Director	CAO

COUNCIL AGENDA
Date: January 13, 2020 Item: 5/R-0

5/R-0

DISTRICT OF WEST VANCOUVER

750 17TH STREET, WEST VANCOUVER BC V7V 3T3

COUNCIL REPORT

Attachments for item 5/R-0 provided under separate cover

Date:	November 25, 2019
From:	Michelle McGuire, Manager of Current Planning and Urban Design and Jenn Moller, Manager of Land Development
Subject:	Development Variance Permit for 4358 Ross Crescent
File:	1010-20-18-037

RECOMMENDATION

THAT Council approve proposed Development Variance Permit No. 18-037 attached as Appendix A to the report by the Manager of Current Planning and Urban Design and the Manager of Land Development dated November 25, 2019.

1.0 Purpose

The purpose of this report is to provide further information to Council regarding the flood construction level associated with a development variance permit for 4358 Ross Crescent.

2.0 Legislation/Bylaw/Policy

Provincial Legislation

The *Local Government Act* requires that Council consider Development Variance Permits.

For development sites that may be subject to flooding such as 4358 Ross Crescent, section 56 of the *Community Charter* authorizes the District's Chief Building Inspector to require a qualified professional report to certify the conditions under which the land may be used safely for the intended use. Furthermore, on this basis, a building permit may only be issued following the condition that the owner of the land covenants with the municipality to use the land in accordance with the conditions specified in the qualified professional's report.

Zoning Bylaw

The site is zoned RS4 (Single Family Dwelling Zone 4) which permits single family housing with a maximum FAR of 0.35.

3.0 Official Community Plan

The OCP supports the development of updated shoreline protection strategies and flood construction level requirements to protect lands from sea level rise, reduce shoreline erosion, preserve and enhance habitat. The development proposal is consistent with the OCP.

4.0 Financial Implications

The applicant pays development application fees as per the Fees and Charges Bylaw, 4989, 2018. Any additional direct or administrative costs are considered cost recoverable and borne by the applicant.

5.0 Background

5.1 Previous Decisions

Council, at its July 22, 2019, regular meeting, passed the following resolutions:

> THAT proposed "Zoning Bylaw No. 4662, 2010, Amendment Bylaw No. 5028, 2019" be adopted.
>
> THAT
>
> 1. Staff seek a second opinion regarding the minimum FCL (flood construction level) for 4358 Ross Crescent;
>
> 2. Staff undertake to review the scope of the work and methodology with residents, including:
>
>   a. mitigation measures; and
>
>   b. consideration of the impacts of engineered fill on overland flooding; and
>
> 3. The work be completed in a timely fashion but no later than four months from this date.

5.2 History

A rezoning and development variance permit application was originally submitted on March 15, 2018 to redevelop 4358 Ross Crescent with a new single family house. As the site at 4358 Ross Crescent is in a coastal area that may be subject to flooding, staff requested a report from a suitably qualified professional to consider flood construction levels and specify how the land and any buildings or other structures within the land would be constructed safely for the proposed residential use. Consideration of the qualified professional report is based on the Province's Flood Hazard Area Land Use Management Guidelines (the "Provincial Guidelines"), in particular sections 3.5 and 3.6, which deal with climate change and sea level rise expected by the year 2100. In addition, the report is to be prepared in accordance with the most recent edition of the Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC (published by the Association of Professional Engineers and Geoscientists of BC).

On April 4, 2019 an updated development variance permit application was submitted along with a qualified professional report from NHC including a proposed flood construction level of 5.80 m geodetic datum (GE) and corresponding plans proposing construction of a new single-family house and garage. The corresponding development plans proposed zoning variances related to the proposed house including variances required to accommodate the FCL.

6.0 Analysis

6.1 Discussion

Site and Context

The site is located in the Stearman Beach area along the south side of Ross Crescent directly adjacent to the Burrard Inlet (Figure 1). The site is bounded by two single family properties to the west and east, Ross Crescent to the north and Burrard Inlet to the south. The subject site and sites in the surrounding Stearman Beach area are relatively low lying with sites along the waterfront that may be subject to flooding due to storm events and sea level rise.

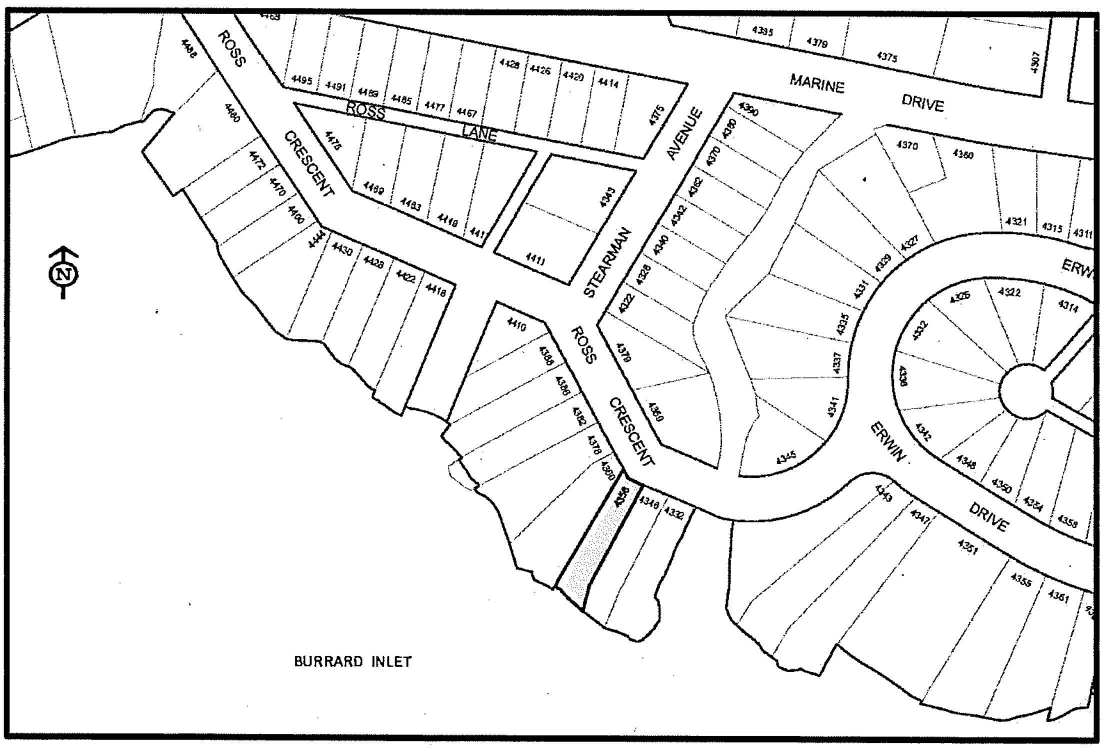

Figure 1: Site and Context

Second Opinion on Minimum Flood Construction Level (FCL)

In accordance with Council's direction, staff met with representatives of the Ross Crescent and Erwin Drive neighbourhoods to discuss the scope of work and methodology for seeking a second opinion on the minimum FCL for 4358 Ross Crescent. Two meetings were held, one on August 6, 2019 and a follow up meeting on September 16, 2019. Further to this, staff are maintaining an open and ongoing dialogue with the residents to provide updates where appropriate.

Following the first meeting with residents, the scope of work was confirmed and a coastal engineering consultant, WSP Canada, was engaged by staff to carry out an independent FCL analysis for the subject site. WSP is also the consultant reviewing District-wide FCL considerations for West Vancouver. The WSP project team members are an interdisciplinary team with professional engineering experience in the areas of coastal and marine works engineering, drainage and flood risk assessment; and coastal hydraulics.

WSP carried out an FCL analysis for the proposed development, taking into account the current development plans proposed by the applicant including berming and retaining walls required to raise the grade of the property. This analysis resulted in an FCL of 6.69 m geodetic datum (GE) (Appendix C). The discrepancy between this analysis and the FCL of 5.80 m GE determined by NHC can be attributed to WSP using a longer wave period, which translates to a greater volume of water within the wave run up. In addition, WSP included in their analysis the proposed berm structure at the south of the property, whereas the NHC analysis used an earlier version of the site development plan which didn't include this structure. If Council approves the development variance permit a condition is included that will require an updated report from the applicant's consultant to account for the berm structure.

The variation in the analysis and recommended minimum FCL between the WSP and NHC report are generally acceptable, with both consultants following the recommended methodology of the Province's Flood Hazard Area Land Use Management Guidelines (the "Provincial Guidelines") and the Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC. As the report prepared by NHC followed the Provincial Guidelines and staff are satisfied with the findings the Chief Building Official can accept the lower FCL of 5.80 m GE subject to modification of the qualified professional report to account for the berm structure as described above. Therefore staff are not requiring further revision to accommodate a higher FCL of 6.69 m GE.

<u>Groundwater Considerations</u>

Neighbourhood residents expressed concerns around the proposal introducing imported engineered fill to the site and the risk of adverse effects it could introduce to natural drainage and the groundwater table. Council also directed staff to include consideration of engineered fill on overland flooding in the scope of work for obtaining a second opinion for the site FCL. In response, staff note that the properties and performance of engineered fill can vary, and the specifics around materials and construction measures would need to be specified by the appropriate qualified professional at time of building permit. To the extent that it has been suggested imported engineered fill could greatly influence the groundwater table, staff have confirmed with a qualified Hydrogeotechnical engineer (engaged to review the localized groundwater table conditions), effects of fill placement on the water table are proportional to the compressibility of the underlying sediments, and based on the coarse-grained (sand, gravel, and cobble) materials encountered in the area, compressibility is low. Accordingly, water level changes resulting from fill placement are expected to be modest.

Mitigation Options

In response to Council direction to review potential mitigation measures WSP provided an overview and analysis that is summarized here.

In general, there are four principle measures available for response to Sea Level Rise:

- Avoid (e.g. setbacks);
- Protect (e.g. seawall, storm surge barrier, dike, beachfill/dune to elevate foreshore land, tidal gate);
- Accommodate (elevate upland and structures);
- Retreat.

The effectiveness of available mitigation measures is often site dependant and related to the natural site conditions and constraints. Considering the coastline as a unit is far more meaningful in terms of opportunity for more innovative solutions that would have a larger footprint and be applied on a larger scale.

The broader piece of work currently underway with WSP will consider such solutions to address coastal flooding in this regard. An example of offshore mitigation measures that could be applied on a broader scale as in a low-lying area such as the Ross Crescent area, could include a breakwater structure. Analysis of such a feature is beyond the scope of WSPs site specific analysis. However, high level magnitude of costs for such measures is being considered as part of the broader study and preliminary indications suggests they are likely to be in the order of magnitude of tens of millions of dollars. Other considerations for offshore mitigation measures include permitting through Provincial and Federal government agencies: Fisheries and Oceans Canada to avoid impact to fish and fish habitat; Transport Canada to ensure that works do not prohibit passage; archaeological permitting, if excavation is required in an area; and, compliance with the District's foreshore Headlease agreement with the Province, relating to the management and control over new encroachments or works on the public foreshore.

Specifically for the subject property potential mitigative measures identified include:

- Inclusion of a recurve parapet at the landward vertical retaining wall of the berm to redirect wave run-up. The seaward vertical retaining wall is largely submerged during the Designated Storm Event, limiting the effectiveness of a recurve parapet at this location.
- Installation of armour rock and/or large woody debris seaward of the seaward vertical retaining wall, as shown on some drawings in the development application, to dissipate the waves before they reach the walls.

Without considering the area as a whole and completion of modeling of adjacent properties, it isn't possible to determine if site-specific measures could have adverse impacts on adjacent properties. For example, the construction of the fill and walls may trigger coastal erosion at adjacent properties lacking shore protection over the short to medium term, while over the long term reflected waves may increase damage to adjacent structures in the event of severe flooding.

As well, the introduction of site specific mitigation measures to minimize flood hazards may impact other factors such as fish and fish habitat. For example, the introduction of a wave capping wall, while minimizing wave effect to property, will result in greater scour and erosion to the beach in front of the wall, which impacts habitat for fish. Broader evaluation of impacts of flood hazards while maintaining the quality of the environmentally sensitive area of the foreshore is being completed through the broader scope of work that WSP is conducting.

Tree retention

In response to concerns raised regarding potential tree removal on the subject site, specifically with respect to the existing Grand Fir ("eagle perch tree"), the applicant engaged an arborist to evaluate the potential to retain mature trees on site. The applicant has submitted supplementary information describing how the eagle perch tree and the existing Cedar tree located on the District Boulevard can be safely retained. The plan describing retention of these two mature trees is attached as Schedule B to Appendix A. Staff support retention of these mature trees and have included a condition in the draft Development Variance Permit (Appendix B) to ensure that measures to protect the trees are confirmed prior to building permit issuance.

Proposed Zoning Variances

As described in the staff report titled "Rezoning and Development Variance Permit for 4358 Ross Crescent" (Appendix B) the applicant has proposed zoning variances to accommodate the siting of the proposed house and garage and variances to accommodate the calculation of average grade relative to the FCL. As described above, based on review of the report from WSP Canada, staff are supportive of the proposed variances and do not recommend any further changes.

6.2 Sustainability

In addition to the sustainability measures described in the staff report titled "Rezoning and Development Variance Permit for 4358 Ross Crescent" (Appendix B) the applicant has proposed retention of two mature trees.

6.3 Public Engagement and Outreach

Prior to public hearing (July 15, 2019) the owner hosted a public information meeting on July 3, 2019 where approximately 30 people were in attendance. At the public information meeting and at the public hearing comments and concerns that were voiced included:

- Concern about proposed increased building height and average grade and the resultant relationship to surrounding properties including overlook and privacy issues/impacts.

- Concern about the bulkiness of the proposed house, setbacks and generally concerns about the proposed zoning variances.
- Concern about the potential for stormwater flow (flooding) onto to adjacent sites due to the raised average grade of the subject site.
- Concern about systemic flooding and drainage issues in the Erwin Drive area. Comments from neighbours have indicated belief that these issues are attributed to issues with the detention system at Erwin Park and excessive groundwater pumping occurring in the area.
- Concern about the loss of mature trees on the site including the Grand Fir ("eagle perch tree").

Responses to public feedback:

- Relationship to adjacent sites (building height and average grade) - The proposal includes terracing up to the FCL at the east and west side yards and from the waterfront to mitigate building height and grade impacts. Staff are satisfied that the proposed landscaping and urban design approach provides a sensitive transition to adjacent sites.
- Building bulkiness and height – The proposal meets the maximum floor area ratio (FAR) within RS4 and is no larger than a zoning compliant house. As well, staff note that it is anticipated that all sites along the waterfront will incrementally be raised with higher building height as development occurs to allow for construction above the FCL in an area that is subject to the risk of flooding.
- Stormwater flooding onto adjacent sites due to the raised grade - The site will be designed so that stormwater runoff would not flow on to adjacent sites but rather would flow into the ocean. District regulation requires that sites are graded/designed to force stormwater to flow out to the ocean (i.e. not onto adjacent sites). This is a condition of the draft Development Variance Permit (DVP).
- Local flooding and drainage issues – Staff have reviewed the functioning of Erwin Park as a detention pond which is by design and occurs during high tide conditions. In response to concerns about localized flooding, staff are seeking an assessment of water table conditions in the vicinity of the Park. The objectives of this work include identifying the relationships between storm water detention in the Park and high groundwater levels and groundwater inflow into foundation sub drain systems at nearby residential properties. The timeline for this work includes several months of monitoring to ascertain any relationships between the natural groundwater table, tidal influences, and storm events. A third party hydrogeotechnical consulting firm has been engaged to carry out this work and staff will report back on their findings under conclusion of the work.

6.4 Other Communication, Consultation, and Research

Planning staff has consulted with District staff on the application and proposed conditions are included in the draft development variance permit addressing staff comments.

7.0 Options

7.1 Recommended Option

After hearing from the public, approve the draft development variance permit.

7.2 Considered Options

a. Request further information (to be specified); or

b. Reject the proposal.

8.0 Conclusion

If approved, the development variance permit would accommodate construction of the proposed house and garage including considerations for development in an area that may be subject to flooding. The proposal is supported by the OCP that provides direction to proactively plan for coastal flooding of sites adjacent to the foreshore. The proposed construction of the house and garage are based on specifications of a qualified professional report submitted as part of the application and are intended to mitigate the impacts of coastal flooding. Based on review of the second opinion provided by WSP on the minimum FCL for the site, staff are satisfied that the minimum FCL provided by NHC is acceptable subject to refinement as conditioned in the draft development variance permit. With accommodation to construct above the site specific FCL, the proposed development can advance without the need for introducing significantly expensive coastline-based measures like breakwaters.

Although the proposed house would be higher than surrounding properties, in order to accommodate the engineering specifications, the proposed building mitigates these impacts with a height of 6.7 m (22 ft.), 0.9 m (3.0 ft.) lower than the maximum of 7.6 m (25 ft.) under RS4 zoning. As well, the proposal provides terracing at the west and east edges of the site to provide a transition in height from adjacent properties and landscaping to screen the proposal. Staff support the proposal and recommend that Council approve the Development Variance Permit.

Author: ______________________________
Michelle McGuire, Manager of Current Planning and Urban Design

Author: ______________________________
Jenn Moller, Manager of Land Development

Appendices:

A- Proposed Development Variance Permit No. 18-037

B- Staff report dated June 4, 2019 "Rezoning and Development Variance Permit 18-037 for 4358 Ross Crescent"

C- WSP Report, dated December 2, 2019

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APPENDIX A

District of West Vancouver

Development Variance Permit No. 18-037

Current Owner: Jennifer and Robert Heffel

This Development Variance Permit applies to:

Civic Address: 4358 Ross Crescent

Legal Description: 030-375-002
Lot A, Block 2, District Lot 582, Group 1 New Westminster District Plan EPP78997
(the "Lands")

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1. For the purposes of this Development Variance Permit, the Lands shall be developed in accordance with the drawings attached and date stamped May 15, 2019, approved by Council, attached as Schedule A, and specifically in compliance with the regulations and variances listed hereunder.

2. Zoning Bylaw No. 4662, 2010 is varied and supplemented for this development proposal in accordance with the following regulations:

   (a) Section 204.09 (RS4 Side Yard and Combined Side Yard) is varied to allow:

      i. the required combined side yard to be reduced from 4.6 m to 3.5 m; and

      ii. the required west side yard for the garage to be reduced from 1.5 m to 1.0 m.

   (b) Section 204.07 (RS4 Front Yard) is varied to allow the required front yard for the garage to be reduced from 9.1 m to 1.0 m.

   (c) Section 120.17 (Average Grade Calculation for Building and Structure Height) is varied to calculate maximum building height using the flood construction level at 5.8 m as average grade.

   (d) Section 120.27 (9) (b) (Yard Provisions and Exemptions) is varied to allow the roof overhang for the garage in the front yard to be increased from 0.6 maximum to 1.0 m.

   (e) Section 204.10 (RS4 Building Height) is varied to reduce the maximum height from 7.62 m to 6.7 m.

   (f) Section 110 (basement definition) is varied to allow the basement to be defined as a storey, the floor of which is located below the flood construction level at 5.8 m.

   (g) Section 130.01 (3) (b) is varied to calculate maximum building height for the accessory building (garage and storage) using the flood construction level at 5.8 m as average grade.

(h) Section 130.15 (7) (Site Landscaping) is varied to allow the impermeable surface in the front yard to be increased from 50% to 56%.

(i) Section 130.1 (2) (c) (Highest Building Face Envelope) is varied to allow maximum highest building face to be calculated using the flood construction level at 5.8 m as average grade.

(j) Sections 120.22 (Retaining Wall Grade Line and Buildup of Grade) and 130.13 (Waterfront Yard Requirement) are varied to allow retaining wall heights as shown in Sheet A1.2 of Schedule A, except that no retaining wall will exceed 1.2 m in exposed face height.

3. The proposed new house and site landscaping must generally be constructed and finished in compliance with attached Schedule “A”.

4. The proposal shall generally incorporate the sustainability elements as follows:

(a) Heat Pump;

(b) All windows, doors + skylights to meet current NAFS energy standard;

(c) Heat Recovery Ventilator;

(d) High performance building envelope - air tight + low air exchanges;

(e) Maximizing of pervious surfaces – gardens + softscape;

(f) Exterior Insulation (if exempt from setback calculations);

(g) Trellis’ on south orientation as passive means to limit solar gain;

(h) Drain Water Heat Recovery; and

(i) Natural Gas Boiler with in floor radiant heat.

Prior to Building permit issuance the Owner shall provide applications plans and information detailing these sustainability elements to the satisfaction of the Director of Planning.

5. The proposal shall incorporate electric vehicle charging in the garage.

6. The proposal shall incorporate electric conduit to enable solar panel installation.

7. Prior to the issuance of a Building Permit the Owner shall:

(a) Confirm required measures to ensure safe retention of the existing trees on site that are proposed for retention as per Schedule B; and

(b) A Tree Replacement Plan shall be submitted to, and approved by, the District Arborist or qualified designate to replace the proposed trees to be removed on the Lands at a ratio of 3:1 for replacement trees whereas replacement trees and plantings are to be native species.

8. Prior to issuance of a Building Permit, submission of an updated qualified professional report with either:

   (a) updated SWASH modelling to match the current development plans (Schedule A) including the berm elevations; or

   (b) inclusion of updated development plans to revise the berm elevations used in the qualified professional report (Schedule C).

9. Prior to issuance of a Building Permit, a suitably qualified professional will identify conditions as enabling the safe use of the land for the use intended with consideration to coastal flooding hazards. A s219 covenant shall be registered against the certificate of title for the Lands certifying that the land will be used in accordance with the conditions specified in a report completed by the suitably qualified professional.

10. Prior to the issuance of a Building Permit and as security for the due and proper completion of the landscaping as set forth in Section 3 of this Development Variance Permit, the Owner shall:

    (a) provide a landscape plan to include site grading that takes into consideration and is integrated with the onsite stormwater management plan as required per the District's Building Bylaw 4400, 2004 Section 9.1.12; and, the requirements set forth Section 8 of this Development Permit.

    (b) provide a landscape cost estimate acceptable to Director of Planning;

    (c) provide security in the amount of 125% of the landscape cost estimate to the District in the form of cash or an unconditional, irrevocable auto-renewing letter of credit issued by a Canadian chartered bank or credit union; and

    (d) maintain the security for a minimum of one year after completion of the landscaping, and not prior to the date on which the District authorizes in writing the release of the security.

11. This Development Variance Permit lapses if construction of the additions and renovations has not commenced, under an issued Building Permit, within 24 months of the date this permit is issued.

THE COUNCIL OF WEST VANCOUVER APPROVED THIS PERMIT BY RESOLUTION PASSED ON____________________.

MAYOR

MUNICIPAL CLERK

THE REQUIREMENTS AND CONDITIONS UPON WHICH THIS PERMIT IS ISSUED ARE ACKNOWLEDGED AND AGREED TO. IT IS UNDERSTOOD THAT OTHER PERMITS / APPROVALS MAY BE REQUIRED INCLUDING PERMITS / APPROVALS FOR BUILDING CONSTRUCTION, SOIL AND ROCK REMOVAL OR DEPOSIT, BOULEVARD WORKS, AND SUBDIVISION.

FOR THE PURPOSES OF SECTION 11, THIS PERMIT IS ISSUED ON_____________.

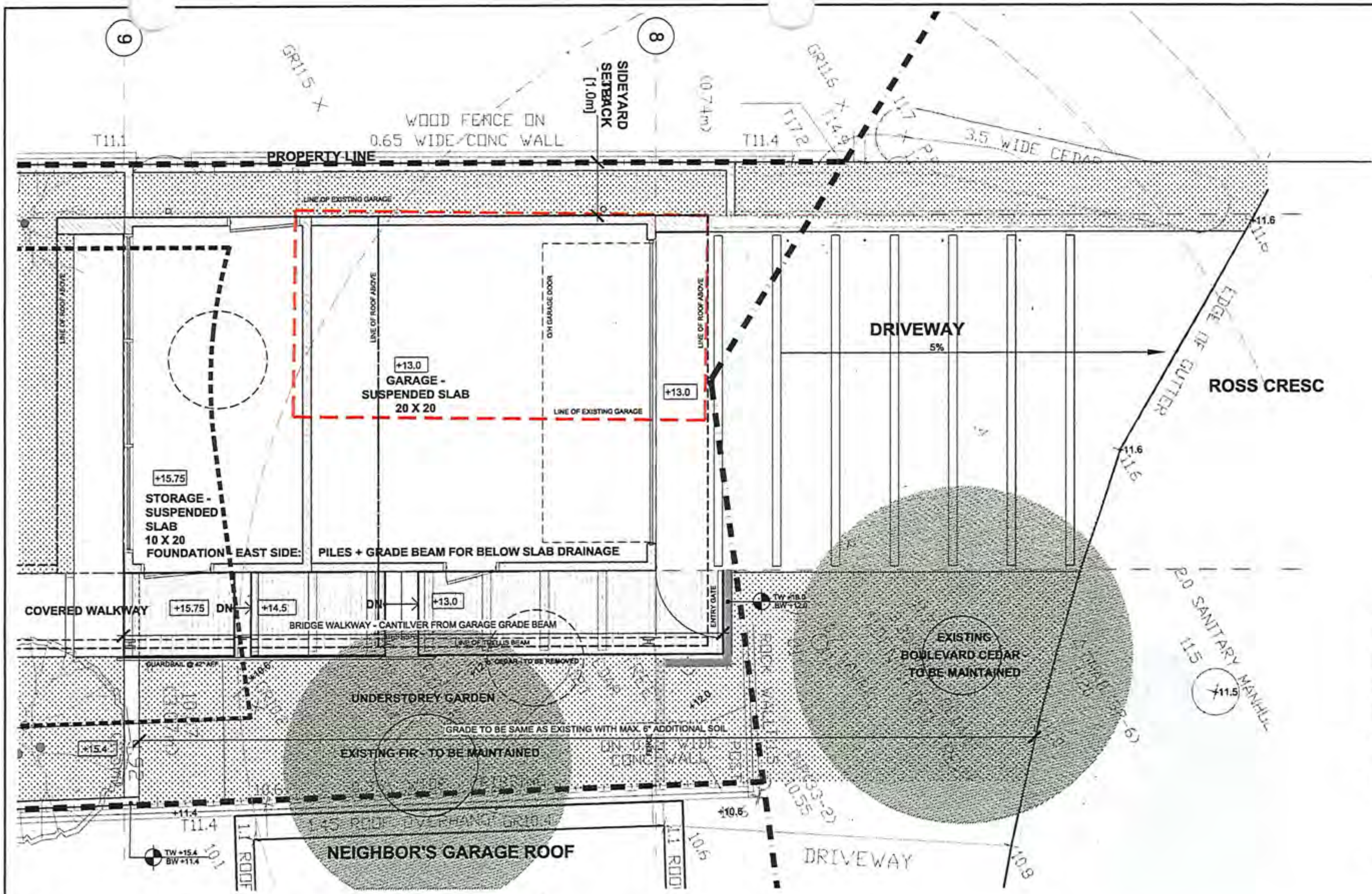
Schedules:

A – Development Plans for 4358 Ross Crescent prepared by Hlynsky and Davis Architects.

B – Proposed Tree Retention Plan.

C – NHC Flood Hazard Assessment – Final Report 4358 Ross Crescent, dated stamped April 4, 2019.

SCHEDULE B



1 GARAGE + STORAGE PLAN
A2.5 1/4" = 1'-0"

HLYNSKY + DAVIS ARCHITECTS INC.

HEFFEL RESIDENCE
4358 ROSS CRESC
W.VAN, BC

GARAGE PLAN

A2.5r

30 Gostick Place | North Vancouver, BC V7M 3G3 | 604.980.6011 | www.nhcweb.com

nhc
northwest hydraulic consultants ltd

SCHEDULE C

NHC Ref. No. 3004524

22 March, 2019

[redacted]

Attention: [redacted]
Via email:

Re: **Flood Hazard Assessment – Final Report**
4358 Ross Crescent, West Vancouver, BC

Dea[redacted]

This letter report summarizes the flood hazard assessment (FHA) study conducted by Northwest Hydraulic Consultants Ltd. (NHC) in support of future building permit for the proposed 4358 Ross Crescent development located within the District of West Vancouver (DWV).

1 INTRODUCTION

A single-family home is being proposed for 4358 Ross Crescent (Lot 7, Block 2, District Lot 582, Group 1, New Westminster District, Plan 4725). The property is located on the north shore of Burrard Inlet within the DWV (**Figure 1**). A number of creeks drain the steep slopes of the coastal North Shore mountains to outlet to Burrard Inlet near the project site; specifically, Claymore Creek, Willow Creek, and Cypress Creeks. The property is potentially at risk to coastal flood hazards from Burrard Inlet as well as riverine flood hazards from the adjacent creeks. NHC has conducted a flood hazard assessment to identify and assess these hazards. This report presents this assessment, the findings, and recommended measures to mitigate the hazard.

The objective of this assessment is to identify and evaluate the flood hazards that may affect the safe development and use of the property with respect to the proposed development and decide if development is possible to an acceptable safety threshold, either without or with mitigation. The currently accepted safety threshold in British Columbia is 0.5% annual exceedance probability (AEP) up to the year 2100. The 0.5% AEP event is often referred to as the 200-year event as such an event is expected, on average, to occur or be exceeded, once every 200 years.

The report has been structured by presenting referenced guidelines, site observations, coastal assessment, riverine assessment, and concluding with findings and recommendations.

Figure 1. Location map of study site.

1.1 Existing FHA Covenants

DWV requires all applicants applying for a building permit to construct buildings in coastal areas to provide a site specific FHA report, prepared by a qualified professional, that confirms the land may be used safely for the use intended.

The report prepared by a qualified engineer must:

- Be prepared in accordance with the most recent edition of the Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC published by Engineers and Geoscientists of BC (EGBC, 2018);
- Be prepared by a qualified registered engineer;
- Be accompanied by the Flood Hazard and Risk Assurance Statement (Appendix A); and
- Identify all floor areas proposed to be constructed below the 4.5 m GSC (Geodetic Survey of Canada) datum and specify use of these areas.

2 REFERENCED GUIDELINES

The following guidelines and regulations were reviewed as part of our investigation of the possible hydrotechnical hazards that could threaten the study property.

- Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC (EGBC, 2018)
- Flood Hazard Area Land Use Management Guidelines (BCMFLNRD, 2018)

- Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use – Draft Policy Discussion Paper (BC Ministry of Environment, 2011a)
- Coastal Floodplain Mapping – Guidelines and Specifications (BC Ministry of Environment, 2011b)
- Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use – Guidelines for Management of Coastal Flood Hazard Land Use (BC Ministry of Environment, 2011c)

3 SITE DESCRIPTION

A site investigation was conducted on January 25th, 2019, by a geomorphologist and coastal engineers from NHC to examine the foreshore morphology as well as to identify the condition of existing foreshore structures, and surrounding beach materials. The weather throughout the site inspection was mostly sunny and relatively calm. The tide level at Point Atkinson was about -0.9 m Geodetic Datum (GD) during the site inspection, which permitted a reasonable extent of the inter-tidal foreshore to be visually inspected. An additional site investigation was conducted on February 26th, 2019 to examine portions of Cypress Creek, which is located 30 m east of the subject property.

The existing foreshore (**Photo 1**) consists of gravel and cobble beach sloping at a roughly 6.6% slope (15H:1V) followed by a 15 m long flat section. In front of the property, the foreshore transitions to a roughly 5% slope (20H:1V) where large woody debris accumulation (**Photo 2**) was observed on top of boulders placed along the width of the property. A vertical concrete wall with crest elevation at El. 3.17 m GD is located between the dwelling and the foreshore (**Photo 3**). The beach faces towards the south-west but is exposed to waves from the west, south, and east.

The existing foreshore protection areas consist of poorly interlocked rock embedded roughly one-third into the sand beds and no toe structure. The neighbouring property to the west consists of a vertical parapet concreate wall with glazing panels and no toe protection (**Photo 4**). The neighbouring property to the east consists of a short wooden wall with glazing panels (**Photo 5**). The site visit was conducted about one month after a storm event (December 20th, 2018) and damages to the glazing panels in the neighbouring properties were observed (**Photos 4 and 5**). It was also indicated by the client's architect at the time of the site visit that the neighbouring properties were flooded during the December 20th, 2018 event while the subject property did not experience significant flooding. This could be due to a combination of two factors: 1) the large woody debris on the foreshore provided some attenuation of incoming waves and 2) the retaining wall located landward of the woody debris was sufficiently high to minimise the amount of wave overtopping.

From east to west Cypress Creek, Willow Creek, and Claymore Creek flow north to south entering Burrard Inlet east (Cypress) and west (Willow Creek and Claymore Creek) of the property. The Cypress Creek channel draining to Burrard Inlet is located about 30 m east of the property. The channel transitions from roughly 15% grade upstream of the railway crossing (480 m upstream) to 5% at the Marine Drive crossing (200 m upstream), and roughly 2% as it approaches Burrard Inlet. The closest crossing, Marine Drive, is provided by a clear span bridge. A 0.5 m deep and 1 m wide ditch running along the creek was observed between top of the bank and Ross Crescent (El. 3.5 m GD) (**Photo 6**). The channel width of the Cypress Creek between the project site and the Marine Drive crossing is relatively consistent, with the width of 10 m. The channel width gradually widens to about 30 m at its mouth (where the creek meets the ocean) and widens (**Photo 7**). Both channel banks are steep, with an elevation of about 4.4 m GD or 2.1 m above the channel bed (**Photo 8**).

Willow Creek, an order of magnitude smaller than Cypress Creek, is located 90 m west of the subject property. Willow Creek flow is conveyed from upstream of Marine Drive through to Ross Crescent within a 1.2 m diameter concrete culvert; approximately 270 m long. A debris trash rack structure was recently installed at the upstream end of the culvert, replacing the previous structure that performed poorly during recent flooding in June, 2016 when flood flows were diverted down the road system, affecting many homes in the area.

Claymore Creek, the smallest of the three creeks has a relatively small watershed and equally small constructed channel with limited flow capacity. Low lying banks appear easily overtopped. The slope of this creek is more than 5% upstream of Marine Drive and flattens to 3 to 5% just upstream of Ross Crescent, and to about 1% near its outlet at Burrard Inlet.

Photo 1. View towards site from south.

Photo 2. Large woody debris accumulation.

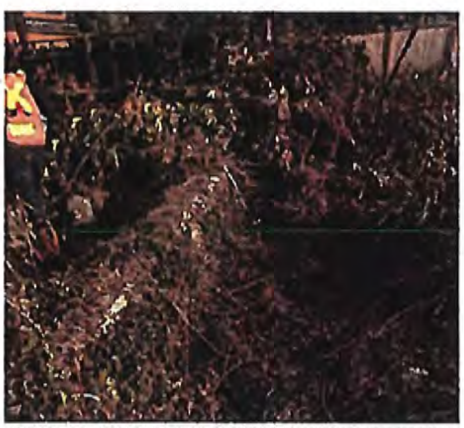


Photo 3. Existing vertical concrete wall.

Photo 4. Property west of project site.

Photo 5. Property east of project site.

Photo 6. Ditch between Cypress Creek and road (looking south).

Photo 7. Cypress Creek channel geometry – looking south.

Photo 8. Cypress Creek right bank.

4 COASTAL FLOOD HAZARD ANALYSIS

Coastal flood hazards are primarily dictated by flood inundation, but can include overflow and spray, shoreline erosion and scour, beach degradation and aggradation, or physical loading from hydraulic forces or wood debris. Flood inundation is the focus of this coastal assessment. Other coastal hazards are of less concern for this assessment based on initial review; that is:

- Overflow and spray can be assessed and addressed through site drainage design follow site design.
- Evidence of shoreline aggradation was identified during the site inspection as a result of woody debris accumulation. No scour was identified along the walls protecting the neighbouring properties.

Canadian Hydrographic Service Chart 3495 (**Table 1**) presents the local tides at Point Atkinson, which is 1.8 km west of the study site. The existing top of wall at the study site is at 3.17 m GD. Coastal flood levels due to tide, storm surge, wave effects and long-term changes in global and local sea level are expected to be higher than this elevation which could lead to flood inundation.

Table 1. **Tidal heights, extremes, and mean water level at Point Atkinson.**

Sea State	Tide Elevation (m Geodetic Datum)
Higher High Water, Large Tide (HHWLT)	2.0
Higher High Water, Mean Tide (HHWMT)	1.3
Mean Water Level (MWL)	0.0
Lower Low Water, Mean Tide (LLWMT)	-2.0
Lower Low Water, Large Tide (LLWLT)	-3.1

4.1 Coastal Flood Level

To reduce the likelihood of damage from coastal flood inundation, the coastal flood level was assessed and used to derive a minimum construction level – the flood construction level (FCL). The FCL provides a level of mitigation to limit the likelihood of flooding for homes located along the coast or rivers and creeks. The FCL is generally based on an event with an AEP of 0.5%, often referred to as the 200-year event; since on average it would be expected to occur or be exceeded once every 200-years. In addition, due to changing conditions (primarily human induced global climate change) future conditions are considered up to the expected life of the project; often considered as the year-2100 (roughly 80 years from present).

The BC Ministry of Environment's published Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use (BC Ministry of Environment, 2011b) and the BC Ministry of Forests, Natural Resource Operations and Rural Development's amendment (BCMFLNRD, 2018) present two approaches for determining the 200-year FCL: 1) combined method and 2) probabilistic method. Parameters that sum up FCL for each method are illustrated in **Figure 2** and **Figure 3**.

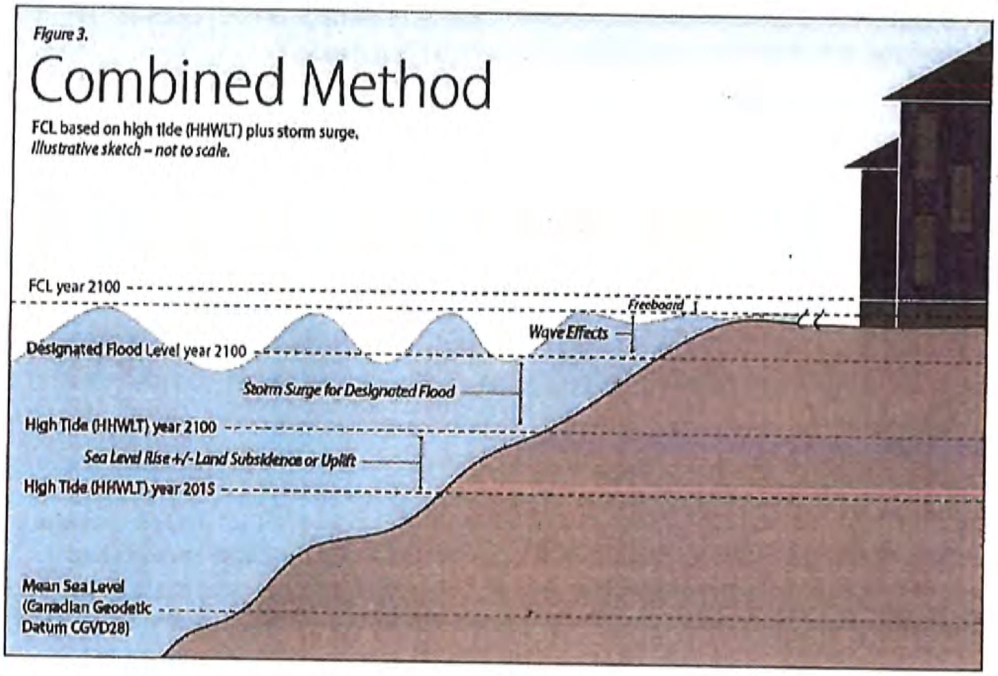


Figure 2. **FCL based on combined method (BCMFLNRD, 2018).**

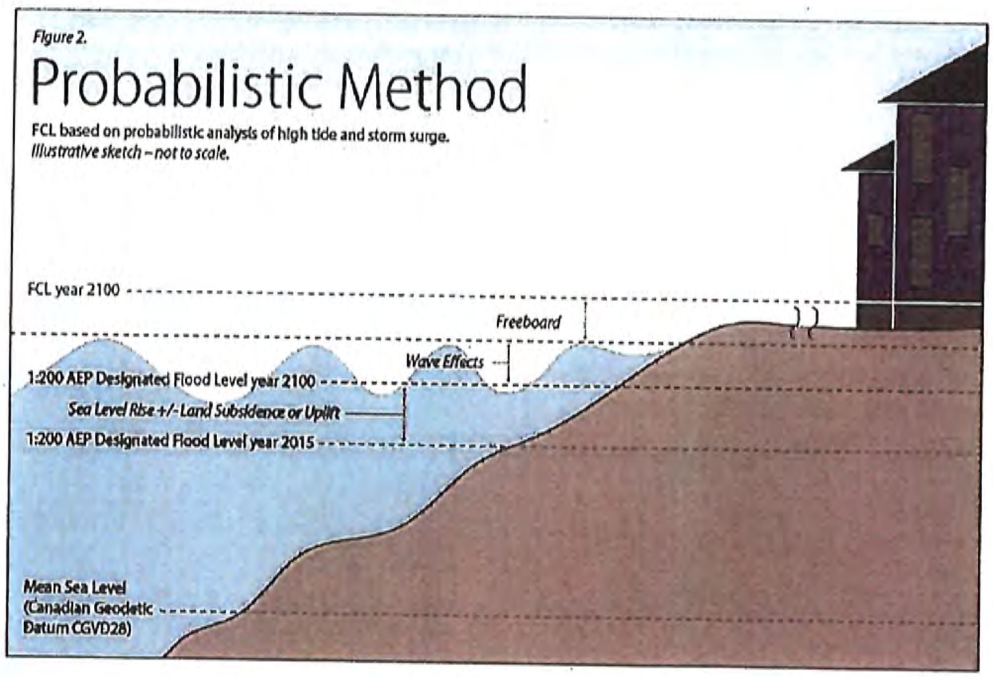


Figure 3. **FCL based on probabilistic analysis (BCMFLNRD, 2018).**

The combined method is based on the combined effects of HHWLT tide, storm surge, wave run-up, and sea level rise (SLR). This approach generally results in conservative calculation of a design flood level, as it is often applied ignoring the probability of the various design events cooccurring (the probability that a 200-year storm surge co-occurs during HHWLT and 200-year wave event is closer to a 4,000-year event, AEP of 0.025%, instead of 200-year event, AEP of 0.5%). For this assessment the joint probability approach has been applied.

4.2 Coastal Flood Construction Level Assessment

The coastal flood construction level using the probabilistic approach is the sum of:

- 1-in-200 AEP total water level as determined by probabilistic analyses of tides and storm surge;
- Allowances for future SLR to the year 2100;
- Allowance for regional uplift or subsidence to the year 2100;
- Estimated wave effects associated with the designated storm with an 1-in-200 AEP; and
- Freeboard.

Each of these components are described in the following sections.

Predicted changes in storm intensity and frequency over the next 81 years, which could influence storm surge and wave effects, are highly variable and inconclusive. Such influence has not been incorporated in this analysis.

4.2.1 Joint Occurrence of Storm Surge and Tides

Coastal flood levels for the 1-in-200 AEP was developed by applying the Empirical Simulation Technique (EST) on the long term observed data (66 years) at Point Atkinson (NHC, 2008). The EST method is recommended by the Coastal Hydraulics Laboratory (of the US Army Corps of Engineers) and FEMA for frequency related studies. The analysis determined that the 1-in-200 AEP water level is 2.89 m GD.

4.2.2 Sea Level Rise

Global climate change is expected to result in increased sea levels resulting from melting of global ice and increased ocean volume due to rising water temperature. Typically, projects are considered to have a service life of roughly 80-years, resulting in designs often considering projections to the year-2100. The BC Provincial Sea Dike Guidelines (BC Ministry of Environment, 2011c) recommends that SLR associated with global climate change will result in a base water level 1 m above that seen in the year 2000 by the year-2100. The rate of SLR is projected to increase as the climate warms (**Figure 4**). Therefore, any increase incorporated in the past 18 years is expected to be minimal and hence ignored.

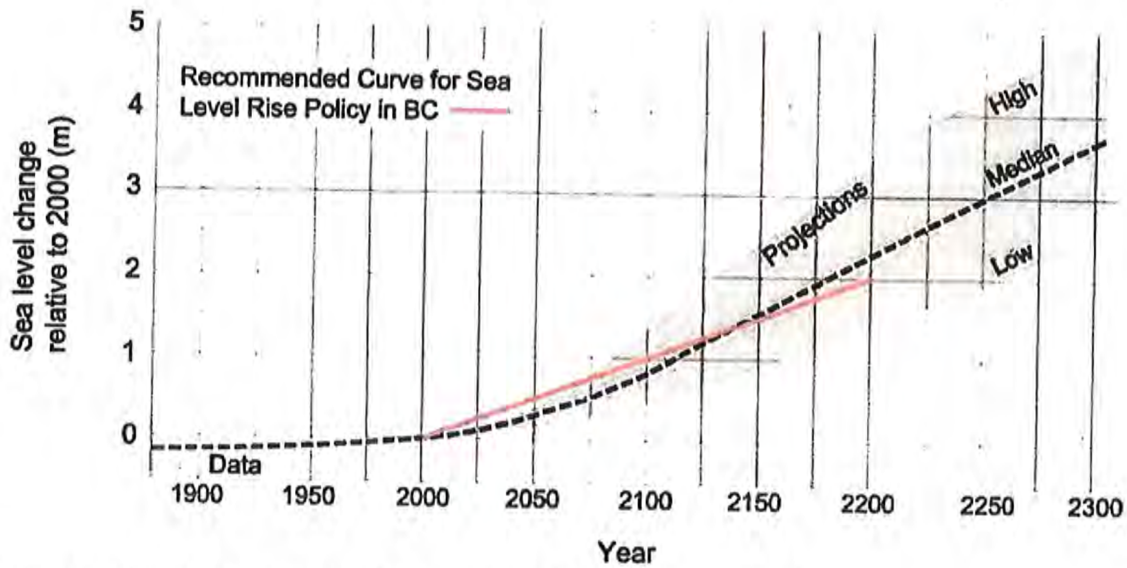


Figure 4. Projected climate change (BC Ministry of Environment, 2011c).

