UBC Intersection Redesign Project

Adam Ostereicher, Alexandr Shklyar, David Tran, Emir Hot, Greg Eng, Sarah Thompson

University of British Columbia

CIVL 446

April 08, 2016

CIVL 447: DETAILED DESIGN REPORT

UBC INTERSECTION REDESIGN PROJECT

Prepared For:
UBC Social Ecological Economic Development Studies Sustainability Program

Prepared By:
T3 CONSULTING

CIVL 447 Team 3:
Greg Eng
Emir Hot
Adam Ostereicher
Sarah Thompson
David Tran
Alexandr Shklyar

April 8, 2016

Executive Summary

The chosen design replaces the current 2-way stop intersection at Marine Drive and Chancellor Boulevard with a single-lane roundabout that includes a separated pedestrian viewing platform. The cost of the project is expected to be $1.7M with a 6 month construction period from May - October 2016. The new intersection will create a safe and user friendly environment befitting of a UBC gateway. The design emphasizes alternative forms of travel, Musqueam partnership, and user safety. For increases in traffic volume during construction, such as the May graduation ceremony, careful planning will ensure that congestion is minimized.

The designed single-lane roundabout utilizes a 40 meter diameter circle and is capable of efficiently handling the projected maximum flow for the 15 year design life. All incoming lanes will have their alignment and width adjusted to incorporate the new roundabout and promote more green space. Bicyclists will be able to use the marked bicycle lanes on all roads and pedestrians will be able to access one of the four signalized crosswalks on each corner; making it user-friendly for all forms of travel. The added green space and signage will revamp the area and give it a modern gateway feel.

The viewing platform will overlook the North Shore mountains and the Burrard Inlet, use sustainable construction material, and will incorporate a Musqueam inspired design. A call for local Musqueam artists will be made to promote community building and ensure that the native community has a voice in the project. The 7 meter high platform, which has a 358 m^2 ground area, will be supported by hidden concrete retaining walls. Timber composite beams and cross-laminated timber panels will be exposed on the facade.

The stormwater management plan will ensure that UBC's commitment to environmental sustainability is maintained both during and after construction.

Table of Contents

List of Figures

List of Tables

1.0 INTRODUCTION

The purpose of this report is to present the detailed engineering design and analysis of the UBC intersection redesign project located at Chancellor Boulevard / East Mall / NW Marine Drive to the UBC Social Ecological Economic Development Studies Sustainability Program.

The intersection includes one of the three arterial roads to the UBC campus and is surrounded by residential neighbourhoods, public trails, and academic facilities. It is a two-way stop controlled intersection that is inefficient, unsafe, and outdated. The objective of this project is to make it user-friendly for all types of transportation and create a clear gateway to UBC. Additionally, a viewing platform is included in the design to improve the area for the local community.

The key components of the improved design are a single-lane roundabout, 40 meters in diameter, and an elevated viewing platform with features influence from the heritage of the Musqueam people. The intersection will feature crosswalks on all four sides and will have marked bicycle lanes on all roads leading into the roundabout. The elevated viewing platform has views of the Burrard Inlet and will be constructed with sustainability as a priority. This project is designed for a 15 year design life and has the ability to conservatively handle the projected maximum vehicle flow rate during its life.

This report will cover in order: roundabout design, viewing platform, stormwater management, construction schedule, and further considerations. Special attention is given towards the geometry and logistics of the roundabout and viewing platform. Detailed design calculations, schedule, cost estimate, and design standards can be found in the appendices.

1.1 Team Member Contributions

The contributions from each team member towards this report are shown in the table below.

TEAM CONTRIBUTIONS		
Team Member	**Role**	**Final Design Report**
Greg Eng	Team Lead, Communications, Recorder, Scheduler, Structural Designer, Construction, Urban Planning	Title Page, Editing and Formatting, Executive Summary, Introduction, Platform Structural Analysis and Design
Emir Hot	Team Lead, Communications, Recorder, Scheduler, geotechnical design, urban planning, transportation design	Introduction, Project Considerations, Cost Estimate, Schedule, Conclusion, Editing and Formatting, Risk, Construction Mitigation, Sample Calculations
Adam Ostereicher	Team Lead, Communications, Recorder, Scheduler, Transportation Designer	Executive Summary, Project Considerations, Cost Estimate, Schedule, Conclusion, Editing and Formatting, Roundabout Design, Sample Calculations
Alexandr Shklyar	Team Lead, Communications, Recorder, Green Space Enforcer, Community Impact Analyzer, Editor	Project Considerations, Environmental Survey, UBC Construction and Sustainability practice, Regulatory Consideration, Green Space, Alternative Construction Material Community Planning, User Information and Consideration, Software and Standards, Editing and Formatting
Sarah Thompson	Team Lead, Communications, Recorder, Scheduler, Transportation Designer, Stormwater Management Planning	Introduction, Stormwater Management, Project Considerations, Viewing Platform Design, Conclusion, Editing and Formatting
David Tran	Team Lead, Communications, Structural and Landscape Designer, Recorder, CAD Modelling	Structural Analysis, Design Material and Geometry, Project Considerations, Synchro Analysis, Cover Page, Editing and Formatting

Table 1: Team Contributions

2.0 ROUNDABOUT DESIGN

In order to determine the most viable solution to the roundabout at North West Marine Drive and Chancellor Boulevard, an analysis was performed, given select parameters. The design must allow for ease of use and safety to all users, meet the high standards required for UBC's gateway, and work within UBC's sustainability and environmental goals. Below are the design details and rationale that led to the final proposal.

2.1 Rationale

The final design for the intersection utilizes a four way, single lane roundabout, with continuous bike lanes, and pedestrian activated crosswalks. Traffic at the intersection is inconsistent in both timing and direction. Traffic at peak hours in the east-west direction is over 1200 vehicles, whereas in the north-south direction, traffic is less than 300 vehicles. As a result, it is essential that traffic not be delayed by lights or stops signs but, instead, allow vehicles to flow smoothly and continuously. Entry flow was determined to be relatively low with moderate circulating flow. Based on Figure 1 provided by the BC Supplement to TAC Geometry Design Guide, it was determined that a single lane was sufficient to safely satisfy the flow requirements.

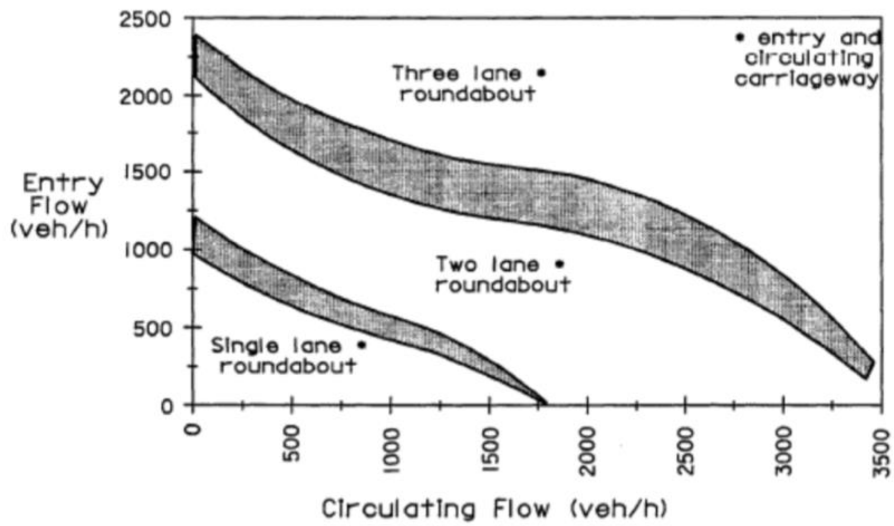


Figure 1: Required Number of Entry and Circulating Lanes

(BC Supplement to TAC Geometric Design Guide, 2007 edition)

Safety was the most important consideration in determining the design. Due to the nature of a roundabout, motor vehicles must reduce speed when approaching the intersection. This drastically improves safety for pedestrians, cyclists, and motorists alike. Pedestrians are granted higher visibility and control with the signalized crosswalk, and cyclists are provided the option of travelling on the road or crossing at the sidewalk to ensure their comfort.

2.2 Geometry

The design is comprised of a 40 meter wide roundabout shifted in the north-east direction compared to the current intersection as seen in Figure 2. A shift is required to reduce the impact on surrounding properties and on the emergency route, as well as limiting vehicle turning radius and entry skew. Due to the initial conditions and drainage requirements, the entire intersection will be sloped at 1.5%.

The raised center island is 24 meters in diameter, with an additional 2 meters on each side acting as a truck apron. Entering lanes are 6 meters wide, and approaching lanes are 6 meters wide. To ensure trucks of a Wb-65 class or smaller have adequate turning space, a truck apron will be included. As per the BC

Supplement to TAC Geometry Design Guide, the truck apron will be 2 meters in width, with a 2% slope down and away from the central island. The interior height of the truck apron is 50 mm.

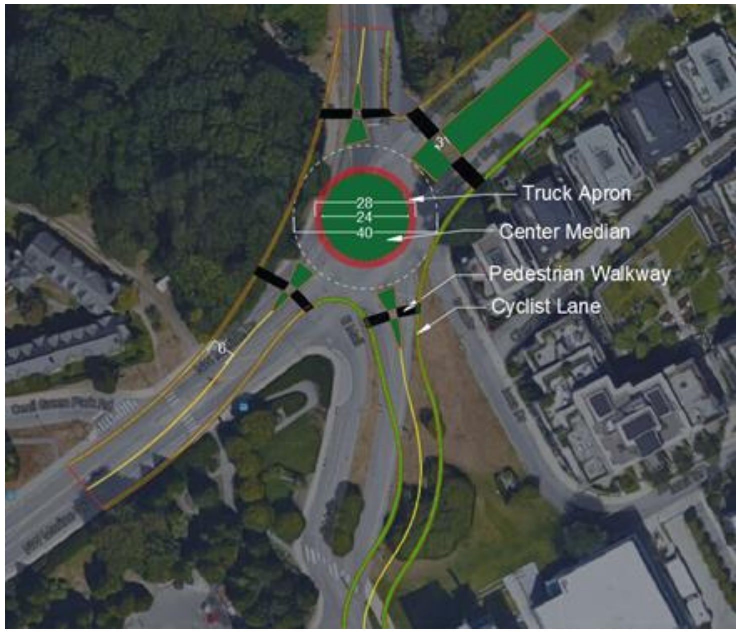


Figure 2: Roundabout Geometry

Cyclists and pedestrians have designated lanes and crossings; the cyclist lanes are 1.5 meters wide and are connected to the road. Pedestrian crosswalks are 3 meters wide and have a 1.5 meter buffer zone in the middle of the splitter islands, for rest when necessary. The splitter islands are 6 meters long closest to the roundabout, offset by 0.5-1 meter and 15 meters in total length. The existing eastern island will be reduced in length to fit the roundabout and split to allow pedestrian crossing.

