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

nhc
northwest hydraulic consultants ltd

NHC Ref. No. 3005277

2020 March 24

Mr. David Cobban
2413 Weymouth Place
North Vancouver, BC, V7K 2Z3

Re: Flood Hazard Assessment
3 Brunswick Beach Road, Village of Lions Bay, BC

This letter report summarizes the flood hazard assessment (FHA) conducted by Northwest Hydraulic Consultants Ltd. (NHC) in support of the future building permit for the proposed 3 Brunswick Beach Road development located within the Village of Lions Bay (Lot 20, Block 18, District Lot 1815, New Westminster District, Plan 10651).

Since no plans were available at the time this assessment was performed, the assessment considers that the ground in front (seaward) of the proposed dwelling will remain at the existing elevation following construction. Raising the ground elevation and/or constructing shoreline protection structures would require a reassessment of the FCL as such modification influences wave runup. Preliminary plans reviewed by NHC following the completion of this assessment suggest that, as the proposed pool and optional wall at the seaward edge of the property protrudes from the surrounding ground, wave runup may be reduced. Additional assessment however is required to quantify this.

1 Introduction

A principal dwelling is being proposed for 3 Brunswick Beach Road to replace an existing dwelling on the property. The waterfront property is located on Brunswick Beach in Howe Sound within the Village of Lions Bay (**Figure 1**). The property is located in Alberta Bay with southwest exposure. The property is potentially at risk from coastal flood hazards from Howe Sound during southerly wind events occurring at high water levels. Because of its relative distance from major creeks and topography of the area, the risk of flood hazard from the nearby creeks is considered to be low, and was therefore not assessed.

The objective of this assessment is to identify and evaluate the flood hazards that may affect the safe development and use of the property. The currently accepted safety threshold in British Columbia is an event with 0.5% annual exceedance probability (AEP) up to the year 2100. Such event is often referred to as the 200-year event.

It is NHC's understanding that the design of the new dwelling has not been initiated and requires results of this assessment as input.

This report presents the findings of an assessment performed by NHC of flood hazards from Howe Sound, accompanied with recommended measures for mitigation. The report has been structured as follows: the pertinent guidelines and references are described first, followed by site observations and coastal flood hazard assessment, and concludes with findings and recommendations.

Figure 1. Satellite imagery of project site.
Source: Google Earth, image taken on July 8, 2010

1.1 Existing FHA Requirements

The Village of Lions Bay requires all applicants for a building permit provide an assessment of flood risk and appropriate minimum flood construction levels (Village of Lions Bay Bylaw No. 431).

According to Village of Lions Bay Bylaw No. 520 Section 4.19, no building or structure shall be constructed, erected, or placed:

1. *Within 15 metres of the natural boundary of a watercourse;*
2. *On ground surface less than:*
   a. *0.7 metres above the 200-year flood level, which level has been established by the Ministry of Environment;*
   b. *3.1 metres above the natural boundary of a water course where the 200-year flood level has not been established; and*
   c. *1.6 metres above the natural boundary of the sea.*

Professional obligations require that a site-specific FHA report that confirms the land may be used safely for the use intended 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), and
- Identify all floor areas proposed to be constructed below the 4.5 m Canadian Geodetic Vertical Datum and specify use of these areas, as applicable.

1.2 Referenced Guidelines

The following guidelines and regulations were reviewed as part of our investigation of the possible flood hazards incident on 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), and
- 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).

2 Site Description

The following site description is based on the survey data (Chapman Land Surveying Ltd. attached as **Appendix B**), available maps, and a site inspection. The site inspection was conducted on Nov. 6, 2019 by Philippe St-Germain, P.Eng. of NHC to examine the shoreline and to identify the condition of surrounding areas. The weather throughout the site inspection was calm. The water level was approximately -0.6 m at the time of the site inspection; this and all elevations in this document are reported with respect to the Canadian Geodetic Vertical Datum of 1928 (CGVD28) unless otherwise stated. The local conversion from CGVD28 to chart datum (CD) is +3.1 m.

The property is bounded by Brunswick Road to the north and the sea to the south. The shoreline in front of the property is naturally armoured beach with pebbles overlying coarse sand. This pebble beach is uniformly sloped at approximately 7H:1V (**Figure 2** and **Figure 3**).

Large wood logs are present at the top of the beach slope in front of the property as well as along most of Alberta Bay (**Figure 4**). Typical riparian vegetation begins directly behind the logs at an elevation of 2.6 to 3.2 m (**Figure 5**).

The property slopes upwards from the waterfront with elevations varying from 4.1 to 9.7 m. From the edge of vegetation the land is sloped approximately 9H:1V over about 22 m and then sloped 3H:1V over about 12 m up to the road. The southern limit of the property is at an offset of approximately 10 m with respect to the edge of vegetation.

Figure 2. Pebble beach in front of property looking southeast. Existing red cabin is on the subject property and is to be removed under current plans.

Figure 3. Surface and subsurface beach sediment in front of property. Boot included for scale.

Figure 4. Woody debris and vegetation at top of beach slope looking northeast.

Figure 5. Woody debris and vegetation at top of beach slope looking southeast.

3 Fluvial Flood Hazards

The property is located at considerable distance away from the closest major creeks, which are Magnesia Creek to the north and Alberta Creek to the south. No outfalls suggesting water channelling were observed along the Alberta Bay shoreline and assessment of land topography in Google Earth did not suggest the presence of any sizable creeks in the vicinity of the property. Accordingly, the risk from creek flooding is deemed low and no further analysis is warranted.

4 Coastal Geomorphic Hazards

The site inspection did not reveal existing signs of land erosion at the property and its vicinity. This may be related to the protection provided by large logs perched at the top of the beach, which appears to have been there for an extended period of time (**Figure 5**). However such logs may be displaced by less frequent but strong southerly storms coinciding with high water, and the likelihood of the logs being displaced, and potentially cause impact damage to the shoreline, will increase as sea level rises.

