CITY OF VANCOUVER

ADMINISTRATIVE REPORT

Report Date: May 30, 2014
Contact: Sean Pander
Contact No.: 604.673.8075
RTS No.: 10576
VanRIMS No.: 08-2000-20
Meeting Date: July 9, 2014

TO: Standing Committee on City Finance and Services

FROM: Deputy City Manager in collaboration with the Chief Building Official, the General Manager of Planning and Development Services and the General Manager of Engineering Services

SUBJECT: Flood Construction Levels

RECOMMENDATION

A. THAT Council approve the amendments to Building By-law No. 10908 to raise flood construction levels to respond to the increased risk of flood damage due to climate change, generally in accordance with Appendix A.

B. THAT the Director of Legal Services be instructed to prepare the necessary amending by-law, generally in accordance with Appendix A.

C. THAT Council rescind the "Flood-Proofing Policies" and replace them with the "Designated Flood Plain Standards and Requirements" in accordance with Appendix B effective January 1, 2015.

D. THAT the General Manager of Planning and Development Services be instructed to make application to amend the Zoning and Development By-law to respond to increased flood construction levels generally in accordance with Appendix C, as follows:

THAT a clause is added in Section 10 so that the Director of Planning may exclude from the computation of floor area, floors located at or below finished grade with a ceiling height of less than 1.5.m;

FURTHER THAT the application be referred to a Public hearing;

AND FURTHER THAT the Director of Legal Services be instructed to prepare the necessary amending by-law, to amend the Zoning &

Development By-law, generally in accordance with Appendix C for consideration at the Public Hearing.

REPORT SUMMARY

The current and anticipated impacts of climate change will affect the City in many ways. Sea level rise will continue to increase flood risk along the City coastline, including the North Arm of the Fraser River.

To address increasing flood risk, buildings built today should be designed for flood resilience throughout their lifespan. City flood-proofing standards require revision to incorporate anticipated sea level rise in line with new Provincial guidelines and current scientific consensus.

This report outlines the recommended changes to existing City flood-proofing standards, how they were determined, how they will be applied and the implications of the changes.

COUNCIL AUTHORITY/PREVIOUS DECISIONS

Section 306(cc) of the Vancouver Charter allows Council to make by-laws that include: with-holding a building permit in respect of any parcel of land situated in a designated flood plain area until the City Building Inspector is satisfied that the elevation or design will reduce or eliminate the risk of flood damage; and requiring a covenant registered against the land acknowledging the risk of flood damage.

On April 12, 1986, City Council endorsed specific flood-proofing policies for the Southlands flood plain. On January 27, 1987, City Council added Provincial flood-proofing standards to these policies for flood plains adjacent to the Fraser River, False Creek, Burrard Inlet and English Bay. The Vancouver Charter was subsequently amended to enable City implementation of the flood-proofing policies via the City's building permit process. The policies were amended in 1995 and again in 2007.

In January 2012, staff began encouraging interim FCLs 1m above existing levels (~4.5m) in response to the Provincial Guideline issued by the Ministry of Environment based on updated global and local climate impact models. The interim levels provided an opportunity to signal the coming change and work proactively with the development and building community to understand impacts and prepare for change.

On July 25, 2012, City Council approved the Climate Change Adaptation Strategy recommending that staff undertake priority actions including an amendment to the Flood-Proofing Policies.

CITY MANAGER'S/GENERAL MANAGER'S COMMENTS

The City Manager recommends approval of the foregoing.

REPORT

Background/Context

The Climate Change Adaptation Strategy adopted by Council in 2012 outlined priority actions to begin preparing for the anticipated impacts of climate change. Priority actions included:

- Develop and implement a City-wide Integrated Stormwater Management Plan (plan development underway. Scheduled completion: Jan. 2015);
- Develop an Urban Forest Strategy (approved by Council on April 16, 2014);
- Develop a back-up power plan (underway);
- Continue sewer separation work (underway);
- Continue water conservation work (underway);
- Incorporate climate change adaptation into the building code; and
- Support the Extreme Hot Weather Committee in expanding the hot weather preparedness work program (mapping and pilot projects underway).

The priority actions specifically related to sea level rise include:

- Complete a Coastal Flood Risk Assessment (CFRA) and develop a city-wide sea level rise adaptation response (underway); and
- Update the City Flood-Proofing Policies including flood construction levels (FCLs). FCLs are the minimum elevation for the first floor a building in a flood plain[1].

Around the world, flood-related impacts of climate change are causing billions of dollars in damage and cities are responding with efforts to enhance flood resilience. In Manhatten, post-Hurricane Sandy, a design competition winner was awarded $335 million in June to begin building shoreline protection. In the aftermath of the 2013 flood, the costliest natural disaster in Canadian history, Calgary is changing flood-proofing standards including updating FCLs.

Current flood risk in the City of Vancouver is manageable but with observed and projected trends in sea level rise (a study by the Province recommended planning for sea level rise of 1m by year 2100); the risk is anticipated to increase significantly during the lifespan of buildings being developed now.

A Provincial study estimated the cost to build flood protection infrastructure in Metro Vancouver (from coastal shoreline and the Fraser River shoreline as far east as the Port Mann Bridge), to meet the projected water level in the year 2100, at $9.5 billion. Vancouver's proactive approach to instituting appropriate FCLs now will reduce future flood damage and may avoid some of these projected infrastructure costs.

Responding to sea level rise is complex as estimates of the amount and timing of the rise vary as do the shorelines and the site-specific risk of flooding around the City. The options available to respond to sea level rise include a range of options: raising FCLs; altering shoreline park design; major infrastructure investment such as those New York City, London and Venice are undertaking. While complex, there is time to plan for sea level rise

[1] A flood construction level (FCL) is the minimum elevation of the underside of a floor system or the top of a concrete slab of a building used for habitation, business or storage of goods damageable by flood water.

and staff are recommending a phased approach to allow for learning and area specific solutions.

Both the Federal and Provincial governments have signaled that this is an important issue by providing financial support and participation in the City's study, however there is no identified funding for, or consolidated Federal or Provincial department working on, responding to sea level rise. Staff will continue to work with the appropriate Departments and Ministries at the Federal and Provincial government to gain support.

The first phase of the Coastal Flood Risk Assessment (CFRA) is complete. This analysis was conducted by experts with the intention of: 1) identifying areas of greatest risk along our shoreline currently; and 2) projecting sea level rise along our shores (see Appendix D for more detailed information). Outputs include:

- Recommended flood construction levels (FCLs) along the coast line for flood resilience to year 2100;
- Flood hazard maps showing flood depth and extent for multiple scenarios; and
- Potential damages, economic loss and population displacement for each scenario.

Increasing FCLs now to improve the flood resilience of new buildings throughout their lifespan is a cost effective tool that can be applied while further adaptations are carefully considered. Increasing neighbourhood elevations incrementally over time via FCLs may decrease the need for more costly, large scale infrastructure investments at a later date.

While FCLs ensure that all new construction of buildings and infrastructure in flood zones is built to appropriate levels, other additional solutions must be developed to address areas of greatest impact. To accomplish this work, the second phase of the CFRA is now underway, with a focus on exploring larger scale responses to complement FCLs and protect existing infrastructure and buildings. Staff will also pursue opportunities to increase neighbourhood flood protection by raising near-shore infrastructure opportunistically as part of large projects such as the Dunsmuir/Georgia viaducts initiative and Northeast False Creek park planning.

Vancouver City staff participated in and helped to lead a regional collaborative for municipalities without dikes to address flood hazard management, which was coordinated by the Fraser Basin Council and the Burrard Inlet Collaborative. Many municipalities, including North Vancouver, Surrey, and West Vancouver are also increasing FCLs to similar levels proposed in this report and are actively planning to prepare for sea level rise through raising dikes and other measures.

Strategic Analysis

Flood Mechanisms

Two drivers are expected to increase the probability of flooding in Vancouver: sea level rise and more intense rainfall, both attributed to climate change.

Increasing FCLs as addressed in this report relates only to shoreline areas impacted by sea level rise and does not respond to potential increases in rainfall-related flood risk across the City. On-going work on sewer separation and the creation of an Integrated

Stormwater Management Plan, as called for in the council approved Adaptation Strategy, are underway to address the issue of increased rainfall.

Phase one of the Coastal Flood Risk Assessment (CFRA) modelled and mapped the anticipated changes in these flood hazards given climate change impacts:

- Flooding from the ocean will occur during extreme high total water levels which are caused by a combination of components that rarely occur simultaneously: high tide, large storm surge, wind set up (friction force of wind on sea surface), wave setup (change in mean water level when waves are present) and wave effect (wave run-up on shore). For example, a combination of these factors contributed to the king tide that flooded Kits Pool in Dec 2012. Note that, of these factors, in Vancouver, only high tide is changing due to climate change (sea level rise) *locally*; in other parts of the world, climate change is also affecting a number of the other factors as well.
- Complex hydraulic and statistical modelling, factoring in a sea level rise of 1m for the year 2100 as per the Provincial guidelines, was carried out to assess the magnitude of these components along Vancouver's shoreline and the probability of them occurring together.
- Several scenarios were modelled and the results provided information on depth, extent, and probability of potential flooding.

This information is integral to assessing larger scale interventions in phase two of the CFRA and appropriately increasing FCLs now. The FCL recommended in this report based on the above modelling work and the local sea level rise projections for all designated flood plains in the City is 4.6m, approximately one meter above the current FCL.

The FCL was calculated following the methodology introduced in the Provincial Guidelines (2011). It is designed to protect people and property from anticipated flood risk to the year 2100 during storm events at high tide with a likelihood of recurrence of once every 500 years (1:500 year return period).This translates to a 0.2% chance of occurring in any given year and is a design standard for dense urban areas.

For more detailed information on coastal flooding and the methods and assumptions used to establish this FCL recommendation, refer to Appendix D.