2.3 Realignment

As per the Kansas Roundabout Guide referenced by the BC Supplement to TAC Geometry Design Guide, there are requirements for the approach of entry lanes to roundabouts. Recommendations are made to avoid skews favoring a left alignment. The proposed relocation of the roundabout results in a skew that necessitates the northern approaching lane, East Mall to be shifted to the east, in order to create a straight entry. If the roundabout had been placed requiring NW Marine Drive to shift, excessive environmental cost and tree removal, would be necessary. In order to comply with UBC's sustainability initiatives, the shift in East Mall would result in the least amount of disruption.

A result of the realignment is the relocation/removal of the trees on East Mall. UBC places high value on every one of it's trees and thus measures have been taken to reduce this impact, as much as possible. Only 6 trees in total will be affected by the realignment, as seen in Figure 3. Preventative measures will be incorporated to avoid total removal of foliage on the East Mall side. The trees highlighted on the left side of Figure 3 are smaller in size and will be relocated onto the viewing platform. The larger cluster of trees highlighted on the right will be removed and replanted in appropriate locations elsewhere on campus.

Figure 3: Trees Affect from Realignment

2.4 Pavement Cross-section

British Columbia utilized standards taken from the Pavement Design Standards (Technical Circulation T-9/95) to determine required depths of pavement and sub layers. Soil types and cross-sections are determined based on the supplied geotechnical analysis taken along Westbrook Mall. This analysis does not directly relate to the current intersection so further testing must be undertaken to ensure certainty. For our for design purposes of pavement depths - the Westbrook Mall information has been used.

The primary sublayer below asphalt in accordance to the geotechnical report, is sand and gravel. Areas approaching the intersection in question showed increasing quantities of fine silts and rock levels above depths of 3 meters. Design standards require 225 mm, of 25 mm of Crush Base Coarse, regardless of soil type, and for our location which is assumed to include fine silts, 300 mm of Select Granular Sub Base is advised.

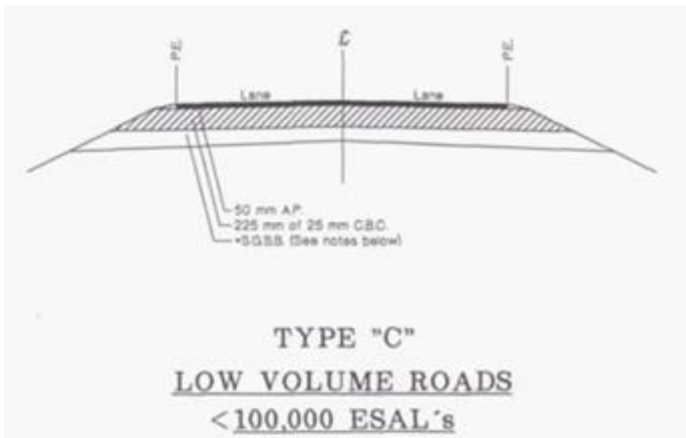


Figure 4: Pavement Design Standards

(Technical Circulation T-9/95)

The required pavement depth is determined based on Equivalent Single Axle Loads (ESAL). Calculations for ESAL can be found in Appendix A. The final ESAL for the intersection project for the 15 year design life is 58,000, which falls below 100,000 for Pavement type C roads. The minimum pavement requirements for type C roads is 50 mm. Including a factor of safety to account for unknown loading factors, 75 mm of pavement will be used.

2.5 Speed

Approaches to the roundabout will maintain a travel speed of 50 km/hr. Speeds in the roundabout will be reduced to 30 km/hr to conform to the Kansas Roundabout Design Guide. Lower speeds are required due to the slope as well as cyclist and pedestrian activity. The formula, $V = 3.4614R^{0.3675}$ provides a "simplified relationship between speed and radius for these two common superelevation rates that incorporates the AASHTO relationship and side friction factors" (Kansas Roundabout Guide, 2nd Edition).

2.6 Pedestrians

Pedestrian crosswalk locations are determined geometrically and independent of loading. The type of crosswalk required is determined based on the Great Britain method, which considers the volume of pedestrians and vehicles, both scaled to the 15 year design life. Calculations to determine the intersection type can be found in Appendix A. Given the future loading of the intersection, it is advised that a signalized crosswalk be utilized to improve safety and effectiveness.

The total crossing distance of the intersection is 43 feet including the splitter island. The Kansas Design Guide recommends using 3 ft/s in calculations of crossing time to cover all walkers; including those who are disabled. The result requires signals to be active for 16 seconds to gives pedestrians ample time to cross.

Detectable warning surfaces are to be installed at all entrances to crosswalks and at entrances to the splitter islands. These raised surfaces are necessary to facilitate those with visual impairments, or those unable to access the activation button. Warning surfaces are required to be a minimum of 2 feet in width and must extend along the entire cross-walk entrance surface. Auditory and visual devices will also be included at all crosswalks to inform pedestrian when crossing is permitted.

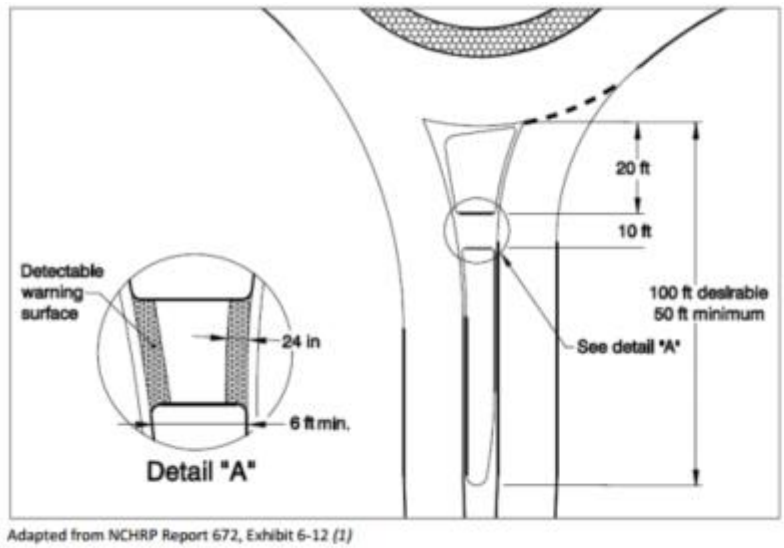


Figure 5: Splitter Island Details

(Kansas Roundabout Guide Second Edition 2014)

2.7 Cyclists

The current cyclist population at the intersection is minimal compared to the other roads around campus. Conventional bike lanes will be used as seen in Figure 6; however, alternative methods for roundabout navigation will be allowed for those uncomfortable travelling with traffic.

A large increase in safety for cyclists is gained as the need to cross traffic for left turns in removed. Cyclists may either travel around to a desired exit, or may make use of the pedestrian crosswalks. To ensure appropriate visibility, bicycle lanes will be painted a highly visual green color to distinguish between other lanes. Parking will not be permitted on the road, which will ensure that bicycles lanes are not blocked.

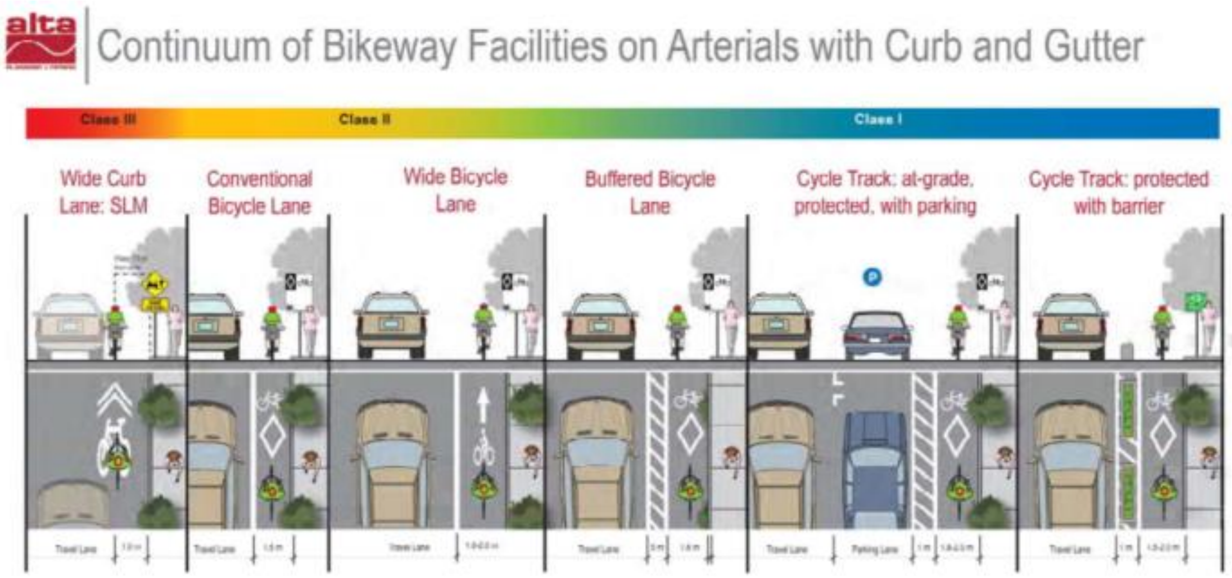


Figure 6: Bicycle Lanes

(Bicycle and Pedestrian Design Guide)

3.0 VIEWING PLATFORM DESIGN

The viewing platform is located on the south-west corner of the intersection. It is split into three levels. The top level is 10 meters above the intersection grade and subsequent levels at 8.5 and 7 meters above. The total floor area of the three levels is 358 m^2. Figure 7 shows the rendering of the platform.

