

DETAILED DESIGN REPORT: Traffic Modifications at the UBC Botanical Garden
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University of British Columbia
CIVL 446
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DETAILED DESIGN REPORT:

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Letter of Transmittal
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21st March 2014

Dr. Siegfried F. Stiemer, CIVL 445 Instructor
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Dear Dr. Stiemer:

Subject: Submission of CIVL 446 Final Report

This is team 8's submissions for the CIVL 446 final technical report entitled "Detailed Design Report: Traffic Modifications at the UBC Botanical Garden" as required by course requirements.

This report will contain engineering solutions that will address some of the shortcomings and inefficiencies at the UBC Botanical Garden. This project will provide detailed design solutions to the environmental issues presented by the impermeable parking lot at the Garden and the busy intersection at Marine Drive and Stadium Road. These will be tackled with engineering focus on the environmental/ hydrological, transportation, and structural disciplines. A project management component will also be included.

We are available to answer any questions and can be contacted at:

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Sincerely yours,

Aaron Schroeder, Elliot Yii, Scott Gardiner, Kyung-Suk Kim, Sean Blake, Surabhi Prasad

Enclosure

Executive Summary

This report provides engineering solutions devised towards the improvement of the UBC Botanical Garden. One issue of concern that is currently troubling the Garden is the environmental concern presented by an impervious parking lot floor; this contributes to soil erosion in the surrounding area and also the contamination of the environment via chemical runoff from vehicle effluent. High traffic speeds in front of the Garden also make it quite dangerous for pedestrians and cyclist, especially in times of inclement weather such as fog.

To address these issues, the report includes detailed designs of the refitting of the parking lot floor using environmentally friendly design, modification of traffic systems around the Garden using a round-about, and signage to support said round-about. These will be discussed in relation to the three main engineering disciplines that will be focused on in this project: transportation in regard to the round-about, structural for the signage to support it, and environmental for the parking lot. Project management information will also be provided.

For the roundabout section of the report, traffic flows will be studied and the roundabout will be designed to meet the minimum requirements set by the Ministry of Transportation. The design of the roundabout will also take the available area into account; design will be restricted to within the existing area of the intersection of Marine Drive and Stadium Road. Signage design for the roundabout will focus on wind loading which consists.

The environmental and hydrological criteria will focus on the refitting of the current parking lot which fitted with an impermeable surface with a permeable flooring. It will discuss in detail how the new layout will reduce issues pertaining to chemical runoff and ground water recharge.

Finally, the project management section of the report will include costing and scheduling for each component.

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1 Project Description

UBC Botanical Garden is a world class research facility and host many biodiversity collections and is widely regarded as one of the leaders in its field. It is located at 6804 Marine Drive SW, Vancouver. However, attendance at the Garden in recent times has been slow and there are several issues concerning the Garden that need to be addressed. Previously, in the CIVL 445 course, a project was set out to come up with the best ideas on how to improve the Garden overall. This project is a continuation of the work done In CIVL 445.

The objective the CIVL 446 project is to complete a detailed design for these ideas. Since the completion of CIVL 445, the best ideas have been chosen and broken down into categories. Of the chosen ideas, Team 8 will present a detailed design specifically on the refitting of the current impervious parking lot floor with a permeable flooring, construction of a roundabout on the intersection of Marine Drive and Stadium Road, and the installation of signage to support said roundabout. This report will concentrate on the structural, environmental/hydrological, and transportation disciplines of civil engineering.

For each discipline the necessary computations and analyses have been carried out and will be included in the body of the report.

2 Roundabout

In this section a roundabout will be discussed as an integral feature of this proposal. This proposed roundabout would replace the current two-way stop intersection in front of the UBC Botanical Garden. This intersection is designate TM 15-036.

A preliminary design has been completed and it is recommended to construct a roundabout at this location for the benefit of road users and the UBC Botanical Garden.

2.1 Background

This section will explore the backgrounds of both roundabouts and the intersection in question.

2.1.1 Background on Roundabouts

Roundabouts have historically been used to a greater extent in European countries. The prevalence of roundabouts in Europe has led to a driving population that is adjusted to their employment in daily driving. It has also provided a significant amount of statistical data on the safety and efficiency of roundabouts when designed and used correctly.

These data have provided encouragement for transportation engineers in North America to consider using them in greater frequency of construction. However, the driving population is generally less comfortable with their use. This inexperience has in turn led to higher accident rates, but is also gradually dropping as the population adjusts their driving.

Drivers at UBC are becoming more effective in the use of roundabouts thanks in large part to the two large-scale roundabouts on campus. Developing the current intersection into a roundabout will greatly benefit the UBC Botanical Garden.

2.1.2 Background on TM 15-036

This intersection, located directly in front of the UBC Botanical Garden main gate, is currently controlled as a two-way stop. It has 5 dated traffic counts, ranging in years from 1985 to 1993, which lists the average annual daily traffic for both directions. The intersection has never been investigated for the warrant of a signalized intersection. The latest survey recorded 7041 AADT.

The intersection today remains completely unchanged except for the projected growth from the previous traffic surveys. As the traffic volumes continue to grow the warrant requirements for a signalized intersection or a roundabout will eventually be met. Speed is also a known issue, due primarily to the sparse traffic controls along SW Marine Drive.

2.2 Benefits

Roundabouts offer numerous benefits over typical signalized intersections. These benefits are explored in greater detail in this section.

2.2.1 Safety

Roundabouts boast significantly lower accident rates and lower accident speeds than conventional intersections. Typically, a 44% drop in the number of accidents and 82% drop in the number of injuries can be expected. (NCHRP)

A serious concern, however, is pedestrian safety. With signalized intersections there are clear, undisputable rules encouraging pedestrian safety. With roundabouts, and their infrequent use in Canada, it is often useful to employ pedestrian crossing signals for the roundabout.

There are also other features that may be used. Dividing islands with protective curbs further enhances pedestrian safety. Raising the crossing height also encourages vehicles to slow down before approaching pedestrian crossings.

Safety measures should be implemented preventatively. To this end, it is vital to consider the safety records of nearby roundabouts and the solutions used to increase safety performance.

Cyclists also benefit from the implementation of roundabouts, with decreased speeds and the elimination of left turn movements. Often cyclists are also encouraged to take a different path and avoid entering the intersection with vehicles entirely, at their discretion.

