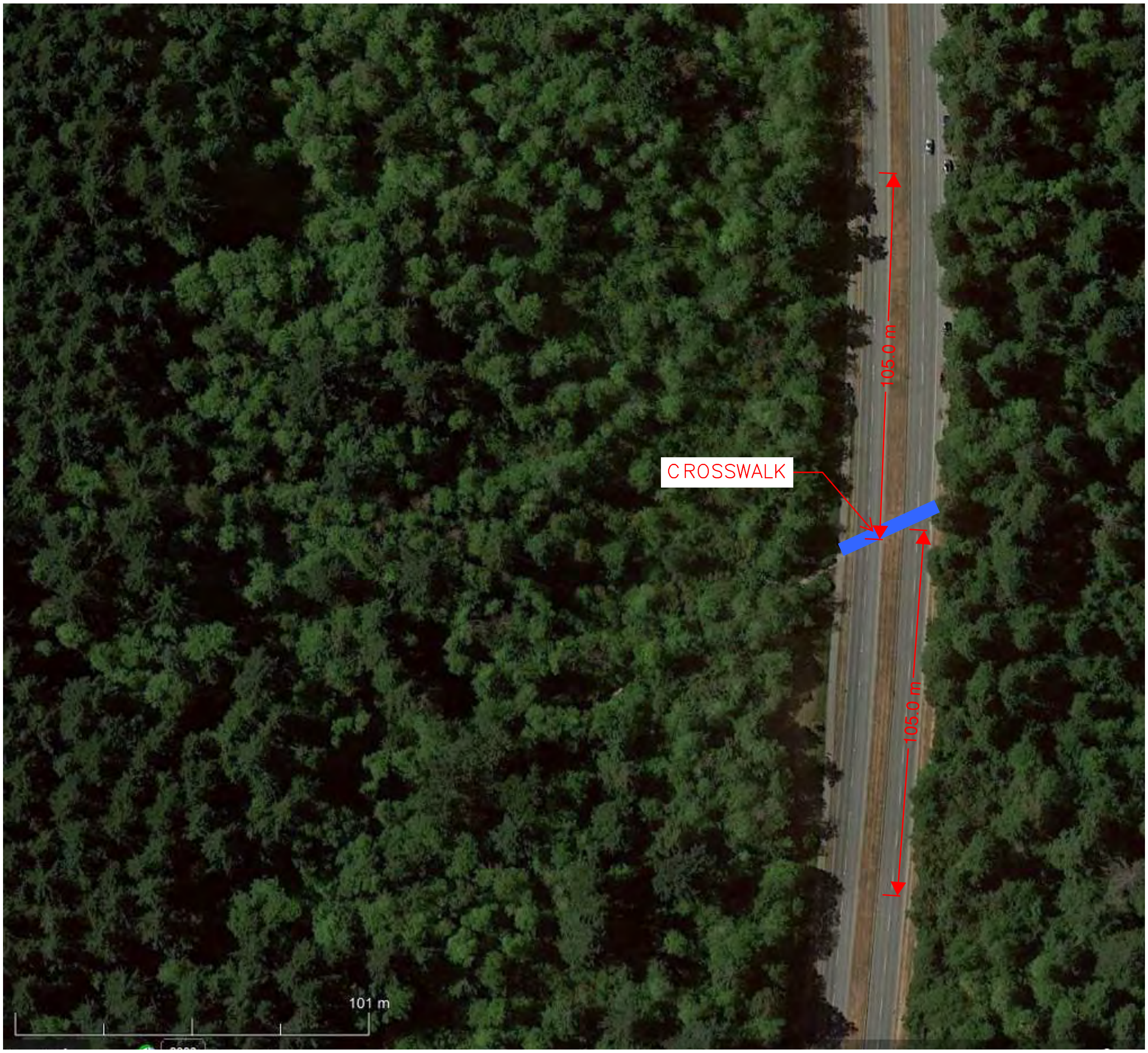
Sight distance > 105m ✓

Intersection

Sight distance > 105m ✓



CROSSWALK
R = 264 m
105.0 m
105.0 m
M = 10 m
67 m


CROSSWALK
105.0 m
105.0 m
101 m


105.0 m
105.0 m
96 m

Design vehicle, for reference, truck should be able to turn with the truck apron

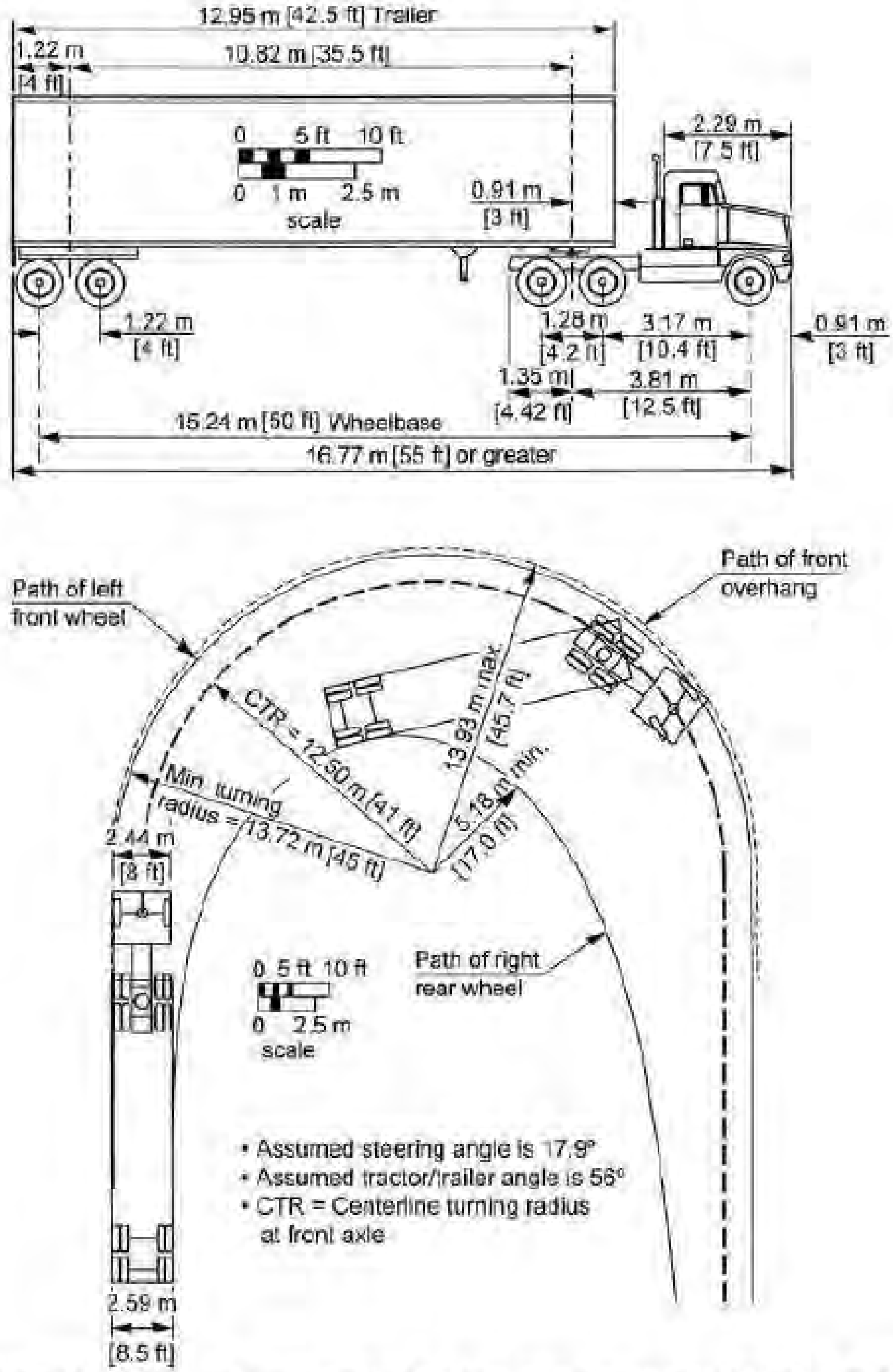
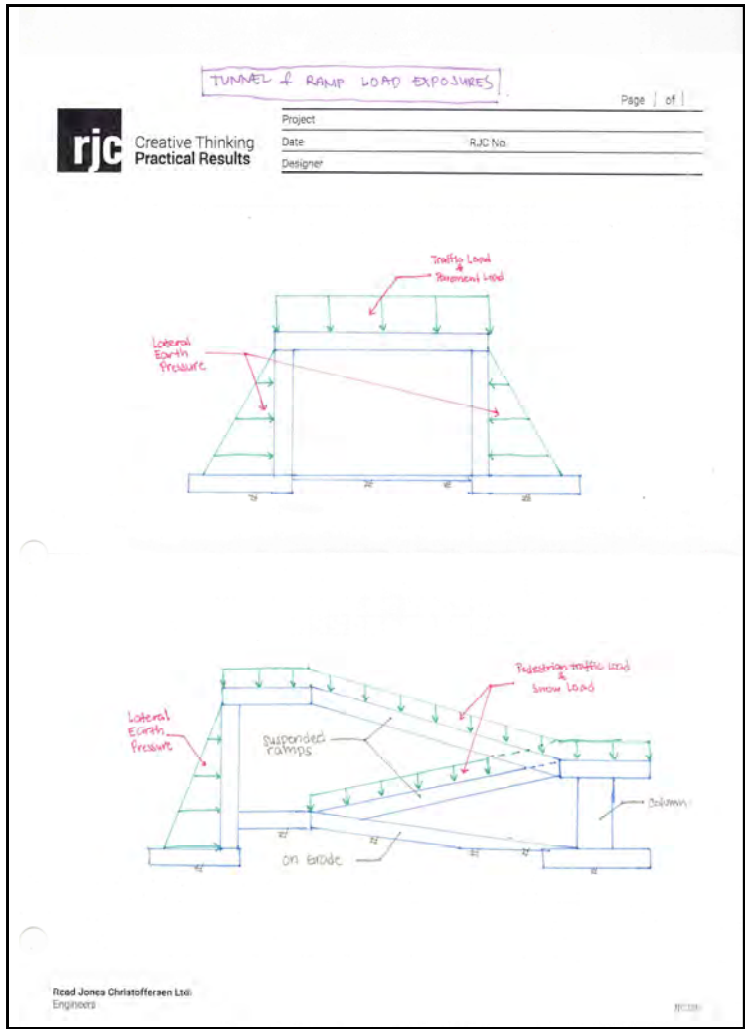
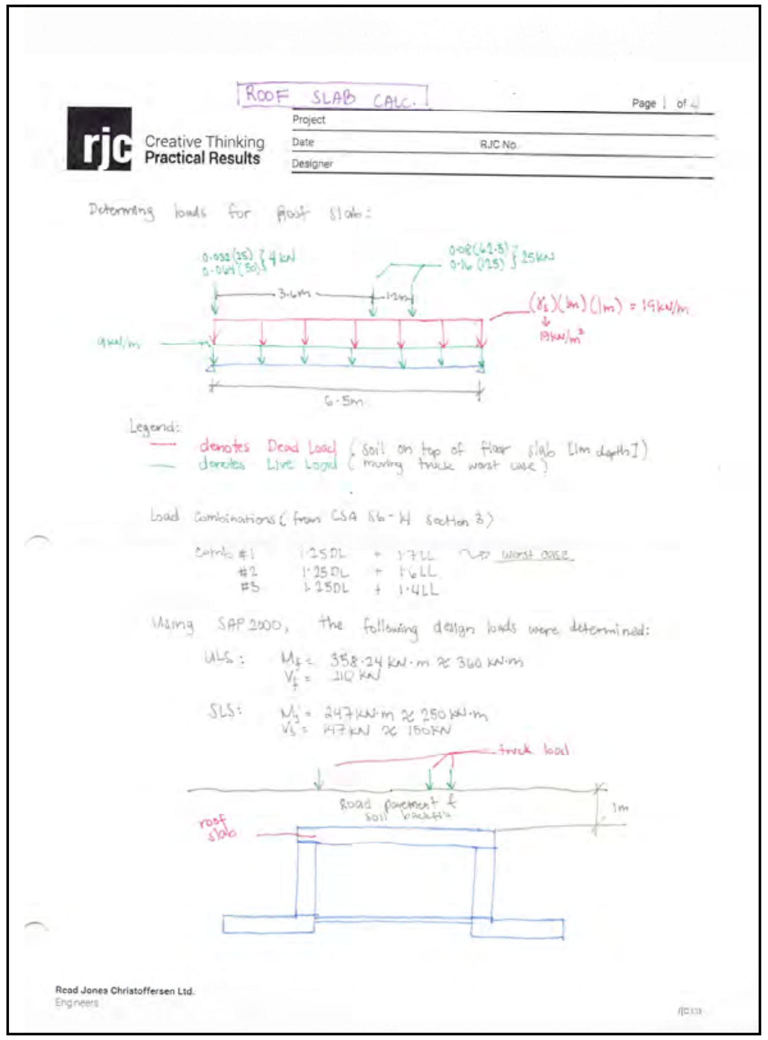
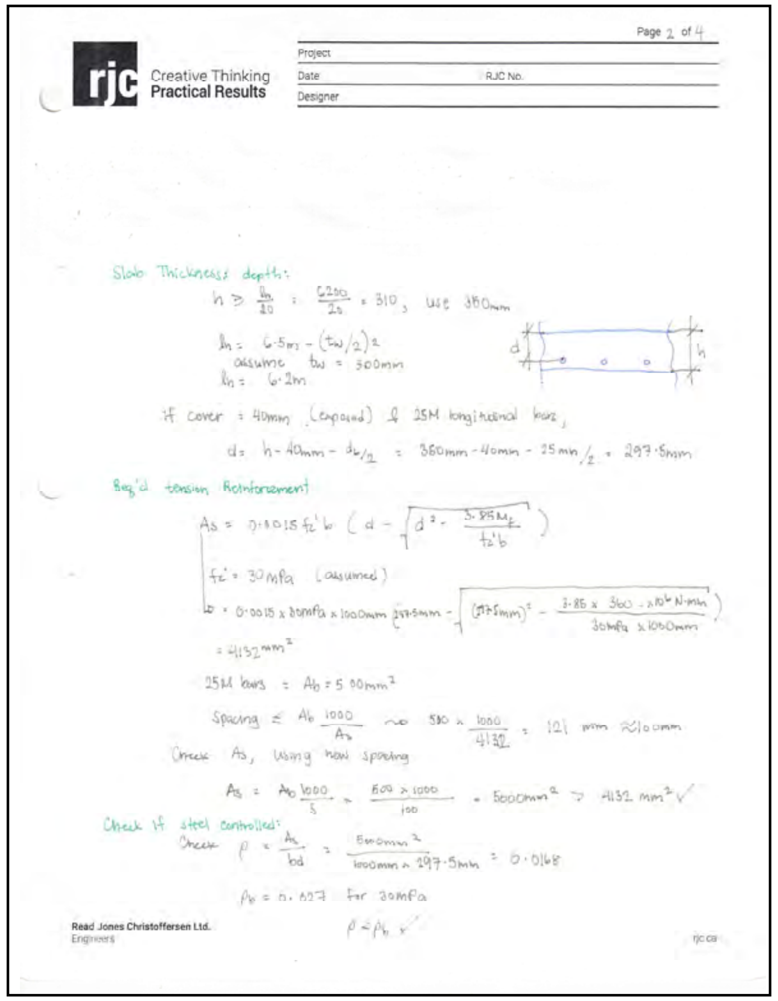


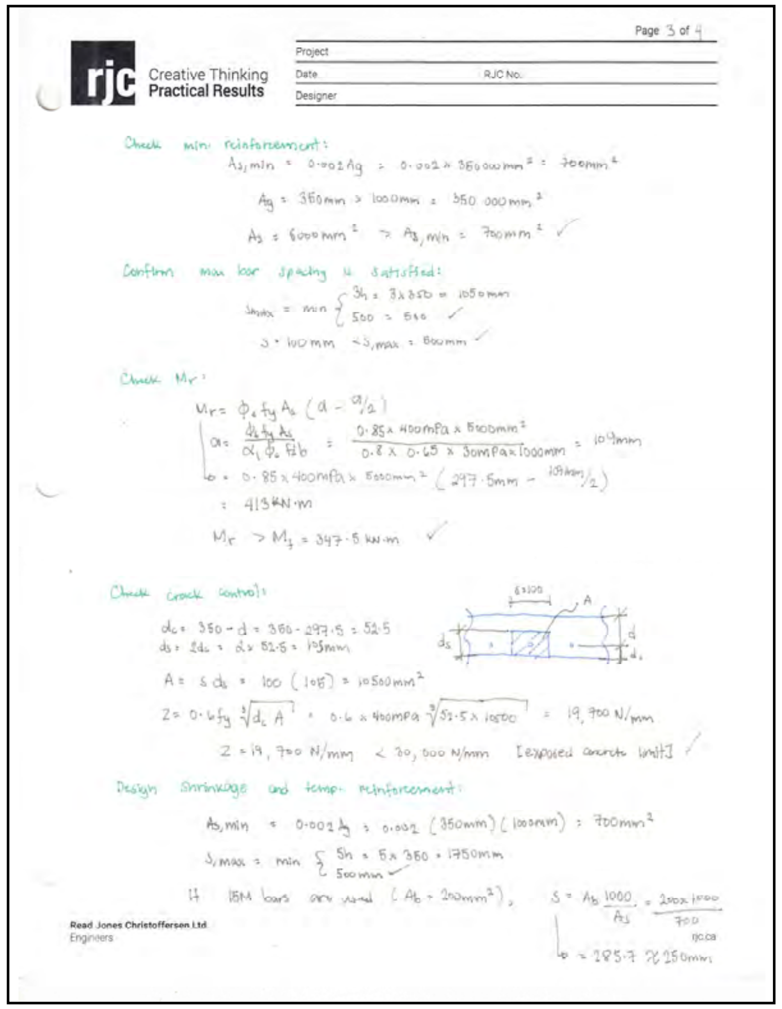
Exhibit 2-14. Minimum Turning Path for Intermediate Semitrailer (WB-15 [WB-50]) Design Vehicle

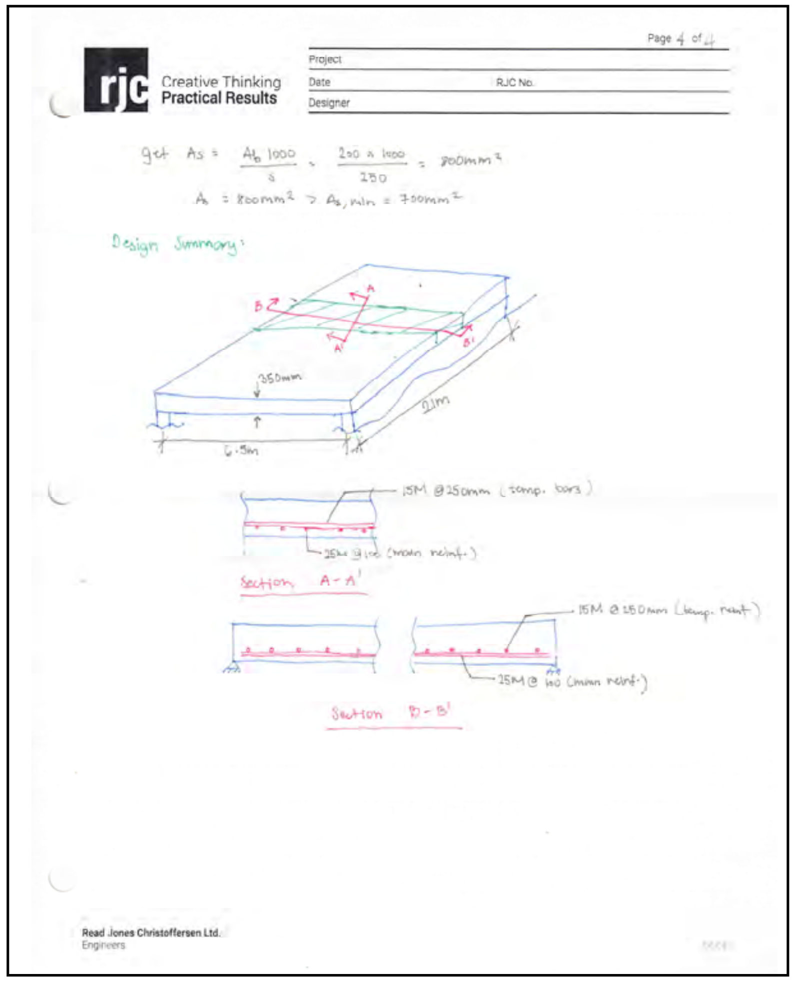
Appendix B – Pedestrian Underpass Structure

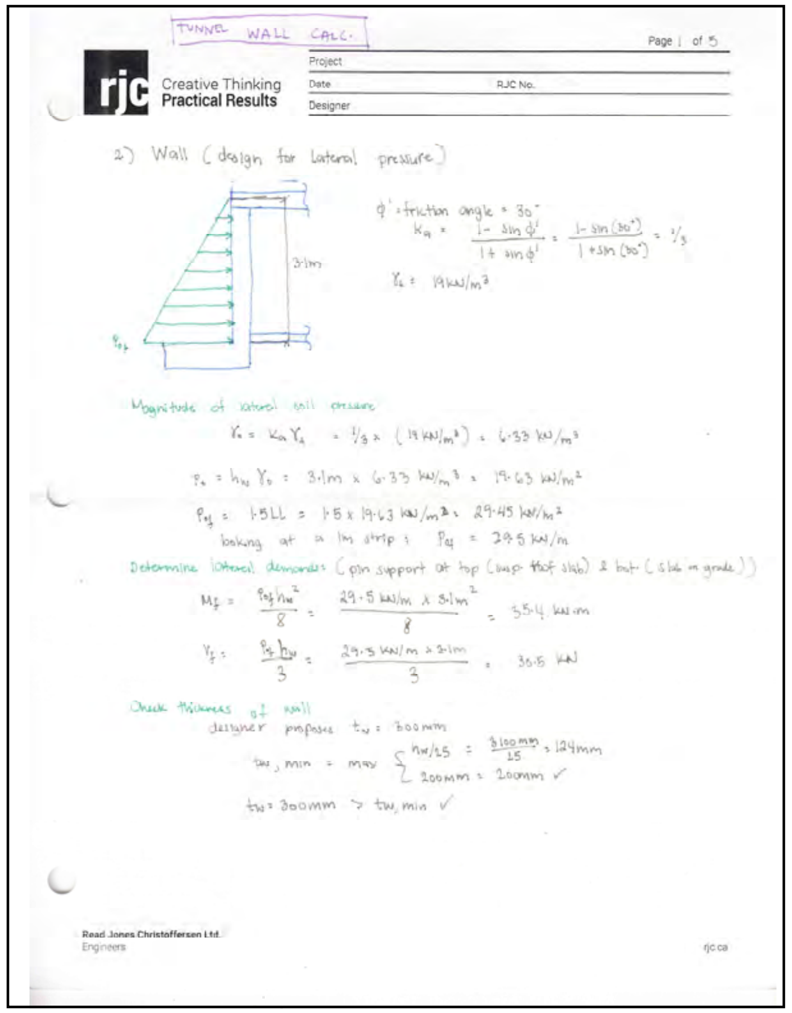


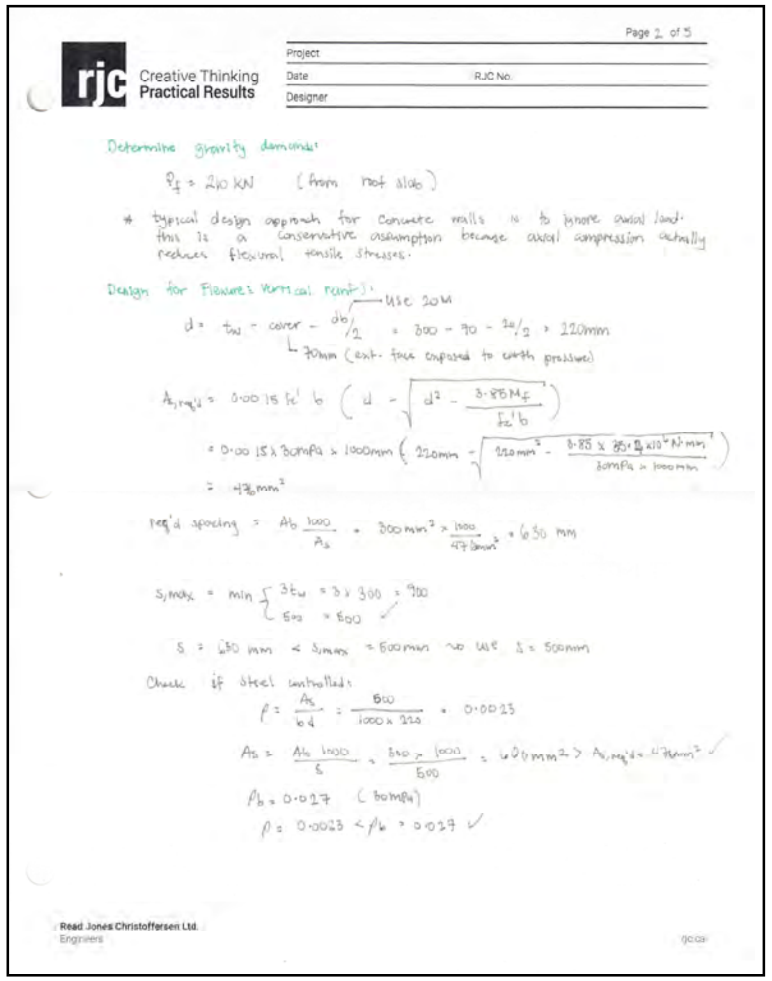


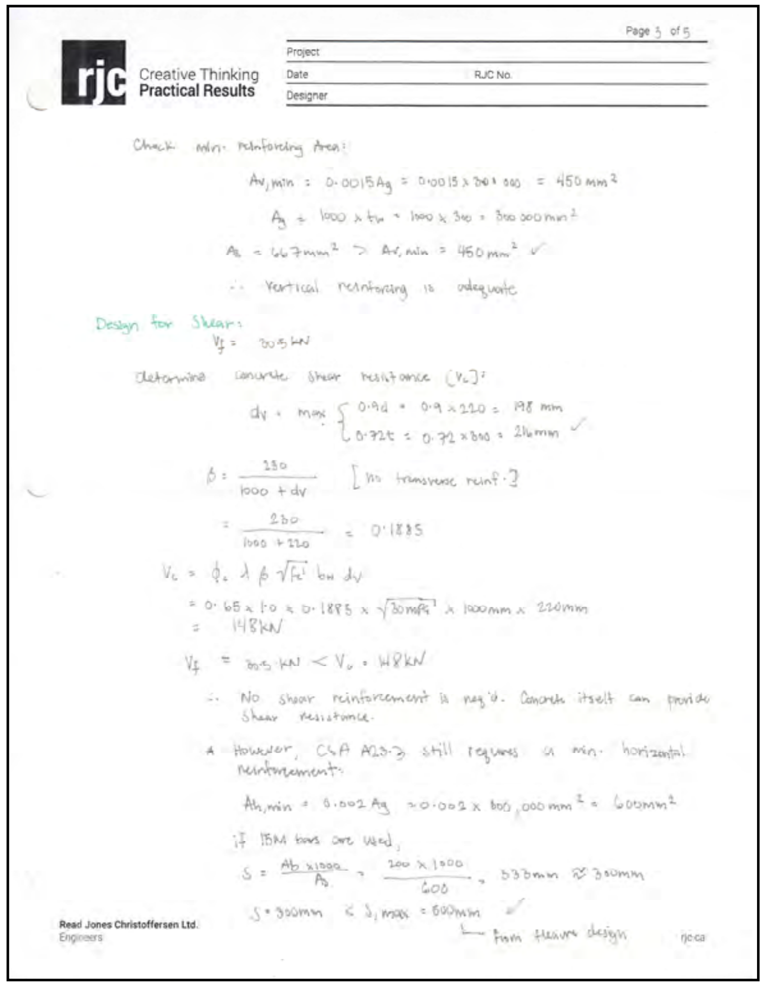












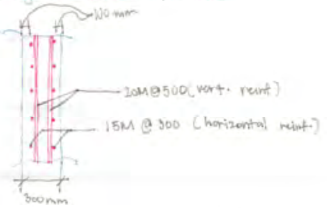
rjc Creative Thinking Practical Results

Project
Date RJC No.
Designer

Layer of reinforcement:

Since $t_w = 300mm > 210mm$, two curtains are required.
each curtain must be placed at $t/3$ from wall surface:
$300/3 = 100mm$

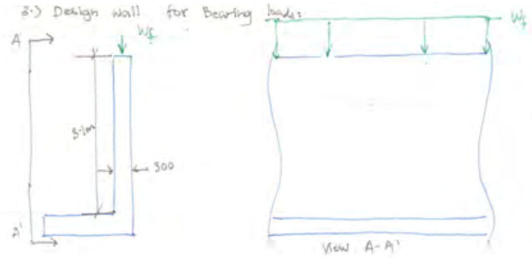
Design summary for lateral pressure:



rjc Creative Thinking Practical Results

Project
Date RJC No.
Designer

3.) Design wall for Bearing loads:

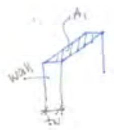


Determine w_f:

w_f is from roof slab load ($P_f = 210$ kN), spaced at every 1m

$$w_f = \frac{P_f}{S} = \frac{210 kN}{1m} = 210 kN/m$$

Check Bearing Resistance:



$B_r = 0.85 \phi_c f_c' A_1$

A_1 = contact Area = $(1000mm \times t_w) = 3 \times 10^5 mm^2$ (300mm)

$= 0.85 \times 0.65 \times 30MPa \times 3\times10^5 mm^2 = 4973 kN$

$B_r = 4973 kN > P_f = 210 kN$ ✓

Check Axial Resistance:

$$P_r = \frac{2}{3} \alpha_1 \phi_c f_c' A_g \left[1 - \left(\frac{k h_w}{32 t_w}\right)^2\right]$$

$k = 1.0$ [pin-pin]

$A_g = 1000mm \times 300mm = 3 \times 10^5 mm^2$

$h_w = 3.1m$

$= 2/3 \times 0.8 \times 0.65 \times 30MPa \times 3.5\times10^5 mm^2 \left[1 - \left(\frac{1 \times 3100mm}{32 \times 300mm}\right)^2\right]$

$P_r = 3260$ kN/m $> W_f = 210$ kN/m ✓

∴ use rebar layout determined from lateral design

STRIP FOOTING CALC

rjc Creative Thinking Practical Results

Project
Date RJC No.
Designer

4) Design for Footing (eccentrically loaded)
$P_f = 210$ kN (roof slab load, $P_s = 147$ kN) ← service load

Determine footing width:

$$q_{max} = \frac{2P_s}{bl} = \frac{2 \times 147 kN}{1m \times l}$$

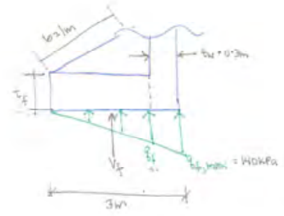
$q_{max} = q_{allowable} = 100$ kPa [provided by geotechnical report]

$$l = \frac{2 \times 147kN}{1m \times 100kPa} = 2.94m \approx 3m$$

Get factored soil bearing pressure:

$$q_{f,max} = \frac{2 \times 210 kN}{1m \times 3m} = 140 kPa$$

Determine footing thickness by checking shear



$$q_f = \frac{q_{f,max}}{l}(l - t_w) = \frac{140kPa}{3m}(3m - 0.3m)$$

$= 126kPa$

$$V_f = q_f \times b \times \left(\frac{l - t_w}{2}\right) = 126kPa \times 1m \left(\frac{3 - 0.3}{2}\right)$$

$= 170.1$ kN

Assume $t_f = 300mm$ then check shear resistance

$V_c = \phi_c \lambda \beta \sqrt{f_c'} b_w d_v$

$d = t_f - cover - d_b/2 = 300mm - 75mm - \frac{20mm}{2} = 215mm$ (use 20M)

(exposed to earth use 75mm)

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Project
Date RJC No.
Designer

$d_v = \max \begin{cases} 0.9d = 0.9 \times 215 = 193.5mm \\ 0.72t_f = 0.72 \times 300 = 216mm ✓ \end{cases}$

$\beta = 0.21$ [A23.3 Cl. 11.3.6.2] [$t_f < 350$]

$V_c = 0.65 \times 1.0 \times 0.21 \sqrt{30} \times 1000 \times 216 = 161.5 kN$

$V_c < V_f$, need shear reinforcement...
(161 < 170)
to avoid using shear reinf., increase t_w to 350mm.