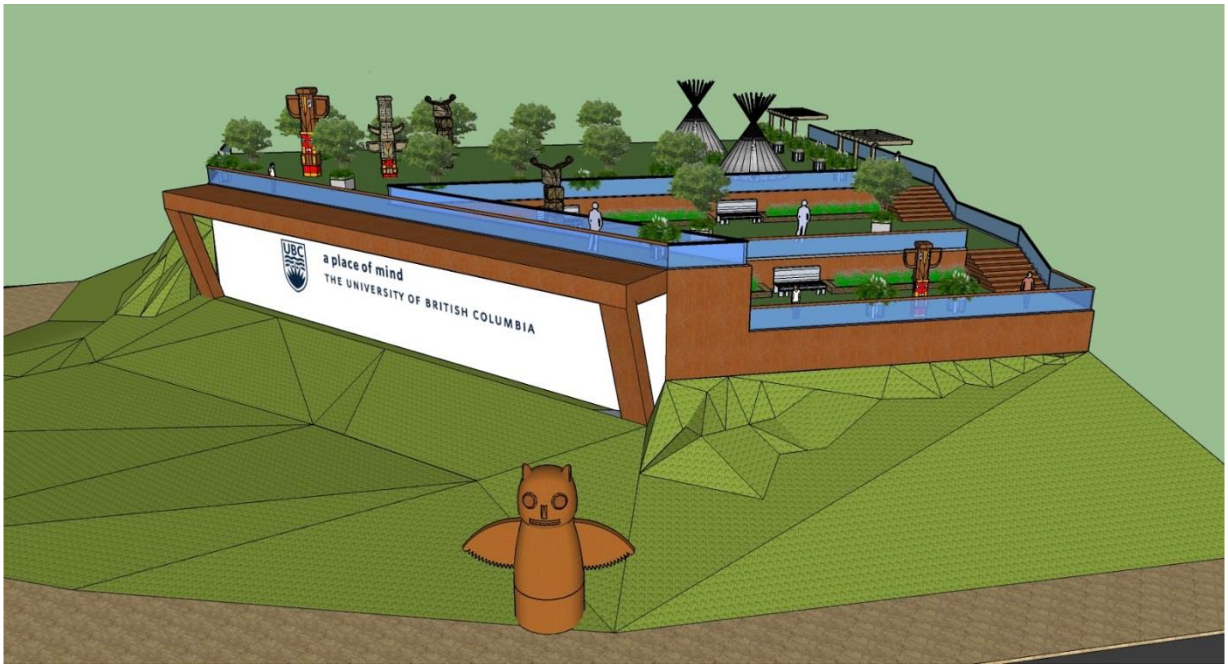


Figure 7: Viewing Platform

The entire platform has been meticulously designed not only to meet regulations, but also to ensure that it creates an exceptional user experience. The use of a one-way entrance and exit assures that the viewing platform is separated from the busy the intersection, creating a safe and reclusive feel for its users. The main level captures the views of the North Shore mountains and the Burrard Inlet. Building materials and art have been influenced by local Musqueam heritage. Green space has been maximized to maintain a natural environment.

To add a modern aesthetic to the viewing platform, all stair railings and guards will be constructed of steel and glass. For accessibility and safety, the railings will satisfy building code requirement (NBCC) by having a required height of over 1067 mm. Also in order to accommodate all users and their needs a ramp system will be included for access for those with impaired movement. It will be designed using a slope of 1:12, as specified by the building code for public amenities.

A key project requirement was to ensure the intersection felt like a gateway. Distinct UBC signage has been chosen for the facade of the viewing platform. The highly visible sign will ensure that there will be no ambiguity for users entering the campus and will provide a similar welcoming feel as the other campus gateways.

Materials used for the platform are all environmentally friendly and locally sourced. The engineered timber products come from manufacturing plants in the interior who use BC grown Spruce-Pine-Fir lumber. Non-structural wood is primarily cedar, which has been suggested by the Musqueam Band. The concrete mix is made using recycled aggregate, which is an environmentally friendly approach that helps reduce our carbon footprint.

3.1 Musqueam Influence

The Musqueam heritage has had a strong influence on the art and materials of the platform. A call for artists has been conducted amongst the local Musqueam community. This ensures a positive social impact by creating local jobs as well as allowing the Musqueam people to submit works, which are truly reflective of their heritage. The chosen art is a collection of totem poles from seven different artists, which will be placed in various locations around the platform. The Musqueam Band's council was closely involved and carefully consulted during all stages of the art selection process; this ensured that the chosen art provided proper representation of their heritage.

The selected construction materials also drew their influence from the Musqueam heritage. Traditional cedar wood will be used for the above grade retaining wall, the stair coverings, as well as other architectural features.

3.2 Landscape Architecture

Green space is maximized on the platform; all floors are covered with grass, which has stone walkways in high traffic areas. Eleven trees will be added to platform, along with numerous shrubs and planters. At the outer region of the platform, berms are used to cover up the concrete retaining wall. This allows for a more aesthetically pleasing design that increases the amount of green space. Benches are placed strategically where people are most likely to rest.

3.3 Structural

The viewing platform's structure is composed of a concrete foundation and timber structure above. The concrete foundation is designed to support and retain soil. The timber structure is used to support part of the elevated slope, as well as the loading capacity from occupancy (live load) and material weight (dead load).

The retaining walls are designed to handle lateral soil pressure, and some extent of the gravity loads. The concrete walls are typically 4.5 meters high, and some are 3 meters to accommodate 1.5 meters of above grade wooden walls, as seen Figure 8. The wood walls are designed to retain built-up soil. All retaining walls will rest on concrete strip footing foundations. The footings will bear a typical loading of approximately 1000 kPa. T3 Consulting used a factored safety of 2.0 for all loading cases to be conservative, as well as design for the worst case scenarios. Sample calculations and a detailed design for a typical retaining wall and footing can be found in Appendix B.

One of the architectural and structural features of the viewing platform is the timber frame, which is located on the facade facing the intersection. The frame is considered as a strut support for the top deck of the viewing platform. It is designed with the intent to relieve some of the dead and live loads from the main structure. The timber frame utilizes: Two 215 x 304 mm Douglas-Fir Larch glulam columns to support nine 105 x 900 mm by 3100 mm long cross-laminated timber (CLT) panels which will span along length of the structure. The connection between the glulam columns and CLT panels will be from a European proprietary or an equivalent local supplier. Each structural member will be engineered as per the CSA 086 standard and the Canadian CLT handbook. Sample calculations for the CLT panels and glulam columns are located in Appendix B.

3.4 Geotechnical

A geotechnical analysis from the Westbrook Mall Pavement Rehabilitation Project was provided by Dr. Yahya Nazhat and considered for geotechnical design. Borehole samples from the nearby site at Chancellor Boulevard and Westbrook Mall give a good indication of the soil conditions at our site. It is determined that fine silt, as well as some trace of sand and gravel can be found on-site. It is concluded that the existing soil conditions are not sufficient for the viewing platform to bear on. Therefore, T3 Consulting recommends using a factor of safety of 2.0 in the analysis and design. The main design property of the soil is its density, which is found to be 9.5 kN/m^3 (from ASCE, 1996, and CIVL 311, Mod 9). A recommendation of further testing is proposed to validate the results.

Excavation in the southwest corner of East Mall and Northwest Marine Drive will proceed in order to lay down a solid concrete foundation for the viewing platform. Since our site is located on a relatively steep slope, it would make it difficult for construction without temporary barriers and ties. The 4.5 m high foundation walls, along with 2.4 m wide strip footings, are sufficient to support the sloped soil. Detailed design and calculations for geotechnical work can be found in Appendix B. The foundation is designed to resist a lateral pressure of about 120 kN/m from existing soil conditions. Once it is constructed, the structure will be backfilled with permeable gravel and coarse sand. A layer of topsoil will cover the gravel in order to create a bed for the grass and other small vegetation that will cover the finished product, as seen in Figure 7. The backfill will not have a problem with drainage as there will be a 100 mm diameter drainpipe at the base of the perimeter footings. Furthermore, a polyester geogrid will be layered at one-meter intervals to ensure that there is adequate soil stability and proper drainage. All excavated material will be removed and reused during the construction of the road.

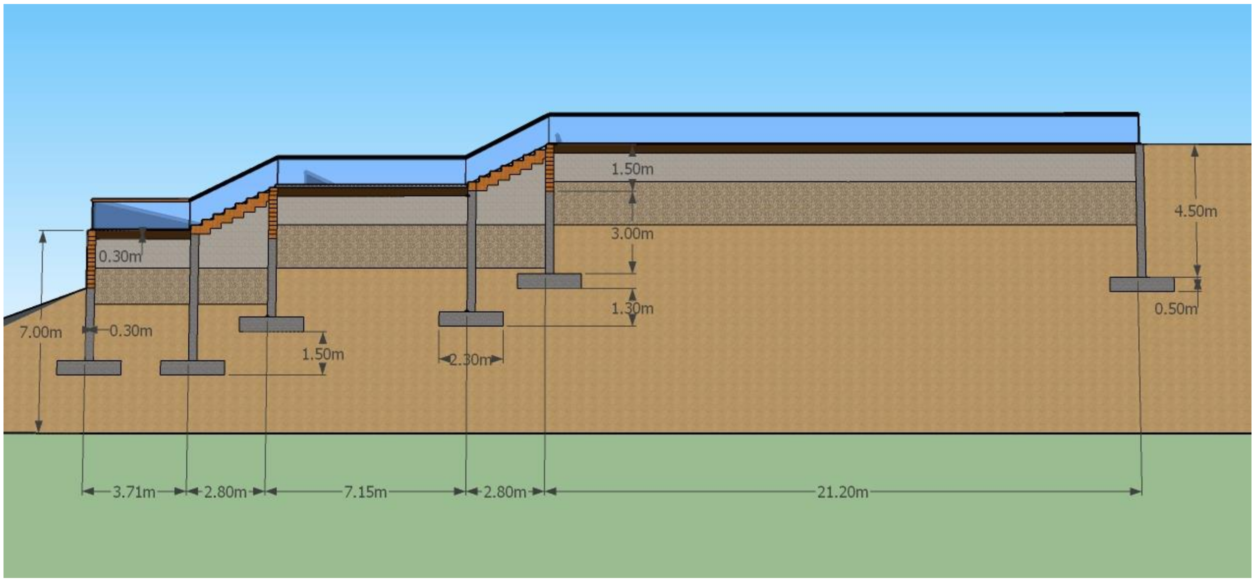


Figure 8: Cross-Section Through Slope

4.0 STORMWATER MANAGEMENT

Stormwater management plays a key role when it comes to sustainability and so it has become a major component in all modern projects. UBC views stormwater as “a resource that is to be managed, rather than wasted” (Stormwater Management). Poor control over stormwater can result in disaster, particularly on the UBC campus. When it is properly harnessed, however, stormwater can become an invaluable resource.