FCL Application and Impacts

In response to Provincial Guideline issued by the Ministry of Environment based on updated global and local climate impact models, staff have been encouraging interim FCLs 1m above existing levels (~4.5m) since January, 2012. The interim levels provided an opportunity to signal the coming change and work proactively with the development and building community to understand impacts and prepare for change.

City staff consulted with the Urban Development Institute, the Association of Professional Engineers and Geoscientists of B.C. the Architectural Institute of B.C., engineering and surveying professionals, the Real Estate Foundation, Port Metro Vancouver, and multiple neighbouring municipalities, among other organizations on the approach outlined in this report. For the most part, these groups support the City's

proactive approach and in several cases over the last two years, the development industry has taken a leadership role by implementing the City's recommended interim FCLs of 4.5m.

Maintaining public safety and protection of property is the priority of flood-proofing standards, but it must be balanced with streetscape continuity, urban design and accessibility principles. The Province's and City's recommended approach is to set the FCL based on a reasonably long building lifespan (to 2100) and then allow applicants that want to negotiate a variance to standard FCLs to do so with supporting analysis from a qualified professional. For example, this approach was taken in the River District area where an engineering analysis was conducted for to account for the unique geographic and hydrological features.

While the new FCLs will be the standard, there is an opportunity to increase flood protection beyond the 4.6m FCL for anticipated increases in sea level beyond 2100 through large new developments in flood zones, including increases for roads and other infrastructure. Any increase associated with large new development opportunities will be based on independent engineering evaluation. Staff will work with applicants starting early in the development process to identify opportunities to increase longer term flood resilience of large sites such as those along the Fraser and in North East False Creek.

Planning and Development Services staff have reviewed the impacts of the proposed FCL of 4.6m and have concluded that this change can be accommodated using the flexibility inherent in current zoning regulations. A minor zoning and development by-law amendment (see Appendix B) is proposed to ensure applicants are not penalized for deeper crawlspaces that may be necessary to construct habitable floor space at the FCL. The new 4.6m FCL requirement does not include crawl spaces, and is a standard that applies to habitable space.

Previously, the by-law outlined the flood prone areas with a written description and did not include a map. Without a map, it has been unclear where these areas are. This report recommends including a map in the by-law, as is best practice among other municipalities. A map has been generated identifying lands subject to the proposed new FCL flood-proofing levels by virtue of their elevation and it will be appended to the Vancouver Building By-law (VBBL) and the associated Designated Floodplain Requirements and Standards policy (See Appendix A for a draft map).

As this FCL change is triggered by new building or major reconstruction projects, as opposed to being retroactive, it will have a negligible impact on the overall cost of building projects. The Insurance Bureau of Canada has signalled that where flood insurance is available (flood insurance for residential buildings exists in Canada only for flooding caused by sewer backups whereas commercial properties have access to overland flood insurance) they do not expect increased FCLs to change flood insurance premiums. Research on house values shows that actual flood events cause impacts on insurance premiums rather than the location of the home being included in an expanded flood zone; therefore we do not expect that the publishing of a flood map will impact home values.

The Province has signalled that every 5 to 10 years they will update local sea level rise projections. City staff will monitor these updates and recommend by-law and policy revisions as necessary. Staff will explore options to put alerts in the City's Planning and Development tracking software to ensure these updates are reviewed.

The recommendations to the FCLs were completed with extensive consultation with Port Metro Vancouver, the BC Ministry of Lands and Natural Resources Operations, Metro Vancouver, Canada Mortgage And Housing Corporation (CMHC), NRCan, CP Rail, CN Rail, Architectural Institute of BC, Association of Professional Engineers and Geoscientists of BC, utilities, insurance companies, and other planning and design community professionals.

Next Steps:

Phase two of the CFRA is underway and scheduled to be completed in summer, 2015. Staff and stakeholder input will be sought to assess additional, location-specific flood protection options in order to develop a high level plan.

Preferred options will be the focus of a third phase of study that will include detailed cost/benefit analysis and design work. This study will result in a long term flood management plan with timelines and capital planning requests.

Implications/Related Issues/Risk (if applicable)

Financial

Approval of this FCL based strategy will likely reduce the need for costly future infrastructure projects.

Environmental

The By-Law states that "No person shall store hazardous or toxic substances below the flood construction level", therefore raising FCLs and requiring storage of hazardous materials above the FCL will reduce the risk of a hazardous material spill in the case of a flood.

CONCLUSION

Adoption of this by-law amendment helps prepare Vancouver for the anticipated impacts of climate change. It will ensure that buildings constructed today are designed for the current flood risk and the flood risk that will exist throughout their expected lifespan. Applying appropriate FCLs is a cost effective first step that will be complemented by larger infrastructure projects that may be required in the future.

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Appendix A: Proposed Amendment to the Vancouver Building By-law for Designated Flood Plains and Flood Construction Level Requirements

BY-LAW NO. _____

A By-law to amend *Building* By-law No. 10908 regarding changes to definitions related to construction safety plans, construction on flood plains and flood construction levels and regulations related to designated flood plains

THE COUNCIL OF THE CITY OF VANCOUVER, in public meeting, enacts as follows:

1. This By-law amends the indicated provisions of the *Building By-law*.

2. In Book I, Division A, Part 1, at the end of Clause 1.1.3.1.(1)(b), Council strikes out "of Division B".

3. In Book I, Division A, Part 1, Council:

a) in Subclause 1.1.3.1.(1)(b)(iv) strikes out "Appendix Note A-1.4.1.2. of Division A (Designated flood plain)" and substitutes "Appendix Note A-1.4.1.2.(1) Designated Flood Plain of Division A"; and

b) in Subclause 1.1.3.1.(1)(b)(v) strikes out "Appendix Note A-1.4.1.2. of Division A (Flood construction level requirements)" and substitutes "Appendix Note A-1.4.1.2.(1) Flood Construction Level Requirements of Division A".

4. In Book II, Division A, Part 1, Sentence 1.1.3.1.(1), Council strikes out "except for Appendix Note A-1.4.1.2. Diagram B – Still Creek flood plain and flood construction levels" and substitutes:

"except for the following Appendix notes in Appendix A of Division A

a) Appendix Note A-1.4.1.2.(1) Designated flood plain, and
b) Appendix Note A-1.4.1.2.(1) Flood construction level requirements."

5. In Books I and II, Division A, Part 1, Sentence 1.4.1.2. (1), Council:

1) strikes out the definitions of "*Designated flood plain*" and "*Flood construction level requirements*" and substitutes:

"Designated flood plain" means those lands in the City which are hereby designated, for the purposes of section 306(cc) of the Vancouver Charter, as

flood plains susceptible to flooding and subject to *flood construction level requirements*, and those lands so designated include:

a) lands located in proximity to the *natural boundary* of Burrard Inlet, English Bay, False Creek and the Fraser River, which are located within the areas shown shaded on the maps attached to this By-law as Diagrams A1 and A2. (See Appendix A for Diagram A1- Burrard Inlet, English Bay, False Creek and Fraser River flood plains and for Diagram A2 - Burrard Inlet, English Bay, False Creek and Fraser River flood plain wave effect zone.); and

b) lands located in the areas shown shaded on the map attached to this By-law as Diagram B. (See Appendix A for Diagram B – Still Creek flood plain and *flood construction levels*.)"

"***Flood construction level requirements***" means:

a) on the Burrard Inlet, English Bay, False Creek and Fraser River flood plains:

(i) for *building*s located within the areas shown shaded on the map attached to this By-law, the underside of a floor system or the top of a concrete slab of a *building* used for habitation, business or storage of goods, shall not be lower than 4.6 m Greater Vancouver Regional District datum. (See Appendix A for Diagram A1- Burrard Inlet, English Bay, False Creek and Fraser River flood plains); and

(ii) for *building*s located in the areas shown shaded on the map attached to this By-law, an additional elevation allowance above 4.6 m may be required for wave run-up, at a level as determined by a Professional Engineer and to the satisfaction of the Chief *Building* Official. (See Appendix A for Diagram A2 - Burrard Inlet, English Bay, False Creek and Fraser River flood plain wave effect zone); and

b) on the Still Creek flood plain:

(i) the underside of a floor system or the top of a concrete slab of any *building* used for habitation, business or storage of goods shall not be lower than the applicable elevation shown on the map attached to this By-law. (See Appendix A for Diagram B - Still Creek flood plain and *flood construction levels*.)"; and

2) strikes out the definition of "Construction Safety Program" and substitutes:

"***Construction Safety Plan*** means a plan containing construction procedures and fire safety measures designed to protect workers on a project, neighbouring private property, public property, and members of the general public."

6. In Books I and II, Division A, Council adds the following defined terms in alphabetical order to Appendix Note A-1.4.1.2.(1):

"Designated Flood Plain

The Burrard Inlet, English Bay, False Creek and Fraser River flood plains are illustrated on Diagram A1 and the wave effect zones are illustrated on Diagram A2. Diagrams A1 and A2 are located at the end of Appendix A.

The Still Creek flood plain is illustrated on Diagram B and is located at the end of Appendix A."; and

"Flood Construction Level Requirements

The Burrard Inlet, English Bay, False Creek and Fraser River flood plains are illustrated on Diagram A1 and the wave effect zones are illustrated on Diagram A2. These diagrams are located at the end of Appendix A.

The Still Creek flood construction levels are illustrated on Diagram B. Diagram B is located at the end of Appendix A."

7. In Books I and II, Division A, at the end of Appendix A, before Diagram B, Council adds Diagram A1 - Burrard Inlet, English Bay, False Creek and Fraser River flood plains, and Diagram A2 - Burrard Inlet, English Bay, False Creek and Fraser River flood plain wave effect zone, attached to this By-law as Schedules 1 and 2.