Comparison of satellite images available in Google Earth from 2003 to 2019 did not reveal noticeable changes in the position of the shoreline in Alberta Bay. The rock outcrop at the western end of Brunswick Beach in conjunction with the coarse nature of the beach materials and the generally rocky nature of the land features in the area promotes stability of the beach. It is not anticipated that analysis of historical air photo extending further back in time would show trends of shoreline change. For this reasons such analysis is not warranted.

Overall, the erosion hazards are deemed low for the site and any future land erosion is expected to manifest itself by a gradual upward progression of the existing pebble beach.

5 Coastal Flood Hazards

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 hydrodynamic forces or wood debris impact. Physical loading is not investigated as part of this assessment as plans for the structures are not available at the time of study.

Canadian Tide and Current Tables (2019, Volume 5) present tides at Point Atkinson, which is 15 km south of the study site (**Table 1**). Despite the higher high water large tide (HHWLT) level being lower than the property, storm surge, wave effects and long-term changes in global and local sea level could result in substantially higher coastal flood levels. Therefore, these effects are analyzed in the following sections.

Table 1. Tidal levels at Point Atkinson

Tidal Level	Meters with Respect to CGVD28	Metres with Respect to CD
Higher High Water, Large Tide (HHWLT)	1.9	5.0
Higher High Water, Mean Tide (HHWMT)	1.4	4.5
Mean Water Level (MWL)	0.0	3.1
Lower Low Water, Mean Tide (LLWMT)	-1.9	1.2
Lower Low Water, Large Tide (LLWLT)	-3.0	0.1

5.1 Coastal Flood Inundation Hazard

To reduce the likelihood of damage from coastal flood inundation, the coastal flood level was assessed and used to derive a minimum construction level for habitable floors– the flood construction level (FCL). The FCL provides a mitigation measure to limit the likelihood of flooding for developments located along the coast.

The FCL is generally based on an event with an AEP of 0.5% (200-year event). In addition, due to global climate change related sea-level rise, future conditions are considered up to the expected life of the project; often up to the year 2100 (roughly 80 years from present).

The BC Ministry of Environment's 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 of the Flood Hazard Area Land Use Management Guidelines (BCMFLNRD, 2018) present two approaches for determining the 200-year FCL: 1) *combined* method and 2) *probabilistic* method. The components used in determining the FCL using each method are illustrated in **Figure 6** and **Figure 7**.

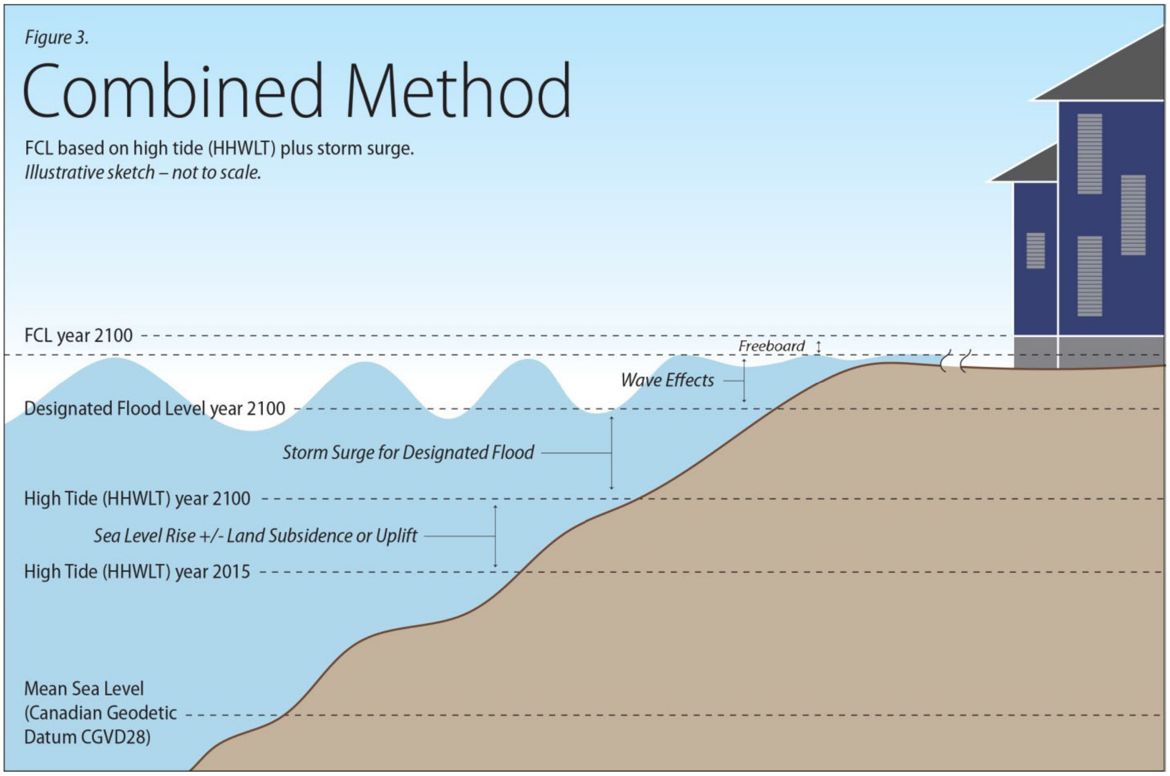

Figure 6. FCL based on combined method (BCMFLNRD, 2018)