Note that the recommended SLR for planning and design in BC was based on a 2008 study by Fisheries and Oceans Canada (Thomson et al., 2008) and MOE (Bornhold, 2008). The authors of those works acknowledge the design SLR for BC is greater than the global mean SLR projected by the IPCC AR4 (2007) for the year 2100 (roughly 40 cm greater). However, more recent studies, such as IPCC AR5 (2014), suggests global mean SLR of up to 1 m or more by the year 2100. These values were based on the Paris Accord being adopted and adhered to, which appears not to be the case.

Other studies have investigated the potential effect of a collapse of the Antarctic ice sheet and have shown that such an event would result in far greater SLR, with estimates that are orders of magnitude larger than the 1 m to 2 m projected over then next 80-180 years. Recent changes in estimates of global mean SLR to the year 2100 or 2200 have not yet been addressed in the context of coastal BC, but based on recent conversations with FLNRORD, the province is amidst a study of SLR to update the 2011 design values. This study is not expected to be complete until April 2019.Despite the 1 m adopted by this flood hazard assessment, residents along the coast should therefore be aware that SLR could be substantially greater over the next 80-years, which may require raising, reconstruction, or relocation.

4.2.3 Local Subsidence

In addition to a rising sea, downward movement of the ground (subsidence) or upward movement (uplift) will influence the local relative sea level. Provincial guidelines (BC Ministry of Environment, 2011c) for local uplift are based on regional estimates and are less applicable than a more site-specific data source (Mazzotti et al., 2009), which suggests that subsidence for this location is on the order of -1 ± 0.5 mm/yr (**Figure 5**). To the year 2100, this translates to a lowering of 0.12 m.

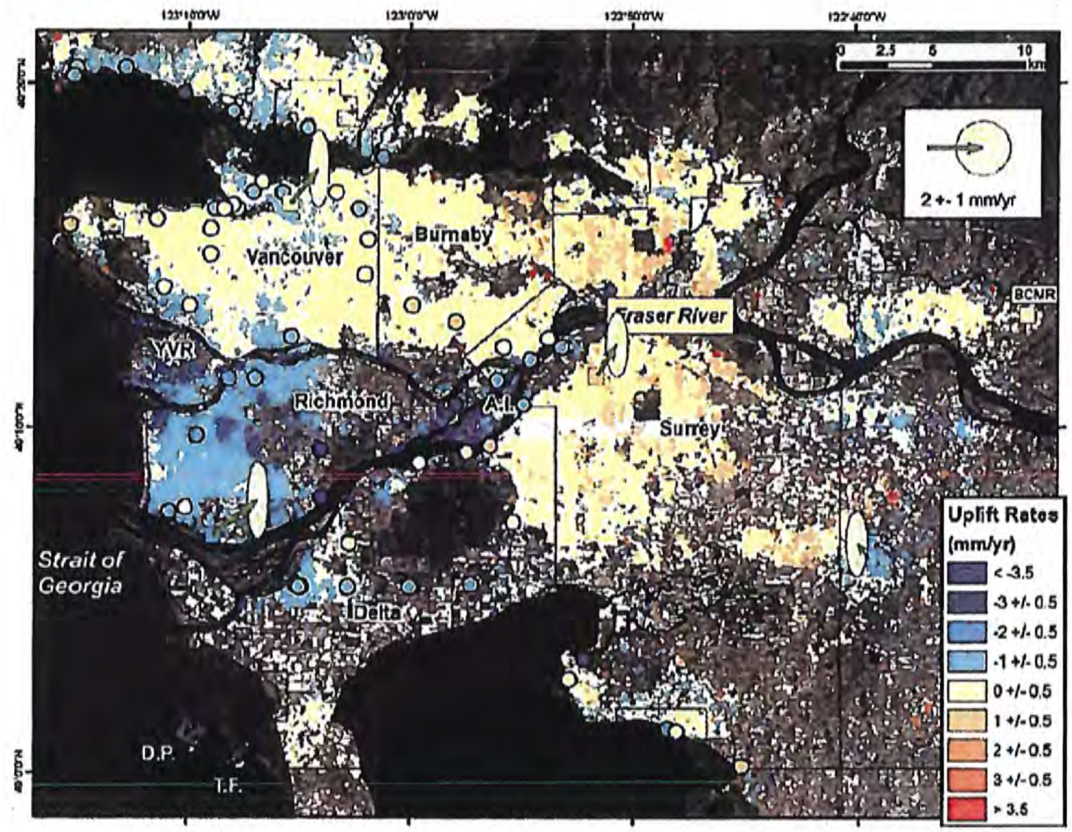


Figure 5. Local subsidence, shown as rate of uplift (Mazzotti et al., 2009).

4.2.4 Wind Analysis

There is one Meteorological Service of Canada (MSC) station in the vicinity of the study area that has a long-term record suitable for wind analysis: Point Atkinson. Twenty years of hourly wind data was used for the study, as summarized in **Table 2.**

Table 2. Point Atkinson station information.

Station	Station ID	Station Location	Period
Point Atkinson	1106200	480768 E 5464953 N	1997–2018

*No data is available for the period between 1959 and 1961.

The local wind climate can be visualized using a wind rose plot, utilizing arrows at the cardinal and inter-cardinal compass points to show the direction from which the winds blow and the magnitude and frequency for a given period. A wind rose showing the direction and magnitude of the winds at Point Atkinson is shown in **Figure 6.**

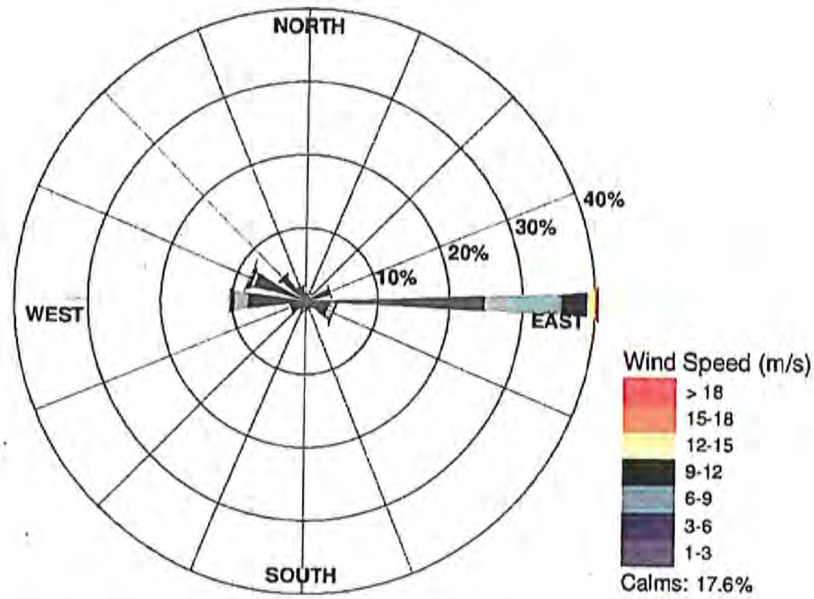


Figure 6. Wind rose based on data from Point Atkinson.

The wind rose shows that wind experienced at Point Atkinson is most frequently from the east and secondly from the west. Frequency analysis was conducted on the Point Atkinson data to obtain the wind speed for the design easterly and westerly storm events. The results are summarized in **Table 3** with the westerly winds being slightly faster than from the east for the same return frequency.

Table 3. Design wind speeds – Point Atkinson.

Event	Easterly		Westerly	
	Speed (m/s)	Speed (km/hr)	Speed (m/s)	Speed (km/hr)
1-in-5 year	20.4	73	21.0	76
1-in-10 year	20.9	75	22.3	80
1-in-50 year	22.2	80	25.2	91

The provincial guideline suggests that the wave effect is to be based on the 0.5% AEP storm event. However, NHC considers that establishing the FCL based on the 0.5% AEP storm event co-occurring with the 0.5% AEP water level (tide and surge) to be overly conservative. For this study, the 50-year (2% AEP) storm events were used to for the flood hazard assessment instead of the 200-year (0.5% AEP) storms.

4.2.5 Nearshore Wave Modelling Analysis

A nearshore wave model (Simulating Waves Nearshore or SWAN) of the Strait of Georgia and Burrard Inlet was developed to model wave generation and propagation from deep water into coastal areas and shorelines. SWAN incorporates physical processes such as wave propagation, wave generation by wind, white-capping, shoaling, wave breaking, bottom friction, sub-sea obstacles, wave setup and wave-wave interactions in its computations (Booij, N. et al., 2004). SWAN version 41.20 was used for this study.

Two model grid resolutions were used for the analysis: a fine grid model of the approaches at Burrard Inlet was nested in a coarse grid model of the Strait of Georgia. The coarse grid measures about 113 km southwest to northeast, and 253 km northwest to southeast, with each grid cell measuring 500 m by 500 m. The fine grid measures about 9 km east to west, and 8 km north to south, with each grid cell measuring 50 m by 50 m. The model's bathymetric grids were generated from digitized Canadian Hydrographic Charts and NOAA 3 arc-second resolution data.

The 50-year event (2% AEP) for each design wind directions (westerly and easterly) were used to drive the SWAN model. For each event, a spatially varying Strait of Georgia wind field was developed and applied to both the coarse and fine grid models. The regional wind stations used to generate the spatially varying wind field are presented in **Table 4**.

Model results showing the 50-year waves from the west and east are presented in **Figure 7**, **Figure 8**, and **Table 5**. Wave height is shown by colour shading, wave direction and relative heights are shown by vectors. The largest waves to reach the project site are from the east. The design significant wave height and mean wave period at the study area are from the east at 1.70 m and 4.64 seconds respectively.

Table 4. Regional wind data sources.

Station	Station ID	Period	Location
Entrance Island	EC ID 1022689	1994 – 2018 (Present)	49°12'31.195" N 123°48'38.001" W
Ballenas Island	EC ID 1020590	1994 – 2018 (Present)	49°21'01.000" N 124°09'37.000" W
Nanaimo Airport	EC ID 1025370	1954 – 2013	49°03'16.000" N 123°52'12.000" W
Nanaimo Airport	EC ID 1025365	2014 – 2018 (Present)	49°03'16.000" N 123°52'12.000" W
Sandheads CS	EC ID 1107010	1994 – 2018 (Present)	49°06'21.225" N 123°18'12.123" W
Saturna Island CS	EC ID 1017101	1994 – 2018 (Present)	48°47'02.067" N 123°02'41.082" W
Sisters Island	EC ID 2027403	1995 – 2018 (Present)	49°29'11.800" N 124°26'05.800" W
Victoria Int'l Airport	EC ID 1018620	1953 – 2013	48°38'50.010" N 123°25'33.000" W
Victoria Int'l Airport	EC ID 1018621	2013 – 2018 (Present)	48°38'50.000" N 123°25'33.000" W
Kelp Reefs	EC ID 1013998	1997 – 2018 (Present)	48°32'51.700" N 123°14'13.320" W
Halibut Bank	C46146	1992 – 2018 (Present)	49°20'24.000" N 123°43'48.000" W
Sentry Shoal	C46131	1992 – 2018 (Present)	49°54'36.000" N 124°59'24.000" W
Pat Bay	C46134	2001 – 2016	48°38'60.000" N 123°30'00.000" W

Table 5. Simulation results of design waves near project site

Event	Easterly Event		Westerly Event	
	Hs (m)	T (s)	Hs (m)	T (s)
1-in-50 year	1.70	4.64	1.41	5.37

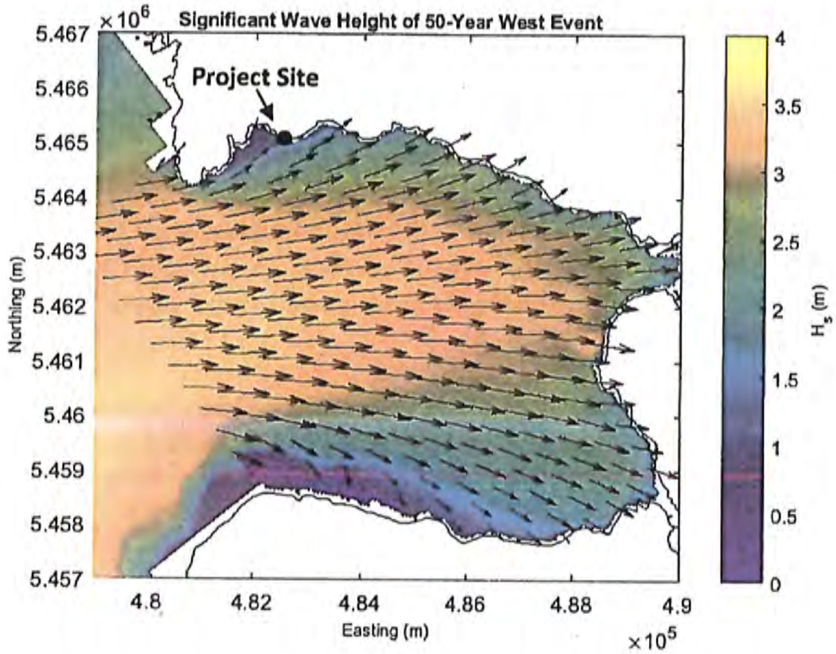


Figure 7. **Significant wave height (Hs) and direction for simulated 50-year westerly event.**

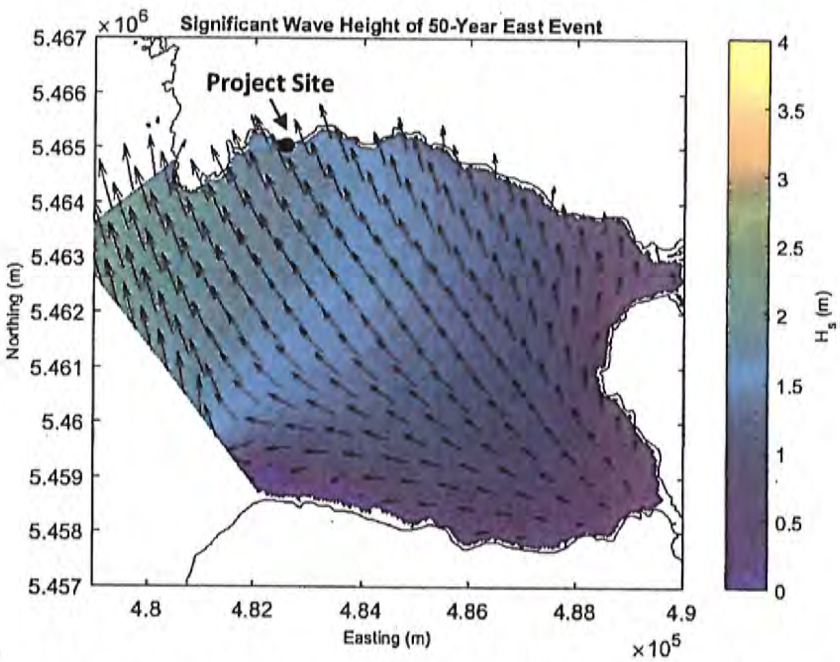


Figure 8. **Significant wave height (Hs) and direction for simulated 50-year easterly event.**

4.2.6 Wave runup and Wave Effect Assessment

Wave runup at the shoreline determines the extent over which waves act. Wave runup is therefore an important parameter to determine flood inundation extents from coastal storms. To determine the maximum wave runup, a Simulating Waves till Shore (SWASH) numerical model was developed to simulate the wave transformation, breaking and overflow on the shoreline (The SWASH team, 2018). For this study, SWASH version 5.01 was used.

To illustrate the effectiveness of the model to this type of application, **Figure 9** shows an example of the SWASH model results against the observed nearshore process during the December 20th, 2018 storm event in West Vancouver. A 20-second long model simulation video can be viewed at https://www.youtube.com/watch?v=qXIFPvBgelI.

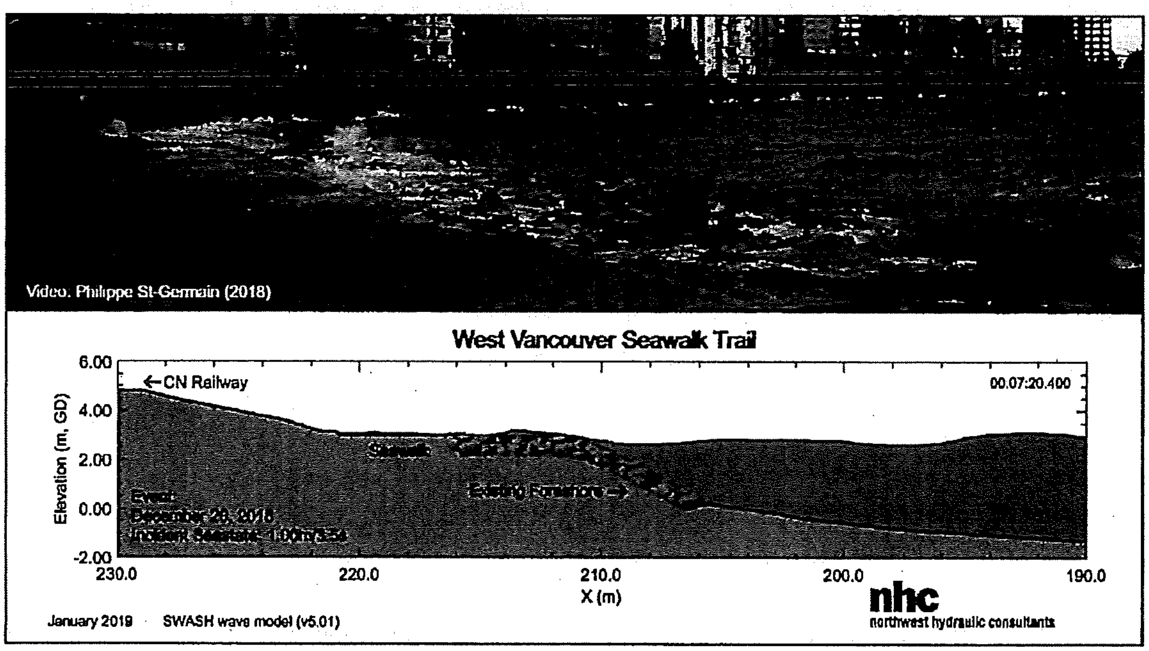


Figure 9. Numerical simulations of wave propagation and overtopping - December 20, 2018 storm event in West Vancouver.

Several simulations were performed as part of the wave runup analysis. A general profile of the study site was created using the architectural drawings provided by the client (**Appendix B**), the foreshore survey data collected during the site visit, and the bathymetry used in the SWAN model. Limited information with respect to the length of certain structural components was provided and therefore some assumptions have had to be made. From the south end of the building, an outdoor dining area was modelled, extending roughly 7 m towards the beach, at an elevation of 5.5 m GD. The outdoor area, is followed by a lawn area at an elevation of 4.78 m GD, transitioning into a beach garden (3.7 m GD) extending until the property limits.

Figure 10 shows a snapshot of the SWASH model output for the proposed design under the future design water level conditions. The result shows that the wave runups were calculated to be 0.9 m and

1.2 m under the current and future design water levels, respectively. The different wave runup values correspond to different DWL and foreshore geometry.

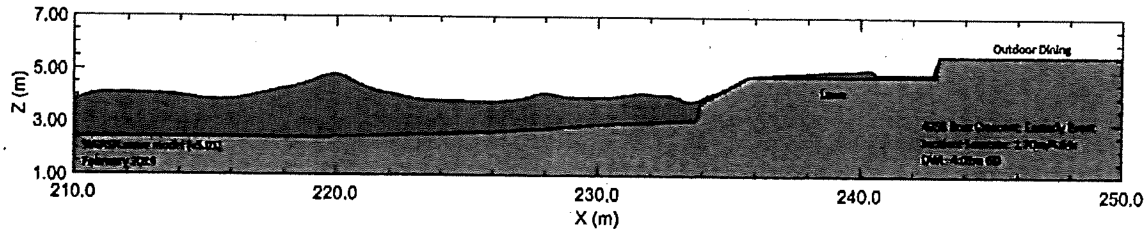


Figure 10. SWASH wave overtopping sample results - proposed design conditions.

Various configurations of soft engineering solutions and 'hard' engineering elements (e.g. concrete walls) were tested to determine if the wave runup component of the CFL could be mitigated. Given the low elevation of the lawn and beach garden proposed, a soft engineering solution is expected to have a limited effect on wave runup. Following discussions with the project architect, options for installing a concrete wall to reduce wave runup potential was not pursued.

4.2.7 Freeboard

The freeboard is applied to account for temporal and spatial variances in wave climate and surge, as well as precision of the calculation overall. Freeboard for infrastructure according to the amendment to the Flood Hazard Area Land Use Management Guidelines (BCMFLNRD, 2018) is 0.6 m when using the probabilistic approach.

4.2.8 Coastal Flood Construction Level

Table 6 summarizes the resulting FCL for the current condition and that predicted for the year 2100.

Table 6. Coastal flood construction levels.

FCL Input	Year 2019 Elevation (m)	Year 2100 Elevation (m) Proposed Design
Tide + storm surge (joint probability)	2.89	2.89
+ wave effect	0.86	1.19
+ Design sea level rise (to year 2100)	0	1.0
+ Subsidence (to year 2100)	0	0.12
Coastal flood level	3.75	5.20
+ Freeboard (m)	0.6	0.6
Flood construction level	**4.35**	**5.80**

Notes:
[1]CFL based on the ground elevation behind the wall.

4.3 Tsunami Hazard

In addition to wave and storm events, high water and coastal property inundation could potentially occur from a tsunami event. Previously denoted as tidal waves, the Japanese term tsunami, is now used to denote long period waves (5 to 60 minutes) that radiate out from the rapid displacement of a large volume of water. The initial displacement can result from an earthquake, landslide, volcanic eruption, glacier calving, or impact from a meteorite. However, major tsunami events generally are a result of earthquakes that produce substantial vertical movement of the sea floor in sufficiently shallow water.

Assessment of tsunami hazards are beyond the scope of this project, however previous studies suggest that the tsunami wave height reaching Vancouver Harbour would be roughly 10% of the tsunami wave height observed at Tofino on the west coast of Vancouver Island (Spaeth and Berkman, 1967) and that run up from a tsunami is expected to be less than 2 m on the North Shore from a tsunamis originating from the Pacific Ocean (Clague et al., 2005). Such an event would be extremely large on the west coast of Vancouver Island assuming the attenuation through the strait is roughly 10%.

The expected maximum tsunami run-up of less than 2 m would be for events far less frequent than the 200-year event, and when added to mean water high high tide (MWHHT), sea level rise, and subsidence, is still below the coastal derived FCL minus freeboard (El. 4.42 m versus El. 5.2 m).

5 RIVERINE FLOOD HAZARD ASSESSMENT

This riverine assessment considers flood hazards from Willow Creek, Claymore Creek and Cypress Creek. Historical flooding has been reported for the area resulting from Willow Creek and Claymore Creek (Vancouver Sun, 2016) and possibly also Cypress Creek (North Shore News, 2016). The Pacific Stream Keepers Federation also reported the occurrence of flooding in 1975 and 1983. Recently, the District of West Vancouver updated the inlet of the Willow Creek at Keith Road by adding a new trash rack to intercept debris prior to culvert blockage. All three creeks are not expected to impose substantial hydrotechnical hazards on the site other than flood inundation. That is, avulsion, channel migration, scour, and erosion risk has not been further investigated. Exposed soils or steep slopes towards Burrard Inlet could suffer erosion during a riverine flood event, but such conditions are not expected for this site.

5.1 Riverine Flood Inundation

5.1.1 Hydrology

The Cypress Creek watershed is gauged; Willow Creek and Claymore Creek are not gauged and have no record of water level or discharge. Cypress Creek gauge data is available for only six years, which is not adequate for performing a reliable peak flow analysis. Therefore, flow was estimated using a regional analysis based on the long term data record from McKay Creek (WSC 08GA061, 1970-2012) and through use of the Rational method. Results from the regional analysis were transposed between sites using the equation $Q_1/Q_2 = (A_1/A_2)^n$; where *Q* is discharge, *A* is contributing watershed area, and *n* is a scaling factor estimated as 0.75 as per Eaton et al (2002). Results of the analysis are shown in the following table (**Table 7**).

To account for climate change, changes to rainfall intensity were investigated using an IDF-CC tool (intensity-duration-frequency climate-change). This suggests an increase in precipitation intensity of 13% to 30% for the 200-year event to the year 2100. The impact to flow may be variable due to changes in snow-pack, timing of events, and ground cover. However, adoption of 30% increase was assumed for this analysis to remain conservative.

Table 7. Design flood flows.

Variable	McKay	Claymore	Willow	Cypress
Watershed area (km^2)	3.6	0.6	0.9	11.8
2-year flow (m^3/s)	5.6	1.5	2.0	13.6
5-year flow (m^3/s)	8.0	2.1	2.8	19.5
10-year flow (m^3/s)	9.9	2.6	3.5	24.2
20-year flow (m^3/s)	11.9	3.1	4.2	29.0
50-year flow (m^3/s)	15.4	4.0	5.4	37.4
100-year flow (m^3/s)	17.7	4.6	6.3	43.2
200-year flow (m^3/s)	20.3	5.3	7.2	49.4
Year 2100, 200-year flow	26.4	6.9	9.3	64.2

5.1.2 Hydraulic Analysis

Since Cypress Creek is located about 30 m east of the property and its 200-year flood flow is roughly eight times larger compared to the other creeks located further from the site, the riverine flood hazard analysis was conducted only for Cypress Creek. To predict flood levels resulting from 200-year flood flows (0.5% AEP) with allowance for climate change, a one-dimensional hydraulic model was constructed using the US Army Corps of Engineers' HEC-RAS software based on Cypress Creek sections and channel slope information collected in the field. To be conservative, it is assumed that the 200-year flood flow (64 m^3/s) coincides with the future 200-year tide level of 4.01 m GD. Manning's roughness value of 0.07, which is the maximum value for channel bed consisting of cobbles with large boulders, was applied.

The model results suggest the flow will overtop the existing bank (elevation at 4.4 m GD) and flood the neighbouring area. The predicted flood depth is about 1.0 m with maximum velocity of 2 m/s. The current road elevation is at 3.5 m. With consideration of 0.6 m freeboard, the riverine FCL value is **5.1 m**. Overland velocities could be high enough to induce erosion and scour if ground cover is not maintained. The riverine FCL is below the coastal FCL, which is considered to govern for the main residence facing the ocean. The garage/studio that is proposed to be constructed at the back of the property (portion of the lot facing Ross Crescent) would not be exposed to elevated flood hazard resulting from wave runup and so the riverine FCL is considered to govern at this location.

6 SUMMARY AND RECOMMENDATIONS

A hydrotechnical flood hazard assessment was conducted for the subject property at 4358 Ross Crescent. It has been found that flooding originating from Burrard Inlet is the governing hazard. From this study, the following recommendations are made for safe use of the property:

1) The calculated riverine flood depth is less than that calculated for coastal flooding, therefore the coastal FCL should be adopted for the main residence while the riverine FCL should be adopted for the garage/studio located near Ross Crescent.

2) The 2100-year design coastal FCL for the project site was found to be 5.8 m GD for the proposed development, including the main residence.

3) The riverine design FCL for the garage/studio structure located at the back of the property adjacent to Ross Crescent was found to be 5.1 m GD.

4) Building entrances and windows to habitable space should be at or above the applicable FCL.

5) The underside of any wooden floor system, or the top of any concrete floor system used for habitation should be above the applicable FCL. An exception to this recommendation for wooden floor systems can be made if the underside of the wooden floor system is inset inside and below the top of concrete foundation, in which case the top of concrete foundation should be above the applicable FCL.

6) No enclosed space to be used for habitation or storage of goods that can be damaged by floodwaters should be below the FCL. An exception to this recommendation can be made if suitable provisions are made to design the space below the FCL such that flood waters cannot enter the space; for instance, a 'floodproof' basement is designed and certified by a qualified engineer.

7) All main electrical and mechanical infrastructure are to be above the applicable FCL. Any electrical supply below the FCL (i.e. outlets or lighting) should be protected by GFCI (ground fault circuit interruption) located above the FCL. . Mechanical infrastructure may be located within a floodproof enclosed space below the FCL if the provisions of Recommendation #4 (above) are met.

8) The residence is set back from the edge of water a minimum of 15 m. Additional set back improves options to address further increases in SLR that may occur as well as shoreline erosion if it becomes a problem in the future.

9) If the site is landscaped with isolated low lying ground between the properties boundary with Burrard Inlet and the proposed residence, than stormwater drainage is designed to accommodate potential spray and overtopping.

10) Any ingress or egress routes existing above the applicable FCL are adequate for evacuation during a flood with loss of electrical power.

11) From all areas below the applicable FCL (i.e. underground parking) an unobstructed means of pedestrian ingress and egress is provided above the FCL, suitable for use under loss of electrical power.

12) Final building plans should be reviewed by qualified registered engineer to ensure they meet the recommendations presented within this FHA.

In addition, it is recommended that the property owner monitor and inspect their property for erosion and beach degradation twice a year to allow further investigation and mitigation if either become a problem in the future.

This flood hazard assessment was conducted following EGBC 2018 Class 1 flood hazard assessment guidelines. A summary of the EGBC criteria for such an assessment is presented in **Table 8.** Hazards other than flood hazards from the Burrard Inlet and the adjacent creeks, such as geotechnical, fire, and wildlife hazards have not been assessed as part of this assessment. Stormwater and sediment management has not been designed or assessed through this study and may also impose hazards if not adequately addressed.

Table 8. Summary of EGBC typical Class 1 flood hazard assessment methods and deliverables

EGBC Flood Hazard Assessment Component	Notes
Typical hazard assessment methods and climate/environmental change considerations	
Site inspection and qualitative assessment of flood hazard	Completed by NHC 2019
Identify any very low hazard surfaces in the consultation area (i.e., river terraces)	Completed by NHC 2019
Estimate erosion rates along river banks	River erosion not applicable to site. Coastal erosion not evident.
1-D or possibly 2-D modelling, modelling of fluvial regime and future trends in river bed changes, erosion hazard maps, possibly paleoflood analysis	2-D coastal and 1-D riverine completed by NHC 2019
Identify upstream or downstream mass movement processes that could change flood levels (e.g., landslides leading to partial channel blockages, diverting water into opposite banks)	Potential blockage of culvert or sediment deposition in the channel considered possible mechanism of the flood scenario
Conduct simple time series analysis of runoff data, review climate change predictions for study region, include in assessment if considered appropriate	Completed by NHC 2019 including allowance for climate change as recommended by MWLAP (2004)
Quantify erosion rates by comparative air photograph analysis	N/A – erosion risk deemed low
Typical deliverables	
Letter report or memorandum with at least water levels and consideration of scour and bank erosion	Completed
Cross-sections with water levels, flow velocity and qualitative description of recorded historic events, estimation of scour and erosion rates where appropriate with maps showing erosion over time	Flow descriptions completed. Erosion risk deemed low

EGBC Flood Hazard Assessment Component	Notes
Maps with area inundated at different return period, flow velocity, flow depth, delineation of areas prone to erosion and river bed elevation changes, estimates of erosion rates	Areas and elevations inundated during the 200-year return period design event described

7 CLOSURE

We hope this work and report meets your current needs. If you have any questions don't hesitate to contact Derek Ray or Edwin Wang by phone **604-980-6011** or email (dray@nhcweb.com | ewang@nhcweb.com).

Sincerely,

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DISCLAIMER

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Consultants Ltd. at the time of preparation, and was prepared in accordance with generally accepted engineering practices.

Except as required by law, this report and the information and data contained herein are to be treated as confidential and may be used and relied upon only b[redacted] its officers and employees. **Northwest Hydraulic Consultants Ltd.** denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents.

REFERENCES

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Appendix A

Flood Hazard and Risk Assurance Statement

APPENDIX J: *FLOOD HAZARD* AND *RISK* ASSURANCE STATEMENT

Note: This Statement is to be read and completed in conjunction with the "*APEGBC Professional Practice Guidelines - Legislated Flood Assessments in a Changing Climate,* March 2012 ("*APEGBC* Guidelines") and is to be provided for *flood assessments* for the purposes of the *Land Title Act*, Community Charter or the *Local Government Act*. Italicized words are defined in the *APEGBC* Guidelines.

To: The *Approving Authority* Date: 2019-03-22

Planning, Permit, and Properties, District of North Vancouver

4358 Ross Crescent, West Vancouver, BC V7V 3A7

Jurisdiction and address

With reference to (check one):

- ☐ Land Title Act (Section 86) – Subdivision Approval
- ☐ Local Government Act (Sections 919.1 and 920) – Development Permit
- ☑ Community Charter (Section 56) – Building Permit
- ☐ Local Government Act (Section 910) – Flood Plain Bylaw Variance
- ☐ Local Government Act (Section 910) – Flood Plain Bylaw Exemption

For the Property:

Lot A, Block 7, District Lot 582, Group 1, New Westminster District, Plan 6662

Legal description and civic address of the Property

The undersigned hereby gives assurance that he/she is a *Qualified Professional* and is a *Professional Engineer* or *Professional Geoscientist.*

I have signed, sealed and dated, and thereby certified, the attached flood assessment report on the Property in accordance with the APEGBC Guidelines. That report must be read in conjunction with this Statement. In preparing that report I have:

Check to the left of applicable items

✓ 1. Collected and reviewed appropriate background information
✓ 2. Reviewed the proposed *residential development* on the Property
✓ 3. Conducted field work on and, if required, beyond the Property
✓ 4. Reported on the results of the field work on and, if required, beyond the Property
✓ 5. Considered any changed conditions on and, if required, beyond the Property
6. For a *flood hazard* analysis or *flood risk* analysis I have:
   - ✓ 6.1 reviewed and characterized, if appropriate, floods that may affect the Property
   - ✓ 6.2 estimated the *flood hazard* or *flood risk* on the property
   - ✓ 6.3 included (if appropriate) the effects of climate change and land use change
   - ✓ 6.4 identified existing and anticipated future *elements at risk* on and, if required, beyond the Property
   - ✓ 6.5 estimated the potential *consequences* to those *elements at risk*
7. Where the *Approving Authority* has adopted a specific level of *flood hazard* or *flood risk* tolerance or return period that is different from the standard 200-year return period design criteria(1), I have
   - ✓ 7.1 compared the level of *flood hazard* or *flood risk* tolerance adopted by the *Approving Authority* with the findings of my investigation
   - ✓ 7.2 made a finding on the level of *flood hazard* or *flood risk* tolerance on the Property based on the comparison
   - ✓ 7.3 made recommendations to reduce the *flood hazard* or *flood risk* on the Property

(1) *Flood Hazard Area Land Use Management Guidelines* published by the BC Ministry of Forests, Lands , and Natural Resource Operations and the 2009 publication *Subdivision Preliminary Layout Review – Natural Hazard Risk* published by the Ministry of Transportation and Public Infrastructure. It should be noted that the 200-year return period is a standard used typically for rivers and purely fluvial processes. For small creeks subject to debris floods and debris flows return periods are commonly applied that exceed 200 years. For life-threatening events including debris flows, the Ministry of Transportation and Public Infrastructure stipulates in their 2009 publication *Subdivision Preliminary Layout Review – Natural Hazard Risk* that a 10,000-year return period needs to be considered.

8. Where the *Approving Authority* has **not** adopted a level of *flood risk* or *flood hazard* tolerance I have:

NA 8.1 described the method of *flood hazard* analysis or *flood risk analysis* used

NA 8.2 referred to an appropriate and identified provincial or national guideline for level of *flood hazard* or *flood risk*

NA 8.3 compared this guideline with the findings of my investigation

NA 8.4 made a finding on the level of *flood hazard* of *flood risk* tolerance on the Property based on the comparison

NA 8.5 made recommendations to reduce *flood risks*

NA 9. Reported on the requirements for future inspections of the Property and recommended who should conduct those inspections.

Based on my comparison between

Check one

- ☐ the findings from the investigation and the adopted level of *flood hazard* or *flood risk* tolerance (item 7.2 above)
- ☑ the appropriate and identified provincial or national guideline for level of *flood hazard* or *flood risk* tolerance (item 8.4 above)

I hereby give my assurance that, based on the conditions contained in the attached flood assessment report,

Check one

- ☐ for subdivision approval, as required by the *Land Title Act* (Section 86), "that the land may be used safely for the use intended".

  Check one
  - ☐ with one or more recommended registered *covenants*.
  - ☐ without any registered *covenant*.
- ☑ for a development permit, as required by the *Local Government Act* (Sections 919.1 and 920), my report will "assist the local government in determining what conditions or requirements under [Section 920] subsection (7.1) it will impose in the permit".
- ☐ for a building permit, as required by the Community Charter (Section 56), "the land may be used safely for the use intended".

  Check one
  - ☑ with one or more recommended registered *covenants*.
  - ☐ without any registered *covenant*.
- ☐ for flood plain bylaw variance, as required by the *Flood Hazard Area Land Use Management Guidelines* associated with the *Local Government Act* (Section 910), "the development may occur safely".
- ☐ for flood plain bylaw exemption, as required by the *Local Government Act* (Section 910), "the land may be used safely for the use intended".

Derek Ray

Name [redacted]

Signa [redacted]

2019-03-22

Date

Address

30 Gostick Place, North Vancouver, BC V7M 3G3

604-980-6011

Telephone

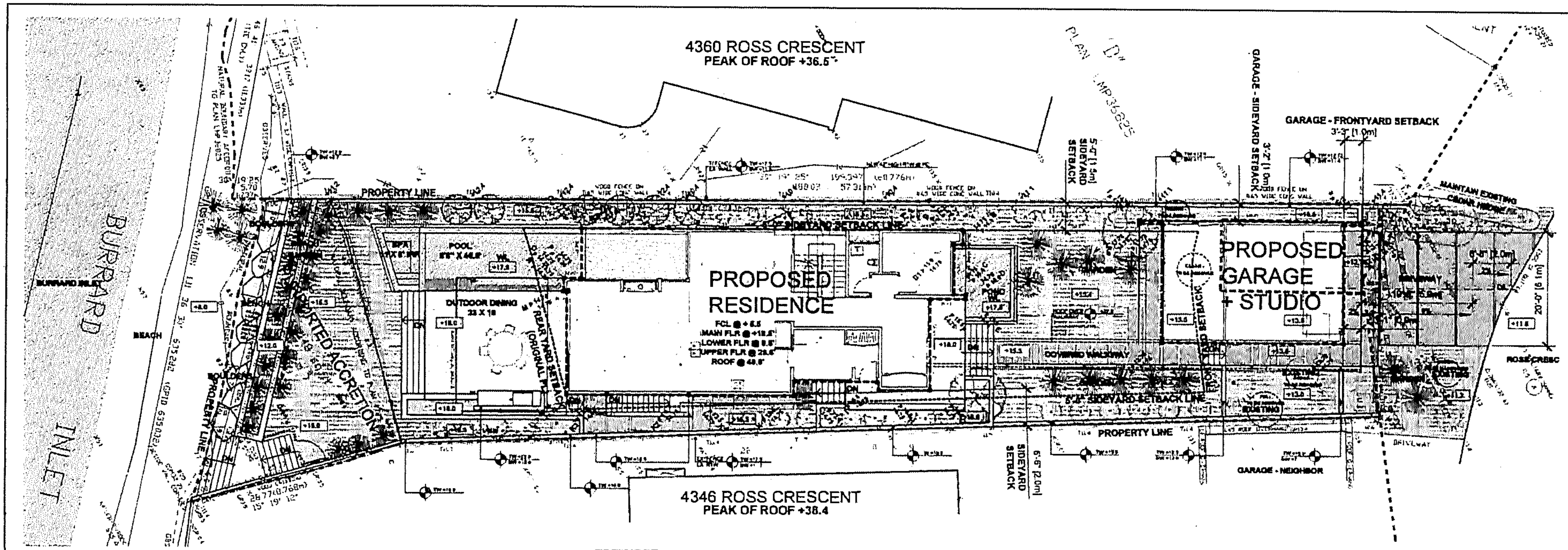
(Affix Professional seal here)

If the *Qualified Professional* is a member of a firm, complete the following.

I am a member of the firm Northwest Hydraulic Consultants Ltd. (NHC)
(Print name of firm)
and I sign this letter on behalf of the firm.

Appendix B

Received Design Drawings



PROJECT STATISTICS

LOT ADDRESS

LEGAL DESCRIPTION:

ZONING

LOT AREA

SITE COVERAGE

FLOOR AREA RATIO

BUILDING + GARAGE SETBACKS

SETBACKS	CURRENT	BYLAW	PROPOSED	BASED ON ACCRETION	VARIANCE REQUIRED	NOTES
FRONT YARD HOUSE	74.278'	30'	70.83'	N/A	NO	
REAR YARD HOUSE	41'	30'	30'	17'	NO	
SIDEYARD EAST	3.48'	6'		N/A	NO	
SIDEYARD WEST	4.3'	5'	5'	N/A	NO	
COMBINED SIDEYARD	7.78'	12'	11.5'	N/A	YES	
FRONT YARD GARAGE	0.17'	30'	3.2'	N/A	YES	This will also trigger roof setback.
SIDEYARD WEST GARAGE	2.78'	6'	3.2'	N/A	YES	This will also trigger roof setback.

TO BE UPDATED

FRONT YARD PAVED AREA

BUILDING HEIGHT

TO BE UPDATED

GARAGE/STUDIO HEIGHT

TO BE UPDATED

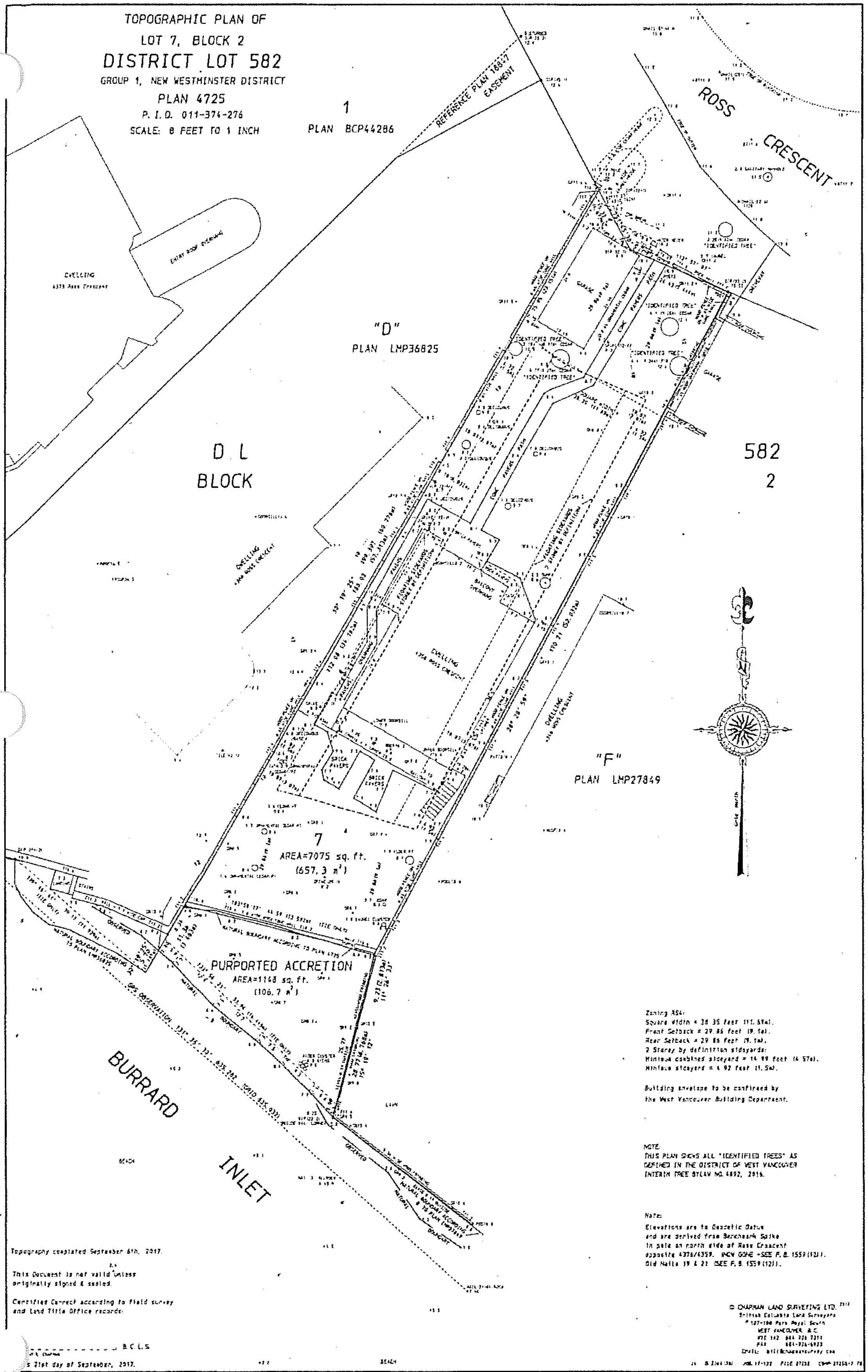
HLYNSKY + DAVIS ARCHITECTS INC.

s. 22(1)

4350 ROSS CRESC
W VAN, BC

SITE PLAN

A1.2



TOPOGRAPHIC PLAN OF
LOT 7, BLOCK 2
DISTRICT LOT 582
GROUP 1, NEW WESTMINSTER DISTRICT
PLAN 4725
P. I. D. 011-374-276
SCALE: 8 FEET TO 1 INCH
1
PLAN BCP44286
REFERENCE PLAN 18807
EASEMENT
ROSS
CRESCENT
"D"
PLAN LMP36825
D. L
BLOCK
582
2
"F"
PLAN LMP27849
7
AREA=7075 sq. ft.
(657.3 m²)
PURPORTED ACCRETION
AREA=1148 sq. ft.
(106.7 m²)
BURRARD
INLET
NOTE:
THIS PLAN SHOWS ALL "IDENTIFIED TREES" AS
DEFINED IN THE DISTRICT OF WEST VANCOUVER
INTERIM TREE BYLAW NO. 4892, 2016.
© CHAPMAN LAND SURVEYING LTD.
WEST VANCOUVER, B.C.
This Document is not valid unless originally signed & sealed.
Certified Correct according to field survey and Land Title Office records.
B.C.L.S.
21st day of September, 2017.