2.2.2 Efficiency

Roundabouts are touted as being more efficient than signalized intersections. The gains in efficiency disappear when traffic volumes exceed 40 000 to 60 000 AADT. This upper limit is well within the expected growth for this intersection.

Additionally, roundabouts are assessed on their efficiency by the flow rate of cars through the intersection. Beyond this level, a signalized intersection is better suited for capacity. Typically, this efficiency translates to an upper maximum of 600 vehicles per hour through the intersection. Even with the projected growth accounted for it is unlikely that a roundabout at TM 15-036 would meet this threshold.

2.2.3 Independent of Power

Roundabouts are also independent of electrical requirements. This advantage over signalized intersections provides a contribution towards the sustainability of transportation mechanics at UBC.

The exception to this would be electric pedestrian warning lights, which will help improve pedestrian safety at the intersection. In the event of a power outage the pedestrians using the intersection would need to be more vigilant.

2.2.4 Noise

Noise levels are often reduced by the use of roundabouts. This is usually accomplished through vehicles not having to come to a complete stop, thereby reducing engine noise.

2.3 Expected Growth

The most recent traffic survey was done in 1993 and produced a traffic volume of 7041 AADT in the intersection. After this survey the intersection was removed from the list of intersections counted regularly by the Ministry of Transportation of BC.

Using this traffic survey and others like it from previous years, a growth rate was established by assuming a compounding growth rate, with respect to the East and West direction of flow. By weighting the average growth rate over this period to the volume of traffic in that particular direction, an overall growth rate of 5.45% per annum was calculated, as shown Appendix C (Roundabout Analysis).

Applying this compounding growth to the future allowed a projected traffic volume for the current year, as well as 10 and 20 years from today. This is shown in

Table 1, below.

Year	AADT
2014	10317
2024	17544
2034	29834

Table 1: Projected Traffic Growth

These growth trends indicate the most probable growth in volume. Despite this, traffic volumes can be highly suspect, especially when considering a localized area where driving and parking policies have a significant impact. As such, there may be an upper limit to the tolerated growth of traffic at UBC. If this proposal is accepted a proper traffic count will be done to determine actual traffic volumes.

2.4 Justification

A roundabout will improve local accessibility into the UBC Botanical Garden and make the area more pedestrian friendly. By slowing traffic down and creating a safer intersection the Botanical Garden can be expected to see greater integration with the rest of the UBC campus. The increase in safety and access furthers the strategic goal of UBC to develop an integrated community on campus.

2.5 Signage

The intersection will require signage to notify drivers of the change in traffic flow. Typical travel speeds along SW Marine Drive are well above the indicated maximum speeds and it will be necessary to provide advanced warning of this intersection. Placing 'reduced speed ahead' signs entering into the area to 40 km/h will help encourage drivers to slow down. The roundabout will ultimately be the largest encumbrance to speed, as well as raised pedestrian crossings that will behave similarly to speed humps.

The design recommends signage to be consistent with the Ministry of Transportation guidelines with added signs along SW Marine Drive to indicate reduced speed ahead and the corresponding maximum speed sign. The signs include 4 yield signs, 4 roundabout ahead signs, 8 pedestrian crossing signs and associated lights, and 4 right turn only signs. Painting on the asphalt will designate bike lanes and any associated signs for cyclists should be identical to the signs used on the existing roundabouts on campus.

2.6 Design

The designing of the intersection used a lot of recommendations provided in the National Cooperative Highway Research Program's *Roundabouts: An Informational Guide*. Some of these recommendations include dedicated turning lanes, raised curbs, and clear visibility at all approaches.

Based on the Government of British Columbia Ministry of Transportation Supplement to the TAC Manual, it is important to use gradual curvatures leading into and exiting the roundabout.

It is strictly written that “camel back” curves are considered poor design. The roundabout design also conforms to these guidelines.

According to the informational guide, with the traffic volume as projected, it would be best to use a single-lane roundabout. This will appropriately convey the required traffic well into the future while providing increased safety for the intersection. The guideline recommends a single-lane roundabout to have an inscribed diameter of 27 to 55 meters, and the BC TAC Supplement recommends 37 to 46 meters. The final design of the roundabout conforms to these with an inscribed diameter of 37.5 meters. This size is consistent with the other roundabouts on campus, as well.

The alignment chosen is a 90-degree angle to each intersection and no offsets. This conscious decision allows for minor impedance of flow-through traffic, helping to reduce speeds. It also gives each major direction two access lanes and two exit lanes. The final design is shown in Figure 1 below.

