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Risk-based land-use guide:
Safe use of land based on hazard risk assessment
Appendices

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Canada

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Appendices

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Publications in this series have not been edited; they are released as submitted by the author.

Contents

Introduction

These appendices accompany the *Risk-based Land-use Guide, Volume 1*. They support and elaborate the guide. Like the guide, they are meant to be supplemented and improved. Improved versions of the guide and appendices are intended to be published at periodic intervals. In addition to this publication, the guide and these appendices are available on line for download and as an editable wiki version.

Appendix A: Background to Development of this Guide

Guide intent

The risk-based land-use guide aims to assist municipal staff to determine whether land-use proposals will be safe for their intended use. It is focussed primarily for land-use planners and development permitting officers. The guide format and content recognizes the integrated contribution of all municipal staff and their councils to land-use decision recommendation and implementation. Stakeholders in the private sector and other levels of government should be able to incorporate the material and principles into their considerations for development and development policy. The guide provides a risk-based building block for land-use recommendation by showing how to:

- integrate hazard risk management into existing land-use management instruments
- assess if the hazard risk of a land-use proposal is acceptable
- consider reducing the risk to tolerable and acceptable levels

The impetus for this guide is the reduction of future losses and disruption from hazardous events. The individuals and agencies who contributed to this guide are motivated by the economic, social, and environmental benefits that can be achieved through increased attention to disaster risk reduction. The guide can be used to decrease potential loss and disruption from hazard events and maximize social, economic and environmental well-being and competitiveness.

This is based on the premises that:

- provincial/territorial legislation requires that local governments take action to prevent, mitigate, or respond to threats to human health and safety, public property, and the environment, within their jurisdictions

- local and regional governments are best positioned to address many of the factors that create high risk, especially through land-use planning and development[1]
- governments urgently need to examine their risk from hazards[2]

The guide aims to address the following objectives and principles:

Objectives

- Decrease requirements for disaster relief, which in turn should reduce insurance claims and premiums, and personal and governmental disaster relief costs.
- Prevent injury and death that can result from land-use decisions that increase risk.
- Increase long term economic, social and environmental sustainability of communities and regions and in turn, their supporting governments and the nation.
- Minimize costs associated with implementing disaster reduction.

Principles

- Show how existing governmental processes and knowledge can be used to effectively make land-use decisions that minimize risk.
- Share practices in risk-based land-use planning and decision-making that can reduce risk. As a living document, it will be updated and improved as we learn more about how to reduce disasters through land-use decisions.
- Reduce disasters by connecting principles and processes of hazard risk management with existing land-use planning practices to reduce risks pro-actively, comprehensively and continuously to acceptable community levels.
- Assist practitioners in incorporating risk reduction principles and approaches into existing practices and policies for land use planning.
- To support planning and decision-making to reduce disaster risk from natural and man-made hazards.
- Where new practices are required, providing a practical, and transferable approach.
- Where possible, make available disaster risk reduction practices and sample documentation from local, national or international sources as example.

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[1] RCC. 2011. Promoting use of disaster risk information in land-use planning. Regional Consultative Committee on Disaster Management, Guideline 3.2, Asian Disaster Preparedness Center, Thailand, 40p. Preventionweb website as Document "24664_24664rccguideline3.2landuseplanning.pdf"

[2] Black, R., Bruce, J., & Egener, I. D. 2010. *Adapting to Climate Change. A Risk Based Guide for Local Governments.* Ottawa, Ontario, Natural Resources Canada.

- Catalogue documents on ongoing basis by practitioners as this guide evolves and improves.
- Personal, public and corporate distribution of responsibility for risk mitigation.
- Intergovernmental coordination and cooperation.

Guide development team

The impetus for the land-use guide arose from a dialogue begun at a September 2009 workshop on risk mitigation systems in western Canada. The attendees were from local, regional, provincial and federal levels of government, academia, geotechnical engineering, and emergency management.

That workshop and follow-up workshops and land-use decision simulation exercises were spearheaded by individuals from agencies and academic institutes in the Metro Vancouver, British Columbia region. They were brought together by the Simon Fraser University Centre for Natural Hazard Research and the Geological Survey of Canada (Natural Resources Canada) based in Vancouver. Key partners in the collaboration included Public Safety Canada, the Justice Institute of British Columbia, Pearces 2 Consulting, Integrated Partnership for Emergency Management for Metro Vancouver, and the District of North Vancouver. In addition to the members of this consortium, the land-use workshops were encouraged by the British Columbia Ministry of the Solicitor General and Public Safety.

Guide's geopolitical focus

The guide was produced in southwestern British Columbia and uses primarily Metro Vancouver situations, practices and expertise. The Metro Vancouver project pilots the production of locally based land-use guides in other parts of Canada. Local guides are thought to best reflect the geology, environment, politics, cultural fabric, and economics that supported urban centres across the country. Therefore, the land-use guide for Metro Vancouver provides a template from which others could build their own land-use guide for disaster risk reduction.

Metro Vancouver's geological and social context is similar to many urban centres in southwest British Columbia, and shares its political context with the rest of the province. Therefore the guide is expected to have application for many British Columbia urban settings.

Development milestones

The draft guide was produced primarily over 4 years from the spring of 2010 to the spring of 2014. It was initiated with a workshop to identify and prioritize hazard risk mitigations for western Canada in the fall of 2009[3]. The initiative itself is based on several avenues of interest in risk reduction through lower risk land-use decisions.[4] Organization of that workshop built on previous research and thinking about increasing investment in hazard risk mitigation. Participants at the 2009 workshop highlighted the correlation between increased disaster losses and increased urban exposure to hazards. Based on recent research and from that correlation, they interpreted that using land in low risk could significantly reduce disaster losses. From that, participants identified a significant gap in support for making land-use decisions that would have a low risk from hazards. From those results, organizers hosted follow-up workshops, discussions, and exercises.

Table A-1: List of risk-based land-use guide milestones

DATE	MILESTONE
2008-12-05	Initiated discussions to host new risk and hazard workshops through the Centre for Natural Hazard Research and Natural Resources Canada Vancouver
2009-02	Began assembling team to develop and host a mitigation focused workshop
2009-05-14	Initiated planning for mitigation workshop
2009-09-28	Held workshop on mitigation of hazard risk: Hazards to Canadian Critical Infrastructure: Reducing the Risk in British Columbia[5]
2009-11-24	Presented workshop results to Canadian Risk and Hazards Network Annual Symposium in Edmonton, Alberta (talk)
2009-11-25	Presented results to Emergency Preparedness Conference, Vancouver, British Columbia (poster)
2009-12-08	Presented workshop results to Fraser Basin Council, Vancouver, British Columbia (talk)
2010-01-13	Initiated planning for workshop on land-use decision support for risk reduction.
2010-03-03	Initiated planning for land-use decision simulation exercise
2010-03-03	Asked a municipal representative for use of an scenario from their municipality for a land-use decision simulation exercise, and initiated assembly of team to develop the land-use decision simulation exercise
2010-03-24	Initiated invitations and advertisement for the workshop and simulation exercise
2010-06-01	Initiated development of the land-use decision simulation exercise
2010-08-31	Completed logistical arrangements for the workshop and exercise
2010-09-03	Completed development of land-use decision simulation exercise

[3] Struik, B., Pearce, L. and Journeay, M. 2010. Risk-based Land-use Decision Support: A guide for decision makers. Canadian Risk and Hazards Network Symposium, Frederiction, New Brunswick, October 2010. CRHNet website as Document "1.7_1.8_struik.pdf"
[4] Struik, B. 2005. Supporting Risk Reduction Land-use Decisions. in Reducing Risk through Partnerships: Proceedings of the 1st CRHNet Symposium, D. Etkin (compiler), Canadian Risk and Hazards Network Symposium, Winnipeg, Manitoba, November 17-19, 2004, p. 24, p. 33.
[5] SFU Centre for Natural Hazard Research website. 2015. Workshops.

DATE	MILESTONE
2010-09-13	Conducted land-use decision simulation exercise; “District of North Vancouver firehall re-development in debris-flood hazard zone”
2010-09-14	Began synthesis of land-use decision simulation exercise learning and preparation of presentation to the workshop
2010-09-17	Conducted land-use workshop; “Land-use decision support: Reducing risk from hazards”
2010-10-08	Debrief of the simulation exercise and workshop. Established compilation process and milestones, and venues of presentation of results
2010-10-29	Presented results and 2-hour workshop of the land-use decision support workshop and land-use decision simulation exercise, Canadian Risk and Hazards Network Annual Symposium, Fredericton, New Brunswick (talk, poster and workshop)
2010-11-24	Presented results and 2-hour workshop of the land-use decision support workshop and land-use decision simulation exercise, Emergency Preparedness Annual Conference, Vancouver, British Columbia (workshop), Fredericton, New Brunswick
2010-12-09	Initiated planning for three events in 2011: 1) Technical review of the land-use guide, 2) land-use decision simulation exercise and 3) land-guide workshop as examination of 2-5 municipal case studies
2010-12-09	Initiated discussions on how to build awareness of the guide at a political level, in particular the Union of British Columbia Municipalities
2010-12-09	Initiated development of a land-use guide explanatory flyer. After a year of agonizing over this, it was left incomplete
2010-12-09	Initiated inquires about likelihood of developing a certified college and university level course on risk-based land-use management
2010-12-09	Developed plan for compilation of workshop and research material and writing of the guide
2011-03-01	Initiated inquiry into certification of the land-use decision simulation exercise for professional educational credits
2011-03-01	Initiated discussions with Royal Roads University to have segment on risk-based land-use management in their Masters of Arts in Disaster and Emergency Management program
2011-03-01	Initiated application to Social Sciences and Humanities Research Council for Funding of workshop
2011-03-01	Initiated development of a video advertisement of the land-use decision simulation exercise as support to municipalities considering contribution of a risk-based land-use decision scenario for a new decision simulation exercise
2011-04-04	Asked the Resilient Cities Working Group of the Canadian National Platform for Disaster Risk Reduction to adopt the risk-based land-use guide initiative as part of its program and that was accepted
2011-04-04	Initiated planning to conduct the District of North Vancouver firehall re-development exercise at Royal Roads University, May 5, 2011
2011-05-05	Conducted one day land-use decision simulation exercise at Royal Roads University using District of North Vancouver firehall scenario
2011-05-13	First meeting of the land-use decision simulation planning committee for 2011
2011-07-13	Rejection of Social Science and Humanities Research Council application for workshop support
2011-09-28	Team re-scoped and changed timelines for initiatives: 1) writing guide, 2) technical meeting, 3) land-use decision simulation, 4) workshop (Dec. 8, 2011 date kept)

DATE	MILESTONE
2011-11-01	District of Squamish decides to provide a risk-based land-use decision scenario for a spring 2012 decision simulation exercise for their staff: scenario 1
2011-11-10	Conducted one day land-use decision simulation exercise at Royal Roads University using District of North Vancouver firehall scenario
2011-12-08	Conduct workshop "Risk-based land-use guide: Reduction risk from natural hazards", Vancouver, British Columbia
2011-12-21	District of Squamish rejects scenario for land-use decision simulation exercise
2012-01-02	Three month term position started at NRCan to collate workshop outputs into the land-guide wiki
2012-02-17	District of Squamish proposed new land-use decision simulation scenario for an exercise in May 2012: scenario 2
2012-03-13	City of New Westminster decides to provide a flood-risk-based land-use decision scenario for a New Westminster staff focused land-use decision simulation exercise
2012-03-13	Partner research project decides to fund the District of Squamish exercise in Squamish to test the JIBC remote simulation exercise technology.
2012-03-30	Term position ends for workshop collation
2012-04-15	Completed summary and outline of guide for use in the simulation exercises at Royal Roads and for City of New Westminster at JIBC
2012-04-26	Conducted one day land-use decision simulation exercise at Royal Roads University using District of North Vancouver firehall scenario
2012-05-09	Development of District of Squamish land-use decision scenario initiated
2012-05-25	Conducted the City of New Westminster flood-risk-based land-use decision simulation exercise at JIBC Simulation lab
2012-08-03	District of Squamish agrees to use a different scenario for an exercise at end of September: scenario 3
2012-08-12	District of Squamish agrees to use a different scenario for an exercise at end of September: scenario 4
2012-08-14	Scripts roughed out for the Squamish exercise
2012-09-14	Date of Squamish exercise moved to November 28, 2012
2012-11-09	District of Squamish shelves commitment to a land-use decision scenario and participating in an exercise
2012-11-15	Conducted one day land-use decision simulation exercise at Royal Roads University using District of North Vancouver firehall scenario
2013-03-22	Contract let to write land-use guide based on existing amassed content and versions
2013-05-02	Conducted one day land-use decision simulation exercise at Royal Roads University using District of North Vancouver firehall scenario
2013-06-27	End of contract to write new version of guide
2013-11-07	Presented on the use of risk-based land-use decision simulation exercises to the Annual Canadian Risk and Hazards Network Symposium, Regina, Saskatchewan
2013-11-07	Conducted mini-workshop at the Annual Canadian Risk and Hazards Network Symposium, Regina, Saskatchewan, on the land-use guide's content, usability and applicability
2013-11-08	Presented update on the land-use guide to the Annual Canadian Risk and Hazards Network Symposium, Regina, Saskatchewan
2013-11-11	Conducted two day land-use decision simulation exercise at Royal Roads University using District of North Vancouver firehall scenario

DATE	MILESTONE
2013-11-14	Began re-write of the land-use guide based on feedback from various sources and particularly at Annual Canadian Risk and Hazards Network Symposium, Regina, Saskatchewan
2014-03-30	Submitted land-use guide for publication through Natural Resources Canada
2014-05-05	Conducted two day land-use decision simulation exercise at Royal Roads University using District of North Vancouver firehall scenario
2014-09-09	Reviewer submitted their evaluation of, and suggested changes to the land-use guide
2014-10-23	Presented update on land-use guide and the new land-use risk management scheme at the Annual Canadian Risk and Hazards Network Symposium in Toronto, Ontario
2014-10-31	Completed re-write of the guide following reviewer suggestions, and based on Struik's revamped risk management scheme
2014-11-04	Conducted two day land-use decision simulation exercise at Royal Roads University using District of North Vancouver firehall scenario, using newly revised land-use guide

Method of development

The guide was developed through three workshops, three mini-workshops, two professional simulation exercises, eight student simulation exercises, and research. Results of progress on the guide were reported annually at the fall Canadian Risk and Hazards Network Symposium and to various stakeholder organizations. It was written through communal authorship and review by experts. These contributors produced the guide for the use of their constituency, based on their knowledge and practices. It is a living document, whereby experts from local, regional, provincial, and national levels of government, academia and the private sector contribute to its ongoing development and improvement.

The three workshops, held in Vancouver, British Columbia, brought together local practitioners of municipal land-use recommendation, permitting, and management. They were joined by stakeholders in land-use from risk management, emergency response, academia, non-municipal government and the private sector. The workshops identified existing practices and needs in municipal land-use management with respect to reducing hazard risk. They recommended how the guide should be structured and the primary knowledge that should be made accessible. Material from these workshops, gathered as posters and page notes, was distilled and compiled to derive the framework and primary content for the guide.

The three mini workshops were hosted across Canada at three conferences in the field of risk management. At these two-hour sessions the guide concept and development status were summarized, and poster outputs from the Vancouver workshops were presented to the participants for review and analysis. The participants were able to add their contributions directly to those from the workshops. Material from the mini workshops was compiled, analysed and incorporated into the guide content.

The professional land-use decision simulation exercises were conducted using the Dr. Donald Rix Public Safety Simulation laboratory at the Justice Institute of British Columbia, New Westminster, British Columbia[6]. Each exercise was developed from an actual land-use decision situation in Metro Vancouver. They were designed for municipal professionals and those who serve them (e.g. geotechnical and engineering consultants). The exercises were intended to identify best practices and gaps in municipal land-use risk reduction. Those observations guided choices of what content would be included in the guide. A substantive reward from the exercises was the group learning in risk management and municipal practice. The two scenarios used for the exercises were a re-development permit for a fire-hall in a debris-flood hazard zone, and a re-development permit for a community centre in a river-flood hazard zone. The debris flood scenario exercise had municipal staff from various municipalities, and the river flood scenario exercise had municipal staff from one municipality.

Eight student land-use decision simulation exercises were conducted at Royal Roads University within their Masters of Arts in Disaster and Emergency Management program. These were conducted twice a year from May 2011 to November 2014. Students were exposed to risk-based land-use practice and did the "fire-hall in a debris-flood hazard zone" decision simulation exercise. They used currently available land-use guide material to guide their exercise analysis and decisions. Their critique of available material was incorporated into improving the guide and supporting material.

What is the risk-based land-use guide?

The guide consists of a primary working volume and this collection of appendices to the guide. The appendices provide background information to the guide concepts and its production. The guide primarily provides information about how to understand, evaluate and monitor hazard risk in a municipality. It provides principles deemed important for deciding how to maintain acceptable levels of hazard risk for use of municipal land.

The guide does not prescribe how to mitigate risk. It does not provide a comprehensive suite of land-use risk mitigation options. Many ways exist to mitigate each of the hazard, exposure to the hazard, and vulnerability to the hazard. The guide provides some references to mitigation options, and alludes to certain general mitigation practice and technique. It gives a method to determine if the risk mitigation options chosen will result in acceptable levels of risk.

[6] Struik, L.C., Grieve, B. and Jones, D.J. 2013. A Canadian risk-based land-use guide: Decision simulations. HazNet, Canadian Risk and Hazards Network Newsletter, vol 4, No. 2, Spring, p. 10-16. CRHNet website.

The guide opens with an overview of instruments a community needs to integrate risk management with land use. The following sections of the guide are based on the three roles that local authorities play in land-use planning and decision-making:

1. Legislative powers to make plans (e.g. public policy), that guide future community development.
2. Adjudicative powers to decide individual permits and proposals (e.g. operational strategies).
3. Role of monitoring and evaluation for safety and security.

Appendix B: Legislation and Regulations in British Columbia Pertaining to Hazard Risk Reduction Primarily through Mitigation (circa 2007)

The following excerpts from British Columbia legislation and regulations provide legal context for land-use risk mitigation. They supplement the social, economic and environmental context for the safe use of land. The appendix material is organized by overarching applicability and by hazard applicability.

Disclaimer: *Sections of acts and regulations are described where pertinent to the safe use of land exposed to natural hazards. The list does not claim to be complete. The descriptions of the acts in this document are not legal descriptions and therefore should not be relied on for compliance to the acts. Acts as described have influence on mitigation of hazard risk. Emergency response legislation is not included unless it has reference to mitigation. Acts described may be superseded.*

Overarching legislation and regulations relevant to all-hazard risk reduction

Emergency Program Act, May 2004.

Part 4 — General

Expenditures

Recovery of costs

17 (1) If an emergency or a disaster is threatened or caused in whole or in part by the acts or omissions of a person and expenditures are made by the government or a local authority to prevent, respond to or alleviate the effects of the emergency or disaster, the person must, on the request of the minister or head of a local authority, pay to the Minister of Finance or the local authority the lesser of

(a) the portion of the expenditures that is equal to the portion of the liability for the occurrence of the emergency or disaster that is attributable to the person, and

(b) the amount demanded by the minister or head of a local authority.

(2) Nothing in subsection (1) relieves a person from any other liability.

Exemption from civil liability

18 No person, including, without limitation, the minister, the other members of the Executive Council, the director, a local authority, the head of a local authority, a member of a local authority, a volunteer and any other person appointed, authorized or required to carry out measures relating to emergencies or disasters, is liable for any loss, cost, expense, damage or injury to person or property that results from

(a) the person in good faith doing or omitting to do any act that the person is appointed, authorized or required to do under this Act, unless, in doing or omitting to do the act, the person was grossly negligent, or

(b) any acts done or omitted to be done by one or more of the persons who were, under this Act, appointed, authorized or required by the person to do the acts, unless in appointing, authorizing or requiring those persons to do the acts, the person was not acting in good faith.

Compensation for loss

19 (1) Despite section 18, if as a result of the acquisition or use of a person's land or personal property under section 10 (1) (d) or 13 (1) (b) or (c), the person suffers a loss of or to that property, the government or the local authority that acquired or used or directed or authorized the acquisition or use of the property must compensate the person for the loss in accordance with the regulations.