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APPENDIX B

Director	CAO

COUNCIL AGENDA
Date: ~~July 15, 2019~~ June 24, 2019 Item: ~~R-1~~ 8

DISTRICT OF WEST VANCOUVER

750 17TH STREET, WEST VANCOUVER BC V7V 3T3

COUNCIL REPORT

Date:	June 4, 2019
From:	Michelle McGuire, Manager of Current Planning and Urban Design
Subject:	Rezoning and Development Variance Permit for 4358 Ross Crescent
File:	1010-20-18-039 and 1010-20-18-037

RECOMMENDATION

Proposed "Zoning Bylaw No. 4662, 2010, Amendment Bylaw No. 5028, 2019" be read a first time.

RECOMMENDATION

Proposed "Zoning Bylaw No. 4662, 2010, Amendment Bylaw No. 5028, 2019" be presented at a public hearing scheduled for July 15, 2019 at 5 p.m. in the Municipal Hall Council Chamber, and that notice be given of the scheduled public hearing.

RECOMMENDATION

Proposed Development Variance Permit No. 18-037 be presented at a public meeting scheduled for July 15, 2019 at 5 p.m. in the Municipal Hall Council Chamber, to be held concurrently with the public hearing scheduled for July 15, 2019 at 5 p.m. in the Municipal Hall Council Chamber, and that notice be given of the scheduled public meeting.

1.0 Purpose

The purpose of this report is to:

- rezone a portion of land from M1 (Marine 1) to RS4 (Single Family Dwelling Zone 4) to consolidate the zoning for the subject site at 4358 Ross Crescent (**Appendix A**); and
- provide for variances proposed as part of the single family house proposal to accommodate development relative to the flood construction level along with variances to accommodate building siting for side yard setbacks and the front yard permeability restriction.

2.0 Legislation/Bylaw/Policy

Provincial Legislation

The *Local Government Act* requires that a public hearing be held on the proposed rezoning bylaw and that Council consider Development Variance Permits.

For development sites that may be subject to flooding such as 4358 Ross Crescent, section 56 of the *Community Charter* authorizes the District's Chief

Building Inspector to require a qualified professional report to certify the conditions under which the land may be used safely for the intended use. Furthermore, on this basis, a building permit may only be issued following the condition that the owner of the land covenants with the municipality to use the land in accordance with the conditions specified in the qualified professional's report.

Official Community Plan (OCP)

The OCP supports the development of updated shoreline protection strategies and flood construction level requirements to protect lands from sea level rise, reduce shoreline erosion, preserve and enhance habitat. The development proposal is consistent with the OCP.

Zoning Bylaw

Due to the accretion of private land along the foreshore, the site is split-zoned RS4 (Single Family Dwelling Zone 4) and M1 (Marine 1). A rezoning is required to consolidate the zoning of the subject site as RS4.

3.0 Background

3.1 Previous Decisions – Not applicable.

3.2 History

A rezoning and development variance permit application was originally submitted on March 15, 2018 to redevelop 4358 Ross Crescent with a new single family house. The initial application was reviewed by staff and further information was requested. As the site at 4358 Ross Crescent is in a coastal area that may be subject to flooding, staff requested a report from a suitably qualified professional to consider flood construction levels and specify how the land and any buildings or other structures within the land would be constructed safely for the proposed residential use. Consideration of the qualified professional report is based on the Province's Flood Hazard Area Land Use Management Guidelines (the "Provincial Guidelines"), in particular sections 3.5 and 3.6, which deal with climate change and sea level rise expected by the year 2100. In addition, the report is to be prepared in accordance with the most recent edition of the Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC (published by the Association of Professional Engineers and Geoscientists of BC).

3.3 Developing a Flood Construction Level for West Vancouver

With the increased risk of flooding due to climate change and sea level rise staff are conducting analysis to develop policy and/or regulations to address the risk of coastal flood impacts. Section 524 of the Local Government Act, "the Act", authorizes the District to designate, as a floodplain, land Council considers may be subject to flooding. Once the District designates land as a floodplain under section 524 of the Act, the District may also specify what is commonly known as a flood construction level for that land. In addition, or alternatively, the District can regulate development in areas prone to flooding by establishing one or more development permit areas under section 488 of the Local Government Act.

In the absence of a bylaw under section 524 of the Act, or a development permit area designation under section 488, there is no legislated "flood construction level" for any particular property in West Vancouver. However, this does not mean the District is obliged to approve permits for construction on land that might be subject to flooding. Section 56 of the Community Charter specifically authorizes the Chief Building Inspector to require "safe use" certifications. In the case of development variance permits, it's open to Council to require an applicant to provide some evidence, for example in the form of a professional certification, that the proposed construction is safe for the intended use. The District requires that homes are constructed that are not knowingly predisposed to flooding events and are safe for habitation. Staff requested that the applicant provide materials from a qualified professional using the most up to date guidelines and data (i.e. the amended provincial regulations and Professional Practice Guidelines) to satisfy this requirement.

4.0 Analysis

4.1 Discussion

Site and Context

The site is located in the Stearman Beach area along the south side of Ross Crescent directly adjacent to the Burrard Inlet (Figure 1). The site is bounded by two single family properties to the west and east, Ross Crescent to the north and Burrard Inlet to the south. The subject site and sites in the surrounding Stearman Beach area are relatively low lying with sites along the waterfront that may be subject to flooding due to storm events and sea level rise.

The Proposal

On April 4, 2019 an updated development variance permit application was submitted with the proposed certified report in draft format including the proposed flood construction level and corresponding plans proposing construction of a new single-family house and garage.

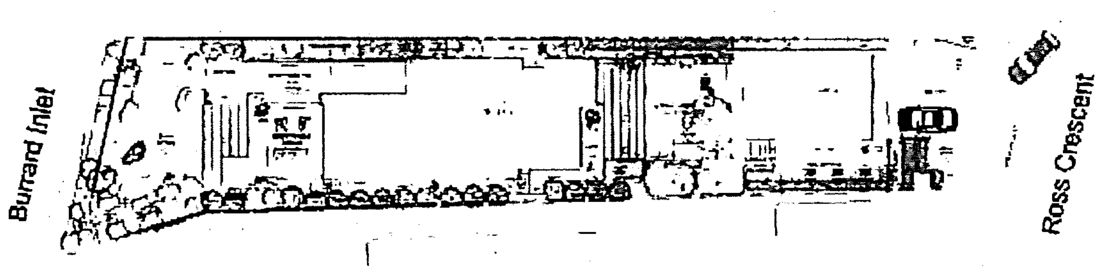


Figure 1: Site Plan

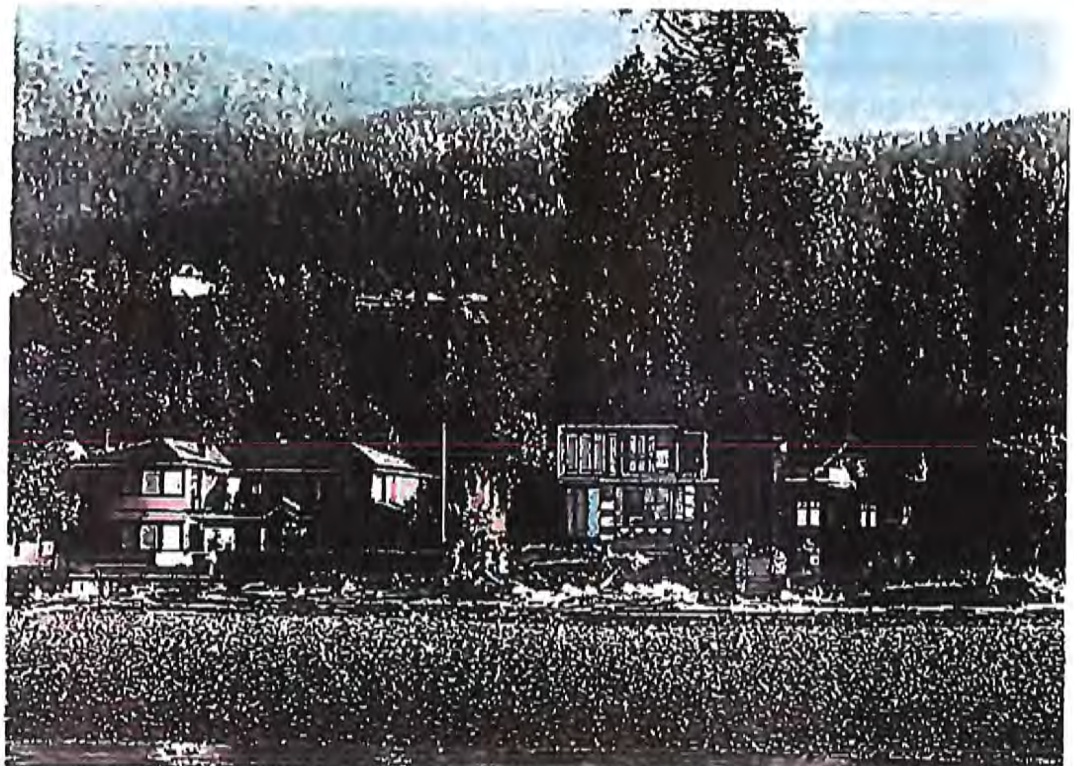


Figure 2: Rendering of the proposed house (looking north from the water)

Key features of the proposal include:

- a 2,878 sq. ft. two-storey house;
- a detached storage building and garage located along Ross Crescent; and
- a "closed" foundation including a basement proposed below the flood construction level with construction requirements specified in the certified report to protect the space from flooding.

In order to accommodate development of the site safe for the proposed uses and the corresponding recommended flood construction level the proposal includes retaining walls at the east and west edges of the site with terracing up to the main level of the house (See Figure 3). To mitigate the impact of increasing grade at the east and west edges of the site all retaining walls are designed to limit the exposed face to 4.0 ft. or less. As well, the application is proposing landscaping along the east and west edges of the site to provide screening and mitigate privacy and overlook impacts.

The "closed" foundation including the basement is proposed as an exception to the requirements under sections 3.5 and 3.6 of the Provincial Guidelines. Staff note that the proposed construction requirements for living space below the flood construction level result in significant excavation of the site to accommodate the necessary engineered fill and associated structure and appurtenances.

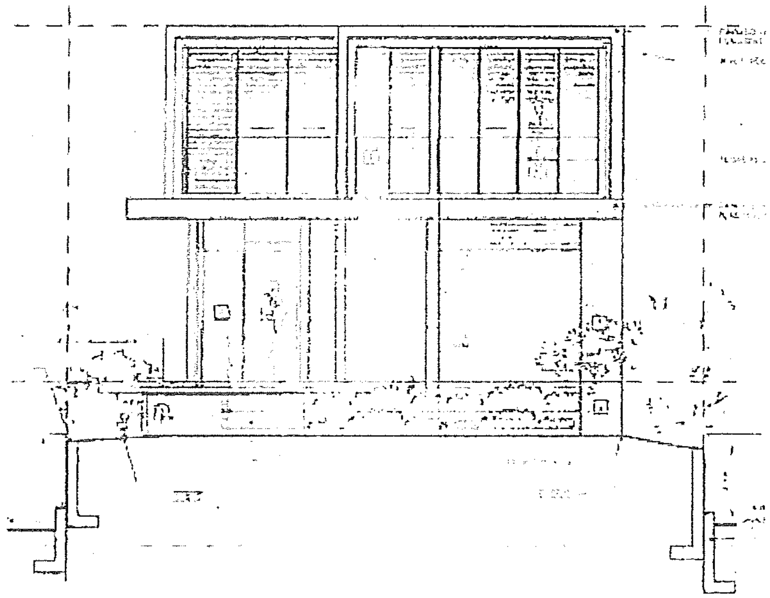


Fig. ... Elevation

Proposed Zoning Variances

The proposed zoning variances are as follows:

- Side Yard and Combined Side Yard:
  - House - The minimum combined side yard in the zoning bylaw is 4.6 m (15 ft.). The existing house is located 1.1 m (3.5 ft.) from the east property line and 1.3 m (4.3 ft.) from the west property line (combined at 2.2 m/7.25 ft. less than what is required). The proposed combined side yard setback is 3.5 m (11.5 ft.) with the east setback at 2.0 m (6.5 ft.) and the west setback at 1.5 m (5 ft.), proposing a variance of 1.1 m (3.5 ft.). For both the west and east side yard setbacks the required minimum of 1.5 m (5 ft.) is provided.
  - Garage - For the existing garage the west side yard is 0.8 m (2.75 ft.) whereas the zoning by-law requires a minimum side yard of 1.5 m (5 ft.). The proposed garage increases the west setback from 0.8 m (2.75 ft.) to 1.0 m (3.2 ft.), proposing a variance of 0.5 m (1.6 ft.).

  Staff are supportive of the proposed side yard setbacks as they increase the distance to adjacent properties as compared to the existing garage and house. As well, for the primary house although the combined sideward setback is 1.1 m less than what is required, the minimum side yards are met. Staff also note that the adjacent house to the east is non-conforming with a side yard less than 1.5 m (5 ft.).

- Front Yard: The minimum front yard in the zoning bylaw is 9.1 m (30 ft.). The existing garage is located 0.06 m (0.2 ft.) from the front property line.

The front yard setback for the proposed garage is 1.0 m (3.2 ft.). As a minor variance is proposed for roof overhang of the garage that extends 0.4 m into the front yard.

Staff support the variance for the front yard for the garage as it increases the distance to the front property line compared to the existing garage and it allows for reduced driveway paving in the front yard. As well, staff note that the existing boulevard width is 16 - 27 ft. in depth and provide a significant buffer from Ross Crescent. Staff note that there are other garages in the area located in similar locations in the front yard of sites

- Front Yard Permeability: The maximum amount of area in the front yard that is allowed to be impermeable is 50%. Due to the location of the proposed garage the proposed impermeable area is increased to 58%.

  Staff support the proposed variance for front yard permeability as the variance is minor and allows for locating the proposed garage within the front yard which minimizes the need for additional driveway paving and vehicle manoeuvering within or onto the site.

- Variances for calculation of average grade based on Flood Construction Level (5.8 m/19.0 ft.)
  - Building Height: The maximum building height in the zoning bylaw is 7.6 m (25 ft.) measured from the lower of average finished or natural grade. The proposed house will be approximately 6.7 m (22 ft.) in height above the flood construction level at 5.8 m (19 ft.) geodetic elevation. This requires a variance for how building height is measured to be calculated using the flood construction level as average grade.
  - Garage Height: The maximum accessory building height in the zoning bylaw is 3.7 m (12.1 ft.) measured from the lower of average finished or natural grade. The proposed variance would permit the accessory building height to be calculated using the flood construction level as average grade.
  - Highest Building Face Envelope: The maximum highest building face in the zoning by-law is 6.7 m (22 ft.). The proposed variance would permit the highest building face envelope to be calculated using the flood construction level at 5.8 m (19.0 ft.) geodetic elevation as average grade.
  - Basement: A basement is defined in the zoning by-law as a storey, the level of which is located more than 0.3 m below the lower of average natural grade elevation or average finished grade elevation. The proposed house includes a basement level located below the flood construction level at 5.8 m (19 ft.) which is above natural grade. The proposed variance would permit the basement to be exempt from floor area calculations as it is located entirely underground and would not be visible at the new grade level.

- Retaining Walls: Retaining walls are measured from natural grade. For a waterfront site retaining walls are not permitted to exceed 4.0 ft. in height from natural grade within the extent of the waterfront yard. In order to accommodate terracing of the site along the west, east and waterfront edges up to the required flood construction level for the proposed house, retaining walls are proposed. The proposed variance would allow for the retaining walls as shown in the attached plans, however, they would be limited to 4.0 ft. or less in exposed face height.

  Staff support the proposed variances for building height, highest building face envelope, basement and retaining walls as the new flood construction level datum is necessary for calculating average grade in order to accommodate building higher in areas that may be subject to flooding. Staff also note that the overall building height is mitigated as the proposed height of the house is 6.7 m (22 ft.), 0.9 m (3.0 ft.) lower than the maximum of 7.6 m (25 ft.) under RS4 zoning.

Zoning Amendment

The zoning amendment is proposed to allow rezoning of a portion of the site (1,148 sq. ft.) along the water's edge from M-1 to RS-4 to amalgamate this portion into the larger site and consolidate the zoning across the whole site (Appendix C). The owner wishes to rezone the portion of accreted land to allow residential use of the area (such as garden and landscaping) and for additional floor area for the proposed house.

Staff are proposing to restrict the construction of hard surfaces and retaining walls within the area to be rezoned to align it with OCP policy to allow for flood protection of the subject property while minimizing use of retaining walls.

Staff support the propose zoning amendment as it:

- is consistent with the properties on either side where land has been accreted and is zoned RS4, and
- it does not allow the proposed house location to move closer to the waterfront, as the waterfront setback remains measured from the previously existing waterfront property line.

New developments where rezoning is proposed are typically expected to deliver Community Amenity Contributions (CACs) intended to address the growth related impacts of new development. The value of the amenity is expected to be proportional to the increased potential of land use in comparison with existing zoning. In this case, the accretion of land is where private land is increased due to natural processes along the foreshore. If the site were created today the M-1 zoned portion would not exist (i.e. the whole site would be zoned RS4) as this zone is intended to apply public foreshore lands. Secondly, it is noted that there are no growth related impacts as the proposal is for a single family house which can already be developed on the existing parcel (i.e. no increase in residential units). Therefore, staff do not recommend a CAC for the proposed rezoning.

4.2 Sustainability

As part of the proposed development variance permit conditions are included which secure a number of sustainability requirements including tree replacement at a minimum of 3:1, electric vehicle charging, solar panel conduit to enable solar panel installation and enhanced energy and sustainability performance measures for the building construction beyond baseline building code requirements.

4.3 Public Engagement and Outreach

Prior to submission of an application the owner hosted a public information meeting on June 26, 2018. The applicant submitted two comment forms received in response to the meeting. Both comment forms expressed support for either tree trimming or removal due to concerns about the size of the existing trees on site, however, it was noted in one form support for retaining the existing "eagle perch" tree. One comment form also noted support for the proposed house plans. Staff also met with an adjacent neighbour on two occasions to go over the submitted plans. Letters from the neighbour were received expressing concerns about the bulkiness and height of the proposed house, setbacks and generally with concerns about the proposed zoning variances.

Following receipt of an updated application with the accompanying draft detailed report staff created a District webpage and mailed a courtesy notice to surrounding property owners within 100 m of the subject site. In response to the notice two e-mails were received with concerns relating to the height of the proposal, increased grade of the site and the potential for flooding on adjacent sites due to the subject site being raised to the flood construction level.

In response to concerns about the increased grading of the site the applicant revised their plans to reduce retaining wall heights so that all walls were limited in height to 4.0 ft. or less of exposed face. With respect to the concern about flooding due to the increased grade of the subject site staff note that the site will be required to be designed so that stormwater runoff would not flow on to adjacent sites but rather would flow into the ocean. In response to concerns about building height and increased average grade, staff note that it is anticipated that other sites along the foreshore will also require increases in grade and building height to accommodate construction in an area that is subject to the risk of flooding.

Following first reading of the proposed bylaw and scheduling a public hearing by Council, staff will give notification of the public hearing and the proposed development variance permit consistent with District policy and legislated requirements to property owners, businesses, and residents. As well the owner will advertise and host a public information meeting as required by the Development Procedures By-law.

4.4 Other Communication, Consultation, and Research

Planning staff has consulted with District staff on the application and proposed conditions are included in the draft development variance permit addressing staff comments.

5.0 Options

5.1 Recommended Option

Give first reading to the proposed zoning amendment bylaw and consider the development variance permit concurrently with the zoning amendment.

5.2 Considered Options

a. Give first reading to the proposed bylaw and set an alternate date for the public hearing (to be specified); or

b. Request further information (to be specified); or

c. Reject the proposal.

6.0 Conclusion

If adopted, the proposed zoning amendment would consolidate the zoning for the subject site, while the development variance permit would accommodate construction of the proposed house and garage including considerations for development in an area that may be subject to flooding. The proposal is supported by the OCP that provides direction to proactively plan for coastal flooding of sites adjacent to the foreshore. The proposed construction of the house and garage are based on specifications of the certified draft report submitted as part of the application and are intended to mitigate the impacts of coastal flooding.

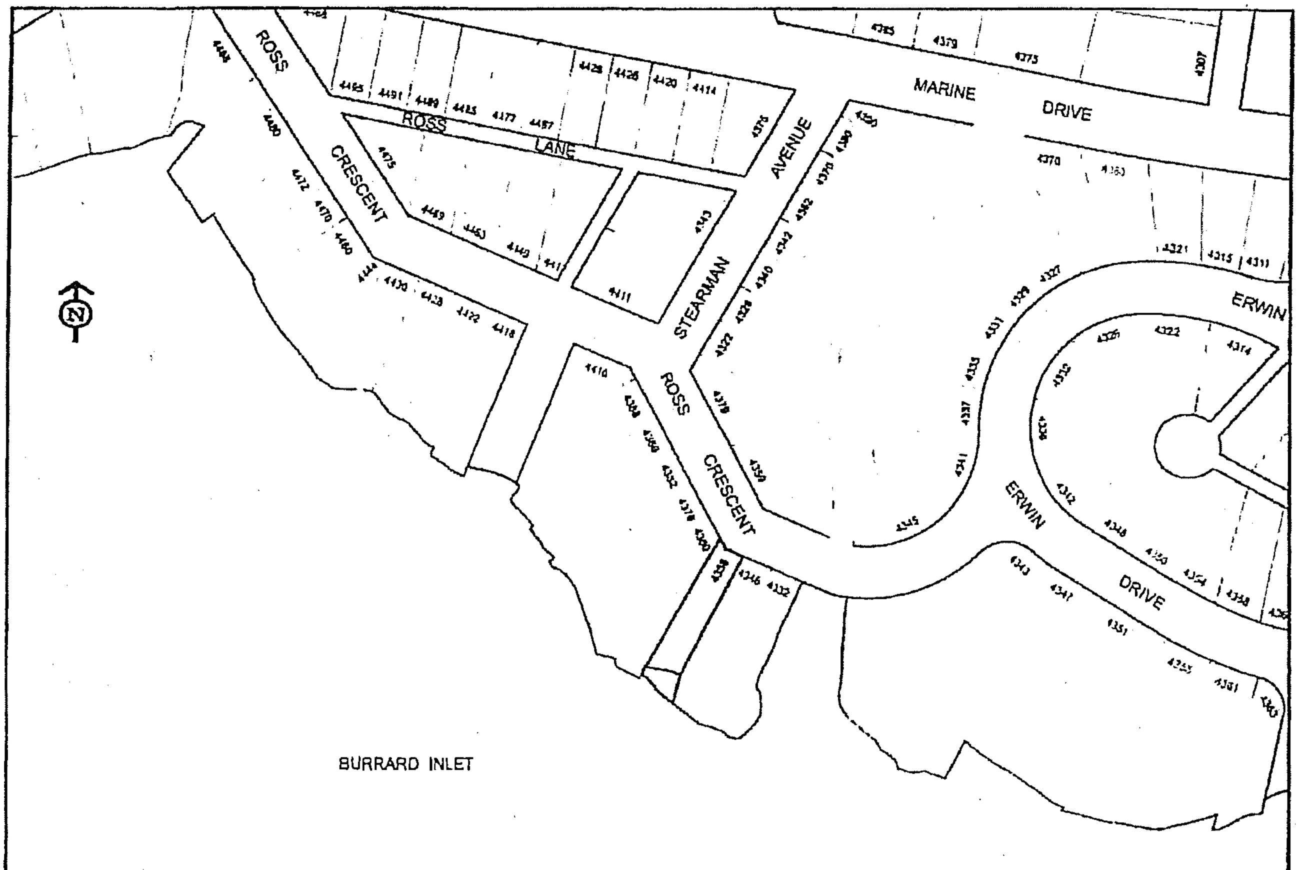
Although the proposed house would be higher than surrounding properties, in order to accommodate the engineering specifications, the proposed building mitigates these impacts with a height of 6.7 m (22 ft.), 0.9 m (3.0 ft.) lower than the maximum of 7.6 m (25 ft.) under RS4 zoning. As well, the proposal provides terracing at the west and east edges of the site to provide a transition in height from adjacent properties and landscaping to screen the proposal. Staff support the proposal and recommend that Council give the proposed rezoning by-law first reading and schedule the Development Variance Permit for consideration.

Author:

Michelle McGuire, Manager of Current Planning and Urban Design

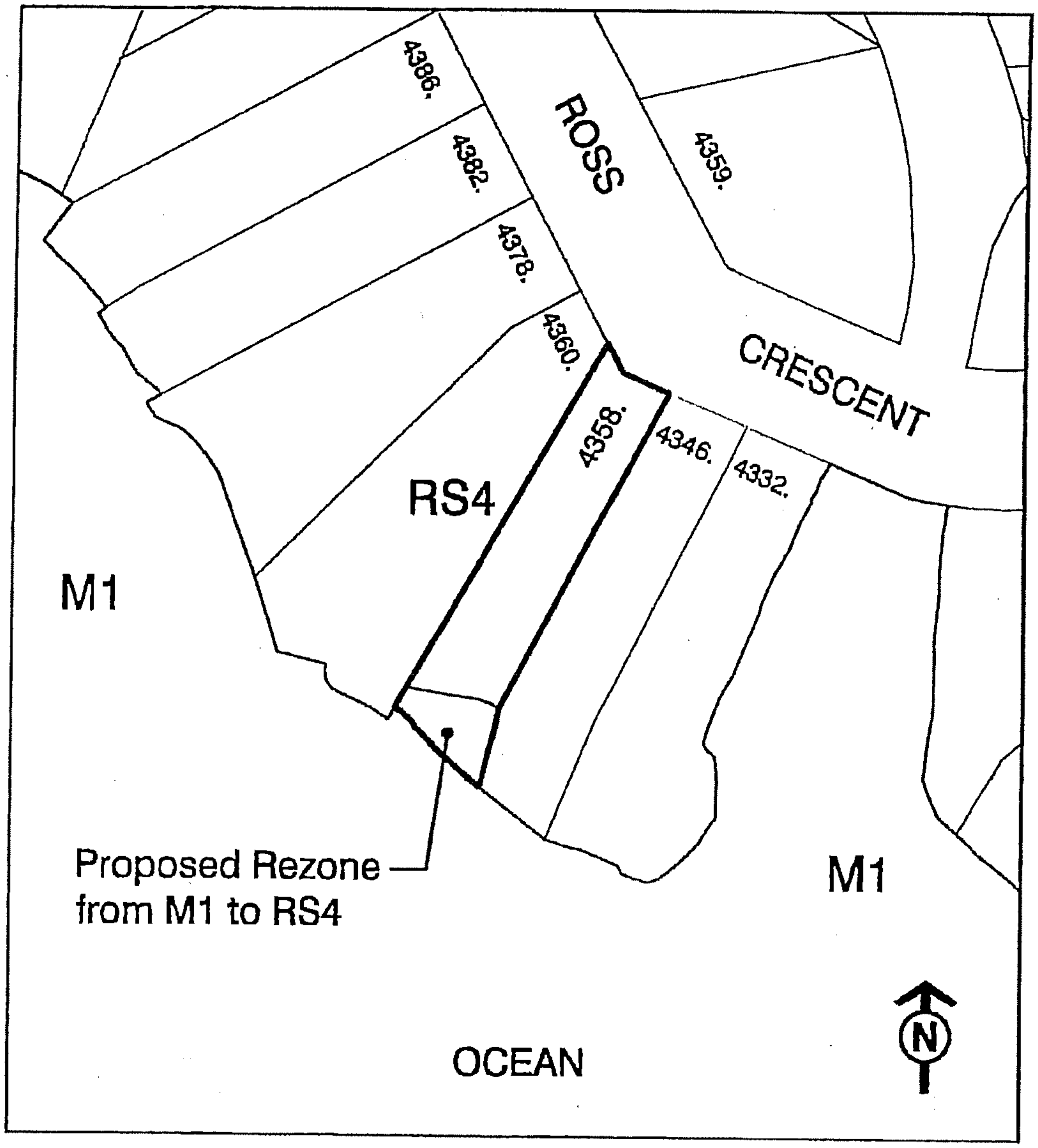
Appendices:
- A- Context Map
- B- Proposed Property Boundary map
- C- Project Profile
- D- "Zoning Bylaw No. 4662, 2010, Amendment Bylaw No. 5028, 2019"
- E- Proposed Development Variance Permit No. 18-037

APPENDIX A
CONTEXT MAP



west vancouver	CONTEXT PLAN	DATE May15/19	REV. 0
	TITLE 4358 Ross Cescent - Rezoning	FILE SK-1	

APPENDIX B
PROPOSED PROPERTY BOUNDARY MAP
(with area to be rezoned)



APPENDIX C
PROJECT PROFILE

Project:	4358 Ross Crescent
Application:	Development Variance Permit No. 18-037
Applicant:	Jennifer and Robert Haffal
Architect:	Hlynsky and Davies Architects Inc.
Address:	4358 Ross Crescent
Legal Description:	Lot 7, Block 2, [illegible] Group ,1New Westminster District Plan 4725
PID:	011-374-276
OCP Policy:	2.6.11
Zoning:	RS4 (Single Family Dwelling Zone 4)
Heritage Register:	N/A
Summary:	A 2-storey plus basement single family dwelling with detached garage and storage building

	BYLAW RS4	PROPOSED OR EXISTING	VARIANCE	COMMENTS/NOTES
Site Area	836 m²	784 m²	n/a	Legal (historic) non-conforming
Site Width & Frontage	22.9 m	Approximately 11.4 m		Legal (historic) non-conforming
Site Coverage	266 m²	256 m²	n/a	Complies
Front Yard Permeability	50%	56%	6	Required to accommodate location of proposed garage
Floor Area Ratio	0.35	0.35	n/a	Complies
Setbacks – House:				
Front Yard (Ross)	9.1 m	21.6 m	n/a	Complies
Waterfront Yard	9.1 m	9.1 m	n/a	Complies
Side Yards (West)	1.5 m	1.5 m	n/a	Complies
Side Yards (East)	1.5 m	2.0 m	n/a	Complies
Side Yards (Combined)	4.6 m	3.5 m	0.9 m	Increases distance to both east and west from existing
Setbacks – Garage:				
Front Yard (Ross)	9.1 m	1.0 m	8.1 m	Increases from existing
Side Yards (West)	1.5 m	1.0 m	0.5 m	Increases distance to west from existing
Height:				
Building Height	7.6 m	6.7 m	Measured from FCL*	FCL proposed to be used for average grade
No. of Storeys	2	2	n/a	Complies
Highest Building Face Envelope	6.7 m	6.7 m	Measured from FCL*	FCL proposed to be used for average grade
Parking:				
Spaces	1	2	n/a	Complies

*Flood Construction Level at 5.8 m (19.0 ft.) as determined by Coastal Engineer report.

APPENDIX P

District of West Vancouver

...ing Bylaw No. 4662, 2010,
...ndment Bylaw No. 5028, 201[illegible]

(4358 Ross Crescent)

Effective Date:

3904317v1

District of West Vancouver

Zoning Bylaw No. 4662, 2010, Amendment Bylaw No. 5028, 2019

Table of Contents

3904317v1

District of West Vancouver

Zoning Bylaw No. 4662, 2010, Amendment Bylaw No. 5028, 2019

A bylaw to rezone a portion of land located at 4358 Ross Crescent to RS4.

Previous amendments: Amendment bylaws 4672, 4677, 4678, 4679, 4689, 4701, 4680, 4710, 4697, 4716, 4712, 4737, 4726, 4736, 4757, 4752, 4767, 4787, 4788, 4784, 4772, 4791, 4805, 4809, 4828, 4854, 4873, 4866, 4895, 4839, 4898, 4927, 4944, 4905, 4974, and 4967.

WHEREAS the Council of The Corporation of the District of West Vancouver deems it expedient to provide for amendment of the zoning bylaw;

NOW THEREFORE, the Council of The Corporation of the District of West Vancouver enacts as follows:

Part 1 Citation

1.1 This bylaw may be cited as Zoning Bylaw No. 4662, 2010, Amendment Bylaw No. 5028, 2018.

Part 2 Severability

2.1 If a portion of this bylaw is held invalid by a Court of competent jurisdiction, then the invalid portion must be severed and the remainder of this bylaw is deemed to have been adopted without the severed section, subsection, paragraph, subparagraph, clause or phrase.

Part 3 Amends Zoning Maps

3.1 Zoning Bylaw No. 4662, 2010, Schedule A, Section 852, Schedule 2, Zoning Maps is hereby amended by changing the zoning of Lands as shown hatched outline on the map in Schedule A to this bylaw,

FROM: M1 – Marine 1

To: RS4 – Single Family Dwelling 4

Schedules

Schedule A – – Zoning Map Amendment

READ A FIRST TIME on

PUBLICATION OF NOTICE OF PUBLIC HEARING on

PUBLIC HEARING HELD on

READ A SECOND TIME on

READ A THIRD TIME on

ADOPTED by the Council on

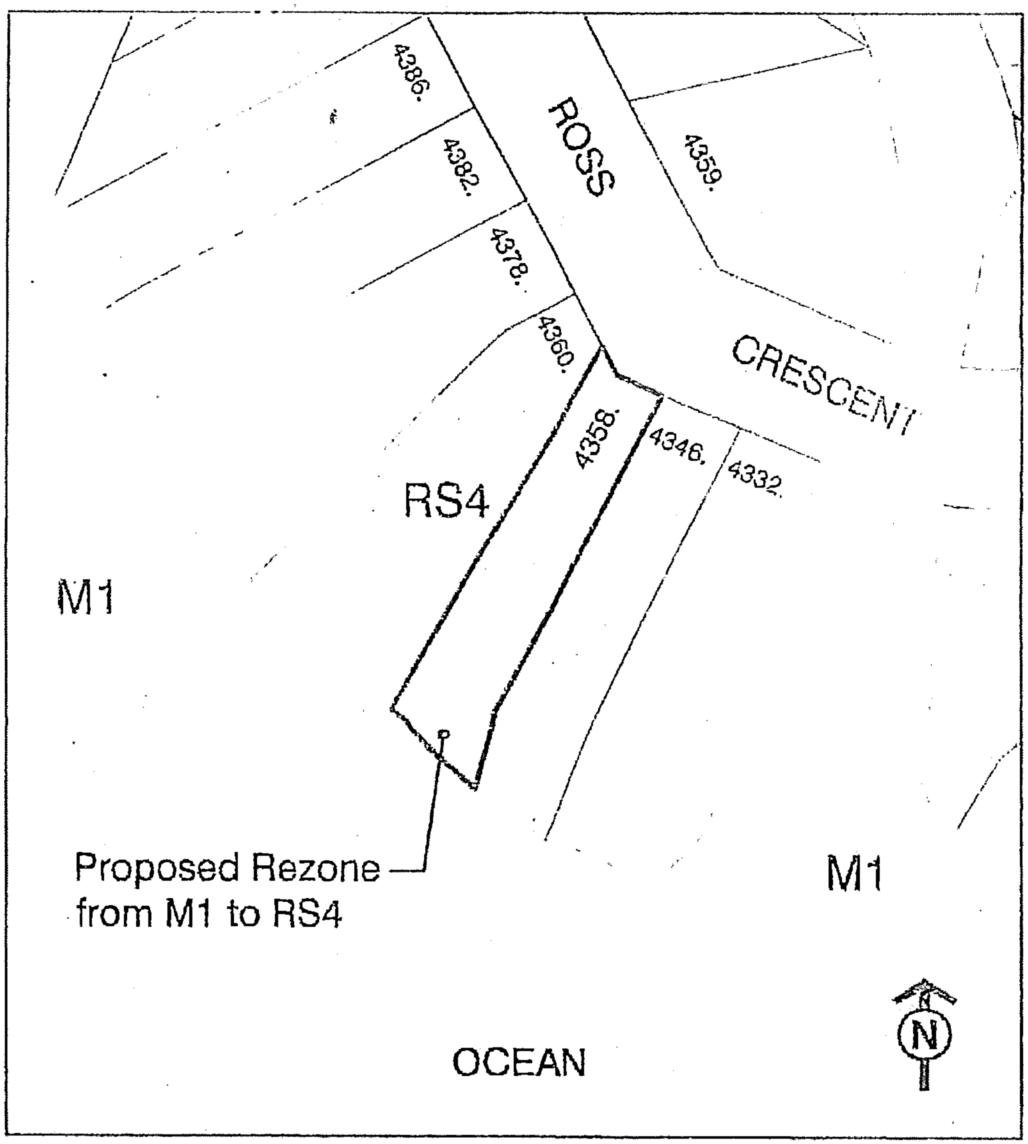
Mayor

Corporate Officer

Schedule A – Zoning Map Amendment

Amendment to Zoning Bylaw No. 4662, 2010, Schedule A, Section 852, Schedule 2, Zoning Maps.

The area shown hatched outline on the map below rezones the subject Land to RS4.



Area to be rezoned from M1 to RS4

APPENDIX E

District of West Vancouver

Development Variance Permit No. 18-037

Current Owner: Jennifer and Robert Heffel

This Development Variance Permit applies to:

Civic Address: 4358 Ross Crescent

Legal Description: 039-375-002 and 011-374-276
Lot 7 and Lot A, Block 2, District Lot [illegible] Group 1 New Westminster District Plan 4725
(the "Lands")

1. For the purposes of this Development Variance Permit, the Lands shall be developed in accordance with the drawings attached and date stamped May 1[illegible], 2019, approved by Council, attached as Schedule A, and specifically in compliance with the regulations and variances listed hereunder.

2. Zoning Bylaw No. 4662, 2010 is varied and supplemented for this development proposal in accordance with the following regulations:

   (a) Section 204.09 (RS4 Side Yard and Combined Side Yard) is varied to allow:

      i. the required combined side yard to be reduced from 4.6 m to 3.5 m; and

      ii. the required west side yard for the garage to be reduced from 1.5 m to 1.0 m.

   (b) Section 204.07 (RS4 Front Yard) is varied to allow the required front yard for the garage to be reduced from 9.1 m to 1.0 m.

   (c) Section 120.17 (Average Grade Calculation for Building and Structure Height) is varied to calculate maximum building height using the flood construction level at 5.8 m as average grade.

   (d) Section 120.27 (9) (b) (Yard Provisions and Exemptions) is varied to allow the roof overhang for the garage in the front yard to be increased from 0.6 maximum to 1.0 m.

   (e) Section 204.10 (RS4 Building Height) is varied to reduce the maximum height from 7.62 m to 6.7 m.

   (f) Section 110 (basement definition) is varied to allow the basement to be defined as a storey, the floor of which is located below the flood construction level at 5.8 m.

   (g) Section 130.01 (3) (b) is varied to calculate maximum building height for the accessory building (garage and storage) using the flood construction level at 5.8 m as average grade.

(h) Section 130.15 (7) (Site Landscaping) is varied to allow the impermeable surface in the front yard to be increased from 50% to 56%.

(i) Section 130.1 (2) (c) (Highest Building Face Envelope) is varied to allow maximum highest building face to be calculated using the flood construction level at 5.8 m as average grade.

(j) Sections 120.22 (Retaining Wall Grade Line and Buildup of Grade) and 130.13 (Waterfront Yard Requirement) are varied to allow retaining wall heights as shown in Sheet A1.2 of Schedule A, except that no retaining wall will exceed 1.2 m in exposed face height.

3. The proposed new house and site landscaping must generally be constructed and finished in compliance with attached Schedule "A".

4. The proposal shall generally incorporate the sustainability elements as follows:

(a) Heat Pump;

(b) All windows, doors + skylights to meet current NAFS energy standard;

(c) Heat Recovery Ventilator;

(d) High performance building envelope - air tight + low air exchanges;

(e) Maximizing of pervious surfaces – gardens + softscape;

(f) Exterior Insulation (if exempt from setback calculations);

(g) Trellis' on south orientation as passive means to limit solar gain;

(h) Drain Water Heat Recovery; and

(i) Natural Gas Boiler with in floor radiant heat.

Prior to Building permit issuance the Owner shall provide applications plans and information detailing these sustainability elements to the satisfaction of the Director of Planning.

5. The proposal shall incorporate electric vehicle charging in the garage.

6. The proposal shall incorporate electric conduit to enable solar panel installation.

7. A Tree Replacement Plan shall be submitted to, and approved by, the District Arborist or qualified designate to replace the proposed trees to

be removed on the Lands at a ratio of 3:1 for replacement trees whereas replacement trees and plantings are to be native species.

8. Prior to issuance of a Building Permit, a suitably qualified professional will identify conditions as enabling the safe use of the land for the use intended with consideration to coastal flooding hazards. A s219 covenant shall be registered against the certificate of title for the Lands certifying that the land will be used in accordance with the conditions specified in a report completed by the suitably qualified professional. .

9. Prior to the issuance of a Building Permit and as security for the due and proper completion of the landscaping as set forth in Section 3 of this Development Variance Permit, the Owner shall:
   (a) provide a landscape plan to include site grading that takes into consideration and is integrated with the onsite stormwater management plan as required per the District's Building Bylaw 4400, 2004 Section 9.1.12; and, the requirements set forth Section 8 of this Development Permit.
   (b) provide a landscape cost estimate acceptable to Director of Planning;
   (c) provide security in the amount of 125% of the landscape cost estimate to the District in the form of cash or an unconditional, irrevocable auto-renewing letter of credit issued by a Canadian chartered bank or credit union; and
   (d) maintain the security for a minimum of one year after completion of the landscaping, and not prior to the date on which the District authorizes in writing the release of the security.

10. This Development Variance Permit lapses if construction of the additions and renovations has not commenced, under an issued Building Permit, within 24 months of the date this permit is issued.

THE COUNCIL OF WEST VANCOUVER APPROVED THIS PERMIT BY RESOLUTION PASSED ON____________________.

____
MAYOR

____
MUNICIPAL CLERK

THE REQUIREMENTS AND CONDITIONS UPON WHICH THIS PERMIT IS ISSUED ARE ACKNOWLEDGED AND AGREED TO. IT IS UNDERSTOOD THAT OTHER PERMITS / APPROVALS MAY BE REQUIRED INCLUDING PERMITS / APPROVALS FOR BUILDING CONSTRUCTION, SOIL AND ROCK REMOVAL OR DEPOSIT, BOULEVARD WORKS, AND SUBDIVISION.

FOR THE PURPOSES OF SECTION 8, THIS PERMIT IS ISSUED ON____________________.

Schedules:

A – Development Plans for 4358 Ross Crescent prepared by Hlynsky and Davis Architects, dated stamped May 15, 2019.