$t_f = 350mm$

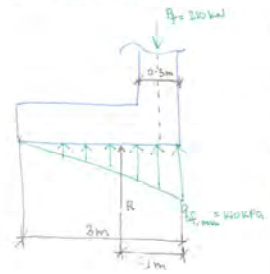
$d = 350mm - 75mm - \frac{20mm}{2} = 265mm$

$d_v = \max \begin{cases} 0.9 \times 265 = 239mm \\ 0.72 \times 350 = 252mm ✓ \end{cases}$

$V_c = 0.65 \times 1.0 \times 0.21 \sqrt{30} \times 1000 \times 252 = 188.4 kN$

$V_c = 188.4 kN > V_f = 170.1 kN$ ✓
∴ no shear reinf. required.

Determine flexural reinf.



$e = \frac{3m}{3} - \frac{0.3m}{2} = 0.85m = 850mm$

$M_f = P_f e = 210kN \times 0.85m = 179 kN\cdot m$

$M_r \geq M_f$

get $A_{s,req'd}$:

$$A_{s,req'd} = 0.0015 f_c' b \left(d - \sqrt{d^2 - \frac{3.85 M_f}{f_c' b}}\right)$$

$= 0.0015 \times 30 \times 1000 \left(265 - \sqrt{265^2 - \frac{3.85 \times 179 \times 10^6}{30 \times 1000}}\right)$

$= 2136mm^2$

rjc Creative Thinking Practical Results

Project
Date RJC No.
Designer

Check if $A_{s,req'd} > A_{s,min}$

$A_{s,min} = 0.002 A_g = 0.002 \times 3.5 \times 10^5 mm^2 = 700mm^2$

$A_g = 350mm \times 1000mm = 3.5 \times 10^5 mm^2$

$A_{s,req'd} = 2136 mm^2 > A_{s,min} = 700 mm^2$ ✓

Get Amount of flexural reinf:

If 25M bars are used: ($A_b = 500mm^2$)

$$S = \frac{A_b \times 1000}{A_s} = \frac{500 \times 1000}{2136} = 234mm \approx 200mm$$

Check if $s < s_{max}$

$s_{max} = \min \begin{cases} 3t_f = 3 \times 350 = 1050 mm \\ 500mm ✓ \end{cases}$

$s = 200mm < s_{max} = 500mm$ ✓

Determine min. longitudinal reinf:

$A_{s,min} = 700mm^2$

If 15M bars are used: ($A_b = 300mm^2$)

$$\# \text{ of bars} = \frac{700mm^2}{300mm^2} = 2.33 \approx 3 \text{ bars}$$

100mm space from vertical face of footing is required for the edge bars. Therefore, the 3-15M bars will be spaced:

$$S = \frac{3000mm - 2(100mm)}{2} = 1400mm$$

$s_{max} = 500mm$; ∴ use $s = 500mm$

determine new A_s using $s = 500mm$

$$A_s = \frac{A_b \times l}{s} = \frac{300 \times 3000}{500} = 1800mm^2$$

$$\# \text{ bars} = \frac{1800mm^2}{300mm^2} = 6 \text{ bars}$$

∴ Use 6-15M for longitudinal bars.

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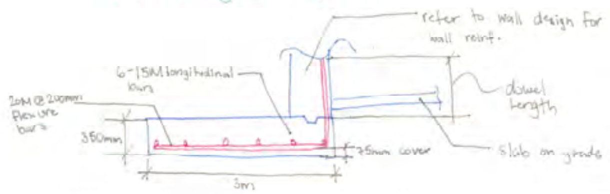
Project
Date RJC No.
Designer

Design Summary of footing:

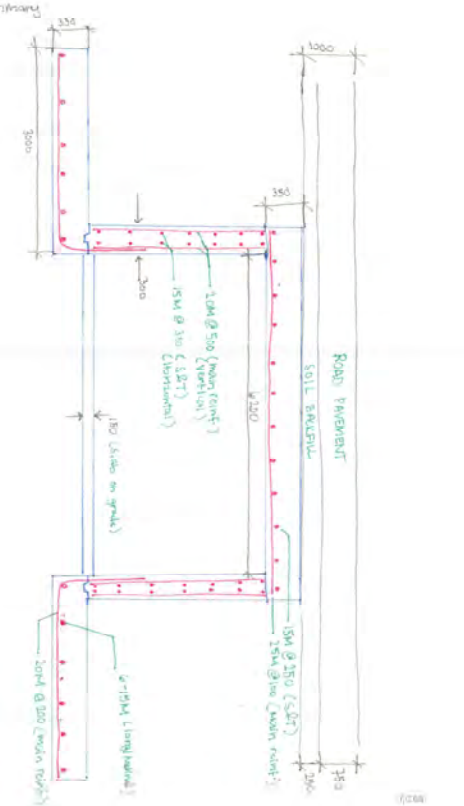


TUNNEL DESIGN SUMMARY

rjc Creative Thinking Practical Results

Project
Date RJC No.
Designer

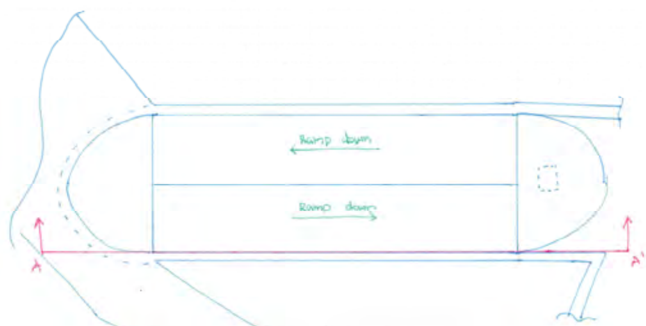
5.) Final design summary



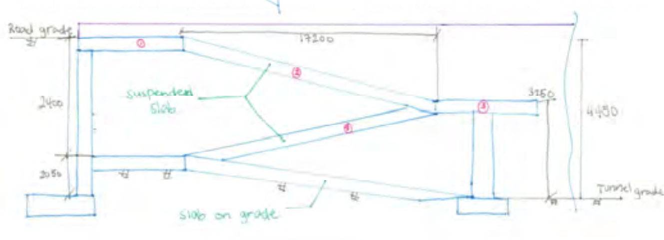
RAMP TYPICAL PLAN & ELEVATION VIEW

rjc Creative Thinking Practical Results

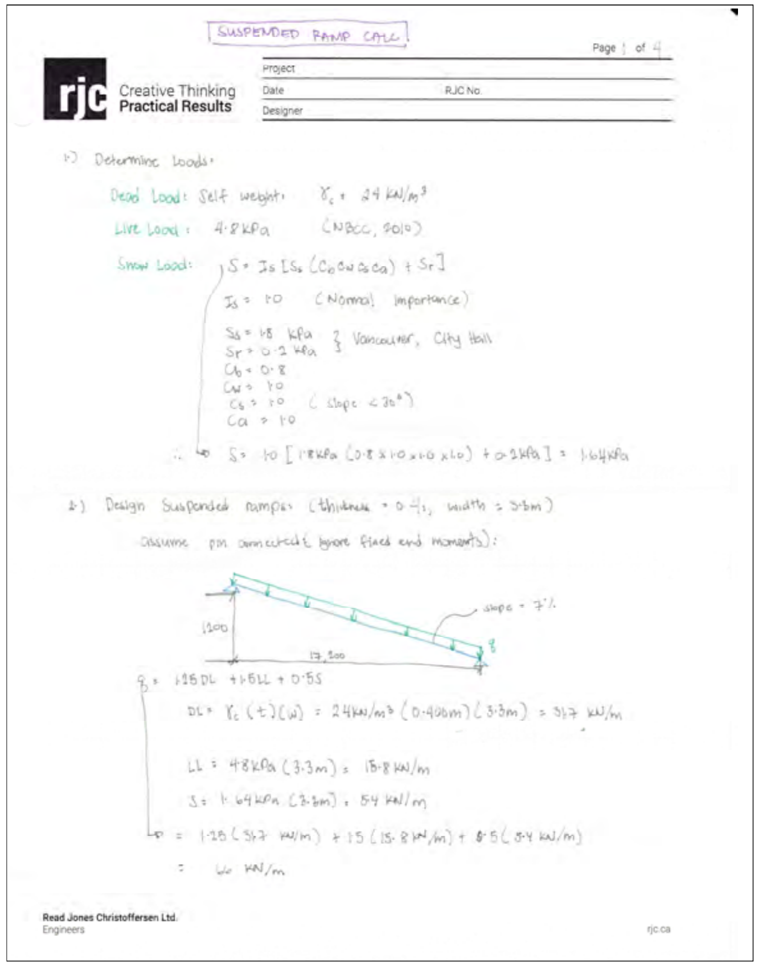
Project
Date RJC No.
Designer

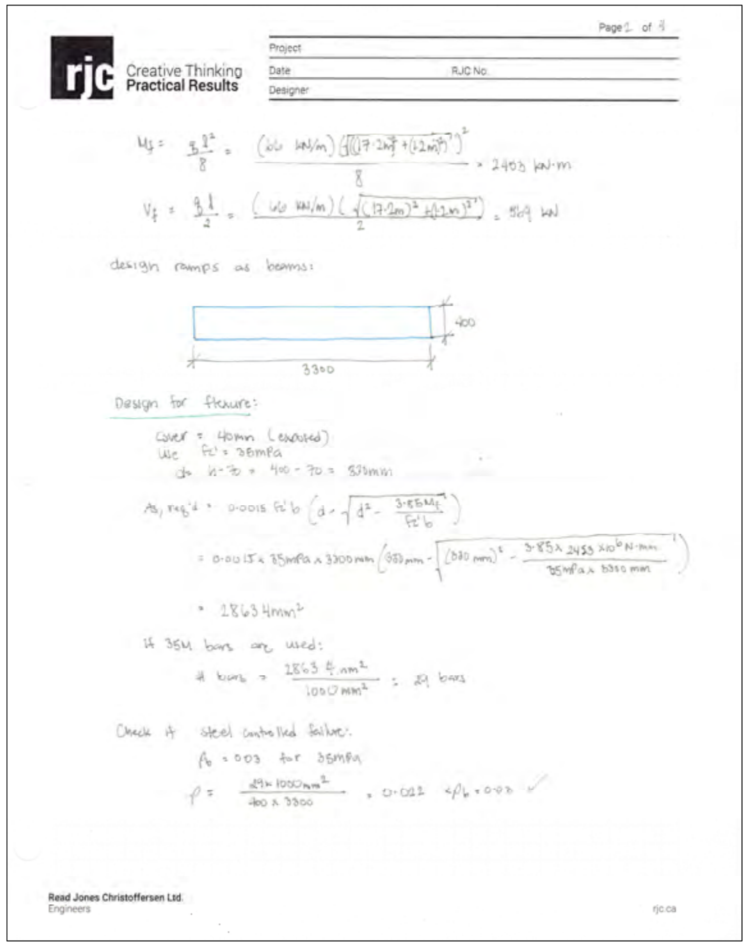


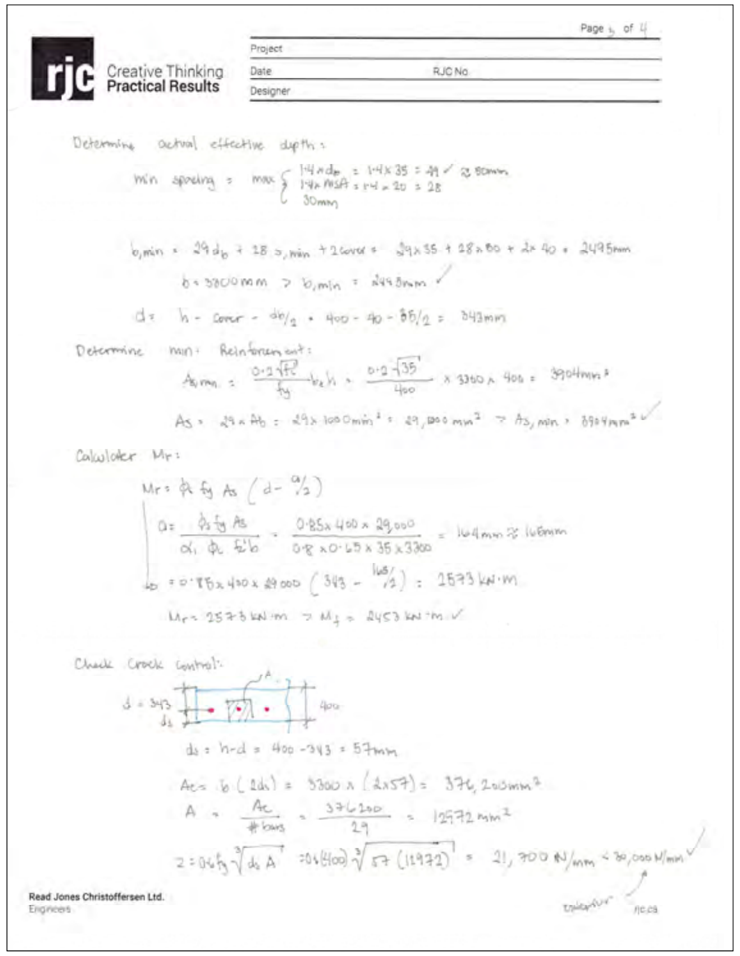
PLAN VIEW

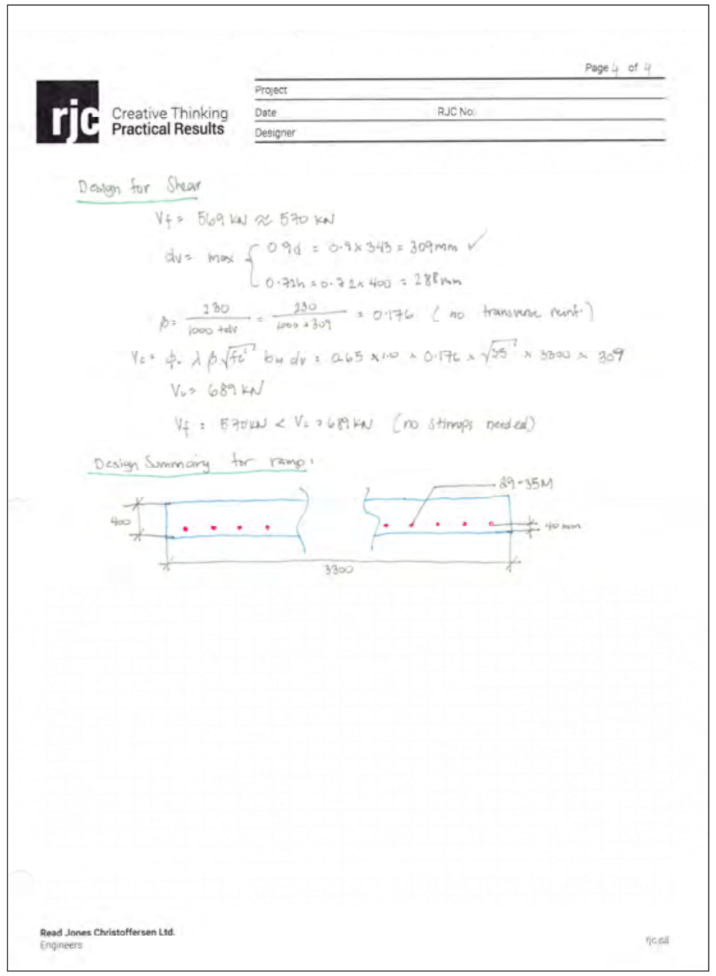


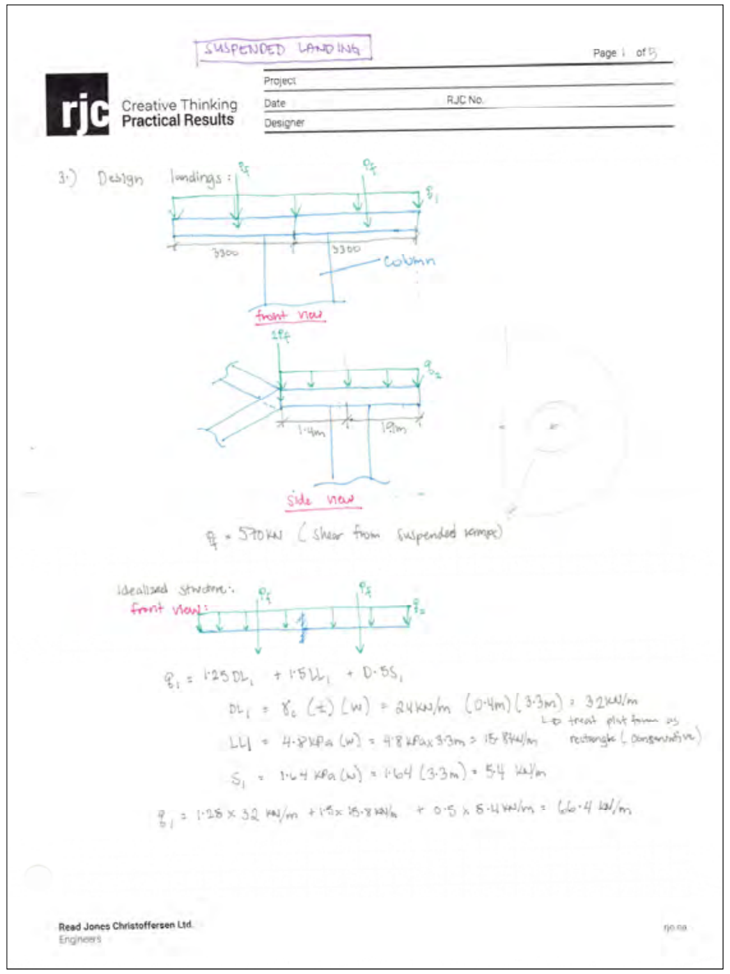
Section A-A'

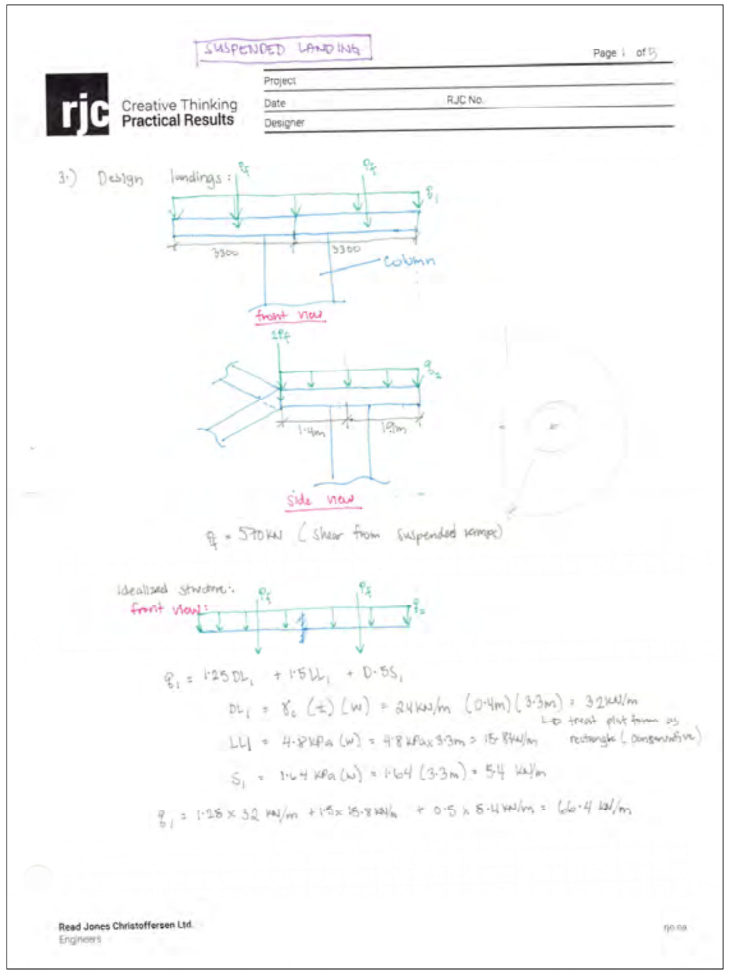


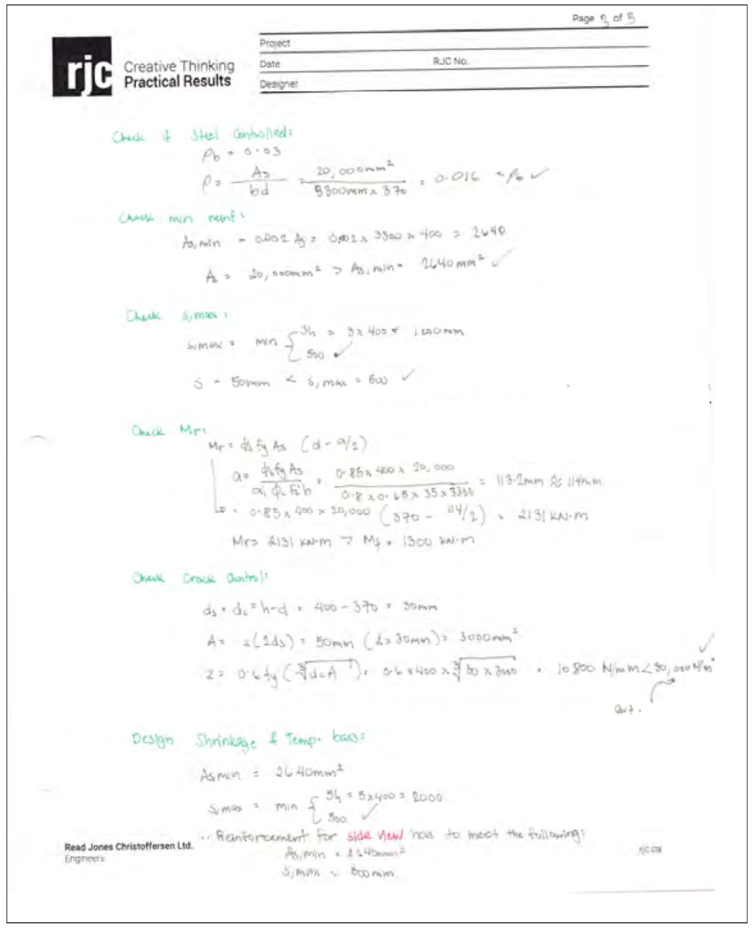


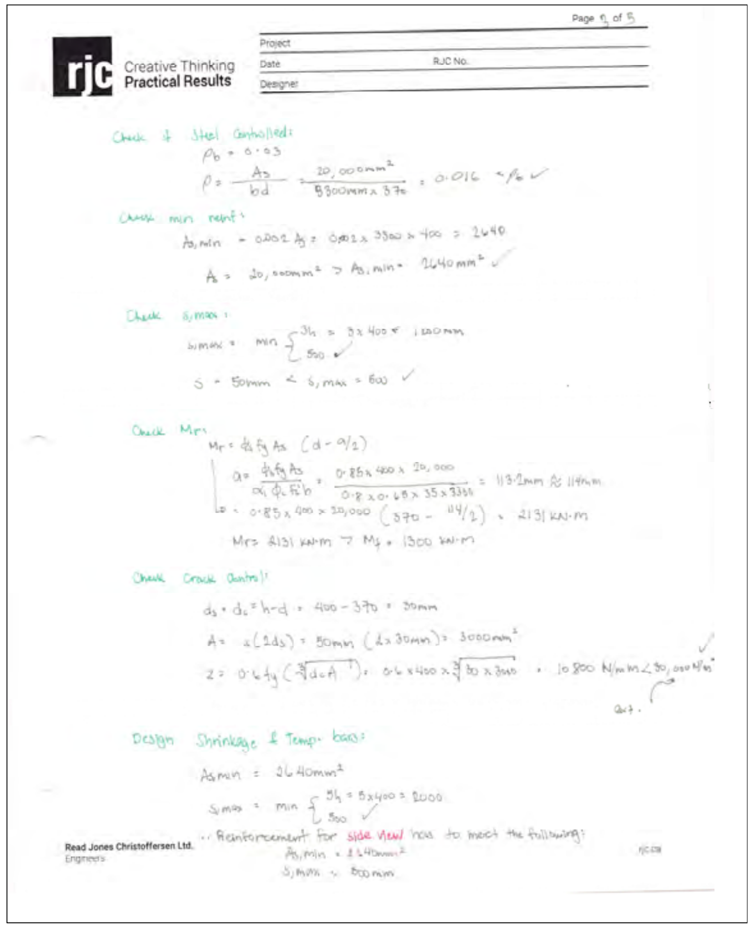







SUSPENDED LANDING
Page 1 of 5
rjc Creative Thinking Practical Results
Project
Date RJC No.
Designer
3) Design landings:
3300 3300
column
front view
side view
1.4m 1.8m
q_1 = 570 kN (shear from suspended ramps)
Idealised structure:
front view
q_1 = 1.25DL + 1.5LL + 0.5S
DL = γ_c (t)(w) = 24 kN/m³ (0.4m)(3.3m) = 32 kN/m
LL = 4.8kPa (w) = 4.8kPa x 3.3m = 15.8 kN/m — to treat plat form as rectangle (conservative)
S = 1.64 kPa (w) = 1.64 (3.3m) = 5.4 kN/m
q_1 = 1.25 x 32 kN/m + 1.5 x 15.8 kN/m + 0.5 x 5.4 kN/m = 66.4 kN/m
Read Jones Christoffersen Ltd. Engineers
rjc.ca

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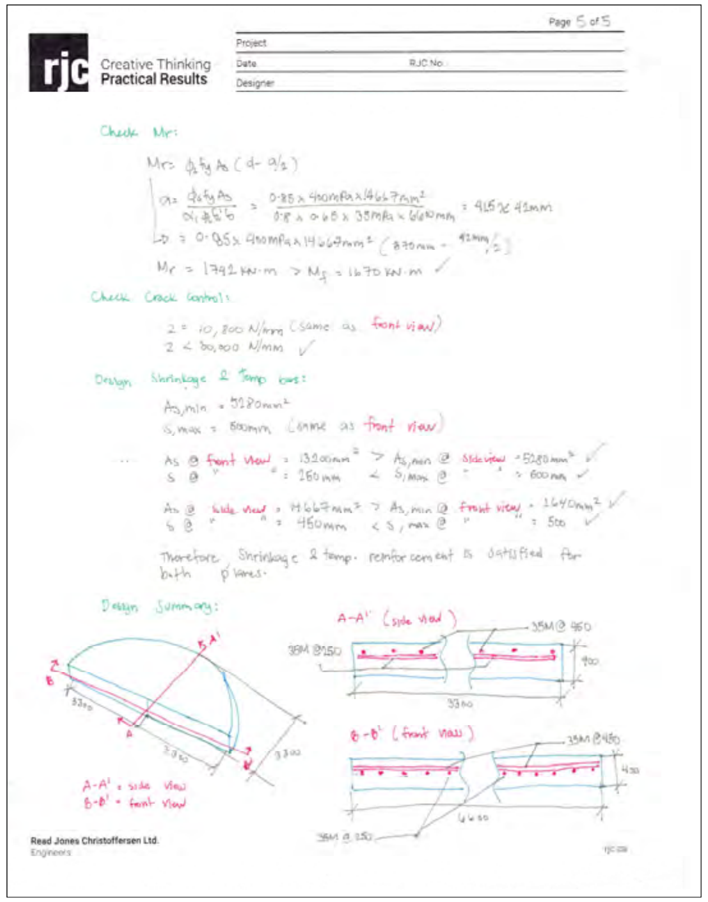
rjc Creative Thinking Practical Results
Project
Date RJC No.
Designer
Check if steel controlled:
ρ_b = 0.03
ρ = As / bd = 20,000mm² / 3300mm x 370 = 0.016 < ρ_b ✓
Check min reinf:
As,min = 0.002 Ag = 0.002 x 3300 x 400 = 2640
As = 20,000mm² > As,min = 2640 mm² ✓
Check s,max:
s,max = min { 3h = 3 x 400 = 1200mm; 500 }
s = 50mm < s,max = 500 ✓
Check Mr:
Mr = $\phi_s f_y A_s$ (d - a/2)
a = $\phi_s f_y A_s$ / $\alpha_1 \phi_c f'_c b$ = 0.85 x 400 x 20,000 / 0.8 x 0.65 x 35 x 3300 = 113.2mm ≈ 114mm
Mr = 0.85 x 400 x 20,000 (370 - 114/2) = 2131 kN·m
Mr = 2131 kN·m > Mf = 1300 kN·m
Check crack control:
ds = dc = h - d = 400 - 370 = 30mm
A = s(2ds) = 50mm (2 x 30mm) = 3000mm²
z = 0.6 fy (∛(dc A)) = 0.6 x 400 x ∛(30 x 3000) = 10,800 N/mm < 30,000 N/mm ✓
Design Shrinkage & Temp. bars:
As,min = 2640mm²
s,max = min { 5h = 5 x 400 = 2000; 500 }
∴ Reinforcement for side view has to meet the following:
As,min = 2640mm²
s,max = 500mm
Read Jones Christoffersen Ltd. Engineers
rjc.ca


