UBC Garden Reimagined

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UBC Botanical Garden Reimagined

A student proposal to build a multipurpose building and overflow parking at the University of British Columbia Botanical Garden and Centre for Plant Research.

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Executive Summary

The proposed multipurpose building will serve as an anchor for the University of British Columbia Botanical Garden (henceforth "UBCBG" or "the Garden") to attract more visitors by introducing recreational and dining services which will target a broader demographic. It will contain a restaurant, a yoga studio, exhibit room, office space, and a café.

In order to accommodate these services, the design team determined that the detailed design will focus on three main components of the project:

- structural framework for the multipurpose building
- rain-water filtration and disinfection system for potable use
- narrowing of SW Marine Drive to provide overflow parking

These components will also serve to reflect the values of sustainability, a concept embedded in the visions of UBC and UBCBG for greener buildings and infrastructure. The disciplines of civil engineering incorporated into the respective components are structural engineering, water resources engineering, and transportation engineering.

Preliminary structural analysis was performed to determine that a steel frame building, using recycled material, will be the ideal system. A detailed design of a typical column and connection was also completed to demonstrate methodology in the structural design that can be replicated for the rest of the building. A floor plan has also been prepared to show the layout of the building.

The rainwater conveyance system for potable use was designed to make the building water self-sufficient. Inspiration for this type of system came from the CIRS (Centre for Interactive Research on Sustainability) Building. The system consists of the following:

- 1200 m^2 roof to collect rainwater
- downspout to convey water
- cistern
- slow sand filter
- UV and Chlorine treatment
- treated water tank

Since the building only uses harvested rainwater, the cistern was designed to store enough water to supply the typical 3-month dry season experienced in Vancouver. Water use was also reduced by 30% in the restaurant to adhere to LEED standards.

In order to increase available parking, the cross section of SW Marine Drive will be narrowed to one lane in each direction, with bike lanes and parking lanes on both sides. The speed will be reduced from 80 km/h to 40 km/h. This option provides the parking that the Garden needs, a safe crossing at Stadium Road, and greater opportunity for travellers to see the facility due to the lower speeds.

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1.0 Introduction

As requested by the University of British Columbia Botanical Gardens (henceforth "UBCBG" or "the Garden"), the design team has prepared a design report covering the design of the major components of the proposed multipurpose building for the Garden's revitalization project. With unsteady visitorship throughout the year, the UBCBG is struggling to generate the revenue to operate and improve existing facilities. This lack of visitorship can be attributed to the tendency of the current features of the garden to only attract a narrow demographic. In addition, a shortage of indoor space to attract visitors during the winter season is also having an adverse effect on visitor attendance for special events. Parking and accessibility of the garden were other key issues that needed to be addressed in this revitalization project. Also of importance in this project is that the building meets LEED Gold standards, a requirement for all new institutional buildings on campus.

1.1 Purpose and Scope

The purpose of this report is to discuss the design of a multipurpose building and overflow parking for the improvement of the UBCBG. The concepts are built around three major focus areas: Increasing visitation to the Garden, improving the sustainability of the Garden, and improving access to the Garden. Furthermore, three main engineering disciplines have been used to achieve these goals: structural, environmental and transportation. Within the structural component, a building framework has been designed, including a detailed design of a typical column and a connection. A rainwater collection system has been designed to increase the Garden's sustainability using environmentally friendly engineering. Transportation demand measures have been discussed to promote sustainable mode use. The design also focuses on improving access to the Garden and increasing available parking for major events held there.

1.2 Background

The UBCBG is one of the oldest in North America with nearly 100 years of history. The 78 acre garden has been continuously committed to its education, research and preservation projects which has led to a facility that is in high regard at an international level. The intent of the design team is to meet the goals and mission of the Garden while increasing revenue, sustainability, and visitorship; the mission is as follows:

> *The mission of the Garden is to assemble, curate and maintain a documented collection of temperate plants for the purposes of research, conservation, education, community outreach and public display.*

The unique combination of research and public enjoyment is one that at times can be one-sided, as it is hard for botanical gardens to stay relevant to the public and maintain a steady visitorship. The design team has been approached by the Garden to design new facilities focusing on the Garden's mandate to remain sustainable, while raising public opinion and interest in the garden itself. The proposed multipurpose building in this report will try to balance education and research with interesting and useful attributes to increase visitorship of the general public, UBC students, horticulturalists and researchers.

2.0 Description of Building

The main goal of this project is to increase revenue and reduce financial stress currently being experienced by UBCBG. To achieve these goals, a number of service and attraction oriented facilities should be included in the building. The design team envisions the multipurpose building including the following attractions:

- **Restaurant**, which would bring people from Vancouver out to the gardens on evenings and weekends. Views of the garden for customers would be maximized.
- **Café**, which would be open to visitors in the garden and to the public.
- **Fitness Room/Yoga Studio,** to attract student and local membership.
- **Exhibit/Lecture Room**, where visitors to the garden could learn interactively about the various plant species cultivated at the garden.

Other areas that would be included in the building are the aesthetically pleasing atrium, a kitchen, office space, a mechanical/electrical room, washrooms, and a stairwell/elevator area.

2.1 Building Location

The optimal location of the building was determined to be in the unused grassy area on the East corner of the Stadium Road – SW Marine Drive (see Figure 1). This location has sufficient space to allow for a building large enough to contain our desired facilities without disrupting the current garden limits.

Figure 1. Location and footprint of multipurpose building

2.2 Building Architecture

Glass is an important design element in the architecture of the building. Visitors are treated with views of the north garden from as many vantages as possible. The overall architectural feel of the building was kept conservative to control costs, while still focusing on meshing with the garden surroundings as much as possible so as not to detract from visitors' experience. Some noteworthy architectural aspects include a hexagonal dome at the entrance to the atrium and the propped restaurant and fitness room areas on the second floor. The overhang will also allow for miniature gardens and pathways to be planted in the atrium space.

2.3 Building Rendering and Layout

A 3D rendering of the building was created using Trimble Sketchup, as shown in Figure 2.

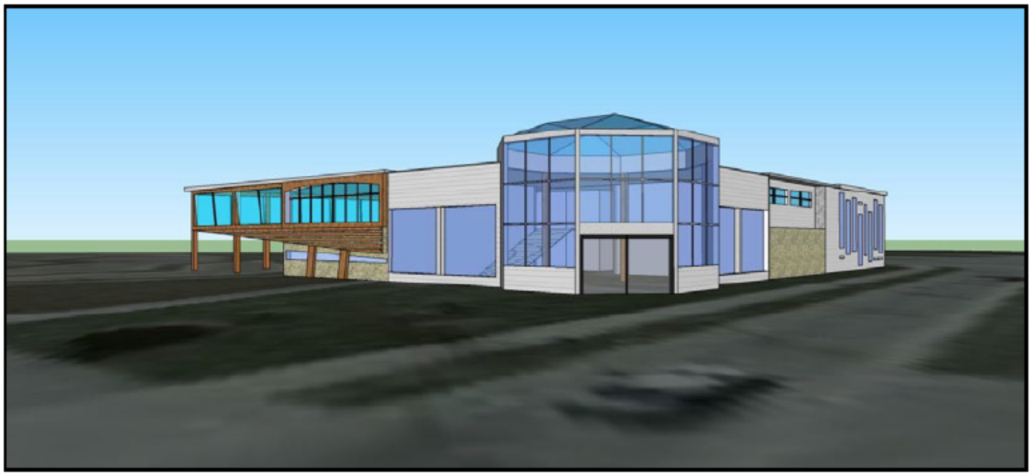


Figure 2. Multipurpose building architectural rendering.

A plan view of the building layout, including partition walls and room designations, was also created, as shown in Figure 3.