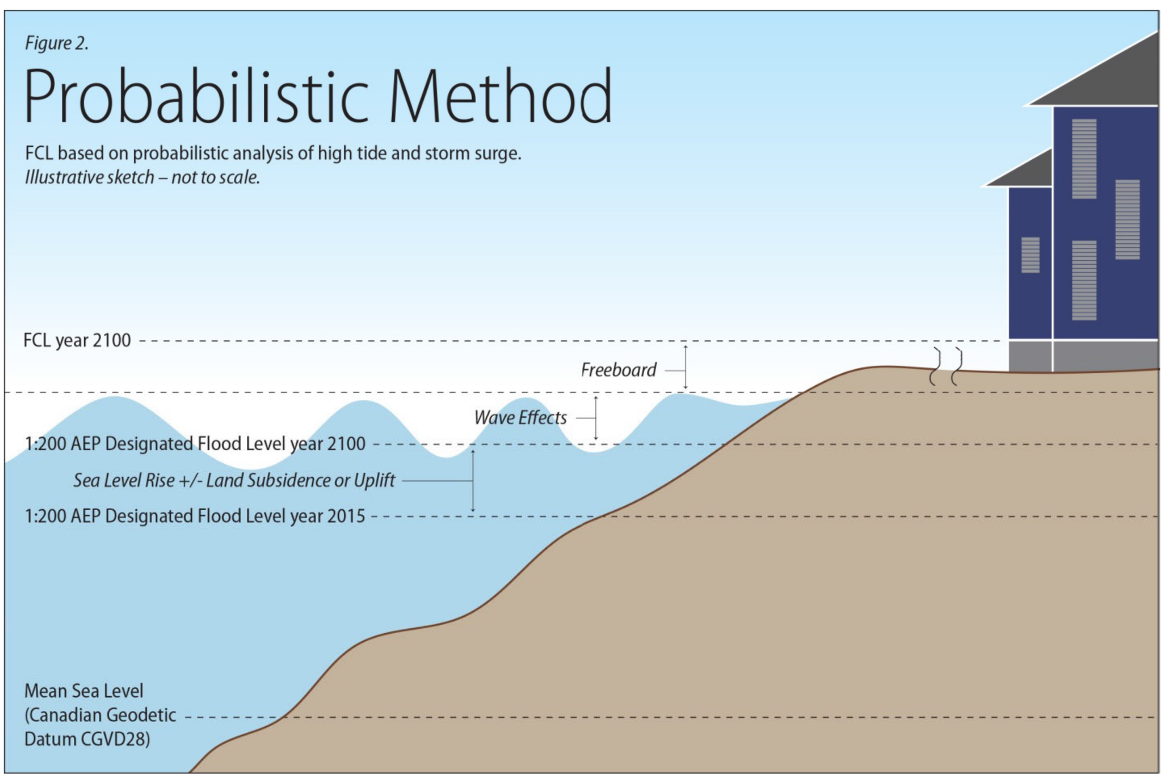

Figure 7. FCL based on probabilistic analysis (BCMFLNRD, 2018)

The combined method is the addition of independent effects of tide, storm surge, and wave run-up, and sea level rise (SLR). This deterministic approach generally results in conservative calculation of a design flood level, as it is applied neglecting the probability of the various design events occurring simultaneously. This is particularly relevant for the fully independent variables of tide and storm surge. For example, the AEP that a 200-year storm surge occurs during HHWLT and 200-year wave event is less than 0.025%; substantially less than the design AEP of 0.5%.

For this assessment a probabilistic approach has been applied, considering the joint probability of tide and storm surge coinciding. This method provides an estimate with an AEP closer to the design AEP of 0.5%.

The coastal FCL using the probabilistic approach is the sum of:

- 0.5% AEP water level as determined by probabilistic analyses of tides and storm surge (the joint probability piece)
- Allowances for future sea level rise (SLR) to the year 2100
- Allowance for regional uplift or subsidence to the year 2100

Designated Flood Level

- Estimated wave effects associated with the designated storm with an 0.5% AEP, and
- Freeboard.

Each of these components are described in the following sections.

Potential changes in storm intensity and frequency over the next 80 years due to climate change could influence storm surge and wave effects. However, predicted changes in storm intensity and frequency are highly variable and inconclusive and therefore have not been incorporated in this analysis.

5.1.1 Joint Occurrence of Storm Surge and Tides

Coastal flood levels for the 0.5% AEP were 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 Federal Emergency Management Agency (of United States Department of Homeland Security) technical documentation for frequency related studies. The analysis determined that the 0.5% AEP water level at Point Atkinson is at an elevation of 2.9 m.

5.1.2 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 80 years, resulting in designs often considering projections to the year-2100.

The BC Provincial Sea Dike Guidelines (BC Ministry of Environment, 2011c) recommend that SLR associated with global climate change will result, by the year 2100, in a base water level 1.0 m above that seen in the year 2000. The rate of SLR is projected to increase as the climate warms (**Figure 8**). Therefore, any increase incorporated in the past 20 years is expected to be minimal and hence ignored.

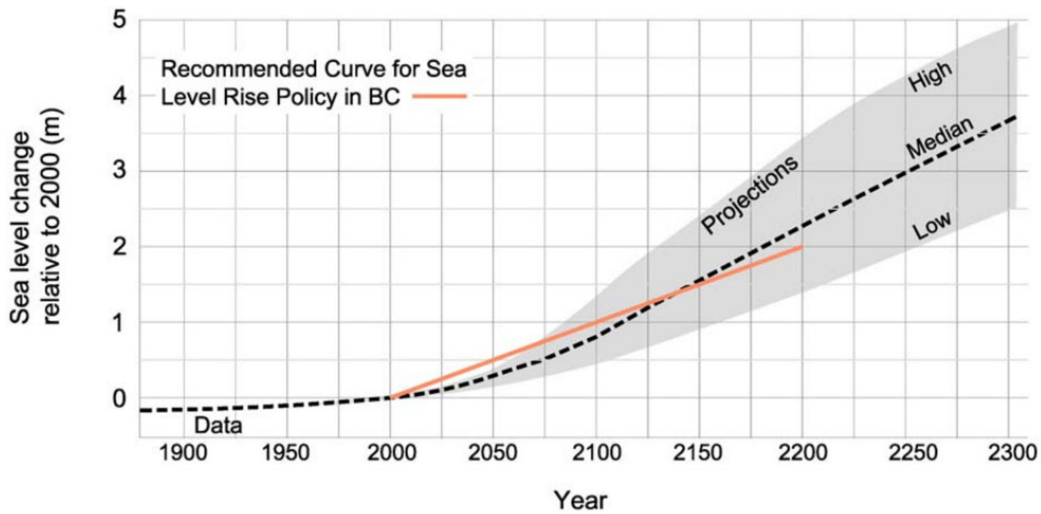

Figure 8. Projected climate change (BC Ministry of Environment, 2011c)

