INTEGRATED FLOOD HAZARD MANAGEMENT PLAN

SQUAMISH

Coastal Flood Risk Mitigation Options

Final Report
September 2017

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CASCADE ENVIRONMENTAL
RESOURCE GROUP LTD

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1. Introduction

In 2014, the District of Squamish (District) retained a multi-disciplinary consulting team led by Kerr Wood Leidal Associates Ltd. (KWL) to prepare an Integrated Flood Hazard Management Plan (IFHMP). The three-year project identified flood protection strategies to provide Squamish with an appropriate level of flood protection. IFHMP deliverables are summarized in the table below.

Table 1-1: IFHMP Deliverable Reports

Deliverable Report
Framework for Community Engagement
Electronic Forum (updated throughout project)
Background Report
Coastal Flood Risk Mitigation Options Report (this document)
River Flood Risk Mitigation Options Report
Integrated Flood Hazard Management Plan

1.1 IFHMP Scope

A fully integrated flood hazard management plan takes a holistic and inclusive approach to:

- **assessing hazards**, by including all relevant potential sources of flooding at a system or watershed scale (coastal; river, creek and lake; urban stormwater; groundwater; and often related hazards such as erosion and, less frequently, landslides or seismic liquefaction);
- **identifying mitigation opportunities**, by including the fullest possible spectrum of actions; and
- **making decisions**, by considering a full range of possible impacts, benefits, and costs for people, the community, and the environment.

In some cases (including Squamish), available resources limit the scope that can be achieved by a single study or assessment. Ideally, results from complementary successive or parallel studies are considered together in making final mitigation decisions.

This report describes the development of the District's coastal flood protection strategy and presents conceptual design considerations for corresponding structural flood mitigation works.

1.2 Purpose and Structure of Report

The District's IFHMP produced a plan which incorporates the latest flood management guidelines, new engineering modelling tools and techniques and best planning practices. For this project, the process itself was instrumental in defining the desired final state of flood protection for the District of Squamish.

The IFHMP Background Report (KWL, 2017) provides a technical foundation for the study. Building on the Background Report, this coastal flood risk mitigation options report identifies a coastal flood hazard mitigation strategy as well as preferred options for flood protection. The structure of the report includes:

- a review of coastal flood hazards (Section 2);
- a coastal flood hazard mitigation strategy for the District of Squamish (Section 3);
- alternative alignments for structural coastal flood protection works (Section 4);
- evaluation criteria for evaluating the alternative alignments (Section 5);
- a summary of consultation activities undertaken regarding coastal flood hazard management and the proposed mitigation strategy (Section 6);
- identification of a preferred sea dike alignment (Section 7);
- preliminary design assumptions for the future sea dike (Section 8); and
- high-level guidance to support implementation of the structural flood protection works (Section 9).

A summary of key points is provided in Section 10.

The report also incorporates several appendices, notably including a summary report on feedback collected at the public open house in October 2014 (Appendix A, prepared by the Arlington Group). Other appendices include detailed evaluation of coastal flood protection alternatives (Appendix B) and a series of internal District of Squamish reports (Appendices C through F).

Initial flood protection concepts were reviewed with the Technical Working Group (TWG) in September 2014 and a partial draft of this report was provided for TWG review and comment in April 2015. A final draft report was presented to District Council on September 29, 2015 and ratified at the regular business meeting of October 6, 2015.

The revised final draft report was made available to the public in October 2015. At the District's request, this report was not finalized until the completion of the IFHMP. Revisions included in this September 2017 final report are limited to minor updates made throughout the balance of the IFHMP.

1.3 IFHMP Project Team

The District of Squamish IFHMP initiative is being led by Municipal Engineer David Roulston, P.Eng. with direction and participation from senior District staff in both Planning and Engineering as well as Mayor and Council.

The multi-disciplinary consulting team includes:

- **Kerr Wood Leidal Associates Ltd.**: project management, hydrotechnical and civil engineering;
- **Arlington Group Planning + Architecture Inc.**: planning, policy and public consultation services;
- **SNC-Lavalin Inc.**: coastal engineering;
- **Thurber Engineering Ltd.**: geotechnical engineering and geoscience expertise; and
- **Cascade Environmental Resource Group**: environmental science.

Preparation of this report was led by David Roche, M.A.Sc., P.Eng. of KWL. Graham Farstad, MA, MCIP of Arlington Group Planning + Architecture provided input on planning issues, while John Readshaw, M.Sc., P.Eng. of SNC-Lavalin provided support and input for the coastal engineering matters. David Sellars, M.Sc., P.Eng. of KWL provided technical review of the full report.

Ten Squamish Nation reserves are located throughout the floodplain, creating an inseparable common interest in flood protection between the District and the Squamish Nation. Technical input and co-ordination of feedback from the Squamish Nation was provided on behalf of Chiefs and Council by Capital Projects Director Buddy Joseph and Squamish Valley Administrator Paul Wick.

Other stakeholders invited to participate in the District's Technical Working Group include:

- Indigenous and Northern Affairs Canada (INAC);
- BC Ministry of Forests, Lands & Natural Resource Operations (MFLNRO) Water Management Branch;
- BC MFLNRO Ecosystems Branch;
- BC Ministry of Justice – Emergency Management BC;
- CN Rail;
- Transport Canada; and
- Vancouver Coastal Health.

The composition of the stakeholder group was adjusted in later phases of the project to incorporate additional interests under discussion during the IFHMP process.

2. Coastal Flood Hazards

On December 9, 2014, the District's water level sensors at the 3rd Avenue tide gates recorded a high-water elevation of approximately 5.5 m Chart Datum (CD) or 2.5 m geodetic. Staff report that water near the Squamish Yacht Club came within about 0.1 m of overtopping the road at Loggers Lane. KWL's joint probability analysis suggests that the combined water level (tide + surge) had a return period of about 5 years.

Hydraulic modelling based on present-day conditions (i.e., 2013 LiDAR data) indicates that most of downtown Squamish is vulnerable to inundation from a coastal flood at return periods less than the present Provincial and District 200-year return period design standard. Figure 2-1 below shows the extent of inundation for a coastal flood event with a return period as low as 50 years. The inundation extents assume present-day development conditions with the stormwater management system overwhelmed. Inundation could be much worse if the 3rd Avenue tide gates and Town Dike were compromised.

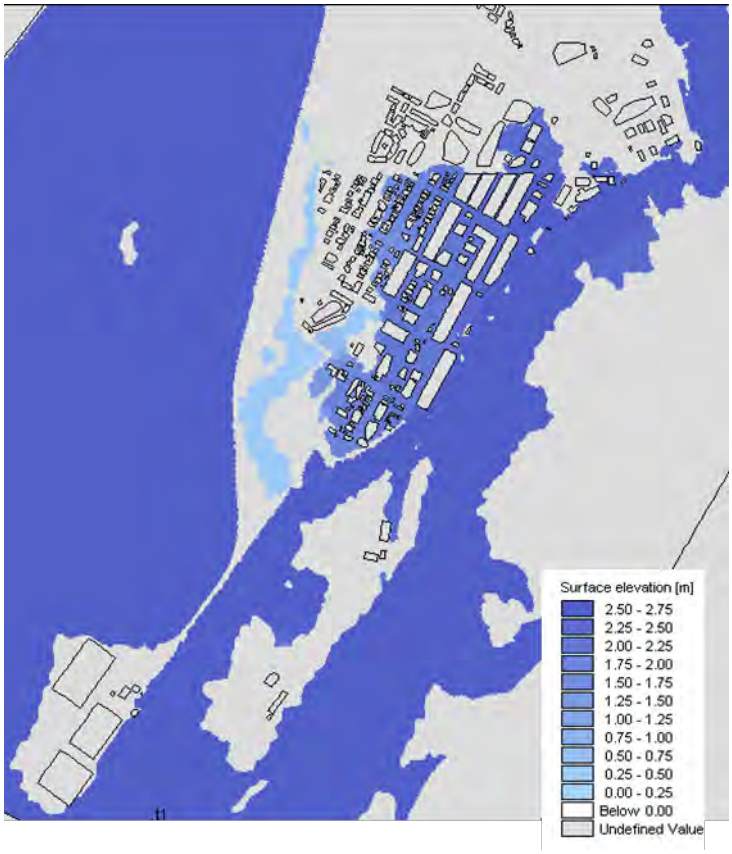

Figure 2-1: Potential Inundation of Downtown during 50-yr. Coastal Flood, Present-Day Conditions

The December 2014 high water event highlighted some long-standing vulnerabilities in the District's coastal flood protection system. These vulnerabilities are magnified by provincial guidance on Sea Level Rise (SLR), which recommends planning for 1 m of SLR by Year 2100 and 2 m by Year 2200 (Figure 2-2). Evidence suggests that SLR is accelerating and will continue past Year 2200.

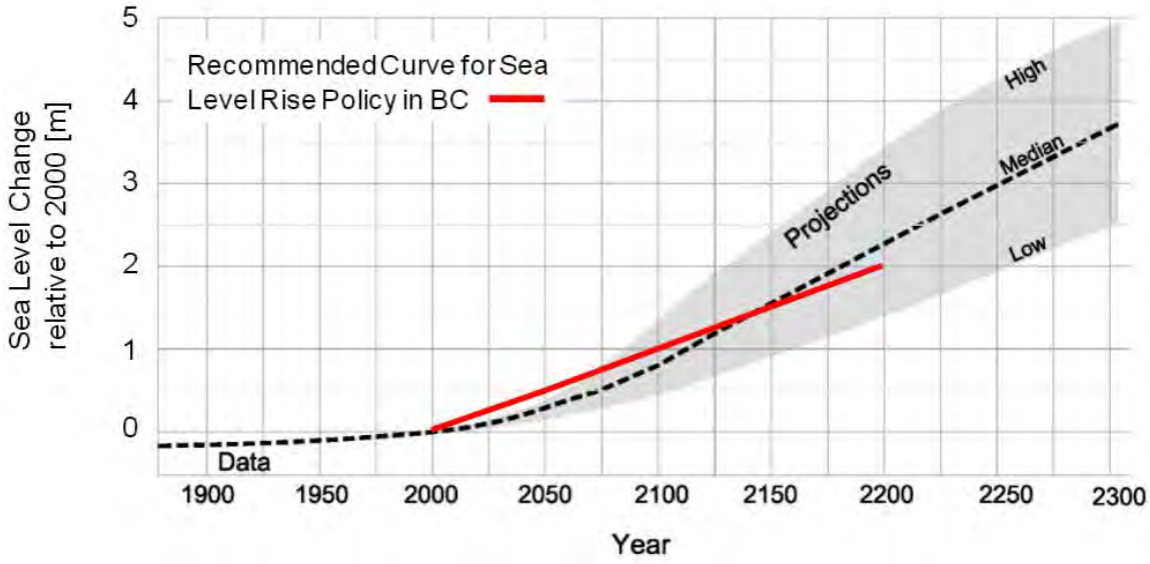

Figure 2-2: Recommended Curve for Sea Level Rise Policy in BC (BC MFLNRO, 2015)

The IFHMP Background Report (KWL, 2017) establishes a still-water Designated Flood Level of 3.99 m geodetic for coastal floods based on a 200-year return period flood at the Year 2100 horizon. The corresponding inundation extent is shown in Figure 2-3.

Wave effects must be incorporated along the District's coastal margins. Appendix C of the IFHMP Background Report includes a wave assessment by SNC-Lavalin Inc. (SNCL, 2015). Site-specific wind setup and wave setup can also contribute to local water levels, but must be evaluated on a site-by-site basis.

The IFHMP Background Report also includes a preliminary discussion of subsidence (land settlement), which can increase potential inundation depths, and recommends further investigation to confirm preliminary allowances.

The possibility of tsunami hazard is acknowledged in the IFHMP Background Report; however, the likelihood of a major tsunami reaching Squamish is considered very low and mitigation is not considered practical at this time. KWL understands that tsunami hazard will be considered in forthcoming revisions to the District's Emergency Response Plan.

Path: O:\0400-0499\463-278\430-GIS\MXD-Rp\Council Presentation Sea Dike Concept\20151009 UPDATE\Figure 2-3 Downtown Squamish Coastal Flood Inundation.mxd Date Saved: 15/02/2017 1:49:26 PM
Author: YBrugman

Town Dike
Existing Crest Elevation: 2.7 - 3.4 m GSC
Required Year 2100 Crest Elevation: > 4.7 m GSC

Stawamus River Dike

SODC Lands

Stawamus I.R. No.24 Training Berm
Existing Crest Elevation: +/- 5 m GSC.
Built in 1999 to mitigate 200-year Return Period Clearwater Flood (Not Debris Flood)

Legend
- Existing Dike
- Stawamus I.R No. 24
- Site A
- Site B
- Limit of Freeboard Zone (4.59 m GSC)
- Areas Below 3.99 m GSC

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Date August, 2017

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District of Squamish - Integrated Flood Hazard Management Plan
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Downtown Squamish Coastal Flood Inundation Including Sea Level Rise to Year 2100

Figure 2-3

3. Coastal Flood Mitigation Strategy

The IFHMP Background Report outlines a number of potential strategies for flood risk mitigation. The various strategies and selected examples of each are outlined in the table below.

Table 3-1: Flood Risk Mitigation Strategies

Strategy	Description	Examples
Protect	**Protect** existing development in its current form and location, balancing costs and increasing vulnerability against societal cost and risk associated with other strategies.	• Construct offshore defenses (e.g., breakwater, bulkhead) • Construct perimeter defences (e.g., sea dike, seawall, sheet wall pilings) • Apply traditional or GreenShores™ approaches to mitigate shoreline erosion
Accommodate	**Accommodate** the potential consequences of ongoing changes by changing human activities and/or infrastructure to increase resilience.	• Raise land elevation with structural fill • Raise elevation of habitable uses above coastal flood risk • Floodproof ground floor parking below residential / commercial uses • Require flood resistant building materials for commercial uses at ground level • Allow water dependent industrial uses
Retreat	**Manage Retreat** by gradually withdrawing potentially-vulnerable infrastructure and services from hazard areas in recognition of their increasing vulnerability.	• Reclaim developed area to natural state as a community amenity
Avoid	**Avoid** increasing the presence or density of potentially-vulnerable populations, infrastructure or services within hazard areas.	• Protect natural river floodway • Broad buffers at coastal margins

In addition to the four key strategies outlined in the table above, the concept of **Accept** is implicit in all discussions. An accept strategy may endorse the status quo level of mitigation (i.e., if existing risk is considered acceptable), but is more frequently an implied part of a more comprehensive strategy that is focussed on defining and advancing the concept of "safe enough". Guidance as to what might constitute "safe enough" (and in some areas, minimum requirements) is available from local, provincial, national, and international sources; however, at this time local communities in BC remain largely responsible for defining the amount of risk the community is willing to accept.

Another type of strategy, **Attack**, involves reclaiming land from an existing natural coastline or floodway. This strategy is most often considered in countries and regions where severe land constraints, very high population densities, and skyrocketing land values justify the substantial costs, risks, and environmental impacts. A typical attack strategy would be in conflict with the principles of integrated flood hazard management, and is not considered appropriate for Squamish.

Different strategies or combinations of strategies will suit different coastal flood hazard areas, as described below.

"Unconnected" Floodplain Areas

In general, isolated or "unconnected" coastal floodplain areas (i.e., where inundation would be confined to a single property or development site) have the greatest flexibility. These "unconnected" floodplain areas can adopt cost-effective, site-specific flood protection measures customized to support a particular development proposal.

Examples of "unconnected" floodplain areas within the Squamish community include Woodfibre, Site 'A', Squamish Terminals, the Squamish Oceanfront Development, Scott Crescent, Waterfront Landing, Inn on the Water, Stawamus I.R. No. 24 and Site 'B'. These sites are shown in Figure 3-1, and span the development cycle from existing (Squamish Terminals) to pending development (Scott Crescent) to undeveloped (Site 'B'). The developer is usually the proponent when considering a flood mitigation strategy for an "unconnected" floodplain site.

"Connected" Floodplain Areas

In contrast to "unconnected" floodplain areas, larger floodplain areas (such as the downtown Squamish peninsula) encompass many different properties and land uses. For flood protection to be effective and reliable, these larger floodplains must adopt a unified and consistent approach. As a result, development must incorporate and comply with the established flood mitigation strategy.

Developing, implementing and enforcing strategies for multi-owner floodplain areas is usually the responsibility of the local government. The District of Squamish has chosen to define a coastal flood mitigation strategy for the community's main coastal floodplain as part of the IFHMP. This area includes downtown Squamish and Dentville as well as parts of the Industrial Park, Business Park, North Yards, and Squamish Nation Yekwaupsum I.R. No. 18. The extents of the coastal floodplain as defined by the Year 2100 200-year return period still-water flood elevation are shown in Figure 2-3.

Coastal Flood Mitigation Strategy: Downtown Squamish "Connected" Area

An IFHMP is a multi-objective process that places flood hazard mitigation in a broader community context. In particular, the Squamish IFHMP seeks to accommodate community objectives in terms of development and environmental protection.

SLR projections suggest that present-day challenges will increase over time, particularly for downtown Squamish. Areas of downtown below 2 m geodetic could be below mean sea level by Year 2200. These challenges will necessitate some difficult decisions about the future of downtown and other coastal areas.

The solutions discussed in the current IFHMP focus on the Year 2100 planning horizon and will cost tens of millions of dollars to implement. Longer-term solutions will be even more costly. To maximize the efficiency of the District's flood protection investments, strategic designs and land acquisition decisions should consider the possibility of upgrades beyond the Year 2100 horizon.

The current IFHMP marks a significant advance in the District's approach to flood hazard management and is only the beginning of a much longer conversation for the local community. As such, respecting and protecting the community's existing and proposed development is considered the highest priority. Based on this conclusion, a strategy of **Protect** is recommended as the primary flood mitigation strategy for the community's connected coastal flood hazard areas.

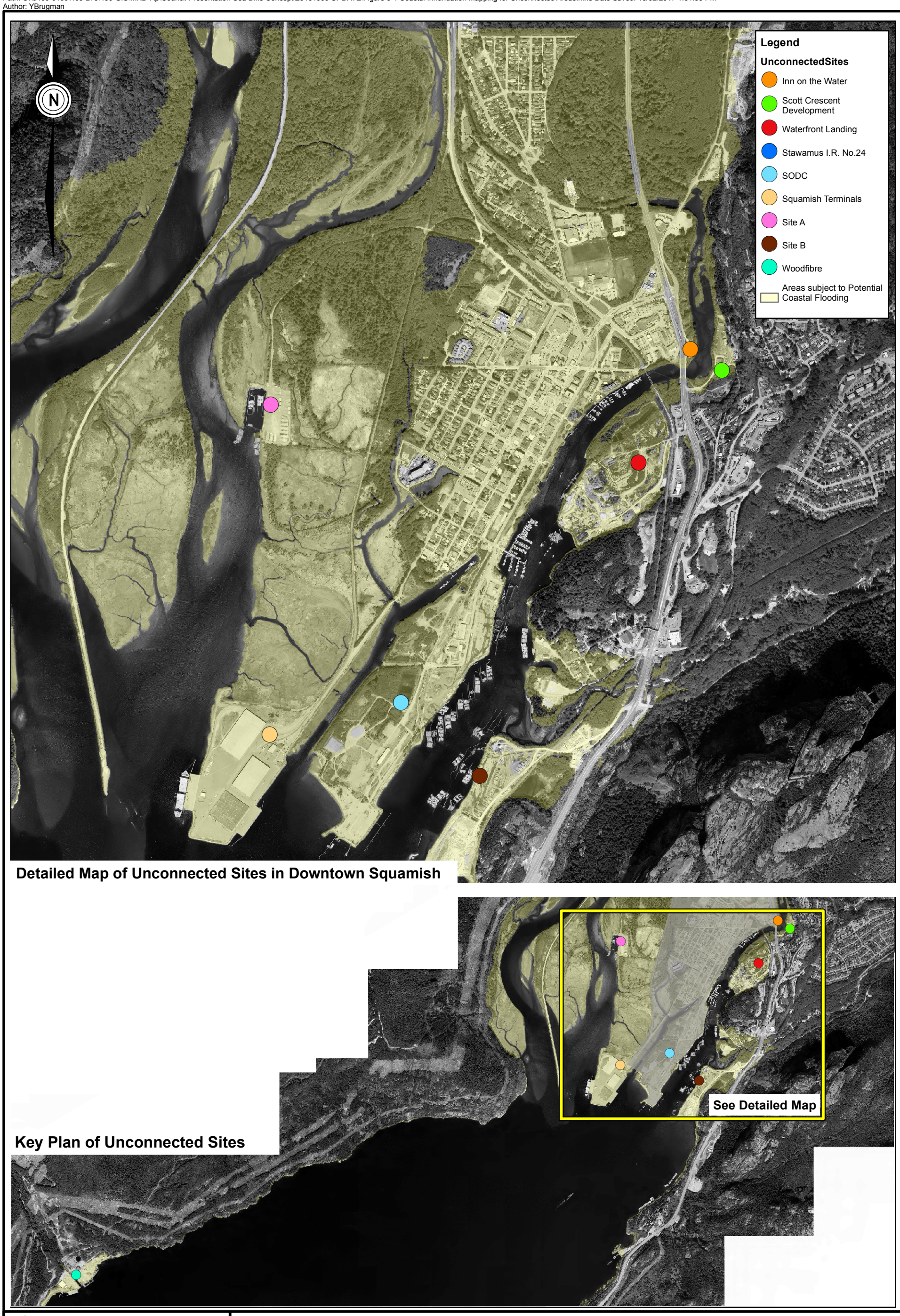
The primary strategy of **Protect** is complemented by secondary measures to **Accommodate** flood hazards, particularly through the establishment of land use restrictions, designated floodways, appropriate Flood Construction Levels (FCLs), and the provision of restrictive covenants to limit District liability. FCLs for the connected coastal floodplain will ultimately address both coastal and river dike breach flood hazards, and were defined during the dike breach modelling phase of this IFHMP.

Finally, KWL recommends that the District adopt a tertiary strategy of strategic **Managed Retreat**, whereby essential infrastructure and lifeline facilities are relocated out of the coastal floodplain as they reach the end of their development life cycle. Examples of the facilities that might qualify for Managed Retreat designation include:

- facilities that provide direct assistance to the public during emergencies (e.g., fire halls, medical facilities, and municipal operations yards);
- facilities that are essential to situation management and response co-ordination during emergency situations (e.g., Municipal Hall and local Emergency Operations Centres);
- facilities where inundation could result in direct harm to the public or the environment (e.g., chemical storage facilities); and/or
- facilities providing essential services that would be offline for an extended period if inundated (e.g., electrical substations).

A prioritized three-part strategy of **Protect – Accommodate – Managed Retreat** balances existing and future objectives, and is considered the most appropriate strategy given this IFHMP's focus on the Year 2100 planning horizon.

Path: O:\0400-0499\463-278\430-GIS\MXD-Rp\Council Presentation Sea Dike Concept\20151009 UPDATE\Figure 3-1 Coastal Innundation Mapping for Unconnected Areas.mxd Date Saved: 15/02/2017 1:51:53 PM
Author: YBrugman



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Potential Development Sites in Unconnected Floodplain Areas

Figure 3-1

4. Coastal Flood Protection Alternatives

The most significant element of the District's coastal flood hazard mitigation strategy is the coastal flood protection perimeter. To protect downtown against the Year 2100 200-year return period coastal flood event, the District will require a sea dike with a crest elevation as high as several metres above existing grade. The footprint associated with this structure will be significant, as will its impacts for adjacent development. At the same time, a sea dike perimeter presents an opportunity to develop community amenities by reconnecting people to the environment as part of the District's trail network.

Establishing a plan for a sea dike has broad community implications including considerations related to growth management, transportation, development regulation, land use management, environmental protection, emergency response planning and long term financial planning.

Like any other civil infrastructure, structural flood protection works like sea dikes are most cost-effective when implemented as part of development or redevelopment activities. Consequently, there are many benefits in establishing a long-term vision and plan for the sea dike as part of the IFHMP, including opportunistically acquiring land tenure, making provision for the sea dike with new infrastructure projects to facilitate its ultimate construction, and leveraging upgrades or funding contributions through new development.

IFHMP Reaches

The Year 2100 coastal flood protection perimeter starts at the Squamish River dike near Squamish Nation Yekwaupsum I.R. No. 18, extends around downtown Squamish and up the Mamquam Blind Channel, and ties into high ground on the east side of Mamquam Blind Channel. The length of this perimeter is about 7 km. The IFHMP Background Report (KWL, 2017) notes that there are currently no standard flood protection works along this alignment.

Key decision points include alignment and shoreline treatment along the perimeter. The length of the route, the diverse local constraints, and the range of options available all add complexity to the selection process. It is possible to vary the sea dike configuration to suit local constraints; however, this flexibility must be balanced against the ease and cost of initial construction, ongoing operation and maintenance, repair, upgrading and eventual replacement.

The IFHMP technical team concluded that a reach-by-reach discussion was the most effective way to assess coastal flood protection alternatives. This approach divides the long coastal perimeter surrounding downtown into five independent reaches to simplify analysis and evaluation. Alignment options for each reach are documented as part of the Public Open House No. 1 report (Appendix A) and summarized below. A summary of the alignment options is shown in Figure 4-1. Each option was compared against the present-day or "status quo" standard of protection.

Reach 1: CN Rail Yards

Reach 1 starts at the Squamish River Dike just south of Yekwaupsum I.R No. 18 and extends south along Government Road to the first CN Rail Crossing near Dentville. This reach is intended to protect the employment and industrial lands (including the CN Rail Yards) and residential neighbourhoods in the area. Alignment options for Reach 1 include:

- Option 1A: Spit Access to Government Road; and
- Option 1B: Government Road.

No hybrid options were considered for Reach 1.

Reach 2: Squamish Estuary

Reach 2 connects south from the intersection of the CN mainline and Squamish Terminals spur line to the intersection of the proposed sea dike with 3rd Avenue. This is the main reach protecting Downtown Squamish from the westward side. Alignment options for Reach 2 include:

- Option 2A: 7th Avenue Connector;
- Option 2B: Bailey Street and Town Dike;
- Hybrid Option 2H1: connecting Options 2A and 2B at Winnipeg Street;
- Hybrid Option 2H2: connecting Options 2A and 2B at Main Street; and
- Hybrid Option 2H3: connecting Options 2A and 2B at the 6th Avenue spur dike.

Reach 3: Cattermole Slough

Reach 3 connects the south end of Reach 2 at 3rd Avenue across (or around) the Oceanfront Peninsula lands to the west end of Vancouver Street near the Mamquam Blind Channel. Alignment options for Reach 3 include:

- Option 3A: 3rd Avenue / Town Dike;
- Option 3B: 3rd Avenue / Squamish Oceanfront Development Lands; and
- Hybrid Option 3H1: Cattermole Slough Crossing from 3rd Avenue to Squamish Oceanfront lands.

Reach 4: Lower Mamquam Blind Channel

Reach 4 provides protection along the Mamquam Blind Channel from Vancouver Street to Highway 99. Alignment options for Reach 4 include:

- Option 4A: Lower Mamquam Blind Channel Foreshore;
- Option 4B: Vancouver Street flood gates / storm surge barrier; and
- Option 4C: Loggers Lane.

No hybrid options were considered for Reach 4. It may be possible to revise the alignment of Option 4B to extend along Loggers Lane for a short distance north of Vancouver Street.

Reach 5: Upper Mamquam Blind Channel

Reach 5 begins at Highway 99 and extends past the Squamish Adventure Centre and across Upper Mamquam Blind Channel to meet high ground at the south end of Smoke Bluffs. Alignment options for Reach 5 include:

- Option 5A: Upper Mamquam Blind Channel Foreshore;
- Option 5B: Highway 99;
- Option 5C: Loggers Lane;
- Hybrid Option 5H1: connecting options 5A and 5B north of Inn on the Water;
- Hybrid Option 5H2: connecting options 5B and 5C at the Highway 99 / Loggers Lane intersection; and
- Hybrid Option 5H3: combining hybrid options 5H1 and 5H2 to follow option 5A around Inn on the Water, option 5B from Inn on the Water to Loggers Lane, and option 5C from Highway 99 to Smoke Bluffs.

Path: O:\0400-0499\463-278\430-GIS\MXD-Rp\Council Presentation Sea Dike Concept\20151009 UPDATE\Figure 4-1 Coastal Flood Protection Options.mxd Date Saved: 15/02/2017 1:53:47 PM
Author: YBrugman

Legend

- Existing Tide Gate
- Existing Floodbox
- Existing Dike
- Railway
- Road
- Proposed Pump Station
- Proposed Tide Gate
- Site A
- Site B

Preliminary Coastal Flood Protection Alignment Options

By Reach

- Reach 1
- Reach 2
- Reach 3
- Reach 4
- Reach 5

Limits of Preliminary Coastal Defence Reaches

Reach 1 - Squamish River Dike to Crescent Slough
Reach 2 - Crescent Slough to 3rd Avenue
Reach 3 - 3rd Avenue to SODC lands
Reach 4 - SODC lands to Highway 99
Reach 5 - Highway 99 to Smoke Bluffs

Squamish Nation
Yekwaupsum I.R. No. 18

Squamish River Dike

REACH 1

Hwy 99 North to Whistler

N

2B

2B

Conservation Area

5H2

REACH 5

5H3

5H1

Town Dike

2H1

2H1

4A,C

REACH 2

Downtown Squamish

2H2

2H2

2H3

2H3

Main St. Pond

Bridge Pond

REACH 4

Squamish River Training Berm

3rd Avenue Tide Gates

New Road Bridge w/ Capacity for Future Flood Barrier Retrofit

SQUAMISH RIVER

CRESCENT SLOUGH

3A

3H1

CATTERMOLE SLOUGH

SODC Lands

Squamish Nation
Stawamus I.R. No. 24

3B

REACH 3

MAMQUAM BLIND CHANNEL

Squamish Terminals

SN Stawamus River Dike

Hwy 99 South to Vancouver

HOWE SOUND

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Coastal Flood Risk Mitigation Options

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Date August, 2017

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Reaches for Upgrading Downtown Squamish Coastal Flood Protection Works

Figure 4-1

5. Evaluation Criteria for Coastal Flood Protection

Five categories of evaluation criteria were selected to encompass a broad range of impacts associated with implementation and operation of the proposed flood protection works. The IFHMP technical team applied a subjective scoring system based on expert judgement to rate each alternative for all criteria and provide an overall score for each category. The overall category evaluations were shared with stakeholders in draft form as input for consultation and community engagement discussions. The final recommendations draw heavily on both the results of the evaluation and the detailed understanding of issues achieved by working through the evaluation process.

The five evaluation categories are described as follows:

1. **Natural:** includes aquatic biota, terrestrial biota & vegetation, water & air quality, footprint of new works and enhancement opportunities.
2. **Economic:** includes flood protection benefits, environmental compensation costs, long-term employment opportunities, capital cost, O&M costs and funding opportunities (cost sharing).
3. **Social / cultural:** includes traditional land use / rights and title, public safety, public consultation, archaeological impacts and future recreation opportunities.
4. **Political / planning:** includes property and access, land tenure / statutory right of way, policy alignment, permit challenges, development impacts, transportation implications and emergency plan implications (e.g., dike closures).
5. **Technical:** includes construction logistics, geometry constraints, project complexity, implementation opportunities, navigation, internal drainage, upstream dike failure, seismic performance, sea level rise adaptability, operation and maintenance (O&M), high water response, and redundancy.

The technical team's detailed evaluation matrix is provided Appendix B. A reach-by-reach summary showing results at the category level is included in Appendix A as part of the community engagement materials.

Figure 5-1 summarizes the overall results for each reach. In some cases, the technical evaluation process was not able to identify a clear overall preference and the balanced evaluation was carried forward throughout the community engagement phase. Five colour-coded levels of preference are used with dark green as the most preferable alternative (or least negative impact) and orange as the least preferable alternative (or most negative impact). "Show stopper" results are shown with a maroon colour and indicate that one or more constraints make an option infeasible.

Figure 5-1: Overall Evaluation by Reach for District of Squamish Coastal Flood Protection Alternatives

6. Community Engagement on Coastal Flood Protection

The District undertook the following community engagement and consultation steps as part of the coastal flood protection options assessment:

- TWG meeting #2 (September 24, 2014);
- Public Open House (October 23, 2014);
- Presentation to District of Squamish Community Development Committee (February 3, 2015);
- Presentation to Squamish Nation Chiefs and Council (February 18, 2015);
- Presentation to Squamish Estuary Management Committee (February 19, 2015);
- Squamish Nation Workshop (March 12, 2015);
- Presentation to District of Squamish Committee of the Whole (April 14, 2015);
- Discussion by District of Squamish Council (April 21, 2015);
- Presentation to District of Squamish Council (May 12, 2015);
- Presentation to District of Squamish Committee of the Whole (June 9, 2015);
- Discussion by District of Squamish Council (June 16, 2015);
- Final presentation to District of Squamish Committee of the Whole (September 29, 2015);
- Final adoption by District of Squamish Council (October 6, 2015); and
- Ongoing opportunities to comment provided through the District's IFHMP website.

Recommendations from District staff (based on an early draft of this report) were initially endorsed by District Mayor and Council at a meeting on April 14, 2015. The TWG was advised of the final outcome of discussions in a follow-up meeting on April 20, 2015. Subsequent council presentations and discussions amended the details of the strategy and resulted in the final version presented herein.

Outcomes from the TWG, public, Squamish Nation and internal District discussions are summarized individually below.

6.1 Technical Working Group Meeting #2

An initial suite of coastal flood protection alignment options was presented at TWG Meeting #2 on September 24, 2014. All five reaches were discussed individually, along with the potential for one of three shoreline treatments (GreenShores™, riprap, or vertical seawall) at each location. The meeting discussions also addressed the proposed flood protection strategy, confirming "Protect" as the primary focus but also emphasizing the need for complementary measures.

Key issues raised during the TWG discussion are summarized below.

- Ideally, the District would look at relocating key buildings outside the flood hazard area as major upgrades to those buildings are required.
- The future sea dike will need to meet structural and seismic standards. Ground improvement is expected to be required for most, if not all, of the coastal flood protection perimeter.

- It is not possible to incorporate the existing Squamish River Training Berm as part of the coastal flood protection perimeter because of environmental considerations within the Squamish River estuary, Skwelwil'em Squamish Estuary Wildlife Management Area, and Crescent Slough. However, if the structure is ultimately decommissioned, it could provide a source of material for construction.
- Coastal flood protection decisions made for this IFHMP will rely on the wave-sheltering effects of Squamish Terminals and the Squamish River Training Berm. The long-term future of these structures is yet to be determined.
- The provincial Inspector of Dikes would prefer that dikes not also serve as public roads; however, there are numerous examples of this around the province including within Squamish.
- Several "closure points" will be required where the sea dike crosses existing railway grades. Locations will be determined by the final sea dike alignment. Protocols for addressing "closure points" as part of flood response efforts must be developed and documented appropriately in the District's Emergency Response Plan.

6.2 Public Open House

The District hosted a public open house at the Squamish Adventure Centre on October 23, 2014. Approximately 70 members of the community attended and were invited to contribute feedback through a number of consultative tools. The public's response is summarized in the October 23 ,2014 Open House Documentation report attached as Appendix A.

Key themes identified from the Open House are outlined below.

- Over 90% of respondents indicated that they were concerned about risks to the Squamish community from Sea Level Rise and coastal flooding.
- About 30% of respondents indicated that they were concerned about risks to the Squamish community from a tsunami.
- Nearly 80% of respondents felt that environmental considerations were "very important" when evaluating flood protection options. In contrast, 20-30% of respondents assigned the same degree of importance to economic (cost) and social / cultural considerations.
- Over 80% of respondents supported the idea of planning for coastal flood hazards at the Year 2100 horizon. Only 4% of respondents felt that this target was not appropriate.
- 75% of respondents said that the District should consider "Avoid" or "Retreat" elements as part of a comprehensive coastal flood hazard mitigation strategy.
- Many attendees agreed that a sea dike along the 7th Avenue Connector alignment (Option 2A) made sense from a flood protection perspective but expressed concerns over the potential environmental impacts of constructing a sea dike within the Squamish River estuary.
- Attendees generally agreed that the Squamish Oceanfront Development lands should be considered an "unconnected" floodplain site and not be part of the coastal flood protection perimeter.
- The idea of a large floodgate structure in Reach 4 appealed to many attendees, particularly if it could be associated with a new bridge crossing. Attendees clearly linked the transportation issues associated with a new bridge in Reach 4 with the need for the 7th Avenue Connector in Reach 2.
- Some attendees expressed concern about whether the community was receiving enough financial support from senior governments for flood protection initiatives.

6.3 District of Squamish Internal Consultation

The District's IFHMP team discussed the proposed alignments with other District staff responsible for planning, engineering, operations, and the environment. Staff then prepared a detailed Report to Council that was presented and discussed at the February 3, 2015 meeting of the District's Community Development Committee. The Report to Council is included as Appendix C.

Key issues raised during the District's internal consultations are summarized as follows:

- District LiDAR indicates that the elevation of the existing mainline railway tracks at the CN North Yards is generally sufficient to stop Reach 1 from inundating downtown until SLR exceeds 1 m. A sea dike is still required at the Year 2100 horizon to prevent localized flooding of areas west of the CN Rail mainline.
- Documentation indicates that BC Rail (now CN Rail) was previously approached regarding use of the railway corridor to Squamish Terminals as a formal sea dike. The District has attempted to engage CN Rail as an active stakeholder for this IFHMP; however, no response was received.
- Option 1B (Government Road) maximizes habitat connectivity for the existing wildlife area.
- Option 2A (7th Avenue Connector) could be contained within the existing 60 m wide transportation corridor designated in the Squamish Estuary Management Plan, and need not encroach into the Skwelwil'em Squamish Estuary Wildlife Management Area.
- Option 2A (7th Avenue Connector) makes sense if the 7th Avenue truck route is constructed. However, the significant costs and environmental encroachment into the estuary make it unlikely that Option 2A would be preferred if the truck route does not proceed.
- Option 2B (Town Dike) would encroach into the existing Main Street Slough and may require some private property acquisition. The existing Town Dike would need to be reconstructed and significantly expanded to meet current design standards.
- Selection of Option 2B (Town Dike) could affect the long-term viability of the Bridge Pond as a stormwater detention facility.
- SLR is expected to necessitate a downtown drainage pump station. A downtown pump station will be required sooner if Option 2B (Town Dike) is selected and the Bridge Pond is phased out of the District's long-term stormwater management plans.
- There is likely to be significant community interest in the decision for Reach 2. It will be very difficult to make an informed decision for this reach before the District's truck routing study is completed.
- Option 3A (along the west side and north end of Cattermole Slough) is the most logical choice for Reach 3. A vertical seawall should be considered for the portion of this alignment that directly fronts Cattermole Slough to provide the same long-term re-development opportunities as are available along the west side of the Mamquam Blind Channel.
- Detailing of the sea dike configuration and alignment near the intersection of Vancouver Street and Loggers Lane will be sensitive to redevelopment activities. Additional consultation with affected property owners will be required to ensure an equitable solution.
- Most of Option 4A could be implemented as part of progressive redevelopment along the west foreshore of the Mamquam Blind Channel. A vertical seawall along the Option 4A alignment is compatible with current plans for the Mireau development.

- The flood gates of Option 4B comprise an active approach to flood hazard mitigation, since they must be mechanically closed to provide flood protection. Active measures are considered less reliable than properly-maintained passive measures such as diking.
- While combining Option 4B flood gates with a bridge should be technically feasible, the advantages are not expected to be sufficient to offset the high capital costs.
- Navigable flood gates spanning the Mamquam Blind Channel (Option 4B) would be of a scale and type not seen previously in BC. Operation, maintenance, and repair would necessitate an entirely new skill set that would in turn require significant ongoing technical and financial commitment from the District. In contrast, other Reach 4 options can be integrated into the existing river dike operation and maintenance program.
- Option 4B would still require "secondary" diking along the Mamquam Blind Channel foreshore to minimize the frequency of flood gate closures. Either Option 4A or 4C would result in dikes that could serve as secondary protection if Option 4B were revisited to manage SLR beyond Year 2100.
- Projections for 1 m SLR by Year 2100 suggest that the existing pedestrian underpass at Highway 99 would be inundated from time to time. The District should review long-term plans for pedestrian and bicycle circulation to optimize compatibility with coastal flood protection works.
- Foreshore flood protection extending around Rose Park should be considered the least desirable option for Reach 5 due to the costs and limited flood protection benefits. As a result, Inn on the Water would be considered as an "unconnected" floodplain area.
- The coastal flood protection perimeter provides a good opportunity for an extension of the recreational trail network around the business park.
- Triggers should be identified to ensure that existing works are upgraded efficiently and on an as-needed basis.
- Any implementation plan must consider both current and future risk (hazards and consequences) as well as the existing level of protection, financial capability, and the actual rates of SLR and community re-development.
- Updated FCLs will be required for the coastal floodplain area to address the combination of dike breach and coastal flood hazards.

6.4 Squamish Nation Input

District representatives met with the Squamish Nation on two occasions to discuss the proposed coastal flood protection options: a meeting of Squamish Nation Chiefs and Council on February 18, 2015 and a subsequent workshop on March 12, 2015. Key input from the Squamish Nation is summarized below:

- The IFHMP process does not meet the requirements for formal First Nations consultation. Formal consultation is not required at this time but is expected to occur as new sections of dike are implemented.
- Squamish Nation activities historically included a much more intensive use of the estuary area than occurs at present. Archaeological assessment and monitoring will be required for all of the proposed alignments.
- Squamish Nation representatives support maximizing connectivity of habitat within the Skwelwil'em estuary wildlife management area in Reach 1.

- Improved access to Squamish Nation Site 'A' may be achieved if Option 2A (7th Avenue Connector) is selected; however, many Nation members are expected to oppose this option on environmental grounds. Squamish Nation councillors expect to be subject to the same conflicting interests as the District when it comes to economic and environmental trade-offs for Reach 2.
- Squamish Nation representatives responded favourably to the idea of deferring a decision on Reach 2 until the District completes its truck routing study.
- The District's coastal flood protection program must not provide a transfer of risk to Stawamus I.R. No. 24 or Squamish Nation interest lands (e.g., Site 'A' or Site 'B'). This should be noted in the IFHMP deliverables.

7. Preferred Coastal Flood Protection Alignments

KWL and District staff worked together to review feedback from the community engagement and consultation process and develop preferred alignments for future coastal flood protection works. The proposed alignments will not result in any transfer of coastal flood risk to the Squamish Nation's lands at Stawamus I.R. No. 24, Site 'A' or Site 'B'. The preferred sea dike concept and alignment is shown in Figure 7-1 summarized in Table 7-1 below.

Of particular note, additional feedback was received from the Sea to Sky Forestry Centre Society after the planned engagement process concluded and alignment options and recommendations had been presented to District Council. This additional feedback led to a potential new hybrid being identified for Reach 5. The new hybrid follows Highway 99 Option 5B north to the Loggers Lane intersection, then transitions to Rose Park foreshore Option 5A to encompass the existing parking lot and potential forestry centre. After further review and discussion with District Council, this new hybrid superceded the previously-recommended Loggers Lane alignment as the preferred alignment for the north section of Reach 5. A summary of post-consultation Reach 5 considerations is included in Appendix D and Appendix F.

Additional feedback received from District Council in September 2015 asked staff to explore any efficiencies that could be realized by integrating SODC flood and erosion protection works into the primary sea dike perimeter. District plans for the Oceanfront Peninsula (defined as areas south of the proposed sea dike between Design Points O and P on Figure 7-1) call for the land to be raised as "high ground", avoiding the need for dike protection. The BC Inspector of Dikes has confirmed that the future ground raised and protected to meet Year 2100 flood levels would not be considered a dike. However, planning measures should incorporate an allowance for future diking to manage sea level rise impacts beyond the 1 m Year 2100 sea level rise allowance.

