Corridor Redesign of Chancellor Boulevard - Team 17
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University of British Columbia
CIVL 445
Themes: Transportation, Community, Land
April 9, 2018

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Detailed Design Report
Corridor Redesign of Chancellor Boulevard

Submitted by: Team 17

Client:
UBC THE UNIVERSITY OF BRITISH COLUMBIA
SEEDS Sustainability Program

Consultant:
DTS Engineering

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Aldin Agustin
Zoe Athans
Kelvin Chen
Matthew Cheung
Anson Lau
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
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.
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<th>Contribution</th>
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</thead>
<tbody>
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<td>Aldin Agustin</td>
<td>- Schedule and construction phasing</td>
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<td>Kelvin Chen</td>
<td>- Cost estimate/Maintenance plan</td>
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<td>- Drawing package</td>
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<tr>
<td>Matthew Cheung</td>
<td>- Cover letter, executive summary, compilation and formatting</td>
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<td>- Introduction and project overview</td>
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<td></td>
<td>- Lighting</td>
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<tr>
<td>Anson Lau</td>
<td>- Stormwater drainage and analysis</td>
</tr>
<tr>
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<td>- Lighting</td>
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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](image)

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

<table>
<thead>
<tr>
<th>Stakeholder Group</th>
<th>Relationship to the Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>UBC Campus and Community Planning</td>
<td>• Will provide funding and approval for the project</td>
</tr>
</tbody>
</table>
| 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 Spirit Park. The park boarders either side of Chancellor Boulevard |
| Pacific Spirit Park Society                                 | • Acts as public stewards and a community portal for various stakeholders in Pacific Spirit 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](image)

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 motorists.

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 Spirit 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 Spirit Park.

6.6 Pedestrian Pathway

![Figure 4. Pedestrian Pathway](image)

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 Spirit Park Parking

![Figure 5. Parking](image)

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

6.8 Bus Stops

![Figure 6. Bus Stops](image)
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 6.2.14: Urban Location – Wide Sidewalk

This configuration represents a common bus stop layout for a city centre, where the sidewalks extend from the curb to the property line or building facade. On these wider sidewalks, there is room for street furniture with pedestrian space in front and behind. The tactile surface at the stop must extend from the curb to the building face.

Figure 8. Configuration of Westbound Bus Stop

Figure 6.2.17: Suburban Location – Bus Bay with Amenities Behind Sidewalk

This configuration represents a common suburban bus stop layout with a bus bay. The sidewalk is placed against the curb at the bus bay and there is sufficient right-of-way to position street furniture behind the sidewalk.

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.

![Image](image.png)

**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

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

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).
Table 3: Design Loads and Considerations

<table>
<thead>
<tr>
<th>Component</th>
<th>Design Load and Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunnel Structure</td>
<td></td>
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</tbody>
</table>
| 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 (e.g., differential settlement)                        |
| Stair-On-Grade                   | • Shrinkage and temperature loads  
                               | • Flexure loads from external factors (e.g., 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

<table>
<thead>
<tr>
<th>Component</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tunnel</td>
<td></td>
</tr>
<tr>
<td>Vertical Clearance</td>
<td>3.1m</td>
</tr>
<tr>
<td>Horizontal Clearance</td>
<td>6.2m</td>
</tr>
<tr>
<td>Span</td>
<td>21m</td>
</tr>
<tr>
<td>Bike Lane</td>
<td>2m per direction</td>
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<tr>
<td>Pedestrian Lane</td>
<td>2m</td>
</tr>
<tr>
<td>Ramp</td>
<td></td>
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<tr>
<td>Slope</td>
<td>7%</td>
</tr>
<tr>
<td>Ramp Width</td>
<td>3.3m</td>
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<tr>
<td>Stair</td>
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<td>Rise</td>
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<td>Run</td>
</tr>
</tbody>
</table>

