UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

# Redesign of Wesbrook Mall and Chancellor Boulevard Final Design Report


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**University of British Columbia**


**CIVL 446**

**April 7, 2017**

Team 12, Engineers-in-Training
The University of British Columbia
2075 West Mall
Vancouver, BC
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April 7th, 2017

Krista Falkner, P.Eng., M.A.Sc
Transportation Engineer
UBC Campus and Community Planning
2210 West Mall
Vancouver, BC
V6T 1Z4

Dear Ms. Falkner,

Re: CIVL 446 Project II - Redesign of Chancellor Boulevard / Wesbrook Mall Intersection at UBC

We are pleased be given the opportunity to redesign the Chancellor Boulevard - Wesbrook Mall intersection. Please see attached for the final design report titled *Redesign of Wesbrook Mall and Chancellor Boulevard*.

This design expands on the recommended option discussed in the summary report submitted on March 3rd, 2017. Included in this report are detailed design drawings, final schedule, and Class A cost estimate.

The intersection is recommended to be signalized and includes bike lanes in all travel directions, as well as crosswalks and pedestrian signals. Construction for this project begins on May 1st, 2017 and concludes on July 19th, 2017. The cost for implementation is $899,341.90.

If you have any questions or concerns, please contact our team representative, Chi-Yan Leung. We look forward to hearing back from you soon.

Sincerely,

Team 12
*Enclosure, Final Design Report*

## EXECUTIVE SUMMARY


The Wesbrook Mall-Chancellor Boulevard intersection is a key point of entry located at the north end of the University of British Columbia (UBC) Vancouver campus. The atypical configuration of the current intersection results in congestion during peak hours and creates unsafe conditions for road users, such as cyclists and pedestrians. The main project objective is to provide a detailed design of a safe and efficient intersection, in addition to meeting the criteria and goals requested by the client. Furthermore, additional objectives include accommodating future traffic volumes that are projected to the year 2041, minimizing project costs, integrating sustainable practices per UBC's Campus Plan, and developing an appealing gateway to UBC.

Technical consideration and constraints include property line locations, underground utilities, geotechnical obstacles, and other technical requirements outlined by federal and provincial codes and standards. An annual growth rate of 2.2% was considered in the projection of future traffic volumes based on UBC's enrollment rate through the past ten years. In lieu of WB-17 trucks, a demo truck was used for the analysis on AutoTurn to ensure that the design is sufficient for truck turning movements. An analysis was conducted on Synchro and SimTraffic to determine the most feasible configuration. Roundabout, stop-controlled, and signalized configurations were analyzed. It was determined that a signalized intersection is the most feasible option that can adequately accommodate the projected future traffic volume in 2041; thus, it was selected for the preliminary design.

Notable features of the design comprise of a signalized configuration with one through/right turn lane in the eastbound direction, one through lane, one through/left turn lane and one left turn lane in the westbound direction, and one left turn/right turn lane in the northbound direction. In addition to the vehicular lanes, the proposed intersection design also includes bike lanes in all travel directions, crosswalks, and traffic and pedestrian/bike signals.

The proposed campus gateway features a concrete archway with the letters "UBC" engraved on a 0.5 m thick steel plate in the center of the gateway. The structure is located on the median on the west side of the intersection, spanning the entire median. The structure is 5m wide, and 8m high. The columns of the arch will be 305x305x13 HSS columns, and will be placed on 1091 x 1091 mm square footings, which are located 1 m below grade.

Geotechnical and structural analysis show that the structure is able to adequately resist design loadings from dead, snow, wind, and earthquake loads.

Construction commences on May 1st, 2017 and finishes in July 19th, 2017. 78 working days are required to complete the project. A working week consists of 7 days, from Monday to Sunday, with the exception of Canadian statutory holidays.

The total cost to implement the selected design is approximately $899k including 6% contingency plus 5% GST. $460k of the total cost goes to purchase of the traffic lights. Funding for the project is from UBC. Additional funding can be acquired from BikeBC and New Building Canada Fund.

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## 1.0 INTRODUCTION

UBC has awarded Team 12 with the Redesign of Wesbrook Mall and Chancellor Boulevard. The project consists of improving the intersection as well as designing a structural gateway into the campus. The purpose of this report is to summarize the final design of the intersection, and will provide all necessary information for the client to proceed with tendering. Such information includes detailed design drawings, schedule, and cost estimate.

The project intersection is a major entrance to UBC. Located at the north end of campus near the Chan Center and Museum of Anthropology, the route can be accessed through West 4th Avenue.

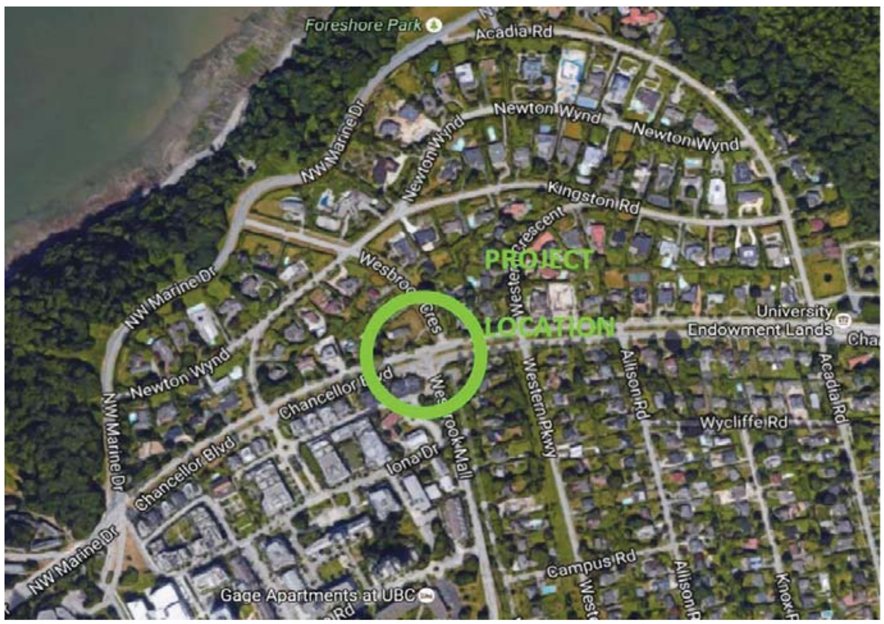



FIGURE 1 PROJECT LOCATION

Prior to the submission of the final design report, previous submissions to the client include a conceptual report (October 24, 2016), a preliminary report (November 28, 2016), followed by a summary report (March 3, 2017). Information in these documents include:

- Decision making process for the intersection
- Stakeholder engagement plan
- Regulations, such as required permits, safety and environmental bylaws
- Previous design costs

Member contributions are summarized in the table below.

#### TABLE 1 MEMBER CONTRIBUTIONS

| ***Member*** | **Contribution** |
|---:|---|
| *Celine Au* | Transportation detailed design<br>Drafting detailed plan drawings |
| *Cliff Chun* | Structural design checks<br>Standard and project review |
| *Chi Yan Leung* | Structural detailed design<br>Drafting transportation cross sections |
| *Yu Feng (York) Liao* | Scheduling<br>Construction and traffic management plan |
| *Mandy Tam* | Structural detailed design<br>Drafting structural drawings |
| *Jiahua (Evan) Yan* | Cost estimate<br>Drafting standards detail (i.e. typical curb basin, curb and gutter) |

## 2.0 DESCRIPTION OF DESIGN

A full detailed drawing set is included in Appendix A. A summary description of the design are below.

### 2.1 TRANSPORTATION DESIGN

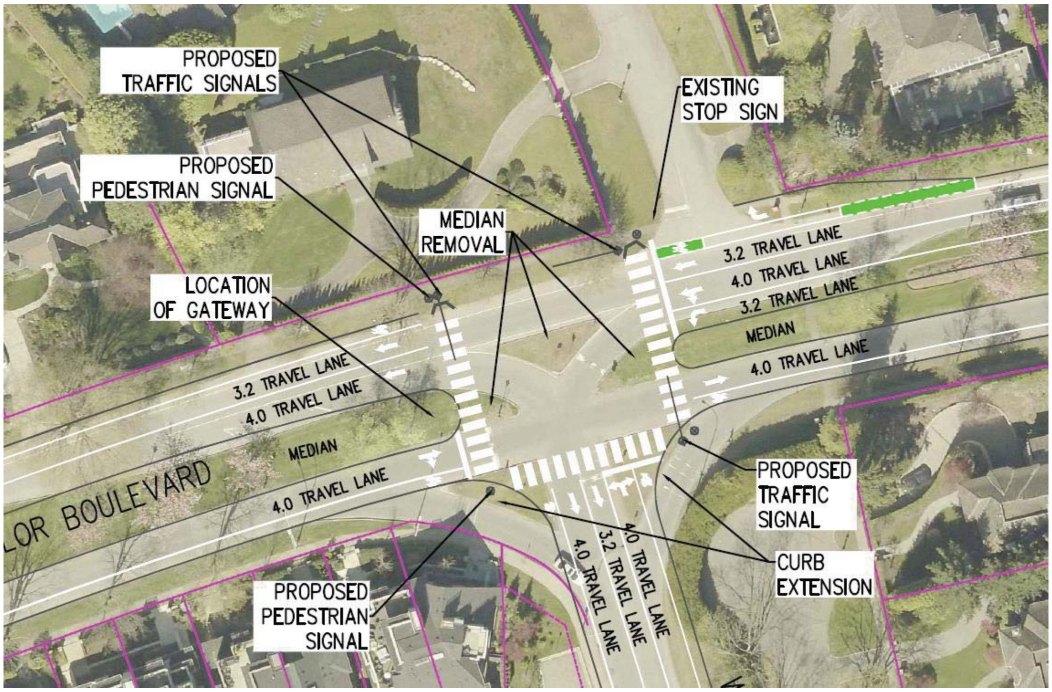



**FIGURE 2 DETAILED DESIGN PLAN VIEW**

The intersection will be improved to be a signalized intersection. Key benefits include increased safety for all users, increased clarity for drivers, and allows for flexibility in design. A signalized intersection was selected in the early design phases during the Synchro analysis, as it was the only option to be able to sustain the future traffic volumes. Other tested intersections included a roundabout and stop intersection.

Eastbound consists of one through/right travel lane. Westbound consists of one through lane, one through/left lane, and one left lane. Northbound consists of one left/right travel lane. Other components include bike lanes in all travel directions, crosswalks, traffic signals, and pedestrian signals. Pavement markings include: paint to delineate lanes, bicycle lane markers, turning arrows, and green surface treatment to highlight conflict areas with cyclists. Above ground, 4 light posts and 1 curb basin will need to be moved.

Below ground, the areas will be highlighted for contractors to be aware of underground utilities when removing medians.

## 2.2 STRUCTURAL DESIGN

The structural design was completed in accordance with the following codes and standards: British Columbia Building Code 2012, CSA A23.3 (Concrete Design Standard) and CSA S16 (Steel Design Standard).

For the structural gateway, design loads tested include: dead, snow, wind, and earthquake. The design life is considered to be 25 years to match the transportation analysis. Specified loadings can be found in the summary table below. Refer to Appendix E for detailed calculations of each design load.

**TABLE 2 SUMMARY OF SPECIFIED LOADS**

| ***Specified Load*** | **Dead** | **Snow** | **Wind** | **Earthquake** |
|---|---|---|---|---|
| *Loading* | 230.56 kN | 2.12 kPa | 0.51 kPa | 52.11 kN |

The gateway is treated as a single storey frame under "other systems" for the seismic-force resisting system. Due to $R_d$ exceeding 1.5, the upper bound of V will be used as the minimum lateral earthquake force. The structure's weight is set as 1.0kN to obtain the seismic loading as a percentage of the weight. Additionally, the minimum factor of safety used for sliding and overturning is 1.5 The figure below shows the arched gateway that will be constructed on the West leg of the intersection.

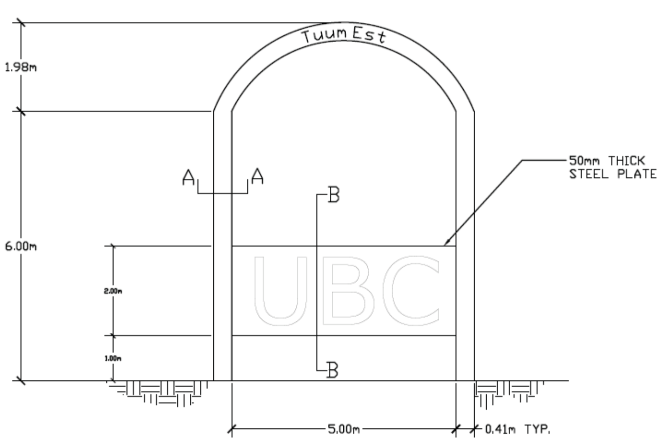



**FIGURE 3 STRUCTURAL GATEWAY**

Detailed drawings of the footing and specific section cuts can be found in Appendix E.

The gateway will be composed of a concrete arch with UBC's motto of *Tuum Est* engraved on it. The structural system of the arch is two 305x305x13 HSS column on each side with the concrete arch placed on top and steel plates with the letters UBC engraved placed in between the two columns. A minimum concrete cover of 50mm will be applied around the columns to prevent the HSS from being exposed to the elements.

For the UBC sign, two 50mm steel plates will be used. Five W310x375 steel beams will be placed between the steel plates to provide reinforcement and ensure deflections caused by wind loading is acceptable. The steel beams are welded to the HSS using fillet welds before the placing of the concrete cover. The steel plates are then bolted to the top W-shape for load transfer from the plates to the beams to the column. The remaining steel beams are to prevent the steel plates from deflecting under strong wind loads and are not gravity load bearing elements.

Two 1091 x 1091 mm square footings will be placed 1 m below grade. The size of the footings do not require shear reinforcement to be designed. The flexural reinforcement consists of 10-15M rebars spaced evenly in each direction, with a 75 mm cover on all sides.

Detailed design calculations and design drawings can be found in Appendix E.

# 3.0 DESIGN CRITERIA

## 3.1 TRANSPORTATION DESIGN

### 3.1.1 ALIGNMENT AND LANE WIDTH

Chapter 2.1 Alignment and Lane Configuration of the TAC Geometric Design Guide for Canadian Roads has been taken into account while designing for the intersection for this project. In addition, the lane widths for roads in all directions follow the design requirements that is suitable for WB-17 trucks

### 3.1.2 AUTOTURN ANALYSIS

AutoTurn was used in the design configuration to ensure WB-17 trucks are able to make turns. The relevant drawing is attached to Appendx A: Drawing T-07.

### 3.1.3 TRAFFIC FLOW PREDICTION

The team has analyzed the future traffic load in both 10 years and 25 years. Traffic is projected using a 2.2% annual average increase based on the enrollment numbers UBC provided from the past ten years. The only adjustment needed for the intersection is to optimize signal timing to complement the growth of the flow.

## 3.2 STRUCTURAL DESIGN

Design loads such as dead load, snow load, wind load, and earthquake load is contained while designing for the structural component of the project. British Columbia Building Code 2012, CSA A23.3 (Concrete Design Standard) and CSA S16 (Steel Design Standard) were followed for the structural design. A reasonable factor of safety (1.5 for sliding and overturning) was ensured throughout the design process.

# 4.0 STANDARDS AND SOFTWARE PACKAGES

## 4.1 TRANSPORTATION DESIGN

To model the intersection, Synchro 6 and SimTraffic were used. Standards include:

- TAC Geometric Design Guide for Canadian Roads
- AASHTO Design and Controls Criteria
- BCMOTI Manual of Standard Signs and Pavement Markings
- MUTCD
- AASHTO Guide for Design of Pavement Structures

## 4.2 STRUCTURAL DESIGN

Standards for the structural component include:

- NBC 2010
- NBC 2010 Structural Commentaries
- CSA A23.3-04
- CSA S16-09

NBC 2010 and NBC 2010 Structural Commentaries were used to determine structural loading as the content reflects those outlined in BCBC 2012. Although NBC 2015 is available, there is no BC version to accompany the new edition.

## 4.3 COST ESTIMATION AND PROJECT SCHEDULING

Cost estimation was mostly done on Microsoft Excel with help of a template. Microsoft Project was used to plan and present the schedule of the project.

# 5.0 TECHNICAL CONSIDERATIONS

## 5.1 TRANSPORTATION DESIGN

The road design is above ground, therefore sanitary, water supply, storm sewage and electrical utilities underneath the intersection will not be affected. During construction activities for the structural gateway, locations and depths of underground utilities are well denoted for the contractors to stay clear. Should there be any utility work required, UBC Energy and Water Service will be contacted to perform the work.

Re-routing has been designed to accommodate vehicles and transit passing through the intersection. Traffic operations will be maintained during all three construction phases. Property Lines are respected and thus both the design and the construction will not interfere with private properties.

The geological composition of the area was determined through drilled wells. The ground surface consists of glacial till, followed by alternating units of silt and Quadra sand as depth increases. Composition of the till is of dense sands, silt and clay in addition to some boulders. According to the geotechnical reports, the soil composition and condition are adequate for the design and the construction of both the intersection and the structural gateway.

Traffic volume was projected using an average annual increase rate of 2.2% based on enrollment data from the past ten years.

Road structure, curb and sidewalk designs are based on City of Surrey construction standard drawings, which are attached in Appendix A.

## 5.2 STRUCTURAL DESIGN

The foundation design considered quadra sand as the soil. The soil was assumed to have a unit weight of 19.8 $kN/m^3$. Using Meyerhof analysis for bearing capacity of soil underneath the footing, the Factor of Safety was calculated to be 7.5. After computing the additional stresses due to bending, it was determined that stresses due to overturning moment are small compared to the axial loading, thus the bearing capacity of the soil under the footing is sufficient.

The footings are designed with a cover of 75 mm due to the exposure class in accordance with CSA A.23.3. Care should be taken to consider the utilities under the soil during excavation and construction to ensure that no underground utilities are disturbed.

# 6.0 CONSTRUCTION

## 6.1 DRAFT PLAN

The Chancellor Boulevard and Wesbrook Mall intersection improvement project sequence are presented in the figure below, some of the key construction requirements of the project include:

- Compliance with WorkSafe BC Standards
- Construction to be complete within a specific timeline
- Adherence to UBC Campus Planning guideline and sustainable goals
- Quality of work must meet the design standards outlined in Section 4.0
- Abide by the regulations set by City of Vancouver
- Continued public access through intersection during construction phase

## 6.2 ANTICIPATED ISSUES

The following sections outline the various issues that may arise during construction, in addition to the measures taken to mitigate or minimize the impact of the issue.

### 6.2.1 TRAFFIC MANAGEMENT

During the construction phase, various legs of the intersection will become inaccessible to road users. Hence, the need for traffic control to direct the flow of vehicles and minimize impact of the construction. Team 12 has developed a detailed traffic management plan with detour routes for vehicles and public transit.

Construction is to take place during the summer at UBC, thus it is expected that there will be less demand for the intersection. Construction will be executed in phases such that the intersection will remain accessible to vehicles.

The phases are outlined in TABLE 3  below. Contractors are responsible for hiring traffic control personnel or flaggers to assist road users passing through the construction area. The contractor is to refer to UBC's Traffic

Management Plan Guidelines for Construction and adhere to the guidelines stipulated. Drawings of signage for each phase can be found in Appendix A.

TABLE 3 TRAFFIC MANAGEMENT PHASES

| Traffic Management Phases | Estimated Time (Days) | Activities | Respective Drawing |
|---|---|---|---|
| **1** | 13 | ● Widen Wesbrook Mall<br>● Traffic signals & pedestrian flasher installation<br>● Wesbrook Mall Pedestrian Sidewalk Construction<br>● Curb extension | T-12<br>T-13<br>T-14 |
| **2** | 23 | ● Widen Chancellor Boulevard West Leg<br>● Gateway Construction | T-15 |
| **3** | 17 | ● Widen Chancellor Boulevard East Leg | T-16 |

The affected bus routes include C18, C20, 44, and 84. Buses are to detour along the specified routes to decrease travel time variability for transit and decrease the demand on the intersection. All bus routes will travel along Wesbrook Mall, University Boulevard and Allison Road. The C18 and C20, in particular, will travel along NW Marine Drive to reach their regular stops. FIGURE 4 and FIGURE 5 illustrate the detours buses will be taking during construction. Regular service will resume upon completion of the project.


FIGURE 4 PROPOSED DETOUR FOR 44, AND 84

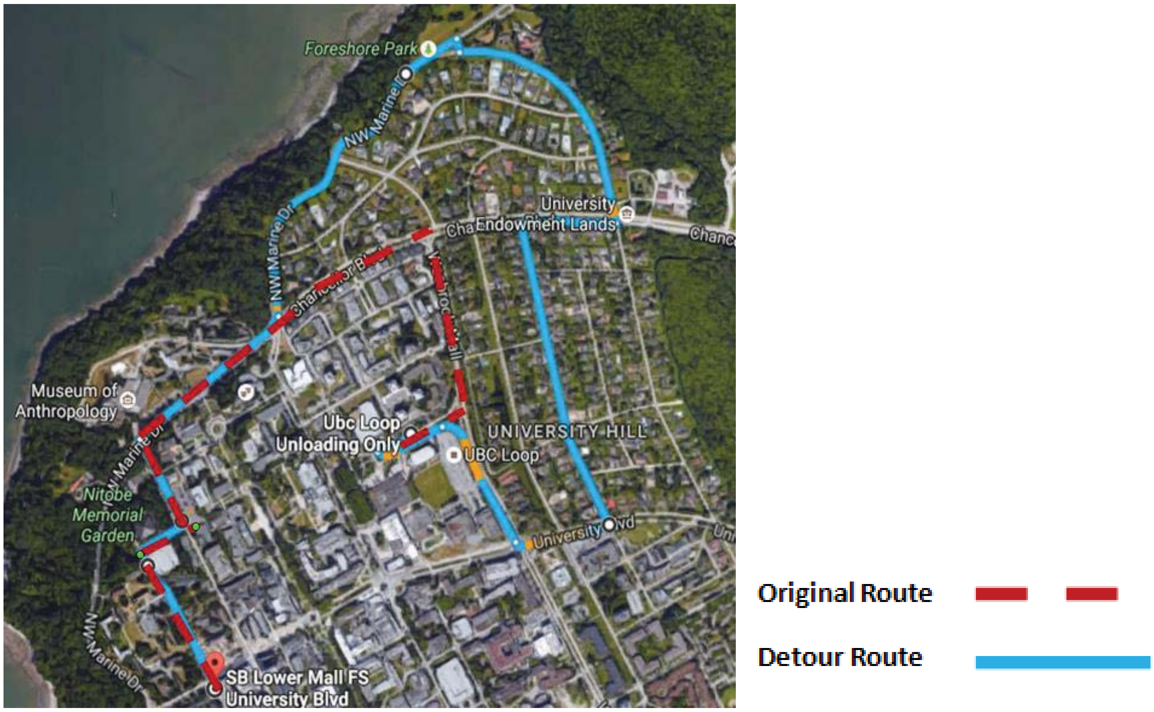



FIGURE 5 PROPOSED DETOUR FOR C18 AND C20

## 6.2.2. NOISE LEVEL AND POLLUTION

Following Vancouver's Noise Control Bylaw 6555, street construction will only be carried out during the following times:

- Monday to Saturday from 7:00AM to 8:00PM
- Sundays and holidays from 10:00AM to 8:00PM

Dust emitted from the site will be controlled with adequate water or dust suppressant. These guidelines will be followed during the construction phase to reduce disturbance to the neighborhood.

## 6.2.3. PLACEMENT OF CONSTRUCTION MATERIAL AND EQUIPMENT

The placement of material and equipment will be analyzed in conjunction with the construction timeline to efficiently use the space available of the surrounding area. Disturbance to the neighborhood will be minimized.

## 6.2.4. POTENTIAL REMOVAL OR RELOCATION OF UNDERGROUND UTILITIES

The existing location of the utilities has been analyzed with site work and do not require relocation at this point in time. Section 5.1 provides more details regarding utility planning during construction.

### 6.2.5. LOST TIME INCIDENCE

The construction schedule provides sufficient float and flexibility such that proceeding tasks and the project schedule are not delayed. In the event of an injury, it is the responsibility of the contractor to ensure that the work carried out is in compliance with WorkSafe BC standards. A Construction Safety Officer is to be on site at all times with a first aid and CPR certification.

### 6.2.6. CONSTRUCTABILITY ISSUES

Unexpected changes in site conditions or incidence may affect the constructability of some components. In the event of an issue, the contractor is to notify and consult the respective designer to confirm that any changes required to construct the item on site are acceptable and adhere to standards. Construction may not proceed for designed components unless an engineer’s approval is recorded on a written document.

## 7.0 SCHEDULE

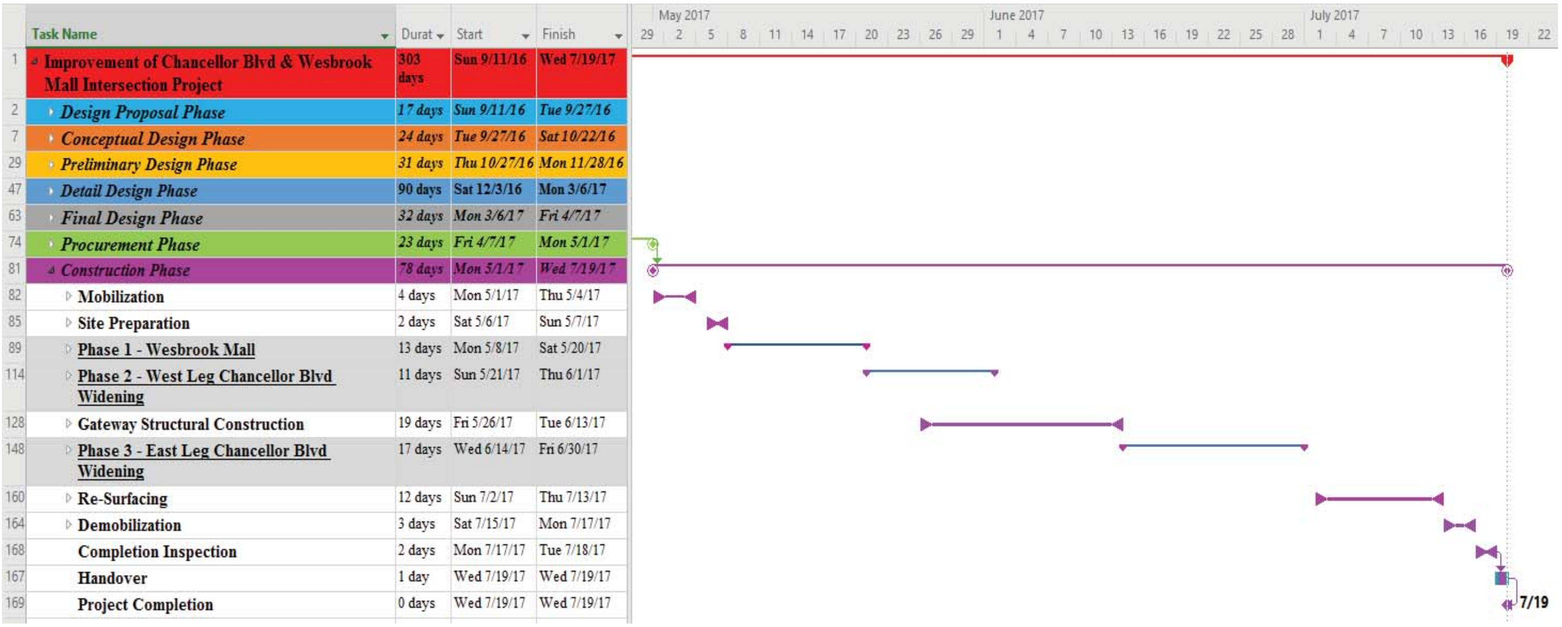
The Wesbrook Mall-Chancellor Boulevard intersection project schedule has been divided into two major phases, design and construction with durations of 225 and 78 working days respectively. A working week consists of 7 days from Monday to Sunday. In order to minimize construction impact in the neighbourhood, the construction is to occur from 8 AM to 5 PM, with the except of Sundays as noted in Section 6.2.2, to condense the construction period. No work activities on the project are required during any Canadian statutory holidays.

