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Squamish Integrated Flood Hazard Management Plan

SUBMITTED BY:

KERR WOOD LEIDAL
consulting engineers

CLIENT:

SQUAMISH

Project Information

Name:	**Squamish Integrated Flood Hazard Management Plan**
Location:	Squamish, BC
Year Completed:	October 2017
Entering Firm:	Kerr Wood Leidal Associates Ltd.
Role of Entering Firm:	Prime Consultant
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Project Outline

Project Summary

In 2014 the District of Squamish retained Kerr Wood Leidal Associates Ltd. to lead a ground-breaking, three-year study to assess its flood hazards and recommend mitigation. The resulting Integrated Flood Hazard Management Plan looks beyond traditional floodplain mapping and systematically considers the interplay of physical, economic, social, and environmental risks. The IFHMP identifies an array of mitigation choices that balance the need for flood protection with impacts to stakeholders, the community, and the environment.

Project Highlights

Innovation

The District of Squamish (the District) faces an unparalleled range of flood-related hazards: river, urban, and coastal floods, dam breaches, debris flows, dike failures, and tsunamis. At the same time, rapid growth has left the community with billions of dollars of assets within its floodplains. In 2004, the Government of British Columbia transferred responsibility for managing development in flood hazard areas to local governments. The District must manage complex flood risks with the resources available to a community of 19,500 people.

In 2011, local governments were directed to plan for 1 m of sea level rise by Year 2100 and 2 m by 2200. Shortly thereafter, the District received a proposal for a new waterfront development. For the project to proceed, the District would have to develop a formal plan for managing sea level rise. The ‘obvious’ solution of a sea dike was not so simple: if the river dikes breached upstream, a sea dike would make the situation worse by trapping water in the historic downtown and turning it into a giant bathtub.

In 2014, the District retained KWL to complete a ground-breaking, three-year assessment of its flood hazards from an integrated, systems-based perspective. Mitigation strategies had to balance flood protection, community growth, and environmental objectives. The resulting IFHMP represents a significant step forward for flood hazard management. **Hazard** assessments consider different sources of flooding and mitigation options in the context of their effects on each other. **Consequence** assessments consider community priorities for different economic, social, and environmental outcomes. **Implementation** looks beyond existing conditions to focus on what can be expected in the coming decades.

Examining the District's complex and intertwined hazards together allowed mitigation strategies to identify and avoid undesirable results. As well, the integrated approach looked beyond traditional floodplain mapping to consider aspects of physical, economic, social, and environmental risk. This required a multidisciplinary team of engineers, planners, and environmental scientists.

The project produced several engineering innovations, including western Canada's most detailed floodplain-scale hydraulic model and a new first-principles approach for establishing sea dike design criteria. The IFHMP takes an unprecedented comprehensive approach to incorporating future development, and adopted European methods to highlight potential challenges for floodplain evacuation. As well, new geographic information system (GIS) tools can extrapolate results from a small number of dike breach models to ensure that planning maps capture the possibility of a dike breach at *any* location along a 20 km dike.

Complexity

The IFHMP began by reviewing over 170 past studies to confirm hazards, understand existing protections, and identify policy gaps. Phase 2 explored coastal flood risk mitigation options. In Phase 3, KWL undertook dike breach and consequence modelling, prepared inundation maps, and developed mitigation tools. Phase 4 consolidated the technical work and produced an Official Community Plan update, a new Floodplain Bylaw, and new Development Permit Area guidelines.

Based on community input, the IFHMP prioritized a new 7 km sea dike around downtown Squamish. Design concepts reflect different community priorities at different locations along the dike. Provincial design methodologies produced conservative crest elevations, which would increase the 'bathtub effect' during an upstream river dike breach. KWL's innovative joint probability approach used first principles theory to produce more accurate flood levels that reduce the 'bathtub effect' while minimizing implementation costs.

Urban densification can increase water levels during a dike breach event. To address this challenge, KWL developed a highly-detailed hydraulic model that represents mitigation and development on a lot-by-lot basis. Results confirm key behaviours like flow concentration along streets and water level increases caused by future development. The detailed model also confirmed that the 'bathtub effect' could be mitigated by intentionally breaching the sea dike at carefully-selected locations.

Mitigation options were evaluated based on regulatory, technical, economic, social, operational, and environmental considerations. Unique recommendations for each part of the community balance local hazards, consequences, and community values. A staged implementation plan addresses urgent risk mitigation priorities, funding constraints, and development opportunities.