(2) Despite section 18, if a person suffers any loss of or to any land or personal property as a result of any other action taken under section 7, 8 (1), 10 (1) or 13 (1), the government or the local authority, as the case may be, that took or authorized or directed the taking of the action may compensate the person for the loss in accordance with the regulations.

Emergency Program Management Regulation

[includes amendments up to B.C. Reg. 200/98]

The act establishes the responsibility of each minister for coordination of the government response to specific hazardous events.

Homeowner Protection Act and Insurance Act: Homeowner Protection Act Regulation

[includes amendments up to B.C. Reg. 360/2004]

Section 11.1.h says a warranty can exclude “accidental loss or damage from acts of nature including, but not limited to, fire, explosion, smoke, water escape, glass breakage, windstorm, hail, lightning, falling trees, aircraft, vehicles, flood, earthquake, avalanche, landslide, and changes in the level of the underground water table which are not reasonably foreseeable by the residential builder;”

Motor Vehicle Act Regulations

B.C. Reg. 26/58

Division 37 Safety Code

Part 1 Interpretation

Section 37.11 exempts emergency vehicles and commercial vehicles being used in disaster relief from “hours of service” requirements.

Section 37.22.5 requires a commercial vehicle used for disaster relief to undergo a driver safety check before going to the start site for disaster relief work.

Flood related

Agricultural Land Commission Act

Agricultural Land Reserve Use, Subdivision and Procedure Regulation

[includes amendments up to B.C. Reg. 546/2004, December 31, 2004]

Section 3.1.n permits the use of agricultural land for works to combat flooding. Section 3.4 seems to permit road widening for flood control purposes.

Creston Valley Wildlife Act 1996

Artificial flooding of the land is controlled by permitting by the management authority (section n13.c)

Permit Regulations

[includes amendments up to B.C. Reg. 201/80]

Section 1.h gives the Creston Valley Wildlife management authority permission to grant permits for flooding, or impounding, diverting or distributing water.

Dike Maintenance Act 1996

Section 1: [Dike Maintenance Act, amends section 1]

re-enacts the definition of "inspector" to include acting and deputy inspectors;

re-enacts the definition of "order" to include other actions of the inspector;

re-enacts the definition of "private dike" to remove the requirements that the dike be built with private funds and protect only the property of the person owning the dike.

Section 2: [Dike Maintenance Act, amends section 2 and enacts section 2.1]

replaces a general supervisory power of the inspector with a more specific power to make orders relative to construction and maintenance of dikes;

extends the inspector's authority to include orders to persons on whose land a dike, other than a private dike, is located;

adds new authority for the inspector to require diking authorities to provide reports, to inspect records, and to audit a diking authority's construction and maintenance program;

permits a person or diking authority to do certain things in respect of a dike, including construction of a new dike, either with the approval of the inspector or in accordance with regulatory standards;

requires an inspector who gives an approval to do certain things in respect of a dike to consider any regulatory standards and other factors relevant to the dike;

adds a definition of "registered mail" and deems anything sent by registered mail to be received by the addressee 14 days after its deposit or on the date of actual receipt;

permits the inspector to amend or revoke an order.

Section 2.2.h gives the diking authority inspector the right to do anything for the construction and maintenance of dikes, including orders respecting flood hazard planning.

Section 3: [Dike Maintenance Act, re-enacts section 3 and repeals section 4]

clarifies that the inspector's authority to take remedial action for failure to carry out an order exists if the order was not carried out by the time specified and if the order was not carried out satisfactorily;

adds a power for the inspector to certify the amount of the debt owing to the government and that remedial work was necessary.

Section 4: [Dike Maintenance Act, amends section 5] prohibits an appeal being taken from an order of the inspector that requires a person or diking authority to comply with regulatory standards or from a refusal of the inspector to grant approval to do certain things in respect of a dike that would not otherwise comply with regulatory standards.

Section 5: [Dike Maintenance Act, re-enacts section 6 and enacts sections 6.1 and 6.2]

adds a maximum fine for an offence committed under this Act;

clarifies that employees, officers, directors or agents can be convicted if they authorize, permit or acquiesce in the commission of an offence;

adds a limitation date for charging someone with an offence under this Act and adds a power for the inspector to certify the date on which the limitation period begins;

clarifies that an action taken in respect of an offence under this Act does not relieve a person or diking authority from any other liability;

adds sections which permit the court to make orders in respect of an offence committed under this Act beyond those orders usually permitted under the Offence Act.

Section 6: [Dike Maintenance Act, repeals section 7] is consequential to the enactment of section 2.1 of the Act by this Bill.

*Section 6.1.*b makes it an offence to hinder a diking authority from protecting a property from flooding. For example: if farm land is periodically flooded to maintain its fertility then a diking authority could prevent that.

Section 7: [Dike Maintenance Act, amends section 8] adds authority to make regulations that establish standards of construction, operation and maintenance in relation to dikes, to prescribe trusts to which a payment may be made under section 6.1 of the Act, and to make different regulations for different classes of dikes, persons, or diking authorities.

"8 …

(2) Without limiting subsection (1), the Lieutenant Governor in Council may make regulations as follows:

…

(b) prescribing trust funds to which a payment under section 6.1 (1) (e) may be made, if those trust funds include as a purpose or objective

(i) the promotion of proper dike construction, maintenance or operation,

(ii) the protection or restoration of the environment from or as a result of flooding,

(iii) the protection of persons or property from flooding, or …

Drainage, Ditch and Dike Act

Section 8: [Drainage, Ditch and Dike Act, amends section 166] permits the minister to transfer a commission's powers from the inspector to a local government if the Lieutenant Governor in Council has first ordered a transfer of those powers from a commission to the inspector.

Section 9: [Drainage, Ditch and Dike Act, amends section 167] is consequential to the amendment to section 166 of the Act by this Bill.

Section 10: [Drainage, Ditch and Dike Act, amends section 168] is consequential to the amendment to section 166 of the Act by this Bill.

Section 11: [Drainage, Ditch and Dike Act, amends section 169] is consequential to the amendment to section 166 of the Act by this Bill.

Section 12: [Drainage, Ditch and Dike Act, amends section 170 (2)] removes an inconsistent authorization to distribute assets and liabilities of a dissolved development district.

Section 13: [Drainage, Ditch and Dike Act, enacts section 170.1] expands the power of the minister responsible for the administration of the Local Government Act to distribute the assets and liabilities of a dissolved development district to a regional district.

Section 14: [Drainage, Ditch and Dike Act, amends section 171] is consequential to the enactment of section 170.1 of the Act by this Bill.

Section 15: [Drainage, Ditch and Dike Act, enacts sections 172 and 173] makes the same powers available to regional districts as are available to municipalities under section 171 of the Act and sets a date for repealing the Act, but permits the date to be extended by regulation.

Emergency Program Act

Compensation and Disaster Financial Assistance Regulation, 2005

"No assistance for structures in flood plain area

15 If an area is designated under the Municipal Act as flood plain and a structure is built or installed in that area after the area has been so designated, no assistance will be provided to repair, rebuild or replace the structure if it is damaged in a flood unless the structure was determined by the Minister of Environment, Lands and Parks or by Canada Mortgage and Housing Corporation to have been properly flood protected."

“"eligible public works" includes streets, roads, bridges, dams, breakwaters, wharves, dikes, levees, drainage facilities, flood control and irrigation systems and publicly owned sewer and water utilities;”

"eligible costs" does not include costs or expenses

(a) recoverable at law, or for which insurance was reasonably and readily available,

(b) of a class or kind for which provision is made in whole or in part under any other program offered by local, provincial, federal or international governments or agencies,

(c) to repair damage caused to a structure or facilities by a hazard if assistance had previously been provided to prevent damage from that or a similar type of hazard and that assistance was not used for that preventive work as required

The Regulation defines the criteria for compensation and for non-compensation. If a disaster damaged structure is on land deemed to be too dangerous for future use then the damaged structure will be moved and repaired to code; except that the owner must buy another piece of land to put the structure on (section 12.2 and 12.4).

Maximum compensation for eligible costs is $300,000 and coverage is 80% of a claim over $1,000 (Section 13).

Section 16 says that compensation may be reduced if the claimant did not act to reduce damage, before, during or after the natural event.

Flood Relief Act, 1996

Section 1 permits the Lieutenant Governor in Council to “(c) enter into agreements with Canada for payment of a portion of the cost incurred by British Columbia, by municipal authorities in the Fraser Valley and by departments and agencies of Canada in repairing, strengthening, constructing and reconstructing dikes in the valley on the basis that Canada bears 75% of the cost.”

Section 2 says a BC municipality can make and administer flood relief agreements with the BC Lieutenant Governor in Council.

Section 7.2.d permits the Lieutenant Governor in Council to prescribe “the extent and nature of work to be undertaken for the building of works for the prevention of flood damage.”

Environmental Management Act 2003

Code of Practice for the Discharge of Produced Water from Coalbed Gas Operations.

The Act defines "proper ecological function", in relation to a seasonal or perennial stream, means the maintenance of adequate vegetation, landforms or large woody debris in or around the stream that are able to dissipate the energy of high water flows, thereby reducing erosion, maintaining good water quality, improving flood-water retention and groundwater recharge and providing habitats that support greater biodiversity;", which is an example of a land-use guide best practise statement.

Environmental Management Act: OPEN BURNING SMOKE CONTROL REGULATION

[includes amendments up to B.C. Reg. 321/2004]

“"maximum reservoir elevation" means the full supply or normal water level plus the design flood surcharge as approved in a water licence issued under the authority of the Water Act;”

Environmental Management Act 2003 Chapter 53

Part 1 – Introductory Provisions

Section 5.f defines one of several powers and function of the Minister as:

“preparing and publishing environmental management plans for specific areas of British Columbia which may include, but need not be limited to, measures with respect to the following:

(i) flood control, flood hazard management and development of land that is subject to flooding;

(ii) drainage;

(iii) soil conservation; …”…

Part 7 — Powers in Relation to Managing the Environment

Division 1 — Assessment, Prevention and Abatement

Section 87 establishes the constraints for the declaration and operation of an environmental emergency, and they include, specifically, floods, landslides and toxic spills or leaks.

…

Part 10 – General

Offences and Penalties

Section 138.3.e grants the Lieutenant Governor in Council the right to make regulations for:

“regulating and imposing requirements and prohibitions respecting flood hazard management, including without limitation, requiring a diking authority as defined in the Dike Maintenance Act, or a local authority as defined in the Community Charter to develop plans or programs in accordance with those regulations or requirements for the purposes of

(i) preventing, mitigating or reducing potential flood hazards,

(ii) protecting the environment and the public from damage caused by flood waters or potential flooding, and

(iii) restoring or enhancing the environment or public safety after a flood or a series of floods.”

Section 4 grants the minister the ability to make regulations as follows:

“…

(b) if land is or would likely be subject to flooding, requiring

(i) a person having an interest in the land or improvements on the land, or

(ii) a person responsible for the development, sale, or other disposition of the land or improvements on the land to disclose the information prescribed by the minister to potential transferees of the land or an interest in the land or the improvements in respect of

(iii) whether the land, any part of the land or any improvements on the land are or may be susceptible to damage by flood waters, and

(iv) steps that have been taken to mitigate that susceptibility;”

Fish Protection Act 2005: Riparian Areas Regulation

The Act’s Regulation intends to restrict development in riparian areas including those within flood plains.

Forest and Ranges Practices Act 2004: Forest Planning and Practices Regulation 2005

Section 47 establishes the characteristics of various stream riparian classes (zones or areas) much as I had envisioned for the classification of hazard zoning areas for a land-use guide. In this case it is for defining the different forest management requirements of the various riparian classes for the maintaining the ecology of forest zones. Section 48 does a similar thing for wetland riparian areas, and section 49 for lake riparian areas. Section 50 prescribes the restrictions for forest practices within those riparian classes.

"*47 (1)* In this section, "active flood plain" means the level area with alluvial soils, adjacent to streams, that is flooded by stream water on a periodic basis and is at the same elevation as areas showing evidence of

(a) flood channels free of terrestrial vegetation,

(b) rafted debris or fluvial sediments, recently deposited on the surface of the forest floor or suspended on trees or vegetation, or

(c) recent scarring of trees by material moved by flood waters.

(2) A stream that is a fish stream or is located in a community watershed has the following riparian class:

(a) S1A, if the stream averages, over a one km length, either a stream width or an active flood plain width of 100 m or greater;

(b) S1B, if the stream width is greater than 20 m but the stream does not have a riparian class of S1A;

(c) S2, if the stream width is not less than 5 m but not more than 20 m;

(d) S3, if the stream width is not less than 1.5 m but is less than 5 m;

(e) S4, if the stream width is less than 1.5 m.

(3) A stream that is not a fish stream and is located outside of a community watershed has the following riparian class:

(a) S5, if the stream width is greater than 3 m;

(b) S6, if the stream width is 3 m or less.

(4) Subject to subsections (5) and (6), for each riparian class of stream, the minimum riparian management area width, and riparian reserve zone width and riparian management zone width, on each side of the stream, are as follows:

Riparian Class	Riparian Management Area (metres)	Riparian Reserve Zone (metres)	Riparian Management Zone (metres)
S1-A	100	0	100
S1-B	70	50	20
S2	50	30	20
S3	40	20	20
S4	30	0	30
S5	30	0	30
S6	20	0	20

(5) If the width of the active flood plain of a stream exceeds the specified width for the riparian management zone, the width of the riparian management zone extends to the outer edge of the active flood plain.

(6) The minister may specify a riparian reserve zone for a stream with a riparian class of S1-A if the minister considers that a riparian reserve zone is required.

(7) The riparian reserve zone for a stream begins at the edge of the stream channel bank and extends to the width described in subsection (4) or (6).

(8) The riparian management zone for a stream begins at

(a) the outer edge of the riparian reserve zone, or

(b) if there is no riparian reserve zone, the edge of the stream channel bank,

and extends to the width described in subsection (4) or (5)."

Homeowner Protection Act and Insurance Act: Building Envelope Renovation Regulation

[includes amendments up to B.C. Reg. 360/2004]

Establishes that unintended water penetration of a home cannot be due to flooding, and that a home warranty can exclude damage caused by catastrophic natural events and unexpected changes in groundwater level.

Land Title Act 1996, Chapter 250

Defines the "right to flood" means a right or power to flood or otherwise injuriously affect land for purposes related to the construction, maintenance or operation of a dam, reservoir or other plant used or to be used for or in connection with the generation, manufacture, distribution or supply of power;

Part 7 — Descriptions and Plans

Division 1 — General

…

Section 16: [Land Title Act, repeals section 82] repeals the authority to designate a flood plain, and to set conditions and to require registration of restrictive covenants for development on land that may be subject to flooding.

Section 17: [Land Title Act, amends section 86 (1)] provides authority for approving officers to require an engineering report in respect of, and to require registration of restrictive covenants for, development on land that may be subject to flooding.

Section 18: [Land Title Act, adds section 219 (9.1) and (9.2)] authorizes the approving officer to modify or discharge a restrictive covenant that was required under section 82 of the Act before the repeal of that section by this Bill.

…

Matters to be considered by approving officer on application for approval

86 (1) Without limiting section 85 (3), in considering an application for subdivision approval, the approving officer may

…

(b) hear from all persons who, in the approving officer's opinion, are affected by the subdivision,

(c) refuse to approve the subdivision plan, if the approving officer considers that

…

(iii) the highways shown in the plan are not cleared, drained, constructed and surfaced to the approving officer's satisfaction, or unless, in circumstances the approving officer considers proper, security is provided in an amount and in a form acceptable to the approving officer,

…

(iv) the land has inadequate drainage installations,

(v) the land is subject, or could reasonably be expected to be subject, to flooding, erosion, land slip or avalanche,

…(d) if the approving officer considers that the land is, or could reasonably be expected to be, subject to flooding, erosion, land slip or avalanche, the approving officer may require, as a condition of consent to an application for subdivision approval, that the subdivider do either or both of the following:

(i) provide the approving officer with a report certified by a professional engineer or geoscientist experienced in geotechnical engineering that the land may be used safely for the use intended;

(ii) enter into one or more covenants under section 219 in respect of any of the parcels that are being created by the subdivision.

…

Local Government Act

[RSBC 1996] Chapter 323

Amendments:

Section 19: [Local Government Act, re-enacts section 910] removes the authority of the minister to designate flood plains and to set construction requirements for development on a designated flood plain, but requires local government bylaws in respect of these things to have regard for ministry policies and standards.

Section 20: [Local Government Act, amends section 966 (6)] is consequential to the re-enactment section 910 of the Act by this Bill.

Part 26 — Planning and Land Use Management

Division 6 — Board of Variance

Section 901 (3) “The board of variance must not make an order under subsection (2) that would do any of the following:

…

(c) deal with a flood plain specification under section 910 (2);"

…

Section 910 specifies the requirements for construction in relation to flood plains. These provisions are specified in the Environmental Management Act and its regulations. The local government can designate an area a flood plain and set the flood levels and setbacks from water bodies and water courses. The local government must comply with Provincial regulations and plans that the local government has created.

"(1.1) If a local government considers that flooding may occur on land, the local government may, by bylaw, designate the land as a flood plain.

(2) If land is designated as a flood plain under subsection (1.1), the local government may, by bylaw, specify

> (a) the flood level for the flood plain, and
>
> (b) the setback from a watercourse, body of water or dike of any landfill or structural support required to elevate a floor system or pad above the flood level.

(3) A local government, in making bylaws under this section, must

> (a) consider the Provincial guidelines, and
>
> (b) comply with the Provincial regulations and a plan or program the local government has developed under those regulations.

(3.1) A bylaw under subsection (2) may make different provisions in relation to one or more of the following:

> (a) different areas of a flood plain;
>
> (b) different zones;
>
> (c) different uses within a zone or an area of a flood plain;
>
> (d) different types of geological or hydrological features;
>
> (e) different standards of works and services;
>
> (f) different siting circumstances;

(g) different types of buildings or other structures and different types of machinery, equipment or goods within them;

(h) different uses within a building or other structure.

(4) If a bylaw under subsection (2) applies,

(a) the underside of any floor system, or the top of any pad supporting any space or room, including a manufactured home, that is used for

(i) dwelling purposes,

(ii) business, or

(iii) the storage of goods which are susceptible to damage by floodwater

must be above the applicable flood level specified by the bylaw, and

(b) any landfill required to support a floor system or pad must not extend within any applicable setback specified by the bylaw.

(5) Subject to the Provincial regulations and a plan or program a local government has developed under those regulations, the local government may exempt a person from the application of subsection (4), or a bylaw under subsection (2), in relation to a specific parcel of land or a use, building or other structure on the parcel of land, if the local government considers it advisable and

(a) considers that the exemption is consistent with the Provincial guidelines, or

(b) has received a report that the land may be used safely for the use intended, which report is certified by a person who is

(i) a professional engineer or geoscientist and experienced in geotechnical engineering, or

(ii) a person in a class prescribed by the minister under subsection (7).

(6) The granting of an exemption, and the exemption, under subsection (5) may be made subject to the terms and conditions the local government considers necessary or advisable, including, without limitation,

(a) imposing any term or condition contemplated by the Provincial guidelines in relation to an exemption,

(b) requiring that a person submit a report described in subsection (5) (b), and

(c) requiring that a person enter into a covenant under section 219 of the Land Title Act.

(7) The minister may make regulations prescribing a class of persons the minister considers qualified, for the purposes of this section, to certify reports referred to in subsection (5) (b)."

It would seem from sections 910.5 through 910.7 that a local government could decide to permit development of a floodplain. It is not clear that the qualified persons or the local government would be liable if the structures were damaged by flooding

Division 9 – Permits and Fees

Section 920.6 refuses a development permit the ability to vary a flood plain specification as set under section 910.

Section 920.7.1 states:

"For land designated under section 919.1 (1) (b), a development permit may do one or more of the following:

(a) specify areas of land that may be subject to flooding, mud flows, torrents of debris, erosion, land slip, rock falls, subsidence, tsunami, avalanche or wildfire, or to another hazard if this other hazard is specified under section 919.1 (1) (b), as areas that must remain free of development, except in accordance with any conditions contained in the permit;

(b) require, in an area that the permit designates as containing unstable soil or water which is subject to degradation, that no septic tank, drainage and deposit fields or irrigation or water systems be constructed;

(c) in relation to wildfire hazard, include requirements respecting the character of the development, including landscaping, and the siting, form, exterior design and finish of buildings and other structures;

(d) in relation to wildfire hazard, establish restrictions on the type and placement of trees and other vegetation in proximity to the development."

