

UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program
Student Research Report

Redesign of Chancellor Boulevard and Wesbrook Mall Intersection at UBC
Yue Lang, Angelina Mak, Ke Ning, Kening Peng, Nobuyoshi Torigoe, Zheru Yi
University of British Columbia

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Executive Summary

The current intersection of Chancellor Boulevard and Wesbrook Mall at the University of British Columbia is inefficient and does not support all modes of travel. A pedestrian sidewalk is missing on multiple sides of the intersection, and the intersection is difficult and potentially dangerous for cyclists to navigate. Therefore, the intersection is to be redesigned such that it meets the anticipated future demands, and be more safe and attractive for pedestrians and cyclists.

The proposed design consists of free-flow along the east and west directions, and a single stop sign at the south approach. This design was the most efficient when tested in Synchro and had the highest capacity, as well as minimizing construction work. This intersection is designed for a 25 year design life. If future demand exceeds the projection, the design makes it easy to install traffic lights at the intersection to compensate. The intersection design was modeled in AutoCAD and SketchUp, and analyzed in Trafficware Synchro.

The gateway design follows the theme of other recent First Nations installations on campus and elsewhere in Vancouver. It seeks to acknowledge the place of the Musqueam and their history in the area. The design is closely inspired by the cedar portals located in Stanley Park, carved by Susan Point, and consists of a wooden arch and sign supported by two concrete columns. The gateway will span the south approach, Wesbrook Mall, from the pedestrian island to the opposite curb. An outreach to engage with local artists to create the artwork on the piece is planned.

Based on the total load including the self-weight calculated from the volume and material properties, wind load, snow load, and any other relevant loads according to the local standard code, the gateway structure will be analyzed using SAP2000 to confirm the safety of the design.

The total pre-tax cost for the project is \$503,068. The cost breakdown is as shown: the permitting fee is \$20,125, the consulting fee is \$27,688, the material cost is \$204,915, the labour fee is \$64,032, equipment cost is \$7,800, and additional surcharges including 5% for bonding/insurance, 5% for mobilization and demobilization, 25% for engineering and construction management (considered separately from the consultant design fee), and 20% for contingencies.

The construction of the intersection will begin on May 1st, 2017 and will be completed on June 15th, 2017. The gateway will be installed once the intersection construction is finished and is expected to take place June 17th. The construction will be done during UBC's summer break in order to take the advantage

of a lower number of students and faculty on campus and to avoid high traffic flow during the regular semesters. During most of the construction phases, the intersection will not be accessible for pedestrians and the traffic. A detour will be provided through nearby neighbourhoods. By taking the advantage of low traffic flow during the summer, detoured traffic will not cause serious noise and traffic congestion.

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1 Introduction

1.1 Purpose and Scope

The purpose of the redesign the intersection of Chancellor Boulevard and Westbrook Mall is to design a new intersection which will be safe, attractive and efficient for not only vehicles but also for pedestrians and bicycles. The traffic growth rates will be determined for the intersection to accommodate anticipated future demands. The growth rate is based on growth on campus and other growth in the surrounding or connecting area.

The scope of the detailed design of the intersection of Chancellor Boulevard and Westbrook Mall including the following items:

- design criteria of the project
- a description of the key components of the design
- detailed design description which include the traffic analysis and safety analysis
- stormwater management for the intersection
- the standards and software packages used in the design
- technical consideration associated with the design
- final design layout for the intersection
- a draft plan of construction work
- schedule for the construction work
- structure and foundation design of the gateway
- an updated cost estimate and schedule
- stakeholder consultation and detailed management plan
- recommendations for environmental impact

1.2 Site Overview

The intersection of Chancellor Boulevard and Wesbrook Mall is an important point of access to UBC. Wesbrook Mall is a main road within UBC campus which connects residences to UBC properties, such as the Walter Gage Apartments, the UBC Hospital, and the UBC bus loop. Chancellor Boulevard is a road which connects with 4th Avenue, which is one of the four east-west roads that provide access to UBC from Vancouver.

1.3 Background

The current intersection of Chancellor Boulevard at Wesbrook Mall is inefficient and does not fully support all modes of travel. On the east of Chancellor Boulevard, there is a University Hill Elementary School. Current intersection does not provide a safe crosswalk for pedestrians. Therefore, it will be significant children who will cross this intersection. Cyclist is not safe at exit of Wesbrook Mall turning to the east of Chancellor Boulevard.

A preliminary design report has been delivered by the consulting company. The detailed design for this new intersection is included in this final report. A welcome sign structure and foundation have been designed as a UBC gateway, which is located crossing the intersection. The detail design was prepared by using the traffic data which was provided by the client, UBC SEEDS Sustainability Program, and the UBC Transportation Plan. City of Vancouver targets to have 12% of trips to be made by bike by 2040. Pedestrians and cyclists are major component of this intersection design.

1.4 Project Description

The intersection is to be redesigned such that it meets the anticipated future demands, and to be more safe and attractive for pedestrians and cyclists.

The safety analysis for the intersection is a major component in the design. The speed of the vehicle, pedestrian and cyclist safety, sight lines and crossing condition for pedestrians are also will be analysis for the design of the intersection. Current intersection does not provide adequate vision for vehicles coming from Wesbrook Mall turning right into the Chancellor Boulevard, and vehicle coming from westbound of Chancellor Boulevard turning left into Wesbrook Mall. There is no bicycle lane on the Wesbrook Mall turning into west of Chancellor Boulevard, and after turning into the Chancellor Boulevard, the cyclist needs to change from the left lane to the right lane on the Chancellor Boulevard.

Currently, the intersection of Chancellor Boulevard at Wesbrook Mall is an entrance to UBC, but there is no gateway structure representing this. A gateway design has been included as part of the scope of this report.

2 Design Criteria

2.1 Design Criteria

The design of the intersection and gateway structure is designed to meet all regulatory requirements. The intersection and gateway structure have considered all design constraints. The list of the design constraints, design life and regulatory considerations are listed below.

2.2 Design Constraints

The intersection of Chancellor Boulevard and Wesbrook Mall has several issues and constraints that need to be considered. Those issues and constraints include the technical, economical, environmental, construction planning, and social aspects. Regulations for designing the intersection and gateway structure are also have been considered.

2.3 Technical Aspects

The current intersection of Chancellor Boulevard at Wesbrook Mall is inefficient and does not fully support all modes of travel. The current intersection does not provide a safe crossover for pedestrians, which are especially significant for children who cross the street. In addition, cyclists are not safe entering the intersection at Wesbrook Mall to turn right onto Chancellor Boulevard. There is no bicycle lane on the Wesbrook Mall turning west onto Chancellor Boulevard, and after turning onto the Chancellor Boulevard, the cyclist needs to change from the left lane to the right lane on the Chancellor Boulevard. Since the City of Vancouver targets to have 12% of trips to be made by bike by 2040, pedestrians and cyclists are a major safety component for this intersection design. The traffic growth rates will be determined for the intersection to accommodate anticipated future demands. The traffic growth rate is based on growth on campus and other growth in the surrounding or connecting area. The

current speed limit for the chancellor boulevard is 50 km per hour. The intersection needs to be designed to accommodate the current speed limit. The speed of the vehicle, pedestrian and cyclist safety, sight lines and the crossing condition for pedestrians will also be analyzed for the design of the intersection. A collision point analysis have also been provided in the following report.

An important consideration for the gateway structure was the size, in order to accommodate decorative artwork. All load combinations have been checked, and a foundation design has been provided.

2.3.1 Economical Aspects

The budget for this project is limited, therefore, we need to design an intersection with a reasonable budget that meets all the requirements. A Class C cost estimate for the implantation of the intended detailed design, which has included the permitting, project management and construction, also the annual operating and maintenance cost, has been provided in Section 5.

2.3.2 Construction Aspects

The Chancellor Boulevard and Westbrook Mall intersection is a major intersection that connects UBC to the city of Vancouver. The traffic volume for this intersection is significant. To minimized the impact on the traffic delay, a suitable construction plan has been prepared for this intersection.

2.3.3 Social Aspects

The final report also must include a stakeholder engagement plan. The stakeholder engagement plan is for the communities that are going to be affected by the intersection design. The property line will also be considered when designing the intersection. Since this area is owned by University Endowment Lands, which occupies the traditional unceded territory of the Musqueam people, the gateway structure includes a plan to for commissioned Musqueam designs to reflect that.

2.3.4 Environmental Aspects

A rain garden has been included in the design to improve stormwater management. Rain gardens can use the natural resources to process the stormwater and can protect water quality and associated aquatic habitats by minimizing pollutants that reach the storm sewer system.