The schedule presents stakeholders and general contractors with the construction concept. Project schedules may undergo changes during the construction period depending on factors such as a change in scope or change in contractors. The project schedule forecasting the implementation date has been developed based on precedent examples with similar scope. The schedule is located in Appendix C in the form of Gantt charts.

*The following presents the highlights of the project schedule:*

- Proposal, Conceptual Design and Preliminary Design activities are restated in the preliminary schedule which consists of 74 working days
- Detail Design Phase for the intersection and gateway occurred over a 3 month window.
- Acquisition of permits proceeded after detailed designs were approved:
  - 40 working days to acquire BC Ministry of Transportation Permit
  - 30 working days to acquire UBC Campus Plan Permit
- Once the permitting phase was complete, a 33-day window was used to finalize the design in the Final Design Phase
- Procurement Phase for tendering is estimated to be a duration of 38 days
- Project construction is scheduled to begin on May 1$^{st}$, 2017, with an estimated 78 working days for the Construction Phase be complete
- The intersection aims to be available for the public on July 19$^{th}$, 2017.

FIGURE 7 on the following page illustrates the key milestones throughout the project timeline.



| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | Improvement of Chancellor Blvd & Wesbrook Mall Intersection Project | 303 days | Sun 9/11/16 | Wed 7/19/17 |
| 2 | *Design Proposal Phase* | *17 days* | *Sun 9/11/16* | *Tue 9/27/16* |
| 7 | *Conceptual Design Phase* | *24 days* | *Tue 9/27/16* | *Sat 10/22/16* |
| 29 | *Preliminary Design Phase* | *31 days* | *Thu 10/27/16* | *Mon 11/28/16* |
| 47 | *Detail Design Phase* | *90 days* | *Sat 12/3/16* | *Mon 3/6/17* |
| 63 | *Final Design Phase* | *32 days* | *Mon 3/6/17* | *Fri 4/7/17* |
| 74 | *Procurement Phase* | *23 days* | *Fri 4/7/17* | *Mon 5/1/17* |
| 81 | *Construction Phase* | *78 days* | *Mon 5/1/17* | *Wed 7/19/17* |
| 82 | Mobilization | 4 days | Mon 5/1/17 | Thu 5/4/17 |
| 85 | Site Preparation | 2 days | Sat 5/6/17 | Sun 5/7/17 |
| 89 | Phase 1 - Wesbrook Mall | 13 days | Mon 5/8/17 | Sat 5/20/17 |
| 114 | Phase 2 - West Leg Chancellor Blvd Widening | 11 days | Sun 5/21/17 | Thu 6/1/17 |
| 128 | Gateway Structural Construction | 19 days | Fri 5/26/17 | Tue 6/13/17 |
| 148 | Phase 3 - East Leg Chancellor Blvd Widening | 17 days | Wed 6/14/17 | Fri 6/30/17 |
| 160 | Re-Surfacing | 12 days | Sun 7/2/17 | Thu 7/13/17 |
| 164 | Demobilization | 3 days | Sat 7/15/17 | Mon 7/17/17 |
| 168 | Completion Inspection | 2 days | Mon 7/17/17 | Tue 7/18/17 |
| 167 | Handover | 1 day | Wed 7/19/17 | Wed 7/19/17 |
| 169 | Project Completion | 0 days | Wed 7/19/17 | Wed 7/19/17 |



FIGURE 6 CONDENSED SCHEDULE

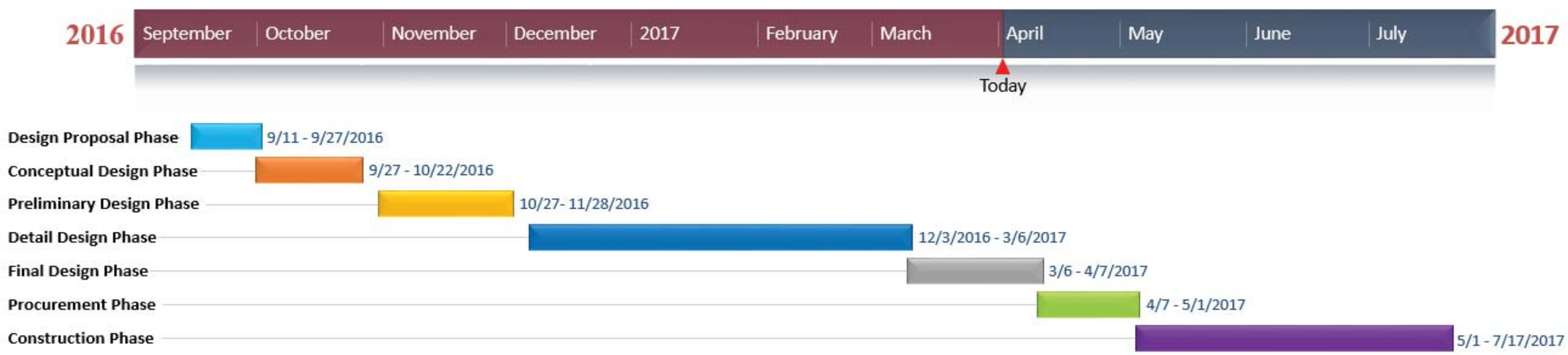



FIGURE 7 PROJECT TIMELINE

# 8.0 COST ESTIMATE

A detailed cost estimate breakdown is in Appendix B. Key values are discussed in the sections below.

## 8.1 PROCUREMENT COST

Procurement phase costs $11.5k. Team members that will be working on the project are five EIT's and a senior project manager, with daily professional service rates of $968 and $1560, respectively.

## 8.2 CONSTRUCTION COST

A general breakdown of construction costs is presented below. This includes costs such as labour cost, equipment cost and material cost. Administrative costs such as permitting, obtaining licenses and other required paperwork are also included.

TABLE 4 CONSTRUCTION COST ESTIMATE

| Construction Phases | Cost |
|---|---|
| **Mobilization** | $8700 |
| **Site Preparation** | $12400 |
| **Phase 1** | $488779 |
| **Phase 2** | $26683 |
| **Structural Gateway Construction** | $6248 |
| **Phase 3** | $35969 |
| **Re-surfacing** | $46868 |
| **Demobilization** | $5000 |
| **Completion/Delivery** | $1380 |
| **General Contractor Misc Cost** | $182255 |
| **Subtotal** | **$ 808,034.0** |
| **6% Contingency** | **$ 48, 482.0** |
| **Total** | **$ 856,516.1** |
| **5% GST** | **$ 42,825.8** |
| **Final** | **$ 899,341.9** |

### 8.2.1 EARTHWORKS

Total area that needs to be excavated and backfilled is about $1100m^2$. Assuming a general depth of 0.55m and a bulk factor of 120%, excavation volume is around $700m^3$ including sloping for easy access and safety. For backfill, a factor of 115% is used to account for waste and compaction. Productivities and unit rates for labor, materials and equipment can be found in Appendix B.

### 8.2.2 CURB AND GUTTER

Some sections of curb need to be re-installed due to extension of curb or removal of old curb. Total length of curb and gutter required to install during all three phases is 267m with a unit price of $70 per meter.

### 8.2.3 MARKINGS

New lane lines that needs to be painted is about 160 meter long and the unit price for the paint job is $80 per meter. Hence, the total cost of new lane lines is approximately $12,800. In addition, the unit price for 16 lane markings, including bicycle lane markings and turning markings, is $180 each which leads to a total cost of $2,880. Finally, stood-up signs that indicate bike lanes should be installed in each direction. A total number of 6 signs are required for the project and the unit price is $300, giving the total cost of $1,800.

### 8.2.4 PERMITS

With the combination of both UBC and the BCMOTI required permits, the total cost of permit is $6,000. Permit regulations are following:

- UBC Planning Development & Building Regulations
- UBC Planning Plumbing/Sprinkler Permit Fee Schedule
- UBC Planning Plumbing/Sprinkler Trade Permits

The application fee for permit will be a one-time cost and the detailed breakdown of the components of the permits are provided in Appendix B.

### 8.2.5 TRAFFIC LIGHTS

The initial cost for traffic light is approximately $153,000 per light including installation. This project will require a total number of three traffic lights in three different intersections. The cost per traffic light comprises of:

- The traffic signal controller
- Sensors for vehicle detection
- Pedestrian push button systems

- Underground concrete bases for pole support
- Signal poles and arms
- Conduit and wiring between the controller and all signal equipment
- Data communications to the traffic management center

#### 8.2.6 TREE REMOVAL

A total of 8 trees are to be removed. Three of which are located on the median that will be removed. Another two will be cut to make room for the construction of the gateway design. The last three trees are to be removed to promote safety by allowing the drivers to see the traffic lights properly. The labor cost for tree removal is $750 per tree and the total cost is $6,000.

### 8.3 OPERATING AND MAINTENANCE COSTS

All lane markings are required to be repainted every 10 years. The average maintenance costs for lane paints and road marking are $4,488 and $306 per year. Additionally, it costs around $8000 a year to operate and maintain a traffic light. Operations and maintenance include electric bills, routine maintenance as well as optimization of traffic signal phasing. Annual operation and maintenance expenses are specified below.

**TABLE 5 MAINTENANCE COST ESTIMATE**

| | | | |
|---|---|---|---|
| **Operating/Maintenance** | $24,000.0 | per yr | lights |
| **Maintenance** | $4,488.0 | per yr | lane marking |
| | $306.0 | per yr | Road Marking |

Additional information regarding to detailed cost breakdowns, construction activities involved, quantities, unit rates, operating cost, maintenance cost and sample calculations are in Appendix B.

## 9.0 CONCLUSION

Team 12's design of a signalized intersection is one that meets all of the project objectives and needs of the community. With the inclusion of bike lanes and pedestrian crosswalks, this design not only increases safety but promotes the use of active transportation in the area. Furthermore, the design will be able to sufficiently sustain traffic volumes up until 2041.

The detailed design presented in this report is feasible at a cost of $899341.90, and can be efficiently constructed within the project time frame.

The structural arch will become a prominent gateway to the campus. While providing a unique aesthetic appeal to the neighbouring community, the arch will also become a strong symbol of UBC that will be easily recognized.

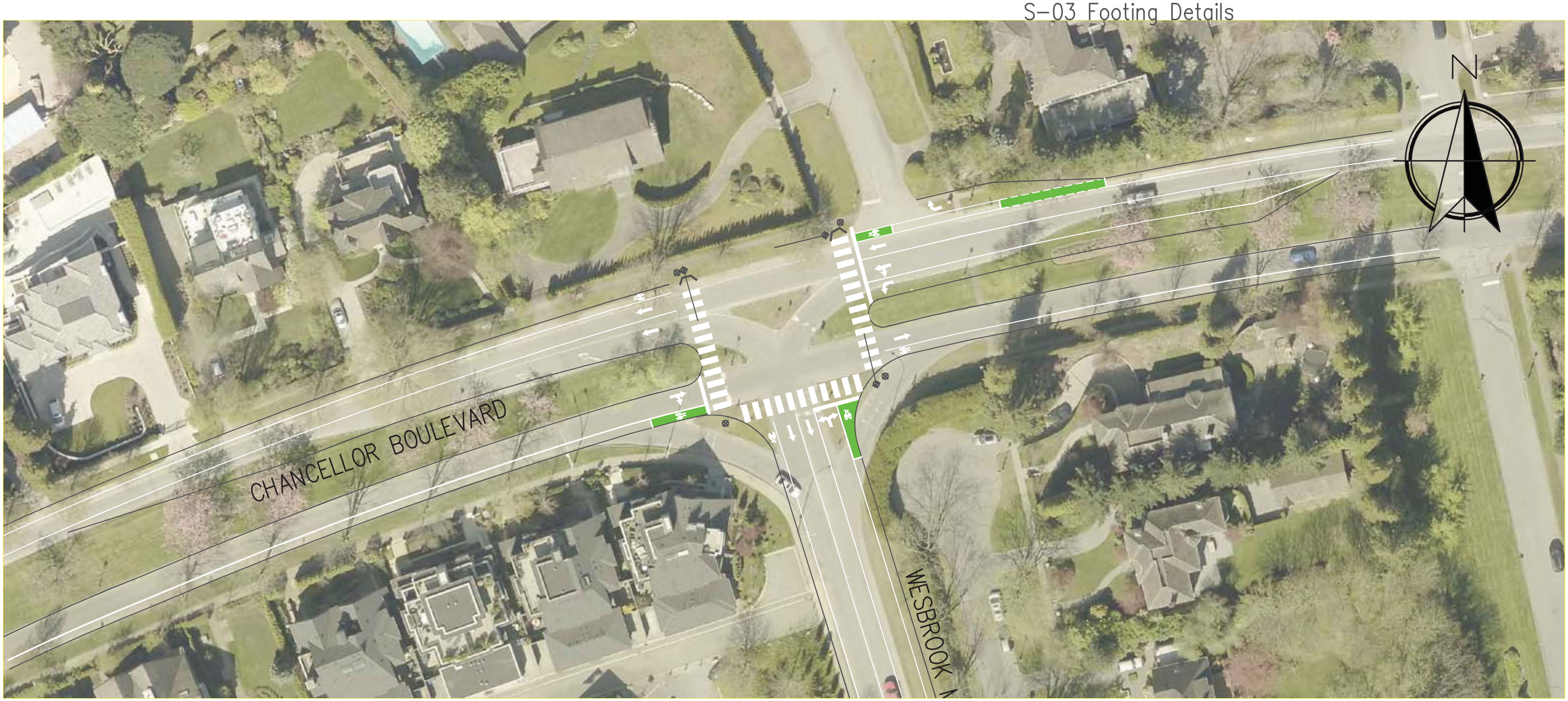
# APPENDIX A : CAD DRAWINGS

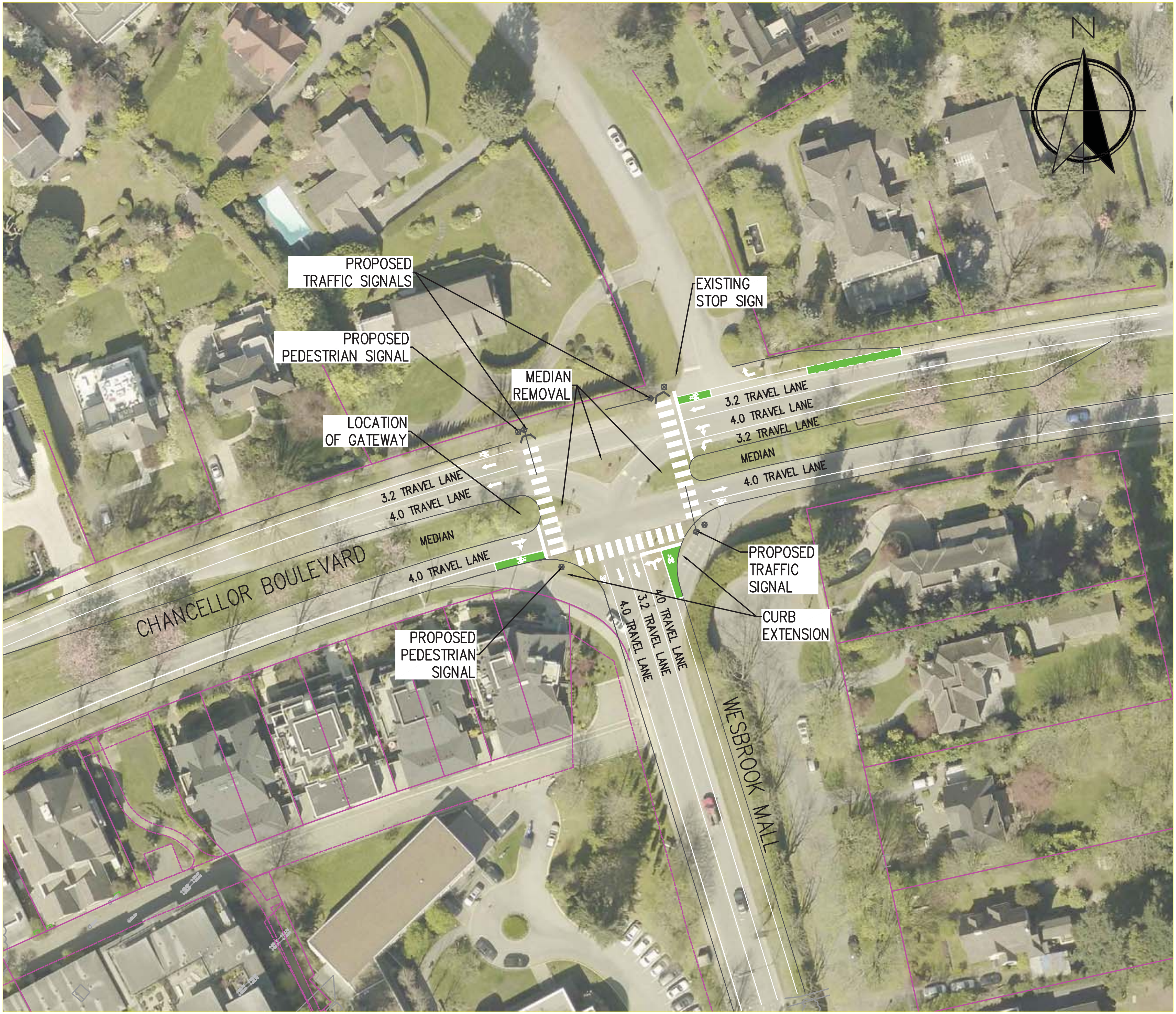
# REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD DRAWING SET

TEAM 12
APRIL 7, 2017

CLIENT : UBC SEEDS

SHEETS
T-01 Detailed Design Drawing
T-02 Geometric Plan Drawing
T-03 Pavement Markings Plan Drawing
T-04 Underground Utilities Plan Drawing
T-05 Median and Pavement Removal Plan Drawing
T-06 Curb Extension Plan Drawing
T-07 AutoTurn Check
T-08 East Section View
T-09 South Section View
T-10 West Section View
T-11 City of Surrey References
T-12 Phase 1 Traffic General Drawing
T-13 Phase 1 Traffic Management sheet 1
T-14 Phase 1 Traffic Management sheet 2
T-15 Phase 2 Traffic Management
T-16 Phase 3 Traffic Management
S-01 Structural Arch
S-02 Structural Details
S-03 Footing Details






| General Notes | | |
|---|---|---|
| No. | Revision/Issue | Date |

Designed By: CA

Drawn By: CA

Firm Name and Address: TEAM 12

Project Name: REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD

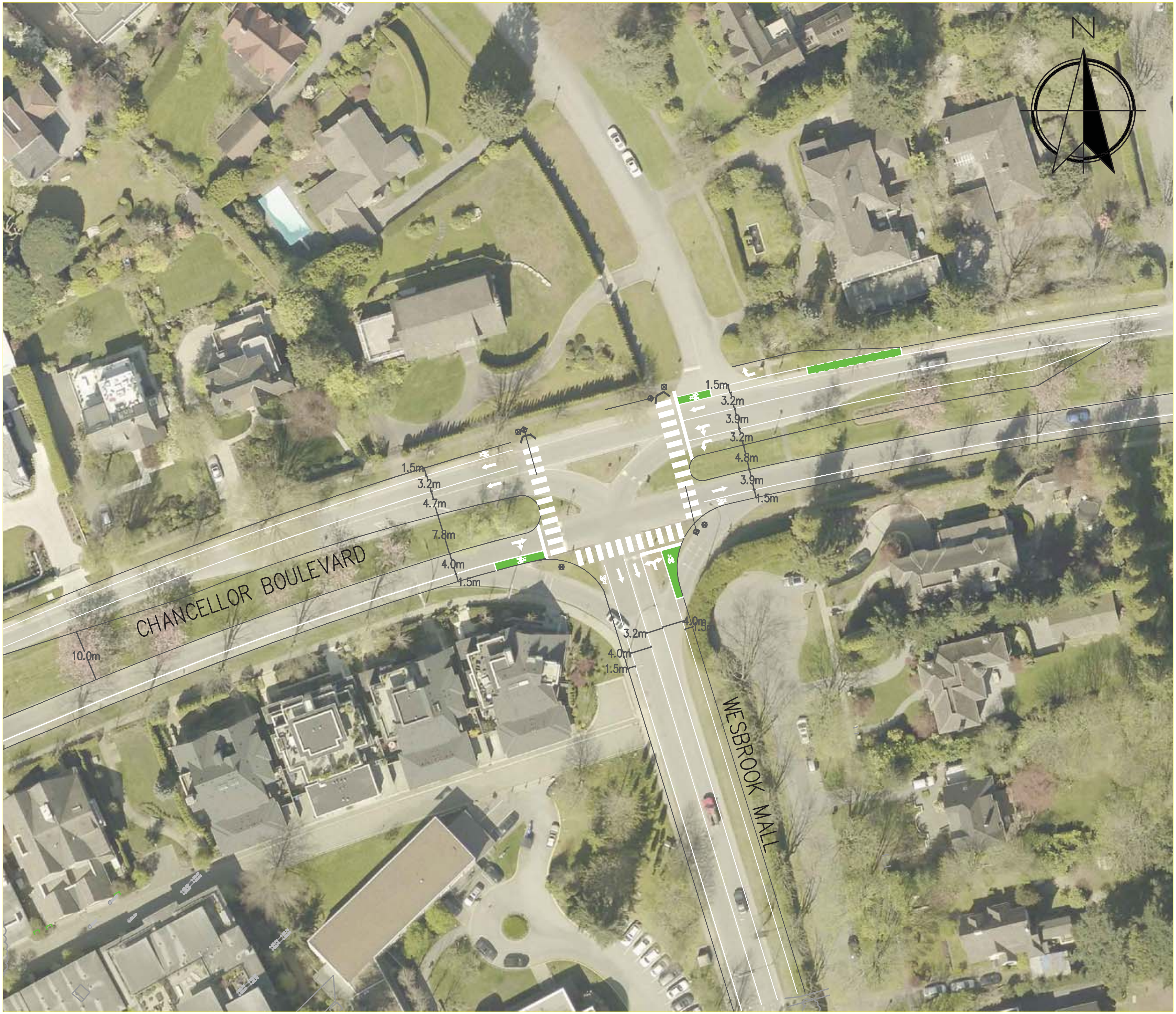
Drawing: DETAILED DESIGN DRAWING

Client: UBC SEEDS

Date: APRIL 7, 2017

Scale: 1:1000

Sheet: T–01




| General Notes | | |
|---|---|---|
| No. | Revision/Issue | Date |

Designed By: CA

Drawn By: CA

Firm Name and Address: TEAM 12

Project Name: REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD

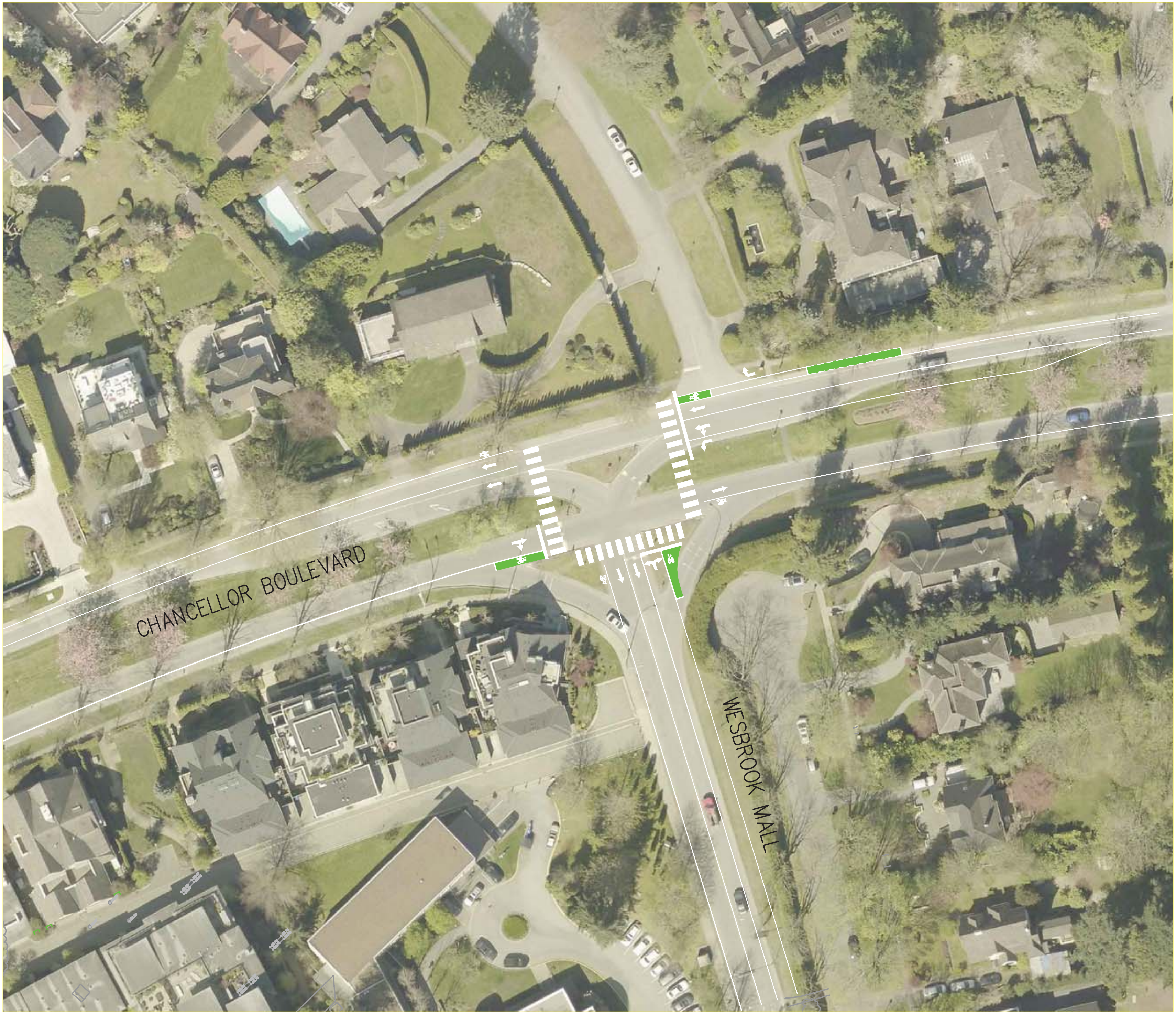
Drawing: GEOMETRIC PLAN DRAWING

Client: UBC SEEDS

Date: APRIL 7, 2017

Scale: 1:1000

Sheet: T-02




| | |
|---|---|
| General Notes | |
| No. | Revision/Issue | Date |

| | |
|---|---|
| Designed By | CA |
| Drawn By | CA |
| Firm Name and Address | TEAM 12 |
| Project Name | REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD |
| Drawing | PAVEMENT MARKINGS PLAN DRAWING |
| Client | UBC SEEDS |
| Date | APRIL 7, 2017 |
| Scale | 1:1000 |
| Sheet | T-03 |


NOTES

1. CONTRACTORS TO CROSS REFERENCE UNDERGROUND UTILITIES WITH SHEET XX DURING PAVEMENT REMOVAL TO ENSURE UNDERGROUND UTILITIES WILL NOT BE REQUIRED TO BE MOVED