Note that the recommended SLR for planning and design in British Columbia is 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 British Columbia is greater than the global mean SLR projected by the IPCC AR4 (2007) for the year 2100 (roughly 0.4 m 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 predictions 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 to 2 m projected over the next 80 to 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 British Columbia, but based on recent conversations with FLNRORD, the province is amidst a study of SLR to update the 2011 design values. This study is expected to be completed by 2020.

5.1.3 Local Subsidence

Vertical movement of the earth surface occurs within coastal BC for a variety of geological reasons. Land is either static, experiencing uplift (rising), or experiencing subsidence (lowering). In addition to a rising sea, land movement will influence the local relative sea level. Provincial guidelines (BC Ministry of Environment, 2011c) recommends an uplift of 1.3 ± 0.2 mm/year at Point Atkinson. To the year 2100, this translates to a rise of 0.1 m.

This uplift is however neglected because movement of the earth can vary over short distances and in that context the site is considered to far from Point Atkinson to rely on this reduction of SLR. Detailed information on earth movement specific to Howe Sound is not available. Neglecting the uplift is conservative as considering it would lower the FCL.

5.1.4 Designated Flood Level

Table 2 summarizes the resulting designated flood level (still water) for the current condition and that predicted for the Year 2100.

Table 2. Designated flood level

Parameter	Year 2019 Elevation (m)	Year 2100 Elevation (m)
Tide + storm surge (joint probability)	2.9	2.9
+ Design sea level rise	0.0	1.0
+ Subsidence	0.0	0.0
Designated Flood Level	**2.9**	**3.9**

5.1.5 Wave Effect Assessment

Since there is no comprehensive measurement of waves in the vicinity of the study site, a high-level wind and wave analysis was conducted to determine the incident wave climate. The wave climate allows one to determine the wave height at the site which is used to perform the flood hazard assessment.

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: Howe Sound - Pam Rocks. The location of the station is shown in **Figure 10** below. Twenty-five years of hourly wind data was used for the study, as summarized in **Table 3**.

Table 3. Pam Rocks station information

Station	Station ID	Station Location	Period of Record
Pam Rocks	10459NN	478310E 5481735 N	1994–2019

The local wind climate can be visualized using a wind rose plot. The plot presents arrows at the cardinal and inter-cardinal compass points to show the direction from which the winds blow, along with associated magnitude and frequency. A wind rose showing the frequency of direction and magnitude of winds at Pam Rocks is shown in **Figure 9**.

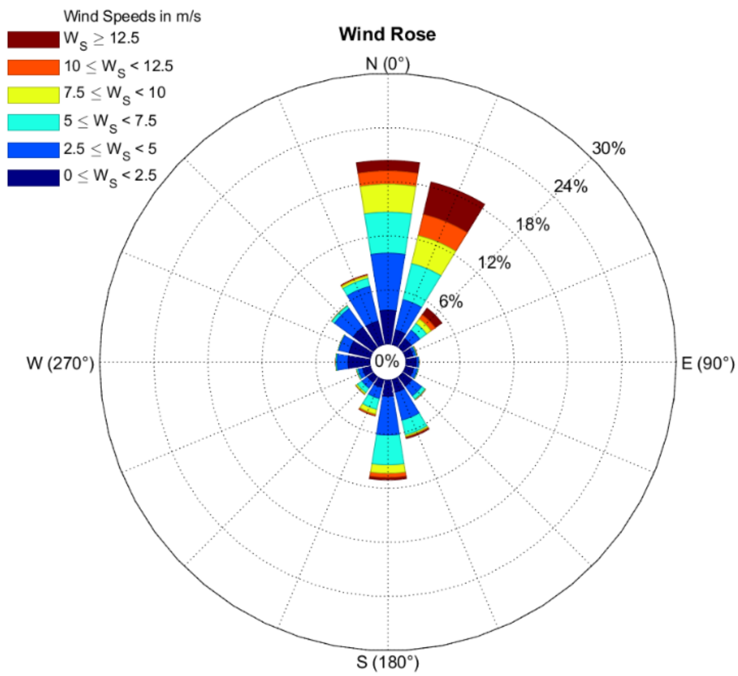

Figure 9. Wind rose for Pam Rocks meteorological station

The wind rose shows that wind experienced at Pam Rocks is most frequently from the north and secondly from the south. As expected, given the orientation of the mountains alongside of Howe Sound, wind from east and west is less frequent and milder. Because Alberta Bay is open from the south to the southwest, it is not directly exposed to the stronger northerly winds. Accordingly, winds that are of concern for this study are winds from the southerly sector. Extreme value frequency analysis was conducted on the wind data from this sector to obtain the wind speed for the design southerly storm. The results are summarized in **Table 4**.

Table 4. Design wind speeds based on Pam Rocks data

Event	Southerly Sector	
	Speed (m/s)	Speed (km/hr)
20% AEP	22.0	79.2
10% AEP	22.7	81.7
2% AEP	24.2	87.1
0.5% AEP	25.3	91.1

Both (BC Ministry of Environment, 2011a) and (BCMFLNRD, 2018) guidelines suggest that the wave effects are to be based on the 0.5% AEP storm in conjunction with the 0.5% AEP water level.