4.1 The UBC Campus

According to UBC Sustainability, the UBC campus sees rainfall of approximately five billion litres per year (Stormwater Management). It is located on a natural aquifer that is composed of porous layers of sand and gravel; in areas where water can infiltrate into the ground, these layers naturally help to slow water flow while also helping to filter it (Stormwater Management). The campus features a vast collection of structures, roads, and walkways. This means that it also features quite a large total impervious area, making it particularly sensitive to stormwater.

Rather than being one large watershed, the campus sits on four smaller watersheds, each with a different draining location (Stormwater Management Infrastructure at UBC Vancouver, 2013). The project site, as indicated by the red circle in Figure 9, is just over 300m south of the shore cliffs, located on a watershed known as the North catchment. Water from the North catchment travels to a spillway known as the spiral drain which provides approximately 4000m^3 of detention, allowing water to slowly drain into the ocean (UBC Integrated Stormwater Management Plan, 2014). The discharge from the spiral drain is limited to 4m^3/s which helps to minimize erosion on the cliffs that surround UBC.

Figure 9: Watersheds on the UBC Campus

(Stormwater Management Infrastructure at UBC Vancouver, 2013)

4.2 The Draft ISMP

This project has been designed in accordance with the UBC Draft Integrated Stormwater Management Plan, henceforward referred to as the "UBC Draft ISMP". Although UBC is not officially a municipality, it has committed itself to providing a similar level of service as the surrounding jurisdictions, such as Metro Vancouver. The Draft ISMP was created to provide a set of guidelines and goals of stormwater management for all projects at UBC.

The two primary forms of stormwater management are infiltration and detention. Infiltration is the act of providing a way for water to get back into the ground where it can then flow to a receiving body of water. Detention is the act of capturing water and storing it for later use or guiding it back to a receiving body through a man-made structure such as a pipe (UBC's Draft Integrated Stormwater Management Plan).

As detailed in the ISMP, UBC faces two primary dangers in regards to stormwater. The first is the erosion of the cliffs that surround the campus. The large total impervious area featured by the campus increases the velocity of the runoff flows; these flows cause destruction of cliffs as they make their way to the ocean. The second is poor water quality due to pollution and sedimentation. Water flowing through construction sites and into drains can pick up unwanted contaminants, and carry them into the ocean if not properly managed.

These dangers have led to the following best management practices for stormwater:

- Prevention of flooding.
- Minimization of erosion at cliffs in Pacific Spirit Park.
- Minimization of flows outside of UBC boundaries, to areas on which UBC has no control.
- Incorporating water quality standards monitoring for stormwater leaving campus boundaries.
- Maintaining water quality standards at a level that meets or exceeds the best practices of the surrounding municipalities.

As well as the stormwater difficulties of the campus as a whole, the project site features additional dangers. There is a rule included in the UBC ISMP which states that, in order to prevent erosion of the surrounding cliffs, infiltration is not an acceptable method of stormwater management for any site that is within 300m of them. The concern is that infiltration does not provide enough control over flow rates. In cases of extreme events, water would flow quickly through the cliffs, causing erosion (Water Management at UBC, 2014). This means that detention methods must be used instead, as they allow water to be released slowly, at a predetermined and controlled rate. As stated earlier, the project site is located just over 300m away from the surrounding cliffs. This means that, while infiltration methods are acceptable, detention methods are better.

The ISMP also recognizes the project site as one of three known problem areas. It is a low point for the surrounding sewer system, indicating that there is likely to be extensive flooding in cases of extreme rainfall events. The pipes of the spiral drain are insufficient to carry the full flows in these circumstances. This is of particular concern due to its close proximity to the UBC rare book collection, which would see irreversible damage.

4.3 Management Strategies

Infiltration is the primary strategy used for stormwater management in this project. For the viewing platform, rather than featuring an impenetrable concrete deck, it will exhibit large areas of green space. This green space will be composed of large grassy berms, which will have a very gentle slope to guide water to the outsides of the platform. The largest slope on the platform is 1:12 and it will only occur at the transition points between access ramps.

KY-31 Tall Fescue grass will be used on the platform as it will aid in infiltration as well as lowering maintenance costs. This particular type of grass is drought resistant and has a high tolerance to cold winters and hot summers. It is resilient and handles traffic well so it will maintain its aesthetic even under conditions of high pedestrian use (Ky-31 Tall Fescue).

Filter strips will be installed in the grassy areas surrounding the viewing platform, on the east splitter island adjacent to the pedestrian walkway, as well as on the center of the roundabout itself (Parking Lot Filter Strips). A 4% buffer will be maintained to ensure that they do not get clogged with sediment. This will allow water to infiltrate slowly while being gently filtered.

We will work closely with Sequoia Landscape Services to ensure that, as they do the landscaping, they incorporate shrubbery and plants that are beneficial to the filtering and infiltration of water. Rock checks will also be encouraged, if they can find a way to implement them that is non-intrusive and aesthetically pleasing.

Figure 10 is a map created by UBC Campus and Community Planning which displays the existing and proposed detention tanks at UBC. The project site is the location of a proposed future detention tank (Implementation, 2013). According to the UBC ISMP, this tank is expected to be 1000m^3. Our designed viewing platform features a three-level deck with a combined surface area of 358 m^2. The top deck is 10 m above grade, with the middle and lower decks being 8.5m and 7m above grade, respectively. This leaves ample room for a detention tank to be constructed within the platform. With a top area of 358 m^2, the tank would only need a height of 2.79m, however the shape could be designed in a way that best allowed water to infiltrate. The grassy top-layer could be maintained in order to provide filtration as the water enters the tank. It could then be stored and treated for other uses such as watering the botanical gardens, or it could simply be slowly released into the spiral drain. UBC intends to complete a risk assessment to determine the prioritization of these smaller detention tanks. We recommend performing this assessment prior to construction of this project in order to determine if these two projects can be combined. If UBC finds that it is prudent to move forward with construction of the proposed detention tank, it would save on construction costs and resources to install it at the same time as the roundabout project.

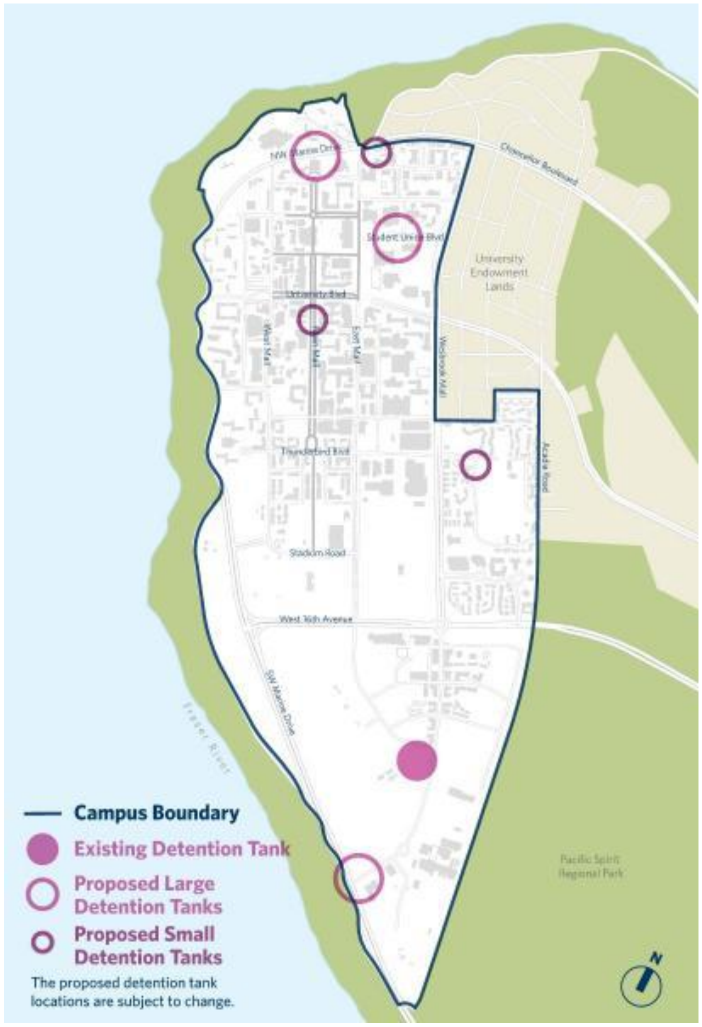


Figure 10: Existing and Proposed Detention Tanks on the UBC Campus

(Implementation, 2013)

4.4 Construction

Construction sediment is one of the most significant causes of poor water quality in UBC's stormwater system. Construction sites are a big source of dust, dirt, and metal contaminants which can easily get mixed into rainwater. In order to ensure that the project does not result in poor water quality, a Construction Sediment Control Program will be strictly enforced on site. Sedimentation tanks will be brought in for the duration of construction, allowing suspended solids to settle so that water can be safely released. Grit screens and grates will be used to cover catch basins, and wheel well washes will be used on the tires of construction vehicles as they leave the site. Water quality on site will be carefully monitored and tested to ensure that it meets the standards set by the UBC Environmental Health and Safety group.

5.0 CONSTRUCTION PLAN

Our team is expecting a six month construction period for completion of both the roundabout and viewing platform. Construction is slated to be on May 10, 2016 and will continue on through to October 17, 2016. The majority of the construction will be done in the summer months to take advantage of the low number of students and faculty members on campus, and to avoid peak traffic flows during the spring and fall semesters.

During certain construction activities, the intersection will not be accessible for users, however detour routes will be provided to accommodate traffic flow. The low traffic volume during the summer allows for detour routes through residential neighborhoods. Clear signage will ensure directions are easily understandable for all forms of traffic. Traffic Controllers will be there to direct traffic during certain construction activities and during increased flow, such as during the graduation ceremony.