Page 5 of 5
rjc Creative Thinking Practical Results
Project
Date
RJC No.
Designer
Check Mr:
Check Crack Control:
Design Shrinkage & Temp bars:
Design Summary:
A-A' (side view)
B-B' (front view)
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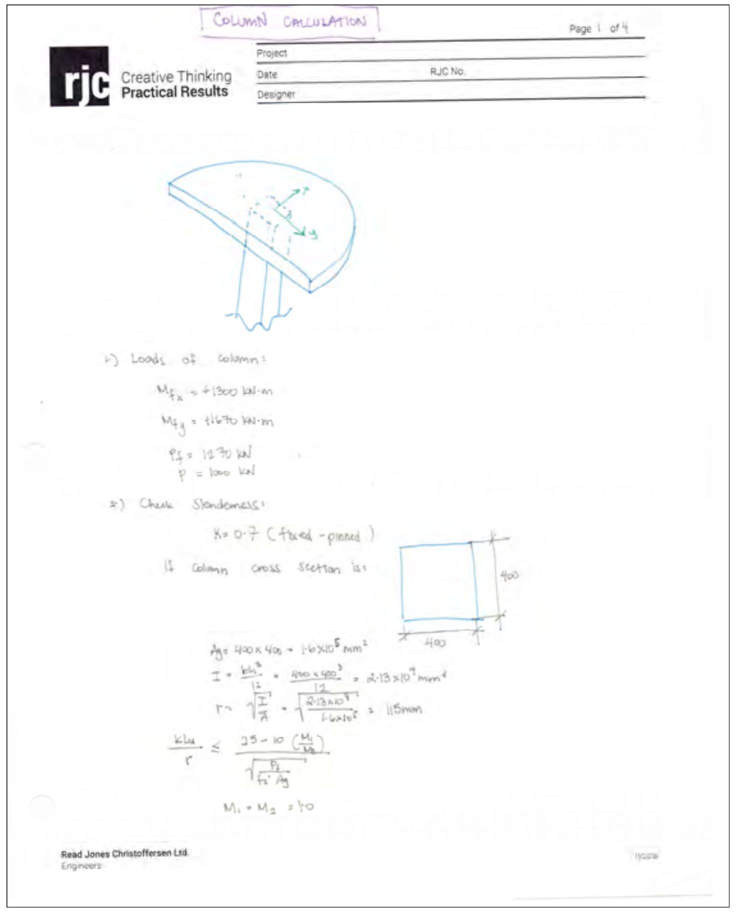
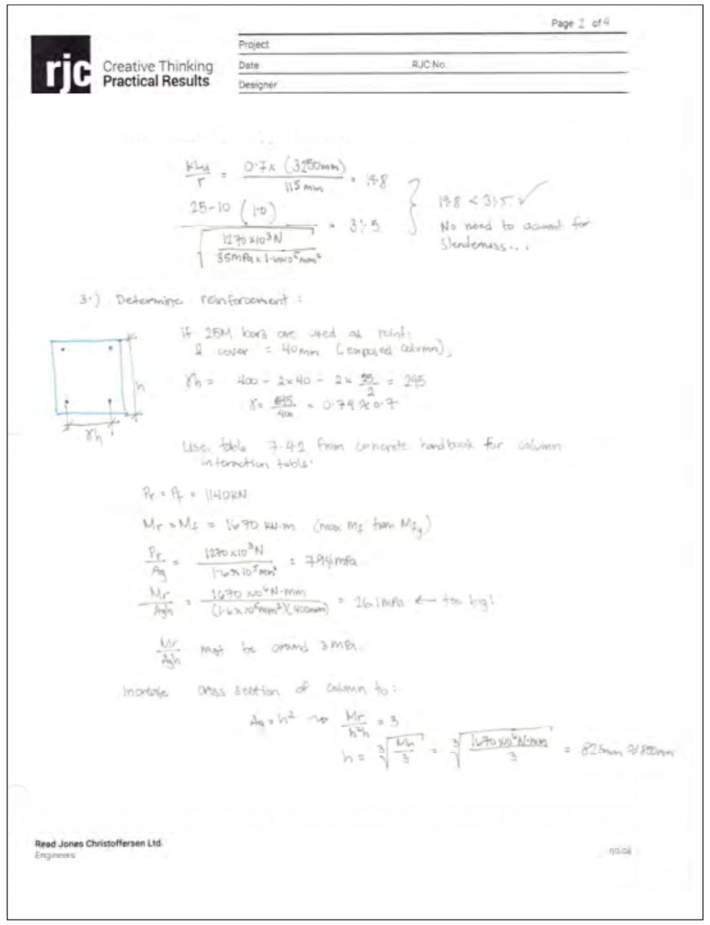
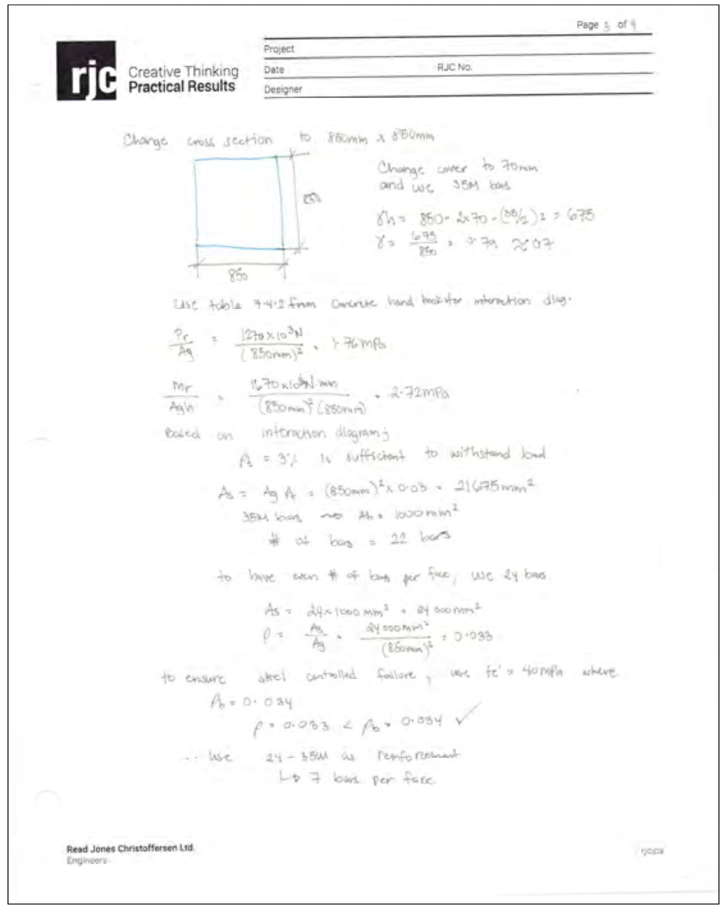
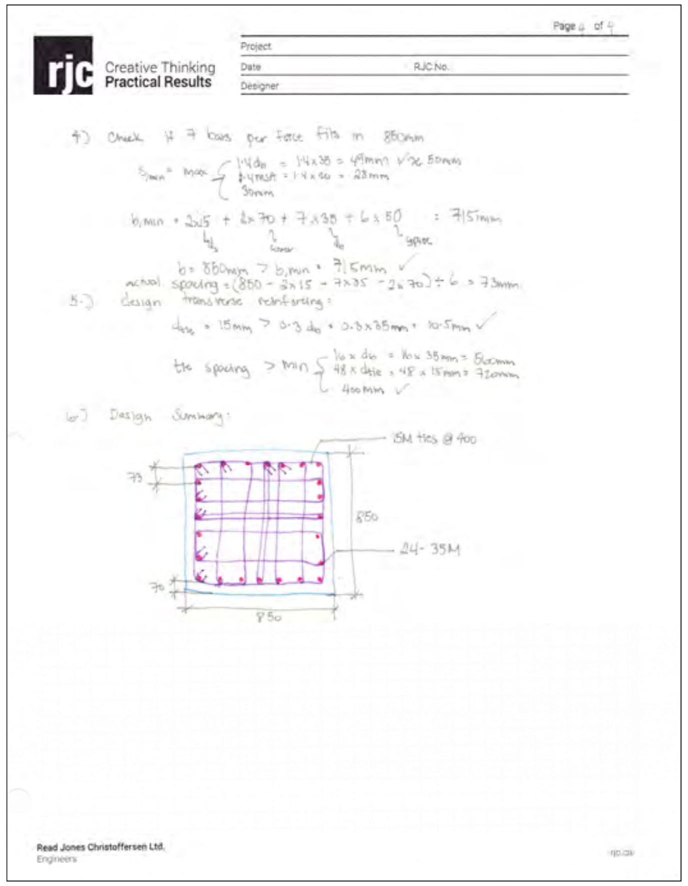
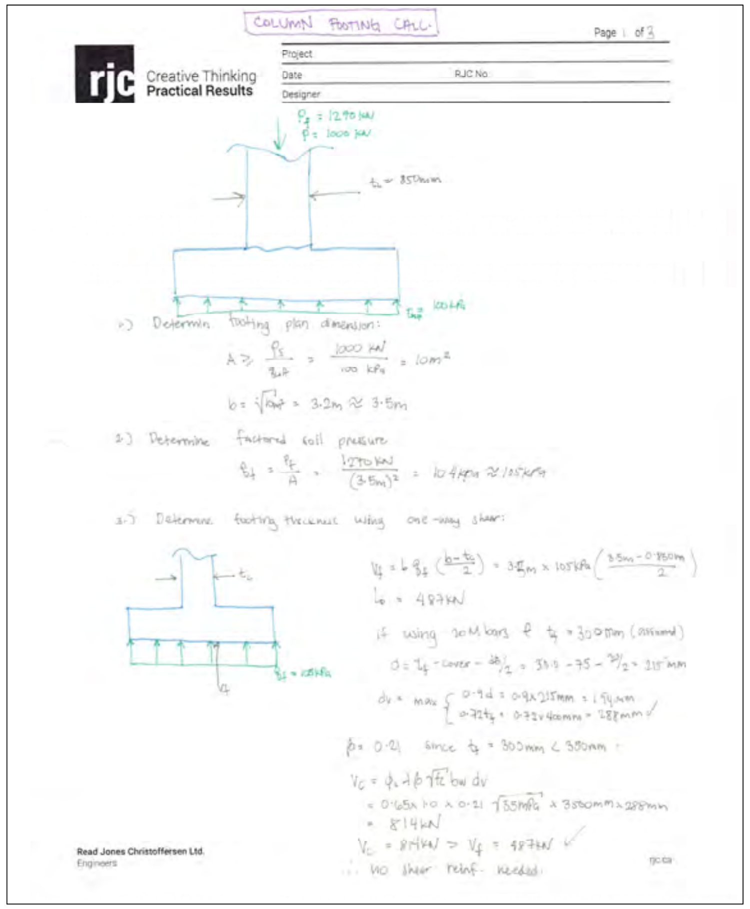
Engineers

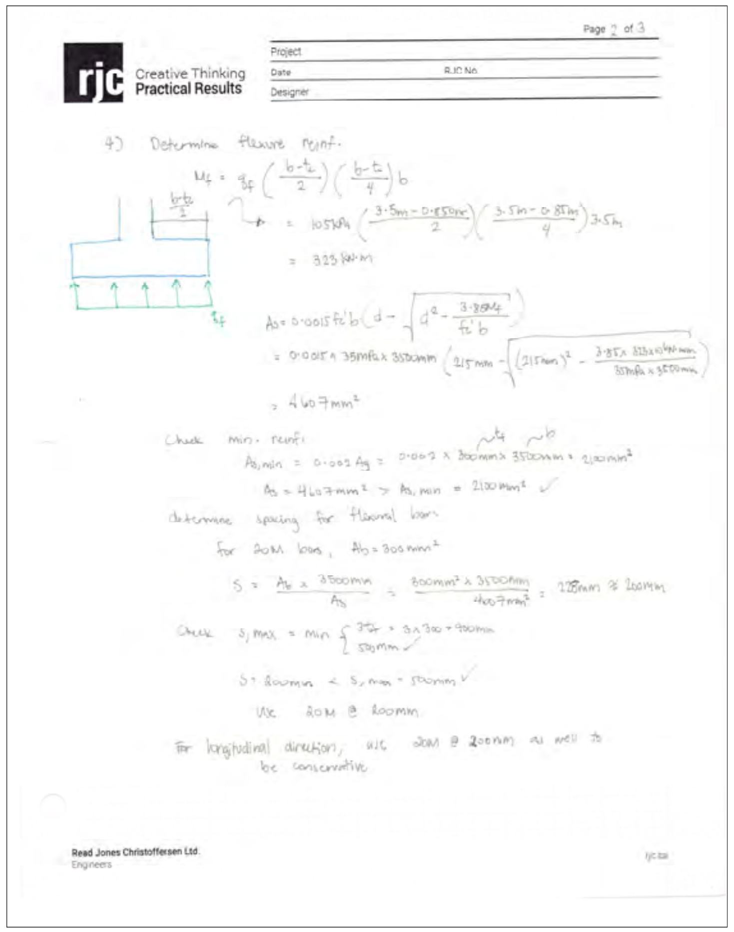

COLUMN CALCULATION
Page 1 of 4
rjc Creative Thinking Practical Results
Project
Date
RJC No.
Designer
1) Loads of Column:
2) Check Slenderness:
Read Jones Christoffersen Ltd.
Engineers

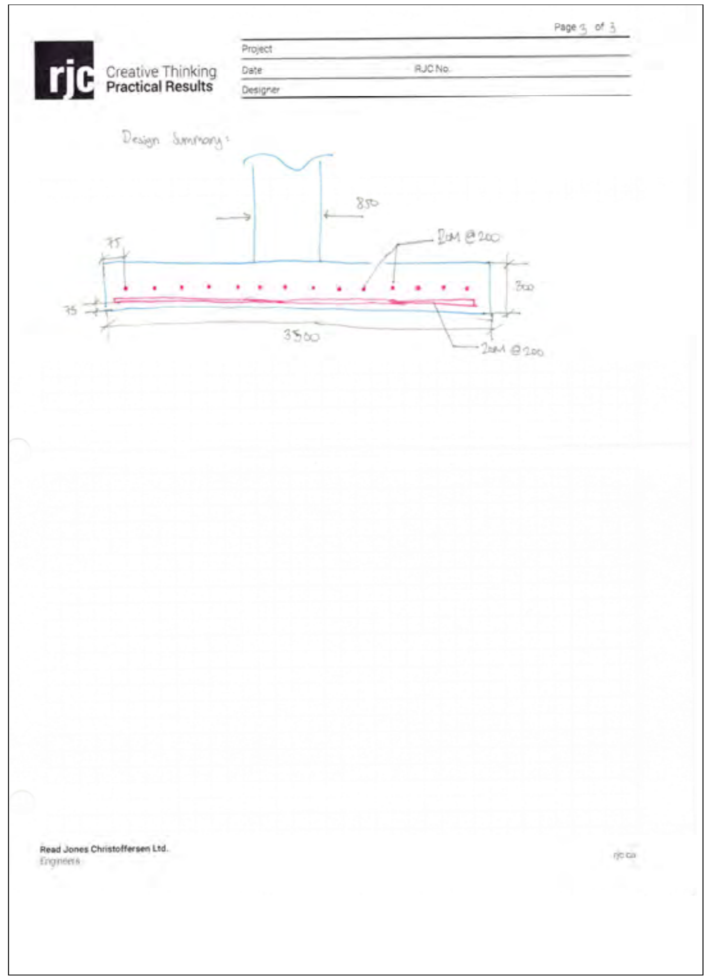

Page 2 of 4
rjc Creative Thinking Practical Results
Project
Date
RJC No.
Designer
3) Determine reinforcement
Read Jones Christoffersen Ltd.
Engineers


Page 3 of 4
rjc Creative Thinking Practical Results
Project
Date
RJC No.
Designer
Change cross section to 850mm x 850mm
Read Jones Christoffersen Ltd.
Engineers


Page 4 of 4
rjc Creative Thinking Practical Results
Project
Date
RJC No.
Designer
4) Check if 7 bars per face fits in 850mm
5) Design transverse reinforcing
6) Design Summary:
24-35M
Read Jones Christoffersen Ltd.
Engineers


COLUMN FOOTING CALC.
Page 1 of 3
rjc Creative Thinking Practical Results
Project
Date
RJC No.
Designer
1) Determine footing plan dimension:
2) Determine factored soil pressure
3) Determine footing thickness using one-way shear:
Read Jones Christoffersen Ltd.
Engineers

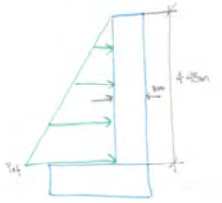

Page 2 of 3
rjc Creative Thinking Practical Results
Project
Date
RJC No.
Designer
4) Determine flexure reinf.
Read Jones Christoffersen Ltd.
Engineers


Page 3 of 3
rjc Creative Thinking Practical Results
Project
Date
RJC No.
Designer
Design Summary:
Read Jones Christoffersen Ltd.
Engineers

Sheet 1

RAMP RETAINING WALL CALC

Project
Date RJC No.
Designer



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

$\phi' = 30° \rightarrow K_a = 1/3$

Determine Loads of walls:

$\gamma_0 = K_a \gamma_s = 1/3\ (19 kN/m^3) = 6.33\ kN/m^3$

$P_0 = h_w \gamma_0 = (4.45m)(6.33\ kN/m^3) = 28.2\ kN/m^2$

$P_{af} = 1.5 P_0 = 1.5 \times 28.2\ kN/m^2 = 42.3\ kN/m^2$

If wall is fixed @ bottom:

$M_f = \frac{P_{af} h_w}{2}\left(\frac{h_w}{3}\right) = \frac{42.3 \times 4.45}{2}\left(\frac{4.45}{3}\right) = 140\ kN{\cdot}m$

$V_f = \frac{P_{af} h_w}{2} = \frac{42.3 \times 4.45}{2} = 94\ kN$

Check thickness of wall:

$t_w = 300mm$

$t_{w,min} = max \begin{cases} h_w/25 = \frac{4450}{25} = 178mm \\ 200mm ✓ \end{cases}$

$t_w = 300mm > t_{w,min} = 200mm$ ✓

Ignore gravity loads (conservative approach)

Design for flexure:

using same "d" as tunnel retaining wall,

$d = 220mm$

Sheet 2

Project
Date RJC No.
Designer

$A_s = 0.0015 f_c' b \left(d - \sqrt{d^2 - \frac{3.85 M_f}{f_c' b}} \right)$

$= 0.0015 \times 30MPa \times 1000 \left(220 - \sqrt{220^2 - \frac{3.85 \times 140 \times 10^6}{30 \times 1000}} \right)$

$= 2050 mm^2$

spacing if 20M bars used, $\frac{A_b\, 1000}{A_s} = \frac{300 mm^2 \times 1000}{2050mm} = 146mm \approx 100mm$

$s_{max} = 500mm$ (same as tunnel retaining wall)

$s = 100mm < s_{max} = 500mm$ ✓

Check if steel controlled:

$\rho = \frac{A_s}{bd} = \frac{2050}{1000 \times 220} = 0.0093$

$\rho = 0.0093 < \rho_b = 0.027$ ✓

Check min reinf. area:

$A_{v,min} = 0.0015 A_g = 450 mm^2$ (same as tunnel wall)

$A_s = \frac{A_b\, 1000}{s} = \frac{800 \times 1000}{100} = 8000 mm^2$

$A_s = 8000 mm^2 > A_{v,min} = 450 mm^2$

∴ use 20M @ 100 for vertical bars

Design for shear

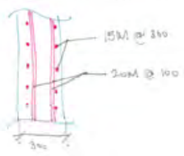
$V_f = 94kN$

$V_c = 148kN$ (from tunnel wall)

∴ no stirrups needed.

Use same horizontal reinf. as tunnel wall.

use 15M @ 300 for horizontal bars



Sheet 3

SLAB-ON-GRADE & STAIR ON GRADE

Project
Date RJC No.
Designer

Slab-on-grade & stair on grade design

design on-grade structures for shrinkage & temp.

min. reinf. for shrinkage & temp. loads = $0.002 A_g$

using $t = 150mm$ (typical SOG thickness)

$A_g = 150mm \times 1000mm = 1.5 \times 10^5 mm^2$

$A_{s,min} = 0.002 A_g = 0.002 \times 1.5 \times 10^5 mm^2 = 300mm^2$

to account for external causes that may expose the SOG to flexure load (eg. diff. settlement), increase $A_{s,min}$ to $600mm^2$

If 15M bars are used,

$Spacing = \frac{A_b \times 1000}{A_{s,min}} = \frac{300mm^2 \times 1000mm}{600mm} = 500mm$

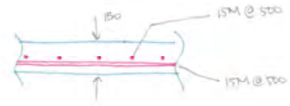
$s_{max} = min \begin{cases} 5h = 5 \times 150 = 750mm \\ 500mm ✓ \end{cases}$

$s = 500 \leq s_{max} = 500mm$ ✓

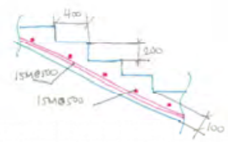
Use 15M @ 500 in both directions for S.O.G and stair on grade.

Detail:

Slab-on-grade



stair-on-grade



Appendix C – Stormwater Drainage and Management

Grate Spacing Calculation

DEPRESSED BC BICYCLE SAFE DRAIN SPACING FOR PROPOSED ROUNDABOUT INTERSECTION

Inputs

SW	paved shoulder width	0	m
s_y	longitudinal grade	0.022	
s_x	crossfall	0.02	
n	Manning's roughness coefficient	0.013	
i	rainfall intensity for t_c = 5 min, 5 year return period	53.85	mm/hr
width	effective width of contributing area	6.6	m
C_w	width weighted runoff coefficient	0.95	
w	inlet catchment width	0.625	m

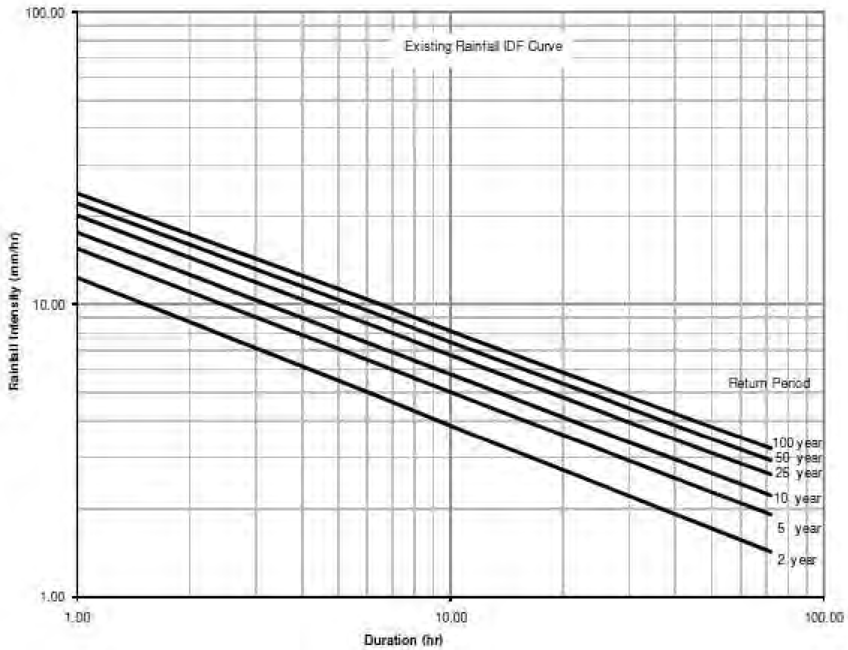
Calculate gutter flow and catchbasin spacing

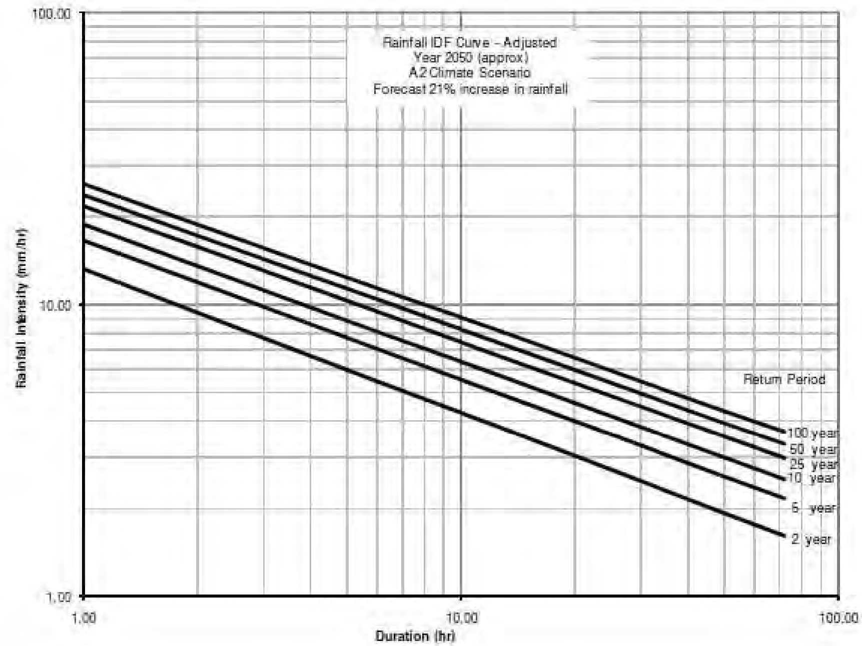
PW	design ponding width	1.2	m
y_0	maximum depth of gutter flow (for pavement)	0.024	m
R_s	crossfall-longitudinal grade ratio	0.93	
w_{eff}	effective inlet catchment width	0.69	m
v	gutter flow velocity	0.928	m/s
Q_0	gutter flow	0.010	m3/s
y_{over}	maximum depth of flow outside catchment width	0.010	m
Q_{over}	overflow	0.0010	m3/s
Q_{int}	intercepted flow	0.0090	m3/s
Eff	inlet efficiency	89.7	%

Outputs

Cb_{one}	initial inlet spacing	106.8	m
Cb_{two}	consecutive inlet spacing	95.8	m

VA01 Rain Gauge Rainfall Data





DURATION	RETURN PERIOD											
	2 year		5 year		10 year		25 year		50 year		100 year	
	Existing	2050, 2 yr, 21% Monthly Rainfall Increase	Existing	2050, 5 yr, 21% Monthly Rainfall Increase	Existing	2050, 10 yr, 21% Monthly Rainfall Increase	Existing	2050, 25 yr, 21% Monthly Rainfall Increase	Existing	2050, 50 yr, 21% Monthly Rainfall Increase	Existing	2050, 100 yr, 21% Monthly Rainfall Increase
1	12.3	13.2	15.5	16.6	17.5	18.8	20.2	21.6	22.1	23.7	24.0	25.8
2	8.7	9.4	11.0	11.9	12.6	13.6	14.5	15.7	15.9	17.2	17.3	18.8
6	5.0	5.5	6.4	7.1	7.4	8.1	8.6	9.4	9.5	10.4	10.3	11.4
12	3.5	3.9	4.6	5.1	5.3	5.9	6.2	6.9	6.8	7.6	7.5	8.3
24	2.5	2.8	3.3	3.7	3.8	4.2	4.4	5.0	4.9	5.5	5.4	6.0
48	1.7	2.0	2.3	2.6	2.7	3.1	3.2	3.6	3.5	4.0	3.9	4.4
72	1.4	1.6	1.9	2.2	2.2	2.5	2.6	3.0	2.9	3.3	3.2	3.7

REV. | DATE | REVISION NOTES | DRAWN | CHECK | APPR

SCALE:
DATE: FEB 2009
DRAWN: GLT
DESIGNED: KH
CHECKED: KH
APPROVED: MJ

PROFESSIONAL SEAL:

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

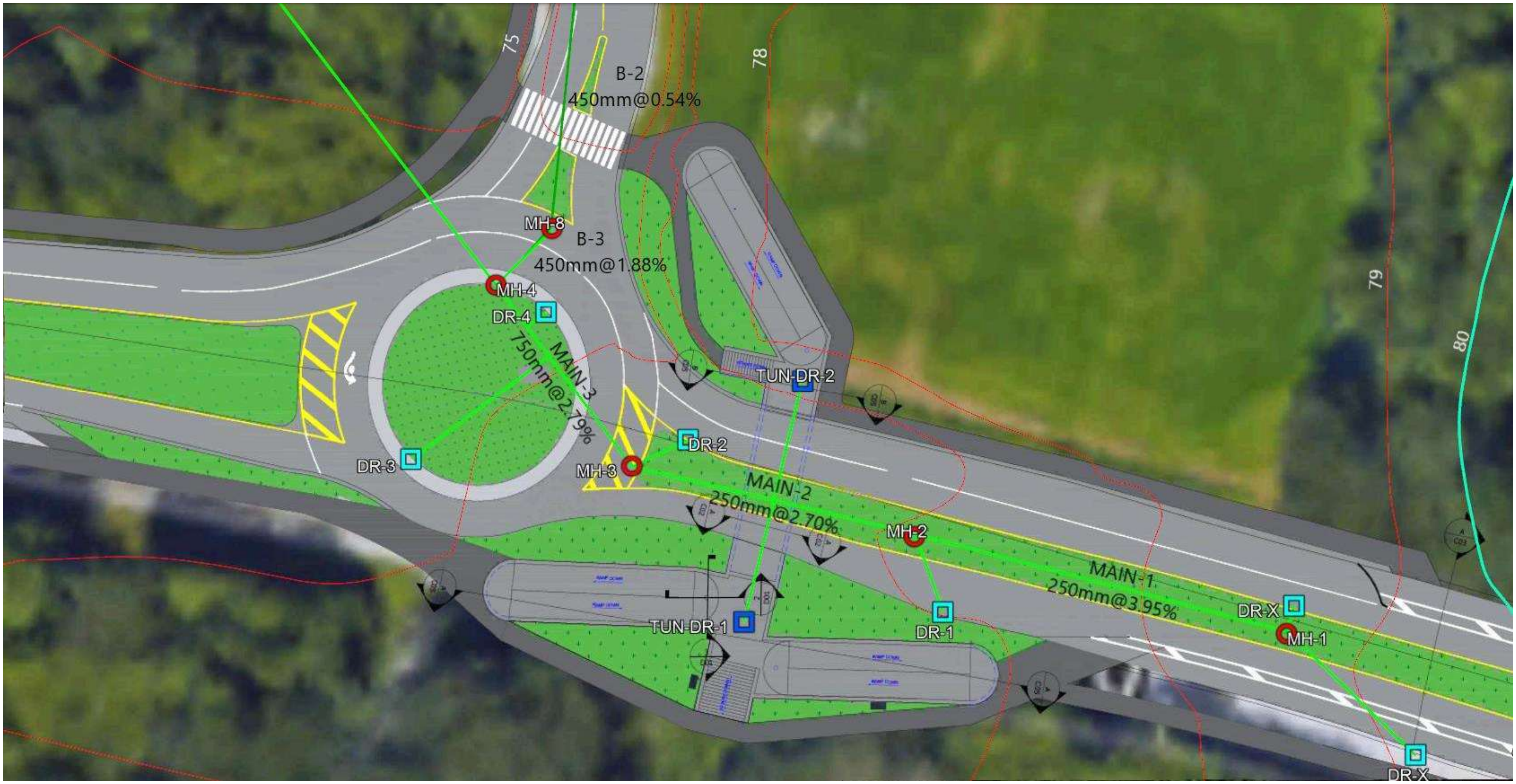
CLIENT: GVRD

PROJECT: METRO VANCOUVER CLIMATE CHANGE ADJUSTED IDF CURVES (LONG DURATION)

TITLE: VA01 - KITSILANO HIGH SCHOOL

PROJECT No.: 0431-006
FIG No.: 6
REV.:

Intersection Storm Sewer Pipe Overview



Sample Calculation for Drainage Pipe Sizing

This example shows the calculation for checking the pipe size between manholes 1 and 2 (MH-1 and MH-2). Parameters that have values that are not calculated are provided in the table below.