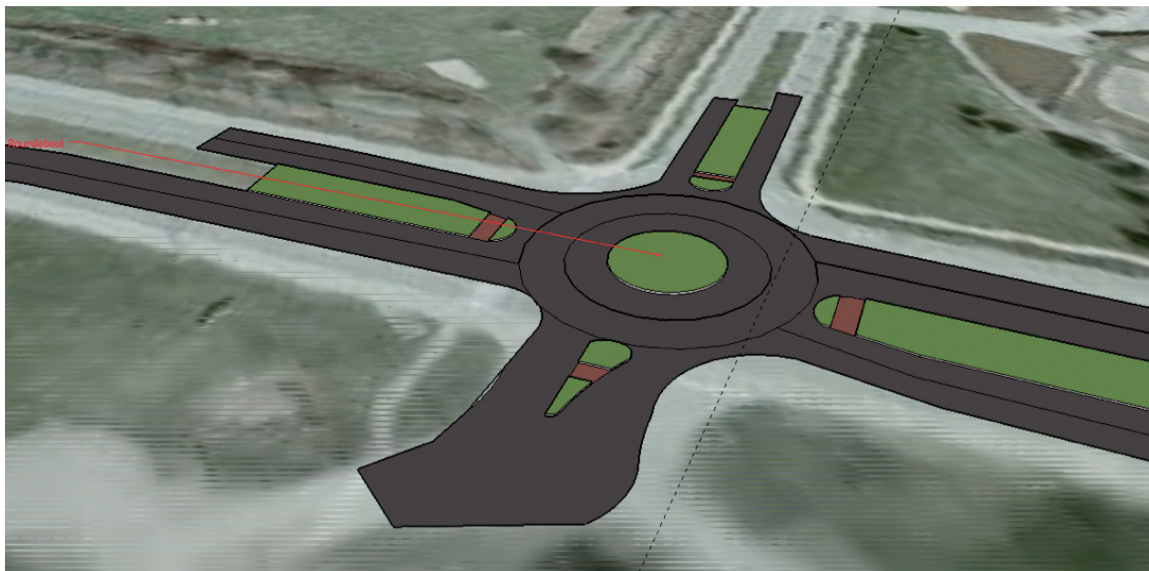


Figure 1: Final design of the roundabout

It is also worth noting that the road width has been expanded so bike lanes can be painted leading to the intersection. It is proposed that special ramps allowing cyclists to go on the sidewalk and avoid going through the roundabout be used, similar to the roundabout on 16th Avenue and Wesbrook Mall. This structuring will ensure that the intersection is safer and more accessible for everyone across a variety of modes of transportation.

2.7 Construction

The construction of the roundabout should commence as soon as possible. The benefits of a roundabout are numerous and they begin to take effect as soon as the roadway is available for use. Due to the increased usage of roads in and around UBC during the fall, it is recommended to prioritize this project to complete by late August. This will also prevent it from interfering with the Apple Festival at the UBC Botanical Garden.

The construction of this roundabout will be able to be completed within a single construction season.

2.8 Maintenance

The roundabout will require regular maintenance, which will be provided by the Ministry of Transportation. This cost is much lower than for that of a signalized intersection and slightly more than a two-way stop. The maintenance expected consists primarily of line painting and repaving of the intersection. Other maintenance may include light fixture repair and spot concrete repairs to curbs if damaged.

3 Structural Component—Signage Foundations:

3.1 Background

In this section, the aspect of structural design will be covered; more specifically the design of the foundations for the round-a-bout signage. Albeit the simplicity, the foundations of the signs are crucial components in the big picture of this round-a-bout and will require the same professional engineering seal that any other structural component big or small would need.

This detailed design will be for the primary signage of the round-a-bout which will be 24” tall by 48” wide aluminum signs arranged to inform drivers, of the UBC Botanical Garden, specifically entering the round-a-bout from either direction of South West Marine Drive.

3.2 Benefits

The benefits of the signage are that it is a simple way to single to the drivers on South West Marine Drive that there is a round-a-bout ahead, to also inform the drivers of the corresponding exits and where they lead, and finally and most importantly to increase the awareness of the UBC Botanical Garden to passing drivers. The benefit of the foundations, corresponding to each sign, is that the signs will not fall over during heavy wind. The main purpose, which is actually a requirement set out by the National Building Code of Canada (NBCC), is that the concrete foundation will prevent the over turning moment induced on the sign by governing wind loads. It can be noted that dead, live, snow, and earthquake loads will be so minor in comparison to the wind loads that they can be excluded from any detailed design calculations. Also note that lighting of the signs is an option that will help with the visibility of the signs at night or under poor visibility conditions.

3.3 Justification

According to the 2010 National Building Code of Canada (NBCC 2010), there are specific values for wind loads for each region in BC. The wind load on the sign must be derived using the corresponding 1/50 wind load value (which is 0.45 kPa); there is also an exposure value (C_e) that must be incorporated. The exposure value (in this case is 0.7), is a co-efficient that lessens the wind load if the specific component in question is in an area of low exposure to the wind. The exposure value also incorporates how high off the ground the component is, as this will also affect the effective force of the wind. Included with the wind load and the exposure value, is what is referred to as the C_pC_g value. The C_pC_g value (for this case is 1.7), is what relates where the component is in relation to the building it is attached too, or in this case, in relation to the ground. It also incorporates a factor that is derived from the ratio of width to height of the component.

3.4 Design

For the design of this footing, the 1/50 design wind load must first be calculated with all of its coefficients. The 1/50 wind load is (0.45 kPa), the coefficients C_e , and C_pC_g are 0.7, and 1.7 respectively. There is also a factor of safety on the wind load of 1.5. These all multiply together to create an effective wind load of 0.8 kPa, acting on the center of the sign. Then using the dimensions of the sign (2'x4'), which translates to an area of 0.75 m² (8 ft²). Multiplying the area and wind load, the force applied to the sign due to the wind is 0.6 kN.

A Simple sum of moments at the bottom corner of the foundation, the point in which it would have to pivot on, produces a result that the mass of the concrete foundation, given its width is 2' (0.6 m), needs to be 3.9 kN or 400 Kg-force. Then using the mass of concrete, and iterating a few times using the foundation dimensions, it is determined that a concrete foundation of 4'x2'x10" will sufficiently hold the sign in place.

3.5 Construction

The construction of the sign foundations is very simple. It involves excavating a hole with similar width and length dimensions as the needed foundation size. The depth of the excavation should be the height needed for the foundation plus approximately 6". Form work is not necessary, and only needed if the excavation is larger than the desired size of the concrete foundation size.

Once the hole is dug, the concrete can be poured in. Once the concrete is in place, the aluminum poles can be inserted into the concrete. After the concrete has set and cured for at least 7 days the sign can be attached to the vertical poles.

An alternative construction method would be to cast the concrete foundations off site, at a pre-cast facility, and to cast them with a short portion of aluminum pipe sticking out. Once they have fully cured, they can be delivered to site, inserted into the ground, the vertical poles can be attached to the bases already secure in the concrete, and finally the sign can be attached to the vertical poles.

3.6 Maintenance

The maintenance for these signs will be minimal. There are no moving parts that require regular upkeep. The only thing to keep in mind is that the fasteners are checked periodically to ensure that they remain tight to avoid them loosening from the oscillating forces on the sign due to the wind.

4 Parking Lot

4.1 Background

The parking lot to the UBC Botanical Gardens is accessed off SW Marine Drive and is located adjacent to the intersection of SW Marine Drive and Stadium Road. The existing parking lot surface is constructed out of impermeable asphalt which covers an area of approximately 2310m² with dimensions of 55m by 42m. The parking lot consists of approximately 75 parking stalls with a grass median in the center as illustrated in **Figure 2** below.