Social and/or Economic Benefits

After producing a full suite of hazard maps, KWL completed a GIS-based assessment of social and economic consequences. The economic assessment used Natural Resources Canada's HAZUS-MH model, which showed that flood damages could exceed $450 million and displace nearly 60% of the community's population. Results also indicate that a dike breach could damage or destroy as many as 1,400 buildings and generate nearly 40,000 tonnes of debris.

Flood risk cannot be eliminated completely. Effective community-driven decision making must be based on the best available engineering analyses to ensure that risks are understood, and that implications of each decision are carefully considered. The IFHMP expanded the traditional engineering role of designing flood protection to a broader one of building sustainable communities. It directly confronts complex sustainability challenges in the form of climate change, natural hazards, development pressures, and the disparate interests of an array of stakeholders who live in the floodplain or have jurisdiction over it.

For small communities like Squamish, benefit-cost analysis is the only sustainable way to justify long-range capital planning decisions involving large capital expenditures. The IFHMP recommended some $80 million in flood protection improvements, and considered all possible measures to minimize the financial burden of flood risk mitigation. This included the emerging role of private flood insurance and anticipated reductions in future disaster assistance from senior government sources.

> *The Squamish IFHMP advances flood risk management in BC and should serve as a template for other communities.*
>
> *– Lotte Flint-Petersen, Former BC Deputy Inspector of Dikes and IFHMP Stakeholder*

Environmental Benefits

The IFHMP's policy tools were crafted with an eye to social sustainability, and include a structured process for granting variances in cases of hardship to protect the vibrancy of existing communities. Long-range planning considered post-disaster criteria and the United Nations-endorsed concept of 'build back better', which guides reconstruction to avoid repeating past mistakes.

Social consequences were considered explicitly through first-of-its-kind GIS mapping developed by KWL specifically for this project. KWL worked with its environmental subconsultant to adapt the new approach for environmental consequence mapping of sensitive habitat areas and storage sites for potentially dangerous materials. Protecting natural overbank areas is another area where the IFHMP considered both environmental and flood protection priorities. Other examples include using environmentally-friendly designs and materials, reconnecting watercourses that were cut off by dikes, and sustainably managing vegetation along the dike system.

The IFHMP's watershed and river management recommendations focus on protecting primary floodway corridors and promoting sustainable land use throughout the watershed. This includes protecting river corridors to preserve flood conveyance and minimize environmental impacts. In diked areas, this means keeping development on the land side of the dike, and allowing development to occur where it will not negatively affect other properties. In areas without dikes, it means minimizing conflicts between natural river processes and development. The IFHMP also recommends continued advocacy for re-forestation and other sustainable land use practices throughout the watershed.

Meeting the Client's Needs

The District's objectives for the IFHMP were to: reduce and share flood risk fairly; support development opportunities; promote sustainability; and produce solutions that are achievable, realistic, and supported by the local community. KWL met these objectives by preparing a detailed strategy that includes over 100 specific tools to manage flood risk. The strategy incorporates elements of protection (diking), accommodation (floodproofing and appropriate land use), avoiding new risks, managed retreat of key infrastructure, and selectively accepting risk where it brings significant benefits for the community. Tools are grouped into seven categories: land use planning, development and building controls, structural flood protection, watershed and river management, public education, emergency planning, and flood insurance. Specific recommendations address a higher design standard for critical dikes, managing densification in high-hazard areas, and directing growth to lower-risk areas of the community.

The IFHMP incorporates the latest flood management guidelines, tools and best practices, anticipating many facets of the World Meteorological Organization's 2017 guidelines for Integrated Flood Management. Key deliverables included a prioritized list of structural flood protection upgrades, significant revisions to the District's Official Community Plan, the District's first floodplain bylaw, and new Development Permit Area guidelines for hazard lands. KWL and District staff successfully tested and refined policies prior to adoption through 'shadow testing' on actual development applications.