2.4 Design Life and loading

The design life for the intersection will be 25 years. The life span of asphalt will be about 20 years; however, regular maintenance can increase the life span of the asphalt road. The gateway structure's life span is about 50 years.

For the intersection, the intersection needs to be accommodate current and future traffic volume that entering the intersection. For the gateway structure, we have considered the self dead load, wind load and seismic load combination to the structure.

2.5 Regulatory and Software packages

The following documents have been used for designing the Chancellor Boulevard and Westbrook Mall intersection:

- BC Supplement to TAC Geometric Design Guide 2007 Edition
- Geometric Design Guide for Canadian Roads (TAC)
- A Policy on Geometric Design of Highways and Streets (AASHTO)

The following documents have been used for designing the UBC gateway structure:

- National Building Code of Canada (2005)
- Terzaghi's Bearing Capacity Theory

- Handbook of Steel Construction (10th ed.) (CISC)
- Concrete Design Handbook (CSA guideline)

Software packages that were used in this design:

- AutoCAD
- SketchUp
- Synchro
- SimTraffic
- SAP2000

3 Design Description

3.1 Intersection Design

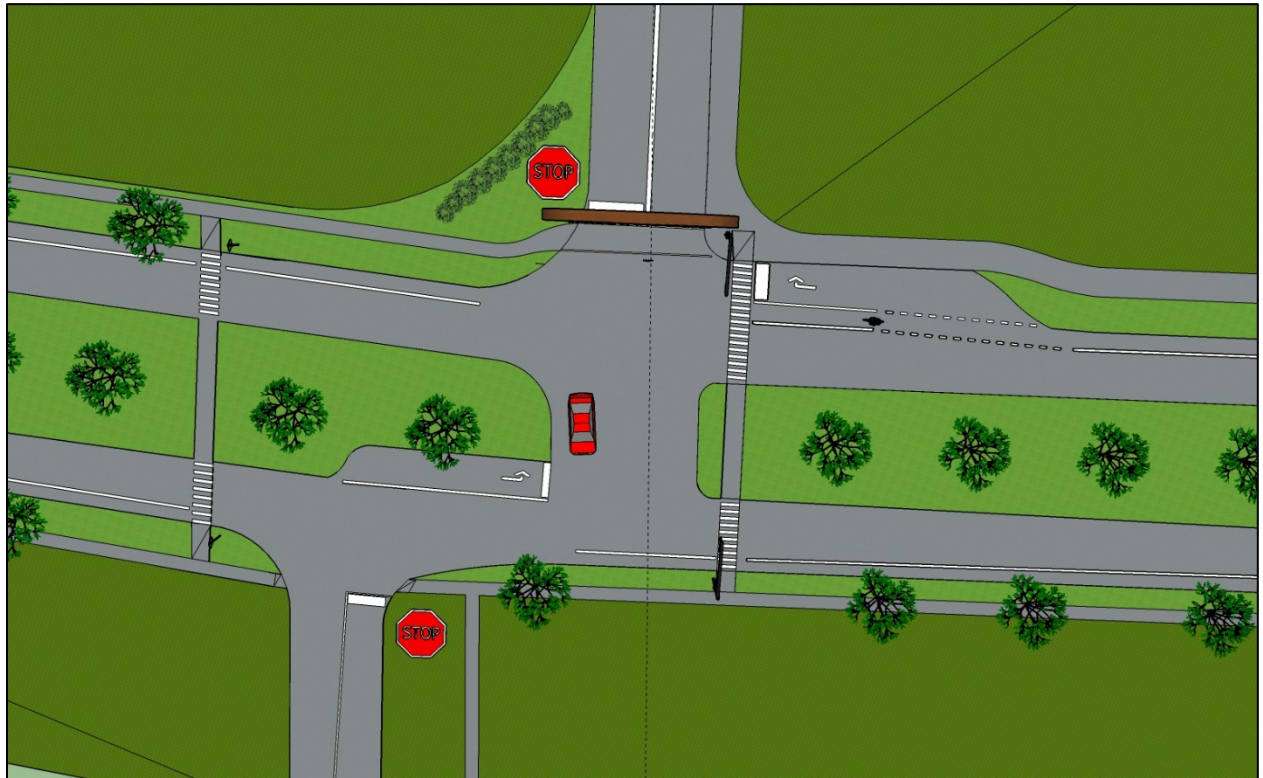


Figure 1: Top-down view of design

The proposed design consists of a single stop sign placed on the south approach from Wesbrook Mall and free flow on the east and west approaches along Chancellor Boulevard. A median allows left turning cars and cyclists from the south approach an easier turning maneuver and prevents cars turning left from Chancellor Boulevard onto Wesbrook Mall from blocking through vehicles. Additional storage lanes for left turn and right turn volumes are added to increase capacity. An additional pedestrian controlled crosswalk is provided on the west side of the intersection. The existing crosswalk east of the intersection was considered sufficient for pedestrian traffic on the east side of the intersection, with an added pedestrian crossing sign to enhance safety. The gateway spans the Wesbrook Mall side of the intersection, welcoming visitors from both directions of Chancellor Boulevard.

3.1.1 Traffic Analysis

The design was analysed using Trafficware Synchro and SimTraffic. The intersection was found to have an ICU Level of Service A. The average delay per vehicle over five simulation runs is summarized in the table below.

Table 1: SimTraffic Analysis Results

Peak Period	Average Delay Per Vehicle (s)
AM (8:15 – 9:15)	10.6
MD (11:30 – 12:30)	4.6
PM (16:30 – 17:30)	4.8

3.1.2 Safety Analysis

As a three-way intersection, the design has nine points of conflict, three of which are crossing. The inclusion of the median is hoped to reduce incidence of serious T-bone collisions by allowing left turning vehicles from Wesbrook Mall onto Chancellor Boulevard to focus on one approach at a time. In addition, providing a raised median has been proven to reduce pedestrian crashes by up to 46% at marked crosswalks (Federal Highway Administration, 2014).

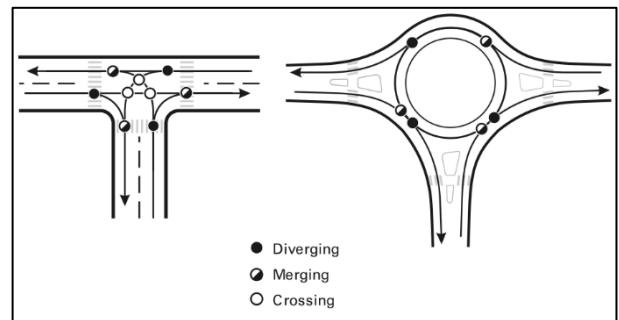


Figure 2: Collision conflict points: intersections vs. roundabouts; via The Federal Highway Administration

A pedestrian controlled signal installed at the west crosswalk increases pedestrian safety, especially in low visibility conditions where the driver may not be able to see the pedestrian.

3.2 Stormwater Management

The adjustment of the medians provides an opportunity to enhance the stormwater management in the intersection. The proposed design includes the construction of a rain garden in the medians, providing source controls for rainwater management.

The Simplified Rainfall Capture Method was used. The following assumptions were made:

- The road is 100% impervious
- Dry soil conditions were assumed (i.e. moisture content at wilting point).
- The capture volume is calculated as the sum of the following four factors:
 - Evaporation: (24-hour evaporation) x (surface area)
 - Growing Medium: (Volume of growing medium) x (Field Capacity–Wilting Point)
 - Rock Pit: (Volume of Rock Pit) x (Available Water Content)
 - Infiltration: (24-hour infiltration) x (surface area)
 - A post-development infiltration rate of 1.5mm/hour was assumed.

Detailed calculations for the input and capture volume can be found in the Appendix E. Table 2 below gives the volumetric reduction criteria for the University of British Columbia area.