Incident Wave Height

Figure 10 shows the open water exposure of Alberta Bay. The bay is exposed to open water fetch from the southwest (SW) and the south-southwest (SSW).

The presence of islands that obstruct wave propagation at the western entrance to Howe Sound (e.g., Keats Island) limits the SW fetch to approximately 16 km. It is not expected that waves from the strait penetrate much into Howe Sound past these islands. At the eastern entrance to Howe Sound, the open water distance to the SSW is relatively long, essentially extending across the Strait of Georgia up to 55 km away from site. Waves generated in the strait propagating into Howe Sound from that direction will be partially obstructed by Bowyer Island and the constriction at between Bowen Island and White Cliff Point.

A coarse wave model of the Strait of Georgia was employed to estimate deep wave conditions incident to the site to capture presence of islands and constrictions. Results suggest a significant wave height of H_s = 2.4 m from the SW direction and H_s = 2.5 m from the SSW direction, both with a peak wave period of T_p = 6.2 sec. The significant wave height corresponds to the mean height of the highest 1/3 of the waves in a storm. Wave conditions associated to the SSW direction are selected for defining the FCL.

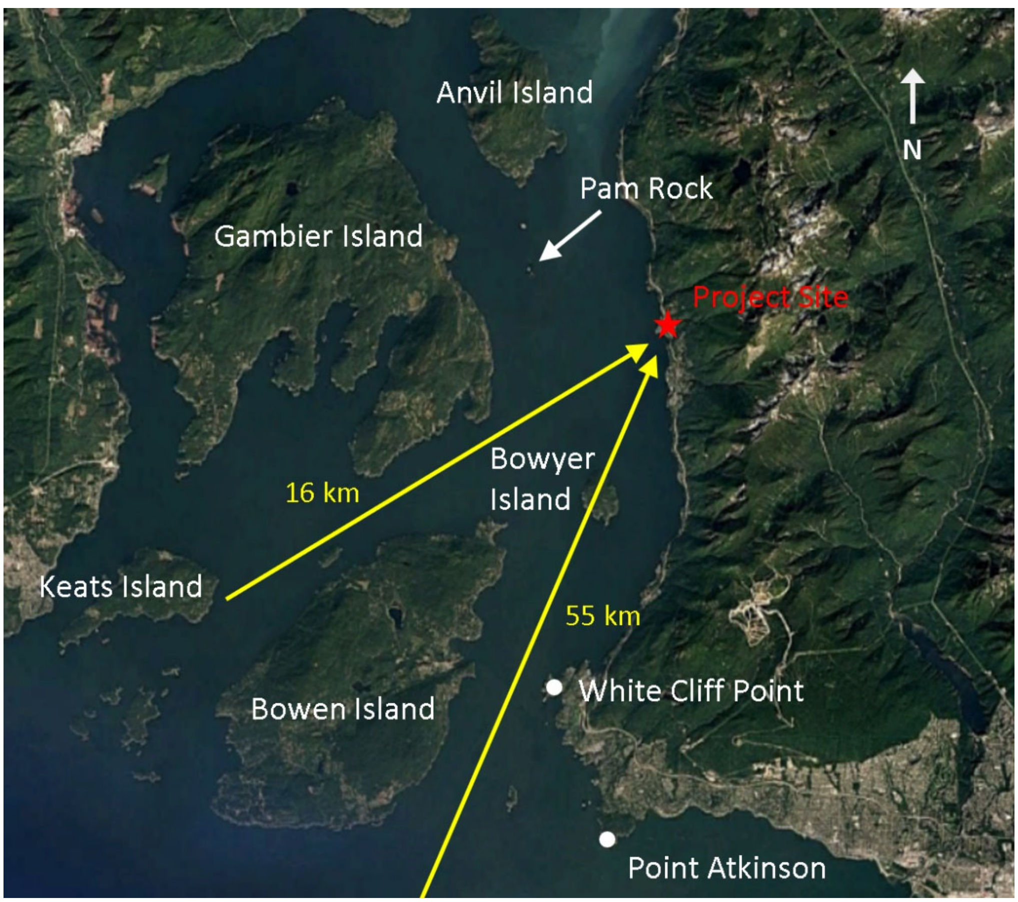

Figure 10. Site open water exposure
Source: Google Earth

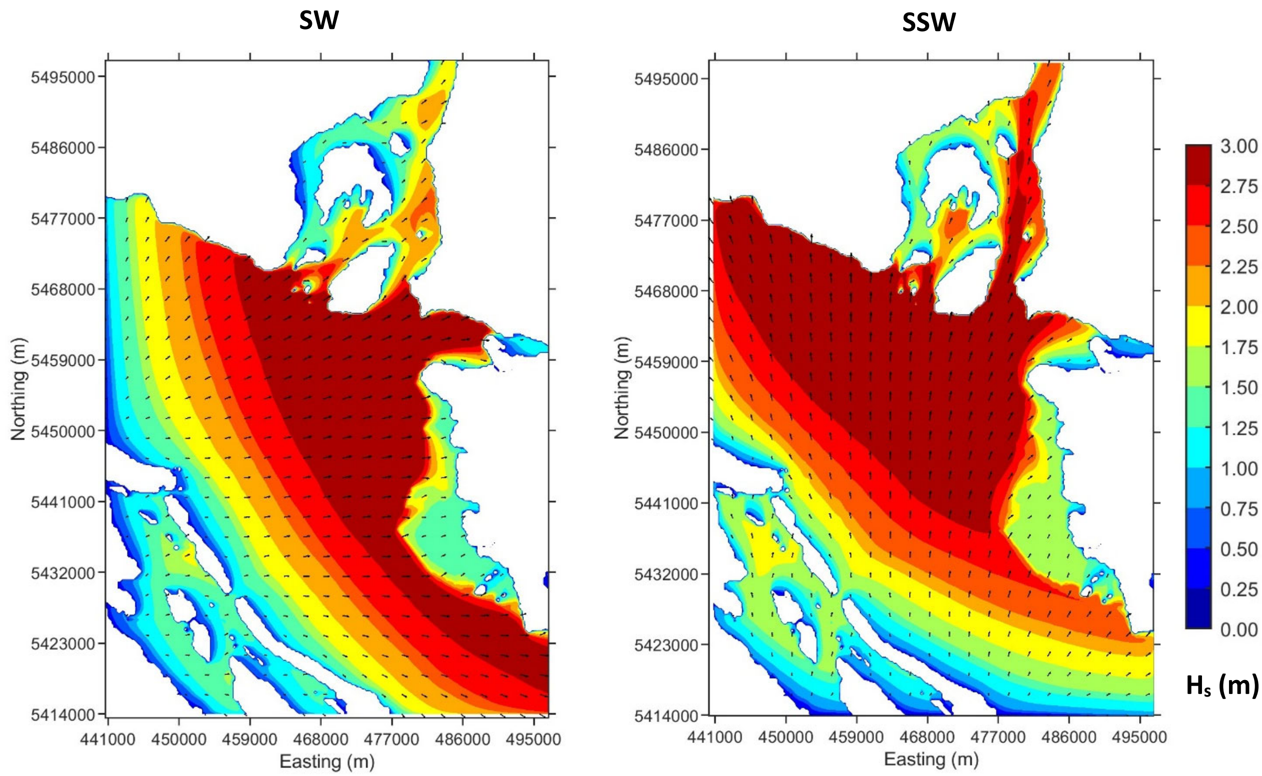

Figure 11. Wave model results for SW (left) and SSW (right) wind conditions.

Wave Effect Analysis

As waves propagate from deep water closer to the shoreline within Alberta Bay, they become affected by the shallower water depth. Such transformation was assessed according to the method of Goda (2000) resulting to a height reduction from H_s= 2.5 m to H_s= 2.2 m at the toe of the pebble beach (0 m depth contour with respect to chart datum).

Wave runup at the shoreline determines the extent over which waves act above a given water level. Wave runup is therefore an important parameter to determine flood inundation extents from coastal storms. The BC Provincial Sea Dike Guidelines (BC Ministry of Environment, 2011b) accept the use of a few criteria for calculation of the wave runup component for design elevation. As normally applied for runup analysis, the 2% exceedance level was adopted for this study – that is the runup from a wave with a height that is expected to be exceeded by 2% of the waves occurring during a storm.

As wave runup is affected by the type of shoreline waves interact with, assumptions are required regarding the characteristics of the future shoreline. Based on site conditions, the pebble beach is expected to naturally progress upland as sea level rises. The current assessment of the FCL considers that the ground in front (seaward) of the proposed dwelling will remain at the existing elevation following construction, allowing the natural progression on the pebble beach.