The presence of future "high ground" on the Oceanfront Peninsula provides an opportunity to simplify and reduce the length of the proposed sea dike by tying into high ground on either side of Loggers Lane. The District will further explore the dike tie-in with future high ground at the Oceanfront Peninsula as part of a dedicated future study of the local area.

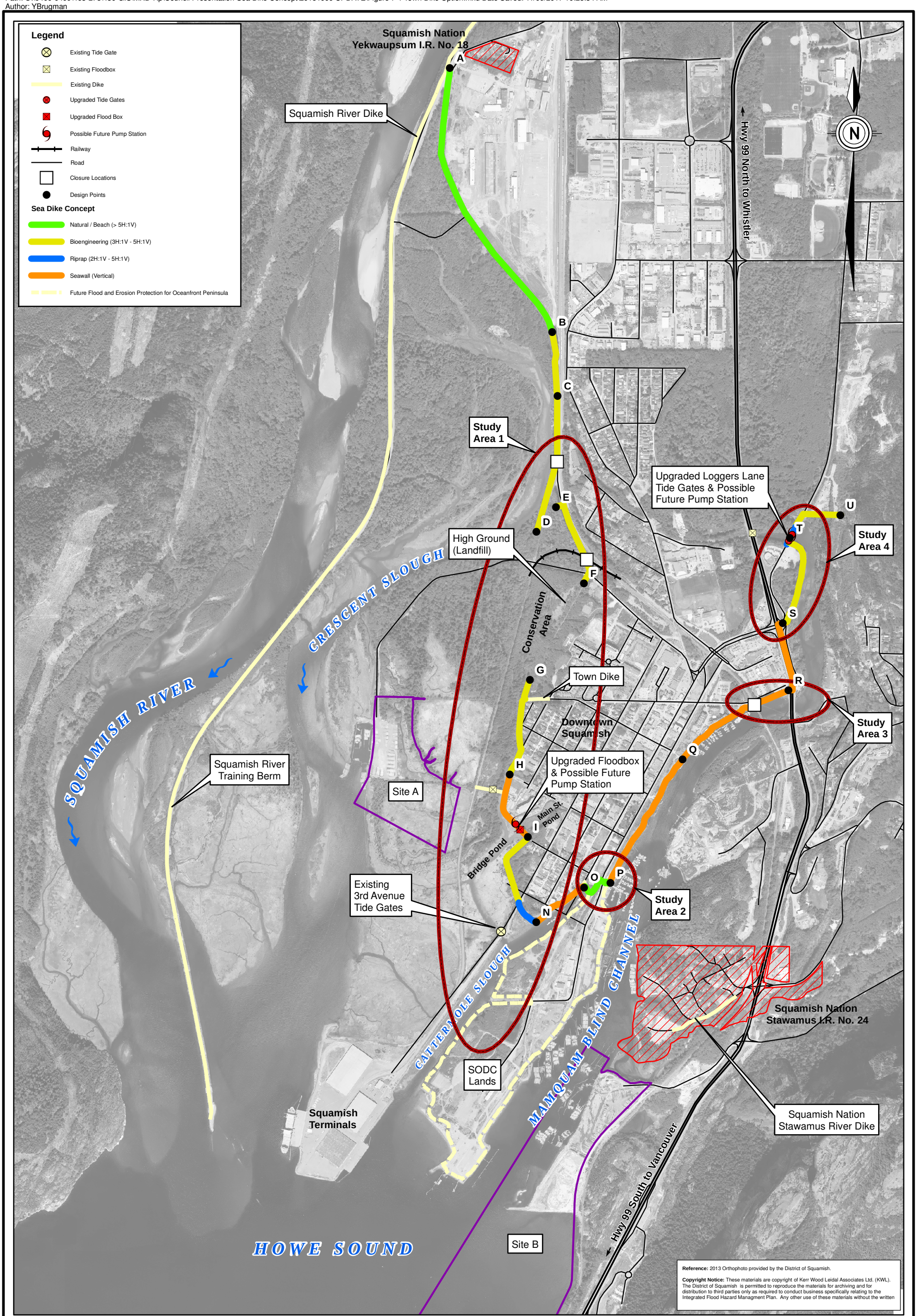
The District completed its downtown truck routing study in early 2017. The truck routing study concluded that the 7th Avenue Connector is "not recommended for future consideration". As a result, the Town Dike (Option 2B) becomes the preferred alignment for Reach 2 and is likely to proceed unless planning, site investigation and/or the Downtown ISMP identify new and significant challenges (e.g., stormwater management issues associated with replacing Bridge Pond). The Town Dike option is shown as the preferred alignment in Figure 7-1. The alternate concept and alignment for the 7th Avenue connector route (Option 2A) is provided for record purposes as Figure 7-2.

Table 7-1: Preferred Coastal Flood Protection Alignments

Reach	Recommendation	Outstanding Issues
Reach 1	• Follow Government Rd. and Bailey St. south from Squamish River dike to CN Squamish Terminals spur crossing.	• None
Reach 2	• Preferred options include Option 2A (7th Avenue Connector) and 2B (Town Dike). KWL has provided two corresponding figures, each showing one of the two potential options for Reach 2. • Adopt Option 2A if the 7th Avenue Connector truck route is selected in the District's upcoming truck routing study. • If a different truck route is selected, consider adopting Option 2B (Town Dike alignment). • The 7th Avenue Connector will not proceed in the short or medium term, making the Town Dike the preferred option. • The alignment will be confirmed through future planning and site investigation. Until the alignment is confirmed, the Town Dike reach remains designated "Study Area #1" on the KWL figures.	• The District's 2017 truck routing study is assumed to have incorporated the important linkages between the 7th Avenue Connector truck route and preferred coastal flood protection alignment (i.e., by incorporating the flood protection benefits and costs into the comparison of alternatives). • A similar process could apply for the upcoming Integrated Stormwater Management Plan (ISMP) for downtown Squamish. The ISMP must define the long-term future of Bridge Pond as a stormwater detention facility, and what measures may be required to secure that future if the District were to adopt coastal flood protection Option 2B (Town Dike). • Further consultation with CN Rail about the future of the existing railway berm would be appropriate prior to commencing any design work, regardless of which option is chosen.
Reach 3	• Follow 3rd Avenue north to the existing Town Dike alignment (if Option 2A is chosen). • Follow the existing Town Dike alignment to the head of Cattermole Slough before traversing private properties and Loggers Lane to reach the Mamquam Blind Channel. • Reduce length of sea dike and simplify alignment by tying into future broadcast fill ("high ground") on Oceanfront Peninsula.	• Design will affect development and re-development opportunities (e.g., SODC access roads, boat ramp at Squamish Yacht Club). • Further consultation regarding alignment and integration for this local area would be appropriate. This is the focus of "Study Area #2" shown on the preferred alignment figures. • Future raising of lands on Oceanfront Peninsula will provide an opportunity to tie the dike into "high ground". Future diking (Year 2200 SLR) may eventually become part of the District's sea dike.

Reach	Recommendation	Outstanding Issues
Reach 4	• Follow the west foreshore of Mamquam Blind Channel north from approximately Vancouver Street to Highway 99.	• The existing bicycle / pedestrian trail crosses beneath Highway 99 via a dedicated underpass. Analysis suggests the underpass may flood during future high water events. • Design of the flood protection works should accommodate the District's long-term plans for bicycle / pedestrian traffic flow between the railway bridge and Highway 99. • This is the focus of "Study Area #3" shown on the preferred alignment figures.
Reach 5	• Allow the existing grade of Highway 99 to form the dike from the north end of the Mamquam Blind Channel bridge to Loggers Lane. • From Highway 99 at Loggers Lane, extend the sea dike out to the foreshore of Rose Park. Follow the foreshore north to Loggers Lane at Upper Mamquam Blind Channel (UMBC). • Raise Loggers Lane across UMBC so that the crossing forms part of the dike. Upgrade the existing floodboxes and tide gates. • Follow the north riparian margin of Mamquam Blind Channel west from Loggers Lane and tie into high ground at Smoke Bluffs.	• Upgrades to the crossing of Upper Mamquam Blind Channel should consider provisions for accommodating dike breach outflow. • UMBC crossing upgrades should also include measures to accommodate a future pump station, if required by the upcoming ISMP. • Regrading of Loggers Lane will need to extend considerably beyond where the road forms the dike to maintain trafficable transitions. • The above considerations are the focus of "Study Area #4" on Figure 7-1 and Figure 7-2. • Development proposals for the District-owned parking lot between Loggers Lane and UMBC should trigger assessment of Study Area #4. • Further assessment should incorporate cost estimates and environmental impacts. • Consultation with the Ministry of Transportation and Infrastructure should include incorporation of Highway 99 into the diking system. • Any redevelopment proposals for Inn on the Water should be treated as "unconnected" floodplain areas.

Path: O:\0400-0499\463-278\430-GIS\MXD-Rp\Council Presentation Sea Dike Concept\20151009 UPDATE\Figure 7-1 Town Dike Option.mxd Date Saved: 11/09/2017 10:25:34 AM
Author: YBrugman



KERR WOOD LEIDAL
consulting engineers

District of Squamish - Integrated Flood Hazard Management Plan
Coastal Flood Risk Mitigation Options

Project No.	Date
463-278	September, 2017

400 0 400 (m)

Preferred Sea Dike Concept
Town Dike Option

Figure 7-1

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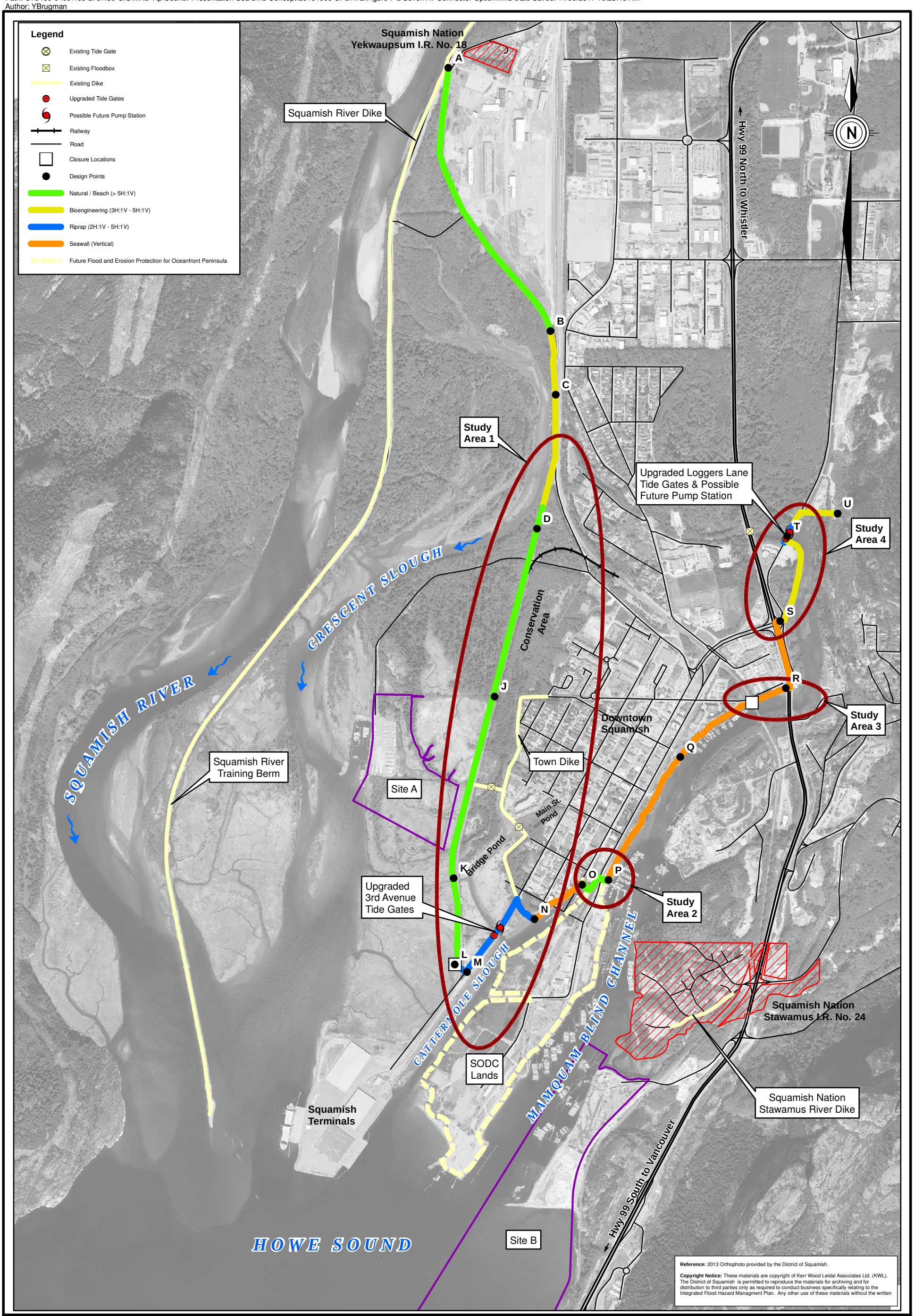

KERR WOOD LEIDAL
consulting engineers

District of Squamish - Integrated Flood Hazard Management Plan
Coastal Flood Risk Mitigation Options

Project No.	Date
463-278	September, 2017

400 0 400 (m)

Alternate Sea Dike Concept
7th Ave Connector Option

Figure 7-2

8. Preliminary Design Assumptions

Table 8-1 identifies key preliminary design assumptions made to support dike breach modelling and other IFHMP initiatives. The dike breach modelling and downtown FCLs should be reviewed if the District adopts different assumptions. The design assumptions below reflect Year 2100 coastal flood values and wave analyses presented in the IFHMP Background Report (KWL, 2017).

Design assumptions and results are shown relative to the "Design Points" labelled A through U on Figure 7-1 and Figure 7-2. Closure points at railway crossings are also shown on the preferred alignment figures. Crucial assumptions regarding Squamish Terminals and the Squamish Spit are documented in the Background Report (KWL, 2017); some of the values in Table 8-1 could change significantly if these assumptions are varied.

Unlike river dikes, most sea dikes are designed to accommodate some amount of wave-induced overtopping. Acceptable average overtopping rates during the design event can be assessed based on the guidance available from the US Army Corps of Engineers' Coastal Engineering Manual (USACE, 2002) or the European Overtopping Manual (Pullen et al., 2007). Examples include:

- **10 L/s per lineal metre**: Low danger to trained, protected staff. May be dangerous to bikers/ pedestrians. Unsafe for driving.
- **0.1 L/s per lineal metre**: No danger to aware pedestrians who expect to get wet. Acceptable for low-speed driving.

Average overtopping rates greater than 10 L/s per lineal metre are generally dangerous. KWL considers 10 L/s/m to be an upper limit of acceptability for average overtopping rates under any exposure conditions.

An internal District report (Appendix E) reviews the IFHMP coastal design criteria and recommends an acceptable overtopping rate of 10 L/s per lineal metre. KWL is able to support this recommendation due to the conservative combination of concurrent 200-year return period wind and water level events, as well as the need to balance mitigation from coastal and dike breach hazards.

Planning-level elevations for the proposed sea dike crest based on an acceptable overtopping rate of 10 L/s/m are summarized in Table 8-1. Overtopping calculations did not allow for additional freeboard, since this would effectively reduce the expected overtopping rate. For all design points, the freeboard required to achieve an average overtopping rate of 10 L/s/m was less than or equal to the minimum 0.6 m freeboard above static water level required by the BC Dike Design and Construction Guide (BC MWLAP, 2003). A minimum 0.6 m freeboard has been applied at all locations.

The preliminary dike crest elevations provided in Table 8-1 are based on wave effects derived from regional wind conditions, a regional wave model, and representative nearshore bathymetry for each section of dike. All points include a minimum 0.1 m allowance for local wind setup, with a higher allowance of 0.2 m at the upstream end of Crescent Slough (Design Points A, B and C) where there is potential for a long fetch over shallow water. The resulting crest elevations are considered suitable for long term planning and the preparation of indicative cost estimates.

A Qualified Professional will need to carry out a site-specific analysis of local wind setup, nearshore wave conditions and wave / dike interaction to confirm assumptions, configuration, and local dike crest elevations as each section of dike is implemented. The District should carefully consider changes to proposed dike crest elevations in terms of their potential impact on adjacent sections of the dike as well as on FCLs for Downtown Squamish. FCLs for downtown were derived assuming a flat dike crest at the elevations provided in Table 8-1.

Table 8-1: Coastal Flood Protection Design Assumptions – 10 L/s/m Acceptable Overtopping Rate

Design Point	Allowance for Local Wind Setup (m)	Crest Elevation (m GD)	Shoreline Treatment	Waterside Dike Slope	Notes
A	0.2	4.8	vegetated	6H:1V	tie-in to river dike minimum dike height
B	0.2	4.8	bioengineered	3H:1V	start bio-engineered treatment
C	0.2	4.8	bioengineered	3H:1V	adjacent to slough
D	0.1	4.7	bioengineered	3H:1V	2A: transition to beach 2B: end foreshore dike
E	0.1	4.7	bioengineered	3H:1V	2B only north railway crossing
F	0.1	4.7	bioengineered	3H:1V	2B only tie-in to high ground
G	0.1	4.7	bioengineered	3H:1V	2B only tie-in to high ground
H	0.1	4.7	seawall	vertical	2B only start seawall at Main St
I	0.1	4.7	bioengineered	3H:1V	2B only; transition to bio-eng. treatment at Vancouver St
J	0.1	4.7	beach	6H:1V	2A only
K	0.1	4.7	beach	6H:1V	2A only
L	0.1	4.7	beach	6H:1V	2A only
M	0.1	4.7	riprap	2H:1V	2A only South end 3rd Ave dike
N	0.1	4.7	riprap	2H:1V	transition to seawall
O	0.1	4.7	seawall w/ wave return	vertical	end of seawall tie into future high ground to cross Loggers Lane
P	0.1	4.7	seawall w/ wave return	vertical	tie-in with high ground / Oceanfront Peninsula seawall
Q	0.1	4.7	seawall w/ wave return	vertical	Mireau development site
R	0.1	4.7	seawall	vertical	tie-in to existing grade at Highway 99
S	0.1	4.7	bioengineered	3H:1V	Loggers Lane at Highway 99
T	0.1	4.7	riprap	2H:1V	Loggers Lane floodbox and tide gate structure
U	0.1	4.7	bioengineered	3H:1V	tie-in at Smoke Bluffs

Note: Dike crest elevations are CGVD28 originating at geodetic benchmark GCM 9274, as described in Section 5.4 of the IFHMP Background Report (KWL (2017).

In particular, wave modelling completed for the IFHMP did not include Bridge Pond and other areas west of CN's Squamish Terminals spur track (design points E through I). In these areas, KWL arbitrarily assumed that significant wave heights would be 50% of those in the adjacent estuary. Wave analysis for Bridge Pond will be required to confirm preliminary dike crest elevations for design points E through I if the District proceeds with the preferred Option 2B (Town Dike) sea dike alignment for Reach 2.

The application of bio-engineering and/or GreenShores to protect the water side face of a sea dike is technically feasible but has not been discussed with, or accepted by, the BC Inspector of Dikes (IOD). A bio-engineered slope treatment may ultimately prove unacceptable to the IOD, or acceptable only with conditions. Conditions that could apply include geometric requirements (e.g., an overwidth dike crest and/or slopes flatter than 3H:1V) as well as limitations on acceptable techniques, types and intensities of vegetation. More conventional erosion protection (e.g., riprap revetments) can be considered for "bio-engineering" locations if the District and the Inspector of Dikes cannot reach agreement on an acceptable bioengineering approach during the detailed design process.

For conceptual design purposes, landside dike slopes (back slopes) are assumed to be 3H:1V. The landside slope of a sea dike must be designed to accommodate overtopping and will require erosion protection commensurate with the chosen overtopping rate.

As per the IFHMP Background Report, KWL anticipates that ground improvement may be necessary beneath many or most sections of the proposed sea dike to meet the BC Inspector of Dikes' criteria for seismic performance. The analysis presented herein is focussed on planning, and ground improvement requirements have not been assessed.

Sea dike implications for FCLs and internal drainage are described separately in the next section.

8.1 Sea Dike Implications for FCLs and Internal Drainage

The District's proposed sea dike creates an inescapable trade-off between challenges pertaining to Flood Construction Levels (FCLs) and internal drainage. More detail on implications for FCLs and internal drainage is provided below.

Sea Dike Implications for Downtown Flood Construction Levels

In the event of a breach along one of the upstream river dikes, the District's sea dike will force water flowing into downtown Squamish to rise until it can flow out over the sea dike into Howe Sound. Flood Construction Levels (FCLs) for the downtown area must address the potential for this "bathtub effect"; the sea dike crest elevations outlined in Table 8-1 will therefore play an integral role in determining FCLs for downtown Squamish.

The final IFHMP recommends Flood Construction Levels for downtown Squamish be established on a site-specific basis by applying the higher of two criteria:

- a single FCL applicable for all areas that is based on water flowing over the sea dike to Howe Sound during a dike breach scenario; and
- a site-specific FCL that considers the potential interaction of any overtopping flows with the proposed development (e.g., building structure) over its design life.

The first FCL criterion is proportional to the lowest crest elevation along the sea dike perimeter, while the second criterion is directly based on the adjacent sea dike elevation, configuration, wave conditions, setback, and other site-specific factors. FCLs for Option 2B (Town Dike) may be subject to revision in the unlikely event that a detailed assessment of potential wave effects within Bridge Pond result in higher

dike crest elevations. The District should identify any potential implications for downtown FCLs as part of the planning work for the sea dike along preferred Option 2B (Town Dike).

Management of Overtopping Flows

Accepting a high average overtopping rate of 10 L/s/m results in a lower dike crest elevations, which in turn results in lower FCLs for downtown Squamish. However, the District's long sea dike perimeter means that these overtopping rates can produce large overtopping volumes. This quantity of water must be managed in a manner analogous to urban stormwater planning. Overtopping flows are often concurrent with precipitation, and gravity drainage is usually not available due to the high coastal water levels.

An order-of-magnitude estimate for overtopping volume can be obtained by assuming that the average overtopping rate of 10 L/s/m will apply over an appropriate storm duration. Example calculations provided in Ausenco Sandwell's 2011 Sea Dike Guidelines assume a six-hour storm event. Assuming several hours of overtopping at the specified rates is considered too conservative for the IFHMP for the following reasons:

- Combining a 200-year return period one-hour wind storm with a 200-year extreme water level will yield a combined return period in excess of 200 years.
- The assumed overtopping rate applies to the design high water condition; however, the high-water condition is a transient value. It takes less than two hours for the largest tides to rise and fall by about 0.1 m, and approximately three hours for the largest tides to rise and fall about 0.3 m.
- Peak wind speeds used in the wave modelling represent one-hour average conditions. Lower wind speeds would act in concert with lower water levels to decrease wave heights, which would reduce overtopping rates both before and after the peak hour.
- In most locations, the sea dike crest elevation is governed by the minimum 0.6 m freeboard rather than the 10 L/s/m overtopping criteria. Expected overtopping rates would be less than 10 L/s/m in these areas.

A conservative but useful approximation of the 200-year return period overtopping volume can be obtained by treating the District's 10 L/s/m acceptable overtopping rate as constant over a peak one-hour period. This order-of-magnitude estimate can then be scaled to reflect different durations.

Assuming 10 L/s/m overtopping for a 5,500 m length from Reaches 1-4, the maximum peak-hour overtopping volume draining to Bridge Pond would be about 200,000 m^3. In comparison, a recent stormwater analysis of the Bridge Pond (EBA, 2014) identified a maximum storage volume (from pond invert to 2.6 m geodetic elevation) of about 125,000 m^3. This suggests that the volume of water overtopping the sea dike could exceed available stormwater storage capacity at Bridge Pond. With Bridge Pond located outside the District's preferred Town Dike alignment, managing the overtopping volume would become even more difficult. A new drainage pump station at Bridge Pond will likely be required in the future.

Peak-hour overtopping flows from Reach 5 have not been considered in the above calculation, since waves in Reach 5 are lower and any flows overtopping the Reach 5 dike are expected to drain to Wilson Slough rather than Bridge Pond. KWL expects that the need for pump stations at both Upper Mamquam Blind Channel and Bridge Pond will be assessed as part of upcoming Integrated Stormwater Management Plans (ISMPs). Potential overtopping flows should also be incorporated into the upcoming ISMP for South Squamish.

8.2 Long-term Redevelopment Vision

Currently, the District's Official Community Plan (OCP) provides a long-term redevelopment vision along the waterfront and recommends a "variety of interfaces with, and varying degrees of proximity to the water", including sea wall, riprap slopes, and natural bank. These "interfaces" will need to reconcile with the need for standardized and continuous flood and erosion protection works along the length of the redevelopment area. Transitions between various foreshore treatments can create potential weak spots in a flood protection system while increasing operation and maintenance (O&M) costs.

The IFHMP incorporates different flood and erosion protection considerations of the long-term redevelopment along the proposed sea dike perimeter through the implementation of floodplain policy. The policy should highlight potential areas of opportunity as well as conflict between the various development objectives. Development and recreation goals for the foreshore provide the context for the IFHMP's forthcoming flood policy and flood protection recommendations.

Development Goals

The District's OCP calls for gradual conversion of the working harbour, transportation corridor and industrial areas to a more urban, mixed-use commercial, recreational, tourist and multiple-family residential neighbourhood. The OCP specifically calls for a water-oriented development with the narrower property dimensions facing the water, and interacting with the water in a variety of ways.

Of particular note, the Marina Estates and Mireau developments represent an existing development constraint for the future of the coastal area, particularly with regard to flood hazard management.

Foreshore Goals

The current OCP envisions "continuous safe and unrestricted pedestrian access for the public along the water's edge" as part of redevelopment along Mamquam Blind Channel. The OCP specifically states that the public walkway should provide a variety of interfaces with, and varying proximity to, the water including sea wall, sea wall plus riprap, pier, pier and dock, walkway on pilings, floating walkway / dock, and natural bank.

8.3 Future Dike Cross Section and Building Setbacks

The design standard for the proposed sea dike is Year 2100 200-year return period flood conditions. It is assumed that the theoretical cross section of the sea dike has the following characteristics:

- A dike crest elevation between 5.7 and 5.8 metres geodetic, referenced to the datum identified in the Background Report (KWL, 2017);
- A dike crest width of 4 meters;
- A landside slope of 3H:1V; and
- Ability to be raised by an additional 1 m (to crest elevation of 5.7 metres or 5.8 metres) to accommodate an additional 1 m of SLR without compromising the above requirements.

The waterside treatment is expected to vary as described in Section 9, and may range from relatively flat to vertical seawall.

The minimum engineering setback required for any new structures or proposed development should be the greater of:

- setback required to protect against waves and erosion; and
- setback to allow implementation of the ultimate structural flood mitigation works (i.e., dike setback).

Additional setback considerations for environmental purposes may also apply.

Appropriate setbacks would normally be confirmed on a site-specific basis by the Qualified Professional (QP) responsible for the Flood Hazard Assessment. However, the presence of a public trail and the role of the District as operation and maintenance authority for any flood and erosion protection works suggest that a minimum allowance should be specified to guide the QP in preparing development applications.

The two classes of setback allowance and statuary rights of way are discussed below.

Wave and Erosion Setback

The 2004 Flood Hazard Area Land Use Management Guidelines prepared by the BC Ministry of Water, Land and Air Protection (now Ministry of Forests, Lands and Natural Resource Operations) include the following statement for coastal flood hazard areas within the Strait of Georgia region:

> *"Buildings should be setback 15 metres from the natural boundary of the sea."*

Allowing for sea level rise impacts, the future estimated natural boundary of the sea is estimated to be defined by the intersection of the ultimate FCL less the freeboard with the ground surface.

According to Ausenco Sandwell (2011), all new buildings that fall within the "sea level rise planning area" for a given time horizon such as the Year 2100 should be provided with a building setback. Ausenco Sandwell recommends building setback to protect from:

- wave and splash-related impacts; and
- erosion of the shoreline.

The building setback for wave and erosion protection recommended by Ausenco Sandwell (2011) is:

> *"[…] the greater of 15 m from the future Estimated Natural Boundary or a distance to where the native land elevation equals the Flood Construction Level."*

Ausenco Sandwell (2011) does not offer explicit guidance on setbacks for sites in which the shoreline will see major modifications as part of development. For the purposes of determining wave and erosion setbacks along the sea dike, KWL interprets building setbacks as being measured from the engineered top of bank (i.e., the waterside crest of fill not including erosion protection or slope retaining measures).

The wave and erosion setback should allow adequate space for the waterfront pathway (where applicable), for wave and splash impacts, and for access to repair and maintain the erosion protection works.

The IFHMP recommends a minimum wave and erosion setback of 15 m. The floodplain bylaw developed as part of the IFHMP policy implementation allows for potential exemptions on a site-by-site basis. Similar to the provincial guidelines, each case will need to demonstrate a hardship, recognizing that economic hardship alone will not be considered sufficient grounds to grant an exemption.

Dike Setback

The 2004 Flood Hazard Area Land Use Management Guidelines include the following statement for areas protected by standard dikes:

> *"Buildings should be located a minimum of 7.5 metres away from any structure for flood protection or seepage control or any dike right-of-way used for protection works. In addition, fill for floodproofing should not be placed within 7.5 metres of the inboard side of any dike right-of-way used for flood protection works."*

The standard 7.5 m setback is reflected in the 1994 FHMP, the 2003 BC Dike Design Guidelines and the 2012 APEGBC Professional Practice Guidelines for Legislated Flood Assessments.

The BC Inspector of Dikes typically defines the inboard (or landside) toe of a dike as the location where a standard dike backslope would intersect the native ground.

While 7.5 m setback from the dike toe is a well-established convention, there are examples where the developer, local authority, and provincial Inspector of Dikes have worked together to provide a site-specific exemption. The IFHMP should provide a mechanism for considering site-specific exemption requests where enforcing the full setback would create a true hardship for the landowner.

It would also be reasonable for the District to waive the setback provisions regarding floodproofing fill placed against the dike in situations where:

- the floodproofing fill is provided as part of the initial design and construction;
- floodproofing fill is geotechnically compatible with the adjacent dike fill; and
- where the composite earthfill structure (dike + floodproofing fill) has been assessed as part of the QP's flood assessment report.

The addition of floodproofing fill should not be allowed to justify encroachment of buildings or infrastructure into the standard dike cross-section (i.e., the cross-section that would be required in the absence of any floodproofing fill). In such cases, for the purposes of determining setback, a theoretical landside dike toe should be implied using the approach described below, adapted from the approach used by the Inspector of Dikes.

If a proposed development includes a foundation below the existing grade, the landside dike toe should be defined as the location where a standard 3H:1V dike backslope would intersect the grade of the subsurface foundation.

If the foundation of the proposed development is at or above the pre-existing native ground elevation, the landside dike toe should be defined as the location where a standard 3H:1V dike backslope would intersect the native ground. Pre-load and other pre-existing site fill should be neglected when defining the native ground elevation.

If any structural or geotechnical component of the dike (e.g., cable tie-back for sheetpile facing on the river or foreshore face) extends beyond the theoretical landside dike toe, setback should be measured from the landward edge of the protruding component.

For the purposes of determining setback requirements, the design and geometry of all parts of the dike (including the landside slope and any protruding structural or geotechnical components) should be based on a 200-year coastal flood with 2 m of sea level rise. With the limits of the sea dike defined for a 200-year coastal flood with 2 m sea level rise, it is reasonable to accept a reduced setback of 3.0 m.

A dike setback should also be protected on the water side of the proposed sea dike, to prevent future float homes and marina slips from interfering with future maintenance activities. The waterside dike setback should be 7.5 m and should be measured from the waterside toe of a dike cross-section designed to protect against a 200-year coastal flood with 2 m of sea level rise.

The recommended setback requirements are shown graphically in Figure 8-1 (for a sea dike with a 2H:1V riprap slope on the waterside face) and Figure 8-2 (for a sea dike with a sheetpile retaining wall).

Rights of Way

It is assumed that the District would acquire legal access to operate, maintain, repair and upgrade flood or erosion protection works as a condition of development approval under a Statutory Right-Of-Way (SROW) agreement. It would be appropriate for the SROW limits to incorporate the minimum setbacks defined above.

Because the SROW agreement will be established concurrently with conceptual design of flood protection works for 2 m of sea level rise, additional setback from the edge of the established Right-of-Way is not required. Right-of-way limits for the proposed sea dike concept are shown in Figure 8-1 and Figure 8-2.

The BC Inspector of Dikes may ask to be a signatory to a SROW agreement involving dike setbacks to ensure they will be consulted on any future changes.

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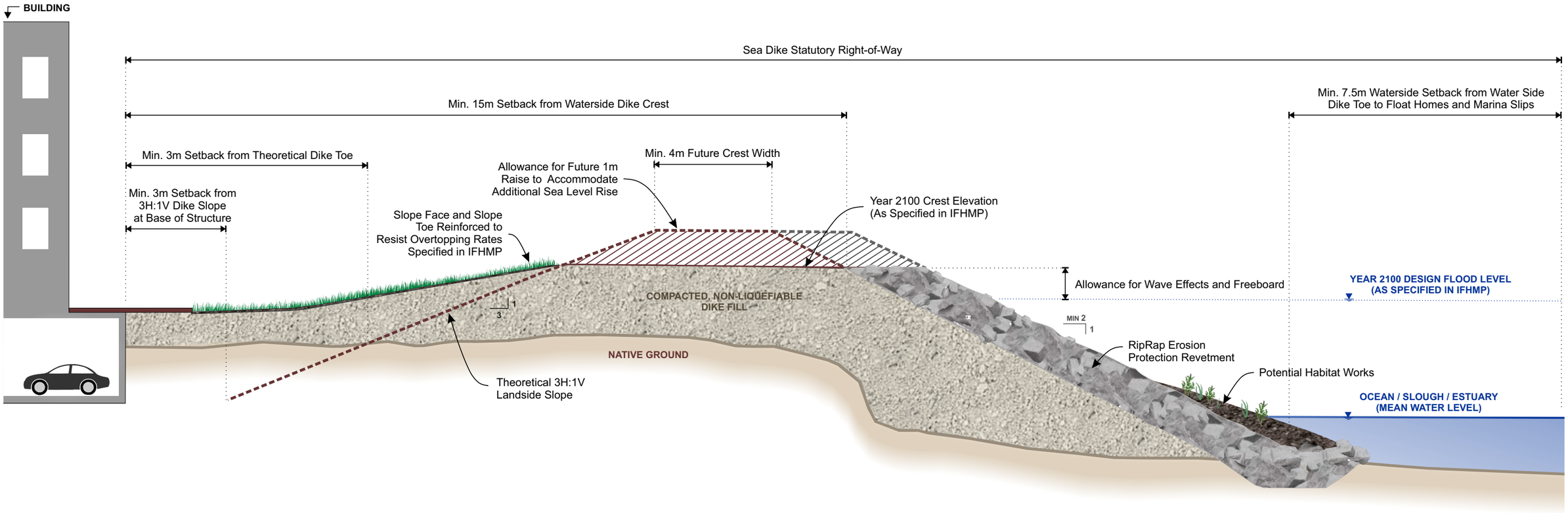

Note:

This dike section illustrates key concepts considered in developing the Squamish IFHMP. It is not intended to form the basis for design. Individual elements must be designed by a qualified professional and will be subject to regulatory review processes.

Project No. 463-278

Date September 2017

Not to Scale

Setback Requirements for Proposed Sea Dike RipRap Slope Alternative

KERR WOOD LEIDAL consulting engineers

Figure 8-1

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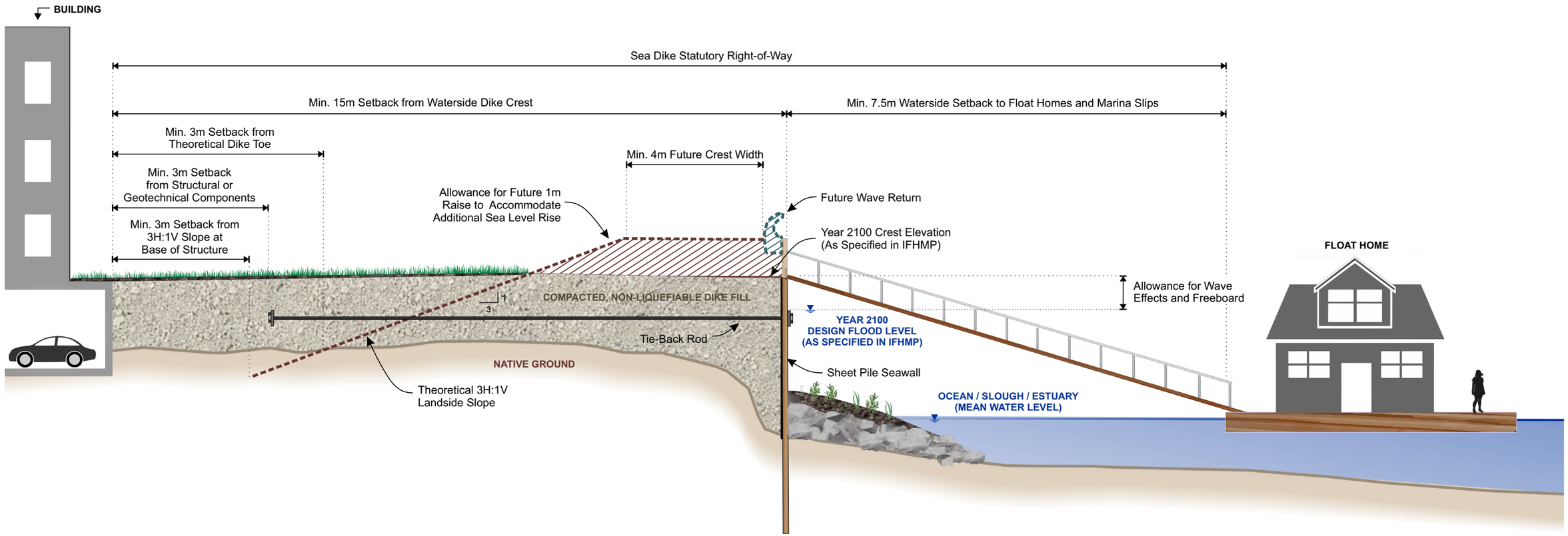

Note:

This dike section illustrates key concepts considered in developing the Squamish IFHMP. It is not intended to form the basis for design. Individual elements must be designed by a qualified professional and will be subject to regulatory review processes.

Project No. 463-278
Date September 2017
Not to Scale

Setback Requirements for Proposed Sea Dike
Sheet Pile Alternative

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Figure 8-2

9. Implementation of Coastal Flood Protection

This section provides a discussion of implementation issues for the proposed sea dike, including design considerations, prioritization and phasing of construction. Additional considerations related to an upstream dike breach are also addressed.

9.1 Design Considerations

The District may wish to offer the QP some guidance on a number of specific design issues as discussed below.

Seepage Analysis

The QP is responsible for evaluating seepage through a proposed dike as part of their flood assessment report. In situations where relief drains are required to mitigate foundation pressures or high exit gradients, this should include evaluation of environmental impacts of any saltwater interception, since this would be delivered to the stormwater system.

Minimum exit gradients should consider the findings of the 2008 dike assessment report prepared for the District by Thurber Engineering (Thurber, 2008).

Seismic Performance

The BC Inspector of Dikes has confirmed that they will apply the most recent seismic guidelines to any new sea dike constructed by or on behalf of the District (BC MFLNRO, 2013). Developers should be advised of this, and should be encouraged to contact IOD for the latest information and revisions.

IOD has also indicated that some flexibility regarding seismic performance of foreshore flood protection works may be considered if a primary dike alignment includes a significant setback from the foreshore.

Off-site Works

To avoid a transfer of risk scenario, the QP's flood assessment report should confirm that a seamless, geometrically-acceptable, equitable, and technically-sound transition of flood and erosion protection works can be achieved between the proposed development property and any adjacent property, under both existing (i.e., initial construction) and future (i.e., ultimate) conditions.

9.2 Prioritization and Phasing

As the local Diking Authority under the Dike Maintenance Act, the District has the ultimate responsibility for implementing, operating and maintaining the recommended coastal flood protection works. Where the opportunity exists, the District may wish to have developers fund and construct sections of the works.

Prioritization and phasing of elements of the proposed coastal flood defences must be considered among the proposed works themselves, among District-wide flood protection initiatives, and among the full range of other District funding priorities.

With a few notable exceptions, most of the District's river dikes provide a standard of protection that meets or exceeds the 200-year return period flood condition. However, Figure 2-1 demonstrates that considerable areas of downtown are currently at risk of flooding from coastal flood events at return periods considerably less than 200 years. More detailed modelling should be undertaken to better understand the vulnerabilities and develop appropriate emergency response plans (e.g., deployment of

equipment and personnel to effect temporary closures). The IFHMP adopts the 3.3 m elevation recommended in the 1994 Flood Hazard Management Plan as a planning threshold for temporary closures.

Priorities regarding permanent coastal flood protection works are shown in Table 9-1 below. These priorities have been integrated into a more complete list of prioritized District-wide flood protection initiatives as part of the final IFHMP.

Table 9-1: Priorities for Sea Dike Implementation

Priority	Recommendation	Timing
1	Upgrade all low-lying areas of the dike perimeter to at least 3.3 m geodetic elevation with an engineered standard dike cross-section.	Immediate
2	Implement a Development Permit Area for Coastal Flood Protection Works that establishes requirements and constraints for site development and redevelopment proposals based on this IFHMP. Where possible, consider accommodating up to 2 m SLR in the future.	Immediate
3	Secure and retain legal land tenure along the ultimate length of the sea dike as properties redevelop or become available. Where possible, consider accommodating up to 2 m SLR in the future.	Ongoing
4	Opportunistically implement segments of sea dike to the Year 2100 crest elevation and configuration as part of ongoing redevelopment.	Ongoing
5	Raise dikes to minimum elevation 4.0 m with sufficient width to allow future capping to design grade.	As funding permits
6	Raise dikes to Year 2100 (1 m SLR) crest elevations and configurations.	Once SLR exceeds 0.3 m, causing still-water design levels to exceed 3.3 m.

The interim elevation of 3.3 m recommended for Priority 1 is based on the nominal present-day 200-year return period design still-water level (excluding any allowance for SLR, wave effects or wind setup) plus 0.3 m freeboard. KWL considers this the lowest reasonable elevation for interim flood protection works. A continuous crest elevation of 3.3 m is also consistent with the recommendations of the 1994 FHMP. Structures built to this crest elevation would not meet current provincial or District flood protection standards, and should be engineered to form part of the Year 2100 sea dike.

The interim elevation of 4.0 m recommended for Priority 5 approximates the crest elevation of the recently reconstructed section of Town Dike along the southern frontage of the Aqua development (west of the 4th Avenue floodbox). A 4.0 m interim elevation also represents 50% of the required increase in height between the 3.3 m elevation proposed in the 1994 FHMP and the ultimate Year 2100 crest elevations recommended in this report.

An interim crest elevation is considered practical and prudent; however, the sea dike may not meet applicable provincial or District standards until it achieves its Year 2100 configuration. The dike should be constructed directly to its Year 2100 elevation (Priority 6 target) as part of Priority 5 construction where sufficient funds are available and value engineering supports the additional costs.

A "trigger" of 3.3 m design still-water level was adopted for Priority 6. The 3.3 m trigger means that sea level will need to rise about 0.3 m above present-day levels before Priority 6 is implemented. This value was selected so that a minimum freeboard of 0.6 m is maintained at all times with respect to the Priority 5 interim dike crest elevation (4.0 m), with an additional 0.1 m allowance to accommodate SLR during an assumed 10-year upgrading program.