Given:

Parameter	Symbol	Value (units)
Drainage Area	A	0.4434 (ha)
Length of Overland Flow	L_{OL}	235 (m)
Slope of Overland Flow	S_{OL}	0.015 (m/m)
100-year Rainfall Intensity for 5 minutes	i_{100Y}	80.02 (mm/hr)
Pipe Properties		
Slope	S	0.034 (m/m)
Diameter	d	250 (mm)
Manning's n	n	0.013
Length	L	74.4 (m)

Calculated:

Runoff coefficient C

Calculated by taking the approximate ratio of distinct areas to total drainage area and multiplying by that area's runoff coefficient based on its properties such as material coverage and slope:

Surface cover is approximately 50% forested and 50% impermeable, with an overland slope of <5%. Consulting Table 1020.A from the TAC Supplement, this results in coefficients of 0.4 and 0.8 respectively. An additional requirement is to add 0.05 for return periods between 10-25 years, and to add 0.10 for return periods greater than 25 years.

$$R_{10-25\,Y} = 50\%(0.4) + 50\%(0.8) + 0.05$$

$$\therefore R_{10-25\,Y} = 0.65$$

Manning's n for Overland Flow

Calculated by using the longest linear path of overland flow, taking the ratio of distinct lengths and multiplying by that section's Manning's coefficient:

$$n = \frac{510m}{1211m}(0.013) + \frac{701m}{1211m}(0.4)$$

$$\therefore n = 0.237$$

Time of Concentration

The time of concentration T_c is calculated by summing the overland flow time T_O and the travel time in the pipe T_t.

Overland Flow Time

The Surrey Design Criteria uses the Kinematic Wave Equation. An initial time of concentration of 5 minutes was assumed:

$$T_O = \frac{6.92 {L_{OL}}^{0.6} {n_{OL}}^{0.6}}{i(t_c = 10\text{ min})_{10Y}{}^{0.4} {S_{OL}}^{0.3}}$$

$$T_O = \frac{6.92(235m)^{0.6}(0.237)^{0.6}}{\left(18.826\left(\frac{5}{60}\right)^{-0.47}\frac{mm}{hr}\right)^{0.4}(0.015)^{0.3}}$$

$$\therefore T_O = 52.84\ min$$

Travel Time

The travel time is calculated assuming full pipe conditions, by dividing the pipe length by the maximum capacity velocity, which is calculated using Manning's Equation. The hydraulic radius R is equal to a quarter of the diameter.

$$T_t = \frac{v_{cap}}{L}$$

$$T_t = \frac{\left(\frac{R^{\frac{2}{3}} S^{0.5}}{n}\right)}{L}$$

$$T_t = \frac{\frac{\left(\frac{250mm}{4}\right)^{\frac{2}{3}}(0.034)^{0.5}}{0.013}}{74.4m}$$

$$\therefore T_t = 0.56\ min$$

The time of concentration is then equal to the sum of the overland flow time and the travel time:

$$T_c = T_O + T_t$$

$$T_c = 52.84min + 0.56min$$

$$\therefore T_c = 53.19min$$

Rainfall Intensity

The rainfall intensity is necessary to determine the design flows, and the equations for the intensities are taken from a report by Metro Vancouver for climate adjusted IDF curves which can be found here:

10-year Intensity and Flow

As the report mentioned above, an equation was used to determine the 10-year storm intensity for a storm duration equal to the time of concentration (in hours) determined earlier:

$$i_{10Y} = 18.826\left(T_C^{-0.47}\right)$$

$$i_{10Y} = 18.826\left(\frac{53.19}{60}hr\right)^{-0.47}$$

$$\therefore i_{10Y} = 19.92\ mm/hr$$

The 10-year storm flow is calculated using the rational method:

$$Q_{10} = \frac{100CiA}{36}$$

$$Q_{10} = 0.65\left(19.92\frac{mm}{hr}\right)(0.4434\ ha)\left(\frac{100}{36}\right)$$

$$\therefore Q_{10} = 15.95\frac{L}{s}$$

100-year Intensity and Flow

Likewise, for the 100-year storm intensity:

$$i_{100Y} = 25.767\left(T_C^{-0.456}\right)$$

$$i_{100Y} = 25.767\left(\frac{53.19}{60}hr\right)^{-0.456}$$

$$\therefore i_{100Y} = 27.22\ \ mm/hr$$

And for the 100-year storm flow:

$$Q_{100} = 0.65\left(27.22\frac{mm}{hr}\right)(0.4434ha)\left(\frac{100}{36}\right)$$

$$\therefore Q_{100} = 23.47\frac{L}{s}$$

Sewer Pipe Capacity

The pipe capacity is calculated using Manning's Equation for a full pipe:

Flow Capacity

$$Q_{cap} = \frac{A_{pipe}\,R^{\frac{2}{3}}\,S^{0.5}}{n}$$

$$Q_{cap} = \frac{\left(\frac{\pi d^2}{4}\right)\left(\frac{d}{4}\right)^{\frac{2}{3}}S^{0.5}}{n}$$

$$Q_{cap} = \frac{(0.250m)^2\left(\frac{\pi}{4}\right)\left(\frac{0.250m}{4}\right)^{\frac{2}{3}}(0.039)^{0.5}}{0.013}$$

$$\therefore Q_{cap} = 0.1181\frac{m^3}{s} = 118.1\frac{L}{s}$$

Velocity Capacity

$$v_{cap} = \frac{R^{\frac{2}{3}}\,S^{0.5}}{n}$$

$$v_{cap} = \frac{\left(\frac{0.250m}{4}\right)^{\frac{2}{3}} (0.039)^{0.5}}{0.013}$$

$$\therefore v_{cap} = 2.41\frac{m}{s}$$

Flow Ratios

These flow ratios are calculated by dividing the 5-year storm flow and the 100-year storm flow with the maximum pipe capacity, and is used to determine whether the design diameter is sufficient.

Q10/Qcap

$$\frac{Q_{10}}{Q_{cap}} = \frac{15.95\frac{L}{s}}{118.1\frac{L}{s}} = 13.5\%$$

Q100/Qcap

$$\frac{Q_{100}}{Q_{cap}} = \frac{23.47\frac{L}{s}}{118.1\frac{L}{s}} = 19.9\%$$

Based on the ratios above, the diameter of 250mm for this particular section of pipe is capable of successfully conveying both the 10-year and 100-year flow.

Manhole Location Summary Table

Manhole ID	Easting (m)	Northing (m)	Ground Elev (m)	Invert Depth (m)	Invert Elev (m)
MH-1	482771.52	5457820.00	78.6	6.00	72.60
MH-2	482722.47	5457832.77	77.1	6.50	70.60
MH-3	482684.81	5457842.22	76.3	6.75	69.55
MH-4	482666.47	5457866.48	75.5	6.80	68.70
MH-5	482659.78	5458030.44	76.0	1.50	74.50
MH-6	482721.66	5457998.43	76.8	1.50	75.30
MH-7	482685.71	5457983.62	76.1	2.00	74.10
MH-8	482673.99	5457874.01	75.5	2.00	73.50

Rational Method Table

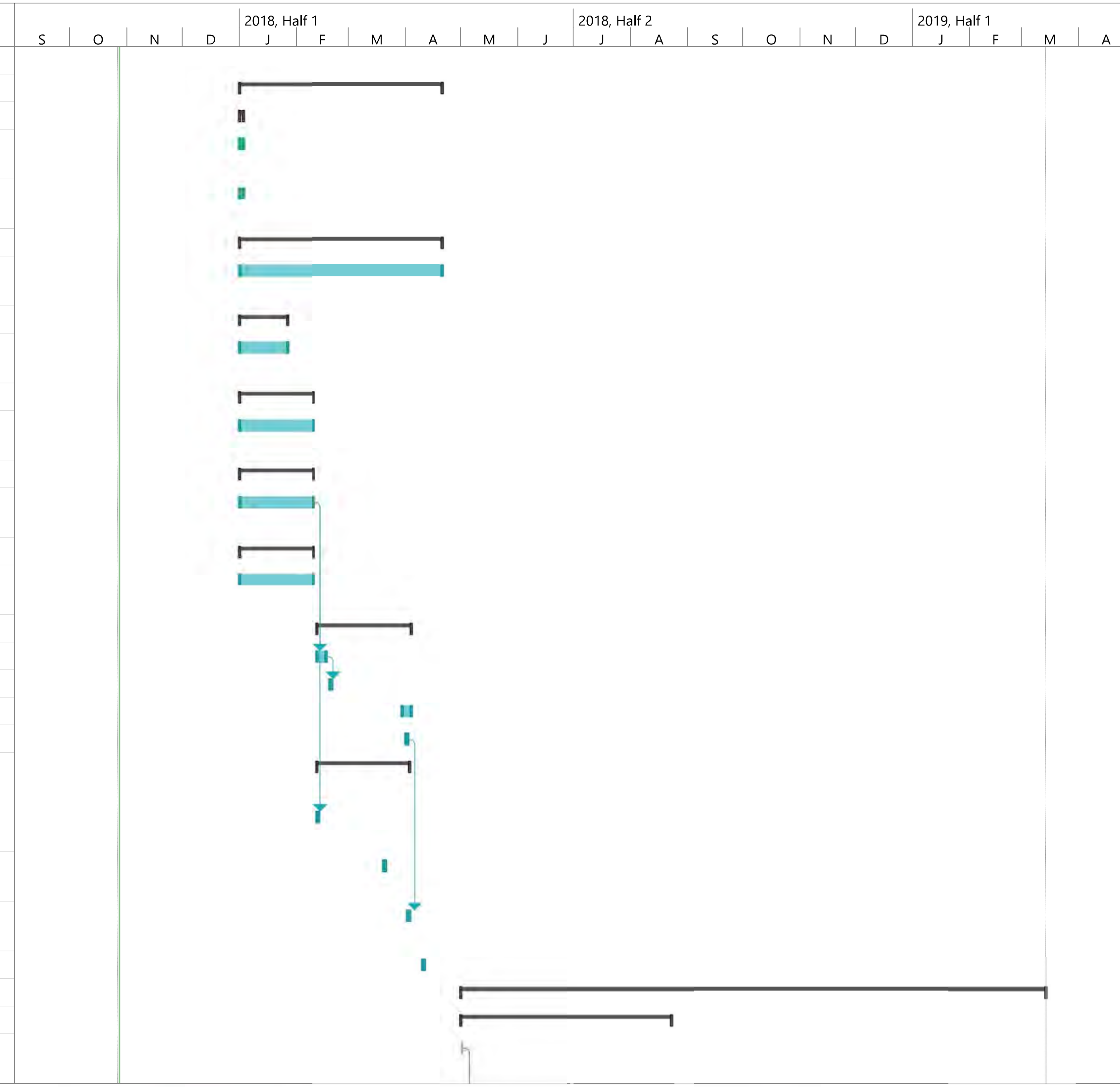
Pipe ID	Manhole		Area (ha)	Runoff Coefficient				Time of Concentration		Intensity			Flow		
	From	To		10-25 year	100-year	Total R*A (10-25 year)	Total R*A (100-year)	Tc (min)	Total (min)	i(10) (mm/hr)	i(25) (mm/hr)	i(100) (mm/hr)	Q(10) (L/s)	Q(25) (L/s)	Q(100) (L/s)
A-1	MH-5	MH-7	0.3179	0.85	0.90	0.2702	0.2861	6.36	6.36	54.07	60.96	71.71	40.58	45.76	56.99
B-1	MH-6	MH-7	0.9874	0.85	0.90	0.8393	0.8887	18.05	18.05	33.11	37.65	44.57	77.20	87.77	110.01
B-2	MH-7	MH-8	1.1473	0.79	0.84	2.0159	2.1385	46.83	71.24	17.37	19.96	23.83	97.25	111.78	141.54
B-3	MH-8	MH-4	0.0000	-	-	2.0159	2.1385	0.08	71.31	17.36	19.95	23.82	97.20	111.73	141.47
MAIN-1	MH-1	MH-2	0.4434	0.65	0.70	0.2882	0.3104	53.19	53.19	19.92	22.85	27.22	15.95	18.29	23.47
MAIN-2	MH-2	MH-3	0.4217	0.76	0.81	0.6087	0.6520	44.81	98.00	14.95	17.23	20.60	25.28	29.13	37.31
MAIN-3	MH-3	MH-4	48.6085	0.57	0.62	30.1694	32.7657	133.39	302.64	8.80	10.23	12.32	737.43	857.51	1121.29

Sewer Pipe Design Summary Table

Pipe ID	Manhole		Sewer Pipe Design							Ratios		
	From	To	Slope (%)	Old Pipe Dia. (mm)	New Pipe Dia. (mm)	Manning's n	Qcap (L/s)	Vcap (m/s)	Length (m)	Q10/Qcap	Q25/Qcap	Q100/Qcap
A-1	MH-5	MH-7	0.75%	250	250	0.013	51.41	1.05	53.521	78.9%	89.0%	110.9%
B-1	MH-6	MH-7	3.09%	300	375	0.013	169.88	2.40	38.881	45.4%	51.7%	64.8%
B-2	MH-7	MH-8	0.54%	400	450	0.013	153.64	1.22	110.235	63.3%	72.8%	92.1%
B-3	MH-8	MH-4	1.88%	400	450	0.013	285.50	2.27	10.642	34.0%	39.1%	49.6%
MAIN-1	MH-1	MH-2	3.95%	250	250	0.013	118.13	2.41	50.685	13.5%	15.5%	19.9%
MAIN-2	MH-2	MH-3	2.70%	250	250	0.013	97.79	1.99	38.828	25.8%	29.8%	38.2%
MAIN-3	MH-3	MH-4	2.79%	650	750	0.013	1270.75	3.83	30.412	58.0%	67.5%	88.2%

Appendix D – Schedule

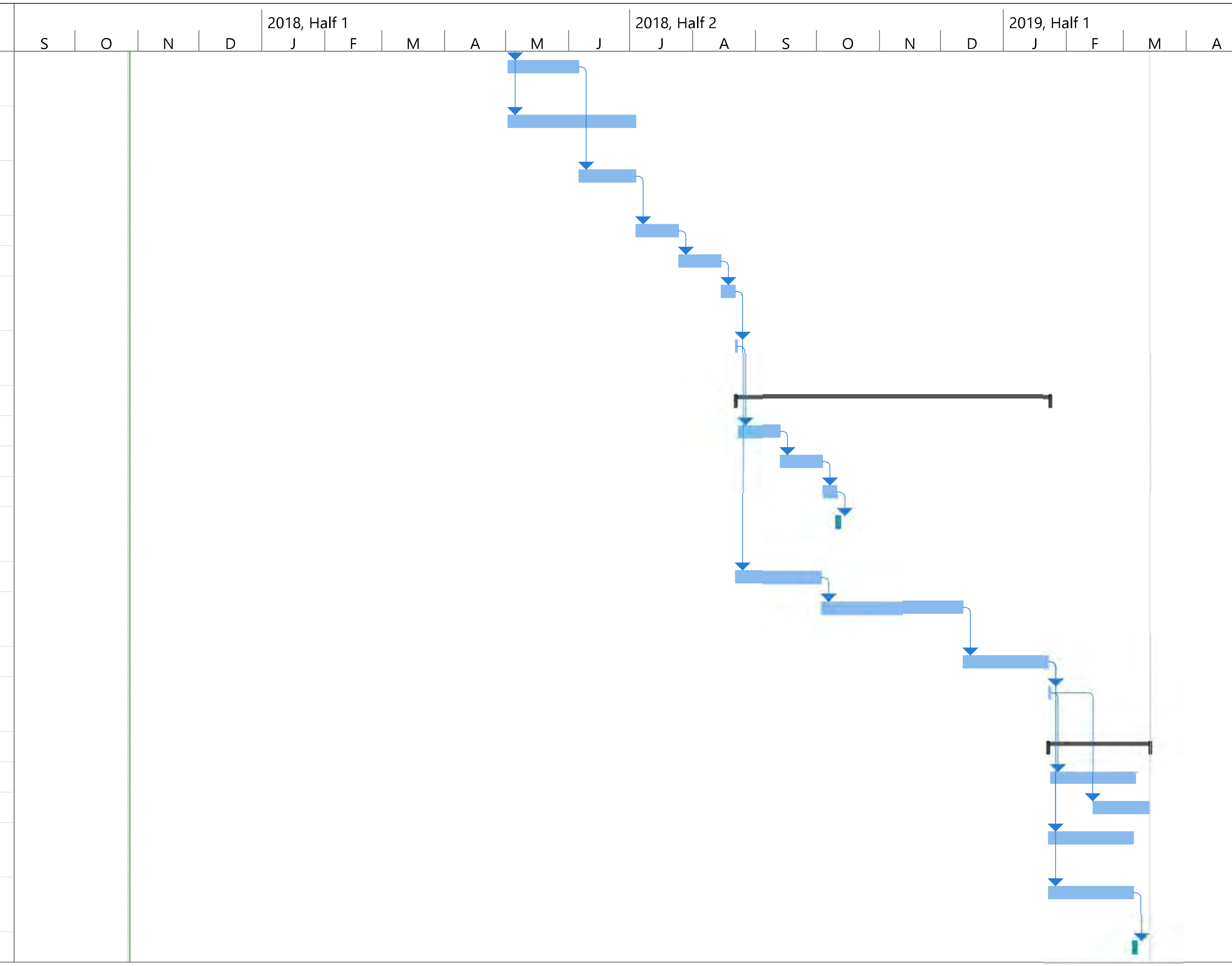
ID		Task Mode	Task Name	Duration	Start	Finish
1						
2			**Preconstruction**	**80 days**	**Mon 18-01-01**	**Fri 18-04-20**
3			**Geotechnical**	**2 days**	**Mon 18-01-01**	**Tue 18-01-02**
4			Topographical Survey	2 days	Mon 18-01-01	Tue 18-01-02
5			Tunnel Bore Sampling	2 days	Mon 18-01-01	Tue 18-01-02
6			**Environmental**	**80 days**	**Mon 18-01-01**	**Fri 18-04-20**
7			Environmental Assessment	80 days	Mon 18-01-01	Fri 18-04-20
8			**Drainage**	**20 days**	**Mon 18-01-01**	**Fri 18-01-26**
9			Design Drawings Development	20 days	Mon 18-01-01	Fri 18-01-26
10			**Electrical**	**30 days**	**Mon 18-01-01**	**Fri 18-02-09**
11			Design Drawing Development	30 days	Mon 18-01-01	Fri 18-02-09
12			**Architectural**	**30 days**	**Mon 18-01-01**	**Fri 18-02-09**
13			Design Drawing Development	30 days	Mon 18-01-01	Fri 18-02-09
14			**Structural**	**30 days**	**Mon 18-01-01**	**Fri 18-02-09**
15			Design Drawing Development	30 days	Mon 18-01-01	Fri 18-02-09
16			**Tendering**	**37 days**	**Mon 18-02-12**	**Tue 18-04-03**
17			Develop Bid Package	5 days	Mon 18-02-12	Fri 18-02-16
18			Send out Bid Package	1 day	Mon 18-02-19	Mon 18-02-19
19			Review Tenders	3 days	Fri 18-03-30	Tue 18-04-03
20			Award Project	1 day	Sun 18-04-01	Sun 18-04-01
21			**Permits**	**36 days**	**Mon 18-02-12**	**Mon 18-04-02**
22			Acquire Building Permit	1 day	Mon 18-02-12	Mon 18-02-12
23			Acquire Tree Cutting Permit	1 day	Tue 18-03-20	Tue 18-03-20
24			Acquire Excavation Permit	1 day	Mon 18-04-02	Mon 18-04-02
25			**Public Consultation**	1 day	Tue 18-04-10	Tue 18-04-10
26			**Construction**	**227 days**	**Tue 18-05-01**	**Wed 19-03-13**
27			**Phase 1**	**82 days**	**Tue 18-05-01**	**Wed 18-08-22**
28			Close off Chancellor Blvd	1 day	Tue 18-05-01	Tue 18-05-01



Project: Capstone Schedule
Date: Sat 17-10-28

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	

ID	Task Mode	Task Name	Duration	Start	Finish
29		Excavate for intersection and underpass	25 days	Wed 18-05-02	Tue 18-06-05
30		Tunnel for underpass	45 days	Wed 18-05-02	Tue 18-07-03
31		Relocate existing underground utilities	20 days	Wed 18-06-06	Tue 18-07-03
32		Fill intersection (north)	15 days	Wed 18-07-04	Tue 18-07-24
33		Road paving (north)	15 days	Wed 18-07-25	Tue 18-08-14
34		Road finishes (north)	5 days	Wed 18-08-15	Tue 18-08-21
35		Open Chancellor Blvd (north lanes)	1 day	Wed 18-08-22	Wed 18-08-22
36		**Phase 2**	**111 days**	**Wed 18-08-22**	**Wed 19-01-23**
37		Fill intersection (south)	15 days	Thu 18-08-23	Wed 18-09-12
38		Road paving (south)	15 days	Thu 18-09-13	Wed 18-10-03
39		Road finishes (south)	5 days	Thu 18-10-04	Wed 18-10-10
40		Open Chancellor Blvd (south lanes)	1 day	Thu 18-10-11	Thu 18-10-11
41		Underpass substructure	30 days	Wed 18-08-22	Tue 18-10-02
42		Underpass superstructure	50 days	Wed 18-10-03	Tue 18-12-11
43		Underpass finishes	30 days	Wed 18-12-12	Tue 19-01-22
44		Tunnel Underpass completed	1 day	Wed 19-01-23	Wed 19-01-23
45		**Phase 3**	**36 days**	**Wed 19-01-23**	**Wed 19-03-13**
46		Mill and fill corridor	30 days	Thu 19-01-24	Wed 19-03-06
47		Paint medians	20 days	Thu 19-02-14	Wed 19-03-13
48		Paving of pedestrian sidewalks	30 days	Wed 19-01-23	Tue 19-03-05
49		Install amber lights and street lights	30 days	Wed 19-01-23	Tue 19-03-05
50		Close building permit	1 day	Wed 19-03-06	Wed 19-03-06



Project: Capstone Schedule
Date: Sat 17-10-28

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	

Appendix E – Cost Estimate

PROJECT COST ESTIMATE
Chancellor Boulevard Rehabilitation Project
Cost Element Worksheet

COST ELEMENT	QUANTITY	UNIT	COST/UNIT	BASE COST	CONTINGENCY %	CONTINGENCY $	TOTAL ESTIMATE	COMMENTS
S1.0 - CONSTRUCTION COST								
S1.1 - ROUNDABOUT CONSTRUCTION								
PREPARE & EXCAVATE	594	m/lane	260.1	154499.4				
NEW CONSTRUCTION ROADWAY (FILL + ASPHALT)	594	m/lane	598	355348.62				total roadlength in roundabout is 171m (circumference) (assume 2 lanes), includes construction, engineering, materials, misc, and drainage/utility relocation
REHABILITATE CONSTRUCTION ROADWAY (MILL & FILL	0	m/lane	150	0				
ROAD MARKING	594	m/lane	9	5149.98				
CURB INSTALLATION	706	m	112	79072				includes supply and installation
CONCRETE MEDIAN	0	m	340	0				
SIGNAGE	20	ea	400	8000				average price per sign including installation from (http://www.transportation.alberta.ca/Content/docType257/Production/UnitPriceList.pdf)
TRAFFIC SIGNAL	0	ea	250000	0				No traffic signal required
TOTAL ROUNDABOUT CONSTRUCTION COST				**602,070**	**20%**	**120,414**	**722,484**	
S1.2 - ROADWAY CONSTRUCTION								
PREPARE & EXCAVATE	0	m/lane	260.1	0				
NEW CONSTRUCTION ROADWAY (FILL + ASPHALT)	0	m/lane	598	0				total roadlength in roundabout is 150m (circumference) (assume 2 lanes), includes construction, engineering, materials, misc, and drainage/utility relocation
REHABILITATE CONSTRUCTION ROADWAY (MILL & FILL	6118	m/lane	150	917625				
ROAD MARKING	6118	m/lane	9	53038.725				
CURB INSTALLATION	0	m	112	0				includes supply and installation
CONCRETE MEDIAN	475	m	340	161500				
SIGNAGE	20	ea	400	8000				average price per sign including installation from (http://www.transportation.alberta.ca/Content/docType257/Production/UnitPriceList.pdf)
TRAFFIC SIGNAL	0	ea	250000	0				No traffic signal required
TOTAL ROADWAY CONSTRUCTION COST				**1,140,164**	**20%**	**228,033**	**1,368,196**	
S1.3 - UNDERPASS CONSTRUCTION								
EXCAVATION	14119	m3	15	211,778				Drainage/Utility relocation included
S1.3.1 - TUNNEL								
CONCRETE - SLAB	74	m3	2000	148,248				
CONCRETE - RETAINING WALL	34	m3	2000	67,680				
REINFORCING STEEL SLAB - SUPPLY	13713	kg	1.33	18,238				
REINFORCING STEEL RETAINING WALL - SUPPLY	5076	kg	1.33	6,751				
REINFORCING STEEL - PLACING	18789	kg	1.38	25,929				
S1.3.2 - RAMPS								
CONCRETE - SLAB	205	m3	2000	410,982				
CONCRETE - RETAINING WALL	114	m3	2000	228,480				
CONCRETE - COLUMN	4	m3	2000	8,815				
REINFORCING STEEL SLAB - SUPPLY	38016	kg	1.33	50,561				
REINFORCING STEEL RETAINING WALL - SUPPLY	17136	kg	1.33	22,791				
REINFORCING STEEL COLUMN - SUPPLY	881	kg	1.33	1,172				
REINFORCING STEEL - PLACING	56033	kg	1.38	77,326				
S1.3.3 - STAIRS								
CONCRETE - SLAB	5	m3	2000	9,600				
CONCRETE - RETAINING WALL	0	m3	2000	0				
REINFORCING STEEL SLAB - SUPPLY	960	kg	1.33	1,277				
REINFORCING STEEL RETAINING WALL - SUPPLY	0	kg	1.33	0				
REINFORCING STEEL - SUPPLY	0	kg	1.33	0				
REINFORCING STEEL - PLACING	960	kg	1.38	1,325				
S1.3.4 - TREE CUTTING								
CUT AND LEVEL	1462	m^2	21.5	31,470				
TOTAL UNDERPASS CONSTRUCTION COST				**1,322,422**	**20%**	**264,484**	**1,586,907**	
S1.4 - ACTIVE TRANSPORTATION FACILITIES								
BIKE LANE MARKINGS	2820	m/lane	9	25,380				
MILL AND FILL EXISTING SIDEWALK	1458	m/sidewalk	150	218,700				
NEW CONSTRUCTION SIDEWALK	448	m/sidewalk	374	167,552				
TOTAL ACTIVE TRANSPORTATION COST				**411,632**	**20%**	**82,326**	**493,958**	
S1.5 - ELECTRICAL								
STREET LIGHTS	71	ea	10000	712,800				Street Light Standard - Supply and Install
TOTAL ELECTRICAL COST				**712,800**	**20%**	**142,560**	**855,360**	
S1.6 - LANDSCAPING								includes supply and planting cost
HYDROSEEDING	7232	m^2	0.88	6,364				
TOTAL LANDSCAPING				**6,364**	**20%**	**1,273**	**7,637**	
S1.7 INFLATION FROM 2013-2018 (105.75%)				**241,238**			241,238	
CONSTRUCTION TOTAL				**4,436,690**	**20%**	**839,090**	**5,275,781**	
S2.0 - DESIGN								
S2.1 - PRELIMINARY DESIGN				88,734				2% of Construction Base Estimate
S2.2 - DETAILED DESIGN SERVICES				354,935				8% of Construction Base Estimate
DESIGN TOTAL				**443,669**			**443,669**	
S3.0 - PROPERTY ACQUISITION								
S3.1 - LAND ACQUISITION				**0**				
PROPERTY ACQUISITION TOTAL				**0**				
S4.0 - PROJECT MANAGEMENT TOTAL				**155,284**	`		**155,284**	3.5% of base construction cost
S5.0 - PLANNING TOTAL				**44,367**			**44,367**	1% of base construction cost
S6.0 - CONSTRUCTION QA/QC TOTAL				**443,669**			**443,669**	10% of base construction cost
S7.0 - OPERATION AND MAINTENANCE TOTAL				**221,835**			**221,835**	5% of base construction cost (maintained by MOTI)
TOTAL				***5,745,514***		***839,090***	***6,584,604***	

Appendix F – References

UBC Transportation Plan

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UBC Transportation Status Report Fall 2016

https://planning.ubc.ca/sites/planning.ubc.ca/files/documents/transportation/reports/UBC2016-TransportationStatusReport-FINAL.pdf

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https://www1.toronto.ca/City%20Of%20Toronto/Engineering%20and%20Construction%20Services/Standards%20and%20Specifications/Files/pdf/Road%20Design%20Guidelines/Lane_Widths_Guideline_Version_2.0_Jun2017.pdf

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http://www.th.gov.bc.ca/popular-topics/faq.htm#pavement

Lighting References

http://www.bclaws.ca/civix/document/id/loo89/loo89/30_78#section7.05

https://www2.gov.bc.ca/assets/gov/government/services-for-government-and-broader-public-sector/buy-goods-services-and-construction/goods-and-services-catalogue/csa-assets/cs-000714_brochure_ael.pdf

Specifications

TAC's Geometric Design Guide

BC MOTI’s BC Supplement to TAC Geometric Design Guide

BC MOTI's Manual of Standard Traffic Signs & Pavement Markings

Manual on Uniform Traffic Control Devices (MUTCD)

the UBC Wayfinding Exterior Signage Standards and Guidelines

NACTO’s Urban Street Design Guide

The Pedestrian Crossing Control Manual for British Columbia

Kansas Roundabout Guide

BC MOTI's Technical Bulletin - Lane Use Signs and Pavement Markings at Multi-Lane Roundabouts