Under the heading "Development variance permits", section 922.1 gives a local government authorization to issue a permit that varies from a by-law made under the rules of the Local Government Act; varying:

“(a) section 694 (1) (j) [construction and layout of trailer courts, etc.];

(b) Division 7 [Zoning and Other Development Regulation], 8 [Use of Land for Agricultural Operations] or 11 [Subdivision and Development Requirements] of this Part;

(c) section 8 (3) (g) [fundamental powers – protection of persons and property] of the Community Charter in relation to matters referred to in section 63 (e) [protection – trailer courts, manufactured home parks and camping grounds] of that Act.”

Essentially the local government could ignore all the rules for the protection of persons and properties from flooding and other catastrophic natural events. In particular trailer courts remain the most vulnerable, perpetuating their preferred use of flood plains. A corollary is that the provisions maintain an increased hazard exposure of the economically poor.

Section 922.2 does not permit a development variance permit to vary from:

“(a) the use or density of land from that specified in the bylaw, or

(b) a flood plain specification under section 910 (2).”

Section 922.3 grants the development variance permit trump over a by-law, further eroding the potential for reduced risk from natural hazards.

Sections 922.4 through 922.8 require the local government to notify the affected lands owners, tenants and neighbours (within a distance specified under the by-law being varied), and to do so directly i.e. without delegating that role to another group or person.

Section 923 permits a local government the control, through by-law, of tree cutting in areas deemed to be susceptible to natural hazards, specifically: “flooding, erosion, land slip or avalanche”.

Local Government Act Regulations

COLUMBIA-SHUSWAP REGIONAL DISTRICT REGULATION [includes amendments up to B.C. Reg. 295/2003]

Section 4 of the Columbia-Shuswap regional district regulation says, “The Columbia-Shuswap Regional District is granted the additional power to provide flood protection, including without limitation the powers of a district municipality under sections 552 and 599 of the Municipal Act 1,2 , as a local service.”

REGIONAL DISTRICT OF CENTRAL KOOTENAY REGULATION [includes amendments up to B.C. Reg. 314/97]

"Flood control

3 The Regional District of Central Kootenay is granted the additional power to acquire, install and maintain drain culverts to provide water diversion systems or other flooding controls including dyking within the regional district, as local services and also the power to contribute financial aid to organizations responsible for the control of flooding, as local services. "

REGIONAL DISTRICT OF EAST KOOTENAY REGULATION [includes amendments up to B.C. Reg. 430/98]

"Maintenance of flood and debris torrent control

3 The Regional District of East Kootenay is granted the additional power to provide maintenance of flood and debris torrent control, including without limitation the powers of a district municipality under sections 552 and 553 of the Municipal Act1, as a local service.

[en. B.C. Reg. 553/95.]"

[RSBC 1996] CHAPTER 323

Tax Rate Limits Regulation

The Peace River – Liard Regional District has "landslip and flood control" measures listed as having a specified maximum tax rate. It is the only one of the 28 districts to have such a government activity.

…

Local Services Act

Community Planning Area No. 28

Dease Lake Land Use Regulation, 1991

[includes amendments up to B.C. Reg. 555/2004, December 31, 2004]

"Floodplain" definition is the "land lower than the applicable flood level or land within a floodplain setback;"

…

"Floodplain designation

9 Designated floodplains are

(a) lands lower than the flood levels specified in section 10 (1), and

(b) lands within a floodplain setback specified in section 10 (3).

Flood levels and floodplain setbacks

10 (1) The following elevations are flood levels:

(a) 755.1 metres Geodetic Survey of Canada datum for lands adjacent to Dease Lake;

(b) 3 metres above the natural boundary of Hotel Creek;

(c) 3 metres above the natural boundary of the Tanzilla River;

(d) 1.5 metres above the natural boundary of Allan Lake and Allan B Lake;

(e) 1.5 metres above the natural boundary of any other body of water or watercourse.

(2) If 2 or more flood levels apply under subsection (1), the higher shall be the flood level.

(3) The floodplain setback of any landfill or structural support required to elevate a floor system or mobile home pad above the flood level is as follows:

(a) 60 metres from the natural boundary of the Tanzilla River;

(b) 30 metres from the natural boundary of Hotel Creek;

(c) 15 metres from the natural boundary of Dease Lake;

(d) 7.5 metres from the natural boundary of Allan Lake and Allan B Lake;

(e) 15 metres from the natural boundary of any other body of water or watercourse.

(4) If 2 or more setbacks apply under subsection (3), there shall be compliance with both or all setbacks."

Local Services Act Regulations

[RSBC 1996] CHAPTER 276

Community Planning Area NO. 28: Dease Lake Land Use Regulation, 1991

[includes amendments up to B.C. Reg. 555/2004, December 31, 2004]

Under the heading “floodplain designation”, section 9 defines a floodplain as being lands below 755.1 m adjacent to Dease Lake and at various setbacks from local creeks, rivers and lakes.

Subdivision Regulations

[includes amendments up to B.C. Reg. 555/2004, December 31, 2004]

Section 4.04 designates conditions for which a subdivision may not be approved. Those conditions include:

“(a) contains

(i) land which is subject to erosion, or

(ii) a parcel which is divided by land subject to erosion into areas not suited to the use to which it is intended,

(b) contains land which

(i) may slip when developed, used or occupied,

(ii) when developed, used or occupied may cause land on an adjacent parcel to slip, or

(iii) may be inundated by a land slip if land above on another parcel slips,

(c) contains land which is subject to flooding so as to render it unsuitable for the use to which it is intended, or

(d) contains land which because of inadequate drainage is not suitable for the use to which it is intended.”

A covenant may be created under section 219 of the Land Title Act which qualifies uses for lands that may be subject to the conditions of section 4.04 (section 4.05). The covenant “shall restrict or prohibit the construction of buildings or structures on, and (or) the use of any parcel or part of such parcel which is subject to any of the conditions described in section 4.04”

Section 4.06 grants a subdivision approving officer the right to request technical information about the land from the land owner. That information includes:

“(a) topographic survey where the terrain is steep, irregular or otherwise difficult to appraise in respect of the subdivision suiting the configuration of the land being subdivided;

(b) spot elevations;

(c) a professional engineer's report on

(i) the effect on soil stability of disturbing natural grades or natural growth, or changing the moisture content of the soil by developing, using or occupying the land;

(ii) groundwater levels and conditions for as much of the year as are considered necessary;

(iii) the depth and extent of flooding and the likely frequency of its occurring.

The section does not provide the approving officer with guidance as to how to determine whether such technical information is necessary. As such the jurisdictions who have professional geological engineers would have the best chance of providing useful evaluation of the natural hazards affecting any land being proposed for a subdivision.

Section .7 specifies the road culvert flood maximum designs for urban and potential urban areas (30 year) and all other areas (10 year).

Municipalities Enabling and Validating Act (No. 3)

[SBC 2001] CHAPTER 44

"Validation of flood plain bylaws

15 (1) A bylaw adopted by a local government under section 910 of the Local Government Act before the date the Miscellaneous Statutes Amendment Act (No. 2), 2004 receives Royal Assent, and actions taken under the bylaw, are confirmed and validated, and the bylaw is conclusively deemed to have been continuously in force from the date of its adoption until the date it is or was repealed by the local government to the extent that it would have been validly adopted under section 910 of the Local Government Act as amended by section 26 of the Miscellaneous Statutes Amendment Act (No. 2), 2004.

(2) An authorization or other permission that was given in relation to a development

(a) by a local government before the date the Miscellaneous Statutes Amendment Act (No. 2), 2004 receives Royal Assent, and

(b) in reliance on an exemption of a type of development, given by the minister under section 910 (6) of the Local Government Act before its repeal by section 19 of the Flood Hazard Statutes Amendment Act, 2003, S.B.C. 2003, c. 72, is confirmed and validated to the extent that it could be validly given by the local government by or in reliance on a bylaw or exemption under section 910 of the Local Government Act as amended by section 26 of the Miscellaneous Statutes Amendment Act (No. 2), 2004, and an action taken under such an authorization or other permission, is confirmed and validated and conclusively deemed to have been validly taken.

(3) This section is retroactive to the extent necessary to give full force and effect to its provisions and must not be construed as lacking retroactive effect in relation to any matter because it makes no specific reference to that matter."

The Flood Hazard Statues Amendment Act, October 31, 2007 is Bill 56. It was introduced to modify various acts that had reference to flood control and flood risk reduction. Those acts include:

Dike Maintenance Act

Drainage, Ditch and Dike Act

Land Title Act

Local Government Act

Ombudsman Act

"Explanatory Notes [for the changes of Bill 56, the Flood Hazard Statutes Amendment Act 2003]

Ombudspersons Act 1996 (name amended 2009)

"35 The Lieutenant Governor in Council may, by order, add authorities to the Schedule.

Schedule

Authorities

…

16 The commissioners of a district defined in section 58 of the Drainage, Ditch and Dike Act and an engineer, commissioner, inspector of dikes, land settlement board, municipality or regional district acting under that Act.

17 The British Columbia Diking Authority and a diking authority under the Dike Maintenance Act.

…"

Public Works Agreement Act [RSBC 1996] CHAPTER 391

The Public Works Agreement Act authorizes a minister of the BC government to carry out agreements with other levels of government to make agreements on various works including flood control.

Vancouver Charter 1953

Part IX - Buildings

"By-laws respecting building regulation

[Section] 306. (1) The Council may make by-laws

…Undue cost of services may prevent certain uses

(u) for prohibiting the construction of any building for residential, commercial, or industrial purposes on land where by reason of its low-lying, marshy, or unstable character the cost of installing water, sewage, or drainage facilities is in the opinion of the Council unduly great;

…

Withholding of permit

(cc) for withholding a building permit in respect of any parcel of land situate in a designated flood plain area until the City Building Inspector is satisfied that the elevation or design will reduce or eliminate the risk of flood damage and for requiring a covenant registered against the land acknowledging the risk of flood damage."

Wildlife Management Areas Regulations No. 9

This regulation defines the Columbia Wetlands Wildlife Management Area as the area within the 200 year flood level of the Columbia River.

Avalanche, Earthquake, Erosion, Mass Movements, Pestilence, Tsunami, Weather, Wildfire

Insurance Act – Insurance Classes Regulation 2007

This regulation defines the types of insurance, including those for natural calamities.

“"crop insurance" means insurance against loss of, or damage to, crops on the field caused by drought, flood, hail, wind, frost, lightning, excessive rain, snow, hurricane, tornado, wildlife, fire, insect infestation, plant disease or other peril;

…

"earthquake insurance" means insurance against loss of or damage to property caused by an earthquake;

…

"hail insurance" means insurance against loss of or damage to crops on the field caused by hail;

…

"weather insurance" means insurance against loss or damage caused by rain, tempest, flood or other climatic condition, but does not include hail insurance or windstorm insurance;

"windstorm insurance" means insurance against loss of or damage to property caused by windstorm, cyclone or tornado.

Local Government Act

[RSBC 1996] CHAPTER 323

Division 9 – Permits and Fees

Section 920.7.1 states:

“For land designated under section 919.1 (1) (b), a development permit may do one or more of the following:

(a) specify areas of land that may be subject to flooding, mud flows, torrents of debris, erosion, land slip, rock falls, subsidence, tsunami, avalanche or wildfire, or to another hazard if this other hazard is specified under section 919.1 (1) (b), as areas that must remain free of development, except in accordance with any conditions contained in the permit;

(b) require, in an area that the permit designates as containing unstable soil or water which is subject to degradation, that no septic tank, drainage and deposit fields or irrigation or water systems be constructed;

(c) in relation to wildfire hazard, include requirements respecting the character of the development, including landscaping, and the siting, form, exterior design and finish of buildings and other structures;

(d) in relation to wildfire hazard, establish restrictions on the type and placement of trees and other vegetation in proximity to the development."

Appendix C: Governance Context in South-western British Columbia

International policy and protocols

The Hyogo Framework for Action 2005-2015

As signatory to the Hyogo Framework, Canada embarked on formal initiative a National Platform for Disaster Risk Reduction. Through the National Platform it has engaged in the Building the Resilience of Nations Communities to Disasters, and the Making Cities Resilient campaigns.

Canadian National Platform for Disaster Risk Reduction

The Platform is intended to be a pan-societal collaboration, one that will ultimately be led by non-government actors. The Platform is initially co-Chaired by Public Safety Canada and a representative of Senior Officials Responsible for Emergency Management (SOREM). It has an Advisory Committee of nine members, five of which are permanent and the rest are elected on a rotating basis.

The Platform[7] is composed of working groups that conduct projects to analyse and recommend disaster risk reduction policy. Present working groups consist of:

- Private Sector Partnership
- Resilient Communities
- Science and Technology
- Voluntary Sector

Making Cities Resilient Campaign

The United Nations International Strategy for Disaster Reduction (UNISDR) hosts the Making Resilient Cities campaign. Their Making Resilient Cities toolkit provides a helpful 10 point "essentials" checklist[8].

Some of the key points from the 10 essentials when it comes to land use management are:

- Maintain up-to-date data on hazards and vulnerabilities, **prepare risk assessments** and use these as the basis for urban development plans and decisions. Ensure this information and plans are available to the public and fully discussed with them.

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[7] Public Safety Canada website. 2015. Keywords; Canadian Platform for Disaster Risk Reduction.
[8] UNISDR website. 2015. Keywords; Resilient Cities Campaign, Resilient Cities Campaign Kit.

- Apply and enforce **realistic, risk-compliant building regulations and land use planning principles**. Identify **safe land for low-income citizens** and develop upgrading of informal settlements.

- **Protect ecosystems and natural buffers** to mitigate floods, storm surges and other hazards to which your city may be vulnerable.

The District of North Vancouver received the UN ***Sasakawa Award*** in 2011 for their efforts to proactively address priorities for risk reduction identified in the Hyogo Framework. They are the first community in the region to adopt community-based risk tolerance criteria.

The ***International Panel on Climate Change (IPCC)*** report, ***Managing the Risk of Extreme Events and Disasters to Advance Climate Change***[9] assesses experience with a wide range of options used by institutions, organizations, and communities to reduce exposure and vulnerability, and improve resilience, to climate extremes.

It highlights how measures to reduce current and future risk have additional benefits: improving livelihoods, conserving biodiversity and improving well-being. Further it highlights low-regrets measures for hazard risk reduction: warning systems, land use planning and sustainable land management, building code innovation and enforcement, education and awareness.

These are important points for framing a convincing business case for risk reduction.

Federal

National Disaster Mitigation Strategy

The Strategy was developed collaboratively by the federal, provincial and territorial governments. It sets out a comprehensive, multi-dimensional approach that anticipates joint contributions, community-based partnerships, and national-level initiatives. It recognizes that mitigation is an important part of a robust emergency management framework.

The Strategy sets out a common vision for disaster mitigation activities in Canada. It provides a template to promote mitigation and integrate it into Canada's evolving emergency management framework. In 2014, the federal government approved a national disaster mitigation program. At writing of this guide, the operation of that program is in

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[9] IPCC website. 2015. *Managing the Risk of Extreme Events and Disasters to Advance Climate Change*.

development. It is meant to support national and provincial mitigation programs primarily in the field of flood disaster reduction[10].

NRCan Regional Adaptation Collaboratives (RACs):

Intergovernmental and intersectoral work on climate change adaptation, includes a series of risk management tools[11].

Provincial

In British Columbia, initiatives for disaster risk reduction through land-use management are distributed through various ministries. They are generally targeted at existing risk mitigation operations such as dikes and a provincial emergency management program. See Appendix B for a summary of provincial legislation that contains elements of some land-use risk management law. Primary responsibility for land-use risk management is delegated to the regional and municipal governments through the various regional and municipal acts.

Regional

Regional governments in British Columbia are given authority to make land-use plans through Part 25 of the Local Government Act, Section 850 (1): "A board may adopt a regional growth strategy for the purpose of guiding decisions on growth, change and development within its regional district".

Once adopted, it has legal effect and member municipal governments are submit to context statements describing how their official community plans will "be made consistent with the regional growth strategy over time" (section 866(2b) Local Government Act 1996). If viewed as a process of collaboration, context statements can be seen as bringing up for discussion potential disagreements between municipalities and the region with regards to land-use management.

Metro Vancouver has instituted a new Regional Growth Strategy in 2011.[12]

It includes Strategy 3.4: "Encourage land use and transportation infrastructure that improve the ability to withstand climate change impacts and natural hazard risks."

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[10] Public Safety Canada website. 2015. NDMS, National Disaster Mitigation Strategy.
[11] Natural Resources Canada website. 2015. Climate-change, Community-adaptation.
[12] Metro Vancouver. 2011. *Regional growth strategy, Bylaw No. 1136, 2010: Metro Vancouver 2014, Shaping our future*. Metro Vancouver, British Columbia, 80p.

As clarification to this strategic statement: Climate change, in itself, is not manifest as a new hazard. The changing climate is changing the frequency and intensity of existing natural hazards that are controlled or triggered by the climate and weather.

To progress on this objective, it is a critical first step that the Regional Growth Strategy be informed by a hazard risk assessment. Risk management strategies can then be employed via evidence-based policy in an iterative fashion.

Land-use guide workshop participants suggested that risk assessments could be conducted at the watershed level. Regional government could coordinate so that risks can be assessed from this perspective (e.g. eco-system based management). This approach may work best for hydrologically related hazards (e.g. flooding, landslide, debris flow, etc.) but caution should be exercised to employ a multi-hazard risk management approach that collectively considers, at minimum, the hazards listed in the Regional Growth Strategy: earthquake, flooding, erosion, subsidence, mudslides and interface fire (Although it is not clear how these were derived as hazards of concern for the region).

Municipal

The Local Government Act requires that hazardous conditions be acknowledged in the Official Community Plan (OCP) with statements and maps, but it does not create a duty to seek out hazard information. The plan may link to other instruments that manage hazard risk such as Development Permit Areas for Hazards.

A study conducted to assess how municipal governments in the Metro region were addressing natural hazard risk in their Official Community Plans found that these plans were not addressing this topic in a comprehensive fashion[13,14]. This is an area where immediate improvements could be made to ensure communities remain adaptive in a changing climate and lessen multi-hazard risk. The research protocol used to evaluate the plans is available as part of Shoubridge's thesis[8]. Its emphasis was on natural hazard mitigation as a result of the provincial and territorial stated priority to address these risks first (as expressed in the National Disaster Mitigation Strategy).

The American Planning Association outlines the importance of integrating hazard risk management into strategic community planning in their professional guidance document[15]

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[13] Shoubridge, J. 2012. Are We Planning a Disaster Resilient Region? An Evaluation of Official Community Plans in Metro Vancouver. University of British Columbia, MA Thesis, 53p. Available online at UBC SCARP website as document "SCARP_2012_gradproject_Shoubridge.pdf"

[14] Stevens, M.R. 2013. Evaluating the Quality of Official Community Plans in Southern British Columbia. Journal of Planning Education and Research, vol. 33, no. 4, p471-490 .

[15] Schwabb, J.C., 2010. Hazard Mitigation: Integrating Best Practices into Planning. American Planning Association, Planning Advisory Service, Report Number 560, 145p.

A free podcast describes the production of local hazard mitigation.[16]

[16] APA. 2015. Podcast : Local Hazard Mitigation. American Planning Association website, Hazards.

Appendix D: Land-use risk management project work plan

A sample project and work plan outline for establishing the community's risk management structure.

Project summary

The Project will enhance the practical integration of Hazard Risk Management into on-going community land-use management. In doing so, it will establish the baseline hazard risk faced by the community. From that risk baseline it will develop a risk management strategy. An operational plan will be developed based on that strategy. That operational plan will use existing land-use management instruments and may require the development of others. The project will:

1. Identify the level of risk that community members and structures face from various hazards of threat.
2. Establish what the community considers priorities for protection.
3. Establish the level of risk that is acceptable for protecting those priorities.
4. Develop a method to ensure the priorities are protected into the future.

The project is multi-year, incremental, and develops a core risk management program that will be revisited through the risk management program itself.

Anticipated outcomes

The project will, over time, reduce the hazard risk faced by those community assets and people deemed to be the community's highest priority for keeping safer.