General Notes

| No. | Revision/Issue | Date |
|---|---|---|
| | | |

Designed By: CA

Drawn By: CA

Firm Name and Address: TEAM 12

Project Name: REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD

Drawing: UNDERGROUND UTILIIES PLAN DRAWING

Client: UBC SEEDS

Date: APRIL 7, 2017

Scale: 1:1000

Sheet: T–04


General Notes

| No. | Revision/Issue | Date |
|---|---|---|
| | | |
| | | |

Designed By: CA

Drawn By: CA

Firm Name and Address: TEAM 12

Project Name: REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD

Drawing: MEDIAN AND PAVEMENT REMOVAL PLAN DRAWING

Client: UBC SEEDS

Date: APRIL 7, 2017

Scale: 1:1000

Sheet: T-05


NOTES
1. CURB EXTENSIONS TO FOLLOW DETAILS AS OUTLINED IN SHEET XX

| General Notes | | |
|---|---|---|
| No. | Revision/Issue | Date |

Designed By: CA

Drawn By: CA

Firm Name and Address: TEAM 12

Project Name: REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD

Drawing: CURB EXTENSION PLAN DRAWING

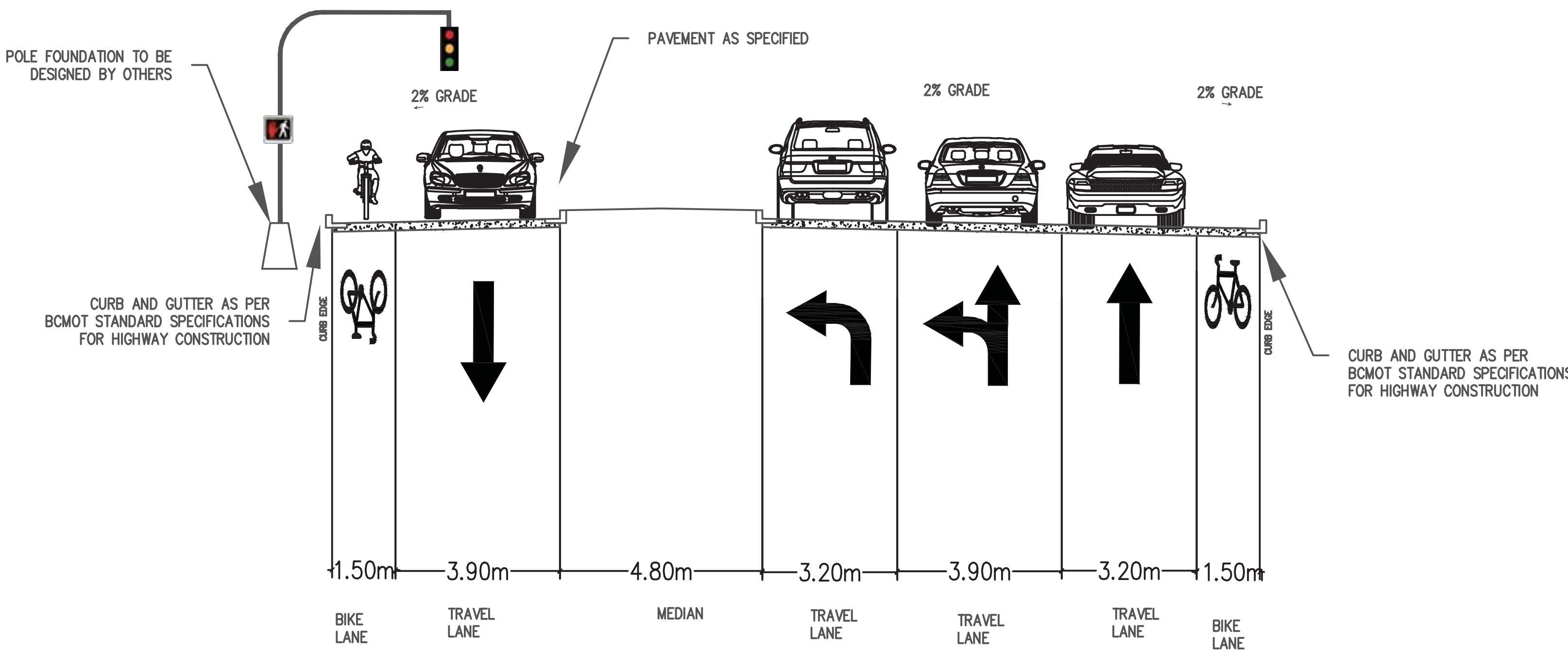
Client: UBC SEEDS

Date: APRIL 7, 2017

Scale: 1:1000

Sheet: T-06


| | |
|---|---|
| General Notes | |
| No. / Revision/Issue / Date | |
| Designed By | CA |
| Drawn By | CA |
| Firm Name and Address | TEAM 12 |
| Project Name | REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD |
| Drawing | AUTOTURN CHECK |
| Client | UBC SEEDS |
| Date | APRIL 7, 2017 |
| Scale | 1:1000 |
| Sheet | T–07 |




General Notes

| No. | Revision/Issue | Date |
|---|---|---|

Designed By: CA

Drawn By: CL

Firm Name and Address: TEAM 12

Project Name: REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD

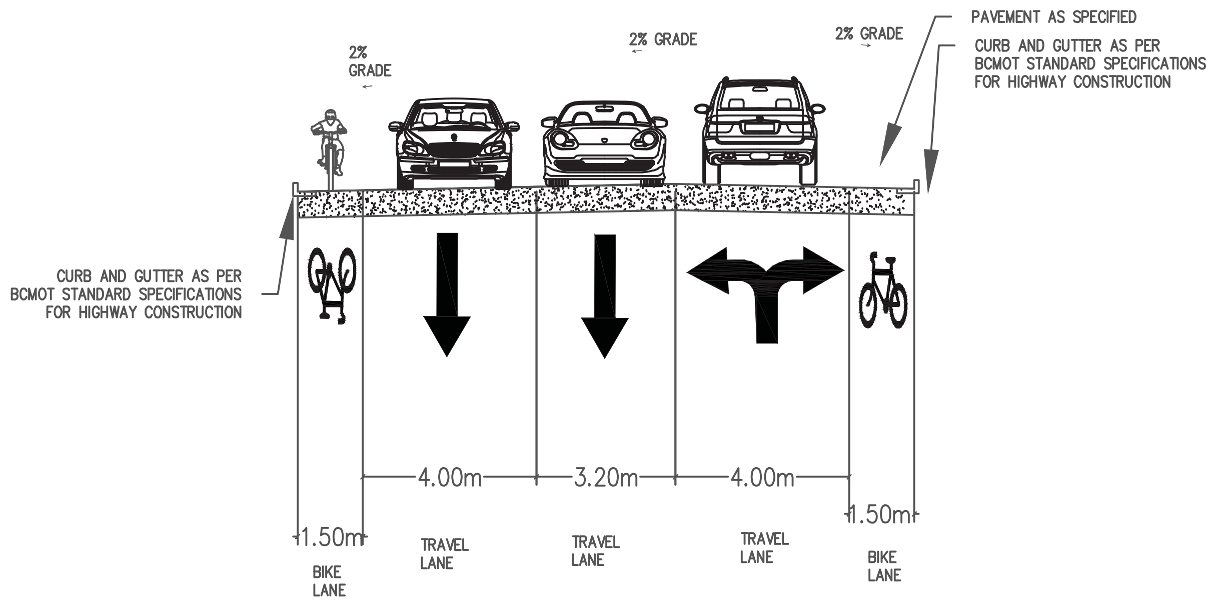
Drawing: EAST SECTION VIEW

Client: UBC SEEDS

Date: APRIL 7, 2017

Scale: NTS

Sheet: T–08




General Notes

| No. | Revision/Issue | Date |
| --- | --- | --- |
| | | |
| | | |

Designed By
CA

Drawn By
CL

Firm Name and Address
TEAM 12

Project Name
REDESIGN OF
WESBROOK MALL
AND
CHANCELLOR BOULEVARD

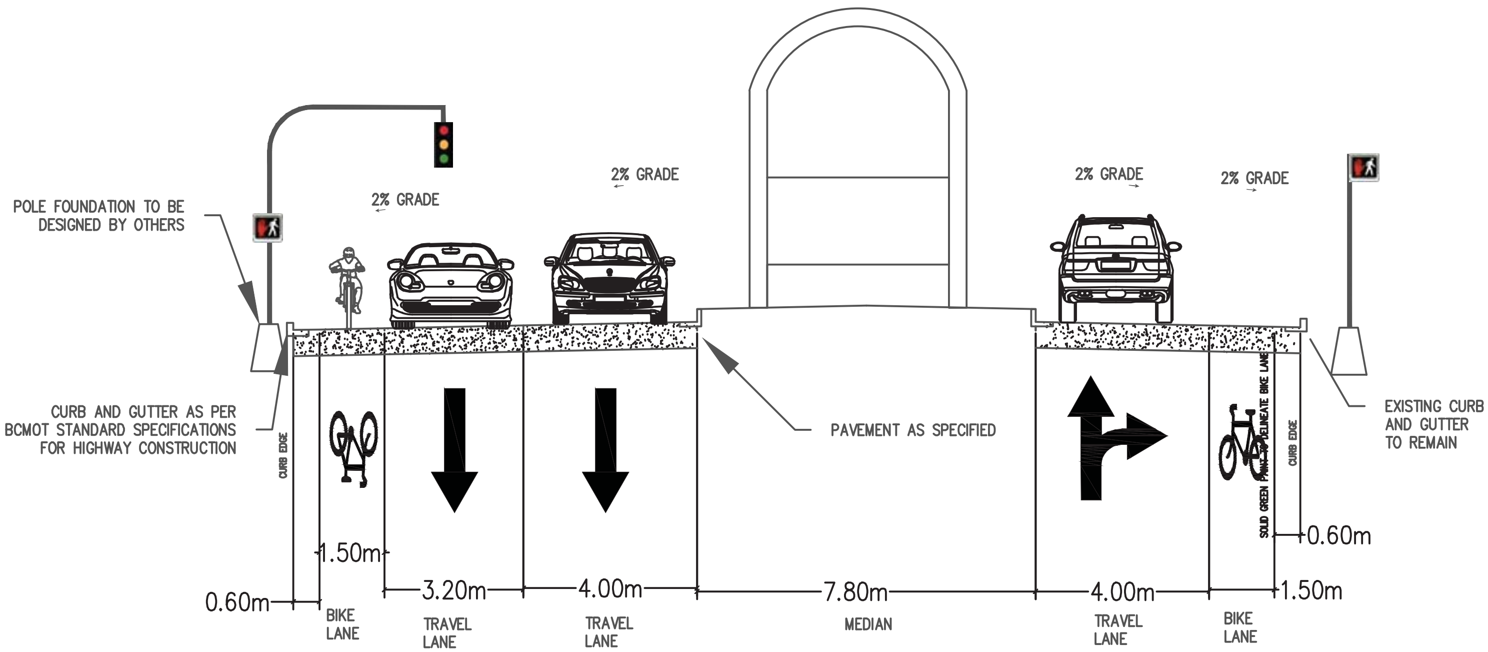
Drawing
SOUTH SECTION VIEW

Client
UBC SEEDS

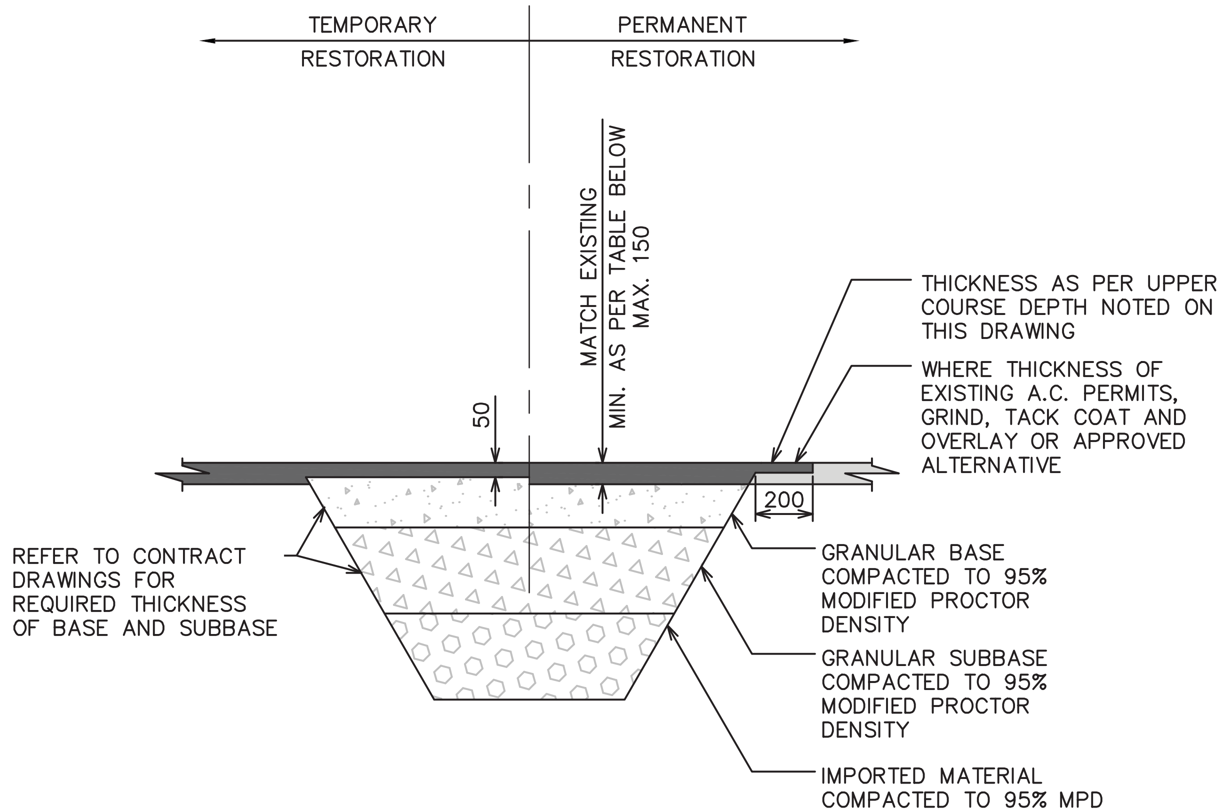
Date
APRIL 7, 2017

Scale
NTS

Sheet
T–09




| | |
|---|---|
| General Notes | |
| No. | Revision/Issue | Date |
| Designed By | CA |
| Drawn By | CL |
| Firm Name and Address | TEAM 12 |
| Project Name | REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD |
| Drawing | WEST SECTION VIEW |
| Client | UBC SEEDS |
| Date | APRIL 7, 2017 |
| Scale | NTS |
| Sheet | T–10 |




| | UPPER COURSE ASPHALT | LOWER COURSE ASPHALT | BASE COURSE | SUB-BASE COURSE |
|---|---|---|---|---|
| ARTERIALS | 50mm SUPER PAVE (12.5mm) | 75mm SUPER PAVE (19mm) | 100mm 19mm CRUSHED GRANULAR BASE | 200mm 75mm CRUSHED GRANULAR SUBBASE |
| COLLECTORS | 40mm UPPER COURSE 1 | 60mm LOWER COURSE 1 | 100mm 19mm CRUSHED GRANULAR BASE | 200mm 75mm SELECT GRANULAR SUBBASE |
| LOCAL ROADS (2) | 40mm UPPER COURSE 2 | 45mm LOWER COURSE 2 | 100mm 19mm CRUSHED GRANULAR BASE | 200mm 75mm SELECT GRANULAR SUBBASE |
| NON-RESIDENTIAL LANES & DRIVEWAYS (2) | 35mm UPPER COURSE 2 | 40mm LOWER COURSE 2 | 100mm 19mm CRUSHED GRANULAR BASE | 100mm 75mm SELECT GRANULAR SUBBASE |
| (2) RESIDENTIAL DRIVEWAYS | 65mm UPPER COURSE 2 (1 LIFTS) | | 100mm 19mm CRUSHED GRANULAR BASE | 100mm 75mm SELECT GRANULAR SUBBASE |

NOTE:
1. REFER TO CONTRACT DOCUMENT SECTIONS 31 23 01, 32 12 16 AND 32 12 17 FOR SPECIFICATIONS.
2. BUTT JOINT TO HAVE 600mm MINIMUM OVERLAP IN LATERAL DIRECTION.

| Revision | Date | Approved |
|---|---|---|
| 3 | | |
| 2 | JULY 2016 | SCOTT NEUMAN |
| 1 | JANUARY 2016 | SCOTT NEUMAN |

All Dimensions Shown In Millimetres, Unless Otherwise Noted

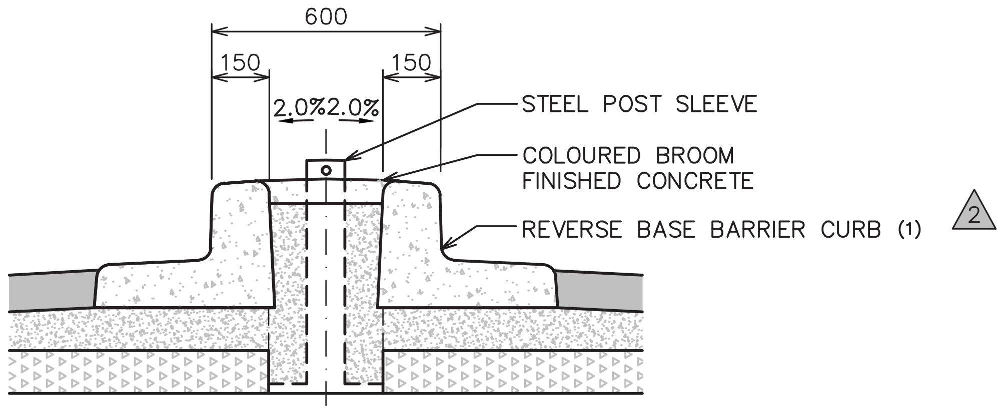
Title **SURFACE ASPHALT REINSTATEMENT AND STANDARD ROAD STRUCTURE SECTIONS**

CITY OF SURREY the future lives here.

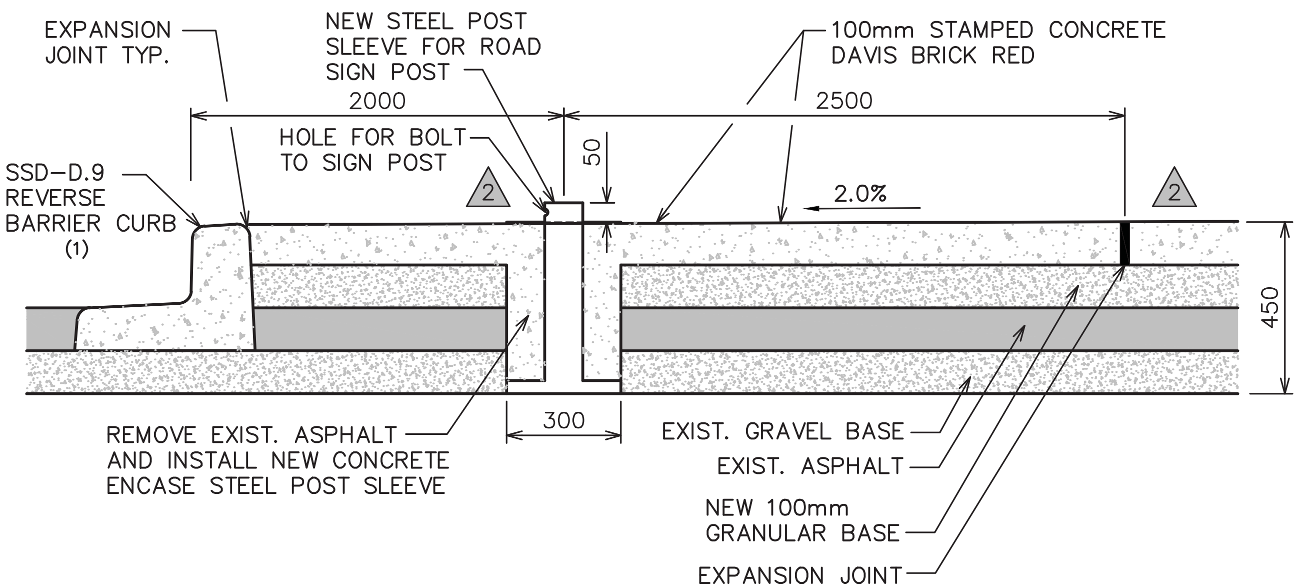
SUPPLEMENTARY STANDARD DRAWINGS

Approved By : [signature]
JANUARY 2016 G.M. Engineering

DRAWING NUMBER
SSD-G.5




## SECTION A–A




## SECTION B–B

2 NOTES: (1) CURB AND GUTTER TO BE BULL NOSE END TO BE NARROW BASE BARRIER CURB AS PER MMCD DWG C4

| | | |
|---|---|---|
| 3 | | |
| 2 | JULY 2016 | JAIME BOAN |
| 1 | JANUARY 2016 | JAIME BOAN |
| | Revision Date | Approved |

All Dimensions Shown In Millimetres, Unless Otherwise Noted

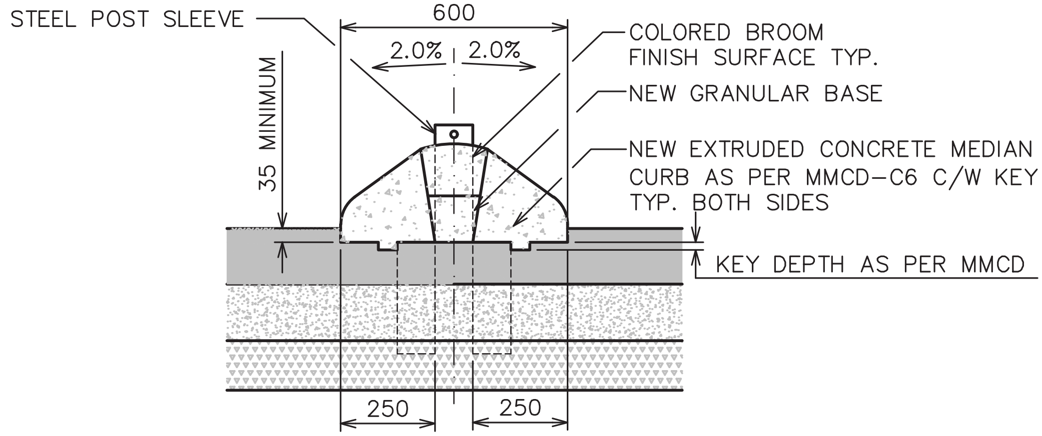
Title **RAISED MEDIAN, BULL NOSE END BARRIER CURB DETAIL**

CITY OF SURREY the future lives here.

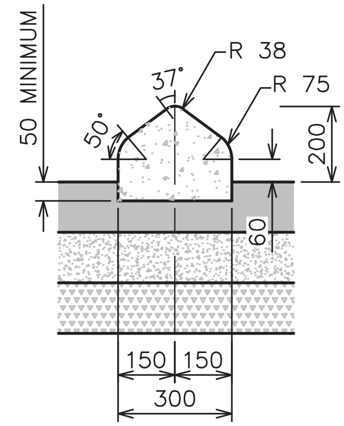
SUPPLEMENTARY STANDARD DRAWINGS

Approved By : JANUARY 2016 G.M. Engineering

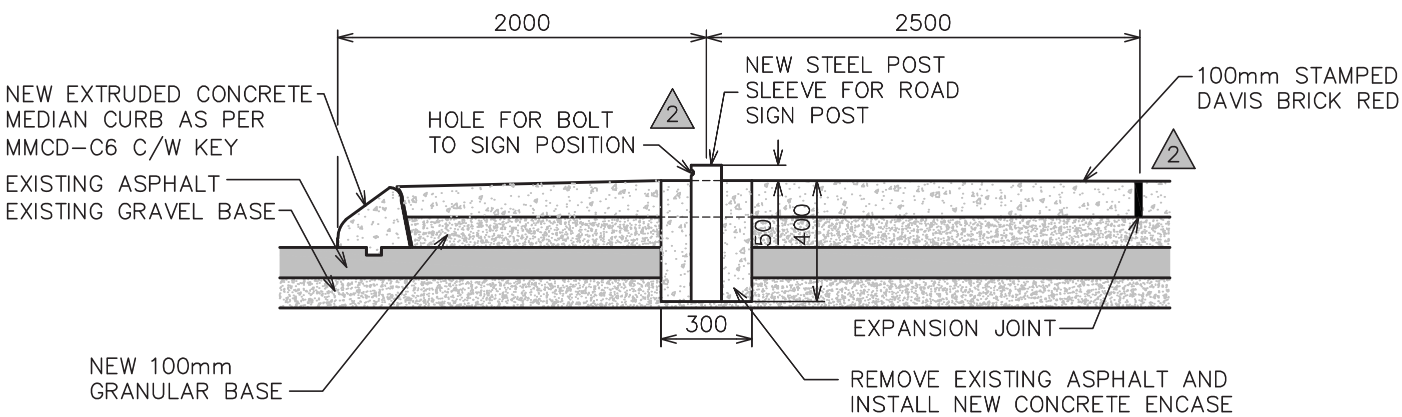
DRAWING NUMBER SSD–R.15.2




**SECTION A-A**
**MEDIAN AT LEFT TURN BAY**
**TYP. SECTION**




**EXTRUDED CONCRETE CURB CENTER**
**DIVIDER NARROW SECTION DETAIL**




**SECTION B-B**

| | | | |
|---|---|---|---|
| 3 | | | All Dimensions Shown In Millimetres, Unless Otherwise Noted |
| 2 | JULY 2016 | JAIME BOAN | |
| 1 | JANUARY 2016 | JAIME BOAN | Title **RAISED MEDIAN, BULL NOSE END EXTRUDED CURB DETAIL** |
| | Revision Date | Approved | |

CITY OF SURREY the future lives here.