Figure 2: Existing Parking Lot

The Botanical Garden parking lot is located in the Trail 7 catchment with all stormwater leading to the Trail 7 outfall which is located to the west of the Garden. Representatives of the Botanical Garden have indicated that there have been issues with erosion of the Trail 7 creek that leads to the Trail 7 Outfall. Stormwater flows from the Trail 7 outfall have also resulted in erosion of the cliff face at Wreck Beach.

Development of the UBC campus has changed the natural hydrology of the land. As development of the campus has progressed, natural vegetated areas have been replaced by impervious surfaces such as parking lots and rooftops. Replacing these areas with impervious surfaces has resulted in higher runoff volumes and velocities as the water is no longer lost by

infiltration and evapotranspiration. Runoff from the impervious surfaces is conveyed to the Trail 7 Creek and Trail 7 outfalls via subsurface drainage pipes and ditches. During storms the surface runoff is carried through these conveyance systems at higher volumes and velocities than it naturally would and is discharged through the creek and outfall. This is a major contributing factor to the accelerated rate of erosion of the creek and cliff face. The Trail 7 outfall is currently elevated several feet in the air due to erosion (**G. P. UBC 2001**). These increased flow rates and velocities also create a risk of flooding.

The decreased rate of infiltration into the soil as a result of increased impervious area also leads to various other problems such as groundwater depletion and water quality. Groundwater recharge helps to maintain base flows in streams and sustain vegetation and wildlife. Stormwater contains contaminants such as sediment, oils, and metals. Infiltration allows the soil to naturally treat contaminants found in stormwater. Directing the flow from impervious surfaces into the subsurface drainage system and ditches eliminates this natural filtration process as the water is no longer able to infiltrate into the soil. This creates pollution at the receiving body of water which has a detrimental effect on the environment and aquatic wildlife. Studies of the levels of contamination at the Trail 7 outfall have shown that the concentration of numerous metals exceed the BC Water Quality guidelines. The concentration of other contaminants such as oils and sediment were consistent with other areas of the lower mainland and below the BC Water Quality guidelines (**Aplin & Martin Consultants Ltd. 2005**).

Since impervious surfaces are the primary source of stormwater runoff, pervious paving has become a popular method to reduce the impervious area of developed sites. Pervious paving allows the water to percolate into an underlying reservoir base where it is stored or discharged into the storm system via a perforated drain line. There are three types of pervious pavers, porous asphalt, grid pavers, or permeable unit pavers. Porous asphalt does not contain any fines in the mix which creates a void space for the water to percolate through. Grid pavers are made of a concrete or plastic structural load bearing matrix that has large voids filled with soil and grass. Permeable unit pavers consist of impervious concrete modular pavers with gapped

joints that allow the water to percolate between the pavers (**District, Stormwater Source Control Design Guidelines 2012 2012**). Pervious pavers are prone to clogging so measures must be taken to ensure sediment does not clog the void spaces. This is achieved by constructing berms to ensure no drainage from outside the parking lot is entering the system. A schematic of a typical pervious paving system is shown below in **Figure 3**.

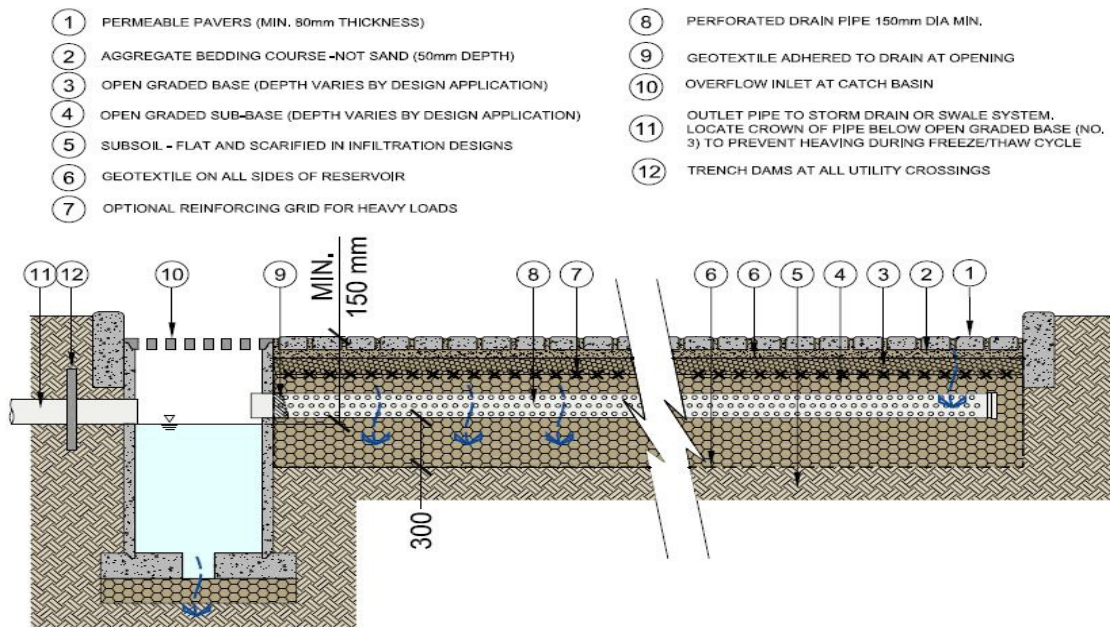


Figure 3: Typical Pervious Pavement Cross Section

4.2 Benefits

Pervious pavers offer numerous benefits over conventional impervious pavement. Aesthetics of the site are improved by providing vegetation where there would typically be asphalt. By increasing the volume of water infiltrated into the soil it reduces the quantity of runoff. This reduces the risk of erosion and flooding and also helps to recharge the groundwater. It can also reduce or eliminate the need for conventional curb and gutter systems and downstream detention facilities reducing the cost of the project. As the water percolates through the soil the quality of the water is improved. Pervious pavers can typically achieve the following removal efficiencies (District, Best Management Practices Guide for Stormwater Management 2014):

- Sediment (85-90%)

- Total phosphorus (65%)
- Total nitrogen (80-85%)
- COD (82%)
- Zinc (99%)
- Lead (98%)

4.3 Justification

UBC has developed an integrated storm water management plan that has the objective of using innovative approaches to reduce stormwater quantity and improve water quality (UBC 2014). Pervious pavement fits the criteria of UBC's integrated stormwater management plan as it will help to achieve both these objectives. It will also help to improve the aesthetics of the Botanical Garden as it will add green space to the parking lot.