Schedule A to
Development Permit 18-037

DRAWING LIST

A1.1a	TITLE SHEET
A1.1b	BRIEF
LDE-1.01	LANDSCAPE MASTER PLAN
L-4.01	TREE AND PLANTING PLAN
A1.2	SITE PLAN
A1.3	CONTEXT PLAN
A1.4	GARAGE COMPLY PLAN
A1.5	PROPOSED vs EXISTING
A1.6	AVERAGE GRADE & RETAINING WALLS
A2.1	LOWER FLOOR PLAN
A2.2	MAIN FLOOR PLAN
A2.3	UPPER FLOOR PLAN
A2.4	ROOF PLAN
A2.5	GARAGE PLAN
A4.1	NORTH ELEVATION
A4.2	EAST ELEVATION
A4.3	SOUTH ELEVATION
A4.4	WEST ELEVATION
A5.1	SECTION NORTH-SOUTH
A5.2	SECTION EAST WEST
A5.3	SECTION GARAGE

HEFFEL RESIDENCE 4358 ROSS CRESCENT

PROJECT TEAM

ARCHITECTURAL

HLYNSKY + DAVIS ARCHITECTS INC.
Project Architect, Katie Hlynsky
2430 Bellevue Avenue, West Vancouver, British Columbia V7V 1E1
(604)925-3031 / katie@hlynsky.ca

LANDSCAPE

PAUL SANGHA LANDSCAPE ARCHITECTURE
125 East 4th Avenue, Vancouver, British Columbia, V5T 1G4
(604)736-2323 / paul@paulsangha.com

INTERIOR

HB DESIGN
#103 - 828 Harbourside Drive, North Vancouver, British Columbia, V7P 3R9
(604)251-9585 / jen@hbvancouver.com

COASTAL ENGINEERING

NHC - NORTHWEST HYDRAULICS CONSULTANTS LTD
30 Gostick Place, North Vancouver, British Columbia, V7M 3G3
(604)980-6011 / DRay@nhcweb.com

HLYNSKY + DAVIS ARCHITECTS INC

HEFFEL RESIDENCE
4358 ROSS CRESC
W VAN, BC

TITLE SHEET

A1.1a

DVP BRIEF

A rezoning based on accreted land and three main variances that trigger additional bylaws impacts due to the new Flood Construction Level and the narrowness of the lot:

a. RE-ZONING:

The lots natural boundary has been re-defined with a new accreted property line currently zoned Marine Use. The accreted land accounts for an additional 107.8 square meters (1160 sq. Ft.). The waterfront property line now conforms with neighbors to the east and west. The neighboring properties are designated Residential for the entirety of their property and were granted accretion at the time without re-zoning process. Due to precedents along the waterfront, we feel that is in keeping with the neighborhood to grant this long narrow lot the same zoning as it's neighbours.

b. COMBINED SIDE-YARD:

The site has is one of the narrowest in the neighborhood with a square width of 38.35' (or 11.69 meters). This restricts the building envelope to a twenty-three foot wide home if complying with fifteen foot combined side yard regulation. The **existing house is non-confirming to both the minimum side-yard on both sides and the combined side-yard.** The west side has a 4.4' (1.45m) set back and the east side a 3.45' (1.06m) setback for a total combined side yard of 7.85' (2.51m). Our current proposal complies with the minimum side yard setbacks having 6.5 feet on the east side and 5 feet on the west side for a total combined side yard setback of 11.5'. The proposed house jogs both horizontally and vertically so that the side yards open up and modify along the length of the house. The proposal is an improvement to setback conditions currently existing. As we are meeting or exceeding the minimum side yard setback of 5'-0" on either side we would request a relaxation due to the narrowness of the lot, our modulation of sidewall plains and the existing precedent.

c. FLOOD CONSTRUCTION LEVEL "FCL" and AVERAGE GRADE DETERMINATION:

Initial DVP Application of February 20, 2018 set the home at the FCL at the posted bylaw requirement of 4.5 meters (15.0'). Initial comments back in the beginning of July 2018 (five months later) did not raise any concern with FCL. At the end of July, WV Planning Department advised they had decided to follow the Provincial Guidelines Addendum that was issued in January 2018. This would be retroactively applied to all applications. All new development in Flood Hazard Areas would be required to set the house based on recommendations by a Coastal Engineer. We retained Northwest Hydraulics . In their report, it was determined that this site would require the house main floor be set at 19'-0" (5.8m). Through the terracing of the site, we have managed to raise the house from the previous proposal to achieve this requirement. The existing site is approximately 4'-0" below the neighboring properties and 11'-0" below FCL. Both neighboring properties currently have retaining walls that allow these flanking sites to comply with the previous 3.5 meter FCL. Based on the existing grade it would not be possible to redevelop this property in conformance to the zoning bylaws. In discussions over the previous fourteen months with Planning, Mayor and Council, we understand that the elevation set by the Coastal Engineer is a non-negotiable requirement. In order to not reduce these properties to having little value or sterilize the potential for development, we are requesting that FCL take priority over existing grade as the determination of Average Grade for Building Height, Highest Building Face and Basement Exemption. The current home based on our approximation is non conforming to existing grade. Our proposed home would therefore be an improvement in relationship to finished grade as it complies with Finished Grade and it is under height in relation to proposed grade (23.94') and Flood Construction Level (22.0') and complies with Highest Building Face by using lower of FCL or proposed grade. The original proposal had the flat roof height at the ridge within a foot of the neighboring properties; however, with the requirement to raise the house by an additional four feet this has then made the proposed roof height at +41. The peak of 4360 Ross is 36.5' which is 4.5' below the proposed height. The Ridge of 4346 is at 38.4' which is 2.6' less than the proposed. With the terraced approach to the landscaping and by conforming with Finished grade we are confident that this should be able to mitigate the appearance of an overly high house. The current non-conforming house and large trees create more shadow on neighboring properties than the proposed house and landscape. There will be more light on both properties following development of this lot. It is also a relatively small home with the footprint of the main floor being a modest 1673 square feet.

d. GARAGE LOCATION:

We are proposing to replace the existing garage with a new garage in the same location to be able to moderate the change of grade between the street and the house. The location of the garage in the frontyard setback is intended to maximize porosity between house and road. If garage was pushed back to comply, a greater amount of hardscape would be required to allow for car turnaround and driveway access. (See diagram A1). The garage location is also similar to other non-conforming structures in the neighborhood including the immediate neighbor. It should be noted that the boulevard at this location is unusually generous so visually the setback is in keeping with neighbors.We are also requesting a variance for the sideyard setback from 5'-0" to 3'-2". This again aligns with the current garage. Due to narrow width of lot neither a complying driveway nor the proposed would meet the 50% porosity requirement. (See diagram A1.4 with porosity calculations)

e. CONCLUSION:

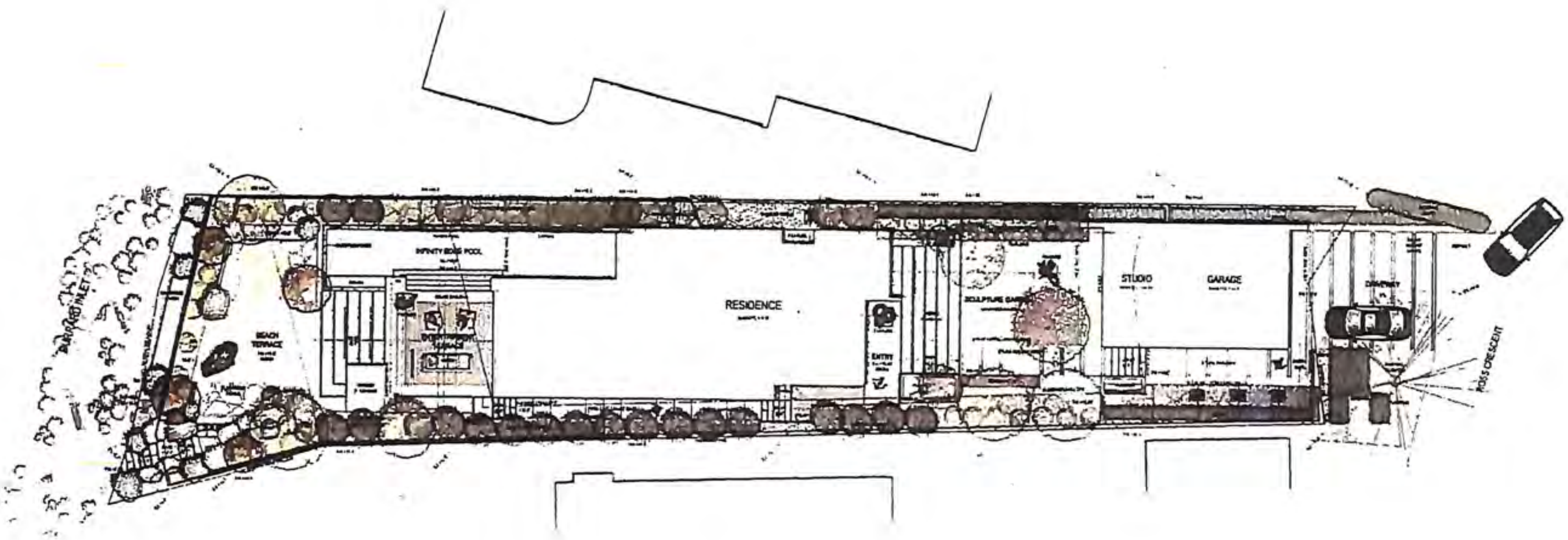
It is important to recognize neighborhood character and avoid bulk. In the summer of 2018, Planning advised that they would consider additional FAR up to .45 to equalize the basement area that would be lost with Development in FCL zones. We did a study of this option and consulted with our Coastal Engineer and Structural Engineers. It was determined that the more beneficial strategy for the neighborhood and our client would be to have a fully tanked basement and stay with the .35 FAR to avoid being out of context with the neighborhood. We are working with Paul Sangha Landscape Architecture to create a site that will keep the Westcoast beach character and include a rigorous re-planting strategy. The interface with neighbors on the east and west sides has been designed to ensure that there is no retaining wall greater than the four foot bylaw. This site will invert the current condition that exists so that this site is no longer in a hole subject to flooding.

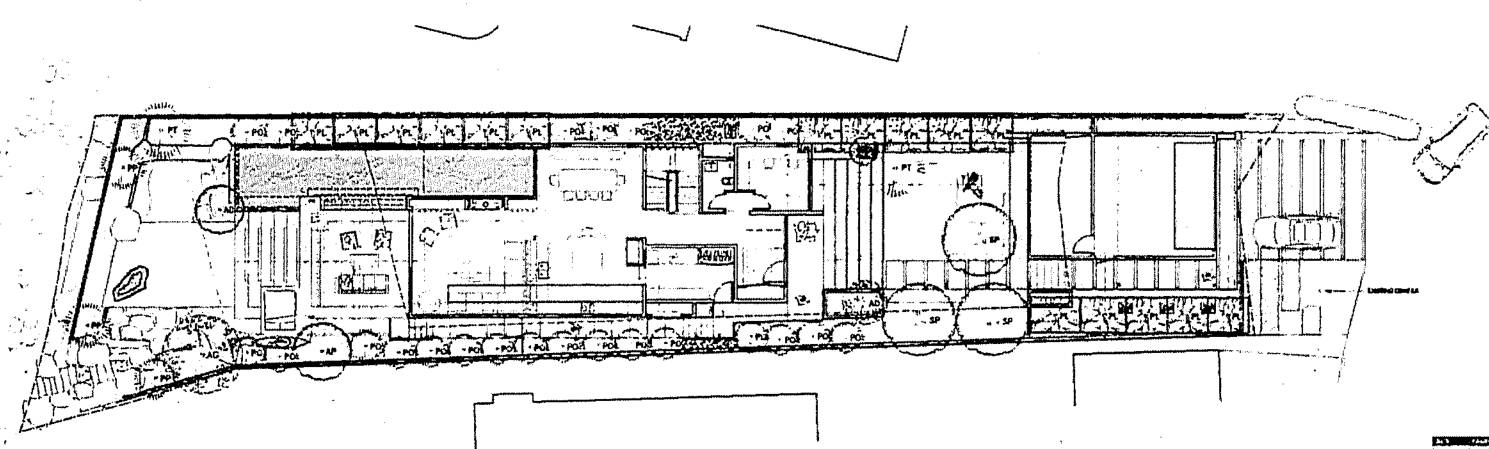
HLYNSKY + DAVIS ARCHITECTS INC.

HEFFEL RESIDENCE
4358 ROSS CRESC
W VAN, BC

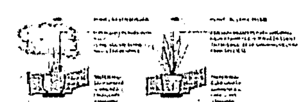
BRIEF

A1.1b


INFINITY EDGE POOL
RESIDENCE
BEACH TERRACE
ENTRY
SCULPTURE GARDEN
STUDIO
GARAGE
ROSS CRESCENT



2 PLANT LAYOUT UNLESS OTHERWISE INDICATED

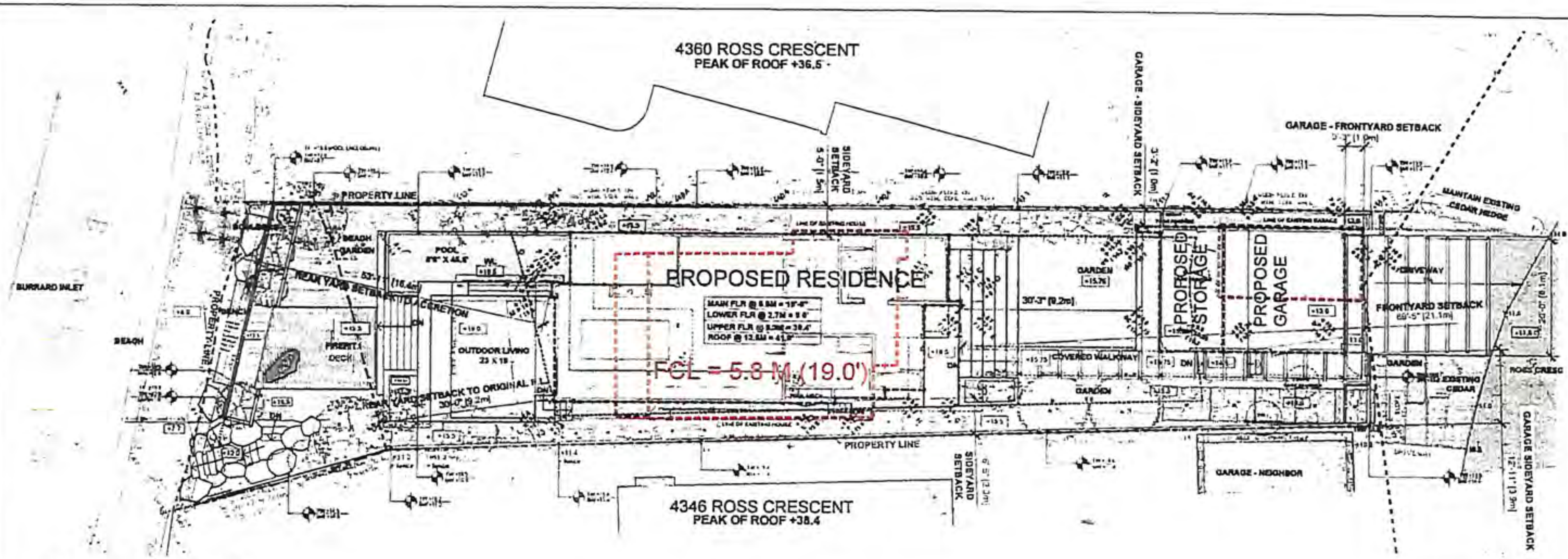


3 PLANTING POSITION UNLESS OTHERWISE INDICATED

PRIVATE RESIDENCE

TREE AND PLANTING PLAN

L-4.01



PROJECT STATISTICS

LOT ADDRESS

LEGAL DESCRIPTION:

ZONING

LOT AREA

SITE COVERAGE

FLOOR AREA RATIO

BUILDING + GARAGE SETBACKS

SETBACKS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NOTES
FRONT YARD HOUSE	[illegible]	[illegible]	[illegible]	N/A	NO	
REAR YARD HOUSE	[illegible]	[illegible]	[illegible]	[illegible]	NO	
SIDEYARD EAST	[illegible]	[illegible]	[illegible]	N/A	NO	[illegible]
SIDEYARD WEST	[illegible]	[illegible]	[illegible]	N/A	NO	[illegible]
COMBINED SIDEYARD	[illegible]	[illegible]	[illegible]	N/A	YES	[illegible]
FRONT YARD GARAGE	[illegible]	[illegible]	[illegible]	N/A	YES	[illegible]
SIDEYARD WEST GARAGE	[illegible]	[illegible]	[illegible]	N/A	YES	[illegible]

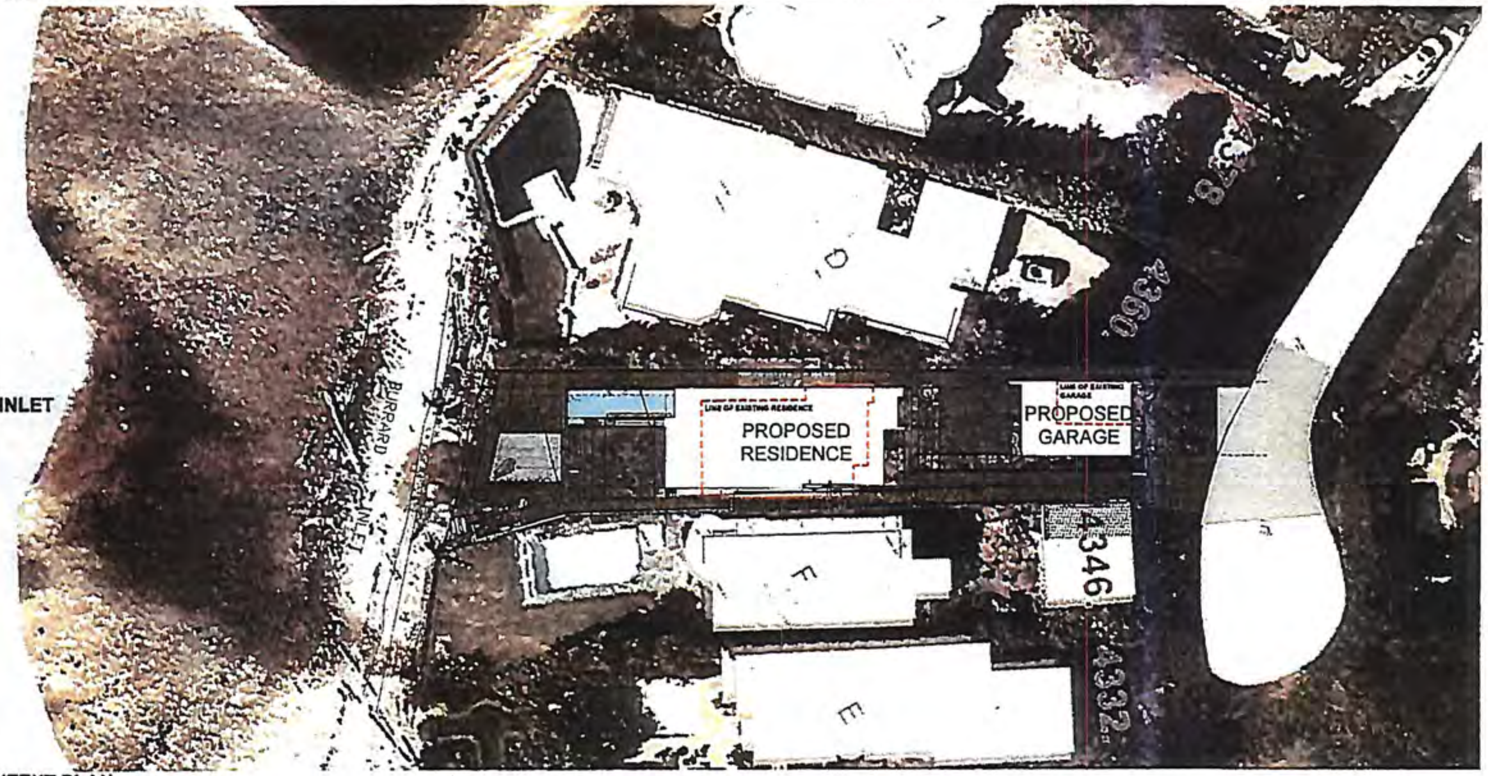
FRONT YARD PAVED AREA

HLYNSKY + DAVIS
ARCHITECTS INC

HEFFEL RESIDENCE
4356 ROSS CRESC
W VAN, BC

SITE PLAN

A1.2



AERIAL CONTEXT PLAN (WEST-MAP UNDERLAY)


EAST ADJACENCY


WEST ADJACENCY


EXISTING GARAGE


TYPICAL RETAINING WALL CONDITION ALONG SIDE YARDS

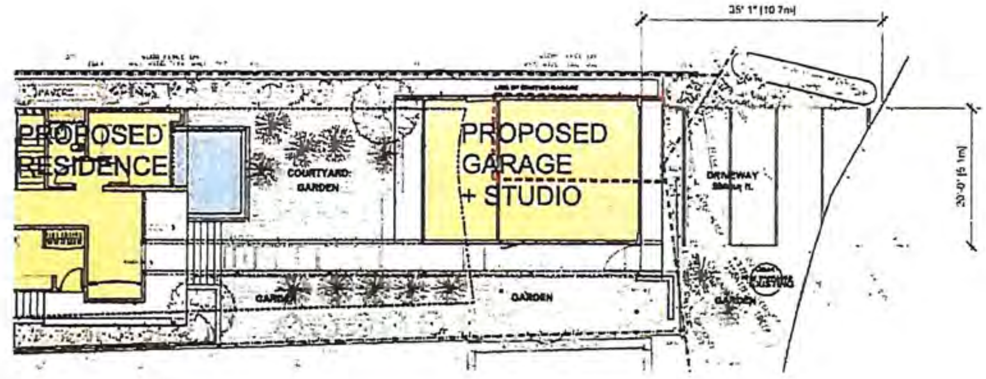

FORESHORE CONDITION

HLYNSKY + DAVIS ARCHITECTS INC

HEFFEL RESIDENCE
4358 ROSS CRESC
W VAN, BC

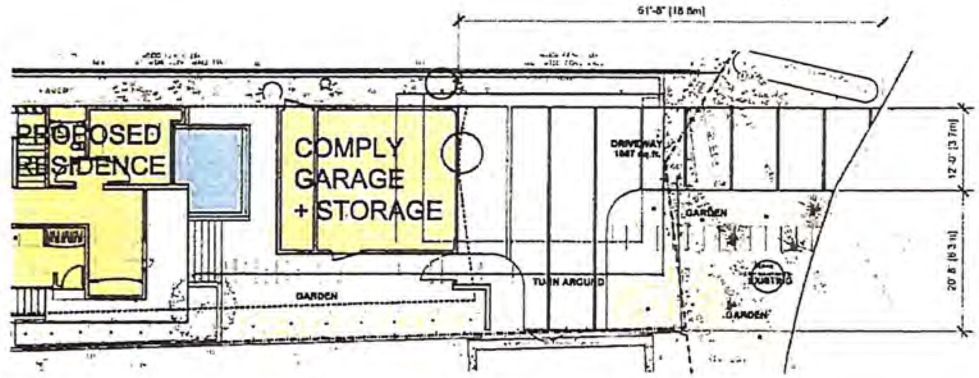
CONTEXT PLAN

A1.3



PROPOSED GARAGE + STUDIO
A1.3 1/8" = 1'-0"

FRONT YARD PAVED AREA



GARAGE WITH COMPLYING SETBACKS
A1.3 1/8" = 1'-0"

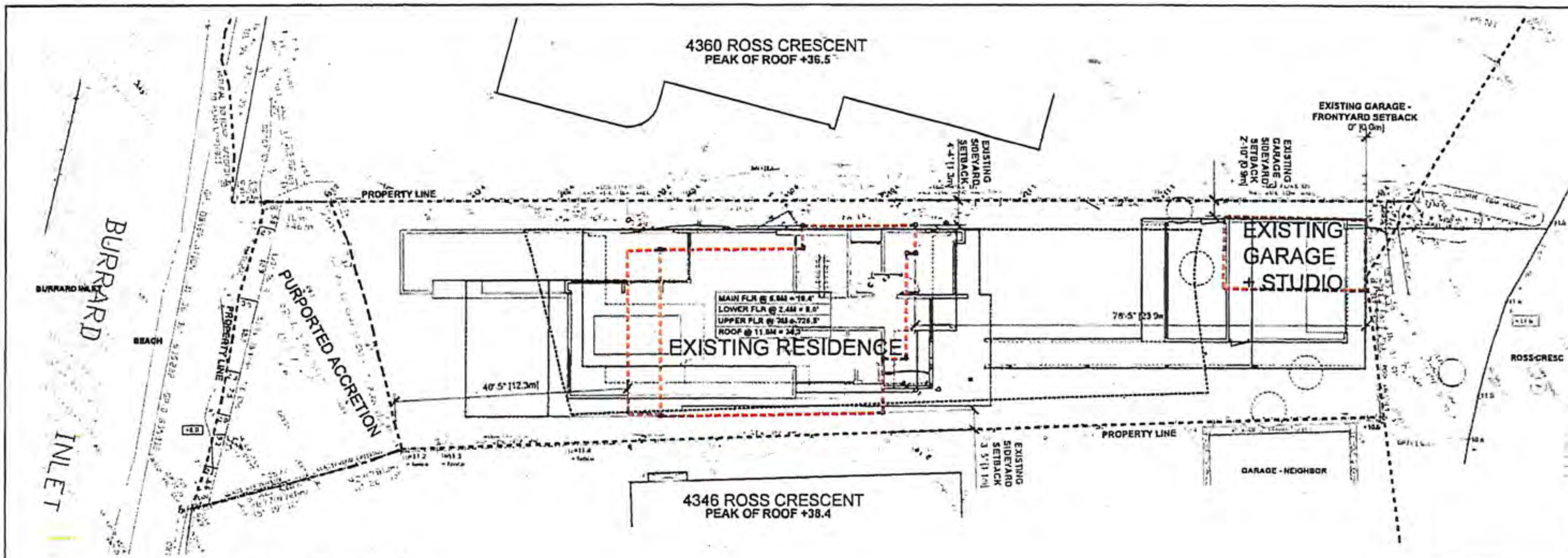
FRONT YARD PAVED AREA

HDA
HLYNSKY + DAVIS ARCHITECTS INC.

HEFFEL RESIDENCE
4350 ROSS CRESC
W VAN, BC

GARAGE COMPLY DIAGRAMME

A1.4



PROJECT STATISTICS - EXISTING

LOT ADDRESS
[illegible] ROSS CRESCENT WEST VANCOUVER BC

LEGAL DESCRIPTION:
[illegible]

	EXISTING	REZONING	COMMENT
ZONING	[illegible]		
LOT AREA	[illegible]		

BUILDING + GARAGE SETBACKS - EXISTING

SETBACKS	EXISTING	REQ'D BYLAW	PROPOSED	BASED ON ACCRETION	VARIANCE REQUIRED	NOTES
FRONT YARD HOUSE	[illegible]	30'	[illegible]	N/A	NO	
REAR YARD HOUSE	41'	30'	30'	[illegible]	NO	
SIDEYARD EAST	[illegible]	5	[illegible]	N/A	NO	Existing non-conforming
SIDEYARD WEST	4.3	5	3	N/A	NO	Existing non-conforming
COMBINED SIDEYARD	[illegible]	15'	[illegible]	N/A	YES	Existing non conforming
FRONT YARD GARAGE	[illegible]	30'	[illegible]	N/A	YES	Existing non-conforming [illegible]
SIDEYARD WEST GARAGE	2.0	[illegible]	[illegible]	N/A	YES	Existing non-conforming [illegible]

BUILDING HEIGHT **APPROXIMATION BASED ON PEAK ELEVATION FROM SURVEY DATA

[illegible]

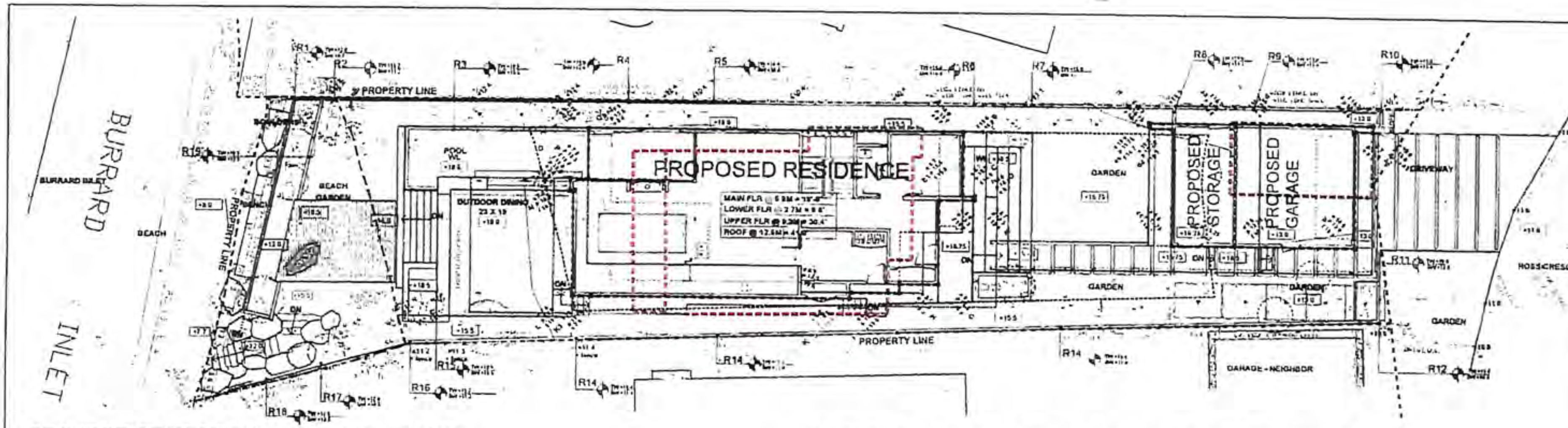
HLYNSKY + DAVIS ARCHITECTS INC.

HEFFEL RESIDENCE
4358 ROSS CRESC
W VAN BC

PROPOSED VS EXISTING

A1.5

111



PROJECT STATISTICS - AVERAGE GRADE

BUILDING HEIGHT [illegible]

[illegible]

GARAGE HEIGHT [illegible]

[illegible]

STUDIO HEIGHT [illegible]

[illegible]

PROJECT STATISTICS - RETAINING WALL SCHEDULE

RETAINING WALL HEIGHTS

	BW	TW	TOTAL HEIGHT (FEET)	NOTES / CONFORMANCE
R1	[illegible]	[illegible]	[illegible]	YES WATERFRONT
R2	[illegible]	[illegible]	4	YES SIDEYARD
R3	[illegible]	[illegible]	[illegible]	YES SIDEYARD
R4	[illegible]	[illegible]	[illegible]	YES SIDEYARD
R5	[illegible]	[illegible]	4	YES SIDEYARD
R6	[illegible]	[illegible]	4	YES SIDEYARD
R7	[illegible]	[illegible]	[illegible]	YES SIDEYARD
R8	[illegible]	[illegible]	[illegible]	YES SIDEYARD
R9	[illegible]	[illegible]	[illegible]	YES SIDEYARD
R10	[illegible]	[illegible]	[illegible]	YES SIDEYARD
R11	[illegible]	[illegible]	4	[illegible]
R12	[illegible]	[illegible]	[illegible]	YES SIDEYARD
R14	[illegible]	[illegible]	4	YES SIDEYARD
R15	[illegible]	[illegible]	[illegible]	YES SIDEYARD
R16	[illegible]	[illegible]	4	YES SIDEYARD
R17	[illegible]	[illegible]	[illegible]	YES SIDEYARD
R18	[illegible]	[illegible]	4	YES SIDEYARD
R19	[illegible]	[illegible]	[illegible]	YES WATERFRONT

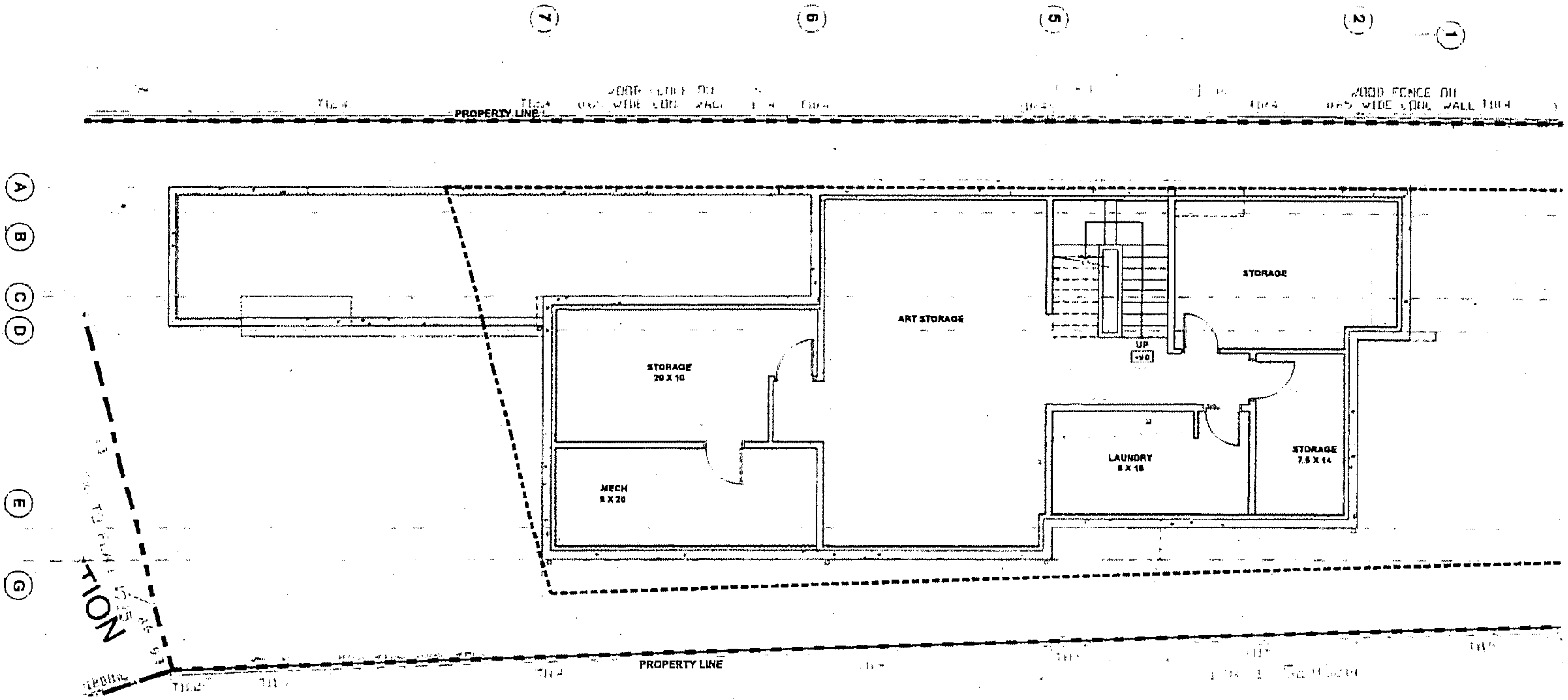
HDA

HLYNSKY + DAVIS ARCHITECTS INC

HEFFEL RESIDENCE
4358 ROSS CRESC
W VAN, BC

AVERAGE GRADE + RETAINING WALLS

A1.6

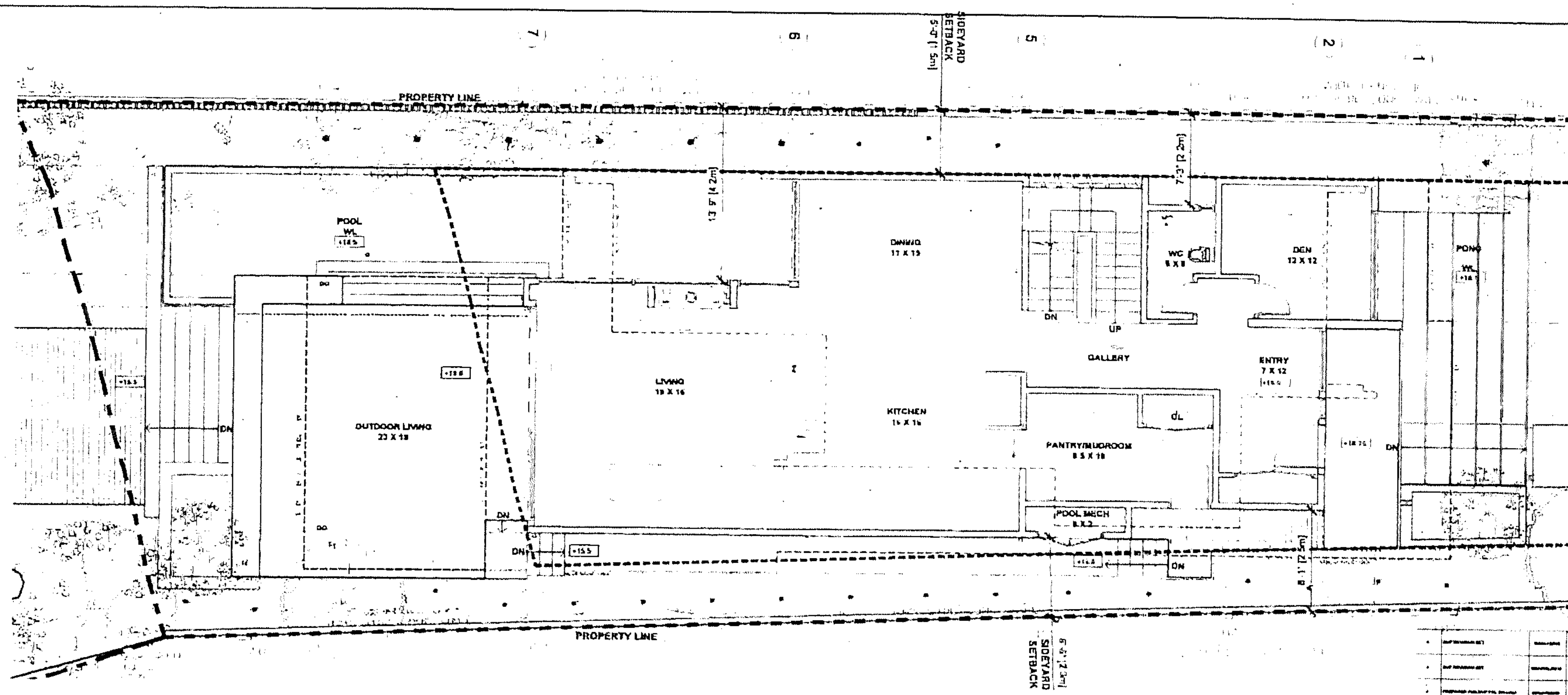


HLYNSKY + DAVIS
ARCHITECTS INC.

HEFFEL RESIDENCE
4358 ROSS CRESC
W.VAN, BC

LOWER PLAN

A2.1

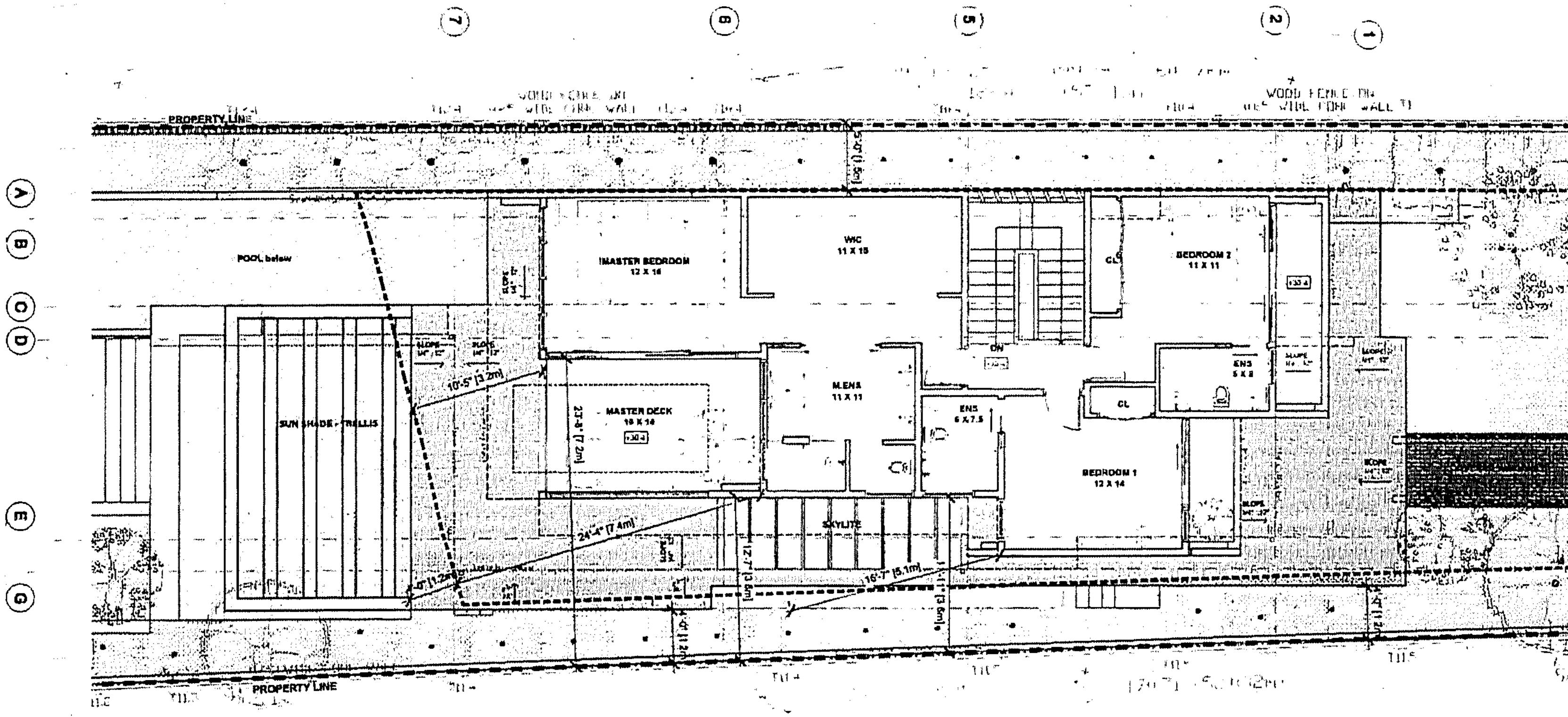


HLYNSKY + DAVIS
ARCHITECTS INC.

HEFFEL RESIDENCE
4358 ROSS CRESC
W.VAN. BC

MAIN PLAN

A2.2



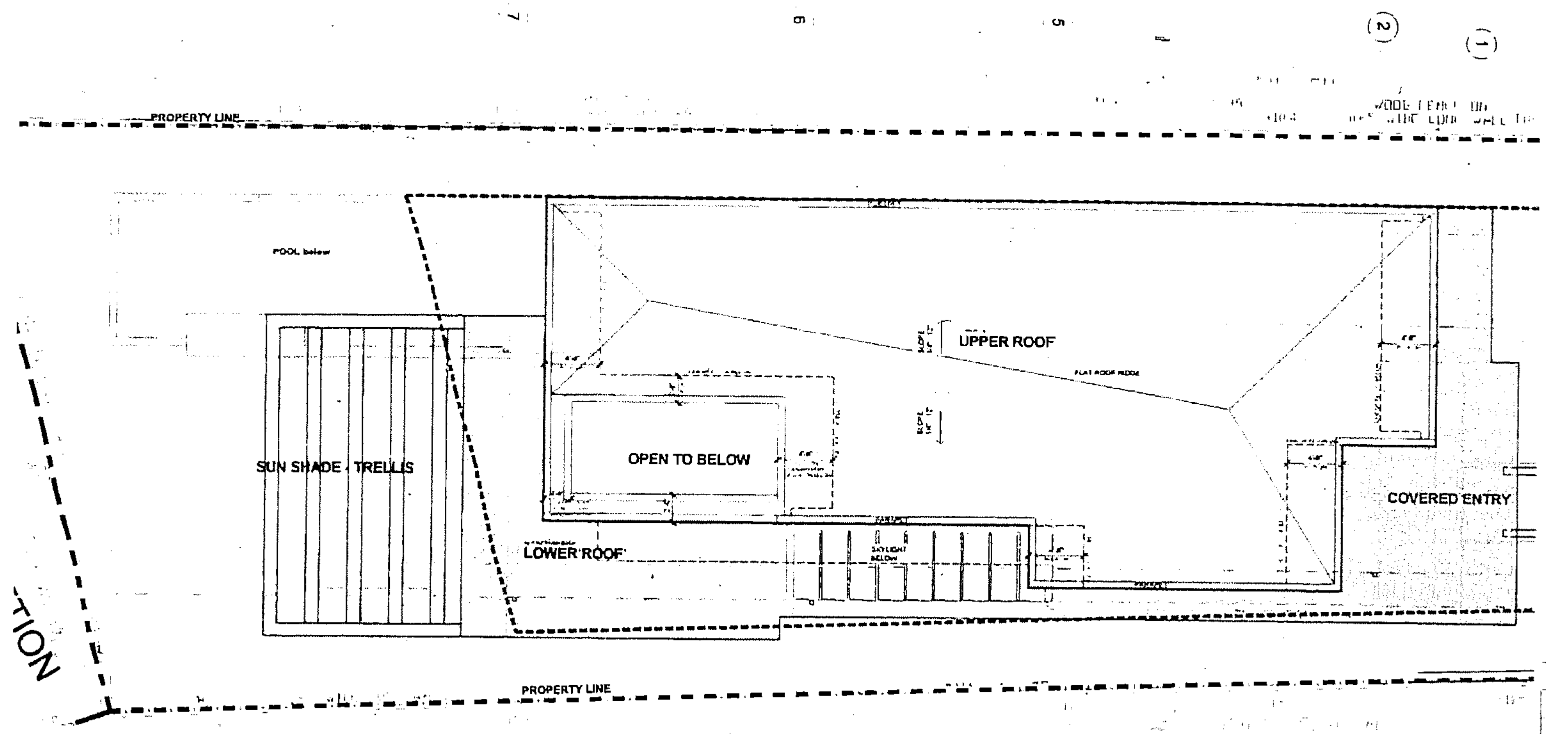
HLYNSKY + DAVIS ARCHITECTS INC.