SUPPLEMENTARY STANDARD DRAWINGS

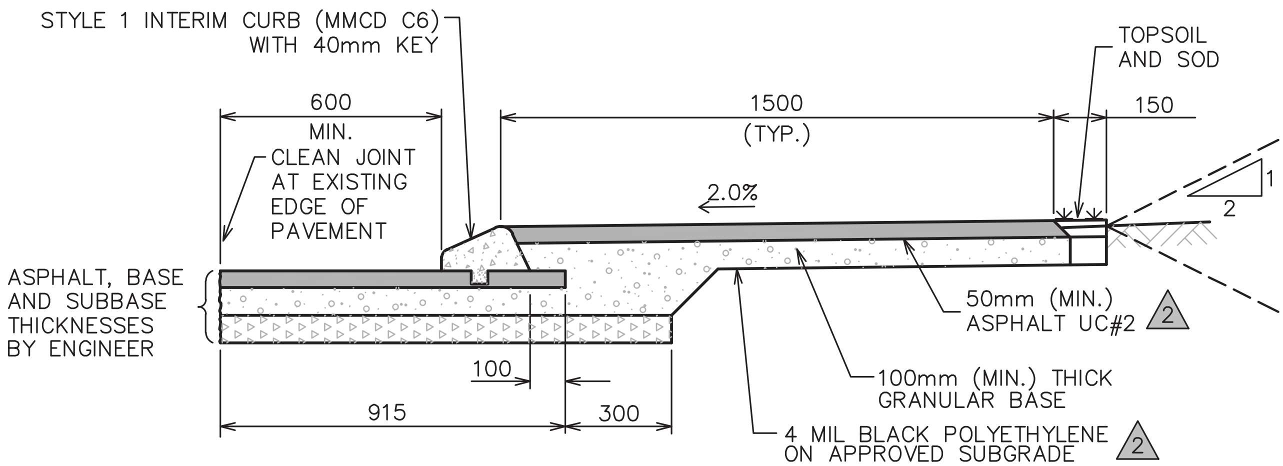
Approved By :

JANUARY 2016

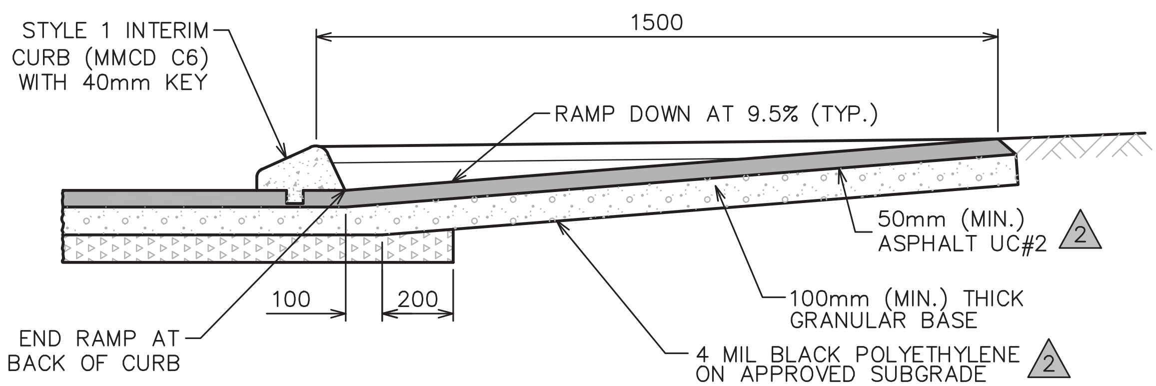
G.M. Engineering

DRAWING NUMBER

SSD-R.15.3




**ELEVATED ASPHALT SIDEWALK**




**ASPHALT SIDEWALK AT WHEELCHAIR RAMP**

| | | |
|---|---|---|
| 3 | | |
| 2 | JULY 2016 | JAIME BOAN |
| 1 | JANUARY 2016 | JAIME BOAN |
| | Revision Date | Approved |

All Dimensions Shown In Millimetres, Unless Otherwise Noted

Title **SIDEWALKS, INTERIM ASPHALT**

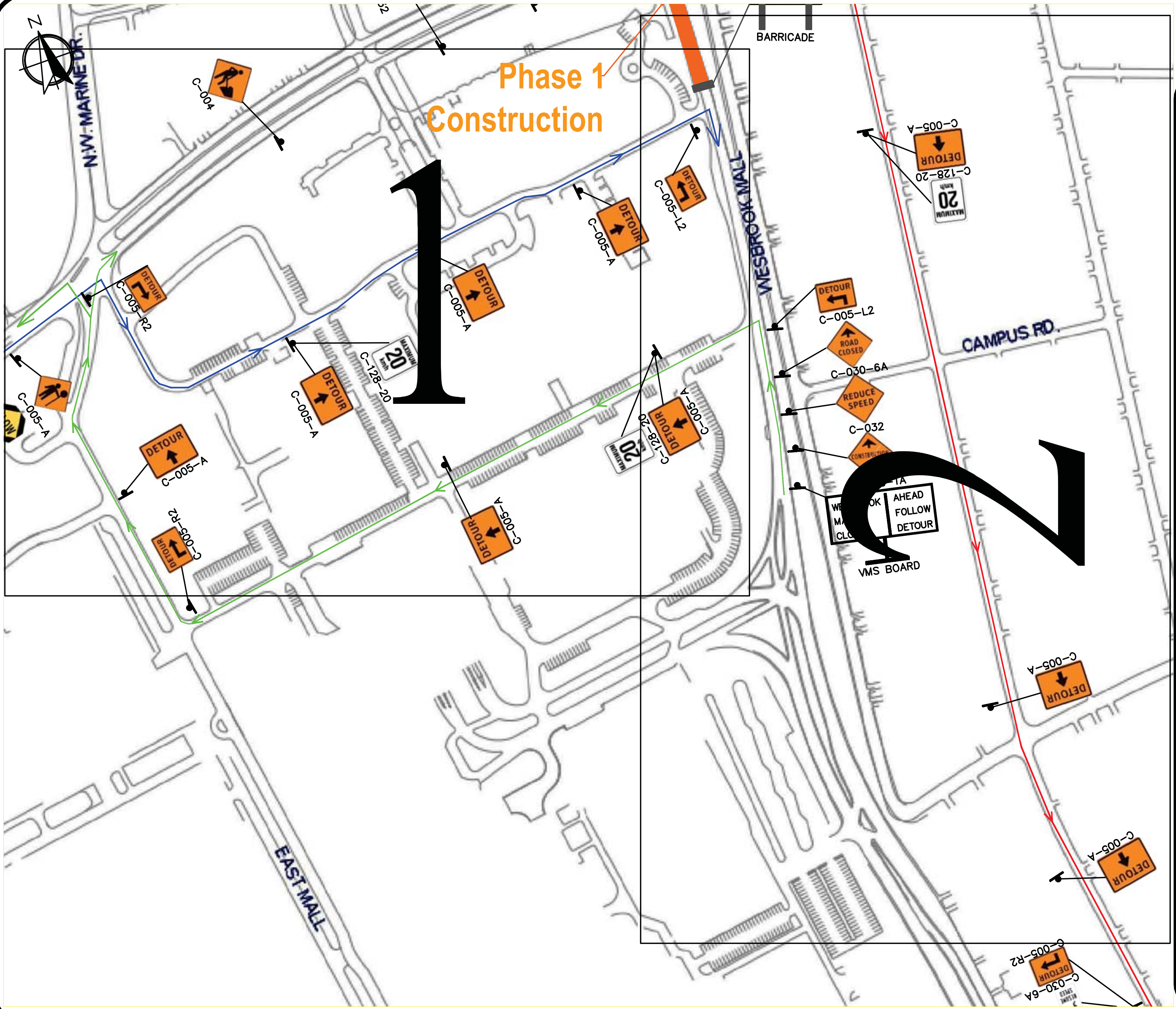
CITY OF SURREY the future lives here.

SUPPLEMENTARY STANDARD DRAWINGS

Approved By : G.M. Engineering

JANUARY 2016

DRAWING NUMBER SSD-R.27




General Notes

| No. | Revision/Issue | Date |
| --- | --- | --- |
| | | |

Designed By: YL

Drawn By: YL

Firm Name and Address: TEAM 12

Project Name: REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD

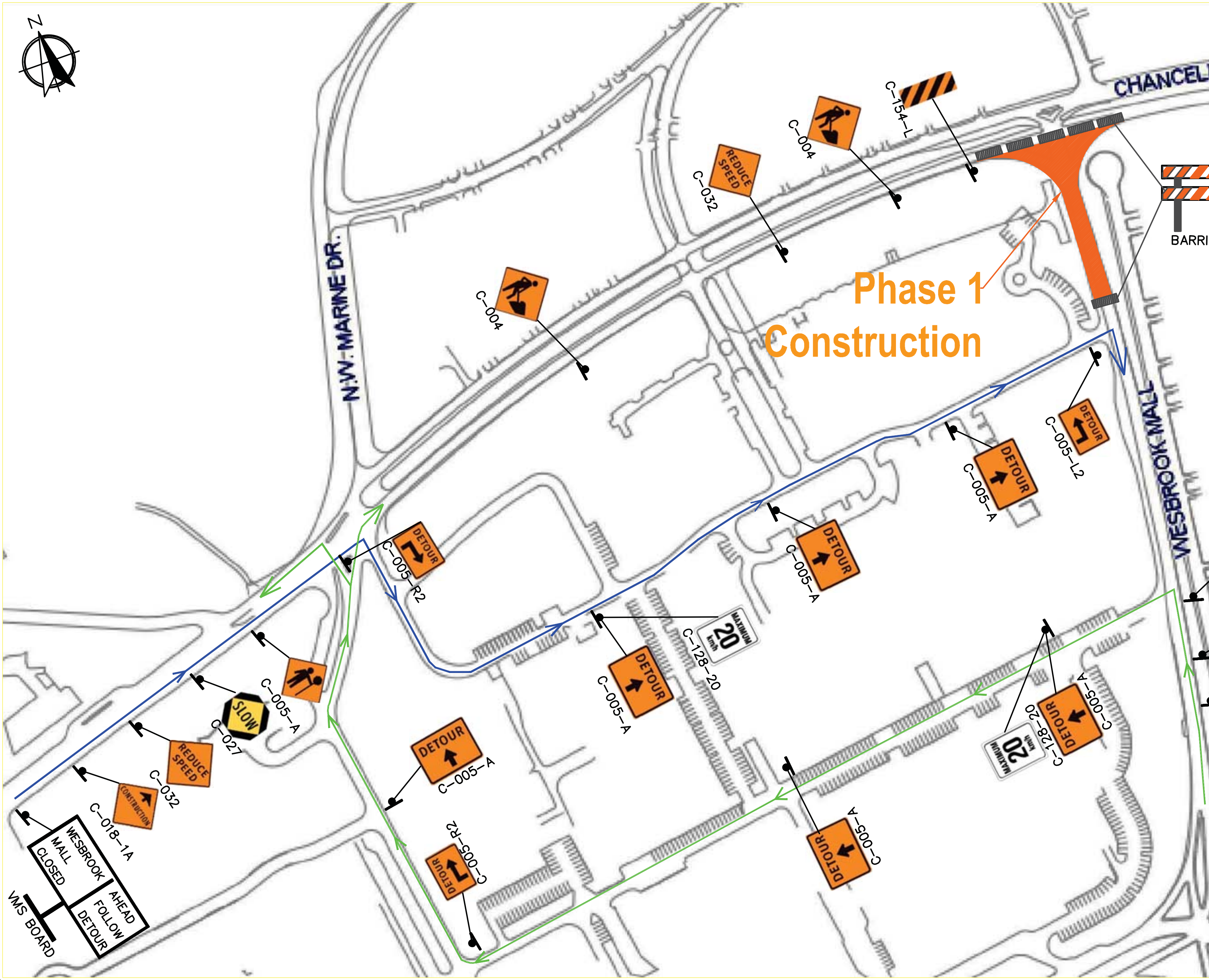
Drawing: TRAFFIC ACCOMMODATION PLAN–PHASE 1

Client: UBC SEEDS

Date: APRIL 7, 2017

Scale: 1:1000

Sheet: T–12




General Notes

| No. | Revision/Issue | Date |
| --- | --- | --- |
| | | |

Designed By: YL

Drawn By: YL

Firm Name and Address: TEAM 12

Project Name: REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD

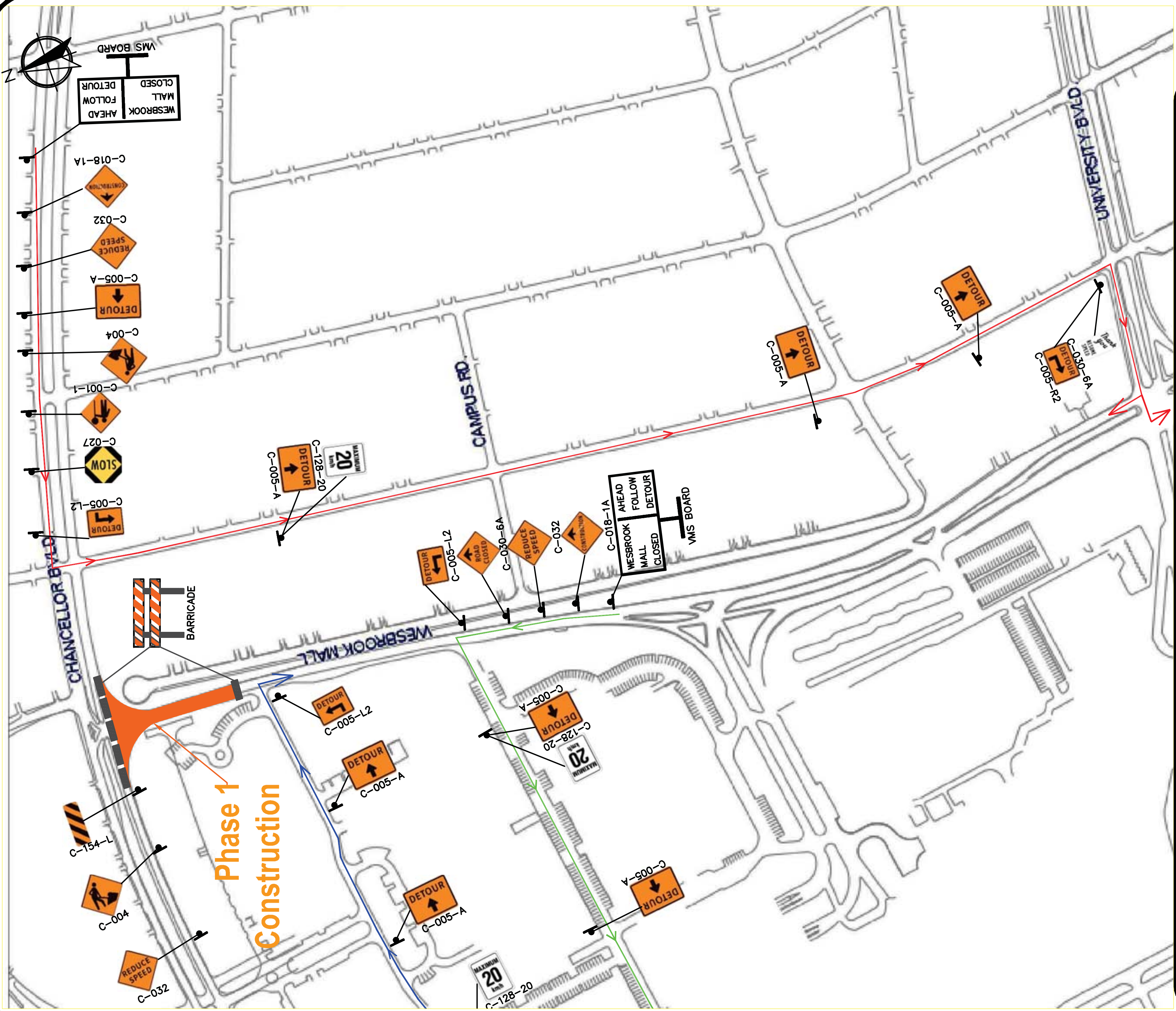
Drawing: TRAFFIC ACCOMMODATION PLAN–PHASE 1 Sheet 1

Client: UBC SEEDS

Date: APRIL 7, 2017

Scale: 1:500

Sheet: T–13




General Notes

| No. | Revision/Issue | Date |
|---|---|---|
| | | |
| | | |

Designed By: YL

Drawn By: YL

Firm Name and Address: TEAM 12

Project Name: REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD

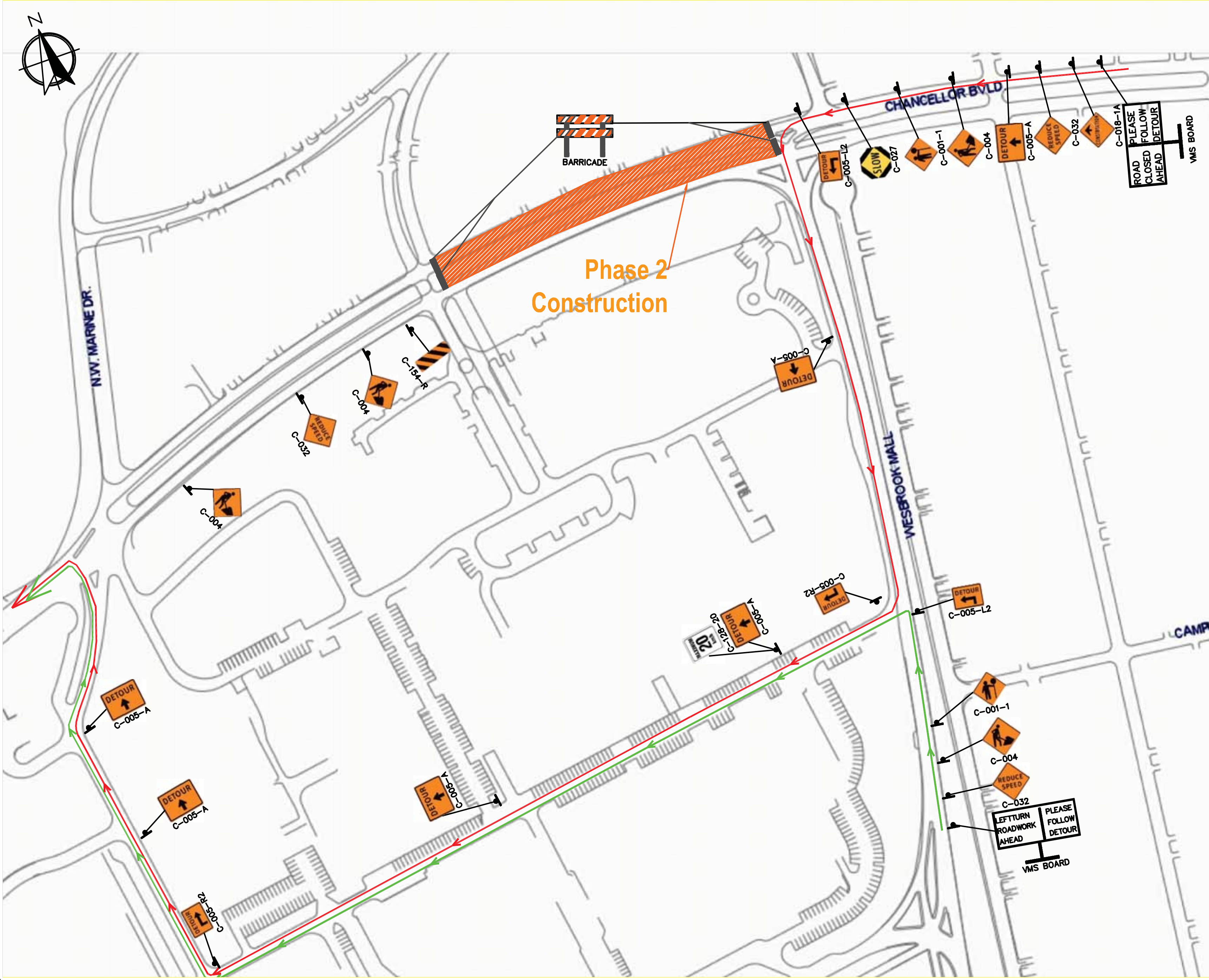
Drawing: TRAFFIC ACCOMMODATION PLAN–PHASE 1 SHEET 2

Client: UBC SEEDS

Date: APRIL 7, 2017

Scale: 1:500

Sheet: T–14




| General Notes | | |
|---|---|---|
| No. | Revision/Issue | Date |

Designed By: YL

Drawn By: YL

Firm Name and Address: TEAM 12

Project Name: REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD

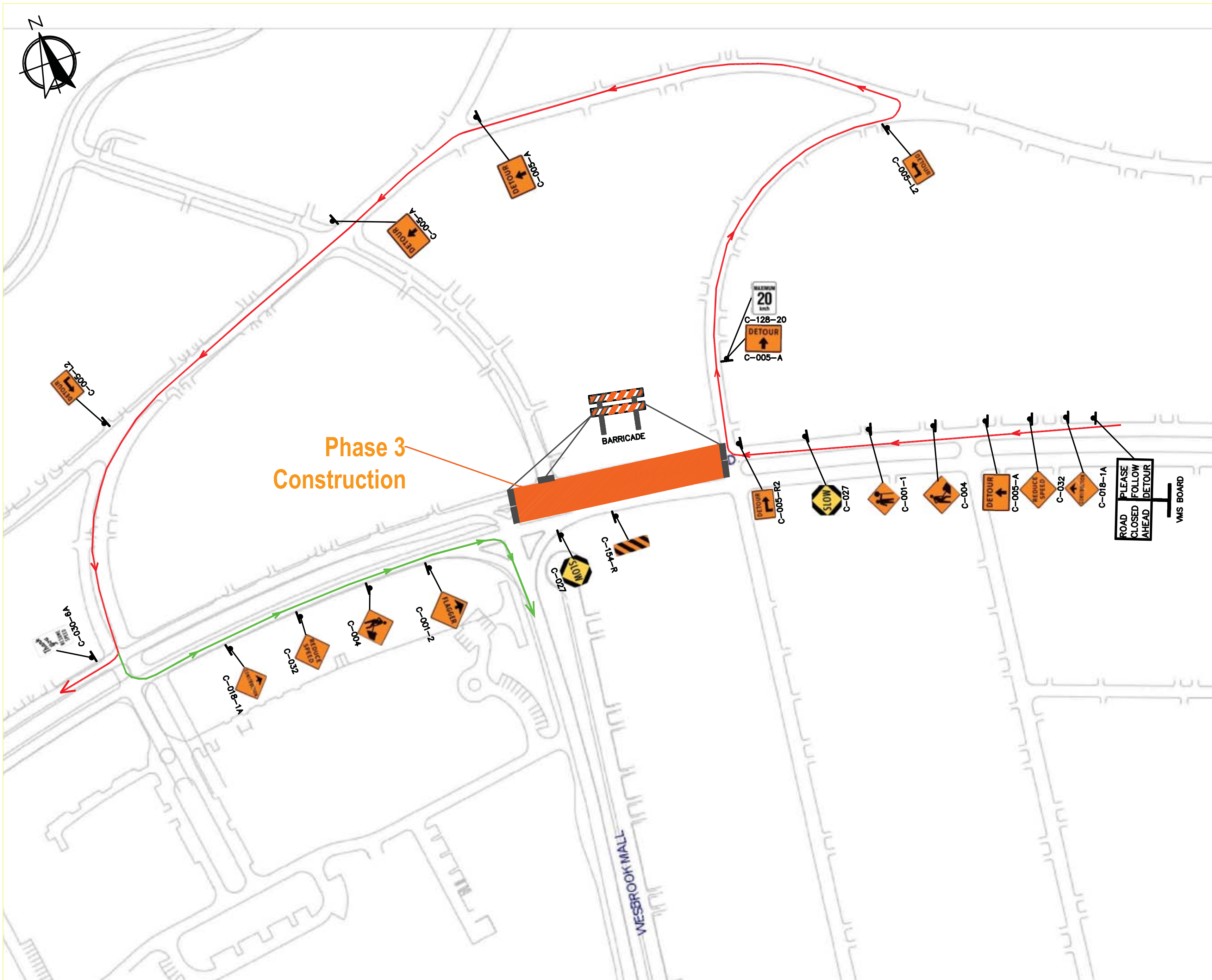
Drawing: TRAFFIC ACCOMMODATION PLAN-PHASE 2

Client: UBC SEEDS

Date: APRIL 7, 2017

Scale: 1:500

Sheet: T-15




| | | |
|---|---|---|
| General Notes | | |
| No. | Revision/Issue | Date |

Designed By: YL

Drawn By: YL

Firm Name and Address: TEAM 12

Project Name: REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD

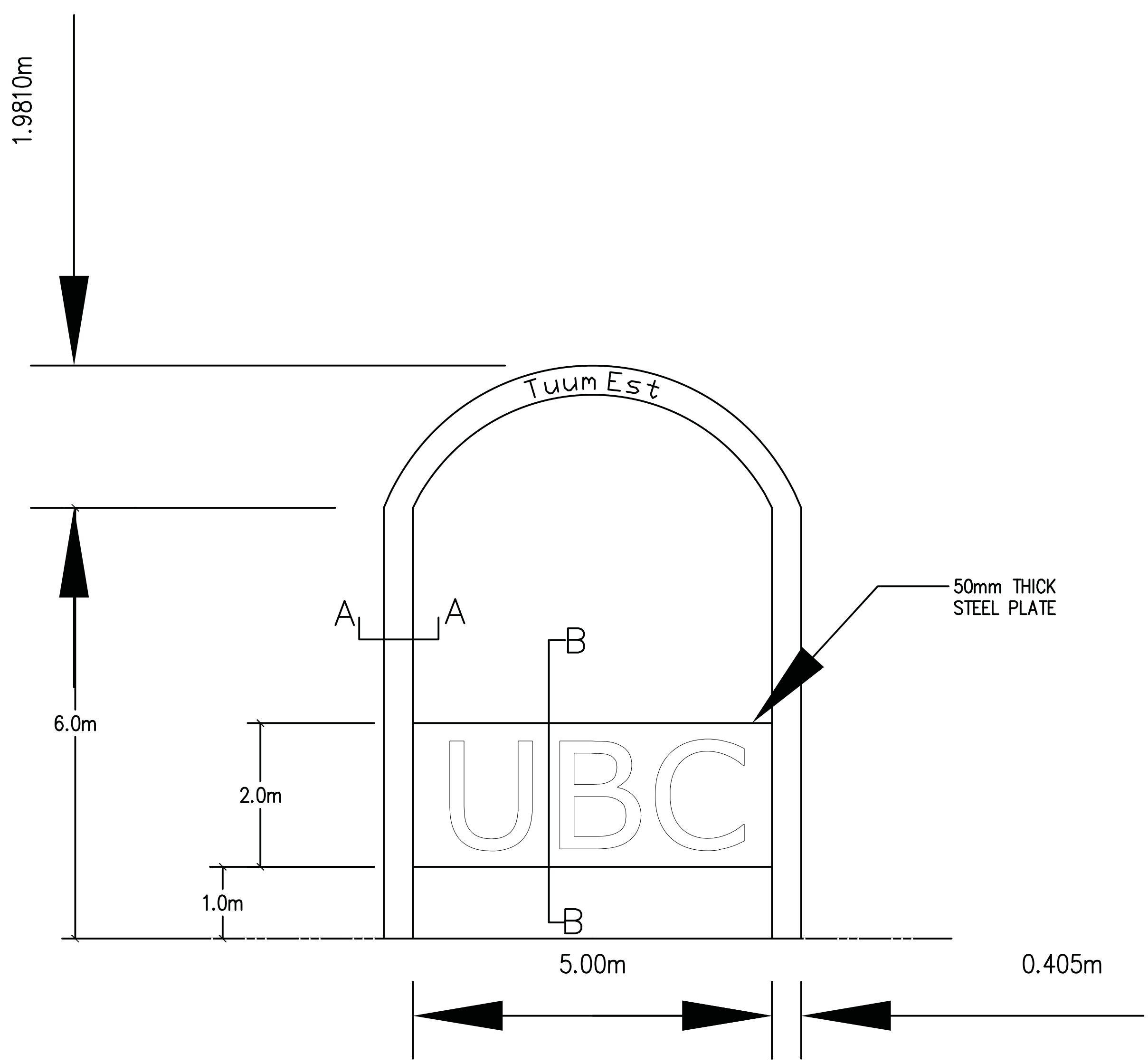
Drawing: TRAFFIC ACCOMMODATION PLAN-PHASE 3