Anticipated outputs

For the community as a whole the project will create a:

- Hazard inventory
- Inventory of hazards of most concern to community and for management
- Assessments for hazards of concern
- Hazard scenarios that can be used for assessing the risk
- Risk assessment for each hazard of concern
- Risk Tolerance Criteria for community priorities
- Risk monitoring and evaluation process
- Risk management tools within land-use instruments and in particular the:

- Strategic Growth Strategy
    - Official Community Plan
    - Development Permit Areas for Hazards
    - Development Permit Applications
    - Geographic Information management databases
    - Public and internal communication and dialogue
    - Emergency Management Plan
    - Transportation Plan
    - Capital Plan
- Risk Management Evaluation and Renewal Plan
- A method for reviewing and mitigating the risk of strategic plans and development proposals based on the risk management plan imbedded in the community's land-use instruments

Work plan

Proponents	Tasks	Resource requirements	Due dates
	Establish scope of communication requirements and protocols for knowledge input, work and outputs		
	Bring together working team and advisory bodies		
	Establish community safety priorities and anticipated community outcomes		
	Acquire needed information and resources		
	Define community risk tolerance for each hazard of concern (tolerance for various disaster losses)		
	Reporting		
Hazard Inventory			
	Identify hazards of concern		
	Priority list of hazard concerns for management		
Assessments for hazards of concern			
	Assess the potential that events from such hazards will occur		
Hazard scenarios that can be used for assessing the risk			
	Create hazard scenarios		
Identify What Could be Harmed			
	Identify people and things exposed to the hazard and that could be harmed		
	Determine how vulnerable those people and things are to harm in a hazard event		
Calculate Potential Losses (risk assessment) for each hazard of concern			

Proponents	Tasks	Resource requirements	Due dates
	Determine the consequences that will result for people, assets and environment exposed to potential events		
Safe land-use recommendations			
	Evaluate if potential losses are acceptable to the community (risk-tolerance criteria)		
	If necessary, determine how to reduce potential losses to acceptable levels		
	Make development recommendation that has acceptable risk		
Risk monitoring and evaluation process			
	Establish risk inspection routine and anticipated outputs		
	Establish scheme to use inspection information to maintain acceptable risk as identified in the community's risk tolerance criteria		
	Establish scheme to incorporate better ways to manage risk into your land-use risk management		
Risk-management tools within land-use instruments			
	Strategic Growth Strategy		
	Official Community Plan		
	Development Permit Areas for Hazards		
	Development Permit Applications		
	Geographic Information management databases		
	Public and internal communication and dialogue		
	Emergency Management Plan		
	Transportation Plan		
	Capital Plan		
Risk Management Evaluation and Renewal Plan			
	Establish cycle for improvement of the risk management plan (e.g. coincide with the OCP cycle)		

Develop criteria for inclusion of stakeholders.

Develop a communication strategy.

Team

The team includes:

1. Staff that are responsible and have expertise in each land-use instrument the community uses. Below the Guide identifies the key instruments.
2. Staff who would conduct a community risk assessment; included are those responsible for managing hazards, asset and demographic information specialists, and those who would manage and do the risk assessment.
3. Community and agency stakeholders who can help identify the priority community assets and define the criteria for how much risk would be tolerated for each of those priorities.

Appendix E: Consultation and Communication

When conducting risk assessments, it is important to involve a variety of stakeholders and clarify a uniting cause at the outset. Framing of common objectives is typically described as 'reducing impacts in terms of deaths, dollars, and downtime'. Taking the time to consult and engage those affected provides a good return on investment.
To engage stakeholders and decision makers, the following have been suggested as informed practice:

- Proactive public consultations, using multiple methods/tools
- Presentations to council on the concept of risk management
- Education for staff regarding purpose, content and application of risk assessment results
- Training to understand professional reports and understand implications of their assessments
- Use of "new media" to get information out and response back
- Website to disseminate information
- GIS mapping of hazard zones, community assets and people (their exposure to a hazard)

Informed practice also suggests that the following actors be engaged, early and often:

- Planners
- Emergency managers
- Municipal and regional engineers (transportation, public works, asset managers)
- Elected officials
- CAO's
- Transportation planners
- GIS technicians and managers
- Environmental professionals (e.g. hydrologists, arborists, water managers)
- Parks and recreation professionals
- Community land-owners and residents
- Developers and business leaders

The goal is to generate buy-in from a variety of actors at the outset, who will assist in implementing risk reduction strategies. This also helps to discover areas of synthesis and co-benefit across departments and levels of governments.

A beneficial practice is to designate and staff a role for a community hazard risk manager. Such a dedicated and coordinating role establishes a focus on proactive disaster risk reduction through land-use and structural mitigation. The role is distinct from that of an emergency manager, who's focus is preparation for effective response to a disaster. The District of North Vancouver, British Columbia staffed a Public Safety Manager and their position could be reviewed as an example of a community hazard risk management. This role includes leading their natural hazards management program[17].

The Natural Resources Canada Quantitative Risk Assessment team (2003 – 2015) developed software tools (Hazus and CommunityViz) that can be used to model hazard risk and engage citizens and professional staff in visualizing the impacts of hazard events and planning for mitigation.

Community consultation example

The following is an example of a risk management community consultation process used by the District of Squamish in conjunction with facilitation by Natural Resources Canada (NRCan). The consultation was part of NRCan's 2004-2009 Risk Assessment Methods Project[18]. The consultation gauged perceptions of community hazard risk and determined priorities for community safety. Such perceptions and priorities set the foundation for a subsequent quantitative or qualitative risk assessment, and are part of step one in the land-use risk management scheme. In addition to consultation at this initial stage of the risk management scheme, consultations and communication are recommended with the other stages of the risk management process.

The consultation workbook extract shared here has been edited from its original. Those edits reflect how the terms – risk, hazard, exposure, vulnerability and consequence – are used in the risk-based land-use guide, and remove some situation specific information.

Start of extract from the Squamish Risk Assessment Methods community engagement workbook.

Workshop Series on Reducing Natural Hazard Risk in Squamish

This workshop series is a key research activity in a partnership between Natural Resources Canada and the District of Squamish. Through their Reducing Risk from Natural Hazards Program, Natural Resources Canada is researching a general approach to link natural hazards planning and land use planning. In partnership with the District of Squamish, Natural Resources Canada is testing and validating this approach that includes 1) the identification of elements at risk, 2) identification of strategies for mitigation, and 3) an evaluation of these strategies in terms of both current and future risk.

[17] District of North Vancouver website. 2015. Natural Hazards Management Program.
[18] Journeay, J.M. (2014) *Disaster Resilience by Design: A framework for integrated assessment and risk-based planning in Canada.* Geological Survey of Canada Open File.

We have structured a set of 5 workshops (4 hours each) to review information, identify areas and groups that may be vulnerable during a natural hazard event, select a set of mitigation strategies to evaluate, and review the results. ….

The results from the workshop will provide valuable information for the residents of Squamish, the District of Squamish, and other agencies who work in the Squamish area. The input provided by the working group will help inform the design of the general risk management approach. All meetings will take place in Squamish.

Workshop Objectives

The objective of this workshop series is to develop scenarios that contribute to reducing the risk of natural hazard events. To do this, we will provide an overview of what is currently known (from existing reports) on the potential for hazards (floods, landslides and earthquakes). The working group will identify and discuss elements at risk (structural, social, environmental, and others) and develop priority indicators to be used to evaluate the final scenarios.

The working group includes representatives from District of Squamish, provincial government, first nation's staff, community organizations, and other federal government agencies. Participation from stakeholders who deal with natural hazards, … and risk as part of their professional responsibilities as well as community organizations who have valuable local knowledge to contribute will greatly benefit the research project and may contribute to local planning. For operational reasons the numbers of participants will be limited. The working group will provide the input necessary for the project to evaluate different risk scenarios that could occur within the municipality. The creation of these risk scenarios may provide the District with an opportunity to consider various risk mitigation strategies. The risk scenarios include single or multiple hazard events (hazard potential), a time period that the hazard occurs within, an assessment of potential hazard event damage and harm (consequences), the capacity to respond, and the identification of the elements at risk.

Participants' Role

Participants will be presented with information on flooding, landslides and earthquakes for the Squamish region. Throughout the workshop series, they will be asked to provide input through small group discussion, work with maps, large group discussion on their values and preferences for allocating future residential and commercial growth as risk scenarios that span 5-30 years are developed for consideration by the participants.

Brief Background

This section would describe the impetus, methodology and anticipated outcome of the community hazard risk analysis

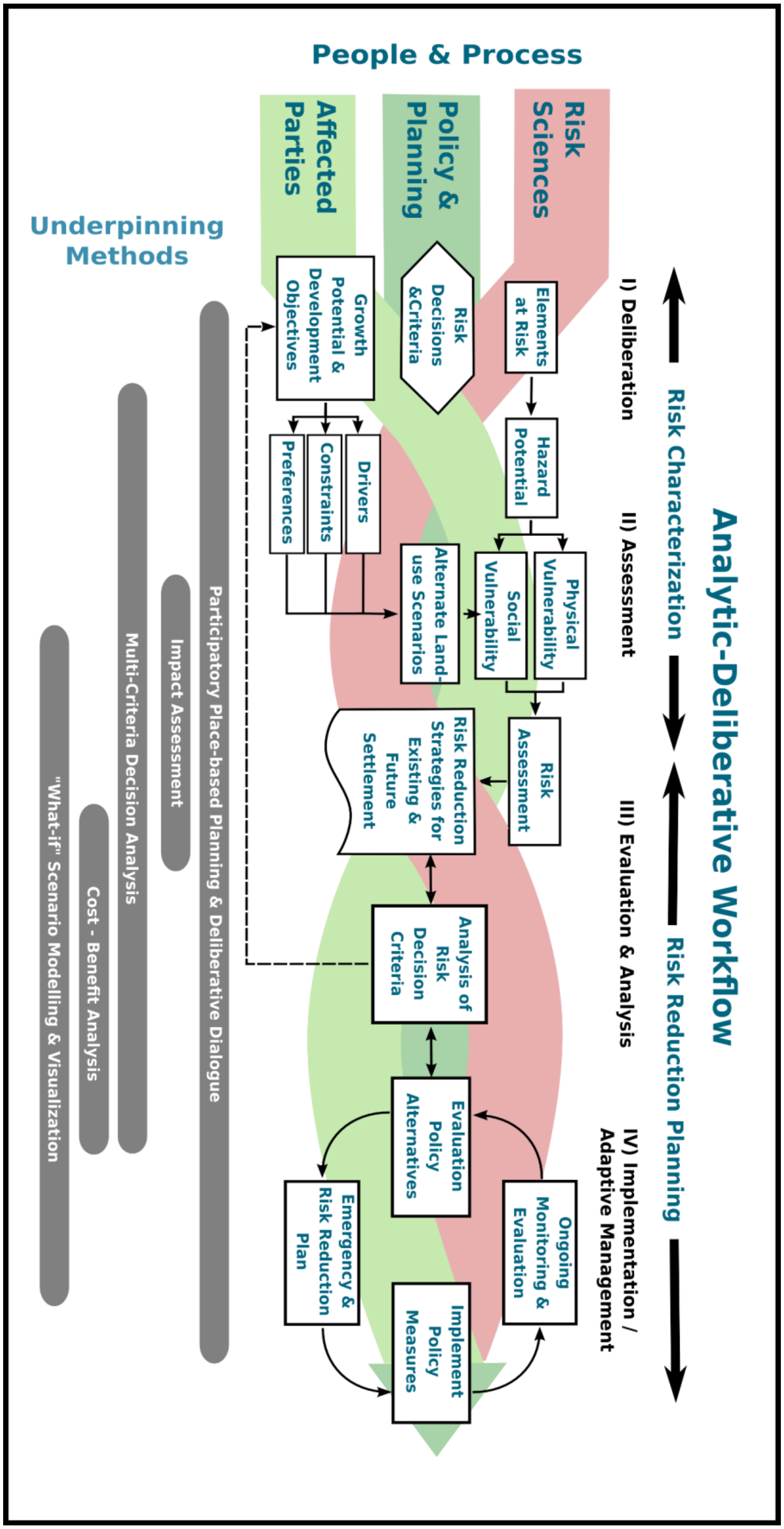
Guide to "Planning Brief"

We have assembled this workbook, called a Planning Brief, to support the participants throughout the workshop process. The Planning Brief will provide each participant with a copy of the worksheets used in the workshops and the subsequent results of the analysis of the information collected. Map information will be provided for use during the workshop and revised versions, based on workshop input may be provided in subsequent workshops. The planning brief will allow participants to have a record of the activities and results in the workshop series which they may use to provide neighbours, friends and colleagues with information on natural hazards, land use planning and risk reduction. The Planning Brief includes:

- Objectives and worksheets for each workshop
- Map folio
- Glossary of terms

Workshop Schedule Summer/Fall 2007

Workshop Title	*Workshop Description*	*Date*	*Location*
Kick-off Meeting	Introduce workshop series & determine project scope (hazards, scale, planning horizon)	…	…
Elements at Risk	Annotate maps and add additional information on , hazard potential using detailed scale maps	…	…
Hazard Impacts and Resiliency	Prioritize elements at risk and identify potential impacts from hazards; Begin to identify potential strategies	…	…
Select Risk Reduction Strategies	Set targets for priority risk elements and discuss strategies to mitigate those risk elements	…	…
Review Risk Reduction Strategies	Present results of land use analysis and potential hazard events with different growth patterns and different mitigation scenarios. Report on targets to reduce risk.	…	…


Analytic-Deliberative Workflow
Risk Characterization
Risk Reduction Planning
I) Deliberation
II) Assessment
III) Evaluation & Analysis
IV) Implementation / Adaptive Management
People & Process
Risk Sciences
Policy & Planning
Affected Parties
Elements at Risk
Hazard Potential
Physical Vulnerability
Social Vulnerability
Risk Assessment
Risk Decisions &Criteria
Alternate Land-use Scenarios
Risk Reduction Strategies for Existing & Future Settlement
Analysis of Risk Decision Criteria
Evaluation Policy Alternatives
Ongoing Monitoring & Evaluation
Implement Policy Measures
Emergency & Risk Reduction Plan
Growth Potential & Development Objectives
Drivers
Constraints
Preferences
Underpinning Methods
Participatory Place-based Planning & Deliberative Dialogue
Impact Assessment
Multi-Criteria Decision Analysis
Cost - Benefit Analysis
"What-if" Scenario Modelling & Visualization

PROCESS & METHODOLOGY for RISK REDUCTION PLANNING

This figure outlines the proposed process and elements that come together to support risk reduction planning. The process has been modified from the National Research Council study "Understanding Risk: Informing Decisions in a Democratic Society" (1996). Each workshop in this series speaks to a set of elements in this flow diagram. Each element in the workflow represents an analytic or deliberative procedure that involves the transformation of information, knowledge and expertise to inform and advance the decision making process. Though represented as a sequential workflow of inputs and outputs, the planning and decision making process is iterative and will evolve in response to ongoing learning, deliberation and feedback.

PROCESS & METHODOLOGY for RISK REDUCTION PLANNING

Risk reduction is a forward looking process of decision analysis that balances trade-offs between public safety and other societal priorities (economy vitality, environment integrity, social fabric and amenities) that influence growth and associated development in hazardous terrains. As such, risk reduction planning needs to be grounded in both competent public discourse and sound science. It is by definition a complex and multi-dimensional process of negotiating choices and consequences against a backdrop of competing interests and scientific uncertainties about the dynamics of human and environmental systems and their vulnerability to natural hazards.

Deliberation is an iterative process of communication that involves the exchange of information and perspectives amongst domain experts, decision makers, and those impacted by the decision making process. It is not based on consensus, but rather on an ongoing and interactive process of learning that leads an increased capacity to make decisions that balance trade-offs between equity, efficiency, and public safety.

The flow diagram from the previous page can be viewed in four stages (although the entire process is iterative):

Stage I of the workflow establishes the overall dimensions of risk for a community or region, and articulates the context and focus for the decision making process. It uses deliberative dialogue as a means to:

- explore and profile known hazards in the region
- document elements that are vulnerable or perceived to be at risk
- delineate the geographic extent and time horizons of interest for the risk assessment process
- determine key risk decisions and performance measures (indicators and targets) that will be used to evaluate risk reduction strategies and policy alternatives

Stage II of the workflow includes the risk analysis component of the workflow involves the assessment of:

- hazard potential (extent, magnitude and likelihood) for single or multiple hazard events
- hazard susceptibility and resilience
- likely consequences and risks (direct and indirect costs) of these hazard events over time horizons that are relevant to the planning process

The land use analysis component of the workflow is driven by anticipated growth potential and strategies (priorities and objectives) defined by the community for managing incremental growth and associated development.

Stage III of the workflow results in scenarios to generate and evaluate strategies for reducing risks associated with existing and/or future settlement patterns through structural mitigation (dams, levees, deflection berms, building codes, etc.), and/or adaptive land use management (zoning, design guidelines, best management practices, etc.). The impacts of proposed risk reduction scenarios are evaluated and compared using performance measures (indicators and targets) identified and agreed upon as part of Stage I.

Stage IV of the workflow represents the implementation phase of the process, where risk reduction strategies are translated into policies to help guide shorter-term emergency preparedness and/or longer-term growth management and development activities.

Dimensions of Risk | List of Worksheets

Worksheet 1: Hazard

1A Hazard type (Priority)

- Rank a list of six natural hazard event scenarios for Squamish based on the level of
concern it causes you.

1B: Hazard type (Frequency & Impact)

- Use reference tables containing descriptions of hazard frequency and hazard impact to record the score that you feel is appropriate for the natural hazard events
listed for Squamish.

Worksheet 2: Damage and Harm

2A Hazard event damage (Community Assets)

- Indicate your level of concern for a list of community assets.

2B: *Hazard event harm (Affected Populations)*

- Indicate your level of concern for a list of types of people (affected populations) affected during and following a natural hazard event.

Worksheet 3: Resilience

…

- Indicate the level of capacity (capability) you feel is currently in place for each resilience support measures in the list.

Worksheet 4: Risk Decisions

- Discuss structural and non-structural mitigation measures to protect key community
  assets, promote public safety and manage risk?

Dimensions of Risk | Worksheets

Worksheet 1A: … HAZARD TYPES

Hazard types

This set of workshops relies on existing publicly available information on floods, landslides and earthquakes for Squamish. Much of this information has been produced by professional engineers and geoscientists under contract from either the province or the District. For the purposes of risk characterization, we are able to evaluate the following hazard event scenarios:

- flooding caused by overtopping of the banks in rivers and creeks (200-year flood event or 220mm precipitation storm flood)
- flooding caused by 20-year river flood or 180mm precipitation storm flood
- ground shaking caused by a shallow crustal earthquake
- ground sharing caused by a deep (benioff zone) earthquake
- debris flow material released from a breached landslide dam on the Cheekye River for two scenarios (provided by Kerr Wood Leidel, 2003):
  - 3 million cubic metres and
  - 7 million cubic metres

A list of natural hazard event scenarios for Squamish is presented below. Please prioritize this list from 1 to 6 where 1 represents the hazard that you are most concerned about and 6 is the hazard that causes you the least concern.

- Floods: Low magnitude
- Floods: High magnitude
- Landslide: large volume of material at Cheekye (7 million m^3)
- Landslide: moderate volume of material at Cheekye (3 million m^3)
- Earthquakes: shallow crustal earthquake
- Earthquakes: subduction zone earthquake

Please use the following space to list other hazards of concern to you that are not presented in the above list: [space removed]

***Worksheet 1B**: Hazard frequency and impact [consequence]*

Exercise to determine, for the three types of hazard events under consideration, the frequency of occurrence and severity of potential impact (consequence). Instructions:

1. Thinking about Squamish, use the Frequency Evaluation Table on the next page to select a score for each hazard. Use the description of occurrence characteristics to help select a score that you feel is most appropriate for each hazard type.
2. Thinking about Squamish, use the Consequence Evaluation Table second table to record the impacts that you think are likely for each of the six natural hazard events listed.