> *Using an integrated approach of considering multiple objectives, rather than just seeking to reduce flood risks, has helped the District find balanced solutions that the community can get behind.*
>
> *– David Roulston, P.Eng., Municipal Engineer, District of Squamish*

Images

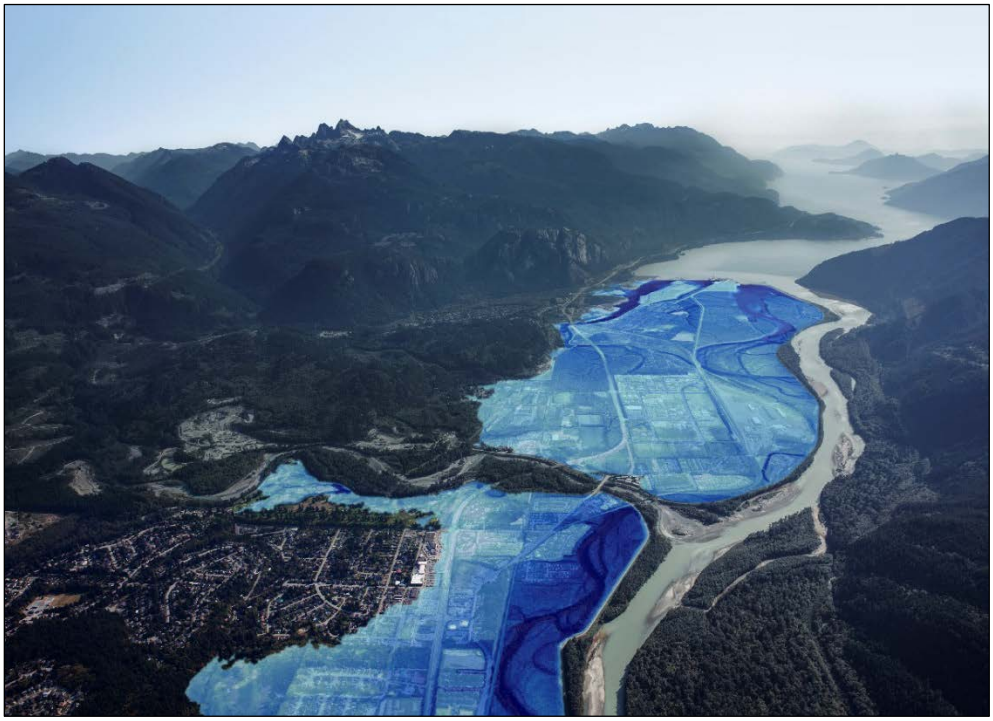

Photo 1: Squamish, BC with inundation extent for a dike breach during a 1-in-200-year river flood superimposed in blue.

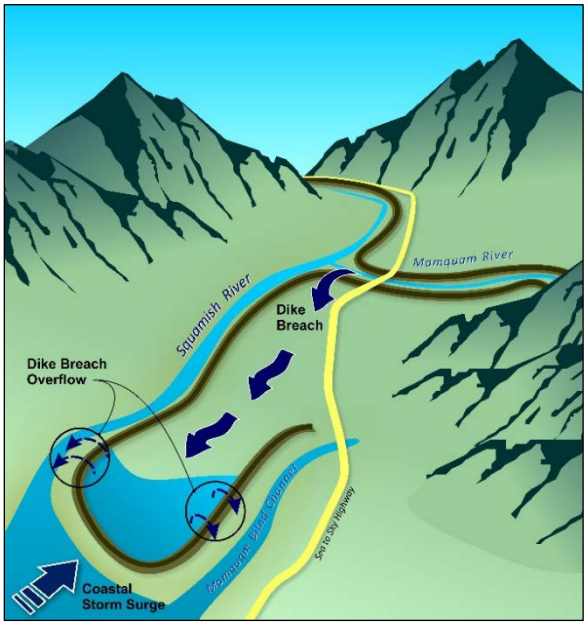

Photo 2: Conceptual illustration of coastal/dike breach flood protection conflicts.