HEFFEL RESIDENCE
4358 ROSS CRESC
W.VAN, BC

UPPER PLAN

A2.3

115



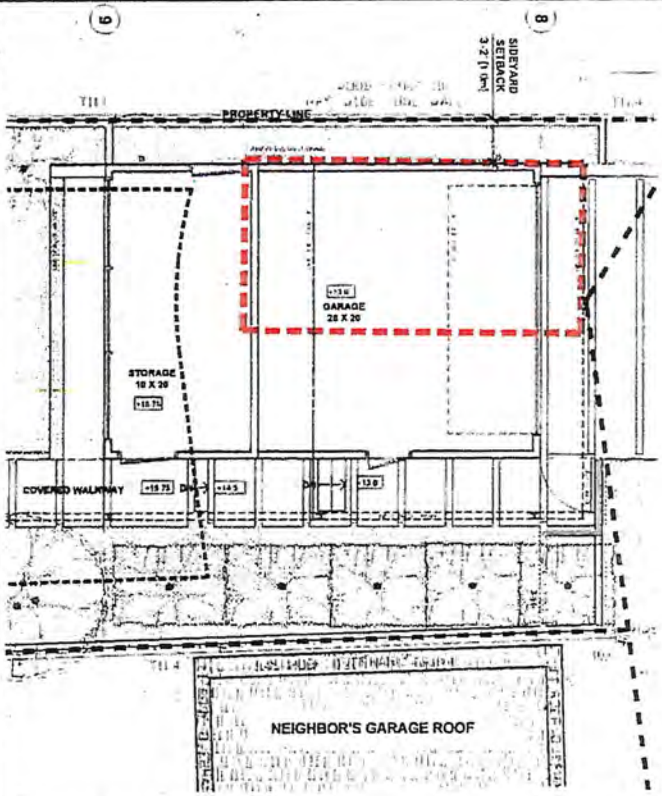
HDA

HLYNSKY + DAVIS
ARCHITECTS INC

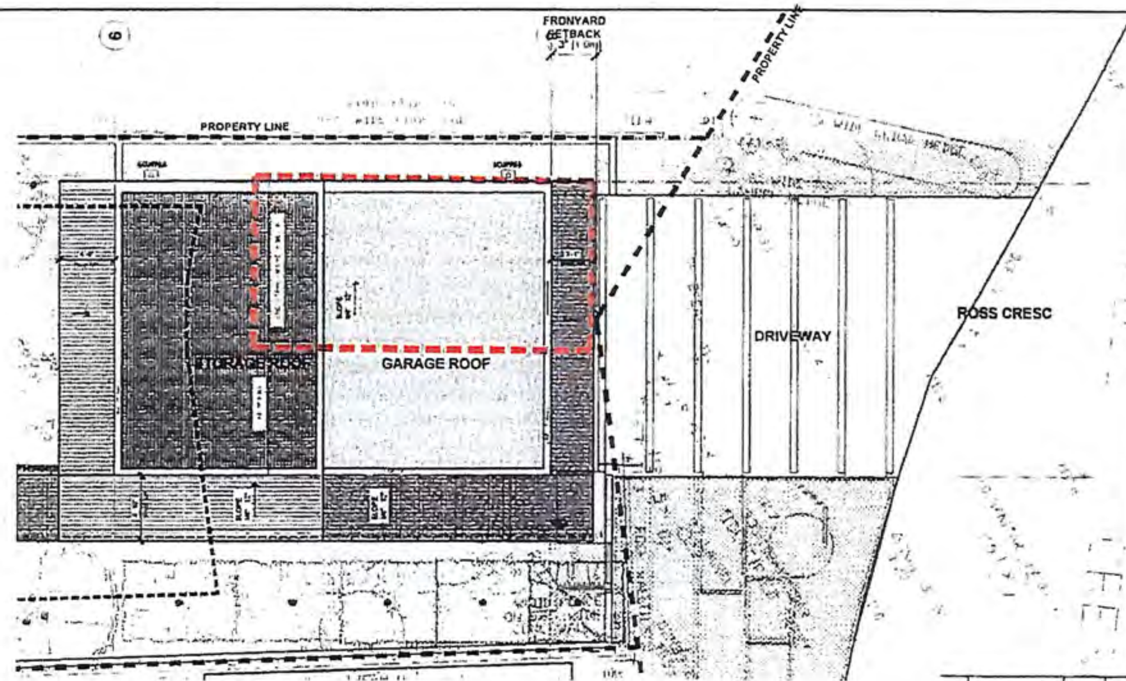
HEFFEL RESIDENCE
4354 ROSS CRESC
W VAN BC

ROOF PLAN

A2.4



GARAGE + STORAGE PLAN



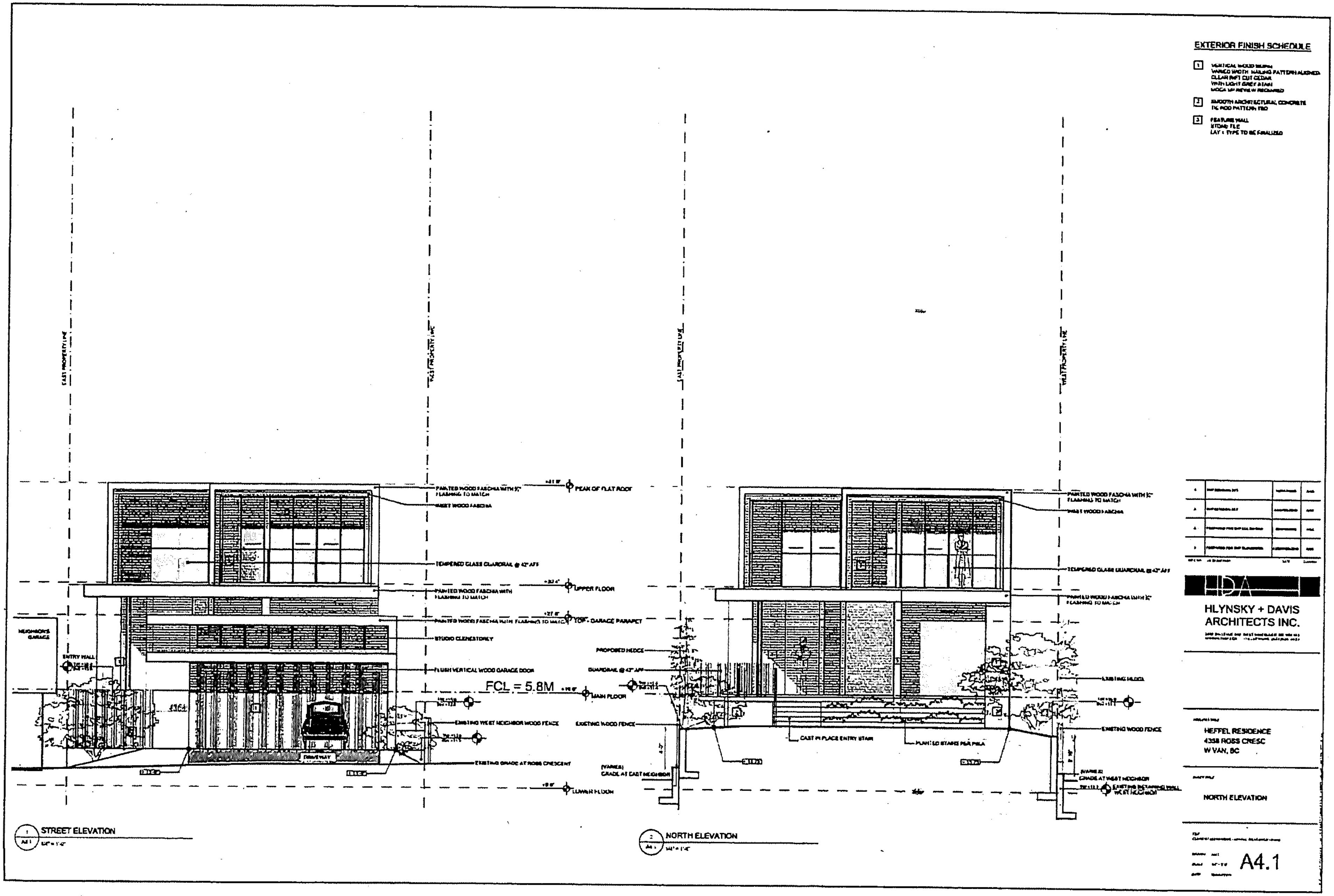
GARAGE + STORAGE ROOF PLAN

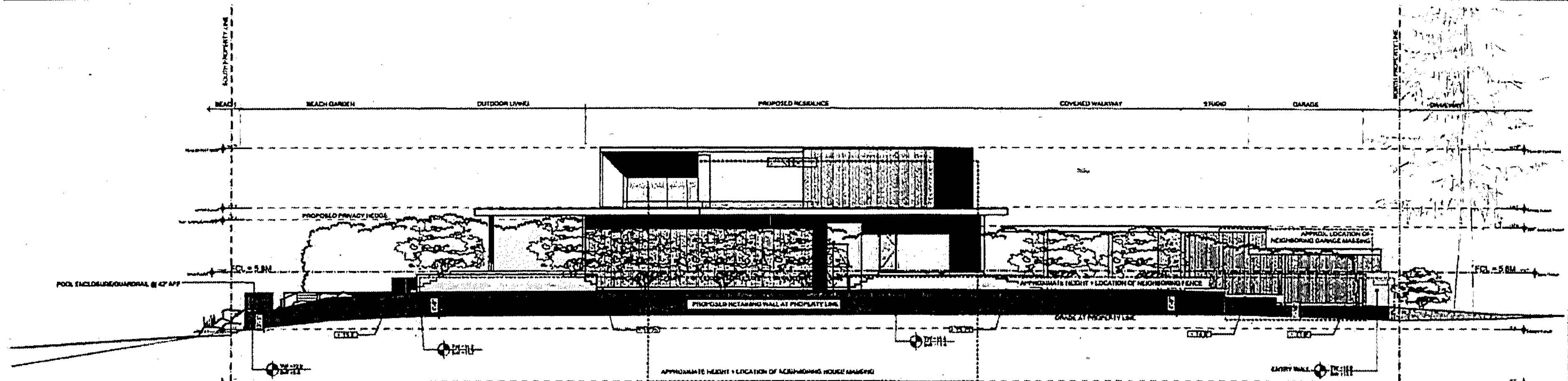
HLYNSKY + DAVIS ARCHITECTS INC.

HEFFEL RESIDENCE
4358 ROSS CRESC
W VAN BC

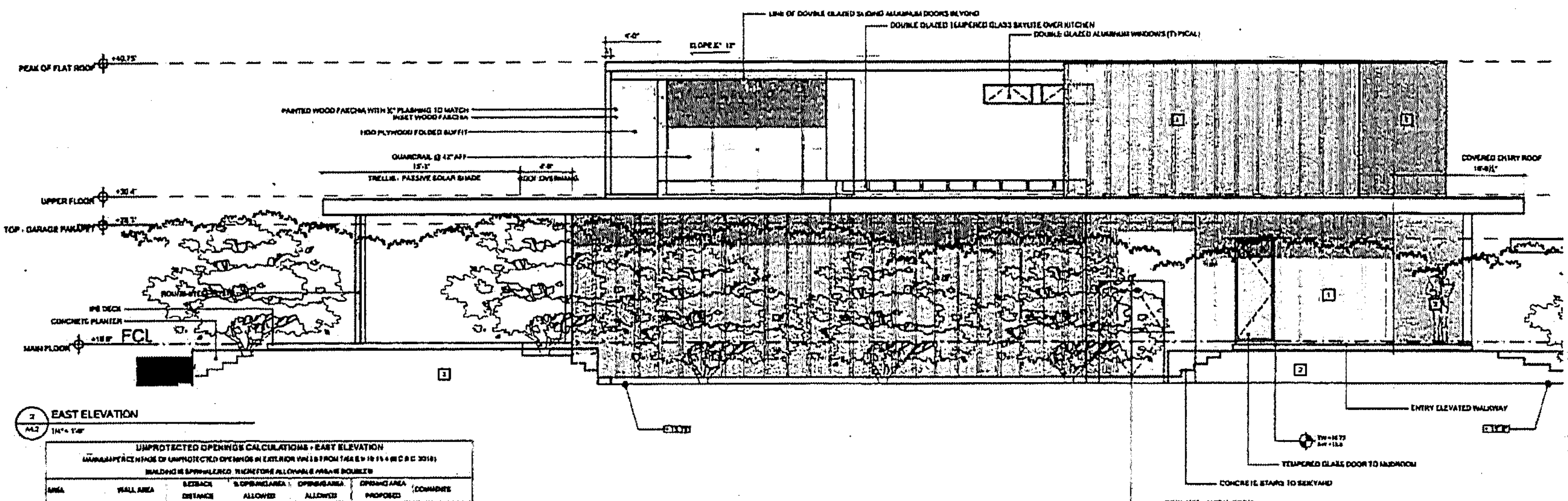
GARAGE PLAN

A2.5


EXTERIOR FINISH SCHEDULE
PEAK OF FLAT ROOF
TEMPERED GLASS GUARDRAIL @ 42" AFF
UPPER FLOOR
TOP - GARAGE PARAPET
STUDIO CLERESTOREY
FLUSH VERTICAL WOOD GARAGE DOOR
FCL = 5.8M
MAIN FLOOR
EXISTING WEST NEIGHBOR WOOD FENCE
EXISTING GRADE AT ROSS CRESCENT
LOWER FLOOR
DRIVEWAY
ENTRY HALL
PROPOSED HEDGE
GUARDRAIL @ 42" AFF
EXISTING WOOD FENCE
CAST IN PLACE ENTRY STAIR
EXISTING HEDGE
HLYNSKY + DAVIS
ARCHITECTS INC.
HEFFEL RESIDENCE
4358 ROSS CRESC
W VAN, BC
NORTH ELEVATION
A4.1
STREET ELEVATION
NORTH ELEVATION



1 / A4.2 EAST ELEVATION - SITE CONTEXT



2 / A4.2 EAST ELEVATION

1/4" = 1'-0"

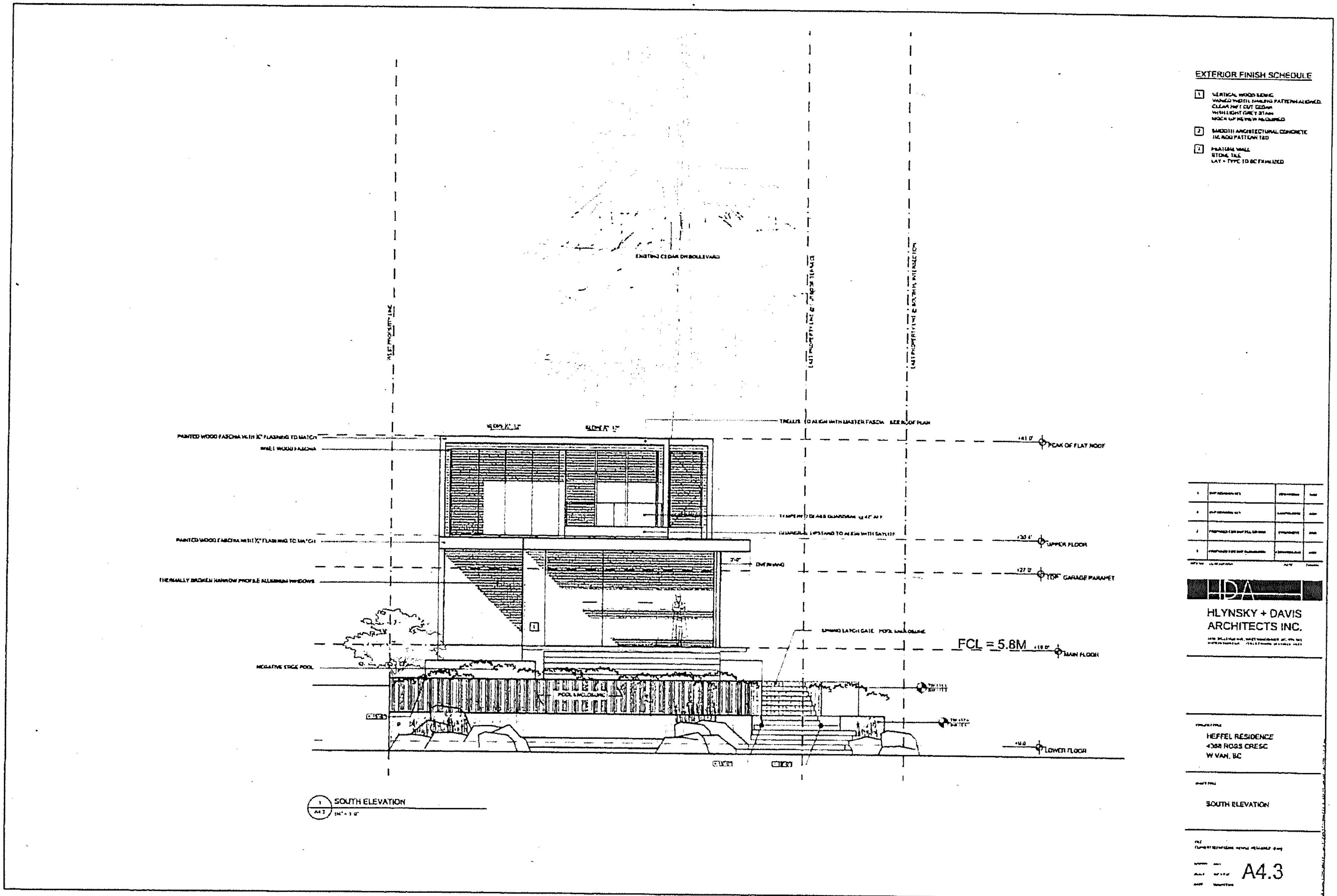
UNPROTECTED OPENINGS CALCULATIONS - EAST ELEVATION						
AREA	WALL AREA	SETBACK DISTANCE	% OPENING AREA ALLOWED	OPENING AREA ALLOWED	OPENING AREA PROPOSED	COMMENTS
EAST	[illegible] sq ft 142.81 sq m	[illegible] [illegible] m	[illegible] %	[illegible] sq ft 23.07 sq m	[illegible] sq ft [illegible] sq m	CONFORMS

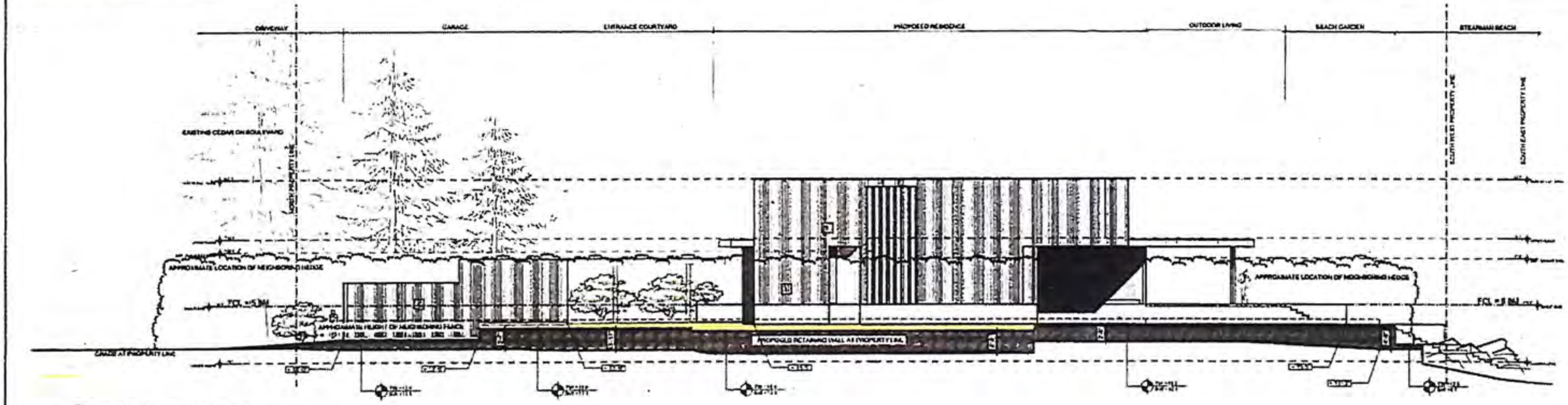
HLYNSKY + DAVIS
ARCHITECTS INC.

HEFFEL RESIDENCE
4356 ROSS CRESC
W VAN, BC

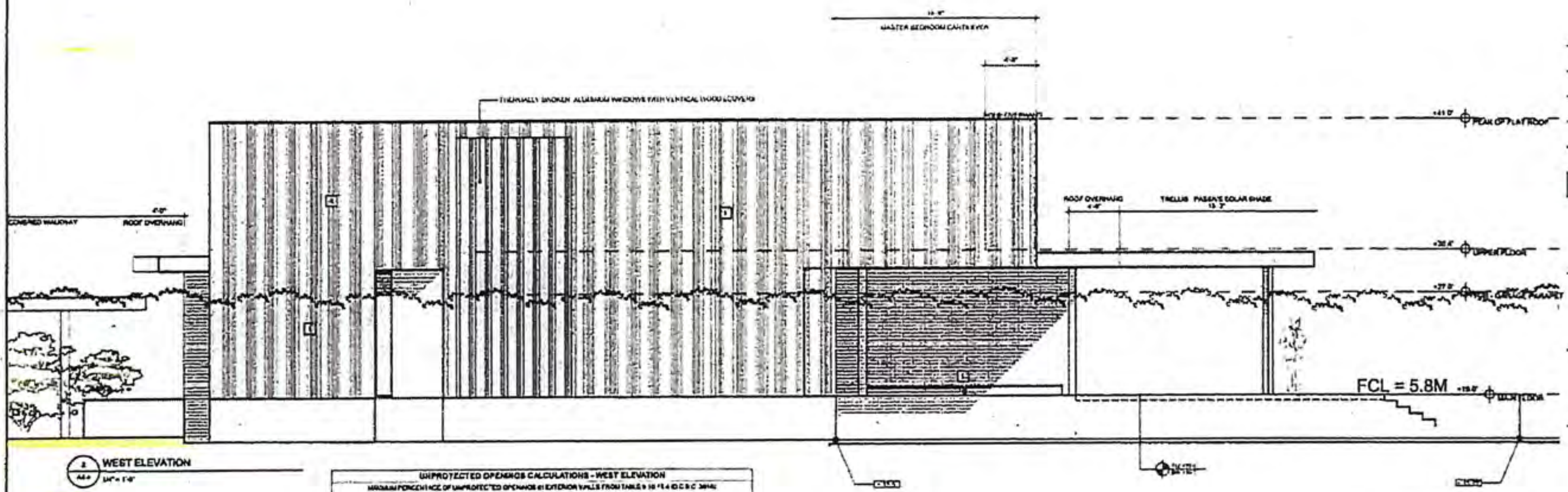
EAST ELEVATION

A4.2


EXTERIOR FINISH SCHEDULE
EXISTING CEDAR ON BOULEVARD
PEAK OF FLAT ROOF
UPPER FLOOR
GARAGE PARAPET
OVERHANG
FCL = 5.8M
MAIN FLOOR
NEGATIVE EDGE POOL
LOWER FLOOR
SOUTH ELEVATION
HLYNSKY + DAVIS
ARCHITECTS INC.
HEFFEL RESIDENCE
4368 ROSS CRESC
W VAN, BC
SOUTH ELEVATION
A4.3



1 WEST ELEVATION - SITE CONTEXT



2 WEST ELEVATION

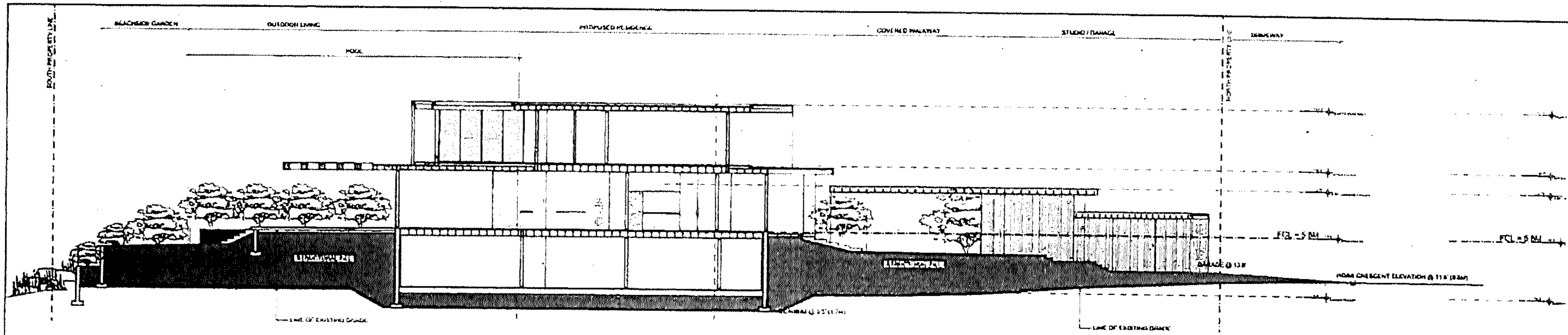
UNPROTECTED OPENINGS CALCULATIONS - WEST ELEVATION						
AREA	WALL AREA	SETBACK DISTANCE	% OPENING AREA ALLOWED	OPENING AREA ALLOWED	OPENING AREA PROPOSED	COMMENTS
PART 1	1330.28 sq.ft 124.43 sq.m	5'-4" 1.50 m	14.0%	167.51 sq.ft 17.42 sq.m	186.91 sq.ft 17.37 sq.m	CONFORMS
PART 2	278.74 sq.ft 25.62 sq.m	13'-0.34" 4.00 m	97.6%	268.12 sq.ft 23.90 sq.m	53.76 sq.ft 4.99 sq.m	[illegible]

HLYNSKY + DAVIS ARCHITECTS INC.

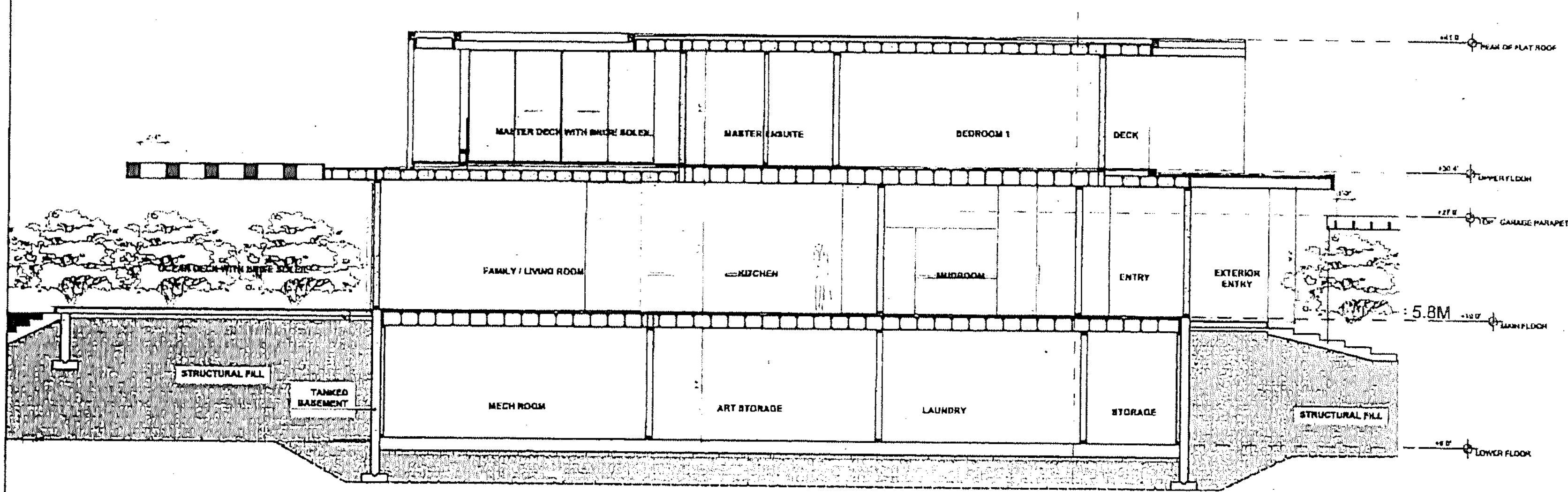
HEFFEL RESIDENCE
4358 ROSS CRESC
W VAN, BC

WEST ELEVATION

A4.4



1 TYPICAL SECTION NORTH - SOUTH
A5.1



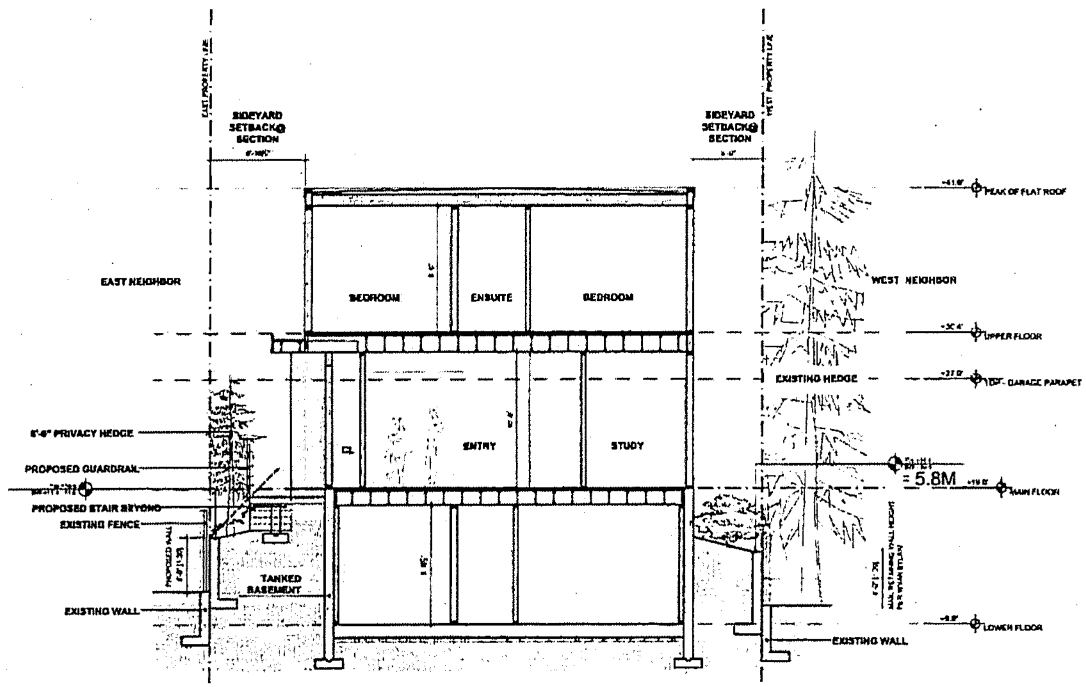
2 TYPICAL SECTION NORTH - SOUTH
A5.1

HLYNSKY + DAVIS ARCHITECTS INC.

HEFFEL RESIDENCE
4358 ROSS CRESC
W.VAN, BC

SECTION - NORTH SOUTH

A5.1



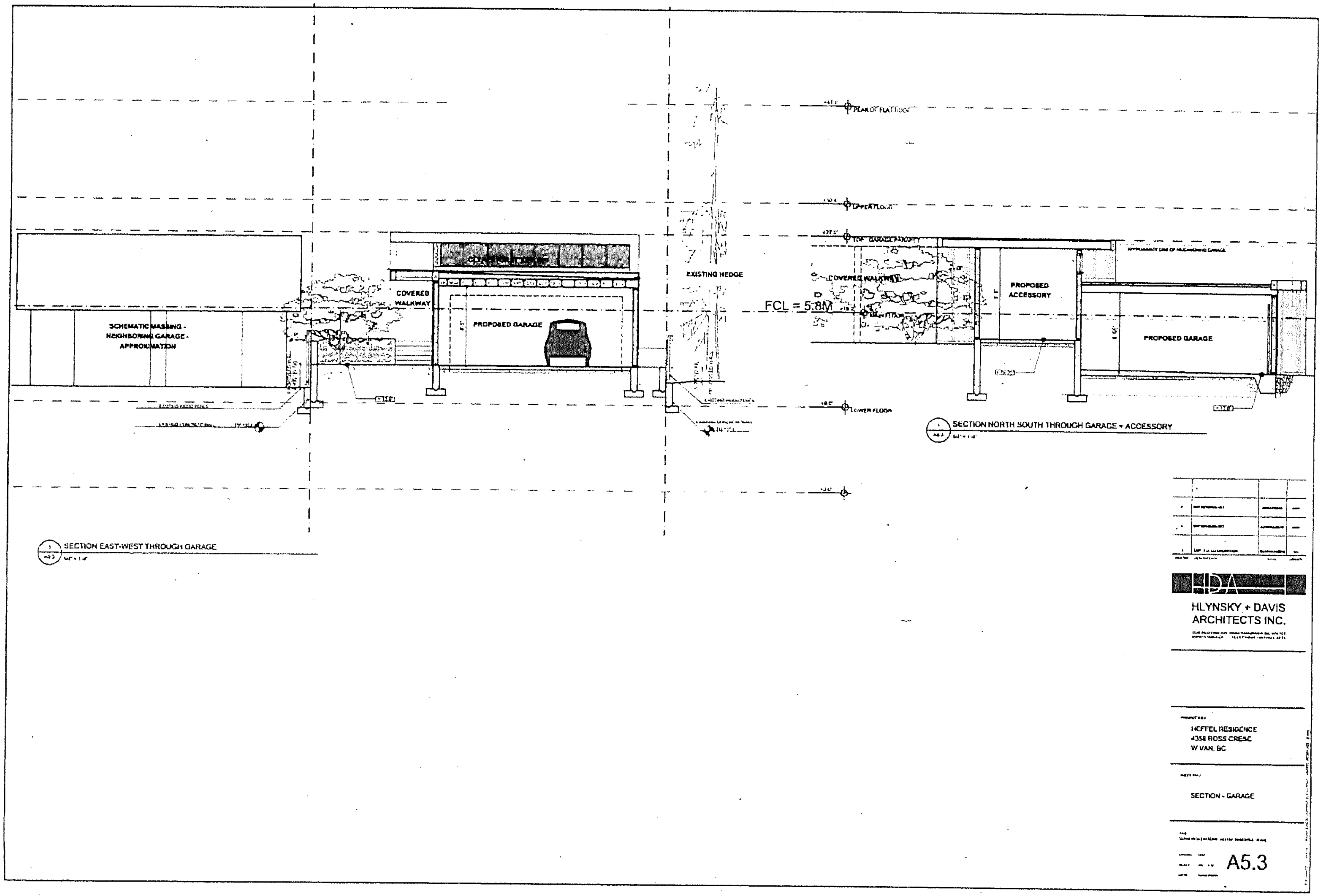
SECTION EAST-WEST AT GREATEST WIDTH

HLYNSKY + DAVIS
ARCHITECTS INC.

HEFFEL RESIDENCE
4358 ROSS CRESC
W VAN, BC

SECTION - EAST WEST

A5.2


SCHEMATIC MASSING - NEIGHBORING GARAGE - APPROXIMATION
COVERED WALKWAY
PROPOSED GARAGE
EXISTING HEDGE
FCL = 5.8M
COVERED WALKWAY
PROPOSED ACCESSORY
PROPOSED GARAGE
LOWER FLOOR
SECTION NORTH SOUTH THROUGH GARAGE + ACCESSORY
SECTION EAST-WEST THROUGH GARAGE
HLYNSKY + DAVIS ARCHITECTS INC.
HOFFEL RESIDENCE
4358 ROSS CRESC
W VAN, BC
SECTION - GARAGE
A5.3

APPENDIX C

DISTRICT OF WEST VANCOUVER

ROSS CRESCENT FLOOD CONSTRUCTION LEVEL

wsp

ROSS CRESCENT FLOOD CONSTRUCTION LEVEL

DISTRICT OF WEST VANCOUVER

PROJECT NO.: 191-12114-00
DATE: DECEMBER 2, 2019

WSP CANADA INC,
840 HOWE STREET, SUITE 1000
VANCOUVER, BC V6Z 2M1
WSP.COM

REVISION HISTORY

FIRST ISSUE

November 6, 2019	Draft Issue			
Prepared by	Prepared by	Reviewed by	Approved By	
Jordan Matthieu	Lisa Lee	Sundar Premasiri	Michael Coull	
REVISED DRAFT				
November 28, 2019	Revised Draft Issue			
Prepared by	Prepared by	Reviewed by	Approved By	
Jordan Matthieu	Lisa Lee	Sundar Premasiri	Michael Coull	
Issued as Final				
December 2, 2019	Final Issue			
Prepared by	Prepared by	Reviewed by	Approved By	
Jordan Matthieu	Lisa Lee	Sundar Premasiri	Michael Coull	

SIGNATURES

PREPARED BY

December 2, 2019

Jordan Matthieu, M.Sc., P.Eng.
Coastal Engineer

Date

APPROVED[1] BY

December 2, 2019

Michael Coull
Director of Ports and Marine

Date

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WSP

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Coastal Engineer: Lisa Lee

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Project Manager: Michael Coull

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FIGURES

EXECUTIVE SUMMARY

A Development Application has been lodged for construction of a new residence on the property 4358 Ross Crescent. A coastal engineer's report (NHC, 2019) prepared to support the Development Application indicates the Flood Construction Level (FCL) to address the potential for coastal flooding is +5.8m. The District of West Vancouver (the District) engaged WSP to provide a second opinion on the FCL for the property, with a detailed narrative on the components used to determine the FCL value.

Guidance for determining the Year 2100 FCL is given in several documents:

- Ausenco Sandwell (2011a). Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use – Sea Dike Guidelines. Prepared for British Columbia Ministry of Environment.
- Ausenco Sandwell (2011b). Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use – Guidelines for Management of Coastal Flood Hazard Land Use. Prepared for British Columbia Ministry of Environment.
- Ausenco Sandwell (2011c). Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use – Draft Policy Discussion Paper. Prepared for British Columbia Ministry of Environment.
- British Columbia Ministry of Environment (2018). Amendment Section 3.5 and 3.6 – Flood Hazard Land Use Management Guidelines.

The 2018 Amendment notes the FCL can be determined by a Probabilistic Method or a Combined Method. The Combined Method is considered to be an overly conservative method. As a long record of recorded water level data is available the Probabilistic Method can be used and has been adopted for this work.

Using the Probabilistic Method, the FCL is determined as the sum of several components:

- The 200-year return period, or 0.5% Annual Exceedance Probability (AEP), total water level
- allowance for future Sea Level Rise (SLR) to the year 2100
- allowance for regional uplift or subsidence to the year 2100
- wave effects from a storm with a return period of 200 years or 500 years
- a freeboard of 0.6m

Methods for determining each component are explained and calculation of the FCL has been carried out.

INPUT DATA

Water levels and wave effects were determined from historical data. Wave conditions at the site are driven by the wind conditions in the Strait of Georgia. Wind and water level data were collected from publicly available sources, with wind data collected for 27 wind stations spread around the Strait and water levels obtained for Point Atkinson tide gauge, some 3km distant from the site. The proximity of the tide gauge to the site is an advantage as the long period of tide data available for Point Atkinson is directly applicable to the site. Extreme high tides, with levels to Canadian Geodetic Datum (CGD), are:

- Higher High Tide level: 1.9 m CGD
- Highest recorded tide level: 2.53 m CGD (this is above some of the ground levels on the existing property)

Wind data was used as an input to a regional wave model. Within the Strait of Georgia, there are two distinct populations of wind events, (i) with winds from a generally Northwesterly direction and (ii) winds from a generally Southeasterly direction, both following the axis of the Strait. At the subject site, winds are generally either Westerly or Easterly due to the topographic steering effects of the North Shore mountains.

SEA LEVEL RISE

Provincial SLR allowance guidance for BC follows pessimistic and conservative projections and indicates a 1 m vertical allowance for the period from 2000 to 2100. Provincial recommendations are slightly higher than 90th percentile projections up to 2070 and fall below the median curve by the early 2100s in recognition that in a planning network, time remains to revise curves upward if academic research or the required response warrants.

WSP's climate change specialists advise following British Columbia recommendations for the vertical allowance concerning sea level rise of 1.0 m by 2100, corresponding to 0.92 m of SLR (i.e. excluding subsidence) from a year 2000 benchmark. Federal estimates place the likely range (10th to 90th percentile) of sea level rise at Point Atkinson at 0.47 m to 0.89 m by 2100. This places the Provincial guideline value for the year 2100 near the 90th percentile estimate of RCP8.5.

As new regional studies become publicly available, the District of West Vancouver should follow Provincial recommendations to update vertical allowance estimates. The District should then revisit the vulnerability, risks and control measures for each infrastructure project having a design life within the revised vertical allowance timeframe.

UPLIFT AND SUBSIDENCE

Uplift and subsidence maps for the Greater Vancouver area indicate a subsidence rate of 1.0 mm/year +/-0.5 mm/year at the site location. For the time between the present and Year 2100, a total settlement allowance of 0.08 m is applied.

WATER LEVEL

The 200-year return period water level (combined tide and storm surge) was determined to be +2.63 m CGD +/-0.03 m.

WAVE EFFECTS

The wind data obtained for the 27 wind stations was used to generate wave conditions at the subject site using the numerical wave model SWAN.

A population of representative storm events was selected from nearby meteorological stations and used to generate an extreme value distribution of wave heights at the 30-m depth contour offshore of the project site. Extreme wave heights and peak periods developed for the site are:

RETURN PERIOD	H_s [m]	T_p [s]	DIRECTION
1	0.93 +/- 0.11	6.09 +/- 0.45	230°
25	1.70 +/- 0.12	8.16 +/- 0.89	230°
50	1.79 +/- 0.12	8.37 +/- 0.97	230°
100	1.87 +/- 0.12	8.55 +/- 1.04	230°
200	1.94 +/- 0.13	8.70 +/- 1.10	230°

JOINT PROBABILITY AND DESIGNATED STORM EVENT

The joint probability of tides, storm surge (residual water level) and waves was assessed. This involved analysis of the long period of tide data and meteorological data. In general, the water levels at the site were found to be independent of the wave and wind conditions.

Since the wave and water level events are independent, the joint probability of a given wave and storm event is simply the combination of the probability of the two events. The severity of the designated storm event is effectively defined by the magnitude of nearshore wave action and the associated water level. Designated Storm Event conditions with 200-year (lower bound) and 10,000-year (upper bound) have been defined at site:

- 200-year return period event resulting from:
  - 10-Year wave H_s = 1.57 m, T_p = 7.85 s,
  - 20-Year water level = 2.44 m
- 10,000-year return period event resulting from:
  - 50-Year wave H_s = 1.79 m, T_p = 8.37 s,
  - 200-Year water level = 2.63 m

WAVE RUNUP

Wave run-up at the project site was simulated using the numerical model SWASH. Year 2100 wave run-up for the undeveloped site is estimated to be 0.70 m for a 10,000-year return period matching previous reporting. The equivalent year 2100 wave run-up for the developed site is estimated to be 2.38 m.

Previous studies have reported a year 2100 run-up of 1.19 m for the developed site. The difference is due to deviations with the proposed berm profile post-development and a shorter offshore wave period used in the previous work.

FCL

FCL levels for the site in the year 2100 following the Probabilistic Method with a combined return period of 10,000 years matching previous reporting for the undeveloped site are:

200-Year Return Period Water Level	+2.63 m
Subsidence	+0.08 m
SLR allowance	+1.00 m
50-Year Return Period Run-Up	+0.70 m
Freeboard	+0.60 m
FCL	+5.01 m

Based on the Development Application lodged for construction of a new residence on the property 4358 Ross Crescent, a year 2100 coastal FCL of 5.8 m has been estimated by Northwest Hydraulic Consultants (NHC) at a 10,000-year return period level. The development includes significant filling of the site to achieve the required coastal FCL of 5.8 m. Based on Drawing A5.1 of the Development Application, WSP has computed the FCL for the as-developed site in the year 2100 following the Probabilistic Method with a return period of 10,000 years matching previous reporting as follows:

200-Year Return Period Water Level	+2.63 m
Subsidence	+0.08 m
SLR allowance	+1.00 m
50-Year Return Period Run-Up	+2.38 m

Freeboard	+0.60 m
FCL	+6.69 m

The largest single source (80%) of the +0.89 m discrepancy between previously report FCL values and those presented in this report is wave run-up against the berm structure. Wave run-up estimates differ primarily due to variations in the berm profile between previous reporting and the Development Application and differing estimates of wave period offshore of the project site.

SETBACK

As per provincial guidelines, the Natural Boundary is taken in this study as the FRP in a given assessment year. The 2100 setback has been defined as the greater of:

— 15m beyond the 2100 estimated Natural Boundary, with the estimated Natural Boundary taken as the FRP;
— The intersection of the 2100 FCL with the ground surface.

The properties surrounding 4358 Ross Crescent are also below the FRP of 4.41 m for the undeveloped site for the Year 2100. As the property at 4358 Ross Crescent has a width of only some 12 m, a strict interpretation of the setback requirement suggests the lot cannot be developed, without some modification of the adjacent lots.

The Provincial Guidelines (2018 Amendment) allow some relaxation of the setback for development of existing lots if meeting the setback guidelines would sterilize the lot whereby "the development approving official may agree to modify setback requirements as recommended by a suitably qualified Professional Engineer experienced in coastal engineering, provided that this is augmented through a restrictive covenant stipulating the hazard, building requirements, and liability disclaimer."

THE PROPOSED DEVELOPMENT

The project site is situated within the estimated year 2100 coastal flood plain. Therefore, an engineered fill (berm with the seaward face comprised of a series of vertical walls) has been proposed by the site developers to ensure the structure meets FCL requirements and is not damaged during storm events. Installing such a berm increases wave run-up compared to the undeveloped site and therefore requires a higher FCL compared to undeveloped conditions to avoid damage to the proposed structure. Wave run-up is the second-largest contributor to the FCL, behind tides and surge, and, consequently, the fill structure's design is a large factor in the FCL. This is largely unavoidable, as wave run-up will necessarily occur at a fill structure exposed directly to wave action. Mitigative measures could be employed to reduce the run-up heights. These could include:

— Inclusion of a recurve parapet at the second vertical retaining wall of the berm to cap wave run-up. The first vertical retaining wall is largely submerged during the Designated Storm Event, limiting the effectiveness of a recurve parapet at this location.
— Installation of armour rock and/or large woody debris seaward of the first vertical retaining wall, as shown on some drawings in the development application, to dissipate the waves before they reach the walls.

Even with mitigative measures in place, it is not necessarily reasonable to design an individual berm structure to achieve the required FCL on a site-by-site basis. Constructed in isolation, the side-slopes of the berm structure (i.e. running parallel to the main axis of the proposed structure), would be directly exposed to wave action in during the Designated Storm Event and require similar slope and crest protection as the seaward face of the berm to ensure that the full fill structure is adequately designed to resist wave action. Furthermore, during the Designated Storm Event in the year 2100, the site is cut off from land access as Ross Crescent is expected to be inundated.

1 INTRODUCTION

A Development Application has been lodged for construction of a new residence on the property 4358 Ross Crescent. Previous work carried out by NHC Consultants (NHC, 2019) in support of the application established a Year 2100 coastal Flood Construction Level (FCL) of +5.8m. The riverine FCL at the back of the property was established to be +5.1m. The existing site is some 3.35m below the FCL, consequently significant filling of the site is required to achieve the FCL of +5.8m.