FREQUENCY SCORE

Hazard Event	Frequency Score
Flood: low magnitude	
Flood: high magnitude	
Landslide: moderate volume at Cheekye (3 million m^3)	
Landslide: large volume at Cheekye (7 million m^3)	
Earthquake: shallow crustal earthquake	
Earthquake: deep (Benioff Zone) earthquake	

IMPACT SCORE

Hazard Event	Impact Score
Flood: low magnitude	
Flood: high magnitude	
Landslide: moderate volume at Cheekye (3 million m^3)	
Landslide: large volume at Cheekye (7 million m^3)	
Earthquake: shallow crustal earthquake	
Earthquake: deep (Benioff Zone) earthquake	

Frequency Evaluation Table

Occurrence Characteristics	Score
Occurrence is commonplace in Squamish	10
Occurs at least once per month in Squamish	9
Occurs at least once per year in Squamish	8
Has occurred once in the past decade in Squamish	7
Has occurred at least once in the past in Squamish	6
Occurrence in commonplace in southwestern British Columbia	5
Occurs at least once per year in southwestern British Columbia	4
Has occurred at least once in the past in southwestern British Columbia	3
Has occurred at least once in the past in Canada	2
Has occurred somewhere in the world, has some potential for occurrence	1

Hazard event Consequence Evaluation Table

Impact Characteristics	Score
Results in widespread or large-scale loss of life. Creates financial losses from which the District of Squamish could not recover.	10
Results in the loss of ten or more lives. Loss of large numbers of private homes, public infrastructure. Loss of public confidence in the municipal government. Interruption of normal business across Squamish. Formal declaration of emergency required.	9
Results in the loss of 5-10 lives. Some loss of private property, public infrastructure. Substantial financial loss for the municipal government. Localized interruption of normal business.	8
Results in the loss of less than 5 lives. Loss of private property. Damage to public infrastructure. Financial loss for the municipal government beyond normal response costs.	7
Results in the loss of a single life. Widespread damage to private property. Major interruption of municipal services and utilities. Large numbers of private homes unfit for habitation.	6
Results in widespread major injuries. Large amount of damage to private property in individual neighbourhoods and locales. Localized interruption of municipal services and utilities. Some homes in individual neighbourhoods are unfit for habitation.	5
Results in widespread minor injuries, some major injuries. [A few] private homes in a single neighbourhood are seriously damaged. Interruption of municipal services and/or utilities in a single neighbourhood.	4
Results in widespread minor injuries, no major injuries. Private homes are damaged, but are not unsuitable for habitation.	3
Results in some minor injuries. Isolated damage to property.	2
Results in no injuries. No property damage.	1

Worksheet 2A: Hazard event damage or Consequence (COMMUNITY ASSETS)

Consequence is the probable damage or harm caused by the probable hazard event.

Community Assets

The nature of natural hazards events, such as floods, earthquakes, and landslides is that their consequence will vary spatially depending on the landscape, underlying geology, natural features and the built environment. Use the large map to identify neighbourhoods or specific community assets in and around the District that have been damaged by natural hazard events such as floods or landslides.

For each community asset listed below, indicate your level of concern by circling the appropriate number where 1 = not at all concerned to 5=extremely concerned. Use the blank spaces provided to add to the list of community assets and indicate your level of concern for any of the ones that you have added.

Community asset Concerned	Not at All Concerned			Extremely	
Residential buildings	1	2	3	4	5
Commercial buildings	1	2	3	4	5
Industrial buildings	1	2	3	4	5
Historically significant buildings	1	2	3	4	5
Culturally significant buildings	1	2	3	4	5
Critical facilities	1	2	3	4	5
Critical infrastructure	1	2	3	4	5
Ecosystem features	1	2	3	4	5
Dangerous goods storage facilities	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5

Worksheet 2A: … Hazard event harm or Consequence

Affected Populations

This discussion is centered on identifying who could be most harmed… during and following a natural hazard event. Factors that may influence how much a group could be harmed include: age, health, income, gender, language ability, race, population growth, education, family structure, social networks, among others.

For each affected population listed below, indicate your level concern by circling the appropriate number where 1 = not at all concerned to 5=extremely concerned. Use the blank spaces provided to add to the list of affected populations and indicate your level of concern for any of the ones that you have added.

Affected Populations Not at All Concerned Extremely Concerned					
Elderly	1	2	3	4	5
Young children	1	2	3	4	5
People living with disabilities (physical or mental)	1	2	3	4	5
Economically disadvantaged	1	2	3	4	5
Non-English speakers	1	2	3	4	5
First Nations people	1	2	3	4	5
Seriously ill / on life support	1	2	3	4	5
Large families	1	2	3	4	5
Single parent families	1	2	3	4	5
Homeless	1	2	3	4	5
Tourists	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5
	1	2	3	4	5

Worksheet 3A: *… Resilience*

…

Resilience is the capacity of people, structures and systems to respond to the impacts (consequences) of natural hazard events. Resilience can be achieved through social and economic factors such as government disaster relief funds, mitigation loans, insurance, communication, risk awareness and public participation.

For each measure indicate the level of capacity (capability) you feel is currently in place by circling the appropriate number where 1 = low level of capacity and 5=high level of capacity. Use the blank spaces provided to add to the list of mitigation measures and rank accordingly.

…[Resilience] Capacity	Low-level capacity				High-level capacity
Emergency preparedness	1	2	3	4	5
Emergency response	1	2	3	4	5
Law enforcement	1	2	3	4	5
Wealth	1	2	3	4	5
Materials	1	2	3	4	5
Equipment	1	2	3	4	5
Recovery plans	1	2	3	4	5
Local emergency funds	1	2	3	4	5
Provincial/ Federal relief funds	1	2	3	4	5
Insurance market	1	2	3	4	5
Mitigation / Reconstruction loans	1	2	3	4	5
Public works	1	2	3	4	5
Communication	1	2	3	4	5
Risk awareness	1	2	3	4	5
Public participation	1	2	3	4	5

Worksheet 4: Risk decisions

Issues of Concern

Depending on time frames of interest, risk reduction decisions consider risk mitigation measures. Risk can be reduced by mitigation of either or all of the hazard, exposure to the hazard or vulnerability to the hazard. Each of those mitigations can be structural and non-structural.

Hazard mitigations mostly attempt to reduce the hazard magnitude. For example: structural flood hazard mitigation measures may include the construction of dikes and deflection berms.

Exposure mitigations attempt to keep vulnerable assets and people from the hazard zone. For example: non-structural exposure mitigation measures can keep homes out of flood plains, and provide for the evacuation of people and animals. Structural exposure mitigation measures can raise a home on stilts or berms above the flood plain.

Vulnerability mitigations primarily attempt to strengthen assets and are mostly structural. For example: flood vulnerability can be reduced by making buildings of waterproof material and strong enough to resist water flow velocities.

To consider this question requires an assessment of multiple hazards and their potential impact on future settlement patterns anticipated or planned over a 30 year period. In this way, non-structural or land-use strategies may be applied as a mitigation measure for natural hazard risk. Please discuss any issues or concerns you have with respect to the decisions for each planning horizon. Use the space below to record your comments.

ISSUES OF CONCERN:

What structural mitigation measures are needed to protect key community assets and promote public safety? [answer space removed]

What are the key strategic land-use and community planning measures needed to manage risk associated with increased growth and development? [answer space removed]

See list of potential mitigation measures identified by the consultation.

Risk mitigation decision options

Structural and non-structural mitigation measures gathered from community consultation and that may protect key community assets and promote public safety.

Building codes

- Extra measures taken for public safety buildings
- Locally appropriate and sound construction method, and progressive

building codes (e.g. seismic, flood proofing)
- Structural assessment of buildings for flood safety / earthquake stability
- Take into consideration new development that is raised higher than existing development for water run-off

Communication

- Communication plans
- Communication system that reaches entire community instantly (like an air-raid siren? Helicopter announcements?)
- More communications to the people living here - most are not prepared to care for themselves in the critical period after a disaster

Debris flow

- Berming in anticipation of debris flow torrents
- Explore options of a deflection berm for Cheekye debris torrent
- Limit/ban development in the Cheekye debris flow area
- Preventing development within a debris slide site (Cheekye fan) - until a deflection berm may be constructed.
- Schools, extended care facilities and such should not be built on hazardous lands i.e. Cheekye Fan area

Education

- Education (community/ council: ability to make wise decision)
- Public education of hazard/risk areas
- This requires a "toolbox" that is encouraged and permitted by the regulatory framework, not cumbersome (e.g. framework).

Flood

- Don't let history repeat itself in allowing residential growth on known existing flood plains where they commonly flood
- Flood plain construction decisions - low density
- Maintaining riparian setbacks and preserving all wetlands (i.e. flood storage)
- Raise the land level for new buildings and building heights leaving ground level for parking only
- Improve flood conveyance - adequately sized culverts and bridges
- A resilient stormwater management system to changing climate and various storm events (ditches permeable, retention, rain gardens)
- Repair and maintain existing storm drainage system that is more than 15 years old
- Innovative drainage systems
- Require flood mitigation regulations
- Drainage
- Pumps
- Pump capacity review / upgrades
- Updated/concise mapping of dyke stability
- New and upgraded dikes
- Dike / water ways
- Dyke pumping station
- Berms
- Dike maintenance
- Earthquake-proofing dikes
- Strengthen the entire diking system rather than patch it
- Do not develop on the dikes
- Dredge river beds
- Ensure adequate berming / flood protection measures

Governance

- Provincial / federal cooperation (DFO)

Land-use

- Avoid obvious sites
- Bridges
- Community planning
- Examples: cluster development, generous riparian setback
- Expropriate lands on flood plains
- How to grow: Innovative site development and planning that is locally relevant.
- Land use risk assessment grid developed with timeline probability consideration - long range planning to use in all areas of community development
- Limit development in flood plains
- Making better decisions in use/ development i.e. unsafe areas - low impact or protected.
- Monitoring foreshore development and limiting growth that could be destroyed by a tsunami
- No residential development in areas of high risk that have not been mitigated by structural measures
- OCP to preserve wetlands (i.e. flood storage)
- Provincial mandated strategies for development
- Public awareness and stringent land development restrictions
- Put development where it makes sense
- Rezone the "good' land - don't rezone the danger land.
- Riparian setback and management (SPR/RAR)
- Subdivisions with drainage systems in place
- Where to grow: strong land use and settlement policies that are based on rationale around natural hazard vulnerability as well as other values and trade-offs. The process for developing these tools - community buy-in and political will, will keep them in place.

Public warning

- Early warning system for flooding
- Effective early warning systems
- Public warning system and public awareness
- Radio broadcast warning system

Risk assessment

- Clean water (risk of loss)
- Risk assessment

Response

- Drills - fanout practices; emergency communications scenarios
- Emergency facilities that will survive events and be usable - refuge centres, emergency ops, critical infrastructure (Water, power, communications), access
- Emergency preparedness education
- Expanded emergency program/ local / provincial

Wildfire

- Keep trees back from buildings at least 20' - fire issue
- What are the key strategic land use and community planning measures needed to manage risk associated with increased growth and development?
- Wildfire interface plan

End of extract from the Squamish Risk Assessment Methods community engagement workbook.

Appendix F: Risk Tolerance Criteria

How do you know if the risk is too high and unacceptable, or is low and acceptable, without knowing the amount of risk you will accept?

Risk-tolerance criteria establish the level of risk the community is willing to accept for any particular hazard.

In the current land development system, site-specific risk assessments are done to determine if a development in a known hazard area will be 'safe for use intended'. This requires an objective threshold for what is considered safe. Professionals asked to make this determination are concerned that 'safe' is a subjective measure made on a case by case basis. 'Safe' could be interpreted to mean 'no risk', whereas residual risk is expected.

In very rare cases, risks can be eliminated. Mostly, risks can merely be reduced to as low as reasonably practicable (ALARP). In some cases, the trade-offs are such that a community may tolerate more risk than other communities for economic, aesthetic or other benefits.

The level of risk a community tolerates may differ for each hazard and for each societal element. Communities should determine what levels of risk they are willing to accept, and periodically revisit those levels and the criteria used to set them.

Methods for establishing risk tolerance criteria

Risk tolerance criteria set acceptable levels of risk the community will tolerate for injury and death, damage to infrastructure, social disruption, economic losses, cultural heritage, environmental damage and destruction or loss of any other community priority resulting from development and land-use decisions. Risk tolerance criteria are set by the municipality and are best created through citizen engagement and in conjunction with key stakeholders (e.g. provincial ministry of public safety, neighbouring municipalities, and private sector).

Communities around the world have set risk tolerance criteria for risk to life and these can be looked to for guidance. Recent British Columbian and Canadian examples were provided by Porter[19], Dercole[20] and Porter and Morgenstern[21], for tolerance of loss of life from landslides. Statistical risk of routine activities can be used as guides; for instance the risk of having a bath (1

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[19] Porter, M. 2006. *District of North Vancouver Berkley landslide risk management: Phase 1 Risk assessment.* Internal Report, District of North Vancouver, 56p. Online access, District of North Vancouver.

[20] Dercole, F. 2009. *Natural Hazards Risk Tolerance Criteria*; Report to council, District of North Vancouver, File: 11.5225.00/000.000, November 10, 6p. Online access. Copy available in this appendix.

[21] Porter, M. and Morgenstern, N. 2013. *Landslide risk evaluation: in Canadian technical guidelines and best practices related to landslides: a national initiative for loss reduction*. Geological Survey of Canada, Open File 7312. 21p.

death in 10,000), driving a car (1 death in 10,000), or flying in a commercial airplane (1 death in 100,000). Britt provides a list of such statistics[22].

The public process

- Seek council approval to develop criteria and apply it to land-use decisions.
- Establish the scope, budget and time for the process.
- Scope: Types of hazards covered, types of criteria to be developed (e.g. for death, injury, physical infrastructure, environment), applicability of criteria (e.g. renovation of past developments, rezoning, new development).
- Budget: for facilitator, publishing, staff overtime for evenings, research.
- Create a community task force, including social and technical experts and concerned stakeholders from the community, municipal staff, province (e.g. emergency program), private sector, federal government (e.g. Health Canada, Industry Canada, Canadian Centre for Security Science, Natural Resources Canada), academics and emergency managers.
- Establish working group or groups, depending on how many criteria are to be established (if possible, have a third party facilitator, researcher, and secretary dedicated to each working group).
- Gain input and feedback and have committees write a report and sign off.
- Bring report to a broader community meeting for discussion and information, if supported, then proceed to council for approval.

Risk tolerance can be shown as a probability that acceptable, tolerable or intolerable losses would result from a hazard event. It can also be shown as a graph on a plot of losses (consequences) versus probability (Fig. F-1). For instance, for potential infrastructure losses from flooding, the community may accept annual losses of 0.00005% of its annual community revenue. In the sample tolerance diagram (Fig. F-1), the units of consequence would vary depending on the priority. If the priority was preservation of life then the scale for consequences would be fatalities and the numbers adjusted accordingly. If the priority was residences, then the scale for consequences would be the number of destroyed residences. The community decides which parts of the graph have the probability of losses that is acceptable, tolerable (as low as reasonably practical) or unacceptable. Such a graph is unique to each community priority, and in most cases, is unique to the hazard.

[22] Britt, R.R. 2005. *The Odds Of Dying*. Livescience website.

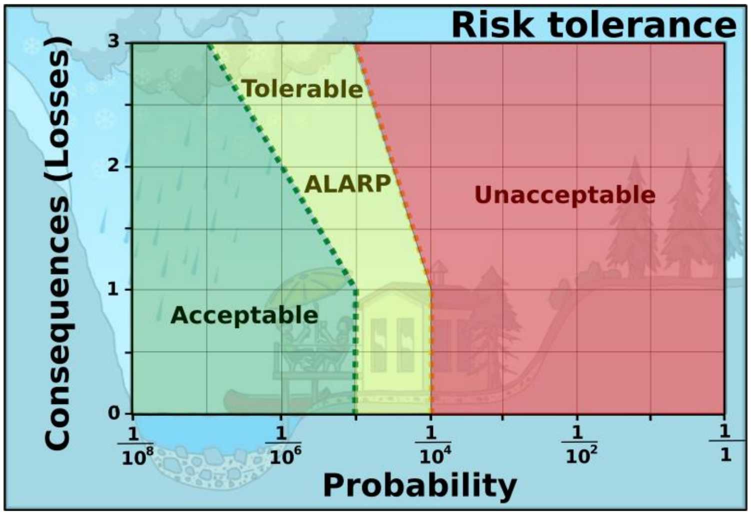

Figure F-1. Example of a graph showing levels of acceptable, tolerable and unacceptable risk. The consequence can be for any type of loss, for example: human lives, structural damage, business disruption, environmental disruption, infrastructure damage. Each of those consequences can be unique to a particular hazard or be multi-hazard.

Distribution of Risk

In this process, council and the community need to decide how to distribute roles and responsibility for risk mitigation. For instance, citizens and industry should handle their private property mitigation and the municipality should handle municipal property mitigation.

Council should decide on liability distribution for past land-use decisions or changes in land-use decisions with regards to hazards risk.

Example of a risk tolerance development process

The District of North Vancouver developed risk tolerance criteria for loss of life from natural hazards, primarily mass movements (landslides and debris flows). Included here is the report to the Council for the District of North Vancouver that proposes, for their consideration and acceptance, that risk tolerance criteria. It refers to the citizen and professional led process in which the criteria were developed and the documentation that described the results of that process.

Following is that report to council[23]

The District of North Vancouver

REPORT TO COUNCIL

[23] Dercole, F. 2009. *Natural Hazards Risk Tolerance Criteria*; Report to council, District of North Vancouver, File: 11.5225.00/000.000, November 10, 6p. Online access.

November 10, 2009
File: 11.5225.00/000.000
Tracking Number: RCA –

AUTHOR: Fiona Dercole, Section Manager Public Safety

SUBJECT: Natural Hazards Risk Tolerance Criteria

RECOMMENDATION:

THAT Council endorse the following as District policy: That applicants for subdivisions, development approvals and building permits may be required to meet the following conditions:

1. *demonstration that natural hazards risks are reduced to As Low as Reasonably Practicable (ALARP); and*
2. *in addition to ALARP, that:*

    A. *the following risk tolerance criteria are satisfied (if a quantitative risk methodology is used):*

      i. *maximum 1:10,000 risk of fatality per year for re-developments involving an increase to gross floor area on the property of less than or equal to 25%;*

      ii. *maximum 1:100,000 risk of fatality per year for new developments and for re-developments involving an increase to gross floor area on the property of greater than 25%.*

    or

    B. *the following Factor-of-Safety (FOS) criteria are satisfied (if factor-of-safety and/or slope displacement methodology is used):*

      i. *for re-developments involving an increase to gross floor area on the property of less than or equal to 25%:*

        a. *under static conditions the slope stability FOS must be greater than 1.3; and*

        b. *under non-static conditions (e.g. for earthquake ground motions) the slope stability FOS must be greater than 1.0 or predicted ground displacement must be less than 0.15 m with a 1:475 annual chance of exceedance;*

      ii. *for new developments and for re-developments involving an increase to gross floor area on the property of greater than 25%:*

a. *under static conditions the slope stability FOS must be greater than 1.5; and*

iii. *under non-static conditions (e.g. for earthquake ground motions) the slope stability FOS must be greater than 1.0 or predicted ground displacement must be less than 0.15 m with a 1:2,475 annual chance of exceedance;*

3. *the assessment methodology should be determined by a Qualified Professional in accordance with the Guidelines for Legislated Landslide Assessment for Proposed Residential Developments in BC published by the Association of Professional Engineers and Geoscientists of BC and dated March 2006, Revised May 2008.*

REASON FOR REPORT:

The purpose of a District policy on risk tolerance criteria is to set the maximum levels of tolerable risks to life for both existing and new developments within our community. On April 14, 2008, Council instructed staff to develop a plan to apply natural hazard risk tolerance criteria within a clearly understood public policy framework and Natural Hazard Management Plan; using the criteria of 1:10,000 risk of fatality per year for existing developments and 1:100,000 risk of fatality per year for new developments (attachment 1).

SUMMARY:

The proposed risk tolerance criteria is based on research, public input, dialogue with subject-matter experts, learning from experiences of other jurisdictions with similar legal frameworks and natural hazard situations, and the District's own experience applying interim risk tolerance criteria. The criteria are expressed both quantitatively and as the minimum factor-of- safety of a slope. Hazard and risk can be assessed using a variety of methodologies; the method of assessment is determined by the Qualified Professional and the decision is based on which approach is most appropriate for the site conditions. In addition to meeting the risk tolerance criteria, risks should be further reduced to as low as reasonably practicable (ALARP), meaning that that the cost involved in reducing the risk further would be grossly disproportionate to the benefit gained.