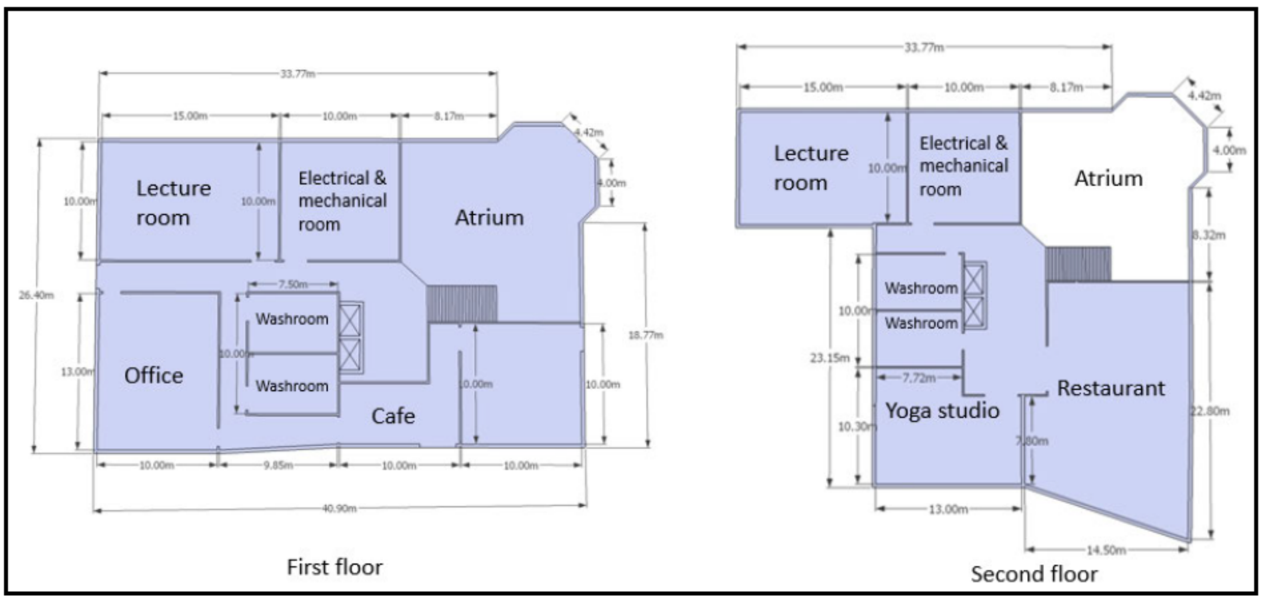


Figure 3. Floor plans of the multipurpose building.

3.0 Structural

Preliminary and detailed designs of the structural system of the multipurpose building were carried out by the design team. The preliminary design includes selection of the structural system and approximate beam and column layout. The detailed design is the sizing of a column and a connection. It is representative of how the full detailed design would be carried out. The design was based on the codes and standards that can be found in Section 7.0 Works Cited.

3.1 Development of Structural System

Several conceptual structural systems for the multipurpose building were considered during development of this detailed design. In order to determine the best possible option, a list of criteria for the project was established, with the criteria being ranked in terms of importance as perceived by the design team. The criteria, in order from most to least important, is shown here:

- **Cost**: The purpose of this project is to increase revenue and make the garden more self-sufficient financially. Therefore costs should be limited wherever possible.
- **External Aesthetics**: The building should not detract from the overall appearance of the gardens and should mesh with its surroundings as much as possible.
- **Speed of Construction**: Visitor experience of the garden will be lessened during construction, so construction should take as little time as possible and occur in the winter. Fast construction will also allow revenue to begin being generated earlier.
- **Internal Aesthetics and Glazing**: The building should be kept comfortable and spacious. Unobstructed views of the garden should be provided wherever possible, particularly on the side of the building overlooking the North Garden.

Based on these criteria it was decided that the multipurpose building would be designed as a basic steel frame structure with steel deck floors. This was chosen because steel frame buildings are economical and relatively quick to construct, while still being conducive to the unique geometry of the building. Steel framing can also be combined with glazing to make attractive architectural features, such as the one used in the atrium of the multipurpose building.

It was also decided to leave the structural system exposed and use glulam beams running diagonally across the long spans in the atrium. This was chosen for architectural purposes and to give visitors a natural feel when entering the building.

3.2 Description of Structural System

The multipurpose building is a steel frame structure consisting of the following components:

- Wide-flange steel beams and girders
- Square HSS steel columns and lateral bracing
- 38mm steel deck floors with 100mm reinforced concrete slabs overlaid (used for both second floor and roof; the ground floor is a reinforced concrete slab on grade)
- Glulam beams (atrium only)

3.3 Preliminary Layout

The preliminary layout of the columns and beams is based on a preliminary loading due to gravity loads only. A SAP2000 model of the structure was created to determine member forces due to the gravity loads. Various beam and column layouts were experimented with to determine the optimal solution.

Braced frames were included in the preliminary layout based on experience of typical steel frame building design; however, the braced frame layout is subject to change as a full analysis of the structure due to lateral loads (wind and earthquake) was not performed.

3.3.1 Gravity Loads

The gravity loads consist of both the self-weight of the building (i.e. dead load, D), the occupancy/use (i.e. live load, L), and the snow load, S. The applicable ultimate limit states (ULS) load combinations can be taken from the National Building Code of Canada 2010 (NBCC) as:

1) 1.4**D**
2) 1.25**D** + 1.5**L** + 0.5**S**
3) 1.25**D** + 1.5**S** + 0.5**L**

The applicable serviceability limit states (SLS) load combination is:

1.0**D** + 1.0**L**

As per Canam, the unfactored dead load of 38mm steel deck (1.21mm gauge) with 100mm concrete topping can be taken as 1.89kPa. The dead load of the beams and columns are automatically calculated by the SAP2000 software. NBCC states that the dead load of the partition walls can be estimated as 1.0kPa when unknown. As the weight of the building façade is also unknown at this point, the 1.0kPa partition load was also applied at the external walls. Based on the Canadian Wood Council Wood Design Manual 2010, the dead load of ceiling fixtures can be estimated as 1.0kPa for preliminary analysis.

NBCC live load requirements for multipurpose areas require a minimum specified live load of 4.8kPa.

The specified snow load was calculated to be 1.82kPa using the equation:

$$\mathbf{S} = I_S[S_S(C_bC_wC_sC_a) + S_r]$$

The worst case area load on any floor is therefore:

Maximum factored gravity load = 1.25**D** + 1.5**L** = 1.25*2.89 + 1.5*4.8 = 10.8kPa

All gravity loads and load cases were input into the SAP2000 model for use in analysis.

3.3.2 Layout Design

The preliminary structural layout drawings can be found at the end of Section 3.

A basic beam-girder-column system was used wherever possible as it was important to keep the structural layout as simple as possible while still accommodating the unique geometry of the building.

The maximum beam spacing was determined from Canam steel deck tables to be 2500mm for a factored load of 12.9kPa, which is greater than the maximum factored load in the multipurpose building. The beam and girder layout was also designed to allow the deck flutes to run in the same direction in all areas of the building, easing construction.

Girder depths were kept manageable by designing the layout so that spans were short enough to allow W530 or shallower girders to support the required loads. From the Canadian Handbook of Steel Construction (HSC) 10th edition beam tables, the lightest W530 beam (W530x66) has a moment resistance of M_r = 484kNm when the compression flange is laterally supported. Results from the SAP2000 model showed that the worst-case girders could span 7500mm with a maximum factored bending moment of 397kNm. The columns were therefore spaced at not more than 7500mm to allow for possible increases in loading during detailed design.

As per NBCC requirements, the girder spans were also checked for serviceability to meet a maximum deflection of L/240; it was found that L/240 is 31.3mm and the maximum girder deflection is 27.6mm.

The SAP2000 results were checked by calculating the factored load and maximum deflection on the worst-case girder based on tributary widths. They were found to be within 20% of the SAP2000 results in all cases.

A similar procedure was used in the design of the smaller beams supporting the deck and spanning between the girders, resulting in required beam sizes of W360 for the required 7500mm spans.

This analysis was repeated on the roof level with the lower gravity loads (maximum snow load was significantly less than the building live load). This resulted in roof girder sizing of W460 and roof beam sizing of W310.

The preliminary sizing of the HSS columns was done using the factored axial compressive resistance tables in the HSC 10th edition. Results from the SAP2000 model showed a maximum axial compression in the worst-case column of 772kN. The columns were considered to be laterally supported in both directions at the foundation, floor and roof. This is an accurate assumption as all columns had beams framing in from two directions at both the floor and roof. The effective column length was therefore taken as the storey height of 12ft (3.65m). As per the HSC column tables, an HSS152x152x9.5 tube has a factored compressive resistance of 1050kN with an effective length of 12ft (3650mm). This column size was chosen for use to allow for possible increases in loading during detailed design. A HSS152x152 with a smaller wall thickness would be used for the second floor columns supporting the roof. The SAP2000 results were again checked using the tributary area of the worst-case column.

The final spacing of the glulam beams spanning the atrium will be determined in the detailed design. Based on typical span-to-depth ratios for glulam beams, the beams will likely have a depth in the range of 700-1000mm.