City of Calgary Roads Construction 2012 Standard Specifcations

DMD & Associates Design and Roadway Lighting

BC Government Street Light Specifications

City of Richmond MMCD Supplemental Specifications

City of Richmond Lighting Specifications

City of Vancouver Utilities Design Construction Manual

Translink Universally Accessible Bus Stop Design Guidelines

Detailed Drawings

UNIVERSITY OF BRITISH COLUMBIA

THE UNIVERSITY OF BRITISH COLUMBIA

SEEDS Sustainability Program

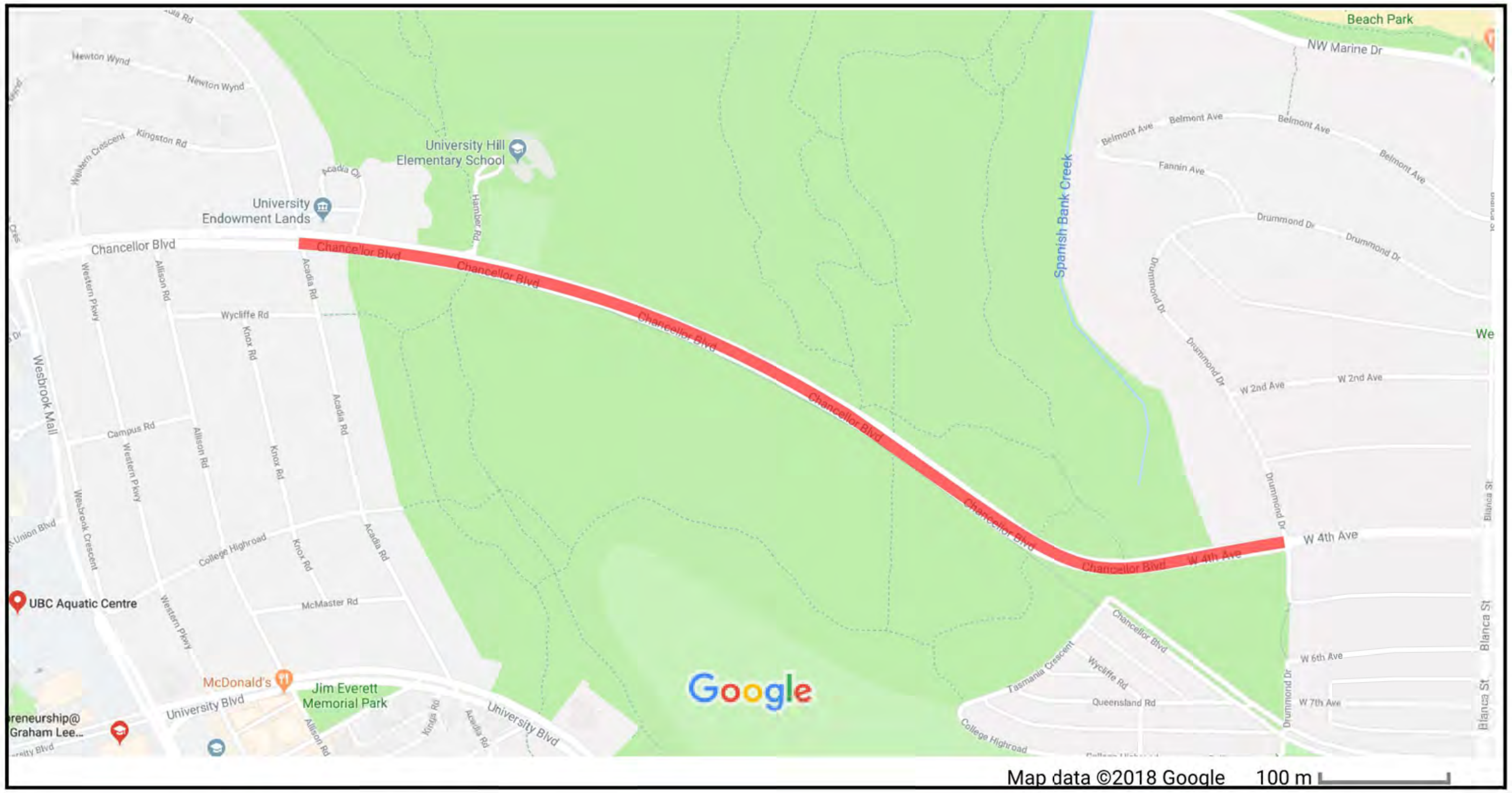
PLANS FOR PROPOSED PROJECT:

CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

CHANCELLOR BOULEVARD, VANCOUVER, BC

LENGTH: 1.75KM

INDEX TO SHEETS:



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DATE: APRIL 2, 2018

PLANS PREPARED BY:

DTS Engineering

SHEET NO.: A1

GENERAL NOTES

GENERAL

1. THIS DRAWING PACKAGE IS CREATED IN FULFILLMENT OF UBC CIVL 446 COURSE REQUIREMENT. THE CONTENTS OF THIS DRAWING PACKAGE IS SUBJECT FOR REVIEW OF A PROFESSIONAL ENGINEER. CONSTRUCTION SHALL NOT COMMENCE WITHOUT THE APPROVAL OF A PROFESSIONAL ENGINEER.
2. VARIOUS REFERENCES IS MADE TO DESIGN GUIDELINES AND SPECIFICATIONS THROUGHOUT THIS GENERAL NOTES. PARTIES INVOLVED IN THE CONSTRUCTION PROCESS INCLUDING OWNER, BUILDER, GENERAL CONTRACTOR, SUBCONTRACTORS, AND SUBCONSULTANTS ARE EXPECTED TO ADHERE TO THOSE REQUIREMENTS.
3. GENERAL CONTRACTOR SHALL VERIFY ALL DIMENSIONS AND ELEVATIONS RELATING TO THE EXISTING CONDITION OF THE SITE BY CONDUCTING ON-SITE MEASUREMENTS AND FIELD SURVEYS.

EARTHWORKS

1. EXCAVATION, BACKFILLING AND COMPACTION PROCEDURES SHALL CONFORM WITH BRITISH COLUMBIA MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE'S (BC MOTI) 2016 STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION

GEOMETRIC ROAD DESIGN

1. THIS DESIGN MEETS THE REQUIREMENT OF TAC'S GEOMETRIC DESIGN GUIDE FOR CANADIAN ROADS AND BC MOTI'S BC SUPPLEMENT TO TAC AND, ALL RELEVANT BC STANDARDS
2. CONTRACTOR TO CONFIRM ALL EXISTING CONDITIONS AND DIMENSIONS ON SITE

GEOMETRIC ROAD DESIGN

1. ALL SIGNAGE AND PAVEMENT MARKINGS TO BE INSTALLED IN CONFORMANCE WITH BC MOTI'S MANUAL OF STANDARD TRAFFIC SIGNS & PAVEMENT MARKINGS
2. CONTRACTOR TO CONFIRM THE LOCATION AND SUITABILITY OF ALL SIGNAGE PRIOR TO INSTALLATION
3. REMOVE ALL EXISTING PAVEMENT MARKINGS AND SIGNAGE UNLESS NOTED IN THE DRAWINGS
4. ROUNDABOUT PAVEMENT MARKINGS AND SIGNAGE TO BE INSTALLED IN CONFORMANCE WITH BC MOTI'S TECHNICAL BULLETIN – LANE USE SIGNS AND PAVEMENT MARKINGS IN MULTI-LANE ROUNDABOUTS
5. SPECIAL CROSSWALKS AND ASSOCIATED PAVEMENT MARKINGS AND SIGNAGE TO BE INSTALLED IN CONFORMANCE WITH THE PEDESTRIAN CROSSING CONTROL MANUAL FOR BRITISH COLUMBIA

UTILITIES

1. ACTUAL UTILITY DEPTHS SHOULD BE CONFIRMED ON SITE BY THE CONTRACTOR BEFORE CONSTRUCTION COMMENCES
2. DAMAGE AND CHANGES TO STORMWATER PIPES NORTH OF THE INTERSECTION MH-5 AND MH-4 SHOULD BE MINIMIZED DURING CONSTRUCTION

STRUCTURAL

CONCRETE

1. ALL CONCRETE MATERIAL PROPERTIES SHALL CONFORM WITH CSA-S6: CANADIAN HIGHWAY BRIDGE DESIGN CODE
2. ALL CONCRETE SHALL BE TESTED IN ACCORDANCE TO CSA A23.1-14/A23.2-14 – CONCRETE MATERIALS AND METHODS OF CONCRETE CONSTRUCTION / TEST METHODS AND STANDARD PRACTICES FOR CONCRETE
3. CONCRETE FORMING AND PLACING SHALL CONFORM WITH INDUSTRY STANDARD PRACTICES AS SPECIFIED BY CSA-S6: CANADIAN BRIDGE DESIGN CODE
4. ALL CONCRETE MUST BE NORMAL WEIGHT (2300KG/M^3) WITH MIXES DESIGNED TO MEET THE FOLLOWING CRITERIA:

STRUCTURAL ELEMENT	28-DAY COMPRESSIVE STRENTH (MPA)
RETAINING WALL	30MPA
TUNNEL WALL	30MPA
TUNNEL RAMPS	35MPA
TUNNEL SUSPENDED SLAB	30MPA
STRIP FOOTING	30MPA
SPREAD FOOTING	30MPA
RAMP COLUMN	35MPA

REINFORCING STEEL

1. ALL REINFORCING STEEL MATERIAL PROPERTIES SHALL CONFORM WITH BC MOTI'S 2016 STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION SECTION 412.
2. UNLESS OTHERWISE NOTED, REINFORCING STEEL SHALL HAVE THE FOLLOWING CONCRETE COVER:

CONCRETE CAST AGAINST GROUND	100mm
TOP OF DECK SLABS	70mm
UNDERSIDES OF DECK SLABS	40mm
OTHER SURFACES	60mm

3. LAP SPLICES OF REINFORCING STEEL SHALL CONFORM WITH CSA-S6: CANADIAN HIGHWAY BRIDGE DESIGN CODE.
4. THE FOLLOWING ARE THE DESIGNATION OF THE REINFORCING STEEL TO BE USED:

BAR DESIGNATION	MASS (KG/M)
10M	0.785
15M	1.570
20M	2.355
25M	3.925
30M	5.495
35M	7.850
45M	11.775
55M	19.625

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Title:

GENERAL NOTES

Project: CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Date: APRIL 2, 2018

Scale: N/A

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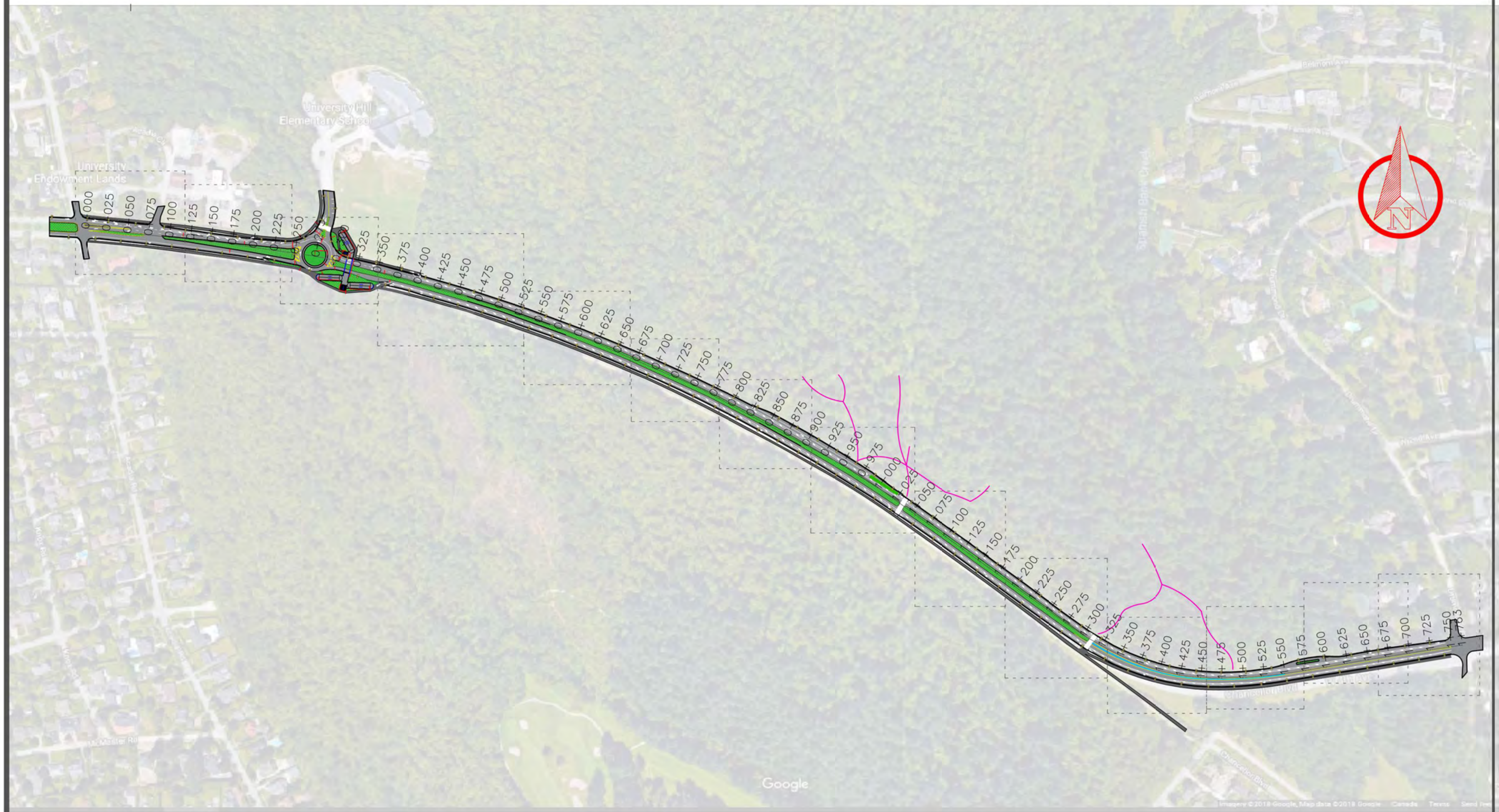

General Notes

—TYPICAL STREET LIGHTING:
71 WATT ATBS LED HEAD FIXTURE

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title:

OVERVIEW DRAWING

Project
CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Date
APR 2, 2018

Scale

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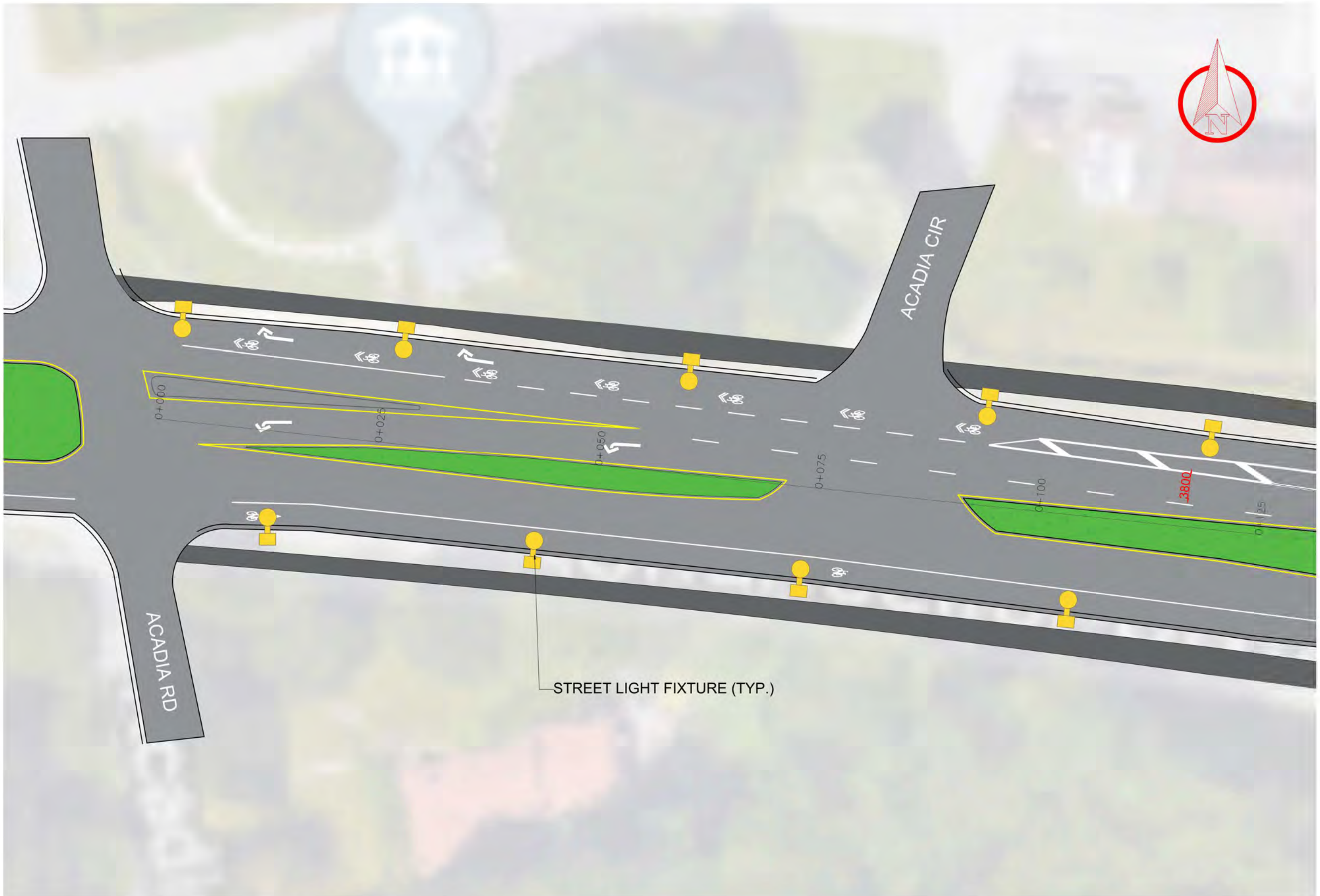

General Notes

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71 WATT ATBS LED HEAD FIXTURE

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DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name:

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

STATION 0+000 TO 0+125

Project: CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Date: APR 2, 2018

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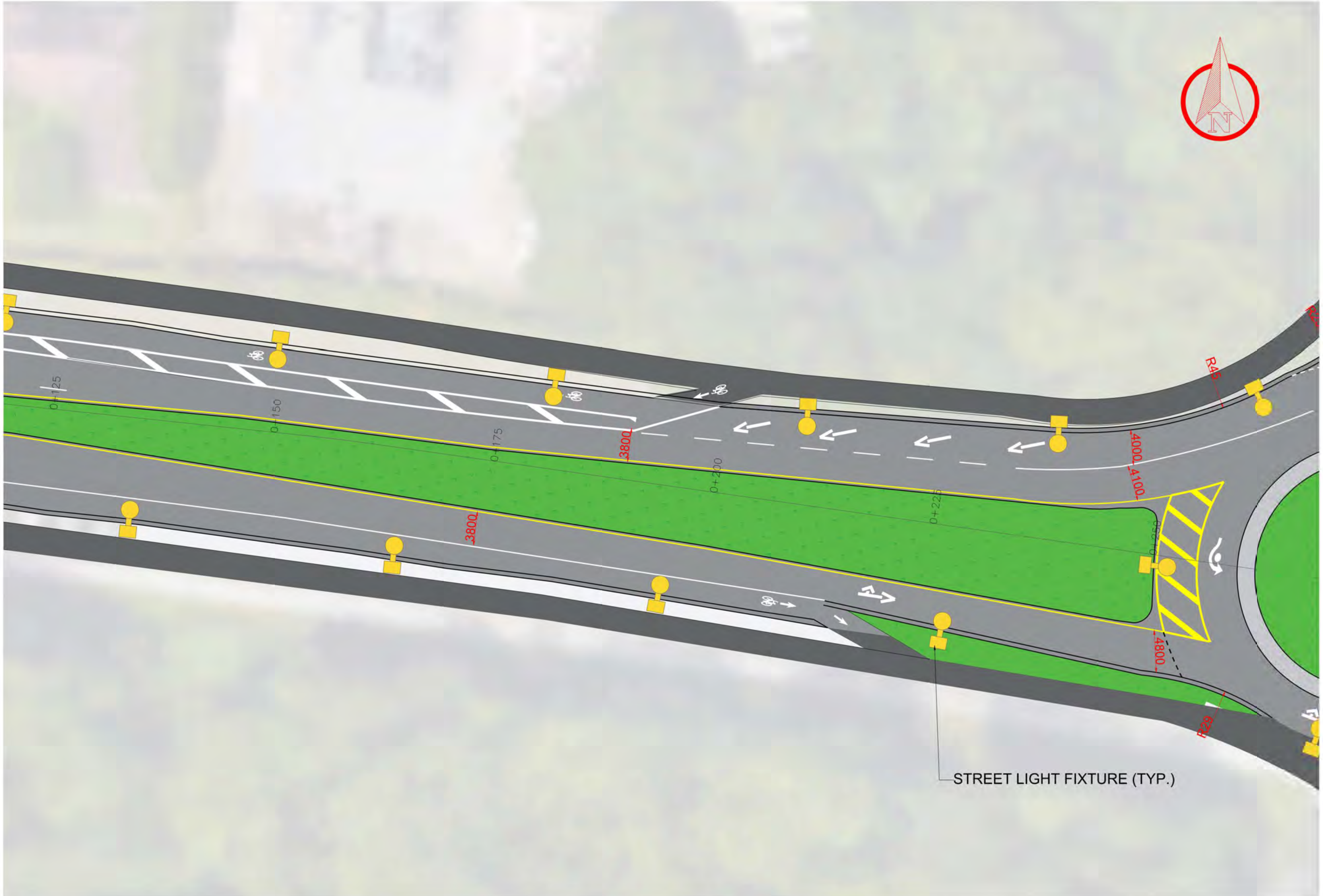

General Notes

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71 WATT ATBS LED HEAD FIXTURE

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DTS ENGINEERING

7284 STRIDE AVENUE
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Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title

STATION 0+125 TO 0+250

Project: CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Date: APR 2, 2018

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General Notes

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7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name:

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title:

STATION 0+255 TO 0+350
(ROUNDABOUT)

Project: CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Date: APR 2, 2016

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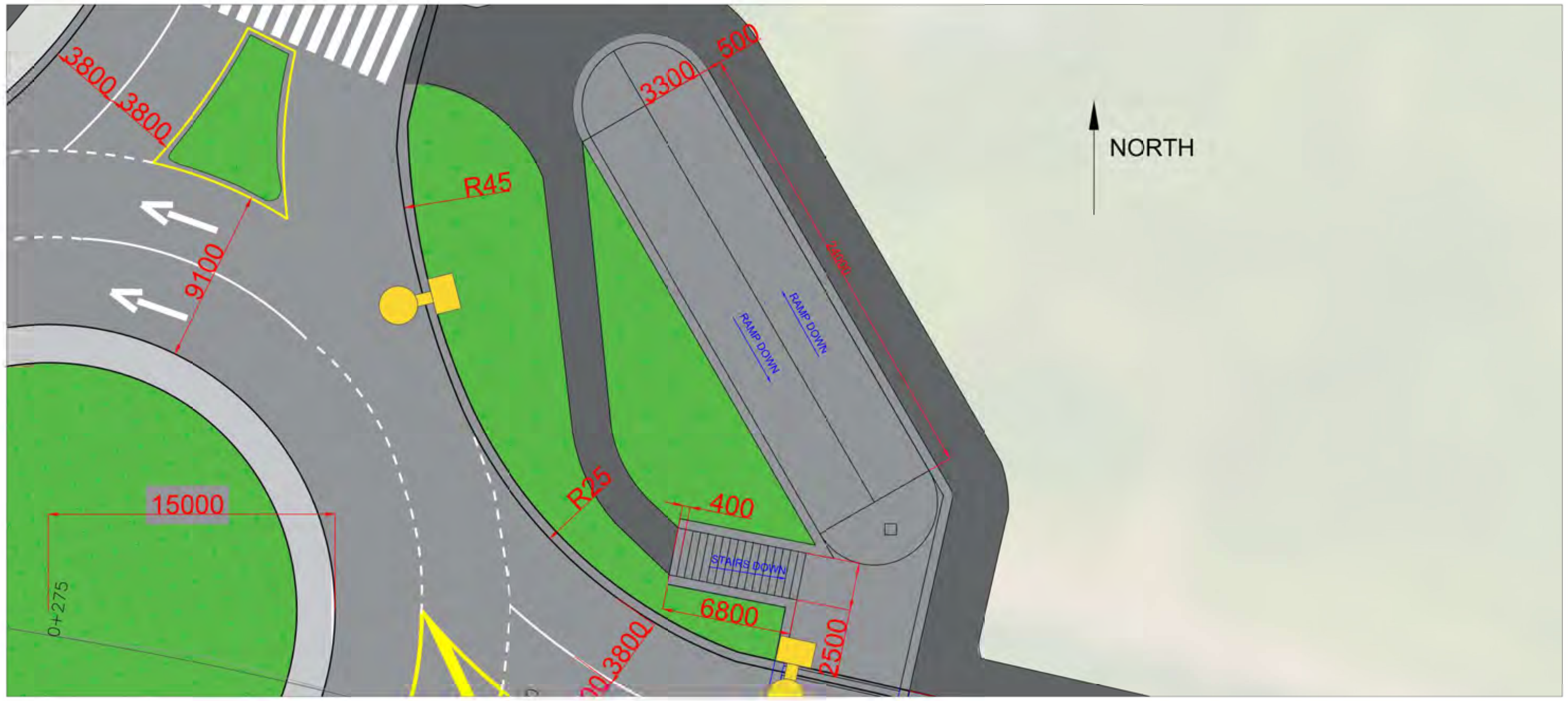

NORTH TUNNEL RAMP
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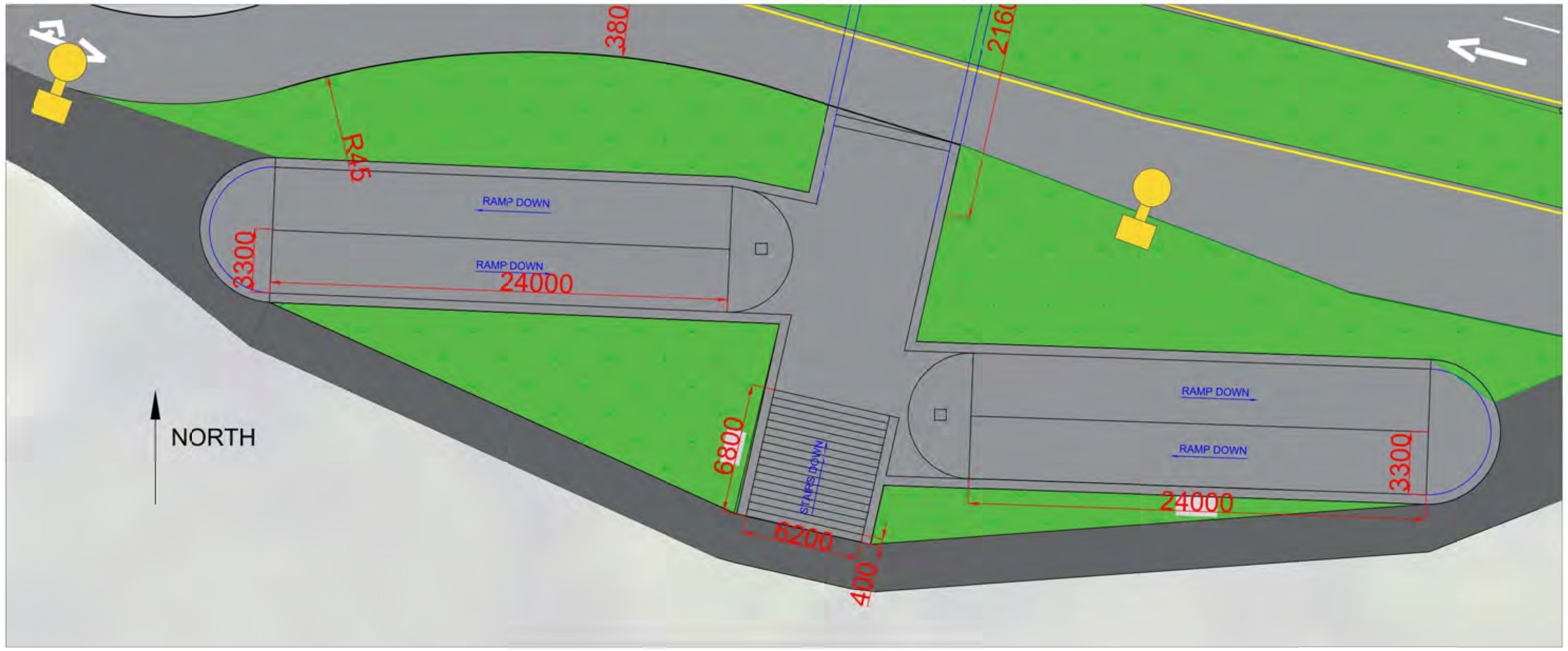

SOUTH TUNNEL RAMPS
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General Notes

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DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title:

TUNNEL RAMPS PLAN

Project
CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

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APR 2, 2018

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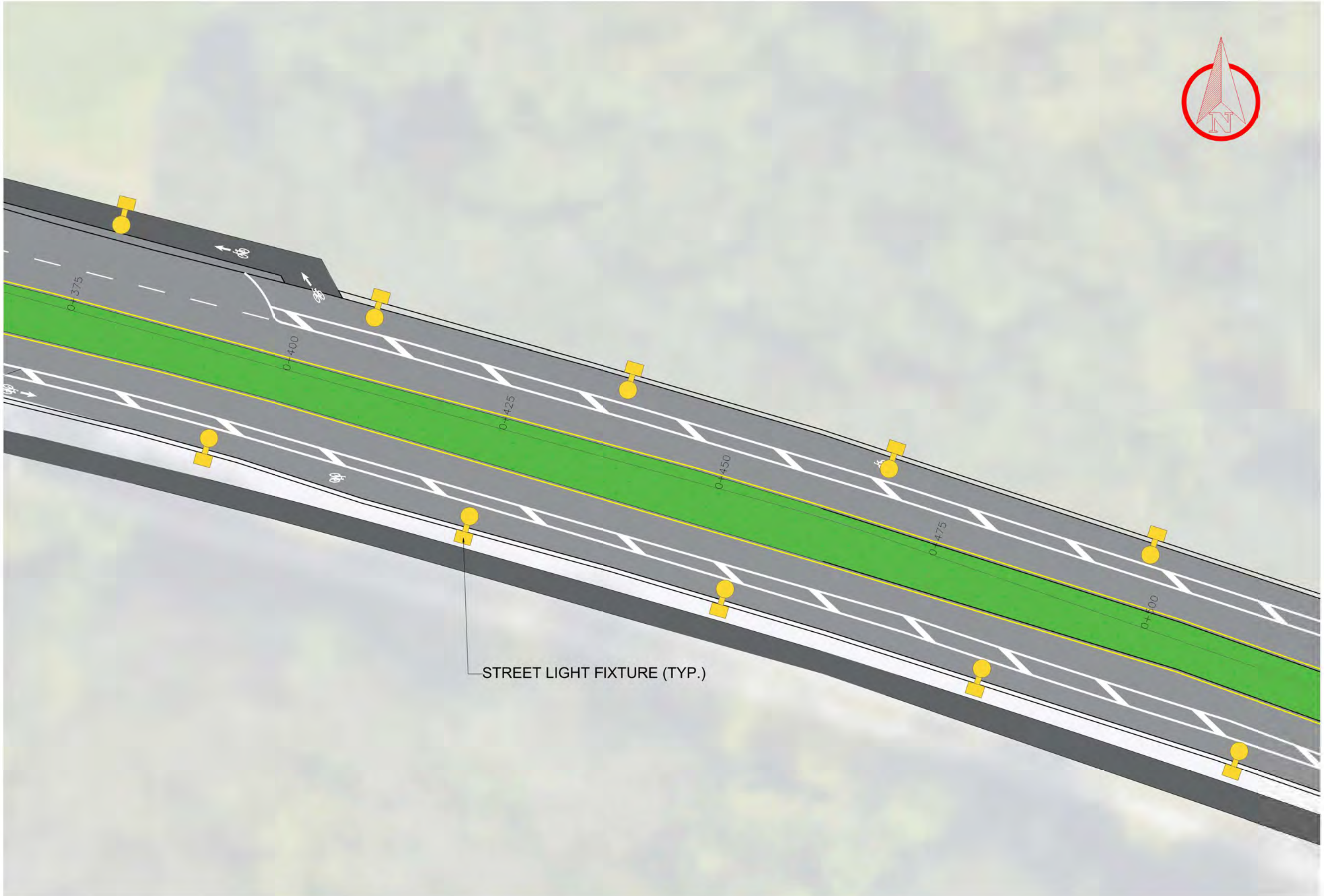

General Notes

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71 WATT ATBS LED HEAD FIXTURE

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Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title

STATION 0+350 TO 0+525

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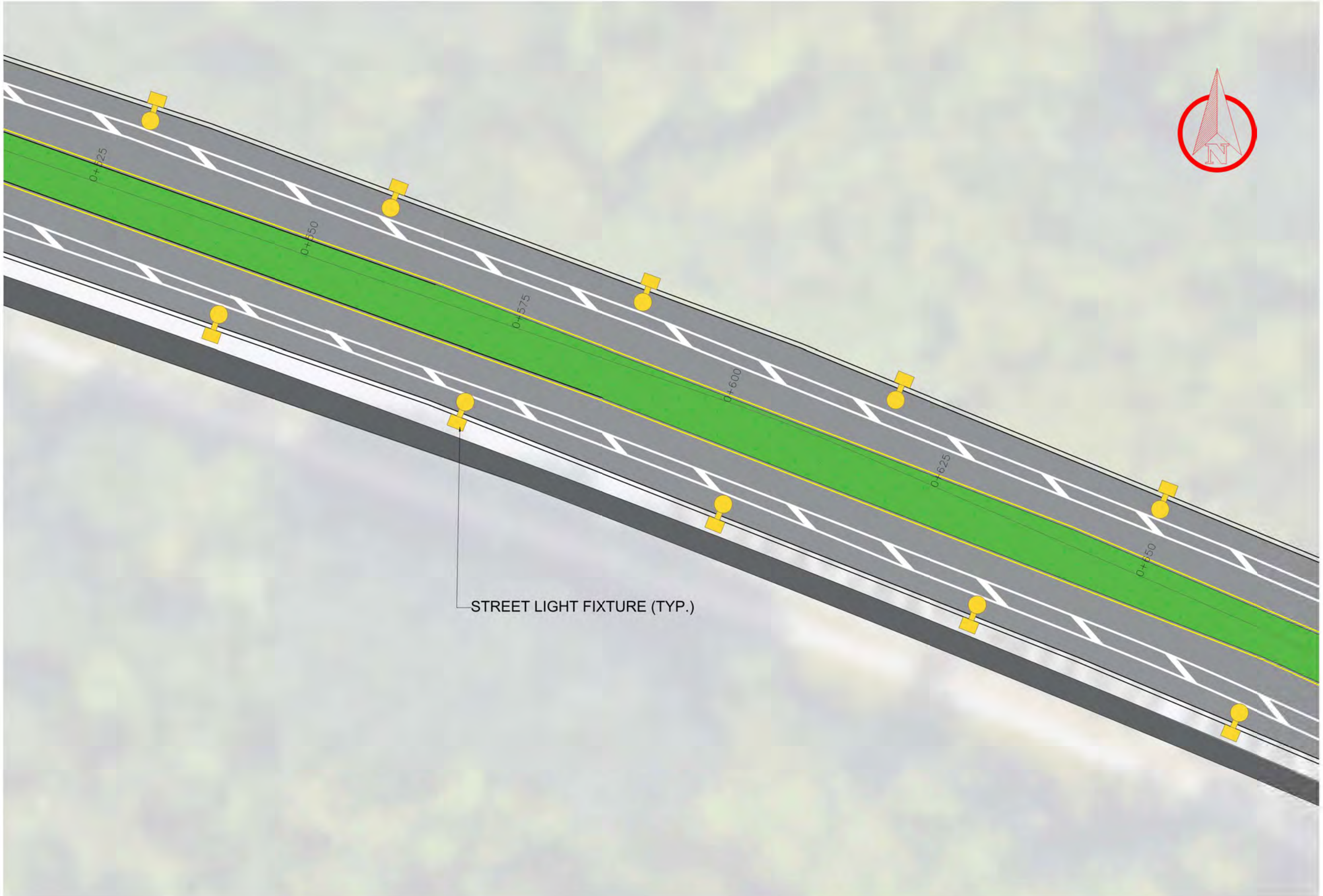

General Notes

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BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title

STATION 0+525 TO 0+650

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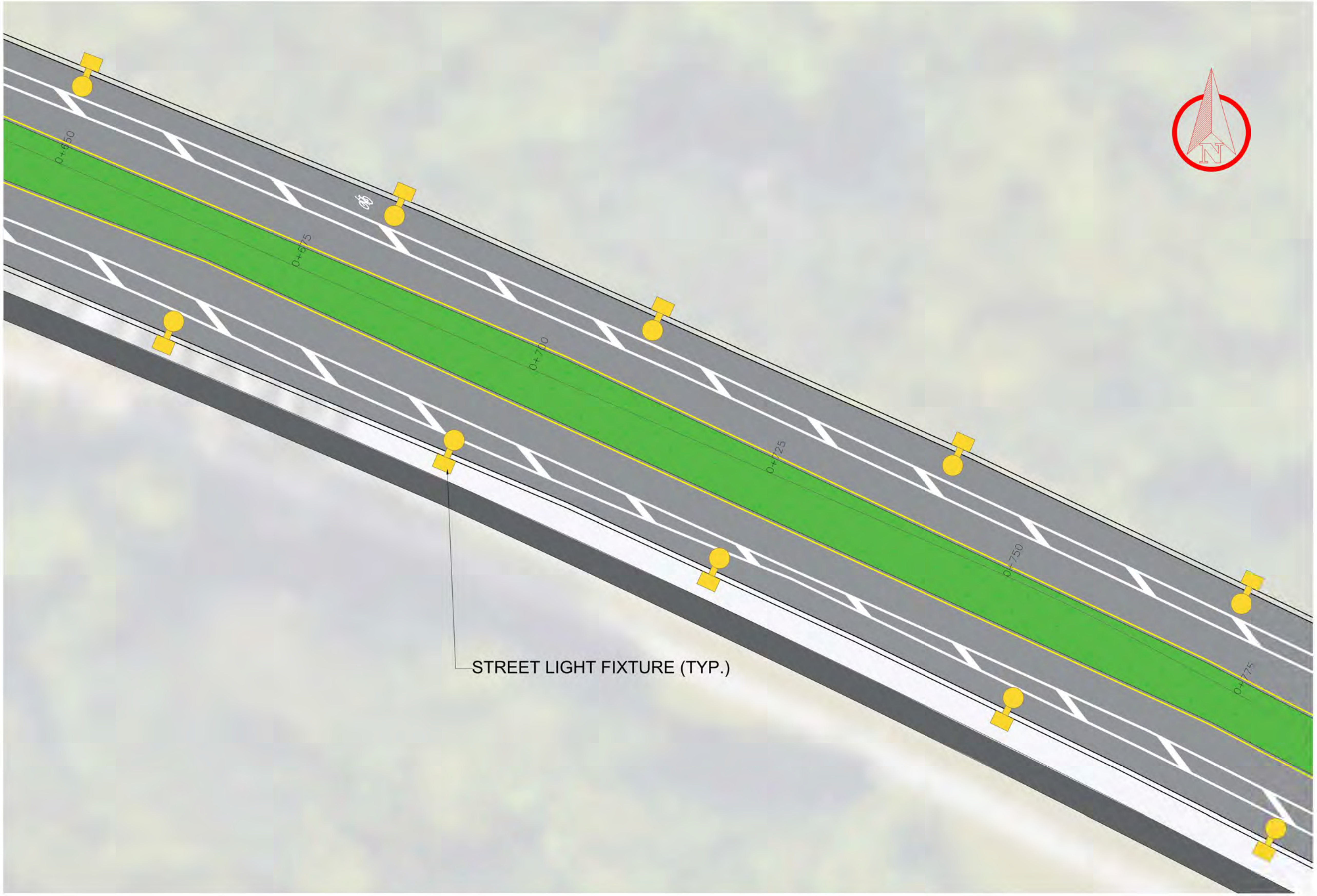

General Notes

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DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name:

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title:

STATION 0+650 TO 0+775

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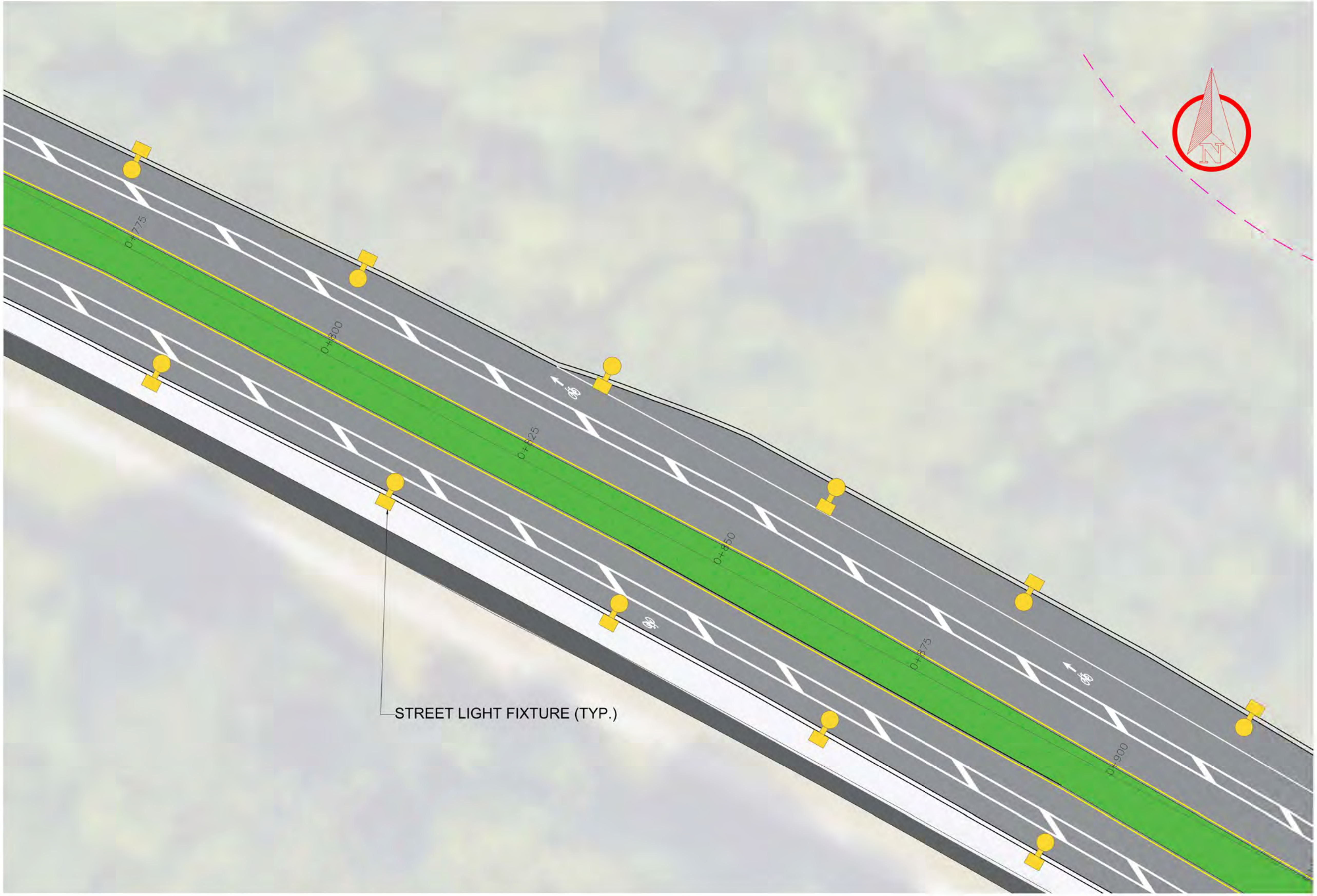

General Notes

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71 WATT ATBS LED HEAD FIXTURE

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Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title

STATION 0+775 TO 0+900

Project
CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Date
APR 2, 2018

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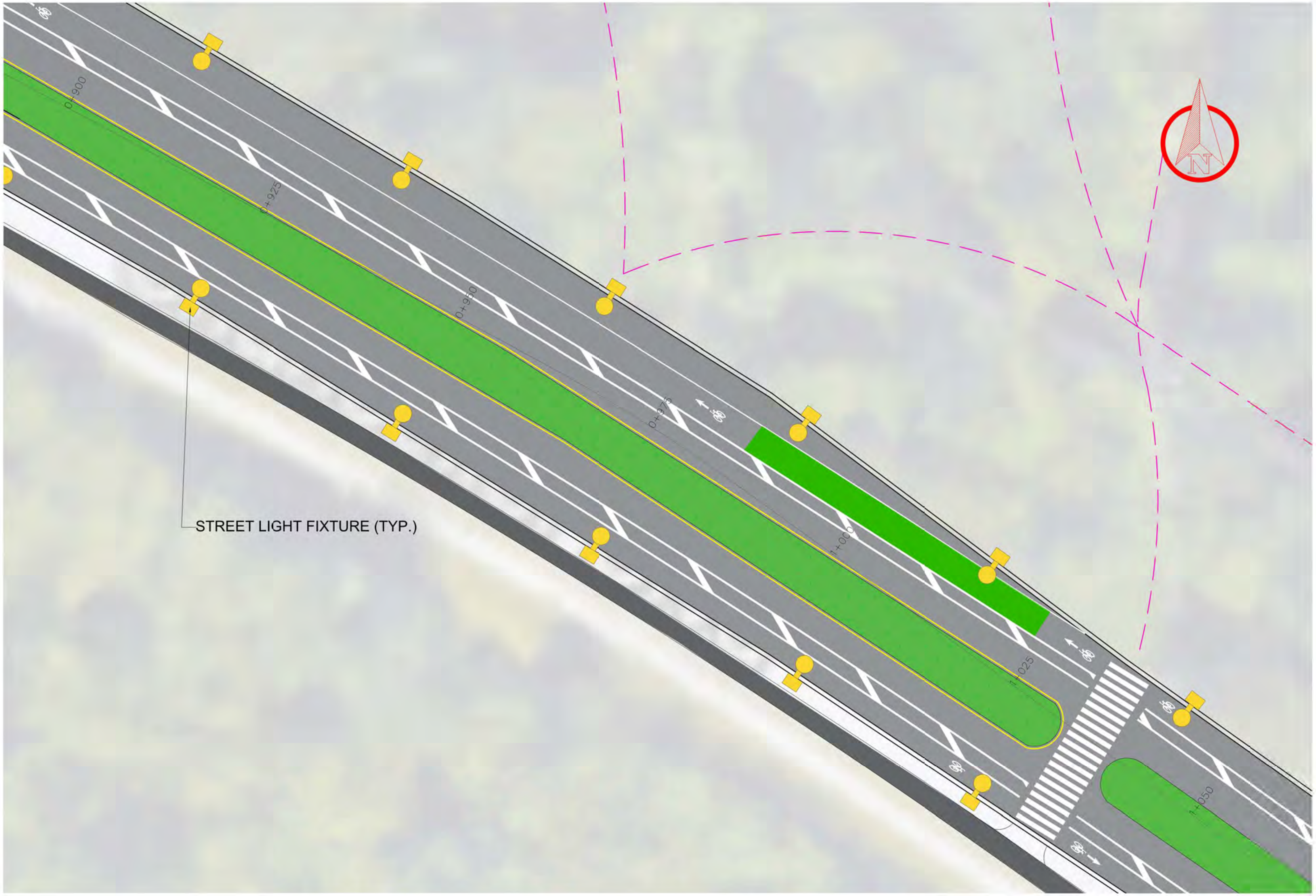

General Notes

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Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title

STATION 0+900 TO 1+050

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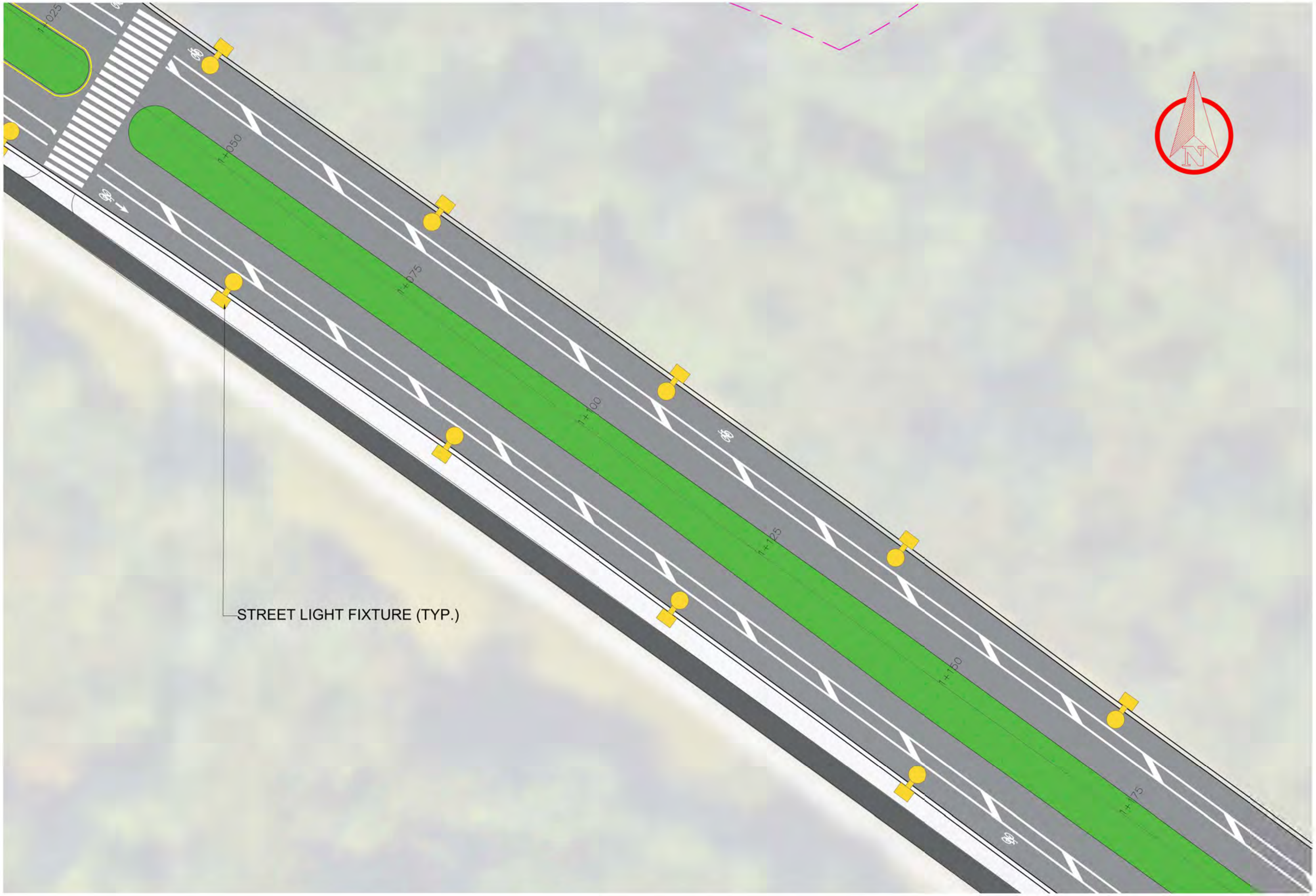

General Notes

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Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title

STATION 1+050 TO 1+175

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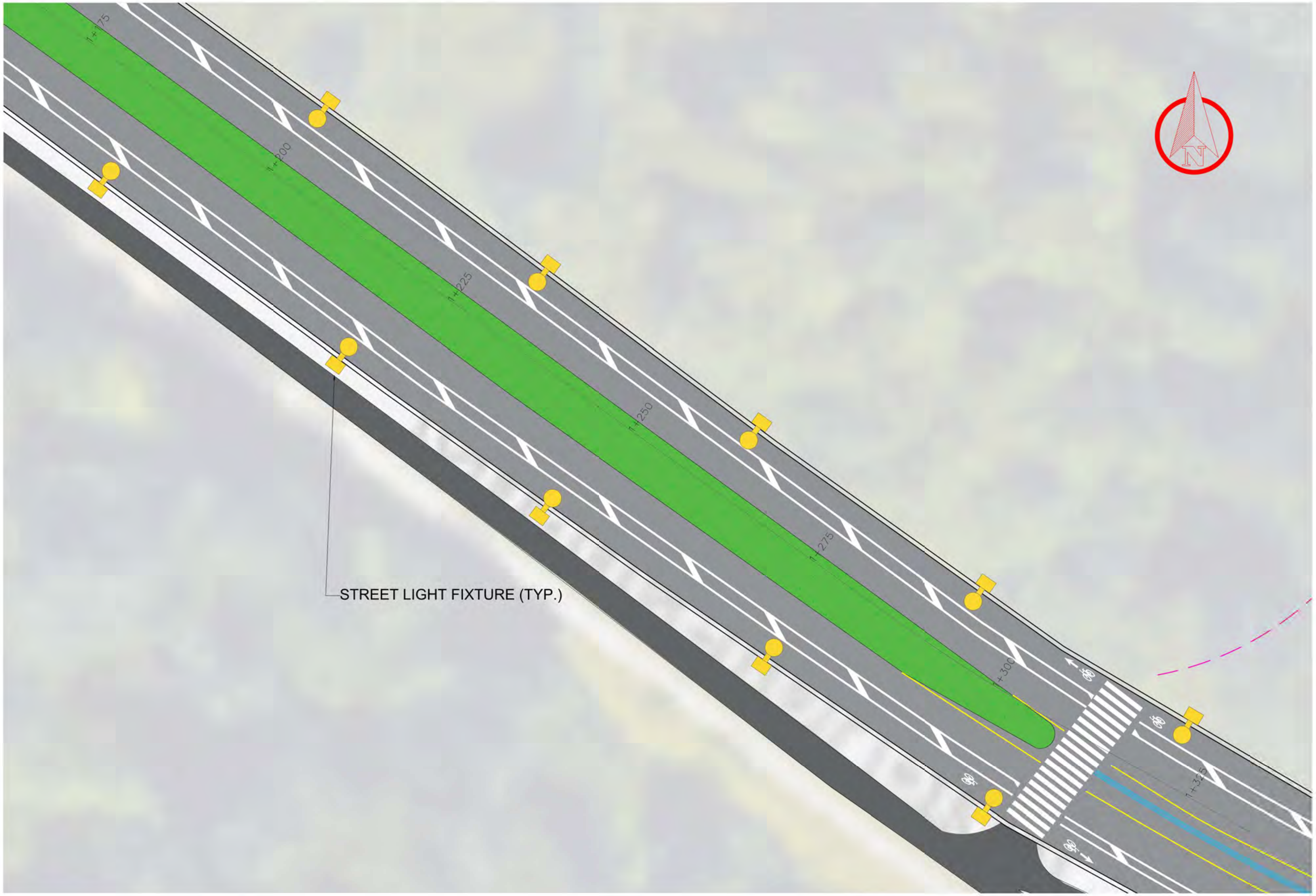

General Notes

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Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title

STATION 1+175 TO 1+325

Project CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD	Sheet B12
Date APR 2, 2018	
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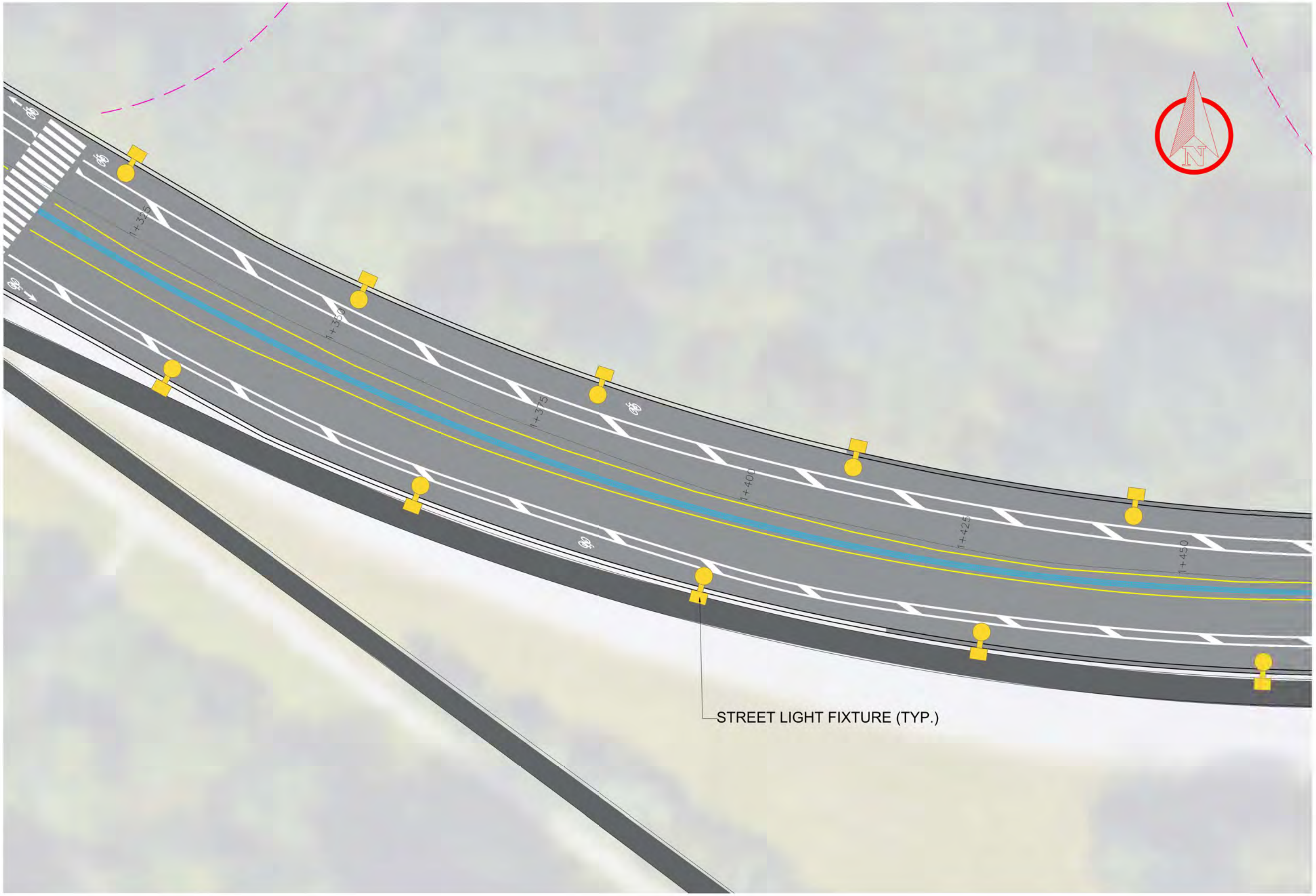


General Notes

-TYPICAL STREET LIGHTING:
71 WATT ATBS LED HEAD FIXTURE

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

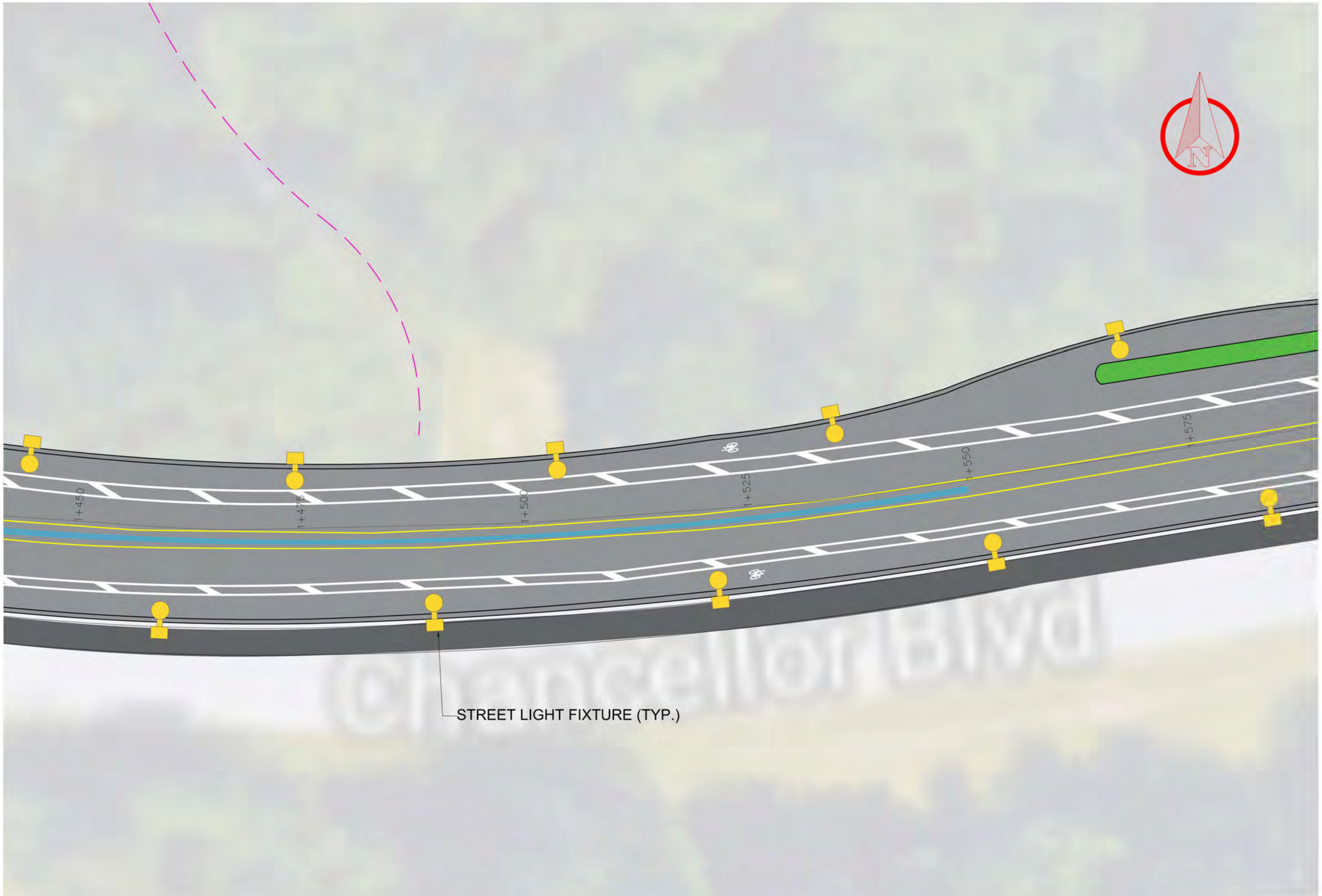
Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title