BACKGROUND:

Risk tolerance criteria have been utilized by the District, on an interim basis, to manage landslide risk since early 2005. In February 2007, Council held a workshop to review the natural hazards management program and approved a plan which included, "establish a process to adopt risk tolerance criteria". The Natural Hazards Task Force was assembled in October 2007 "to provide a forum to gather input from an informed, broad-based community perspective regarding quantitative tolerable risk or risk acceptance criteria for landslides and other natural hazards". The task force presented their recommendations to District Council in April, 2008. Council instructed staff to develop a plan to apply natural hazard risk tolerance criteria within a clearly understood public policy framework and Natural Hazard Management Plan; using the risk tolerance criteria proposed by the task force.

EXISTING POLICY:

Currently there are no District policies specifically regarding risk tolerance for natural hazards. Related policies include:

Development guidelines for subdivision and building plan approval on sloping terrain #8-3320-3.

Section 56, Community Charter, authorizes the Chief Building Official (CBO) to require a hazard report from a suitable Qualified Professional where the CBO considers the land is subject to a particular hazard

Hazard trees are managed according to Tree Work Policy #13-5280-1

BC Building Code sets criteria for building design requirements for seismic hazards.

ANALYSIS:
Risk Tolerance

Differences exist between tolerable risks and acceptable risks. Tolerable risks can be tolerated in order to realize some benefit, are not negligible, and should be kept under review and reduced further if possible. Acceptable risks are considered broadly acceptable to the public and efforts to further reduce risks are not warranted. The ALARP principle applies to risks within the tolerable range. Under the common-law system, risk reduction should be achieved if reasonable opportunities exist. For a risk to be ALARP it must be possible to demonstrate that the cost involved in reducing the risk further would be grossly disproportionate to the benefit gained.

The Association of Professional Engineers and Geoscientists of BC (APEGBC) Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in British Columbia (2008, p.4) state that "It is not the role of a Professional Engineer or Professional Geoscientist to define levels of safety; they must be established and adopted by the local government or provincial government after considering a range of social values."

The District follows the Canadian Standards Association CAN/CSA Q850-97 Risk Management: Guidelines for Decision-makers. The Risk Evaluation phase of the CSA Guidelines steer the decision-maker to "compare estimated risk against stakeholder acceptance criteria". In the absence of a formal policy on risk tolerance criteria, the District has been utilizing risk tolerance criteria developed by other jurisdictions such as Hong Kong, Australia and the United Kingdom. These criteria and risk management frameworks are similar to the District's proposed risk tolerance criteria.

Risk tolerance is rooted in community values and risk perception. The District's Natural Hazards Task Force was initiated in 2007 to engage the community regarding natural hazards and risk tolerance. Risk communication is a critical component of the risk management process; it is essential that the District continues dialogue about risk tolerance and risk reduction with stakeholders – including the public, property owners, scientific *community, developers and educators. While the District now has four years of experience in applying risk tolerance criteria (on an interim basis), it is expected that risk tolerance criteria will need to be reviewed from time to time to reflect changes in community planning best practices, advances in engineering and technology, socioeconomics, and community perceptions of risk.*

Hazard and Risk Assessment

Areas of potential landslide hazard can be assessed using a risk-based approach or by means of a factor-of-safety approach. The APEGBC Guidelines (2008, p. 22) state that "the decision whether to carry out and report the results of a landslide analysis quantitatively or qualitatively also depends on how the adopted level of landslide safety is expressed, and/or the requirements of the Approving Authority."

A qualitative hazard assessment or partial risk analysis should be performed by a Qualified Professional as an initial step in estimating whether a landslide hazard may be present for areas identified on the slope hazard map. If these preliminary analyses demonstrate that risks to life are likely broadly acceptable, then further risk assessment may not be required. Where a qualitative hazard assessment and/or partial risk analysis demonstrates that risks to life are likely tolerable or possibly unacceptable, the District requires that a more detailed risk assessment be performed. Where a detailed landslide risk assessment is required by the District, the Qualified Professional shall determine which approach is most appropriate for the local site conditions, based on the nature of the potential landslide hazard and its location relative to the area of existing development, re-development, or proposed new development. It is recognized that landslide hazard and risk assessment is not an exact science and that some factors in the risk estimation process are subjective by nature.

Risk Management

Existing and ongoing quantitative risk analyses study risk to loss of life from landslide and debris flow hazards in the District. Other hazards, such as wildfire and flooding, tend to occur in such a manner and timeframe that those at risk may be able to evacuate as a risk-reduction measure. Therefore, the resulting risk life may be estimated to be relatively low. Placing a higher value on life safety is consistent with the British Columbia Emergency Response Management System (BCERMS) goals. However, risks to the environment, critical infrastructure and public health from these hazards may be higher when compared to landslide or debris flow risks. These factors should be considered as part of a broader decision-making framework and will also be addressed through the Hazard Development Permit Areas that are currently being development with the District Planning department.

Risk tolerance criteria should not supersede industry best practices and should be considered an addition to existing requirements for issuing building and development permits. Likely the most practical method to implement a policy on risk tolerance criteria is through the District's Official Community Plan via Development Permit Area guidelines. Risk tolerance criteria can also be applied during the building permit and sub-division application process by using up-to-date hazard maps to identify landslide and debris flow hazard areas and steer qualified professionals towards the APEGBC guidelines. The Qualified Professional should present risk *reduction options along with the associated approximate costs and benefits of each mitigation option, demonstrating the ALARP principle.*

Society is generally less accepting of risks today as in the past. The proposed risk tolerance criteria takes this into consideration by proposing two-tiered criteria, with more stringent criteria for new development. Figure 1 below illustrates the application of the proposed policy on risk tolerance criteria.

Figure 1:

Type of Application	*1:10:000 +ALARP*	*1:100,000*	*FOS>1.3 (static)*	*FOS>1.5 (static)*
Building Permit (<25% increase to gross floor area)	*X*		*X*	
Building Permit (<25% increase to gross floor area and/or retaining walls >1.2m)		*X*		*X*
Re-zoning		*X*		*X*
Sub-division		*X*		*X*
New Development		*X*		*X*

Concurrence:

Planning, Permits and Bylaws and the North Shore Emergency Management Office concur with the recommendations in this report. The Municipal Solicitor has reviewed this report and provided comments in the Liability/Risk section, below.

Financial Impacts:

The proposed risk tolerance criteria are already being used on an interim basis; no additional financial impacts are expected if risk tolerance criteria are formally adopted. There may be financial impacts for developers/property owners in terms of retaining geotechnical engineering consultants to conduct detailed risk assessments for properties where landslide or debris hazards have the potential to result in loss of life, but these impacts already exist as part of the District's requirements for development and building permit applications. The proposed policy only further clarifies the requirements.

Liability/Risk:

The setting of risk tolerance criteria at the Council policy level as recommended in this Report (rather than on an ad hoc basis by staff at the operational level) will assist in reducing liability exposure because bona fide policy decisions are generally protected from liability exposure whereas operational decisions are not. The criteria will also assist in the making of good, clear, consistent and defensible policies in the future relating to natural hazard risks, and, again, such policies can reduce liability exposure.

Public Input:

The District's Natural Hazards Task Force facilitated two public sessions - an open house and a public meeting - to obtain input from the broader community regarding the recommended *risk tolerance criteria. An electronic survey was also administered on the District website. The results of their findings and recommendations are documented in the April 2008 report to Council (attachment 2).*

Conclusion:

Endorsement of the proposed risk tolerance criteria will set clear requirements for applicants for subdivisions, development approvals and building permits in terms of landslide and debris flow risk management. The criteria should be applied in addition to already existing requirements.

It is anticipated that as the District's experience applying risk tolerance criteria continues to develop, the criteria will need to be revisited and perhaps adjusted to meet the future needs of our community. Ongoing discussion with stakeholders is paramount, as risk tolerance criteria is determined more by social values than by technical advances.

Fiona Dercole

Section Manager, Public Safety

Attachments:

1. *Natural Hazards Task Force – Risk Tolerance Criteria. Report to Council, April 3, 2008.*
2. *Recommendations on Risk Tolerance Criteria for the District of North Vancouver. April 2008.*

End of report to the District of North Vancouver Council, 2009, on acceptance of a District risk tolerance criteria for loss of life from a natural hazard event.

Appendix G: Strategic Planning for Safe Development

Strategic Planning generally refers to long-range planning (20-50 years) that attempts to coordinate multiple objectives. Strategic plans can be focused on a geographic area (e.g. a municipality), but can also be for sectors (e.g. transportation). Here, as the focus is on land use, the emphasis will be on plans for geographic areas.

Regional and municipal levels of strategic plans are most relevant for land use in BC's Lower Mainland. At both these levels, federal and provincial laws and regulations must be abided by and considered.

Regional Growth Strategy

The authority that regional governments have to make plans stems from Part 25 of the Local Government Act, Section 850 (1): ***A board may adopt a regional growth strategy for the purpose of guiding decisions on growth, change and development within its regional district.***

Once adopted, it has legal effect for the regional government and the municipal governments that are members must submit context statements describing how their local plans are consistent with the regional growth strategy.

Metro Vancouver has instituted an updated Regional Growth Strategy in 2011.[24]

It includes the strategy: ***Encourage land use and transportation infrastructure that improve the ability to withstand climate change impacts and natural hazards.***

The Regional Growth Strategy, critically, directs the location of future growth in the region. It sets out an urban containment boundary, urban centres, and frequent transit development areas. This is generally where new density will be targeted in the region. Metro Vancouver works closely with Translink (the regional transit authority) to develop coherence between increases of population density and transit provision.

A regional, multi-hazard risk assessment would be the first step in 'encouraging land use and transportation infrastructure that can 'withstand impacts of natural hazards'. This type of assessment was suggested by workshop participants as something that would be of great value to them.

[24] Metro Vancouver. 2011. *Regional growth strategy, Bylaw No. 1136, 2010: Metro Vancouver 2014, Shaping our future.* Metro Vancouver, British Columbia, 80p.

Official Community Plans

The Official Community Plan is the highest level of policy ***guiding*** growth and development in BC municipalities. These plans are generally formulated with 20-30 year time horizons and reviewed every five years. Once adopted, these plans form the legal foundation for the zoning and subdivision bylaws and provide guidance for public infrastructure spending.

Land Use:

- ☐ Does the future land use map clearly identify hazard areas?
- ☐ Do land use policies discourage development/redevelopment within hazard areas?
- ☐ Does the plan provide adequate space for future growth in areas outside of hazard areas?

Transportation:

- ☐ Do transportation plans limit access to hazard areas?
- ☐ Is transportation planning used to guide growth to safe locations?
- ☐ Are transportation systems designed to function under disaster conditions? (e.g. evacuation routing and capacity?)

Environment:

- ☐ Are environmental systems that protect development from hazards identified and mapped?
- ☐ Do environmental policies maintain and restore protective ecosystems?
- ☐ Do policies provide incentive to development that is located outside of protective systems?

Area planning

These plans recognize the capability and provide the development criteria to reduce hazard risk through reconstruction of areas with high risk assets. Are they formulated with a land supply/demand analysis that takes into account amount of available safe land?

Appendix H: Development Permit Areas

Development Permit Areas represent a unique, added level of land use control. DPAs are generally used when hazard threats are uncertain. You know there is a likely hazard but are not certain of the risks at the parcel level, so you place lines on a map, that delineate hazard zones and proposals for development in these areas will generally require further analysis. You can establish DPAs for hazards that run with the land, for example slope failure or liquefaction susceptibility (as opposed to something more general such as 'earthquake').

The DPA approach is the only way to address land alteration as this is not covered in the zoning bylaw. For example, restrictions on cutting and filling of the land or vegetation removal could be specified through DPAs.

DPAs can also be used to guide redevelopment in built-out areas where floodplain bylaws cannot be established.

In most cases, the only way to restrict density is through the zoning bylaw. However, specific to hazard risk, you can restrict use and density through a DPA.

- DPAs can specify building construction materials (e.g. for wildfire risk management)

Informed practice suggests:

- It is important to consider competing objectives (e.g. vegetation removal vs. preservation, for reducing wildfire risk and promoting slope stability)*Heighten awareness around connections to other tools (e.g. ensure there is staff understanding of interfaces between zoning, building bylaws and development permitting and how they all work to together to address hazards)

Some limitations of the DPA approach:

- Decisions are being made at the parcel level, so might not attend to considerations regarding transportation and other life lines.
- Conditions imposed are only as strong as their enforcement and monitoring (e.g. ensuring a berm was constructed to standard and maintained over time)
- End-users suggest there is a lack of hazard information upon which to base DPAs and need, for example, regional multi-hazard risk maps

The QP system: Establishing terms of reference for products and services commissioned from consultant to make them useable for planning purposes.

Example of development permit area for wildfires and relevant official community plan[25]

"Wildfires

A. Objectives

The Wildfire Hazard DPA and corresponding development approval information areas are established to:

1. ensure that development within the Wildfire Hazard DPA is managed in a way that:
    a. minimizes the risk to property and people
    b. promotes activities to reduce wildfire hazards while still addressing environmental issues; and
    c. minimizes the risk of fire to the District's forests;
2. proactively manage conditions affecting potential fire behaviour… thereby minimizing adverse impacts;
3. conserve the visual and ecological assets of the forest for the benefit of present and future generations; and
4. reduce the risk of post-fire landslides, debris flows and erosion.

B. Exemptions

All development is exempt from the requirement to obtain a wildfire hazard development permit other than the construction and installation of a new building or structure for which a building permit is required pursuant to the District's Building Regulation Bylaw.

C. Guidelines:

1. Applicants may be required to provide a preliminary assessment report and detailed assessment report prepared by a qualified professional.
2. New buildings or structures and associated accessory buildings and structures should be located as far away from any wildfire risk areas as is reasonably possible…
3. For parcels located entirely within a wildfire risk area, guideline number 2 does not apply, but new buildings or structures and associated accessory structures should be located as far away from any contiguous undeveloped forested areas or areas containing hazardous forest fuel
4. The following fire resistive materials and construction practices should be required for all subject development in the Wildfire Hazard DPA:

[25] Based on the District of North Vancouver, BC

a) fire retardant roofing materials b) decks, porches and balconies should be sheathed with fire resistive materials; c) all eaves, attics, roof vents and openings under floors should be screened to prevent the accumulation of combustible material d) exterior walls should be sheathed with fire resistive materials, e) solid composite decking materials or fire-resistive treated wood, f) all windows should be tempered or double-glazed, g) all chimneys and wood-burning appliances should have approved spark arrestors, and h) building design and construction should generally be consistent with the National Fire Protection Association… "

This DPA is linked to the Official Community Plan | Schedule B

Example map of a Development Permit Area for Flooding

Development permit areas are designated as zones on a map. Each zone represents an area subject to a particular magnitude of hazard. Developments in each zone are subject to certain prescriptive mitigations or descriptive goals of acceptable risk for that hazard magnitude and for the development type. In the case of flood hazard, each zone represents a range of flood magnitude (e.g. 1-2 metre flood water depth) requiring similar mitigations (Fig. H-1). The mitigations prescribed, and goals for acceptable risk for each flood hazard zone are described in the Development Permit Area documentation to accompany the map.

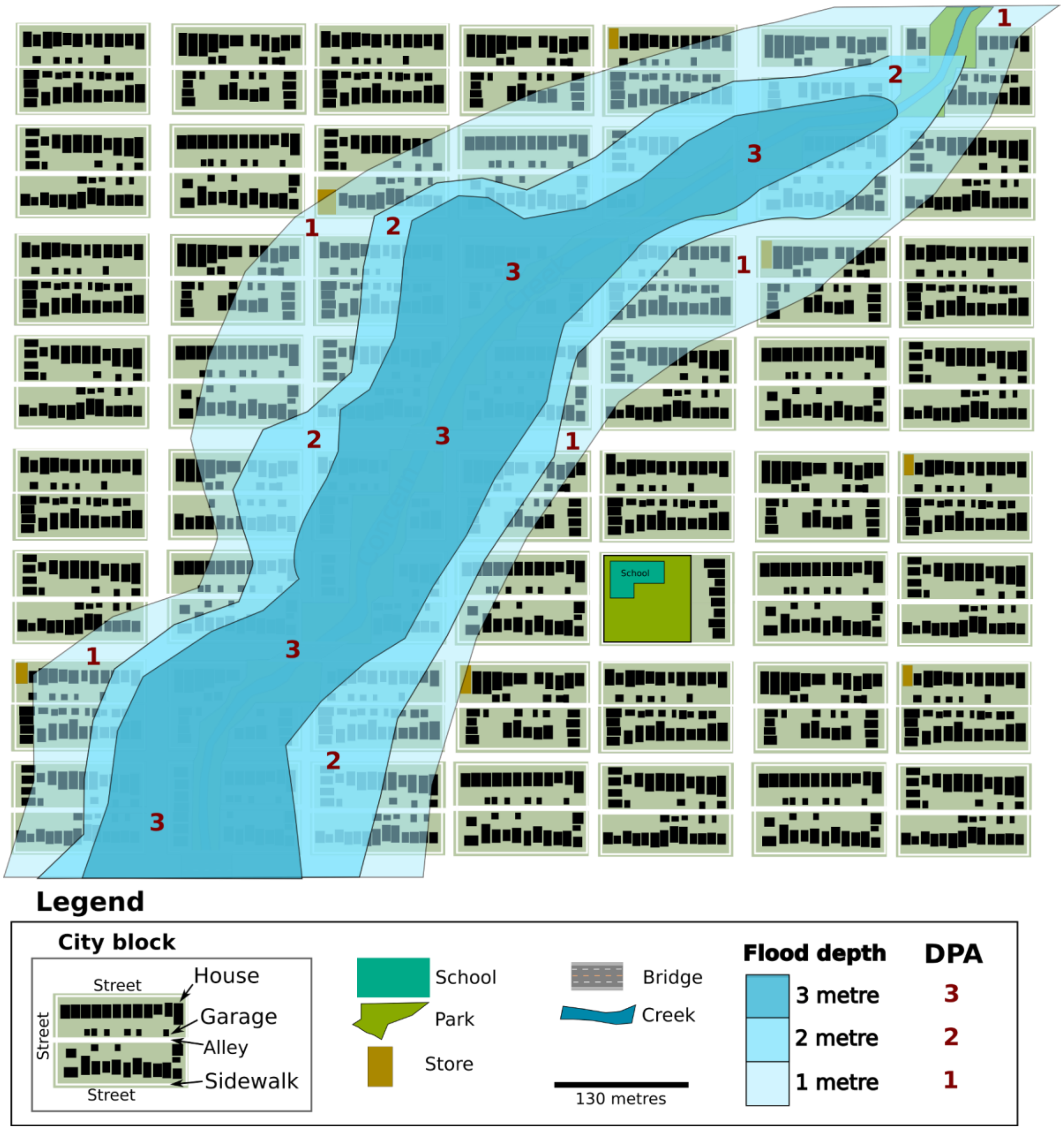

Figure H-1. Example Development Permit Areas for Flood Hazard (DPA) for a fictitious city and hazard situation. DPA zones correspond to flood depth zones for a 1:200 year flood. The city and hazard scenario are also used in Appendix K to describe flood hazard risk assessment incorporating the Delphi method.

Appendix I: Zoning Bylaw

The main role of zoning is to specify the locations of various uses and associated siting, densities and floor space ratios.

Reducing hazard risk using the zoning bylaw, will in some cases be more politically feasible or appropriate than using a development permit area approach. This tool will be the most powerful tool for addressing hazardous lands that are not yet built out (e.g. greenfield) but may not be as useful in addressing built-out areas (e.g. existing development).

The challenge is often to balance a new direction in the OCP (e.g. restrictions on the use of hazardous lands) with the existing uses on the lots.

To incorporate risk reduction in the zoning bylaw, the following are key concerns:

- Is the zoning bylaw updated?
- Does the zoning bylaw conform to the OCP in terms of discouraging development/redevelopment in hazard-prone areas? (e.g. use zoning for open-space dedication or reducing density in hazard lands)
- Does the bylaw contain hazard overlay zones that set conditions for land use within the zones?
- Do zoning procedures recognize hazard areas as limits on zoning changes that allow greater intensity/density of use?
- Does the zoning bylaw work with any other existing tools (e.g. DPAs and ESAs) to prohibit development within wetlands, floodways and floodplains?

Appendix J: Risk Assessment Method

Introduction

The guide provides a framework for risk reduction at the local and regional level. It is based on a version of the internationally accepted principles of risk management (CAN/CSA Q 850-97), modified to emphasise land-use. They include:

1. Establish your needs
2. Define hazard potential
3. Identify what could be harmed and by how much (exposed and vulnerable)
4. Calculate potential losses (assess risk)
5. Recommend safe land-use (mitigation strategy)
6. Monitor decision success

These steps follow a broader approach of structured decision-making (SDM)[26], which is an informed practice for making strategic decisions in circumstances where uncertainty and disagreement are high. The steps of SDM and risk management are intended to be used iteratively and can be employed for rapid assessment by a small project team or an in-depth, strategic planning process with deep community engagement.