Table 2: Volumetric Reduction Criteria

Volumetric Reduction Criteria		
2-yr, 24-hour rainfall	55.70	mm
72% 2-yr, 24-hour rainfall	40.10	mm
Intensity	2.32	mm/hr
72% DFO	1.67	mm/hr
	-	

Figure 3 below is a plan drawing of the on-site control measures

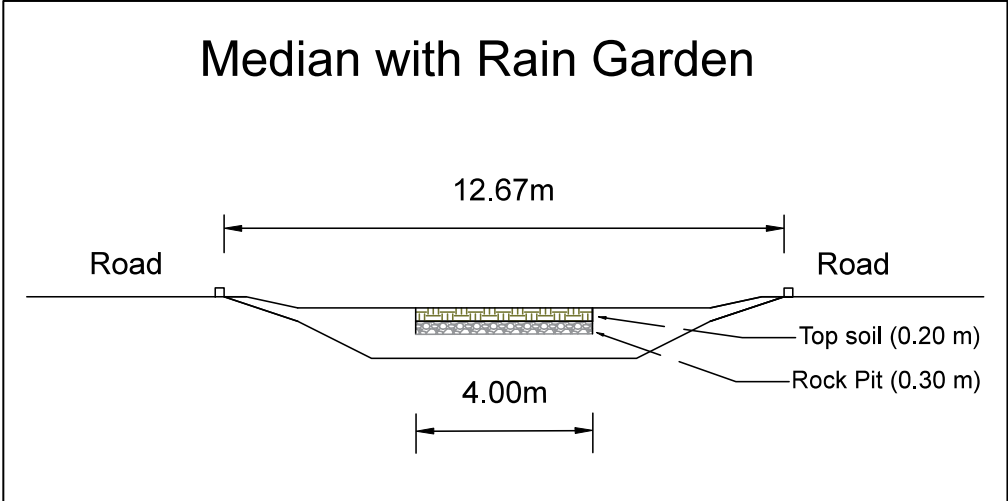


Figure 3: On-site Source Controls

3.3 Gateway Design



Figure 4: Gateway Render

Figure 4 above shows the location of the UBC gateway. The gateway design consists of a simple wooden arch structure supported by two wooden columns. A wooden sign runs across the base of the arch. The gateway design is intended to bear artistic work from an artist chosen from the First Nations community, to be discussed following community consultation at a later date.

3.3.1 Structural Design and Analysis

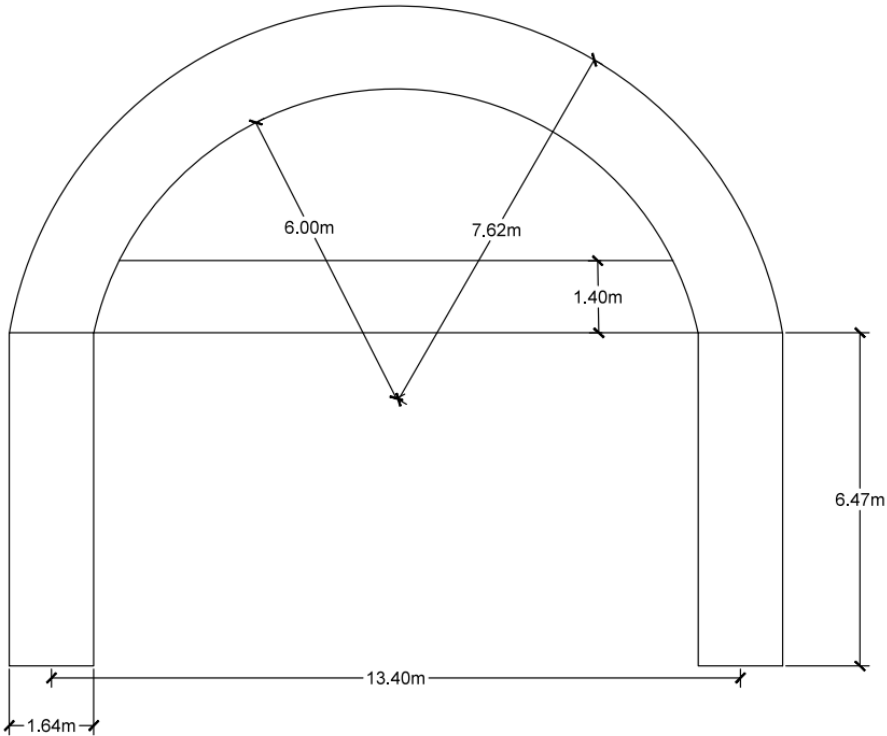


Figure 5: Gateway Structure

The gateway structure includes two columns and one arch beam. To ensure and check that all minimum requirements are satisfied, self-weight, earthquake load, and wind load are assumed to be applied on the structure. The structure with all load applied could be analyzed and therefore checked by SAP2000.

The material of gateway structure consists of 4000PSI Light Weight concrete and wood. In order to minimize the self-weight of the structure, the arch beam and UBC sign are designed to use wood. To support all loads and ensure the stability, the column has to be reinforced concrete. The earthquake load and wind load are added based on NBCC 2010 Standard.

Table 3: SAP2000 Structural Analysis Results

Maximum Reaction Force	217 KN
Maximum Shear Force	25.85 KN
Maximum Moment	111 KN*m

According to the result from SAP2000, the weakest part of the structure is the moment resistance of the column which has to undertake 111KNm moment. As a result, the column is designed as 1.6 m wide and 0.87 m depth with 5 35M reinforcing rebars in both directions. To release the moment, one joint is simply pin supported and the other one is fixed. The reactions at two joint are 205 and 217 kN respectively, and therefore the foundation with footing could be determined. With all designed loads and materials applied on the structure, SAP2000 checked that all structure properties satisfied the minimum requirements.

3.3.2 Column Design

From the architectural requirement, the column needs to be 1640mm in length, 870mm wide, and 6.47m tall. The maximum factor load is 217.62 KN, and maximum factored moment is 111.49 KN.m . Minimum steel reinforcement area is determined to be 16000 square mm. Therefore, we decided to install 16- 35M. By checking the slenderness ratio, we changed factored moment to magnified factored moment. From the integration diagram, the column can fully support the magnified moment and factored load from the SAP 2000 result.

The minimum clear cover for the exposure concrete surface needs to be 40mm, and the maximum longitudinal rebar spacing for concrete column is 500mm. The minimum longitudinal rebar spacing needs to be 50.4 mm from the calculation. Therefore, there will be 5 rebars in length with 373.75 mm spacing and 40 mm clear cover on each side. There also 5 rebars in the width direction with 181.25 mm spacing and 40 mm clear cover. The tie size in this column is 15M. The maximum tie spacing in the column is 300mm. Therefore, the tie reinforcement is 15M with a spacing of 300mm.

Sample calculations for the column design can be found in Appendix C.

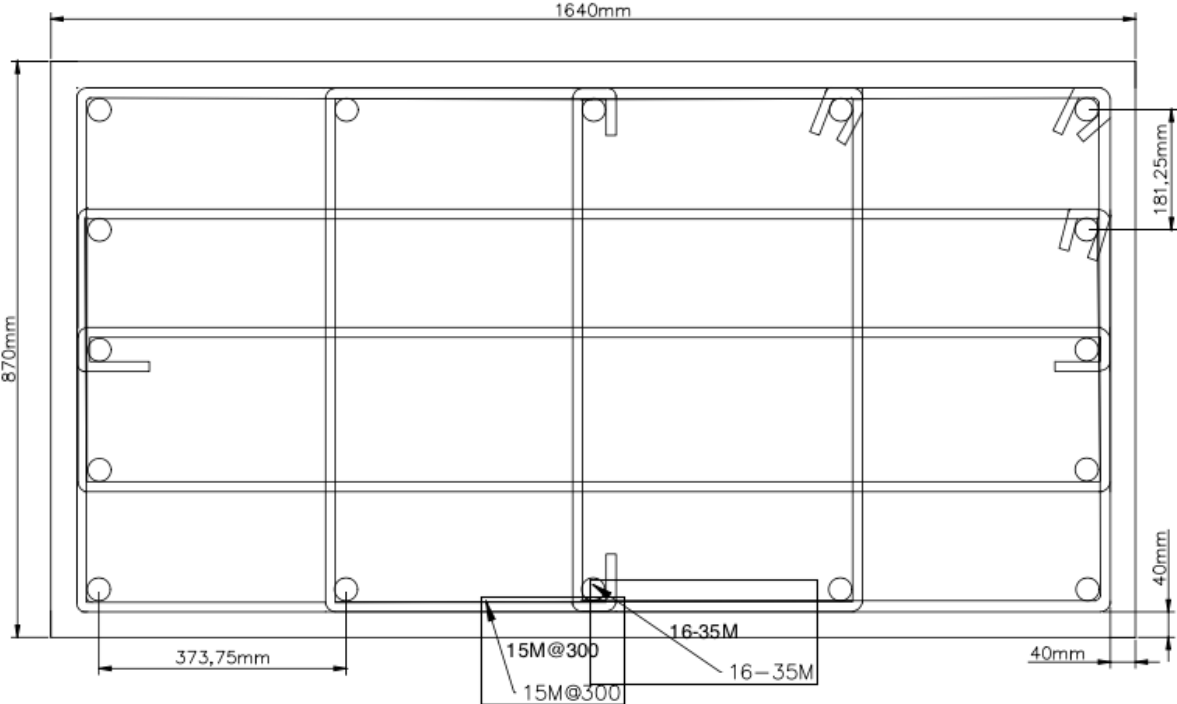


Figure 5 Column Specification

3.3.3 Foundation Design

Since the structural load given by the gateway design is not over 2000 kg, the soil near the surface is capable for supporting the gateway. A shallow foundation is a very good choice for the gateway design

based on the structural load and soil condition. Three general types of shallow foundation are used in construction: strip footing, pad footing, and raft footing. Based on our design, the structural load is been transferred to soil by two-point load, and therefore pad footing is the best choice here. Two pad footings should be built for supporting structural load, each with a width and length of 2.5 m. The pad footing is buried 1.5 m below the surface. The structural load given is 422 KN and the pressure given to each footing is about 33.76 kPa, By simply applying Terzaghi's Bearing Capacity Theory to the pad footings, the ultimate bearing capacity is calculated to be 1164.6 kPa, which is much greater than the loading pressure. Before setting the foundation, the soil needs to be consolidated to avoid significant settlement or the gateway design.