The District is seeking a second opinion on the Flood Construction Level and has engaged WSP to carry out this work.

Our work focusses on the determination of an appropriate FCL to address the coastal flooding hazard.

2 BACKGROUND

The foreshore fronting the site is described in NHC 2019 as:

> "existing foreshore consists of gravel and cobble beach sloping at roughly 6.6% slope (15H:1V) followed by a 15m long flat section. in front of the property, the foreshore transition to a roughly 5% slope (20H:1V) where large woody debris accumulation was observed on top of boulders placed along the width of the property."

The beach area in front of the property is shown in Figure 1 and Figure 2.

Engineers from WSP inspected the site on two occasions:

- During a low tide event on 15 September 2019
- During a high tide event on 3 November 2019

These site visits confirmed the beach area in front of the property is as described by NHC.

Figure 1 - Photo of Foreshore Area Fronting 4358 Ross Crescent

Figure 2 - Photo of Upper Beach Area Fronting 4358 Ross Crescent

The following drawings related to the application have been obtained from the District's website:

- A1.1a: Title Sheet
- A1.1b: Brief
- LDE-1.01 R0: Landscape Masterplan
- L-4.01 R0: Tree and Planting Plan
- A1.2: Site Plan
- A1.3 Context Plan
- A1.4: Garage Comply Diagramme
- A1.5: Proposed Vs Existing
- A1.6: Average Grade and Retaining Walls
- A2.1: Lower Plan
- A2.2: Main Plan
- A2.3 Upper Plan
- A2.4: Roof Plan
- A2.5: Garage Plan
- A4.1: North Elevation
- A4.2: East Elevation
- A4.3: South Elevation
- A4.4: West Elevation
- A5.1: Section – North-South
- A5.2: Section – East West
- A5.3 – Section Garage

Levels obtained from a survey on and around the site are shown on several drawings. Based on these drawings ground levels are summarised as Follows:

- On the property at 4358 Ross Crescent – approximately between +2.23m (+7.3 ft) and +3.05 m (+10 ft),
- No. 4360 adjacent property to the west – ground levels on the waterside part (southern face) of the property are shown to be between +3.87 m (+12.7 ft) and 4.18 m (13.7 ft),
- No. 4346, adjacent property to the east – ground levels on the waterside part (southern face) of property are shown to be +3.2 m (+1.5 ft)

The existng levels at No. 4358 are below those of the adjacent properties.

3 COMPONENTS OF THE FLOOD CONSTRUCTION LEVEL

The FCL is comprised of several water level components caused by different physical processes:

- Astronomical tidal level
- Storm surge
- Wave effects
- Sea Level Rise (SLR)
- Land subsidence or uplift

Flood Hazard Area Land Use Management Guidelines (Ausenco Sandwell, 2011a, 2011b, 2011c) provide recommendations on estimation of FCL for coastal shoreline areas. Amendment Sections 3.5 and 3.6 "Flood Hazard Area Land Use Management Guidelines" provides updated guideline on estimating the FCL for coastal areas (BCMoE 2018). This amendment recommends two approaches, a Probabilistic Method and a Combined Method. The combined method is considered as an overly conservative approach and as a long record of recorded water level data is available, the Probabilistic Method has been adopted in this analysis.

The Year 2100 FCL shall be determined as the sum of:

- The 200-year return period, or 0.5% Annual Exceedance Probability (AEP), total water level as determined by probabilistic analyses of tides and storm surge;
- Allowance for future SLR to the years 2100;
- Allowance for regional uplift, or subsidence to the years 2100;
- Estimated wave effects associated with the Designated Storm with a return period of 200 or 500 years; and
- A minimum freeboard of 0.6 m.

These components are illustrated in Figure 3.

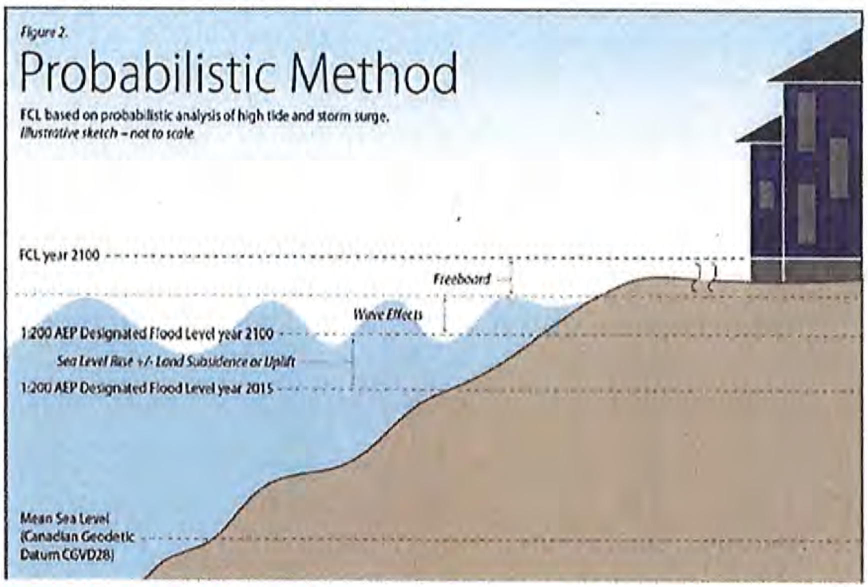


Figure 3 Probabilistic Method

The FCL is largely determined by the still water level (SWL) associated with a Designated Flood Event and wave effects associated with a Designated Storm Event. Provincial guidelines indicate that a 200-year return period water level (Designated Flood Event) should be combined with a 200-year return period wave condition (Designated

Storm Event). Given that water levels and wave conditions are not strictly related in the Strait of Georgia, the combined return period of these two designated events (i.e. the probability that they occur simultaneously) is, assuming independence, approximately 40,000 years. Ausenco Sandwell (2011a) suggests that an appropriate design return period for areas with extensive foreshore development and no dykes should be 10,000 years over an assessment horizon of 100 years, which forms a more reasonable upper bound that is more in line with international standards. For the purposes of this analysis, combinations of water levels and wave conditions equal to 200, 10,000 and 40,000-year return periods are considered. FCL values are reported for 200-year and 10,000-year return periods:

- **200-Year Return Period:** The level has been adopted as a reasonable lower bound, corresponding to the lower bound of design return period of diking along the Lower Fraser River (200 to 500 year estimated return period based on the 1894 flood of record) and being in-line with an overall 200-year joint probability approach indicated by guidelines (BCMoE).
- **10,000-Year Return Period:** This level has been adopted as a reasonable upper bound following from guideline values presented in Ausenco Sandwell (2011a) for highly developed shorelines. Given that a 200-year return period flood level is proscribed, this necessarily corresponds to a 50-year return period wave condition.

4 ENVIRONMENTAL CONDITIONS

4.1 DATA SOURCES

4.1.1 WINDS

A total of 27 wind stations spread throughout the Strait of Georgia have been used in various aspects of this study. The full set of 27 stations was applied in interpolating wind fields for the numerical model used to derive offshore wave conditions (Section 6.1). Stations at Point Atkinson (1106200), Vancouver International Airport (YVR) (1108395), Halibut Bank (C46146) and Sand Heads (1107010) were used to define the population of extreme events at the project site (Section 4.2). Table 4-1 presents complete list of meteorological stations used in this study.

Data for Canadian meteorological stations were obtained via Environment and Climate Change Canada (ECCC), data for Canadian buoys were obtained via the Department of Fisheries and Oceans (DFO) and data for American meteorological stations were obtained via the National Oceanographic and Atmospheric Administration (NOAA). Data were obtained from the start of measurement at each station to September 18, 2019, the date of data download.

Table 4-1 - Summary of employed meteorological data

STATION NAME	STATION NUMBER	SOURCE	START YEAR	END YEAR	LATITUDE	LONGITUDE	ELEVATION
Kelp Reefs	1013998	ECCC	1997	2019	48.547694	123.237033	-
Saturna Island	1017101	ECCC	1994	2019	48.783906	123.044745	24.40 m
Victoria Int. Airport	1018620	ECCC	1953	2013	48.647225	123.425833	19.50 m
Ballenas Island	1020590	ECCC	1994	2019	49.350278	124.160278	14.50 m
Entrance Island	1022689	ECCC	1994	2019	49.208664	123.810556	7.60 m
Nanaimo Airport	1025365	ECCC	2014	2019	49.054444	123.870000	28.00 m
Sisters Island	1027403	ECCC	1995	2019	49.486611	124.434944	20.00 m
Grief Point	1043304	ECCC	1997	2019	49.804611	124.525222	10.00 m
Sechelt	1047172	ECCC	2007	2019	49.457994	123.715263	86.20 m
Point Atkinson	1106200	ECCC	1996	2019	49.330361	123.264722	14.00 m
Sand Heads	1107010	ECCC	1994	2019	49.105894	123.303368	11.00 m
Tsawwassen Ferry	1108291	ECCC	2012	2019	49.003911	123.133344	7.30 m
YVR	1108395	ECCC	2014	2019	49.195000	123.181944	4.30 m
Vancouver Harbour	1108446	ECCC	1976	2019	49.295353	123.121869	2.50 m
West Vancouver	1108824	ECCC	1994	2019	49.347042	123.193308	170.20 m
Pam Rocks	10459NN	ECCC	1994	2019	49.487778	123.299453	7.10 m
Squamish Airport	10476F0	ECCC	1982	2019	49.783208	123.161194	53.70 m
Halibut Bank	C46146	DFO	1992	2019	49.340000	123.726667	3.00 m
Sentry Shoal	C46131	DFO	1992	2019	49.906667	124.985000	3.00 m
Pat Bay	C46134	DFO	2001	2016	48.650000	123.450000	3.00 m

STATION NAME	STATION NUMBER	SOURCE	START YEAR	END YEAR	LATITUDE	LONGITUDE	ELEVATION
Campbell River A.	1021261	ECCC	1979	2013	49.951944	125.273056	108.80 m
Comox Airport	1021830	ECCC	1953	2019	49.716667	124.900000	25.60 m
Chatham Point	1021480	ECCC	1994	2001	50.333194	125.445556	22.90 m
White Rock	1108910	ECCC	1994	2019	49.018056	122.783889	13.00 m
Bellingham Airport	WBAN:24217	NOAA	1990	2019	48.793890	122.537220	45.40 m
Orcas Island	WBAN:04224	NOAA	2006	2019	48.708330	122.910560	9.40 m
Whidby Island	WBAN:24255	NOAA	1995	2019	48.350000	122.666670	14.30 m

4.1.2 WATER LEVELS

Measured water levels have been obtained via the Canadian Hydrographic Services (CHS) for Point Atkinson (Station 7795), which is 2 km from the project site. As this gauge is so close to the project site, no further gauge data was employed in this study. The tidal levels at Point Atkinson are published in Chart Datum (CD), defined as the plane of lowest normal tide, and must be converted to Canadian Geodetic Datum (CGD). CD is approximately -3.066 m CGD at Point Atkinson based on the most recent information obtained from the CHS (Canadian Hydrographic Service, 2018). Several different conversions have been adopted in past studies using Point Atkinson as a data source:

- 3.04 m: Triton (2006)
- 3.10 m: NHC (2014)
- 3.06 m: Kerr Wood Leidal (2015)

Discrepancies between the current CHS conversion from CD to CGD and those applied in previous studies should be accounted for in any comparison of results.

Hourly data are available at Point Atkinson over a 105-year period from 1914 to 2019. Overall the record is 74% complete, with 34% completeness before 1950, 95% completeness from 1950 to 2019 and 98% completeness between 1961 and 2018. The Point Atkinson water level record is generally considered to be continuous from 1961 onwards. In this 105-year record, 82 years had sufficient data to be considered complete. The effective record length, found from the number of hourly records, for this station is 77 years. A frequency analysis was conducted to estimate flood levels for various return period using the 77 years of effective annual water level data.

In addition to the measured water levels, the CHS has provided predicted tidal levels for the full period of record at Point Atkinson, allowing the determination of the residual water level (storm surge). Table 4-2 presents the typical tidal levels at Point Atkinson, as well as the highest recorded water level of 2.53 m on December 16, 1982 at 15:00 UTC, which is 0.90 m above the predicted tide of 1.63 m at the time of measurement. This highest recorded water level is above some of the ground levels on the exiting property.

Table 4-2 - Summary of tidal conditions at Point Atkinson

TIDAL CONDITION	WATER LEVEL (m, CGD)
Higher High Water, Large Tide (HHWLT)	1.9
Higher High Water, Mean Tide (HHWMT)	1.3
Mean Water Level (MWL)	0
Lower Low Water Mean Tide (LLWMT)	-2.0
Lower Low Water, Large Tide (LLWLT)	-3.2
Highest Recorded Still Water Level	2.53

4.1.3 WAVES

Measured wave conditions have been obtained via the DFO at Halibut Bank (Buoy C46146). This buoy is centrally located in the Strait of Georgia and has been used for model calibration (Section 6.1.3) and to define the population of extreme events at the project site (Section 4.2). The location of this buoy is noted in Table 4-1.

4.2 REGIONAL WIND PATTERNS

Regional wind patterns drive wave conditions in the Strait of Georgia and, ultimately, wave effects at the project site. Figure 4 presents a selection of wind roses from the meteorological stations considered in this study. Wind directions are presented in the meteorological convention (i.e. an Easterly wind is from the east) and show the general directional trends in the Strait of Georgia. Within the Strait of Georgia, there are two distinct populations of wind events, with winds from a generally Northwesterly direction and winds from a generally Southeasterly direction, following the axis of the Strait. Local variations in the trend are present near major topographic features such as Howe Sound, where winds are generally Northerly or Southerly and near the mouth of the Fraser Valley and Burrard Inlet where there is a strong Easterly component to the wind climate. At the project site, winds are generally either Westerly or Easterly due to the topographic steering effects of the North Shore mountains.

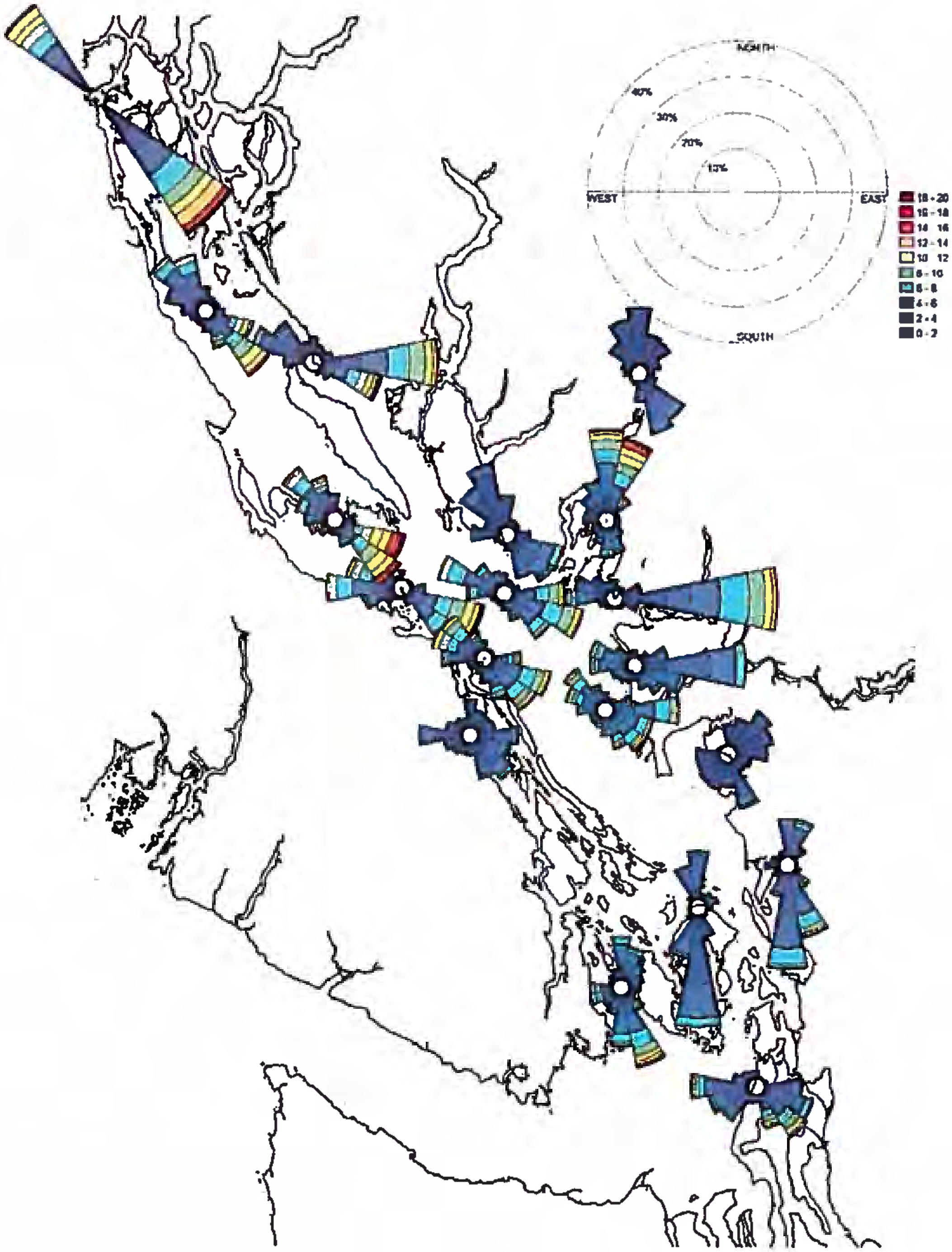


Figure 4 - Wind roses at selected meteorological stations, wind directions in meteorological convention, units of m/s

5 SEA LEVEL RISE

Sea level directly responds to variations in the global water cycle (Rhein et al., 2013). Sea level may then evolve:

- when the ocean cools or warms,
- when water is transferred between the ocean and continents (evaporation and precipitation), between the ocean and ice sheets (snow, freezing and ice melting), and
- when water is reallocated to different ocean regions due to tide variability and changes in the dynamics of the climate system.

Sea level can vary on different scales:

- time scales ranging from hours to centuries,
- spatial scales from less than one kilometer to global, and
- with height variations from one millimeter to a meter or even more. (Larger level variations are mainly due to tides).

Variations in sea level mainly impact people, infrastructure and the environment in coastal areas. Coupled with variations in storm surges, tide heights and extreme precipitation, they are one of the major threats to sustainable development of coastal regions.

5.1 SEA LEVEL RISE IN THE RECENT PAST

Sea level has always evolved, and sometimes very rapidly: 130 m between the last ice age about 21,000 years ago and the beginning of the current interglacial period, about 1 meter per century. Such changes can only be explained by natural variations. Since the beginning of the industrial period at the end of the 19th century, sea level has risen by about 20 cm (Figure 5, Rhein et al., 2013). This is mainly due to global temperature rise that has reached +1°C at global scale recently (GISS Surface Temperature Analysis, 2019). Atmosphere temperature rise leads to two phenomena influencing sea level rise:

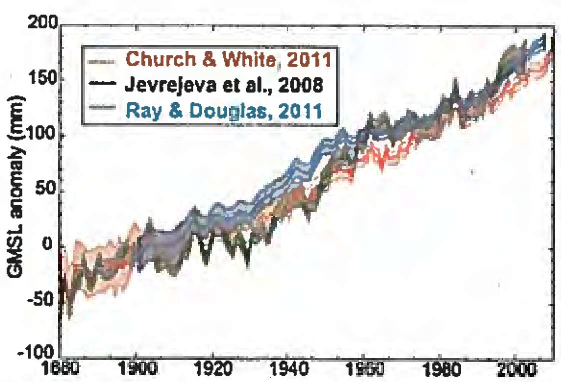


Figure 5 - Yearly average global mean sea level rise reconstructed from tide gauges (1900–2010) by three different approaches

- The more sea water temperature rises, the more the water expands. Water expansion is a major influence on past changes in sea level and is expected to make the greatest contribution to sea level rise over the 21st century.
- Higher temperature enhances sea ice and glacier melting. Antarctica, Greenland and mountain glaciers store large amounts of water. It melts more and more with temperature rise. Water previously stored on land as ice and snow is then added to the ocean.

Over the past 20 years, it is certain that globally averaged sea level has risen with a mean rate of 3.2±0.4 mm per year. However, regional patterns of sea level rise remain a reality due to high winds, ocean circulation, tide heights and continental topography (Figure 6).

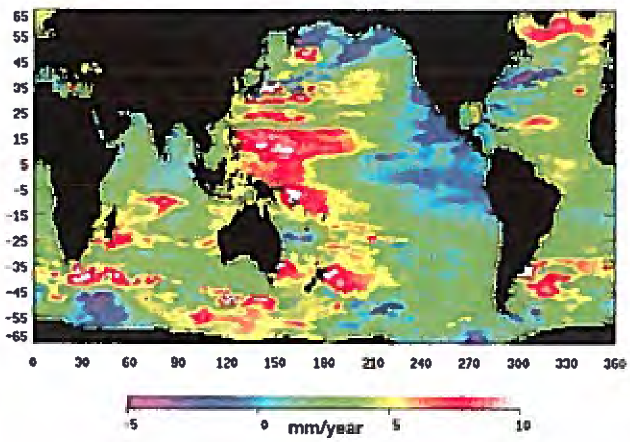


Figure 6 - Spatial representation of the mean rate of sea level rise between 1993 and 2018 (Jet Propulsion Laboratory, NASA, created with data from the Topex/Poseidon and Jason-1 satellites)

Observations for the West Coast of Canada are slightly below the global average. An assessment led by the Pacific Climate Impacts Consortium has enabled the estimate of historical sea level rise for the Vancouver area by using data collected at tide gauges Figure 7). Average sea level rose by 3.7 cm at Vancouver, less than in Prince Rupert and more than in Tofino. These discrepancies are mainly due to the combined impacts of climate change and vertical land movements. In general, the coast of British Columbia is currently rising due to post-glacial rebound (i.e. the rising of land due to past thinning and retreat of massive ice sheet). Plus, the shifting of the tectonic plates generates vertical land motion causing parts of Vancouver Island to rise. That is why, the southwest coast of Vancouver Island rose by about 25 centimetres, while the vertical land motion of Prince Rupert is negligible. This explains the difference in sea level change between different sites.

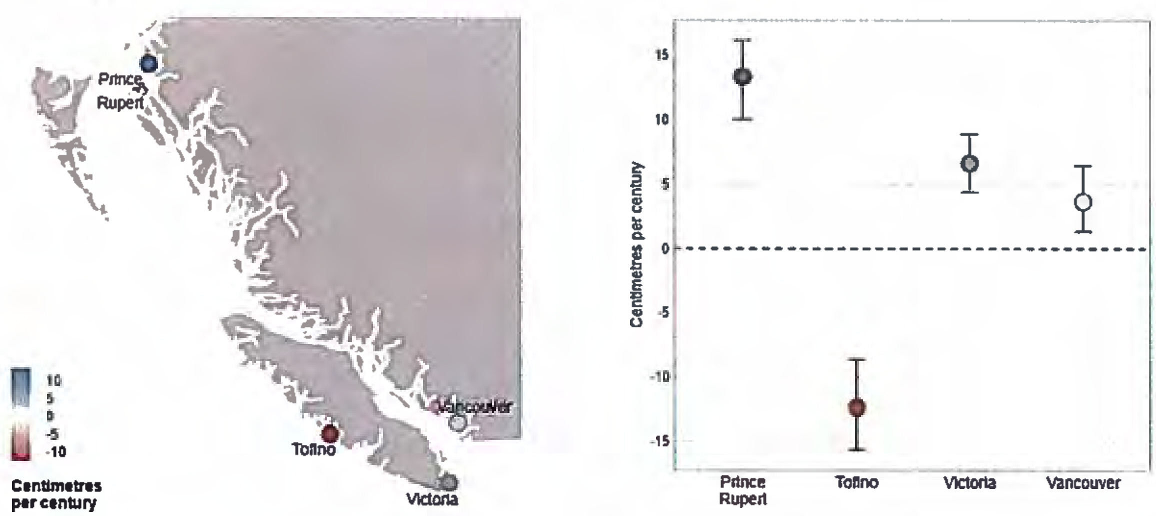


Figure 7 - Historical sea level rise between 1910 and 2014 on the Canadian West Coast (PCIC, 2016)

5.2 SEA LEVEL RISE IN THE FUTURE

Future climate conditions are projected using different greenhouse gas (GHG) emission scenarios, known as Representative Concentration Pathways (RCPs). These RCPs provide a range of possible trajectories of how global land use and emissions of GHGs and air pollutants may change throughout the 21st century. They are named according to their radiative forcing values (the change in net irradiance in the atmosphere due to external drivers) in the year 2100: 2.6, 4.5, 6.0, and 8.5 Wm^{-2} (IPCC, 2013). Therefore, RCP2.6 represents the least carbon intensive pathway while RCP8.5 represents the most. While RCP2.6 represents the lowest carbon scenario, it corresponds to a level of decarbonization which exceeds most ambitious decarbonization scenarios (Figure 8).

Figure 9 shows the evolution of the global mean sea level rise according to climate projections of RCP2.6 and RCP8.5 simulations. If we account for uncertainty ranges due to inter-model spread, sea level will rise by 26 to 98cm by the end of the century compared to the 1986-2005 period (Church et al., 2013). As highlighted for the RCP2.6 scenario, sea level rise will continue to rise, even if GHG emissions decrease drastically to get almost null. The deep ocean responds slowly to climate change, and expansion of the ocean due to temperature rise is likely to continue for several centuries. Glaciers, ice caps and ice sheets are also expected to continue to shrink with the melted ice increasing the volume of water in the ocean.

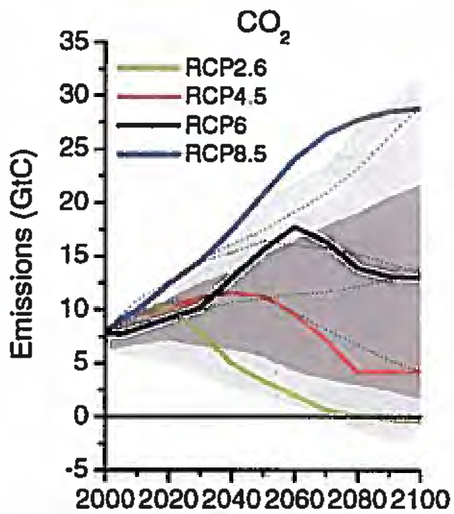


Figure 8 - Evolution of global anthropogenic emissions of greenhouse gases under different RCP scenarios (Van Vuuren et al., 2011)

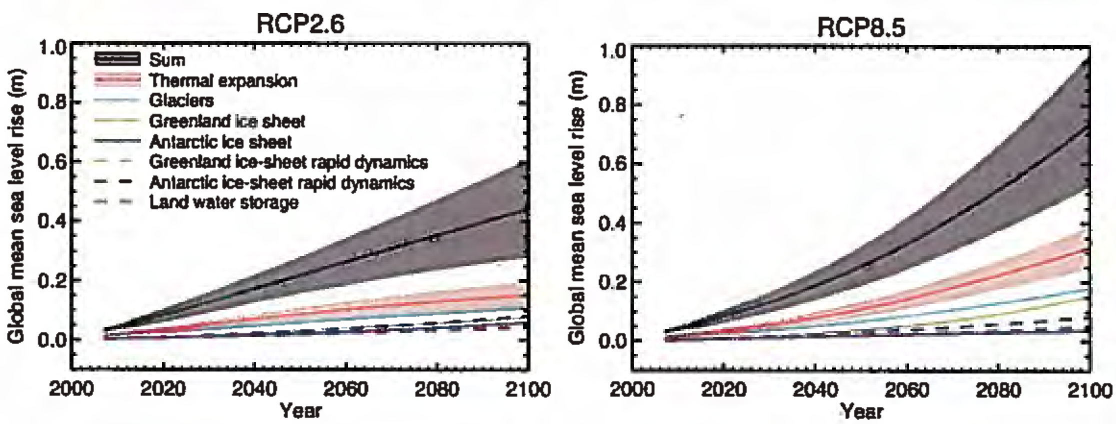
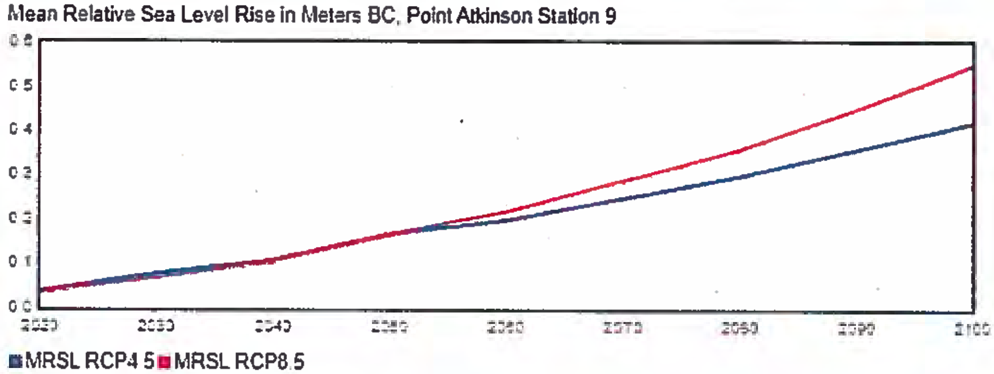


Figure 9 - Projections from process-based models of global mean sea level rise relative to 1986–2005 and its contributions as a function of time for RCP2.6 and RCP8.5 (Church et al., 2013)

The rate and magnitude of sea level rise will not be uniform from one region to another. It will reflect variations in ocean warming and redistribution of heat and mass under the influence of ocean currents (PCIC, 2016). Projections for the Canadian West Coast are given by the CAN-EWLAT tool for all weather stations (Fisheries and Ocean Canada, 2019). It uses a conservative approach: the tool is based on historical records and does not incorporate projected changes in storm tides over the 21st century because the current state of knowledge of future projections of storminess is limited. The most representative mean projections for West Vancouver are given for the station of

Point Atkinson (Figure 10). Increases in sea level are given from 2010 onwards, meaning that historical increase and uncertainty should be added to projected values. By the end of the century, sea level may then rise by 32 to 89 cm in the West Vancouver area compared to the beginning of the industrial period based on the range of 10th and 90th percentile estimates from RCP4.5 and RCP8.5 scenarios. Best estimates using RCP8.5 place the range of sea level rise between 0.47 m and 0.89 m by 2100, with a mean value of 0.55 m.



	2020	2030	2040	2050	2060	2070	2080	2090	2100
MRSL RCP4.5	0 04	0 08	0 11	0 17	0 2	0 25	0 3	0 36	0 42
MRSL RCP8.5	0 04	0 07	0 11	0 17	0 22	0 29	0 36	0 45	0 55

Figure 10 - Sea level rise projected from 2010 onwards under RCP4.5 and RCP8.5 for Point Atkinson, British-Columbia

Vertical allowances are recommended changes in the elevation of coastal infrastructure required to maintain the current level of flooding risk in a future scenario of sea level rise. The Ministry of Environment of British Columbia has recommended that the sea level rise curve presented in Figure 11 should be used for sea level rise policy and adaptation planning (BC Ministry of Environment, 2013).

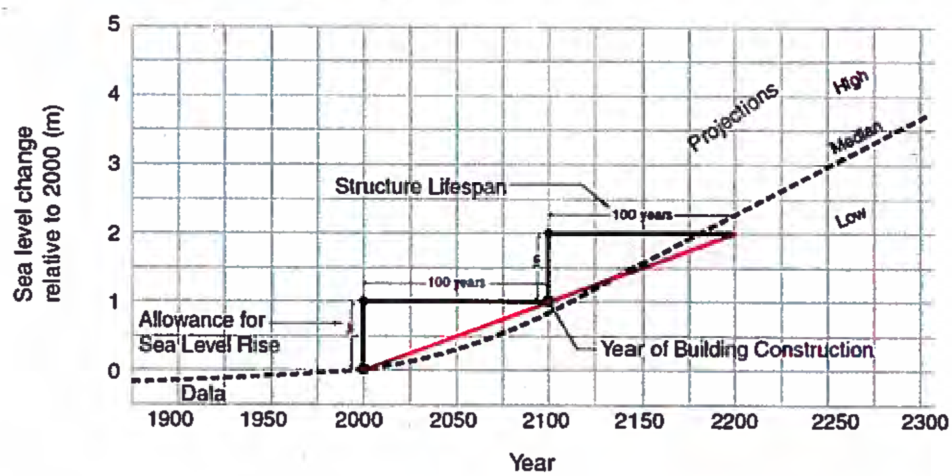


Figure 11 - Vertical allowance suggested the Ministry of Environment of British Columbia (Ausenco Sandwell, 2011)

These recommendations follow pessimistic and conservative projections given by the RCP8.5 scenario. The recommended curve is slightly higher than the 90th percentile of projections up to 2070 and moves below the median curve by the early 2100s with the recognition that in a planning network, time remains to revise curves upward, if academic research or the required response warrants. According to the 2013 scientific knowledge status, Ministry's recommendations are considered consistent for efficient adaptation measures.

5.3 LATEST RESEARCH AT GLOBAL SCALE

Latest research points to a possible impact considerably higher than estimates made in 2013 and summarized by the IPCC (Church et al., 2013). Sea level rise numbers have been trending upwards in the last 6 years. This is mainly because scientists have been learning more about the potential modes of instability in Greenland and the Antarctic ice sheets in particular. Several new ice sheet models have been generated, focusing on the dynamic contribution of ice sheets to sea level change, which remains the key uncertainty in future projections (Church et al., 2013), particularly beyond 2050 (Kopp et al., 2014; Nauels et al., 2017; Slangen et al., 2017; Horton et al., 2018). Results from these models have suggested that the West Antarctic is losing far more ice than ever before. According to these new projections, sea level rise at the end of the century is projected to be faster under all scenarios compared to 2013 findings. Global mean sea level will rise by 29 to 59 cm under RCP2.6 compared to 2000-levels, and by 61 to 110 cm under RCP8.5 (Figure 12). For RCP8.5, estimates for 2100 are higher and the uncertainty range larger than in Church et al. (2013). Beyond 2100, sea level will continue to rise for centuries due to continuing deep ocean heat uptake and mass loss of the Greenland and Antarctic ice sheets and will remain elevated for thousands of years.

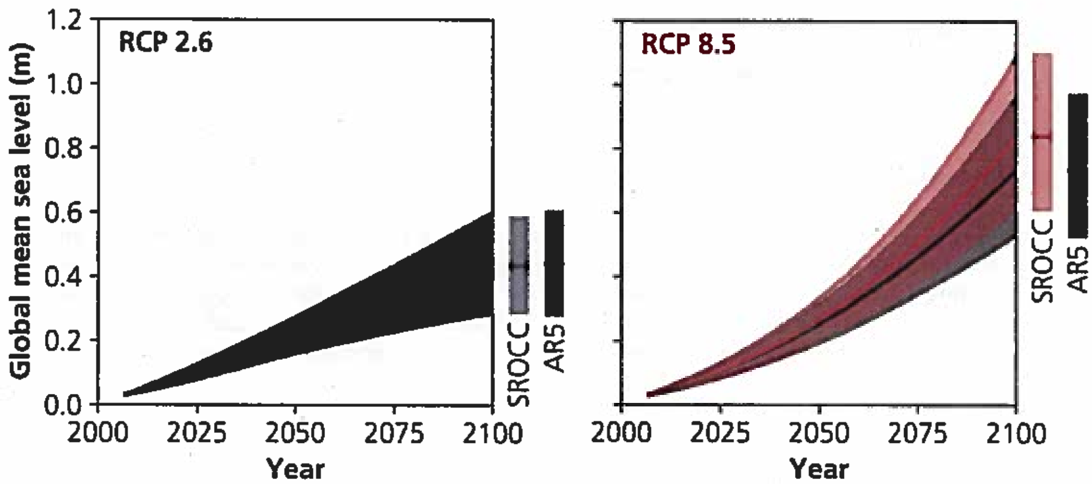


Figure 12 - Projections of mean sea level rise from the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC, Oppenheimer et al., 2019), compared to Church et al. (2013) results (AR5)

Some studies even predict higher increases in sea level. For instance, Bamber et al. (2019) used new techniques to study interactions between several ice sheets processes and their dependencies. For a 5°C of warming (similar to high projections of the RCP8.5 scenario), there is a 5% chance that sea level may rise up to 178 centimetres by the end of the century. By 2200, this 5% chance may give 7.5 metres. Therefore, research shows that there are some catastrophic scenarios that could occur, but chances of that happening are low.

Like results brought by Church et al. (2013), new projections of sea level rise are region-dependent. As highlighted in Figure 13, the West Coast of Canada is likely to experience sea level rise below the global average (between 40 to 80 cm by 2100 under the RCP8.5 scenario compared to 2000-values, only by eye-inspection). However, catastrophic increases as highlighted by Bamber et al. (2019) remain also possible for every region of the globe. Events having a chance of occurring once every 100 years may become frequent (once every 2 years) by the end of the century. Given the lack of regional studies incorporating findings of Oppenheimer et al. (2019) for British Columbia coastlines, allowance for sea level rise should be revised at a later stage.

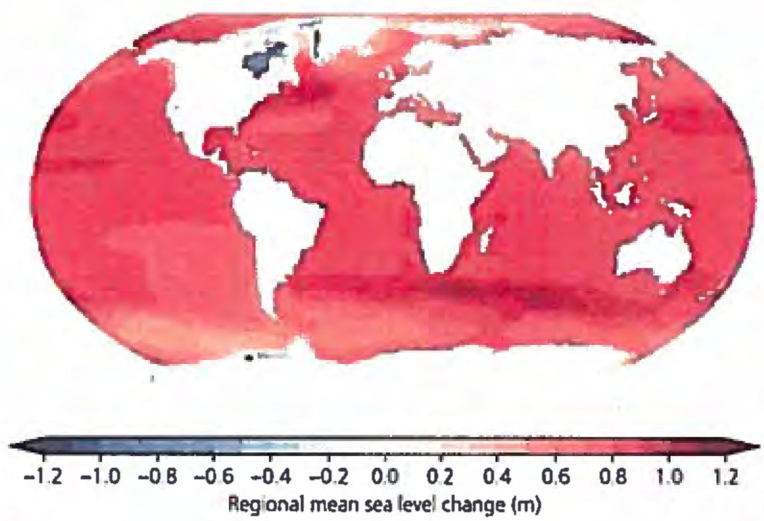


Figure 13 - Regional sea level rise for RCP8.5 by 2081-2100 (Oppenheimer et al., 2019)

5.4 LOCAL UPLIFT AND SUBSIDENCE

The Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use Draft Policy Paper for existing crustal movement along coastal BC shorelines indicate a regional uplift value between 1 to 3 mm per year. However, the Geological Survey of Canada provides a more detailed analysis of the local uplift and subsidence values. Figure 14 maps subsidence and uplift rates for the lower mainland and shows that the study site is subsiding at a rate of 1 mm/year +/- 0.5 mm/year. For the purposes of this study, a subsidence rate of 1 mm/year is applied.

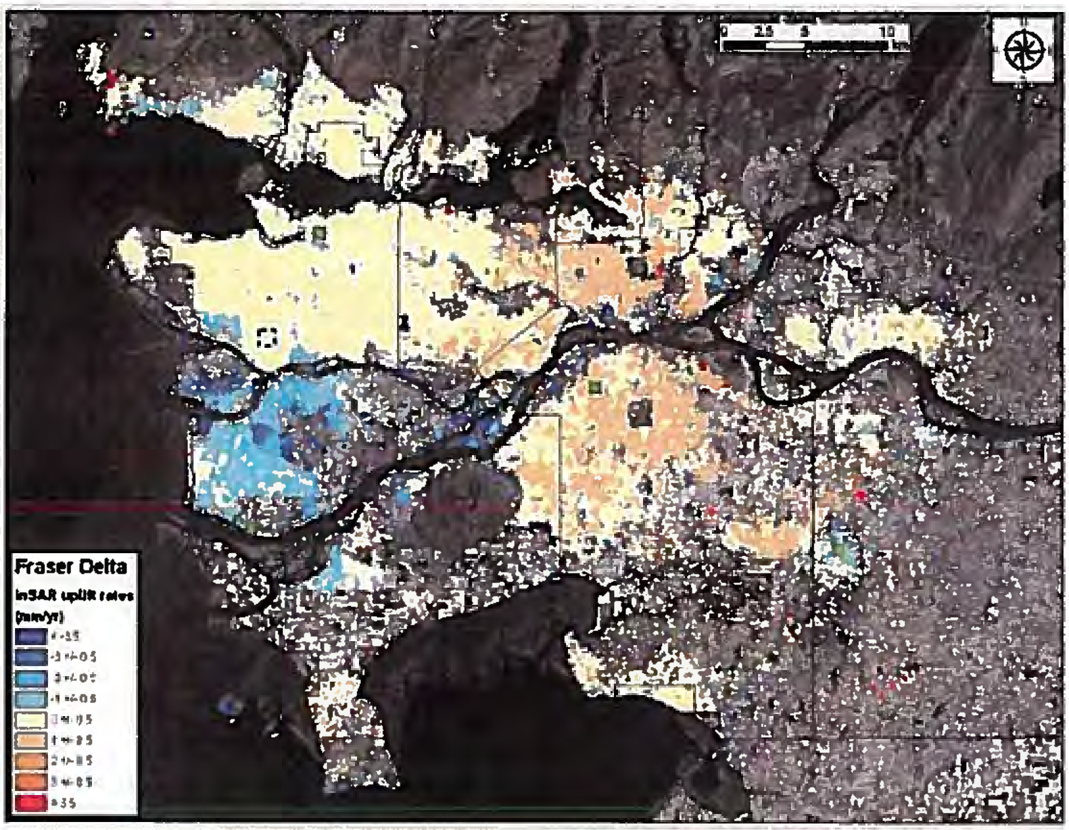


Figure 14 - Vertical land motion in the Fraser Delta-Greater Vancouver area (Thomson et al, 2008)

5.5 APPLIED SEA LEVEL RISE

WSP's climate change specialists would advise to follow British Columbia recommendations for the vertical allowance concerning sea level rise of 1.0 m by 2100, benchmarked to MSL in the year 2000. Federal estimates place the likely range of sea level rise at Point Atkinson at 0.47 m to 0.89 m, which, incorporating subsidence estimates from Section 5.4 results in a vertical allowance of 0.55 m to 1.01 m. This places the Provincial guideline value for the year 2100 near the 90th percentile estimate of RCP8.5 combined with an upper bound estimate for subsidence.

As new regional studies become publicly available, the District of West Vancouver should follow Provincial recommendations to update vertical allowance estimates. The District should then revisit the vulnerability, risks and control measures for each infrastructure project having a design life within the revised vertical allowance timeframe.

6 WAVE EFFECTS

This section presents the derivation of the wave effects component of the FCL. This section is broken down into three main subsections:

- **Section 6.1:** In this section the derivation of regional wave conditions is presented, including the interpolation of wind fields from regional stations for use in the numerical wave model SWAN and the validation of this wave model.
- **Section 6.2:** This section presents the derivation of extreme wave conditions immediately offshore of the project site, considered to be at the 30 m depth contour. A validation of the approach used to estimate the at site extreme value distribution is presented, as well as the associated wave periods and water levels.
- **Section 6.3:** This section presents the derivation of wave effects at the project site for undeveloped and developed site conditions using the numerical model SWASH. Best estimate and sensitivity tests are presented for 200-year, 10,000-year and 40,000-year return period events.

6.1 OFFSHORE WAVE CONDITIONS

6.1.1 WIND FIELD INTERPOLATION

Wind fields for the Strait of Georgia have been generated from measured wind at 27 meteorological stations presented in Table 4-1. The interpolation was carried out in two stages:

Temporal Interpolation: The 27 meteorological generally have concurrent measurements from the mid 1990s onwards. There are, however, occasional gaps in each wind record that require filling prior to completing a spatial interpolation of winds across the entire Strait of Georgia. Temporal data gaps have been filled using the following procedure:

1. Wind records at every station were sorted into directional (e.g. 337.5° to 22.5°, 22.5° to 67.5°, etc.), and magnitude (e.g. 0 m/s to 5 m/s, 5 m/s to 10 m/s, etc.) bins.
2. The empirical cumulative distribution function (ECDF) was determined for each directional and magnitude bin at every station
3. For each station, the ECDF of every other station was then scaled using a linear regression to match the EDCF of measured winds at that station.
4. A surrogate wind record was created at each station using every other station, resulting in 26 potential surrogate records.
5. The predictive capacity of each surrogate record was then ranked by root mean square error (RMSE) and bias for magnitude and direction.
6. Data gaps were then filled from the highest ranked surrogate record. If that record was not available at the time of the gap, then the second highest ranked surrogate record was used, and so on.

By using the ECDF of the recorded winds, statistical properties of each wind record are generally better represented by the resulting surrogate dataset. Similarly, it was found that the timing and direction of wind events moving through the Strait of Georgia was better represented by this approach than, for instance, using a directional linear regression or direct substitution from a nearby station.

Spatial Interpolation: With complete records for each of the 27 meteorological stations derived from the temporal interpolation, spatial wind fields were interpolated using a biharmonic spline interpolation. Nearest-neighbour and natural neighbour interpolation schemes were tested but were found to give unreliable extrapolation results and unrealistic blending of wind fields across topographic breaks, for example between Howe Sound and English Bay. Wind speed correction factors were applied where appropriate to account for land-based stations and to adjust winds speeds to a standard 10-m elevation.