5.1 Construction Schedule

Construction of the roundabout and viewing platform will take place within the same period of time, with the viewing platform construction taking 78 of the total 160 working days. Having these two construction activities simultaneously will reduce mobilization costs and reduce total construction time. A complete construction schedule detailing construction activities and the time associated with each activity is available in Table 6.1 (Appendix C). Below is the general work breakdown structure for both the roundabout and the viewing platform.

5.1.1 Roundabout Construction Breakdown

1. Removal and demolition of existing intersection, road surface, sub-surface soil.
2. Construction of the central island, excavation, and installation of signage, road construction.
3. Placement of foundation and installation of base materials
4. Compaction of base and site grading with vibratory roller.
5. Laying and compacting asphalt.

5.1.2 Viewing Platform Construction Breakdown

1. Site preparation and removal of obstructions.
2. Excavation to required depth.
3. Soil compaction and preparation.
4. Concrete retaining wall installation.
5. Installation of footings and foundation.
6. Support erection. The majority of the platform will be precast offsite.
7. Frame installation and finishing.

5.1.3 Construction Outsourcing

Our team intends on hiring a number of subcontractors for construction. Our primary goals when hiring subcontractors are to ensure that they have all had experience working in the lower mainland on projects of similar scale and, if possible, firms that have done work with UBC in the past. Our team looked at minimizing overall expenses while also ensuring sufficient quality of work.

- Footings and Excavation: Matcon Civil Constructors Inc.
- Laying and Compacting Asphalt: Catmandu Excavating
- Landscaping: Sequoia Landscape Services
- Precast Timber Sections: Pickles Timberframes
- Precast Concrete Sections: Architectural Precast Structures

5.2 Cost Estimate

The total estimated cost for the construction of the Chancellor Boulevard roundabout and the viewing platform equates to approximately $1.7 million. This includes the total construction cost and all consultation fees associated with the project; comprising consultation from a Geotechnical engineer, Civil engineer, and Transportation Engineer.

Alberta's Ministry of Transportation has established an average unit price of construction estimation report by compiling and analyzing construction cost data for various transportation-related projects, including roundabout construction. This data was used to breakdown the costs of different components of construction. The table on the following page is a Class C cost estimate which breaks down the construction costs.

Construction of the roundabout was divided into 15 primary activities, with a unit price in Canadian dollars associated with each activity. This unit price was then multiplied by the number of "units" of work needed to complete the Chancellor Intersection. Please note: units of work change depending on construction activity; for example, excavation the unit of measurement was 1 m^3.

The unit costs of the roundabout construction include both Material and Labor costs. The total construction cost also includes a 20% markup to account for project risks, such as construction delay due to late delivery of materials. Please see Risk in Appendix E for further information.

On top of the principle construction costs there will also be an Operating and Maintenance cost of approximately $35 thousand dollars per year. The majority of the maintenance costs are associated with sustaining the greenery at the intersection.

Lastly, the cost of the viewing platform is also included in this cost breakdown. This cost includes total materials and labor costs required to complete the platform. The total cost of the platform is $210,000.

5.3 Construction Mitigation

Our team has put an emphasis on ensuring that a variety of mitigation measures are taken during the construction of the roundabout and viewing platform. Throughout the proposed construction process, we will strive to ensure that energy use, noise pollution, and air pollution are kept to a minimum, while ensuring minimal disturbance of the current green space and vegetation.

The following list consists of the main mitigation measures we have taken to ensure sustainable construction that remains in tune with UBC's sustainability initiatives.

1. The construction site must always have adequate barriers, signage, and lighting for the safety of both the workers and the public. Barriers refer to both noise reduction barriers, and air pollution barriers
2. Site Preparation activities must be done prior to construction to ensure minimal impact on vegetation and wildlife.
3. Entrances to construction zone must be swept and/or water flushed during construction to avoid excess dust
4. Construction fencing will be set up around UBC trails near construction site to prevent access to trails and minimize effects of construction on wildlife and vegetation
5. During transportation to and from the construction site, fine particulate materials must be covered and contained
6. Periodic watering of unpaved areas must take place during construction to avoid excess dust
7. Vehicular speeds must be limited during construction to avoid excess dust and air pollution
8. Noise reduction **-** Crews must limit the noisiest construction activities to daytime hours
9. Must ensure use of construction equipment in good repair, fitted with functioning mufflers, and in compliance with the noise emission standards outlined in the Ministry of the Environment guidelines

10. Government approval must be obtained prior to any road closures. Local police, ambulance, and fire departments must be given notification regarding any road closures.
11. Must ensure that all on-site workers have proper training. (occupational safety training required)
12. Must ensure that a licensed paramedic is on site at all times throughout construction.
13. Construction will follow Vancouver's bylaws, and will take place between the hours of 7:30am and 5pm, Monday through Saturday.
14. Any work that must be done under dry conditions will be postponed in the event of heavy rain.
15. If any work defect is found during any stage in the project life, proper remediation and correction must be made immediately.
16. Storm Water Works & Erosion and Sediment Control – *Detailed further in their respective section.* Plans will be made to keep runoff flows low, runoff velocity low, minimize erosion, and prevent sediments from entering into storm water system
17. Must use erosion and sedimentation control to prevent the migration of sediments beyond the work site
18. All construction waste materials will be collected and stored onsite near the entrance of trail 3 on NW Marine drive. Site must be prepared prior to commencement of construction
19. Construction materials will be stored on site. A temporary material storage area will be constructed on the corner of Iona drive. Site must be prepared prior to commencement of construction
20. Proper restoration, site cleanup and remediation actions will take place post construction. This refers to replacing any trees or vegetation that had been removed during construction.

6.0 RISK ANALYSIS

Our team has performed a detailed risk analysis to identify the major risks associated with the UBC Chancellor Intersection project, and to discuss their potential impacts. Planned response and mitigation methods to minimize or avoid any negative impacts will also be detailed.

Our team has categorized the risks into 13 "Risk Areas" (detailed below) which are most relevant to the project. Please note that many of these risks listed below potentially fall into more than one Risk Area, and choosing which Risk Area was based on our teams collected discretion.

Risk Areas:

- Regulatory
- Construction
- Operations
- Stakeholders
- Customer
- Political
- Geotechnical
- Environmental
- Material
- Safety
- First Nations
- Economic
- Management

This risk analysis will discuss all of the risks involved in the different stages of the project, with particular attention being paid to environmental risks, regulatory risk and construction risk. An emphasis has been put on these three risk areas due to the fact that the regulatory phase and construction phase are stages in which most projects encounter complications. Furthermore, growing environmental awareness is causing social and reputational challenges for firms who follow environmentally unfriendly construction practices, as such, our team considered environmental risk to be a particularly vital risk area.

1. **Construction Risk -** Projects in the construction industry generally involve a much greater degree of risk due to the complexity involved in coordinating various activities simultaneously. In order to mitigate the level or risk involved in the Chancellor Boulevard design, a slightly longer

construction time has been associated with the project. Furthermore, a 20% markup has been included to the total cost of construction to take into account for potential risk. The roundabout could potentially be designed within a few months, but in order to ensure that proper procedure, consultation and construction methods are followed, a 6 month construction schedule is recommended.

2. **Environmental Risk -** This risk is a subsection of the construction risk. This involves mitigation of any and all potential negative environmental impacts, such as minimizing excess construction waste, proper green space restoration, minimizing air pollution etc.
3. **Regulatory Risk -** This risk happens early in the construction phase, special emphasis is put onto permitting, and meeting regulations due to the fact that failing to do so results in projects being either significantly delayed or completely rejected. Charges pressed by regulatory agencies for failing to meet regulations tend to be quite high.

A qualitative risk analysis is attached in Appendix E of this report. The qualitative risk analysis was created using a risk matrix in which probability was plotted against impact to identify the most significant risks requiring attention. A Risk Probability Guide and a Risk Impact Guide were used to determine the probability, and impact of each risk respectively.

The qualitative risk analysis was expanded on using a Risk Register which categorized each respective risk, and gave a probability as well as impact of occurrence. The current severity of the risk along with the previous severity are also labelled to allow us to track whether or not a certain risk is becoming a larger concern, smaller concern, or staying the same. Mitigation or avoidance strategies and risk status are also labelled, along with the risk owner, and support team.

7.0 PROJECT CONSIDERATIONS

The following sections cover environmental, societal, and engineering design considerations associated with the project.

7.1 Green Space

In accordance to UBC's commitment to sustainability, ample green space has been allocated in the roundabout, as well as the viewing platform. It is important to remember that vegetation, including grass, flowers, shrubs, and trees shall not be removed unless there is no other appropriate measure to work around them. In the case that vegetation is removed, it must be replanted before closure of the project. A sediment control plan must be followed to prevent erosion of the loose soil during the time that the vegetation is being transplanted.

The center of the roundabout will primarily be covered with grass and will have shrubs along with flowers to create a welcoming feel into the campus. Choosing appropriate vegetation for this area is important because it will help mitigate stormwater runoff. It is important that proper drainage is constructed under all green space due to the high risk zone that this project is located in. Grass and shrubs will also be the primary vegetation located on the four corners of the roundabout. Planting shrubs on the outer edge of the roundabout will encourage pedestrians to use the automated crosswalks as it will funnel them towards one of the corners. This will create a safer intersection for all users and the shrubs will not impact the driver's sight distance.

The viewing platform will focus on traditional Musqueam art and will feature addition foliage. Native flowers and shrubs will be planted around the viewing platform, as well as the addition of eleven new trees. Professional gardening expertise will be required to help maintain the garden beds and look after all of the vegetation regularly.

7.2 Alternative Construction Materials

Using alternative construction materials in our design allows the owner to have more options that focus on sustainability and the cost of construction. As part of environmental stewardship, all material selected will be local and environmentally friendly.

Much of the project uses concrete, so we are able to minimize our carbon footprint by using recycled-concrete aggregate (RCA) to supplement regular aggregate used in concrete construction. Regular aggregate can be mixed with RCA to create cheaper and more environmentally friendly concrete. This mixture has similar strength parameters as regular concrete, but it will be more sustainable. Strict construction practices are crucial when working with RCA.

Asphalt paving is a common construction practice that will be used onsite. Currently, the redesigned intersection will have an impervious surface for the heavy vehicle traffic and stormwater management. The traditional approach can be replaced with natural paving solutions. This is accomplished by using the existing in-situ soil and gravel, along with a natural resin for stability, and a paver sealer for an impervious finish. This method helps promote environmental stability, and has fewer impacts compared to the traditional asphalt pavement method. The total cost difference associated with these two can be as high as 60%.