Site-Specific Interim Measures

Site-specific interim measures may be considered at some locations. Examples of potentially-acceptable interim measures include the following:

- The CN Rail mainline and Squamish Terminals berm provide protection for much of Reaches 1 and 2.
- The crest height of the existing Town Dike along the southern limits of the Aqua development is commensurate with Priority 5 levels, although the cross-section does not meet geometry or seismic requirements for a standard dike.
- It may be possible to raise the existing pathway up to about 1 m (i.e., to at least Priority 5 level) along the waterfront of Marina Estates before implementing a more expensive vertical seawall.

A QP must confirm the adequacy of any such interim measures on a site-by-site basis. The QP must also identify the threshold (if any) where changing flood and erosion hazard would exceed the capacity of the interim measures, and provide direction on further mitigation to be considered at that time.

9.3 River Dike Breach Considerations

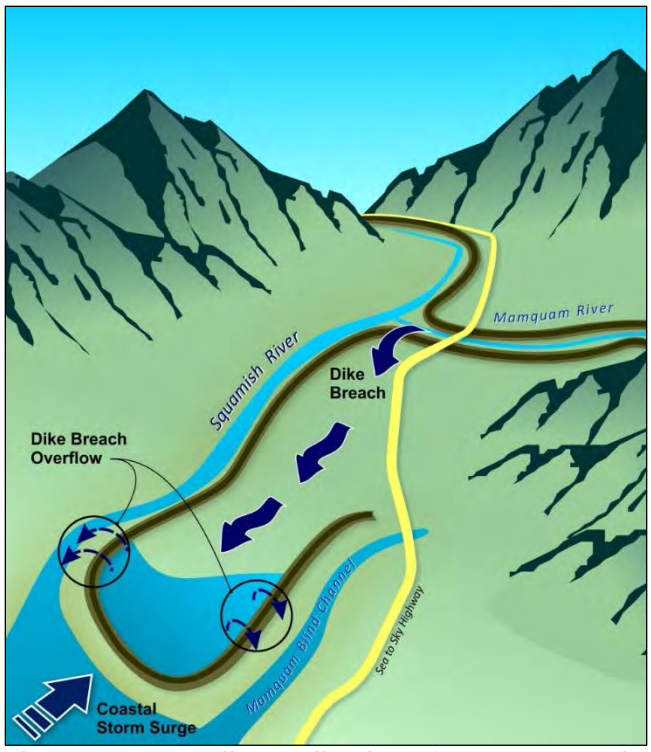


Figure 9-1: Sea Dike Implications for Upstream River Dike Breach

The proposed sea dike has the potential to trap water and elevate flood risk in downtown Squamish during an upstream river dike breach, as shown in Figure 9-1.

To offset the more severe consequences and avoid elevating flood risk, appropriate measures to mitigate river dike breaches should be implemented prior to or concurrently with the closure of coastal flood defences. In particular, a higher standard of protection should be adopted for the upstream river dikes to offset the increase in consequence created by enclosing Downtown Squamish within a sea dike.

River dike breach mitigation measures are also expected to include provisions in the Emergency Response Plan that identify locations where the sea dike can be breached to allow water to flow out into Howe Sound. Implementation of such emergency response measures should be considered in the design of the sea dike at the locations of potential outlet breaches.

10. Summary

1. Much of downtown Squamish is presently at risk of inundation from a coastal flood event with a return period of less than 200 years.
2. Risk from coastal flood events is expected to increase significantly over time due to SLR. Provincial guidance recommends planning for 1 m of SLR by Year 2100 and 2 m by Year 2200.
3. Areas of the District that could be subjected to coastal flood hazards by Year 2100 include a large coastal floodplain (the downtown peninsula) as well as several unconnected floodplain areas.
4. Unconnected floodplain areas typically have more flexibility than large floodplains for managing and mitigating coastal flood hazards. In these areas, the flood hazard management strategy can often be adapted to complement a specific development proposal.
5. Larger floodplains encompass many different properties and land uses, and must adopt a unified and consistent strategy for flood hazard management. Developing, implementing and enforcing these common strategies is usually the responsibility of the local government.
6. A three-part coastal flood hazard management strategy is recommended for the downtown Squamish floodplain, including the following elements:
    - **Protect** the contiguous floodplain area by providing a ±7 km perimeter of structural flood protection works (i.e., sea dikes).
    - **Accommodate** the hazards by establishing appropriate land use restrictions, designated floodways, floodproofing measures such as FCLs, and restrictive covenants.
    - **Managed Retreat** of essential infrastructure and lifeline facilities from the coastal flood hazard area as they reach the end of their development life cycle.
7. The greatest costs and impacts of the recommended strategy will be associated with establishing an appropriate sea dike perimeter around the downtown peninsula. The District has chosen to develop a plan for coastal flood protection as part of this IFHMP. The single most significant element of the plan is the sea dike alignment.
8. The coastal flood protection perimeter extends from the Squamish River dike near Squamish Nation Yekwaupsum I.R. No. 18 around downtown and up the Mamquam Blind Channel to high ground near Smoke Bluffs. The perimeter was divided into five reaches and alignment options were defined for each reach.
9. Alignment options were evaluated reach-by-reach against natural, economic, social / cultural, political / planning, and technical criteria.
10. The initial evaluation of alignment options was refined through a consultation and community engagement process that included the IFHMP Technical Working Group, a public open house and electronic forum, two meetings with the Squamish Nation, a presentation to the Squamish Estuary Management Committee, and internal discussions with District staff as well as Mayor and Council.
11. The District's community engagement and consultation activities produced a preferred alignment generally as follows:
    - Government Road from the Squamish River dike to Bailey Street (Reach 1);
    - Along the existing Town Dike to 3rd Avenue (Reach 2);
    - Along 3rd Avenue and Cattermole Slough to the intersection of Vancouver Street and Loggers Lane (Reach 3);

- Along the foreshore of Mamquam Blind Channel to Highway 99 (Reach 4); and
- Along Highway 99 to Loggers Lane, then following Rose Park foreshore to the existing Upper Mamquam Blind Channel crossing before turning east to meet high ground at Smoke Bluffs (Reach 5).

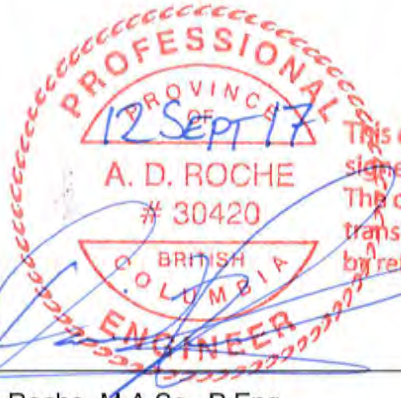
12. Subsequent discussions with the Inspector of Dikes identified an opportunity to simplify the Loggers Lane crossing by tying the sea dike into future broadcast fill ("high ground") at the north end of the Oceanfront Peninsula. Options and details will be reviewed as part of Study Area #2.
13. The proposed alignments will not result in any transfer of coastal flood risk to the Squamish Nation's lands at Stawamus I.R. No. 24, Site 'A' or Site 'B'.
14. Areas where additional study and/or consultation is required include the lower Squamish Estuary (Study Area #1, including the future role of Bridge Pond in stormwater management), the north end of the Oceanfront Peninsula (Study Area #2, including tie-in with future "high ground"), Highway 99 at Mamquam Blind Channel (Study Area #3), and from Loggers Lane at Highway 99 to Upper Mamquam Blind Channel (Study Area #4).
15. Preliminary design parameters were established for various locations along the coastal flood protection perimeter. These parameters include acceptable average overtopping rate during the design event, preferred waterside slope treatment, and required freeboard.
16. The resulting preliminary dike crest elevations are generally governed by the minimum provincial standard freeboard of 0.6 m rather than wave overtopping criteria.
17. The preliminary Year 2100 200-year return period sea dike crest elevation is 4.7 m to 4.8 m geodetic. Dike designs should allow for future raising to accommodate an additional 1 m of sea level rise.
18. Preliminary dike crest elevations along the preferred Town Dike alignment in Reach 2 (Option 2B) will require additional wave analysis.
19. Bioengineering and/or GreenShores approaches to erosion protection for the District's sea dike have not been discussed with or accepted by the BC Inspector of Dikes. Conventional treatments can be considered if future consultation concludes that bioengineering and/or GreenShores alternatives are not acceptable for a particular site.
20. The landside slope of a sea dike must be designed to accommodate overtopping and will require erosion protection commensurate with the chosen overtopping rate.
21. Ground improvement may be required along the sea dike alignment to meet BC Inspector of Dikes' seismic performance criteria. The need for ground improvement has not been assessed as part of this planning-level study.
22. The preliminary dike crest elevations will play an integral role in determining FCLs for downtown Squamish.
23. The volume of water overtopping the sea dike during the design event is expected to exceed available stormwater storage capacity at Bridge Pond and Upper Mamquam Blind Channel. The need for pump stations at one or both locations should be assessed as part of the upcoming District ISMP.
24. New development and redevelopment should maintain a minimum wave and erosion setback of 15 m from engineered top of bank.

25. Dike setbacks should generally reflect the 7.5 m minimum standard from the landside toe of any existing flood protection structure, but should also provide a minimum 3 m setback from the landward extent of a future dike designed to protect against the 200-year coastal flood with 2 m of sea level rise. The scenario providing the largest setback should govern. Examples are shown in Figure 8-1 and Figure 8-2.
26. Requirements for setback of floodproofing fill from a dike may be waived where the floodproofing fill and flood protection structure will be constructed concurrently under the QP's design and supervision.
27. Requirements for setback from the edge of a flood protection SROW may be waived where the SROW is established concurrently with development approvals and where the proposed SROW incorporates all future works and corresponding setbacks.
28. Some areas along the margin of the coastal floodplain are currently at risk from coastal flood events having return periods considerably less than 200 years. The District's emergency response plans should be updated to ensure that equipment and personnel are available to effect temporary closures in the event of a severe coastal flood event prior to completion of an interim sea dike perimeter.
29. Other priorities for immediate consideration are to raise existing areas to a minimum elevation (e.g., 3.3 m as per the 1994 FHMP) and to ensure that sea dike considerations are incorporated from the outset of any development or redevelopment applications.
30. Priorities for ongoing consideration include acquiring legal land tenure along the eventual sea dike footprint, and opportunistically leveraging development proposals to provide upgrades and/or funding for the ultimate sea dike.
31. As District funding permits, remaining portions of the sea dike should be raised to provide a level of protection at least equal to 4.0 m geodetic elevation. Where possible, work should consider cost-effective measures to simplify and expedite future upgrades.
32. Given the District's funding constraints, the District could defer upgrading the sea dike to ultimate Year 2100 crest elevations until SLR observations exceed 0.3 m and raise still-water design levels beyond 3.3 m geodetic elevation.
33. Site-specific interim approaches to implementing the sea dike may be available and cost-effective at some locations. Value engineering will be required on a case-by-case basis to determine the optimal approach.
34. To avoid elevating flood risk in the downtown Squamish and Dentville areas, upstream river dikes should be upgraded to provide a higher level of protection prior to, or concurrently with, the closure of coastal flood defenses.
35. Allowance for emergency excavation of outlet dike breaches should be considered during sea dike design at designated locations.

11. Report Submission

Prepared by:

KERR WOOD LEIDAL ASSOCIATES LTD.



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Revision History

Revision #	Date	Status	Revision Description	Author
0	September 12, 2017	FINAL	Update and issue for final IFHMP.	DR
F	October 16, 2015	REVISED FINAL DRAFT	Added figure for unconnected floodplain sites. Incorporated District Council direction to explore opportunities to incorporate SODC flood and erosion protection works.	DR

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Appendix A

October 23, 2014 Open House Documentation

Integrated Flood Hazard Management Plan:

October 23rd 2014 Open House Documentation

District of Squamish

SQUAMISH

Table of Contents

1 Introduction

The first Open House for the Integrated Flood Hazard Management Plan (IFHMP) was held in Squamish on Wednesday, October 23rd, 2014. The Open House was held to provide information on flood risks in Squamish and collect public feedback on long-term coastal flood protection options for sea level rise. Approximately 70 members of the community attended the Open House, which was held in the Squamish Adventure Centre. This report serves to document how the Open House was organized, record information provided by those attending, and provide an analysis of comments from the public and project team members.

1.1 Open House Agenda

The Open House was conducted from 5:00 pm to 8:00 pm and was facilitated by the project team consisting of David Roulston and Tamsin Mills (District of Squamish), Dave Roche and David Sellars (KWL), John Readshaw and Jessica Wilson (SNC-Lavalin), Graham Farstad and Amanda Grochowich (Arlington Group), Mike Nelson Cascade Environmental), and Greyson Herdman (Quest University co-op student).

Participants were invited to sign in at the door and to place a small red dot on a map of Squamish to indicate where they lived. An inset map of the greater Squamish area was provided for attendants who were from out of town. Participants were given a handout sheet to assist them in understanding options for protecting Squamish from coastal flood risks. The handout described the different reaches where flood protection measures were being analyzed, the flood protection options for each reach, and a key for technical terms (Appendix A). Seventeen storyboards were provided in the Squamish Adventure Centre open space areas (Photos 1 and 2, Appendix B).

Photo 1 – Introductory Storyboards

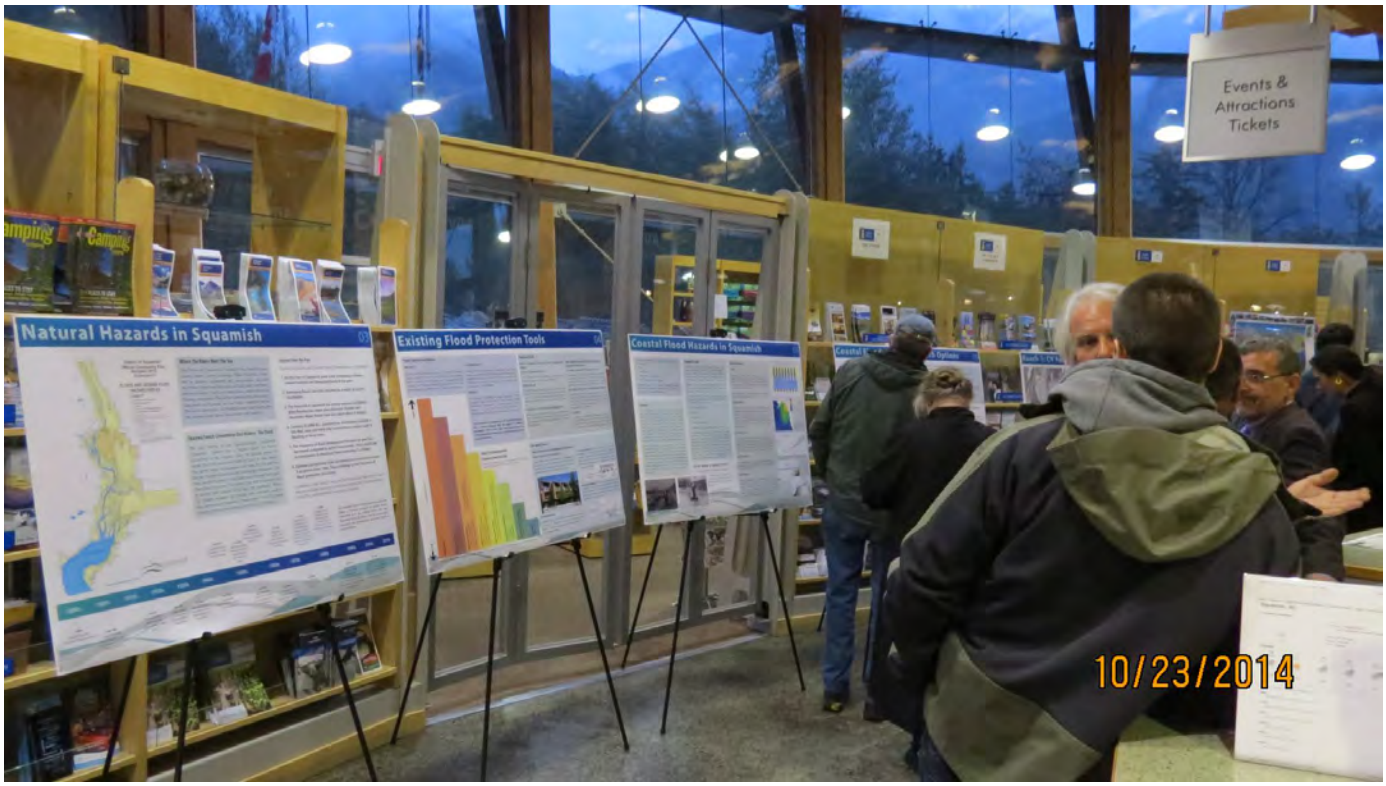


Photo 2- Team of Experts Answering Questions

The District used a 'teach yourself' technique for the Open House in effort to convey a substantial amount of technical information to the public. Attendees were invited to walk around the circular Adventure Centre to review the poster boards designed by the project team. In their interpretive walk, participants viewed storyboards describing background material on the IFHMP, coastal hazards affecting Squamish, and options for addressing coastal flood risks in Squamish. Project team members were situated throughout the display materials to help answer questions and provide additional information on flood risks and mitigation strategies. Upon reviewing storyboards, attendees were encouraged to provide comments on specific questions the District had prepared.

1.2 Attendance

Sixty-five attendees signed-in at the Open House. However, not all of the people who attended the Open House at the Squamish Adventure Centre signed in. By the end of the evening, the most of the hand-out sheets were taken (approximately 150 copies) indicating more than the 65 attendees were interested and involved with the material.

Participants[1] were in attendance from every neighbourhood within the District of Squamish. Garibaldi Highlands and Garibaldi Estates were the best-represented neighbourhoods at the Open House with a total of one third of all attendees (Table 1). Brackendale and Downtown Squamish were the next best represented neighbourhoods. The residents from Dentville who attended were clustered in a block surrounding Magee Street. This is likely an indication of publicity through word of mouth. Concerned residents from Dentville

[1] A large majority of attendees placed a dot on the map of Squamish indicating their residential location.

indicated a particular interest in the effect the Interceptor Dike would have on their properties. Attendants from Vancouver mentioned that they were interested in purchasing property in Squamish and were concerned about what flood hazards would affect properties in different neighbourhoods.

The location of attendees suggests that flood hazard management is a topic of widespread interest regardless of whether or not residents are living in or above the floodplain (Photo 3). This reinforces the view there is public interest in understanding coastal flood mitigation options in Squamish.

Table 1-Residential Location of Attendees

Location	# Of Attendees	Proportion
Brackendale	9	14%
Garibaldi Estates	10	15%
Garibaldi Highlands	12	18%
North Yards	3	4%
Business & Industrial Park	1	1%
Dentville	7	11%
Downtown	9	14%
Hospital Hill	5	7%
Valleycliffe	4	6%
Vancouver	2	3%
Other	3	4%
Total	**65**	**100%**

Photo 3- Map Showing Residential Location of Attendees

2 Open House Activities

2.1 Introductory Storyboards

Five storyboards introduced the subject matter of the Open House. These storyboards (see Photo 1) were designed to familiarize the public with the purposes of the IFHMP, the project team, and the timeframe of the project. A background storyboard provided information on the flooding history in Squamish. This transitioned into the different current coastal flooding hazards facing Squamish. A synopsis of coastal flood protection tools, other legislative tools and flood hazard management strategies relevant to the District were also provided.

A sixth storyboard contained a map of the downtown sector identifying the five flood protection reaches in downtown Squamish as well as other coastal locations. It introduced the options (i.e. route locations or alignments) for coastal flood protection as well as the evaluation criteria for those options.

2.2 Coastal Flood Protection Reach Storyboards

The coastal flood protection storyboards divided coastal areas surrounding Downtown Squamish into five reaches. Each storyboard addressed a specific reach. A description of the reach along with an aerial map, photos, and the intention of flood protection measures was provided. These provided participants with a visual and descriptive representation of where flood protection works have been proposed. Additionally, storyboards contained the mitigation options specific to each reach. This included the location, work required to implement flood protection, and a description of how it would affect Downtown Squamish.

Evaluation criteria were used to quantify flood mitigation options for each reach. The criteria consisted of natural, economic, social/cultural, political/planning, and technical material. The evaluation results were displayed through a colour scheme for each specific reach. They were rated as Most Preferable Alternative (Dark Green) to Least Preferable Alternative (Orange) and Show Stopper (Red). Each of the flood mitigation option posters contained a color scheme of dots related to the evaluation criteria. Based on the scores of the individual criteria, the evaluation gave an overall score presented for visual interpretation of specific mitigation options. In addition, points to consider were listed to inform participants on specific implications of flood protection measures within each reach. The following is a description of the specific reaches and flood protection options that each poster evaluated:

Reach 1: CN Rail Yards

Reach 1 starts at the Squamish River Dike just south of Yekwaupsum I.R 18 and runs south along Government Road to the first CN Rail Crossing near Dentville. Flood protection options for Reach 1 are intended to keep coastal floodwaters from entering the employment and industrial lands (including the CN Rail Yards) and residential neighbourhoods. Mitigation options that were discussed for Reach 1 were:

- Status Quo
- 1A- Split Access to Government Road
- 1B- Government Road

Reach 2: Squamish Estuary

Reach 2 connects south from the intersection of the CN mainline and spur lines south to the intersection of the CN Rail with 3rd Avenue. This is the main reach protecting Downtown Squamish from the westward side. Mitigation options that were discussed for Reach 2 were:

- Status Quo
- 2A- 7th Ave Connector
- 2B- Bailey Street to the Town Dike
- 2H1- Winnipeg Street Hybrid
- 2H2- Main Street Hybrid
- 2H3- 6th Ave Spur Dike Hybrid

Reach 3: Cattermole Slough

Reach 3 connects the south end of Reach 2 at 3rd Avenue, past (or around) the SODC lands, to the west end of Vancouver Street near the Mamquam Blind Channel. Mitigation options that were discussed for Reach 3 were:

- Status Quo
- 3A- 3rd Ave/Town Dike
- 3B- 3rd Ave/SODC
- 3H1- Town Dike to SODC Hybrid

Reach 4: Lower Mamquam Blind Channel

Reach 4 provides protection along the Mamquam Blind Channel from Vancouver Street to Highway 99. Mitigation options that were discussed for Reach 4 were:

- Status Quo
- 4A- Lower Mamquam Blind Channel Foreshore
- 4B- Vancouver Street Bridge
- 4C- Loggers Lane South

Reach 5: Upper Mamquam Blind Channel

Reach 5 connects the Highway 99 crossing, past the Squamish Adventure Centre to high ground south of the Smoke Bluffs. Mitigation options that were discussed for Reach 5 were:

- Status Quo
- 5A- Upper Mamquam Blind Channel Foreshore
- 5B- Highway 99
- 5C- Loggers Lane North
- 5H1- Upper Mamquam Blind Channel Foreshore to Highway 99
- 5H2- Highway 99 to Loggers Lane
- 5H3- Highway 99 to Loggers Lane

2.3 Comment Posters

Three comment boards concluded the Open House community consultation (Photos 4 and 5). The purpose of the three comment boards was to collect feedback from the public. To accomplish this, 18 questions were presented and participants were encouraged to place sticky dots to indicate their level of concern or importance on a variety of questions calling for a quantitative response. In addition, each question contained a space for open ended comments where participants could write sticky notes. This enabled participants to also view the comments of other participants.

Questions #1-#4 assessed participants' level of concern with different flood risks in Squamish (sea level rise

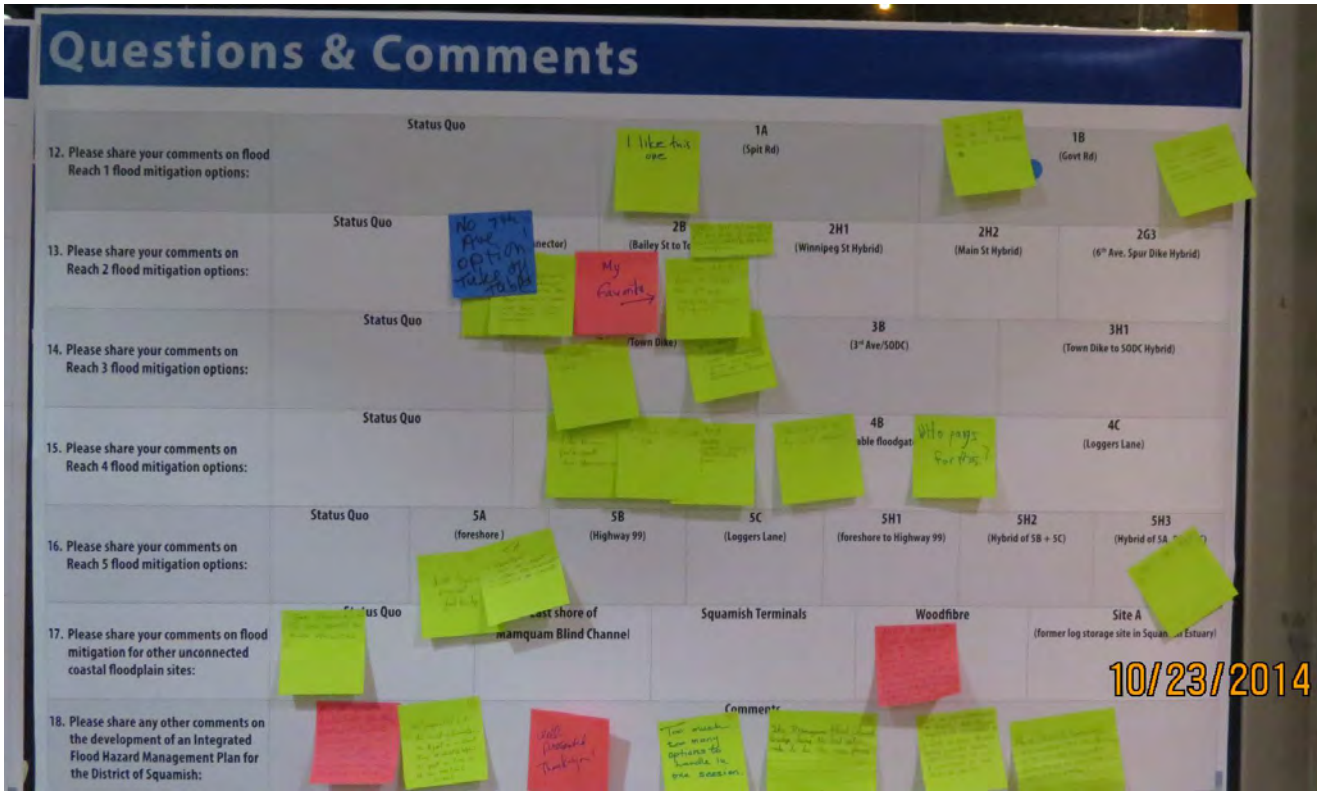
and storm surge, rivers, and tsunamis). Levels of concern varied from Very Concerned, Somewhat Concerned, Not Concerned, and Undecided/Not Sure. Questions #5-#7 measured the importance of economic, natural, and social considerations in evaluating flood protection measures. Levels of importance varied from Very Important, Somewhat Important, Less Important than other impacts and Undecided/Not Sure. Questions #8-#11 measured opinion on adequacy of protection and sea level rise adaption strategies. Responses were limited to Yes, No, Undecided/Not Sure using the sticky dots. Qualitative comments were also encouraged using the post-it notes provided.

Photo 4- Poster with Quantitative Response Questions (Sticky Dots)

Questions #12-#18 were designed to generate specific comments. Questions #12-#16 asked respondents to comment on flood mitigation options for Reach 1-5. Comment boxes were available for each specific mitigation option with each reach. Question #17 asked respondents to comment on flood mitigation for other unconnected floodplain sites and Question #18 asked respondents to share any other comments on the development of an Integrated Flood Hazard Management Plan for the District of Squamish.

Through the methods applied to the Open House, the Project Team was first able to inform the public of the hazards, reasons for coastal flood protection, and flood protection options and subsequently gather their educated opinions on the matter.

Photo 5- Poster with Qualitative Response Questions (Post-it Notes)



Following the Open House, all storyboards were posted on the [District of Squamish website.]

3 Response Analysis

3.1 Community Response

Residents who attended the Open House were encouraged to provide their opinion on flood risks, mitigation strategies, and specific flood protection works. All responses to Questions #1-#11 as well as bar graphs showing the distribution of quantitative responses to Questions #1-#10 can be found in Appendix C. Verbatim qualitative comments to Questions #12-#18 are provided in Appendix D.

Following the Open House, a survey was made available online through the project website. Four on-line responses were provided as of November 21, 2014. Individual comments were added to Appendices B and C. All Open House and on-line responses were left anonymous.

Question 1

How concerned are you about the risk Squamish faces from flooding due to sea level rise and associated coastal storms over the next decade (10 years)?

Question 1 received 28 responses and one comment. Of the responses, 11 (39%) were very concerned, 15 (54%) were somewhat concerned and 2 (7%) were not concerned. No undecided/not sure responses were given. The comments ranged from sea level rise needing to be the primary filter for development proposals, to encouraging the District to stop putting people investments at risk - or rather stop allowing people to put themselves at risk.

Question 2

How concerned are you about the risk Squamish faces from flooding due to sea level rise and associated coastal storms over the next century (100 years)?

Question 2 received 22 responses and no comments. Of the responses, 12 (55%) were very concerned, 7 (32%) were somewhat concerned, 2 (9%) were not concerned and 1 (4%) respondent was undecided/unsure.

Question 3

How concerned are you about the risk Squamish faces from flooding due to the 5 rivers in the District?

Question 3 received 27 responses and two comments. Of those responses, 23 (85%) were very concerned and 4 (15%) were somewhat concerned. No undecided/not sure responses were given. One respondent stated that river flooding might well be the most serious issue in the "near term." Another felt we are far too reliant on our dikes and pumps and should work to floodproof all residences in flood risk areas.

Question 4

How concerned are you about the risk Squamish faces from a tsunami?

Question 4 received 26 responses and two comments. Of those responses, 1 (4%) was very concerned, 7 (27%) were somewhat concerned, 13 (50%) were not concerned and 5 (19%) were undecided/not sure. One respondent stated that they were not concerned of a tsunami from the outer coast, but from a Howe Sound landslide. Another comment referenced the risk of a "Garibaldi jammer" (i.e. uncontrolled release of water from the Garibaldi Barrier above the Daisy Lake reservoir) and asked if it poses the same risk and if we were

hit by a tsunami last time one occurred?

Question 5

How important do you think economic impacts (e.g., cost) should be to the choice of a flood risk mitigation approach?

Question 5 received 26 responses and one comment. Of the responses, 7 (27%) felt it was very important, 18 (69%) felt it was somewhat important and 1 (4%) felt it was not important. No undecided/not sure responses were given. A respondent commented that it is a bit of a moot point if there is enough money to pay for it.

Question 6

How important do you think natural considerations (e.g., environmental impacts) should be in the choice of a flood risk mitigation approach?

Question 6 received 27 responses and one comment. Of the responses, 21 (78%) felt it was very important, 4 (15%) felt it was somewhat important and 2 (7%) felt it was less important than other impacts. No undecided/not sure responses were given. A respondent commented on the need to have a win/win situation and allow for a robust natural environment, as often the easy way is the one that is taken.

Question 7

How important do you think social/cultural impacts should be to the choice of a flood risk mitigation approach?

Question 7 received 25 responses and no comments. Of the responses, 5 (20%) felt that it was very important, 13 (52%) felt that it was somewhat important and 7 (28%) felt it was less important than other impacts. No undecided/not sure responses were given.

Question 8

The IFHMP is basing flood protection on a "design storm" with a 1 in 200 chance (1/2 of 1%) of occurring in any given year based on expected conditions for year 2100. How would you describe the level of protection this standard would provide for downtown and other areas?

Question 8 received 24 responses and one comment. Of the responses, 5 (21%) felt that it was adequate, 14 (58%) felt that it was not adequate and 5 (21%) were undecided/unsure. One comment was received in opposition to the 7th Avenue connector, as the respondent felt it is not an appropriate location for a dyke. Instead, upgrades should be made to the existing dike.

Question 9

The District is considering an approach that involves planning flood protection works to meet expected conditions for the year 2100 based on phased implementation (e.g. as opportunities arise with site redevelopment, local financial contribution, senior government cost sharing, observations confirming that sea level is rising). Are you in agreement with this approach?

Question 9 received 22 responses and three comments. Of the responses, 18 (82%) said yes, 1 (4%) said no and 3 (14%) were undecided/not sure. Comments varied. One respondent asked if this strategy would be adequate if climate change progresses more quickly than we anticipate. Another respondent was concerned

that the strategy leaves no protection or was unsure if it would entail little islands of protection. Finally, a respondent was in agreement, but did not agree with building the 7th Ave Connector as it would encroach too much into the precious estuary.

Question 10

Should the District of Squamish consider an 'Avoid' or 'Retreat' strategy as part of a comprehensive approach to coastal or river flood hazards?

Question 10 received 24 responses and three comments. Of the responses, 18 (75%) said the District should consider the two strategies, 3 (12.5%) said the District should not consider the two strategies, and 3 (12.5%) were undecided/not sure. One respondent commented that we should definitely not be building housing on SODC lands. Another felt the question was flawed and asserted that all options should be considered.

Question 11

If yes, what specific Avoid or Retreat options for critical infrastructure should be considered at part of the Integrated Flood Hazard Management Plan?

Question 11 was catered solely to comments in response to Question 10. It generated two comments. The first respondent asked for a definition and clarification of "Avoid' and 'Retreat'. Another respondent voiced a view that it is "stupid that our evacuation and emergency infrastructure is at risk-stupid being a euphemism for something really profoundly stupid."

3.2 Community Comments

Participants were encouraged to respond to questions surrounding the five different reaches where flood mitigation options were being assessed. They were given the choice to provide comments on specific mitigation options within the reach. The number of comments provided was very limited compared to the more general questions in #1-#11. The following is a synthesis of comments provided.

Question 12

Please share your comments on Reach 1 flood mitigation options.

Status quo received no comments.

Option 1A (Split road) received one comment in favour.

1B (Government Road) received three comments. Two comments were in favour, mentioning that it would allow the river to expand and a road upgrade would be nice. One comment mentioned concern of gas infrastructure already in place.

Question 13

Please share your comments on Reach 2 flood mitigation options.

Status quo received one comment recognizing that it would bolster existing footprint, that there is no roadway except for a maintenance crest (4m?), and it would allow for penetrating to restore flows to Bridge pond (with flood boxes).

2A (7th Ave Connector) received three comments. Comments varied with one requesting the 7th Avenue

connector be taken off the table, another requesting use of existing disturbance through use of the road (technically easy without dealing with multiple land owners) and a third supporting the benefits of trails and environmental access.

2B (Bailey St to Town Dike) received two comments. One comment was in opposition to 2B and also voiced a view that the 7th Avenue connector should not be built. The other comment provided a new option (Bailey St-6th Ave) believed to be best for truck-road connections to the waterfront.

No hybrid options received any comments.

Question 14

Please share your comments on Reach 3 flood mitigation options.

3A (Third Ave/Town Dike) received two comments in favour, recognizing that it is cheaper, less technical and joins all dykes for use by residents and visitors.

Status Quo, 3B (3rd Ave/SODC) and 3H1 (Town Dike to SODC Hybrid) received no comments.

Question 15

Please share your comments on Reach 4 flood mitigation options.

Status Quo received one question about flood control at South end of SODC lands.

4A (Foreshore) received three comments. One comment suggested building a tidal barrier further south above the Stawamus mouth, another comment was in favour, and a third suggested a seawall and transferring costs to the developer.

4B (Navigable floodgates) received one comment that it would be too costly to build and operate.

4C (Loggers Lane) received no comments.

Question 16

Please share your comments on Reach 5 Flood Mitigation options.

5A (Foreshore) received two comments. One was in favour recognizing that it is out of sight, will revegetate and should be cheap. Another preferred the Scott Crescent proposed footbridge.

No other options received any comments.

Question 17

Please share your comments on flood mitigation for other unconnected coastal floodplain sites:

Status Quo received one comment suggesting a shift in responsibility to land owners for flood protection.

Woodfibre received one comment recognizing a need to look at risks emanating from the proposed Woodfibre LNG site and not just leave up to proponents due to risks and coping mechanisms that will affect all of Squamish.

No other unconnected coastal sites received any comments.

Question 18

Please share any other comments on the development of an Integrated Flood Hazard Management Plan for the District of Squamish.

Question 18 received eight comments. Responses recognized the high quality of information presented and style of presentation, but commented that the sheer amount of information presented was hard to digest and a post online was desired so people could re-read. Additional comments were provided from Dentville property owners over the effects of the interceptor dike location. Concern was voiced over capabilities of current diking systems and how those will be addressed in the IFHMP. Finally, opinions regarding the 'best options' were provided and residents voiced an interest in understanding details of the District's main focus.

3.3 Panel Response

The panel of experts were asked to provide comments from conversations that they had throughout the Open House. The following themes emerged:

Suitability of Venue - Squamish Adventure Centre

- The location was very central.
- The location was just about perfect for the number of people attending as it gave a sense of vibrancy without being overcrowded.

Presentation of Information

- Participants were appreciative that a wealth of information was provided to the public in non-technical jargon.
- The storyboards were well received as the combination of maps and pictures helped to make complex information understandable.
- There was some concern that the amount of information was a bit overwhelming.
- Most attending the Open House were unaware and/or surprised to learn that the District had a website for the project.
- Numerous requests were made for the information to be accessible and for the survey to be made available online after the Open House. [Note: this was done within 2 working days].
- The handout with a summary of the Open House Reaches and definitions of terms used in flood hazard management was useful to participants.
- Many Squamish residents are very knowledgeable about the nature of flood hazards.
- The response rate to different flood risks was high but was much lower for the reach options as the subject matter is more complex and technical.

Climate Science

- Consensus that sea level rise (SLR) is occurring and needs to be addressed on an ongoing basis.
- A significant minority were concerned that the Province's SLR projections are too conservative or the rate of increase for SLR is being underestimated.

Hazard Uncertainty

- Several people asked where dike breaches could occur and where the most significant hazards were located - Squamish River or Mamquam River.

- There was concern that public safety was not being given a high enough priority in maintaining structural protection.
- Concerned was expressed about the limited areas for development in Squamish outside the floodplain (i.e. not in a hazard zone).
- People asked why we were worrying about coastal flood hazards - aren't the rivers the priority? [Note: this will be covered in Open House #2].

Project Cost and Flood Protection Costs

- What is the project cost and who would be paying for it?
- There were questions raised about how flood protection will be implemented and funded.
- Considering the numerous flood hazards, some concern was expressed if Squamish was receiving sufficient financial assistance from senior governments for structural protection.

Flood Hazard Mitigation in Specific Reaches/Locations

- **Reach 2**
  - Environmental impacts for the 7th Avenue connector are a significant concern.
  - In general, there was heavy debate over the environmental impacts of Reach 2 options. Many people would like more information.
  - Many were pleased that the slough area east of the rail line in Reach 2 would be maintained.
  - Desire to evaluate the preferred downtown trucking route from the Squamish Terminals in conjunction with determining a sea dike alignment.
  - Some expressed a preference for a bridge over the Mamquam Blind Channel as a truck route, which may eliminate the need for 7th Ave Connector truck traffic.
  - Most indicated that combined ROW Option 2A "made sense" and "was logical" although Option 2B also received support.

- **Reach 3 - SODC Lands**
  - Option 3B preferred
  - General consensus expressed that SODC should provide its own flood protection.
  - How would SODC contribute to protection of Downtown Squamish? (Broader scope of work than just the SODC lands was anticipated.)
  - How high will the dikes have to be to protect SODC lands?

- **Reach 4**
  - Interest was expressed in potential alternate locations for Option 4B.
  - Option 4B may be atop old wood waste and have poor foundation soils.
  - The cost of Option 4B will be prohibitive if there is a need to get tall-masted keel boats through the opening.
  - More information was requested on Option 4B (Vancouver Street crossing to Waterfront Landing). One participant offered to prepare a model.
  - Frustration was expressed that the weight of discussions to date seemed to center on options for Reach 2 with a relative lack of discussion/studies or reports on the options for Reach 4.
  - There was considerable appeal expressed about the tidal floodgates (and corresponding bridge) over the Mamquam Blind Channel.
  - There is a clear link in the public mind between the transportation issues surrounding Option 2B and the tidal barrier and bridge option for Reach 4.

- **Dentville**
    - The rationale for the interceptor dike was understood and favourably received by some.
    - Information was requested on the location and impact of the Interceptor dike.
    - Residents in Dentville expressed concern about the added risk of an Interceptor Dike.
    - Can the interceptor dike be relocated north of Dentville?

Appendix A – Open House Handout Sheet

Integrated Flood Hazard Management Plan

October 23rd, 2014
Squamish Adventure Centre

The focus of this Open House is to look at options for protecting Squamish from coastal flood risks. You will find: Storyboards with background material on the Integrated Flood Hazard Management Plan (IFHMP) and process; the coastal hazards affecting Squamish; and options for addressing coastal flood risk in Squamish. Comments and feedback are encouraged. Any questions, feel free to ask any of the Team Members!

To properly address the range of coastal hazards, the IFHMP has divided the coastal areas surrounding Downtown Squamish into 5 reaches and several unconnected coastal areas:

Reach 1: CN Railyards (Boards 7-8)

- South along Government Road to where CN Spur line joins the CN Mainline.

Reach 2: Squamish Estuary (Boards 9 – 10)

- South from the intersection of the CN Mainline to 3rd Avenue

Reach 3: Cattermole Slough (Boards 11 – 12)

- Connects the south end of Reach 2 to the east end of Vancouver Street adjacent to the Mamquam Blind Channel

Reach 4: Lower Mamquam Blind Channel (Boards 13-14)

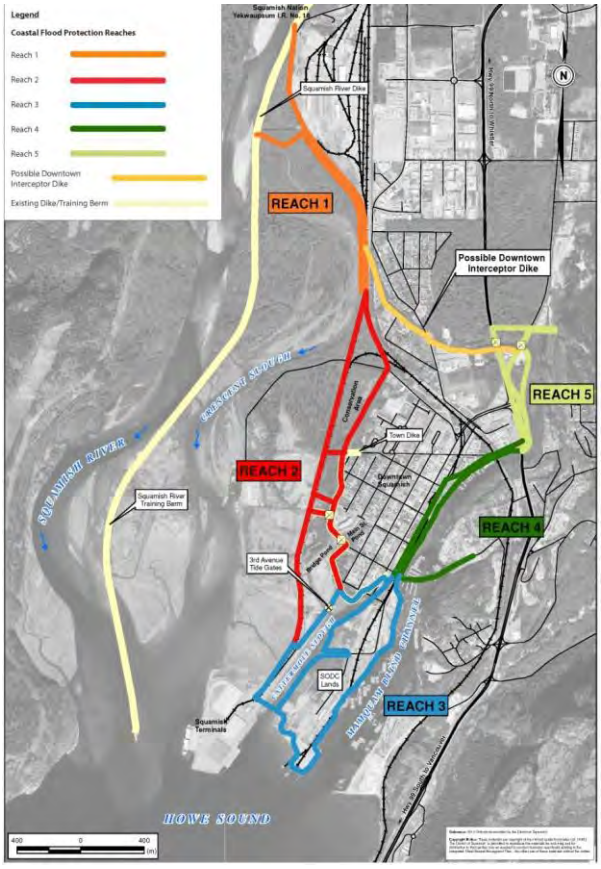
- Runs north along the Mamquam Blind Channel from Vancouver Street to Highway 99

Reach 5: Upper Mamquam Blind Channel (Boards 15-16)

- Connects from the Highway 99 crossing to the Smoke Bluffs

Other Coastal Areas (Board 17)

- Consists of four coastal locations on the east side of the Mamquam Blind Channel and three existing/former industrial sites.