8. In Books I and II, Division C, Part 1, Council strikes out Article 1.5.2.11. and substitutes:

"1.5.2.11. Permits in Designated Flood Plain

1) If a *building* is located on a *designated flood plain* the *Chief Building Official* may

   a) require plans and supporting documents to demonstrate that the elevation or design of the *building* incorporates *flood construction level requirements* intended to reduce the risk of flood damage,
   b) require that a covenant acknowledging the risk of flood damage be registered against the land, and
   c) withhold issuance of a *permit* until the requirements of the *Chief Building Official* have been satisfied.

2) The Chief Building Official *may increase the* flood construction level requirements *or the* setback requirements *as provided in Article 2.2.8.5.*

3) The *Chief Building Official* may relax the *flood construction level requirements* or the setback requirements in this By-law as provided in Article 2.2.8.6."

9. In Book I, Division C, Part 2, Council strikes out Subsection 2.2.8. and substitutes:

"2.2.8. *Building*s on Designated Flood Plains

2.2.8.1. Exemptions from Flood Construction Level Requirements

1) *Flood construction level requirements* do not apply to:

a) *alteration* of an *existing building*, not including *reconstruction* as defined in this By-law. (See Appendix A),

b) *alteration* of an *existing building* to increase the *building area* by less than 25 per cent of the total *building area* existing as of [*date of enactment of the By-law*], if
(i) the number of *dwelling units* is not increased,
(ii) there is no further encroachment into setbacks required by this By-law, and
(iii) there is no further reduction in the *flood construction level*,

c) enclosed parking areas, including bicycle and residential storage areas, in a *multiple dwelling*, if there is
(i) an unobstructed non-mechanized means of pedestrian ingress and egress to the areas, above the *flood construction level*, and
(ii) a sign posted at all entry points warning of the risk of flood damage,

d) *buildings* and portions of *buildings* used as a carport or garage,

e) non-residential accessory *building*s, and

f) loading facilities used for water oriented industry.

2.2.8.2. Design Considerations on Designated Flood Plains

1) For *buildings* constructed on *designated flood plains*, the *building* designer shall comply with by-law requirements regarding *construction* materials and service equipment installations below *flood construction level requirements,* to the satisfaction of the *Chief Building Official*. (See Article 1.5.2.11. of Division C.)

2.2.8.3. Construction Considerations on Designated Flood Plains

1) For *buildings* constructed on *designated flood plains, construction* of the *buildings* to *flood construction level requirements* shall be achieved, to the satisfaction of the *Chief Building Official,* by

a) the structural elevation of the floor system of the *building*
b) the use of adequately compacted fill, or
c) a combination of structural elevation and compacted fill.

2) No person shall install furnaces, electrical switchgear, electrical panels, fire protection systems or other fixed *building* services susceptible to flood damage, below the *flood construction level,* unless such services are protected from flood damage and accessible for servicing during a flood, to the satisfaction of the *Chief Building Official*.

3) No person shall store hazardous or toxic substances below the *flood construction level*.

4) All piping, wiring and conduit penetrations shall be water stopped and sealed to prevent water seepage into the *building*.

2.2.8.4. Setback Requirements on Designated Flood Plains

1) Subject to the provisions of this By-law, no *building*, structural support or fill shall be constructed or located within

a) 30 m of the *natural boundary* of the Fraser River,
b) 15 m of the *natural boundary* of Burrard Inlet, English Bay or False Creek,
c) 5 m of the *natural boundary* of Still Creek,
d) 7.5 m of any structure erected for flood protection or seepage control, or
e) in the case of a *building*, structural support, or fill located on a bluff in a *designated flood plain*, where the toe of the bluff is subject to erosion or is closer than 15 m from the natural boundary, a setback measuring 3.0 times the height of the bluff as measured from the toe to the crest of the bluff.

2.2.8.5. Increase of Flood Construction Level and Setback Requirements on Designated Flood Plains

1) The *Chief Building Official* may increase the *flood construction level requirements* or the setback requirements in this By-law if, in the opinion of the *Chief Building Official,* a higher *flood construction level* or a greater setback is necessary as the result of a site-specific geological or hydrological feature.

2.2.8.6. Relaxation of Flood Construction Level and Setback Requirements on Designated Flood Plains

1) The *Chief Building Official* may relax the *flood construction level requirements* in this By-law in accordance with Article 1.5.2.11., if

a) the *owner* demonstrates to the satisfaction of the *Chief Building Official,* that, due to existing site characteristics and the location of existing infrastructure, it is impractical to meet the *flood construction level requirements*,
b) the *owner* demonstrates to the satisfaction of the *Chief Building Official,* the proposed construction methods are designed to mitigate flood damage, and

c) the *owner* provides a report, to the satisfaction of the *Chief Building Official*, stamped by a professional engineer, certifying that the habitable space in the *building* will be safe during a flood if a lower *flood construction level* is applied.

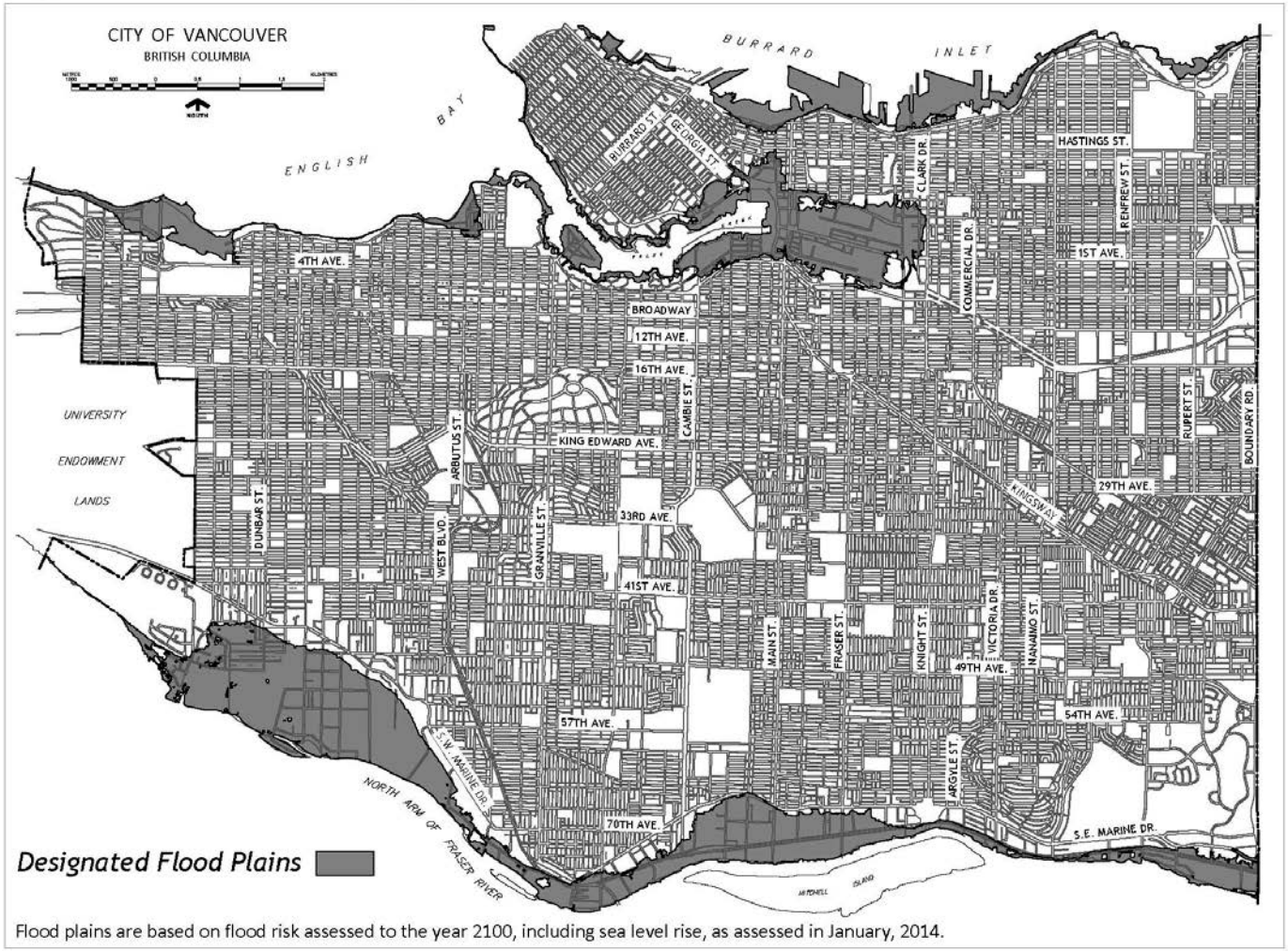
2) The *Chief Building Official* may relax the *setback requirements* in this By-law in accordance with Article 1.5.2.11., if

a) the *owner* demonstrates to the satisfaction of the *Chief Building Official*, that, due to existing site characteristics and the location of existing infrastructure, it is impractical to meet the setback requirements,
b) if considered necessary by the Chief Building Official, the owner agrees to construct erosion protection works to mitigate flood damage and erosion, and
c) the *owner* provides a report, to the satisfaction of the *Chief Building Official*, stamped by a professional engineer, certifying that the habitable space in the *building* will be safe during a flood if a reduced setback requirement is applied."

10. A decision by a court that any part of this By-law is illegal, void, or unenforceable severs that part from this By-law, and is not to affect the balance of this By-law.

11. This By-law is to come into force and take effect on January 1, 2015, immediately following enactment of Building By-law, No. 10908.

Diagram A1: Burrard Inlet, English Bay, False Creek and Fraser River Flood Plains



Flood plains are based on flood risk assessed to the year 2100, including sea level rise, as assessed in January, 2014.

