New approaches for managing flood risk in the face of climate change

Squamish, BC is finding its own balance between nature, growth, and flood risk

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Catastrophic floods made front-page news again this summer as Hurricane Harvey hammered southeastern Texas. For many in BC, the human tragedy recalls the record-smashing floods of 2013 in the eastern Rockies and this spring's unprecedented high water on Okanagan lakes. Climate change is on the minds of many, and each new story leaves people asking: Could it happen here? What are we doing about it?

In 2004, municipal governments in BC became responsible for managing flood risk in their communities. Faced with competing demands and limited resources, many communities walk a tightrope between growth and responsible stewardship. Adding climate change to the mix can make the difficult task seem impossible. Where does a community begin?

The District of Squamish has spent the past three years answering those questions. Its new Integrated Flood Hazard Management Plan provides a balanced, community-driven blueprint that can respond to local risk tolerance, guide community development, prioritize capital investment, and support sustainable growth in one of the most beautiful but hazardous places in Canada.

NATURAL BEAUTY, NATURAL HAZARDS

Squamish is located at the head of Howe Sound, where five pristine mountain rivers meet the sea. The community of 18,300 enjoys a spectacular natural setting that supports tourism, outdoor recreation, transportation, and forestry. However, these natural advantages come at a price: Downtown Squamish and adjacent areas are at risk of coastal flooding from sea level rise, storm surge, and tsunamis. Most of the community has been built within the floodplains of the Squamish, Mamquam, Cheakamus, Stawamus and Cheekeye Rivers. At the north end of Squamish, the Cheekeye Fan has the potential for catastrophic debris flows from the flanks of Mt. Garibaldi. All of these overlapping hazards leave Squamish literally surrounded by flood risk.

Rapid growth over the past century has left Squamish with billions of dollars of assets within the floodplain. Numerous floods over the same period meant the growing community became dependent on a network of dikes for flood safety. Most businesses, institutions and gathering places in Squamish are now in areas potentially vulnerable to flooding if the dikes breach. More worryingly, the latest information and climate change science indicate that some local dikes do not meet provincial standards.

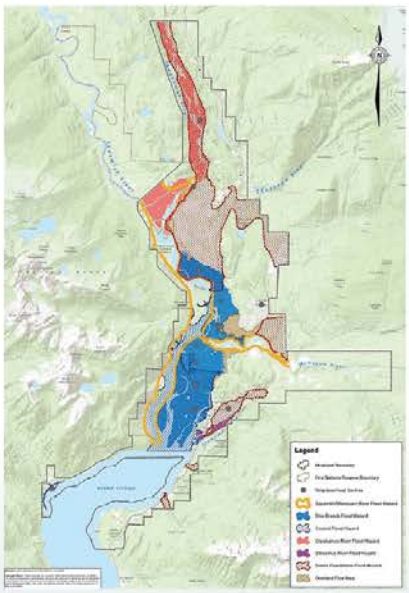

Figure 1

Figure 2

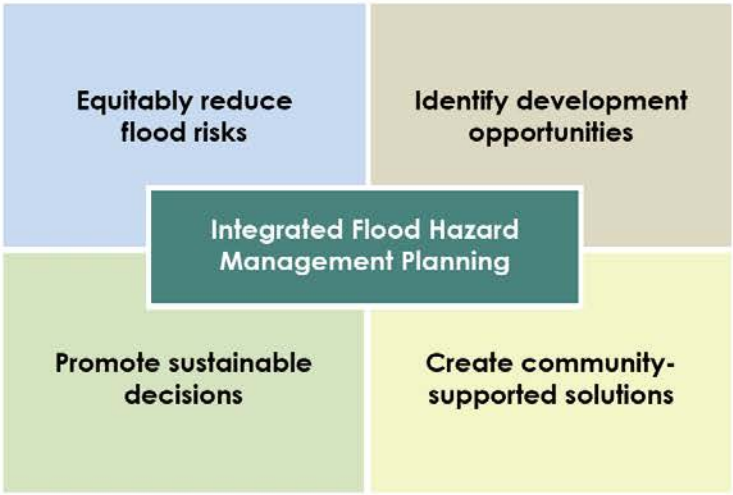

Figure 3

THE NEED FOR A PLAN

The district's first Flood Hazard Management Plan was completed in 1994. The 1994 plan set out Flood Construction Levels for the community and proposed development guidelines through a new floodplain bylaw. Over the years, community growth and economic diversification made key parts of the plan obsolete. At the same time, science provided an improved understanding of flood hazards and the effects of climate change, while engineering developed new and better tools for flood hazard management. Then in 2011, the provincial government issued guidelines recommending that local governments plan for 1m of sea level rise by Year 2100 and 2m by Year 2200.

Shortly after the province's guidelines were released, the district received a proposal for a new waterfront development in downtown Squamish. The proposed development fit with many district priorities, including downtown revitalization and a growth-oriented vision that would see the population nearly double by 2031. For the development to proceed, however, the district would have to address sea level rise, and that meant that a sea dike would have to be incorporated into the foreshore of the development.