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
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 \( \text{m}^3/\text{s} \);
- \( R \) is the runoff coefficient, which is unitless;
- \( A \) is the tributary drainage area, in hectares;
- \( I \) is the rainfall intensity, in \( \text{mm/hr} \); 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:

\[ R = \frac{A_1 R_1 + A_2 R_2 + \cdots + A_n R_n}{A_1 + A_2 + \cdots + A_n} \]

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

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

### 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.

\[ T_t = \frac{V_{Manning}}{L_{pipe}} = \frac{2}{nL_{pipe}} \frac{R^{3.5}S^{0.5}}{nL_{pipe}} = \frac{(D^{0.67})}{0.013L_{pipe}} \]

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 \( Q_s/Q_{capacity} \) 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 S.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 $Q_{10}/Q_{\text{capacity}}$ and $Q_{25}/Q_{\text{capacity}}$ 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 ($\S$ 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.

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:

\[
\text{Illuminance} = \frac{\text{lumen per pole}}{\text{road width} \times \text{pole spacing}} \times \text{utilization factor} = \frac{6300 \text{ lumens}}{7.5m \times 30m} \times 0.85 = 23.8 \text{ lux}
\]

\[
\text{Light Spread} = \tan\left(\frac{\text{beam angle}}{2}\right) \times \text{Height} = \tan\left(\frac{120°}{2}\right) \times 9.12m = 31.7m \text{ diameter}
\]

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](image)

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](image-url)
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.

![Phase 3 Diagram](image)

**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.

<table>
<thead>
<tr>
<th>Item</th>
<th>Base Cost</th>
<th>Contingency (20%)</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roundabout</td>
<td>602,070</td>
<td>120,414</td>
<td>722,484</td>
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<tr>
<td>Roadway</td>
<td>1,140,164</td>
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<td>1,368,196</td>
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<td>Underpass</td>
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<td>264,484</td>
<td>1,586,907</td>
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<td>Active Transportation</td>
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<td>Electrical</td>
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<td>Design Cost</td>
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<tr>
<td>Maintenance</td>
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<tr>
<td>Inflation Cost (2013 to 2018)</td>
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<tr>
<td>Total Project Cost</td>
<td></td>
<td></td>
<td>6,584,604</td>
</tr>
</tbody>
</table>
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:

<table>
<thead>
<tr>
<th>Project Management</th>
<th>• Assume 3.5% of total construction cost</th>
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</thead>
<tbody>
<tr>
<td>Planning</td>
<td>• Assume 1% of construction base estimate</td>
</tr>
<tr>
<td>Design</td>
<td>• Preliminary Design - 2% of construction base estimate</td>
</tr>
<tr>
<td></td>
<td>• Detailed Design Services – 8% of construction base estimate</td>
</tr>
<tr>
<td>Property Acquisition</td>
<td>• Pacific Spirit Regional Park is owned by Metro Vancouver and Chancellor Blvd is owned by MoTi and UBC.</td>
</tr>
<tr>
<td></td>
<td>• 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</td>
</tr>
<tr>
<td></td>
<td>• Assume government entities agree on shared ownership of tunnels or roundabout and therefore no property acquisition is required</td>
</tr>
<tr>
<td></td>
<td>• Allocate cost for tree cutting</td>
</tr>
<tr>
<td>Environmental</td>
<td>• Assume no environmental compensation cost</td>
</tr>
<tr>
<td>Construction</td>
<td>• Mill and Fill existing roadway except for roundabout area</td>
</tr>
<tr>
<td>Roadway</td>
<td>• Grading construction cost include construction, materials supplied by MOT, miscellaneous and utility relocation, but does not include engineering design or property acquisition</td>
</tr>
<tr>
<td></td>
<td>• Paint markings for roadways as a separate cost</td>
</tr>
<tr>
<td></td>
<td>• Signage as a separate cost</td>
</tr>
<tr>
<td></td>
<td>• No detectors or intersection lighting</td>
</tr>
<tr>
<td></td>
<td>• Assume Roundabout area is all new roadway construction</td>
</tr>
<tr>
<td>Utilities</td>
<td>• Assume 50m spacing between lighting on both sides</td>
</tr>
<tr>
<td></td>
<td>• Only require super elevation to provide drainage on main road</td>
</tr>
<tr>
<td></td>
<td>• Roundabout and tunnel to install new drainage to existing storm system</td>
</tr>
<tr>
<td></td>
<td>• Allocate $30,000 for ITS system</td>
</tr>
<tr>
<td>Active Transportation</td>
<td>• Rehabilitate sidewalk by assuming using a hot in place asphalt with add mix and rejuvenating agent @ 50mm depth</td>
</tr>
<tr>
<td></td>
<td>• Includes centre line marking, geotechnical evaluations, construction cost, labour, equipment and materials</td>
</tr>
<tr>
<td></td>
<td>• Bicycle lanes only require paint marking</td>
</tr>
<tr>
<td>Underpass</td>
<td>• Split cost into subsections:</td>
</tr>
<tr>
<td></td>
<td>o Excavation</td>
</tr>
<tr>
<td></td>
<td>o Tunnel concrete</td>
</tr>
<tr>
<td>Landscaping</td>
<td>1248667859mm² of landscaping. Quantity determined from AutoCAD</td>
</tr>
<tr>
<td>-------------</td>
<td>---------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| 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
From A to B: Sight Distance