Diagram A2: Burrard Inlet, English Bay, False Creek and Fraser River Flood Plain Wave Effect Zone

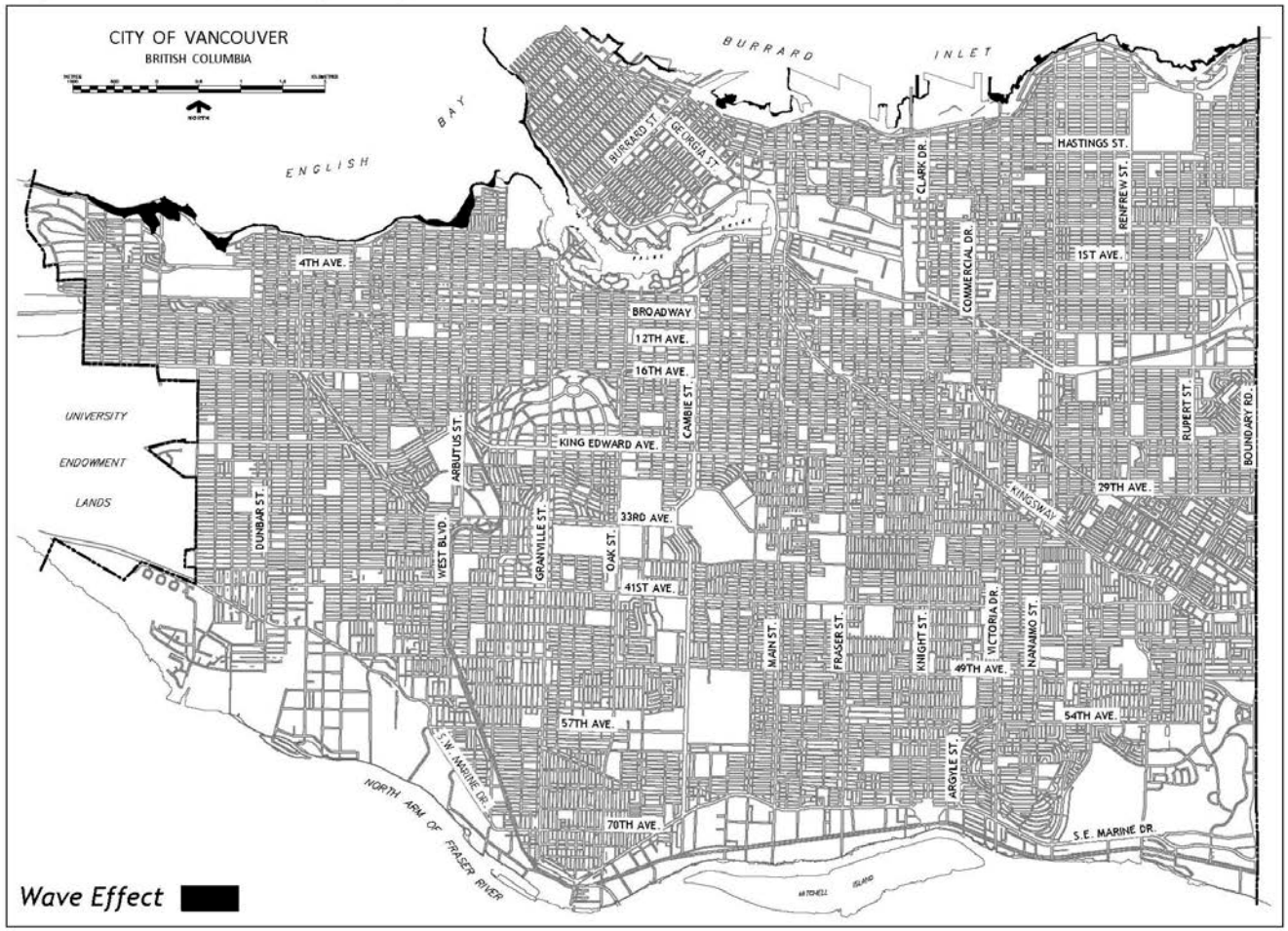
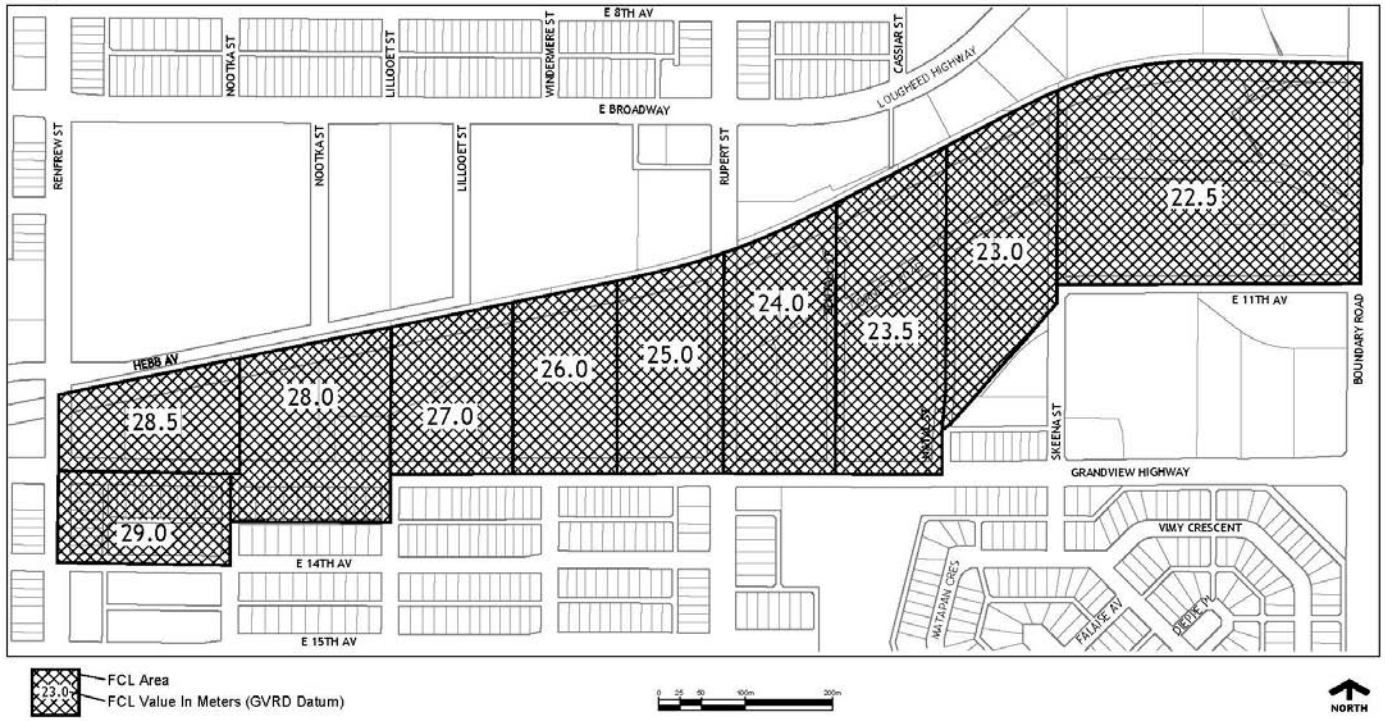


Diagram B: **Still Creek Flood Plain and Flood Construction Levels**



City of Vancouver ***Land Use and Development Policies and Guidelines***
Community Services, 453 W. 12th Ave Vancouver, BC V5Y 1V4 ☞ 604.873.7344 fax 604.873.7060
planning@vancouver.ca

Appendix B - New Policy Document

FLOOD PLAIN STANDARDS AND REQUIREMENTS

adopted by City Council on (Effective date…)

The purpose of this document is to provide guidance on meeting the City's designated flood plain standards as described in the Vancouver Building By-law and applied to building permits and subdivisions**.** The flood plain standards apply to all lands designated as flood plains and subject to flood construction level (FCL) requirements. Further review and revision of the designated flood plain areas and associated regulations is anticipated as global sea level rise and storm surge projections are refined over time and local impacts are better understood.

Note: Pages 6 to 12 of this document contain the relevant sections of the Vancouver Building By-law related to construction on flood plains, flood construction levels, regulations related to designated flood plains and designated flood plain maps. For more information, visit the City of Vancouver website at www.vancouver.ca ***(****link added when complete)*

The City's flood construction levels (FCLs) and regulations seek to:

- reduce or prevent injury, human trauma and loss of life in the case of a flood,
- to minimize property damage during flooding events, and
- to reduce the amount of time it takes to return to operational functionality when flood waters recede.

Provincial Standards

The Province of BC publishes guidelines to support local governments in drafting flood management related policies and bylaws. The most recent official guidelines are the 2004 "Flood Hazard Area Land Use Management Guidelines" with current draft guidelines that include sea level rise: "Climate Change Adaptation Guidelines for Sea Dikes and Coastal Flood Hazard Land Use" (January 2011).

In general, flood construction levels[1] (FCLs) are determined by site specific modelling as outlined in the Provincial Guidelines. The setback requirements are from the Provincial Guidelines and vary depending on the flood hazard type.

Flood Resilience

Enhancing flood resilience is achieved by:

- Meeting FCLs through the placement of fill and/or structural means;
- Restricting development near the water and requiring buildings to be setback;

[1] A flood construction level is the minimum elevation of the underside of a floor system or the top of a concrete slab of a building used for habitation, business or the storage of goods damageable by flood water.

- Providing adequate drainage systems; and
- Implementing flood resilient construction measures to reduce the damage caused from flooding and reduce the recovery time from flood events.

For buildings located on a designated flood plain, the Chief Building Official may require that a restrictive covenant be registered against the title of the property under section 219 of the Land Title Act. The property owner should expect to enter into a covenant early in the building permit application process with finalization required prior to occupancy. For subdivision requirements, please see the section below.

Flood Construction Levels (FCLs)

The underside of a floor system (wood or steel) or the top of a concrete slab of any building used for habitation, business or storage of goods shall not be lower than 4.6m from GVRD datum[2] in designated flood plains as outlined on Diagrams A1and B on pages 10 and 12 of this document.

In certain areas of the City, shown on Diagram A2 on page 11 of this document, an elevation in addition to the FCL for wave run-up may be required as determined by a Professional Engineer.