The proposal helped the district realize that it had no formal plans for how to manage sea level rise. There was no vision for the sea dike form, height, and alignment – all of which were needed to guide waterfront development. On top of this, the district realized that coastal floods were only part of the problem. If the river dike was to breach upstream of downtown, a sea dike could trap water and turn the downtown area into a giant bathtub. It was clear – Squamish needed a new plan to manage flood risk.

FRAMING THE QUESTION

The complex and intertwined nature of the local hazards meant that mitigation options had to consider different hazards together to avoid unintended and undesirable results. The district also wanted to look beyond traditional floodplain mapping and consider aspects of physical, economic, social, and environmental risk. Meeting these objectives requires an integrated approach to flood risk management.

Integrated flood management takes a systems-based (as opposed to fragmented) approach to understanding and addressing flood risk. For Squamish, it meant the district needed a team of experts covering river, coastal, civil and geotechnical engineering as well as urban planning and environmental resources. At the same time, project outcomes needed community support to ensure that they could and would be implemented.

The district's vision for a new Integrated Flood Hazard Management Plan (IFHMP) adopted the four broad objectives shown in Figure 3.

The district's search for a team of experts took a unique approach. The district stated its budget and challenged consultants to develop a scope of work that could answer a series of key questions:

1. What tools can help Squamish plan and build future development in a manner that minimizes risk?
2. What impact will current and future development have on flood risk management?
3. How should the district adapt to climate change and sea level rise?
4. How should upgrades to flood protection systems be financed?
5. What have similar communities already done, and can those measures be applied in Squamish?
6. How should social, cultural, environmental and economic considerations factor into the new IFHMP?

IN SEARCH OF NEW SOLUTIONS

The consulting community responded strongly to the district's challenge. In 2014, the district selected a team led by Kerr Wood Leidal Associates (KWL), who organized the project into four main phases:

- The **Phase 1** background analysis reviewed over 170 flood studies and reports dating back to the 1950s to identify sources of flooding, flood protection systems, and policy gaps.
- The **Phase 2** assessment explored coastal flood risk mitigation options and produced a conceptual design for a future sea dike.
- In **Phase 3**, KWL undertook detailed dike breach modelling, prepared inundation maps, and developed a suite of flood risk mitigation tools for the Squamish, Mamquam, and Cheakamus Rivers.
- **Phase 4** consolidated the previous technical work and produced an Official Community Plan update, a new Floodplain Bylaw, and new Development Permit Area guidelines.

With this project structure, decisions made at each step could be incorporated into the next phase of analysis. Discussions during Phase 1 helped guide the mayor and council toward a shared vision for the level of coastal flood risk that the community

was prepared to accept. Council input led to the development of a new approach that provides more accurate coastal flood levels and should save millions of dollars in dike construction and floodproofing over the life of the IFHMP.

Council's preferred risk management approach prioritized a new 7 km sea dike around downtown Squamish, an expensive but critically important decision given the implications of sea level rise for the low-lying downtown core. Conceptual alignment and foreshore treatment for the future sea dike became the subject of a multi-objective evaluation process. With buy-in from council and the public, the sea dike became the downstream boundary for Phase 3 dike breach modelling of the Squamish River and Mamquam River floodplain.

MODELLING FOR THE FUTURE

During Phase 3, a detailed two-dimensional hydraulic model was developed to simulate flow through a dike breach spreading out across the floodplain, around buildings and along roads Assumptions for both future development and climate change were incorporated so that IFHMP floodproofing targets could remain stable for the service life of a new structure. The innovative dike breach model also addressed the potential for dikes to breach anywhere along their length and mapped dangerous combinations of flood depth and velocity.

Figure 4

The IFHMP inundation maps provided input for a detailed consequence assessment. Estimated economic damages from a dike breach could reach $447 million. As many as 1,400 buildings would be damaged or destroyed and over 50% of the population of Squamish could be displaced.

Social consequences were assessed using a new GIS-based process that incorporated displacement of residents, disruption of employment, and interruption of community services. Results show that social consequences are governed by the loss of critical community facilities such as schools, wastewater treatment infrastructure, and fire halls. A similar approach was applied to identify environmental risks associated with sensitive habitat areas and storage sites for potentially dangerous materials.

COMMUNITY INVOLVEMENT

Putting a plan like the Squamish IFHMP into practice is all about building community support. Public consultation occurred throughout Phases 2, 3 and 4. Even with its relatively intensive level of engagement, IFHMP discussions skirted around some of the most difficult issues like gradual retreat of key infrastructure, selective property buy-outs, and opportunities to build back better after a disaster. Some parts of the process became iterative. While the dialogue maintained a positive focus on solutions, it became apparent that consensus was not a realistic goal.