Key Flood Hazard Terminology

Alluvial Fan: fan-shaped deposit of sediment crossed and built up by streams and rivers

Flood Construction Level (FCL): the minimum required elevation for a habitable area (the interior space of a building intended for living)

Flood Hazards : the features of flooding that have adverse impacts on elements at risk such as the depth of water, speed of flow, duration, and water quality

Floodplain: an area of land adjacent to a body of water that may experience flooding during periods of high water levels

Floodproofing: any combination of structural and non-structural changes to a building designed to reduce or eliminate flood damage. There are two main forms of floodproofing – dry or wet floodproofing.

Freshet: annual peak flow of water in a river resulting from snow and ice melt

IFHMP: Integrated Flood Hazard Management Plan

Riparian Area: interface between land and water

Risk: The likelihood of a negative event occurring combined with the magnitude of the potential consequences. Risk = Likelihood (Probability) x Consequence

Sediment: naturally occurring material that is broken down by natural processes, such as weathering or erosion, and is transported by the action of wind, water or ice

Fee simple: form of real estate ownership

SODC: Squamish Oceanfront Development Corporation

Storm surge: a coastal flood during a storm event affected by atmospheric pressure, wind runup, wave momentum, the tide, ocean currents and temperature

Navigable floodgates: a set of gates that can be opened or closed to admit or exclude water. When open, marine vessels will be able to pass through

Feel free to provide your answers and comments provided on the posters after reviewing the storyboards

Stay tuned to the District's Facebook and Twitter – there will be other opportunities for public engagement and input!

Any questions, just ask!

Appendix B – Open House Storey Boards

Squamish Integrated Flood Hazard Management Plan

SQUAMISH

Squamish IFHMP

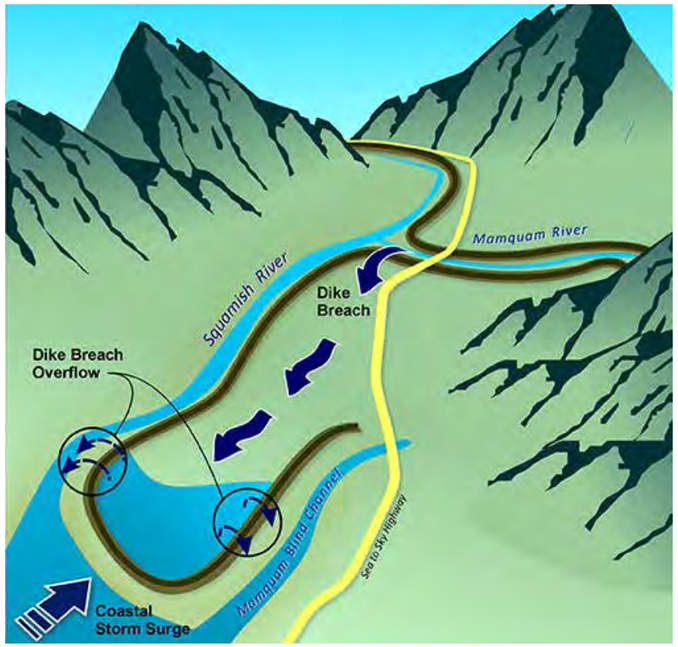
In 1994, the District of Squamish completed its first Flood Hazard Management Plan (FHMP) to manage and mitigate the flood risk for the District.

A generation after its adoption, the FHMP now needs to be revisited and updated. The update process will take into account:

- Growing population
- Legislative and regulatory changes
- New professional standards
- Provincial guidance
- Flood hazard assessment best practices
- Climate change

WHAT IS AN INTEGRATED FLOOD HAZARD MANAGEMENT PLAN?

- The 1994 Flood Hazard Management Plan for Squamish is being updated.
- The new plan will be called the Integrated Flood Hazard Management Plan (IFHMP).
- The IFHMP will guide development and land use in Squamish for years to come. The IFHMP process provides an opportunity for Squamish to maintain its commitment to livability and sustainability by incorporating the latest flood management guidelines, new engineering modeling tools and techniques, and best planning practices.
- An effective IFHMP will depend on community engagement and public support.
- A financially-responsible budget, reflecting the size of the community, will further support the implementation of the IFHMP.



WHAT MAKES UP AN IFHMP?

Phase 1: Flood Mitigation Background Analysis

This first step is designed to summarize the existing information surrounding Squamish's:

- Hydrology
- Geohazards
- Anticipated climate change
- Future coastal water levels
- Extent and condition of existing flood protection
- Existing policy tools that manage flood hazards

Phase 2: Coastal Flood Hazard Mitigation Options

Several coastal flood defence options have been developed and are presented at this first Open House for your input on the options, risks, consequences, and potential mitigation measures.

Phase 3: River Floodplain Modelling and Risk Analysis

Technical risk assessments will be conducted on the Squamish and Mamquam Rivers followed by the Cheakamus, Cheekeye and Stawamus Rivers. Results will be presented at the second Open House in the fall of 2015.

Phase 4: Integrated Flood Hazard Management Plan

The final phase of the IFHMP involves the preparation of the Integrated Flood Hazard Management Plan, which will recommend both technical and policy solutions. The Draft IFHMP will be presented at the third Open House – Winter 2015/16 – and to Council in the winter of 2016.

SQUAMISH

PROJECT TEAM

KERR WOOD LEIDAL
consulting engineers

CASCADE ENVIRONMENTAL
RESOURCE GROUP LTD

the Arlington Group
Planning + Architecture Inc.

SNC·LAVALIN

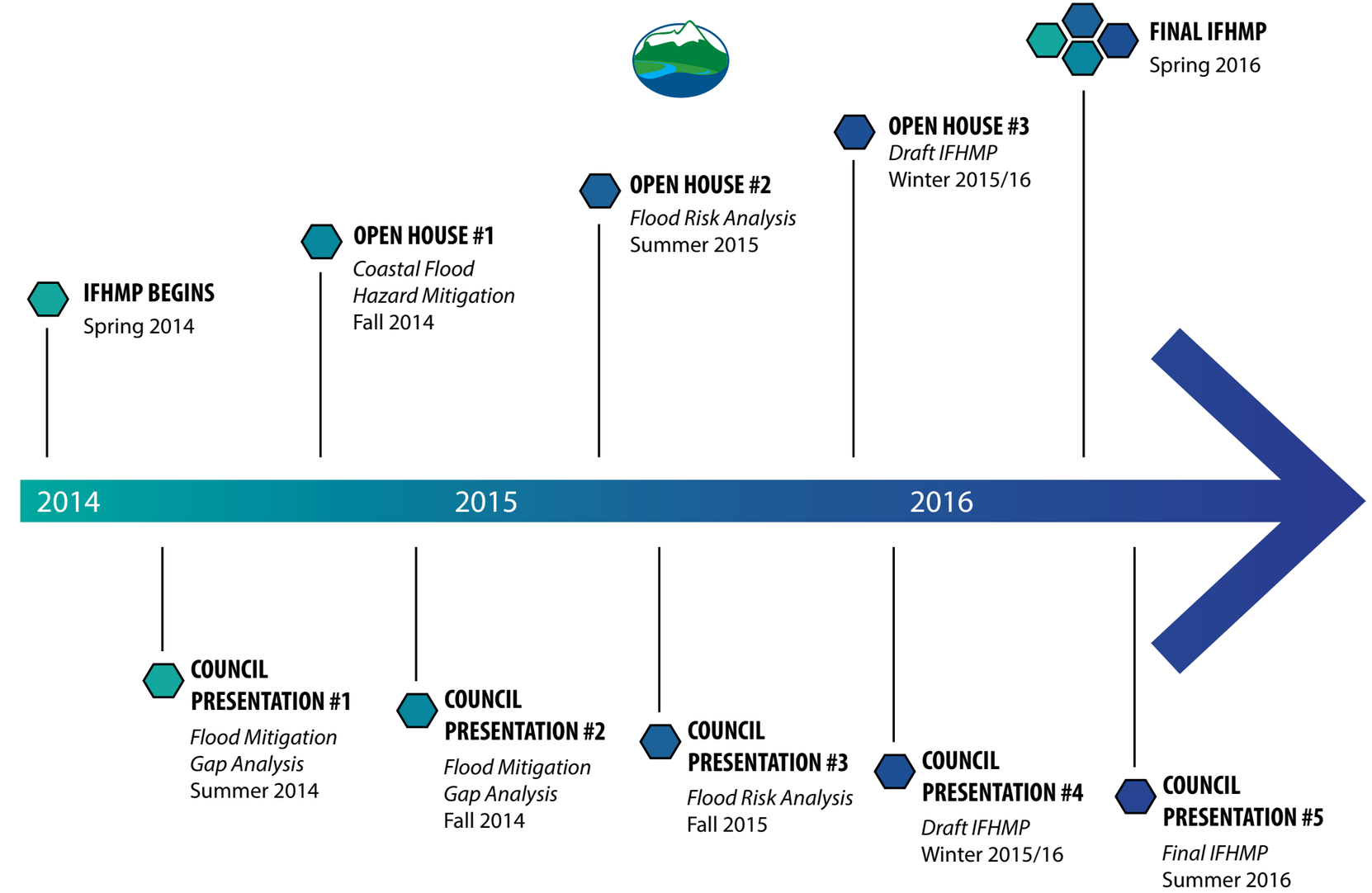
THURBER ENGINEERING LTD.

STAKEHOLDERS

PUBLIC

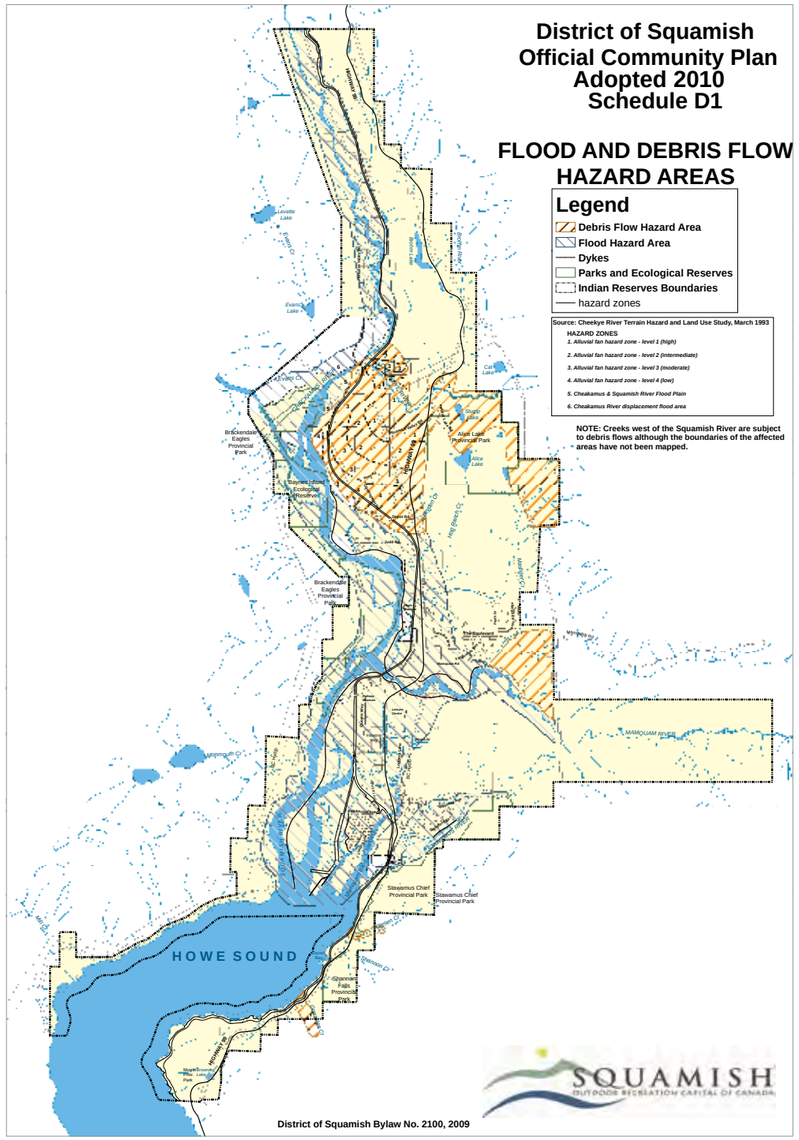
TECHNICAL WORKING GROUP & SḴWXWÚ7MESH ÚXWUMIXW (SQUAMISH NATION)

Integrated Flood Hazard Management Plan (IFHMP) Public Consultation Schedule



Keep up to date and provide feedback on the IFHMP at www.squamish.ca/floodhazard

Natural Hazards in Squamish



Where the Rivers Meet the Sea

The District of Squamish is located at the head of Howe Sound where 5 rivers converge. These mountain rivers, fed by glaciers, snowmelt and precipitation, descend from their steep mountain tops carrying water, sediment, and on occasion, rocks and other debris. When these fast flowing rivers reach the gently sloping valley, they tend to slow down and spread out, and leave sediment behind. The terms alluvial fan and floodplain are used to describe the riparian areas along these lower river reaches.

Sḵwx̱wú7mesh Úxwumixw Oral History - The Flood

The oral history of the Sḵwx̱wú7mesh Úxwumixw (Squamish Nation) has a legend called the Flood. According to the legend, when the people began to forget their old ways and failed to listen to their elders, the game began to disappear and then the fish and the berries. People became hungry and began to quarrel. Still they wouldn't listen to their elders and change their ways. Then the rains came. The waters rose and the people had to anchor their canoes to Nch'ḵay' (Mt. Garibaldi). When the waters receded, the people who survived came to their senses and listened to their elders. Then the game and the fish and the berries returned in abundance.

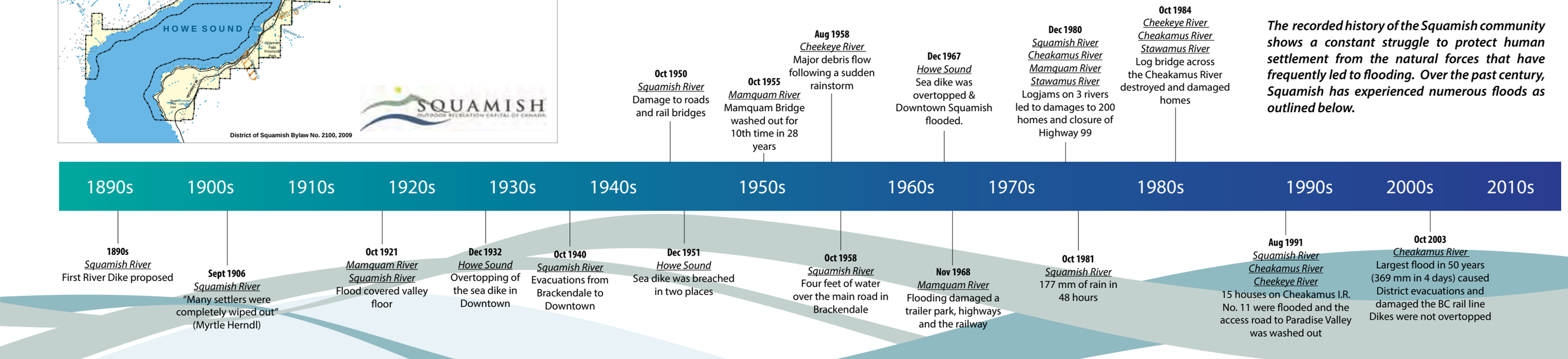
Lessons from the Past

Several conclusions can be drawn from the flood history in Squamish:

1. **All the rivers in Squamish pose a risk of flooding. All have caused multiple and damaging floods in the past.**
2. **Damaging floods have also occurred as a result of coastal inundation.**
3. **The flood risk in Squamish has strong seasonal variations. Most flooding has taken place between October and December. Major floods have also taken place in August.**
4. **Contrary to other B.C. communities, the freshet (typically in late May, June and early July) has not been a major cause of flooding on local rivers.**
5. **The frequency of flood damages over the past 30 years has decreased compared to earlier time periods. This is attributed to investments in structural flood protection (i.e. dikes).**
6. **Extreme precipitation (rain and snow) has occurred on at least 5 occasions since 1980. These continue to test the limits of flood protection structures.**

In addition to the 5 major rivers and their tributaries, the District's land area also includes numerous small, steep creeks that can present flood, debris flow, sedimentation, and erosion hazards.

The recorded history of the Squamish community shows a constant struggle to protect human settlement from the natural forces that have frequently led to flooding. Over the past century, Squamish has experienced numerous floods as outlined below.



Existing Flood Protection Tools

Flood Adaptation Options

PROTECT

The use of structures such as dikes and seawalls to protect people, property and infrastructure from flood hazards. With increasing flood hazards and vulnerability, this strategy may become prohibitively expensive and have limited long-term effectiveness in highly vulnerable areas.

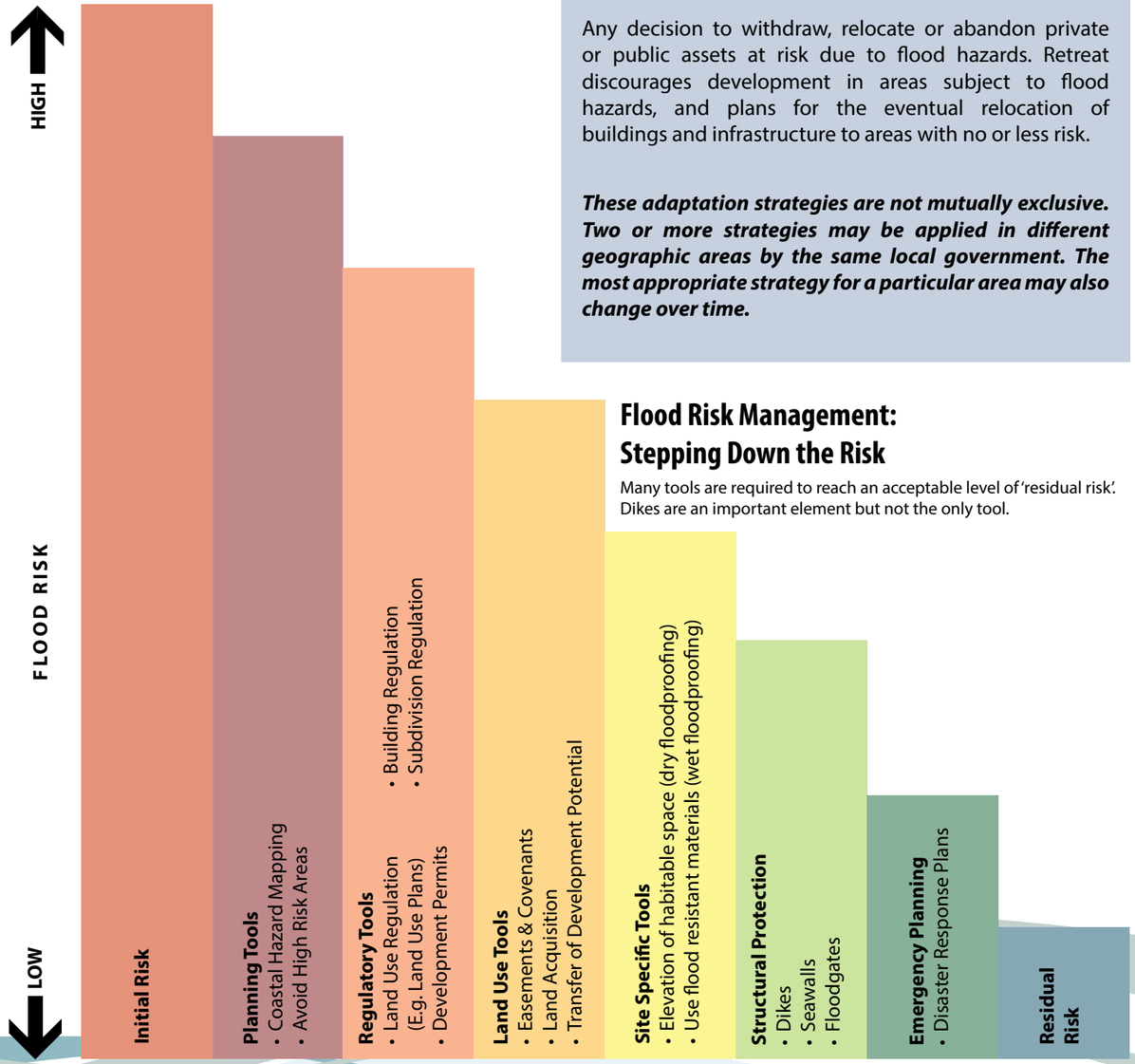
ACCOMMODATE

Allows continued occupation of floodable areas while changes are made to human activities and/or infrastructure to adapt to flood hazards. Accommodation can also involve retrofitting a building or making it more resilient to the consequences of flood waters.

RETREAT

Any decision to withdraw, relocate or abandon private or public assets at risk due to flood hazards. Retreat discourages development in areas subject to flood hazards, and plans for the eventual relocation of buildings and infrastructure to areas with no or less risk.

These adaptation strategies are not mutually exclusive. Two or more strategies may be applied in different geographic areas by the same local government. The most appropriate strategy for a particular area may also change over time.



Flood Risk Management: Stepping Down the Risk

Many tools are required to reach an acceptable level of 'residual risk'. Dikes are an important element but not the only tool.

Adapted from: U.S. Army Corps of Engineers & Sea Level Rise Primer (Arlington)

Regulatory Tools

District of Squamish Existing policy tools to manage flood hazards:

OFFICIAL COMMUNITY PLAN

Details Guiding Principles and Policies concerning flood hazard management for both rivers and coast.

ZONING BYLAW

Regulates land use including restrictions on land use, the siting of land uses to reduce hazards, the elevation of land uses to meet Flood Construction Levels, requirement for structural protection and the use of covenants to reduce risk.

SECTION 910 OF THE LOCAL GOVERNMENT ACT

Permits a local government to enact a bylaw designating land as a floodplain and establishing specific building and siting requirements. To date, the District has not enacted a floodplain bylaw.

Other Legislative Provisions in the District's flood hazard management toolkit consist of:

SECTIONS 85 AND 86 OF THE LAND TITLE ACT

This authorizes the Approving Officer to refuse subdivision approval if the land is subject to flooding and to require a report by a Qualified Professional (Engineer or Geoscientist) that the land may be used safely for the intended use.

SECTIONS 55 AND 56 OF THE COMMUNITY CHARTER

If the Building Inspector considers construction to be on land subject to flooding, mud or debris flows, or any other risk, he/she can require the land owner to provide a report certified by a Qualified Professional that the land may be used safely for the intended use.

COVENANT

A covenant can specify flood mitigation measures that must be adhered to such as requiring building elements (e.g. furnaces, boilers and hot water tanks) to be above the FCL. A covenant on title applies to future property owners.

Site Specific Tools

These tools help create additional flood protection measures:

FLOOD CONSTRUCTION LEVEL (FCL)

Is the minimum required elevation for a habitable area (the interior space of a building intended for living). In Squamish, this is determined on a site specific basis by a Qualified Professional (Engineer or Geoscientist).

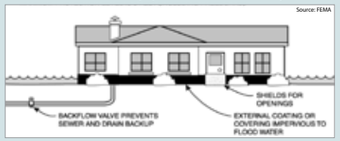
Habitable space constructed above the ground level parking

FLOODPROOFING

The combination of structural and non-structural changes to a building designed to reduce or eliminate flood damage. There are two main forms of floodproofing – dry or wet floodproofing.

Dry floodproofing is when the building has been made watertight below the level that needs flood protection to prevent flood waters from entering the building. That may include sealing the walls with waterproof coatings, impermeable membranes or a supplemental layer of masonry or concrete.

Dry floodproofing for a residence



Wet floodproofing is when the non-habitable portion of a building is designed to allow floodwaters to enter and exit the building. This form of floodproofing reduces the likelihood of structural damage and collapse but is only practical in limited situations.

Wet floodproofing for a basement

Coastal Flood Hazards in Squamish

Coastal flood hazards in Squamish are affected by the combination of:

- tides
- storm surge
- local wind and wave effects
- wave impacts on the shoreline

Decision-makers must consider the combined effects of all these processes to establish an appropriate level of safety for coastal development.

Tsunamis

All communities on the BC Coast face a threat from tsunamis generated by major earthquakes around the Pacific Rim. Communities along the Strait of Georgia are favoured by topography since an offshore tsunami would lose considerable energy passing through the Juan de Fuca Strait and the Strait of Georgia. The most significant tsunami risk for Squamish is likely to be a megathrust earthquake in the nearby Cascadia Subduction Zone. Local tsunami waves can also be generated by a large landslide within Howe Sound.

Tsunami hazards can be amplified if the natural characteristics of the wave match the natural characteristics of an inlet. This contributed to the wide spread damage in Port Alberni during the 1964 tsumani. A preliminary assessment suggests that Howe Sound is unlikely to experience the wave amplification that affected Port Alberni during the 1964 tsunami. More study is required to better assess the tsunami risk in Squamish.

Squamish at Risk

The District has a very long coastline at Howe Sound, ranging from Watts Point in the east to Woodfibre in the west. Much of the foreshore is relatively steep and undeveloped. Exceptions include Woodfibre and most of the Crescent Slough to Stawamus I.R. No. 24 area.

Between Crescent Slough and Stawamus I.R. No. 24, river estuaries and sloughs allow coastal hazards to penetrate more deeply into the community.

Flood hazards affect a majority of the developed areas of Squamish. Neighborhoods potentially vulnerable to coastal flood hazards include:

- Downtown Squamish
- Dentville
- North Yards
- Squamish Business Park
- Stawamus I.R. 24 and Yekwaupsum I.R. No. 18.

Key community infrastructure within the floodplain includes the Municipal hall, emergency response services , BC Hydro's Squamish substation, Wastewater Treatment Plant, Public Works Yard, Animal Control & Pound Office, Squamish Elementary School, Mamquam Elementary School, Howe Sound Secondary School, Brennan Park Recreation Centre, Squamish Public Library, West Coast Railway Heritage Park, and numerous commercial and industrial facilities.

The Best Strategy for Squamish May Vary

- Protect has applied to Downtown Squamish
- Accommodate has applied to new residential development to elevate habitable space above the flood risk
- Avoid has applied to some environmentally sensitive areas
- Retreat may be selectively required in the future

Squamish River after 1940 flood, Image 042 (Photo courtesy of Squamish Public Library Digital History Collections, *squamishlibrary.digitalcollections.ca*)

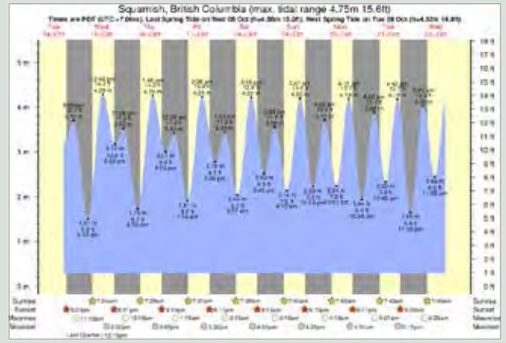
Intersection of Victoria and Cleveland Ave during 1940 flood, Image 018 (Photo courtesy of Squamish Public Library Digital History Collections, *squamishlibrary.digitalcollections.ca*)

Natural Hazards

TIDES

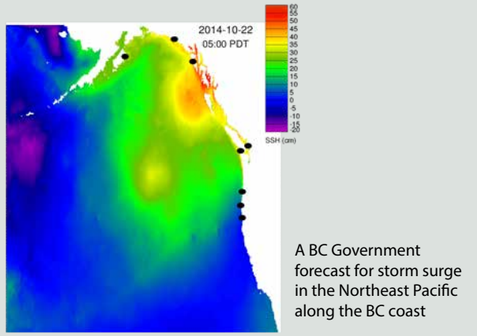
Tides are the rise and fall of sea levels due to the gravitational forces of the Moon and the Sun on the Earth. The term 'king tides' is sometimes used to refer to the highest of high tides. They are of particular concern in association with winter storms.

Over the long term, high tides will increasingly encroach on coastal areas due to sea level rise.



STORM SURGE

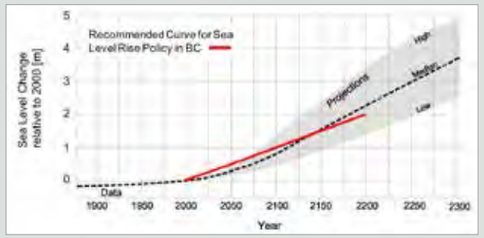
Water levels along BC's coast are affected by external conditions including atmospheric pressure, wind, wave momentum, ocean currents and temperature. Rising sea levels will slowly but relentlessly increase the risk of flooding in Squamish. Scientists are in the early stages of studying how climate change could affect storm surge behaviour.



A BC Government forecast for storm surge in the Northeast Pacific along the BC coast

SEA LEVEL RISE

One of the most important climate change impacts is sea level rise due to warmer ocean temperatures and melting of ice. Provincial Guidance anticipates sea level rise of 1.0 metre by the year 2100 and 2.0 metres by the year 2200. This is illustrated on the graph to the right.



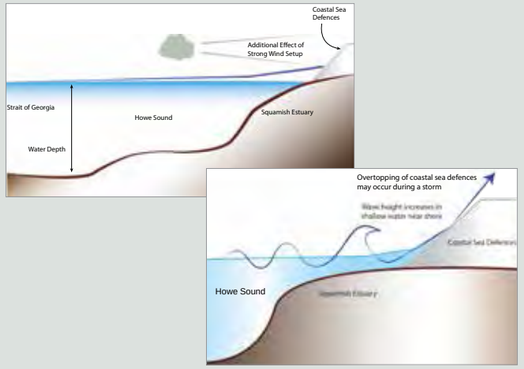
Ministry of Environment Guidelines for Management of Coastal Flood Hazard Land Use - 2011

LOCAL EFFECTS

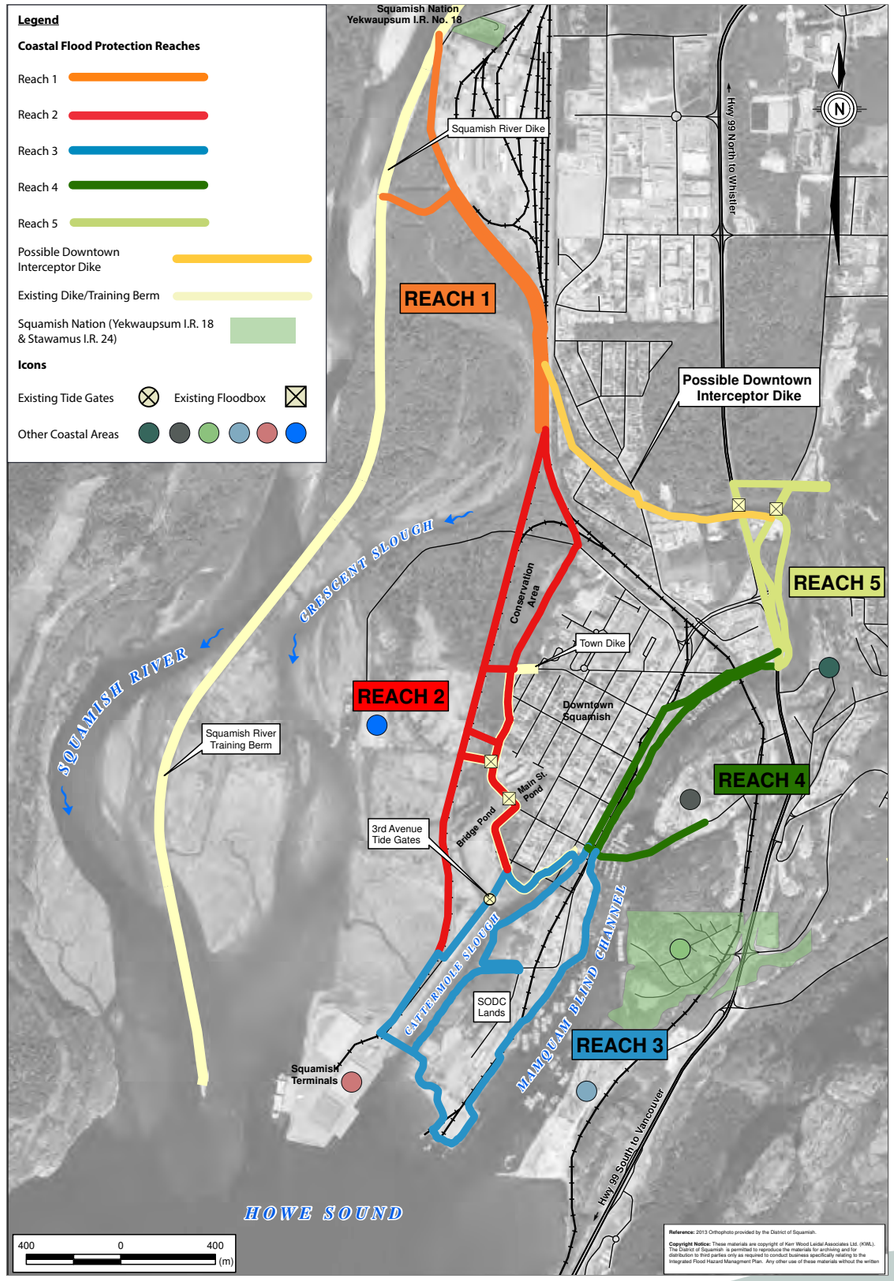
Local wind, wave and surge effects can contribute to sustained high water levels and increase the likelihood of coastal flooding.

WIND WAVES

Waves are generated by a sustained wind over water. Waves have the potential to overtop or breach coastal sea defences and flood low-lying coastal areas. Waves also present significant erosion hazards. Wave conditions are very site-specific and will vary considerably along the District's coastal margins.



Coastal Flood Protection Reach Options



There are a wide variety of options and alignments for achieving effective coastal flood protection for the downtown area of Squamish. To simplify decisions, the IFHMP divides the coastal areas surrounding Downtown Squamish into five reaches. Option and alignment decisions for each reach are largely independent of other reaches.

IFHMP Reaches:

Reach 1: CN Railyards (Boards 7-8)

- South from the Squamish Nation Yekwaupsum I.R. No 18 along Government Road to the first CN Rail Crossing near Dentville

Reach 2: Squamish Estuary (Boards 9 -10)

- South from the intersection of the CN Mainline to the CN Rail Crossing at 3rd Avenue. This is the main reach to protecting Downtown Squamish from the westward side

Reach 3: Cattermole Slough (Boards 11 - 12)

- Connects the south end of Reach 2 to the west end of Vancouver Street near the Mamquam Blind Channel

Reach 4: Lower Mamquam Blind Channel (Boards 13 - 14)

- Runs north along the Mamquam Blind Channel from Vancouver Street past Highway 99

Reach 5: Upper Mamquam Blind Channel (Boards 15 - 16)

- Connects the Highway 99 crossing to Smoke Bluffs

Other Coastal Areas (Board 17)

- Four coastal locations on the east side of the Mamquam Blind Channel will require site specific flood hazard mitigation:
  - Scott Crescent Development
  - Waterfront Landing (former Interfor site)
  - Stawamus I.R. No. 24
  - Site B
- Three existing and former industrial sites are also included and will require site specific flood hazard mitigation:
  - Squamish Terminals
  - Site A
  - o Woodfibre (not on map)

How the Boards are Organized:

- Map(s) highlighting the location of each Reach and the possible mitigation options
- Brief description of each Option within each Reach.
- Evaluation Matrix of Options within each Reach
  - o Six colours ranging from Most Preferable Alternative (Dark Green) to Least Preferable Alternative (Orange) and Show Stopper (Red).
- Summary points to consider and site photos!

Evaluation Criteria for Coastal Flood Protection Options

Natural: Includes aquatic and land-based vegetation, local ecology, water and air quality, expected footprint of the new flood protection works and enhancement opportunities.

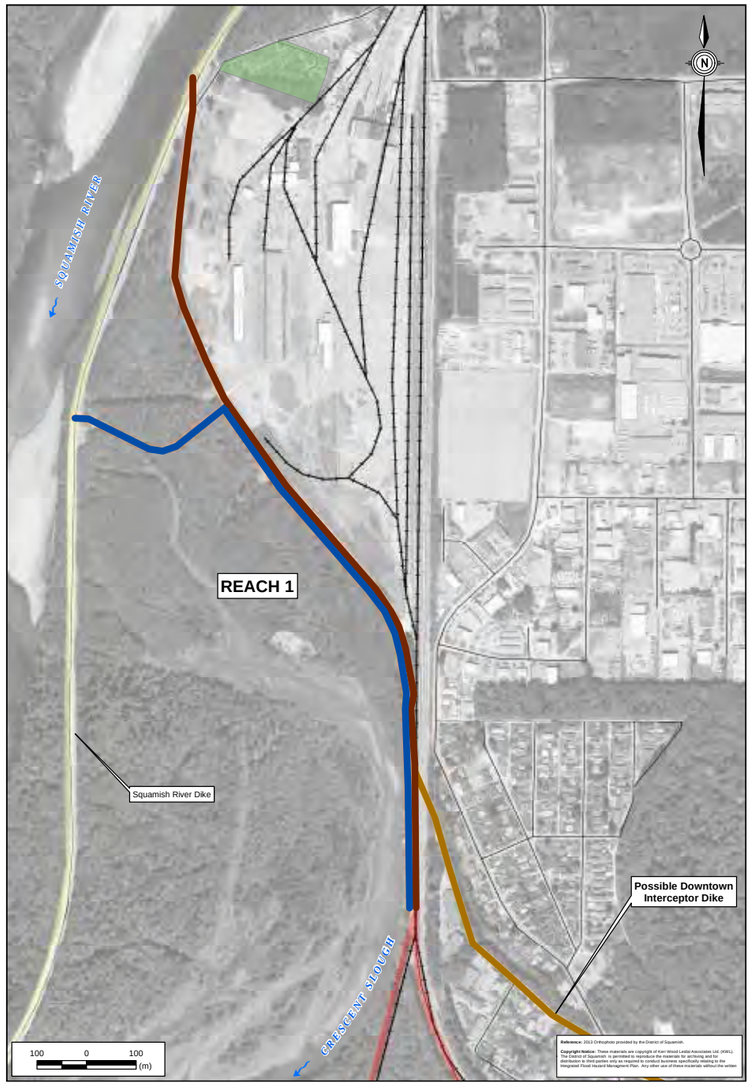
Economic: Covers the expected flood protection benefits, environmental compensation costs, long-term employment opportunities, potential cost sharing opportunities, and capital, operating, and maintenance costs.

Social/Cultural: Covers traditional land uses and rights, public safety, level of public consultation, archaeological impacts and potential recreational opportunities.

Political/Planning: Covers land tenure and access issues, alignment with District policy, approval challenges, development impacts, transportation implications and emergency plan implications.

Technical: Covers project complexity and design constraints, phasing opportunities, internal drainage and upstream dike failure, marine navigation, seismic performance, future adaptability and redundancy.

Reach 1: CN Railyards



Legend

Coastal Flood Protection Options

Option 1A — Option 1B

Coastal Flood Protection Reaches

Reach 2 — Existing Dike/Training Berm

Possible Downtown Interceptor Dike

Icons

Squamish Nation (Yekwaupsum I.R. 18)

Aerial view of Reach 1 in upper right

View west along Spit Road - Option 1A - at intersection with Squamish River Dike Road

View north along Government Road

Reach 1 starts at the River Dike and runs south along Government Road to the first CN Rail Crossing near Dentville. Flood protection options for Reach 1 are intended to keep Squamish River floodwaters from entering the employment + industrial lands (including the CN Railyards) and residential neighbourhouds.

Reach 1 Mitigation Options:

Status Quo

- Nothing new will be built. Community risks will be limited until after the year 2100.

1A – Spit Access to Government Road (Blue)

- Raise the Spit Access from Squamish River Dyke Road to Government Road.
- Raise Government Road from the Spit Access south to the first CN Rail crossing near Dentville.
- The raised Spit Access section would look very similar to the existing Squamish River dike with a gravel driving surface and vegetation on both sides.
- Government Road would be paved for two-way traffic.
- Spit Access and Government Road would be raised to the Flood Construction Level.

1B – Government Road (Brown)

- Raise Government Road south to the first CN Rail crossing near Dentville. This would create a road dike similar to Centennial Way, where it currently forms the south Mamquam dike .
- Government Road would be paved for two-way traffic.
- Spit Access and Government Road would be raised.

View south along Government Road, just south of paved section (estuary on right)

View north overlooking Squamish Estuary with Crescent Slough in foreground

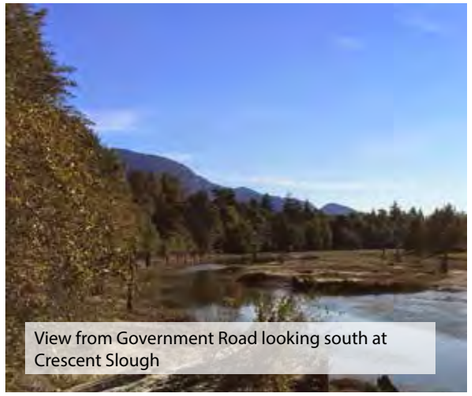
Reach 1: CN Railyards

Reach Options / Evaluation Criteria	Status Quo	Option 1A	Option 1B
Natural			
Economic			
Social			
Political			
Technical			
Overall			

Most Preferable Alternative/ Least Negative Impact

Least Preferable Alternative/ Most Negative Impact

Show Stopper!!



View from Government Road looking south at Crescent Slough

View north along Squamish River Dike above Government Road on right

View north from Training Berm

View north along Government Road with Squamish River Dike on left

Points to Consider:

- Status Quo manages coastal risk until year 2100.
- Dike options presented in 1A and 1B would generally follow Government Road.
- Government Road would be serviceable with a paved surface.
- Both Options 1A and 2B could follow Green Shores™ principles.
- Dike location reinforces the separation of Industrial use from Greenways.
- Both options are relatively straightforward to implement.
- Overall costs are expected to be similar for both options.
- Both options maintain recreational opportunities.
- Reach 1 coastal flood protection benefits are local (CN Railyards, Yekwaupsum I.R. No. 18, Railway Museum)

View from Training Berm overlooking Squamish Estuary (Mount Garibaldi in background)

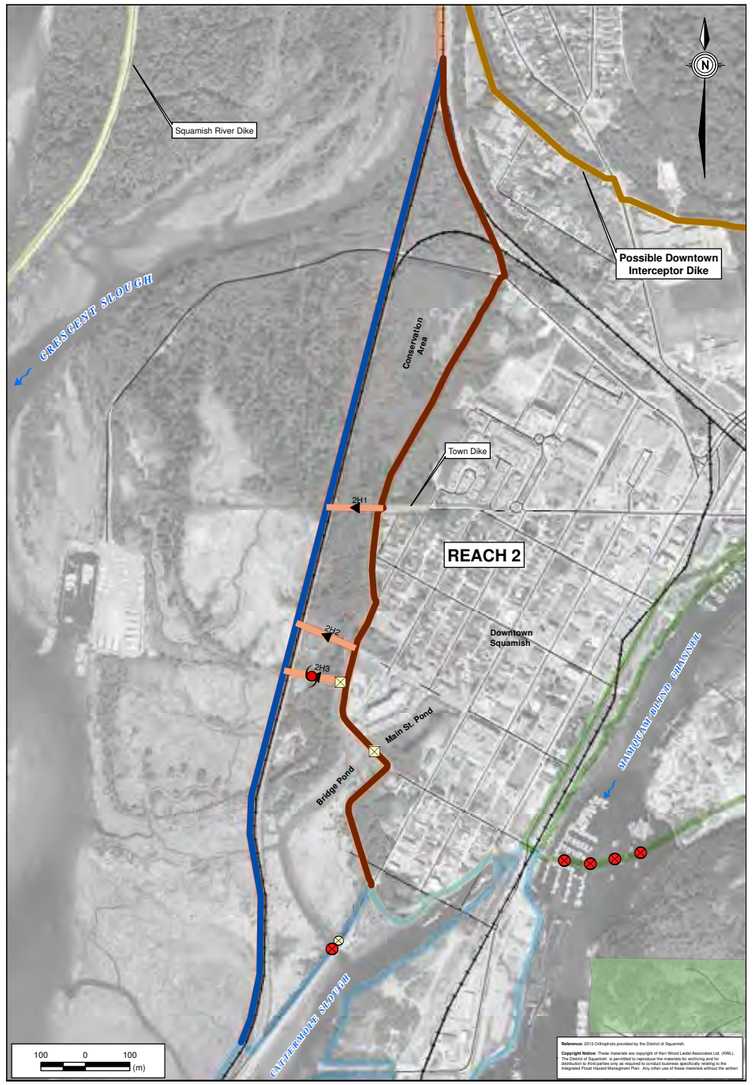
View north along Squamish River Dike of Spit Road south

View south along Squamish River Dike near intersection with Government Road

View north along Squamish River Dike to Mount Garibaldi

View south along Government Road adjacent to Crescent Slough

Reach 2: Squamish Estuary



Legend

Coastal Flood Protection Options	Option 2A	
Option 2B	Hybrid	
Coastal Flood Protection Reaches	Reach 1	Reach 3
Reach 4	Squamish River Dike/Training Berm	
Possible Downtown Interceptor Dike		
Icons	Squamish Nation (Stawamus I.R. 24)	Existing Floodbox
Proposed Pump Station	Existing Tidegate	Proposed Tidegate

Aqua development adjacent to Town Dike

View south of Bridge Pond in Squamish Estuary

View north along CN spur line and Squamish Estuary. Flood hazard mitigation under Option 2A would be to left of railline

Reach 2 connects south from the intersection of the CN mainline and spur lines to CN Rail Crossing south to 3rd Avenue. This is the main reach protecting Downtown Squamish from the westward side.