In some cases it may be impossible or impractical to implement the FCL due to existing City infrastructure and other constraints (e.g., a significantly lower street). Contingent on a report by a Professional Engineer, the Chief Building Official may provide conditional approval on a site by site basis of a reduction in elevation for such site specific issues. It may also be impossible or impractical to meet the FCLs solely by landfill due to smaller lot size, topography, site grade changes and impacts to adjacent streetscapes. In these situations, a combination of flood-resilient construction measures and elevation by structural means will be required. For large assemblies, a higher elevation may be possible through raising the entire site, including roads, thereby providing longer term resilience. In all these instances, it is important to have the City development, planning and building staff brought into the discussion early in the design process. Please seek preliminary guidance at the City Enquiry Centre.

The Director of Planning may exclude floors located at or below finished grade with a ceiling height of less than 1.5 m. from the computation of the floor area, in order to achieve flood construction levels on sites located in a designated flood plain in an R district.

Subdivision Approval

Under the provisions of Section 86 of the Land Title Act, the Subdivision Approving Officer, when approving a subdivision on lands within a designated flood plain may require a Professional Engineer's report certifying that the land may be used safely for the intended purpose and/or require the owner of the property to enter into a covenant under section 219 of the Land Title Act to establish flood plain requirements and a waiver of liability in favour of the City in the event of any damage caused by flooding or erosion. The covenant will be registered at the time of subdivision and may be modified later. Where the land proposed to be subdivided may not be used safely, the Subdivision Approving Officer may refuse to approve a proposed subdivision. Similar provisions are available under the Strata Property Act and the Bare Land Strata Regulations.

Covenant Measures

The owner of land seeking approval of a subdivision or building permit in a designated flood plain area should expect to enter into a covenant registered against the land title. The covenant will require application of flood plain standards and requirements and a waiver of liability in favour of the City in the event of any damage caused by flooding or erosion. Covenant conditions are to be registered with priority over all other charges requested against the property, save for those in favour of the City.

Where a situation arises in which consent to subdivision and/or a building permit would normally be refused due to a high flooding hazard, but it is nevertheless deemed appropriate to allow the subdivision and/or building permit due to extenuating circumstances, the owner may also be required to include in the "waiver' clause a provision to cover existing buildings that are to be retained on the property.

[2] The City of Vancouver uses the GVRD datum. It is the datum used in the Vancouver integrated survey area listings published by the Province for the City of Vancouver. The vertical datum is based on mean sea level.

Filling and Drainage

The documents listed below provide additional information for lands within the RA-1 district (Southlands).

- Southlands RA-1 Guidelines
- Planning – By-law Administration Bulletins
    - Height Relaxation – RA-1 District

In all other zones in the designated flood plain, increasing site grade by using fill as outlined in this document will be considered on a site by site basis. Please seek pre-application guidance beginning with the City's Enquiry Centre.

Where landfill is used to raise the natural ground elevation, the following are required as part of a Development Permit Application:
General principles

a) A Filing and Drainage Plan prepared by a registered engineer, to the satisfaction of the Chief Engineer. The Plan will show that run-off from the site, including from impervious and filled areas, will not be directed to adjacent properties. Where necessary, permeable materials and/or detention systems should be used to limit and control excess runoff. The Plan will include:
    i) existing and proposed grades of the subject site;
    ii) existing grades of the adjoining site measured 3.1m from the common property line; and
    iii) proposed drainage treatments.
b) Fill placement shall be supervised by a geotechnical engineer in such a manner as to have no net effect on adjacent properties and the overall hydraulic conditions of the flood-prone area.
c) The toe of the landfill slope should be no closer to the natural boundary than the prescribed setback and the face of the landfill slope should be adequately protected against erosion from flood flows, wave action, ice or other debris.
d) All flood-proofing fill and impervious surfaces should be inconspicuously integrated into the prevailing topography and landscaping to avoid any detrimental impacts on adjacent properties. This can be achieved by ensuring that:
    i) the 4.5 m fill apron follows the outline of the building footprint;
    ii) no abrupt changes in grade occur at property lines; and
    iii) a 20% transition to base grade is provided.
e) In narrow side yard conditions, the apron size may be reduced or flood proofing should be provided by structural means.
f) The use of retaining walls, terracing and rockeries will be considered when an apron of constant slope cannot be provided due to site constraints.
g) Building height is measured from the existing grade prior to development and fill placement.

Limits on Fill Areas

City Flood Plain Standards may, in certain instances, extend flood proofing requirements to non-habitable buildings that are used for storage of goods damageable by flood-waters. Further, the Chief Building Official may require flood construction level standards for *any* building in a designated flood plain. The City may make the determination during the initial enquiry or scoping sessions what, if any, special requirements are applicable and which approving authorities need to be brought in early into the Development Permit process.

Limits on Fill Elevations

To protect the amenity of low lying areas where FCLs apply, the following height limits to fill elevations exist:

a) In all cases, where a flood construction level exists, fill is required to a minimum of 0.9m (3ft) above the elevation of the street fronting the site.
b) If the elevation of the adjacent street is greater than 2.5m GVRD datum, the FCL can be achieved by fill alone.
c) If the elevation of the adjacent street is less than 2.5m GVRD datum, fill is limited to 2.6m GVRD datum.
d) Non-flood proofing fill is permitted, but is limited to a maximum .6 m (2 ft.) above base surface[3] of the existing grades, determined by an interpolative average of the four corners of the site.

Pre-Loading

Pre-loading requires a Development Permit (DE) to allow for an evaluation of the site and neighbouring properties. An application for a DE can be made either separately or as part of a comprehensive site and building DE. Applicants are advised to have their comprehensive site and building DE approved before proceeding with pre-loading. Applicants, who begin pre-loading before the location, shape and size of the development is approved, *do so at their own risk*. Although staff may give preliminary advice on the general direction of the development, a final evaluation cannot be completed until after a formal DE application is made.

Required documentation for a pre-loading DE application includes the following:

- Geotechnical analysis of the soil conditions and general specification for the pre-load.
- Site plan showing property boundaries, existing buildings, landscaping, proposed building(s) and an outline of the pre-load area, indicating how long the pre-load is required.
- Drainage plan for the entire property during the pre-loading.
- Survey of existing and proposed grades.
- Sectional profile of the pre-load.
- Details of any protective barriers required for existing trees.
- Arborist report for any trees requiring a protective barrier.

As a condition of approval, all DE's related to pre-loading will have a time limit for the pre-load material to be permitted on site. If the DE does not proceed and becomes void after one year, any pre-loading material on site should be removed.

Final Grades

Supervision during site re-grading is to be monitored by a registered engineer with a signed Letter of Assurance submitted at completion of grading. Additionally, a re-survey of completed grades will be required to ascertain that the final grades are in conformance with the approved construction documents and a Survey Certificate prepared by a B.C. Land Surveyor verifying flood plain standards.

[3] Base Surface means that hypothetical surface determined by joining the official established building grades at all corners of the site, provided however that where official established building grades cannot be obtained through application to the City Engineer, existing grades shall be used. For the purpose of measuring the height of a building at any point, the elevation at that point on the base surface shall be determined by interpolating from the official established building grades or, where official established building grades cannot be obtained, from existing grades;

Training and Erosion Protection Works[4]

Works include any structures used to prevent a stream from leaving its channel or used to minimize erosion (dikes, sea walls, revetments etc.). Where works are required, the approving officer should require details of the design, construction, operation and maintenance of works prior to final approval of a subdivision or a relaxation of the requirements in a covenant. Works are to be designed and certified by a professional engineer.

1. If the erosion protection works or training works are built on private property and intended to protect only the property of the person owning the training works and property on which they are located (including a strata corporation) an ongoing maintenance program may be assured through the addition of relevant requirements to the covenant registered under section 219 of the Land Title Act.
2. If the erosion protection or training works, when constructed, will protect multiple properties of more than one person, then an ongoing operation and maintenance program and registered easements, land dedications or combinations thereof, and access to structures must be assured. In addition,
    a) The training works require the approval of the Inspector of Dikes. An approved Operation and maintenance manual for the training works is to be prepared as a condition of subdivision approval and a copy is to be sent to the Inspector of Dikes.
    b) Approvals under the provincial Water Act and federal Fisheries Act are also normally required for both training and erosion protection works.
    c) For erosion protection works, an approved operation and maintenance manual for the local government is to be prepared as a condition of approval.

Reference Documents

Vancouver Building By-law No.10908

Section 2.3.7, 1A.6.1.9Books 1 and 2, Division A, Part 1, sentence 1.4.1.2
Books 1 and 2, Division A, Appendix A diagrams A1, A2, B
Books 1 and 2, Division C, Part 1, 1.5.2.11
Book 1, Division C, Part 2, 2.2.8

Government of British Columbia, Land Title Act

Section 86 “Subdivided Land Subject to Flooding”

[4] Training works are any wall, dike or protective structure used to prevent a stream from leaving its channel at a given location. This includes any debris flow training structures including basins, trash racks or other works. Erosion protection works include any structures such as sea walls, revetments, etc. used to minimize erosion of a property.

Flood Construction Levels and Regulations related to Designated Flood Plains

Vancouver Building By-law No. 10908

The following sections of the Vancouver Building By-law No. 10908 related to flood construction levels and regulations for buildings on designated floodplains are provided for your convenience. Please refer to the Vancouver Building By-law for complete information.

Definitions (Books 1 and II, Division A, Part 1, Vancouver Building By-law)

1. **Designated floodplain:** means those lands in the City which are hereby designated**,** for the purposes of section 306(cc) of the Vancouver Charter, as flood plains susceptible to flooding and subject to *flood construction level requirements*, and those lands so designated include:

    a) lands located in proximity to the *natural boundary* of Burrard Inlet, English Bay, False Creek and the Fraser River, which are located within the areas shown shaded on the maps attached to this By-law as Diagrams A1 and A2. (See Appendix A for Diagram A1- Burrard Inlet, English Bay, False Creek and Fraser River flood plains and for Diagram A2 - Burrard Inlet, English Bay, False Creek and Fraser River flood plain wave effect zone.); and

    b) lands located in the areas shown crosshatched on the map attached to this By-law as Diagram B. (See Appendix A for Diagram B – Still Creek flood plain and *flood construction levels*.)"