STATION 1+325 TO 1+450

Project CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD	Sheet B13
Date APR 2, 2018	
Scale 1:200	



General Notes

–TYPICAL STREET LIGHTING:
71 WATT ATBS LED HEAD FIXTURE

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title

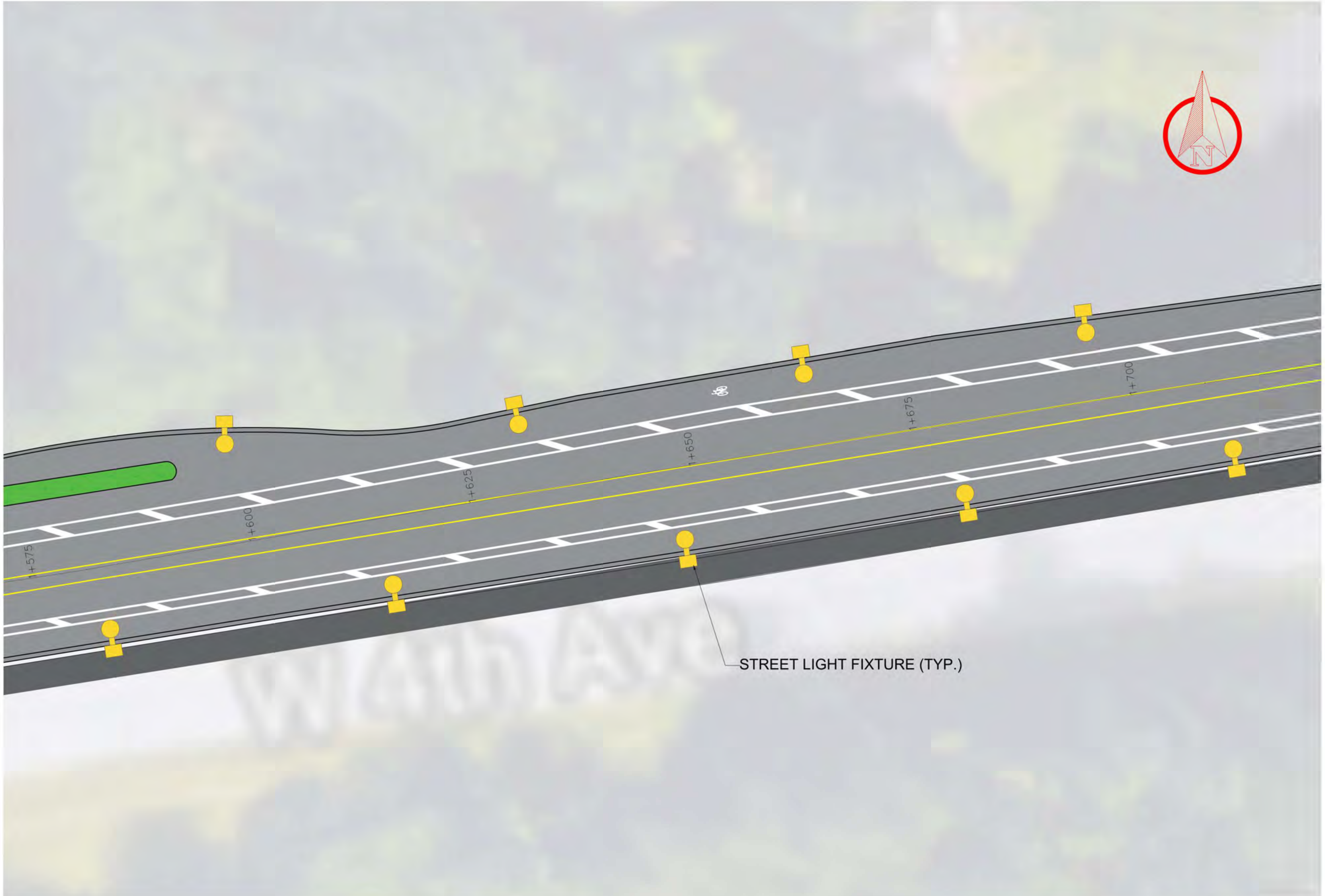
STATION 1+450 TO 1+575

Project: CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Date: APR 2, 2018

Scale: 1:200

Sheet: B14



General Notes

–TYPICAL STREET LIGHTING:
71 WATT ATBS LED HEAD FIXTURE

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title

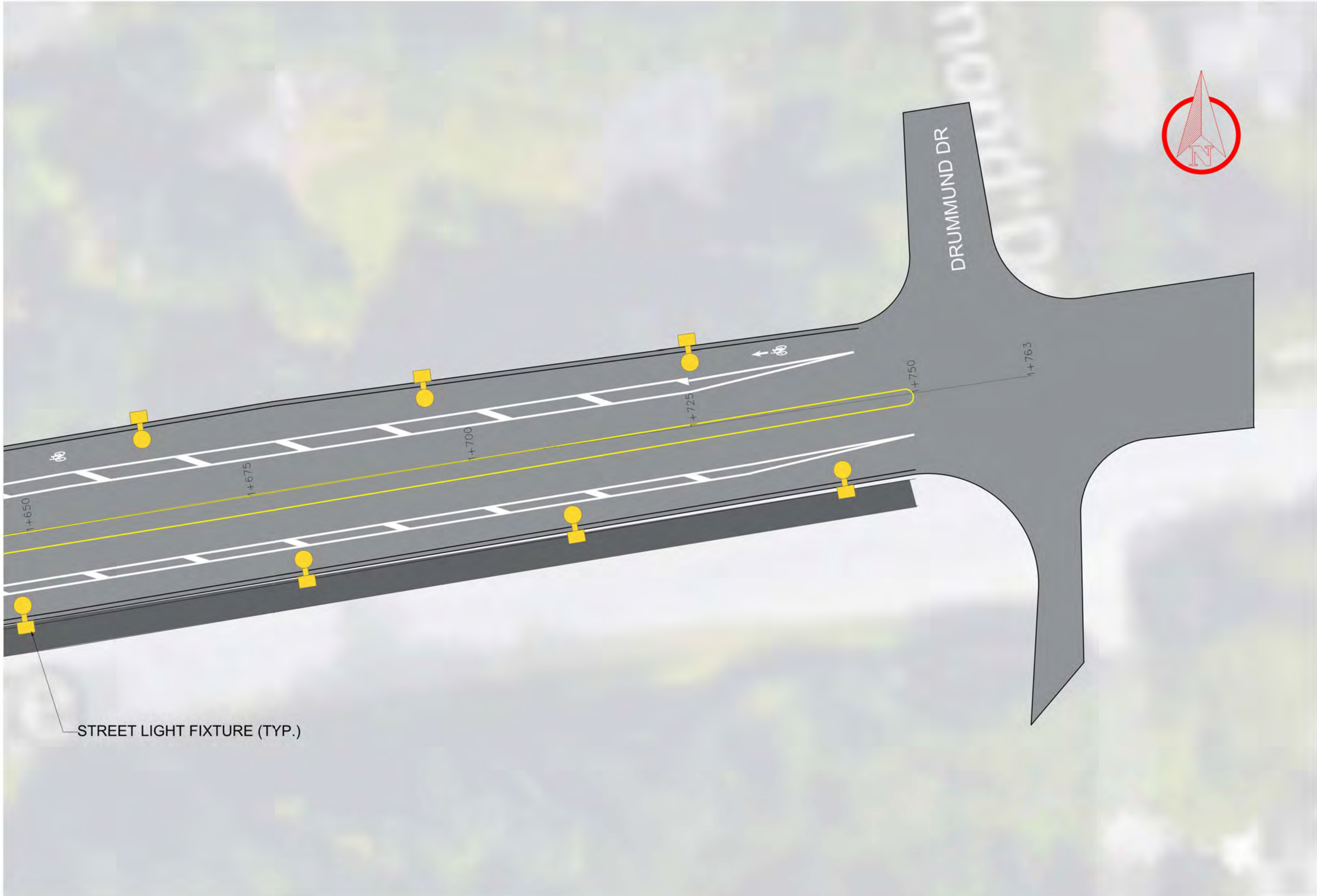
STATION 1+575 TO 1+700

Project: CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Date: APR 2, 2018

Scale: 1:200

Sheet: B15



General Notes

–TYPICAL STREET LIGHTING:
71 WATT ATBS LED HEAD FIXTURE

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title

STATION 1+676 TO 1+775

1:200

B16

General Notes

-TYPICAL STREET LIGHTING:
71 WATT ATBS LED HEAD FIXTURE

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

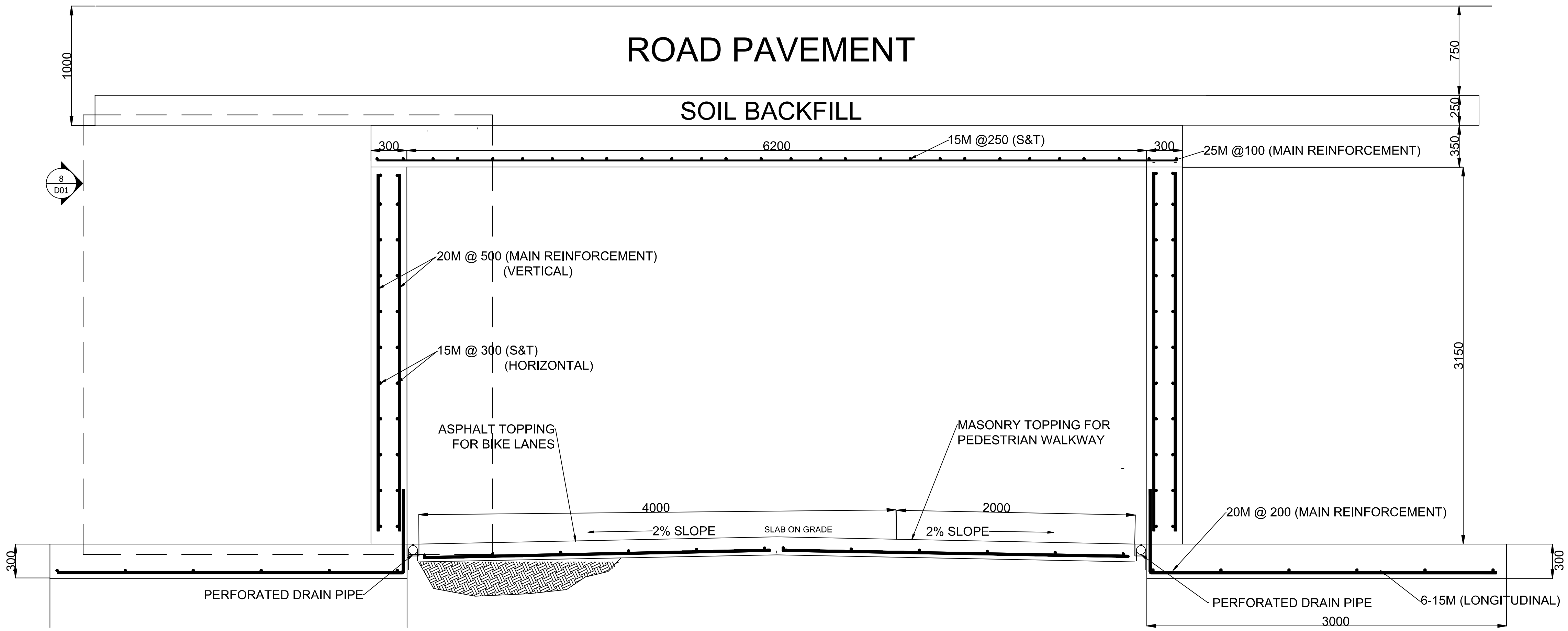
Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title:

CROSS SECTION CALL-OUT PLAN

Project: CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD	Sheet: C01
Date: APR 2, 2018	
Scale: 1:250	



TUNNEL CROSS SECTION
SCALE: 1:20

A
C02

General Notes

-TYPICAL STREET LIGHTING:
71 WATT ATBS LED HEAD FIXTURE

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title:

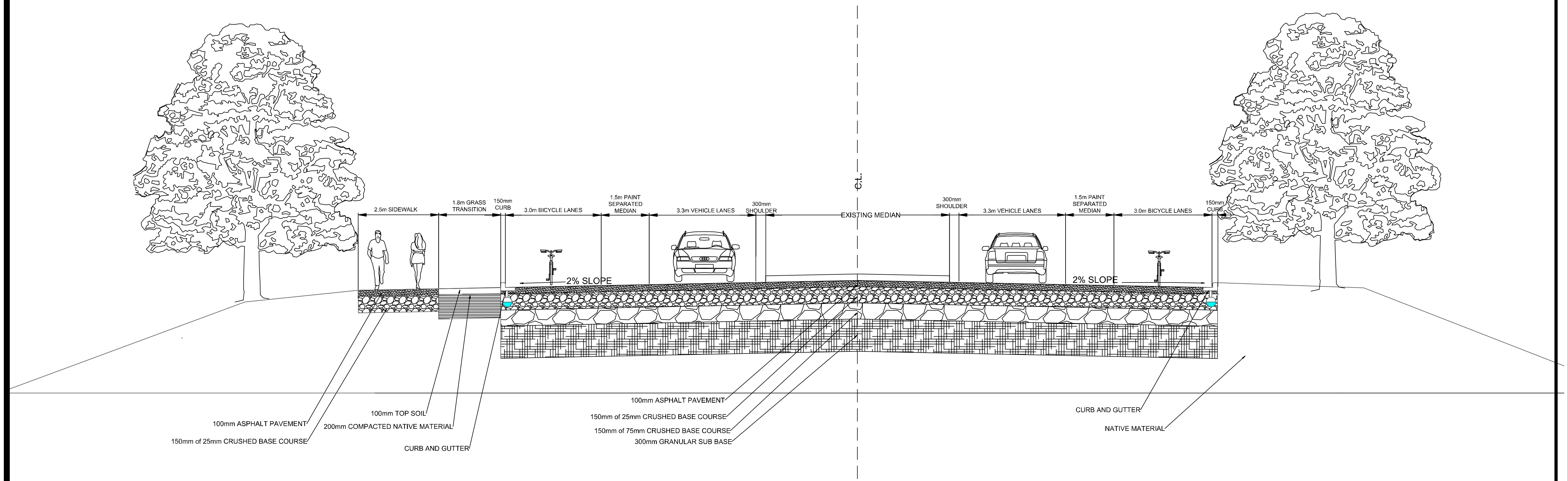
CROSS SECTION - TUNNEL

Project
CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Date
APR 2, 2018

Scale
AS NOTED

Sheet
C02



TYPICAL NEW ROAD CROSS SECTION
SCALE: 1:50

A
C03

General Notes

–TYPICAL STREET LIGHTING:
71 WATT ATBS LED HEAD FIXTURE

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

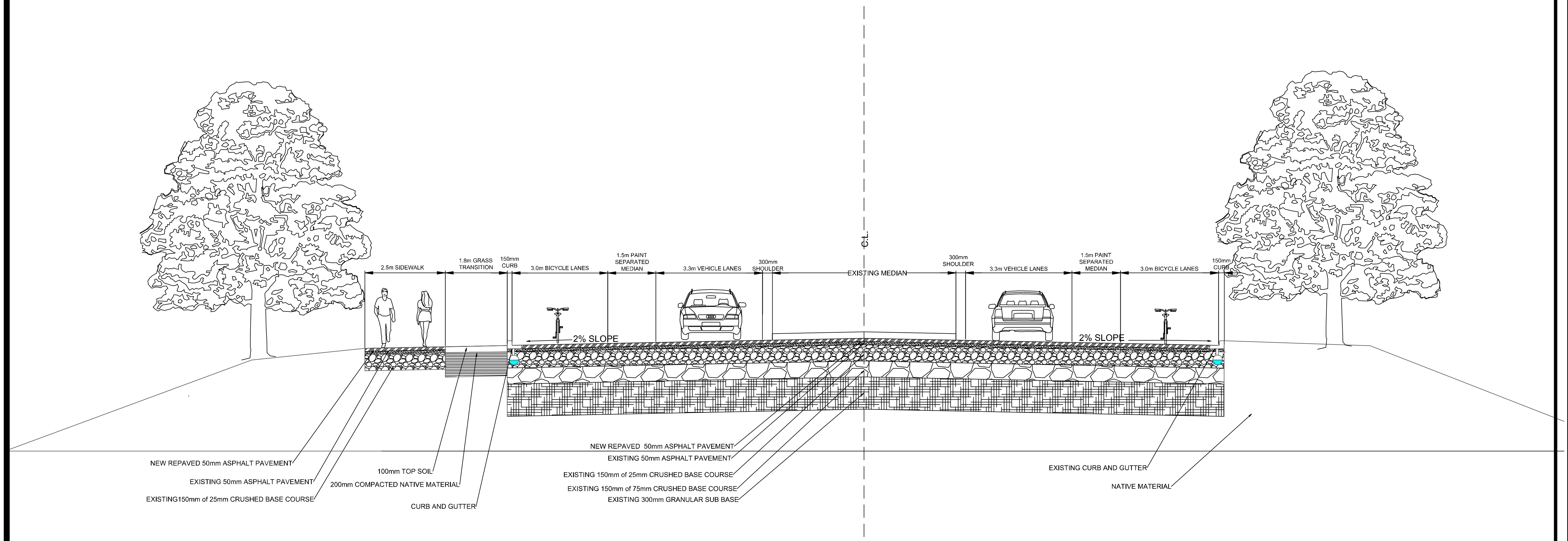
Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title:

CROSS SECTION - NEW ROADWAY

Project: CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD	Sheet
Date: APR 2, 2018	C03
Scale: AS NOTED	



TYPICAL ROAD CROSS SECTION
SCALE: 1:50

A
C04

General Notes

–TYPICAL STREET LIGHTING:
71 WATT ATBS LED HEAD FIXTURE

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title:

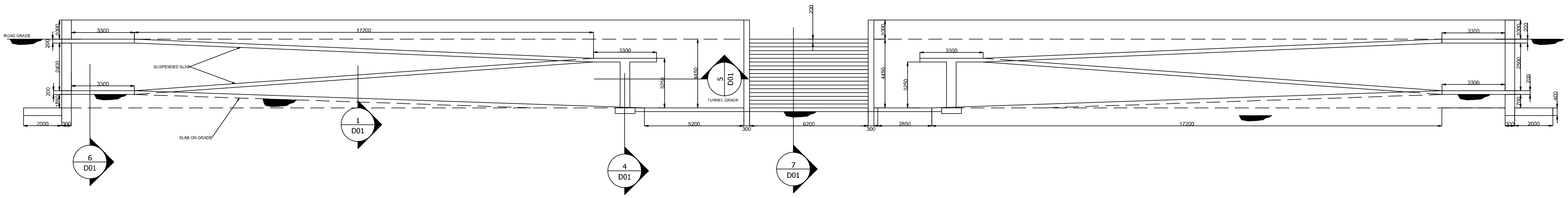
CROSS SECTION - EXISTING ROADWAY

Project
CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

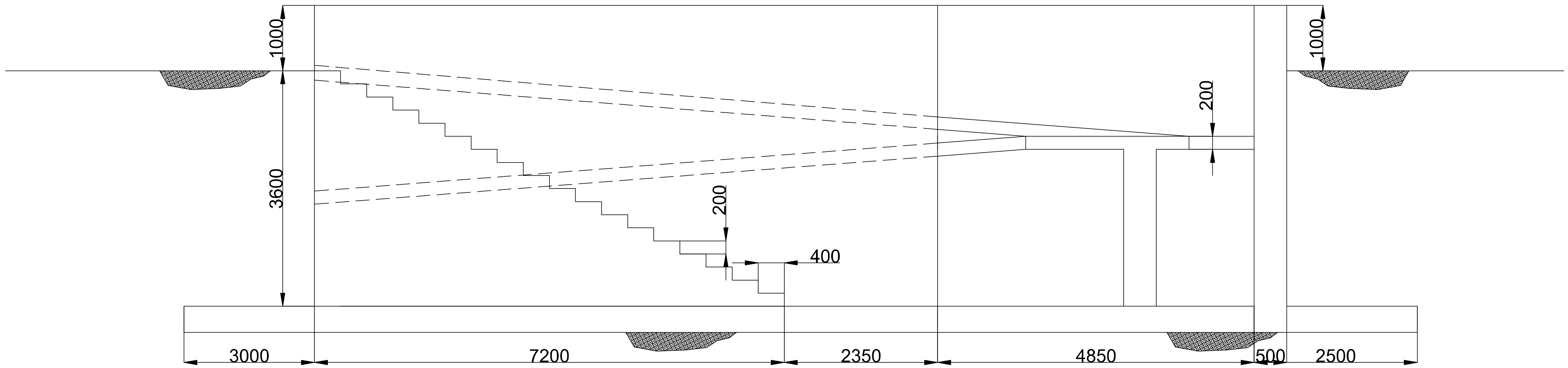
Date
APR 2, 2018

Scale
AS NOTED

Sheet
C04



SOUTH TUNNEL RAMP AND STAIR
SCALE: 1:110
A
C05



NORTH TUNNEL RAMP AND STAIR
SCALE: 1:30
B
C05

General Notes

-TYPICAL STREET LIGHTING:
71 WATT ATBS LED HEAD FIXTURE

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title:

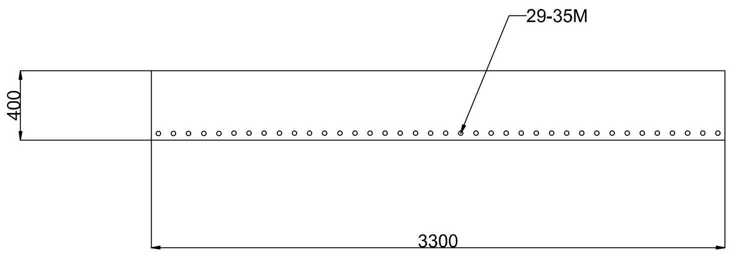
SOUTH AND NORTH
RAMP/STAIRS

Project
CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

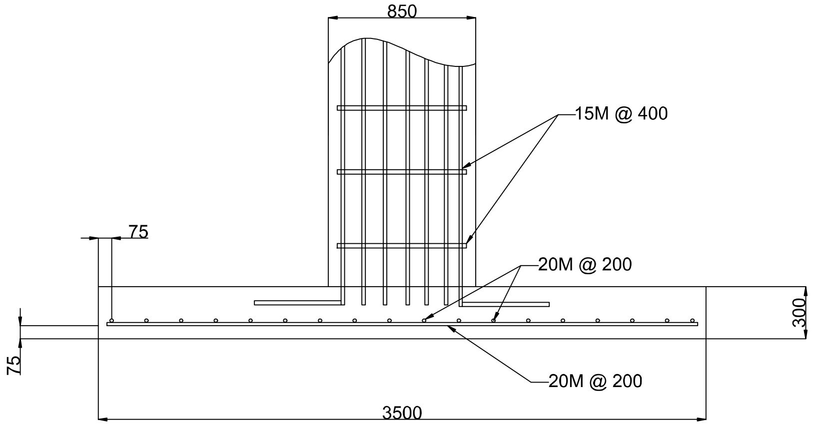
Date
APR 2, 2018

Scale
AS NOTED

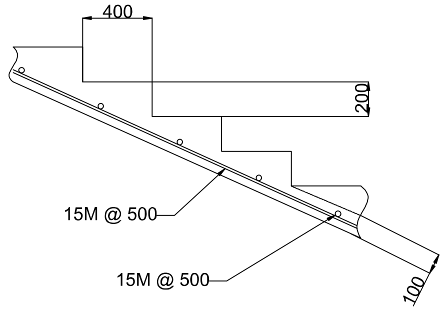
Sheet
C05



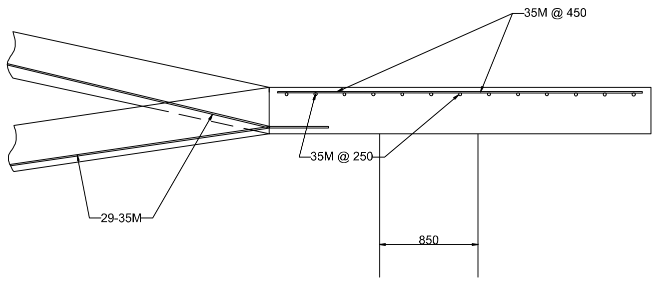
1 TYPICAL RAMP DETAIL
Scale: 1:20



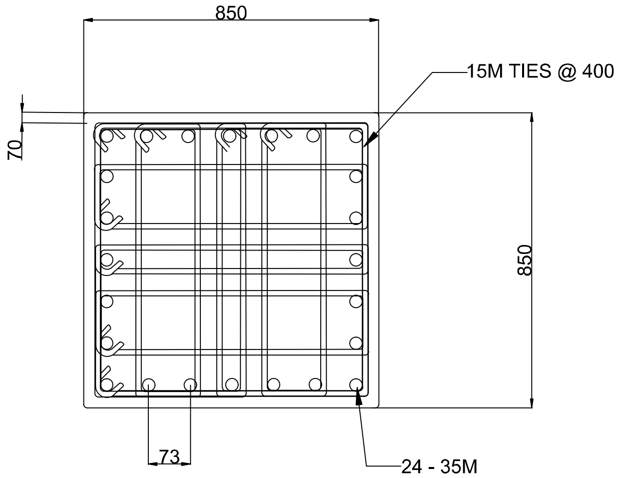
4 TYPICAL COLUMN FOOTING DETAIL
Scale: 1:20



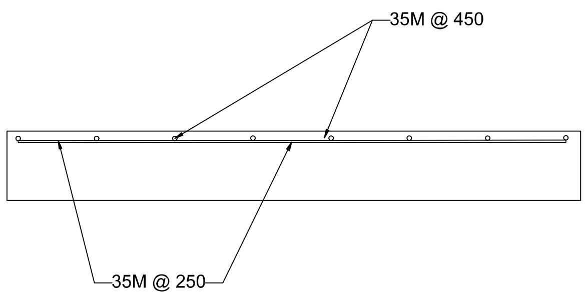
7 TYPICAL ON-GRADE STAIR DETAIL
Scale: 1:20



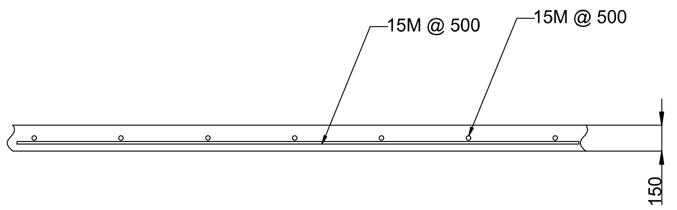
2 TYPICAL LANDING DETAIL
Scale: 1:30



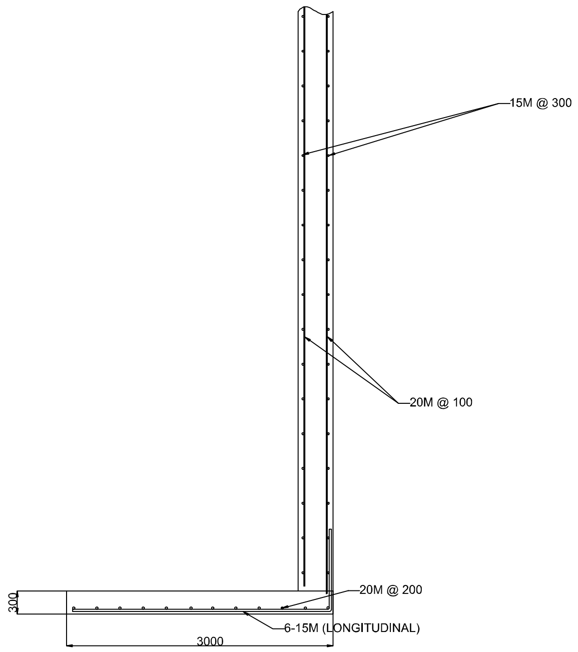
5 TYPICAL COLUMN FOOTING DETAIL
Scale: 1:10