Reach 2 Mitigation Options:

Status Quo

- Nothing new will be built. Existing risk will remain and will increase over time due to sea level rise.

Option 2A – 7th Ave Connector (Blue)

- Build the proposed 7th Ave Connector as a Sea Dike on the west side of the CN Rail spur line from the CN mainline junction to 3rd Ave.

Option 2B – Bailey Street to the Town Dike (Brown)

- Raise Bailey Street from the northmost CN crossing south to the existing Town Dike and upgrade the Town Dike to 3rd Ave.

Option 2H1 – Winnipeg Street Hybrid

- Follow the Bailey Street alignment south to Winnipeg Street and then step out to the west side of the CN Rail spur. This is a hybrid version of 2A and 2B.

Option 2H2 – Main Street Hybrid

- Follow Bailey Street/Town Dike alignment south to Main Street then out to the west side of the CN Rail spur. This is a hybrid version of Options 2A and 2B.

Option 2H3 – 6th Ave Spur Dike Hybrid

- Follow Bailey Street/Town Dike south to existing spur dike at the 6th Ave floodbox and then west to the CN Rail spur. This is a hybrid version of Options 2A and 2B.

View north along CN spur line west of Aqua development

Reach 2: Squamish Estuary

Reach Options / Evaluation Criteria	Status Quo	Option 2A	Option 2B	Option 2H1	Option 2H2	Option 2H3
Natural						
Economic						
Social						
Political						
Technical						
Overall						

Most Preferable Alternative/ Least Negative Impact — Least Preferable Alternative/ Most Negative Impact — Show Stopper!!

View of stormwater storage pond and vertical stacked rock wall protecting Aqua development

View south along Crescent Slough from Government Road

Points to Consider:

- Status Quo does not address increasing coastal risk.
- The Squamish Estuary Management Plan (SEMP) guides land and water uses in the estuary from the Squamish River to the Mamquam Blind Channel.
- The SEMP designates the highly valuable ecosystem on the west side of the estuary for conservation purposes and supports industrial/commercial development on the east side.
- The SEMP development area includes a 60 m wide future transportation corridor along the west side of the CN Rail spur.
- Option 2A and all hybrid options could take place within the SEMP transportation corridor.
- Option 2A provides an opportunity to enhance the natural environment by reconnecting the Squamish River with Crescent Slough.
- Option 2A has a high potential to follow Green Shores ™ principles.
- Option 2A is the least complex to implement.
- Options 2B is the most complex to implement.
- Option 2B has the lowest potential to follow Green Shores ™ principles.

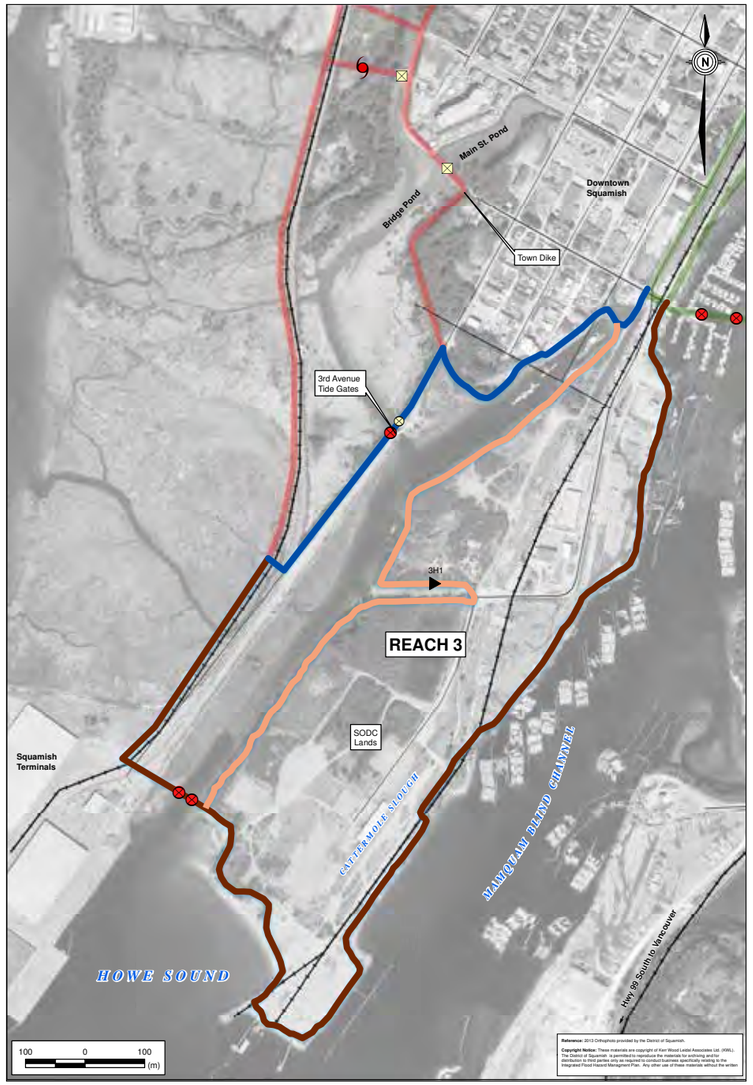
View south along CN Spur. Flood mitigation Option 2A would be on right of rail line

Town Dike - encroachments on top and along toe of dike restrict access

Town Dike near end of Pemberton Ave.

View north of Town Dike near 6th Ave

Reach 3: Cattermole Slough



Legend

Coastal Flood Protection Options

Option 3A

Option 3B

Option 3H1 (Hybrid)

Coastal Flood Protection Reaches

Reach 2

Reach 4

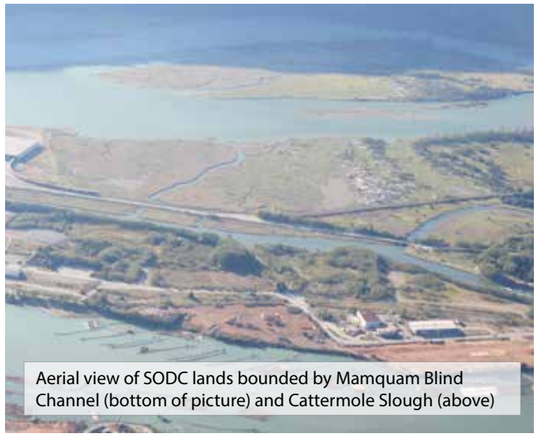
Icons

Existing Floodbox

Proposed Pump Station

Existing Tidegate

Proposed Tidegate



Aerial view of SODC lands bounded by Mamquam Blind Channel (bottom of picture) and Cattermole Slough (above)

View south along upper Cattermole Slough

Reach 3 connects the south end of Reach 2 at 3rd Avenue, past the SODC lands, to the west end of Vancouver Street near the Mamquam Blind Channel.

Reach 3 Mitigation Options:

Status Quo

- Nothing new will be built. Existing risk will remain and will increase over time due to sea level rise.

3A – 3rd Ave/Town Dike (Blue)

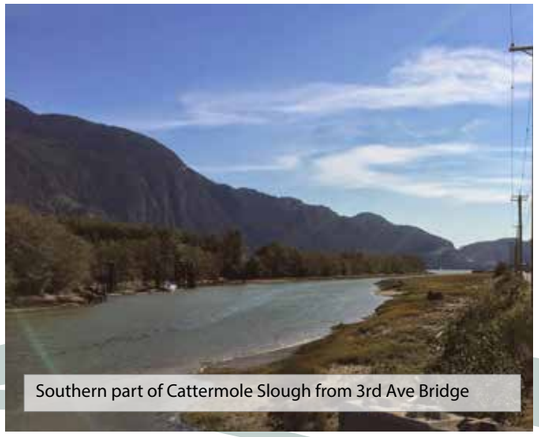
- Connection from the raised Option 2A (in red) at 3rd Avenue north to the end of Option 2B (red) and then along the existing Town Dike alignment to Vancouver Street. Downtown would not depend on SODC as part of the flood protection perimeter, and SODC could specify its own flood protection as part of the redevelopment.

3B – 3rd Ave/SODC (Brown)

- Connection from elevated Option 2B (red) to a raised 3rd Avenue south past the end of Option 2A (red), then across the Cattermole Slough and around the SODC lands to Vancouver Street.

3H1 – Town Dike to SODC Hybrid

- Connection from Option 2A (red) to 3rd Avenue north to the end of Option 2B, then along the Town Dike to the east side of Cattermole Slough and then around the SODC lands to Vancouver Street.



Southern part of Cattermole Slough from 3rd Ave Bridge

View down Mamquam Blind Channel from Marina at foot of Vancouver Street

Squamish Estuary west of CN Spur and all mitigation options

Reach 3: Cattermole Slough

Reach Options / Evaluations Criteria	Status Quo	Option 3A	Option 3B	Option 3H1
Natural				
Economic				
Social				
Political				
Technical				
Overall				

Most Preferable Alternative/ Least Negative Impact

Least Preferable Alternative/ Most Negative Impact

Show Stopper!!

View of estuary looking west

View south along Mamquam Blind Channel with SODC lands on right. Foreshore mitigation Options 3B & 3H1 applicable

View of Cattermole Slough

View of Cattermole Slough looking east from 3rd Ave

Points to Consider:

- Status Quo does not address increasing coastal risk along Reach 3
- Option 3A is the least costly and least complex option in Reach 3
- Option 3A is not dependent on SODC land development for implementation.
- Option 3B is costly compared to 3A and is dependent on the development of SODC lands.
- Option 3H1 requires the largest area in order to build the flood protection.
- Option 3H1 is the most complex option in Reach 3.

View of Cattermole Slough looking from 3rd Ave

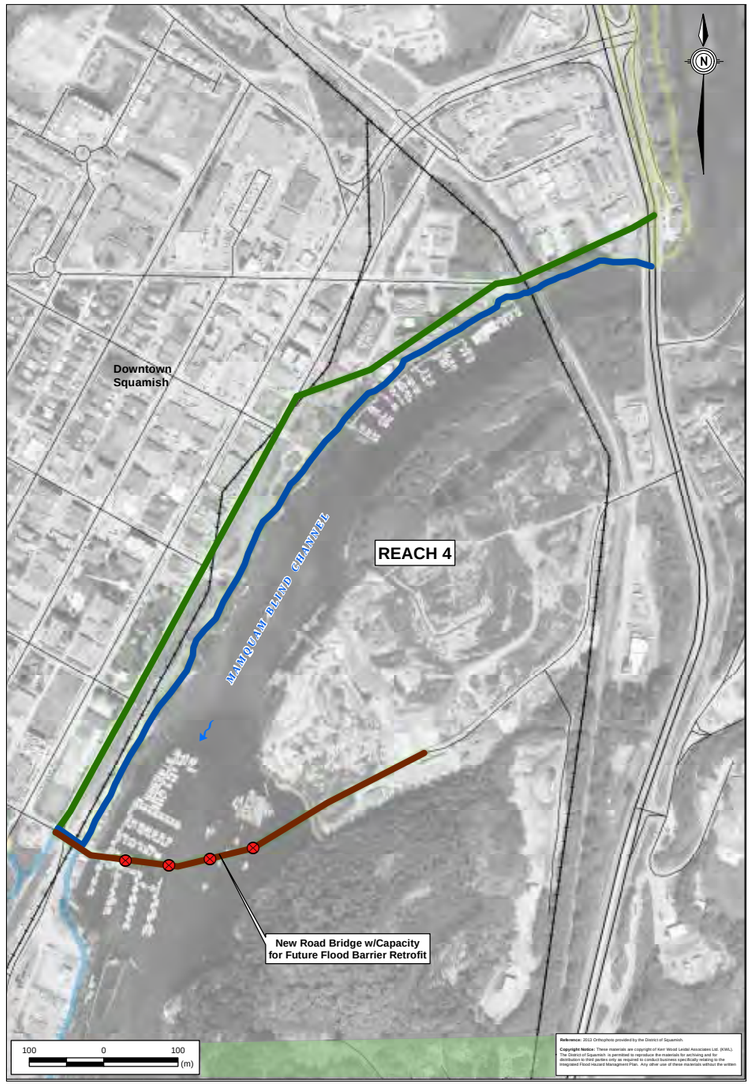
View of 3rd Ave Tidegates looking west towards Bridge Pond

Close up of 3rd Ave Tidegates

Calm water on Howe Sound from end of Squamish River Dike-Training Berm

South end of Squamish River Dyke/Training Berm

Reach 4: Lower Mamquam Blind Channel



Legend

Coastal Flood Protection Options

Option 4A — Option 4B — Option 4C

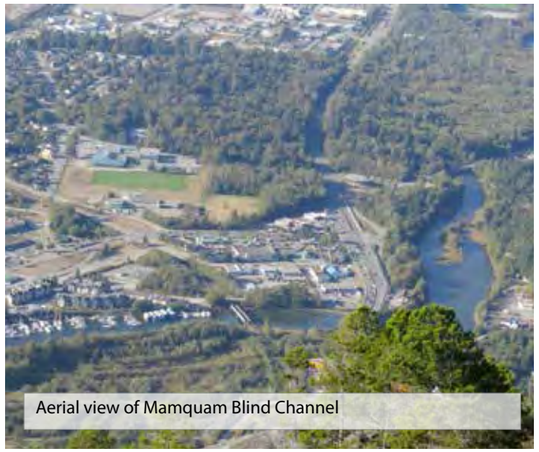
Coastal Flood Protection Reaches

Reach 3 — Reach 5

Icons

Squamish Nation (Stawamus I.R. 24) — Proposed Tidegate

Aerial view of Mamquam Blind Channel with Marina in centre



Aerial view of Mamquam Blind Channel

Reach 4 provides protection along the Mamquam Blind Channel from Vancouver Street to Highway 99.

Reach 4 Mitigation Options:

Status Quo

- Nothing new will be built. Existing risk will remain and will increase over time due to sea level rise.

Option 4A – Lower Mamquam Blind Channel Foreshore (Blue)

- Build a new dike along the foreshore of the Mamquam Blind Channel from Vancouver Street north to Highway 99.

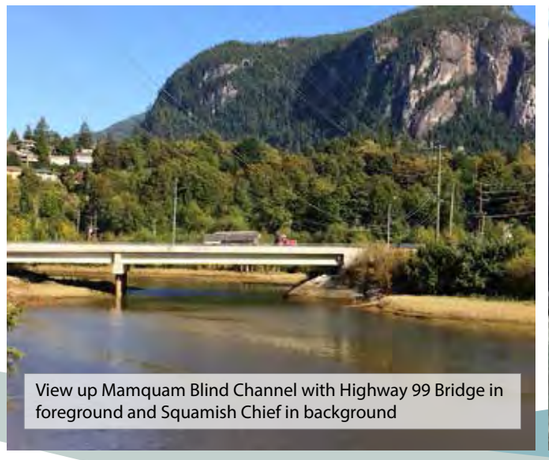
Option 4B – Vancouver Street Bridge (Brown)

- Build navigable floodgates across the Mamquam Blind Channel. This Option could include a new bridge from Vancouver Street to Waterfront Landing.

Option 4C – Loggers Lane South (Green)

- Raise Loggers Lane from Vancouver Street north to Winnipeg Street, then east to the Mamquam Blind Channel foreshore and then north to Highway 99.

View south along Mamquam Bridge with CN Bridge in foreground



View up Mamquam Blind Channel with Highway 99 Bridge in foreground and Squamish Chief in background

View south of Mamquam Blind Channel with new waterfront park in foreground

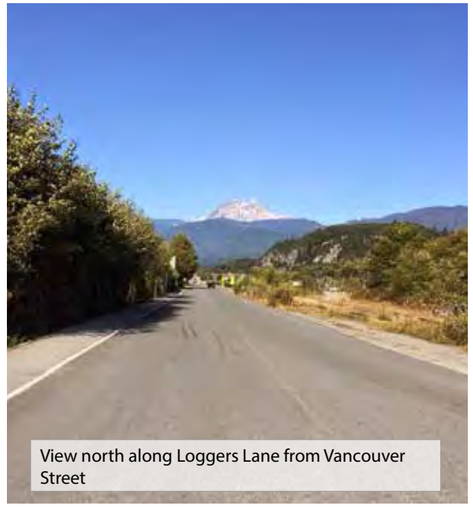
Reach 4: Lower Mamquam Blind Channel

Reach Options / Evaluations Criteria	Status Quo	Option 4A	Option 4B	Option 4C
Natural				
Economic				
Social				
Political				
Technical				
Overall				

Most Preferable Alternative/ Least Negative Impact

Least Preferable Alternative/ Most Negative Impact

Show Stopper!!



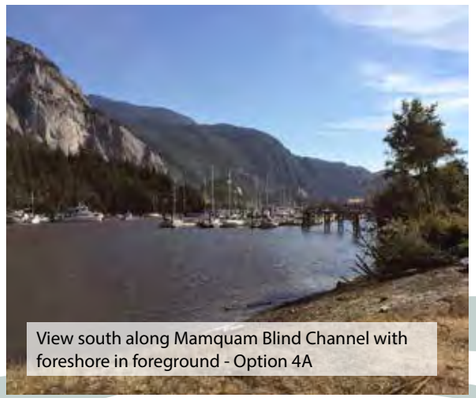
View north along Loggers Lane from Vancouver Street

View south along Loggers Lane. Option 4c flood mitigation would require elevation of roadway

Points to Consider:

- Status Quo does not address increasing coastal risk along Reach 4.
- Option 4A provides a potential cost-sharing opportunity through future development.
- Option 4A could integrate a seawall into the design concept which would require a floodgate constructed in Reach 5.
- Option 4A shoreline protection could be implemented over several phases.
- Option 4B would have very high capital and operational costs to build and maintain a major floodgate structure.
- Option 4B could provide a secondary vehicular access to Downtown.
- Option 4B would reduce shoreline protection costs on both sides of the Mamquam Blind Channel, but some secondary works would still be required
- Navigable floodgates for Option 4B would be significantly more expensive than non-navigable gates but would allow navigation under most conditions
- With Option 4C, a secondary dike would be required in order to develop lands along the shoreline.
- Option 4C includes complex design constraints and would also require floodgates constructed in Reach 5.

View north along Mamquam Blind Channel. Option 4A would involve flood protection along foreshore



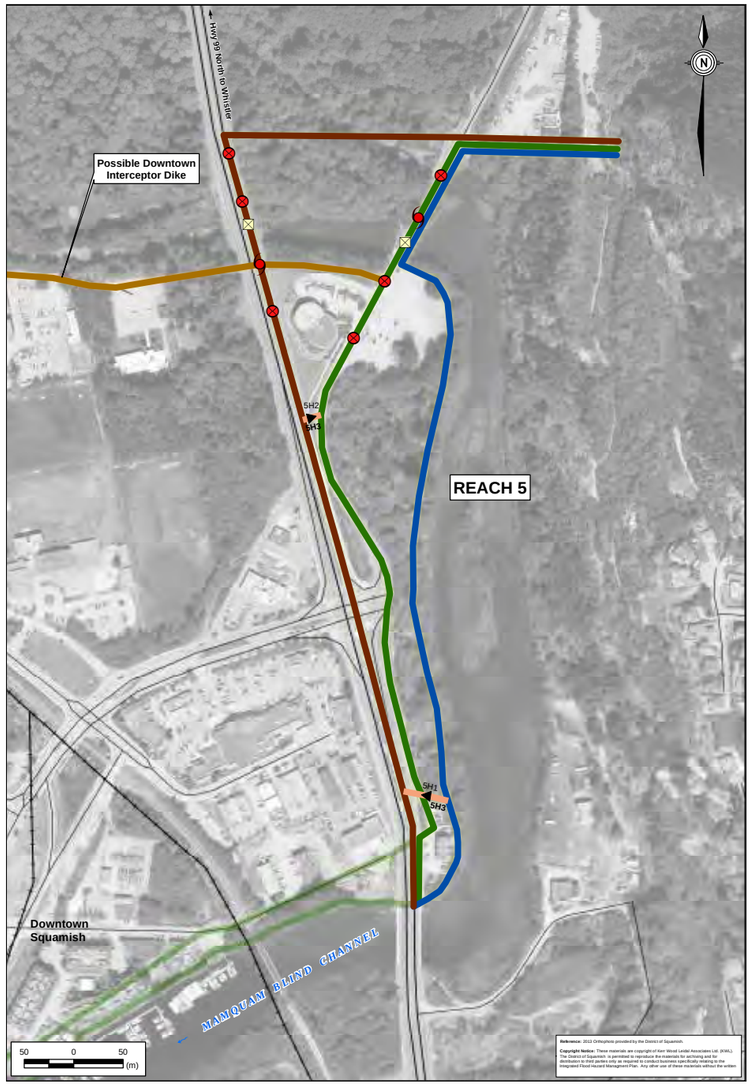
View south along Mamquam Blind Channel with foreshore in foreground - Option 4A

Closed floodgates on the Maeslankering (Netherlands) Option 4B would involve navigable floodgates

Floodgates along the River Thames (U.K.) Option 4B would involve navigable floodgates

Greenshores™ treatment - Dockside Green LEEDS Platinum project, Victoria BC

Reach 5: Upper Mamquam Blind Channel



Legend

Coastal Flood Protection Options

Option 5A — Option 5B

Option 5C — Option 5H1, 5H2 & 5H3 (Hybrids)

Coastal Flood Protection Reaches

Reach 4 — Possible Downtown Interceptor Dike

Icons

Proposed Pump Station — Existing Floodbox — Proposed Tidegate

Aerial view of Upper Mamquam Blind Channel Highway 99 in centre and CN Rail on left

Squamish Adventure Centre with Loggers Lane - Option 5C - on right

Squamish Adventure Centre with Highway 99 - Option B - on right

Reach 5 connects the Highway 99 crossing, past the Squamish Adventure Centre, up to Smoke Bluffs.

Reach 5 Mitigation Options:

Status Quo

- Nothing new will be built. Existing risk will remain and will increase over time due to sea level rise.

Option 5A – Upper Mamquam Blind Channel Foreshore (Blue)

- Build a new dike along the Mamquam Blind Channel foreshore.

Option 5B – Highway 99 (Brown)

- Raise Highway 99 to serve as dike and provide spur dike north of Squamish Adventure Centre and then east to foot of Smoke Bluffs.

Option 5C – Loggers Lane North (Green)

- Raise Loggers Lane from Highway 99 north past Adventure Centre and then east to foot of Smoke Bluffs.

Option 5H1 – Upper Mamquam Blind Channel Foreshore to Highway 99

- Upper Mamquam Blind Channel Foreshore dike around the Inn on the Water and merge into Highway 99. This Option is a Hybrid of 5A and 5B.

Option 5H2 – Highway 99 to Loggers Lane

- Highway 99 alignment transitions to Loggers Land alignment south of the Squamish Adventure Centre. This Option is a hybrid of 5B and 5C.

Option 5H3 – Highway 99 to Loggers Lane

- Follows Upper Mamquam Blind Channel foreshore alignment around Inn on the Water, then Highway 99 alignment from Inn on the Water to south of Adventure Centre, then Loggers Lane alignment to Smoke Bluffs. This Option is a hybrid of 5A, 5B, and 5C.

Reach 5: Upper Mamquam Blind Channel

Reach Options / Evaluation Criteria	Status Quo	Option 5A	Option 5B	Option 5C	Option 5H1	Option 5H2	Option 5H3
Natural							
Economic							
Social							
Political							
Technical							
Overall							

Most Preferable Alternative/ Least Negative Impact

Least Preferable Alternative/ Most Negative Impact

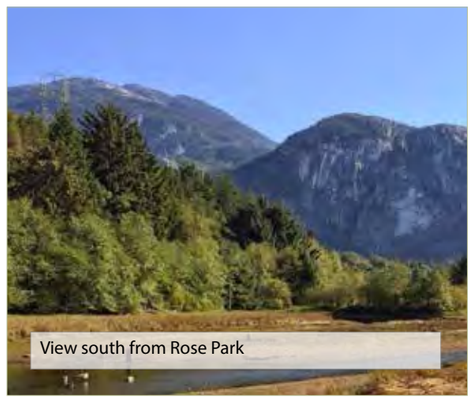
Show Stopper!!

View from Inn on the Water

View west of Upper Mamquam Blind Channel west of Highway 99

Points to Consider:

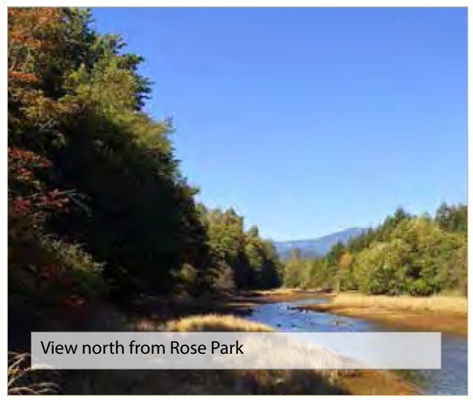
- Status Quo does not address increasing coastal risk along Reach 5.
- All options will require large floodgate capacity to let water out in the event of an upstream dike breach.
- Option 5A would impact a large amount of environmentally sensitive land.
- Option 5C would take place primarily along the existing infrastructure corridor.
- If flood gates are built in Reach 4 (Option 4B), floodbox & pump station costs in Reach 5 can be deferred.
- Options 5B and 5H1 would not protect the Squamish Adventure Centre.
- Options 5A and 5H2 are in conflict with the Upper Mamquam Blind Land Use Plan (2012).



View south from Rose Park

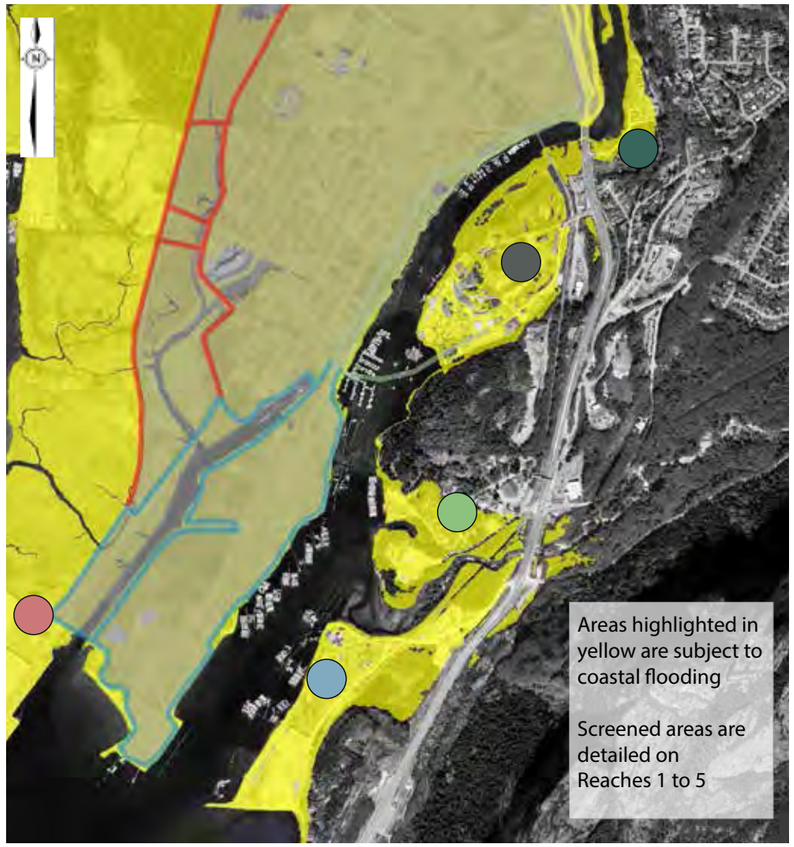
Shoreline view south from Inn on the Water

View to south of Inn on the Water



View north from Rose Park

Box culvert under Highway 99 at Wilson Slough have insufficient capacity for dike breach outflows




East side of Mamquam Blind Channel with Squamish Chief in background


Aerial view of Site B and Stawamus I.R. 24


Aerial view of Waterfront Landing

East Shore – Mamquam Blind Channel

Scott Crescent Development 3.3 hectare medium-density development of up to 425 units. Site-specific flood hazard mitigation measures were proposed by a Qualified Practitioner and accepted by the District.

Waterfront Landing Neighbourhood Plan provides for 1,500 residential dwellings as well as a marina, commercial and recreational facilities, and wetlands on the 21.5 hectare site.

Stawamus I.R. No. 24 The Squamish Nation is contemplating a range of development options for the undeveloped lower-elevation portions of the reserve.

Site B Under the 2011 Intergovernmental Cooperation Accord, the District and the Squamish Nation agreed to explore employment-generating activities for this 64-hectare site.

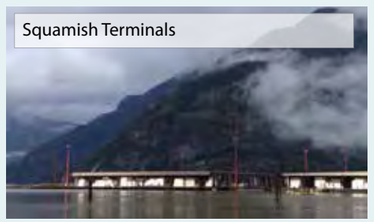
Existing and Former Industrial Sites

Squamish Terminals Intermodal transportation terminal at the end of the CN Spur line

Site A Future use for this former log storage site is yet to be determined.

Woodfibre A Liquified Natural Gas (LNG) terminal is the latest redevelopment proposal for this 68-hectare former pulp mill site.


Woodfibre


Squamish Terminals


Structural floodproofing in Downtown Squamish


Stawamus River setback dike on I.R. 24 downstream of CN Rail Bridge

Each of the sites is vulnerable to coastal flood hazards but can support a broader variety of mitigation options than the main "downtown" peninsula. The IFHMP calls these areas "unconnected coastal floodplain areas" because flooding of any one site need not affect other lands. "Unconnected" floodplain areas can adopt cost-effective, site-specific flood protection measures customized to support a particular development proposal.

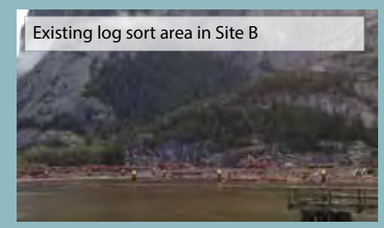
Possible options include the following:

Avoid/Retreat
- Reclaim area to natural state as a community amenity
- Possible locations – intertidal areas, Squamish Estuary

Accommodate
- Raise elevation of habitable uses above coastal flood risk
- Floodproof ground floor parking below residential/commercial uses
- Require flood resistant building materials for commercial uses at ground level
- Allow water dependent industrial uses (e.g. log sort)
- Undertake Green Shores TM approach along shoreline

Protect
- Raise land elevation with structural fill
- Construct offshore defenses (e.g. breakwater, bulkhead)
- Construct perimeter defences (e.g. sea dike, seawall, sheet wall pilings)


Big Sky Golf Course Clubhouse during 2003 Flood (Pemberton, BC)


Existing log sort area in Site B

Questions & Comments

1. How concerned are you about the risk Squamish faces from flooding due to sea level rise and associated coastal storms over the next decade (10 years)?	Very Concerned	Somewhat Concerned	Not Concerned	Undecided/Not Sure	Comments
2. How concerned are you about the risk Squamish faces from flooding due to sea level rise and associated coastal storms over the next century (100 years)?	Very Concerned	Somewhat Concerned	Not Concerned	Undecided/Not Sure	Comments
3. How concerned are you about the risk Squamish faces from flooding due from the 5 rivers in the District? (i.e. Squamish, Mamquam Cheekeye, Cheakamus and Stawamus)	Very Concerned	Somewhat Concerned	Not Concerned	Undecided/Not Sure	Comments
4. How concerned are you about the risk Squamish faces from a tsunami?	Very Concerned	Somewhat Concerned	Not Concerned	Undecided/Not Sure	Comments
5. How important do you think economic impacts (e.g., cost) should be to the choice of a flood risk mitigation approach?	Very Important	Somewhat Important	Not Important	Undecided/Not Sure	Comments
6. How important do you think natural considerations (e.g., environmental impacts) should be to the choice of a flood risk mitigation approach?	Very Important	Somewhat Important	Less important than other impacts	Undecided/Not Sure	Comments

Questions & Comments

7. How important do you think social / cultural impacts should be to the choice of a flood risk mitigation approach?	Very Important	Somewhat Important	Less important than other impacts	Undecided/Not Sure	Comments
8. The Integrated Flood Management Plan is basing flood protection on a "design storm" with a 1 in 200 chance (1/2 of 1%) of occurring in any given year based on expected conditions for Year 2100. How would you describe this level of protection this standard would provide for downtown and other areas?	Adequate	Not adequate	Undecided/Not Sure	Comments	
9. The District is considering an approach that involves planning flood protection works to meet expected conditions for the year 2100 based on phased implementation (e.g. as opportunities arise with site redevelopment, local financial contribution, senior government cost sharing, observations confirming that the sea level is rising). Are you in agreement with this approach?	Yes	No	Undecided/Not Sure	Comments	
10. Should the District of Squamish consider an 'Avoid' or 'Retreat' strategy as part of a comprehensive approach to coastal or river flood hazards?	Yes	No	Undecided/Not Sure	Comments	
11. If yes, what specific 'Avoid' or 'Retreat' options for critical infrastructure should be considered as part of the Integrated Flood Hazard Management Plan?	Comments				

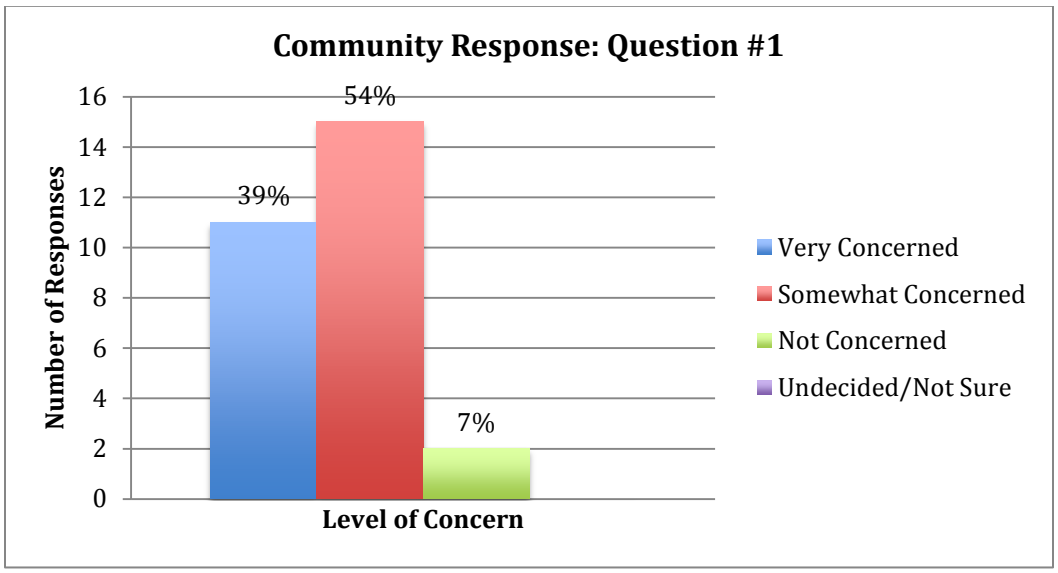
Questions & Comments

12. Please share your comments on flood Reach 1 flood mitigation options:	**Status Quo**		**1A** (Spit Rd)		**1B** (Govt Rd)	
13. Please share your comments on Reach 2 flood mitigation options:	**Status Quo**	**2A** (7th Ave Connector)	**2B** (Bailey St to Town Dike)	**2H1** (Winnipeg St Hybrid)	**2H2** (Main St Hybrid)	**2G3** (6th Ave. Spur Dike Hybrid)
14. Please share your comments on Reach 3 flood mitigation options:	**Status Quo**	**3A** (3rd Ave/Town Dike)	**3B** (3rd Ave/SODC)	**3H1** (Town Dike to SODC Hybrid)		
15. Please share your comments on Reach 4 flood mitigation options:	**Status Quo**	**4A** (foreshore)	**4B** (navigable floodgates)	**4C** (Loggers Lane)		
16. Please share your comments on Reach 5 flood mitigation options:	**Status Quo**	**5A** (foreshore)	**5B** (Highway 99)	**5C** (Loggers Lane)	**5H1** (foreshore to Highway 99)	**5H2** (Hybrid of 5B + 5C)	**5H3** (Hybrid of 5A, 5B + 5C)
17. Please share your comments on flood mitigation for other unconnected coastal floodplain sites:	**Status Quo**	**East shore of Mamquam Blind Channel**	**Squamish Terminals**	**Woodfibre**	**Site A** (former log storage site in Squamish Estuary)	
18. Please share any other comments on the development of an Integrated Flood Hazard Management Plan for the District of Squamish:	**Comments**					

Appendix C – Questions #1-#11 Responses

OPEN HOUSE RESPONSES (in-person)

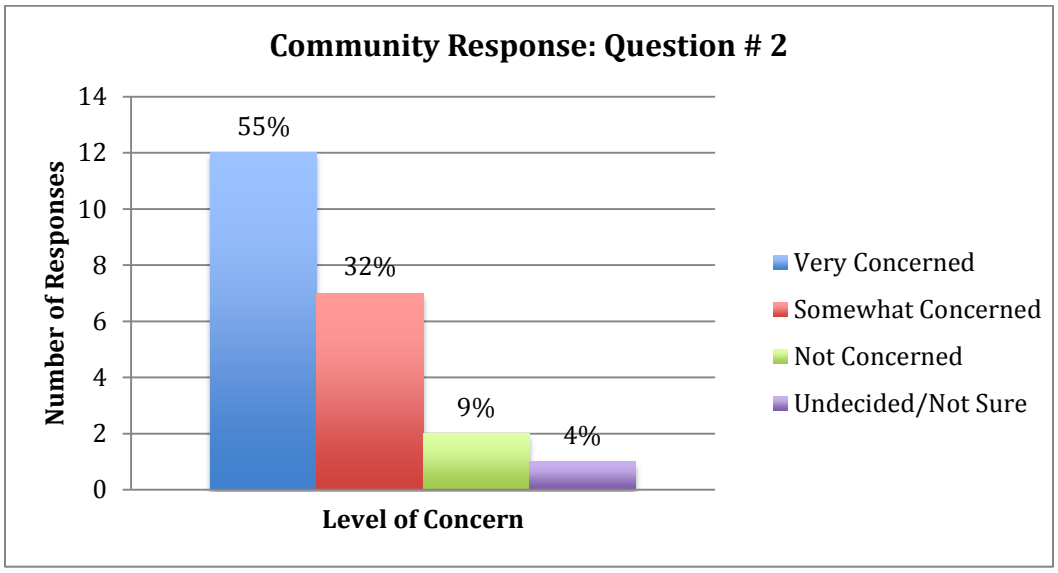
Question #1: How concerned are you about the risk Squamish faces from flooding due to sea level rise and associated coastal storms over the next decade (10 years)?



Comments:

"It needs to be the primary filter for development proposals-stop putting people's investments at risks-or rather stop allowing people to put themselves at."

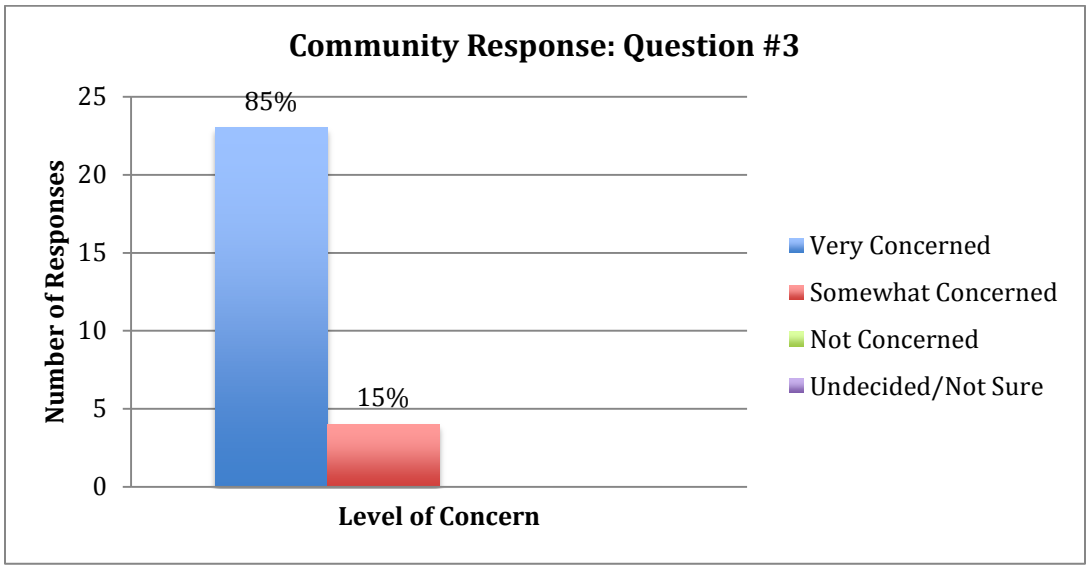
Question #2: How concerned are you about the risk Squamish faces from flooding due to sea level rise and associated coastal storms over the next century (100 years)?



Comments:

None

Question #3: How concerned are you about the risk Squamish faces from flooding due to the 5 rivers in the District?