3.4 Detailed Design of Component

One component of the structural system was chosen to be subject to detailed design. The methods of analysis used in the detailed design of this component are representative of the methods that could be used for the detailed design of the entire structure.

The component chosen for detailed design was a steel HSS column. A sample pin-ended beam-column connection is also included in the detailed design. This component was chosen because it involves both member and connection design and is a standard component that is replicated many times throughout the structure.

Note that while the calculations of the resistance of the member are accurate, the loading calculations are only approximate as they are based on gravity-only load cases rather than a complete structural analysis as specified in NBCC 2010.

Compression members generally fail in two kinds of buckling: local buckling and overall buckling. Therefore, the detailed design will be based on the local section requirement (ref. Clause 11.2) and overall member strength requirement (ref. Clause 13.3.1). The known parameters are:

Table 1. HSS Member Properties.

Member Parameters	
Factored axial load (C_f)	772 kN
Member length (L)	3650 mm
Yield strength (F_y)	300 MPa
Elastic Modulus of steel (E)	200000 MPa

Based on the preliminary design, an HSS 152×152×9.5 member is selected first for detailed analysis. Section properties taken from HSC 6-102:

Table 2. Section Properties.

HSS 152×152×9.5	
Area (A)	5210 mm^2
Wall thickness (t)	9.53 mm
Depth (d)	152 mm
Radius of Gyration (r)	57.6 mm

3.4.1 Column Calculations

Width-to-thickness ratio ($\frac{b_{el}}{t}$) = $\frac{d-(4\times t)}{t} = \frac{152-(4\times 9.53)}{9.53} = 11.95$ (Cl 11.3.2(b))

Since $\frac{b_{el}}{t} = 11.95 < \frac{670}{\sqrt{F_y}} = 35.8$, the requirement for local buckling is met. (Cl 11.2)

According to the Clause 10.4.2.1, the slenderness ratio of a member in compression shall not exceed 200. The slenderness of the column = $\frac{KL}{r} = \frac{1.0\times 3650}{57.6} = 63.4 < 200$, the requirement is satisfied.

Factored axial compressive resistance (Cr) = $\emptyset A F_y (1 + \lambda^{2.68})^{-1/1.34}$

$$\lambda = \left(\frac{KL}{r}\right)\sqrt{\frac{F_y}{\pi^2 E}} = \left(\frac{1\times 3650}{57.6}\right)\sqrt{\frac{300}{\pi^2 200000}} = 0.781$$

$$C_r = 0.9 \times 5210 \times 300 \times (1 + 0.781^{2.68})^{-1/1.34} = 1030\ kN$$

Since $C_r = 1030\ kN > C_f = 772\ kN$, the factored axial compressive resistance is greater than the factored axial load, the requirement for overall buckling is met (Cl 13.3.1).

In conclusion, the HSS 152×152×9.5 column satisfies the design requirement and has a design efficiency of 75%. This is acceptable in the preliminary stage as it allows for possible load increases that may be determined during the detailed design.

3.4.2 Shear Tab Connection Calculations

A shear tab beam-column connection is a simple and economical connection where a single plate is welded vertically onto the column with the beam bolted to the plate. Since the maximum factored shear load through the connection is 202kN, four bolts with 310mm long plate was chosen to be the trial design according to HSC Table 3-41. The data is summarized below:

Table 3. Summary of connection parameters.

Item	Specification
Supporting member	HSS 152×152×9.5 column
Supported member	W530 Girder
Connection type	Shear tab connection
Factored shear load (kN)	202
Number of bolts n	4
Type of bolts	M20 A325M bolts
Connection plate length (mm)	310
Estimated resistance (kN)	294
Plate thickness (mm)	8
Weld size D (mm)	6

<u>Bolt & Bearing Resistance:</u>

$Br = 3\emptyset_{br} ntdF_u = 3 * 0.8 * 4 * 8\ mm * 20\ mm * 450\ MPa = 691\ kN$ (Cl 13.12.1.2a)

$Vr = 0.7 \times 0.6\emptyset_{br} nmA_b F_u = 0.7 \times 0.6 \times 0.8 \times 4 \times 1 \times 314\ mm^2 \times 830\ MPa = 350\ kN$ (Cl 13.12.1.2c)

Plate Shear Resistance:

$$Tr = \emptyset_u \left[U_t A_n F_u + 0.6 A_{gv} \frac{F_y + F_u}{2}\right]$$

1) $A_n = (110\,mm - 75\,mm - 20\,mm/2) \times 8\,mm = 200\,mm^2$

$A_{gv} = (310\,mm - 35\,mm) \times 8\,mm = 2200\,mm^2$

$Tr = 0.75 \times \left[1.0 \times 200 \times 450 + 0.6 \times 2200 \times \frac{350+450}{2}\right] = 464\,kN$

2) $A_n = 0\,mm^2$

$A_{gv} = 310\,mm \times 8\,mm = 2480\,mm^2$

$Tr = 0.75 \times 0.6 \times 2480 \times \frac{350+450}{2} = 446\,kN$

3) $A_n = 20\,mm^2$

$A_{gv} = (310\,mm - 35\,mm) \times 2 \times 8\,mm = 4400\,mm^2$

$Tr = 0.75 \times \left[1.0 \times 20 \times 450 + 0.6 \times 4400 \times \frac{350+450}{2}\right] = 799\,kN$

Fillet Weld Resistance:

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

$= 0.67 \times 0.67 \times (0.707 \times 6\,mm) \times 490\,MPa \times (1.00) \times 0.85$

$= 0.793\,kN/mm$

$\theta = 0^o$ (axis of weld segment is in the line of action of applied force)

$$M_w = \frac{0.85 + \theta_1/600}{0.85 + \theta_2/600} = \frac{0.85 + 0/600}{0.85 + 90/600} = 0.85$$

$Vr = 2 \times 0.793\,kN/mm \times 310\,mm = 492\,kN$

$Vr = 0.67\emptyset_w A_m F_u = 0.67 \times 0.67 \times (620\,mm \times 6\,mm) \times 450\,MPa = 751\,kN$

In conclusion, this connection design is adequate for 202kN factored shear load. In addition, since the resistance for bolt shear has the lowest value of 350kN, the bolt shear resistance is the governing factor in this connection. A diagram of this connection is presented in Figure 4.