Regular paints and finish can contain volatile organic compounds (VOC) and can cause damage to the environment and are harmful to human health. As such, all paints used will be low-VOC or zero-VOC, such as water based paints and sealers. The benefits of using these are: easy cleanup, lower landfill pollution and ozone depletion, reduced groundwater contaminants, as well as less harmful toxins give off.

7.3 Community Impact

The location of the intersection requires high attention to community impact, as it will affect the local communities both throughout the construction period, and after it is completed.

During construction, attention to noise reduction has been addressed and noise related work events have been scheduled accordingly. Travel delay times will be kept to a minimum to not cause any inconvenience local residents and users. Surrounding routes should expect an increase in traffic volume as there will be detours set up throughout the construction period, but the effect should be at a minimum.

Once the roundabout is complete the area will have numerous improvements including being safer, more inviting, and more user friendly. The roundabout will be intuitive, and will encourage alternative forms of travel. Access to Trail 5 will reopen and the area will be more stable after construction. Overall, the proposed roundabout design will create a more pleasant experience for all users.

7.4 User Information and Consideration

Residents in the neighborhood and users of the intersection will need to plan ahead to give themselves more time when traveling through this area. Traffic delays are expected to occur during the summer months of construction; however, they will be minimized with the help of good scheduling. Residents and users will have information regarding commute delays on a digital display board, which will be placed at both ends of the approaching intersection. This will help inform travelers of any expected delays, and detours that are available.

Traffic control is important and the site will require flag workers to help guide traffic during construction. Cyclists, as well as drivers, have to be aware that detour routes may be setup during the construction period. Proper signage will be placed to ensure that there is no confusion for anyone using the detour route. Since this intersection serves as a truck route, changes will be made to make sure that truck drivers are still able to access Northwest Marine Drive. The expected graduation ceremony at The Chan Centre has also been accounted for, and no major construction activities are scheduled during that week.

7.5 Software and Standards

The roundabout design required the use of software to come up with the structure and a set of standards that can be referenced as a check. The design followed the specifications outlined in the Kansas Roundabout Guide 2014. A vehicle projection model was developed with the help of Synchro. With reference to the building codes, structural design codes, and roundabout design criteria, we were able to determine the most efficient solution for replacing the old intersection. More information regarding the design standards and software used can be found in Appendix F.

8.0 CONCLUSION

Upon detailed review and analysis of the intersection at Chancellor Blvd. and NW Marine Drive it can be determined that remedial measures must be taken to improve efficiency and user safety. This report has outlined the benefits of utilizing a single lane roundabout with emphasis on safety, community involvement, and meeting UBC's sustainability goals. The use of green conscious design ensures that existing trees and plants are minimally removed. In addition, the proposed viewing platform will foster improved relations with the Musqueam people and act as a hub for community gatherings, as well a place for viewing pleasure.

This report offers solutions to meet the given constraints and conforms to the restrictions governed by the site. UBC's and the Musqueam people's visions and goals have been integrated into the design for a positive community impact. Special attention has been given to ensuring proper detention methods are used for stormwater to ensure adequate drainage.

A construction plan and cost estimate outline the proposed fees and schedule moving forward. Summer months for construction imply lower traffic volumes with ceremonial events receiving special attention. Cost estimates are comparable to other projects completed at UBC with additional prices associated with the viewing platform at the southwest corner.

The associated risk to this project is lower due to its similarity to the project at 41st in UBC, and as such, this solution offers further simplicity for construction and maintenance. From the findings in the report above it can be concluded that the proposed roundabout design offer an effective, safe alternative to the current intersection.

REFERENCES

BC Supplement to TAC Geometric Design Guide, 2007 edition. Ministry of Transportation. Retrieved January 27th, 2016, from http://www.th.gov.bc.ca/publications/eng_publications/geomet/tac/TAC_2007_Supplement/2007BC_Supplement_to_TAC.pdf

Roundabouts: An Informational Guide Second Edition. Nation Cooperation Highway Research Program. Retrieved February 20th, 216, from http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_672.pdf

Accommodating Trucks in Single and Multilane Roundabouts. Retrieved February 20th, 2016, from http://www.ourston.com/files/Resources/Documents/Trucks/TRB%20Accommodating%20Trucks%20on%20Single%20and%20Multilane%20Roundabouts.pdf

Review of Truck Characteristics as Factors in Roadway Design. Nation Cooperation Highway Research Program. Retrieved February 21st, 216, from http://nacto.org/docs/usdg/nchrprpt505_harwood.pdf

Pavement Design Standards (Technical Circulation T – 9/95). Ministry of Transportation and Highways. Retrieve February 21st, 2016, from http://www.th.gov.bc.ca/publications/circulars/all /t_circ/1995/t09-95.pdf

Kansas Roundabout Guide Second Edition 2014. Kittleson & Associates Inc. Retrieve February 21st, 2016, from https://www.ksdot.org/Assets/wwwksdotorg/bureaus/burtrafficeng/Roundabouts/Roundabout_Guide/KansasRoundaboutGuideSecondEdition.pdf

Capital Regional District Pedestrian and Cycling Master Plan Design Guidelines. Capital Regional District. Retrieved March 25th, 2016 from https://www.crd.bc.ca/docs/default-source/regional-planning-pdf/Pedestrian-Cycling-Master-Plan/pcmp_design_guidelines_lowres.pdf?sfvrsn=2

Crossing Solutions at Roundabouts and Channelized Turn Lanes for Pedestrians with Vision Disabilities. Nation Cooperation Highway Research Program. Retrieved March 25th, 2016 from http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_674.pdf

Mitigation of Environmental Effects During Initial Construction. Retrieved on March 17th/2016 from http://www.partnershipborderstudy.com/pdf/7-23-09/Mitigation%20during%20construction.pdf

Risk Mitigation Planning, Implementation, and Progress Monitoring. Systems Engineering Guide. Retrieved on March 15th/2016 from http://www.mitre.org/publications/systems-engineering-guide/acquisition-systems-engineering/risk-management/risk-mitigation-planning-implementation-and-progress-monitoring

Risk Management Planning. BC Open Textbooks Project Management. Retrieved on March 16th/ 2016 on https://opentextbc.ca/projectmanagement/chapter/chapter-16-risk-management-planning-project-management/

Project Cost Estimating Guidelines. Transportation and Infrastructure Project Management. Retrieved on March 20th/ 2016 from http://www.th.gov.bc.ca/publications/planning/guidelines/cost_estimating_guidance.pdf

Foundation and Earth Retaining Structures, 3rd Edition. Budhu, M. John Wiley & Sons. 2011

Reinforced Concrete Design A Practical Approach, Brzev and Pao. Pearson Custom Publishing. 2009

UBC Integrated Stormwater Management Plan (2014). UBC Campus and Community Planning. Retrieved April 4, 2016 from http://planning.ubc.ca/sites/planning.ubc.ca/files/documents/projects-consultations/consultations/UBC%20Draft%20ISMPv4_April%202014.pdf

Stormwater Management. UBC Sustainability. Retrieved April 4, 2016 from https://sustain.ubc.ca/campus-initiatives/water/stormwater-management.

UBC's Draft Integrated Stormwater Management Plan. UBC Campus and Community Planning. Retrieved April 4, 2016 from http://planning.ubc.ca/vancouver/projects-consultations/consultations-engagement/integrated-stormwater-management-plan/detention

Ky-31 Tall Fescue. Lacrosse Seed. Retrieved April 4, 2016 from http://www.lacrosseseed.com/ky-31-tall-fescue/.

Why does UBC need an Integrated Stormwater Management Plan?. UBC Campus and Community Planning. Retrieved April 4, 2016 from http://planning.ubc.ca/vancouver/projects-consultations/consultations-engagement/integrated-stormwater-management-plan/ism-at-ubc

Klein, Daniel R. et al., Water Management at UBC (2014). The Institute for Resources, Environment, and Sustainability. Retrieved April 4, 2016 from https://watergovernance.ca/wp-content/uploads/2014/08/UBC-IRM-Strategy-with-a-Water-Lens-FINAL-Aug-2014.pdf

Parking Lot Filter Strips. Lake Superior Streams. Retrieved April 4, 2016 from http://www.lakesuperiorstreams.org/stormwater/toolkit/filterstrips.html

Implementation (2013). UBC Campus and Community Planning. Retrieved April 4, 2016 from http://planning.ubc.ca/vancouver/projects-consultations/consultations-engagement/integrated-stormwater-management-plan/Implementation

Stormwater Management Infrastructure at UBC Vancouver (2013). UBC Campus and Community Planning. Retrieved April 4, 2016 from http://planning.ubc.ca/vancouver/projects-consultations/consultations-engagement/integrated-stormwater-management-plan/Infrastructure

APPENDIX A: INTERSECTION SAMPLE CALCULATIONS

Loading:

Asphalt Density: 22.78kN/m^3
Load = Density * Thickness
22.78 * 0.075m
=1.71kPa
Concrete Density 23.6kN/m^3
23.6 * ⅓ * 0.15m (cone thickness)
=1.18kPa

Stopping Sight Distance:
d = (1.47)(t)(V) + 1.075*(V^2/a)

d = (1.47)(2.5)(30km/hr) + 1.075*($(30km/hr)^2$ / 11.2 ft/s^2)

d = 30m

Where

d = stopping sight distance, ft;

t = perception–brake reaction time, assumed to be 2.5 s

V = initial speed, mph; and a driver deceleration, assumed to be 11.2 ft/s2 .