3 TYPICAL LANDING DETAIL
Scale: 1:20



6 TYPICAL ON-GRADE SLAB DETAIL
Scale: 1:20



8 TYPICAL RETAINING WALL DETAIL
Scale: 1:30

General Notes

-TYPICAL STREET LIGHTING:
71 WATT ATBS LED HEAD FIXTURE

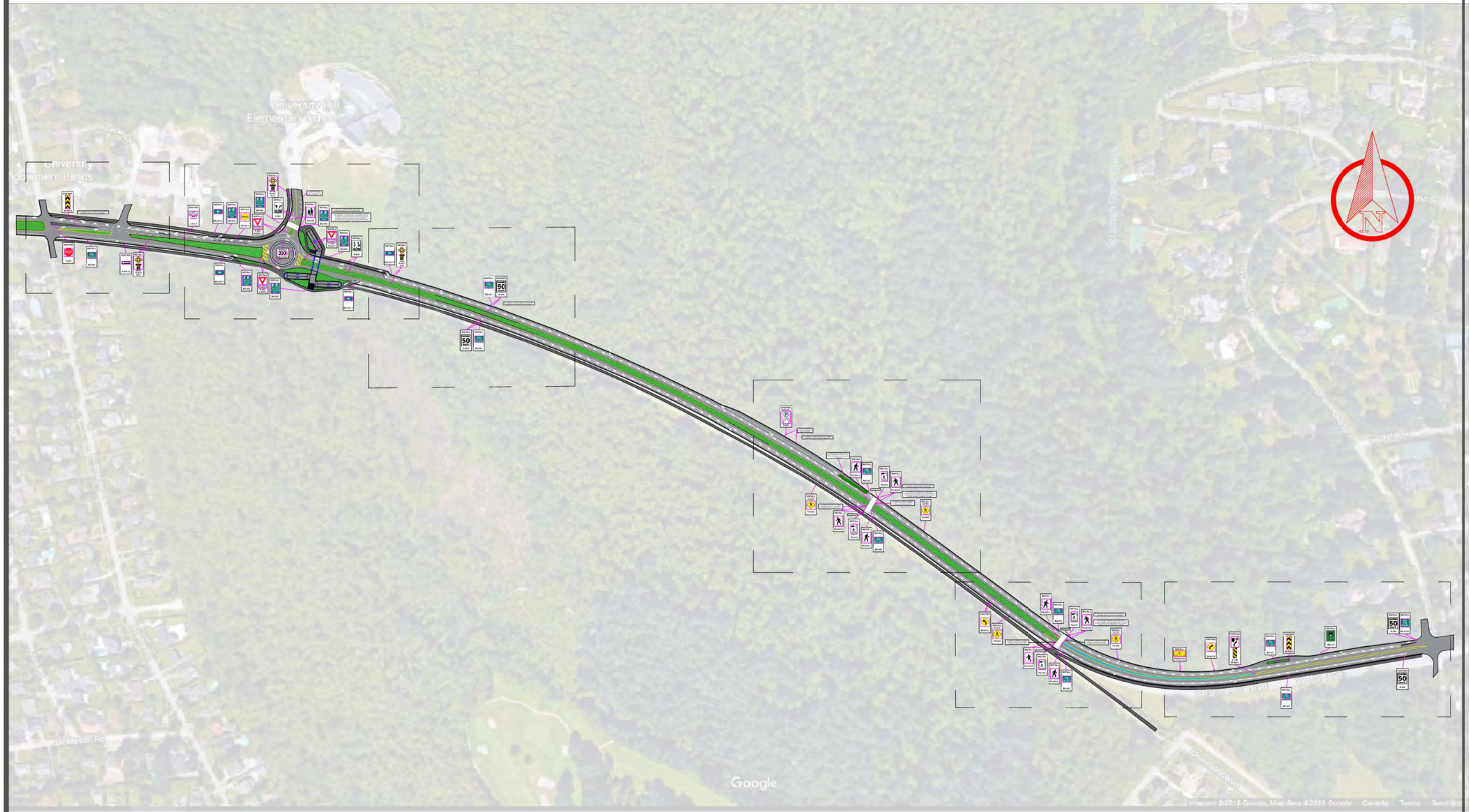
1	DATE ISSUED	APR 2, 2018

Firm Name and Address
DTS ENGINEERING
7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name
CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Title:
LIST OF DETAILED ASSEMBLY

Project: CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD
Date: APR 2, 2018
Scale: AS NOTED
Sheet: D01



General Notes

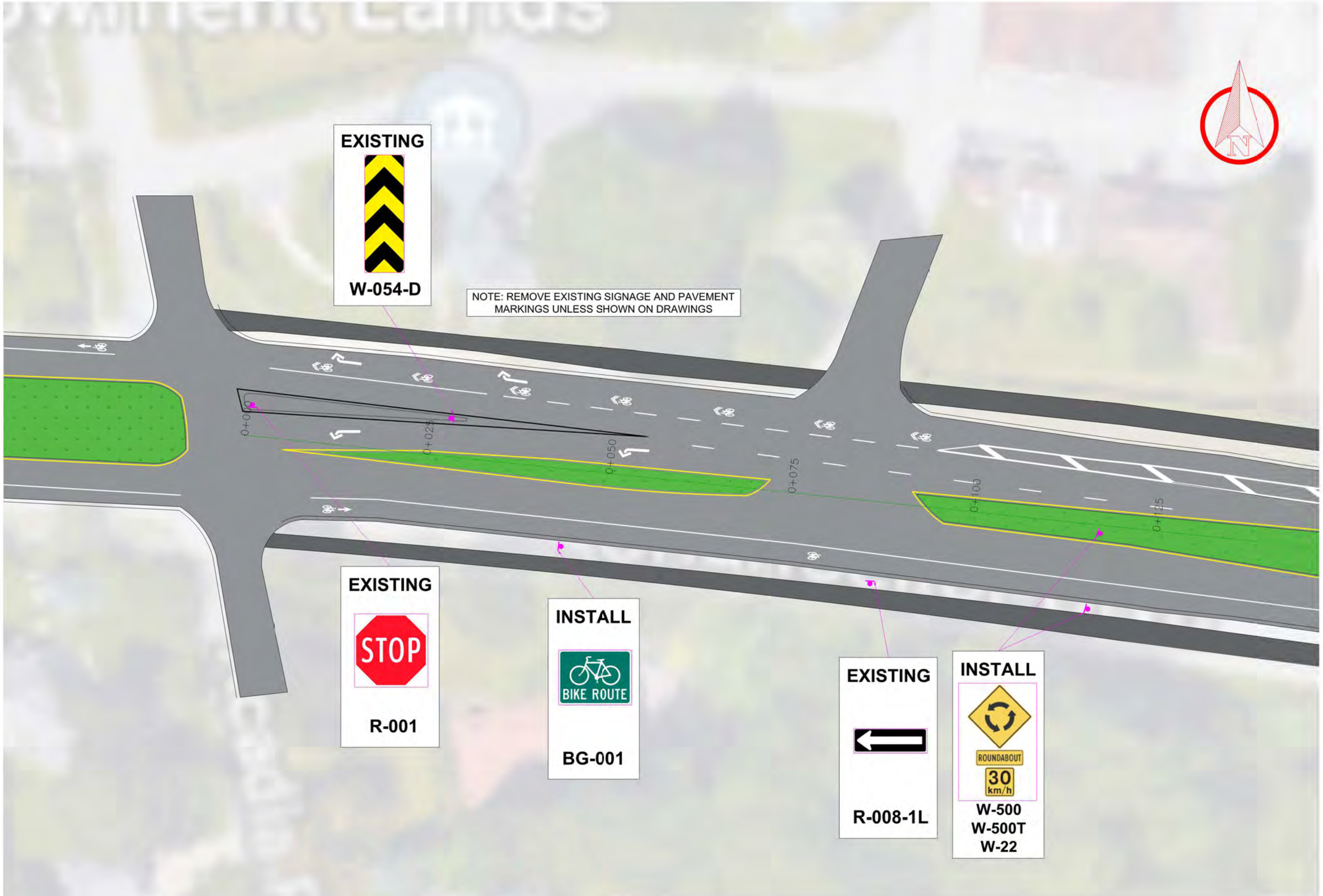
1	DATE ISSUED	APR 2, 2018

Firm Name and Address
DTS ENGINEERING
7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name
CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Title:
SIGNAGE OVERVIEW PLAN

Project: CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD	Sheet
Date: APR 2, 2018	E01
Scale: 1:200	



General Notes

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Title

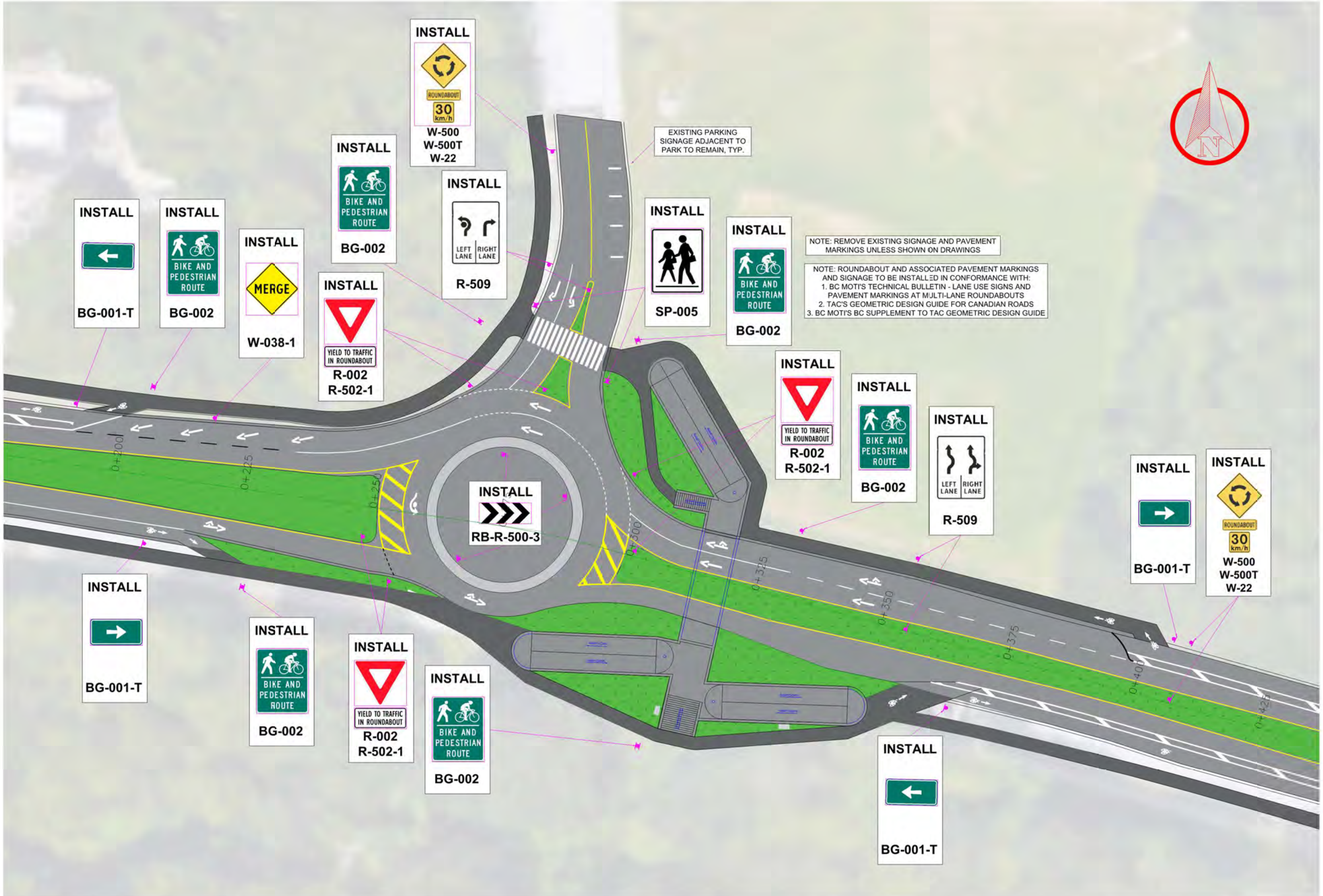
STATION 0+100 TO 0+125

Project: CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Date: APR 2, 2018

Scale: NTS

Sheet: E02



General Notes

1	DATE ISSUED	APR. 2, 2018

Firm Name and Address:
DTS ENGINEERING
7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project name:
CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Title:
STATION 0+200 TO 0+425

Project: CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD
Date: APR. 2, 2018
Scale: NTS
Sheet: E03

General Notes

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title

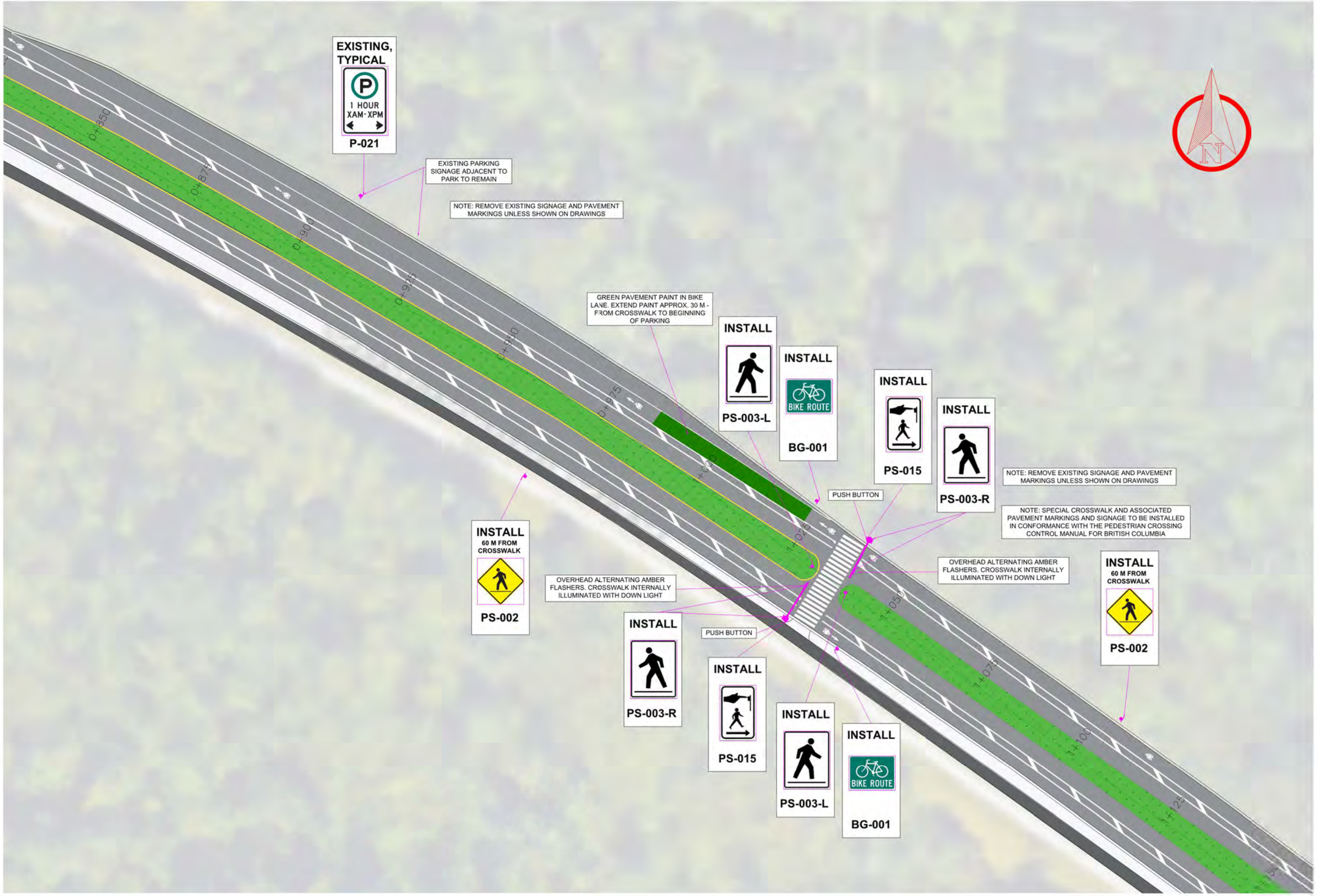
STATION 0+400 TO 0+600

Project
CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Date
APR 2, 2018

Scale
NTS

Sheet
E04



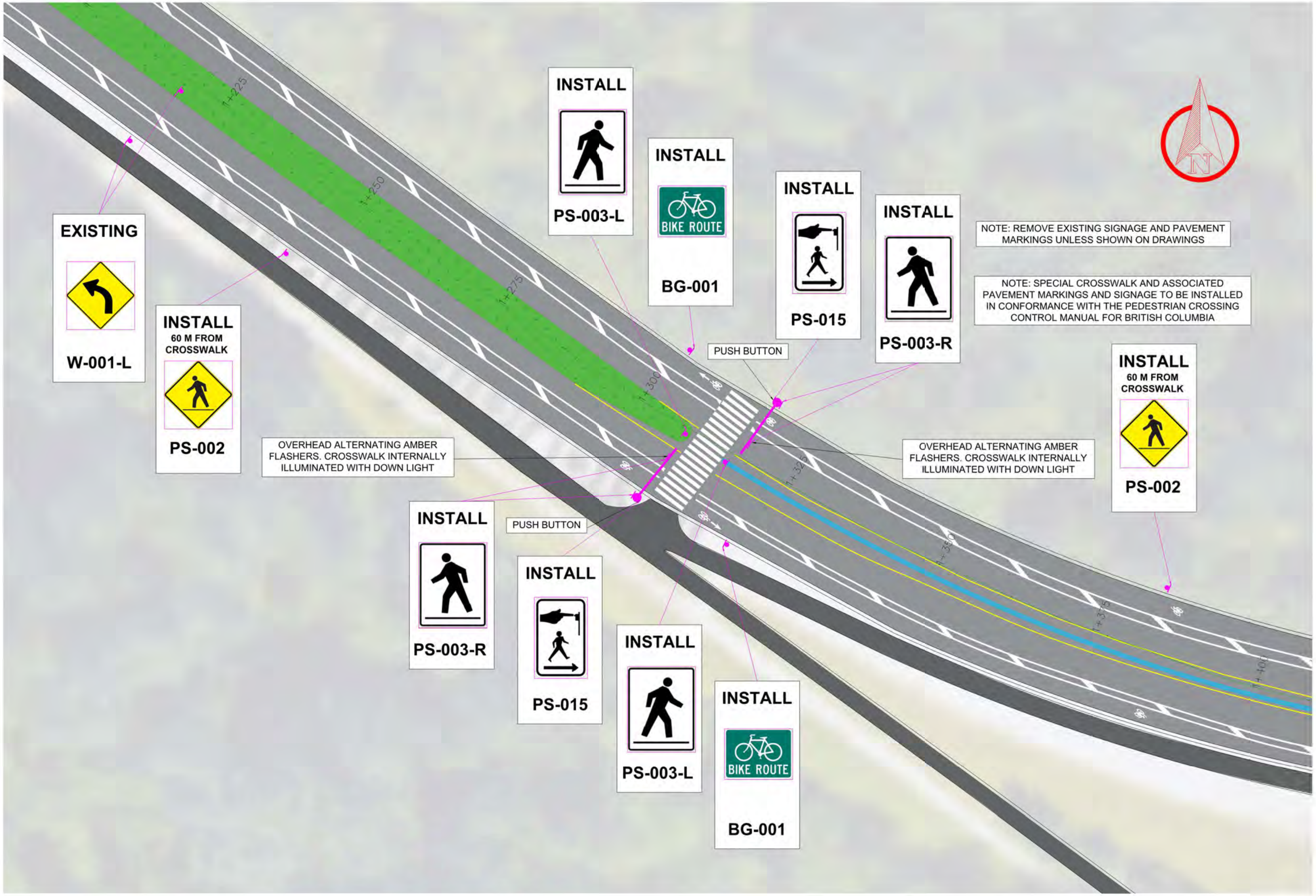
General Notes

1	DATE ISSUED	APR 2, 2018

Firm Name and Address
DTS ENGINEERING
7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name
CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD
Title
STATION 0+850 T0 1+150

Project: CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD
Date: APR 2, 2018
Scale: NTS
Sheet: E05



General Notes

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

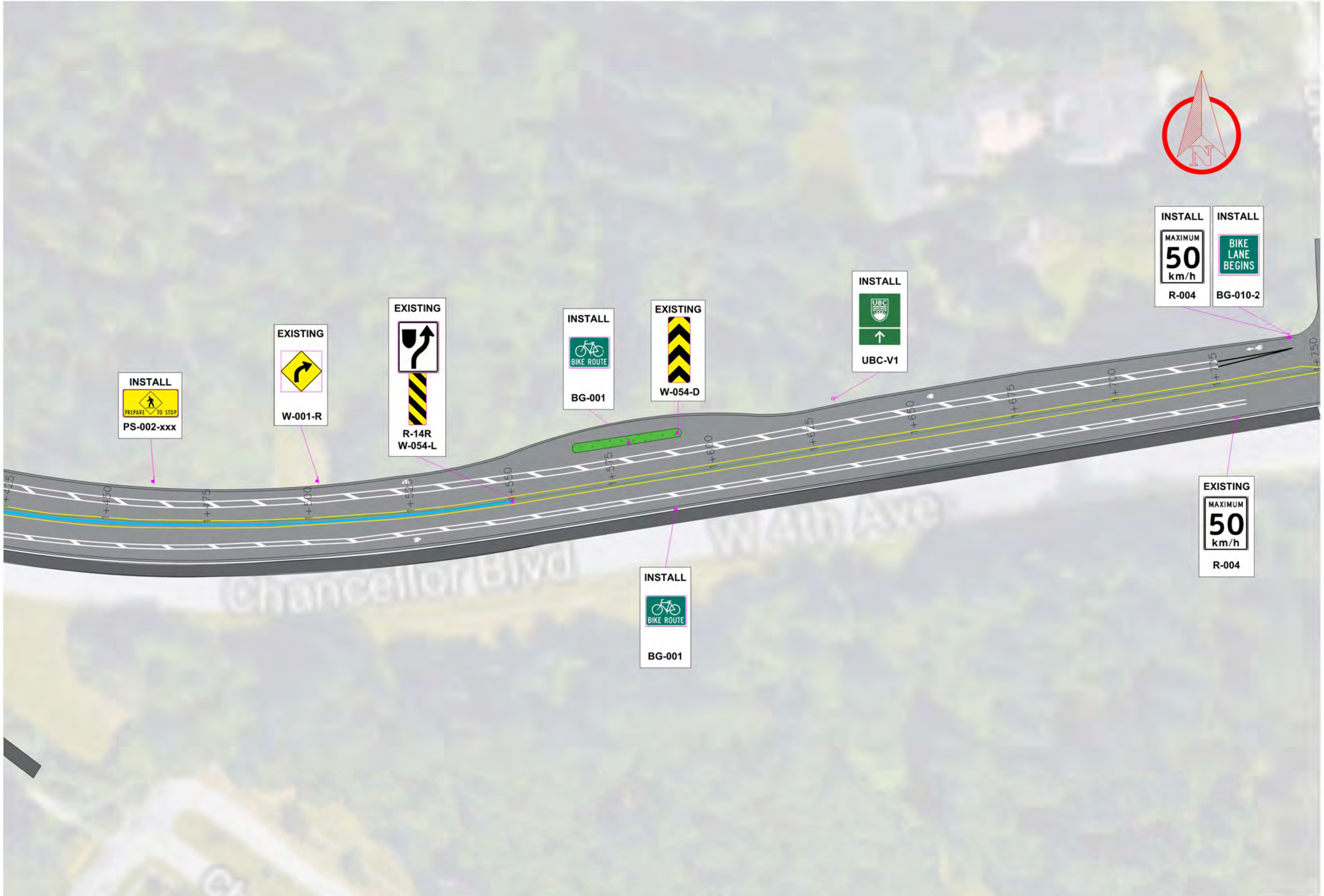
Project Name

CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Title

STATION 1+225 TO 1+400

Project: CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD	Sheet
Date: APR 2, 2018	E06
Scale: NTS	



General Notes

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name:

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title:

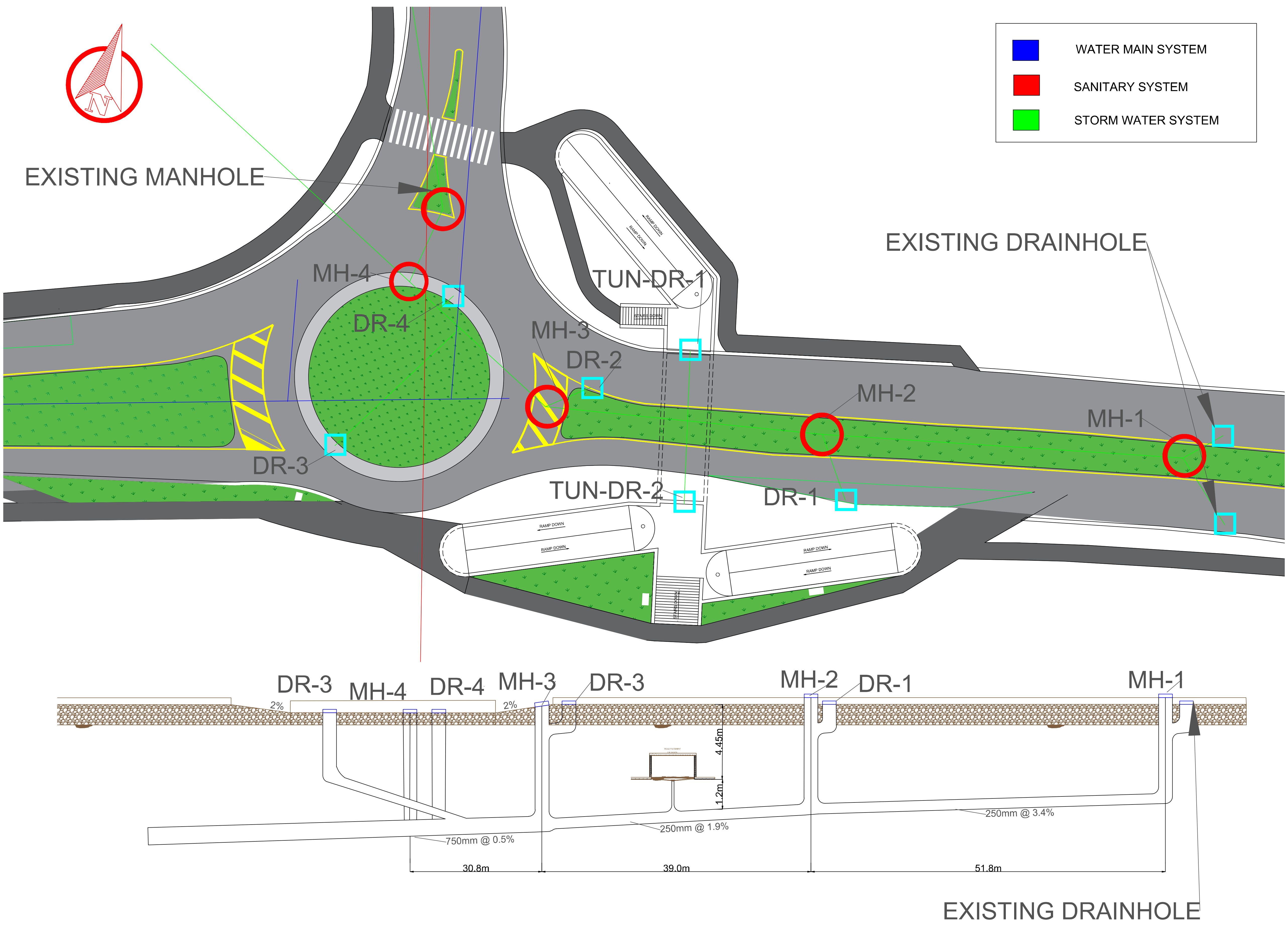
STATION 1+450 TO 1+750

Project: CORRIDOR REDESIGN OF CHANCELLOR BOULEVARD

Date: APR 2, 2018

Scale: NTS

Sheet: E07



General Notes

–TYPICAL STREET LIGHTING:
71 WATT ATBS LED HEAD FIXTURE

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title:

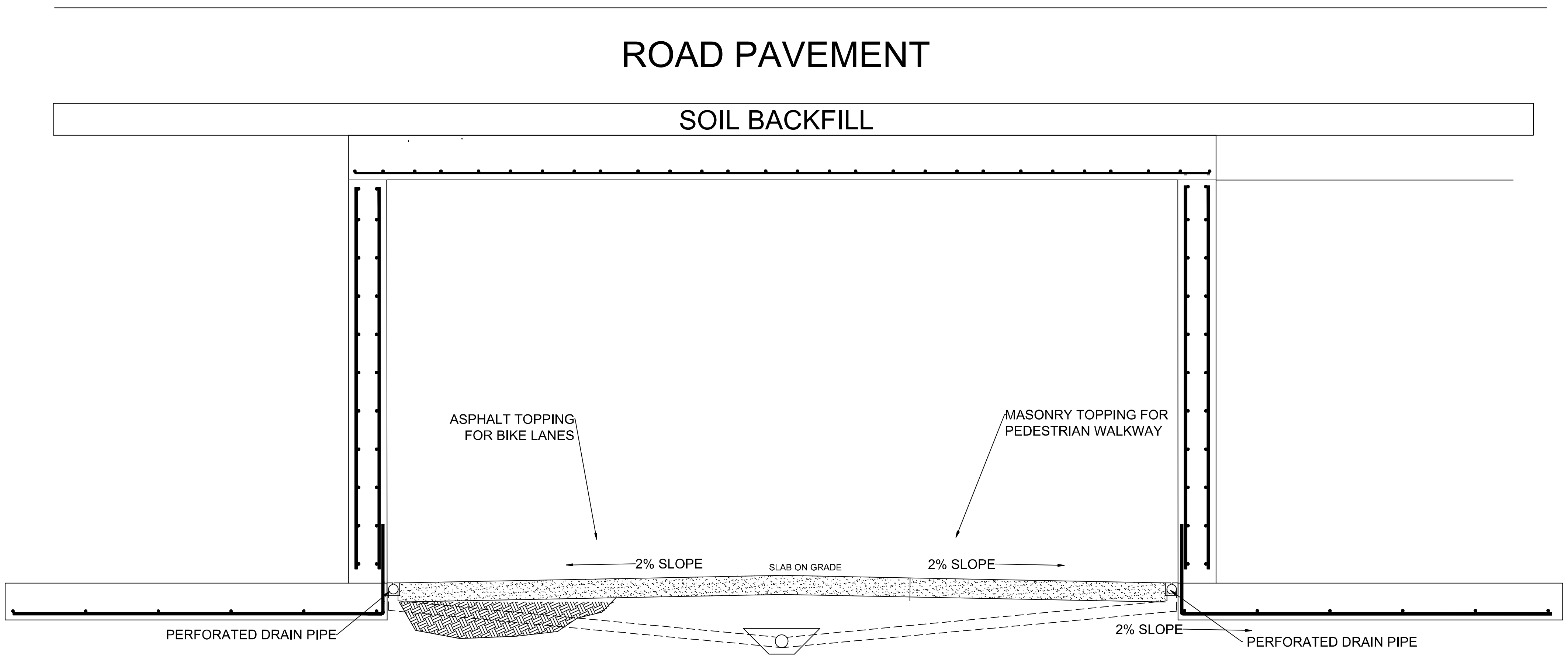
ROUNDABOUT UTILITY PLAN

Project
CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Date
APR 2, 2018

Scale

Sheet
F01



General Notes

—TYPICAL STREET LIGHTING:
71 WATT ATBS LED HEAD FIXTURE

1	DATE ISSUED	APR 2, 2018

Firm Name and Address

DTS ENGINEERING

7284 STRIDE AVENUE
BURNABY BC V3N 1V2

Project Name

CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Title:

TUNNEL UTILITY PLAN

Project
CORRIDOR REDESIGN OF
CHANCELLOR BOULEVARD

Date
APR 2, 2018

Scale
1:20

Sheet
F02