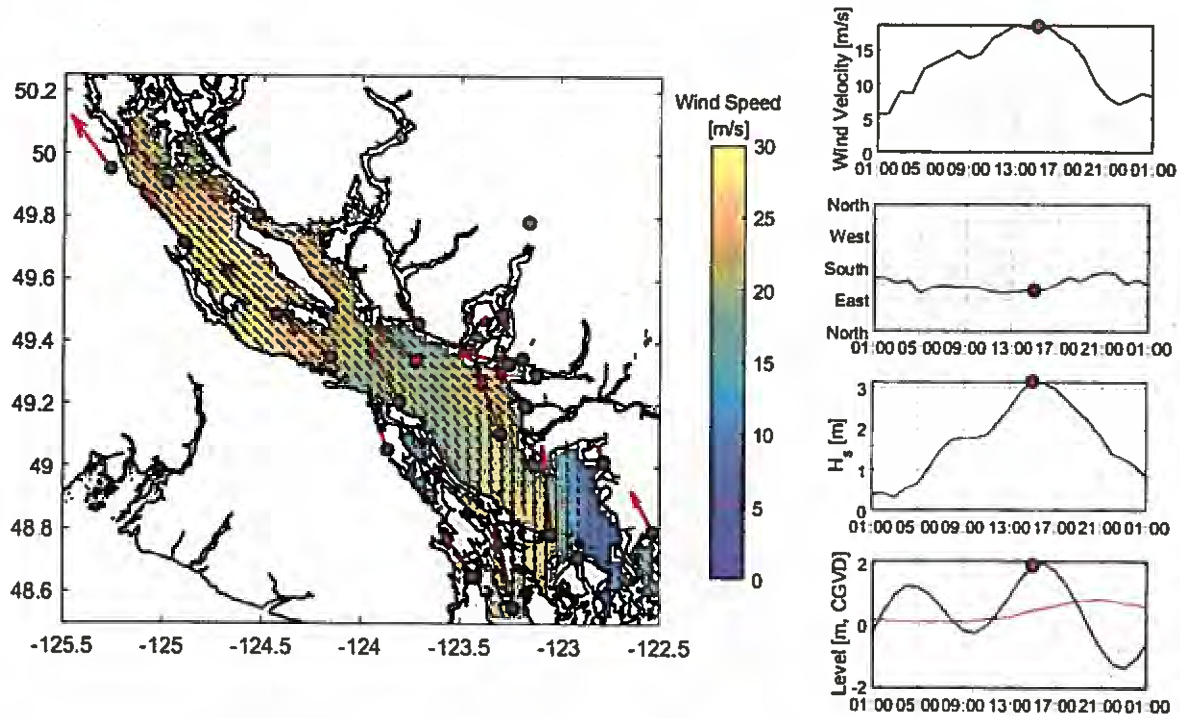


Figure 15 - Interpolated wind fields on March 12, 2012 at 15:00 UTC.

Notes. On the main panel grey dots are meteorological stations with the location of Halibut Banks highlighted in red Top left panel plots wind speed at Halibut Bank middle-upper left panel plots wind direction at Halibut Bank middle-lower left panel plots significant wave height at Halibut Bank and lower left panel presents combined water level (black) and residual water level (red) at Point Atkinson

Figure 15 presents an overview of the interpolation events, for a Southeasterly large storm event on March 12, 2012 at 17:00 UTC, which caused considerable damage through the northern Strait of Georgia. This event corresponds to a 10-year wave event and 25-year wind event at Halibut Bank. Water levels at Point Atkinson were a 5-year return period residual water level and a 99.9th percentile combined water level, just below a 1 year return period event.

Figure 16 presents interpolation results for a large Northwesterly wind event on December 15, 2006 at 11:00 UTC, which causes widespread damage in Stanley Park. This event corresponds to a 1-year wave event at Halibut Bank (largely outside of primary wind event), a 40-year wind event and a 10-year residual water level at Point Atkinson. Combined water levels at Point Atkinson were 94th percentile (i.e. below a return period event).

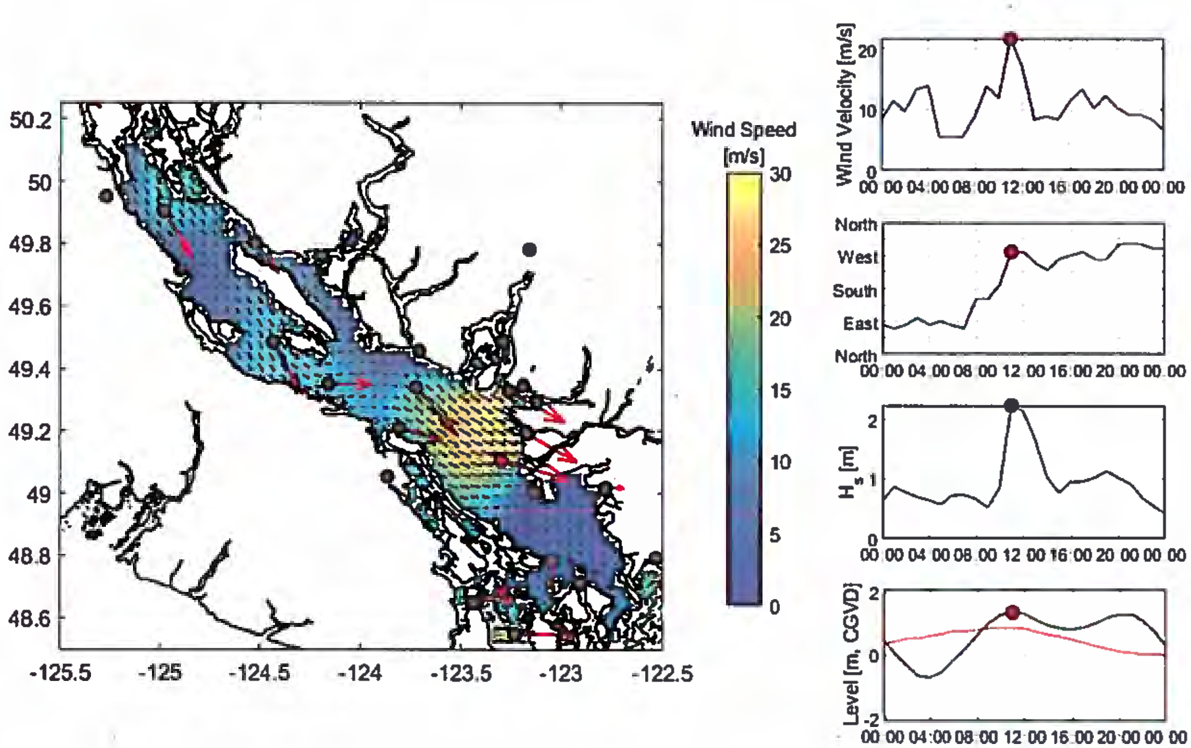


Figure 16 - Interpolated wind fields on December 15, 2006 at 11:00 UTC.

Notes. On the main panel, grey dots are meteorological stations with the location of Halibut Banks highlighted in red. Top left panel plots wind speed at Halibut Bank, middle-upper left panel plots wind direction at Halibut Bank, middle-lower left panel plots significant wave height at Halibut Bank and lower left panel presents combined water level (black) and residual water level (red) at Point Atkinson

6.1.2 SWAN MODEL DEVELOPMENT

SWAN is third generation wave model developed by Delft University of Technology. This model can be used to generate wind driven waves in coastal regions as well as in in land waters. SWAN can simulate shoaling and refraction due to bathymetry along with other physical processes such as whitecapping and depth induced wave breaking.

A SWAN model was built extending from Campbell River in the north to Orcas Island in the south. Howe Sound to the north of the project site was also included in the model. An outline of the SWAN model extent is shown in Figure 17 below. The various channels and passes on the southwestern boundary of Gulf Islands were not included in the model region. The model shoreline was set to the northern shoreline of the Gulf Islands. The tight grouping of the islands would prevent much wave energy from transferring from the southern side of these islands to the northern portion. This region is also far removed from the study side and any benefit of including this region would not be worth the added computational expense of including it. Many of the small islands in Strait of Georgia were excluded from the model, however most of the large islands were included inside the model domain. This was done to balance the time needed to build the model with the computational time needed to run simulations. SWAN can remove dry, or land nodes during a simulation, however including a large number of always dry nodes in the model domain can increase the computational time during a simulation. Setting up the model boundaries to exclude all land nodes would increase the amount of time need to build the model.

Bathymetry data for the bay area was taken from NOAA. The bathymetry near the project site was supplemented with more detailed information from Canadian Hydrographic Services and topography from 2013 LiDAR (0.5 m accuracy) from District of West Vancouver's GIS data.

Two model versions were created, the first was a structured grid with 500 m spacing. This model was used setup and calibrate the main model. The structured version of SWAN supports parallel processing and this allowed many runs to be performed quickly to test model setup and troubleshoot any issues with model performance. Once the model parameters were confirmed, the final calibration tests were simulated using an unstructured model.

The unstructured version of SWAN was used so that project area could be modeled with high resolution while keeping the computational coast of simulations low. The unstructured version does not natively support parallel processing so each simulation can be very time consuming. Most of the model domain had a 500 m mesh spacing. The resolution of the model was increased to 50 m near the project site. The model resolution was also increased to 100 m near the terminals at Roberts Bank, the Iona Outfall Jetty and around some small channels between islands in Howe Sound. The final model domain is shown in Figure 17 below.

Figure 17 - Unstructured SWAN mesh

Model data was extracted at several locations offshore of the study site to be used to drive the SWASH wave run-up model. Figure 18 below shows these locations as well as details of the mesh near the project site.

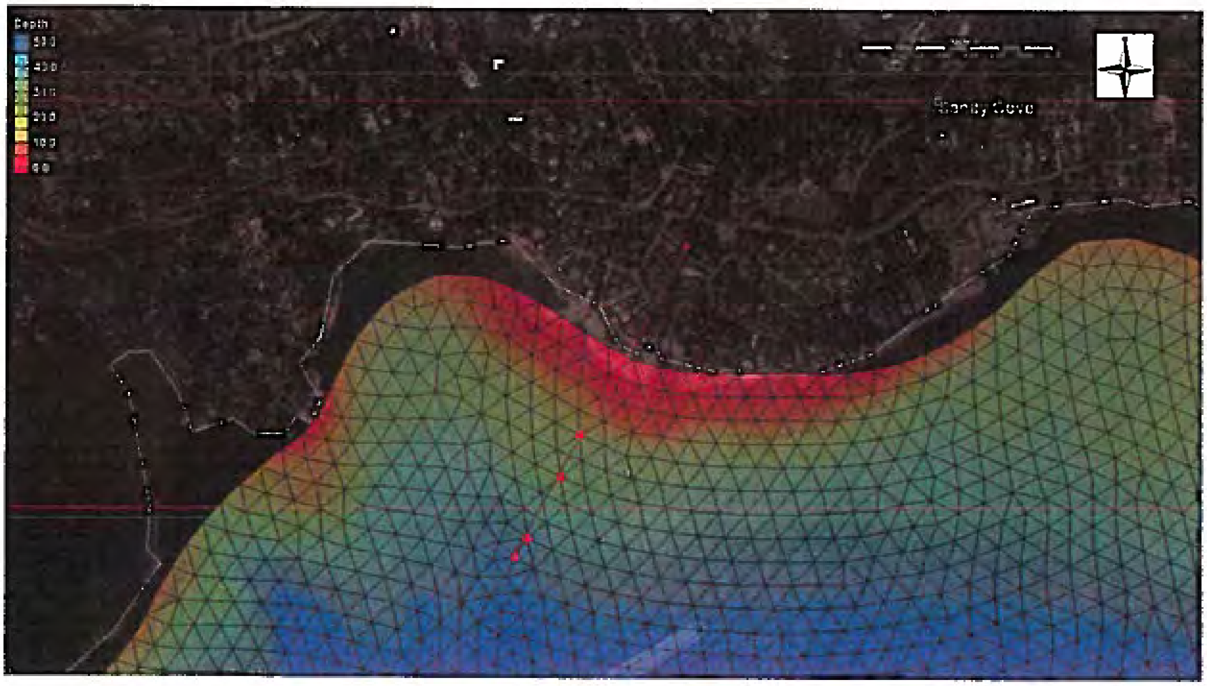


Figure 18 - Detail of unstructured mesh near study site with model extraction points shown in red.

6.1.3 CALIBRATION AND VALIDATION

Interpolated wind fields in SWAN were calibrated against measurements at meteorological stations throughout the model domains and against the resulting wave height and period recorded at Halibut Bank. Seven wind and wave events were then selected for validation on the basis of representing a range of wind directions, having a distinct wind peak or having backing or veering winds (i.e. a complex wind and wave field). A period of 24 hours surrounding the peak of the event was simulated to generate bias, RMSE and r^2 statistics. Table 6-1 presents the results of this validation exercise. Overall, the model has a very low 0.03 m bias for wave height and 0.18 s bias for wave period, meaning that the model, on average across 6 storm events, over predicts wave height by 0.03 m and wave period by 0.18 s. Considering only the peaks of the storms, the model overpredicts wave height by an average of 0.07 m and wave period by 0.21 s, which is an excellent validation result. The overall RMSE for observed versus simulated wave height is 10% of the average peak wave height and is a similar 10% for wave period. r^2 coefficients are 0.94 and 0.75 for wave height and period, respectively. It should be noted that the lower r^2 value for wave period is likely due to the different spectral binning employed in the measured wave spectra at Halibut Bank and the simulated wave spectra within SWAN.

Table 6-1: Validation test cases

PEAK DATE[1]	H_s					T_p				
	Observed Peak (m)	Modeled Peak (m)	Bias (m)	RMSE (m)	r^2	Observed at Peak (s)	Modeled at Peak (s)	Bias (s)	RMSE (s)	r^2
23 Apr 2002, 04:00	1.51	1.54	-0.07	0.12	0.91	4.79	4.94	0.01	0.48	0.65
14 Dec 2001, 17:00	2.77	3.22	0.00	0.24	0.93	6.92	7.23	0.18	0.50	0.75
29 Oct 2003, 00:00	1.60	2.00	0.14	0.21	0.95	5.33	6.15	0.27	0.46	0.93
02 Apr 2010, 21:00	3.49	3.00	-0.10	0.25	0.92	6.92	7.11	0.19	0.49	0.67
24 Dec 2006, 21:00	1.78	1.90	0.04	0.19	0.97	5.33	5.45	0.06	1.06	0.50
12 Mar 2012, 13:00	3.15	3.14	0.16	0.24	0.96	6.92	7.31	0.36	0.52	0.94
Overall			**0.03**	**0.21**	**0.94**			**0.18**	**0.59**	**0.75**

[1] Simulation period is 24 hours surrounding each peak event

6.2 DETERMINATION OF DESIGNATED STORM CONDITION

6.2.1 REGIONAL EXTREME VALUE ANALYSIS

6.2.1.1 METHODOLOGY

Estimates of the extreme values at a regional scale are required to derive appropriate water level and wave effect components for simulating the wave effects component of the FCL at site. For this study, a peaks-over-threshold approach combined with a three-parameter extreme value distribution fit has been adopted.

WINDS

For the analysis of extreme wind speeds, the wind record at the four nearest long-term stations exposed to representative conditions in the Strait of Georgia have been analyzed:

— Point Atkinson (1106200)
— Sand Heads (1107010)
— YVR (1108395)
— Halibut Bank (C460146

Nearby stations at West Vancouver, Vancouver Harbour, Sechelt and Tsawwassen Ferry Terminal have not been used in this analysis either due to a short period of record or topographic features and/or instrument locations that make these stations inappropriate for estimating extreme values.

Extreme value distributions were fit to winds from each station.

WATER LEVELS

Both combined (tide and surge) and residual (surge) water levels have been analyzed. Combined water levels are based on the hourly measured water level at Point Atkinson (7795) converted to CGD. Residual water levels have been determined as the measured water level minus the predicted tide to determine the deviation of actual water level conditions from predicted. This deviation represents the residual water level (surge) at the project site. Predicted tidal levels have been provided by the CHS.

DERIVATION OF SITE-SPECIFIC CONDITIONS

Through the model calibration efforts presented in Section 6.1.3 it was observed that extreme wind events at a given meteorological station (e.g. at Point Atkinson, Entrance Island, Ballenas Island) did not necessarily correspond to a correspondingly extreme wave height at the Halibut Bank Buoy. This is true of the relationship between windspeed and wave height at the buoy itself, there the largest recorded waves occur over a range of local wind speeds. This means that the extreme wind events at a range of stations need to be considered to accurately estimate the extreme wave events at a given location as the extreme waves can be generated from a wide range of wind conditions not necessarily represented by a single meteorological station.

In general, the most robust approach to determining a site-specific extreme value distribution for wave action in such a complex coastal environment would be to employ a decadal hindcast or measurement of wave conditions to directly estimate the extreme value distribution. This is both a time-consuming and costly approach inappropriate for all but large-scale infrastructure projects. For this project, the site-specific extreme value distribution has been determined based on simulations of a representative sample of storm events in the Strait of Georgia and locally in English Bay to derive a sufficient number of samples to define the extreme value distribution of waves at the project site. From these samples of the underlying wave population, the extreme value distribution can then be estimated with confidence. The following procedure was followed:

- Derive the extreme value distribution of wind speed at the four selected meteorological stations and of water levels at Point Atkinson.
- Determine the minimum number of peak events required to define the extreme value distribution for winds at each station. The minimum number of events was deemed to be the number of events required to derive an extreme value distribution consistent with the optimized distribution.
- Use the numerical wave model SWAN to simulate (Section 6.1) the ensemble of peak events and export the resulting wave conditions offshore of the project site at several depth contours.
- Estimate the resulting extreme value distribution for wave height and use the resulting return period level wave conditions to drive a nearshore wave runup model (Section 6.2).

A validation of this approach is presented in Section 6.2.4.

6.2.1.2 EXTREME VALUES

WINDS

Table 6-2 presents return period level winds for each of the selected meteorological stations while Table 6-2 presents return period level winds from the Northwest, defined as 225° +/- 90°, and Table 6-4 presents corresponding return period level winds from the Southeast, defined as 135° +/- 90°. Return period level wind speeds are broadly similar across the three shore stations at Point Atkinson, Sand Heads and YVR, with Halibut Bank reporting slightly lower extreme wind speeds. The values in Table 6-2, Table 6-3 and Table 6-4 have not been corrected for instrument height or type, with the three shore stations measuring winds at between 11.0 m and 19.5 m and Halibut Bank reporting from a discus buoy with an anemometer height of 5.0 m. A typical correction to a standard 10 m measurement height for a buoy of this type would be 1.11 to 1.17, depending on environmental conditions and ambient wave height, bringing its extreme wind speeds in line with the shore station values.

Table 6-2: Summary of extreme omnidirectional winds with 95% confidence bounds

RETURN PERIOD	POINT ATKINSON (m/s)	SAND HEADS (m/s)	YVR (m/s)	HALIBUT BANK (m/s)
2	20.56 +/- 0.61	21.14 +/- 0.61	18.64 +/- 0.51	17.29 +/- 0.30
5	21.72 +/- 0.62	22.45 +/- 0.62	20.26 +/- 0.52	18.20 +/- 0.31
10	22.57 +/- 0.63	23.41 +/- 0.63	21.42 +/- 0.52	18.84 +/- 0.32

RETURN PERIOD	POINT ATKINSON (m/s)	SAND HEADS (m/s)	YVR (m/s)	HALIBUT BANK (m/s)
25	23.68 +/- 0.66	24.65 +/- 0.65	22.91 +/- 0.53	19.65 +/- 0.33
50	24.50 +/- 0.68	25.57 +/- 0.68	24.01 +/- 0.53	20.24 +/- 0.34
75	24.97 +/- 0.69	26.11 +/- 0.69	24.64 +/- 0.54	20.58 +/- 0.35
100	25.31 +/- 0.71	26.49 +/- 0.70	25.08 +/- 0.54	20.81 +/- 0.35
200	26.11 +/- 0.73	27.39 +/- 0.73	26.13 +/- 0.55	21.37 +/- 0.37
500	27.17 +/- 0.78	28.58 +/- 0.77	27.50 +/- 0.56	22.08 +/- 0.39
1,000	27.95 +/- 0.81	29.46 +/- 0.80	28.52 +/- 0.57	22.61 +/- 0.40

Table 6-3: Summary of extreme Northwesterly (225° +/- 90°) winds with 95% confidence bounds

RETURN PERIOD	POINT ATKINSON (m/s)	SAND HEADS (m/s)	YVR (m/s)	HALIBUT BANK (m/s)
2	19.49 +/- 0.84	18.71 +/- 0.67	18.24 +/- 0.45	15.33 +/- 0.80
5	21.21 +/- 0.86	20.10 +/- 0.68	19.93 +/- 0.46	16.60 +/- 0.82
10	22.40+/- 0.87	21.06 +/- 0.70	21.12 +/- 0.46	17.52 +/- 0.84
25	23.88 +/- 0.90	22.24 +/- 0.72	22.61 +/- 0.46	18.70 +/- 0.88
50	24.95 +/- 0.92	23.09 +/- 0.74	23.69 +/- 0.47	19.58 +/- 0.91
75	25.56 +/- 0.94	23.58 +/- 0.75	24.31 +/- 0.47	20.09 +/- 0.94
100	25.98 +/- 0.95	23.91 +/- 0.76	24.74 +/- 0.47	20.45 +/- 0.95
200	26.98 +/- 0.98	24.70 +/- 0.78	25.76 +/- 0.47	21.30 +/- 0.99
500	28.26 +/- 1.02	25.71 +/- 0.81	27.07 +/- 0.48	22.41 +/- 1.05
1,000	29.20 +/- 1.05	26.45 +/- 0.83	28.04 +/- 0.48	23.25 +/- 1.10

Table 6-4: Summary of extreme Southeasterly (135° +/- 90°) winds with 95% confidence bounds

RETURN PERIOD	POINT ATKINSON (m/s)	SAND HEADS (m/s)	YVR (m/s)	HALIBUT BANK (m/s)
2	19.70 +/- 0.41	20.79 +/- 0.61	15.16 +/- 0.71	16.66 +/- 0.28
5	20.47 +/- 0.42	22.19 +/- 0.62	16.62 +/- 0.71	17.51 +/- 0.28
10	20.97 +/- 0.43	23.20 +/- 0.63	17.66 +/- 0.72	18.15 +/- 0.29
25	21.57 +/- 0.44	24.47 +/- 0.64	18.99 +/- 0.73	18.99 +/- 0.30
50	21.98 +/- 0.45	25.39 +/- 0.66	19.96 +/- 0.74	19.62 +/- 0.32
75	22.21 +/- 0.46	25.92 +/- 0.67	20.52 +/- 0.74	20.00 +/- 0.33
100	22.37 +/- 0.47	26.29 +/- 0.67	20.91 +/- 0.75	20.26 +/- 0.33
200	22.74 +/- 0.48	27.17 +/- 0.69	21.84 +/- 0.76	20.89 +/- 0.35
500	23.20 +/- 0.50	28.31 +/- 0.72	23.05 +/- 0.77	21.73 +/- 0.38
1,000	23.53 +/- 0.51	29.15 +/- 0.74	23.95 +/- 0.78	22.37 +/- 0.40

WATER LEVELS

Table 6-5 presents a summary of extreme water levels at Point Atkinson for a range of return periods with 95% confident intervals. Extreme values are presented for combined water levels, which are the actual recorded levels at Point Atkinson including astronomical tides and meteorological effects, and the residual water level, which is the non-tidal component of the combined water level (storm surge).

Combined water levels are presented for the period 1914 to 2019 and 1999 to 2019 to investigate any effects of sea level rise on return period level water levels. The period 1914 to 1999 was also analyzed separately, but the extreme values were identical to the 1914 to 2019 period to two decimal places. Combined water levels are slightly higher over the period 1999 to 2019 compared to 1914 to 1999 (2019) but remain within the 95% confidence bounds for the complete period of record. Residual water levels are presented for the complete period of 1914 to 2019 as there was not a significant temporal trend in residual levels and better extreme value distribution fits were obtained with a longer period of record. Therefore, extreme values calculated over the period of 1914 to 2019 have been used in this analysis.

Table 6-5: Summary of extreme water levels

RETURN PERIOD	COMBINED LEVEL 1914 TO 2019 (m CGD)	COMBINED LEVEL 1999 TO 2019 (m CGD)	RESIDUAL LEVEL 1914 TO 2019 (m)
2	2.23 +/- 0.03	2.24 +/- 0.05	0.76 +/- 0.03
5	2.32 +/- 0.03	2.33 +/- 0.06	0.84 +/- 0.03
10	2.39 +/- 0.03	2.39 +/- 0.06	0.89 +/- 0.03
25	2.46 +/- 0.03	2.47 +/- 0.06	0.95 +/- 0.03
50	2.52 +/- 0.03	2.53 +/- 0.06	0.99 +/- 0.03
75	2.55 +/- 0.03	2.56 +/- 0.06	1.01 +/- 0.03
100	2.57 +/- 0.03	2.59 +/- 0.06	1.03 +/- 0.03
200	2.63 +/- 0.03	2.64 +/- 0.07	1.07 +/- 0.03
500	2.70 +/- 0.03	2.72 +/- 0.07	1.11 +/- 0.03
1,000	2.75 +/- 0.03	2.77 +/- 0.07	1.15 +/- 0.03

6.2.2 JOINT PROBABILITY

To establish appropriate combinations of water levels and waves, hereafter referred to simply as the Designated Storm Event, the following section investigates the joint probability of the largest components of the FCL:

- Tides
- Residual Water Levels (Surge)
- Waves

The tidal range at Point Atkinson is up to 5.1 m, which accounts for the vast majority of water level variations at the project site. As tides are completely independent of meteorological conditions the largest component of the SWL is by necessity independent of wave action and storm surge.

Meteorological conditions in the broader eastern Pacific Ocean determine the residual water level in the Strait of Georgia. Although the largest recorded combined water levels at Point Atkinson (i.e. those above the highest astronomical tide) are associated with positive residual water levels, these positive residual water levels are no more or less likely to correspond to a high tide or low tide and is therefore independent of the combined (astronomical + residual) water level. Figure 19 presents a scatter diagram of residual and combined water levels at Point Atkinson. On this figure, the effect of positive and negative surge can be seen at the highest and lowest recorded water levels. From Figure 20 it can be seen that the largest water level residuals (i.e. those above 0.8 m) are, as expected, associated with higher overall water levels (right panel), but are not associated to any particular tidal stage.

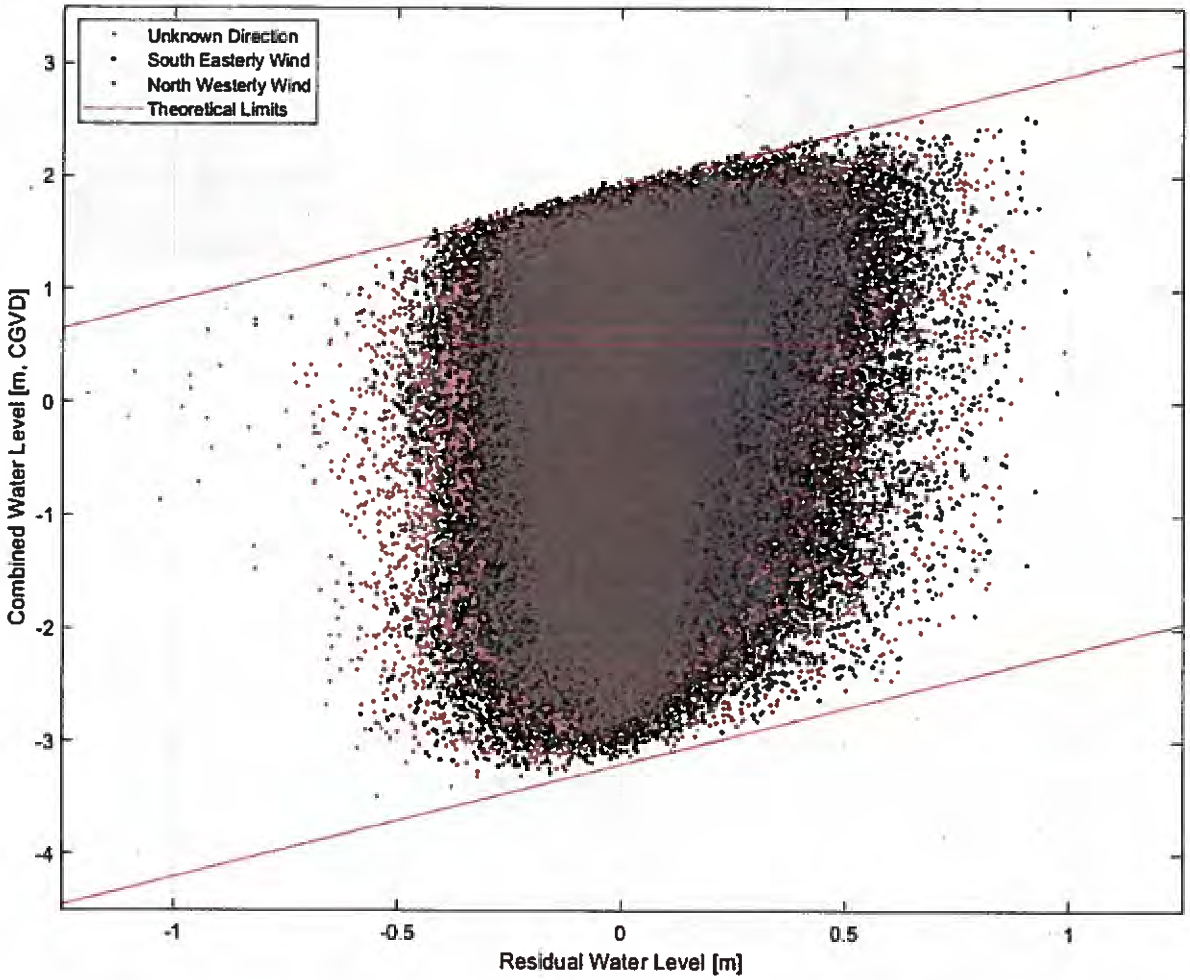


Figure 19 - Plot of residual water level versus combined water level at Point Atkinson. The theoretical combined water level limits based on the highest and lowest astronomical tides is plotted as red lines.

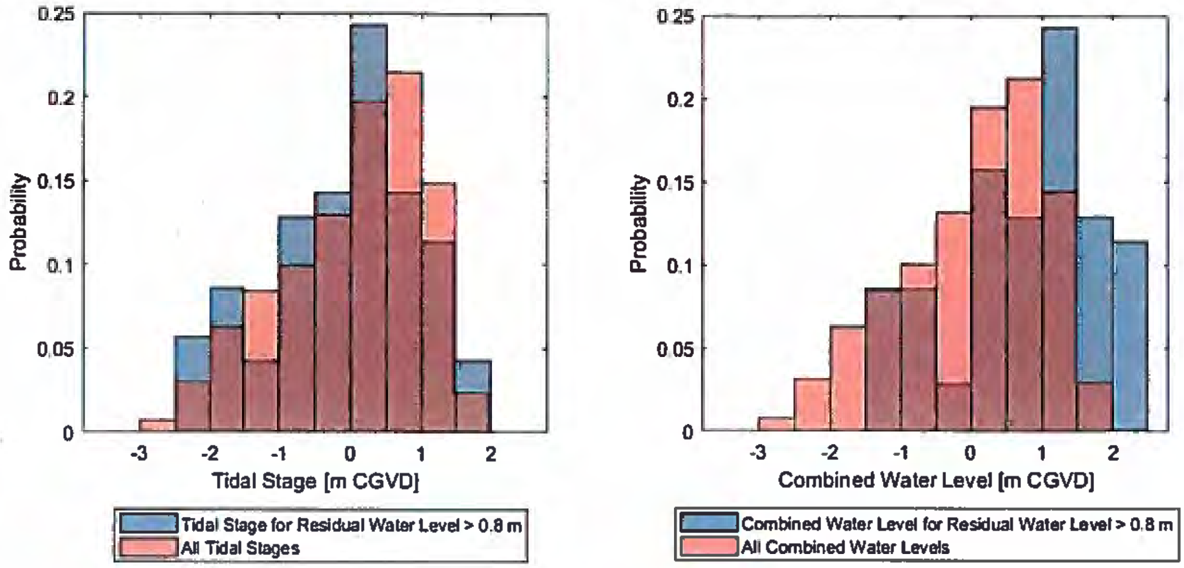


Figure 20 - Histogram of tidal stage and combined water levels for the complete data set and for water level residuals above 0.8 m.

Waves and winds in the Strait of Georgia are dependant, however residual water levels have an ambiguous relationship to both wave action and wind speed. Although large positive residual water levels are associated with major storm events, these storm events do not necessarily cause a peak wind or wave condition locally in the Strait of Georgia. This can generally be attributed to the storm systems that generate large residual water level events being very large scale, causing storm surges across much of the British Columbian and Alaskan coastline relatively simultaneously, whereas the wave conditions in the Strait of Georgia are local wind-waves.

Figure 21 presents scatter plots of measured significant wave heights and wind speeds at the Halibut Bank buoy versus residual and combined water levels at Point Atkinson. Large wave events at Halibut Bank (i.e. wave heights over 2.0 m) are almost always associated with a positive residual water level (Figure 21 bottom left panel), however neither can be used as a reliable predictor of the other due to the degree of scatter. There is a directional bias for Southeasterly events in this relationship, likely because the largest wave events recorded at the buoy are associated with Southeasterly winds. When the effect of tide is included, these same wave events can be shown to have no distinct relationship to the combined water level (Figure 21 top left panel). The same trends hold true for wind speed, as can be seen on the right panels of Figure 21.

Attempts to fit a conditional probability distribution to winds, waves, combined water levels and residual water levels, was not successful, with the relationship between peak values not meeting a reasonable statistical threshold for dependence. Amongst the tested variables and data sets, the highest p-value for tests of statistical dependence, between wave height and residual water level, was 0.043 which remains below the typical 0.05 threshold for significance. In attempting to assign various conditional marginal distributions to the available data, fits were either failed or of unreasonably low quality.

Although a large wind or wave event will be accompanied by some degree of positive residual water level, due to the overwhelming influence of tides on the overall water level during a storm event, it is not reasonable to assume that a given return-period storm event will be associated with a given return-period combined water level. Therefore, it is reasonable to assume independence between water levels and wave/wind conditions at the project site during a designated or design storm condition.

Since the wave and water level events are independent, the joint probability of a given wave and storm event is simply the combination of the two marginal distribution functions. The marginal distribution for combined water levels was presented in Section 6.2.1.2 with the extreme values summarized in Table 6-5. The marginal distribution of the offshore waves near the project site are presented in Section 6.2.4 below with the extreme values summarized in Table 6-6. The joint probability distribution is shown in Figure 23.

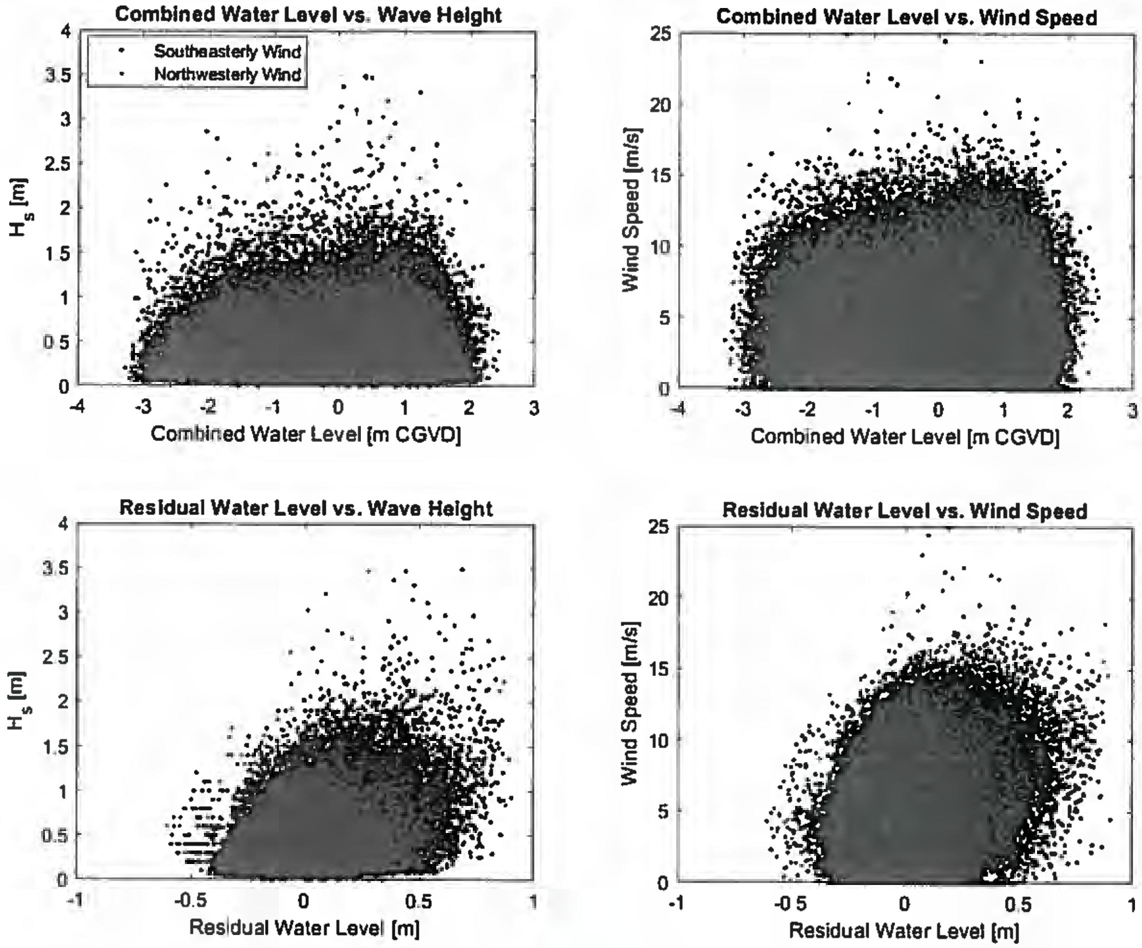


Figure 21 - Left Panels, plot of residual and combined water level at Point Atkinson versus significant wave height at Halibut Bank. Right Panels, plot of residual and combined water level at Point Atkinson versus wind speed height at Halibut Bank

6.2.3 EVENT SELECTION

Table 6-6 presents a summary of the storm events used to develop the extreme value distribution of wave heights offshore of the project site. As discussed in Section 6.2.1, these events were selected such that the total number of events across all reference stations were sufficient to define the extreme value distribution at each station. By combining events from four regional stations surrounding the project site, a population of storm events sufficient to define the extreme value distribution offshore of the project site has been derived. Each of the storm events in Table 6-6 were simulated over a 24 hour period using the numerical wave model described in Section 6.1, with wave height, period and direction exported at several locations along the 30 m depth contour offshore of the project site.

Table 6-6: Selected storm events used to develop the extreme value distribution of wave heights offshore of the project site

DATE	REGIONAL WIND CONDITIONS				WATER LEVEL[1]	WAVE CONDITIONS AT SITE		
	REFERENCE STATION	SPEED (M/S)	RP (YEARS)	DIRECTION		H_S[2] (M)	T_P (S)	DIRECTION
15 Dec 2006, 12:00	Point Atkinson	24.2	39	290°	1.314	1.71	7.76	230
17 Dec 1998, 19:00	Point Atkinson	22.8	12	290°	0.104	1.53	7.17	230
24 Nov 1998, 08:00	Point Atkinson	22.2	7	100°	1.474	1.07	3.45	167
02 Apr 2010, 22:00	Halibut Bank	19.4	19	120°	-1.766	1.12	5.71	198
20 Dec 2018, 21:00	Sand Heads	25.6	51	190°	0.324	1.33	6.77	212
03 Mar 1999, 18:00	Sand Heads	24.7	26	160°	1.074	1.08	3.52	162
14 Dec 2001, 15:00	Sand Heads	23.6	12	290°	1.744	1.64	8.69	231
08 Feb 1999, 13:00	Sand Heads	22.2	4	140°	0.104	0.91	6.12	182
29 Oct 2003, 04:00	YVR	22.8	23	270°	1.484	1.24	7.75	230
15 Dec 2000, 13:00	YVR	22.2	16	270°	-0.696	1.34	7.33	230
31 Mar 1997, 01:00	Point Atkinson	20.6	2	100°	-1.106	0.96	6.13	174
23 Oct 2001, 16:00	Point Atkinson	22.2	7	300	0.154	1.20	7.09	234
16 Dec 2001, 01:00	Halibut Bank	24.9	100+	91°	1.364	0.83	6.00	159
06 Jan 2007, 06:00	Halibut Bank	19.5	21	316°	-0.846	1.13	7.21	229
12 Mar 2012, 13:00	Halibut Bank	18.7	9	111°	0.944	1.07	3.46	161
29 Nov 2001, 15:00	Halibut Bank	18.1	4	293°	1.354	1.37	7.90	229
01 Dec 1998, 21:00	Sand Heads	21.7	3	140	1.664	1.11	5.90	193
06 May 2002, 15:00	Halibut Bank	18.0	4	233	-0.316	0.79	5.37	229
15 Jan 2008, 01:00	Point Atkinson	22.2	7	290	-0.736	1.61	7.90	229
23 Apr 2002, 04:00	Halibut Bank	17.8	3	297	-1.696	1.20	7.25	231
08 Apr 2010, 10:00	YVR	21.7	12	290	1.574	1.38	7.28	230
12 Nov 2007, 16:00	Sand Heads	21.7	3	140	1.974	1.04	6.50	167
28 Oct 1999, 09:00	Point Atkinson	20.6	2	90	-2.056	0.67	3.11	139
19 Nov 2009, 02:00	Sand Heads	21.7	3	150	1.164	0.99	6.40	163
18 Jan 2010, 12:00	Point Atkinson	20.6	2	100	0.134	1.07	6.59	171
27 Apr 2004, 21:00	YVR	20.0	4	300	-0.606	1.16	6.95	229

[1] Combined water level at Point Atkinson
[2] Modeled significant wave height near project site

6.2.4 METHODOLOGICAL VALIDATION

WAVE HEIGHT

The events selected to construct the synthetic extreme value distribution of wave heights at the project site have been validated by comparing the empirical extreme value distribution derived from measured wave heights at

Halibut Bank to the synthetic extreme value distribution derived from simulated wave heights during each event presented in Table 6-6. The results are presented in Table 6-7, where it can be seen that return periods less than 200 years are generally slightly overpredicted (0% to 10%) by the synthetic distribution, while return periods longer than 200 years are generally under predicted by the synthetic distribution (-3% to -6%). Taken across all return periods between 2 and 500 years, covering the typical range of design vales, the deviation between the empirical and synthetic extreme wave heights is 0.6%, compared to a 95% confidence bound of 1.8% on the empirical distribution itself. Therefore, the any difference between the empirical and synthetic distributions of extreme wave heights is not statistically significant and the approach outlined in Section 6.2.1.1 can be applied with confidence at the project site.

Table 6-7: Deviation between empirical and synthetic extreme value distributions at Halibut Bank

RP (YEARS)	EMPIRICAL H_s (M)	SYNTHETIC H_s (M)	DIFFERENCE
2	2.50	2.52	1%
5	2.80	3.06	9%
10	3.04	3.34	10%
25	3.36	3.63	8%
50	3.60	3.81	6%
75	3.75	3.91	4%
100	3.85	3.97	3%
200	4.11	4.12	0%
500	4.44	4.29	-3%
1000	4.70	4.41	-6%

WAVE PERIOD

To complete a description of the extreme sea state, a wave period must be associated with the extreme wave heights estimated in Section 6.2.4.1. The most common approach is to fit an exponential regression curve to simulated values of H_s and T_p to estimate an appropriate wave period to accompany return-period level wave heights. The use of an exponential function has some theoretical backing in, for example, the form of equations used in wind-wave growth models where the wave period is related to wave height via an exponential curve. Figure 22 below presents the regression curve, with 95% confidence bounds, derived from simulations of the selected storm events at Halibut Bank, with the overall measured wave record plotted as an H_s-T_p scatter. The synthetic H_s-T_p regression curve closely follows the distribution of measured H_s-T_p values through the range of measured data, as would be expected for results from a calibrated wave model. Based on this comparison, it is reasonable to infer that a similar approach will produce a valid relationship between H_s and T_p at the project site.