4.4 Design

The proposed type of pervious paver is a grid paver with grass planted in the voids as it will improve the aesthetics of the site. Pervious pavement is limited to low traffic areas and can therefore only be applied to the parking stalls and the laneways must remain impervious pavement. The existing parking lot has 0.273 hectares of impervious pavement. The proposed parking lot will reduce the area of impervious pavement to 0.122 hectares by installing 0.15 hectares of pervious pavement. This is a 45% reduction of impervious cover for the site. The drainage for the parking lot will consist of a gravel reservoir base and a perforated drain line which leads to a lawn basin at the downstream end of each permeable pavement section. The lawn basins will then tie into a manhole located in the grass median which then ties into the existing storm system. A layout of the proposed parking lot is shown in Figure 4.



Figure 4: Plan View of Parking Lot

To determine the runoff volumes from the site the rational method was used as per the specifications in the UBC Technical Guidelines. The UBC Technical Guidelines state that the storm service system should be designed to convey the 10 year storm and the time of concentration shall be 10 minutes when the flow path length is less than 100 metres. From the IDF curve in the UBC Technical Guidelines an intensity of 40mm/hr was found. Using these values and runoff coefficients also stated in the technical guidelines the runoff flow rates were calculated. By installing pervious pavement the runoff volumes are reduced by 55%. These values are summarized in Table 2.

Table 2: Summary of Runoff Flow Rates

Existing Parking Lot							
Zone	C	A (sq.m)	A (Ha)	C Composite	TC (min)	I (mm/hr)	Q (cms)
Asphalt	0.95	2725.38	0.273	0.842	10	40	0.0306
Open Grass	0.3	542	0.054				
SUM		3267.38	0.327				

Proposed Parking Lot							
Zone	C	A (sq.m)	A (Ha)	C Composite	TC (min)	I (mm/hr)	Q (cms)
Impermeable Asphalt	0.95	1223	0.122	0.543	10	40	0.020
Permeable Asphalt	0.3	1502	0.150				
Grass	0.3	542	0.054				
SUM		3267.38	0.327				

The discharge pipes were sized to convey the 10 Year, 10 minute storm using mannings formula. From mannings formula it was found that the required pipe diameter was 150mm. However, UBC Technical Guidelines state that the minimum pipe size is 200mm, so a 200mm diameter pipe was chosen for all discharge pipes.

To determine the depth of gravel required for the reservoir layer the GVRD Stormwater Source Control Design Guidelines were used. The guidelines specify that the depth of the rock reservoir (D_R) should be calculated using the equation $D_R = \frac{K_S \times T \times 24}{n}$. Where K_S is the saturated hydraulic conductivity (mm/hr), T is the time to drain (days), and n is the porosity. Based on previous geotechnical reports it was assumed that the soil underlying the parking lot is glacial till (Ltd. 2009) which has a typical K_S value of 4.9mm/hr and porosity of 0.42 (McCarthy 2007). Using these values with a time to drain of 1 day, the required depth of the rock reservoir is

250mm. However, the GVRD BMP Guide states that in order to achieve water quality improvement the minimum depth should be 450mm. Therefore a gravel depth of 450mm governs.

The 10 year 24 hour precipitation is 81.2mm which results in a volume of 265m³ of water on the parking lot. The storage capacity of the gravel was calculated to be 203 m³ by multiplying the porosity of the gravel by the volume of gravel. This makes the proposed parking lot capable of storing 76% of the 10 Year 24 hour storm.

4.5 Construction

The construction of the parking lot should be completed at the same time as the roundabout to minimize mobilization costs. All construction practices should be in accordance with the latest MMCD standards and specifications as per the UBC Technical Guidelines. An erosion and sediment control plan will be required to minimize the risk of erosion as well as contaminants and sediment entering the storm system during construction. A detailed breakdown of the construction schedule and process is outlined in the construction management section.

4.6 Maintenance

The expected life span of pervious pavement is 5-10 years. Maintenance is relatively low, with the turf only requiring maintenance such as watering, fertilizing, and mowing. The use of pesticides and fertilizers that have adverse effects on concrete products should be avoided (District, Best Management Practices Guide for Stormwater Management 2014)

5 Construction Management

5.1 Project Delivery Approach

Before the owner organizes the members of the project team, the desired project delivery method would be determined. Two potential project delivery methods are applicable for this project: design-bid-build and design build. Each delivery method has different benefits and restrictions and the selection of the delivery method must consider the balance between cost and performance.

The design-bid-build delivery method has relatively low owner's involvement in the construction process and the risk during construction phase is almost allocated on the contractor and sub-contractors. However, this method is not flexible and difficult to reduce the time required during the design or construction phase. This approach allows for fast tracking and good value engineering with good collaboration between design and construction teams.

The design-build project delivery is recommended with selection based on qualifications. The qualifications will evaluate on the basis of corporate history, relevant company and team member past experiences, design and building philosophies to name a few. This method should ideally reduce the overall duration of the project, total cost and maintain the same level of quality as compared to design-bid-build project delivery. If the communication by design team and construction team is properly maintained throughout the duration of the project, it will improve the efficiency and quality of the project.

5.2 Schedule

A 25-day construction schedule is expected for the roundabout and parking lot construction. The construction is scheduled to start on July 7th 2014 and completed by August 8th, 2014. This will avoid the peak traffic flows around UBC during school season and the Apple Festival at the UBC Botanical Garden. During the parking lot construction, Thunderbird parking lot will be temporarily used as an alternative. Construction of the roundabout and parking lot will be commenced at the same time to minimize mobilization costs and to reduce schedule

requirements. A complete schedule with a MS Project Gantt chart and spreadsheet schedule is provided in Appendix A (Schedule). The following sections are the construction process of roundabout and parking lot.