For shear reinforcement, the factored shear force at critical section is calculated to be 1.9KN/m, and the shear resistance at critical section is about 600 KN/m, so no shear reinforcement is required.

For flexural reinforcement, the factored moment at critical section is calculated to be 28 kN*m/m, thus the required area of flexural reinforcement is calculated to be 136 mm²/m. With the minimum requirement of the reinforcement is 2500 mm²/m, so the reinforcement area is set to be 2500 mm²/m. The reasonable spacing for rebar is about 400 mm.

The foundation dowel for column is used for making installation of preassembled reinforcing bar cages easier.

Assumptions made:

- Soil type: sand
- Friction angle: 38 degrees
- Water table: below foundation.
- $N_r = 67$, $N_q = 49$.

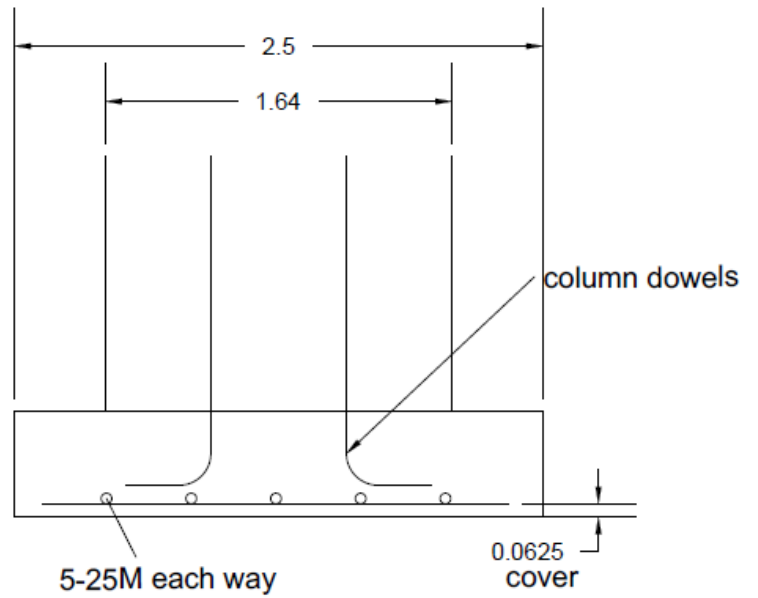


Figure 6: Foundation Front View

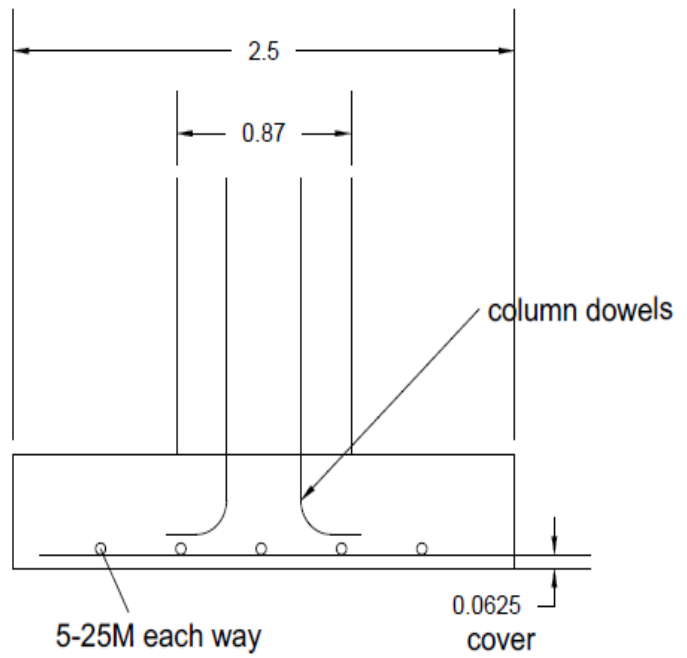


Figure 7: Foundation Side View

4 Construction Plan

The construction of this project will begin on May 1st, 2017 and will be completed on June 15st, 2017.

The construction will be done during UBC's summer break in order to take the advantage of a lower number of students and faculty on campus and to avoid high traffic flow during the regular semesters.

The intersection will be fully closed to pedestrians and the traffic during the entire construction period in order to reduce the construction duration and ultimately the project cost. A detour will be provided through nearby neighborhoods. By taking the advantage of low traffic flow during summer, detoured traffic will not cause serious noise and traffic congestion.

4.1 Project Work Breakdown

Our approach for the schedule was predicated on an estimated construction duration of 46 days, consisting of 8-hour work days. The estimates of individual activities (as referenced by the work breakdown) are based on the best judgment and knowledge. A detailed work breakdown and a schedule including different construction phases, sub-activities and associated periods of time are provided in Appendix B.

In general, work included in the Work Breakdown Schedule is organized by a top-down approach, like the Work Breakdown Structure. For example, the overall execution of Task 1.2: Removal and Demolition is allocated to the project manager. Individual tasks with lower hierarchy, such as Task 1.2.2: Removal of Underground Utility Pipes would be executed by, for example, the project manager assistant. The approach and plan for execution of work, therefore, is discretized into individual activities to avoid confusion, streamline processes, and clarify responsibility.

The schedule has been set up with tasks organized mainly sequentially since only a limited working space can be provided on the intersection. Thus, heavy construction tasks should not be overlapped with each other in most cases to keep enough space for construction activities and on-site storage.

In order for the project to stay on schedule, it is very important to closely monitor the times for each sub-section. As can be seen on the schedule, most of the tasks are allocated on the critical path of this project which means that if at any time the tasks within the sub-sections start to be delayed, certain sequential tasks will be delayed as well. Therefore, any activities that assume higher probability of risk and delays are given an appropriately increased duration, and scheduled accordingly to optimize float. It is also very critical to ensure that all the sub-constructors will complete their tasks on time and a smooth transition can be made between each sub-section.

A short-term schedule is very necessary for this project. As mentioned before, any off-set of sub-sections will potentially cause a delay of the whole project. Therefore, the manager should hold a weekly meeting to track the progress, and update the short-term schedule immediately. All sub-contractors affected will then be notified immediately.

4.2 Traffic Management Plan

During the construction period, detour routes will be provided to take traffic around the construction site. Temporary warning signs, road markings, lighting, safety barriers and traffic controllers will be provided in order to maintain public safety at all times, and to provide user with advanced warning of impact and direct them to alternative routes. The detour map for public traffic is provided in Appendix B.

4.3 Construction Safety Management

The construction process places a strong emphasis on the safety of not only workers, but also on the public, wildlife, environment, and adjacent infrastructure. Construction projects pose new hazards to people and things that change on an hourly basis. There must be strict and monitored safety measures in place to ensure that not one person or thing is harmed through the process of construction. The fact that the construction site is close to residential area also generates a potential safety risk on nearby residents. Safety management for this project is of importance and should not be overlooked.

The project supervisor, project safety representative or any other project member who will be in some sort of leadership role onsite should have a strong grasp on all safety measures and concerns for all stages of the project. Safety should be monitored and reported on by the supervisor every week ensuring if more adequate safety measures need to be attained.

The safety of the workers and the public is of grave importance and can be managed appropriately with the given safety management tasks. A safety management guide for different phases of the project is provided in Appendix B.

5 Cost Estimate

The following section details the cost management with regard to the redesign of Chancellor Boulevard and Wesbrook Mall Intersection. Special attention is given to the construction phase of the project.

The project cost estimate is projected from relevant information or data, using the best judgment, past experience, simple mathematical calculations and historic data. The level of the estimate for this report roughly follows a Class C level estimate. The project definition is in the range of 5-15%. The quality of the project cost estimate is, for all intents and purposes, accurate to within 20%.