To assess land-use hazard risk, the land-use guide emphasises three core steps of the risk management framework (Steps 2 to 4):

Step 2: Define the hazard potential
Step 3: Identify what could be harmed
Step 4: Calculate potential losses

The components of these steps; hazard, exposure and vulnerability are described in appendices F, G and H. Here we describe how the components are used to estimate risk: the probability of a consequence. The risk is estimated from a calculation of the losses for a probable or real hazard event. Those losses can be calculated for existing communities of people, structures and resources, or for model communities of people, structures and resources. Therefore it can be used to estimate existing risk and future risk. Comparing the risk between existing and future communities is how to determine if development plans will achieve acceptable levels of risk and how much potential savings could be amassed through the development. We provide examples of qualitative and quantitative tools to make those estimates.

[26] Structured Decision Making website. 2015.

Risk assessment

Risk is the probability of something bad happening. Assessing hazard risk is to determine the potential that a possible hazard event will create losses. It is therefore a function of the probability of a hazard-event induced consequence (loss). The elements of the function can be divided into three parts:

Probability of a certain magnitude of a hazard occurring (hazard)

Probability of a certain degree of exposure to the hazard (exposure)

Probability of a certain amount of damage caused by the hazard event (vulnerability)

If any one of these parts is not probable then the risk is zero. If the risk is zero then no losses can occur. If no losses can occur, then a disaster cannot happen. In reality, for an existing hazard, each of these parts has some probability. Risk management ensures acceptable risk by managing each of these parts where practically possible. Management actions to reduce as a whole are risk mitigations. Hazard mitigation generally reduces the magnitude of an event. Exposure mitigation reduces the amount a person, structure, and resource is exposed to the hazard. Vulnerability mitigation strengthens the person, structure or resources to withstand the forces of the hazard.

It can be very complex, and therefore resource intensive, to thoroughly calculate each of these three parts. Therefore risk assessments are often done using approximations or components of the risk. Greg Paoli provided an overview of the pros and cons of using a particular risk assessment method along the continuum from highly qualitative and approximate methods to highly quantitative and exact methods[27]. He concluded that well controlled qualitative estimates are less resource intensive for one-off assessments, and that quantitative estimates are less resource intensive when the assessment will be re-run (recommended). He suggested that a “sweet spot” exists in the risk assessment continuum where useable results can be determined: where the assessment has enough rigour to be reproducible and justifiable and does not become overwhelmed by detail.

One option to reduce the risk assessment effort is to calculate a single loss-estimate for a single probable hazard scenario. A full risk assessment would calculate the losses from a range of probable events. The single loss-estimate could assume that the exposure and vulnerability will have a 100%, or other set, probability.

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[27] Paoli, G. 2013. *Comparative risk assessment: A complex design problem.* Risk Assessment Users Group, Slide deck and podcast. RAUG MHRISK website.

Existing and future conditions

Risk assessments can be performed to assess existing conditions and, when coupled with projections can assess predicted or modeled, future conditions. Projections could include changes in the natural environment (e.g. sea level rise), built environments (e.g. future infrastructure or build out of planned residential density) as well as population socio-demographics (aging population). Current local and regional acceleration of changing climate has induced changes to various climate related or climate influenced hazards. Such changes require periodic re-evaluation of the hazard risk.

A guide to land-use management in a changing climate is available from the Canadian Institute of Planners and through NRCan's Risk Management web pages: keywords “climate-change, community-adaptation”.

Information regarding British Columbia’s Regional Climate Change Adaptation Collaborative can be found at the NRCan website using keywords “climate-change, community-adaptation, regional-collaborative”.

With the changing nature of climate projections, generally, a precautionary approach should be used with regards to extreme weather events and sea level rise.

Risk assessment tools

Introduction

Risk assessment tools are quantitative or qualitative. They each serve a purpose and they each have their pros and cons. Quantitative tools are more resource effective when risk assessment is used repeatedly for planning and development proposals. Qualitative tools are more resource effective for situations where they will be used once in long time, or where the outputs do not need to be rigorous.

Quantitative tools require more up-front resources to create appropriate data sets. Once created those data sets can be used repeatedly and modified relatively easily. Since the data does not change extensively over 5-10 year time frames they can be re-used as-is throughout that time, with the addition or modification, where needed, to test planning models or development proposals. The tools will provide a reproducible loss estimate and risk assessment.

The data sets for a quantitative tool consist of a GIS map of the hazard scenario, GIS inventory of the location and descriptive details for buildings, transportation routes, resource lifelines, essential facilities, critical infrastructure, groups of people, natural resources, and the like (community inventory), and databases of vulnerability information for each inventory type, as damage functions. The tool will have the capability to calculate the losses based on that data.

Qualitative tools require up-front investment in the design of the necessary workshops and the bringing together and management of subject matter experts and their contributions to the analysis. Each of them relies on some form of the Delphi method that has experts provide opinions about what the results to certain situations may be. The degree of resources required to compile community inventory information is mostly to map various structure types, the distribution of people and natural resources. Analysis can be done using extensive data on inventory, though typically the information is gathered, like the others, from the expertise of the workshop. Qualitative tools cannot provide reproducible results except at the highest levels of analysis (e.g. "Extensive damage will occur").

Quantitative risk assessment tools

One example of a standard North American quantitative risk assessment tool is presented. Murray Journeay reviewed quantitative tools from North America, Europe, Australia and New Zealand[28]. Although dated, his work remains a useful source for tools that could be considered for your purposes.

Hazus-MH – A quantitative loss-estimation tool

Introduction

Hazus[29] is a risk analysis program that includes computer software, training and user support. The computer software provides quantitative, reproducible, defensible, potential losses of life and property from a model, or real, earthquake, flood, hurricane or storm-surge. It supports hazard risk mitigation planning, and emergency response and recovery. It is developed and maintained by the United Sates of America's Federal Emergency Management Agency (FEMA). FEMA provides Hazus as no-cost shareware that operates as a plugin to the ESRI company's GIS software ArcMap. The Hazus software is currently being modified, under agreement with FEMA, by Natural Resources Canada and its partners, to be functional in Canada (2014)[30]. Journey and others provide a use case example for application of the Hazus earthquake module to the District of North Vancouver[31]. Natural Resources Canada maintains the Canadian version of Hazus and distributes that version for use in Canada[32].

To calculate hazard event losses, Hazus, like any other risk analysis tool, uses three sets of data:

[28] Journeay, J.M. (2015) Disaster Resilience by Design: A framework for integrated assessment and risk-based planning in Canada. Geological Survey of Canada Open File. (in publication).
[29] FEMA. 2014. *Hazus*. FEMA Hazus website.
[30] Ulmi etal. 2014. Hazus-MH 2.1 Canada user and technical manual: earthquake module. Geological Survey of Canada, Open File 7474, 245pp.
[31] Journey et al. 2015. A profile of earthquake risk for the District of North Vancouver. Geological Survey of Canada, Open File, in review.
[32] NRCan. 2014. *Hazus Canada*. Hazus Canada website.

1) Hazard scenarios.
2) A detailed GIS inventory of people and property in the area of concern (assets).
3) Damage functions.

Hazus software comes with sufficient of that data to calculate losses directly from the distribution copy. Data distributed with Hazus is sufficient to calculate potential losses that provide a general overview of the risk situation. The Hazus user can replace and augment the data that comes with Hazus. For community neighbourhood-level risk management planning, appropriate specific hazard scenarios and municipality-maintained GIS inventories should be used instead of those that come with Hazus. Hazus is distributed with a data management tool to simplify the input of community data (Comprehensive Data Management Tool – CDMS).

Hazus functionality and each of its technical parameters and equations are fully described in its technical and user manuals. All of the parameters are available in the Hazus databases.

Hazus goal

Hazus is designed to increase safety from natural hazards by informing hazard risk management decisions. It supports mitigation, recovery, preparedness and response planning and operations. Government planners, GIS specialists, and emergency managers use Hazus to determine potential disaster losses. Hazus results show how much damage and disruption, and how many casualties will happen, and it shows where they will happen. Knowledge about those potential losses are used to design and test programs that reduce the risk of land development and use (mitigation and recovery), and to guide emergency response preparedness and response.

Hazus can be used to measure the reduction in losses caused by changing how, and where, structures are built. Such cost-benefit analyses are used for strategic community planning and disaster recovery planning. Hazus can create realistic disaster scenarios for use in emergency response planning. Its maps can guide response and compensation decisions during a disaster, using either the predicted event scenario or the actual one.

Primarily, Hazus disaster-loss scenarios can guide long-term strategic renewal of high risk areas of the community. Those strategic plans have the potential to be activated as recovery plans post-disaster.

Hazard scenarios

Hazus requires a credible hazard scenario with descriptive parameters specific to that model or a real hazard event. Hazard scenarios are required for any quantitative and qualitative hazard risk analysis, and therefore are not unique to Hazus. The USA version of Hazus comes with hazard scenarios and tools to calculate hazard scenarios. In Canada, it is recommended that hazard scenarios be imported into Hazus by the user. A hazard scenario describes the physical parameters that define a hazard event. The scenario for each hazard type requires data specific to that hazard. For example: a flood scenario for Hazus requires information about the height of the flood water above ground level across the area flooded; for an earthquake it requires the distribution and nature of the ground shaking intensity. Certain other characteristics can be added to the analysis to calculate more realistic losses. For example: for an earthquake, data about landslide susceptibility, liquefaction susceptibility and type, and distribution of geological materials (soils map) can be included to determine the effect of ground disturbance and influence on local shaking intensity.

Inventory of people and property

The inventory of people and property (assets) that can be impacted by the hazard event, requires a finite and specific list of variables. That inventory contains information about the exposure of the assets, and about the nature of the assets. For example: for a wood construction house, Hazus uses the 3 dimensional GIS location, square footage (USA units), number of stories, year built (for seismic code determination), with or without basement, and replacement value. It can use more information about the house to refine the damage calculation and for specific hazard types.

Hazus organizes the information about the assets by areas defined by census divisions and by specific structure. Information about people is stored solely by census divisions. Hazus does not store information about individuals.

Hazus is capable of calculating losses for most assets in a municipality, regional infrastructure and special facility. These include: people, buildings, industrial and commercial complexes, lifelines (water, sewer, power, and transportation), social service facilities, emergency management facilities, critical infrastructure and high loss facilities (e.g. hydro-electric dams, nuclear power plant)

Damage functions

Hazus has a database of functions that describe what amount of damage can occur in a particular hazard event. It has those functions for each type of collection of people, structure, and material good (e.g. building contents, cars, and agricultural crops). Hazus uses those functions to calculate the damage caused by a particular hazard event for assets exposed to that event. It can calculate that damage for a collection of assets in a census area, or for individual structures. The function calculates those losses based on the amount of vulnerability of each asset to the characteristic of the hazard event that causes damage (e.g. shaking intensity, depth of water, force of wind).

Hazus includes a database of asset vulnerability as part of its damage function database. The measure of vulnerability is based on the characteristics of the asset as described in the asset inventory database.

Comprehensive Data Management System

The Comprehensive Data Management System (CDMS) assists with building the Hazus dataset. It translates data from fields that exist in non-Hazus databases into Hazus database fields. The

CDMS operates as a stand-along software program. Output databases from the CDMS are imported into the study regions established for each Hazus run. The study region is the area of interest and is a sub-set of a provincial dataset.

Further information can be found at:

USA Federal Emergency Management Agency: www.FEMA.gov/Hazus

Geological Survey of Canada, Vancouver, BC: www.hazuscanada.ca

Qualitative risk assessment tools

Qualitative risk assessment tools all rely on a variation of the Delphi method for their analytical component. The Delphi method will be summarized and a few examples of its application in risk assessment provided.

Delphi method

Delphi means you bring together subject matter experts in each of the components of the risk analysis to give their opinion about each measure. Those measures are recorded and then used to calculate a result. Where informed methods to quantify and calculate each variable of risk for each hazard is not available or not warranted, then expert opinion is the informed practice of choice. Conducting a rigorous Delphi analysis requires controls throughout the method for the results to be useful[33]. It requires thorough understanding and recording of the uncertainty at each stage of the method and in the results.

The term "Delphi" comes from Greek culture, where the most esteemed oracle was from the city of Delphi.

Delphi analysis relies on expert assignment of a qualitative level between 0 and 100% or very low to very high for each variable. The variables are generally assembled as grids to generate a measure derived from two relative variables (see Fig. J-1)

[33] Hallowell, M.R. and Gambatese, J.A. 2010. *Qualitative Research: Application of the Delphi Method to CEM Research.* Journal of Construction Engineering and Management. Vol. 136, No. 1, p. 99-107. An excellent summary of the requirements of conducting a Delphi analysis in any field.

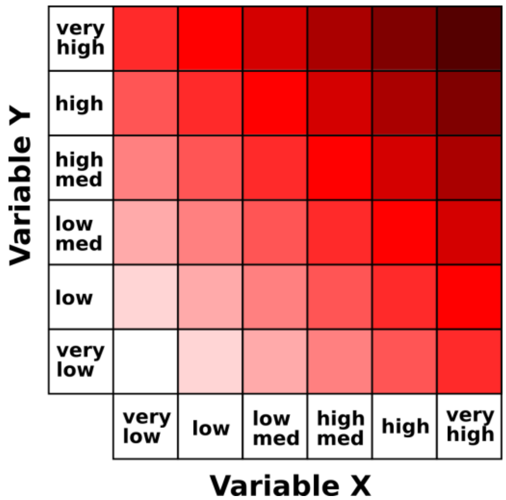

Figure J-1. Sample Delphi expert variable grid. Assignment of an x and y will create a single position on the grid and that position will define a measure of the function of x and y (a value is assigned to each colour). In an example from hazard risk analysis the x variable can be a measure of asset exposure and the y variable can be a measure of asset vulnerability to a particular hazard intensity and the result will be a measure of the consequence of the hazard event for that asset.

Hazard risk analysis can be done in various ways using this technique. It can be designed to follow the risk assessment scheme of the land-use guide's risk management framework. Although a similar suite of decision matrices and maps could be used for the various hazards; the scenarios, exposure and vulnerability measures would be unique for each hazard. An example Delphi risk assessment is summarized below. To achieve somewhat rigorous, reproducible and defensible results, the operation of the Delphi assessment should be conducted under the guidance of the rules set by Hallowell and Gambotese.[33]

Sample Delphi risk assessment approach

Establish the hazard of concern

Qualified professional describes a hazard scenario and its probability of occurrence / recurrence (return period).

A list of scenarios of a particular hazard will be generated based on the probability of occurrence. For example, for floods; five scenarios are often developed; they can be based on the 1:10, 1:50, 1:100, 1:200, and 1:500 year events. The flood water depth would be determined for each event and would be mapped for the area of concern (Fig. J-2).

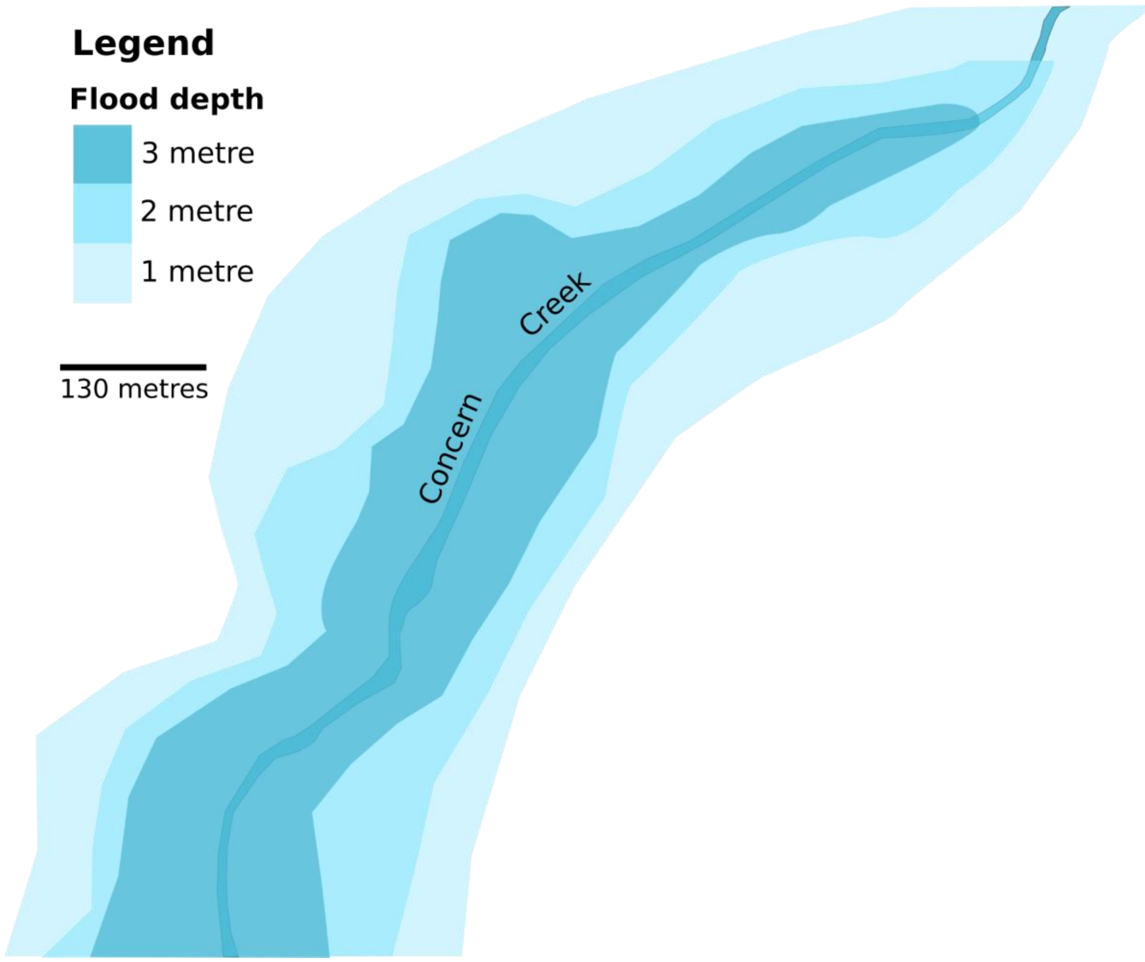

Figure J-2. Sample flood hazard scenario used in a risk assessment. It features a map of the depth of the flood water (flood depth grid).

Determine asset exposure to hazard

A qualified professional determines the degree to which a community asset (or areas of community assets) and a person (or groups of people) are exposed to the hazard in the particular scenario. The calculation can be done structure by structure, person by person; or as aggregates of structures and people.

The professional determines the exposure by measure and by location in the community (on a map). Mapping the exposure values provides a more powerful tool for managing the risk, because hazard risk is location based (Fig. J-3, J-4)).

Figure J-3. Sample map of a community inventory dominated by wood-frame residential houses. The area is crossed by "Concern Creek" of Figure J-2.