Intersection Sight Distance:
d = (1.47)($V_{major, enterimg}$)(tc)

d = (1.45)(18.64mph)(5.0)

d = 40m

Where

Vmajor = design speed of conflicting movement, mph, discussed below

tc = critical headway for entering the major road, s, assumed to be 5.0 s

Pedestrian Signalized Intersection:

$PV^2 > 10^8$

where:

P = Projected peak hourly pedestrian traffic (15 years)

V = Projected peak hourly vehicle traffic (15 years)

$49 * 1370^2$

=91968100

Pedestrian crossing speed: 3ft/s

Pedestrian Signal Phasing: (Distance/Speed)*1.20 (safety factor)

(43ft / 3ft/s) * 1.20

=16 second crossing time

Equivalent Single Axle Load:

ESAL = AADT * HVP * HVDF * NALV * TDY

where:

ESAL = Equivalent single axle loads per lane per year (for the base year)
AADT = Average annual daily traffic (all lanes & both directions)
HVP = Heavy vehicle percentage (divided by 100, to express as a decimal)
HVDF = Heavy vehicle factor (% (as a decimal) of heavy vehicles in design lane)**
NALV = Number of equivalent axle loads per vehicle (ESAL's per vehicle)
TDY = Traffic days per year

Note: ESAL's (base year) x 20 yr. traffic growth rate factor = 20 year Design ESAL's. Where there is no data, a growth rate factor of 2% is reasonable.

https://www.th.gov.bc.ca/publications/Circulars/All/T_Circ/2015/t01-15.pdf

$ESAL = 5140 * 0.026 * 0.02 * 2 * 365 * 20 * 1.02^{20}$

=57986

Type C asphalt requirement

APPENDIX B: VIEWING PLATFORM SAMPLE CALCULATIONS

Typical Strip Footing Bearing Capacity:

Sub-surface Soil Conditions:	Dense Silt					
Soil Pressure:	9.5 kN/m^3		Factored Load:	12.5 kPa	=>	132.5 kN/m
			Material Self-weight:	0.72 kPa	=>	7.6 kN/m
			Total Loading:			140.1 kN/m
Factor of Safety:	**2.0**					

Tributary Area of Factored Loading:	width	10.6 m
	Length	17.1 m

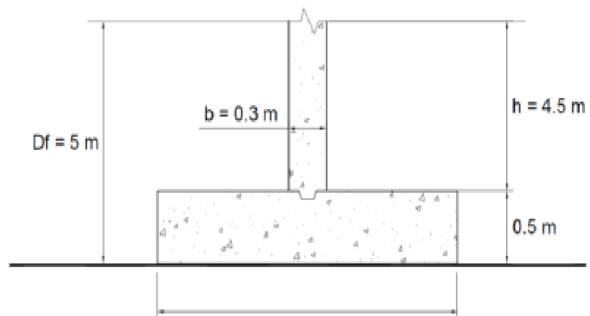
Factor Soil bearing Pressure:	Qf	998.4 Kpa

Dimensions:

Width, B:	2.4 m (2400 mm)
Depth, Df:	5 m (5000 mm)

Bearing Capacity Factors:

Φ'p	35 °
Ny	36
Nq = e^(πtanΦ'p)*tan^2(45°+(Φ'p/2))	33.3



Typical Footing Foundation

$$q_{ult} = q_u + \gamma D_f = \gamma D_f (N_q) + \frac{1}{2}\gamma B N_\gamma$$

$$q_u = \gamma D_f (N_q - 1) + \frac{1}{2}\gamma B N_\gamma$$

$$q_a = (q_u / FOS) + \gamma D_f$$

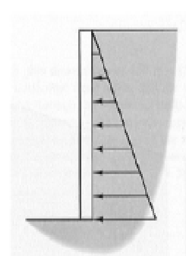
Capacities:

Ultimate Gross Bearing Capacity, Qult:	1992.2 kPa
Ultimate Net Bearing Capacity, Qu:	1944.7 kPa
Allowable Bearing Capacity, Qa:	1019.8 kPa

Thus, Qa > Qf

Typical Retaining Wall Capacity:

Laterial Soil Pressure:	47.5 kPa
Lateral Load:	118.8 kN/m



$$P_a/b = \frac{G_h H^2}{2}$$

$$G_h = \gamma K_a$$

Concrete Wall Dimensions

width, b	0.3 m
height, h	4.5 m

Concrete Strength, F'c	35 Mpa
Capacity:	165.1 kN/m

thus, Wall Capacity > Lateral Load

APPENDIX C: CONSTRUCTION SCHEDULE

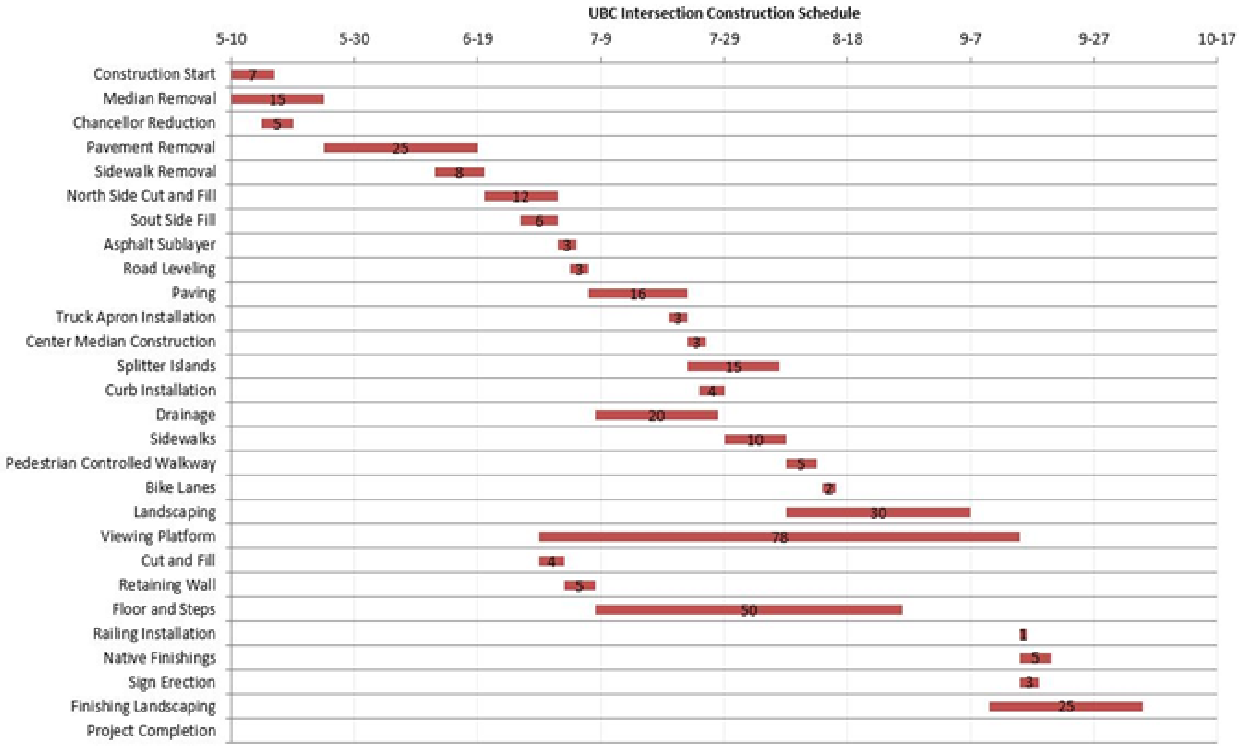


Table 2: Construction Schedule

APPENDIX D: COST ESTIMATE

Description of Work	Quantity	Units	Unit Price	Cost	% Cost Breakdown
Median Removal	1	ea.	$10,000	$10,000	1.0
Chancellor Median Reduction	1	ea.	$15,000	$15,000	1.5
Existing Pavement Removal	150	l.m.	$110	$16,500	1.6
Excavation (fill)	1000	m^3	$30	$30,000	3.0
Asphault road construction	190	l.m.	$1,600	$304,000	29.9
Roundabout Construction	550	s.m.	$290	$159,500	15.7
Curb Installation	150	l.m.	$80	$12,000	1.2
Drainage (storm drains, leveling	20	ea.	$300	$6,000	0.6
Viewing Platform	350	s.m.	$600	$210,000	20.7
Pedestrian Controller Walkways	4	ea.	$20,000	$80,000	7.9
Sidewalk removals	300	l.m.	$25	$7,500	0.7
Utilities (signs, hydrants)	15	ea.	$700	$10,500	1.0
Sidewalk construction	300	l.m.	$85	$25,500	2.5
Landscaping	3000	s.m.	$35	$105,000	10.3
Bike Lanes	300	l.m.	$80	$24,000	2.4

Sub-total contruction Cost	$1,015,500
20% Coningencies	$203,100.0
Construction Cost	$1,218,600.0
Consulation Cost	$353,394
Sub-Total	$1,571,994.0
10% Profit Markup	$157,199.40
Total	$1,729,193.40

Consultation Costs	Cost %	Cost
Geotechnical Engineer	10	$121,860
Civil Engineer	4	$48,744
Transportation Engineer	15	$182,790

Total	$353,394

Table 3: Project Cost Breakdown

APPENDIX E: RISK

	Risk Probability Guide				
Numerical Score	1	2	3	4	5
Rating	Rare	unlikely	moderate	likely	almost certain
Probability of Occurance	surprised if this happned	less likely to happen than not	just as likely to happen as not	more than likely to happen than not	woul be surprised if this didn't happen
Intervention Difficulty	Your normal management processes should easily ensure an acceptable outcome	Careful oversight of your normal management processes will probably bring about an acceptable outcome	Additional time and effort will be required to move toward an acceptable outcome	Your resources and authority are sufficient to permit only a minor effect on the outcome	Your ability to affect the outcome is effectively zero

Table 4: Risk Probability Guide

Risk Impact Guide					
Numerical Score	1	2	3	4	5
Rating	negligable	low	medium	high	extreme
Cost	Insignificant cost increase	less than 5%	5% to 10%	10% to 20%	greater than 20%
Schedule	insignificant project slippage	less than 5%	5% o 10%	10% to 20%	slippage greater than 20%
Functionality	Functionality decrease barely noticeable	Minor areas of functionality are affected	Major areas of functionality are affected	Functionality reduction unacceptable to the client	Project end item is effectively unusable
Quality	Quality degradation barely noticeable	Only very demanding operations are affected	Quality reduction requires client approval	Quality reduction unacceptable to the client	Project end item is effectively unusable
External corridor	Insignificant changes to customers' processes	Only small aspects of customers' processes are changed	Significant changes to customers' processes	Unacceptable changes to customers' processes	Project end item is effectively unusable
Benefits	Insignificant loss	Benefit loss >2%	Benefit loss >5%	Benefit loss >7%	Benefit loss >10%
Service	Barely noticeable by Customer	Short-term impact, Easily rectified	Delivery standards drop >3%	Delivery standards drop >5%	Delivery standards drop >10%