5.2.1 Roundabout Construction Process

1. Demolition of existing road surface and remove the pieces or collection loose gravel. Soil investigation is not required.
2. Construction of the central island which includes excavation and installation of the signage during the road construction. The foundation of signage will be pre-cast offsite.
3. Installation of base materials to provide the foundation for the pitch allowing sufficient water drainage and durability of the road. Natural aggregates replaced from crushed concrete waste will be used as base materials and it will reduce consumption and costs in manufacturing virgin aggregates.
4. Grading and compacting the base with a vibratory roller for easier asphalt laying. Proper grading and compacting will prevent unlevel of the road and reduce holes and depressions.
5. Laying and compacting of asphalt.

5.2.2 Parking Lot Construction Process

1. Demolition of existing parking surface.
2. Excavate to required depth 450 mm by removing excess dirt and compact sub soil.
3. Installation of 300 mm gravel layer as free-draining material.
4. Installation of sub-drain pipes and wrap it with geotextile filter to allow the passage of water at high rates and retain in-situ soil without clogging. The drain pipes need to be connected to a manhole which leads to the existing storm system.
5. Installation and compaction of 150 mm gravel layer to be used as a bedding layer for the sub-drain pipe.
6. Laying of grid paver and implanting grass through large voids.

5.3 General Requirements

The following strategies and requirements will be used during the construction of roundabout and parking lot. A construction waste management plan will be implemented during the construction to reduce environmental impacts.

- Adequate and proper barricades, traffic signs and lights shall be required for the safety of workers and public traffic. The permission of road closure must be obtained from the appropriate authority in the Ministry and it shall be notified to the local police and fire department, ambulance, and public transit.
- Occupational health and safety program shall be given prior to construction commencement.
- Construction debris will be 50 % recycled or salvaged. Waste material will be sorted and segregated on site. The area for collection of recyclable materials will be designated at the side parts of UBC botanical Garden entrance.
- Storm water works and appurtenances shall be installed in accordance with the latest MMCD standards and specifications as per the UBC Technical Guidelines.
- An erosion and sediment control plan will be implemented to prevent contaminants and sediments penetrating into the storm system during construction, keep runoff velocity low and minimize the risk of erosion.
- If any fault, defect, or injury which adversely affect the strength, durability, or safety of work is found, proper remediation or correct will be immediately made.
- If the weather is unfavourable for any particular work, the work will be postponed by the authorization of the contractor.
- Construction will follow Vancouver's construction bylaw requirements and occur from 7:30 AM to 5 PM on weekdays.

A construction trailer will be installed at the corner of SW Marine Drive and botanical Garden entrance. All materials will be laid down and stored along the street with proper barricades to protect all materials and equipment from vandals, thieves and unauthorized access.

6 Cost Estimate

The total cost of the project is expected to be \$441,268. This includes material, equipment, and labour costs associated with the roundabout, signage, and permeable parking lot in addition to an added contingency of 10% due to construction done on campus. The cost estimate was done using two different methods: RS Means and Unit Material Cost based on industry values.

6.1 Roundabout

Cost estimation for the roundabout was done by comparing our proposed roundabout to an already constructed one in the US with similar dimensions. Their cost estimation was based on the Opinion of Probable Construction Cost (OPCC). The items included within the estimate are related to pavement demolition and reconstruction, traffic island construction, drainage inlets and pipe connections, signing and pavement markings, intersection safety lightings, and temporary barricades for traffic control during construction. The following table demonstrates the cost breakdown including all labour and material costs:

DESCRIPTION	UNIT	QUANTITY	UNIT COST	TOTAL COST
Removal of concrete pavements and curbs	SQM	3200	\$5.00	\$16,000
Trench Excavation	CM	350	\$20.00	\$7,000
Stabilized Base	SQM	70	\$10.00	\$700
Decorative Pavers	SQM	250	\$20.00	\$5,000
Concrete directional island	SQM	950	\$30.00	\$28,500
Truck Apron	SQM	250	\$50.00	\$12,500
Select fill and grass feeding	SQM	3000	\$2.00	\$6,000
Drainage inlet	EA	5	\$2,500.00	\$12,500
Convert inlet to manhole	EA	3	\$2,000.00	\$6,000
Reconstruction of concrete sidewalks	SQM	7500	\$10.00	\$75,000
Reconstruction of concrete curbs	SQM	3500	\$10.00	\$35,000
Concrete road pavement	SQM	350	\$60.00	\$21,000
Traffic signs	EA	30	\$250.00	\$7,500
Barricades and traffic handling	EA	3	\$5,000.00	\$15,000
Pavement markings	EA	1	\$15,000.00	\$15,000
Intersection safety lighting	EA	1	\$10,000.00	\$10,000
SUB-TOTAL				\$272,700
CONTIGENCIES (15%)				\$40,905
TOTAL				\$313,605

Table 3-Cost Estimate for Roundabout

6.2 Signage Footings

Cost estimation for the footing was done using RS Means data from 2007 in USA. Therefore adequate time and location indexes were needed to adjust the total cost to present worth in Vancouver. The following table indicates the value of the indexes used and the ratios that need to be multiplied to determine the overall cost.

ADJUSTMENT FOR TIME AND LOCATION		
INDEXES	VALUES	RATIOS
Time Index 2010	183.5	1.083
Time Index 2007	169.4	
Location Index Vancouver	106.6	1.066
Location Index USA	100	
Time Index 2014	202.7	1.105
Time Index 2010	183.5	

Table 4-Time and Location Indices

While using RS Means, the following assumptions were made regarding the construction of the footing:

- a bucket size of 0.57 m³
- common earth excavation
- pumped concrete
- cast-in-place

By applying the above assumptions, the total cost for the signage footing is expected to be \$70.08. A more detailed cost estimate, including all material, equipment, and labour costs of the footing, is included in Appendix B (Cost Estimate).

6.3 Permeable Pavement Parking Lot

Cost estimation for the parking lot was done using a unit material cost for each component of the design. Estimates are based on industry values and may not reflect the actual unit material cost if construction is done on campus during the summer. Items included within the estimate are the pavements (Turfstone), the layer of gravel and bedding sand beneath the pavements, and grass seedings for decorative purposes. The following table is a rough cost estimate of the permeable parking lot:

PRODUCT	UNIT PRICE	QUANTITY	TOTAL COST
Turfstone	\$3.08/ft ²	16200 ft ²	\$49,896
Gravel	\$48/cy	700 cy	\$33,600
Bedding Sand	\$36/cy	50 y	\$1,800
Grass seed	39.95/bag	1 bag	\$39.95
SUB-TOTAL			\$85,336
<i>Labour costs (assume \$35/hr)</i>			
<i>Work schedule (7 working days)</i>			
<i>Total man hours (56 hours)</i>			
TOTAL LABOUR			
COSTS			\$1,960
TOTAL DELIVERY			
COST			\$200
TOTAL			\$87,496

Table 5-Cost Estimate for Parking Lot

7 Conclusion

In conclusion, the detailed designs in this report are for the construction of a roundabout on the intersection of Marine Drive and Stadium Road, signage for said roundabout, and the refitting of the Garden parking lot with permeable flooring.