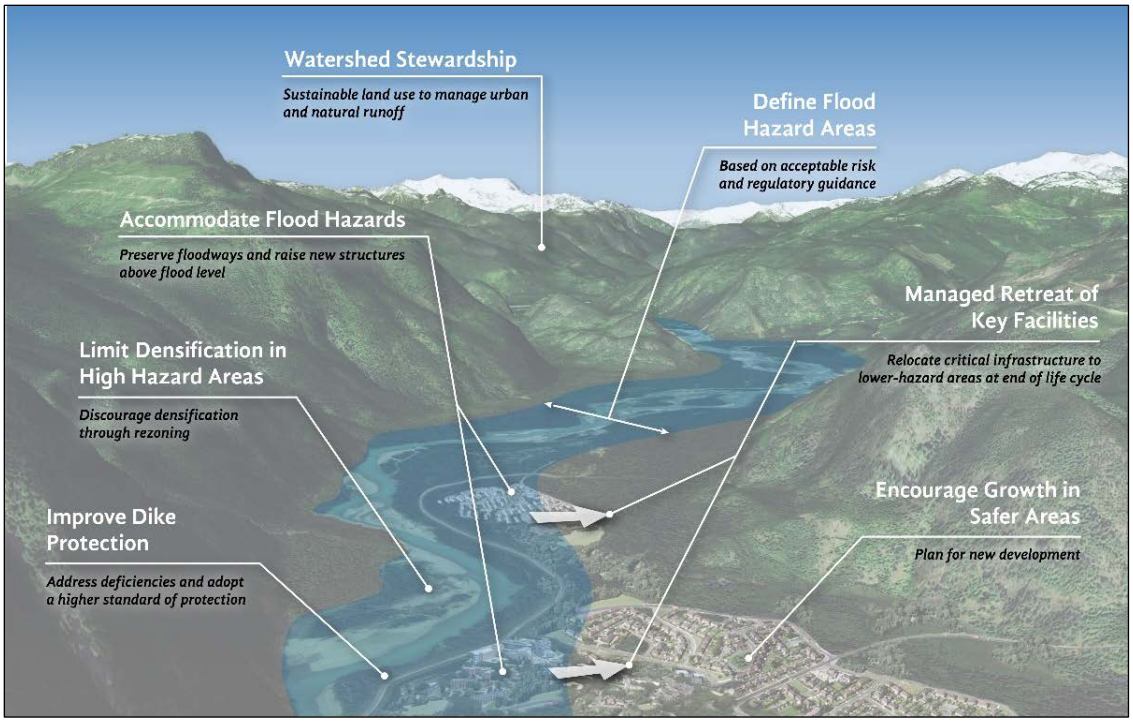

Image 3: Main mitigation strategies for both river and coastal flood hazards in Squamish.

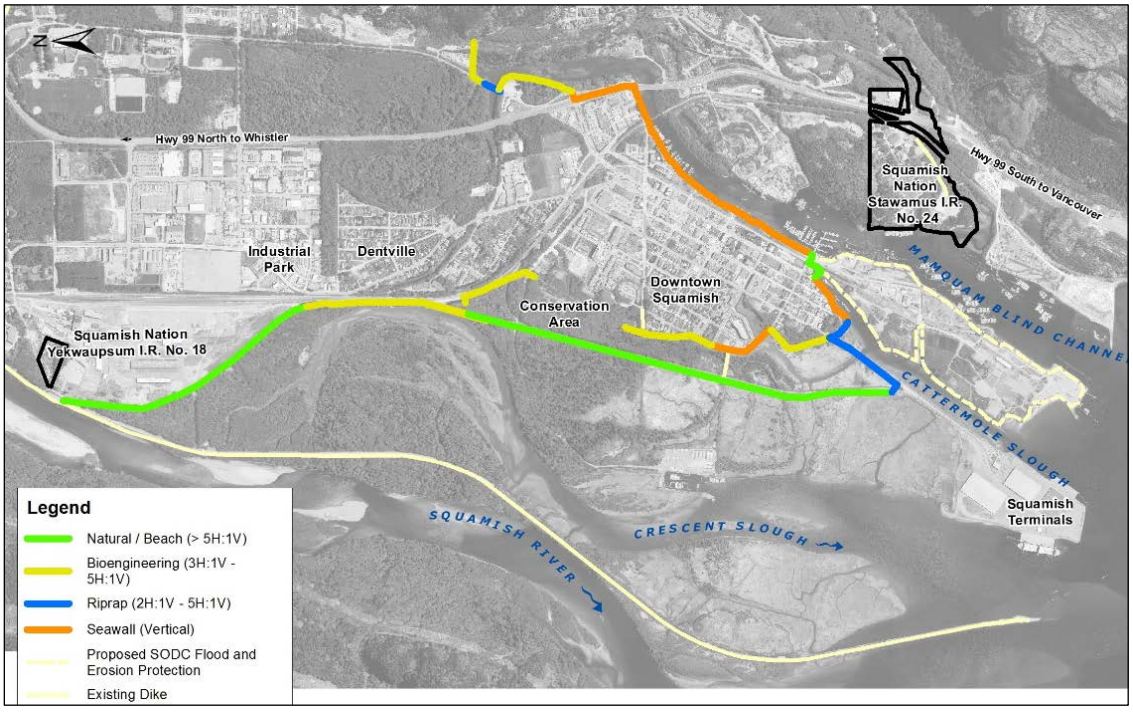

Image 4: Potential alignments for new sea dike to protect downtown Squamish.