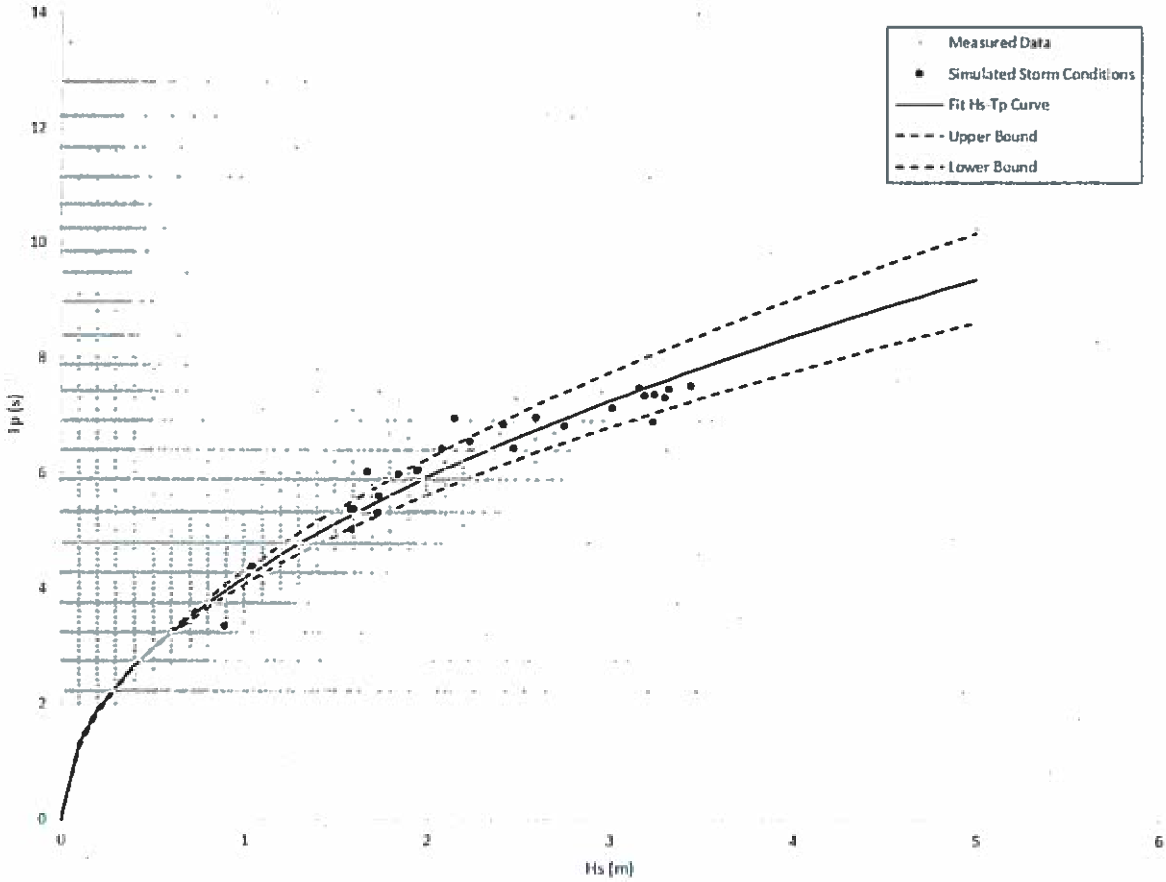


Figure 22 – H_s-T_p scatter diagram showing fit of return-period level H_s-T_p estimate at Halibut Bank

6.2.5 AT-SITE EXTREME VALUE ANALYSIS

EXTREME VALUE DISTRIBUTION

For each of the 27 storm event simulations summarized in Table 6-6 the wave height, period and direction of waves was exported at several locations for a range of different depths offshore of the project site corresponding to the boundary of the nearshore SWASH model presented in Section 0. The maximum H_s across these export locations, as well as the associated wave period and direction, was then determined.

Table 6-8 presents the resulting extreme value distribution on these wave heights. Figure 23 presents the corresponding joint probability distribution of significant wave height and water level at the project site derived from the marginal distribution of wave height at the project site and waver levels at Point Atkinson. Section 6.2.2 presents the methodology behind the derivation of this joint marginal distribution. To estimate an appropriate wave period for each return period level wave event, a regression of H_s and T_p was carried out to associate a likely peak period. A distinction is made between simulated peak periods and associated peak periods by noting the associated peak period as $T_{p,ass}$. The derivation of the associated peak period is presented in Section 6.2.5.2

Table 6-8: Extreme significant wave heights and associated peak period offshore of the project site with 95% confidence bounds

RETURN PERIOD	H_s (m)	$T_{p,ass.}$ (s)	DIRECTION (°)
2	1.23 +/- 0.11	6.97 +/- 0.45	230°
5	1.44 +/- 0.11	7.53 +/- 0.65	
10	1.57 +/- 0.11	7.85 +/- 0.77	
25	1.70 +/- 0.12	8.16 +/- 0.89	
50	1.79 +/- 0.12	8.37 +/- 0.97	
75	1.83 +/- 0.12	8.46 +/- 1.00	
100	1.87 +/- 0.12	8.55 +/- 1.04	
200	1.94 +/- 0.13	8.70 +/- 1.10	
500	2.03 +/- 0.13	8.89 +/- 1.18	
1,000	2.09 +/- 0.13	9.02 +/- 1.23	

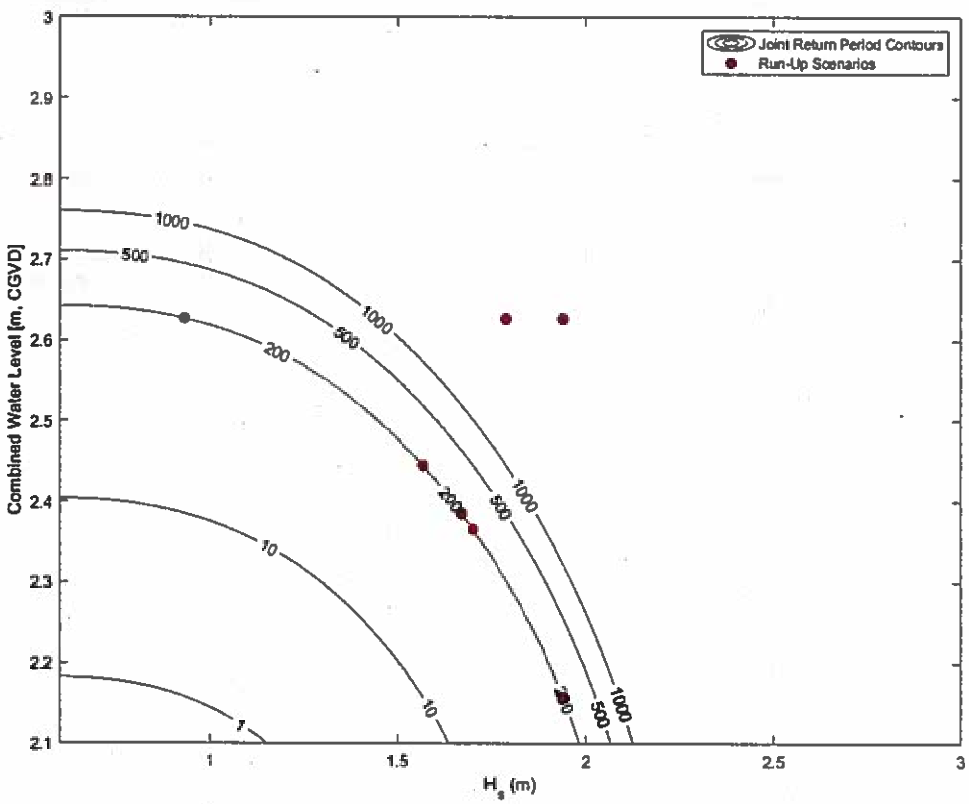


Figure 23 - Joint probability distribution for waves and water levels

DERIVATION OF ASSOCIATED PEAK WAVE PERIOD AND DIRECTION

To derive the associated peak wave period for each extreme event given in Table 6-8, an exponential regression curve has been fit to the simulated values of H_s and T_p at the project site. This approach is documented in Section 6.2.1.1 and validated in Section 6.2.4.

It is apparent from Table 6-8 that $T_{p,uss}$ is relatively long as compared to the associated H_s the could be expected from a wind-wave field generated within English Bay. This is due to the largest waves at the project site being generated in the Strait of Georgia by larger scale weather systems and propagating into the project site. As waves are attenuated between the open waters of the Strait of Georgia and more sheltered project site, the wave height is reduced, and the incident wave angle becomes clustered between Southwest and South. While wave height is reduced due to diffraction, refraction and shoaling, wave period is largely unchanged, hence the periods more typical of more open-water conditions. To interpret this, it is useful to compare Figure 22 and Figure 24. Each of these figures displays results from the same storm events, simply at different locations. Figure 22 presents results from Halibut Bank, where simulated wave periods match measured periods closely. Figure 24 presents results from the project site overlaid with measured H_s-T_p data from Halibut Bank for comparison. From the simulated results (plotted as variously colored triangles), the combined effects of diffraction, refraction and shoaling have reduced the wave height as compared to the companion results presented on Figure 22 without significantly altering the wave period.

On Figure 24, the simulated wave events at the project site have been divided into three primary populations:

- **Southwesterly:** this population of wave events (blue triangles on Figure 24) is generated by north-westerlies in the strait and approach the site with incident wave angles clustering around 230° (229° - 234°). These events are associated with relatively longer periods and larger wave height.
- **Southerly:** this population of wave events (green triangles on Figure 24) is generally generated by south-easterlies in the strait and approaches the site with incident wave angles clustering around 190° (160° - 210°). These events have a moderately period and wave height. Two events in this population were comprised of locally generated wind-waves in English Bay, which are the two events plotting considerably below the trend for Southerly wave events.
- **Southeasterly:** the single event (red triangle on Figure 24) in this population is derived from a local wind-wave event in English Bay.

As southwesterly waves at the project site are associated with the largest wave height and result in a direct exposure of Steerman Beach to wave action, an incident wave angle of 230° has been associated with extreme wave heights at the project site.

Wind-waves generated within English Bay did not form a significant part of the extreme value distribution at the site, which was dominated by larger waves generated in the Strait, and hence were not included in the determination of the extreme value distribution.

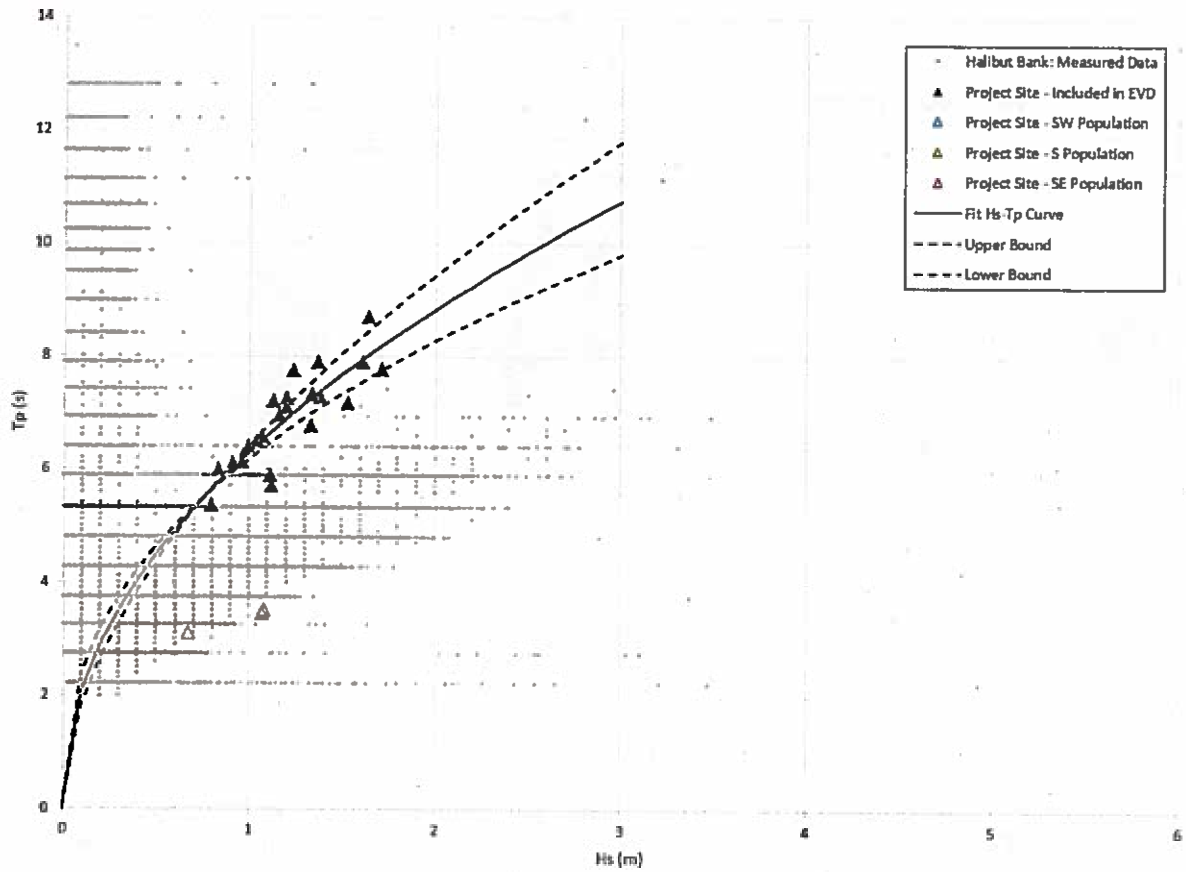


Figure 24 - H_s-T_p scatter diagram showing fit of return-period level H_s-T_p estimate at the project site

6.2.6 DESIGNATED STORM EVENT

For this project, the Designated Storm Event has been defined as a 10,000-year return period storm condition. As discussed in Section 6.2.2, wave heights and water levels can be considered independent variables at the project site. While large wave heights, and storm events generally, are associated with a positive residual water level at Point Atkinson (i.e. storm surge), there is no discernible trend between the magnitude of wave action and the magnitude of positive residual water level. Essentially, despite wave action and storm surge being related, wave action is a poor predictor of storm surge and vice-versa. With the added effect of tidal action, there is effectively no statistical relationship between wave height and water level at the project site. Storm direction has been defined as the direction from which the largest waves at the project site come from, 230° or West-Southwest. There is a considerable component of smaller wave heights from 170°, or South-Southeast, but the storm direction has been assigned to the larger of these two incident wave directions.

The severity of the designated storm event is effectively defined by the magnitude of nearshore wave action and the associated water level. A 10,000-year storm event could be comprised of a range of potential wave heights and water levels with the same overall equal likelihood of occurrence, ranging from a high-water level combined with a moderate wave height to a severe wave condition at a moderate water level. Depending on the local site conditions, different combinations of wave height and water level may result in different wave effects at the shoreline for the same return period. Table 6-9 includes two variant Designated Storm Conditions a 40,000-year return period event adhering to guidance documents, and a 10,000-year event.

Table 6-9: Summary of 200-year return period Designated Storm Event and two variants on guideline conditions in the year 2020

WAVE CONDITIONS				WATER LEVEL		OVERALL
RETURN PERIOD	H_s [m]	T_p [s]	DIRECTION	RETURN PERIOD	SWL [m, CGD]	RETURN PERIOD
200	1.94	8.70	230	1	2.16	200
1	0.93	6.09	230	200	2.63	200
25	1.70	8.16	230	8	2.37	200
10	1.57	7.85	230	20	2.44	200
20	1.67	8.09	230	10	2.39	200
200	1.94	8.70	230	200	2.63	40,000
50	1.79	8.37	230	200	2.63	10,000

6.3 AT-SHORE WAVE CONDITIONS

6.3.1 SWASH MODEL DEVELOPMENT

SWASH is a general-purpose numerical tool for simulating non-hydrostatic, free-surface, rotational flows and transport phenomena in one, two or three dimensions. The governing equations are the nonlinear shallow water equations including non-hydrostatic pressure and some transport equations, and provide a general basis for simulating wave transformation in both surf and swash zones due to nonlinear wave-wave interactions, interaction of waves with currents, interaction of waves with structures, wave damping due to vegetation, and wave breaking as well as runup at the shoreline, complex changes to rapidly varied flows typically found in coastal flooding.

The model bathymetry and topography has been derived from NOAA's 3-arc second bathymetric data set of the area, data purchased from Canadian Hydrographic Service and topography from a 2013 LiDAR (0.5 m accuracy) survey commission by the District of West Vancouver. Figure 25 presents an overview and the SWASH section model for the project site. The section was oriented to be shore-normal and is approximately parallel to the incident wave angle. The berm structure proposed for the project site has been parameterized from Drawing A5.1 obtained from the District of West Vancouver. The lower panel of Figure 25 presents a general arrangement of the digitized structure and Figure 26 presents a comparison between Drawing A5.1 and the SWASH model domain.

The model has been set-up as follows, with specific parameters noted where they deviate from default:

- **Spatial Resolution:** 0.5 m (offshore) to 0.1 m (shoreline), with the spatial resolution having been optimized to achieve a run-up value independent of the grid-cell size.
- **Timestep:** Variable, 0.001 s baseline
- **Roughness:** A uniform manning's roughness value of 0.027 has been applied, which is a conservative value for the primarily sand-gravel-cobble shoreline.
- **Run-Up Calculation:** Run-up has been determined as the maximum vertical water level with a detection threshold of 0.05 m (i.e. the vertical level at which the water depth exceeds 0.05m).
- **Wave Field Representation:** The H_s and T_p associated with a given return period event has been applied at the boundary assuming a JONSWAP spectrum with standard parameters. To get a statistically representative time-domain reconstruction of the wave spectrum and ensure that a reasonable representation of the maximum wave height is included in the simulation, several simulation lengths have been tested between 1 and 3 hours. No significant deviations in run-up were observed for simulation times longer than 1 hour, so a 1 hour simulation time has been used, corresponding to a storm of 400 to 500 waves.

- **Spatial Variability:** Run-up levels computed in the section model have been checked against a two-dimensional SWASH model of the general area and found to be representative. This two-dimensional model has not been applied to derive the run-up values directly due to run-time limitations.

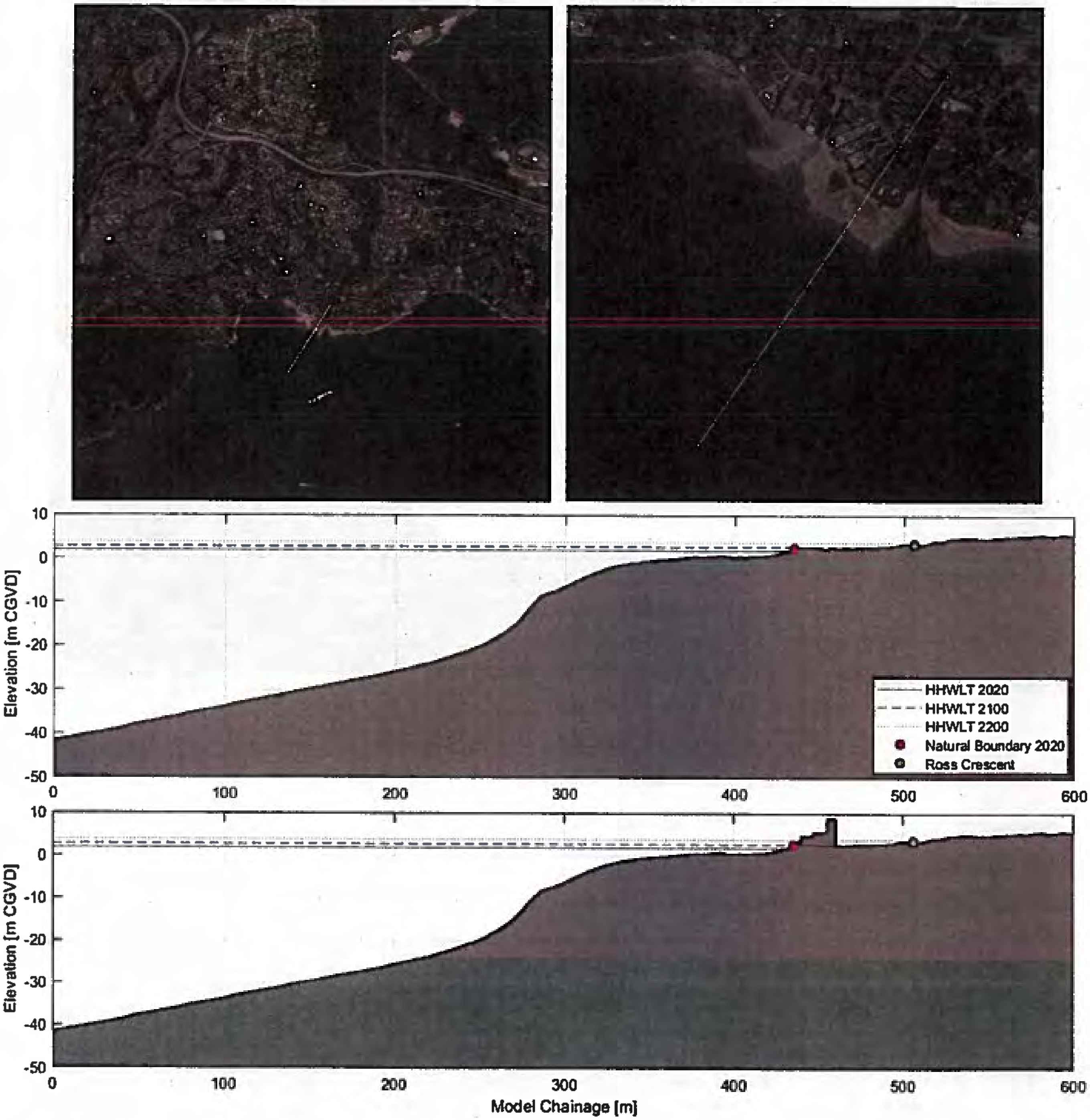


Figure 25 SWASH section model general setting (top left), local setting (top right), bare earth surface (middle) showing the highest astronomical tide in 2020, 2100 and 2200 with the 2020 Natural Boundary and the centreline of Ross Crescent and the bare earth surface with the proposed (partial) structure superimposed (bottom).

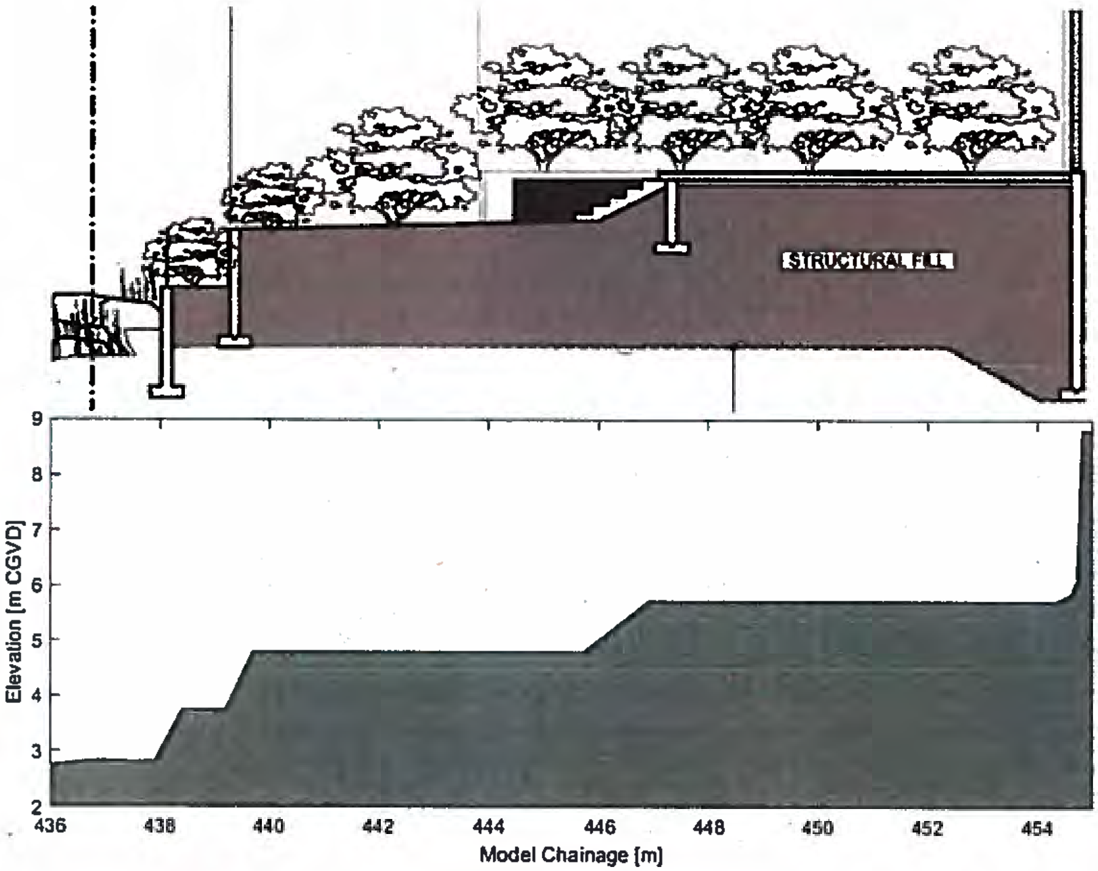


Figure 26 Parameterization of berm structure at 4358 Ross Crescent

6.3.2 WAVE RUN-UP

UNDEVELOPED SITE CONDITIONS

The resulting wave run-up (wave effect) of the Designated Storm Condition has been simulated at the project site. Table 6-10 presents wave run-up at the shoreline in 2100, respectively, for 200, 10,000 and 40,000-year return period events. In these tables, run-up can be interpreted as the Flood Construction Reference Plane (FCRP), with the wave-effect being the difference between SWL and the FCRP. Run-up is typically presented statistically as the elevation exceeded by some percentage of the waves (e.g. 50%, 10%, 2%) of a given storm event. Ideally, the run-up elevation would be specified such that the magnitude, duration and frequency of the run-up elevation is specified at a reasonable limit to prevent damage to upland structures but not so conservative that it precludes all contact between run-up and the upland structure. For example, the Federal Emergency Management Agency (FEMA) has previously taken the mean run-up level ($R_{50\%}$) as an appropriate metric for wave run-up, whereas recent advice from the National Flood Insurance Program (NFIP) defines run-up height as the elevation exceeded by not more than 2% of waves in a storm event ($R_{2\%}$). In this report, the maximum run-up value is presented to match previous reporting on site and in the absence of specific Provincial guidance, which represents a minor conservatism in the results given that the waves are depth-limited at the shoreline.

For the 200-year return period Designated Storm Event, a range of water level and wave height return periods have been simulated to determine the worst-case combination. These simulations are drawn from values on the 200-year joint return period contour presented previously in Figure 23. It has been found that combinations of moderate return-period water levels and waves result in the largest run-up at a 200-year return period level, with very similar run-up levels. This is attributed to events occurring at high water levels and low wave heights being subject to extensive dissipation along the relatively shallow and wide inundated beach and back-beach area, limiting wave effects at this extreme end of the 200-year wave-water level distribution (see Section 2). At the other extreme of large waves combined with low water levels, breaking along the foreshore tends to limit the upland propagation of waves.

Considering longer-return period combinations, a 10,000-year event comprised of a 200-year water level and 50-year wave height results in an 8% higher FCRP, which is only marginally different from the worst-case 200-year event. This difference rises to 10% for a 40,000-year event. These relatively minor differences are, firstly, due to the similarity of large return-period events and, secondly, due to the sensitivity testing carried out on the 200-year return period event to locate the worst-case combination of waves and water levels.

It should be noted that the wave effects presented in Table 6-10 are for bare-earth conditions at the project site, not accounting for future planned structures or coastal works. Table 6-11 presents sensitivity testing of the 200, 40,000 and 10,000-year return period conditions based on the 95th percentile confidence bounds of the H_s and T_p curve fits to assign uncertainty bounds to the wave-effects. Simulations were carried out at the central estimate values of water level presented in Table 6-10. Based on the sensitivity testing presented in Table 6-11, the central estimate values presented in Table 6-10 are generally (with the exception of Case 6) towards the upper end of the uncertainty bound. This implies, firstly, that run-up values are not necessarily normally distributed between the uncertainty bounds and that the central estimate figures are a generally good representation of worst-case conditions for a given return period.

Table 6-10: Summary of wave effects in 2100 for central estimate values of wave height, wave period and water level

CASE	RETURN PERIOD			SLR	SUBSIDENCE	2100 SWL	WAVE EFFECT	RUN-UP
	OVERALL	WAVE HEIGHT	WATER LEVEL	(m)	(m)	(m, CGD)	(m)	(m, CGD)
1	200	200	1	1.0	0.08	3.24	0.71	3.95
2	200	1	200	1.0	0.08	3.71	0.18	3.89
3	200	25	8	1.0	0.08	3.45	0.71	4.16
4	200	10	20	**1.0**	**0.08**	**3.52**	**0.65**	**4.17**
5	200	20	10	1.0	0.08	3.47	0.64	4.11
6	40,000	200	200	1.0	0.08	3.71	0.70	4.41
7	10,000	50	200	1.0	0.08	3.71	0.77	4.45

Table 6-11: Sensitivity testing of H_s-T_p bounds of 200, 40,000 and 10,000-year return period events

CASE	LOWER BOUND				UPPER BOUND				RANGE
	H_s	T_p	WAVE EFFECT	RUN-UP	H_s	T_p	WAVE EFFECT	RUN-UP	RUN-UP
	(m)	(s)	(m)	(m, CGD)	(m)	(s)	(m)	(m, CGD)	(m, CGD)
4	1.46	7.25	0.39	3.91	1.68	8.56	0.68	4.20	+/ 0.15
6	1.81	7.93	0.65	4.36	2.07	9.61	1.02	4.73	+/- 0.16
7	1.67	7.67	0.58	4.29	1.91	9.19	0.80	4.51	+/- 0.16

DEVELOPED SITE CONDITIONS

Run-up analysis was carried out for the developed profile shown in Figure 26. Figure 27 presents an extract from the model output graphics showing a trace of the free surface position over a period of an hour, the location of the 2020 top-of-beach, the 2100 (200-year event) SWL and maximum run-up position.

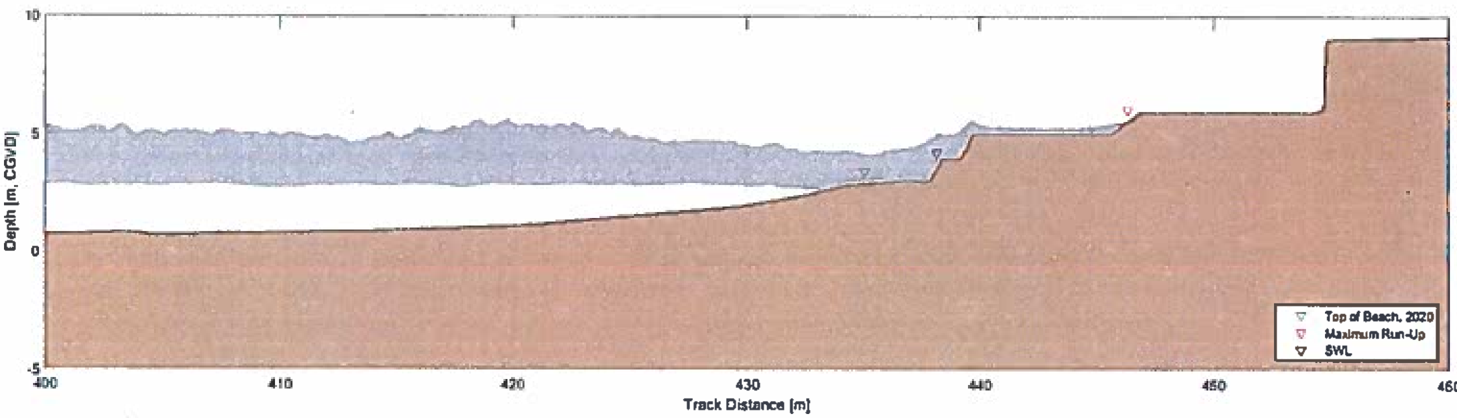


Figure 27 Wave run-up output graphics

Table 6-12 presents the outcome of the developed site run-up level estimates for the year 2100. Run-up levels are in the range from 2.2 m to 2.4 m for events ranging from 200 to 40,000-year return periods. This gives a dimensionless run-up (R_u/H_s) in the range of 1.34 to 1.40, which is well within the typical range of values reported at coastal structures (e.g. USACE, 2006). Table 6-13 presents sensitivity testing of the 200, 40,000 and 10,000-year return period conditions based on the 95th percentile confidence bounds of the H_s and T_p curve fits to assign uncertainty bounds to the wave-effects. Simulations were carried out at the central estimate values of water level presented in Table 6-12

Table 6-12: Summary of wave effects in 2100 for central estimate values of wave height, wave period and water level

CASE	RETURN PERIOD			SLR	SUBSIDENCE	2100 SWL	WAVE EFFECT	RUN-UP
	OVERALL	WAVE HEIGHT	WATER LEVEL	(m)	(m)	(m, CGD)	(m)	(m, CGD)
4	200	10	20	1.0	0.08	3.52	2.21	5.73
6	40,000	200	200	1.0	0.08	3.71	2.15	5.86
7	10,000	50	200	1.0	0.08	3.71	2.38	6.09

Table 6-13: Sensitivity testing of H_s-T_p bounds of 200, 40,000 and 10,000-year return period events

CASE	2100 SWL	LOWER BOUND				UPPER BOUND				RANGE
		H_s	T_p	WAVE EFFECT	RUN-UP	H_s	T_p	WAVE EFFECT	RUN-UP	RUN-UP
	(m, CGD)	(m)	(s)	(m)	(m, CGD)	(m)	(s)	(m)	(m, CGD)	(m, CGD)
4	3.52	1.46	7.25	2.05	5.57	1.68	8.56	2.29	5.81	+/- 0.12
6	3.71	1.81	7.93	2.15	5.86	2.07	9.61	2.79	6.09	+/- 0.32
7	3.71	1.67	7.67	2.15	5.86	1.91	9.19	2.38	6.09	+/- 0.12

The run-up value for the year 2100 water level is in the range of 2.2 m to 2.4 m, which is larger than the run-up value of 1.19m previously reported for the site by NHC (2019). This is partly due to the different form adopted for the berm adopted in the NHC work compared to that used here and partly due to the longer wave periods (8 sec) that have been applied in this study. NHC run-up values applied a design condition based on wind-waves generated within English Bay ("Easterly Event" case), which tend to have a shorter period (5 sec) than waves generated in the Strait of Georgia (see Section 6.2.4). For the sake of comparison, tests have been conducted with wave periods representative of waves generated in English Bay based on a 200-year return period water level and a 50-year return period wave condition (Table 6-14). The reduction in wave period is shown to have a significant effect on the run-up value.

Table 6-14: Comparison of 10,000-year return period run-up level to comparable run-up generated by local wind-waves

CASE	2100 SWL	H_S	T_P	WAVE EFFECT	RUN-UP	DEVATION FROM BASELINE
	(m, CGD)	(m)	(s)	(m)	(m, CGD)	(m)
7	3.71	1.79	5.0	0.21	3.92	- 2.17
7	3.71	1.79	6.0	1.09	4.80	- 1.29
7	3.71	1.79	7.0	1.86	5.57	- 0.52

7 FLOOD CONSTRUCTION LEVEL

7.1 UNDEVELOPED SITE CONDITIONS

7.1.1 FCL

Table 7-1 presents the FCL levels for the site in the year 2100 following the Probabilistic Method (Section 3) with a combined return period of 10,000 years, comprised of a 200-year return period water level and a 50-year return period wave height and for the existing site. A FCL of 5.01 m is recommended for the undeveloped site at a 10,000-year return period event comprised of a 200-year water level and 50 year wave event. Table 7-2 presents the FCL calculation performed for the same time periods applying the Probabilistic Method with a combined return period of 200-years. The 200-year event applied in Table 7-2 is comprised of a 10-year return period wave height and 20-year return period water level in 2100. A FCL of 4.77 m is recommended for the undeveloped site at a 200-year return period event comprised of a 20 year water level and 10 year wave event.

Both tables present a central (best) estimate value for FCL, along with a likely range based on the 95% confidence interval (where available) and an estimated upper bound value. For wave action, the likely range has been defined by sensitivity testing summarized in Table 6-11 and applied to the central estimate value. The purpose of presenting the 95% confidence bound (upper bound) value is to ensure that the addition of a 0.60 m freeboard is sufficient to account for the uncertainty in establishing the central estimate value for the FCL. In both cases, it has been found that the uncertainty level in the FCL calculation is 0.22 m to 0.23 m, which considerably less than the 0.60 m freeboard recommendation for the Probabilistic Method. It bears noting that the 0.30 m freeboard allowance recommended for the Combined Method may be more appropriate for this analysis as the uncertainty levels associated with the FCL have been quantified.

Table 7-1: Year 2100 Flood Construction Level, following the baseline Probabilistic Method at a 10,000-year return period level – undeveloped site conditions

PARAMETER	2100: 10,000-YEAR RP		
	Central Estimate	**Likely Range**	**Upper Bound**
Designated Flood Level[1], 2020	2.63 m	0.03 m	2.66 m
Sea Level Rise from 2020	1.0 m		
Land Subsidence from 2020	0.08 m	0.04 m	0.12 m
Designated Future Flood Level	**3.71 m**	**0.07 m**	**3.78 m**
Designated Storm Wave Effects[2]	0.70 m	0.16 m	0.86 m
Flood Construction Reference Plane	**4.41 m**	**0.23 m**	**4.64 m**
Freeboard Allowance	0.60 m		
Flood Construction Level	**5.01 m**		

[1] Designated Flood Level, defined as the 200-year return period combined water level at Point Atkinson
[2] Designated Storm Event, defined as a 50-year return period wave event

Table 7-2: Flood Construction Level, extending Probabilistic Method to include the joint occurrence of tides, surge and wave action at 200-year return period level – undeveloped site conditions

PARAMETER	2100: 200-YEAR RP		
	Central Estimate	Likely Range	Upper Bound
Designated Storm Water Level[1], 2020	2.44 m	0.03 m	2.47 m
Sea Level Rise from 2020	1.0 m		
Land Subsidence from 2020	0.08 m	0.04 m	0.12 m
Designated Future Flood Level	**3.52 m**	**0.07 m**	**3.59 m**
Designated Storm Wave Effects[1]	0.65 m	0.15 m	0.80 m
Flood Construction Reference Plane	**4.17 m**	**0.22 m**	**4.39 m**
Freeboard Allowance	0.60 m		
Flood Construction Level	**4.77 m**		

[1] 200-year return period designated storm event accounting for the joint probability of tides, surge, and waves

7.1.2 SETBACK

A set-back line for undeveloped site conditions cannot be provided as the site is fully inundated at the year 2100 FCL. It should be noted that the site is also below the Flood-Construction Reference Plane (FRP) and FCL for present-day sea levels at a 200-Year return period level.

7.2 DEVELOPED SITE CONDITIONS

7.2.1 FCL

Based on the Development Application lodged for construction of a new residence on the property 4358 Ross Crescent, a year 2100 coastal FCL of 5.8 m has been estimated by NHC at a 10,000-year return period level. The development includes significant filling of the site to achieve the required coastal FCL of 5.8 m. For this study, the proposed berm structure proposed for the project site has been parameterized from Drawing A5.1 of the Development Application obtained from the District of West Vancouver.

Based on the results of the present study, the year 2100 FCL for the developed project site, presented in Table 7-3, has been estimated to be 6.69 m at a 10,000-year return period level, based on a 200-year return period water level and 50-year return period wave event. At a 200-year return period level, the developed project site has an estimated year 2100 FCL of 6.33 m based a 10-year return period wave height and 20-year return period water level. The calculation of this 200-year return period FCL is presented in Table 7-4.

For both the 10,000-year and 200-year return period year 2100 FCLs, it has been found that the uncertainty level in the FCL calculation is 0.19 m, which considerably less than the 0.60 m freeboard recommendation for the Probabilistic Method.

The sources of the +0.89 m discrepancy between NHC (2019) and this report (5.8 m vs. 6.69 m) at a 10,000-year return period level are as follows:

- **Designated Flood Level:** Differing calculation methodologies in the determination of the combined tide and storm surge water level. In WSP's interpretation, NHC has, following the Empirical Simulation Technique proposed by the US Army Corps of Engineers, separated tide and surge signals and used a bootstrapping technique to estimate return-period level combined water levels. WSP has performed an extreme value analysis directly on the measured water levels at Point Atkinson to determine the 200-year return period water level directly. Based on the long period of record at Point Atkinson, this more straightforward data treatment is felt to be a more robust approach. Despite mixing the deterministic tidal signal with the stochastic surge signal, the long period of record at Point Atkinson produces

-0.26 m difference

– **Land Subsidence:** WSP applies the central estimate of land subsidence of 1 mm/year and accounts for the provided uncertainty range of +/- 0.5 mm/year in the upper bound estimate of the FCL. NHC applies the upper bound value of 1.5 mm/year directly

-0.03 m difference

– **Wave Effects:** The wave effect differential is partially due to differences in berm shape between WSP's and NHC's simulations of wave run-up. In this report, the berm profile was based on drawings presented in the development application. The major factor influencing the run-up value at the project site, however, is the wave period of the designated storm event. Applying a similar wave period to that presented in NHC (2019), the resulting wave run-up values are within 10%, however, WSP has found that the most severe run-up events are generated by longer-period waves propagating to site from the Strait of Georgia. As discussed in Section 6.3.2, wave run-up is very sensitive to wave period, with longer periods resulting in more run-up.

+1.19 m difference

– **Rounding Accuracy:** Values in both reports are presented to two decimal places, resulting in an minor (insignificant) rounding error when summing FCL components between reports.

-0.01 m difference

Table 7-3: Year 2100 Flood Construction Level, following the baseline Probabilistic Method at a 10,000-year return period level – developed site conditions

PARAMETER	2100: 10,000-YEAR RP		
	Central Estimate	**Likely Range**	**Upper Bound**
Designated Flood Level[1], 2020	2.63 m	0.03 m	2.66 m
Sea Level Rise from 2020	1.0 m		
Land Subsidence from 2020	0.08 m	0.04 m	0.12 m
Designated Future Flood Level	**3.71 m**	**0.07 m**	**3.78 m**
Designated Storm Wave Effects[1]	2.38 m	0.12 m	2.50 m
Flood Construction Reference Plane	**6.09 m**	**0.19 m**	**6.28 m**
Freeboard Allowance	0.60 m		
Flood Construction Level	**6.69 m**		

[1] Designated Flood Level, defined as the 200-year return period combined water level at Point Atkinson
[2] Designated Storm Event, defined as a 50-year return period wave event

Table 7-4: Flood Construction Level, extending Probabilistic Method to include the joint occurrence of tides, surge and wave action at 200-year return period level – developed site conditions

PARAMETER	2100: 200-YEAR RP		
	Central Estimate	Likely Range	Upper Bound
Designated Storm Water Level[1], 2020	2.44 m	0.03 m	2.47 m
Sea Level Rise from 2020	1.0 m		
Land Subsidence from 2020	0.08 m	0.04 m	0.12 m
Designated Future Flood Level	**3.52 m**	**0.07 m**	**3.59 m**
Designated Storm Wave Effects[1]	2.21 m	0.12 m	2.33 m
Flood Construction Reference Plane	**5.73 m**	**0.19 m**	**5.92 m**
Freeboard Allowance	0.60 m		
Flood Construction Level	**6.33 m**		

[1] 200-year return period designated storm event accounting for the joint probability of tides, surge, and waves

7.2.2 SETBACK

Setback is based on the defined location of the Natural Boundary, which is a concept used in existing literature and is the location that reflects a change in vegetation and soil based on effects of the sea. It is often difficult to determine and its technical basis is site and time specific. In general, the Natural Boundary is taken as the visible high-water mark, which is influenced by the recent history of storms at the site. As per provincial guidelines, the Natural Boundary is taken in this study as the FRP in a given assessment year. The 2100 setback has been defined as the greater of:

- 15m beyond the 2100 estimated Natural Boundary, with the estimated Natural Boundary taken as the FRP;
- The intersection of the 2100 FCL with the ground surface.

The properties surrounding 4358 Ross Crescent are also below the FRP of 4.41 m for the undeveloped site for the Year 2100. As the property at 4358 Ross Crescent has a width of only some 12 m, a strict interpretation of the setback requirement suggests the lot cannot be developed, without some modification of the adjacent lots.

The Provincial Guidelines (2018 Amendment) allow some relaxation of the setback for development of existing lots if meeting the setback guidelines would sterilize the lot whereby "the development approving official may agree to modify setback requirements as recommended by a suitably qualified Professional Engineer experienced in coastal engineering, provided that this is augmented through a restrictive covenant stipulating the hazard, building requirements, and liability disclaimer."

8 APPROPRIATENESS OF PROPOSED BERM STRUCTURE

The project site is situated within the estimated year 2100 coastal flood plain. Therefore, an engineered fill (berm) has been proposed by the site developers to ensure the structure meets FCL requirements and is not damaged during storm events. Installing such a berm does not alter the SWL associated with surge events, but the design and position of the berm has a large influence on the wave run-up. The proposed berm (fill with the seaward face comprised of a series of vertical walls) increases wave run-up compared to the undeveloped site and therefore requires a higher FCL compared to undeveloped conditions to avoid damage to the proposed structure. Wave run-up is the second-largest contributor to the FCL, behind tides and surge, and, consequently, the fill structure's design is a large factor in the FCL. This is largely unavoidable, as wave run-up will necessarily occur at a fill structure situated within a floodplain, but this does result in a dependency between the FCL and berm design. The relationship between the developed site FCL and proposed structure is as follows:

- Based on estimates of the year-2100 conditions for the undeveloped site, the site lies within the 2100 SLR Planning Area (future coastal flood plain)
- The decision has been made to construct a building within the future coastal flood plain, triggering a requirement for protection against high water and wave action
- The site is relatively compact, and it appears the designers would like to position the building as near as feasible to the present-day water line, therefore the building is proposed to be constructed on engineered fill with a series of vertical walls producing a tiered outdoor recreation area.
- The design of the berm results in a post-development FCL above the undeveloped site's FCL due to wave run-up against the fill's shoreward face.

Regardless of differences between the FCL values reported in this document and presented previously for the site, a berm structure crest elevation could be defined such that the site is protected against coastal flooding through to the year 2100. However, it is not necessarily reasonable to design a berm structure to achieve this crest elevation on a site-by-site basis. Constructed in isolation, the side-slopes of the berm structure (i.e. running parallel to the main axis of the proposed structure), would be directly exposed to wave action in during the Designated Storm Event and require an equivalent analysis as that conducted for the seaward face of the berm to ensure that the full fill structure is adequately designed to resist wave action. Furthermore, during the Designated Storm Event in the year 2100, the site is cut off from land access as Ross Crescent is expected to be inundated.

Taking the proposed development plan as it stands, there are mitigative measures that could be employed to reduce the run-up heights at the seaward face of the structure. These could include:

- Inclusion of a recurve parapet at the second vertical retaining wall of the berm to cap wave run-up. The first vertical retaining wall is largely submerged during the Designated Storm Event, limiting the effectiveness of a recurve parapet at this location.
- Installation of armour rock and/or large woody debris seaward of the first vertical retaining wall, as shown on some drawings in the development application, to dissipate the waves before they reach the walls.

Assessment of these options is beyond the scope of this report and would required detailed analysis.

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