The benefits for the roundabout are increased fuel economy, intersection functionality and overall safety. It reduces the electrical demand, brings down maintenance costs, and is a sustainable development. Also, signage for the roundabout will be a very inexpensive way to direct traffic through the round-a-bout, and are essential in helping promote the UBC Botanical Garden to passer-byers.






















Fitting a permeable flooring will improve the aesthetic of the area, improve groundwater recharge, prevent erosion and flooding, as well as improve the economics of the project by preventing the necessity for water treatment infrastructure downstream.

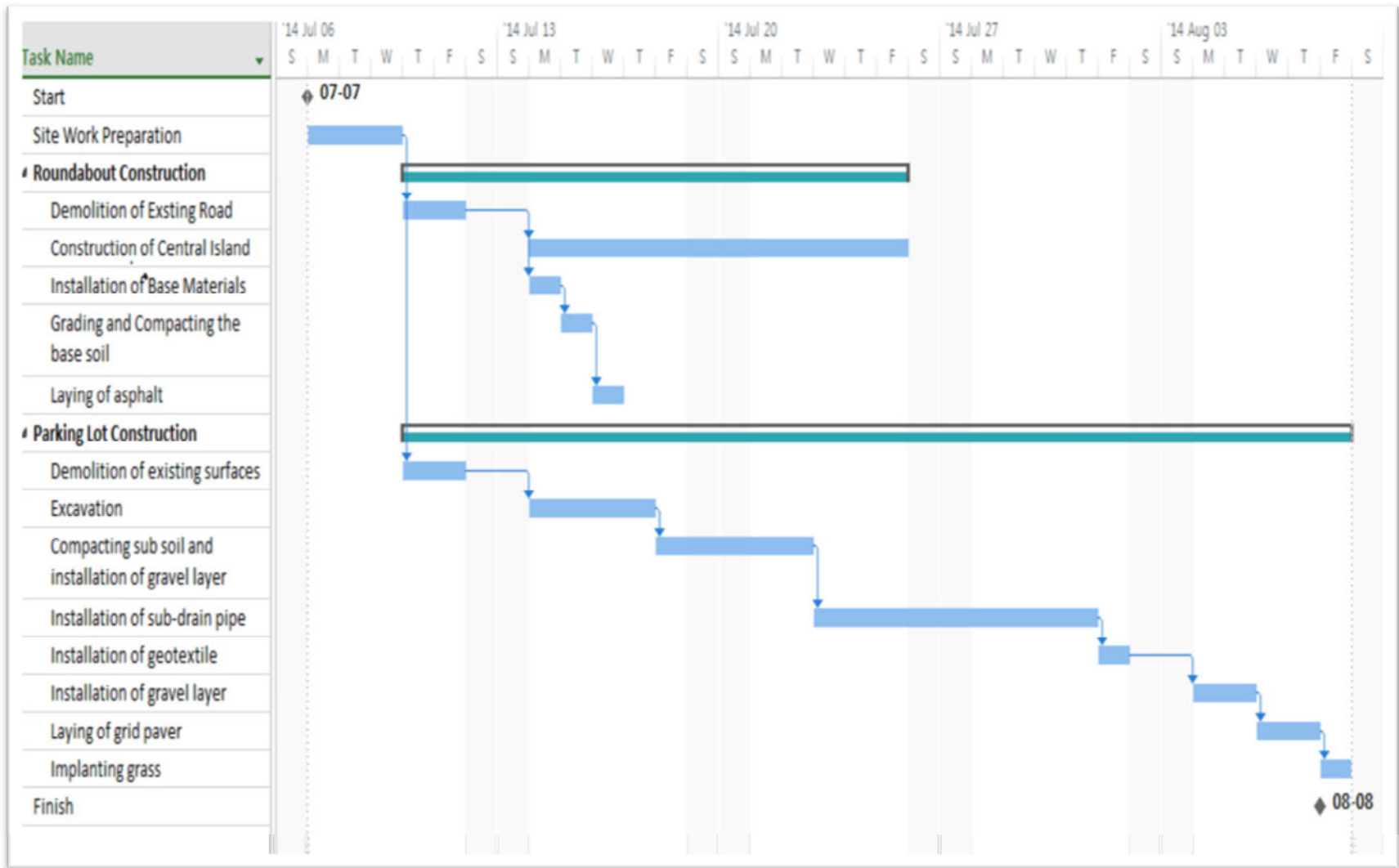
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Appendix A (Schedule)

		Task Mode ▾	Task Name ▾	Duration ▾	Start ▾	Finish ▾	Predecessors
1			Start	0 days	Mon 14-07-07	Mon 14-07-07	
2			Site Work Preparation	3 days	Mon 14-07-07	Wed 14-07-09	
3			▸ Roundabout Construction	12 days	Thu 14-07-10	Fri 14-07-25	
4			Demolition of Existing Road	2 days	Thu 14-07-10	Fri 14-07-11	2
5			Construction of Central Island	10 days	Mon 14-07-14	Fri 14-07-25	4
6			Installation of Base Materials	1 day	Mon 14-07-14	Mon 14-07-14	4
7			Grading and Compacting the base soil	1 day	Tue 14-07-15	Tue 14-07-15	6
8			Laying of asphalt	1 day	Wed 14-07-16	Wed 14-07-16	7
9			▸ Parking Lot Construction	22 days	Thu 14-07-10	Fri 14-08-08	
10			Demolition of existing surfaces	2 days	Thu 14-07-10	Fri 14-07-11	2
11			Excavation	4 days	Mon 14-07-14	Thu 14-07-17	10
12			Compacting sub soil and installation of gravel layer	3 days	Fri 14-07-18	Tue 14-07-22	11
13			Installation of sub-drain pipe	7 days	Wed 14-07-23	Thu 14-07-31	12
14			Installation of geotextile	1 day	Fri 14-08-01	Fri 14-08-01	13
15			Installation of gravel layer	2 days	Mon 14-08-04	Tue 14-08-05	14
16			Laying of grid paver	2 days	Wed 14-08-06	Thu 14-08-07	15
17			Implanting grass	1 day	Fri 14-08-08	Fri 14-08-08	16
18			Finish	0 days	Fri 14-08-08	Fri 14-08-08	