Client: UBC SEEDS

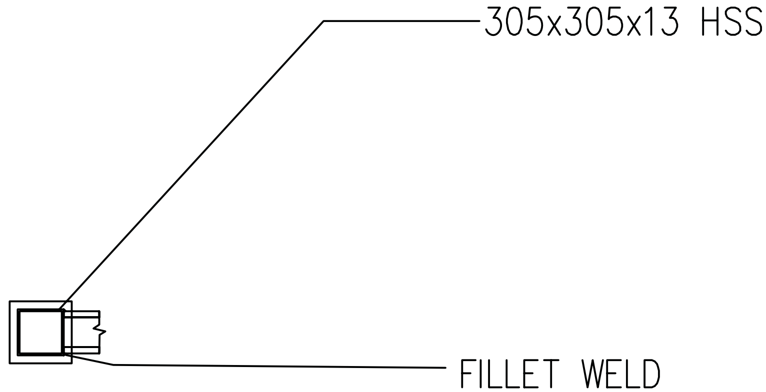
Date: APRIL 7, 2017

Scale: 1:500

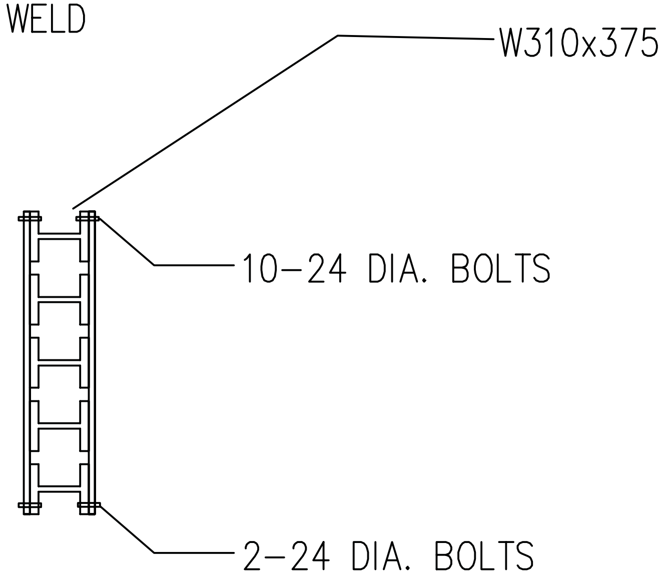
Sheet: T-16




| | |
|---|---|
| General Notes | |
| No. / Revision/Issue / Date | |
| Designed By | MT |
| Drawn By | MT |
| Firm Name and Address | TEAM 12 |
| Project Name | REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD |
| Drawing | STRUCTURAL ARCH |
| Client | UBC SEEDS |
| Date | APRIL 7, 2017 |
| Scale | 1:100 |
| Sheet | S01 |




SECTION A–A




SECTION B–B

| General Notes | | |
|---|---|---|
| No. | Revision/Issue | Date |

Designed By: MT

Drawn By: MT

Firm Name and Address: TEAM 12

Project Name: REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD

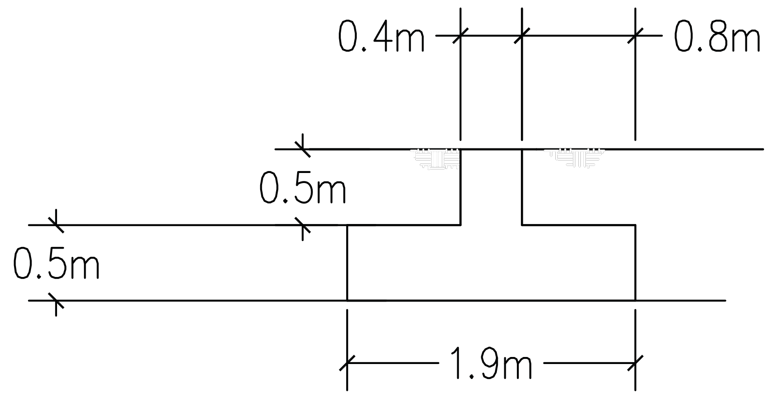
Drawing: STRUCTURAL DETAILS

Client: UBC SEEDS

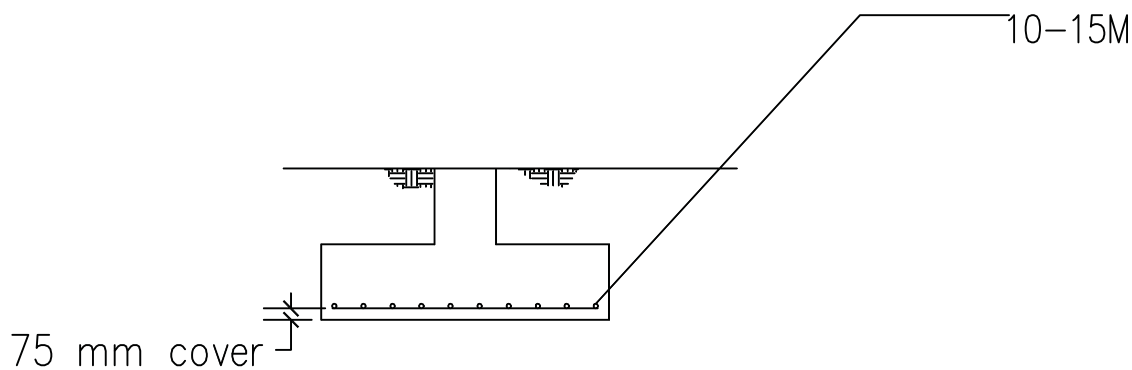
Date: APRIL 7, 2017

Scale: 1:50

Sheet: S02




FOOTING




TYPICAL FOOTING DETAIL

General Notes

| No. | Revision/Issue | Date |
| --- | --- | --- |

Designed By: MT

Drawn By: MT

Firm Name and Address: TEAM 12

Project Name: REDESIGN OF WESBROOK MALL AND CHANCELLOR BOULEVARD

Drawing: FOOTING DETAIL

Client: UBC SEEDS

Date: APRIL 7, 2017

Scale: 1:50

Sheet: S03

# APPENDIX B : COST ESTIMATE BREAKDOWN

| Team Member | Mandy Tam | Cliff Chun | Evan Yan | Celine Au | York Liao | Chi Yan Leung | Dr. Armin Bebamzadeh |
|---|---|---|---|---|---|---|---|
| **Qualification** | EIT | EIT | EIT | EIT | EIT | EIT | Supervisory Engineer |
| **Professional Service Hourly Rate** | $ 121.00 | $ 121.00 | $ 121.00 | $ 121.00 | $ 121.00 | $ 121.00 | $ 195.00 |
| **Detailed Design Phase** | | | | | | | |
| Team Meetings (hr) | 3 | 3 | 3 | 3 | 3 | 3 | 0 |
| Site Visits (hr) | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Review Meetings (hr) | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Research (hr) | 2 | 2 | 2 | 2 | 2 | 2 | 0 |
| Field Survey (hr) | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 0 |
| Detailed Design: Geotechnical Analysis (h | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Detailed Design: Intersection (hr) | 1.5 | 1.5 | 1.5 | 3 | 1.5 | 1.5 | 0 |
| Detailed Design: Gateway (hr) | 5 | 3 | 1 | 1 | 1 | 3 | 0 |
| Drafting and Modeling (hr) | 2.5 | 1 | 1 | 1 | 1 | 1 | 0 |
| Schedule (hr) | 1 | 1 | 1 | 1 | 5 | 1 | 0 |
| Cost (hr) | 1 | 1 | 6.5 | 1 | 1 | 1 | 0 |
| Permit Application Preparation (hr) | 2 | 2 | 2 | 2 | 2 | 2 | 0 |
| Client Consultation for Detailed Design (h | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 0 |
| Summary Design Report (hr) | 2 | 2 | 2 | 3.5 | 2 | 3 | 0 |
| Presentation Preparation (hr) | 2 | 2 | 2 | 4 | 2 | 2 | 0 |
| Detailed Design Presentation (hr) | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Sub-total Cost** | **$ 3,509.00** | **$3,085.50** | **$3,509.00** | **$3,448.50** | **$3,327.50** | **$ 3,206.50** | **$ 390.00** |
| **Minor Disbursements (5%)** | **$** | | | | | | **1,023.80** |
| **Total Cost for Detailed Design** | **$** | | | | | | **21,499.80** |
| **Procurement Phase** | | | | | | | |
| Team Meetings (hr) | 2 | 2 | 2 | 2 | 2 | 2 | 0 |
| Review Meetings (hr) | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| IFT for Contractor | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 0 |
| Bid Package Preparation for Tender | 4 | 4 | 4 | 4 | 4 | 4 | 0 |
| Contractor Submission Period | 2 | 2 | 2 | 2 | 2 | 2 | 0 |
| Bid Selection Process | 3 | 3 | 3 | 3 | 3 | 3 | 0 |
| Client Consultation for Selected Bid (hr) | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| Bid Award to Contractor | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| **Sub-total Cost** | **$ 1,815.00** | **$1,815.00** | **$1,815.00** | **$1,815.00** | **$1,815.00** | **$ 1,815.00** | **$ 97.50** |
| **Minor Disbursements (5%)** | **$** | | | | | | **549.38** |
| **Total Cost for Procurement Phase** | **$** | | | | | | **11,536.88** |

| Summary | | |
|---|---|---|
| **Total Cost for Detailed Design** | **$** | **21,499.80** |
| **Total Cost for Procurement Phase** | **$** | **11,536.88** |
| **Total Cost of Consultation** | **$** | **33,036.68** |

## Detailed Construction Cost Breakdown

| | | |
|---|---|---|
| **Mobilization** | **$** | **8,700.0** |
| **Communication** | $ | 1,050.0 |
| **Toilets** | $ | 600.0 |
| **Office Supplies** | $ | 3,000.0 |
| **Transportation** | $ | 3,000.0 |
| **Trailer** | $ | 1,050.0 |
| **Site Preparation** | **$** | **12,400.0** |
| **Temporary Service** | $ | 4,100.0 |
| **Site tools, Equipment** | $ | 2,000.0 |
| **Safety Provision** | $ | 1,500.0 |
| **Dampproofing** | $ | 300.0 |
| **Firestopping** | $ | 500.0 |

| | |
|---|---|
| Survey | $ 4,000.0 |
| **Phase 1 - Wesbrook Mall** | **$ 488,779.0** |
| Detour Setup | $ 6,500.0 |
| Earthwork (Island Removal) | |
| Excavation, Trenching | $ 2,154.0 |
| Backfill, Compaction | $ 4,274.0 |
| Earthwork (Road) | |
| Excavation, Trenching | $ 3,431.1 |
| Backfill, Compaction | $ 6,808.0 |
| Utility Trenching | $ 512.0 |
| Traffic Signals & Pedestrian Flashers Installation | **$ 459,000.0** |
| Sidewalk Construction | $ 500.0 |
| Curb & Gutter Extension | $ 5,600.0 |
| **Phase 2 - West Leg Chancellor Blvd Widening** | **$ 26,683.4** |
| Detour Setup | $ 12,500.0 |
| Earthwork (Road) | |
| Excavation, Trenching | $ 1,102.8 |
| Backfill, Compaction | $ 2,188.1 |
| Utility Trenching | $ 164.5 |
| Median Construction + Curb & Gutter Work | $ 4,480.0 |
| Structural Gateway Construction | **$ 6,248.0** |
| Earthwork | $ 763.0 |
| Gateway Footing Construction | $ 1,856.0 |
| Gateway Column Construction | $ 1,538.0 |
| Gateway Concrete Arc Construction | $ 1,841.0 |
| Gateway Finishing | $ 250.0 |
| **Phase 3 - East Leg Chancellor Blvd Widening** | **$ 35,969.1** |
| Detour Setup | $ 7,300.0 |
| Earthwork (Road) | |
| Tree Removal | $ 6,000.0 |
| Excavation, Trenching | $ 4,711.2 |
| Backfill, Compaction | $ 9,347.9 |
| Median Construction + Curb & Gutter Work | $ 8,610.0 |
| **Re-Surfacing** | **$ 46,867.6** |
| Asphalt | $ 24,000.0 |
| Final Asphalt | $ 5,387.6 |
| Lane Paint | $ 12,800.0 |
| Road Markings | $ 2,880.0 |
| Bike Lane Signs | $ 1,800.0 |
| **Demobilization** | **$ 5,000.0** |
| Waste Management | $ 5,000.0 |

| | |
|---|---|
| **Completion Inspection** | **$ 1,000.0** |
| **Handover** | **$ 380.0** |
| **General Contractor Miscellaneous** | **$ 182,255.0** |
| **Insurance and Bonds** | $ 2,500.0 |
| **Material Testing** | $ 3,500.0 |
| **Permits** | |
| **BC Minister of Transportation** | $ 1,008.0 |
| **UBC** | $ 5,772.0 |
| **Courier** | $ 300.0 |
| **Staff** | $ 169,175.0 |
| **Subtotal** | **$ 808,034.0** |
| **6% Contingency** | **$ 48, 482.0** |
| **Total** | **$ 856,516.1** |
| **5% GST** | **$ 42,825.8** |
| **Final** | **$ 899,341.9** |

## Unit Rates

| ***Labor*** | **$/hr** |
|---|---|
| *Superintendent* | 58.21 |
| *Foreman* | 49.17 |
| *Senior Project Manager* | 70 |
| *Project Manager* | 65 |
| *Project Coordinator* | 35 |
| *Safety Officer* | 50 |
| *Site Coordinator* | 35 |
| *Flagger* | 25 |

| ***Materials*** | **$** | **unit** |
|---|---|---|
| *Pit Run* | 25 | $/m3 |
| *Drain Rock* | 35 | $/m3 |
| *Asphalt* | 24 | $/m2 |
| *Final Asphalt* | 5 | $/m2 |
| *Tip Fee* | 20 | $/load |
| *Paint Bike Lane* | 80 | $/m |
| *Curb* | 70 | $/m |
| *Bike Marking* | 180 | $/ea |
| *Bike Lane Signs* | 300 | $/ea |
| *Traffic Signal* | 150000 | $/ea |
| *Traffic Signal Installation* | 3000 | $/ea |
| *Trailers* | 350 | $/month |

| ***Equipment*** | **(Labour) $/hr** | **(Equipment) $/hr** |
|---|---|---|

| | | |
|---|---|---|
| *Median Excavator* | 39.2 | 140 |
| *Truck* | / | 100 |
| *bobcat* | 40.48 | 65 |
| *Roller* | 41.31 | 65 |

## Sample Calculations

Sample calculations for staff cost. Other general contractor’s costs are estimated similarly

| | | | Labour | | | Material | Equipment | | Subcontract | | | | | | - |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Description | Qty | Unit | man hr | total mh | Rate | Rate | Qty | Rate | Qty | Rate | Labour | Material | Equip. | Sub. | Total |
| Staff | | | | | | | | | | | - | - | - | - | - |
| project start-up | | | | | | | | | | | - | - | - | - | - |
| Project Manager | 1 | wk | 32 | 32 | 65 | | | | | | 2,080 | - | - | - | 2,080 |
| Project Co-Ordinator / Student | 1 | wk | 16 | 16 | 35 | | | | | | 560 | - | - | - | 560 |
| project duration | | | | | | | | | | | - | - | - | - | - |
| Project Manager | 9 | wk | 32 | 288 | 65 | | | | | | 18,720 | - | - | - | 18,720 |
| Project Co-Ordinator / Student | 9 | wk | 8 | 72 | 35 | | | | | | 2,520 | - | - | - | 2,520 |
| Safety Staff | | | | | | | | | | | - | - | - | - | - |
| Safety Officer - office work | 9 | wk | 40 | 360 | 50 | | | | | | 18,000 | - | - | - | 18,000 |
| Safety Audits & Training | 9 | wk | 2 | 18 | | | | | | | - | - | - | - | - |
| Site Staff | | | | | | | | | | | - | - | - | - | - |
| Superintendent | 10 | wk | 32 | 320 | 58.21 | | | | | | 18,627 | - | - | - | 18,627 |
| Foreman | 10 | wk | 40 | 400 | 49.17 | | | | | | 19,668 | - | - | - | 19,668 |
| Site Coordinator x5 | 50 | wk | 40 | 2,000 | 35 | | | | | | 70,000 | - | - | - | 70,000 |
| Flagger x2 | 19 | wk | 40 | 760 | 25 | | | | | | 19,000 | - | - | - | 19,000 |
| Subtotal | 169,175 | | | | | | | | | | - | - | - | - | - |

Sample calculations for excavation cost

| | | | Labour | | | Material | Equipment | | Subcontract | | | | | | - |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Description | Qty | Unit | man hr | total mh | Rate | Rate | Qty | Rate | Qty | Rate | Labour | Material | Equip. | Sub. | Total |
| **Backfill** | | | | | | | | | | | | | | | |
| **sub-base** | | | | | | | | | | | | | | | |
| Volume: | 216 | m3 | | | | | | | | | | | | | |
| Waste & Compaction: | 115% | | | | | | | | | | | | | | |
| Import Material: | 248 | m3 | | | | 25 | | | | | - | 6,196 | - | - | 6,196 |
| Productivity | 25 | m3/hr | | | | | | | | | | | | | |
| MEX Placing | 9.91 | hrs | 1 | 10 | 39.2 | | 1 | 140 | | | 388 | - | 1,388 | - | 1,776 |
| Bobcat Spread | 9.91 | hrs | 1 | 10 | 40.48 | | 1 | 65 | | | 401 | - | 644 | - | 1,045 |
| Roller Compact | 9.91 | hrs | 1 | 10 | 41.31 | | 1 | 65 | | | 409 | - | 644 | - | 1,053 |
| subtotal: | 10,070 | | | | | | | | | | | | | | |
| **Island =** | **1,903** | | | | | | | | | | | | | | |
| **Phase 1 =** | **3,031** | | | | | | | | | | | | | | |
| **Phase 2 =** | **974** | | | | | | | | | | | | | | |
| **Phase 3 =** | **4,162** | | | | | | | | | | | | | | |
| $/m3 (neat volume): | 46.7 | | | | | | | | | | | | | | |

Sample calculations for costs of backfilling sub-base. Costs for base and asphalt are done in a similar way.

| | | | Labour | | | Material | Equipment | | Subcontract | | | | | | - |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Description | Qty | Unit | man hr | total mh | Rate | Rate | Qty | Rate | Qty | Rate | Labour | Material | Equip. | Sub. | Total |
| **Excavation** | | | | | | | | | | | | | | | |
| neat volume = | 592.6305 | m3 | | | | | | | | | | | | | |
| bulk factor = | 120% | | | | | | | | | | | | | | |
| bulk volume = | 711 | m3 | | | | | | | | | | | | | |
| MEX production rate = | 35 | m3 / hr | | | | | | | | | | | | | |
| MEX hours = | 20 | hrs | 1 | 20 | 39.2 | | 1 | 140 | | | 796 | - | 2,845 | - | 3,641 |
| Trucking to dump site | | | | | | | | | | | | | | | |
| truck volume = | 11.00 | m3 | | | | | | | | | | | | | |
| Trucking to dump site = | 711 | m3 | | | | | | | | | | | | | |
| calculated loads = | 65 | ea | | | | | 1 | 20 | | | - | - | 1,293 | - | 1,293 |
| cycle time off site = | 1 | hrs | | | | | | | | | | | | | |
| calculated truck hours = | 64.65 | hrs | | | | | 1 | 100 | | | - | - | 6,465 | - | 6,465 |
| subtotal = | 11,399.00 | | | | | | | | | | | | | | |
| **Island =** | **2,153.99** | | | | | | | | | | | | | | |
| **Phase 1 =** | **3,431.09** | | | | | | | | | | | | | | |
| **Phase 2 =** | **1,102.76** | | | | | | | | | | | | | | |
| **Phase 3 =** | **4,711.16** | | | | | | | | | | | | | | |
| unit price = | $ 16.03 | $/m3 | | | | | | | | | | | | | |
| Unit Rate (neat volume) = | $ 19.23 | $/m3 | | | | | | | | | | | | | |

Sample calculations for cost of constructing foundation of the gateway structure

| | | | Labour | | | Material | Equipment | | Subcontract | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Description | Qty | Unit | man hr | total mh | Rate | Rate | Qty | Rate | Qty | Rate | Labour | Material | Equip. | Sub. | Total |
| Columns and Arch are pre-cast | | | | - | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| Concrete Formwork | | | | | | | | | | | | | | | |
| form & strip | | | | - | | | | | | | - | - | - | - | - |
| strip footings | 4 | m2 | 1.00 | 4 | 41.30 | 30.00 | 1 | 15.00 | | | 165 | 120 | 60 | - | 345 |
| grind & patch | 1 | m2 | 0.10 | 0 | 41.30 | 2.00 | | | | | 4 | 2 | - | - | 6 |
| pour concrete | | | | - | | | | | | | - | - | - | - | - |
| footings, foundation walls | 5 | m3 | 1.00 | 5 | 41.30 | | | | | | 206 | - | - | - | 206 |
| Concrete Reinforcing | | | | - | | | | | | | - | - | - | - | - |
| supply and install reinforcing steel | 1 | sub | | - | | | | | 1 | 230 | - | - | - | 230 | 230 |
| Cast-in-Place Concrete | | | | - | | | | | | | - | - | - | - | - |
| foundations | 5 | m3 | | - | | 142.00 | | | | | - | 710 | - | - | 710 |
| waste | 2.5% | lot | | - | | 710 | | | | | - | 18 | - | - | 18 |
| pumping | | | | - | | | | | | | - | - | - | - | - |
| pump hours | 1 | hrs | | - | | | 1 | 165 | | | - | - | 165 | - | 165 |
| meter charge | 3 | m3 | | - | | | 1 | 4.00 | | | - | - | 11 | - | 11 |
| pump travel | 1 | trips | | - | | | 1 | 165 | | | - | - | 165 | - | 165 |
| Concrete Finishing | | | | - | | | | | | | - | - | - | - | - |
| N/A | - | m2 | | - | | | | | - | - | - | - | - | - | - |
| Subtotal | | | | | | | | | | | 375 | 850 | 401 | 230 | 1,856 |

Sample calculations for first costs of painting and signage

| First Cost | | | |
|---|---|---|---|
| | Length (m) | $/m | Total $ |
| Bike Lane Paint | 160.0 | 80.0 | 12800.0 |
| Curb and Gutter | 267.0 | 70.0 | 18690.0 |
| **Phase 1 =** | 80.0 | 70.0 | **5600.0** |
| **Phase 2 =** | 64.0 | 70.0 | **4480.0** |
| **Phase 3 =** | 123.0 | 70.0 | **8610.0** |
| | $/ea | ea | Total $ |
| Road Marking | 180.0 | 16.0 | 2880.0 |
| Bike Lane Signs | 300.0 | 6.0 | 1800.0 |
| | $/m2 | m2 | Total $ |
| Final Asphalt | 5.0 | 1077.5 | 5387.6 |

Sample calculations for maintenance cost of painting and signage

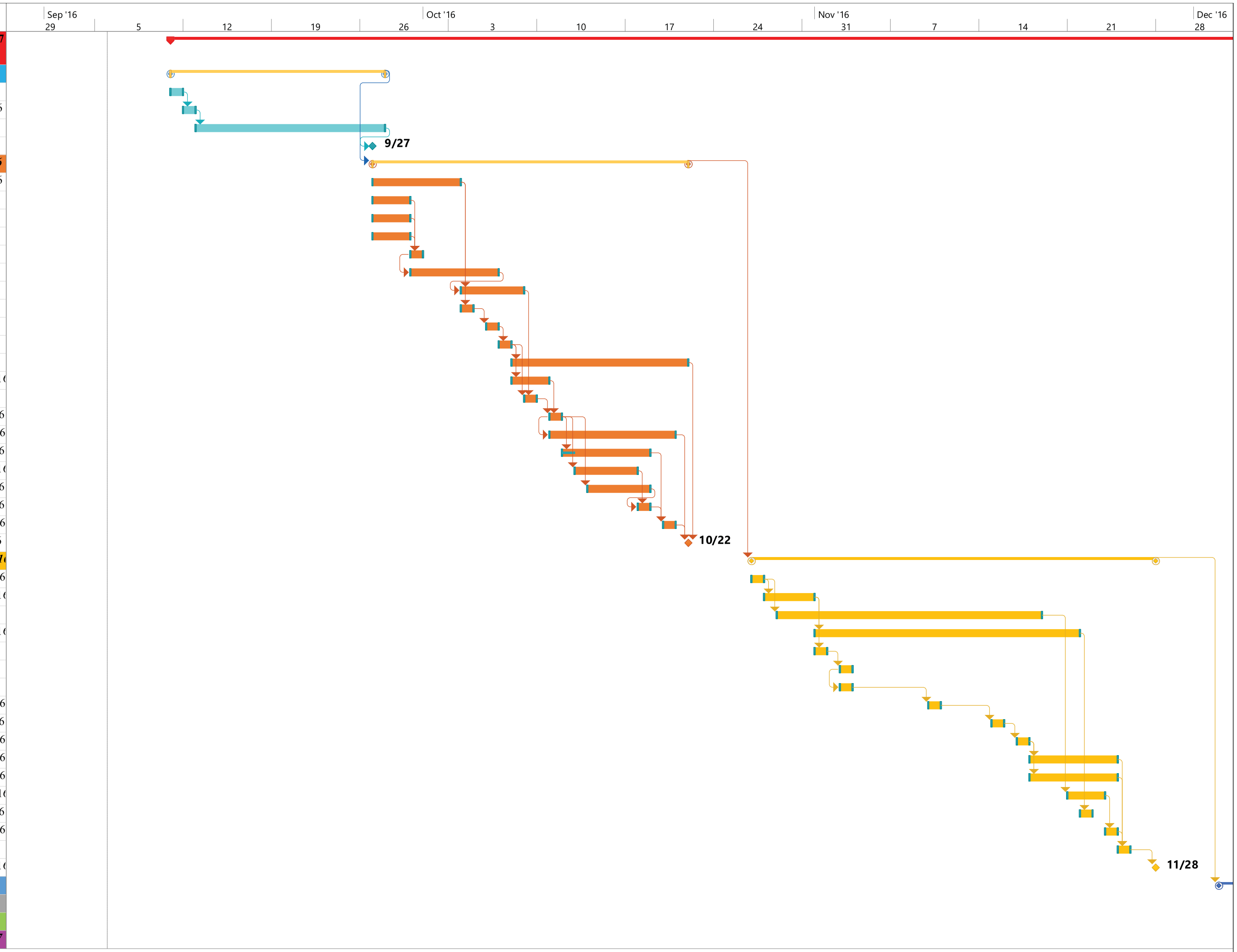
| | Maintenance (Redo every 10 yrs) | | | |
|---|---|---|---|---|
| | Length (m) | $/m | Total $ | $/yr |
| Bike Lane Paint | 561.0 | 80.0 | 44880.0 | 4488.0 |
| | $/ea | ea | Total $ | $/yr |
| Road Marking | 180.0 | 17.0 | 3060.0 | 306.0 |

## Permit Costs

| Development Permits | Area (100m^2) | Unit Cost (Dollars/100m^2) | Cost (Dollars) |
|---|---|---|---|
| Minor Applications | | 1500 | 1500 |
| | **Subtotal** | | **1500** |
| Major Applications | 5 | 300 | 1500 |
| | 10 | 110 | 1100 |
| | **Subtotal** | | **2600** |
| Site Changes | Area (100m^2) | Unit Cost | Cost |
| | 10 | 125 | 1250 |
| | 5 | 85 | 425 |
| | **Subtotal** | | **1675** |
| Alterations | Area (100m^2) | Unit Cost | Cost |
| | 1 | 290 | 290 |
| | **Subtotal** | | **290** |
| Revisions | **Subtotal** | | **160** |
| **Total Cost** | | | **6225** |
| **Plumbing Permits** | Quantity | | Cost (Dollars) |
| First 30 m | 1 | | 35 |
| Additional Length (240m) | 8 | | 160 |
| Backflow Prevention Device | 3 | | 225 |
| Watermain tie-ins/valve installation | 1 | | 75 |
| Sanitary/storm sewer tie-ins | 1 | | 75 |
| Manhole installation | 6 | | 0 |
| Catch Basin | 5 | | 0 |
| Firelines and Hydrants | 2 | | 52 |
| **Total Cost** | | | **622** |
| **Construction Noise Regulation - Variance Permit** | | | **148** |
| **Total Permit Cost (UBC)** | | | **6995** |
| | | | |
| **Utility Permit** | | | 660 |
| **Sidewalks and Landscaping Permit** | | | 200 |
| **Total Permit Cost (Municipal and Provincial)** | | | **860** |
| | | | |
| **Final Permit Cost** | | | **7855** |