However, the quality of project cost estimates is subjected to a variety of factors such as the current economic situation of the project. These factors can greatly influence the quality of project costs estimates. Furthermore, related component pieces are estimated to the best of our ability.

Table 4: Cost Summary

Item `	Cost (\$CAD)
Permit Fees	20125
Project Consulting Fees	27688
Material Cost	204915
Labour Cost	64032
Equipment Cost	7800
Additional Surcharges	178508
Total cost	503068

5.1 Project Cost Plan and Cash Flow Analysis

The grand total estimate for the project is approximately \$503,068 (CAD, 2017). This includes permitting fee, consulting cost, construction cost, maintenance cost, and a contingency of 20%. The cost estimate was based on a construction schedule of 46 working days, with 8 hours of work completed each day. Additional surcharges added to the cost estimate included 5% for bonding/insurance, 5% for mobilization and demobilization, 25% for engineering and construction management (considered separately from the consultant design fee), and 20% for contingencies. An additional \$7,500 in maintenance is expected to be incurred over the 25-year lifespan of the project.

5.1.1 Permit Fees

Since the construction site is at an intersection, occupation permit is absolutely needed for the construction. This is required by the government for any constructions occupancy, electricity use, trees removal, etc. The permit fee depends on the duration of the construction and the size and complexity of the project. The construction duration is about 46 days (from 1 May to 15 June 2017), and the length of the road for construction is about 70 meters. With the unit price, the total permitting fee is estimated to be about \$20,125. For details please refer to Appendix E.

5.1.2 Project Consulting Fee

Based on the standard hourly rate and total working hours, consulting cost of the Chancellor Boulevard/Westbrook Mall Intersection project is estimated to be \$ 40,000. The minimum estimated cost for basic consulting services is \$ 34,000. However, consultants and technical services with further professionals are highly recommended, and thus the suggested estimated cost is \$ 40,000.

In order to complete the consulting service and submit the preliminary report by the date of November 28, the group of UBC engineering students (E1) will be working 30 labor working hours per week, and

the total amount of working hours is estimated to be 240. The number of hours for basic technical services (T1) is suggested to be a total of 10 hours. According to the standard rate of \$ 121 per hour for E1 and \$ 101 per hour for T1, the total cost before tax is therefore \$ 30,050. In addition, an 8% disbursements charges will be added, which covers all local travel and communication expenses, production of drawings and documents, and computer and software costs. As a result, including 5% goods and services tax (GST), the minimum consulting cost is calculated to be \$ 34,000. With strong recommendation, consultants with specialization shall be hired to supervise the work. A specialist engineer (E4) with average 2 working hour per week will be considered. It is also suggested to include T4 Technologist with a total of 10 working hours. With the standard hourly rate of \$ 195 for E4 and \$ 144 for T4, a total cost of \$ 4,560 is added. With 8% disbursements fee, the total consulting cost is \$27,688.

5.1.3 Maintenance Cost

A major roadway component is made of asphalt at the top surface, and concrete beneath the asphalt. The life span of asphalt for a new road is typically about 20 years. Because the road is suffering the freeze-thaw cycle damage every year, road condition should be checked at least once a year by City of Vancouver in order to maintain a good condition. If preventative measures are taken usually, the road could last about 50 years. If preventative measures are not executed very well, a road base may only keep working for only 25 years. A usual maintenance fee for such a small intersection should not exceed \$250 per year. By increasing the maintenance fee to \$300, we can assume the road is not under taken preventative measures, thus it can last for 25 years. In total, a 25 years maintenance fee is about $25 \times 300 = \$7500$.

6 Additional Recommendations

The following recommendations have been provided for consideration as the project moves from design to construction phase:

6.1 Environmental Impact Analysis

The most negative environmental impact for this project would be the construction process. The major negative impact will be the construction waste and noise. For reducing the construction noise, All construction equipment should achieved noise emission standard outlined in the Ministry of Environmental guidelines. During the construction, recycled aggregate is used to reduce the carbon footprint. During the construction, a tree protection zone is required by the UBC Technical Guidelines and the construction should not cross the tree protection zone.

The rain garden provides a positive impact to the site by using natural resources to process the stormwater. Rain gardens reduce pollutants from the road from reaching the storm sewer system.

6.2 Detailed Traffic Forecast

The traffic volume projections used in the Synchro models was fairly simplistic, using a multiplier to current volumes equal to increase in projected population. Information from a more detailed regional 4-step transportation model would provide more accurate traffic projections and therefore a more accurate traffic simulation model to ensure that the design provides adequate .

6.3 Risk Analysis

The following table shows the risks that have been identified, and the corresponding responses and recommendations to mitigate or eliminate the risks are given.

Table 5: Risk Register

Risk #	Description	Response
1	Gateway structural failure caused by wind, earthquake, and self-weight load.	Avoid by taking all load applied into consideration. Check all loads according to the codes to ensure the stability.
2	Storm water (rain garden) management failure	Avoid by correctly expecting the local rainfall to ensure the total volume of rain garden.
3	Schedule delays	Mitigate the risk by assigning more float to high risk activities. Ensure the critical path has sufficient redundancy.
4	Cost underestimate	Avoid by accurately calculating all number of material, equipment, labour, etc. Add a 20% contingency.
5	Construction noise to local residence	Mitigate by working at the appropriate time.
6	Traffic congestion caused by intersection inefficiency.	Minimize by ensuring performance of the intersection. Correctly calculate the current and expected traffic volume.
7	Injury	Avoid risk by ensuring that construction contractor is reputable, and follows site specific safety plan. Make a safety management plan to regulate the construction activities.

The risks above were evaluated in a risk matrix as shown below, incorporating the appropriate mitigation strategies.

Table 6: Risk Matrix

Probability	Almost Certain					
	Likely	5				
	Moderate		3	4		
	Unlikely			6		
	Rare				7	1
		Negligible	Low	Medium	High	Extreme
		Impact				

6.4 Stakeholder Consultation and Detailed Management Plan

6.4.1 Stakeholder Identification

The following stakeholders have been identified:

UBC SEEDS:

UBC SEEDS is the client and owner for this project. The project must meet their specifications and satisfaction to proceed.

UBC CIVL 445 Team 15:

The project design team, UBC CIVL 445 Team 15, is responsible for the redesign of the intersection, which is expected to be a resolution to current issues. Therefore, an effective report including a sufficient work plan will be provided by the design team. Generally, the team's work basically determines the performance of the new intersection.

UBC students and faculty:

UBC students and faculties are the major beneficiaries of the project since they use the intersection most. Due to the significant increase in efficiency and safety of the intersection, the traffic congestion and potential accident could be effectively avoided especially in peak hours. For those who do not drive, the new intersection becomes more considerable. Moreover, UBC department of safety is able to reduce the cost of repairing and maintenance.

Public and general road users:

Similar with the previous stakeholder, the public and other general road users could also benefit from the project and be protected from potential risks. In addition, the gateway sign clearly shows the location for those who are not familiar with the local area.

Neighbourhood:

People living in the surrounding area will be influenced by the construction. As a result, the impact on neighborhood and inconvenience should be minimized during construction. However, once the project is completed, they are also able to benefit from the new intersection such as the low risk, high efficiency, and convenience. Furthermore, all related occupancies should be permitted by the surrounding area. The University Neighbourhood Association will be considered as a representative of the community as a whole.

Ministry of Transportation and Infrastructure:

The Ministry of Transportation and Infrastructure is the owner of the intersection and is responsible for transport infrastructure and law in the Canadian province of British Columbia. All design and construction plan involved in the project should meet the requirements and criteria ruled by Ministry of Transportation and Infrastructure.

City of Vancouver:

City of Vancouver is highly concerned about the efficiency and risk of the intersection. With the increasing number of traffic volume, the government hopes that the intersection could be improved to be safer and more efficient.

TransLink:

Due to the inconvenience, TransLink should adjust the bus schedule and route during the construction time. Once the project is finished, they could benefit from the high efficiency of the new intersection.

Construction company/sub-contractor:

They provide labor service, site survey, materials, and equipment. Thus, they are responsible for all construction working. They have to insure the safety of neighbor, the safety of worker, and the quality of material. Obviously, these companies could finally gain profit from the project.

Media:

The general media is able to inform public via newspaper, internet, and social media. Those positive information could gather more concerns form public.

First Nations communities

The project takes place on the University Endowment Lands, which consists of unceded First Nations territories. It is important to engage the First Nations communities in any projects that take place here.

An initial open house available to all community members who wish to learn more about the project will be set for the week of April 19. Once preliminary feedback has been gathered, further community consultation and engagement plans will help the project move forward.