2. **Flood construction level requirements** means:

    a) on the Burrard Inlet, English Bay, False Creek and Fraser River flood plains:

        (i) for *building*s located within the areas shown shaded on the map attached to this By-law, the underside of a floor system or the top of a concrete slab of a *building* used for habitation, business or storage of goods, shall not be lower than 4.6 m Greater Vancouver Regional District datum. (See Appendix A for Diagram A1- Burrard Inlet, English Bay, False Creek and Fraser River flood plains); and

        (ii) for *building*s located in the areas shown shaded on the map attached to this By-law, an additional elevation allowance above 4.6 m may be required for wave run-up, at a level as determined by a Professional Engineer and to the satisfaction of the Chief *Building* Official. (See Appendix A for Diagram A2 - Burrard Inlet, English Bay, False Creek and Fraser River flood plain wave effect zone)

    b) on the Still Creek flood plain:

        (i) the underside of a floor system or the top of a concrete slab of any *building* used for habitation, business or storage of goods shall not be lower than the applicable elevation shown on the map attached to this by-law. (See Appendix A for Diagram B – Still Creek floodplain and flood construction level.)

Permits in Designated Flood Plain (Books I and II, Division C, Part 1 – Article 1.5.2.11)

1. If a *building* is located on a *designated flood plain* the *Chief Building Official* may

a) require plans and supporting documents to demonstrate that the elevation or design of the *building* incorporates *flood construction level requirements* intended to reduce the risk of flood damage,
b) require that a covenant acknowledging the risk of flood damage be registered against the land, and
c) withhold issuance of a *permit* until the requirements of the *Chief Building Official* have been satisfied.

2. The *Chief Building Official* may increase the *flood construction level requirements* or the

setback requirements as provided in Article 2.2.8.5.

3. The *Chief Building Official* may relax the *flood construction level requirements* or the setback requirements in this By-law as provided in Article 2.2.8.6."

Buildings on Designated Flood Plains (Book 1, Division C, Part2 – Article 2.2.8.1 – subsection 2.2.8)

2.2.8.1. Exemptions from Flood Construction Level Requirements

1. *Flood construction level requirements* do not apply to:

a) *alteration* of an *existing building* , not including *reconstruction* as defined in this By-law. (See Appendix A),
b) *alteration* of an *existing building* to increase the *building area* by less than 25 per cent of the total *building area* existing as of [*date of enactment of the By-law*], if
    i) the number of *dwelling units* is not increased,
    ii) there is no further encroachment into setbacks required by this By-law, and
    iii) there is no further reduction in the *flood construction level*,
c) enclosed parking areas, including bicycle and residential storage areas, in a *multiple dwelling*, if there is
    i) an unobstructed non-mechanized means of pedestrian ingress and egress to the areas, above the *flood construction level*, and
    ii) a sign posted at all entry points warning of the risk of flood damage,
d) *buildings* and portions of *buildings* used as a carport or garage,
e) non-residential accessory *building*s, and
f) loading facilities used for water oriented industry.

2.2.8.2. Design Considerations on Designated Flood Plains

1**.** For *buildings* constructed on *designated flood plains*, the *building* designer shall comply with by-law requirements regarding *construction* materials and service equipment installations below *flood construction level requirements,* to the satisfaction of the *Chief Building Official*. (See Article 1.5.2.11. of Division C.)

2.2.8.3. Construction Considerations on Designated Flood Plains

1**)** For *buildings* constructed on *designated flood plains*, *construction* of the *buildings* to *flood construction level requirements* shall be achieved, to the satisfaction of the *Chief Building Official,* by

a) the structural elevation of the floor system of the *building*
b) the use of adequately compacted fill, or
c) a combination of structural elevation and compacted fill.

2) No person shall install furnaces, electrical switchgear, electrical panels, fire protection systems or other fixed *building* services susceptible to flood damage, below the *flood construction level*, unless such services are protected from flood damage and accessible for servicing during a flood, to the satisfaction of the *Chief Building Official*.

3) No person shall store hazardous or toxic substances below the *flood construction level*.

4) All piping, wiring and conduit penetrations shall be water stopped and sealed to prevent water seepage into the *building*.

2.2.8.4. Setback Requirements on Designated Flood Plains

1) Subject to the provisions of this By-law, no *building*, structural support or fill shall be constructed or located within

a) 30 m of the *natural boundary* of the Fraser River,
b) 15 m of the *natural boundary* of Burrard Inlet, English Bay or False Creek,
c) 5 m of the *natural boundary* of Still Creek,
d) 7.5 m of any structure erected for flood protection or seepage control, or
e) in the case of a building, structural support, or fill located on a bluff in a designated flood plain, where the toe of the bluff is subject to erosion or is closer than 15 m from the natural boundary, a setback measuring 3.0 times the height of the bluff as measured from the toe to the crest of the bluff.

2.2.8.5. Increase of Flood Construction Level and Setback Requirements on Designated Flood Plains

1) The *Chief Building Official* may increase the *flood construction level requirements* or the setback requirements in this By-law if, in the opinion of the *Chief Building Official*, a higher *flood construction level* or a greater setback is necessary as the result of a site-specific geological or hydrological feature.

2.2.8.6. Relaxation of Flood Construction Level and Setback Requirements on Designated Flood Plains

1) The *Chief Building Official* may relax the *flood construction level requirements* in this By-law in accordance with Article 1.5.2.11., if

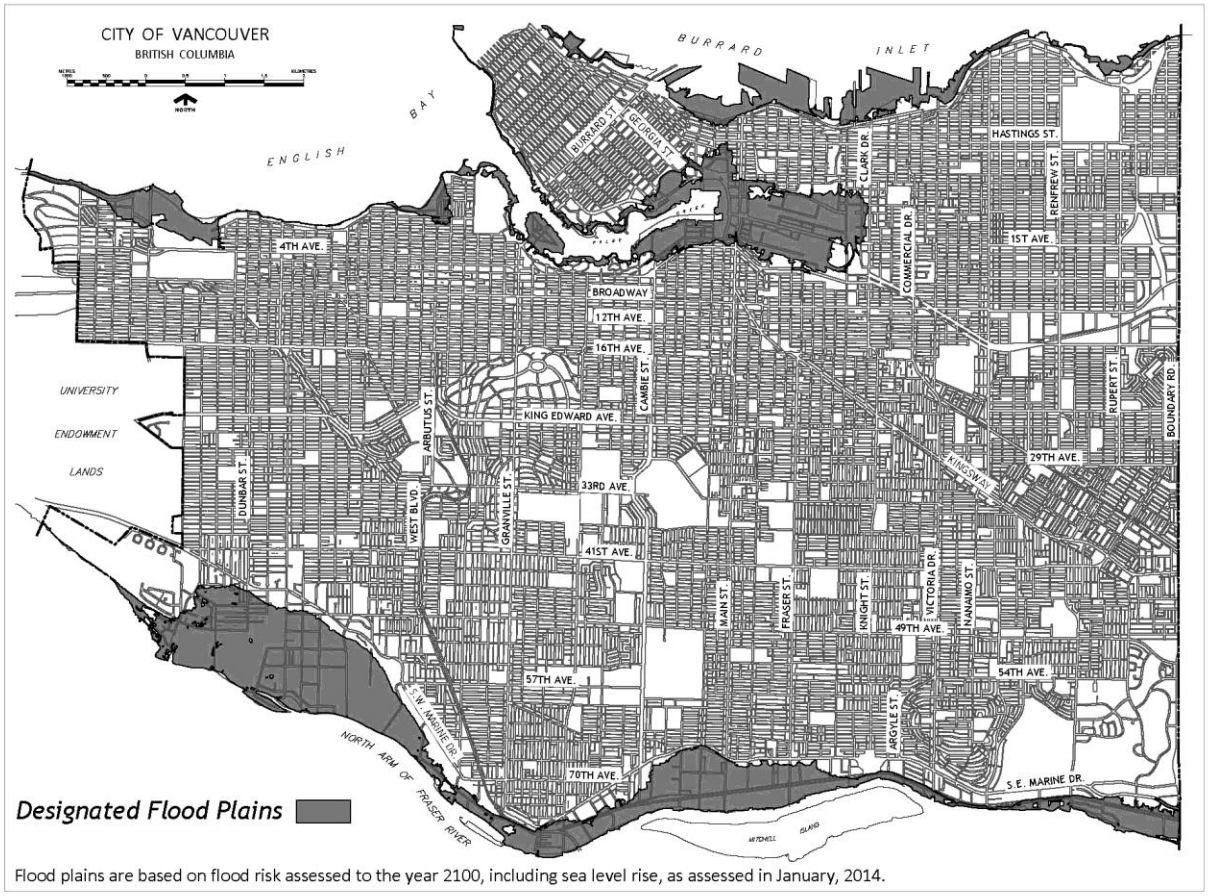
a) the *owner* demonstrates to the satisfaction of the *Chief Building Official*, that, due to existing site characteristics and the location of existing infrastructure, it is impractical to meet the *flood construction level requirements*,
b) the *owner* demonstrates to the satisfaction of the *Chief Building Official*, the proposed construction methods are designed to mitigate flood damage, and
c) the *owner* provides a report, to the satisfaction of the *Chief Building Official*, stamped by a professional engineer, certifying that the habitable space in the *building* will be safe during a flood if a lower *flood construction level* is applied."