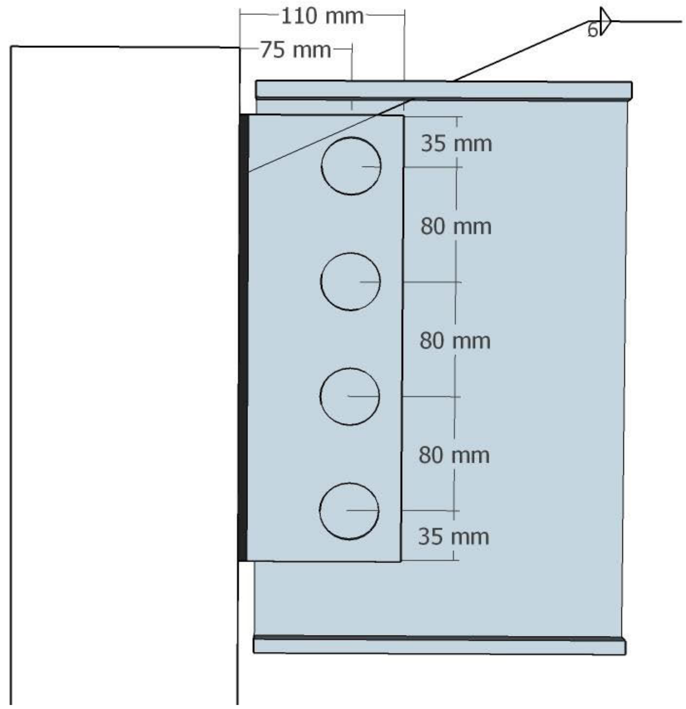
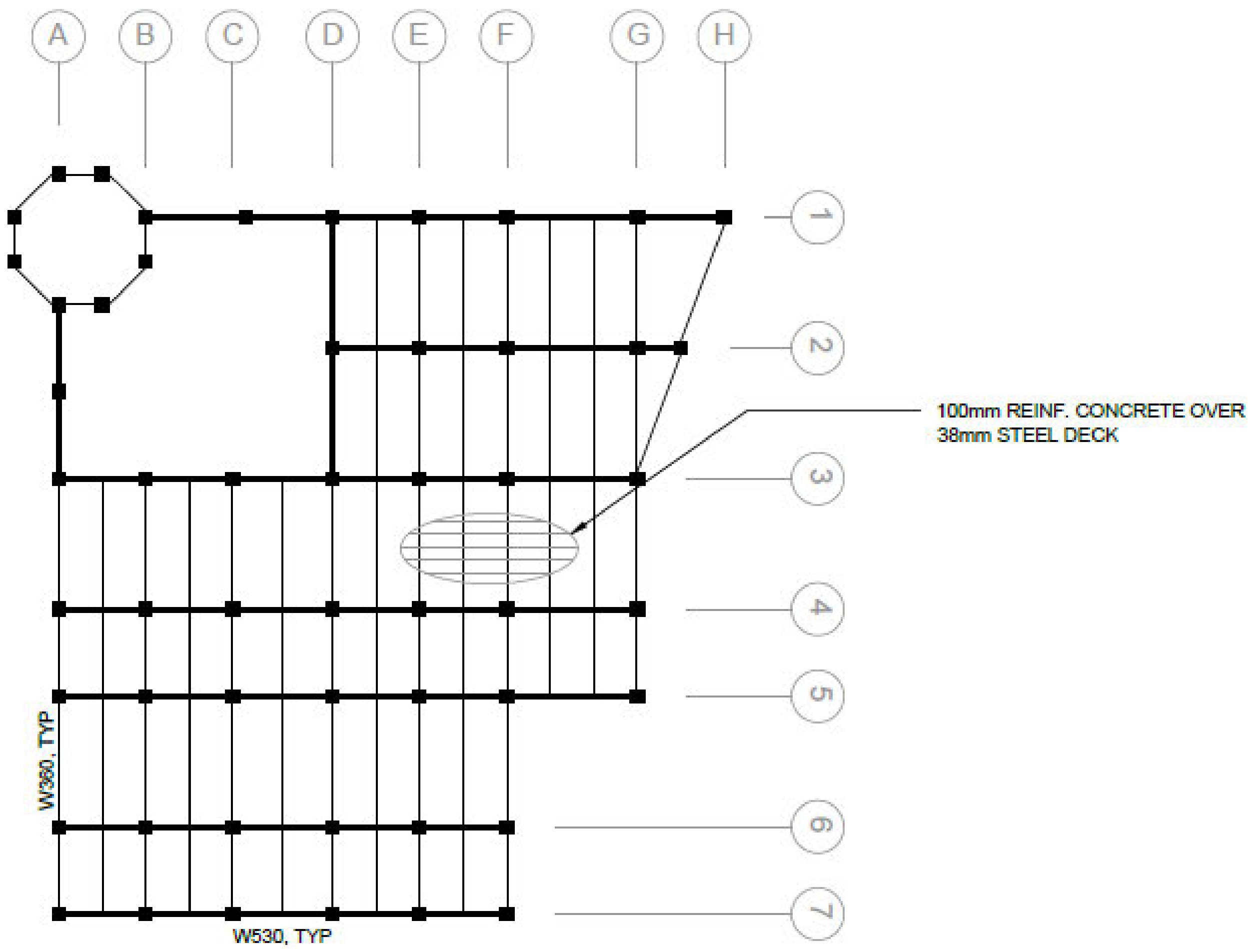
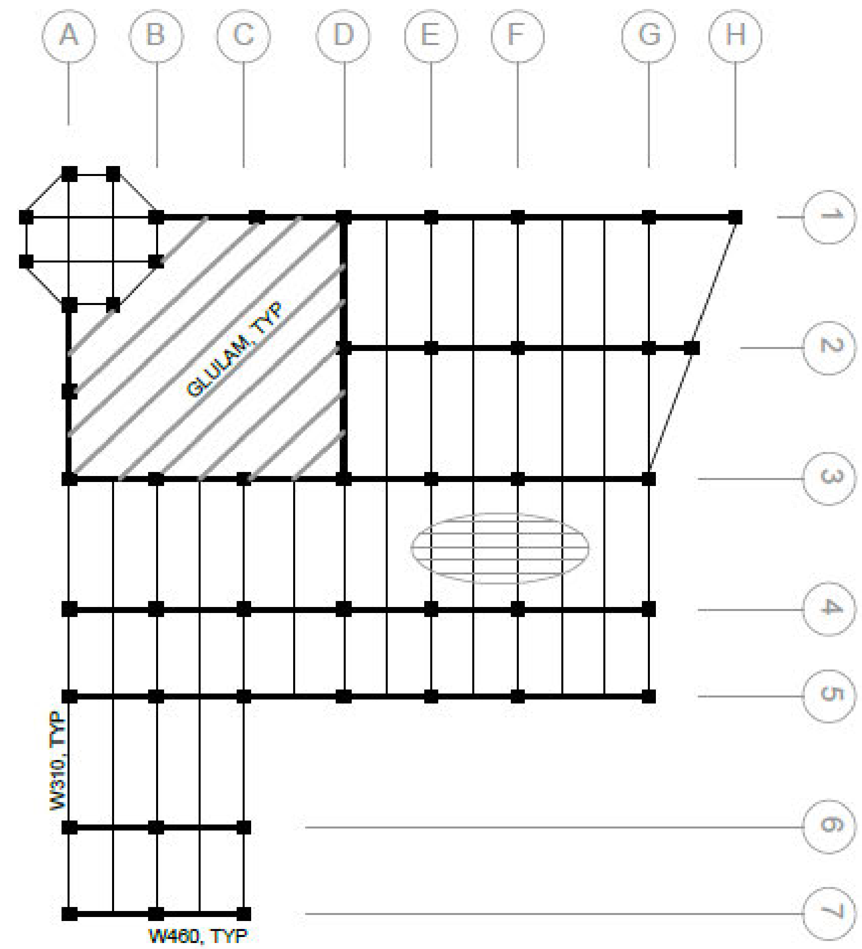


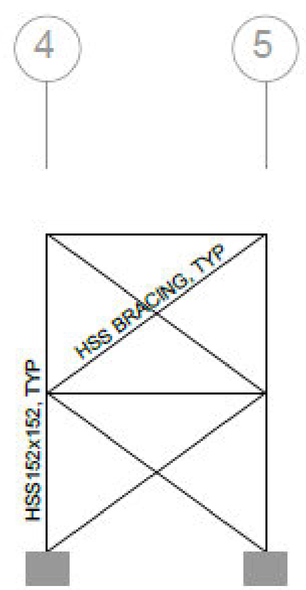
Figure 4. Shear tab connection diagram



2nd FLOOR PLAN VIEW
Scale 1:400



ROOF PLAN VIEW
Scale 1:400



ELEVATION VIEW (BRACED FRAME)
Scale 1:160

Revision	Date
0	2014 March 20

UBC Botanical Garden Multipurpose Building

Structural Layout | Sheet 1

Drawn	KM
Designed	KM
Checked	MJ

4.0 Rainwater Collection System for Potable Use

UBC as a whole seeks to reduce its environmental impact by minimizing potable water use, increasing water re-use and minimizing wastewater conveyance off-site. Upgrading the Garden's facilities to completely isolate the property from Vancouver's potable water system will reduce the Garden's environmental impact and economic impact on the university's budget. The UBC Water Action Plan delineates five focal priorities: rainwater harvesting, reduced water use, efficient landscape irrigation, reduced wastewater generation and water use management in building operations. The proposed rainwater collection system meets almost all of these criteria and is thereby a worthy addition to any building on the UBC campus.

The design of the rainwater collection system for the multipurpose building began with the intent to allow the new visitor center to be completely water self-sufficient. Through a simple system, rainwater will be harvested from the roof and stored in a cistern within the building. An emergency connection to the municipal distribution system will be necessary in the case of extreme drought and to supply the fire suppression system. Vancouver has a large amount of annual rainfall but there is a three month dry season that is of concern for a building that uses only rainwater for its potable consumption. A cistern with the capacity to hold enough water to supply a three month demand cycle in the dry season has been sized based on a daily water demand of the building. A representative water systems schematic is shown in Figure 5.