Based on the above assumptions, the wave runup is estimated using methodology presented by Poate *et al.* (2016), which has been developed specifically for beaches composed of coarse granular material such as pebbles based on field monitoring. The results are summarized in the following table.

Table 5. Wave effects

Parameter	Year 2019	Year 2100
Design Wave Height (m)	2.2	2.2
Design Wave Period (s)	6.2	6.2
Equivalent Foreshore Slope (˚)	8	8
Designated Flood Level (m)	2.9	3.9
Wave Runup[1] (m)	2.8	2.8

Notes:

1. Wave runup is measured from the designated flood level

5.2 Coastal Flood Construction Level

Table 6 summarizes the resulting FCL for the current condition and that predicted for the Year 2100. A 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 guidelines (BCMFLNRD, 2018) is 0.6 m when using the joint probabilistic approach.

The FCL adopted by the Village of Lions Bay is 1.6 m above the existing natural boundary of the sea, as per Bylaw No. 520 Section 4.19 2c. This is on average an elevation of 4.5 m, with the existing natural boundary interpreted as the edge of vegetation as per the site topographic survey (**Appendix B**). The year 2100 FCL of 7.3 m is 2.8 m above this level.

Table 6. Coastal flood construction levels

FCL Input	Year 2019 Elevation (m)	Year 2100 Elevation (m)
Tide + storm surge (joint probability)	2.9	2.9
+ wave effect	2.8	2.8
+ Design sea level rise (to year 2100)	0.0	1.0
+ Subsidence	0.0	0.0
Coastal flood level	5.7	6.7
+ Freeboard	0.6	0.6
Flood construction level	**6.3**	**7.3**

5.3 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 tsunamis generally are a result of earthquakes that produce substantial vertical movement of the sea floor.

Lions Bay can be affected by Tsunamis originating in the Pacific Ocean propagating in the Juan de Fuca Straight and the Strait of Georgia, as well as local sources in the Straight of Georgia and Howe Sound. Fisheries and Oceans Canada (DFO, n.d.) simulated a large Cascadia subduction zone tsunami, originating a few hundred kilometres offshore of Vancouver Island. This work suggested that tsunami waves propagating through the Juan de Fuca Strait and the Strait of Georgia would be approximately 0.5 m in Howe Sound. The last such large tsunami occurred in 1700 and has an average reoccurrence of 500 years. Local tsunami sources that could potentially impact the project site include a potential slump of the Fraser River delta (Rabinovich *et al.*, 2003), shallow crustal faults under the Strait of Georgia (Clague, 2005), and subaerial and submarine landslides in Howe Sound (Westmar, 2005).

In comparison to storms, the probability of a tsunami to occur and affect Howe sound is considerably small. Hence, tsunami hazard is not considered to govern the FCL for the site.