2) The Chief Building Official may relax the setback requirements in this By-law in accordance with Article 1.5.2.11., if

a) the owner demonstrates to the satisfaction of the Chief Building Official, that, due to existing site characteristics and the location of existing infrastructure, it is impractical to meet the setback requirements,
b) if considered necessary by the Chief Building Official, the owner agrees to construct erosion protection works to mitigate flood damage and erosion, and
c) the owner provides a report, to the satisfaction of the Chief Building Official, stamped by a professional engineer, certifying that the habitable space in the building will be safe during a flood if a reduced setback requirement is applied."

Appendix A: Flood Plain Diagrams

Diagram A1: Burrard Inlet, English Bay, False Creek and Fraser River Flood Plains



Flood plains are based on flood risk assessed to the year 2100, including sea level rise, as assessed in January, 2014.

Diagram A2: Burrard Inlet, English Bay, False Creek and Fraser River Flood Plain Wave Effect Zone

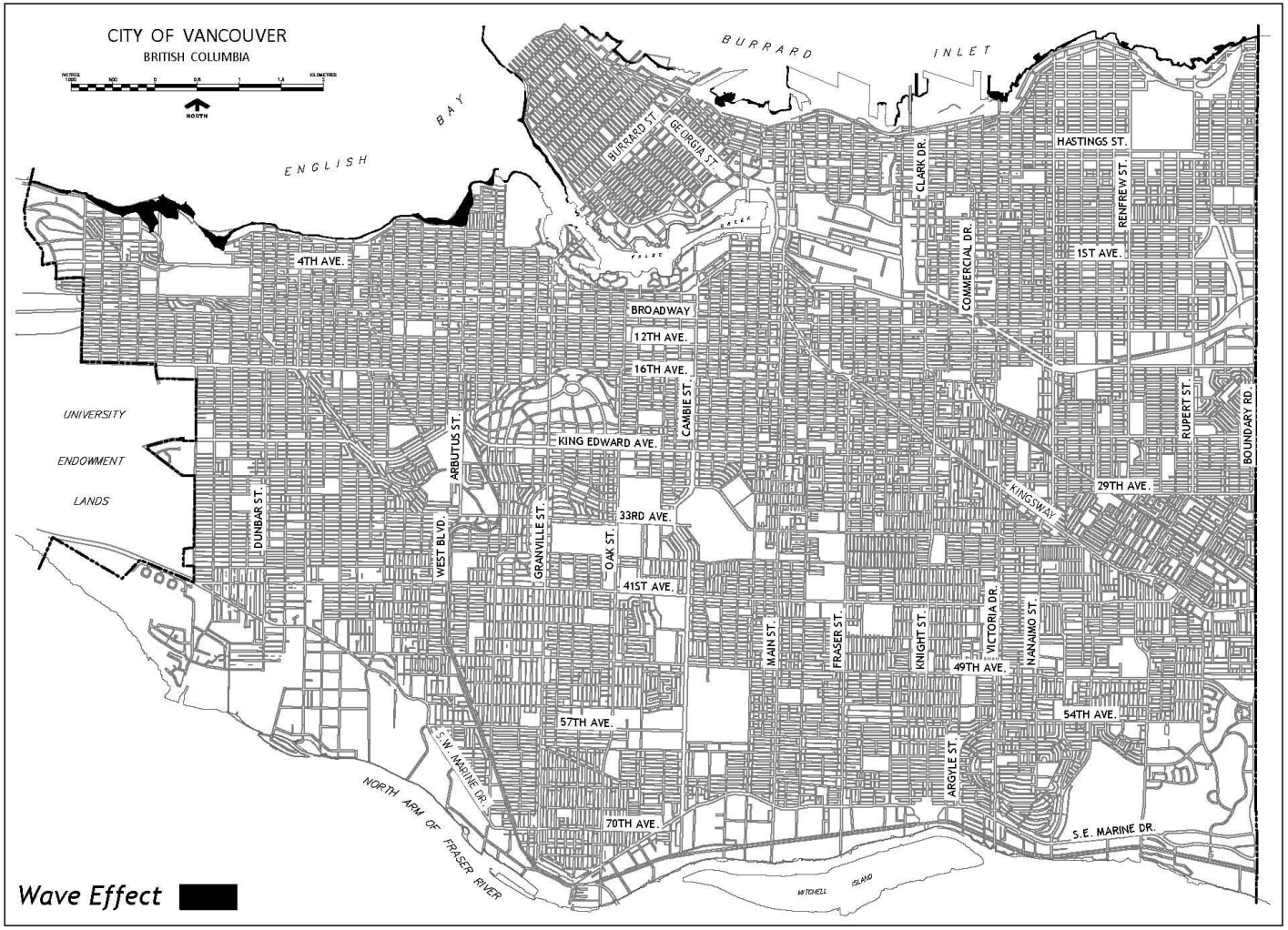
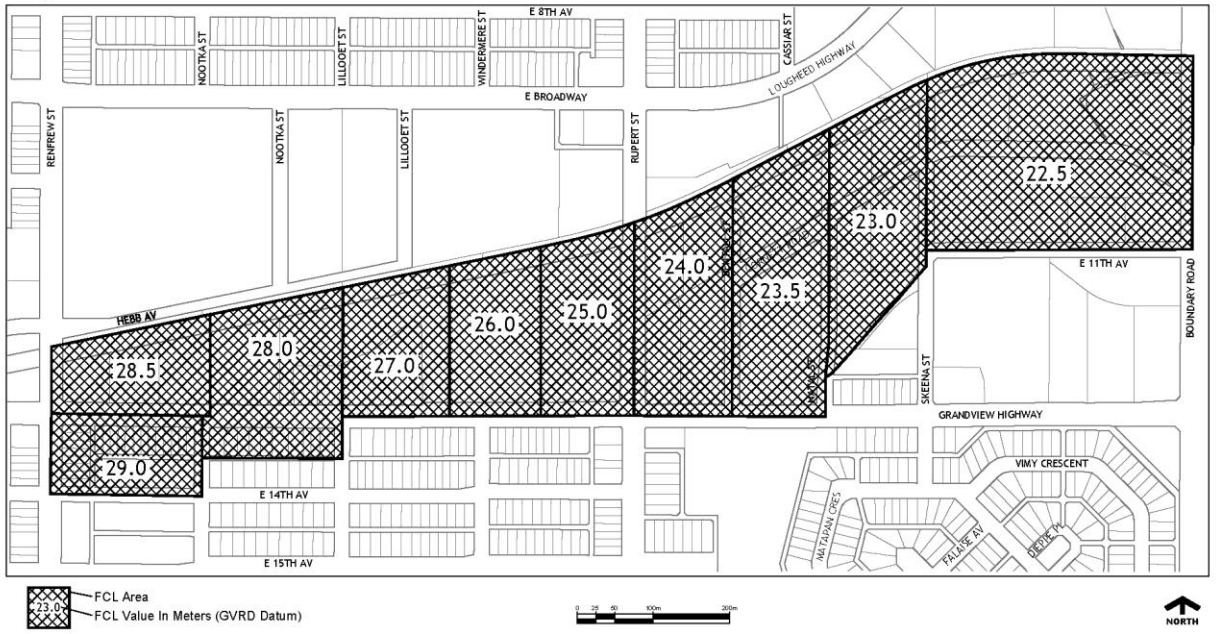


Diagram B: **Still Creek Flood Plain and Flood Construction Levels**



Appendix C: Proposed Zoning and Development By-law Section 10 Wording

1. Section 10 - Floor Area Exclusions for Sites in a Designated Flood Plain in a R District

The Director of Planning may exclude floors located at or below finished grade with a ceiling height of less than 1.5 m. from the computation of the floor area, in order to achieve flood construction levels on sites located in a designated flood plain in an R district.

Appendix D: Flood-Proofing Standards, Flood Mechanisms and Methods of Establishing FCLs

1) History of City of Vancouver Flood-proofing standards:

On April 12, 1986, City Council endorsed specific flood-proofing policies for the Southlands flood plain. On January 27, 1987, City Council indicated support for the existing Provincial flood-proofing standards adopting setback and elevation requirements (flood construction levels – FCLs) for new construction on lands subject to flooding adjacent the Fraser River, False Creek, Burrard Inlet and English Bay. The Vancouver Charter was subsequently amended to enable City implementation of the flood-proofing policies via the City's building permit process. The policies were amended in 1995 and again in 2007.

In 2004, the Province delegated to municipalities its responsibility respecting flood-proofing standards. To assist municipalities, the Province published guidelines ("Flood Hazard Area Land Use Management Guidelines") and a model covenant. The subsequent 2007 amendment to City flood-proofing policies recommended the continuation of the setback and elevation requirements as they were, with inclusion of new flood prone areas adjacent to Still Creek and in the False Creek Flats.

The 2007 amendment also signalled that additional revisions would be required to adapt to climate change when more specific local estimates were developed. In 2011, the B.C. Ministry of Environment published a new methodology for calculating FCLs including local estimates of sea level rise, in new draft "Guidelines for Management of Coastal Flood Hazard Land Use". The 2012 City Climate Change Adaptation Strategy directed staff to amend existing flood proofing policies in light of this new information.

The City implemented an interim FCL in January 2012 (existing FCLs (~3.5m) +1m) while undertaking comprehensive ocean and overland modelling required to calculate appropriate FCLs. The modelling is detailed in section 2.0 below.

a) Flood Management Standards:

The B.C. design standard is a 1:200 year return period water level plus "freeboard" (0.6m standard safety factor) to accommodate uncertainties such as wave action. It is based on the 1894 Fraser River flood event which affected a broad area of Southern B.C. Prior to the 2011 Ministry of Environment guidelines, FCLs were largely based on this design standard.

The 2011 guidelines provided a new methodology for calculating FCLs to determine extreme water levels inclusive of sea level rise. The guidelines stipulate establishing management parameters (FCLs and setbacks) that anticipate flood levels that are applicable to the end of the lifespan of the buildings in question.The design and planning time frame of 2100 is recommended.