# APPENDIX C : SCHEDULING

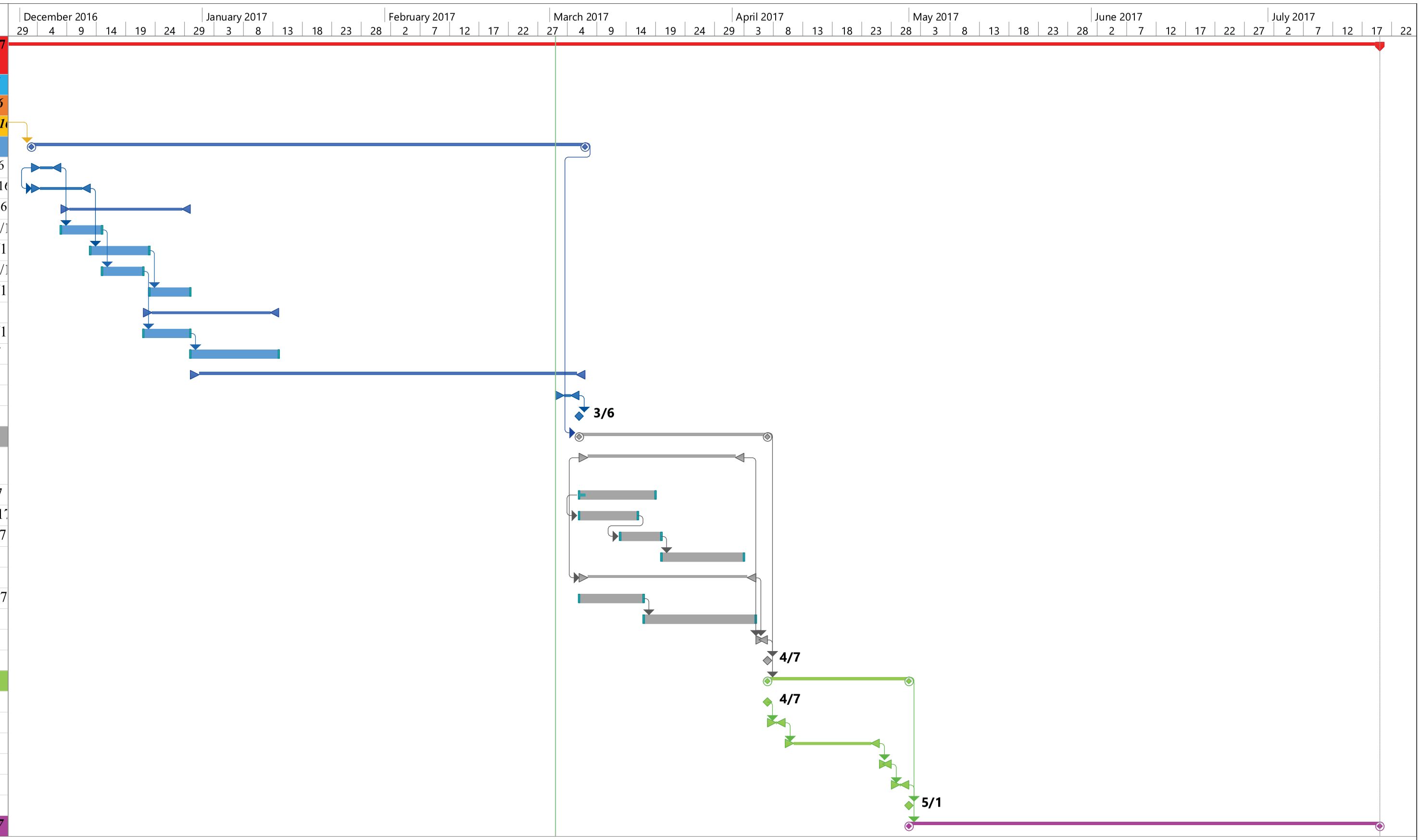
| ID | Task Name | Duratio | Start | Finish |
|---|---|---|---|---|
| 1 | **Improvement of Chancellor Blvd & Wesbrook Mall Intersection Project** | **303 days** | **Sun 9/11/16** | **Wed 7/19/17** |
| 2 | ***Design Proposal Phase*** | ***17 days*** | ***Sun 9/11/16*** | ***Tue 9/27/16*** |
| 3 | **IFT (Issues for Tender) for Design** | 1 day | Sun 9/11/16 | Sun 9/11/16 |
| 4 | **Team Assemble** | 1 day | Mon 9/12/1( | Mon 9/12/16 |
| 5 | **Prepare for Proposal** | 15 days | Tue 9/13/16 | Tue 9/27/16 |
| 6 | **Proposal Submission** | 0 days | Tue 9/27/16 | Tue 9/27/16 |
| 7 | ***Conceptual Design Phase*** | ***24 days*** | ***Tue 9/27/16*** | ***Sat 10/22/16*** |
| 8 | **Research & Gather Information** | 7 days | Tue 9/27/16 | Mon 10/3/16 |
| 9 | **Review Client Information** | 3 days | Tue 9/27/16 | Thu 9/29/16 |
| 10 | **Modelling of Client Provided Data** | 3 days | Tue 9/27/16 | Thu 9/29/16 |
| 11 | **Initial Code Review** | 3 days | Tue 9/27/16 | Thu 9/29/16 |
| 12 | **Team Meeting 1** | 1 day | Fri 9/30/16 | Fri 9/30/16 |
| 13 | **3 Conceptual Designs Completed** | 7 days | Fri 9/30/16 | Thu 10/6/16 |
| 14 | **Analyze Conceptual Design** | 5 days | Tue 10/4/16 | Sat 10/8/16 |
| 15 | **Review Meeting 2** | 1 day | Tue 10/4/16 | Tue 10/4/16 |
| 16 | **Team Meeting 2** | 1 day | Thu 10/6/16 | Thu 10/6/16 |
| 17 | **Site Visit 1** | 1 day | Fri 10/7/16 | Fri 10/7/16 |
| 18 | **Conceptual Design Report** | 13 days | Sat 10/8/16 | Fri 10/21/16 |
| 19 | **Stakeholder Engagement 1** | 3 days | Sat 10/8/16 | Mon 10/10/1( |
| 20 | **Team Meeting 3** | 1 day | Sun 10/9/16 | Sun 10/9/16 |
| 21 | **Select Preferred Design** | 1 day | Tue 10/11/1 | Tue 10/11/16 |
| 22 | **3D Model for Preferred Design** | 10 days | Tue 10/11/1 | Thu 10/20/16 |
| 23 | **Drafting for Designs** | 7 days | Wed 10/12/ | Tue 10/18/16 |
| 24 | **Conceptual Design Cost Estimates** | 5 days | Thu 10/13/1 | Mon 10/17/1( |
| 25 | **Draft Design Presentation** | 5 days | Fri 10/14/16 | Tue 10/18/16 |
| 27 | **Review Meeting 3** | 1 day | Tue 10/18/1 | Tue 10/18/16 |
| 28 | **Team Meeting 4** | 1 day | Thu 10/20/1 | Thu 10/20/16 |
| 26 | **Conceptual Design Report & Presentation** | 0 days | Sat 10/22/1( | Sat 10/22/16 |
| 29 | ***Preliminary Design Phase*** | ***31 days*** | ***Thu 10/27/1*** | ***Mon 11/28/1(*** |
| 30 | **Team Meeting 5** | 1 day | Thu 10/27/1 | Thu 10/27/16 |
| 31 | **Stakeholder Engagement 2** | 4 days | Fri 10/28/16 | Mon 10/31/1( |
| 32 | **Design Drawings for Preliminary Design** | 20 days | Sat 10/29/1( | Fri 11/18/16 |
| 33 | **Detail 3D Model** | 20 days | Tue 11/1/16 | Mon 11/21/1( |
| 34 | **Review Meeting 4** | 1 day | Tue 11/1/16 | Tue 11/1/16 |
| 35 | **Site Visit 2** | 1 day | Thu 11/3/16 | Thu 11/3/16 |
| 36 | **Team Meeting 6** | 1 day | Thu 11/3/16 | Thu 11/3/16 |
| 37 | **Team Meeting 7** | 1 day | Thu 11/10/1 | Thu 11/10/16 |
| 38 | **Review Meeting 5** | 1 day | Tue 11/15/1 | Tue 11/15/16 |
| 39 | **Team Meeting 8** | 1 day | Thu 11/17/1 | Thu 11/17/16 |
| 40 | **Detailed Scheduling for Preliminary Desig** | 7 days | Fri 11/18/16 | Thu 11/24/16 |
| 41 | **Preliminary Design Report** | 7 days | Fri 11/18/16 | Thu 11/24/16 |
| 42 | **Code Review for Preliminary Design** | 3 days | Mon 11/21/1 | Wed 11/23/1( |
| 43 | **Review Meeting 6** | 1 day | Tue 11/22/1 | Tue 11/22/16 |
| 44 | **Preliminary Design Complete** | 1 day | Thu 11/24/1 | Thu 11/24/16 |
| 45 | **Team Meeting 9** | 1 day | Fri 11/25/16 | Fri 11/25/16 |
| 46 | **Preliminary Report Submission** | 0 days | Mon 11/28/1 | Mon 11/28/1( |
| 47 | ***Detail Design Phase*** | ***90 days*** | ***Sat 12/3/16*** | ***Mon 3/6/17*** |
| 63 | ***Final Design Phase*** | ***32 days*** | ***Mon 3/6/17*** | ***Fri 4/7/17*** |
| 74 | ***Procurement Phase*** | ***23 days*** | ***Fri 4/7/17*** | ***Mon 5/1/17*** |
| 81 | ***Construction Phase*** | ***78 days*** | ***Mon 5/1/17*** | ***Wed 7/19/17*** |




Project: Project Schedule Detail
Date: Thu 3/2/17

Project Phase

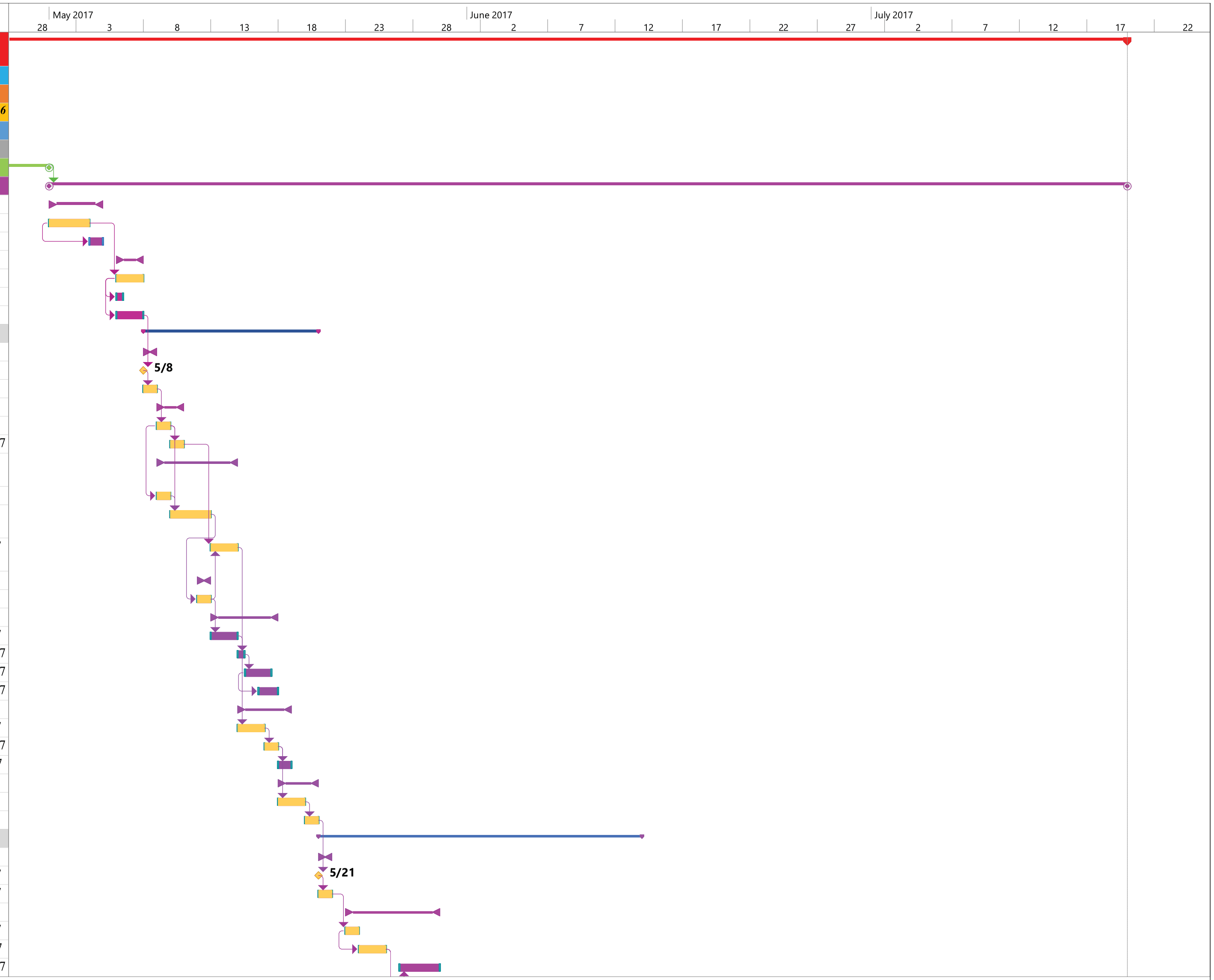
| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | **Improvement of Chancellor Blvd & Wesbrook Mall Intersection Project** | **303 days** | **Sun 9/11/16** | **Wed 7/19/17** |
| 2 | ***Design Proposal Phase*** | ***17 days*** | ***Sun 9/11/16*** | ***Tue 9/27/16*** |
| 7 | ***Conceptual Design Phase*** | ***24 days*** | ***Tue 9/27/16*** | ***Sat 10/22/16*** |
| 29 | ***Preliminary Design Phase*** | ***31 days*** | ***Thu 10/27/1*** | ***Mon 11/28/1*** |
| 47 | ***Detail Design Phase*** | ***90 day*** | ***Sat 12/3/16*** | ***Mon 3/6/17*** |
| 48 | **Field Survey** | 5 days | Sat 12/3/16 | Wed 12/7/16 |
| 49 | **Detail Design: In-depth Geotechnical Anal** | 10 days | Sat 12/3/16 | Mon 12/12/1 |
| 50 | **Detail Design: Intersection** | 20 days | Thu 12/8/16 | Thu 12/29/16 |
| 51 | Utilities Layout | 7 days | Thu 12/8/1 | Wed 12/14/1 |
| 52 | Lane/Curb Layout | 10 day | Tue 12/13/ | Thu 12/22/1 |
| 54 | Pavement Design | 7 days | Thu 12/15/ | Wed 12/21/1 |
| 53 | Signal Phasing | 5 days | Fri 12/23/1 | Thu 12/29/1 |
| 55 | **Detail Design: Gateway** | 20 days | Thu 12/22/1 | Fri 1/13/17 |
| 56 | Foundation Design | 6 days | Thu 12/22/ | Thu 12/29/1 |
| 57 | Structural Design | 14 day | Fri 12/30/1 | Fri 1/13/17 |
| 60 | **Permitting Application Preparation** | 65 days | Fri 12/30/16 | Mon 3/6/17 |
| 59 | **Client Consultation for Detail Design** | 4 days | Thu 3/2/17 | Sun 3/5/17 |
| 58 | **Presentation & Detail Design Summary R** | 0 days | Mon 3/6/17 | Mon 3/6/17 |
| 63 | ***Final Design Phase*** | ***32 days*** | ***Mon 3/6/17*** | ***Fri 4/7/17*** |
| 64 | **Final Design Drawing - Intersection Improvement** | 28 days | Mon 3/6/17 | Sun 4/2/17 |
| 65 | Final Design Drawing - Signal Phasing | 13 day | Mon 3/6/1 | Sat 3/18/17 |
| 66 | Final Design Drawing - Utilities Layout | 10 day | Mon 3/6/1 | Wed 3/15/1 |
| 67 | Final Design Drawing - Lane/Curb Layout | 7 days | Mon 3/13/1 | Sun 3/19/17 |
| 68 | Final Design Drawing - Pavement Design | 14 day | Mon 3/20/1 | Sun 4/2/17 |
| 69 | **Final Design Drawing - Gateway** | 30 days | Mon 3/6/17 | Tue 4/4/17 |
| 70 | Final Design Drawing - Geotechnical Fou | 11 day | Mon 3/6/1 | Thu 3/16/17 |
| 71 | Final Design Drawing - Structural | 19 day | Fri 3/17/17 | Tue 4/4/17 |
| 73 | **Client Consultation for Final Design** | 2 days | Wed 4/5/17 | Thu 4/6/17 |
| 72 | **Final Design Drawing Submission** | 0 days | Fri 4/7/17 | Fri 4/7/17 |
| 74 | ***Procurement Phase*** | ***23 days*** | ***Fri 4/7/17*** | ***Mon 5/1/17*** |
| 75 | **IFT for Contactor** | 0 days | Fri 4/7/17 | Fri 4/7/17 |
| 76 | **Bid Package Preparation For Tender** | 3 days | Fri 4/7/17 | Sun 4/9/17 |
| 77 | **Contractor Bid Submission Period** | 15 days | Mon 4/10/1 | Tue 4/25/17 |
| 78 | **Bid Selection Process** | 2 days | Wed 4/26/1 | Thu 4/27/17 |
| 79 | **Client Consultation for Selected Bid** | 3 days | Fri 4/28/17 | Sun 4/30/17 |
| 80 | **Bid Award to Contractor** | 0 days | Mon 5/1/17 | Mon 5/1/17 |
| 81 | ***Construction Phase*** | ***78 days*** | ***Mon 5/1/17*** | ***Wed 7/19/17*** |




Project: Project Schedule Detail
Date: Thu 3/2/17

Project Phase

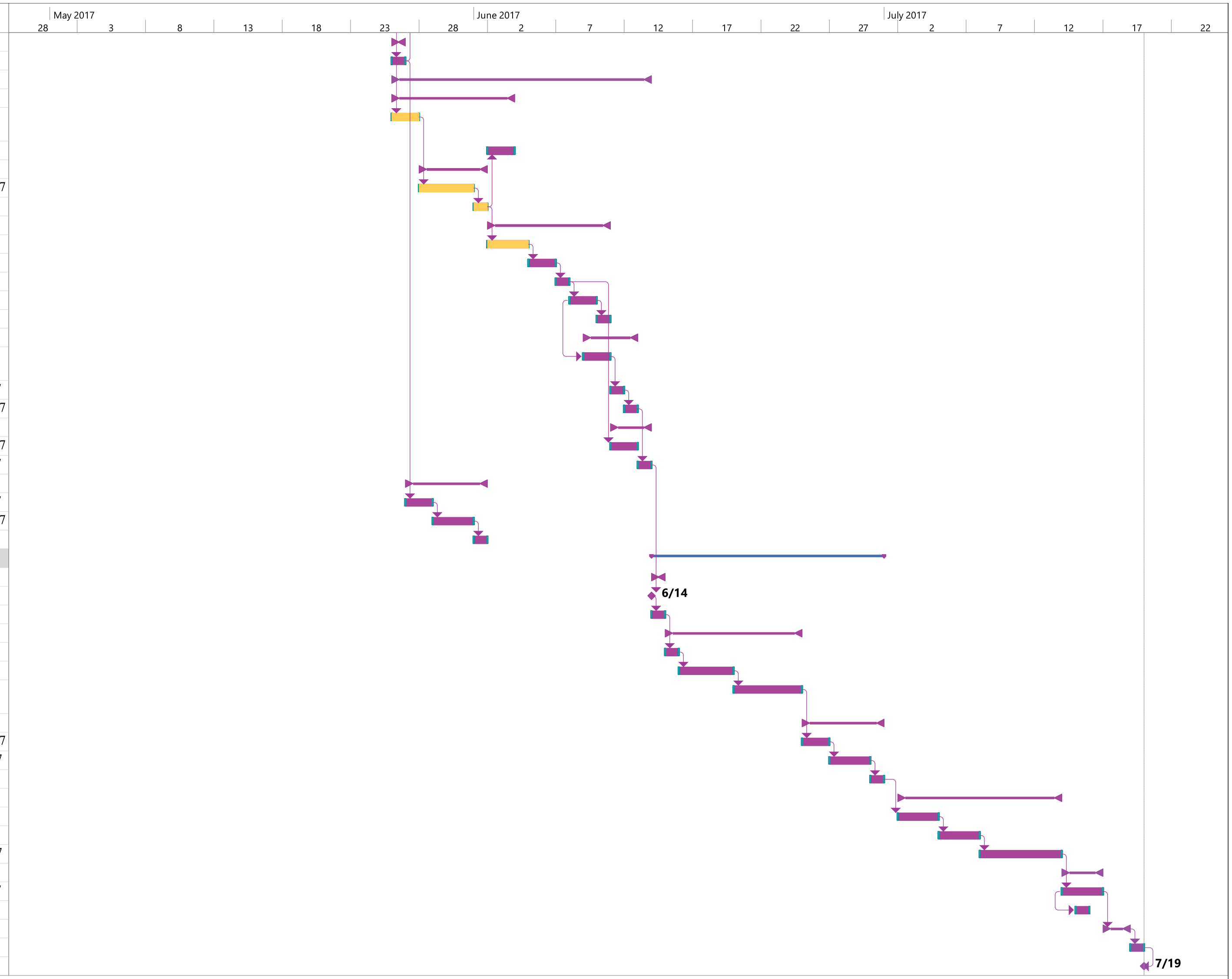
| ID | Task Name | Duratio | Start | Finish |
|---|---|---|---|---|
| 1 | **Improvement of Chancellor Blvd & Wesbrook Mall Intersection Project** | 303 days | Sun 9/11/16 | Wed 7/19/17 |
| 2 | ***Design Proposal Phase*** | 17 days | Sun 9/11/16 | Tue 9/27/16 |
| 7 | ***Conceptual Design Phase*** | 24 days | Tue 9/27/16 | Sat 10/22/16 |
| 29 | ***Preliminary Design Phase*** | 31 days | Thu 10/27/1 | Mon 11/28/16 |
| 47 | ***Detail Design Phase*** | 90 day: | Sat 12/3/16 | Mon 3/6/17 |
| 63 | ***Final Design Phase*** | 32 days | Mon 3/6/17 | Fri 4/7/17 |
| 74 | ***Procurement Phase*** | 23 days | Fri 4/7/17 | Mon 5/1/17 |
| 81 | ***Construction Phase*** | 78 days | Mon 5/1/17 | Wed 7/19/17 |
| 82 | **Mobilization** | 4 days | Mon 5/1/17 | Thu 5/4/17 |
| 83 | *Transport and setup trailer for temporary work office* | 3 days | Mon 5/1/17 | Wed 5/3/17 |
| 84 | *Transport necessary equipments* | 1 day | Thu 5/4/17 | Thu 5/4/17 |
| 85 | **Site Preparation** | 2 days | Sat 5/6/17 | Sun 5/7/17 |
| 86 | *Prepare area for materials & equipments storage* | 2 days | Sat 5/6/17 | Sun 5/7/17 |
| 87 | *Implement new bus route for C20, C18, 84* | 0.5 day | Sat 5/6/17 | Sat 5/6/17 |
| 88 | *Setup flaggers & work perimeter* | 2 days | Sat 5/6/17 | Sun 5/7/17 |
| 89 | **Phase 1 - Wesbrook Mall** | 13 days | Mon 5/8/17 | Sat 5/20/17 |
| 90 | **Detour Setup - Phase 1** | 1 day | Mon 5/8/17 | Mon 5/8/17 |
| 91 | *Setup flaggers & temporary signages* | 0 days | Mon 5/8/17 | Mon 5/8/17 |
| 92 | *Mob barriers, pylons, fence for traffic accomendatio* | 1 day | Mon 5/8/17 | Mon 5/8/17 |
| 93 | **Earthwork (Island Removal)** | 2 days | Tue 5/9/17 | Wed 5/10/17 |
| 94 | *Demo of existing islands & remove demo debris* | 1 day | Tue 5/9/17 | Tue 5/9/17 |
| 95 | *Backfill & compact to grade with road base* | 1 day | Wed 5/10/1 | Wed 5/10/17 |
| 96 | **Earthwork (sidewalk & curb extension, widen Wesbrook, traffic signal installation)** | 6 days | Tue 5/9/17 | Sun 5/14/17 |
| 98 | *Tree and brush removal* | 1 day | Tue 5/9/17 | Tue 5/9/17 |
| 97 | *Excavation on both side of the road for widening and curb extension* | 3 days | Wed 5/10/17 | Fri 5/12/17 |
| 99 | *Backfill, pavement layout & compact to grade with road base* | 2 days | Sat 5/13/17 | Sun 5/14/17 |
| 100 | **Utility Trenching** | 1 day | Fri 5/12/17 | Fri 5/12/17 |
| 101 | *Tie in electrial for traffic signals* | 1 day | Fri 5/12/17 | Fri 5/12/17 |
| 102 | **Traffic Signals & Pedestrian Flashers Installati** | 5 days | Sat 5/13/17 | Wed 5/17/17 |
| 103 | *Footing formwork* | 2 days | Sat 5/13/17 | Sun 5/14/17 |
| 104 | *Pour & strip footing* | 0.5 day | Mon 5/15/1 | Mon 5/15/17 |
| 105 | *Erect and install traffic light* | 2 days | Mon 5/15/1 | Wed 5/17/17 |
| 106 | *Electrical and mechanical work* | 1.5 day | Tue 5/16/1 | Wed 5/17/17 |
| 107 | **Sidewalk Construction** | 4 days | Mon 5/15/1 | Thu 5/18/17 |
| 108 | *Sidewalk formwork & wire mesh installation* | 2 days | Mon 5/15/1 | Tue 5/16/17 |
| 109 | *Pour & strip sidewalk* | 1 day | Wed 5/17/1 | Wed 5/17/17 |
| 110 | *Sidewalk finishing & vegetation* | 1 day | Thu 5/18/1 | Thu 5/18/17 |
| 111 | **Curb & Gutter Extension** | 3 days | Thu 5/18/17 | Sat 5/20/17 |
| 112 | *Curb & Gutter formwork* | 2 days | Thu 5/18/1 | Fri 5/19/17 |
| 113 | *Pour & strip Curb & Gutter* | 1 day | Sat 5/20/17 | Sat 5/20/17 |
| 114 | **Phase 2 - West Leg Chancellor Blvd Widening** | 23 days | Sun 5/21/17 | Tue 6/13/17 |
| 115 | **Detour Setup - Phase 2** | 1 day | Sun 5/21/17 | Sun 5/21/17 |
| 116 | *Setup flaggers & temporary signages* | 0 days | Sun 5/21/1 | Sun 5/21/17 |
| 117 | *Mob barriers, pylons, fence for traffic accommendation* | 1 day | Sun 5/21/1 | Sun 5/21/17 |
| 118 | **Earthwork (Northwest lane addition)** | 7 days | Tue 5/23/17 | Mon 5/29/17 |
| 120 | *Tree and brush removal* | 1 day | Tue 5/23/1 | Tue 5/23/17 |
| 119 | *Excavation on Northwest median for additonal lane* | 2 days | Wed 5/24/1 | Thu 5/25/17 |
| 121 | *Backfill, pavement layout & compact to grade with ro* | 3 days | Sat 5/27/17 | Mon 5/29/17 |