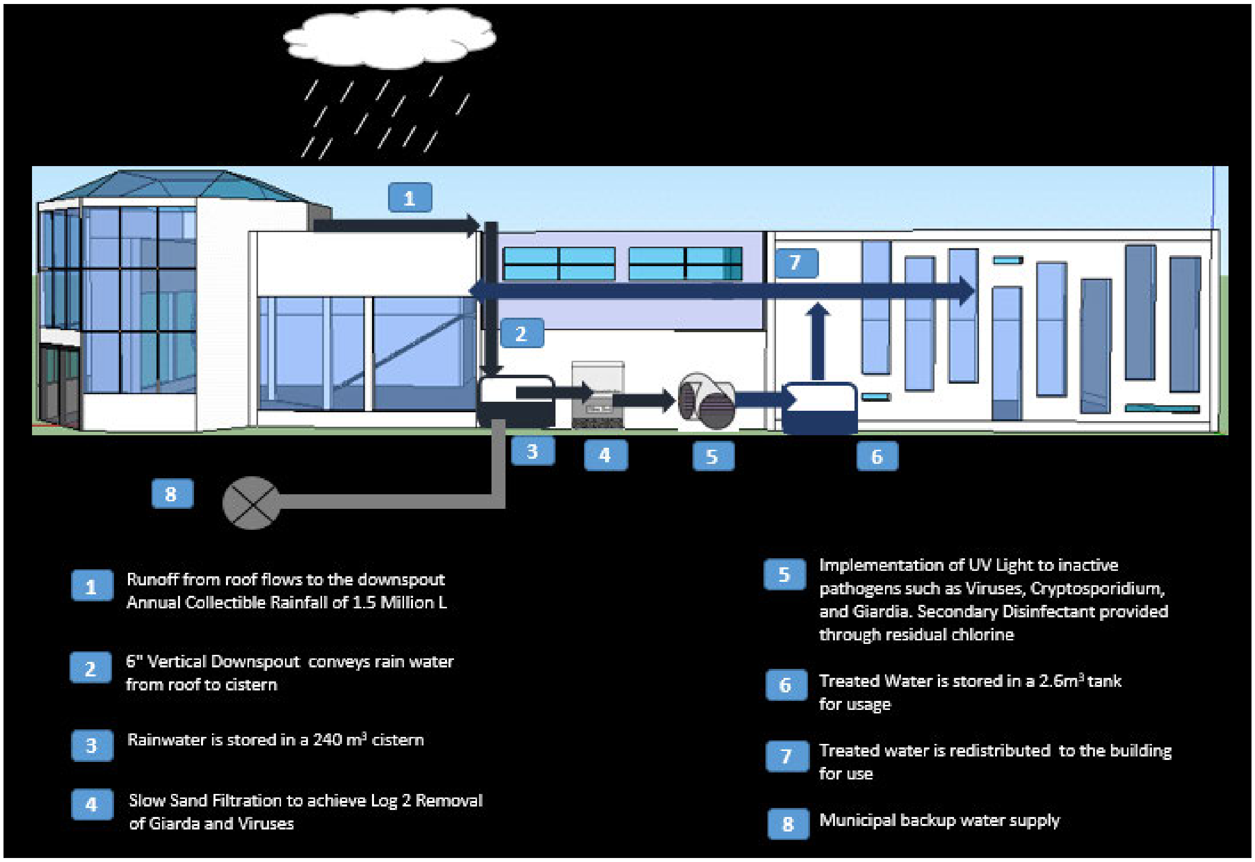


Figure 5 Water Systems Schematic

4.1 Determination of Water Demand

The water demand was derived from scaling down the water use of the Centre for Interactive Research on Sustainability (CIRS) Building for the gross floor area of the new building (Sustainability, 2014). This was deemed acceptable as the building should be built to high standards of water use efficiency in order to be self-sufficient, similar to CIRS. CIRS is 5675 m^2 while the proposed building has 1700 m^2 this leads the scaling to be approximately 500 L/day. It is also necessary to increase this value with the demand of the restaurant. To develop demand of a restaurant a usage value of 30 L/seat is typical among standard restaurants but as this building will be meeting LEED Gold standards for water use this number was reduced by 30% to 21 L/seat. With 100 seats in the restaurant this leads to a demand of 2100 L/day. Total water demand for the proposed building can be assumed to be 2600 L/day. This usage rate can easily be supplied by Vancouver's annual rainfall. The yearly amount of collectible water was determined to be approximately 1.5 million litres. The volume was obtained by multiplying the roof area by the average annual rainfall expected at UBC. An annual rainfall of 1226 mm, based on data acquired from CIRS, was used in determining the volume of collectible water. (Centre for Integrated Research of Sustainability, 2013)

4.2 Tank Sizing

The storage tank was sized based on the total demand of 2600L/day and a 3 month storage cycle. The total storage volume required for this period was determined to be approximately 235 m^3. In order to meet the dimensional constraints of the mechanical room, the width and length of the tank will be 8 x 10 m. The height of the tank will be 3 m to accommodate the inflow of water with a total storage tank volume of 240 m^3.

4.3 Downspout Sizing

The vertical downspout size was determined using a Short Duration Rainfall Intensity-Duration-Frequency (IDF) curve developed by Environment Canada. The 100 year rainfall intensity was used to determine an appropriate downspout diameter. The time of concentration on the rooftop was calculated using the Kinematic Wave Equation for Overland Sheet Flow (Ohio DOT, 2005):

$$\mathrm{T}_c = \frac{\mathrm{K}}{\mathrm{i}^{0.4}} * \left(\frac{nL}{s}\right)^{0.6}$$

Where K is an empirical constant equal to 6.92 for metric units, i is the rainfall intensity, n is the manning coefficient, L is the length of flow and s is the gradient of the roof. The length of flow was determined to be 50m from the furthermost point to the intake of the downspout and the rooftop gradient is 2%. The manning coefficient is 0.014 for impervious rooftop surfaces. The time of concentration and 100 year rainfall intensity was determined to be 2.92 min and 95mm/hr based on reiteration and the IDF curve below.

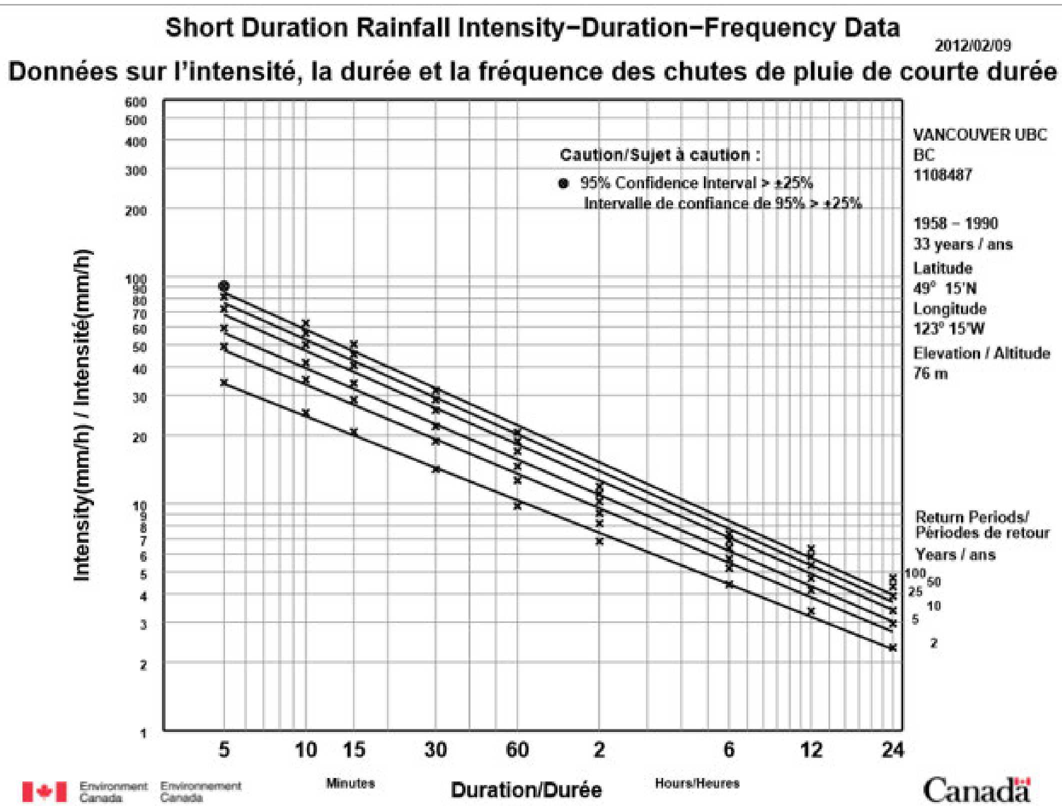


Figure 6. Intensity-Duration-Frequency Data from Environment Canada. (Canada, 2014)

Standard vertical downspout sizes were used to determine a pipe size that could withstand a rainfall intensity of 100 mm/hr. It was found that a 6 inch pipe for the building's 1200 m^2 roof will be sufficient to withstand the 100 year rainfall intensity of 95 mm/hr.