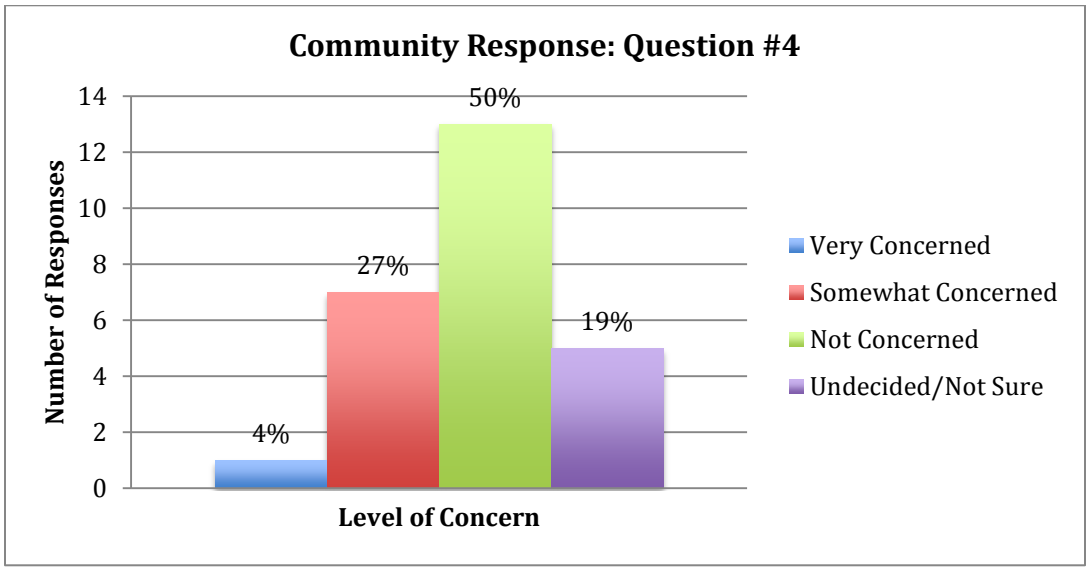


Comments:

"This may well be the most serious issue in the near term!"

"Far too reliant on our dikes and pumps-work to floodproof all residences in flood risk areas."

Question #4: How concerned are you about the risk Squamish faces from a tsunami?



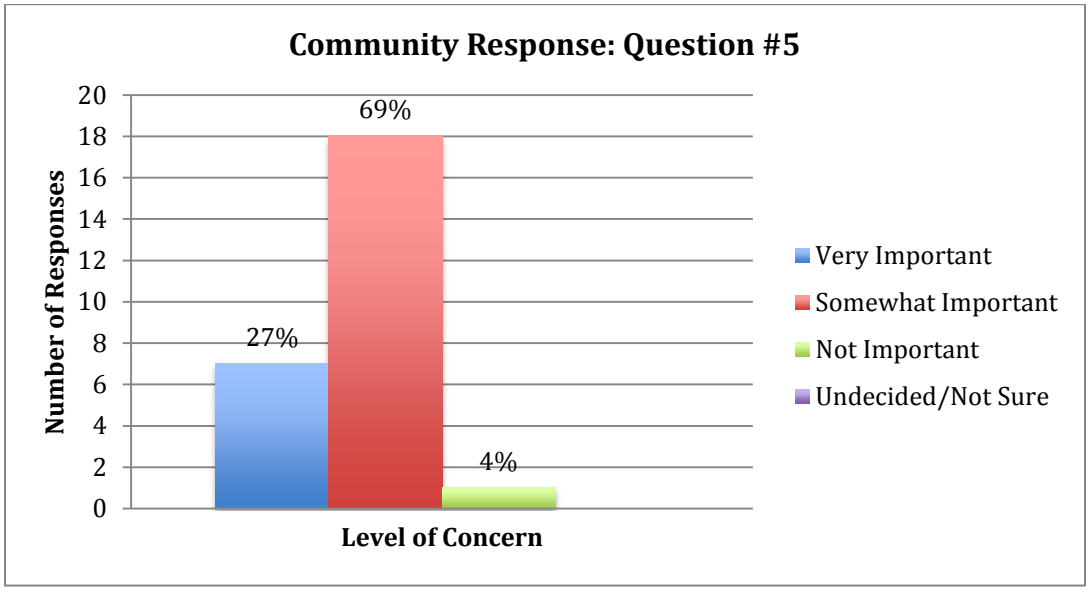
Comments:

Not from the outer coasts; From Howe Sound slide!

How concerned are we that Garibaldi will have another jammer? Same risk? Did Squamish get hit by tsunami "last time"?

Question #5: How important do you think economic impacts (e.g., cost) should be to the choice of a flood risk

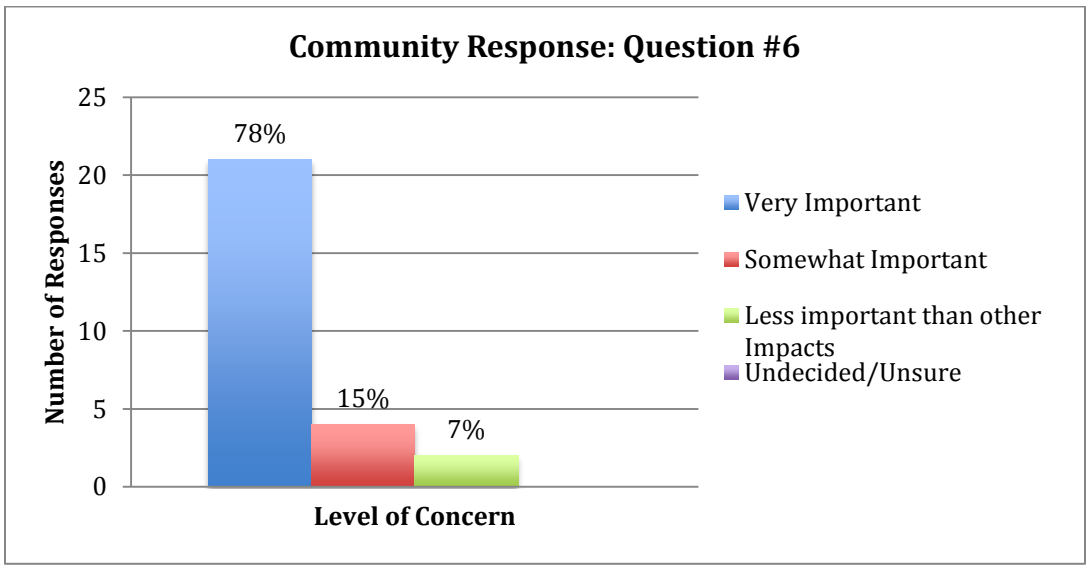
mitigation approach?



Comments:

"Bit of a moot point if there is enough money to pay…"

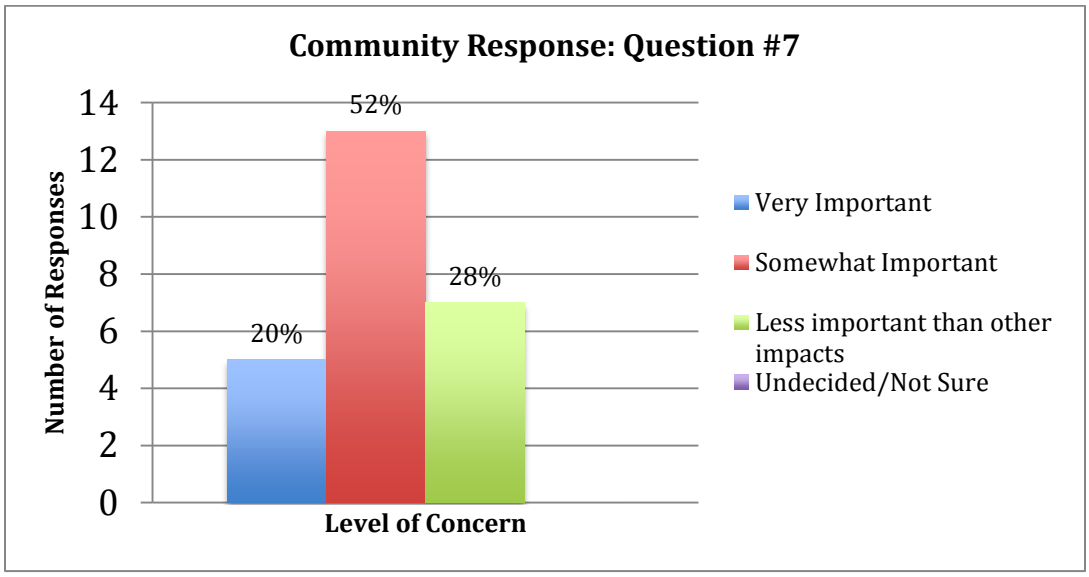
Question #6: How important do you think natural considerations (e.g., environmental impacts) should be in the choice of a flood risk mitigation approach?



Comments:

"Need to have win/win and allow for a robust natural environment-so often it is simply the easy way"

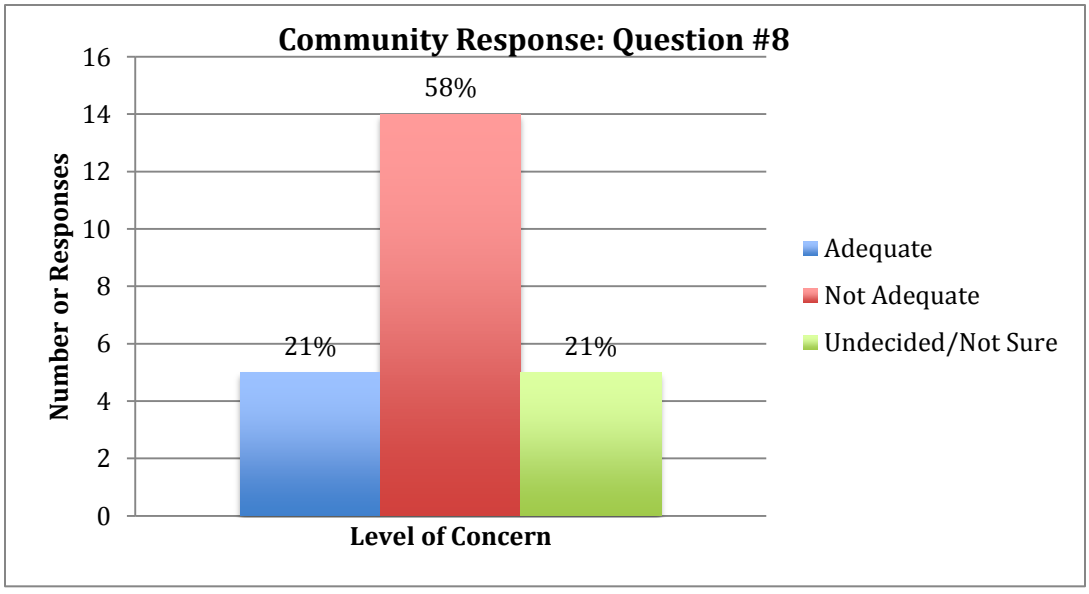
Question #7: How important do you think social/cultural impacts should be to the choice of a flood risk mitigation approach?



Comments:

None

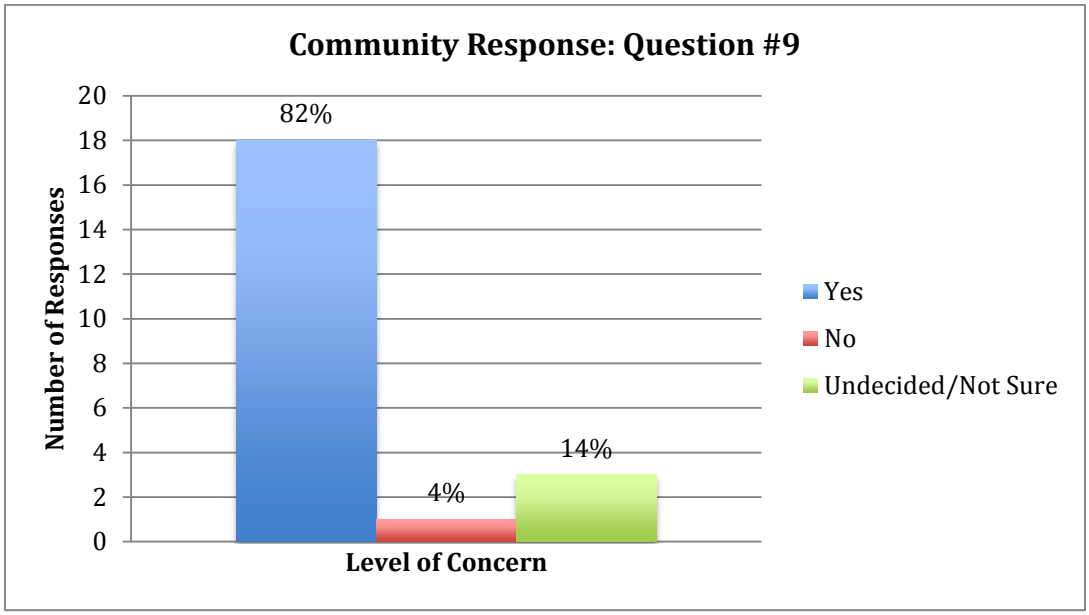
Question #8: The IFHMP is basing flood protection on a "design storm" with a 1 in 200 chance (1/2 of 1%) of occurring in any given year based on expected conditions for year 2100. How would you describe the level of protection this standard would provide for downtown and other areas?



Comments:

No 7th Avenue Connector and not an appropriate to location for a flood dyke. Dyke upgrades to existing structure!

Question #9: The District is considering an approach that involves planning flood protection works to meet expected conditions for the year 2100 based on phased implementation (e.g. as opportunities arise with site redevelopment, local financial contribution, senior government cost sharing, observations confirming that sea level is rising). Are you in agreement with this approach?



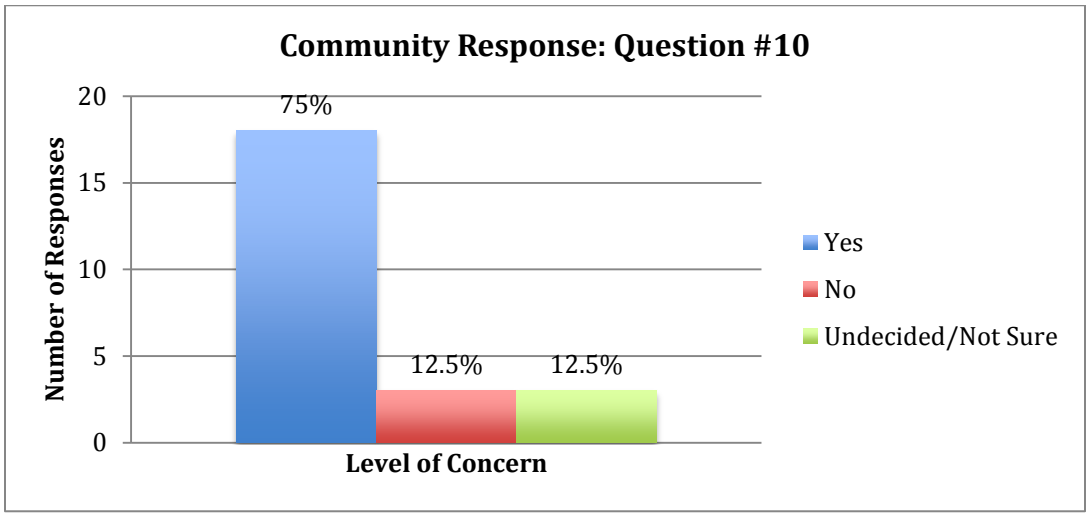
Comments:

"Will this strategy be adequate if climate change progresses more quickly than we anticipate?"

"OK-But I do not agree with building the 7th Ave Connector Road-It would encroach too much into our precious estuary."

"But doesn't that effectively leave no protection or are we creating little islands of protection that expand?"

Question #10: Should the District of Squamish consider an 'Avoid' or 'Retreat' strategy as part of a comprehensive approach to coastal or river flood hazards?



Comments:

"We definitely should not be building housing on SODC lands"

"FLAWED Question-Of course all options should be considered. It is whether or not this is the only option or #1 priority

"Please define and clarify terms e.g. 'Avoid' and 'Retreat'"

"Stupid that our evacuation and emergency infrastructure is at risk-stupid being a euphemism for something really profoundly stupid."

Question #11: If yes to Question #10, what specific 'Avoid' or 'Retreat' options for critical infrastructure should be considered as part of the Integrated Flood Hazard Management Plan?

Comments:

None

OPEN HOUSE RESPONSES (on-line)

Questions	Response 1	Response 2	Response 3	Response 4
Question 1 - How concerned are you about the risk Squamish faces from flooding due to sea level rise and associated coastal storms over the next decade?	Not Concerned	Very Concerned		Very Concerned
Question 2 - How concerned are you about the risk Squamish faces from flooding due to sea level rise and associated coastal storms over the next century?	Somewhat Concerned	Very Concerned		Very Concerned
Question 3 - How concerned are you about the risk Squamish faces from flooding due to the 5 rivers in the District?	Not Concerned	Very Concerned		Very Concerned
Question 4 - How concerned are you about the risk Squamish faces from a Tsunami	Not Concerned	Somewhat Concerned		Very Concerned
Question 5 - How important do you think economic impacts (e.g. cost) should be to the choice of a flood mitigation approach?	Not Important	Very Important		Very Important
Question 6 - How important do you think natural considerations (e.g. environmental impacts) should be to the choice of a flood risk mitigation approach	Very Important	Less important than other impacts		Very Important
Question 7 - How important do you think social/cultural impacts should be to the choice of a flood risk mitigation approach?	Less important than other impacts	Less important than other impacts		Somewhat Important

Question 8 - The Integrated Flood Hazard Management Plan is basing flood protection on a "design storm" with a 1-in-200 chance (1/2 of a 1%) of occurring in any given year based on expected conditions for Year 2100. How would you describe this level of protection this standard would provide for downtown and other areas?	Adequate	Not Adequate		Not Adequate
Question 9 - The District is considering an approach that involves planning flood protection works to meet expected conditions for the year 2100 based on phased implementation (e.g. as opportunities arise with site redevelopment, local financial contribution, senior government cost sharing, observations confirming that sea level is rising). Are you in agreement with this approach?	No	No		Yes
Question 10 - Should the District of Squamish consider an 'Avoid' or 'Retreat' strategy over a 'Protect' strategy as part of a comprehensive approach to coastal or river flood hazards?	Yes	Undecided/Not sure		No
Question 11 - If yes, what specific 'Avoid' or 'Retreat' options for critical infrastructure should be considered as part of the Integrated Flood Hazard Management Plan?	This town was built on a floodplain…..It will flood at some time….whether we do something or not. Accept it.			

Appendix D – Comment Board Responses

OPEN HOUSE RESPONSES (in-person)

Question #12

Please share your comments on Reach 1 flood mitigation options.

1A (split road)

> "I like this one!"

1B (Government Rd)

> "1B is the way to go, allow the river to expand"
>
> "But what about gas infrastructure"
>
> "1B-follow natural flow of river-road upgrade would be nice"

Question #13

Please share your comments on Reach 2 flood mitigation options.

Status Quo

> "Bolster existing footprint. No roadway except of maintenance crest (4m?) Allow for penetrating to restore flows to Bridge pond (with flood boxes)"

2A (7th Ave Connector)

> "No 7th Ave option! Take off table!"
>
> "Use existing disturbance-cheap along road-technically easy-why deal with multiple land owners?"
>
> "Trails and environmental access"

2 (Bailey St to Town Dike)

> "I don't like 2B and don't think the 7th Ave connector should be built"
>
> "Option 2 #3, Bailey St-6th Ave is best for truck-road connections to the waterfront"

Question #14

Please share your comments on Reach 3 flood mitigation options.

3A (Third Ave/Town Dike)

> "I like this one!"

"No brainer, cheaper, less technical, join all dykes for use by residents and visitors"

Question #15

Please share your comments on Reach 4 flood mitigation options.

Status Quo

"What about flood control at South end of SODC land?"

4A (Foreshore)

"Tide barrier further south above Stawamus mouth"

"I like this one!"

"Transfer costs to developer, Seawall!"

4B (Navigable floodgates)

"Too costly to build and operate"

Question #16

Please share your comments on Reach 5 flood mitigation options.

5A (Foreshore)

"Out of sight, will re-vegetate, should be cheap!"

"Scott Crescent proposed footbridge"

Question #17

Please share your comments on flood mitigation for other unconnected coastal floodplain sites.

Status Quo

"Shift responsibility to land owners for flood protection"

Woodfibre

"Need to look at risks emanating from the proposed Woodfibre LNG site and not just leave up to proponents. WFLNG risks and coping mechanisms affect all Squamish and should not be ignored or avoided."

Question #18

Please share any other comments on the development of an Integrated Hazard Management Plan for the District of Squamish.

> "All the "other unconnected areas" should at least be considered, if not analyzed from a risk management perspective as each does impact Squamish in some way"
>
> "Well presented but too much information to digest in a short time. Would be helpful to post online so we can read and re-read"
>
> "Well presented, thank you!"
>
> "Too much, too many options to handle in one session"
>
> "The Mamquam Blind Channel bridge, being the best option, needs to be the main focus"
>
> "Lots of information to digest and provide meaningful comments on. I hope as plans progress there will be more opportunities to view and comment on the planning process."
>
> "As a Dentville homeowner, I am concerned about the effect of the interceptor dike location. Perhaps through the green belt North of the neighbourhood?"
>
> "Concerned about dikes, reliance on pumps and tidal structures…move it, lift it, flood harden….mandatory boats in every bedroom?"

OPEN HOUSE RESPONSES (on-line)

Questions	Response 1	Response 2	Response 3	Response 4
Question 12 - Please share your comments on Reach 1 flood mitigation options: Status Quo	I am okay with how it is			
Question 12 - Please share your comments on Reach 1 flood mitigation options: Option 1A				
Question 12 - Please share your comments on Reach 1 flood mitigation options: Option 1B				
Question 13 - Please share your comments on Reach 2 flood mitigation options: Status Quo				

Question 13 - Please share your comments on Reach 2 flood mitigation options: Option 2A	I am totally against this option is not required and not the best option. The SEMP plan, which is almost 20 years old and outdated, allows for this corridor only "if and when" required. That time has not yet arrived, and hopefully we are 20 years smarter!			
Question 13 - Please share your comments on Reach 2 flood mitigation options: Option 2B				
Question 13 - Please share your comments on Reach 2 flood mitigation options: Option 2H1				
Question 13 - Please share your comments on Reach 2 flood mitigation options: Option 2H2				
Question 13 - Please share your comments on Reach 2 flood mitigation options: Option 2H3				
Question 14 - Please share your comments on Reach 3 flood mitigation options: Status Quo				
Question 14 - Please share your comments on Reach 3 flood mitigation options: Option 3A	As long as this option allows for full tidal flow to the Bridge Pond area, to revitalize the estuary area			
Question 14 - Please share your comments on Reach 3 flood mitigation options: Option 3B				
Question 14 - Please share your comments on Reach 3 flood				

mitigation options: Option 3H1				
Question 15 - please share your comments on Reach 4 flood mitigation options: Status Quo				
Question 15 - please share your comments on Reach 4 flood mitigation options: Option 4A				
Question 15 - Please share your comments on Reach 4 flood mitigation options: Option 4B	I believe this refers to 4B not 3B, and I would be in favour of a bridge linking south to the highway.			
Question 15 - Please share your comments on Reach 4 flood mitigation options: 4H1				
Question 16 - Please share your comments on Reach 5 flood mitigation options: Status Quo				
Question 16 - Please share your comments on Reach 5 flood mitigation options: Option 5A	I am against any diking that will interfere with the wetlands in the Upper Mamquam Blind			
Question 16 - Please share your comments on Reach 5 flood mitigation options: Option 5B				
Question 16 - Please share your comments on Reach 5 flood mitigation options: Option 5C				
Question 16 - Please share your comments on Reach 5 flood mitigation options: Option 5H1	No, as will again impact the upper Mamquam Blind			
Question 16 - Please share your comments on Reach 5 flood mitigation options: Option 5H2				

Question 16 - Please share your comments on Reach 5 flood mitigation options: Option 5H3				
Question 17 - Please share your comments on flood mitigation options for other unconnected coastal floodplain sites: Status Quo				
Question 17 - Please share your comments on flood mitigation options for other unconnected coastal floodplain sites: East Shore of Mamquam Blind Channel				
Question 17 - Please share your comments on flood mitigation options for other unconnected coastal floodplain sites: Squamish Terminals				
Question 17 - Please share your comments on flood mitigation options for other unconnected coastal floodplain sites: Woodfibre				
Question 17 - Please share your comments on flood mitigation options for other unconnected coastal floodplain sites: Site A				

Question 18 - Please share any other comments on the development of an Integrated Flood Hazard Management Plan for the District of Squamish:	While I understand the requirement for a comprehensive dike plan, I am opposed to the concept of the 7th Ave/Connector dike/road. It is not necessary. By all means build up Bailey St, even put a road on it. But diking an estuary is not a requirement to ensure the town is protected. It is unfortunate that the town was not built at a higher level, but the estuary is actually a great addition to a dike plan when left to function naturally. It is a giant sponge. I would encourage this portion of the plan be reworked, the road (sorry dike) moved to head south out of town across the Mamquam Blind. I am also opposed to any interruptions in the flow in the Upper Mamquam Blind habitat area.		I asked a question at the Open House #1, about the global warming effects on Squamish, specifically having to do with the assumption that rivers will be extra temperamental. I was told this will be addressed in the second open house. So could you please let me know when that will be? Thank you, [redacted]	

KERR WOOD LEIDAL
consulting engineers

Appendix B

Coastal Flood Protection Solution Alternatives Evaluation Matrices

District of Squamish Integrated Flood Hazard Management Plan

COASTAL FLOOD PROOFING FOR SQUAMISH IFHMP: SOLUTION ALTERNATIVES MATRIX

KWL File No. 463.278-400

Printed: April 2, 2015

Kerr Wood Leidal Associates Ltd.
The Arlington Group Planning + Architecture Inc.
SNC-Lavalin Inc.
Thurber Engineering Ltd.
Cascade Environmental Resource Group

REACH 1				
Categories	**Criteria**	**Do Nothing** **Status Quo**	**1A** **Spit Access - Govt Rd (blue)**	**1B** **Government Road (brown)**
Description		**Build no new works at this time. Accept consequences of future coastal flood damage.**	**Raise Spit Access from Squamish R dike to Gov't Rd then raise Gov't Rd south to first CN Rail crossing**	**Raise Gov't Rd from closest approach to Squamish R dike south to first CN Rail crossing**
	Overall Score	**3.5**	**3.6**	**3.7**
Natural	Species of Special Concern		most work in previously disturbed areas (MN)	most work in previously disturbed areas (MN)
	Aquatic Biota		Incursion into Crescent Slough at south end of Reach 1 (DR) Slight incursion into Crescent Slough if connector needs to be raised (MN)	Incursion into Crescent Slough at south end of Reach 1 (DR)
	Terrestrial Biota & Vegetation			slightly less clearing? (MN)
	Water and Air Quality		Sedimentation possible from construction and O&M at south end (DR)	Sedimentation possible from construction and O&M at south end (DR)
	Footprint of New Works	N.A. as no new works are proposed (GF)	New works generally follow existing Govt. Road (GF) Slightly shorter route (MN)	New works closely follow existing Govt. Road (GF)
	Enhancement Opportunities		Dike provides a good separation from floodway (GF) Supports better reconnection of Squamish River estuary (DR) Considerable opportunity for environmental enhancement if training berm is abandoned (DR)	Dike provides clear separation from floodway (GF) Possible better connection at upper end of crescent slough if training berm is abandoned (MN) Considerable opportunity for environmental enhancement if training berm is abandoned (DR)
	Score	**4.5**	**3.3**	**3.7**
Economic	Flood Protection Benefits		Protection at Year 2100 limited to a narrow strip along Government Road that includes Yekwaupsum I.R. No. 18. Much more significant benefits for SLR scenarios beyond 1 m (DR) Would allow more effective transition for backwater effects from abandoning training berm (DR)	Protection at Year 2100 limited to a narrow strip along Government Road that includes Yekwaupsum I.R. No. 18. Much more significant benefits for SLR scenarios beyond 1 m (DR)won't protect FortisBC gas line (DR)
	Environmental Compensation Costs	None (DR)		
	Long-term Employment Opportunities		Additional development land will be created north of Spit access road but its potential is limited. (GF)	Additional development land not anticipated(GF)
	Capital Cost	None (DR)		
	O&M Costs	None (DR)		
	Funding Opportunities (Cost Sharing)	N/A	Possible specified area for nearby industry (GF)	Possible specified area for nearby industry (GF)
	Score	**3.8**	**3**	**2.8**
Social / Cultural	Traditional Use / Rights & Title			
	Public Safety	Status quo does not address risk (GF)	Improves safety (GF) Limited improvement relative to status quo (DR)	Improves safety (GF) Limited improvement relative to status quo (DR)
	Public Consultation	No consultation required (DR)	Minimal impact for all options (GF)	Minimal impact for all options (GF)
	Archaeological Impacts	No additional impact (GF)	Limited impact except to road (GF)	Limited impact except to road (GF)
	Recreation Opportunities	Training berm provides wind surfer access (GF)	Recreation opportunities reduced if training berm is abandoned (GF) Loss of DMA requirement to maintain spit access (DR)	Recreation opportunities reduced if training berm is abandoned (GF) Loss of DMA requirement to maintain spit access (DR)
	Score	**3.2**	**3.4**	**3.4**
Political / Planning	Property and Access	N/A Existing access good but vulnerable (GF)	Simple access (DR)	Simple access (DR)
	Land Tenure / Statutory Right of Way	No change in existing land tenure and ROW (GF)	Alignment follows most of road ROW (GF)	Some widening of road ROW likely (GF)
	Policy Alignment	Existing training berm bisects floodway, there is an opportunity to reclaim setback areas (GF) Does not address flood protection (DR)	Generally separates natural area from CNR (GF)	Best separates ESA from CNR land (GF)
	Permitting Challenges	SN may raise objections if Yekwaupsum is isolated (DR)	Dike would mainly follow existing Govt. Road (GF)	Dike would follow existing road alignment (GF)
	Development Impacts	Development limited by flood hazard (DR)	Low impact along CN Rail yard. Would accommodate additional development north of Spit access road (GF)	Low impact along CN Rail yard (GF)
	Transportation Implications	Status quo does not provide flood protection for Hwy 99 and CN Rail transportation corridors (GF)	Transportation corridor would separate land uses (GF)	Transportation corridor would separate land uses (GF) Redevelopment of Government Road required regardless for 7th Ave connector (DR)
	Emergency Plan Implications (Closures)	Greatest risk of emergencies (GF) Flood contingency planning required (DR)	Reduced risk of emergency with Govt. Rd. dike (GF)	Reduced risk of emergency with Govt. Rd. dike (GF)
	Score	**2.0**	**4.1**	**4.3**
Technical	Construction Logistics	N.A. (GF)	Spit access road can be upgraded separately (GF) Temporary Govt Road closure may be required (DR)	Temporary Govt. Road closure may be required (GF)
	Geometry Constraints	N.A. (GF)	Spit access has two 90 degree angles (GF) Tie-in to Government Road requires a raised intersection and ramping of Government Road to meet grade (Dsell , DR)	Alignment has long tangents and radii (GF)
	Complexity	N.A. (GF)	Low complexity compared to other reaches (GF)	Low complexity compared to other reaches (GF)
	Implementation Opportunities (e.g., phasing)	N.A. (GF)	Spit access could be a separate phase (GF) Works could be deferred as lowest priority for downtown protection (DR)	Phasing would require repeated disruption of traffic along full length (DR) Works could be deferred as lowest priority for downtown protection (DR)
	Navigation	No impact (DR)	No impact (DR)	No impact (DR)
	Internal Drainage	Free outflow condition (DR)		
	Upstream Dike Breach	Free outflow condition (DR)		
	Seismic Performance	N/A		
	Adaptability (for further SLR)			
	O&M / High Water Response			
	Redundancy	No redundancy proposed in Reach 1 (GF)	Full redundancy at Year 2100 design flood levels provided by ground elevation at North Yards (DR)	Full redundancy at Year 2100 design flood levels provided by ground elevation at North Yards (DR)
	Score	**4.25**	**3.818181818**	**4**
Protection Concepts	Standard Sea Dike	N/A		
	Greenshores Approach	N/A	Only applies to riparian sections (DR) Excessive footprint required for riparian sections (DR) Vulnerable to dynamic erosion if channel reactivated (DR)	Only applies to riparian sections (DR) Excessive footprint required for riparian sections (DR) Vulnerable to dynamic erosion if channel reactivated (DR)
	Seawall Structure	N/A	Only applies to riparian sections (DR) Higher cost but could minimize riparian encroachment (DR) Undesirable unless severe land constraint (GF)	Only applies to riparian sections (DR) Higher cost but could minimize riparian encroachment (DR) Undesirable unless severe land constraint (GF)
	Score		**3.3**	**3.3**
General Notes			Removal of training berm would have offsetting environmental (positive) and recreational (negative) impacts. Recreational impacts would be severe unless alternate and equivalent wind sports venue is provided (GF)	Removal of training berm would have offsetting environmental (positive) and recreational (negative) impacts. Recreational impacts would be severe unless alternate and equivalent wind sports venue is provided (GF)

REACH 2

Categories	Criteria	Do Nothing Status Quo	2A 7th Ave Connector (blue)	2B Bailey St - Town Dike (brown)	2B - 2H1 - 2A Winnipeg Street Hybrid (brown-pink-blue)	2B - 2H2 - 2A Main Street Hybrid (brown-pink-blue)	2B - 2H3 - 2A 6th Ave Spur Dike Hybrid (brown-pink-blue)
Description		**Build no new works. Accept consequences of future coastal flood damage.**	**Build 7th Ave Connector as a sea dike west of CN Rail SQT spur from CN mainline jct to 3rd Ave**	**Raise Bailey St from northmost CN crossing south to existing Town Dike, then upgrade Town Dike to 3rd Ave.**	**Follow Bailey St alignment south to Winnipeg Street then step out to west side of CN Rail SQT spur**	**Follow Bailey St / Town Dike alignment south to Main Street then out to west side of CN Rail SQT spur**	**Follow Bailey St / Town Dike south to existing spur dike at 6th Ave floodbox then west to CN Rail SQT spur**
	Overall Score	4	4	2	3	3	2
Natural	Species of Special Concern				Would provide better connectivity between area labelled "conservation area" on map with wildlife management area to west (MN)		
	Aquatic Biota		I think there is an old channel immediately beside this alignment across from the "conservation area", but this argument is moot if the transportation corridor is built (MN) Extends riparian work further south along Crescent Slough (DR)	Immediately beside upper Cattermole slough/ditch (MN)	Avoids impacts to both Main Street Slough & Crescent Slough (DR)		
	Terrestrial Biota & Vegetation			Least disturbance, most connectivity (DR)	Would provide better connectivity between area labelled "conservation area" on map with wildlife management area to west (MN)		
	Water and Air Quality						
	Footprint of New Works	N.A. as no new works are proposed (GF)	Larger due to co-location with 7th Ave Connector (DR) Already planned into SEMP (DR)	Co-located with existing works			
	Enhancement Opportunities	Status quo does not provide enhancement opportunities (GF)	Opportunity to re-connect Squamish River to Crescent Slough (DR) Could consider a culvert crossing to re-water Cattermole Creek (DR)	Essentially the same as status quo Town Dike (DR)	CN Rail line limits enhancement potential (GF) Opportunity to reconnect Cattermole Creek to bridge pond (DR)	CN Rail line limits enhancement potential (GF) Opportunity to reconnect Cattermole Creek to bridge pond (DR)	CN Rail line limits enhancement potential (GF)
	Score	**4.0**	**2.8**	**2**	**3.2**	**2.3**	**2.2**
Economic	Flood Protection Benefits	Status quo does not provide flood protection (GF)		Will not protect CN Rail, link to Squamish Terminals, or Bridge Pond stormwater storage / habitat area (DR)	Will not fully protect CN Rail spur but protects most vulnerable parts (DR)	Will not fully protect CN Rail spur (DR)	Will not fully protect CN Rail spur (DR)
	Environmental Compensation Costs	None (DR)	Largest impacted environmental footprint (GF)	Has most aquatic habitat (GF) Builds on existing structure, but where impacts occur they are significant (DR)			
	Long-term Employment Opportunities	Flooding could disrupt long-term employment in Squamish Downtown (DR)	Additional development land not anticipated but flood protection is essential for Downtown Squamish (GF)	Additional development land not anticipated but flood protection is essential for Downtown Squamish (GF)	Additional development land not anticipated but flood protection is essential for Downtown Squamish (GF)	Additional development land not anticipated but flood protection is essential for Downtown Squamish (GF)	Additional development land not anticipated but flood protection is essential for Downtown Squamish (GF)
	Capital Cost	None (DR)	Most exposed, high cost to co-locate with 7th Ave Connector	Significant costs of engineering to accommodate infrastructure			
	O&M Costs	None (DR)	Has no residential interface & alignment generally straight (GF)	Has most curvature & high residential interface (GF)	Has low residential interface (GF)	High curvature & residential interface	High curvature & residential interface (GF)
	Funding Opportunities (Cost Sharing)	N/A	Some cost sharing potential with Downtown Squamish (GF) Cost-sharing potential with transportation and environmental initiatives (DR)	Some cost sharing potential with Downtown Squamish (GF)	Some cost sharing potential with Downtown Squamish (GF)	Some cost sharing potential with Downtown Squamish (GF)	Some cost sharing potential with Downtown Squamish (GF)
	Score		**3.3**	**2.7**	**3.0**	**2.7**	**2.5**
Social / Cultural	Traditional Use / Rights & Title						
	Safety	Status quo does not address risk (GF)	Significant improvement relative to status quo (DR)	Significant improvement relative to status quo (DR)	Significant improvement relative to status quo (DR)	Significant improvement relative to status quo (DR)	Significant improvement relative to status quo (DR)
	Public Consultation	No consultation required (DR)	Least disruption to downtown Squamish (GF)	Modest disruption to Downtown Squamish (GF) Close proximity to existing residences (DR) Public recreation walkway in sensitive intertidal area (DR)			
	Archaeological Impacts	No additional impact (GF)		Modest footprint & low likelihood of middens, etc. (GF)			
	Recreation Opportunities		Lowest amenity due to distance from residential area (GF)	Highest amenity value due to residential proximity (GF)	Good amenity value due to residential proximity (GF)	High amenity value due to residential proximity (GF)	High amenity value due to residential proximity (GF)
	Score		**3.2**	**3.4**	**3.2**	**3.2**	**3.2**
Political / Planning	Property and Access	N/A Existing access good but vulnerable (GF)	Least complicated ownership & access (GF)	Highest ownership & access challenges (GF)	Limited ownership & access issues (GF)	High ownership & access issues (GF)	High ownership & access issues (GF)
	Land Tenure / Statutory Right of Way	No change in existing land tenure and ROW (GF)	Least complicated land tenure (GF)	Most complicated land tenure (GF)	Land tenure relatively straightforward (GF)	Land tenure challenging (GF)	Land tenure challenging (GF)
	Policy Alignment	Does not address flood protection (GF)	All options provide policy alignment (GF) Provides support for implementing OCP goal of 7th Ave connector (DR)	All options provide policy alignment but proximity of dike provides best recreational amenity (GF)	All options provide policy alignment (GF) Not as good as either primary alternative (DR)	All options provide policy alignment (GF) Not as good as either primary alternative (DR)	All options provide policy alignment (GF) Not as good as either primary alternative (DR)
	Permitting Challenges	None (DR)	Least complications	Most complications (GF)			
	Development Impacts	Existing development at risk (GF) New development constrained by flood hazard (DR)	Least complications for adjacent lands (GF) Could spur economic development if developed as transportation route (DR)	Would need to work with existing and proposed development	Limited complications for adjacent lands (GF)		
	Transportation Implications	Status quo does not provide flood protection for Hwy 99 and CN Rail transportation corridors (GF)	Easiest to service (GF) Supports 7th Ave Connector (DR) Would need to raise 3rd Ave at crossing (DR)	Could serve as emergency route (GF) Upgrading Government Road could support back route into downtown	Could serve as emergency route (GF) Upgrading Government Road could support back route into downtown	Could serve as emergency route (GF) Upgrading Government Road could support back route into downtown	Could serve as emergency route (GF) Upgrading Government Road could support back route into downtown
	Emergency Plan Implications (Closures)	Greatest risk of emergencies (GF) Flood contingency planning required (DR)	Could serve as uninterrupted emergency route (GF) Alignment crosses CN Rail once (DR)	Alignment includes crosses CN Rail twice (GF)	Alignment includes crosses CN Rail three times (GF)	Alignment includes crosses CN Rail three times (GF)	Alignment includes crosses CN Rail three times (GF)
	Score	**2.3**	**4.3**	**2.4**	**3.0**	**2.6**	**2.6**
Technical	Construction Logistics	N.A. (GF)	Pioneer road required (DR)	Construction in close proximity to developed areas (DR)	No in-water work (DR)	No in-water work, but private property considerations (DR)	Needs to deal with development and in-water work and pioneering a road (DR)
	Geometry Constraints	N.A. (GF)	Features long tangents and arcs (GF) sharper corner to turn alignment to cross 3rd Ave (DR)	Very tight geometric constraints between development and Main Street Slough (DR)	Sharp angles contrast with Option 2A (GF) Line of sight issues (mtce and CPTED) (DR)	Sharp angles contrast with Option 2A (GF) Line of sight issues (mtce and CPTED) (DR)	Sharp angles contrast with Option 2A (GF) Line of sight issues (mtce and CPTED) (DR) Very tight constraints btw development & Main st slough (DR)
	Complexity	N.A. (GF)					
	Implementation Opportunities (e.g., phasing)	N.A. (GF)	Majority of capital costs associated with access and footprint of additional structure (DR) Phasing would need to be tied to redevelopment of 7th Ave connector and would involve very significant disturbances due to construction traffic, etc. (DR)	Existing structure provides some protection (DR)			Existing structure provides some protection (DR)
	Navigation	No impact (DR)	Navigation should not be affected (GF)	Navigation should not be affected (GF)	Navigation should not be affected (GF)	Navigation should not be affected (GF)	Navigation should not be affected (GF)
	Internal Drainage	Free outflow condition (DR)	Existing tide gates would require significant upgrade (DR) Pump station may be required at 3rd Ave tide gates (DR)	Would require spur dike or internal pump station (DR) Pump station may be required at 3rd Ave tide gates (DR)	Maintain connectivity with Bridge Pond (DR) Pump station may be required at 3rd Ave tide gates (DR)	Maintain connectivity with Bridge Pond (DR) Pump station may be required at 3rd Ave tide gates (DR)	Would require spur dike or internal pump station (DR) Pump station may be required at 3rd Ave tide gates (DR)
	Upstream Dike Breach	Free outflow condition (DR)	CN Rail line offers additional protection and conservation area provides some reserve capacity (GF) Conservation area could provide internal floodway (DR)	No appreciable floodway (DR)			
	Seismic Performance	N.A. (GF)	New standard dike must meet seismic req.(GF) Ground densification would be required for road (DR)	Existing dike will require rebuilding to meet seismic req. (GF) Ground densification could be problematic adjacent to structures (DR)	Existing dike will require rebuilding to meet seismic req. (GF)	Existing dike will require rebuilding to meet seismic req. (GF)	Existing dike will require rebuilding to meet seismic req. (GF) Ground densification could be problematic adjacent to structures (DR)
	Adaptability (for further SLR)		Impact to, and cost of raising, 7th Ave Connector (DR)	Repeated impact to adjacent development and public amenity space (DR)			
	O&M / High Water Response		Would affect road traffic on 7th Ave connector	Private property and environmental impacts must be considered	Less effect to road traffic on 3rd Ave connector		
	Redundancy	RR and Town dike provide some but inadequate flood protection (GF)	Town Dike offers some secondary protection if dike west of CNR is constructed (GF)	CN Rail line offers some initial protection if Town Dike is upgraded (GF) Some redundancy but not in District control (DR)	2A and 2B comments also apply to hybrid options (GF)	2A and 2B comments also apply to hybrid options (GF)	2A and 2B comments also apply to hybrid options (GF)
	Score		**3.7**	**2.1**	**3.2**	**2.7**	**2.0**
Protection Concepts	Standard Sea Dike	N.A. (GF)					
	Greenshores Approach	N.A. if nothing is done (GF)	Greenshores is preferred option along 2A, as adjacent to wildlife management area (MN)	Elevation change to conservation area poses a challenge and location of CN Rail line restricts environmental benefits (GF) Assumes that green shores would take up too much room and intrude into adjacent watercourses/habitat (MN)	Similar constraints to 2B but less significant (GF)	Similar constraints to 2B but less significant (GF)	Similar constraints to 2B but less significant (GF)
	Seawall Structure	N.A. (GF)	I've assumed that seawall structures would be unacceptable in this area for due to proximity to wildlife management area/ valuable habitat etc (MN)	Seawall structure may be acceptable in place of rockstack wall along Main Street Slough and Bridge Pond (DR)	I've assumed that seawall structures would be unacceptable in this area for due to proximity to wildlife management area/ valuable habitat etc (MN)	I've assumed that seawall structures would be unacceptable in this area for due to proximity to wildlife management area/ valuable habitat etc (MN)	Seawall structure may be acceptable in place of rockstack wall along Main Street Slough(DR)
	Score			**2.3**			**2.7**
General Notes							

COASTAL FLOOD PROOFING FOR SQUAMISH IFHMP: SOLUTION ALTERNATIVE MATRIX FOR REACH 3

District of Squamish - Integrated Flood Hazard Management Plan KWL File No. 463.278-400

IMPACT COLOUR CODES

5 | 4 | 3 | 2 | 1

Most Preferable Alternative or Least Negative Impact ⟷ Least Preferable Alternative or Most Negative Impact Show Stopper!