The community engagement process did provide at least one clear and nearly unanimous theme that shaped the district's response: all practicable methods should be used to manage flood risk. In response, the district adopted a broad spectrum of mitigation strategies and tools with a balance unique to each local hazard area. Some areas prioritized a higher standard

of protection for existing development. In other areas, development will need to accommodate flood hazards. Growth will be carefully controlled in the highest hazard areas and redirected toward areas of lower risk. Risk mitigation will be aligned with SmartGrowth principles, and the district will review opportunities to relocate critical infrastructure to lower-risk areas as it reaches the end of its service life.

CREATING A COHESIVE PLAN

Specific IFHMP tools knit together elements of land use planning, building regulations, structural protection, river management, public education, and emergency planning while acknowledging the growing importance of flood insurance to mitigate disaster losses. In particular, the district adopted a higher standard of protection for the dikes protecting the heart of the community – a decision that will cost tens of millions of dollars and take decades to implement. To realize these goals the district will need more than the IFHMP's prioritized list of capital projects: funding and executing the work will require long-term co-operation from the provincial and federal governments, developers, and of course local ratepayers.

The IFHMP schedule meshed with major updates to the district's Official Community Plan (OCP), Comprehensive Emergency Management Plan (CEMP), and several complementary bylaws. The result is one of the most extensive flood policy reboots created under BC's current legislative regime. Although the goal was a single policy framework, legal and administrative requirements split the policy into four key tools:

- The **OCP**, which establishes land use policy and acceptable risk thresholds.
- A new **Floodplain Bylaw** that defines floodplain areas, minimum setbacks, and Flood Construction Levels while making careful allowance for exemptions and variance requests.
- A new **Development Permit Area** for flood and debris flow hazards, where development will be managed to protect corridors that can convey floodwater safely through the community.
- A new annex specific to flood response planning in the **CEMP**.

Integrating flood risk management measures into a broader suite of policy updates allowed additional time for the District to "shadow test" and refine the policies by considering how they would affect incoming development proposals.

CONFRONTING FLOOD RISK

Like Squamish, many communities face the challenges of climate change, overlapping hazard areas, at-risk historical development, and competing priorities. The Squamish IFHMP offers a unique opportunity to share experience with others who may be contemplating their own flood risk management decisions. Some of Squamish's keys to success were recognized in advance, while others were found along the way:

- **Don't be afraid to ask big questions.** Recognize that resource limitations will constrain your ability to find all the answers. The first step is to figure out what answers you really need to make tough decisions.

> **"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 Squamish IFHMP Stakeholder*

- Recognize that **flood risk cannot be eliminated completely.** To be effective, community-driven decision-making must be based on the best available information to ensure that risks are understood, and that the implications of each decision are carefully considered.
- Take an integrated or systems-based approach that puts the **focus on building sustainable communities**. An integrated approach will often produce different outcomes than a process that focuses solely on flood risk.
- **There is no free lunch.** Managing flood risk, particularly in the face of climate change, means there is no way to avoid tough choices. Failure to act is, in itself, a choice with its own risks and costs.
- **One size will not fit all**, even within a single community. Decisions must suit local hazards, development, priorities, and risk tolerances. Consensus among all stakeholders may not be possible.
- **Education and engagement are essential** for the public as well as decision-makers. The time and effort required to craft a clear narrative and engage the community should not be underestimated.

The Squamish IFHMP tackled difficult problems, difficult discussions, and difficult decisions that at times stretched the capacity of the project team. However, the resulting plan provides a foundation on which Squamish can build and grow for the next decade and beyond. While the IFHMP is complete, the project represents a beginning rather than an end. Discussions must continue about what is, for Squamish, an existential question of how one community can balance nature, growth and flood risk in the face of ongoing climate change.

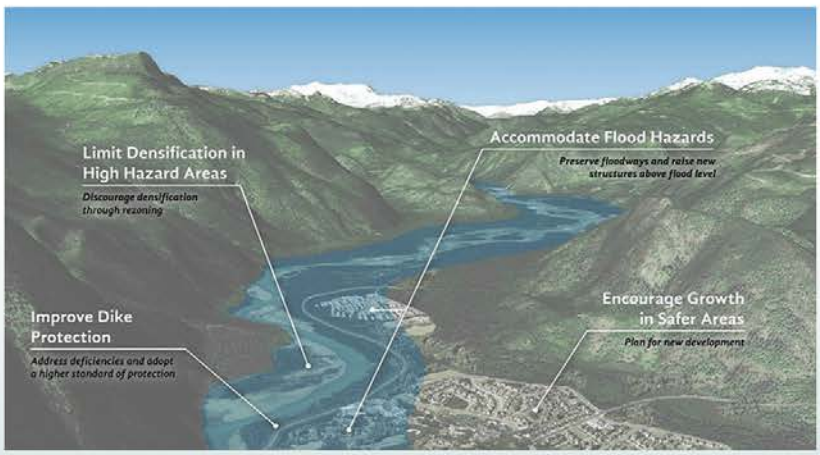

Figure 5

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