Project: Project Schedule Detail
Date: Sat 4/1/17

Project Phase

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 122 | **Utility Trenching** | 1 day | Fri 5/26/17 | Fri 5/26/17 |
| 123 | *Tie in electrial for traffic signals* | 1 day | Fri 5/26/17 | Fri 5/26/17 |
| 128 | **Gateway Structural Construction** | 19 days | Fri 5/26/17 | Tue 6/13/17 |
| 129 | **Earthwork** | 9 days | Fri 5/26/17 | Sat 6/3/17 |
| 130 | *Excavation on west Chancellor Blvd median for footing construction* | 2 days | Fri 5/26/17 | Sat 5/27/17 |
| 131 | *Backfill & compact with coarse sand to median gr* | 2 days | Fri 6/2/17 | Sat 6/3/17 |
| 132 | **Gateway Footing Construction** | 5 days | Sun 5/28/17 | Thu 6/1/17 |
| 133 | *Foundation footing formwork, rebar & HSS instal* | 4 days | Sun 5/28/1 | Wed 5/31/17 |
| 134 | *Pour & strip foundation footing* | 1 day | Thu 6/1/17 | Thu 6/1/17 |
| 135 | **Gateway Column Construction** | 9 days | Fri 6/2/17 | Sat 6/10/17 |
| 136 | *Splice HSS Beam & weld w-section to HSS Beam* | 3 days | Fri 6/2/17 | Sun 6/4/17 |
| 137 | *Column formwork part.1/2* | 2 days | Mon 6/5/17 | Tue 6/6/17 |
| 138 | *Pour & strip Column Part.1/2* | 1 day | Wed 6/7/17 | Wed 6/7/17 |
| 139 | *Column formwork part. 2/2* | 2 days | Thu 6/8/17 | Fri 6/9/17 |
| 140 | *Pour & strip Column Part.2/2* | 1 day | Sat 6/10/17 | Sat 6/10/17 |
| 141 | **Gateway Concrete Arc Construction** | 4 days | Fri 6/9/17 | Mon 6/12/17 |
| 142 | *Shoring construction & column-arc connection formwork* | 2 days | Fri 6/9/17 | Sat 6/10/17 |
| 143 | *Erect and install pre-casted concrete arc* | 1 day | Sun 6/11/1 | Sun 6/11/17 |
| 144 | *Pour and strip column-arc connection* | 1 day | Mon 6/12/1 | Mon 6/12/17 |
| 145 | **Gateway Finishing** | 3 days | Sun 6/11/17 | Tue 6/13/17 |
| 146 | *Concrete patching & UBC plate installation* | 2 days | Sun 6/11/1 | Mon 6/12/17 |
| 147 | *Column-arc connection finishing* | 1 day | Tue 6/13/1 | Tue 6/13/17 |
| 124 | **Median Construction + Curb & Gutter Work** | 6 days | Sat 5/27/17 | Thu 6/1/17 |
| 125 | *Backfill & compact to grade with existing median soi* | 2 days | Sat 5/27/17 | Sun 5/28/17 |
| 126 | *Curb & gutter formwork + vegetation* | 3 days | Mon 5/29/1 | Wed 5/31/17 |
| 127 | *Pour & strip curb & gutter* | 1 day | Thu 6/1/17 | Thu 6/1/17 |
| 148 | **Phase 3 - East Leg Chancellor Blvd Widening** | 17 days | Wed 6/14/1 | Fri 6/30/17 |
| 149 | **Detour Setup - Phase 3** | 1 day | Wed 6/14/1 | Wed 6/14/17 |
| 150 | *Setup flaggers & temporary signages* | 0 days | Wed 6/14/1 | Wed 6/14/17 |
| 151 | *Mob barriers, pylons, fence for traffic accomendatio* | 1 day | Wed 6/14/1 | Wed 6/14/17 |
| 152 | **Earthwork (median construction, lane extenstio** | 10 days | Thu 6/15/17 | Sat 6/24/17 |
| 154 | *Tree and brush removal* | 1 day | Thu 6/15/17 | Thu 6/15/17 |
| 153 | *Excavation on Northeast median for additonal lane* | 4 days | Fri 6/16/17 | Mon 6/19/17 |
| 155 | *Backfill, pavement layout & compact to grade with road base* | 5 days | Tue 6/20/17 | Sat 6/24/17 |
| 156 | **Median Construction + Curb & Gutter Work** | 6 days | Sun 6/25/17 | Fri 6/30/17 |
| 157 | *Backfill & compact to grade with existing median soi* | 2 days | Sun 6/25/1 | Mon 6/26/17 |
| 158 | *Curb & gutter formwork + vegetation* | 3 days | Tue 6/27/1 | Thu 6/29/17 |
| 159 | *Pour & strip curb & gutter* | 1 day | Fri 6/30/17 | Fri 6/30/17 |
| 160 | **Re-Surfacing** | 12 days | Sun 7/2/17 | Thu 7/13/17 |
| 161 | *Final asphal placement & compaction* | 3 days | Sun 7/2/17 | Tue 7/4/17 |
| 162 | *Lane paint & road marking* | 3 days | Wed 7/5/17 | Fri 7/7/17 |
| 163 | *Singal placement & Traffic signal testing* | 6 days | Sat 7/8/17 | Thu 7/13/17 |
| 164 | **Demobilization** | 3 days | Sat 7/15/17 | Mon 7/17/17 |
| 165 | *Demobilize trailer and necessary equipments* | 3 days | Fri 7/14/17 | Sun 7/16/17 |
| 166 | *Waste control* | 1 day | Sat 7/15/17 | Sat 7/15/17 |
| 168 | **Completion Inspection** | 2 days | Mon 7/17/17 | Tue 7/18/17 |
| 167 | **Handover** | 1 day | Wed 7/19/17 | Wed 7/19/17 |
| 169 | **Project Completion** | 0 days | Wed 7/19/17 | Wed 7/19/17 |




Project: Project Schedule Detail
Date: Sat 4/1/17

Project Phase

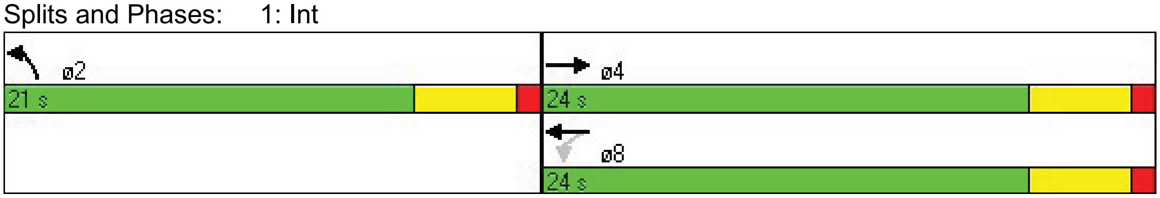
# APPENDIX D : SYNCHRO AND SIMTRAFFIC REPORTS

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Storage Length (m) | | 0.0 | 90.0 | | 0.0 | 0.0 |
| Storage Lanes | | 0 | 1 | | 1 | 0 |
| Total Lost Time (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| Leading Detector (m) | 15.2 | | 15.2 | 15.2 | 15.2 | |
| Trailing Detector (m) | 0.0 | | 0.0 | 0.0 | 0.0 | |
| Turning Speed (k/h) | | 14 | 24 | | 24 | 14 |
| Lane Util. Factor | 1.00 | 1.00 | 0.91 | 0.91 | 1.00 | 1.00 |
| Ped Bike Factor | 1.00 | | 1.00 | 1.00 | 0.98 | |
| Frt | 0.976 | | | | 0.889 | |
| Flt Protected | | | 0.950 | 0.985 | 0.991 | |
| Satd. Flow (prot) | 1797 | 0 | 1597 | 3312 | 1589 | 0 |
| Flt Permitted | | | 0.370 | 0.795 | 0.991 | |
| Satd. Flow (perm) | 1797 | 0 | 620 | 2670 | 1588 | 0 |
| Right Turn on Red | | Yes | | | | Yes |
| Satd. Flow (RTOR) | 31 | | | | 258 | |
| Headway Factor | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| Link Speed (k/h) | 50 | | | 50 | 50 | |
| Link Distance (m) | 223.5 | | | 129.8 | 293.8 | |
| Travel Time (s) | 16.1 | | | 9.3 | 21.2 | |
| Volume (vph) | 373 | 82 | 98 | 109 | 54 | 248 |
| Confl. Peds. (#/hr) | | 8 | 8 | | 3 | 3 |
| Confl. Bikes (#/hr) | | 1 | | | | 5 |
| Peak Hour Factor | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| Adj. Flow (vph) | 389 | 85 | 102 | 114 | 56 | 258 |
| Lane Group Flow (vph) | 474 | 0 | 51 | 165 | 314 | 0 |
| Turn Type | | | Perm | | | |
| Protected Phases | 4 | | | 8 | 2 | |
| Permitted Phases | | | 8 | | | |
| Detector Phases | 4 | | 8 | 8 | 2 | |
| Minimum Initial (s) | 4.0 | | 4.0 | 4.0 | 4.0 | |
| Minimum Split (s) | 21.0 | | 21.0 | 21.0 | 21.0 | |
| Total Split (s) | 24.0 | 0.0 | 24.0 | 24.0 | 21.0 | 0.0 |
| Total Split (%) | 53.3% | 0.0% | 53.3% | 53.3% | 46.7% | 0.0% |
| Maximum Green (s) | 19.0 | | 19.0 | 19.0 | 16.0 | |
| Yellow Time (s) | 4.0 | | 4.0 | 4.0 | 4.0 | |
| All-Red Time (s) | 1.0 | | 1.0 | 1.0 | 1.0 | |
| Lead/Lag | | | | | | |
| Lead-Lag Optimize? | | | | | | |
| Vehicle Extension (s) | 3.0 | | 3.0 | 3.0 | 3.0 | |
| Recall Mode | None | | None | None | Max | |
| Walk Time (s) | 5.0 | | 5.0 | 5.0 | 5.0 | |
| Flash Dont Walk (s) | 11.0 | | 11.0 | 11.0 | 11.0 | |
| Pedestrian Calls (#/hr) | 8 | | 3 | 3 | 3 | |
| Act Effct Green (s) | 15.3 | | 15.3 | 15.3 | 17.2 | |
| Actuated g/C Ratio | 0.38 | | 0.38 | 0.38 | 0.42 | |
| v/c Ratio | 0.68 | | 0.22 | 0.16 | 0.38 | |
| Control Delay | 15.1 | | 10.7 | 8.3 | 4.3 | |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Queue Delay | 0.0 | | 0.0 | 0.0 | 0.0 | |
| Total Delay | 15.1 | | 10.7 | 8.3 | 4.3 | |
| LOS | B | | B | A | A | |
| Approach Delay | 15.1 | | | 8.9 | 4.3 | |
| Approach LOS | B | | | A | A | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Cycle Length: 45 | |
| Actuated Cycle Length: 40.6 | |
| Natural Cycle: 45 | |
| Control Type: Semi Act-Uncoord | |
| Maximum v/c Ratio: 0.68 | |
| Intersection Signal Delay: 10.4 | Intersection LOS: B |
| Intersection Capacity Utilization 57.2% | ICU Level of Service B |
| Analysis Period (min) 15 | |

Splits and Phases: 1: Int

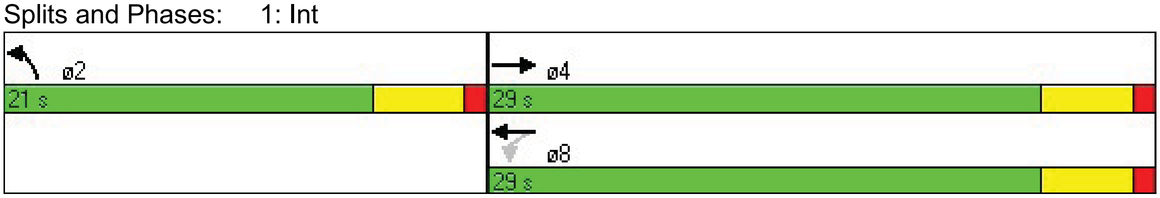


| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Storage Length (m) | | 0.0 | 90.0 | | 0.0 | 0.0 |
| Storage Lanes | | 0 | 1 | | 1 | 0 |
| Total Lost Time (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| Leading Detector (m) | 15.2 | | 15.2 | 15.2 | 15.2 | |
| Trailing Detector (m) | 0.0 | | 0.0 | 0.0 | 0.0 | |
| Turning Speed (k/h) | | 14 | 24 | | 24 | 14 |
| Lane Util. Factor | 1.00 | 1.00 | 0.91 | 0.91 | 1.00 | 1.00 |
| Ped Bike Factor | 1.00 | | 1.00 | 1.00 | 0.97 | |
| Frt | 0.976 | | | | 0.889 | |
| Flt Protected | | | 0.950 | 0.985 | 0.991 | |
| Satd. Flow (prot) | 1796 | 0 | 1597 | 3312 | 1584 | 0 |
| Flt Permitted | | | 0.297 | 0.749 | 0.991 | |
| Satd. Flow (perm) | 1796 | 0 | 498 | 2516 | 1583 | 0 |
| Right Turn on Red | | Yes | | | | Yes |
| Satd. Flow (RTOR) | 32 | | | | 294 | |
| Headway Factor | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| Link Speed (k/h) | 50 | | | 50 | 50 | |
| Link Distance (m) | 223.5 | | | 129.8 | 293.8 | |
| Travel Time (s) | 16.1 | | | 9.3 | 21.2 | |
| Volume (vph) | 465 | 102 | 122 | 136 | 68 | 310 |
| Confl. Peds. (#/hr) | | 10 | 10 | | 4 | 4 |
| Confl. Bikes (#/hr) | | 1 | | | | 6 |
| Peak Hour Factor | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| Adj. Flow (vph) | 484 | 106 | 127 | 142 | 71 | 323 |
| Lane Group Flow (vph) | 590 | 0 | 64 | 205 | 394 | 0 |
| Turn Type | | | Perm | | | |
| Protected Phases | 4 | | | 8 | 2 | |
| Permitted Phases | | | 8 | | | |
| Detector Phases | 4 | | 8 | 8 | 2 | |
| Minimum Initial (s) | 4.0 | | 4.0 | 4.0 | 4.0 | |
| Minimum Split (s) | 21.0 | | 21.0 | 21.0 | 21.0 | |
| Total Split (s) | 29.0 | 0.0 | 29.0 | 29.0 | 21.0 | 0.0 |
| Total Split (%) | 58.0% | 0.0% | 58.0% | 58.0% | 42.0% | 0.0% |
| Maximum Green (s) | 24.0 | | 24.0 | 24.0 | 16.0 | |
| Yellow Time (s) | 4.0 | | 4.0 | 4.0 | 4.0 | |
| All-Red Time (s) | 1.0 | | 1.0 | 1.0 | 1.0 | |
| Lead/Lag | | | | | | |
| Lead-Lag Optimize? | | | | | | |
| Vehicle Extension (s) | 3.0 | | 3.0 | 3.0 | 3.0 | |
| Recall Mode | None | | None | None | Max | |
| Walk Time (s) | 5.0 | | 5.0 | 5.0 | 5.0 | |
| Flash Dont Walk (s) | 11.0 | | 11.0 | 11.0 | 11.0 | |
| Pedestrian Calls (#/hr) | 10 | | 4 | 4 | 4 | |
| Act Effct Green (s) | 18.9 | | 18.9 | 18.9 | 17.2 | |
| Actuated g/C Ratio | 0.43 | | 0.43 | 0.43 | 0.39 | |
| v/c Ratio | 0.75 | | 0.30 | 0.19 | 0.49 | |
| Control Delay | 16.5 | | 12.0 | 7.8 | 6.3 | |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Queue Delay | 0.0 | | 0.0 | 0.0 | 0.0 | |
| Total Delay | 16.5 | | 12.0 | 7.8 | 6.3 | |
| LOS | B | | B | A | A | |
| Approach Delay | 16.5 | | | 8.8 | 6.3 | |
| Approach LOS | B | | | A | A | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Cycle Length: 50 | |
| Actuated Cycle Length: 44.3 | |
| Natural Cycle: 50 | |
| Control Type: Semi Act-Uncoord | |
| Maximum v/c Ratio: 0.75 | |
| Intersection Signal Delay: 11.6 | Intersection LOS: B |
| Intersection Capacity Utilization 69.0% | ICU Level of Service C |
| Analysis Period (min) 15 | |

Splits and Phases: 1: Int

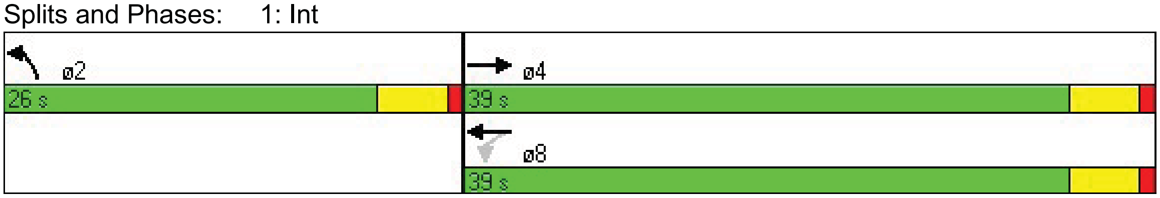


| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Storage Length (m) | | 0.0 | 90.0 | | 0.0 | 0.0 |
| Storage Lanes | | 0 | 1 | | 1 | 0 |
| Total Lost Time (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| Leading Detector (m) | 15.2 | | 15.2 | 15.2 | 15.2 | |
| Trailing Detector (m) | 0.0 | | 0.0 | 0.0 | 0.0 | |
| Turning Speed (k/h) | | 14 | 24 | | 24 | 14 |
| Lane Util. Factor | 1.00 | 1.00 | 0.91 | 0.91 | 1.00 | 1.00 |
| Ped Bike Factor | 0.99 | | | | 0.97 | |
| Frt | 0.976 | | | | 0.889 | |
| Flt Protected | | | 0.950 | 0.985 | 0.991 | |
| Satd. Flow (prot) | 1793 | 0 | 1597 | 3312 | 1579 | 0 |
| Flt Permitted | | | 0.140 | 0.598 | 0.991 | |
| Satd. Flow (perm) | 1793 | 0 | 235 | 2010 | 1577 | 0 |
| Right Turn on Red | | Yes | | | | Yes |
| Satd. Flow (RTOR) | 26 | | | | 197 | |
| Headway Factor | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| Link Speed (k/h) | 50 | | | 50 | 50 | |
| Link Distance (m) | 223.5 | | | 129.8 | 293.8 | |
| Travel Time (s) | 16.1 | | | 9.3 | 21.2 | |
| Volume (vph) | 648 | 142 | 171 | 190 | 94 | 432 |
| Confl. Peds. (#/hr) | | 14 | 14 | | 5 | 5 |
| Confl. Bikes (#/hr) | | 1 | | | | 6 |
| Peak Hour Factor | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| Adj. Flow (vph) | 675 | 148 | 178 | 198 | 98 | 450 |
| Lane Group Flow (vph) | 823 | 0 | 89 | 287 | 548 | 0 |
| Turn Type | | | Perm | | | |
| Protected Phases | 4 | | | 8 | 2 | |
| Permitted Phases | | | 8 | | | |
| Detector Phases | 4 | | 8 | 8 | 2 | |
| Minimum Initial (s) | 4.0 | | 4.0 | 4.0 | 4.0 | |
| Minimum Split (s) | 21.0 | | 21.0 | 21.0 | 21.0 | |
| Total Split (s) | 39.0 | 0.0 | 39.0 | 39.0 | 26.0 | 0.0 |
| Total Split (%) | 60.0% | 0.0% | 60.0% | 60.0% | 40.0% | 0.0% |
| Maximum Green (s) | 34.0 | | 34.0 | 34.0 | 21.0 | |
| Yellow Time (s) | 4.0 | | 4.0 | 4.0 | 4.0 | |
| All-Red Time (s) | 1.0 | | 1.0 | 1.0 | 1.0 | |
| Lead/Lag | | | | | | |
| Lead-Lag Optimize? | | | | | | |
| Vehicle Extension (s) | 3.0 | | 3.0 | 3.0 | 3.0 | |
| Recall Mode | None | | None | None | Max | |
| Walk Time (s) | 5.0 | | 5.0 | 5.0 | 5.0 | |
| Flash Dont Walk (s) | 11.0 | | 11.0 | 11.0 | 11.0 | |
| Pedestrian Calls (#/hr) | 5 | | 5 | 5 | 14 | |
| Act Effct Green (s) | 30.9 | | 30.9 | 30.9 | 22.2 | |
| Actuated g/C Ratio | 0.50 | | 0.50 | 0.50 | 0.36 | |
| v/c Ratio | 0.90 | | 0.75 | 0.28 | 0.79 | |
| Control Delay | 27.5 | | 53.3 | 9.2 | 22.3 | |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Queue Delay | 0.0 | | 0.0 | 0.0 | 0.0 | |
| Total Delay | 27.5 | | 53.3 | 9.2 | 22.3 | |
| LOS | C | | D | A | C | |
| Approach Delay | 27.5 | | | 19.7 | 22.3 | |
| Approach LOS | C | | | B | C | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Cycle Length: 65 | |
| Actuated Cycle Length: 61.2 | |
| Natural Cycle: 65 | |
| Control Type: Semi Act-Uncoord | |
| Maximum v/c Ratio: 0.90 | |
| Intersection Signal Delay: 24.2 | Intersection LOS: C |
| Intersection Capacity Utilization 92.1% | ICU Level of Service F |
| Analysis Period (min) 15 | |

Splits and Phases: 1: Int

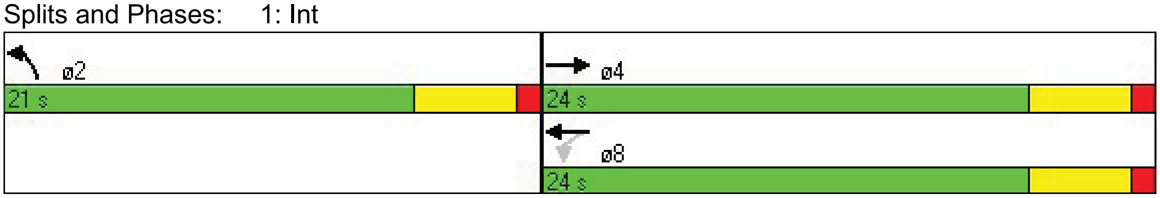


| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Storage Length (m) | | 0.0 | 90.0 | | 0.0 | 0.0 |
| Storage Lanes | | 0 | 1 | | 1 | 0 |
| Total Lost Time (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| Leading Detector (m) | 15.2 | | 15.2 | 15.2 | 15.2 | |
| Trailing Detector (m) | 0.0 | | 0.0 | 0.0 | 0.0 | |
| Turning Speed (k/h) | | 14 | 24 | | 24 | 14 |
| Lane Util. Factor | 1.00 | 1.00 | 0.91 | 0.91 | 1.00 | 1.00 |
| Ped Bike Factor | 1.00 | | 1.00 | 1.00 | 0.98 | |
| Frt | 0.976 | | | | 0.889 | |
| Flt Protected | | | 0.950 | 0.985 | 0.991 | |
| Satd. Flow (prot) | 1797 | 0 | 1597 | 3312 | 1589 | 0 |
| Flt Permitted | | | 0.370 | 0.795 | 0.991 | |
| Satd. Flow (perm) | 1797 | 0 | 620 | 2670 | 1588 | 0 |
| Right Turn on Red | | Yes | | | | Yes |
| Satd. Flow (RTOR) | 31 | | | | 258 | |
| Headway Factor | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| Link Speed (k/h) | 50 | | | 50 | 50 | |
| Link Distance (m) | 223.5 | | | 129.8 | 293.8 | |
| Travel Time (s) | 16.1 | | | 9.3 | 21.2 | |
| Volume (vph) | 373 | 82 | 98 | 109 | 54 | 248 |
| Confl. Peds. (#/hr) | | 8 | 8 | | 3 | 3 |
| Confl. Bikes (#/hr) | | 1 | | | | 5 |
| Peak Hour Factor | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| Adj. Flow (vph) | 389 | 85 | 102 | 114 | 56 | 258 |
| Lane Group Flow (vph) | 474 | 0 | 51 | 165 | 314 | 0 |
| Turn Type | | | Perm | | | |
| Protected Phases | 4 | | | 8 | 2 | |
| Permitted Phases | | | 8 | | | |
| Detector Phases | 4 | | 8 | 8 | 2 | |
| Minimum Initial (s) | 4.0 | | 4.0 | 4.0 | 4.0 | |
| Minimum Split (s) | 21.0 | | 21.0 | 21.0 | 21.0 | |
| Total Split (s) | 24.0 | 0.0 | 24.0 | 24.0 | 21.0 | 0.0 |
| Total Split (%) | 53.3% | 0.0% | 53.3% | 53.3% | 46.7% | 0.0% |
| Maximum Green (s) | 19.0 | | 19.0 | 19.0 | 16.0 | |
| Yellow Time (s) | 4.0 | | 4.0 | 4.0 | 4.0 | |
| All-Red Time (s) | 1.0 | | 1.0 | 1.0 | 1.0 | |
| Lead/Lag | | | | | | |
| Lead-Lag Optimize? | | | | | | |
| Vehicle Extension (s) | 3.0 | | 3.0 | 3.0 | 3.0 | |
| Recall Mode | None | | None | None | Max | |
| Walk Time (s) | 5.0 | | 5.0 | 5.0 | 5.0 | |
| Flash Dont Walk (s) | 11.0 | | 11.0 | 11.0 | 11.0 | |
| Pedestrian Calls (#/hr) | 8 | | 3 | 3 | 3 | |
| Act Effct Green (s) | 15.3 | | 15.3 | 15.3 | 17.2 | |
| Actuated g/C Ratio | 0.38 | | 0.38 | 0.38 | 0.42 | |
| v/c Ratio | 0.68 | | 0.22 | 0.16 | 0.38 | |
| Control Delay | 15.1 | | 10.7 | 8.3 | 4.3 | |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Queue Delay | 0.0 | | 0.0 | 0.0 | 0.0 | |
| Total Delay | 15.1 | | 10.7 | 8.3 | 4.3 | |
| LOS | B | | B | A | A | |
| Approach Delay | 15.1 | | | 8.9 | 4.3 | |
| Approach LOS | B | | | A | A | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Cycle Length: 45 | |
| Actuated Cycle Length: 40.6 | |
| Natural Cycle: 45 | |
| Control Type: Semi Act-Uncoord | |
| Maximum v/c Ratio: 0.68 | |
| Intersection Signal Delay: 10.4 | Intersection LOS: B |
| Intersection Capacity Utilization 57.2% | ICU Level of Service B |
| Analysis Period (min) 15 | |