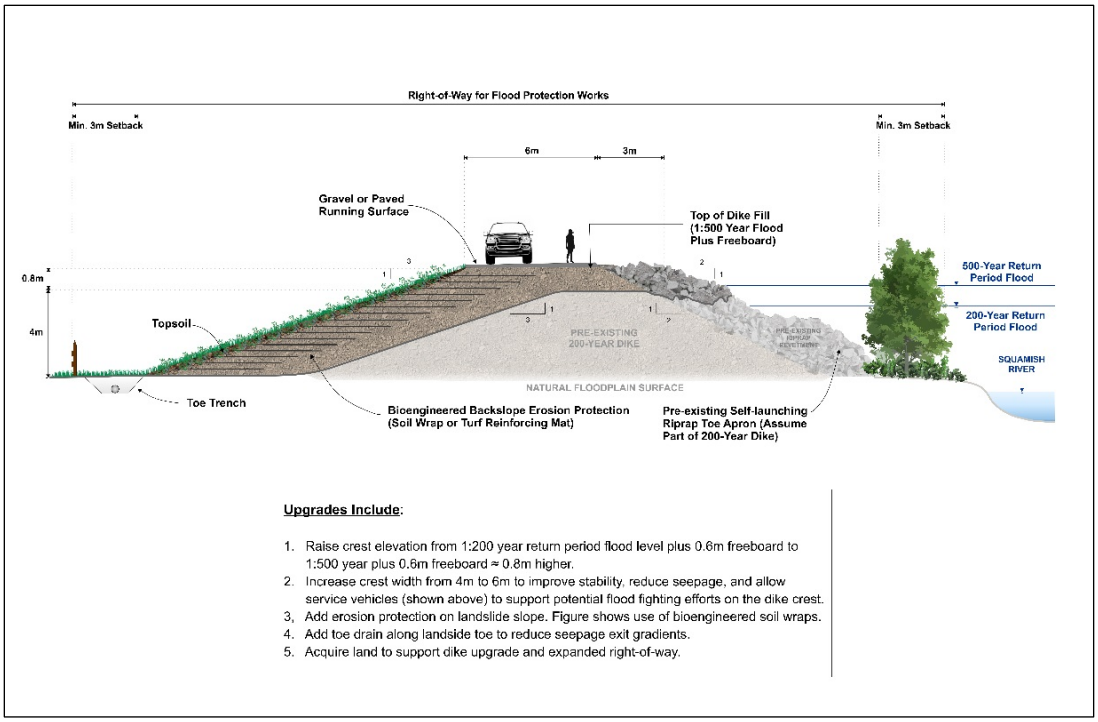

Image 5: Recommended 'Super Dike' concept for Squamish River dike upgrades.