4.4 Filtration and Disinfection

The rainwater will also need to be prepared for potable use and meet all health standards. The standard for drinking water includes a 4 log removal of viruses and 3 log removal of bacteria such as Cryptosporidium and Giardia. This will be accomplished using filtration, disinfection and pH adjustment (Crittenden).

A slow sand filter will be used for removal of large particles and some pathogens and an activated carbon filter will remove metals and organics from atmospheric contaminants. Slow sand filters provide 2 log removal of both Giardia and viruses but no removal of Cryptosporidium. Because this type of filtration system requires little or no mechanical power or replaceable parts and minimal maintenance, it is very cost effective and sustainable in practice. To size a slow sand filter for use in this filtration system, a surface loading rate (SLR) of 0.04 m/hr has been taken with a flow rate (Q) of 0.217 m^3/hr to determine a required area of 5.425 m^2. This calculation leads to a sand filter size of 2.35 m by 2.35 m with a depth of 1m. These numbers are calculated using the following equation:

$$Q = SLR * A$$

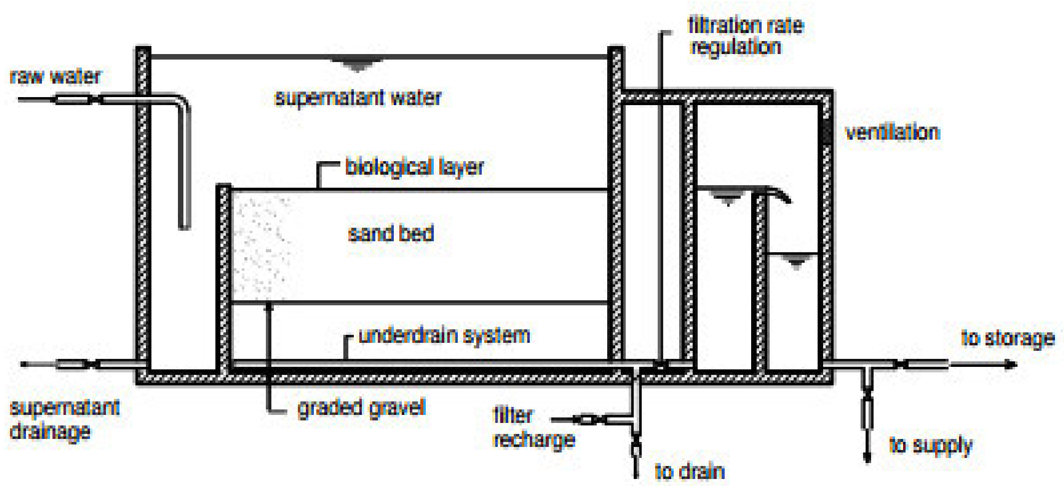


Figure 7. Diagram of a slow sand filter (Ludwig, 2014).

Beyond filtration, the water will need to be disinfected using UV light to kill or inactivate Cryptosporidium. A dose of 12 mJ/cm^2 is required to provide 3 log removal of Cryptosporidium, this dose also far exceeds the dose of 2.1 mJ/cm^2 required to provide the further 1 log removal necessary for Giardia contamination. With these filtration and disinfection systems in place, 3 log removal of both Giardia and Cryptosporidium have been provided as required by the health authority. In order to meet 4 log removal standards for viruses, secondary disinfectant in the form of chlorine will be added to the treated water storage tank. This tank has a design retention time of 12 hours or 720 minutes. 4 log removal of viruses using chlorine has a required Ct of 746 (mg/L * min) for water being stored at 20 degrees Celsius. This leads to a chlorine concentration of 1.04 mg/L in the treated water storage tank. Baffling should be introduced to the treated water tank to ensure average contact time is proportional to the design retention time. The acidity of typical rainfall in the Vancouver area has a pH of approximately 4, while health standards require the pH for drinking water to be between 6 and 9. To make the treated water more basic and more palatable, sodium bicarbonate needs to be added.

Figure 8. Typical UV disinfection system.

4.5 Water System Cost

The downspout was designed to be a 6” PVC vertical pipe, with bell and spigot connections leading into the cistern. This pipe size is priced at approximately $35 per 3m standard length. The slow sand filter cost was approximated using the volume of sand required to construct the slow sand filter. The density of sand is approximately 1400 kg/m^3. The unit cost of sand is $30/ton, providing a cost of $231 for the slow sand filter. The UV disinfection can be provided by a single UV Dynamics 13 GPM MR400ETP2-220 w/2 x 20" Big Blue Filter which has a unit cost of $872.74. Finally a treated water storage tank will cost $501.95 for a 700 gallon (or 2640 litre) vertical plastic storage tank. This tank is HDPE and is translucent to allow for manual water level readings. The total combined cost is therefore $1710.69 for the rainwater collection and treatment system.

Table 4. Cost Estimate for Water System

Item	Description	Source	Cost
Downspout	PVC piping	Home Depot (Depot, 2014)	$105
Slow Sand Filter	7.7 tons of Sand	Youngs Sand And Gravel (Gravel, 2014)	$231
UV Disinfection	13 GPM UV Disinfector	Van Isle Water (Water, 2014)	$872.74
Treated Water Tank	700 Gallon Tank 64” dia x 60”H	Plastic-Mart (Plastic-Mart, 2014)	$501.95
Total	-	-	$1,710.69

5.0 Transportation

This section discusses the detailed design of the transportation component of the project.

5.1 Introduction

Investigation into traffic demands and overflow parking have been part of the design team's proposal for the multipurpose building. Current regulations at UBC prevent the construction of new parking lots as per the 2005 Strategic Transportation Plan. Due to this policy, construction of a parking lot on current green space to manage overflow volumes is not a politically feasible option; however, other parking options have been considered, such as on-street parking and a multipurpose outdoor space.

Currently, Southwest Marine Drive is designated as a highway. It is signed as 80 km/h until Stadium Road, followed by a warning sign and a speed reduction to 40 km/h. Shortly after this, there is a four-way stop. Additionally, there is a crosswalk across the 80 km/hr stretch. This is a dangerous situation for both cyclists and motorists since neither party expects the other in this unconventional set up.

Figure 9. Photo of SW Marine Drive Crosswalk at Stadium Road

5.1.1 Literature Review

The UBC Technical Guidelines and the 2005 Strategic Transportation Plan are the primary sources of guidance governing design for roadways and land use on campus. SW Marine Drive is currently under provincial jurisdiction; therefore the BC Ministry of Transportation Supplement to TAC also applies to any changes along SW Marine Drive. Other manuals that apply are Transportation Association of Canada's TAC Manual, the Manual of Standard Traffic Signs and Pavement Markings, and the Manual of Uniform Traffic Control Devices. The design team has also taken into consideration the principles of Greenroads V1.5 and Complete Streets.

5.2 Alternatives

Three alternatives have been proposed for addressing the need for additional parking for the UBCBG and the proposed multipurpose building. These alternatives include the narrowing of SW Marine Drive, a conventional parking lot, and a multipurpose green parking space.

5.2.1 Alternative 1: Narrowing SW Marine Drive

In order to meet the parking needs for the UBCBG, while subsequently improving safety for all road users, the design team proposes the narrowing of SW Marine Drive as a potential solution to the current safety concerns raised by UBCBG director Douglas Justice. The complete design is shown in **Error! Reference source not found.**.