REACH 3					
Categories	**Criteria**	**Do Nothing** **Status Quo**	**3A** **3rd Ave / Town Dike (blue)**	**3B** **3rd Ave / SODC (brown)**	**3A - 3H1 - 3B** **Town Dike - SODC Hybrid (blue-pink-brown)**
Description		**Build no new works. Accept consequences of future coastal flood damage.**	**From Option 2A, raise 3rd Ave north to end of Option 2B, then follow existing Town Dike to Vancouver St**	**From Option 2B, raise 3rd Ave south to end of Option 2A, then across slough and around SODC lands**	**From Option 2A, 3rd Ave north to end of 2B, then Town Dike to SODC lands, around SODC lands to Vancouver St**
	Overall Score	**3.6**	**3.7**	**2.4**	**2.9**
Natural	Species of Special Concern		Most of work would be on existing infrastructure (MN)	Tide gate could interfere with Cattermole slough (MN)	Benefit would be removal of old creosote walls and piles, but may be done in any case by SODC (MN)
	Aquatic Biota		Would be similar to present situation, with but with raised existing infrastructure (MN)	Tide gate could interfere with Cattermole slough (MN)	Benefit would be removal of old creosote walls and piles, but may be done in any case by SODC (MN)
	Terrestrial Biota & Vegetation		Most of work would be on existing infrastructure (MN)	Lower-value habitat (DR)	Largest footprint (MN)
	Water and Air Quality	existing creosote pile/walls would remain (MN)	Existing creosote pile/walls would remain (MN)	Some creosote walls would be removed, but others could remain (MN)	Benefit would be removal of old creosote walls and piles, but may be done in any case by SODC (MN)
	Footprint of New Works	N.A. as no new works are proposed (GF)		Footprint includes in-channel areas (DR)	Land configuration will require a very large protective footprint (GF)
	Enhancement Opportunities	Assumes enhancement opportunities limited by existing creosote walls and piles (MN)			
	Score	**3.7**	**3.5**	**2.0**	**3.5**
Economic	Flood Protection Benefits	Status quo does not provide flood protection (GF)			
	Environmental Compensation Costs	None (DR)			
	Long-term Employment Opportunities	Flooding could disrupt long-term employment in Squamish Downtown (DR)	Does not include SODC lands. Flood protection for SODC should proceed independently as a privately funded initiative (GF)	Essential for SODC. Note that separate flood protection for SODC would provide redundancy and enable timing of flood protection to proceed separate from Downtown Squamish (GF)	Essential for SODC. Note that separate flood protection for SODC would provide redundancy and enable timing of flood protection to proceed separate from Downtown Squamish. This option has a very limited connection with the Town Dike (GF)
	Capital Cost	None (DR)			
	O&M Costs	None (DR)			
	Funding Opportunities (Cost Sharing)	N.A.			Cost-sharing opportunities with SODC
	Score		**3.8**	**2.8**	**3.0**
Social / Cultural	Traditional Use / Rights & Title			SODC land already highly disturbed (GF)	SODC land already highly disturbed (GF)
	Safety	Status quo does not address risk (GF)	Significant improvement to status quo	More complex system, more risk of flooding	Longest length of system, higher risk of failure
	Public Consultation	No consultation required (DR)	Will interface with downtown streets and existing properties. (DR) Could disrupt Squamish Terminals during raising of 3rd Ave (DR)	Would significantly change hydraulic function of Cattermole Creek (DR) Would involve extensive discussions with SODC. Schedule risk (DR)	Would involve significant discussions with SODC. Schedule Risk (DR)
	Archaeological Impacts	No additional impact (GF)	None expected due to overlap with existing infrastructure (DR)	SODC land already highly disturbed (GF)	SODC land already highly disturbed (GF)
	Recreation Opportunities		Town Dike will be enhanced for recreation purposes	SODC needs to provide recreation opportunities regardless (DR)	Walking track / running trail around SODC? Good access to beaches, parks, etc. (DR)
	Score		**4.0**	**2.8**	**3.2**
Political / Planning	Property and Access	N/A Existing access good but vulnerable (GF)	Access in Downtown a challenge (GF) A couple of properties affected (DR)	Access a challenge only in Downtown (GF)	Access a challenge only in Downtown (GF)
	Land Tenure / Statutory Right of Way	No change in existing land tenure and ROW to support flood protection (GF)	Additional ROW anticipated in Downtown; land tenure also a challenge (GF)	Additional ROW required from SODC (DR)	Additional ROW required from SODC (DR)
	Policy Alignment	Does not address flood protection (GF)	Upgrade to 3rd Ave tide gate will support environmental operation of Bridge Pond tide gates		Flood protection works will be required for SODC (DR)
	Permitting Challenges	None (DR)	No challenges anticipated (DR)	Likely challenges for tide gate structure (DR)	
	Development Impacts	Existing development at risk (GF) New development constrained by flood hazard (DR)	Least complicated - affects only a couple of properties (DR)	Affects SODC (DR)	Affects SODC (DR)
	Transportation Implications	Status quo does not provide flood protection for Hwy 99 and CN Rail transportation corridors (GF)	Would require raising some streets and intersections		
	Emergency Plan Implications (Closures)	Status quo includes two rail crossings (GF)			
	Score	**2.7**	**3.0**	**2.6**	**2.6**
Technical	Construction Logistics	N.A.		Floodgates add to construction challenges (GF)	
	Geometry Constraints	N.A.			
	Complexity	N.A.		Floodgates add to project complexity (GF)	Large perimeter adds to complexity (GF)
	Implementation Opportunities (e.g., phasing)	N.A.	Can be broken into at least 2 phases (GF)	Can be phased as SODC proceeds (GF)	Can be phased as SODC proceeds (GF)
	Navigation	No impact (DR)	Least impact on Cattermole Slough (GF)	Floodgates makes additional challenge (GF)	May affect some existing moorings along Cattermole Slough (DR)
	Internal Drainage	Free outflow condition (DR)	Requires outlet to Mamquam Blind Channel and / or Cattermole Slough (GF)	Can drain to Cattermole Slough and out via tide gates	Requires outlet to Mamquam Blind Channel and / or Cattermole Slough (GF)
	Upstream Dike Breach	Free outflow condition (DR)	Interceptor dike essential (GF)	Interceptor dike essential (GF) Tide gate provides some relief flow (DR)	SODC can be separated from Downtown (GF)
	Seismic Performance	N.A.	Wider dikes due to roads (DR) Not on foreshore	Seismic design of tide gates may be costly (DR) Extensive foreshore diking (DR)	Extensive foreshore diking (DR)
	Adaptability (for further SLR)		Further encroachment toward downtown (DR)	Would need to be integrated into proposed SODC development (DR) Upgrade to navigation gates would be significant cost (DR)	Possible but cost-prohibitive (DR)
	O&M / High Water Response			Would involve maintenance of a floodgate system	Long perimeter for maintenance
	Redundancy	Status quo does not provide flood protection redundancy (GF)	SODC dike provides buffer to downtown, reduces waves (GF)	SODC dike provides buffer to downtown, reduces waves (GF)	SODC dike provided buffer to Downtown. Interceptor dike needed for Downtown (GF)
	Score		**4.0**	**2.2**	**2.5**
Protection Concepts	Standard Sea Dike	N.A.	most of work would be on existing infrastructure (MN)		
	Greenshores Approach	N.A. if nothing is done (GF)		Large area extent along MBC would likely benefit from Green Shores approach (MN)	Greenshores potential high (GF)
	Seawall Structure	N.A.	Merit of seawall is questionable (GF)	Merit of seawall is questionable (GF) Reasonable to expect SODC to implement in some areas (DR)	Merit of seawall is questionable (GF) Reasonable to expect SODC to implement in some areas (DR)
	Score		**3.0**	**4.7**	**4.7**
General Notes			SODC is a very large project (26 ha). The brownfield site should be considered as a separate development with its own structural flood protection from Downtown Squamish due to its size and essentially undeveloped status (GF)	Assume Option 3B (or fill equivalent) is needed if SODC is to proceed but such flood protection could be undertaken as a separate privately funded project. There is no existing residential development to protect and all industrial development will be replaced. A public diking subsidy for an entirely new development is not warranted. Navigable flood gates across Cattermole Slough will be required. (GF)	Assume Option 3A-3H1-3B (or fill equivalent) is needed if SODC is to proceed but such flood protection could be undertaken as a separate privately funded project. There is no existing residential development to protect and all industrial development will be replaced. A public diking subsidy for an entirely new development is not warranted. (GF)

REACH 4

Categories	Criteria	Do Nothing Status Quo	4A Lower MBC Foreshore (blue)	4B Vancouver Street Bridge (brown)	4C Loggers Lane South (green)
Description		Build no new works. Accept consequences of future coastal flood damage.	New dike along foreshore of Mamquam Blind Channel from Vancouver Street to Highway 99	New vehicle bridge crossing from Vancouver Street to Waterfront Landing including navigable flood gates	Raise Loggers Lane from Vancouver St to north of Winnipeg St then east to foreshore and north to Hwy 99.
	Overall Score	**3.5**	**3.1**	**3.1**	**2.5**
Natural	Species of Special Concern			Depends on passage of salmon and interference with other species, need to know schedule of gate operations, but gates upstream at end of Loggers Lane Creek if not here (MN)	No significant impact to natural environment
	Aquatic Biota		temporary impacts to fish habitat but may yield a net improvement (DR)	assumes that there could be minor interference with fish movements, and immediately loss of habitat through siting (MN)	
	Terrestrial Biota & Vegetation		largest foreshore impact (DR)	would not entail raising other dykes, but is there a requirement for internal flood protection? (MN) Some internal flood protection required (DR)	most works would be on existing roads, away from channel (MN)
	Water and Air Quality	assumed to be the worst scenario due to presence of creosote retaining walls (MN) Walls would likely be replaced by progressive development, but outside scope of this study (DR)			assumed to be the worst scenario due to presence of creosote retaining walls (MN) Walls would likely be replaced by progressive development, but outside scope of this study (DR)
	Footprint of New Works	N.A. as no new works are proposed (GF)	Assumed to be the least preference among the options due to length and proximity to water (MN)		Requires wider footprint due to traffic access across Loggers Lane
	Enhancement Opportunities		Assumed to be the least preference among the options due to length and proximity to water (MN) Would see replacement of creosote walls (DR) Foreshore upgrades could potentially include habitat benches (DR)		
	Score	**3.3**	**3.3**	**3.5**	**2.7**
Economic	Flood Protection Benefits	Status quo does not provide flood protection (GF)		Addresses dike breach scenario	Does not protect foreshore land south of Winnipeg St. (GF)
	Environmental Compensation Costs	None (DR)	Greenshores potential (GF) Would involve seawalls, marinas as per OCP DPA 4 (DR) Environmental compensation addressed in SEMP - flood protection encroachment considered allowable (DR)		Minimal cost anticipated (GF)
	Long-term Employment Opportunities	Flooding could disrupt long-term employment in Squamish Downtown (DR)	new seawall helps to revitalize downtown area (DR)	Provides secondary access to Downtown Squamish and SODC lands which could serve as a major revitalization element (GF) New seawall helps to revitalize downtown area (DR)	Limited redevelopment potential for MBC (GF)
	Capital Cost	None (DR)	High cost for flood protection in constrained land area (GF)	Large cost for bridge structure that retains navigability and includes flood gates (GF)	Flood protection is within constrained road allowance and surplus RR corridor, which must allow for transition to adjacent lands (GF)
	O&M Costs	None (DR)	sheet pile seawall would be vulnerable to marine processes and corrosion, ultimately require replacement (DR)	High ultimate operating cost for bridge with moveable elements (GF)	
	Funding Opportunities (Cost Sharing)	N.A. (GF)	Subject to viability of development, given cost of flood hazard mitigation (GF) Mireau project suggests redevelopment could support majority of costs, provided flood risk planning levels are reasonable (DR)	Potential benefiting area could include entire Downtown (GF) High costs could be shared with Cost-sharing opportunity with transportation initiative outlined in OCP (DR) Developers could be asked to make offsetting contributions in lieu of higher local flood protection works (DR) Additional savings realized by avoiding needs for significant upgrades to manage dike breach flows upstream at Loggers Lane (DR)	Potential benefiting area could include entire Downtown (GF) Some potential for offsetting costs from developers, but offset by additional complexity and costs for development that must address different Loggers Lane frontage elevations at different time horizons (DR)
	Score		**3.7**	**3.0**	**2.7**
Social / Cultural	Traditional Use / Rights & Title		Large impact not anticipated (GF)	Large impact not anticipated (GF)	Large impact not anticipated (GF)
	Safety	Status quo does not address risk (GF)		Safety depends on proven mechanical systems (DR)	foreshore land is outside primary dike (DR)
	Public Consultation	No consultation required (DR)	Property implications of revetment/dike/sheet pile wall will be significant & impede implementation of MPC plan. (GF) Significant discussions required with each developer (DR)	Project will be expensive. Attracting Provincial funding will be a major challenge. (GF) High-profile project expected to attract a lot of attention (DR)	Will leave land east of Loggers Lane and south of Winnipeg St. unprotected and likely preclude implementation of MBC plan (GF) Consultation would be a challenge due to significant logistical impacts (DR)
	Archaeological Impacts	No additional impact (GF)	Large impact not anticipated (GF)		Minimal impact to existing road anticipated (GF)
	Recreation Opportunities	No change (GF)	Flood protection would include recreation corridor (GF)	Could be a public retreat feature (DR) New crossing could include bike infrastructure connection up to Loggers Lane trails (DR) Secondary flood protection would include recreational corridor (DR)	No recreation benefit anticipated (GF) Could limit ability to implement e.g., bicycle infrastructure along Loggers Lane due to geometric constraints and complex traffic movements (DR)
	Score		**3.6**	**3.2**	**2.8**
Political / Planning	Property and Access	N.A. (GF)	Private property impacts anticipated to be significant (GF)		Access through existing developments north of Winnipeg St. will be a challenge (GF)
	Land Tenure / Statutory Right of Way	No change in existing land tenure and ROW to support flood protection (GF)	Private property impacts anticipated to be significant (GF)		Most of route is located on existing dedicated roadway and surplus RR corridor except north of Winnipeg St. (GF)
	Policy Alignment	Status quo does not address risk management (GF)	Policy alignment good but implementation poses a major challenge (GF) Good alignment with goals of DPA 4 but triggered by development could mean long horizon to public use (DR)	Aligned with DPA 4 goals, OCP long-term plan for new crossing and traffic management for SODC (DR)	Route does not provide flood protection to lands along MBC south of Winnipeg St. (GF) Significant traffic complications for Loggers Lane (DR)
	Permitting Challenges	None (DR)	Property owners with restricted development potential will not be co-operative (GF) Most significant environmental footprint (DR)	Will require environmental and Transport Canada approvals (DR)	Low impact if contained within road and surplus RR corridors, except portion of route north of Winnipeg St. (GF)
	Development Impacts	Status quo does not provide flood protection (GF) New development constrained by flood hazard (DR)	Land requirement to meet new FCL requirement will pose major challenge (design and/or loss of development land) (GF)	Would greatly strengthen Downtown Squamish and SODC lands (GF)	Negative impact on lands outside dike south of Winnipeg St. (GF)
	Transportation Implications	Status quo does not provide flood protection for Hwy 99 and CN Rail transportation corridors (GF)	Maintains Loggers Lane as transportation corridor but adds seawall for pedestrians and bicycle traffic (DR)	Provides secondary access to Downtown Squamish and SODC lands which could serve as a major revitalization element (GF)	Low impact anticipated (GF) Significant logistical challenges to traffic management along raised Loggers Lane (DR)
	Emergency Plan Implications (Closures)	Status quo includes two at grade rail crossings (GF) Flood risk management plan required for downtown (DR)	Crosses rail line at CN Bridge (DR)	Will allow alternate access to Downtown. Assumes RR grade separation. (GF) Flood gates would need to be closed manually or automatically during high-water conditions	CN Bridge crossing below FCL (GF)
	Score	**2.3**	**2.6**	**3.7**	**2.4**
Technical	Construction Logistics	N.A. (GF)	Challenge will be to integrate flood protection with new development (GF)	Major bridge project with infrastructure upgrading to Highway 99 interchange required (GF)	Challenges will be to integrate with adjacent lands (GF)
	Geometry Constraints	N.A. (GF)	Need to co-ordinate between different developers at different times (DR)	Favourable alignment with existing roads, options available (DR)	Very tight geometric constraints (DR)
	Complexity	N.A. (GF)	Relatively straightforward seawall concept (DR)	Major bridge project with significant linkages to Downtown and Highway 99 required (GF)	Very complex to implement due to impacts to traffic flow to/from and across Loggers Lane (DR)
	Implementation Opportunities (e.g., phasing)	N.A. (GF)	Shoreline protection could proceed in phases (GF) Phasing may include some works deferred with financial contribution from developer (DR)	Bridge cannot be built in phases (GF) No need to install flood protection components until required (DR)	Phasing difficult as road continuity and access to adjacent properties are needed (GF)
	Navigation	N.A. (GF)	May be some impacts for marinas (DR)	Flood gates would be a permanent navigation impact (DR)	
	Internal Drainage	Free outflow condition (DR)	Requires outlet to Mamquam Blind Channel and / or Cattermole Slough (GF) Pump station likely required for downtown (DR)	Can use Mamquam Blind Channel as stormwater storage (DR)	Requires outlet to Mamquam Blind Channel and / or Cattermole Slough (GF) Pump station likely required for downtown (DR)
	Upstream Dike Breach	Free outflow condition (DR)	Flood gates required in Reach 5 (DR)	High-capacity flood gates would provide outflow, secondary protection would provide conveyance capacity under some conditions (DR) Does not completely mitigate risk during high-water events (DR)	Flood gates required in Reach 5 (DR)
	Seismic Performance	N.A. (GF)	Would need to meet Inspector of Dikes seismic standards and consider potential for liquefaction. (DR) Ground improvement may be required (DR)	Structure would need to be engineered for seismic loads (DR) May be sited on liquifiable sediments, increasing construction costs (DR)	Would need to meet IOD seismic guidelines but setback avoids foreshore liquefaction issues (DR)
	Adaptability (for further SLR)		Would need to be integrated into proposed development. Further upgrades would be problematic (DR)	Could be designed to have higher gates. Increasing closure rate would affect navigation and eventually aquatic habitat (DR)	Further increases not really feasible (DR)
	O&M / High Water Response		O&M work would disrupt a popular trail and occur in people's backyards	O&M simplified by dedicated access and shorter alignment, but need to maintain major floodgates	O&M would disrupt traffic on an important roadway
	Redundancy	Status quo does not provide flood protection, let alone redundancy (GF)	No redundancy	If supplemented by shoreline protection (GF) Secondary flood protection required to minimize nuisance closures of flood gates under future conditions and to allow deferred construction (DR)	Floodproofing of foreshore properties would likely result in a de facto secondary dike (DR)
	Score		**2.7**	**2.4**	**2.2**
Protection Concepts	Standard Sea Dike	N/A	Possible but work with Mireau development has shown a very significant footprint (DR)	Would involve less dyke along water (MN) Typical example at Marina Estates (DR)	Would involve less dyke along water (MN)
	Greenshores Approach	N/A	Assumed to be non-achievable due to proximity and space restrictions (MN)	Does not fit with OCP or SEMP vision for blind channel	N.A. (GF)
	Seawall Structure	N/A	Given a preferred status as it would take up less room; assumed enhancement measures would be built in (MN)	Easily achievable as secondary flood protection	
	Score				
General Notes				Bridge option is not standalone; protection along the Mamquam Blind channel right bank is also needed. (GF) Excellent functional option, high cost is major obstacle (DR)	

REACH 5

Categories	Criteria	Do Nothing Status Quo	5A Upper MBC Foreshore (blue)	5B Highway 99 (brown)	5C Loggers Lane North (green)	Hybrid 5A-5H1-5B Upper MBC Foreshore to Hwy 99 (blue-pink-brown)	Hybrid 5B-5H2-5C Hwy 99 to Loggers Lane (brown-pink-green)	Hybrid 5H1+5H2 Hwy 99 to Loggers Lane (brown-pink-green)
Description		**Build no new works. Accept consequences of future coastal flood damage.**	**New dike along foreshore of Upper Mamquam Blind Channel**	**Raise Highway 99 as required and provide spur dike tie to high ground at foot of Smoke Bluffs**	**Raise Loggers Lane from Highway 99 north to meet high ground at foot of Smoke Bluffs**	**Foreshore Dike wraps around Inn on the Water and ties into Highway 99**	**Foreshore Dike is primarily along Highway 99 but wraps around Squamish Adventure Centre**	**Foreshore Dike is primarily along Highway 99 but wraps around Squamish Adventure Centre**
	Overall Score	**3.6**	**2.9**	**3.1**	**3.2**	**2.7**	**3.4**	**3.5**
Natural	Species of Special Concern		Temporary habitat impacts with GreenShores approach (DR)					
	Aquatic Biota		location immediately along channel would impact foreshore (MN) Temporary habitat impacts with Greenshores approach (DR)		Most works would be on existing infrastructure (MN) Most significant impacts would be associated with upgrades to floodgates (DR)	Location immediately along channel would impact foreshore (MN)	Most works would be on existing infrastructure (MN) Most significant impacts would be associated with upgrades to floodgates (DR)	Most works would be on existing infrastructure (MN) Most significant impacts would be associated with upgrades to floodgates (DR)
	Terrestrial Biota & Vegetation		Location immediately along channel would impact foreshore (MN)	Would entail disturbance of vegetation north of Adventure Centre (MN)		Location immediately along channel would impact foreshore (MN)		
	Water and Air Quality				Opportunities for water control through flap gates etc. (MN)		Opportunities for water control through flap gates etc. (MN)	Opportunities for water control through flap gates etc. (MN)
	Footprint of New Works	N.A. as no new works are proposed (GF)	Large structure required to control flooding within narrow passageway (GF) Similar short footprint, but along foreshore of MBC (MN) Largest footprint in most sensitive area (DR)	Grade transition will extend footprint further north and east-west link though forest will also have large footprint (GF) Longest alignment but some may already be at-grade (DR)	Some elevation of road may be required (GF) Shortest footprint on existing infrastructure (MN) Grade transition will extend footprint further north (DR)	Large structure required to control flooding within narrow passageway (GF) Similar short footprint, but along foreshore of MBC (MN)	Some elevation of road may be required (GF) Shortest footprint on existing infrastructure (MN) Grade transition will extend footprint further north (DR)	Some elevation of road may be required (GF) Shortest footprint on existing infrastructure (MN) Grade transition will extend footprint further north (DR)
	Enhancement Opportunities	Enhancement not realized with status quo (GF)	Greenshores approach along natural foreshore provides opportunities for targeted enhancement (GF) Floodboxes could be removed if floodgates are built in Reach 4 (DR)	Some Greenshores potential to mitigate sharp drop-off to Wilson Slough (GF) Potential for removing flap gate were Loggers Lane crosses MBC, but likely required just upstream (MN) Floodboxes could be removed if floodgates are built in Reach 4 (DR)	Opportunities to improve connectivity through upgraded flap gates etc. (DR) Floodboxes could be removed if floodgates are built in Reach 4 (DR)	Greenshores approach along natural foreshore provides opportunities for targeted enhancement (GF) Floodboxes could be removed if floodgates are built in Reach 4 (DR)	Greenshores approach along natural foreshore provides opportunities for targeted enhancement (GF) Floodboxes could be removed if floodgates are built in Reach 4 (DR)	Greenshores approach along natural foreshore provides opportunities for targeted enhancement (GF) Floodboxes could be removed if floodgates are built in Reach 4 (DR)
	Score	**4.2**	**2.0**	**3.8**	**3.5**	**2.7**	**3.5**	**3.7**
Economic	Flood Protection Benefits	Status quo lacks flood protection; increases risk if Wilson Cres. diversion dike is constructed (GF)		Alignment would not protect the Squamish Adventure Centre, considered to be an iconic building (GF) Would not protect Inn on the Water (DR)	Would protect Adventure Centre but not Inn on the Water (DR)	Would protect Inn on the Water but not Adventure Centre DR)	Would protect Squamish Adventure Centre but not Inn on the Water (GF)	Would protect both Squamish Adventure Centre and Inn on the Water (GF)
	Environmental Compensation Costs	None (DR)			Should have the least aquatic interface (GF)			
	Long-term Employment Opportunities	Flooding could disrupt long-term employment in Squamish Downtown (DR)	No additional development lands will be created (GF)	No additional development lands will be created (GF)	No additional development lands will be created (GF)	No additional development lands will be created (GF)	No additional development lands will be created (GF)	No additional development lands will be created (GF)
	Capital Cost	None (DR)	Floodbox costs avoided and pump station likely deferred if flood gates are built in Reach 4 (DR) Dedicated flood protection structure without road significantly reduces cost (DR)	Costs would need to include a new structure (higher or lower) at Loggers Lane to avoid backwater issues during dike breach (DR) Upgrades would need to be to MOTI standards (DR) Floodbox costs avoided and pump station	Would involve significant road upgrades (DR) Floodbox costs avoided and pump station likely deferred if flood gates are built in Reach 4 (DR)	Floodbox costs avoided and pump station likely deferred if flood gates are built in Reach 4 (DR) Dedicated flood protection structure without road significantly reduces cost (DR) May require acquisition of Inn	Would involve significant road upgrades (DR) Floodbox costs avoided and pump station likely deferred if flood gates are built in Reach 4 (DR)	Would involve significant road upgrades (DR) Floodbox costs avoided and pump station likely deferred if flood gates are built in Reach 4 (DR)
	O&M Costs	None (DR)	All options have high O&M costs with floodboxes (GF) Additional costs to maintain dedicated flood protection structure (DR) Floodbox costs avoided and pump station likely deferred if flood gates are built in Reach 4 (DR)	All options have high O&M costs with floodboxes (GF) Floodbox costs avoided and pump station likely deferred if flood gates are built in Reach 4 (DR)	All options have high O&M costs with floodboxes (GF) Floodbox costs avoided and pump station likely deferred if flood gates are built in Reach 4 (DR)	All options have high O&M costs with floodboxes (GF) Additional costs to maintain dedicated flood protection structure (DR) Floodbox costs avoided and pump station likely deferred if flood gates are built in Reach 4 (DR)	All options have high O&M costs with floodboxes (GF) Floodbox costs avoided and pump station likely deferred if flood gates are built in Reach 4 (DR)	All options have high O&M costs with floodboxes (GF) Floodbox costs avoided and pump station likely deferred if flood gates are built in Reach 4 (DR)
	Funding Opportunities (Cost Sharing)	N.A.	Minimal or no cost sharing potential (GF)	Potential cost sharing with MOTI (GF) Likely a low priority for MOTI, cost sharing would be offset by higher capital cost (DR)	Minimal or no cost sharing potential (GF)	Minimal or no cost sharing potential (GF)	Minimal or no cost sharing potential (GF)	Minimal or no cost sharing potential (GF)
	Score		**3.0**	**2.8**	**3.0**	**2.5**	**3.2**	**3.3**
Social / Cultural	Traditional Use / Rights & Title							
	Safety	Status quo does not address flood risk (GF)		Adventure Centre unprotected (GF) Inn on the Water unprotected (DR)	Inn on the Water unprotected (DR) Adventure Centre protected (DR)	Squamish Adventure Centre unprotected (GF) Inn on the Water protected (DR)	Inn on the Water unprotected Squamish Adventure Centre protected (GF)	Inn on the Water protected Squamish Adventure Centre protected (GF)
	Public Consultation	No consultation required (DR)	Consultation required with environmental regulators	Detailed consultation required with MOTI		Consultation required with environmental regulators (DR) Close consultation required with Inn on the Water (DR)	Consultation required with environmental regulators (DR) Close consultation required with Inn on the Water (DR)	Consultation required with environmental regulators (DR) Close consultation required with Inn on the Water (DR)
	Archaeological Impacts	No additional impact (GF)						
	Recreation Opportunities	No change (GF)	Foreshore Trail Opportunity (GF)	N.A. (GF)	Potential Cycling Improvement (GF)	Foreshore Trail Opportunity (GF)	Foreshore Trail Opportunity (GF)	Potential Cycling Improvement (GF)
	Score		**3.2**	**2.8**	**3.6**	**2.6**	**3.4**	**4.0**
Political / Planning	Property and Access	N.A. (GF)		Some widening may be required for additional elevation of Highway 99 (GF)	May require acquisition of Inn on the Water (GF)	Worst option for access and encroachment with Inn on the Water (DR) May require property acquisition (GF)	May require acquisition of Inn on the Water (GF)	Worst option for access and encroachment with Inn on the Water (DR) May require property acquisition (GF)
	Land Tenure / Statutory Right of Way	N.A. (GF)	Riparian impact and foreshore ROW required (GF)	Some riparian impact (GF)		Riparian impact and foreshore ROW required (GF)		
	Policy Alignment	Status quo does not provide policy alignment (GF)	Conflicts with Upper Mamquam Blind Channel plan for natural area (DR)			Conflicts with Upper Mamquam Blind Channel plan for natural area (DR)		
	Permitting Challenges	None (DR)	Environmental approvals (GF)	MOTI and environmental approvals (GF)		Environmental approvals (GF)		
	Development Impacts	Status quo does not address flood protection (GF)	Adventure Centre Protected (GF)	Highway 99 will become flood resilient but Adventure Centre will be unprotected (GF)	Adventure Centre Protected (GF)	Adventure Centre Protected (GF)	Adventure Centre Protected (GF)	Adventure Centre Protected (GF)
	Transportation Implications	Status quo does not provide flood protection of transportation corridors (GF)	Loggers Lane will make that road and highway 99 more flood resilient (GF)	Highway 99 will become more flood resilient (GF)	Elevation of Loggers Lane will make that road more flood resilient (GF)	Elevation of Highway 99 (0.8 m) will make provincial highway more flood resilient (GF)	Elevation of Loggers Lane will make that road more flood resilient (GF)	Elevation of Loggers Lane will make that road more flood resilient (GF)
	Emergency Plan Implications (Closures)	Flood risk management plan required for downtown (DR)	Highway 99 will be below dike elevation (GF)		Highway 99 will be below dike elevation (GF)	Highway 99 will be below dike elevation (GF)	Highway 99 will be below dike elevation (GF)	Highway 99 will be below dike elevation (GF)
	Score	**1.8**	**2.9**	**2.9**	**3.4**	**2.7**	**3.4**	**3.3**
Technical	Construction Logistics	N.A. (GF)	Tide and season dependent (DR)	Highway 99 disruptions (DR)	Interruptions to Loggers Lane (DR)	Tide and season dependent (DR)	Interruptions to Loggers Lane (DR)	Interruptions to Loggers Lane (DR)
	Geometry Constraints	N.A. (GF)				Would need to allow for access to Inn on the Water (DR)	Would need to allow for access to Inn on the Water or, alternatively, property acquisition (DR)	Would need to allow for access to Inn on the Water or, alternatively, property acquisition (DR)
	Complexity	N.A. (GF)						
	Implementation Opportunities (e.g., phasing)	N.A. (GF)		much of alignment may already be at grade (Gradient constraints) (DR)	Phasing would require multiple disruptions to traffic (DR)			
	Navigation	N.A. (GF)	Floodbox upgrades (DR)	Floodbox upgrades (DR)	Floodbox upgrades (DR)	Floodbox upgrades (DR)	Floodbox upgrades (DR)	Floodbox upgrades (DR)
	Internal Drainage	Free outflow condition (DR)	built in Reach 4 (DR) May need to re-grade park to drain north to floodboxes or	Future pump station likely required at MBC unless flood gates built in Reach 4 (DR)	Future pump station likely required at MBC unless flood gates built in Reach 4 (DR)	Future pump station likely required at MBC unless flood gates built in Reach 4 (DR) Would "pathtub" Inn on the Water	Future pump station likely required at MBC unless flood gates built in Reach 4 (DR)	Future pump station likely required at MBC unless flood gates built in Reach 4 (DR)
	Upstream Dike Breach	Free outflow condition (DR)	Would require capacity to pass breach flows (DR) May be vulnerable to erosion under dike breach velocities (DR)	Would require capacity to pass breach flows (DR)	Would require capacity to pass breach flows (DR)	Would require capacity to pass breach flows (DR)	Would require capacity to pass breach flows (DR)	Would require capacity to pass breach flows (DR)
	Seismic Performance	N.A. (GF)	Most susceptible to liquefaction	Existing road fills have presumably been stabilized for seismic loads (DR)		Most susceptible to liquefaction	Existing road fills have presumably been stabilized for seismic loads (DR)	Existing road fills have presumably been stabilized for seismic loads (DR)
	Adaptability (for further SLR)			Highest cost if required to raise Highway 99 (DR)		Highest cost if required to raise Highway 99 (DR)		
	O&M / High Water Response		O&M work would require environmental approvals	O&M work may require MOTI authorization but traffic implications should be manageable	O&M could disrupt traffic on Loggers Lane			
	Redundancy	Status quo does not provide flood protection, let alone redundancy (GF)	Redundancy not a feature of Reach 5 options (GF) Secondary flood protection would provide redundancy if Reach 4 flood gates are implemented (DR)	Redundancy not a feature of Reach 5 options (GF) Secondary flood protection would provide redundancy if Reach 4 flood gates are	Redundancy not a feature of Reach 5 options (GF) Secondary flood protection would provide redundancy if Reach 4 flood gates are implemented (DR)	Redundancy not a feature of Reach 5 options (GF) Secondary flood protection would provide redundancy if Reach 4 flood gates are implemented (DR)	Redundancy not a feature of Reach 5 options (GF) Secondary flood protection would provide redundancy if Reach 4 flood gates are implemented (DR)	Redundancy not a feature of Reach 5 options (GF) Secondary flood protection would provide redundancy if Reach 4 flood gates are implemented (DR)
	Score		**3.2**	**3.1**	**2.8**	**2.9**	**3.5**	**3.5**
Protection Concepts	Standard Sea Dike	N.A. (GF)			most works would be on existing infrastructure (MN)	Most works would be on existing infrastructure	Majority of works would be on existing infrastructure	Majority of works would be on existing infrastructure
	Greenshores Approach	N.A. if nothing is done (GF)	Would likely require green shore approach, other options are likely unacceptable (MN) Would need to consider erosion under dike breach flows (DR)	Not on foreshore (DR)	Not on foreshore (DR)	Would likely require greenshores approach, other options are likely unacceptable (MN) Would need to consider erosion under dike breach flows (DR)	Not on foreshore (DR)	Not on foreshore (DR)
	Seawall Structure	N.A. (GF)	Conflicts with Upper Mamquam Blind Channel plan for natural area (DR)	Not on foreshore (DR)	Not on foreshore (DR)	Conflicts with Upper Mamquam Blind Channel plan for natural area (DR)	Not on foreshore (DR)	Not on foreshore (DR)
	Score							

General Notes
All options assume a diversion dike along Wilson Crescent to protect Downtown Squamish in the event of an upstream dike breach (GF)

Height of structure and need for flood boxes is significantly reduced if flood gates are built in Reach 4 (DR)
Temporary environmental impacts and technical considerations balanced by lower cost (DR)

Height of structure and need for flood boxes is significantly reduced if flood gates are built in Reach 4 (DR)
Upgrades may not be required immediately (DR)
Best philosophy may be to use Highway 99 for now then re-evaluate options 5A and 5B when

Height of structure and need for flood boxes is significantly reduced if flood gates are built in Reach 4 (DR)

Height of structure and need for flood boxes is significantly reduced if flood gates are built in Reach 4 (DR)

Height of structure and need for flood boxes is significantly reduced if flood gates are built in Reach 4 (DR)

Height of structure and need for flood boxes is significantly reduced if flood gates are built in Reach 4 (DR)

KERR WOOD LEIDAL
consulting engineers

Appendix C

Report to Council for February 3, 2015 Meeting of District of Squamish Community Development Committee

(Excluding RTC Appendices)

REPORT TO: Council FOR: Comm. Dev. Committee
REPORT FROM: Engineering
PRESENTED: February 3, 2015 FILE:
SUBJECT: Integrated Flood Hazard Management Plan – Council Update #2 – Coastal Flood Protection Strategy

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Recommendation:

That Council approves the following resolutions:

THAT the District of Squamish receive information on coastal flood protection strategies and provide the Integrated Flood Hazard Management Plan (IFHMP) project team feedback and priorities to consider when finalizing a recommendation on coastal flood protection strategy.

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1. Purpose:

The purpose of this report is to provide an update to Council on the status of the IFHMP and to present information on the coastal flood protection strategy, primarily relating to a future sea dike alignment. Staff request feedback and priorities to consider in finalizing the strategy before returning to Council with a recommendation seeking resolution on a coastal flood protection strategy.

2. Background:

The three-year IFHMP was initiated in 2014 to update the obsolete 1994 Flood Hazard Management Plan. The primary objective of the IFHMP is to determine a coastal flood protection strategy, identify structural works (i.e new dikes and dike upgrades) and recommend policy updates (i.e OCP amendments, Development Permit areas, Floodplain Bylaw, etc.) that will provide long-term planning guidance and achieve an appropriate level of flood protection for the District of Squamish.

Thus far, the project team has completed a Background Report that documents all known flooding and geo-hazards within Squamish. On August 19, 2014 the project team presented this work to Council and Council accepted a methodology for determining coastal design flood levels (see Attachment 2 for details).

As directed by Council, the project team has completed further work analyzing coastal design water levels in Squamish which has allowed for a slight reduction in the local effects component. Updated results for the coastal 'still water' level (i.e excluding wave effects) have been reduced from 4.16m (as presented in August 2014) to 3.99m and are summarized in the table below.

Component	January 2015 values
1:200 year, 'Joint probability' of tide/storm surge	2.69 m
+ Allowance for local effects (wind setup, local subsidence, etc)	0.30 m
+ Sea Level Rise to Year 2100 per Provincial guidelines	+1.00 m
= Year 2100, Coastal 'Still Water' Level	**3.99 m**
+ Freeboard	0.6m
= Year 2100, Coastal FCL (excluding wave effects)	**=4.59m**

Wave effects must be added on top of the coastal FCL to determine the required height of the sea dike. Wave effects vary by location based on wave exposure and the type of sea dike, therefore the coastal FCL (height of the sea dike) is expected to vary by location.

Based on the above, despite different methodologies used to determine coastal FCL, Squamish is very closely aligned with other municipalities when comparing 'apples to apples'. For comparison purposes, the following is a summary of other municipalities:

Municipality	Coastal FCL
District of Squamish	4.59m + wave effects
City of Vancouver	4.6m + wave effects
City of North Vancouver	4.5m + wave effects

The current phase of the IFHMP involves establishing a coastal flood protection strategy which primarily includes determining sea dike type and alignment. Determining a coastal flood protection strategy is a high-level visioning exercise with broad and significant implications for long range community planning aspects including financial, growth, infrastructure, transportation, development regulation, land use management, OCP amendments, environmental and emergency response.

In addition, a coastal flood protection strategy must be incorporated into the next phase of the project (dike-breach inundation mapping of the Squamish and Mamquam River floodplains), since a continuous sea dike along the coastal perimeter will create a 'bathtub effect' in the event of an upstream river dike breach (see Attachment 3 for further details) and affect FCLs.

The IFHMP scope of work, progress to date and Background Report are laid out in detail in Attachments 1, 2 and 3 respectively.

3. Project Information:

Based on the coastal flood hazard review, it is expected that downtown Squamish, Dentville, Logger's Lane and portions of the Business Park and North Yards would all be affected by current or future coastal flood hazards. The hazard area (including 1m sea level rise) is

illustrated in Attachment 4. There are several strategies being considered by Squamish and other coastal communities including:

- Protect – building protective structures to keep coastal waters away from infrastructure on the coastal floodplain
- Accommodate – raising buildings and roads to reduce impacts of flooding
- Retreat (or Managed Retreat) – relocating vulnerable development away from the hazard area
- Avoid – restricting further development within the hazard area to flood-tolerant land uses

In Squamish's case, based on the extensive value of development within the coastal flood area, the project team recommends a combination of strategies including protect, accommodate and managed retreat, as follows:

- **Protect** historical development in the downtown area by constructing a perimeter sea dike that can accommodate present-day predictions for Sea Level Rise to the year 2100.
- **Accommodate** future flood conditions by ensuring that all new development within the coastal flood hazard area will meet minimum coastal FCLs at the end of their design life.
- **Retreat** by opportunistically relocating lifeline buildings and essential infrastructure to lower-risk areas as they reach the end of their current design life.

This report focuses on the 'protect' aspects of the recommended strategy, specifically a future sea dike type and alignment. In order to simplify the analysis, three (3) types of sea dike were considered and Squamish's coastal perimeter was broken into five (5) separate 'reaches' with several alignment options provided per reach. Dike types and reaches are listed below and illustrated in Attachment 5.

Sea Dike Types	**Sea Dike Reaches**
Seawall (vertical face)	CN North Yards
Earthfill Embankment (sloped face)	Squamish Estuary
GreenShores™ Treatment	Cattermole Slough
	Lower Mamquam Blind Channel
	Upper Mamquam Blind Channel

A detailed 'multi-objective' analysis was completed for each reach considering factors including environmental, economic, social/cultural, political/planning and technical. In addition, the Project Team held a Public Open House on October 23, 2014 presenting options to the public and gathering feedback (see Attachment 6 for documentation). The results of these events have led to preliminary recommendations contained in this report. Finally, staff and KWL will be presenting the information detailed herein to Squamish Nation Chiefs and Council on February 18, 2015 to obtain additional feedback before returning to Council with a final recommendation on sea dike type/alignment.

The following sections provide a high-level summary of the sea dike options, considerations and recommendations. To expedite Council's review, minimal discussion has been included for options where more obvious choices exist. Refer to Attachment 5 for an illustration of the alignment options and Attachment 7 for more detailed considerations.

4. Department Comments

Sea Dike Type

The three types of shoreline treatment considered for the perimeter sea dike include:

- GreenShores™ – relatively flat slope, typically vegetated and relying on natural elements for erosion protection. This is the most environmentally-friendly shoreline treatment and was developed to balance engineering and environmental objectives. Due to flat gradient, this treatment typically occupies the largest footprint and is most suited where land is available and environmental values are highest. The flatter, softer slope usually results in lowest wave effects.
- Earthfill embankment – a typical dike slope (e.g., 3H:1V side slopes) usually incorporating rip-rap erosion protection. This option has a smaller footprint than a GreenShores™ treatment. Wave effects depend on the slope and composition of the embankment. Steep, impermeable embankments can experience the largest wave effects among the three treatments listed.
- Vertical seawall – the sloping face of the above solutions is replaced with a vertical engineered structure such as a steel sheet pile backfilled with suitable material. A small footprint makes this suitable for sites with limited land availability. Interaction with the marine environment (e.g., recreation pathways, marina access) is maximized but environmental enhancement opportunities are limited. A vertical face results in larger wave effects than GreenShores™ or a moderate riprap embankment slope.