5.4 Building Setback

The provincial flood hazard area land use guideline (BCMFLNRD (2018)) recommends that the building setback should be at least the greater of 1) 15 m from the future estimated natural boundary of the sea at year 2100 and 2) landward of the location where the natural ground elevation contour is equivalent to the year 2100 FCL.

Considering the potential for the beach to naturally progress upland in the future, it is anticipated that the relative height between the edge of vegetation and the high water mark remains similar in the future (1 m on average above HHWLT). Accordingly the future natural boundary is estimated to be at an elevation of:

HHWLT + Sea Level Rise + Relative Height Difference

1.9 m + 1.0 m + 1.0 m = 3.9 m

This estimation of the future natural boundary corresponds approximately to the seaward limit of the property, which is at an elevation of approximately 4.1 m.

The calculated 2100 FCL of 7.3 m intersects the existing ground at a location close to the upland limit of the property.

A setback of 15 m from either the locations recommended by BCMFLNRD (2018) as indicated above considerably limits the development of the property, if not completely. Applying a 15 m setback to the future natural boundary approximately results in only the upper 12 m of property able to be constructed on. This would further be limited by any road setback requirements. Applying a 15 m setback from the location where the 2100 FCL intersects existing land would result in even less area to be constructed on.

With the erosion hazard deemed low for the site, a setback of 15 m from the existing natural boundary is considered safe. This setback is in accordance with the Village of Lions Bay's bylaws. Nevertheless, it is recommended that mitigation measures be implemented to prevent undermining of the building's foundation as a result of erosion or scour. Such measures are suggested further below.

6 Summary and Recommendations

A flood hazard assessment was conducted for the property located at 3 Brunswick Beach Road in the Village of Lions Bay. It is expected that coastal flooding originating from Howe Sound is the primary mechanism for flood hazards (i.e., in comparison to riverine hazards). From this assessment, the hazard was characterized and the property deemed safe for use provided the following recommended mitigation measures are adhered to:

1) An FCL of 7.3 m is adopted for the site for long-term infrastructure (design life >= 30 years); an FCL of 6.3 m may be adopted for short-term infrastructure (design life < 30 years).
2) A 15 m setback from the existing natural boundary is adopted for this site.
3) The underside of any wooden floor system, or the top of any concrete floor system used for habitation is at or above the applicable FCL.
4) Building entrances and windows to habitable areas are no lower than the applicable FCL.
5) Any areas below the FCL, such as an underground parking or crawl space provide pedestrian exits that extend to or above the FCL and are adequate for evacuation during a flood and under lack of electrical power.
6) Main electrical switchgear (i.e., control panel, fuse, circuit breaker) is above the FCL. Any electrical supply below the FCL (i.e., lighting or electrical outlets) is protected by ground fault circuit interruption (GFCI) located above the FCL or protected through other methods approved safe up to the FCL by an qualified professional.
7) Mechanical equipment is above the FCL or otherwise constructed to be safe for inundation up to the FCL.
8) Any structure that is above ground and below the FCL or reliant on erodible soils that extend below the FCL is protected against or designed to withstand erosion from wave runup; this could potentially be achieved through either:
    a. Founding of structures on bedrock;
    b. Founding of structures on supports capable to withstand exposure to at least 1 m below the adjacent ground;
    c. Armouring foundation to protect against erosion and scour (such armouring is to be designed by a qualified professional).
9) Shoreline conditions and any scour and erosion mitigation measures are inspected annually and following any large wave event occurring at high water level (waves in excess of 1 m within

Alberta Bay). If substantial shoreline changes are identified, then a qualified professional is retained to provide assessment.

10) Preliminary and final building plans are formally reviewed by a qualified registered engineer to ensure they meet the recommendations presented within this FHA prior to construction.

This assessment is based on ground slopes between the beach and the house of approximatively 8H:1V. Any changes to this slope, such as construction of a seawall, infilling the yard to reduce frequency of flooding, etc. could alter the FCL and should therefore only be done in conjunction with a review by a qualified professional.

Despite the results and application of recommended mitigations, a residual flood hazard from Howe Sound still exists; that is, less frequent events (AEP <0.5%) may exceed the design values and mitigation measures presented. Furthermore, hazards other than flood hazards from Howe Sound, 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.

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 7**.

Table 7. 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 shoreline	Completed by NHC 2019
1-D or possibly 2-D modelling, modelling of fluvial regime and future trends in river bed changes, erosion hazard maps, possibly paleoflood analysis	Not Applicable
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)	Not Applicable
Conduct simple time series analysis of runoff data, review climate change predictions for study region, include in assessment if considered appropriate	Climate change related to sea level rise reviewed. Analysis of runoff data not applicable.
Quantify erosion rates by comparative air photograph analysis	Analysis not performed. Current erosion risk deemed low.
Typical deliverables	
Letter report or memorandum with at least water levels and consideration of scour and bank erosion	Completed by NHC 2019
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	Not Applicable
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	Not Applicable

7 Closure

We hope this work and report meets your current needs. If you have any questions don't hesitate to contact Philippe St-Germain or Dale Muir by phone (604-980-6011) or by email (pstgermain@nhcweb.com | dmuir@nhcweb.com).

Sincerely,

Northwest Hydraulic Consultants Ltd.

Prepared by:

PROFESSIONAL PROVINCE OF C. S. St-GERMAIN # 43141 BRITISH COLUMBIA ENGINEER

March 24, 2020

Philippe St-Germain, P.Eng.,
Coastal Engineer

Reviewed by:

on the behalf of

Dale Muir, P.Eng.,
Principal

DISCLAIMER

This document has been prepared by **Northwest Hydraulic Consultants Ltd.** for the benefit of **David Cobban** for specific application to the **flood hazard assessment for a building permit on the property located at 3 Brunswick Beach Road, Village of Lions Bay**. The information and data contained herein represent **Northwest Hydraulic Consultants Ltd.** best professional judgment in light of the knowledge and information available to **Northwest Hydraulic 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 by **David Cobban. 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.