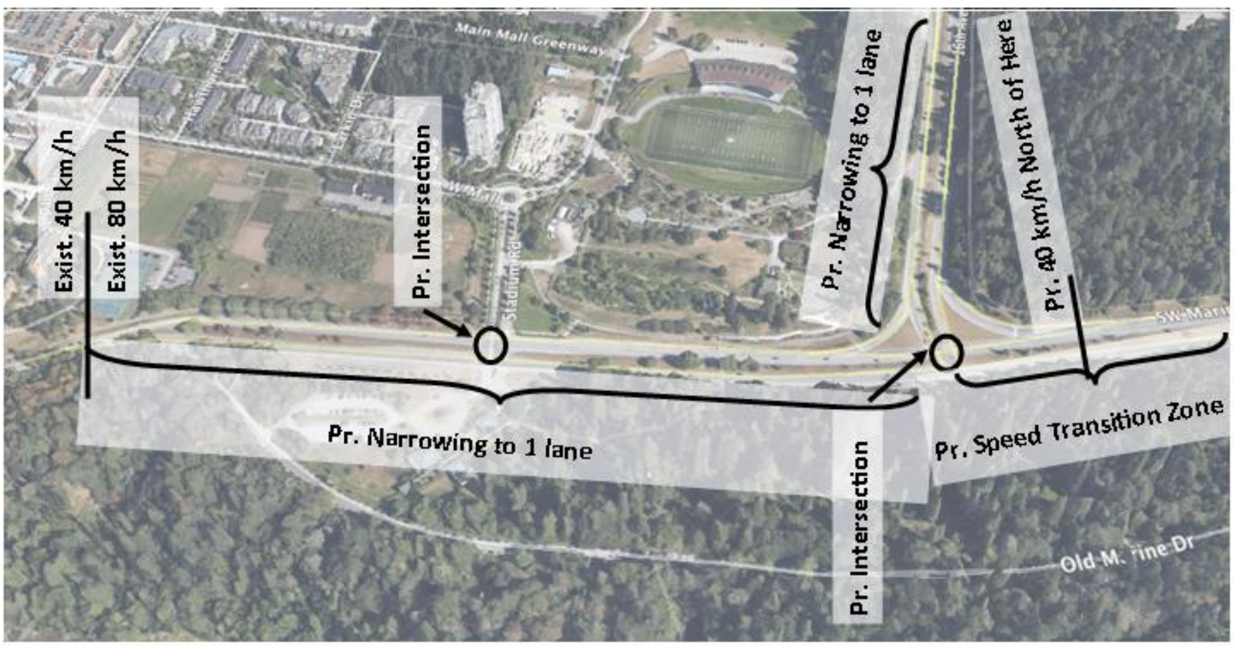


Figure 10. Proposed road layout. Note: not detailed design.

This alternative includes replacing the cross section in Figure 11 with the new one in Figure 12. As well, the speed limit would be reduced from 80 km/h to 40 km/h to match the northern section beyond the gardens. A detailed design can be found at the end of this section, which focuses on the section of SW Marine Drive north of Stadium Road. It should be noted that the detailed design does not include details for proposed intersection reconfigurations.

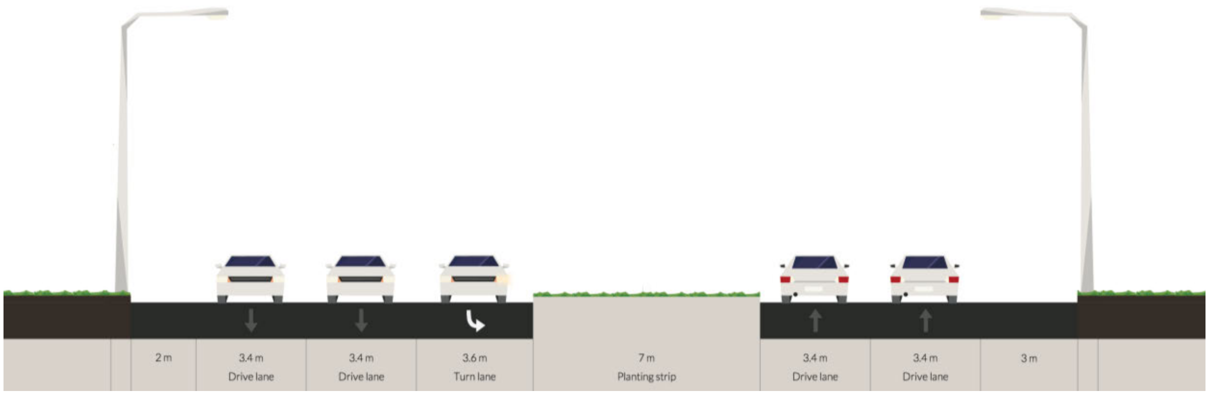


Figure 11. Current average cross-section of SW Marine drive (Streetmix)

Figure 12. Proposed new cross section of SW Marine Drive (Streetmix)

5.2.2 Alternative 2: Conventional Parking Lot

The reconfiguration of the existing parking lot will not provide a significant increase in stalls; therefore, additional parking needs to be found somewhere else, shown in the figure below.

Figure 13. Potential Locations for Additional Parking. Background from Google Maps.

Additional parking can be realized by removing the roundabout structure in front of the existing visitor's centre, as marked by P1 in the image above. This is an ideal place for parking because it is closer to the building. Not all of this area would be reserved for general parking, as some of the additional parking would be reserved for registered carpool vehicles, and electric vehicle charging stations.

The parking area marked P2 on Figure 13 is an effective location due to its proximity to the proposed multipurpose building. The access for the parking lot would be shared with the access for the works yard. These options are not being proposed because the 2005 Strategic Transportation Plan prevents new parking lots from being built.

5.2.3 Alternative 3: Multipurpose Green Parking Space

Since the 2005 Strategic Transportation Plan prevents new parking lots from being built, one alternative would be to construct a multipurpose green parking space. This is effectively a flat, wide expanse of lawn. Its durability is improved by some type of permeable paving material.

This space is not explicitly meant for parking, but has road access and gated entrance. It can be used as overflow parking for special events, such as during Apple Fest or weddings. Alternatively, it can be used as a staging ground for smaller events, which prevents the great lawn from being trampled. A typical multipurpose space would be placed near the sidewalk and the building. A typical layout, showing the sidewalk, access, position of luminaires, and extent of the surface material, is shown below.

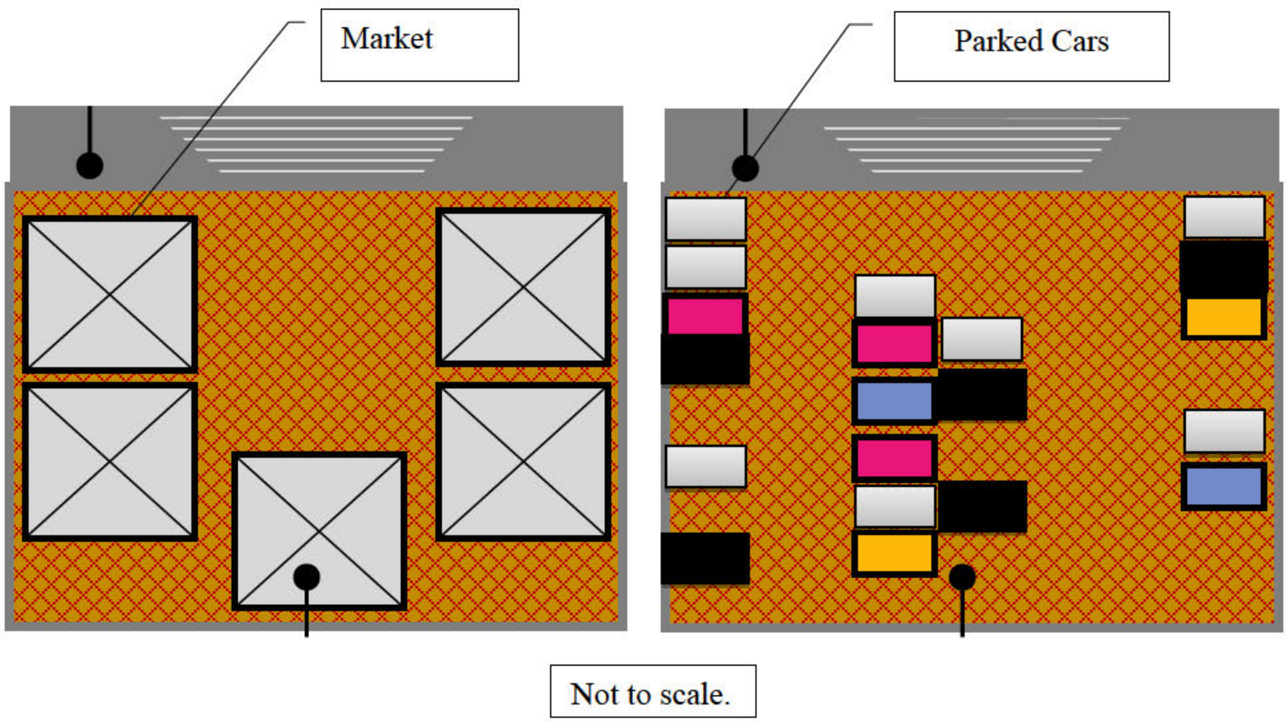


Figure 14. Potential uses of the multipurpose outdoor space.