Geometric Design Guide Exh. 3-1 Stopping

<table>
<thead>
<tr>
<th>Design Speed</th>
<th>Design Stopping Sight</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 km/hr</td>
<td>50 m</td>
</tr>
<tr>
<td>50 km/hr</td>
<td>65 m</td>
</tr>
<tr>
<td>60 km/hr</td>
<td>85 m</td>
</tr>
<tr>
<td>70 km/hr</td>
<td>105 m</td>
</tr>
</tbody>
</table>

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

Crosswalk (Far East Side)

Horizontal Curve:

\[ M = R \left[ 1 - \cos \frac{2\pi S}{2R} \right] \]

\[ M \approx 10 m \]
\[ R \approx 260 m \]

\[ 10 = 260 \left[ 1 - \cos \frac{2 \pi \times 145}{2 \times 260} \right] \]

\[ s = 145 m \rightarrow v = 80 \text{ km/hr} \] Design Speed √ 0 km

Stopping Sight = 105 m < 148 m √

Crosswalk

Sight distance > 105 m √

Intersection

Sight distance > 105 m √
Design vehicle, for reference, truck should be able to turn with the truck apron.


- Assumed steering angle is 17.9°
- Assumed tractor/trailer angle is 56°
- CTR = Centerline turning radius at front axle
Appendix B – Pedestrian Underpass Structure
Appendix C – Stormwater Drainage and Management

Grate Spacing Calculation

DEPRESSED BC BICYCLE SAFE DRAIN SPACING FOR PROPOSED ROUNDABOUT INTERSECTION

**Inputs**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SW</td>
<td>paved shoulder width</td>
<td>0 m</td>
</tr>
<tr>
<td>s_v</td>
<td>longitudinal grade</td>
<td>0.022</td>
</tr>
<tr>
<td>s_x</td>
<td>crossfall</td>
<td>0.02</td>
</tr>
<tr>
<td>n</td>
<td>Manning's roughness coefficient</td>
<td>0.013</td>
</tr>
<tr>
<td>i</td>
<td>rainfall intensity for t_c = 5 min, 5 year return period</td>
<td>53.85 mm/hr</td>
</tr>
<tr>
<td>width</td>
<td>effective width of contributing area</td>
<td>6.6 m</td>
</tr>
<tr>
<td>C_w</td>
<td>width weighted runoff coefficient</td>
<td>0.95</td>
</tr>
<tr>
<td>w</td>
<td>inlet catchment width</td>
<td>0.625 m</td>
</tr>
</tbody>
</table>