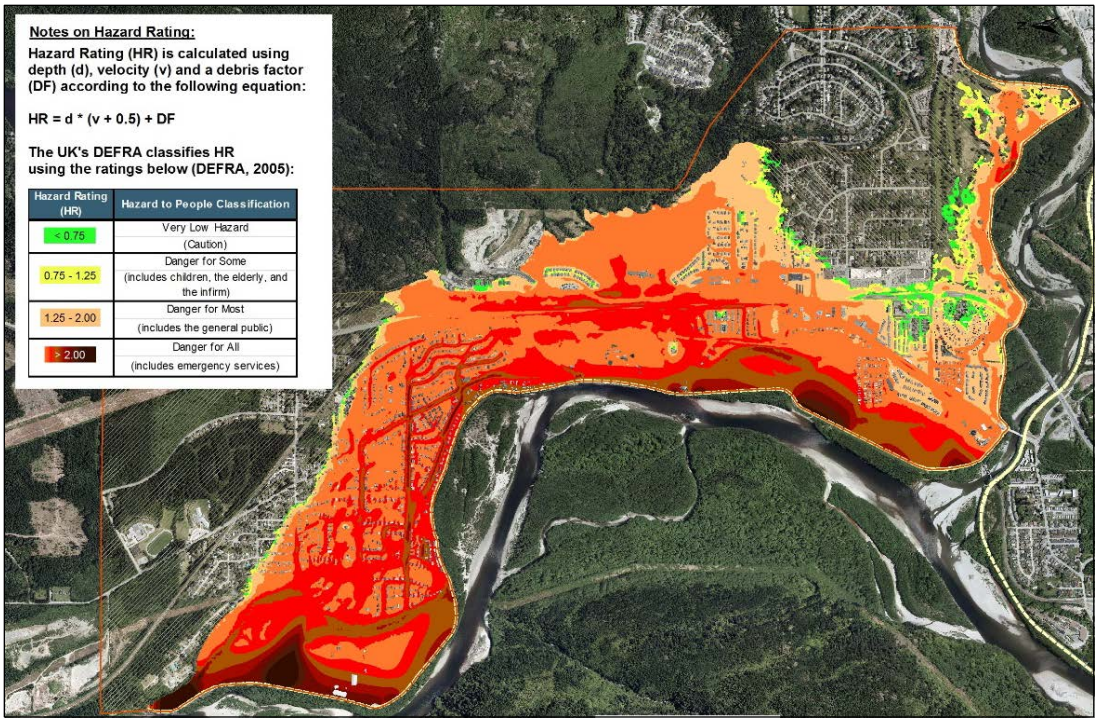

Image 6: Maximum hazard ratings for upper floodplain dike breach scenarios.

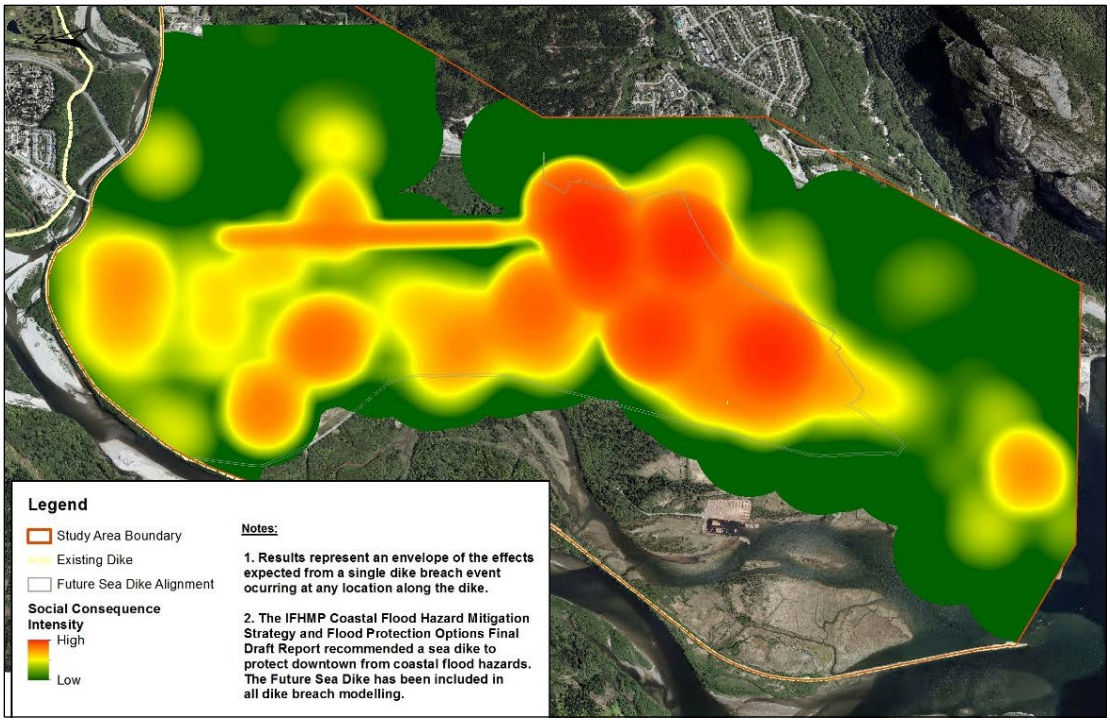

Image 7: Social consequence mapping for composite lower floodplain dike breach scenarios.