2) Arriving at an FCL: Ocean and Overland Scenario Modelling

a) Flood Mechanisms:

Identified flood hazards in Vancouver today include:

- Flooding of low lying coastal areas during extreme coastal events (high tides combined with storms);
- Flooding in the Still Creek –Brunette River Basin due to heavy precipitation;
- Flooding of the Fraser River floodplain when river levels rise generally as a result of high ocean water levels; and
- Localized ponding of rainwater in low lying areas when adjacent ocean or river water levels are high thereby limiting sewer capacity. Historically an issue in Southlands and the False Creek Flats.

Flooding from the ocean will occur during extreme high total water levels which are caused by a combination of components that rarely occur simultaneously: high tide, large storm surge, wind set up (friction force of wind on sea surface), wave setup (change in mean water level when waves are present) and wave effect (wave run-up on shore). Complex hydraulic and statistical modelling was carried out to assess the magnitude of these components along Vancouver's shoreline and the probability of them occurring together. Please see the section below for a more detailed description of each water level component.

A 1998 study by the Greater Vancouver Regional District found that certain areas along Still Creek between Renfrew Street and Boundary Road were prone to flooding. The 2007 amendment to the City's flood-proofing standards included measures for the Still Creek flood zone. Still Creek may be affected by heavier rainfall but is not anticipated to have increased flood hazard from sea level rise given it is 20m above sea level rise at its lowest point. Metro Vancouver will begin a review of Still Creek flood hazard in 2016.

Given south Vancouver's location near the mouth of the Fraser River, the areas adjacent to the river are influenced more by ocean conditions than by the spring snowmelt runoff (freshet). Highest water levels are associated with high tide and winter storm conditions. Sea level rise will therefore also affect flood risk in Fraser River neighbourhoods.

The FCLs resulting from the modelling detailed in the sections that follow is intended to ensure all new construction in areas subject to ponding will be suitably above both ponding and flooding hazards.

b) Components of total water height*:*

A brief discussion of the various components of high water level affecting all ocean shorelines and, to an extent the Fraser River, follows below including climate change implications.

Tides are typically the largest contributor to high water events in the City region. They have a range of about 5.1m and a maximum elevation of 2.0m Geodetic Datum (GD). They are larger in the winter and smaller in the summer with yearly large tides, 'King Tides', occurring every year usually between November and February. Tides result from the gravitational interaction of the sun, moon and earth and will not be affected by climate change.

Storm surge observed in Vancouver is usually associated with high energy storms that propagate off the Pacific and into BC coastal waters. Storm surge is the second largest contributor to high water events in the City region, usually peaking at less than 0.5m but can be greater than 1m. They persist for a time period of a few hours to a few days. Scientific information on the expected future changes in storms approaching BC coastal waters and their characteristics, specifically the intensity of storms, their related wave conditions and associated storm surges is only starting to emerge. Based on available information, it is reasonable to conclude that no significant change is expected.

The Strait of Georgia is a semi-enclosed basin such that waves are entirely locally generated. West of the First Narrows, the City is most vulnerable to waves and winds coming from the North-West; east of the First Narrows, the City is most vulnerable to waves from the North-east. Water levels are affected both by waves changing the mean elevation of the water level and by how they interact with the shoreline. Sea level rise will change the depth of water at the shoreline thereby influencing wave run-up.

Wind setup is associated with strong local on shore winds blowing over shallow water which typically does not last more than a few hours. The only area of the City with significant susceptibility to wind setup is False Creek where wind setup reaches 10cm. The effects of climate change on wind are again inconclusive for our region. There is some evidence that summer winds will increase while winter winds decrease.

Sea level rise due to global climate change is an important factor driving increases in flood hazard. The two main mechanisms that contribute to sea level rise are thermal expansion (water expands as it warms), and the melting of major land-based stores of ice such as glaciers and ice sheets.

For context, notable historical coastal events for Vancouver include the following total water levels relative to Geodetic Datum (GD):

- 1962: 2.18m GD associated with Typhoon Frieda
- 1967: 2.57m GD causing flooding at the foot of the Burrard Bridge
- 1977: 2.48m GD causing flooding of Kitsilano Pool
- December, 2012 King Tide event: 2.66m GD causing flooding of Kitsilano Pool and Jericho Beach areas.

Existing FCLs based on current flood hazard and those proposed to include sea level rise are appropriate relative to the water levels of the events above.

c) Modelling Overview:

The modelling approach accepted by the Province, and used here, involves assessing the joint probability of the individual total water height components (storm surge, tide, waves, wind setup) using a long historic record, and then carrying out a statistical analysis to determine the design water level for the return period event specified (1:200 through 1:10,00). Sea level rise is included prior to running the model. Once shoreline water levels are established through ocean modelling, they are input into an overland flood model representing the urban environment. This provides information on depth and extent of potential flooding.

Modelling on the Fraser River used the existing Fraser River Model (MIKE11 Model) developed for the Fraser Basin Council in 2006 and updated by the BC Ministry of Environment in 2008.

d) Modelling Assumptions:

Scenario planning and assessment is an important tool of climate change adaptation given the variability in estimates of when and to what extent things will change. The CFRA technical advisory committee (TAC) recommended modelling flood hazard for one current and four future scenarios. The scenarios differed in terms of:

- design and planning time frame (year 2100 or 2200),
- magnitude of sea level rise (60cm, 1m or 2m),and
- and return period (1:200, 1:500, 1:10,000).

The TAC includes the head of the provincial Flood Safety Section, natural disaster experts from Natural Resources Canada and academia, local sea level rise experts, Port Metro Vancouver, rail companies, CMHC and City staff.

The coastline was divided into four congruent zones and each zone was modelled via the ocean and overland model for each of the five scenarios. For Zone 5, the Fraser River, the MIKE11 model was run for each of the five scenarios. Outputs included recommended FCLs for each zone for each scenario with corresponding maps of flood plain extents and wave effect zones.

i) Design and Planning Time Frame:
The year 2100 is the current standard for planning for sea level rise. The New York City post-Superstorm Sandy resilience plan targets 2100 as does the Thames Estuary 2100 Risk Management Plan. The provincial guidelines suggest planning to 2100 for permanent structures given the assumed 100 year or less lifespan of most infrastructure. As the upward trend in sea level is not expected to stop in the year 2100, 2200 was also modelled to provide insight for longer term planning issues. Current year (2013 at the time) was modelled as a base case.

ii) ***Sea Level Rise***:
Estimates of the amount of sea level rise by the end of the century vary depending on the future greenhouse gas emission scenario chosen and the extent of ice sheet melt included. There are two common prediction methods: predicting the future

from similar conditions in the past (semi-empirical) and physics-based computer modelling (process-based). The projections from the two methods are converging as the process based models, as used by the Intergovernmental Panel on Climate Change (IPCC), are including more processes such as ice-sheet discharge and glacial melt. The IPCC's recent fifth assessment report (2013), estimates a range of global mean se level increase from 28cm to 98cm by 2100 (average of 60cm). Two semi-empirical studies by Horton (2008) and Vermeer and Rahmstorf (2009) project 74cm and 1.24m respectively by 2100. The BC Ministry of Environment, after completing a scan of projections and figures used by jurisdictions in the U.S, Australia and the Netherlands, chose a number at the higher end of the range envelope: 1m by 2100. Sea level rise of 60cm, 1m and 2m were modelled in this study.

iii) Return Period:

A return period is an estimate of the likelihood of an event such as a flood occurring. In modelling and applying an FCL, structures will be designed to withstand an event with a certain return period plus sea level rise. British Columbia uses a 1:200 year return period while most provinces use the less conservative 1:100 year event with the exception of Saskatchewan that uses 1:500. The UK Environment agency uses a 1:200 year event as a 'sea flood' and the Federal Emergency Management Agency in the U.S. uses 1:100 to define the ocean flood zone. To put these numbers in perspective, the 2013 Calgary floods have an estimated return period of between 1:50 and 1:100 while the minimal flooding we experienced during the 2012 King Tide is estimated at a 1:50 year return period. The technical advisory committee agreed that modelling to a lower likelihood event 1:500 year and 1:10,000 year return period) than traditionally used was warranted given the potential consequences of flooding in an urban centre. It is not expected that storm return periods will change significantly within the modelled time period. The freeboard applied covers the uncertainties associated with future storminess changes.

iv) Freeboard:

Freeboard is an internationally applied factor to account for uncertainties that are not directly included or considered in design. The standard 0.6m freeboard is recommended to account for uncertainties in sea level rise projections, storminess and any modelling uncertainties.

v) Wave Zone:

In limited areas of the City, given their shoreline characteristics and elevation, waves will add height to the total height of floodwater. Wave zones have been modelled and may require a small increase in FCLs to account for waves in cases where more general wave attenuation efforts are not pursued.

e) Recommended FCL:

Staff and the TAC looked to local and international best practice in choosing which scenario to use for FCL recommendations. A more conservative water level than the Provincial standard was chosen given the potential consequences of flooding in

Vancouver's heavily urbanized environment. In response to the 2013 Calgary floods, Alberta is using a 1:500 year return period in high consequence areas. Otherwise, FCL modelling is consistent with the Province's recommendations to include 1m of sea level rise and use the time horizon of 2100.

Year	Sea Level Rise	Return Period	Freeboard (m)	FCL (m)
2100	1.0 m	1/500	0.6	4.6

As a result of the research and modelling completed as phase one of the Coastal Flood Risk Assessment, it is recommended that the existing City standards change as follows:

- The FCL is increased from the existing 3.5m level to 4.6m. The FCL is consistent across the City with the exception of Still Creek where FCLs will remain the same as set in 2007 contingent on an upcoming Metro Vancouver study planned for 2016.
- The 4.6m FCL applies throughout the flood-prone area mapped as 'designated floodplain' in the by-law.
- Property owners within wave effect boundary will require advice from a Professional Engineer on whether an additional elevation for waves is required.