**Calculate gutter flow and catchbasin spacing**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PW</td>
<td>design ponding width</td>
<td>1.2 m</td>
</tr>
<tr>
<td>y_0</td>
<td>maximum depth of gutter flow (for pavement)</td>
<td>0.024 m</td>
</tr>
<tr>
<td>R_s</td>
<td>crossfall-longitudinal grade ratio</td>
<td>0.93</td>
</tr>
<tr>
<td>w_eff</td>
<td>effective inlet catchment width</td>
<td>0.69 m</td>
</tr>
<tr>
<td>v</td>
<td>gutter flow velocity</td>
<td>0.928 m/s</td>
</tr>
<tr>
<td>Q_0</td>
<td>gutter flow</td>
<td>0.010 m3/s</td>
</tr>
<tr>
<td>y_over</td>
<td>maximum depth of flow outside catchment width</td>
<td>0.010 m</td>
</tr>
<tr>
<td>Q_over</td>
<td>overflow</td>
<td>0.0010 m3/s</td>
</tr>
<tr>
<td>Q_int</td>
<td>intercepted flow</td>
<td>0.0090 m3/s</td>
</tr>
<tr>
<td>Eff</td>
<td>inlet efficiency</td>
<td>89.7 %</td>
</tr>
</tbody>
</table>

**Outputs**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cb_one</td>
<td>initial inlet spacing</td>
<td>106.8 m</td>
</tr>
<tr>
<td>Cb_two</td>
<td>consecutive inlet spacing</td>
<td>95.8 m</td>
</tr>
</tbody>
</table>
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:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Value (units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage Area</td>
<td>A</td>
<td>0.4434 (ha)</td>
</tr>
<tr>
<td>Length of Overland Flow</td>
<td>L_{OL}</td>
<td>235 (m)</td>
</tr>
<tr>
<td>Slope of Overland Flow</td>
<td>S_{OL}</td>
<td>0.015 (m/m)</td>
</tr>
<tr>
<td>100-year Rainfall Intensity for 5 minutes</td>
<td>i_{100Y}</td>
<td>80.02 (mm/hr)</td>
</tr>
</tbody>
</table>

**Pipe Properties**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope</td>
<td>S</td>
<td>0.034 (m/m)</td>
</tr>
<tr>
<td>Diameter</td>
<td>d</td>
<td>250 (mm)</td>
</tr>
<tr>
<td>Manning’s n</td>
<td>n</td>
<td>0.013</td>
</tr>
<tr>
<td>Length</td>
<td>L</td>
<td>74.4 (m)</td>
</tr>
</tbody>
</table>

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.

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

\[ \therefore R_{10-25Y} = 0.65 \]

**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:
\[ T_o = \frac{6.92L_{DL}^{0.6}n_{DL}^{0.6}}{i(t_c = 10 \text{ min})_{10Y}^{0.4}S_{DL}^{0.3}} \]

\[ T_o = \frac{6.92(235m)^{0.6}(0.237)^{0.6}}{(18.826\left(\frac{5}{60}\right)^{-0.47} \text{mm/hr})^{0.4}(0.015)^{0.3}} \]

\[ \therefore T_o = 52.84 \text{ min} \]

**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.

\[ T_t = \frac{v_{cap}}{L} \]

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

\[ T_t = \frac{\left(\frac{250\text{mm}}{4}\right)^{0.2}(0.034)^{0.5}}{0.013} \]

\[ \frac{74.4m}{T_t} = 0.56 \text{ min} \]

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

\[ T_c = T_o + T_t \]

\[ T_c = 52.84 \text{min} + 0.56 \text{min} \]

\[ \therefore T_c = 53.19 \text{min} \]

**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:

\[ i_{10Y} = 18.826(T_c^{-0.47}) \]

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

\[ \therefore i_{10Y} = 19.92 \text{ mm/hr} \]
The 10-year storm flow is calculated using the rational method:

\[
Q_{10} = \frac{100CiA}{36}
\]

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

\[
\therefore Q_{10} = 15.95 \frac{L}{s}
\]

100-year Intensity and Flow
Likewise, for the 100-year storm intensity:

\[
i_{100Y} = 25.767 \left( T_c^{-0.456} \right)
\]

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

\[
\therefore i_{100Y} = 27.22 \frac{mm}{hr}
\]

And for the 100-year storm flow:

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

\[
\therefore Q_{100} = 23.47 \frac{L}{s}
\]

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

Flow Capacity

\[
Q_{cap} = \frac{A_{pipe} R^2 S^{0.5}}{n}
\]

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

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

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

Velocity Capacity

\[
\nu_{cap} = \frac{R^2 S^{0.5}}{n}
\]
\[ v_{cap} = \frac{\left(\frac{0.250m}{4}\right)^{\frac{2}{3}} (0.039)^{0.5}}{0.013} \]

\[ \therefore v_{cap} = 2.41 \frac{m}{s} \]

**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.

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

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

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

<table>
<thead>
<tr>
<th>Manhole ID</th>
<th>Easting (m)</th>
<th>Northing (m)</th>
<th>Ground Elev (m)</th>
<th>Invert Depth (m)</th>
<th>Invert Elev (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MH-1</td>
<td>482711.52</td>
<td>5457820.00</td>
<td>78.6</td>
<td>6.00</td>
<td>72.60</td>
</tr>
<tr>
<td>MH-2</td>
<td>482722.47</td>
<td>5457832.77</td>
<td>77.1</td>
<td>6.50</td>
<td>70.60</td>
</tr>
<tr>
<td>MH-3</td>
<td>482684.81</td>
<td>5457842.22</td>
<td>76.3</td>
<td>6.75</td>
<td>69.55</td>
</tr>
<tr>
<td>MH-4</td>
<td>482666.47</td>
<td>5457866.48</td>
<td>75.5</td>
<td>6.80</td>
<td>68.70</td>
</tr>
<tr>
<td>MH-5</td>
<td>482659.78</td>
<td>5458030.44</td>
<td>76.0</td>
<td>1.50</td>
<td>74.50</td>
</tr>
<tr>
<td>MH-6</td>
<td>482723.66</td>
<td>5457988.43</td>
<td>76.8</td>
<td>1.50</td>
<td>75.30</td>
</tr>
<tr>
<td>MH-7</td>
<td>482685.71</td>
<td>5457983.62</td>
<td>76.1</td>
<td>2.00</td>
<td>74.10</td>
</tr>
<tr>
<td>MH-8</td>
<td>482673.99</td>
<td>5457874.01</td>
<td>75.5</td>
<td>2.00</td>
<td>73.50</td>
</tr>
</tbody>
</table>

## Rational Method Table

<table>
<thead>
<tr>
<th>Pipe ID</th>
<th>Manhole</th>
<th>Area (ha)</th>
<th>Runoff Coefficient</th>
<th>Total R^A (10-25 year)</th>
<th>Total R^A (100-year)</th>
<th>Tc (min)</th>
<th>Total (min)</th>
<th>i(10) (mm/hr)</th>
<th>i(25) (mm/hr)</th>
<th>i(100) (mm/hr)</th>
<th>Q(10) (l/s)</th>
<th>Q(25) (l/s)</th>
<th>Q(100) (l/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>MH-5</td>
<td>0.3179</td>
<td>0.85 0.90 0.2702 0.2861</td>
<td>6.36 6.36</td>
<td>54.07 60.96 71.71</td>
<td>40.58 45.76 56.99</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-1</td>
<td>MH-6</td>
<td>0.9874</td>
<td>0.85 0.90 0.8393 0.8887</td>
<td>18.05 18.05</td>
<td>33.11 37.65 44.57</td>
<td>77.20 87.77 110.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-2</td>
<td>MH-7</td>
<td>1.1473</td>
<td>0.79 0.84 2.0159 2.1385</td>
<td>46.83 71.24</td>
<td>17.37 19.96 23.83</td>
<td>97.25 111.78 141.54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-3</td>
<td>MH-8</td>
<td>0.0000</td>
<td>- - 2.0159 2.1385</td>
<td>0.08 71.31</td>
<td>17.36 19.95 23.82</td>
<td>97.20 111.73 141.47</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAIN-1</td>
<td>MH-1</td>
<td>0.4434</td>
<td>0.65 0.70 0.2882 0.3104</td>
<td>53.19 53.19</td>
<td>19.92 22.85 27.22</td>
<td>15.95 18.29 23.47</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAIN-2</td>
<td>MH-2</td>
<td>0.4217</td>
<td>0.76 0.81 0.6087 0.6520</td>
<td>44.81 98.00</td>
<td>14.95 17.23 20.60</td>
<td>25.28 29.13 37.31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAIN-3</td>
<td>MH-3</td>
<td>48.6085</td>
<td>0.57 0.52 30.1694 32.7657</td>
<td>133.39 302.64</td>
<td>8.80 10.23 12.32</td>
<td>737.43 857.51 1121.29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Sewer Pipe Design Summary Table