Table 5: Risk Impact Guide

PROBABILITY						
	Almost Certain	5	10	15	20	25
	Likely	4	8	12	16	20
	Moderate	3	6	9	12	15
	Unlikly	2	4	6	8	10
	Rare	1	2	3	4	5
		negligable	low	medium	high	extreme
				IMPACT		

Table 6: Risk Matrix Guide

Risk	Category
Project Delayed	Regulatory
Project Rejected	Regulatory
Restrictive Conditions Invoked	Regulatory
Charges by regulatory Agencies	Regulatory
Lost Tools	Construction
Collapsed Hole	Construction
Protests & Lack of public support	Activism
Construction material quality insufficient	Equipment and Material Risk
Materials or equipment not deliverd on time	Equipment and Material Risk
Excavation performance not as high as expected	Equipment and Material Risk
New stakeholders request change throughout project	Shareholders
scope is poorly defined or documented by owners	Shareholders
Heavy extended rainfall during construction	Other
Safety incident results in Fatality	Construction
Safety incident results in injury	Construction
Heavy extended snowfall during construction	Other
public objections	Activism
laws, new legal requriements with construction	Political
Increase in material cost	Economic
Economic downturn	Economic
Tax Change	Political
Design Errors and Ommision	Human Resource
Design taking longer than anticipated	Human Resource
Stake Holders request late Changes	Shareholders
Failure to carry out works in accorance to contract	Construction
Serious noise pollution by construction	Construction
Enviromental analysis incomplete	Environmental
Unexpected requirments to minimize/mitigate environmental impact	Environmental
construction costs underestimated	Human Resource
technological changes	other
contradiction in construction documents	Human Resource
lack of protection on construction site	Construction
delayed deliveries	Management
inexperienced workforce	Management
scheduling errors, delays	Management
project team conflicts	Management
Important documentation/information overlooked in tender	Management
Unexpected Geological Conditions	geotechnical
Site is found to have Archeological significance	geotechnical
Construction workers go on strike	Management
Improper manaagment of site waste	Environmental
Excessive Concrete Dust	Environmental
Excessive sewage runoff;	Environmental
Erosion due to large runoff	geotechnical
incorrect operation or failure of operater	operating
Slope Failure	geotechnical
Sinkhole failure	geotechnical
Earthquake	geotechnical
Project does not have support of First Nations	First Nations
UBC Event Halts Construction	Construction

Table 7: Risk Matrix Guide

Risk Categoy	Risk ID	Risk	Probability	Impact	Current Severity	Previous Severity	Change in Severity
Regulatory	1	Project Delayed	4	2	8	***	***
Regulatory	2	Project Rejected	2	2	8	***	***
Regulatory	3	Restrictive Conditions Invoked	4	2	8	***	***
Regulatory	4	Charges by regulatory Agencies	2	3	6	***	***
Construction	5	Lost Tools	3	1	3	***	***
Construction	6	Collapsed Hole	2	5	10	***	***
Activism	7	Protests and lack of public support	2	2	4	***	***
Equipment and	8	Construction material quality insufficient	3	3	9	***	***
Equipment and	9	Materials or equipment not deliverd on time	3	4	12	***	***
Equipment and	10	Excavation performance not as high as expected	3	5	15	***	***
Shareholders	11	New stakeholders request change throughout project	1	4	4	***	***
Shareholders	12	scope is poorly defined or documented by owners	1	4	4	***	***
Other	13	Heavy extended rainfall during construction	4	4	16	***	***
Construction	14	Safety incident results in Fatality	1	4	8	***	***
Construction	15	Safety incident results in injury	2	4	8	***	***
Other	16	Heavy extended snowfall during construction	3	1	3	***	***
Activism	17	public objections	2	3	6	***	***
Political	18	laws, new legal requriements with construction	1	3	3	***	***
Economic	19	Increase in material cost	4	3	12	***	***
Economic	20	Economic downturn	1	4	4	***	***
Political	21	Tax Change	1	4	4	***	***
Human Resour	22	Design Errors and Ommision	3	4	12	***	***
Human Resour	23	Design taking longer than anticipated	2	5	10	***	***
Shareholders	24	Stake Holders request late Changes	2	5	10	***	***
Construction	25	Failure to carry out works in accorance to contract	2	4	8	***	***
Construction	26	Serious noise pollution by construction	4	1	4	***	***
Environmental	27	Enviromental analysis incomplete	2	4	8	***	***
Environmental	28	Unexpected requirments to minimize/mitigate environmen	1	5	5	***	***
Human Resour	29	construction costs underestimated	4	4	16	***	***
other	30	technological changes	1	4	4	***	***
Human Resour	31	contradiction in construction documents	3	4	12	***	***
Construction	32	lack of protection on construction site	2	4	8	***	***
Management	33	delayed deliveries	3	4	12	***	***
Management	34	inexperienced workforce	1	5	5	***	***
Management	35	scheduling errors, delays	4	4	16	***	***
Management	36	project team conflicts	2	2	4	***	***
Management	37	Important documentation/information overlooked in tend	1	4	4	***	***
geotechnical	38	Unexpected Geological Conditions	4	4	16	***	***
geotechnical	39	Site is found to have Archeological significance	1	5	5	***	***
Management	40	Construction workers go on strike	1	3	3	***	***
Environmental	41	Improper manaagment of site waste	2	3	6	***	***
Environmental	42	Excessive Concrete Dust	4	1	4	***	***
Environmental	43	Excessive sewage runoff;	4	1	4	***	***
geotechnical	44	Erosion due to large runoff	2	5	10	***	***
operating	45	incorrect operation or failure of operater	2	4	8	***	***
geotechnical	46	Slope Failure	3	4	12	***	***
geotechnical	47	Sinkhole failure	2	5	10	***	***
geotechnical	48	Earthquake	4	4	16	***	***
First Nations	49	Project does not have support of First Nations	3	5	15	***	***
Construction	50	UBC event halts construction	3	5	15	***	***

Table 8: Risk Register

Mitigation/Avoidance strategy	Status	Risk Owner	Support Team
ensure all regulatory reqruirments are met	Active	***	Team A Consulting
ensure all regulatory reqruirments are met	Active	***	Team A Consulting
ensure all regulatory reqruirments are met	Active	***	Team A Consulting
ensure all regulatory reqruirments are met	Active	***	Team A Consulting
ensure construction workers have all necessary tools and that a high quality onsite storage facility is set up	Active	***	Team A Consulting
more boreholes possible for further geotech data, excavation in safe area's	Active	***	Team A Consulting
be open with public regarding project, benefits and the need for the project	Active	***	Team A Consulting
Only purchase pipe from high quality, trusted producers	Active	***	Team A Consulting
ensure delivery method, and plan for material to be delivered in advance	Active	***	Team A Consulting
work with excavation firms with good reputation to minimize risk of error	Active	***	Team A Consulting
Accept this risk	Active	***	Team A Consulting
define scope thoroughly and in the early stages of design	Active	***	Team A Consulting
plan for rain, it is very common in vancouver, read meteorology reports in advance	Active	***	Team A Consulting
have safety plan in place prior to construction	Active	***	Team A Consulting
have safety plan in place prior to construction	Active	***	Team A Consulting
read meteorology reports in advance	Active	***	Team A Consulting
be open with public regarding project, benefits and the need for the project	Active	***	Team A Consulting
accept this risk, but nearly impossible	Active	***	Team A Consulting
buy material in advance	Active	***	Team A Consulting
accept this risk, cannot control the market	Active	***	Team A Consulting
accpet this risk	Active	***	Team A Consulting
ensure detailed design is done as early as possible and thoroughly checked by a number of engineers	Active	***	Team A Consulting
complete design and details of design in early stages of project	Active	***	Team A Consulting
accept this risk	Active	***	Team A Consulting
ensure that there are no indescrepancies in legal contracts	Active	***	Team A Consulting
use latest noise pollution reduction techniques	Active	***	Team A Consulting
complete EA as early as possible if needed	Active	***	Team A Consulting
have thorough understanding of Environmental requirments well in advance	Active	***	Team A Consulting
complete detailed construction cost early, and have multiple parties look over it	Active	***	Team A Consulting
accept this risk	Active	***	Team A Consulting
construction documents done early, and understood by all potential parites, contractor, subcontractors	Active	***	Team A Consulting
have safety plan in place prior to construction	Active	***	Team A Consulting
ensure that all deliveries are made well in advance prior to construction and are on the worksite	Active	***	Team A Consulting
work with labour crews that are supplied by firms with a good reputation, past business with UBC	Active	***	Team A Consulting
make sure schedule is completed early. Potential delays associated with potential charges	Active	***	Team A Consulting
if possible hire teams that have worked together in the past, have a strong management voice	Active	***	Team A Consulting
thorough understanding of all documentation / documents looked over by legal representation	Active	***	Team A Consulting
hire geotechnical engineer to do a geotechnical analysis of the land	Active	***	Team A Consulting
hire engineer specializing in anthropology to do analysis of the land	Active	***	Team A Consulting
ensure workers are satisfied / have a backup crew that you are able to call	Active	***	Team A Consulting
hire skilled and experienced construction managers	Active	***	Team A Consulting
proper waste and construction byproduct management	Active	***	Team A Consulting
proper waste and construction byproduct management	Active	***	Team A Consulting
have detailed waste water management plan	Active	***	Team A Consulting
ensure all who operate pipe are qualified	Active	***	Team A Consulting
have geotechnical engineer survey land to find areas which are potentially dangerous	Active	***	Team A Consulting
geotechnical analysis to get potential for sinkholes, it will be very low	Active	***	Team A Consulting
consult with Earthquake engineers to mitigate and ensure potential damage is minimal. high strength mate	Active	***	Team A Consulting
have consistent meetings with first nations throughout the life of the project	Active	***	Team A Consulting
Ensure that we obtain a calender of all events taking place on campus during consturction of roundabout	Active	***	Team A Consulting

Table 8: Risk Register (cont'd)

APPENDIX F: DESIGN STANDARDS & SOFTWARE

The follow design standards and software were used for engineering design and analysis of this project:

- Vehicle Traffic Modelling: Synchro 6
- Building Code: NBCC / BCBC
- Timber Design: CSA 086
- Concrete Design: CSA A23.3
- Kansas Roundabout Guide 2014
- FHWA Roundabout Information Guide
- BC Supplement to TAC Geometric Design Guide