Appendix B (Cost Estimate)

Detailed Cost Estimate of Footing

Footing 1200mm x 610mm x
size: 250mm
Volume: 0.183 m³

Item #	Cost Code	ITEM DESCRIPTION	QTY	Units	Productivity (wh/m ³)	Daily Output (m ³ /day)	Duration (days)	Worker-Hours
1	31 23 16.16 6035	EXCAVATION	0.300	m ³	0.233	68.81	0.0044	0.0699
2	03 31 5.70 2450	PLACING CONCRETE	0.183	m ³	1.288	49.7	0.0037	0.2357

LABOR				MATERIAL		EQUIPMENT		TOTAL COST
Unit Labor Pricing (/hr)	Unit Crew Pricing (/day)	Total Unit Labor Cost	Total Labor Cost	Unit Cost	Total Cost	Unit Cost	Cost	
\$87.88	\$1,406.04	\$20.48	\$6.15	\$0.00	\$0.00	\$8.25	\$2.48	\$8.62
\$60.63	\$3,880.14	\$78.09	\$14.29	\$158.40	\$28.99	\$16.61	\$3.04	\$46.32

TOTAL = \$54.94

LABOR				MATERIAL		EQUIPMENT		TOTAL COST
Unit Labor Pricing (/hr)	Unit Crew Pricing (/day)	Total Unit Labor Cost	Total Labor Cost	Unit Cost	Total Cost	Unit Cost	Cost	
\$87.88	\$1,406.04	\$20.48	\$6.15	\$0.00	\$0.00	\$8.25	\$2.48	\$8.62
\$60.63	\$3,880.14	\$78.09	\$14.29	\$158.40	\$28.99	\$16.61	\$3.04	\$46.32

TOTAL = \$54.94

ADJUSTMENT FOR TIME AND LOCATION

TIME INDEX 2007-2010	1.083234947	\$59.51
LOCATION INDEX US-VAN	1.066	\$63.44
TIME INDEX 2010-2014	1.104632153	\$70.08
TOTAL COST = \$70.08		

Appendix C (Roundabout Analysis)

EAST		MADT												MADT Ratio											
Year	AADT	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985 *	3,024	2,370	2,521	2,830	2,957	3,067	3,369	3,814	3,963	3,180	2,983	2,645	2,542	0.78	0.83	0.94	0.98	1.01	1.11	1.26	1.31	1.05	0.99	0.87	0.84
1986 *	2,890	2,468	2,485	2,742	2,810	2,911	3,100	3,200	3,271	3,038	2,948	2,850	2,820	0.85	0.86	0.95	0.97	1.01	1.07	1.11	1.13	1.05	1.02	0.99	0.98
1989 *	2,860	1,613	1,650	2,290	2,374	2,976	3,363	4,192	4,469	3,582	3,229	2,269	2,177	0.56	0.58	0.80	0.83	1.04	1.18	1.47	1.56	1.25	1.13	0.79	0.76
1990 *	2,444	2,211	2,208	2,435	2,454	2,525	2,614	2,659	2,673	2,573	2,439	2,389	2,130	0.90	0.90	1.00	1.00	1.03	1.07	1.09	1.09	1.05	1.00	0.98	0.87
1993 *	3,383	2,959	3,202	3,293	3,350	3,682	3,724	3,335	3,627	3,531	3,396	3,274	3,202	0.87	0.95	0.97	0.99	1.09	1.10	0.99	1.07	1.04	1.00	0.97	0.95

WEST		MADT												MADT Ratio											
Year	AADT	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1985 *	3,001	2,811	2,884	3,052	3,030	3,081	3,156	3,195	3,174	3,080	2,926	2,772	2,838	0.94	0.96	1.02	1.01	1.03	1.05	1.06	1.06	1.03	0.98	0.92	0.95
1986 *	2,943	2,722	2,715	2,794	2,871	3,063	3,240	3,338	3,402	3,241	2,790	2,560	2,550	0.92	0.92	0.95	0.98	1.04	1.10	1.13	1.16	1.10	0.95	0.87	0.87
1989 *	3,569	3,169	3,333	3,476	3,679	3,769	3,938	3,850	3,861	3,702	3,435	3,375	3,258	0.89	0.93	0.97	1.03	1.06	1.10	1.08	1.08	1.04	0.96	0.95	0.91
1990 *	2,493	2,329	2,331	2,561	2,572	2,568	2,616	2,655	2,631	2,587	2,414	2,394	2,244	0.93	0.94	1.03	1.03	1.03	1.05	1.06	1.06	1.04	0.97	0.96	0.90
1993 *	3,658	3,361	3,651	3,693	3,630	3,756	3,892	3,804	3,856	3,753	3,658	3,455	3,387	0.92	1.00	1.01	0.99	1.03	1.06	1.04	1.05	1.03	1.00	0.94	0.93

Year	East				West				Total			
	AADT	n difference	volume difference	Growth per annum	AADT	n difference	volume difference	Growth per annum	AADT	n difference	volume difference	Growth per annum
1985	3024	1	-134	-4.43%	3001	1	-58	-1.9%	6025	1	-192	-3.2%
1986	2890	3	-30	-0.3%	2943	3	626	6.6%	5833	3	596	3.3%
1989	2860	1	-416	-14.5%	3569	1	-1076	-30.1%	6429	1	-1492	-23.2%
1990	2444	3	939	11.4%	2493	3	1165	13.6%	4937	3	2104	12.6%
1993	3383				3658				7041			
			Avg. Growth	3.58%			Avg Growth	7.18%			Avg Growth	5.45%

Thus, predicted growth

Year	AADT
2014	10317
2024	17544
2034	29834