The sea dike can be comprised of a combination of different types of shoreline treatment; however, frequent transitions and "corners" should be minimized to simplify maintenance and reduce opportunities for failure.

Reach 1 – CN North Yards (Squamish River Dike to Crescent Slough)

Option 1B (follow Government Road to intersection with Squamish River dike) is recommended for Reach 1. The primary basis for recommending this option is that it provides the highest degree of habitat connectivity for the estuary. The other option under consideration (Option 1A) bisects the existing natural area by raising the Spit Access Road.

This reach has the most natural protection at present due to the reduced wave effects associated with its location at the head of the vegetated estuary.

The Reach 1 sea dike is required to protect local areas in and around the North Yards assuming 1m of sea level rise but will not be needed for protection of downtown Squamish until sea level increases by more than 1m.

The Reach 1 dike is expected to be a standard earthfill embankment in areas where it follows Government Road. Along the Crescent Slough riparian area, staff anticipates that the dike will use bioengineering techniques to maximize environmental values while minimizing encroachment into Crescent Slough. Further work and consultation is required to determine whether the railway berm could function as an interim sea dike at this location.

Reach 2 – Squamish Estuary (Crescent Slough to 3rd Avenue) – **Primary focus for discussion**

Two primary options have been considered in reach 2:

- Option 2A, involving a GreenShores™ dike along 7th Avenue Connector alignment immediately west of the CN Rail tracks serving Squamish Terminals, and
- Option 2B (a mixture of two or three dike types following Government Road and the existing Town Dike alignment).

Considerations for the two options are summarized in the table below.

Option	Benefits	Challenges
Option 2A - 7th Avenue Connector	*opportunity to combine with potential future truck route (allows cost sharing and sharing construction footprint) *can be implemented within transportation corridor already established in the Squamish Estuary Management Plan *protects CN Rail spur to Squamish Terminals *sea dike can be built using Greenshores principles to help mitigate environmental impacts *potential to decommission Squamish River training berm to enhance water flow into estuary and relocate material to 7th Ave connector *no interface with residential properties *straight alignment *least disruption to downtown *straight alignment facilitates operations and maintenance *maximizes lifespan and utility of existing downtown stormwater system (including Bridge Pond)	*cost and environmental impacts are likely disproportionate if completed as a stand-alone project (i.e without the 7th Ave truck route). *Option is **recommended** if 7th Avenue Connector truck route is confirmed by upcoming Downtown Truck Route study *environmental sensitivity through estuary *more exposed to waves than Option 2B, means dike may need to be higher *requires raising 3rd Avenue at intersection with sea dike
Option 2B - Town Dike	*reduced environmental disturbance due to co-location with existing dike *CN Rail line provides some initial protection from waves as well as initial flood protection redundancy *upgraded dike can become an improved recreational/trail amenity *Shorter alignment would reduce capital costs	*existing dike is substandard and would require reconstruction to meet seismic standards *existing dike does not have adequate space for upgrade at all locations *most complicated land tenure; expropriation of properties along 6th Avenue may be required *likely requires infilling a portion of Main St. slough causing environmental impacts *environmental impacts of encroachment into Bridge Pond *impacts stormwater storage for downtown, and raises questions about the long-term viability of Bridge Pond for stormwater storage *interface with residences would create construction and maintenance difficulties *would not protect CN Rail spur serving Squamish Terminals

Overall, Option 2A would be strongly preferred from an engineering perspective if the 7th Avenue Connector truck route proceeds, due to the relatively small incremental impacts (financial, environmental, and logistical) that would be required to upgrade the road to meet flood protection standards.

Conversely, if the 7th Avenue Connector truck route is not preferred, staff anticipates that the designation of the corresponding transportation corridor in the Squamish Estuary Management Plan may be revisited. This could provide an opportunity to offset some of the anticipated environmental impacts associated with the Town Dike alignment while avoiding controversial work in the estuary.

The District intends to complete a Downtown Truck Route Study in 2015, therefore it is recommended to defer a final decision on Reach 2 until the truck routing study is completed. If the 7th Avenue Connector is the preferred truck route, it would be recommended to select Option 2A. If an alternate truck route is preferred, then the recommendation would likely be to upgrade the Town Dike. Staff has solicited (but has not yet received) comments from CN Rail on these options.

In order to continue progress on the IFHMP, the next phase of the project (floodplain mapping) will proceed under the assumption that Option 2A is selected. However, the preferred sea dike alignment will need to be confirmed prior to completion of the IFHMP in 2016. In addition, staff recommends that the benefits of co-locating the sea dike and 7th Avenue Connector be considered during the Downtown Truck Routing study.

Reach 3 – Cattermole Slough (3rd Avenue to SODC lands)

Option 3A (standard earthfill embankment along the west side of Cattermole Slough to Vancouver St) is recommended for Reach 3. The primary basis for recommending this option is that it is simpler to implement, has a shorter length of sea dike that reduces capital and maintenance costs, and minimizes vulnerability. Option 3A also follows the alignment of the existing sea dike (which would require significant upgrading).

Some challenges with Option 3A include potential private property impacts associated with upgrading the existing dike as well as raising the road grade along Vancouver Street to cross Loggers Lane and tie in with the proposed sea dike along the Mamquam Blind Channel (MBC).

Option 3B involves crossing Cattermole Slough and would require a complex flood gate structure. Options that extend the dike alignment along all or part of the SODC lands would unnecessarily link flood protection for downtown with flood protection for SODC. These options would introduce additional stakeholders to be consulted on construction and maintenance issues.

Reach 4 – Lower Mamquam Blind Channel (SODC lands to Highway 99)

Three primary options were considered for this reach including:

- Option 4A – Sheet pile dike along foreshore of MBC
- Option 4B – Navigable flood gates that span the Mamquam Blind Channel, potentially including a bridge crossing from Vancouver Street to Waterfront Landing
- Option 4C – Setback dike along Logger's Lane/Pemberton Ave

Option 4A is recommended for Reach 4. Option 4A avoids complexities associated with Options 4B and 4C, maintains viable development sites along Logger's Lane/Pemberton, minimizes access issues, and can be largely funded through anticipated re-development along the MBC. On June 24th, 2014 Council provided an approval in principle for a sheet pile dike concept for

the proposed Mireau development on Logger's Lane at Winnipeg St. The Mireau concept is compatible with Option 4A.

The Option 4B flood gates would have to accommodate frequent marine traffic and would remain open to marine traffic during all but the largest storms meaning that a lower dike would still be required along the MBC foreshore. As such, the benefits of such a structure are limited. In addition, mechanical gates in a marine environment can be subject to reliability concerns as experienced at the 3rd Avenue tide gates. Based on this analysis, Option 4B is not recommended due to cost, complexity, reliability and environmental challenges.

Option 4C is not recommended due to several significant challenges including:

- cutting off access to development sites fronting or backing onto Logger's Lane/Pemberton Ave,
- restricting multi-modal traffic flow along Loggers Lane (relative to any at-grade option),
- inducing settlement of existing utilities, and
- leaving properties along west side of MBC "outside the dike".

Reach 5 – Upper Mamquam Blind Channel (Highway 99 to Smoke Bluffs)

Three options were considered including:

Option 5A – Greenshores dike along Upper Mamquam Blind Channel foreshore
Option 5B – Raise Highway 99 as required and tie to high ground at foot of Smoke Bluffs
Option 5C – Raise Logger's Lane from Highway 99 to foot of Smoke Bluffs

Option 5A is recommended for Reach 5. Option 5A provides protection for the Inn on the Water, Rose Park and potential future uses for the parking area adjacent to the Adventure Centre. Options 4B and 4C would leave those areas without flood protection.

Unconnected Coastal Floodplain Areas

The IFHMP refers to sites that are disconnected from the main downtown peninsula as 'unconnected coastal floodplain areas' because flooding of any one site need not affect other lands. The IFHMP will recommend that these areas adopt cost-effective, site-specific flood protection measures customized to support a particular development proposal. These sites do not affect the foregoing sea dike discussion. Examples of unconnected coastal floodplain areas include Scott Crescent Development, Waterfront Landing, Squamish Nation Stawamus I.R 24, Site B, SODC (assuming Council endorses Option 3A for Reach 3), Squamish Terminals, Site A, and Woodfibre. See Page 17 of Attachment 7 for additional information.

Implementation

Determining a coastal flood protection strategy is a high-level, visioning exercise. However, recognizing that sea level rise is a progressive process, the implementation plan must consider:

- highest risk areas based on current hazards, existing level of protection, and development density,
- financial capability,

- actual rate of sea level rise based on updated science and observation and its implications for future risk, and
- rate of re-development.

These factors will be considered in later stages of the IFHMP and when preparing capital plans.

Dike Breach Implications

As previously mentioned, the construction of a perimeter sea dike around downtown could create a 'bathtub effect' that exacerbates the consequence of a dike breach along the Squamish River or Mamquam River. Water from a river dike breach could rapidly inundate downtown Squamish, rising behind the sea dike until it reaches an elevation where it can flow over the top of the dike to Howe Sound and the adjacent waterways.

During the course of the IFHMP, the project team discussed the concept of an 'interceptor' dike that would redirect dike breach floodwaters into the Upper Mamquam Blind Channel before they could reach downtown. The interceptor dike would generally follow along the south side of Wilson Slough and the Upper Mamquam Blind channel and would require substantial upgrades to culverts crossing under Highway 99 and Logger's Lane to allow flood waters to pass unimpeded into the MBC.

An interceptor dike provides a fully redundant level of protection for downtown that could potentially justify the exclusion of dike breach implications when establishing downtown FCLs. However, an interceptor dike also brings several significant challenges, including:

- Potential transfer of risk (increased FCLs) in the Dentville neighborhood due to flows being redirected across the floodplain toward the MBC
- Logistical/design challenges associated with routing a new dike through an existing neighborhood, including maintaining access to existing properties and infrastructure settlement
- Environmental impacts associated with constructing all or part of a riverside dike along an existing watercourse
- Significant capital cost and additional long-term maintenance costs to build and maintain a new dike structure
- High levels of interest and concern at Public Open House #1 where Dentville residents expressed a clear reluctance to accept a transfer of risk
- Limitation of benefits to downtown only – would not increase protection for North Yards, Business Park, Industrial Park or Dentville neighborhoods (depending on alignment)

Given these challenges, and the importance of protecting downtown, the project team carried out a review of alternatives to the interceptor dike. The results were interpreted with due regard for the long-term financial commitment required to construct new sea dikes as well as the current 200-year level of protection provided by the river dikes. The project team concluded that any foreseeable investment available for an interceptor dike would be better directed toward increasing the standard of protection provided by the existing Squamish and Mamquam River dikes. This could include:

- Upgrading the dikes to meet seismic standards

- Raising the Squamish/Mamquam River dikes to protect against larger floods such as 1:500 or 1:1000 year return period floods;
- Widening the dikes to mitigate the possibility of seepage or piping failures
- Improving erosion protection along both the dike slope and riverbank to ensure that the dike is not damaged or undercut by flowing water or floating debris
- Providing erosion protection on the land side of the dike to mitigate failure during a brief overtopping event

The benefits of this alternative are that it would:

- improve protection for all areas south of the Mamquam River as opposed to just downtown,
- avoid the transfer of risk to Dentville,
- leverage the value of existing diking assets, and
- avoid logistical complications associated with the interceptor dike.

As such, staff recommends that upgrades to the lower Squamish River / south Mamquam River dike be confirmed as a preferred alternative over an interceptor dike concept for the purposes of the 2016 IFHMP.

5. Implications:

a) Budget:

The length of Squamish's coastal perimeter requiring protection (excluding SODC) is approximately 7km. Using an average rate of $6000/m (based on recent cost estimates for the Mireau development sea dike) and including a 30% contingency would result in a preliminary order of magnitude cost estimate of $55,000,000 to construct the sea dike to accommodate 1m of sea level rise. Upgrading the Squamish/Mamquam River dikes to a higher standard would add additional cost. Historically, the majority of Squamish's dike construction has received grant funding from the Provincial and Federal governments. This cost estimate will be refined as the project proceeds, however it is necessary to begin incorporating anticipated capital expenditures into the District's Long Term Financial Plan.

b) Policy:

The IFHMP will make recommendations for new flood hazard management policy in the final stage of the project per OCP policy #25-13.

c) Environmental

As described throughout. In addition, the Project Team has included Squamish Streamkeepers, Squamish River Watershed Society, Squamish Environmental Society and Squamish Estuary Management Committee as members of the IFHMP stakeholder group. As such, the District has consulted with and will continue to consult these groups throughout the project.

6. Attachments:

1) Report to Council – Integrated Flood Hazard Management Plan – Award of Proposal, January 21, 2014

2) Report to Council – Integrated Flood Hazard Management Plan – Council Update #1, District of Squamish, August 19, 2014
3) Integrated Flood Hazard Management Plan – Draft Background Report, Kerr Wood Leidal, August 2014
4) Coastal Flood Inundation Map, Kerr Wood Leidal, July 2013
5) Preliminary Alignments for Upgrading Downtown Squamish Coastal Flood Protection Works, Kerr Wood Leidal, August 2014
6) October 23, 2014 Open House Documentation
7) Public Open House presentation boards

7. Alternatives to Staff Recommendation:

Staff Recommendation:

THAT the District of Squamish direct staff to pursue alternate coastal flood protection strategies.

_____

David Roulston, P.Eng
Municipal Engineer

_____ _____

Rod MacLeod
Director of Engineering

Robin Arthurs
GM, Corporate Services

_____ _____

Gary Buxton
GM, Development Services & Public Works

Joanne Greenlees
GM, Financial Services

CAO Recommendation:

That the recommendation of Engineering be approved.

_____

C. Becker, CAO

KERR WOOD LEIDAL
consulting engineers

Appendix D

Report to Council for May 12, 2015 Special Meeting of District of Squamish Council

REPORT TO:	Council	FOR:	Special
REPORT FROM:	Engineering		
PRESENTED:	May 12, 2015	FILE:	IFHMP
SUBJECT:	Integrated Flood Hazard Management Plan – Council Update #4 – Coastal Flood Protection Strategy Update		

Recommendation:

That Council approves the following resolution:

> **THAT** the District of Squamish adopt the "Integrated Flood Hazard Management Plan - Coastal Flood Protection Strategy", as described in Kerr Wood Leidal's *Coastal Flood Hazard Mitigation Strategy and Coastal Flood Protection Options* Technical Memorandum, subject to expanding the scope of Special Study Area #4 to evaluate the optimal dike alignment in Reach 5 when a development proposal comes forward for 38400, 38540 Logger's Lane in order to select an alignment that meets both development objectives and District priorities with respect to environmental, economic and technical objectives.

1. Purpose:

The purpose of this report is to recommend a modification to the Coastal Flood Protection Strategy to address concerns over the Reach 5 sea dike alignment in relation to the proposed Sea to Sky Forestry Centre.

2. Background:

A Coastal Flood Protection Strategy was presented to Council at Committee of the Whole on April 14, 2015 and received endorsement during the meeting. Upon further reflection, Council directed staff to return to Council to discuss modifying the strategy to incorporate considerations relating to the proposed Sea to Sky Forestry Centre.

3. Project Information:

Detailed project information was summarized in the April 14, 2015 Council report.

4. Department Comments

In the Coastal Flood Protection Strategy presented to Council on April 14, 2015, the dike alignment for Reach 5 – Upper Mamquam Blind Channel (UMBC), was shown to follow Highway 99 from the Mamquam Blind Channel, north to Logger's Lane, along Logger's Lane to the northern foreshore of the Upper Mamquam Blind Channel and east to the Smoke Bluffs. This dike alignment would place 38400, 38540 Logger's Lane (Rose Park) on the water side of the dike alignment.

It is understood that the District has been in negotiations with Sea to Sky Forestry to lease a portion of the lands for the use of a proposed Sea to Sky Forestry Centre. The proponents expressed concern that the proposed dike alignment would leave their development site on the water side of the dike.

Staff have reviewed these concerns and prepared preliminary considerations related to the detailed dike alignment as follows:

Financial

Option 5A (UMBC foreshore) is the most costly option as it requires the greatest length of new dike construction. Utilizing Highway 99 which is already raised to an adequate level to provide protection for 1m of Sea Level Rise provides significant cost savings to the District.

- Hwy 99/Logger's Lane = 130m of new dike x $6000/m = $780,000
- Option 5A = 700m of new dike x $6000/m = $4,200,000

Environmental

- Highway 99/Logger's Lane - would require minimal new building footprint for the dike and is anticipated to have less significant environmental impacts.
- Option 5A would require construction within the foreshore and is anticipated to cause greater disturbance/environmental impact. A 'Greenshores' type dike could be used to mitigate impacts.
- Option 5A would cause substantial impact to Rose Park.

Geotechnical

- Highway 99/Logger's Lane – minimal concern over Highway 99, some concern over challenging soils underlying Logger's Lane
- Option 5A – significant concern over compressible, liquefiable soils underlying dike alignment

Development Objectives

- Highway 99/Logger's Lane
    - Adequate building setbacks would be required on the water side of dike to ensure the District's ability to inspect/maintain the dike
    - Development would need to be compatible with dike alignment to ensure no adverse impacts
- Option 5A
    - Greenshores type dike has very large footprint (minimum 30m width) that would likely encroach on the preliminary development plan. When considering dike setbacks, this could impact development objectives.
    - Being on the land side of dike does not provide a reduction in the building flood construction level (FCL). Building FCL's within a floodplain are specified as 'secondary flood mitigation measures' beyond the primary protection of a dike.
    - If a dike is required to protect the development, there are significant regulatory approvals required (Water Act, Dike Maintenance Act, Department of Fisheries and Oceans approval)
    - If a dike is required to protect the development, it may introduce delays while the District seeks funding to construct the dike.

Insurance

- Overland flood insurance is not currently provided in Canada. If this changes at some point in the future, it is anticipated that as long as a Qualified Professional has specified appropriate mitigation measures (FCL, erosion protection, setbacks, etc) to allow the building to be 'safe for intended use', then insurance companies may provide overland flood insurance.

Discussion

It is important to recognize that dike protection is not necessarily the optimal method of flood mitigation. There are many mitigation measures that may be considered for coastal development including dike protection, raising

the entire site with fill to an appropriate FCL and providing erosion protection or simply raising the structure above the FCL. Staff's preliminary review has shown significant challenges associated with dike protection including mitigation cost, regulatory approvals, technical considerations and development objectives.

For example, the recently rezoned Scott Crescent development and the proposed Squamish Oceanfront Development lands both propose to provide flood protection through a combination of site fill, erosion protection and raising buildings to an appropriate flood construction level.

There are complex considerations that should be considered when making a detailed dike alignment decision. Given the preliminary state of the design for the Sea to Sky Forestry Centre and that a Qualified Professional (QP, likely a coastal engineer) has not yet been engaged, it is recommended to defer a decision on the dike alignment until Sea to Sky Forestry has engaged a QP to review mitigation measures.

Special Study Area #4 was designated to review required upgrades to floodboxes and tide gates at the Logger's Lane/Mamquam Blind Channel crossing. It is proposed to expand the scope of the study to review the optimal dike alignment once Sea to Sky Forestry has retained a QP and prepared site plans for their proposed development.

5. Implications:

a) **Budget:**

As discussed above, the dike alignment will have significant long term financial implications.

b) **Policy:**

N/A

c) **Environmental**

As discussed above, dike alignment will affect the environment along the Mamquam Blind Channel.

6. Attachments:

1) *Coastal Flood Hazard Mitigation Strategy and Coastal Flood Protection Options Technical Memorandum*, Kerr Wood Leidal, April 1, 2015
2) Report to Council – Integrated Flood Hazard Management Plan – Council Update #3 - Coastal Flood Protection Strategy

7. Alternatives to Staff Recommendation:

Staff Recommendation:
THAT the District of Squamish direct staff to pursue alternate coastal flood protection strategies.

_____
David Roulston, P.Eng
Municipal Engineer

_____	_____
Rod MacLeod Director of Engineering	Robin Arthurs GM, Corporate Services
_____	_____
Gary Buxton GM, Development Services & Public Works	Joanne Greenlees GM, Financial Services

CAO Recommendation:
That the recommendation of Engineering be approved.

_____
C. Becker, CAO

KERR WOOD LEIDAL
consulting engineers

Appendix E

Report to Council for June 9, 2015 Meeting of District of Squamish Committee of the Whole

REPORT TO:	Council	FOR:	Special
REPORT FROM:	Engineering		
PRESENTED:	June 9, 2015	FILE:	IFHMP
SUBJECT:	Integrated Flood Hazard Management Plan Council Update #5 – Coastal Flood Protection Strategy Update		

Recommendation:

That Council approves the following resolution:

THAT the District of Squamish adopt the design parameters for determining sea dike crest elevations as outlined in this report.

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1. Purpose:

The purpose of this report is to review potential options and considerations related to revising the sea dike crest elevations proposed in the April 14th, 2015 RTC.

2. Background:

On August 19th, 2014 Council adopted a methodology for calculating coastal flood construction levels based on the draft amendment to the Province's *Flood Hazard Land Use Area Management Guidelines*. The selected methodology is the least conservative of several options presented in the Provincial guidelines. This methodology strikes a balance between improved coastal flood protection and increasing implementation challenges while meeting Provincial regulatory requirements. Based on the methodology, preliminary sea dike elevations have been determined based on:

- 1:200 year return period tide/storm surge determined by 'joint probability' analyses
- Estimated wave effects associated with a concurrent 1:200 year return period wind event
- Allowance for 1m Sea Level Rise (SLR) to Year 2100
- Local effects (wind setup, local surge, subsidence, etc)
- Freeboard allowance

Based on the above, a preliminary analysis recommended Year 2100 dike crest elevations ranging from 4.7m to 5.4m. These values were informally accepted by Council on April 14th, 2015. However, in subsequent meetings, Council expressed concerns about the sea dike crest elevation and requested that the project team explore potential opportunities to reduce the sea dike elevation while still providing an acceptable level of flood protection.

3. Project Information:

Detailed project information has been included in previous Council reports and is summarized in the May 12, 2015 Council report (see Attachment 1).

4. Department Comments

Squamish is a complex environment with both river and coastal flood hazards. The District must strike a careful balance in setting the sea dike crest elevation, since the sea dike will protect against coastal hazards but will also trap water in the downtown core in the event of an upstream river dike breach. Lowering the elevation of the sea dike increases the potential for coastal flooding, but reduces the consequences of a river dike breach (i.e water would not pond as high prior to overflowing the dike into Howe Sound). Conversely, raising the elevation of the sea dike decreases the potential for coastal flooding but increases the consequences of a river dike breach.

Flood Construction Levels (FCLs) for buildings in dike-protected areas are typically determined based on modeling that determines how high floodwaters will rise during a dike breach event. The final sea dike elevation will therefore also influence decisions on flood construction levels for new development in the downtown (FCLs will be discussed in detail during the next phase of the project).

Given the planning implications of the sea dike elevation, the project team initiated a review of the methodology for determining sea dike crest elevations. The goal of the review was to determine whether there is an acceptable engineering solution that can reduce dike breach implications while maintaining an appropriate level of coastal flood protection. Detailed evaluation of each of the components comprising the sea dike elevation is included in Appendix A. A brief summary is as follows:

Component	Considerations
1:200 year joint probability of high tide/storm surge	This is the least conservative standard available. No opportunity for reducing requirement.
Estimated wave effects associated with a concurrent 1:200 year return period inflow wind event	Assuming that 1:200 year return period wind event coincides with a 1:200 year high tide/storm surge may be a conservative assumption. Recommended to use a standard 'wave overtopping rate' of 10 L/s/m. This provides fairly significant reductions in the dike elevation at some locations.
Local effects (wind setup, local surge, land subsidence)	Significant effort has been invested to reduce this as much as possible. Further work not guaranteed to reduce elevation any further. No change recommended.
Allowance for 1m Sea Level Rise (SLR) to Year 2100	This allowance follows Provincial guidance which is based on the latest available science. Deviation from 1m allowance is unlikely to gain regulatory approval. No change recommended.
Freeboard allowance	Some conservative assumptions have been built into the methodology for determining dike crest elevation. It is recommended to use 0 m freeboard in combination with a defined wave overtopping rate. However, where wave effects are less than 0.6m, a minimum 0.6m freeboard should be applied.

The review concluded that the sea dike crest elevations presented on April 14th, 2015 provide a reasonable and prudent level of coastal flood protection. However, the review also confirmed that several subjective and potentially conservative assumptions can be revisited in light of the benefits of mitigating dike breach consequences. In particular, some of the conservative assumptions built into the methodology could justify accepting higher wave overtopping during short-duration coastal flood conditions.

Based on the evaluation in Appendix A, and taking into account Council's preference for reducing implicit conservativism in the sea dike crest elevations, the IFHMP team recommends adopting sea dike crest elevations based on the 1 in 200 year return period still-water level plus 1 m SLR allowance and the greater of:

- Wave effects associated with an acceptable overtopping rate of 10 L/s/m combined with 0 m freeboard, **or**
- 0.6m freeboard allowance.

An overtopping rate of 10 L/s/m is generally considered the highest allowable overtopping rate that does not present a danger to properly trained, protected persons working on the dike. Applying freeboard to the dike crest elevation over and above the wave effects component would effectively decrease the expected overtopping rate below what has been deemed acceptable.

In some cases, wave effects are less than 0.6m. In these cases, applying a minimum 0.6m freeboard above the 'still-water level' is recommended and is consistent with the standard applied to river dikes. The IFHMP team considers this to be a "minimum acceptable" elevation for the District's sea dike.

Revised dike crest elevations associated with these changes are presented in the table below. As noted, in some cases, the wave effects component was less than 0.6m, leaving little opportunity for further reduction. allowance for 10 L/s/m overtopping.

Design Point	Previously Recommended Elevation (m GD)	New Recommendation (m GD)	Reduction From Previous
A	4.8	4.8	0
B	5.0	4.8	0.2
C	5.4	4.8	0.6
D	5.3	4.7	0.6
E	4.9	4.7	0.2
F	4.9	4.7	0.2
G	5.0	4.7	0.3
H	5.1	4.7	0.4
I	5.2	4.7	0.5
J	4.7	4.7	0
K	4.7	4.7	0
L	4.7	4.7	0
M	4.9	4.7	0.2
N	5.4	4.7	0.7
O	5.4	4.7	0.7
P	5.4	4.7	0.7
Q	5.4	4.7	0.7
R	5.1	4.7	0.4
S	4.8	4.7	0.1
T	4.8	4.7	0.1
U	5.0	4.7	0.3

In making this recommendation, the following implications must be noted:

- The revised elevations will need to be presented to, and accepted by, the Provincial Inspector of Dikes.

- Proper drainage of overtopping flows must be incorporated into new development located adjacent to the dike as well as future drainage plans for the downtown to avoid damage to structures.
- Accepting higher overtopping rates could lead to localized flooding and public safety issues during extreme coastal storms. This could necessitate emergency response measures such as keeping the public away from seawalls during storms and evacuating low-lying areas.
- Significant, prolonged wave overtopping can be damaging to a dike and the dike must be built accordingly to avoid erosion damage during a coastal storm.
- The sea dike elevation will influence flood construction levels for the next generation of development. As such, this must be considered as a long-term 'visioning' decision and it should be recognized that any future changes that lead to a higher dike may result in near-term development being built too low, and vice versa.

5. Implications:

a) **Budget:**

Reduced dike elevation will reduce the cost of constructing the sea dike. However, allowing increased overtopping will require enhanced erosion protection that could increase the cost of constructing the sea dike.

b) **Policy:**

Reducing the elevation of the sea dike increases the potential for coastal flooding, but reduces the consequences of a river dike breach. It is recommended to adopt a balanced approach to these risks as recommended in this document.

c) **Environmental**

A lower sea dike will generally tend to reduce the required footprint, which generally tends to reduce environmental disturbance.

6. Attachments:

1) Report to Council – Integrated Flood Hazard Management Plan – Council Update #4 - Coastal Flood Protection Strategy

7. Alternatives to Staff Recommendation:

Staff Recommendation:
THAT the District of Squamish direct staff to pursue alternate coastal flood protection strategies.

_____
David Roulston, P.Eng
Municipal Engineer

_____	_____
Rod MacLeod Director of Engineering	Robin Arthurs GM, Corporate Services
_____	_____
Gary Buxton GM, Development Services & Public Works	Joanne Greenlees GM, Financial Services

CAO Recommendation:
That the recommendation of Engineering be approved.

_____
C. Becker, CAO

Appendix A

The IFHMP project team reviewed each component that makes up the sea dike crest elevation to assess whether the combination of conservative assumptions creates room for a more realistic interpretation to mitigate the consequences of a river dike breach. The evaluation is summarized below.

1. **Component**: 1:200 year return period of tide and storm surge determined by joint probability analysis.
   Value: 2.69m (18.9ft chart datum)
   Considerations:
   - The 1:200 year return period is the least conservative value that meets Provincial standards and guidelines. It is also consistent with the level of protection Provincially mandated for river dikes.
   - The 'Joint probability' method of calculating the 1:200 year return period water level yields a result 0.15 m lower than the alternative 'combined' approach.

   Recommendation:
   - The least conservative assumptions possible have been made for this component while still meeting Provincial guidelines. No change is recommended.

2. **Component**: Estimated wave effects associated with a concurrent 1:200 year return period inflow wind event
   Value: 0.1m-1.3m (0.3ft- 4.3ft) depending on location
   Considerations:
   - Preliminary analysis indicates that the combination of 1:200 year return period high-water (tide and storm surge) and 1:200 year return period inflow wind event is not supported by historical data (i.e it is likely a conservative assumption to use 1:200 year winds during a 1:200 year storm surge event).
   - Nonetheless, given the lack of presently available local storm surge/wind data, it is not possible to determine conclusively what combination of tide, wind, and storm surge will result in a 1:200 year design condition. As such, the conservative assumption of concurrent 1:200 year wind and water level events is appropriate.
   - Both wind and high tide events are typically short duration (±3 hr duration with ±1 hr at or near peak value). Even if the wind and water level events occurred concurrently, the design overtopping condition would be limited to a short amount of time.
   - Dike crest elevation varies significantly with the acceptable wave overtopping rate chosen. A range of overtopping rates from 10 L/s/m to 0.1 L/s/m are typically considered acceptable depending on public access, adjacent land use and similar considerations.
   - For safety reasons, dikes are designed using formulations that account for the variation in overtopping along a length of dike. The overtopping rate allowed in IFHMP calculations represents the "worst case" expected along the length of dike; average overtopping rates would be less than the design overtopping rate calculated for a single location.
   - Adopting a 10 L/s/m allowable overtopping rate is acceptable for the conservative assumption of concurrent 1:200 year wind and water level events, and would result in a more modest overtopping rate for any lesser combination of wind, surge and tide.
   - Dike breach implications suggest that it would be prudent to manage any residual uncertainty about overtopping by further strengthening the dike against overtopping flows in lieu of adopting a higher dike crest.

   Recommendation:

   The previously-recommended sea dike crest elevations provide reasonable and prudent protection against coastal flooding. However, in the case of Squamish, the combination of conservative assumptions that would

otherwise be recommended creates unacceptable trade-offs by increasing the consequences of an upstream dike breach event. To address these concerns, the IFHMP team recommends adopting sea dike crest elevations based on the 1 in 200 year return period still-water level plus 1 m SLR allowance and the greater of:

- Wave effects associated with an acceptable overtopping rate of 10 L/s/m combined with 0 m freeboard, **or**
- 0.6m freeboard allowance.

Component: Allowance for 1m Sea Level Rise (SLR) to Year 2100
Value: 1m (3ft)
Considerations:

- 1m SLR represents the latest and best guidance provided by the Provincial government. As a planning figure, the recommended 1 m allowance was appropriately conservative with regard to predictions available at the time of publication. The guideline has been widely adopted in engineering assessments prepared for other municipalities and private industry.
- Deviation from the provincial SLR guidance is not likely to gain regulatory approval from the Inspector of Dikes.
- Sea level rise is predicted to continue beyond 1 m. Therefore, while there is some uncertainty as to how quickly it will occur, the value itself is an appropriate planning target. If SLR occurs more slowly than predicted, then dikes built today with a 1m allowance will serve their intended purpose for a longer time. If it occurs more quickly, then upgrades will be required sooner.

Recommendation:

- No change is recommended; i.e., continue to use the Provincial guideline of 1m.
- Dike construction should be phased according to the implementation plan contained in the Coastal Flood Protection Strategy. This will allow the District to take advantage of evolving state of knowledge and the latest SLR predictions prior to making a final commitment to construction.

3. **Component**: Local effects (wind setup, local surge, land subsidence)
Value: 0.3 m – 0.5 m (1 ft – 1.5 ft)

Considerations:

- Significant analysis has been invested to reduce this value as much as reasonable based on the available data.
- Further refinements would require additional data collection and analysis, requiring additional budget and time delays to the project.
- Additional analysis may not allow reductions to the local effects and could even potentially increase the value.

Recommendation:

- No change is recommended; i.e., continue to use a 0.3m allowance for local effects plus additional site-specific allowances for local wind setup.

4. **Component**: Freeboard allowance
Value: 0-0.6m (0-2ft)

Considerations:

- Freeboard accounts for uncertainties in technical elements of the design methodology.
- Individual conservative assumptions about known uncertainties initially resulted in even more conservative combinations of factors being built into the methodology for determining dike crest elevation.

- 1m allowance for SLR is included which may or may not happen within the next 100 years. However, the 1m allowance provides time to further refine uncertainties in the future (i.e 1m of 'freeboard' is essentially provided for present day conditions)
- The dike has been designed for an acceptable overtopping rate. Adding additional freeboard would reduce overtopping below what has been determined as acceptable.

Recommendation:

- It is recommended to use 0 m freeboard in combination with a defined wave overtopping rate. However, where wave effects are less than 0.6m, a minimum 0.6m freeboard should be applied to the still-water level in keeping with provincial design criteria for standard dikes.

KERR WOOD LEIDAL
consulting engineers

Appendix F

Report to Council for September 29, 2015 Meeting of District of Squamish Committee of the Whole

(Excluding RTC Attachments)

REPORT TO: Council
REPORT FROM: Engineering
PRESENTED: September 29, 2015
SUBJECT: Integrated Flood Hazard Management Plan – Council Update #6 – Coastal Flood Protection Strategy Update

FOR: Committee of the Whole

FILE: IFHMP

Recommendation:

That Council approve the following resolution:

THAT the District of Squamish adopt the Coastal Flood Mitigation Strategy as described in Kerr Wood Leidal's *Coastal Flood Hazard Mitigation Strategy and Flood Protection Options* draft report.

and

THAT District staff finalize the report by maintaining Reach 5 as a Special Study Area and selecting the Foreshore dike as the preferred alignment in Reach 5.

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1. Purpose:

The purpose of this report is to finalize the Coastal Flood Mitigation Strategy, particularly with respect to Reach 5, and confirm the Foreshore dike as the preferred alignment in Reach 5.

2. Background:

The Coastal Flood Protection Strategy has been presented to Council on several occasions in 2015. Generally, the main points of concern involved dike height and the alignment in Reach 5 along the Upper Mamquam Blind Channel. Following detailed discussion with Council, the dike height and sea dike implementation plan have been adopted by Council. The final items requiring resolution are Reach 5 dike alignment and endorsement of the overall Coastal Flood Protection Strategy. Chronology of prior Council meetings is summarized below:

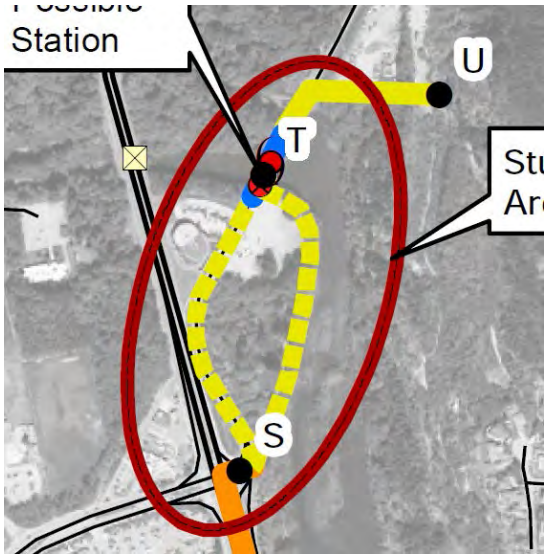
Date	Purpose	Council Decision
February 3, 2015	Receive draft report for information and get initial feedback.	Endorsed
April 14, 2015 - Committee of Whole	Adopt Coastal Flood Protection Strategy Avoid further investigation of interceptor dike	Endorsed in principle Endorsed in principle
April 21, 2015 - Regular Council	Same as above	Defer decisions for further discussion at COW due to concerns regarding Reach 5 dike alignment and dike height.
May 12, 2015 – Committee of the Whole	Resolve Reach 5 alignment and dike height issues. Adopt Coastal Flood Protection Strategy	Deferred to next COW for further discussion due to ongoing concerns on dike height.
June 9, 2015 – Committee of the Whole	Adopt parameters for determining dike elevation Adopt the sea dike implementation plan.	Endorsed in principle Endorsed in principle

June 16, 2015 – Regular Council	Adopt parameters for determining dike elevation Adopt the sea dike implementation plan.	Carried

3. Project Information:

Detailed project information was summarized in the *Coastal Flood Hazard Mitigation Strategy and Flood Protection Options* draft report (see Attachment 1).

4. Department Comments



There are two preferred dike alignments for Reach 5 that have been short-listed as shown and described below:

1. Logger's Lane - Highway 99 from MBC to Hwy 99/Logger's Lane intersection, Logger's Lane to Upper MBC, east to Smoke Bluffs
2. Foreshore - Highway 99 from MBC to Hwy 99/Logger's Lane intersection, east to foreshore, north to UMBC, east to Smoke Bluffs

In the Coastal Flood Protection Strategy presented to Council on April 14, 2015, the recommended dike alignment for Reach 5 – was the Logger's Lane alignment described above. This dike alignment placed 38400, 38540 Logger's Lane (Rose Park) on the water side of the dike alignment. Sea to Sky Forestry expressed concern that the proposed dike alignment would leave the proposed Sea to Sky Forestry Centre on the water side of the dike and suggested the Foreshore alignment described above.

Staff reviewed the suggested Foreshore alignment in the May 12, 2015 Council report taking into account financial, environmental, geotechnical considerations as well as development objectives. Based on the complexity of considerations, the May 12 report recommended identifying the Reach 5 area in the vicinity of Rose Park as a 'Special Study Area' to be reviewed in detail once Sea to Sky Forestry came forward with a development proposal. This option was considered by Council; however the decision was deferred once discussion shifted to dike height.

In order to lay out factors in the decision making process, each alignment option is evaluated in Appendix A on a broad range of considerations with advantages given to the two alignments based on the Project Team's evaluation.

Based on the evaluation, both dike alignments are deemed to be technically feasible. A decision between them is subjective and involves trade-offs between different opportunities and challenges. The Project team recommends adopting a preferred alignment in order to provide a future vision for planning purposes. Deferring a decision on a preferred alignment leaves the decision wide-open, making future area planning difficult.

It is also recommended to maintain the Reach 5 dike alignment as a 'Special Study Area' warranting further review. It must be recognized that the decision is being made on conceptual dike designs and with relatively high-level analysis. The preferred alignment should be confirmed at the preliminary design stage.

Finally, the Foreshore alignment is recommended based on improved land use and development opportunities arising from dike protection.

The result of the recommendations is that the proposed Sea to Sky Forestry Centre will be on the land side of the dike, and Reach 5 remains a special study area until the preliminary design stage of the dike.

Site B Considerations

In a previous Council discussion, there was a question about whether future fill at the SODC lands or Site B on the east side of the Mamquam Blind Channel would reduce wave heights, thereby allowing for a reduction in the sea dike height. The wave analysis already completed included future plans for filling at the south end of the SODC lands. As such, this is already taken into consideration. It is possible that future fill at Site B could have the effect of reducing wave heights by a very small amount; however given Council's previous motion to include a freeboard allowance in the dike height any reduction in wave height would not impact the recommended sea wall height.

The motion was to include a freeboard allowance equal to the greater of (1) 0.6m freeboard or (2) wave effects associated with a 1:200 year wind event. Given the already small height of waves in the Mamquam Blind Channel (less than 0.6m), any reduction in wave height from future fill at Site B would not impact the recommended sea dike height. As such, potential future fill at Site B has no effect on recommended sea wall height and no further work is recommended.

5. Implications:

a) **Budget:**

The cost to build a sea dike along Squamish's coastal perimeter has been estimated to cost $55,000,000. It is anticipated that this work will be phased over many years depending on the observed rate of sea level rise. It is also anticipated that the majority of dike construction will take place with Provincial/Federal funding as has historically occurred.

b) **Policy:**

N/A

c) **Environmental**

Construction of a sea dike along the foreshore will have some environmental impact, however this is planned to be mitigated through the use of 'Green Shores' dikes that utilize bio-engineering for erosion protection wherever possible.

6. Attachments:

1) *Coastal Flood Hazard Mitigation Strategy and Flood Protection Options* draft report, Kerr Wood Leidal, July, 2015

7. Alternatives to Staff Recommendation:

Staff Recommendation:
THAT the District of Squamish adopt the Coastal Flood Mitigation Strategy as described in Kerr Wood Leidal's *Coastal Flood Hazard Mitigation Strategy and Flood Protection Options* draft report.

and

THAT District staff finalize the report by maintaining Reach 5 as a Special Study Area and selecting the Logger's Lane dike as the preferred alignment in Reach 5.

_____
David Roulston, P.Eng
Municipal Engineer

_____	_____
Rod MacLeod	Robin Arthurs
Director of Engineering	GM, Corporate Services

_____	_____
Gary Buxton	Joanne Greenlees
GM, Development Services & Public Works	GM, Financial Services

CAO Recommendation:
That the recommendation of Engineering be approved.

_____
Linda Glenday, Deputy CAO

Appendix A – Detailed Considerations Table

Consideration	Importance	Logger's Lane	Foreshore	Advantage
Cost	High	Smaller construction footprint. Need to replace utilities under existing roadway. Need to re-grade, re-construct property access to 38400 Logger's Lane and Adventure Centre.	It would be necessary to raise Logger's Lane at Highway 99/Cleveland and at the Logger's Lane/MBC crossing and transition down to existing grade requiring additional construction. Likely more difficult geotechnical conditions increasing cost and complexity.	Slight advantage Logger's Lane
Environment	High	Minimal additional construction footprint.	Significant construction in environmentally sensitive area.	Logger's Lane
Future Land Use / Development Opportunities /Property Access	High	Doesn't protect 38400 Logger's Lane. Development would need to respect riparian setbacks and dike setbacks thereby constraining development space. More significant impacts access to Adventure Centre.	Protects 38400 Logger's Lane facilitating development. Facilitates property access from Logger's Lane	Foreshore
Design / Technical	Moderate	Likely better geotechnical conditions Minimal erosion protection required for setback dike Need to re-locate utilities Need to resolve property access issues	Difficult geotechnical conditions requires consideration More significant erosion protection	Tie
Operations and Maintenance /Emergency Response	Moderate	Logger's Lane transportation could be impacted in emergency situations	Easier to maintain dike as it will not be a road	Foreshore
Community Amenity	Moderate	Dike would function as road. No measurable benefit	Dike can function as waterfront trail Protects park land	Foreshore
Permitting	Low	Inspector of Dikes prefers not having roads function as dikes	Requires Department of Fisheries and Oceans and Water Act approvals	Logger's Lane