Table 7: Stakeholder Register

Number	Stakeholder	Location: Internal/External (I/E)	Role in Project	Current Status	Influence level: High/Medium/Low (H/M/L)	Power level: High/Medium/Low (H/M/L)	Stakeholder Management Strategies
1	UBC CIVL 445 Team 15	I	Design team, providing report and work plan	Supportive	H	L	Keep informed
2	UBC students and faculties	E	Major beneficiary who concerns the project most	Supportive	H	M	Manage closely
3	Public and general users	E	Road user, beneficiary	Neutral	M	L	Monitor
4	Neighborhood	E	Beneficiary but impacted by construction	Supportive	H	L	Keep informed
5	Ministry of Transportation and Infrastructure	E	Owner of the intersection, proving all requirements and criteria	Supportive	H	H	Manage closely
6	City of Vancouver	E	Government	Supportive	L	H	Keep satisfied
7	Translink	E	Adjust schedule and route	Neutral	M	M	Keep informed
8	Construction company/sub-contractor	I	Construction working, material and equipment supplier, providing labor	Supportive	H	M	Manage closely
9	Media	E	Inform public any concerns related	Neutral	L	M	Keep satisfied
10	UBC SEEDS	I	The client	Supportive	H	H	Manage closely
11	First Nations	E	Project takes place on unceded University Endowment Lands	Neutral	M	L	Keep satisfied

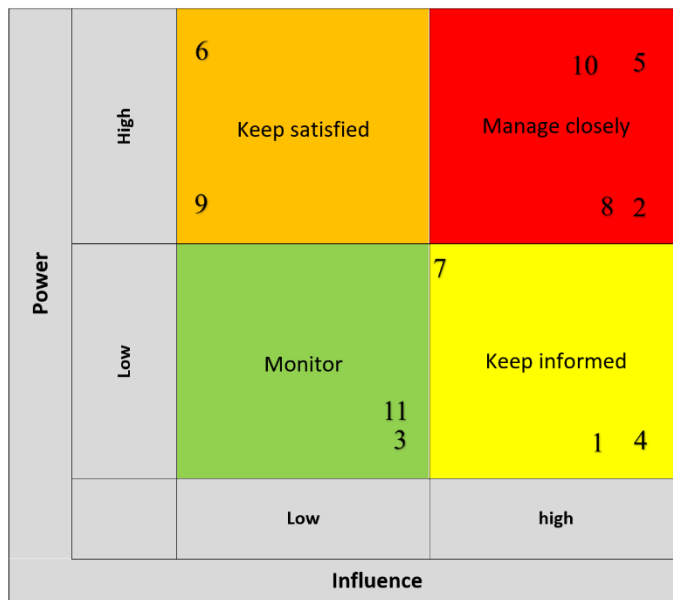


Figure 8: Stakeholder Matrix

7 Conclusion

To summarize the design: the redesigned intersection consists of a one-way stop, with the single stop sign placed on the south approach to the intersection. Additional elements of the design include left and right turn storage bays and an additional crosswalk with pedestrian controlled crossing lights. The design provides a safe and attractive travel path for pedestrians, cyclists, and vehicles alike. The median is designed as a rain garden for the intersection which will control the stormwater. The design life for the intersection is 25 years. The gateway structure is comprised of two reinforcement concrete pillars supporting a wooden arch. The sign is attached separately from the arch. The pad footing is selected for gateway structure. The traffic safety and capacity of the designed intersection was analyzed using the Synchro and the gateway capacity has been checked by SAP 2000. The layout of the intersection and gateway was drawn with SketchUp and AutoCAD. The construction work will start on May 1st, 2017, and finishes on June 15th 2017, which coincides with UBC's summer break. The intersection will close during the construction and the construction work plan includes a detour path. The estimated cost of the project is \$503,068

8 References

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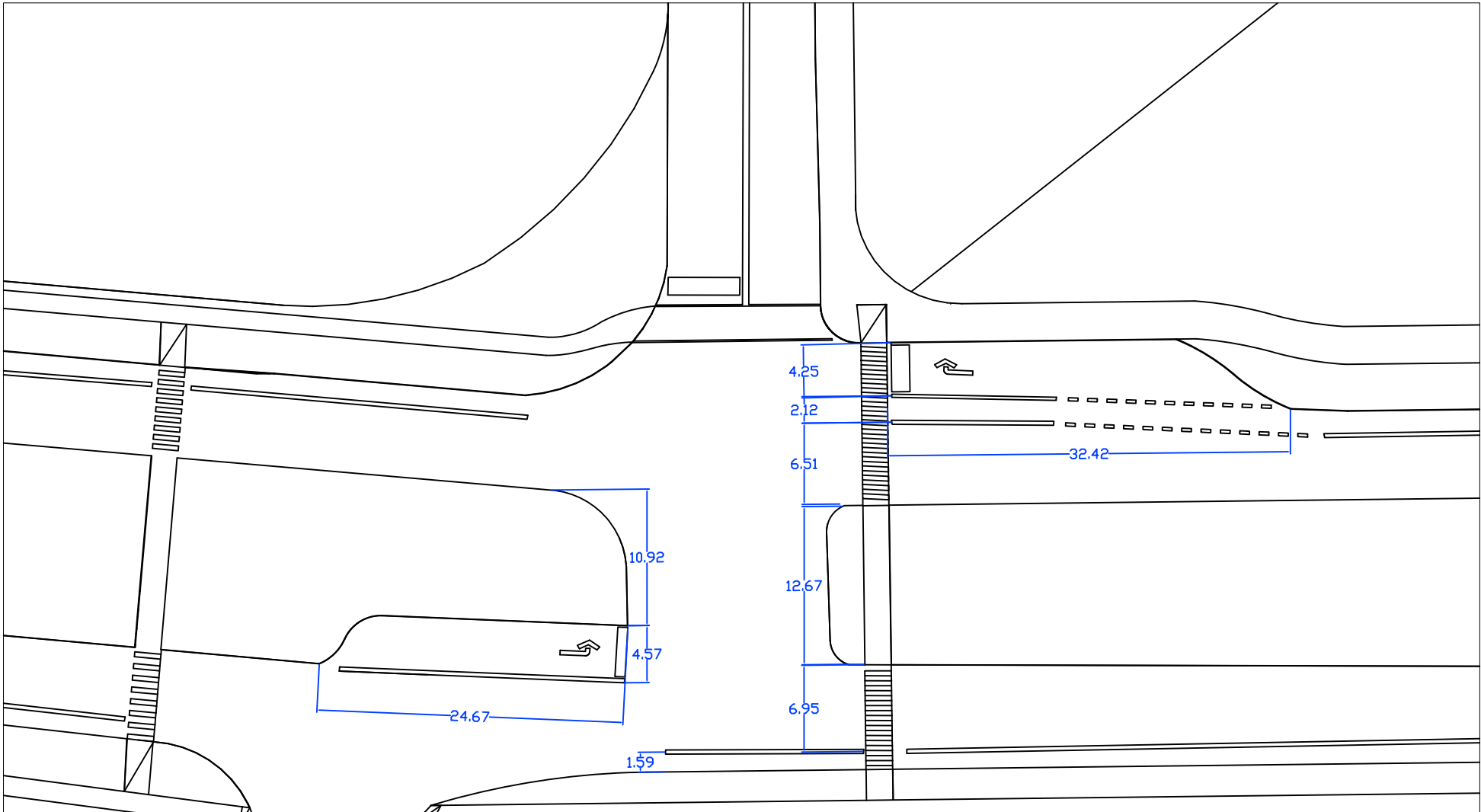
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Appendix A: Design Drawings