<table>
<thead>
<tr>
<th>Pipe ID</th>
<th>Manhole</th>
<th>Sewer Pipe Design</th>
<th>Ratios</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Old Pipe</td>
<td>New Pipe</td>
</tr>
<tr>
<td>A-1</td>
<td>MH-5</td>
<td>MH-7</td>
<td>0.75% 250 250</td>
</tr>
<tr>
<td>B-1</td>
<td>MH-6</td>
<td>MH-7</td>
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<td>MH-8</td>
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<td>B-3</td>
<td>MH-8</td>
<td>MH-4</td>
<td>1.88% 400 450</td>
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Appendix D – Schedule

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<td>Close off Chancellor Blvd</td>
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<td>Tue 18-05-01</td>
<td>Tue 18-05-01</td>
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Project: Capstone Schedule
Date: Sat 17-10-28

Page 1
# PROJECT COST ESTIMATE
## Chancellor Boulevard Rehabilitation Project
### Cost Element Worksheet

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<thead>
<tr>
<th>COST ELEMENT</th>
<th>QUANTITY</th>
<th>UNIT</th>
<th>COST/UNIT</th>
<th>BASE COST</th>
<th>CONTINGENCY</th>
<th>TOTAL ESTIMATE</th>
<th>COMMENTS</th>
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<td><strong>81.1 - CONSTRUCTION COST</strong></td>
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<td><strong>81.1.1 - ROUNDABOUT CONSTRUCTION</strong></td>
<td>694</td>
<td>square feet</td>
<td>260.1</td>
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<td></td>
<td>5% of base construction cost (maintained by MOTT)</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>$5,746,574</td>
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<td>$839,090</td>
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<td>$6,585,664</td>
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</tbody>
</table>
Appendix F – References

UBC Transportation Plan


UBC Transportation Status Report Fall 2016


University Hill Elementary School Enrollment Data


Stakeholder References

https://planning.ubc.ca/

https://www2.gov.bc.ca/gov/content/governments/organizational-structure/ministries-organizations/ministries/transportation-and-infrastructure

https://facultystaff.students.ubc.ca/

https://bikewalkubc.org/

http://go.vsb.bc.ca/schools/uhe/Pages/default.aspx

https://uhillpac.wordpress.com/

http://www.metrovancouver.org/services/parks/parks-greenways-reserves/pacific-spirit-regional-park

http://pacificspiritparksociety.org/

http://vancouver.ca/streets-transportation/transportation-2040.aspx

http://www.universityendowmentlands.gov.bc.ca/


http://www.musqueam.bc.ca/

maps.gov.bc.ca/ess/sv/cadb/

Tunnel References

http://staff.fit.ac.cy/eng.is/lectures/ACEG220/ACEG220%20Retaining%20walls.pdf


Speed Reduction References

http://www.ctre.iastate.edu/pubs/ltcd/calming.pdf
https://www.drivingtests.co.nz/resources/are-wider-roads-safer-and-how-are-road-widths-decided/

Cost Estimate References

https://www.nap.edu/read/22914/chapter/11#329
http://www.th.gov.bc.ca/popular-topics/faq.html#pavement

Lighting References

http://www.bclaws.ca/civix/document/id/lo089/lo089/30_78#section7.05

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 Specifications
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
INDEX TO SHEETS:

A. GENERAL INFORMATION
   A.1 TITLE SHEET
   A.2 GENERAL NOTES

B. ROADWAY PLAN
   B01: Overview Drawings
   B02: Station 0+000 – Station 0+125
   B03: Station 0+125 – Station 0+250
   B04: Station 0+225 – Station 0+350 (Roundabout)
   B05: Tunnel Ramps Plans
   B06: Station 0+350 – Station 0+525
   B07: Station 0+525 – Station 0+650
   B08: Station 0+650 – Station 0+775
   B09: Station 0+775 – Station 0+900
   B10: Station 0+900 – Station 1+050
   B11: Station 0+050 – Station 1+175
   B12: Station 1+175 – Station 1+325
   B13: Station 1+325 – Station 1+450
   B14: Station 1+450 – Station 1+575
   B15: Station 1+575 – Station 1+700
   B16: Station 1+675 – Station 1+775

C. CROSS SECTION DRAWINGS
   C01: Roundabout Overview
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   C03: Cross-Section: New Roadway
   C04: Cross-Section: Existing Roadway
   C05: Cross Section: South and North Ramps/Stairs

D. TUNNEL DETAILS
   D01: List of Tunnel Details

E. SIGNAGE PLAN
   E01: Signage Overview Plan
   E02: Station 0+100 to Station 0+125
   E03: Station 0+200 to Station 0+425
   E04: Station 0+400 to Station 0+600
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E. UTILITIES
   F01: Roundabout Utility Plan
   F02: Tunnel Utility Plan

DATE: APRIL 2, 2018

PLANS PREPARED BY:

SHEET NO.: A1
GENERAL

1. The owner reserves the right to make changes to the Plan and specifications at any time, so long as said changes result in equitable adjustments to the contract price.

2. The contractor shall be responsible for the supply and placement of materials and for the installation of work in accordance with the plans and specifications.

3. The contractor shall provide all labor and equipment necessary to complete the work in a timely and satisfactory manner.

EARTHWORKS

1. Erosion protection and sediment control measures shall be provided to control sediment and soil erosion.

GEOMETRIC ROAD DESIGN

1. This section contains the geometric design of the road and the required standards for road design.

GEOMETRIC ROAD DESIGN

1. All grades and profiles shall be installed in accordance with the standards of good engineering practice.

2. The contractor shall be responsible for the design and installation of all necessary drainage systems.

3. The contractor shall be responsible for the installation of all necessary paving materials.

4. All drainage systems shall be installed in accordance with the applicable standards.

5. The contractor shall be responsible for the installation of all necessary lighting and signage.

6. The contractor shall be responsible for the installation of all necessary guardrails and barriers.

7. The contractor shall be responsible for the installation of all necessary traffic control devices.

8. The contractor shall be responsible for the installation of all necessary road markings.

9. The contractor shall be responsible for the installation of all necessary road signs.

10. The contractor shall be responsible for the installation of all necessary road safety devices.

11. The contractor shall be responsible for the installation of all necessary road construction equipment.

12. The contractor shall be responsible for the installation of all necessary road construction materials.

13. The contractor shall be responsible for the installation of all necessary road construction tools.

14. The contractor shall be responsible for the installation of all necessary road construction vehicles.

15. The contractor shall be responsible for the installation of all necessary road construction personnel.

16. The contractor shall be responsible for the installation of all necessary road construction facilities.

17. The contractor shall be responsible for the installation of all necessary road construction procedures.

18. The contractor shall be responsible for the installation of all necessary road construction strategies.

19. The contractor shall be responsible for the installation of all necessary road construction policies.

20. The contractor shall be responsible for the installation of all necessary road construction guidelines.

21. The contractor shall be responsible for the installation of all necessary road construction specifications.

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STREET LIGHT FIXTURE (TYP.)
NOTE: REMOVE EXISTING SIGNAGE AND PAVEMENT MARKINGS UNLESS SHOWN ON DRAWINGS.

EXISTING

W-054-D

EXISTING

R-001

INSTALL

BG-001

EXISTING

R-008-1L

INSTALL

W-500
W-500T
W-22