The figure above shows the typical multipurpose outdoor space. It is made of durable, permeable paving stones. As an example of what can be done with such a space, the figure above shows the space being used for a Saturday market and for overflow parking.

5.3 Decision Matrix

In order to determine which solution best meets the needs of the existing Botanical Gardens and the proposed multipurpose building, a decision matrix has been created to evaluate each alternative based on three key factors. The decision matrix is shown below:

Table 5. Decision Matrix

Design Factors		Alternative 1: Narrowing SW Marine Brive	Alternative 2: Conventional Parking Lot		Alternative 3: Multipurpose Outdoor Space
			P1	P2	
Capacity	Daily Capacity	4	4	3	0
	Special Events Capacity	4	2	2	2
Proximity	To Multipurpose Building	2	1	4	4
	To UBC BG Main Entrance	2	4	1	2
Overall Safety	Cyclist Safety	3	0	0	0
	Pedestrian Safety	3	0	0	0
	Motorist Safety	3	2	2	2
	TOTAL:	21	13	12	10

Table 6. Rating Scheme of Decision Matrix

Rating	Explaination
0	Does not address this aspect
1	Poorly adddresses this aspect
2	Moderately addresses this aspect
3	Effectively addresses this aspect
4	Completely addresses this aspect

The decision making factors are discussed in the following sections, under the categories of capacity, proximity, and overall safety.

5.3.1 Capacity: Daily and Special Events

In order to provide the required parking increase for the proposed multipurpose building, approximately, 100 parking spaces must be added for daily use by visitors to this facility. This value of 100 parking spaces is based on the preferred ratio of 0.2 parking spaces per building user, as outlined by the 2005 Strategic Transportation Plan. Additional parking space to accommodate special events must also be taken into consideration. This is in response to the Botanical Gardens' need for additional parking during large events. Currently, visitors are being shuttled from the UBC parkades to the gardens via an expensive shuttle service.

5.3.2 Proximity to UBCBG Main Entrance and Multipurpose Building

Proximity to the main entrance of the UBCBG and the proposed multipurpose building are two key elements to providing convenient parking for visitors to these spaces. Proximity was evaluated based on walking distance from the furthest parking spaces, provided by each alternative, to the entrance gates of the gardens, and the atrium of the multipurpose building.

5.3.3 Cyclist, Pedestrian, and Motorist Safety

Designing for access to the gardens and multipurpose building should take into consideration infrastructure improvements that improve safety for all road users. Cyclist safety while travelling along SW Marine Drive is of major concern due to the current high speeds and lack of prescribed space for cyclists. Pedestrian safety concerns are of a similar nature, with vehicle speeds causing unsafe crossing conditions. As well, the lack of sidewalks on the south side of SW Marine Drive provide for dangerous conditions for pedestrians walking along the shoulder. For motorist safety, vehicle speeds, parking manoeuvres, parking lot access and egress, and turning movements were taken into consideration.

5.4 Traffic Demand Management

While much of the design process has been focused on providing vehicle parking as a result of an increase in visitorship to the garden, the promotion of sustainable modes of transportation has also been considered. The shift from personal vehicles to sustainable modes, through marketing and integration of traffic demand measures, was a key component in the selection of a parking management scheme.

Several TDMs have been incorporated into the design of the multipurpose building: secure indoor bike parking, showers, and change rooms. Covered bike parking is located in highly visible areas. Other TDMs include adding a bike route to improve access to the garden, providing sidewalks and lighting to improve walking conditions for pedestrians, using speed tables or a pedestrian activated crossing light at crosswalks, and providing space for future transit improvements.

5.5 Recommended Alternative

Based on the findings from the decision matrix and the ability to incorporate the proposed TDMs into each design, Alternative 1 is being proposed as a solution to providing parking for the proposed multipurpose building. This option provides the parking that the Garden needs, a safe crossing at Stadium Road, and greater opportunity for travellers to see the facility due to the lower speeds.

6.0 Cost Estimate and Implementation Plan

RS Means was used to calculate the cost estimate of the multipurpose building, and a financing schedule was prepared, showing different options based on possible funds generated.

6.1 RS Means Cost Estimate

RS Means uses many assumptions in its data. It is not an appropriate tool for detailed cost estimates. Since the project is still in the preliminary stages of design, a detailed cost estimate is not required. A standard institutional building of this size should cost approximately $4.3 Million, according to the model.

Building Parameters

Building Type:	College, Student Union with Precast Concrete Panel / Steel Frame
Location:	VANCOUVER, BC
Stories:	2
Story Height (L.F.):	12.00
Floor Area (S.F.):	20,719.00
Labor Type:	STD
Basement Included:	No
Data Release:	Year 2014 Quarter 1
Cost Per Square Foot:	$207.18
Building Cost:	$4,292,500.00

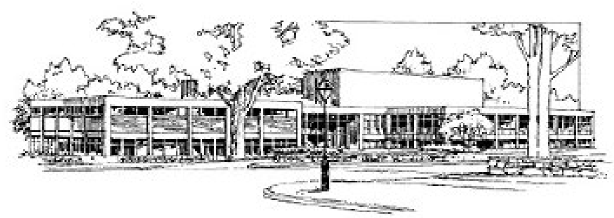


Figure 15. Output Summary from RS Means Online Tool

The figure above shows some of the inputs used in the model.

6.2 Implementation Plan

The cost of the building is much greater than the current budget of the UBCBG. In this case, three scenarios were considered to determine the amount of funds needed to be generated to reduce the annual cost to an affordable level.

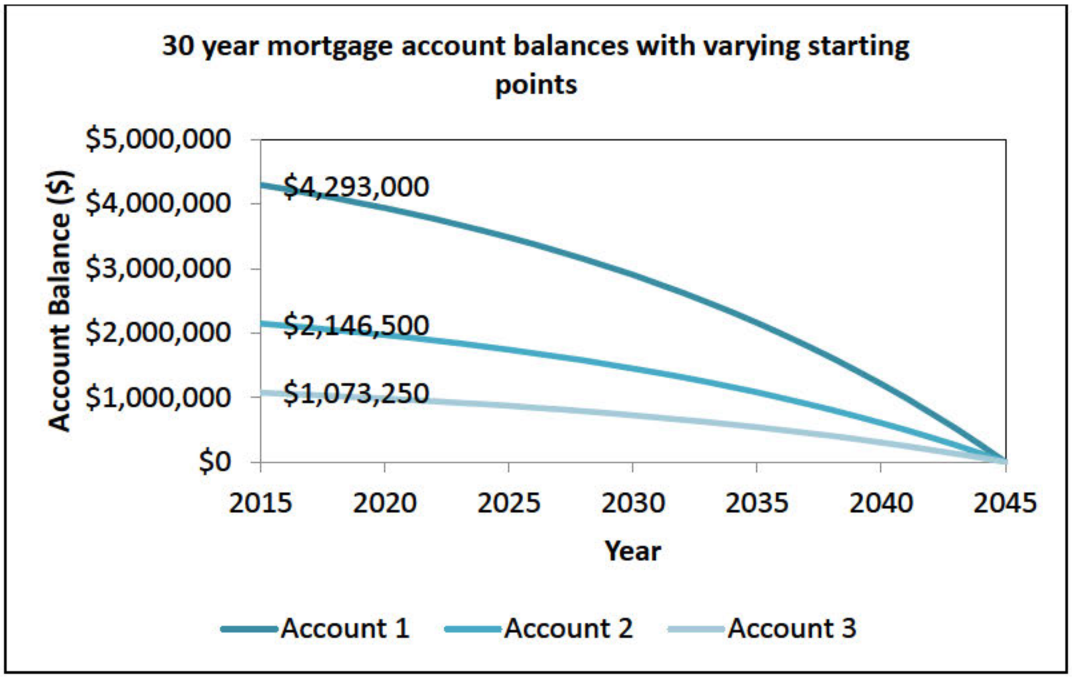


Figure 16. Chart showing mortgage schemes for varying starting payments.

The graph above shows the account balances of three different mortgages over 30 years with an interest rate of 5%, each with different starting points. If the UBCBG fronts the entire cost of the project and takes out a loan of $4,293,000, then the annual payment over 30 years will be just over $279,000. At half the starting cost of $2,146,000, the annual cost is also half: $139,600. If the UBCBG can get any other fraction of the cost paid for, then the same fraction applies to the annual cost over 30 years.

This model assumes that the roadwork is paid by the university and not by the UBCBG.

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