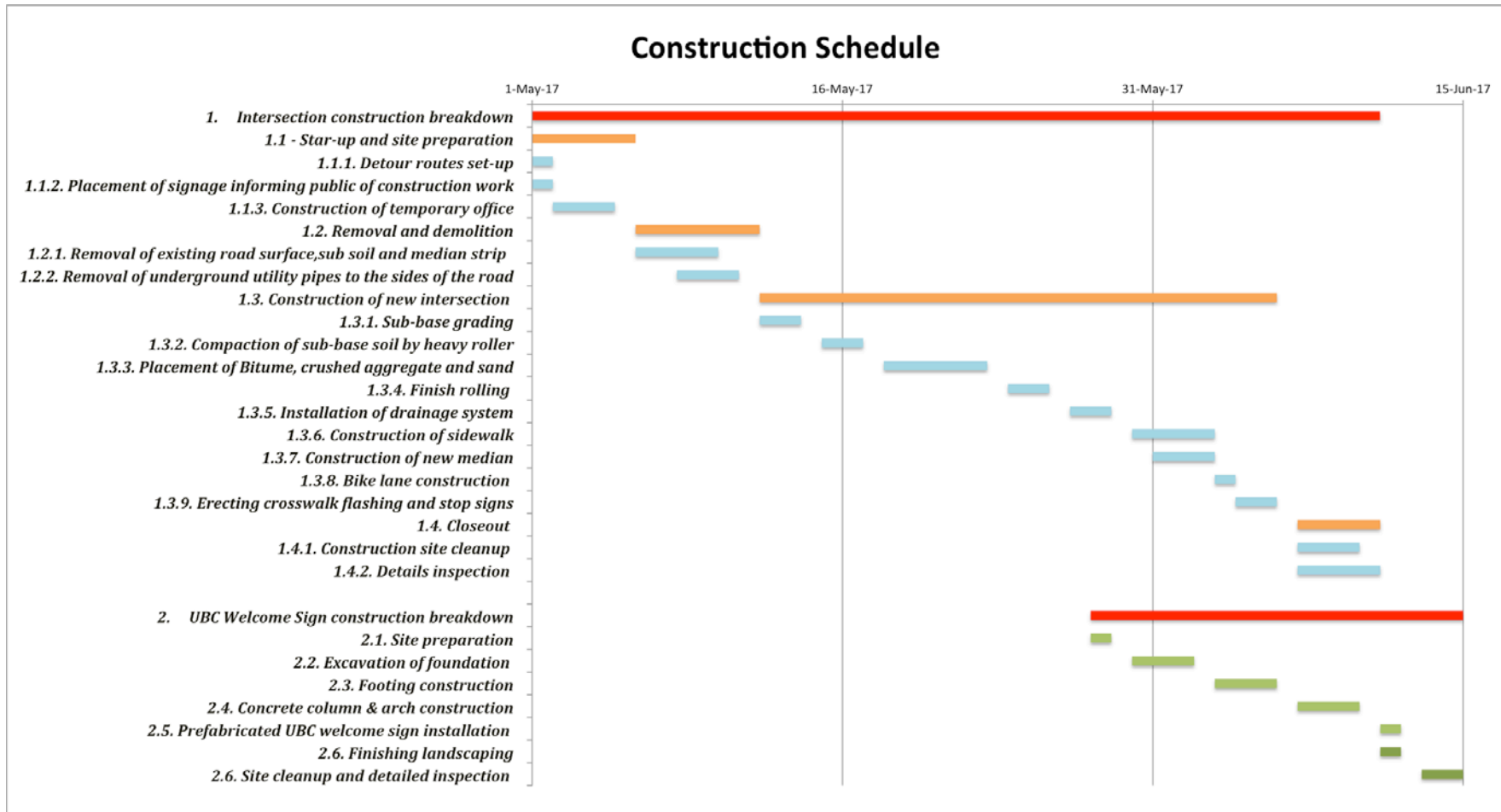


All units in metres

Drawn By: Angelina Mak	Team 15
Date: 04-06-2017	Drawing No: A-1
Drawing Title: Intersection Dimensions	
Project: Chancellor Boulevard and Wesbrook Mall Intersection Redesign	

Appendix B: Construction Work Plan

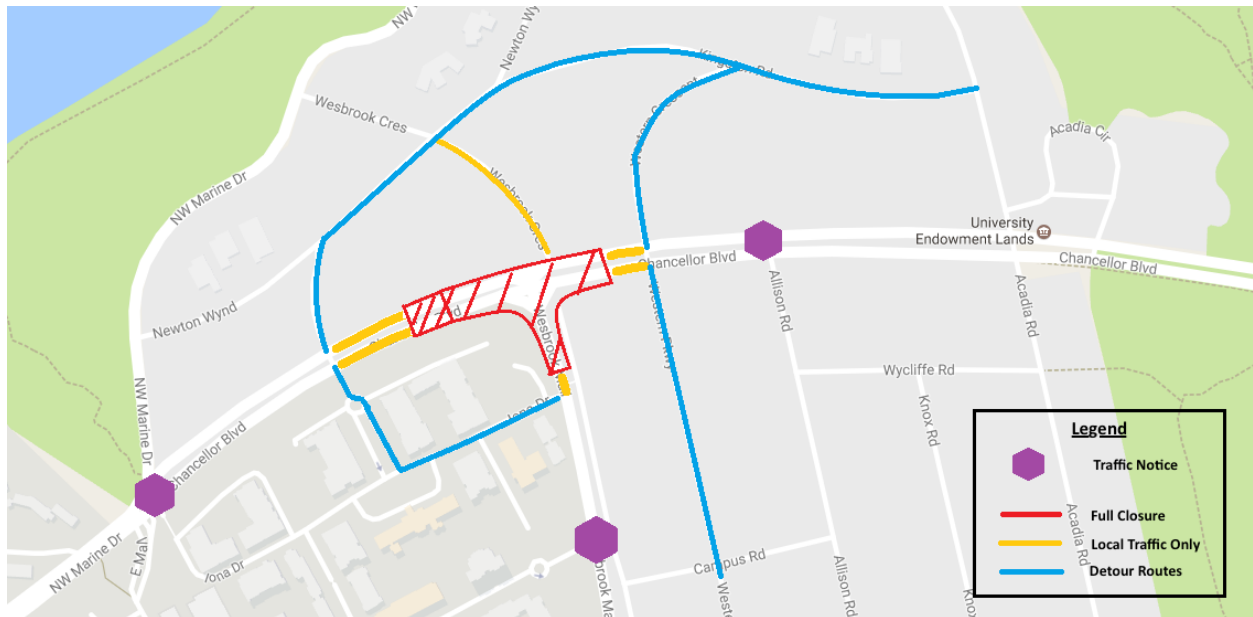
B-1 Construction Schedule



B-2 Work Breakdown

	Start date	Duration(days)	End date
1. Intersection construction breakdown	1/May/17	41	11/Jun/17
1.1 - Star-up and site preparation	1/May/17	5	6/May/17
1.1.1. Detour routes set-up	1/May/17	1	2/May/17
1.1.2. Placement of signage informing public of construction work	1/May/17	1	2/May/17
1.1.3. Construction of temporary office	2/May/17	3	5/May/17
1.2. Removal and demolition	6/May/17	6	12/May/17
1.2.1. Removal of existing road surface, sub soil and median strip	6/May/17	4	10/May/17
1.2.2. Removal of underground utility pipes to the sides of the road	8/May/17	3	11/May/17
1.3. Construction of new intersection	12/May/17	25	6/Jun/17
1.3.1. Sub-base grading	12/May/17	2	14/May/17
1.3.2. Compaction of sub-base soil by heavy roller	15/May/17	2	17/May/17
1.3.3. Placement of Bitume, crushed aggregate and sand	18/May/17	5	23/May/17
1.3.4. Finish rolling	24/May/17	2	26/May/17
1.3.5. Installation of drainage system	27/May/17	2	29/May/17
1.3.6. Construction of sidewalk	30/May/17	4	3/Jun/17
1.3.7. Construction of new median	31/May/17	3	3/Jun/17
1.3.8. Bike lane construction	3/Jun/17	1	4/Jun/17
1.3.9. Erecting crosswalk flashing and stop signs	4/Jun/17	2	6/Jun/17
1.4. Closeout	7/Jun/17	4	11/Jun/17
1.4.1. Construction site cleanup	7/Jun/17	3	10/Jun/17
1.4.2. Details inspection	7/Jun/17	4	11/Jun/17
2. UBC Welcome Sign construction breakdown	28/May/17	18	15/Jun/17
2.1. Site preparation	28/May/17	1	29/May/17
2.2. Excavation of foundation	30/May/17	3	2/Jun/17
2.3. Footing construction	3/Jun/17	3	6/Jun/17
2.4. Concrete column & arch construction	7/Jun/17	3	10/Jun/17
2.5. Prefabricated UBC welcome sign installation	11/Jun/17	1	12/Jun/17
2.6. Finishing landscaping	11/Jun/17	1	12/Jun/17
2.6. Site cleanup and detailed inspection	13/Jun/17	2	15/Jun/17
Total Duration		46	

B-3 Detour Route



B-5 Safety Guide

1. Setup safety management
1.1. During setup stage, set up all first aid stations and first aid trailer. Ensure all safety permits required on site board are up and visible to public as required.
1.2. Appoint and assigns project safety personnel
1.3. Develop a site-specific safety plan that all workers must be educated on
2. Traffic & public access safety management
2.1. Restricting public access from where work/setup is taking place as required
2.2. Place adequate signage and flaggers/traffickers in place throughout where work is and signage as required
3. Construction work safety management
3.1. Ensure hazard reducing measures are in place, for example, adequate lighting equipment for nighttime work
3.2. Conduct regular project safety audits with foremen/workers
3.3. Ensure temporary safety barriers are up where work is being completed
3.4. Conduct regular project safety audits with foremen/workers
3.5. Ensure only trained individuals are handling or operating such machinery or chemicals which they are professionally qualified to be working with