8 References

BC Ministry of Environment (2011a). *Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use – Draft Policy Discussion Paper.*

BC Ministry of Environment (2011b). *Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use – Guidelines for Management of Coastal Flood Hazard Land Use.*

BC Ministry of Environment (2011c). *Climate Change Adaption Guidelines for Sea Dikes and Coastal Flood Hazard Land Use – Sea Dike Guidelines.*

BCMFLNRD (2018). *Flood Hazard Area Land Use Management Guidelines Sea Level Rise Amendment.*

Booij, N., Haagsma, Ij.G., Holthuijsen, L.H., Kieftenburg, A.T.M.M., Ris, R.C., van der Westhuysen, A.J., and Zijlema, M. (2004). *SWAN User Manual SWAN Cycle III Version 40.41.* Delft University of Technology, The Netherlands.

Bornhold, B. D. (2008). *Projected sea level changes for British Columbia in the 21st Century.* Province of British Columbia, Victoria, BC. 10 pp.

Clague et al. (2005). *Tsunami Hazard to North and West Vancouver, British Columbia*. Centre for Natural Hazard Research, Simon Fraser University. 25 pp.

DFO (n.d.). *Modelling Large Tsunamis Generated by Cascadia Subduction Zone Earthquakes, https://www.dfo-mpo.gc.ca/science/data-donnees/tsunamis/modele-tsunami-model-eng.html, referred to on* Nov. 27, 2019*.*

Eaton, B., Church, M., and Ham, D. (2002). Scaling and regionalization of flood flows in British Columbia, Canada. *Hydrological Processes*, 16, 3245–3263.

EGBC (2018). *Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC*.

EurOtop (2016). *Manual on wave overtopping of sea defences and related structures. An overtopping manual largely based on European research, but for worldwide application.* Van der Meer, J.W., Allsop, N.W.H., Bruce, T., De Rouck, J., Kortenhaus, A., Pullen, T., Schüttrumpf, H., Troch, P. and Zanuttigh, B.

Goda, Y. (2000). "Random Seas and Design of Maritime Structures", 2nd edition, World Scientific.

IPCC (2007). *Contribution of Working Groups I, II and III to the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change. Core Writing Team, Pachauri, R.K. and Reisinger, A. (Eds.). Geneva, Switzerland.* 104 pp.

IPCC (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland*. 151 pp.

Mazzotti, S., Lambert, A., Kooij, M. V. der, and Mainville, A. (2009). Impact of anthropogenic subsidence on relative sea-level rise in the Fraser River Delta. *Geology*, 37, 771–774.

NHC (2008). *Fraser River Hydraulic Model Update* (Final Report). Report prepared by Northwest Hydraulic Consultants for the BC Ministry of Environment. 31 pp.

Poate, T. G., McCall, R. T., and Masselink, G. (2016). *A new parametrerisation for runup on gravel beaches*, Coastal Engineering, 117, 176-190.

Rabinovich, A.B., Thomson, R.E., Bornhold, B.D., Fine, I.V., and Kulikov, E.A. (2003). *Numerical modelling of tsunamis generated by hypothetical landslide in the Strait of Georgia, British Columbia,* Pure And Applied Geophysics, 160, 1273-1313.

Schardong, A., Gaur, A., Simonovic, S. P., and Sandink, D. (2018). *Computerized Tool for the Development of Intensity-Duration-Frequency Curves under a Changing Climate*.

Spaeth, M. G., and Berkman, S. C. (1967). *The tsunami of March 28, 1964, as recorded at tide stations*.

Thomson, R. E., Bornhold, B. D., and Mazzotti, S. (2008). *An examination of the factors affecting relative and absolute sea level in Coastal British Columbia*. Canadian Technical Report of Hydrography and Ocean Sciences. 49 pp.

Westmar (2005). *Tsunami Probability and Magnitude Study for Village of Lions Bay*.

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: 2020-03-19

Planning and Development Services, Village of Lions Bay

PO Box 141, 400 Centre Rd, Lions Bay, V0N 2E0

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 20, Block 18, District Lot 1815, New Westminster District, Plan 10651

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*

___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".

Philippe St-Germain

Name (print)

Signature

Address

30 Gostick Place, North Vancouver, BC V7M 3G3

604-980-6011

Telephone

Date

PROFESSIONAL PROVINCE OF BRITISH COLUMBIA C. S. St-GERMAIN # 43141 ENGINEER

March 24, 2020

(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)
and I sign this letter on behalf of the firm. (Print name of firm)

Appendix B

Received Site Legal Survey

TOPOGRAPHIC PLAN OF
LOT 20, BLOCK 18
DISTRICT LOT 1815
GROUP 1, NEW WESTMINSTER DISTRICT
PLAN 10651
P.I.D. 009-322-477
SCALE: 8 FEET TO 1 INCH

Notes:
Elevations are to Geodetic Datum and are derived from GNSS observations at Rebar (24-1):
Elevation = 6.56

Zoning: RS-1

Field ties completed July 15, 2019.

This Document is not valid unless originally signed & sealed.

Certified Correct according to Plan 10651, and LMP52535:

_______________________, B.C.L.S.
William R. Chapman
this 19th day of July, 2019.

Building envelope to be confirmed by the Municipality of Lions Bay.

© CHAPMAN LAND SURVEYING LTD. 2019
British Columbia Land Surveyors
#107-100 Park Royal South
WEST VANCOUVER, B.C.
V7T 1A2 604-926-7311
FAX 604-926-6923
EMAIL sandy@chapmansurvey.com

LIONS BAY BOOK:2333(22) JOB:19-061 FILE:1077 DRAWN BY:KS
COMP: Q:\Eagle\1077\Lot 20-19061\MS1077-20-19061-TOP.dwg