Splits and Phases: 1: Int

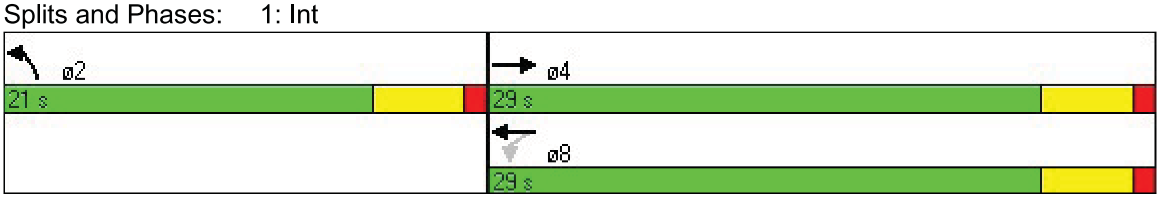


| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Storage Length (m) | | 0.0 | 90.0 | | 0.0 | 0.0 |
| Storage Lanes | | 0 | 1 | | 1 | 0 |
| Total Lost Time (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| Leading Detector (m) | 15.2 | | 15.2 | 15.2 | 15.2 | |
| Trailing Detector (m) | 0.0 | | 0.0 | 0.0 | 0.0 | |
| Turning Speed (k/h) | | 14 | 24 | | 24 | 14 |
| Lane Util. Factor | 1.00 | 1.00 | 0.91 | 0.91 | 1.00 | 1.00 |
| Ped Bike Factor | 1.00 | | 1.00 | 1.00 | 0.97 | |
| Frt | 0.976 | | | | 0.889 | |
| Flt Protected | | | 0.950 | 0.985 | 0.991 | |
| Satd. Flow (prot) | 1796 | 0 | 1597 | 3312 | 1584 | 0 |
| Flt Permitted | | | 0.297 | 0.749 | 0.991 | |
| Satd. Flow (perm) | 1796 | 0 | 498 | 2516 | 1583 | 0 |
| Right Turn on Red | | Yes | | | | Yes |
| Satd. Flow (RTOR) | 32 | | | | 294 | |
| Headway Factor | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| Link Speed (k/h) | 50 | | | 50 | 50 | |
| Link Distance (m) | 223.5 | | | 129.8 | 293.8 | |
| Travel Time (s) | 16.1 | | | 9.3 | 21.2 | |
| Volume (vph) | 465 | 102 | 122 | 136 | 68 | 310 |
| Confl. Peds. (#/hr) | | 10 | 10 | | 4 | 4 |
| Confl. Bikes (#/hr) | | 1 | | | | 6 |
| Peak Hour Factor | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| Adj. Flow (vph) | 484 | 106 | 127 | 142 | 71 | 323 |
| Lane Group Flow (vph) | 590 | 0 | 64 | 205 | 394 | 0 |
| Turn Type | | | Perm | | | |
| Protected Phases | 4 | | | 8 | 2 | |
| Permitted Phases | | | 8 | | | |
| Detector Phases | 4 | | 8 | 8 | 2 | |
| Minimum Initial (s) | 4.0 | | 4.0 | 4.0 | 4.0 | |
| Minimum Split (s) | 21.0 | | 21.0 | 21.0 | 21.0 | |
| Total Split (s) | 29.0 | 0.0 | 29.0 | 29.0 | 21.0 | 0.0 |
| Total Split (%) | 58.0% | 0.0% | 58.0% | 58.0% | 42.0% | 0.0% |
| Maximum Green (s) | 24.0 | | 24.0 | 24.0 | 16.0 | |
| Yellow Time (s) | 4.0 | | 4.0 | 4.0 | 4.0 | |
| All-Red Time (s) | 1.0 | | 1.0 | 1.0 | 1.0 | |
| Lead/Lag | | | | | | |
| Lead-Lag Optimize? | | | | | | |
| Vehicle Extension (s) | 3.0 | | 3.0 | 3.0 | 3.0 | |
| Recall Mode | None | | None | None | Max | |
| Walk Time (s) | 5.0 | | 5.0 | 5.0 | 5.0 | |
| Flash Dont Walk (s) | 11.0 | | 11.0 | 11.0 | 11.0 | |
| Pedestrian Calls (#/hr) | 10 | | 4 | 4 | 4 | |
| Act Effct Green (s) | 18.9 | | 18.9 | 18.9 | 17.2 | |
| Actuated g/C Ratio | 0.43 | | 0.43 | 0.43 | 0.39 | |
| v/c Ratio | 0.75 | | 0.30 | 0.19 | 0.49 | |
| Control Delay | 16.5 | | 12.0 | 7.8 | 6.3 | |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Queue Delay | 0.0 | | 0.0 | 0.0 | 0.0 | |
| Total Delay | 16.5 | | 12.0 | 7.8 | 6.3 | |
| LOS | B | | B | A | A | |
| Approach Delay | 16.5 | | | 8.8 | 6.3 | |
| Approach LOS | B | | | A | A | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Cycle Length: 50 | |
| Actuated Cycle Length: 44.3 | |
| Natural Cycle: 50 | |
| Control Type: Semi Act-Uncoord | |
| Maximum v/c Ratio: 0.75 | |
| Intersection Signal Delay: 11.6 | Intersection LOS: B |
| Intersection Capacity Utilization 69.0% | ICU Level of Service C |
| Analysis Period (min) 15 | |

Splits and Phases: 1: Int

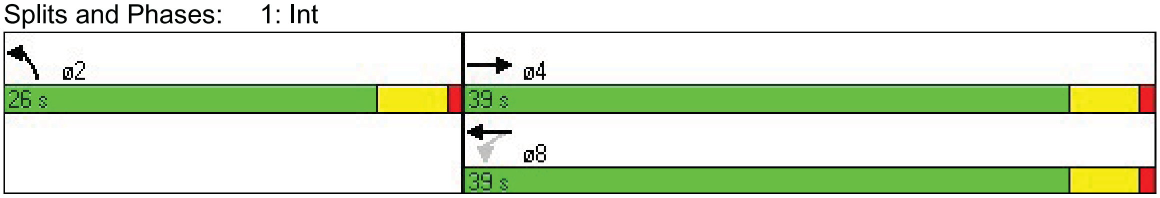


| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Lane Configurations | | | | | | |
| Ideal Flow (vphpl) | 1900 | 1900 | 1900 | 1900 | 1900 | 1900 |
| Storage Length (m) | | 0.0 | 90.0 | | 0.0 | 0.0 |
| Storage Lanes | | 0 | 1 | | 1 | 0 |
| Total Lost Time (s) | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| Leading Detector (m) | 15.2 | | 15.2 | 15.2 | 15.2 | |
| Trailing Detector (m) | 0.0 | | 0.0 | 0.0 | 0.0 | |
| Turning Speed (k/h) | | 14 | 24 | | 24 | 14 |
| Lane Util. Factor | 1.00 | 1.00 | 0.91 | 0.91 | 1.00 | 1.00 |
| Ped Bike Factor | 0.99 | | | | 0.97 | |
| Frt | 0.976 | | | | 0.889 | |
| Flt Protected | | | 0.950 | 0.985 | 0.991 | |
| Satd. Flow (prot) | 1793 | 0 | 1597 | 3312 | 1579 | 0 |
| Flt Permitted | | | 0.140 | 0.598 | 0.991 | |
| Satd. Flow (perm) | 1793 | 0 | 235 | 2010 | 1577 | 0 |
| Right Turn on Red | | Yes | | | | Yes |
| Satd. Flow (RTOR) | 26 | | | | 197 | |
| Headway Factor | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 | 0.99 |
| Link Speed (k/h) | 50 | | | 50 | 50 | |
| Link Distance (m) | 223.5 | | | 129.8 | 293.8 | |
| Travel Time (s) | 16.1 | | | 9.3 | 21.2 | |
| Volume (vph) | 648 | 142 | 171 | 190 | 94 | 432 |
| Confl. Peds. (#/hr) | | 14 | 14 | | 5 | 5 |
| Confl. Bikes (#/hr) | | 1 | | | | 6 |
| Peak Hour Factor | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 | 0.96 |
| Adj. Flow (vph) | 675 | 148 | 178 | 198 | 98 | 450 |
| Lane Group Flow (vph) | 823 | 0 | 89 | 287 | 548 | 0 |
| Turn Type | | | Perm | | | |
| Protected Phases | 4 | | | 8 | 2 | |
| Permitted Phases | | | 8 | | | |
| Detector Phases | 4 | | 8 | 8 | 2 | |
| Minimum Initial (s) | 4.0 | | 4.0 | 4.0 | 4.0 | |
| Minimum Split (s) | 21.0 | | 21.0 | 21.0 | 21.0 | |
| Total Split (s) | 39.0 | 0.0 | 39.0 | 39.0 | 26.0 | 0.0 |
| Total Split (%) | 60.0% | 0.0% | 60.0% | 60.0% | 40.0% | 0.0% |
| Maximum Green (s) | 34.0 | | 34.0 | 34.0 | 21.0 | |
| Yellow Time (s) | 4.0 | | 4.0 | 4.0 | 4.0 | |
| All-Red Time (s) | 1.0 | | 1.0 | 1.0 | 1.0 | |
| Lead/Lag | | | | | | |
| Lead-Lag Optimize? | | | | | | |
| Vehicle Extension (s) | 3.0 | | 3.0 | 3.0 | 3.0 | |
| Recall Mode | None | | None | None | Max | |
| Walk Time (s) | 5.0 | | 5.0 | 5.0 | 5.0 | |
| Flash Dont Walk (s) | 11.0 | | 11.0 | 11.0 | 11.0 | |
| Pedestrian Calls (#/hr) | 5 | | 5 | 5 | 14 | |
| Act Effct Green (s) | 30.9 | | 30.9 | 30.9 | 22.2 | |
| Actuated g/C Ratio | 0.50 | | 0.50 | 0.50 | 0.36 | |
| v/c Ratio | 0.90 | | 0.75 | 0.28 | 0.79 | |
| Control Delay | 27.5 | | 53.3 | 9.2 | 22.3 | |

| Lane Group | EBT | EBR | WBL | WBT | NBL | NBR |
|---|---|---|---|---|---|---|
| Queue Delay | 0.0 | | 0.0 | 0.0 | 0.0 | |
| Total Delay | 27.5 | | 53.3 | 9.2 | 22.3 | |
| LOS | C | | D | A | C | |
| Approach Delay | 27.5 | | | 19.7 | 22.3 | |
| Approach LOS | C | | | B | C | |

| Intersection Summary | |
|---|---|
| Area Type: Other | |
| Cycle Length: 65 | |
| Actuated Cycle Length: 61.2 | |
| Natural Cycle: 65 | |
| Control Type: Semi Act-Uncoord | |
| Maximum v/c Ratio: 0.90 | |
| Intersection Signal Delay: 24.2 | Intersection LOS: C |
| Intersection Capacity Utilization 92.1% | ICU Level of Service F |
| Analysis Period (min) 15 | |

Splits and Phases: 1: Int



# APPENDIX E : STRUCTURAL CALCULATIONS

Calculation Date: 2017-03-02

## Calculation of Dead Loads

**HSS Columns:** 305x305x13

| | | |
|---|---|---|
| Length | 12 | m |
| Density | 1.11 | kN/m |

Dead Load: 13.32 kN

**Concrete Arch:**

| | | |
|---|---|---|
| Volume | 1.109009 | $m^3$ |
| Density | 24 | $kN/m^3$ |

Dead Load: 26.62 kN

**Concrete Cover:**

| | | |
|---|---|---|
| Volume | 0.9009 | $m^3$ |
| Density | 24 | $kN/m^3$ |

Dead Load: 21.62 kN

**Steel Plates:** 50 mm plates

| | | |
|---|---|---|
| Area | 20 | $m^2$ |
| Density | 3.85 | $kN/m^2$ |

Dead Load: 77 kN

**W-Shape** W310x375

| | | |
|---|---|---|
| Length | 25 | m |
| Density | 3.68 | kN/m |

Dead Load: 92 kN

Total Dead Load: 230.56 kN

**Earthquake Overturning Force**

| Component | Dead Load | | DL*min.EQ force | Center of mass (m) | | |
|---|---|---|---|---|---|---|
| Arch | 26.62 | KN | 6.015 | 6 | 36.09 | knM |
| Plate and Column | 203.9416 | KN | 46.09 | 2 | 92.18 | knM |
| | | | | | 128.27 | knM |

Calculation Date: 2017-03-02

## Calculation of Earthquake Loads and Effects (Section 4.1.8. of NBC 2010)

**Input Parameters:**

| | | | | | |
|---|---|---|---|---|---|
| Importance Category: | Normal | → | $I_E$: | 1.0 | (NBCC 2010 Table 4.1.8.5) |
| Province: | British Columbia | → | $S_a(0.2)$: | 0.880 | |
| Site Location: | West Vancouver | | $S_a(0.5)$: | 0.620 | |
| | | | $S_a(1.0)$: | 0.330 | |
| | | | $S_a(2.0)$: | 0.170 | |
| | | | PGA: | 0.430 | (NBCC Table C-2) |
| Site Class: | C | → | $F_a$: | 1.0 | (NBCC 2010 Table 4.1.8.4.B.) |
| | | | $F_v$: | 1.0 | (NBCC 2010 Table 4.1.8.4.C.) |
| SFRS Material: | Steel | | | | |
| SFRS Type: | Limited ductility moment-resisting frames | → | $R_d$: | 2.0 | |
| | | | $R_o$: | 1.3 | (NBCC 2010 Table 4.1.8.9) |
| Height of Structure | 7.98 m | | | | |
| Number of storeys | 1 | | | | |
| Type of SFRS | Other systems | → | $T_a$: | 0.237 | (NBCC 2010 Cl. 4.1.8.11. (3)) |
| | | | $M_v$: | 1.0 | (NBCC 2010 Table 4.1.8.11) |
| | | | J: | 1.0 | (NBCC 2010 Table 4.1.8.11) |
| | | | S(T): | 0.8475907 | (NBCC 2010 Cl. 4.1.8.4.(7)) |
| Weight of Structure | 1.0 kN | | | | (Use 1.0kN to get seismic load as a percentage of weight) |

**Calculation of Minimum Lateral Earthquake Force:**

Minimum lateral earthquake force, V

$V = S(T_a)M_vI_EW/(R_dR_o)$ = 0.326 (NBCC Clause 4.1.8.11.(2))

Lower bound of V for moment-resisting frames, braced frames, and other systems

$S(2.0)M_vI_EW/(R_dR_o)$ = 0.065 (NBCC Clause 4.1.8.11.(2)b)

Upper bound of V for buildings NOT on site Class F and with $R_d \geq 1.5$

$(2/3)S(2.0)I_EW/(R_dR_o)$ = 0.226 (NBCC Clause 4.1.8.11.(2)c) (Governs)

Therefore, the minimum lateral earthquake force used for analysis is: 0.225641026
(as a % of weight)

Calculation Date: 2017-03-02

## Calculation of Specified Wind Load (Cl. 4.1.7.1. of NBC 2010)

**Input Parameters:**

| | | | | | | |
|---|---|---|---|---|---|---|
| Importance Category: | Normal | → | $I_w$ = | 1.00 | (ULS) | (NBCC 2010 Table 4.1.7.1) |
| | | | $I_w$ = | 0.75 | (SLS) | (NBCC 2010 Table 4.1.7.1) |
| Province: | British Columbia | | | | | |
| Site Location: | West Vancouver | → | p = | 0.48 | kPa | (NBCC Table C-2) |
| Terrain: | Rough | | | | | |
| $Elev_{top\ of\ roof}$: | 7.98 | | | | | |
| $Elev_{top\ of\ wall}$: | 7.98 | | | | | |
| $Elev_{top\ of\ grade}$: | 0.000 | | | | | |
| Reference height (h): | 7.98 m | → | $C_e$ = | 0.70 | | (Par. 7, Commentary I, NBC 2010 Structural Commentaries) |
| Roof Slope: | 0 | | | | | (NBCC 2010 Clause 4.1.7.1.(5)) |
| α: | 0 ° | | | | | |

**Components and Cladding - Walls:**

Consider the arch as a wall/cladding structure and use the appropriate table in the Structural Commentary

| | | | |
|---|---|---|---|
| Ds: | 5.82 | m | (Least horizontal dimension) |
| H: | 7.980 | m | (H is defined above in image for Load Case A) |
| End zone width z: | 1.0 | m | (Note 7, Figure I-7, Commentary I, NBC 2010 Structural Commentaries) |
| End zone width y: | 6 | m | (Note 6, Figure I-7, Commentary I, NBC 2010 Structural Commentaries) |

**Components and Cladding - Walls:**

| | | | |
|---|---|---|---|
| $L_{wall}$ = | 5.82 | m | (Length of wall) |
| $L_{gable}$ = | 5.82 | m | (Length of gable) |
| z = | 1.0 | m | |
| H = | 7.980 | m | |
| h = | 7.98 | m | |

| | Area ($m^2$) | $C_pC_g$ (-) | p (kPa) | $C_pC_g$ (-) | p (kPa) |
|---|---|---|---|---|---|
| $E_{wall}$ | 8.0 | 1.53 | 0.51 | -1.79 | -0.60 |
| $W_{wall}$ | 30.5 | 1.37 | 0.46 | -1.58 | -0.53 |
| $E_{gable}$ | 8.0 | 1.53 | 0.51 | -1.79 | -0.60 |
| $W_{gable}$ | 30.5 | 1.37 | 0.46 | -1.58 | -0.53 |

Use p = 0.51 kPa

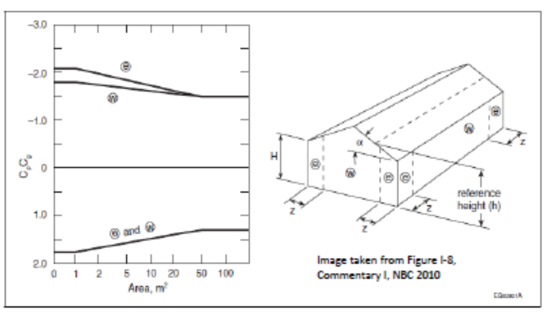



Image taken from Figure I-8, Commentary I, NBC 2010

Calculation Date: 2017-03-02

## Calculation of Specified Snow Load (Cl. 4.1.6.2. of NBC 2010)

**Input Parameters:**

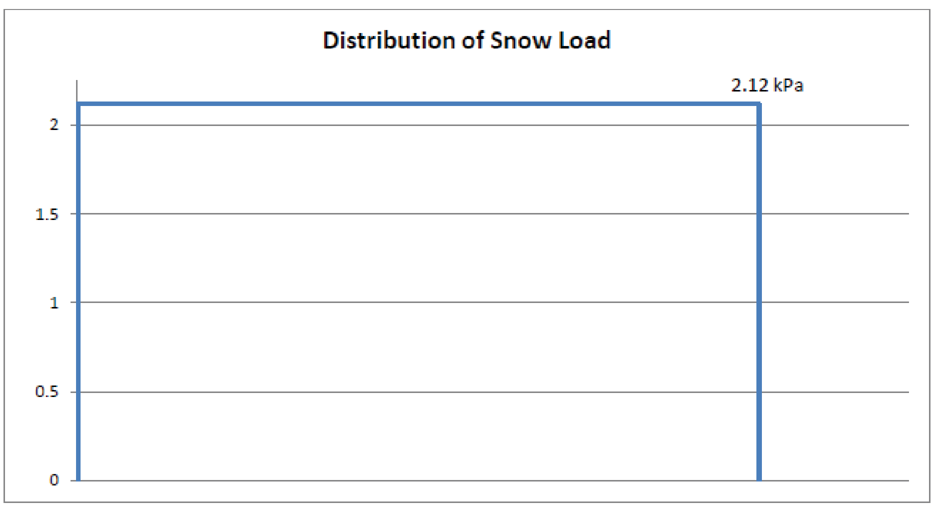
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Importance Category: | Normal | | → | $I_s$: | 1.0 | (ULS) | (NBCC 2010 Table 4.1.6.2) |
| | | | | $I_s$: | 0.9 | (SLS) | (NBCC 2010 Table 4.1.6.2) |
| Province: | British Columbia | | → | $S_s$: | 2.4 | kPa | (NBCC Table C-2) |
| Site Location: | West Vancouver | | | $S_r$: | 0.2 | kPa | (NBCC Table C-2) |
| shorter roof plan dimension = w = | 0.41 | m | | $C_w$: | 1.0 | (NBCC Cl. 4.1.6.2 (3), (4)) | |
| longer roof plan dimension = l = | 5.82 | m | | | | | |
| $l_c = 2w - w^2/l =$ | 0.8 | m | → | $C_b$: | 0.8 | (NBCC Cl. 4.1.6.2 (2)) | |
| α= | 0 | ° | → | $C_s$: | 1.0 | (NBCC Cl. 4.1.6.2 (5), (6)) | |
| Slippery Roof? | No | | | | | | |
| | | | Case I Loading | $C_a$: | 1.0 | (Par. 33, Commentary G, NBC 2010 Structural Commentaries) | |

**Calculation and Graphical Display of Snow Load:**

$S = I_s[S_s(C_bC_wC_sC_a) + S_r]$

**Case I Loading (ULS):**

2.12 kPa




Approximate the snow load as a distributed load. (This is a conservative overestimation, at the very edge of the arch, there is less snow due to the large slope)

Calculation Date: 2017-03-03

## Structural Verification

| | | |
|---|---|---|
| Dead Load: | 230.56 | kN |
| Snow Load: | 2.12 | kPa |
| Wind Load: | 0.51 | kPa |
| Earthquake Load: | 52.11 | kN |

Governing Load Case for Vertical Loads:
1.25DL + 1.5SL 295.79 kN

Governing Case for Lateral Shear (at Base):
1.0EQ 52.11 kN

Governing Case for Overturning
0.9DL + 1.4WL 12.59 kN

**Bearing Capacity:**

Each footing takes half of the gravity load

| | | |
|---|---|---|
| Area of footing: | 3.65 | $m^2$ |
| Load per footing | 40.54 | kPa |

Soil is quadra sand, base of footing at 1.0 below grade

| | | | | |
|---|---|---|---|---|
| Unit weight of sand | 19.8 | $kN/m^3$ | | |
| Effective Unit Weight | 10 | $kN/m^3$ | | |
| From Meyerhof: | | | | |
| $N_q$ | 18.4 | | | |
| $N_\gamma$ | 15.7 | | | |
| Vertical effective stress | 10 | kPa | | |
| Bearing Capacity | 303.948 | kPa | FOS= | 7.5 |

**Compressive Strength of HSS**

From S16-09, page 4-50, the compressive strength for an HSS 305 x 305 x 13 with effective length 6m
Cr = 3920 kN 4% of steel capacity used

**W310x375 Check**

Wind load causes bending on the plate:

| | | | |
|---|---|---|---|
| Maximum moment: | 0.6375 | kNm | (per W shape) |
| Moment Capacity: | 2520 | kNm | (per 1 W310x375) |
| Deflection: | 10.28 | mm | (per W shape) |
| Allowable Deflection | 16.67 | mm | (L/300) |

**HSS Check**

| | | | |
|---|---|---|---|
| Shear Capacity: | 1841 | kN | 3% of steel capacity used |
| Moment Capacity: | 561.6 | kNm | 9% of steel capacity used |

**HSS Deflection:**

**Wind**

| | | |
|---|---|---|
| Deflection (per column) | 0.35 | mm |
| **h/300 check** | **20.00** | **mm** |

**Earthquake**

| | | |
|---|---|---|
| Deflection (bottom 1m) | 0.00 | mm |
| Deflection (top 3m) | 0.09 | mm |
| **Total Deflection** | **0.09** | **mm** |

**Sliding Check**

Friction factor between soil and concrete 0.5

| | | | | |
|---|---|---|---|---|
| Applied Force | 52.11 | kN | | |
| Resisting (Sliding) Force | 115.28 | kN | FOS= | 2.21 |

**Overturning Check**

Wind load is distributed evenly over the height:

| | | | | |
|---|---|---|---|---|
| Moment arm of wind: | 3.99 | m | | |
| Overturning Moment: | 50.23 | kNm | | |
| Resisting Moment: | 198.17 | kNm | FOS = | 3.95 |

**Earthquake Overturning**

Overturning Moment

| **Component** | **Dead Load** | **EQ Force** | **Moment arm** | **Overturning** |
|---|---|---|---|---|
| Arch | 26.62 KN | 6.02 | 6 | 36.092 knM |
| Plate and Column | 203.9 KN | 46.09 | 2 | 92.182 knM |
| | | | | **128.27 knM** |

Tipping

| | | | | |
|---|---|---|---|---|
| Overturning Moment | 128.27 | kNm | | |
| Resisting Moment | 843.85 | kNm | FOS= | 6.58 |

Overturning out of Plane

| | | | | |
|---|---|---|---|---|
| Overturning Moment | 128.27 | kNm | | |
| Resisting Moment | 198.17 | kNm | FOS= | 1.54 |

Check increased bearing on soil due to overturning moment:

$q_{max} = P/A + My/I$, where P/A is the bearing capacity calculated due to centric loading, and M is the greatest bending moment from the different load cases considered.

The greatest overturning moment is nearly 130 kNm

$I = Lh^3/12$, where L = 1.91 m and h = 0.5 m. y is the distance from the centroid to the farthest fibre, which is equal to L/2 = 1.91 m/2.

Plugging in the values, the stress from the bending moment is equal to 6.24 Pa, which is nearly negligible compared to the bearing capacity of the axial load.

Steel Connection Design:

Fillet Weld connection for the W-shape to HSS

Length of weld is 330 mm

Using CSA S16-09, Cl. 13.13.2.2.

$V_r = 0.67\phi_w A_w X_u(1.00 + 0.50\sin^{1.5}\theta)M_w$

$\phi_w = 0.67$
$\theta = 0^o$ (longitudinal weld)
$M_w = 1.0$ (single weld orientation)

Equal leg lengths of 10 mm, throat size = 7.071 mm

Then $A_w = 7.071 \times 330 = 2333.43\ mm^2$
$X_u = 490$ MPa (G40.21 Grade 300)
$V_r = 513.3$ kN

This is the shear capacity of one weld, there will be a total of 20 welds for 5 W-shapes, and the shear capacity is much higher than the self weight of the beams and plate, therefore, the connection is sufficient.

Bolt connection of Plate to W – shape

Check the tensile capacity of the steel plate:
$T_r$ is the minimum of the following:

$T_r = \phi A_g F_y$
$T_r = \phi_u A_{ne} F_u$
$T_r = 0.75[U_t A_n F_u + 0.6(F_y+F_u/2)A_{gv}$

$T_r = \phi A_g F_y$ = 0.9 x 50 x 5000 x 350 = 78750 kN

Use 50 24 dia. bolts spaced 100 mm apart

Then $T_r = \phi_u A_{ne} F_u$ = 769.5 kN, using $A_{ne} = 0.6\ A_n$.

Finally, using edge distance 30 mm, $T_r = 0.75[U_t A_n F_u + 0.6(F_y+F_u/2)A_{gv}$ = 1822.5 kN

Therefore the tensile resistance is more 769.5 kN which is much greater than the self weight of the plates, and the connection is sufficient.

Check the shear resistance of the bolts: the unit factored shear resistance of an A325M bolt is 279 MPa, assuming the threads are intercepted.

The area of one 24 dia. bolt is 452 $mm^2$, and there are a total of 100 bolts on each side. Thus the shear capacity is 12610 kN using 50 bolts.

Modify the design to use only 2 bolts on the bottom of the plate at either end, and decrease the number of bolts along the top to have 10 bolts spaced at 500 mm.

Then shear capacity of the connection is 1514 kN. The tensile capacity of the plate will increase as the number of bolts decrease, so no need to check again.

Footing Detailed Calculations

Given the following parameters:

Concrete cover = 75 mm
15M reinforcement
b = l = 1.91 m
h = 0.5 m
Load per footing = 148 kN = $P_f$
$q_f$ = 41 kPa

Calculate effective depth:

d = h - cover - $d_b/2$ = 500 - 75 - 15/2 = 415 mm

Critical Perimeter = $b_0$ = 4(t+d) = 4(410+415) = 3300mm

Then $V_c = v_c \times b_0 \times d$, where $v_c = 0.38\lambda\phi_c\sqrt{(f'_c)}$

$v_c$ = 0.38(1)(0.65)(sqrt(30)) = 1.35

$V_c = v_c \times b_0 \times d = 1.35 \times 3300 \times 415 = 1849$ kN

$V_f = q_f\,[A – (t+d)^2] = 41[1910^2 – (410+415)^2] = 122$ kN

Since $V_c >> V_f$, then shear reinforcement is not required

Factored Bending Moment is given by the following equation:

$M_f = q_f \times ((l-t)/2) \times ((l-t)/4) \times b = 22$ kN

Set $M_r = M_f$, then use $A_s = 0.0015f'_cb(d-\sqrt{(d^2 – (3.85M_r/(f'_cb))})})$

Then $A_s = 155\ mm^2$

$A_{smin} = 0.002A_g = 1910\ mm^2$, so use 10 15M bars

Required spacing = $A_b$*1000/$A_s$ = 100 mm

The reinforcement in both directions is identical since the footing is square. The reinforcement details can be found on the structural drawings.