Appendix C: Sample Calculations

Foundation

Reinforcement depth:

$$d = h - \text{cover} - \frac{d_{rebar}}{2}$$
$$d = 500 - 75 - \frac{25.2}{2} = 412.5 \text{ mm}$$

Factored shear force:

$$V_f = q_f * b * \left(\frac{l-t}{2} - d \right)$$
$$V_f = 33.76 * 2.5 * \left(\frac{2.5 - 1.64}{2} - 0.4125 \right) = 1.9 \text{ KN / m}$$

Factored Shear resistance:

$$V_c = \phi_c * \lambda * \beta * \sqrt{f'_c} * b * 0.72h$$
$$V_c = 0.65 * 1 * 0.21 * \sqrt{25} * 2500 * 0.72 * 500 = 614 \text{ KN / m}$$

Factored moment at critical section:

$$M_f = q_f * \left(\frac{l-t}{2} \right) * \left(\frac{l-t}{4} \right) * b$$
$$M_f = 33.76 * \left(\frac{2.5 - 0.87}{2} \right) * \left(\frac{2.5 - 0.87}{4} \right) * 2.5 = 28 \text{ KN * m / m}$$

Reinforcement Area:

$$A_s = 0.0015 * f'_c * b * \left(d - \sqrt{d^2 - \frac{3.85 * M_r}{f'_c * b}} \right)$$
$$A_s = 0.0015 * 25 * 2500 * \left(413 - \sqrt{413^2 - \frac{3.85 * 28 * 10^6}{25 * 2500}} \right) = 196 \text{ mm}^2 / \text{m}$$

Minimum reinforcement requirement:

$$A_{smin} = 0.002 * h * b$$

$$A_{smin} = 0.002 * 500 * 2500 = 2500 \text{ mm}^2 / \text{m}$$

Bar Spacing for flexural reinforcement:

$$s \leq A_{bar} * \frac{1000}{A_s}$$

$$s \leq 500 * \frac{1000}{2500} = 200 \text{ mm}$$

Structure

Sample calculation for column design:

Slenderness Check :

$$P_f = 205.46 \text{ KN} \quad f'_c = 25 \text{ MPa} \quad f_y = 400 \text{ MPa} \quad \phi_c = 0.85$$

$$L_u = 6.47 \text{ m} \quad r = 261 \text{ mm} \quad M_1 = 0 \text{ KN} * \text{ m} \quad M_2 = -25.67 \text{ KN} * \text{ m}$$

$$E_c = 22500 \text{ MPa} \quad I_g = 9 * 10^{10} \text{ mm}^4$$

$$\frac{KL_u}{r} \leq \frac{25 - 10 \left(\frac{M_1}{M_2} \right)}{\sqrt{\frac{P_f}{f'_c * A_g}}}$$

$$\frac{KL_u}{r} = \frac{1 * 6470}{261} = 24.79$$

$$\frac{25 - 10 \left(\frac{M_1}{M_2} \right)}{\sqrt{\frac{P_f}{f'_c * A_g}}} = \frac{25 - 10 \left(\frac{0}{-25.67} \right)}{\sqrt{\frac{205.46}{25 * 870 * 1640}}} = 10.42$$

$$C_m = 0.6 + 0.4 \frac{M_1}{M_2} = 0.6$$

$$EI = \frac{0.4E_c I_g}{1 + \beta_d} = \frac{0.4 * 22500 * 9 * 10^{10}}{1 + 1} = 4.05 * 10^{14} N * mm^2$$

$$P_c = \frac{\pi^2 * EI}{(KL_u)^2} = \frac{3.14 * 4.05 * 10^{14}}{(1 * 6470)^2} = 95487 KN$$

$$\delta = \frac{C_m}{1 - \frac{P_f}{\phi_m * P_c}} = \frac{0.6}{1 - \frac{205.46}{0.75 * 95487}} = 0.6 < 1$$

$$M_c = M_2 = 25.67 KN * m$$

Min Bars Spacing:

$$d = 36mm \quad MAS = 20mm$$

Max of :

$$1.4 * d = 1.4 * 36 = 50.4 mm$$

$$1.4 * MAS = 1.4 * 20 = 28mm$$

30mm

$$S_{min} = 50.4mm$$

Appendix D: Source Control Calculations

Kwantlen Park		
2-yr, 24-hour rainfall	55.70	mm
72% 2-yr, 24-hour rainfall	40.10	mm
Intensity	2.32	mm/hr
72% DFO	1.67	mm/hr

UBC Technical
Guideline

Typical lot dimension		
Width of Road	19.8	m
Area	20	m ² /m
Input Volume	0.80	m ³ /m

Capture Area		
Width of Rain garden	4.0	m
Depth of Topsoil	0.20	m
Evaporation	0.0040	m ³ /m
Growing Medium	0.16	m ³ /m
Rock Pit	0.42	m ³ /m
Infiltration	0.14	m ³ /m
Total Capture Volume	0.73	m ³ /m

Percent Impervious	1
Depth of rock pit	0.3

Appendix E: Detailed Cost Estimate

Detailed Cost Estimate

Item	Description	Unit	Unit Cost	Unit Rate	Total Price \$CAD	Comments
1	Permit Fees					
1.1	Equipment and materials	46	47.38	day	2179.48	Backhoe, concrete truck, disposal bin, moving container, site trailer
1.2	Site protection - flat fee	1	524.77	each	524.77	Covered walkway, hoarding, street closure
1.3	Site protection - additional cost per length	70	17.74	lineal metre	1241.80	
1.4	Temporary asphalt construction access ramp	1	145.75	each	145.75	
1.5	Site service	2	218.64	month	437.28	
1.6	Tree protection - first tree	1	66	tree	66.00	
1.7	Tree protection - subsequent trees	24	190	tree	4560.00	
1.8	Electrical permit - first cost	1	7630	each	7630.00	When the estimated cost exceeds \$500,000 but does not exceed \$1,000,000: \$7,630.00, plus for every \$1,000 of the estimated cost, or part thereof, over \$500,000: \$8.35.
1.9	Electrical permit - subsequent cost	400	8.35	\$1,000	3340.00	
	SUBTOTAL FOR TASK				20125.08	
2	Project Consulting Fees					
2.1	E1 Professional services	121	240	hour	29040.00	
2.2	T1 Technical services	10	101	hour	1010.00	
2.3	E4 Professional services	16	195	hour	3120.00	
2.4	T4 Technical services	10	144	hour	1440.00	
2.5	Disbursements fee (8%)	-	-	-	27688.00	
	SUBTOTAL FOR TASK				27688.00	
3	Materials					
3.1	Concrete for road construction	420	210	cu. m.	88200.00	
3.2	Pedestrian controlled crossing signal	8000	2	each	16000.00	
3.3	Pipe	70	200	m	14000.00	
3.4	Rain gardens	70	450	lineal metre	31500.00	
3.5	Gateway - artist's fee	1	50000	each	50000.00	

Detailed Cost Estimate

3.6	Gateway - concrete	19	210	cu. m.	3990.00	
3.7	Gateway reinforcement	35	35	month	1225.00	
	SUBTOTAL FOR TASK				204915.00	
	4 Labour					
						6 labourers working 8 hours per day for 46
4.1	Labourer	2208	18	man-hour	39744.00	days
4.2	Flagger	736	15	man-hour	11040.00	2 flaggers working 8 hours per day for 46 days
4.3	Security guard	736	18	man-hour	13248.00	2 security guards working 8 hours per day for 46 days
	SUBTOTAL FOR TASK				64032.00	
	5 Equipment					
5.1	Concrete mixer truck	3	1000	week	3000.00	
5.2	Excavator	3	600	week	1800.00	
5.3	Truck crane	4	300	unit-week	1200.00	2 truck cranes working for 2 weeks
5.4	Crane	2	400	week	800.00	
5.5	Compactor	2	500	week	1000.00	
	SUBTOTAL FOR TASK				7800.00	
	CONSTRUCTION COST SUBTOTAL				324560.08	
	Bonding/Insurance	5%			16228.00	
	Mob/Demob	5%			16228.00	
	Engineering & Construction Management	25%			81140.02	
	Contingencies	20%			64912.02	
	TOTAL AMOUNT (excl. tax)				503068.12	