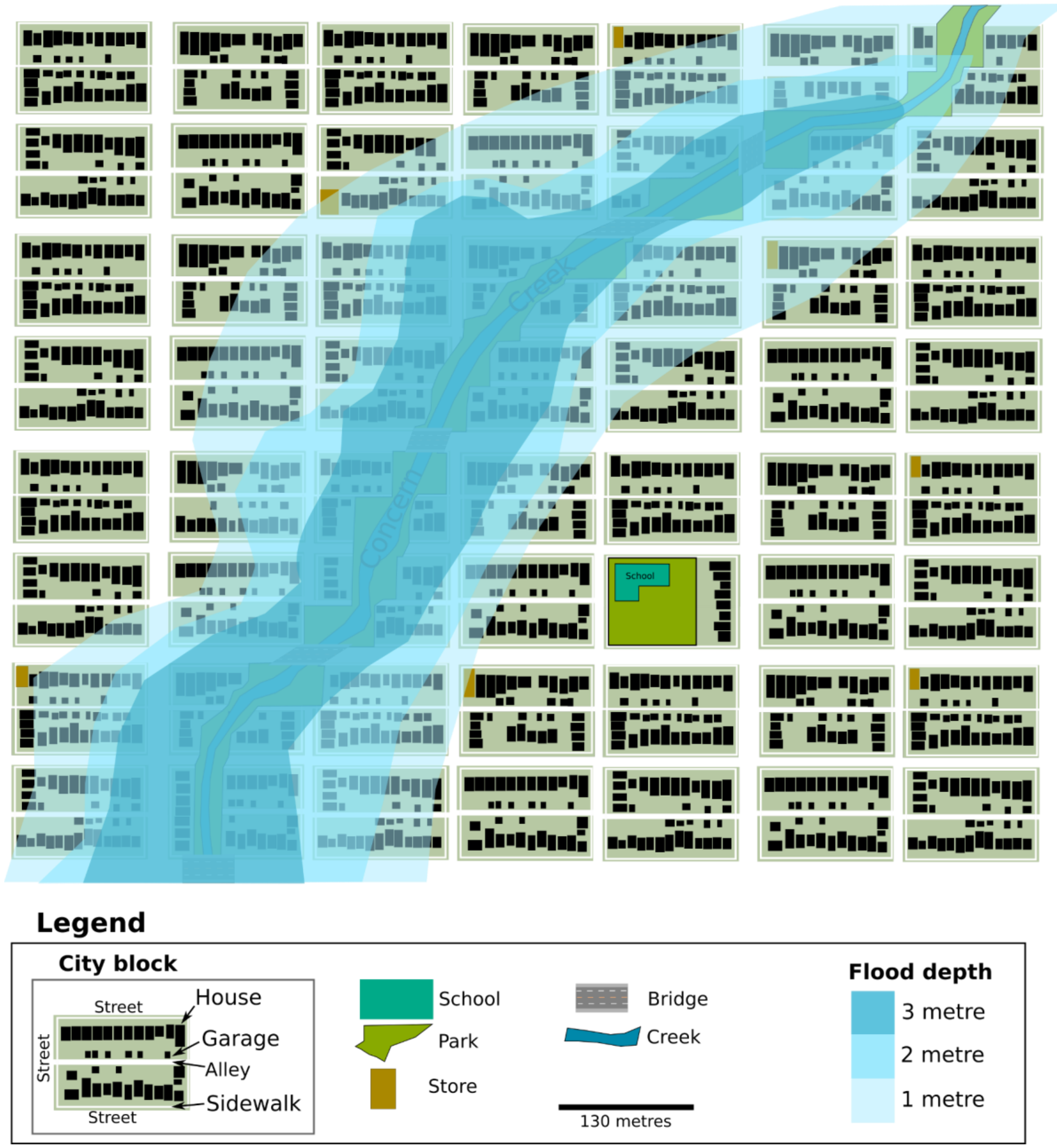

Figure J-4. Map of community inventory and the flood hazard scenario, indicating the community assets exposed to the flood hazard.

Determine asset vulnerability to hazard

Qualified professional determines how vulnerable an asset is to the hazard based on its exposure level. For physical assets this is best done by establishing the replacement cost of the asset that can be destroyed by the hazard in that scenario. For people, it is based on the extent of potential injury (Fig. J-5).

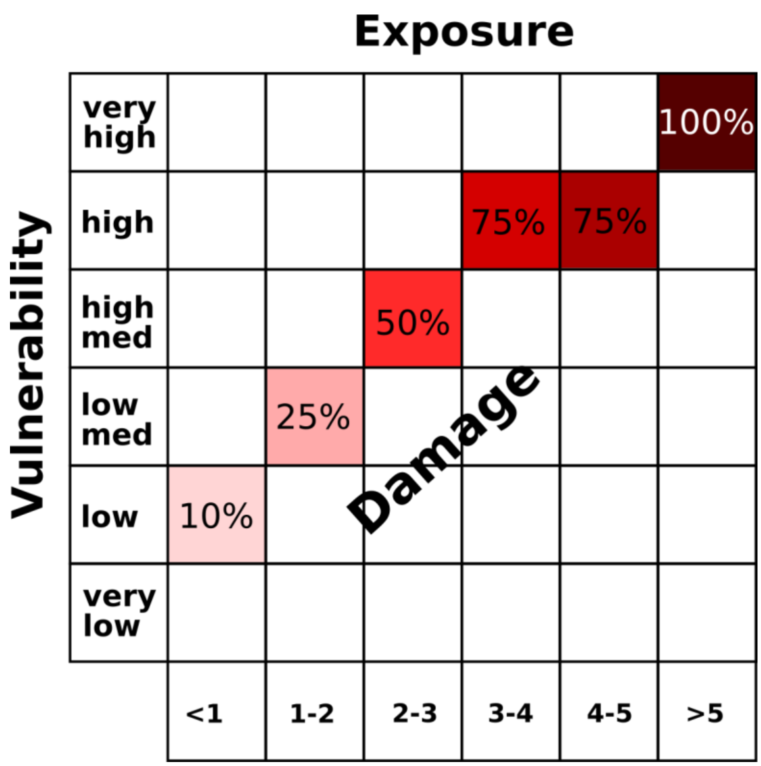

Figure J-5. Estimates of the vulnerability of a wood-framed house with no basement as exposed to various metres of elevation of flood water resident for a day. The matrix provides a graph of potential damage from the flood water (damage function). In a Delphi based qualitative risk assessment, experts in flood damage would provide their interpretation of the potential damage cause for each type of structure, infrastructure of concern to the community. They would produce a graph such as this for each of the different types of structures.

Determine the consequence of the hazard event (estimate losses)

The consequence will be derived from various plots of the exposure versus the vulnerability. For example: high exposure of low vulnerability would result in low to moderate percentage of damage.

The financial consequences of the damage would be calculated based on the percentage of loss. If a group of homes is worth $10 million (Metro Vancouver home replacement values 2014) and they suffered an average of 30% losses then the financial loss would be $3 million. Figure J-6 uses the sample community inventory of this section to illustrate how the vulnerability analysis of Figure J-5 is used to determine model losses caused by the flood hazard scenario.

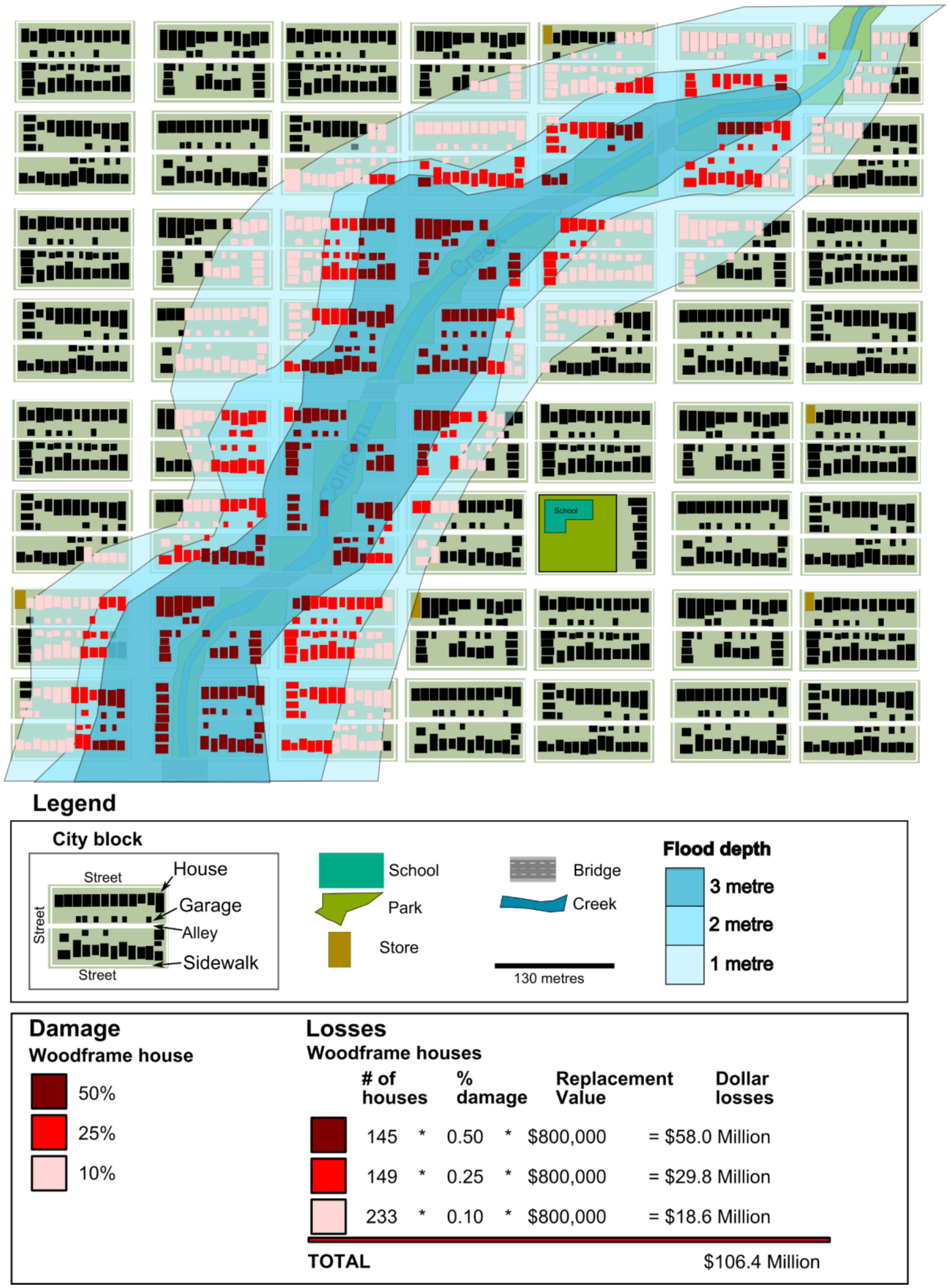

Figure J-6. Shows the distribution of flood damage to wood framed houses as determined from mapping the damage measures from the matrix / graph of Figure J-5 (damage function). Financial losses of wood-framed houses caused by the flood scenario damage is determined from the number of damaged houses in each of the flood zones, the percentage damage per house type, and the replacement cost per house type. The replacement *costs for this example are set to one value. In an actual risk determination they could be the actual value of each house. Business losses from the damaged stores are not included in this map. Including losses from the damaged stores would require a damage function for the store structure types, replacement cost of the buildings, and the financial losses caused by lost business. Business disruption would, in part, be a consequence of damage to infrastructure, business buildings, lost employee and customer time and disrupted supply chains. A chart that sums these factors from the various consequence matrices would provide a value of business disruption.*

The risk of that hazard event in the Delphi analysis (function of probability and consequence) will be an accumulation of the consequences for the assets and persons in the area of interest for that particular probability of hazard occurrence. Refinement of the risk can be done by considering the probability of the asset vulnerability.

Many different risk analysis tools exist that use the Delphi method. Their differences are primarily based on the variables measured, which generally reflect the needs of the organization using the tool.

The risk determined from the above example sequence of calculations is specifically about the risk of losses, and therefore about the disaster losses. It does not determine the community's ability to cope with the disaster (resilience). Factors related to coping capacity can be incorporated into such an analysis. Some methods concentrate on determining the capacity of a community to cope with a disaster[34,35], rather than the disaster potential. Those methods can be used in conjunction with the risk of losses to determine overall community resilience.

Examples of available qualitative risk assessment tools

- HVRA – British Columbia Hazard Risk and Vulnerability Assessment
- HIRA – Ontario Hazard Identification and Risk Assessment
- AHRA – Public Safety Canada All Hazards Risk Assessment
- CBP – Defense Research and Development Canada's Capability-based planning

The ***BC Hazard, Risk and Vulnerability Assessment*** (HRVA) is the existing British Columbia provincial tool for multi-hazard risk assessment[36]. The British Columbia Emergency Management website includes helpful tips and contact information for hazard subject matter experts. The HRVA provides considerable latitude for how it is used and therefore what results can be achieved. It uses terminology differently than in this guide, and its method is different. It merges risk (probability of a consequence) and coping capacity and therefore reflects back to the user their perceptions of event consequences and response capability. Its method is to define a disaster scenario, and assess how likely that scenario could occur.

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[34] Murphy, C. and Gardoni, P. 2010. *The Capability Approach in Risk Analysis*. In Handbook of Risk Theory. Roeser, S., Hillerbrand, R. Sandin, P. and Peterson, M. (Eds) Springer Netherlands, P. 979-997.
[35] JIBC. 2013. *Rural Disaster Resilience Planning*. JIBC website.
[36] British Columbia Emergency Management Website. 2015. Hrva.

The ***Ontario HIRA*** is similar in design and intent to the BC HRVA. It separates hazard scenarios more clearly from consequence and provides more categories of measures.

The ***All Hazard Risk Assessment*** was designed for federal departments to assess the risk of their management portfolios of various hazards.

Capability based planning schemes focus on the coping capacity[37].

Other tools and guidelines

In British Columbia, hazard specific guidelines are available from APEG BC for landslides[38] and flooding[39] and the Ministry of Environment for sea level rise and sea dyke guidelines. See also the national landslide guide that includes descriptions of landslide risk assessment[40].

Risk assessment resources

These are agencies that can provide some guidance on risk assessment as a science and for certain applications.

- APEGBC (Association of Professional Engineers and Geoscientists of British Columbia)
    - Geotechnical consulting firms
- University engineering, geotechnical and planning departments
    - UBC Civil Engineering
    - UBC SCARP
    - UBC Earth and Ocean Sciences
    - SFU Earth Sciences Department
    - SFU Climate Change Adaptation
    - Royal Roads University Disaster Management
    - Justice Institute of BC, Research Division
- Provincial Ministries
    - Public Safety and Solicitor General, Emergency Management BC
    - Environment
- Federal Departments

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[37] Murphy, C. and Gardoni, P. 2010. The Capability Approach in Risk Analysis. In Handbook of Risk Theory. Roeser, S., Hillerbrand, R. Sandin, P. and Peterson, M. (Eds) Springer Netherlands, P. 979-997.

[38] Gerath et al. 2010. *Guidelines for legislated landslide assessments for proposed residential development in British Columbia*. Association of Professional Engineers and Geoscientists, 76pp.

[39] Church et al. 2012. *Professional practice guidelines – legislated flood assessments in a changing climate in BC*. Association of Professional Engineers and Geoscientists, 144pp.

[40] Bobrowsky et al. 2014. *Landslide guidelines and best practices for professional engineers and geoscientists* in, Education, Professional Ethics and Public Recognition of Engineering Geology; Lollino, G (ed.); Arattano, M (ed.); Giardino, M (ed.); Oliveira, R (ed.); Peppoloni, S (ed.); Engineering Geology for Society and Territory vol. 7, p. 229-232, doi:10.1007/978-3-319-09303-1 45 (ESS Cont.# 20130353)

- Public Safety Canada, Victoria and Burnaby
- Natural Resources Canada, Pacific Division, Vancouver, and Sidney
- Defense Research and Development Canada, Ottawa
- Centre for Safety and Security, Regina, Saskatchewan
- Agriculture Canada, Saskatoon, Saskatchewan
- Health Canada
- Industry Canada
- Transportation Canada

Community risk assessment checklist

Table J-1: Community risk assessment checklist prior to evaluating land-use proposals

Y(yes) N(no)	Needs to be Done	Needs to be Updated	Section 1: Have You?	Action List	Timeline: Due date
			Has the community developed a risk tolerance rating?		
			Started a Resource library of Maps: GIS: Web Links etc.		
			Put in place a tool (or tools) to calculate the potential losses from a hazard event?		
			A map and information of all community assets that can be affected by a hazard?		
			Made an Inventory of Hazards that affect the community?		
			Assessed the potential of the community hazards?		
			Made a short list of those hazards with most potential to disrupt the community through damage, injury and death?		
			Created hazard event scenarios (example: maps of water depths of a 200 year flood event)?		
			Evaluated the risk from your hazard short list? Most easily done by evaluating the losses caused by particular hazard event scenarios and plotting those to see a risk profile (Appendix J).		
			Do you have a risk evaluation for the community?		

Appendix K: Hazard Identification and Assessment

Hazard information and assessment for a risk assessment is used to understand the potential threats of concern to the community or region. It identifies the hazards and assesses their potential to create an event such as a flood or industrial accident. The hazard assessment process involves four steps, the last of which is used in the risk assessment:

1. Identify the hazard types in areas that are in or could affect your jurisdiction (hazard identification)
2. Determine which of those hazard types pose the most threat (hazard threat priority
3. Determine the probability of an event caused by each hazard of concern (hazard assessment), and
4. Develop hazard scenarios

Identification of the hazards, setting their priorities in the community and assessing the probability of them occurring could be done through broad, community-wide review (referred to in some communities as 'State of the Environment' reports). The work could be more project-focused (focused on new subdivision approval or town centre planning). Hazard assessments and scenarios should be developed by hazard experts. Once a hazard scenario is developed it is used with exposure, vulnerability and damage functions to generate assess the risk.

This guide provides introductory information, links and resources for identifying hazards. It is emphasized that these processes should be open and involve affected stakeholders; including government staff, members of the community and decision makers (Appendix E). Early and frequent engagement helps to ensure that actions are taken, based on the identification of hazards, to reduce risks.

Hazard inventory

Working with the community and experts, identify and map all possible hazards that affect the community (see Appendix E for example of community consultation for hazard identification and other aspects of risk assessment). Some hazard events will have happened to the community and its citizens in living memory and be in historical records. Some hazard events may have happened before recorded history and would be evidenced in the geological record.

Sample hazard list

Hazard lists are provided by Emergency Management British Columbia as part of its Hazards Risk and Vulnerability Assessment toolkit[41]

1. Flood
2. Earthquake
3. Landslide
4. Tsunami
5. Interface fire
6. Storm (wind, snow, rain, hail, ice, sleet)
7. Extreme cold
8. Extreme heat
9. Drought
10. Tornado
11. Hurricane
12. Meteorite (Bolide)
13. Space weather (sun spot flare)
14. Infectious disease
15. Pestilence
16. Bombing (chemical, nuclear)
17. Chemical spill / release (solid, liquid, gas)
18. Radioactive release
19. Accident (vehicles, planes, industrial plant, boats, explosion, storage, pipeline, dam)

A variety of informational resources can be used to identify hazards of concern, for example:

- Community historical records (archives)
- Citizen and staff memory and ancestral stories
- Federal and Provincial hazard maps
- Community engineering reports
- Research articles (academics, government, non-profits)
- Environmental assessments
- Local subject matter experts, the HRVA toolkit lists subject matter experts

Generally, to inform land-use planning and decision making, a relatively high degree of certainty about the hazard characteristics will be required. However, uncertainty in identifying hazards can rarely be eliminated. The physical environment and human understanding are ever-changing.

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[41] PEPBC (2003). *British Columbia Hazard Risk and Vulnerability Analysis Tool Kit.* Ministry of Public Safety and Solicitor General, Provincial Emergency Preparedness, Victoria: Queens Printer, 62p

Accordingly, the precautionary principle should apply and the best available knowledge be used to make informed decisions.

A hazard inventory catalogues the types of known or suspected hazards to the community. Such a catalogue records the nature and maps the distribution of the hazard. Such inventories are made from the collective knowledge of community members and others (government, academic, industry and other experts), or are commissioned from geotechnical, engineering, public safety and other experts.

Engaging community members in hazard identification provides an opportunity to confront perceived hazards that provide no real or substantive threat to the community. Generally experts in hazards will be required to identify records of pre-historic hazard events that provide a magnitude and recurrence interval for probable hazard events or to identify factors that can measure hazards that have no historic record.

Community comprehensive hazard map

You will need a hazard inventory map to create a hazard assessment map and report, necessary for the risk assessment.

Journeay and co-workers provide a comprehensive technique for community identification of hazards, and how to use that information to create hazard inventory maps (Appendix E). In summary; community stakeholders are engaged in workshops to gather their cumulative knowledge of local hazards on maps and charts. Experts in hazards are available to guide the process and summarize results as final maps showing the potential distribution of hazardous zones and the potential severity and return period of those hazards. Experts should be municipal staff where available, and can be supplemented with external professionals familiar with the municipality.

If completing a rapid assessment, (as opposed to an in-depth strategic planning process), hazard experts can be employed to gather the required knowledge from existing reports, interpretation and mapping.

The inventory requires a map view of zones (areas) affected by the hazard. If possible each hazard should have a separate zone for each hazard magnitude and its potential return period (statistical recurrence interval). For example valley flood levels are generally considered reached statistically every certain number of years (e.g. 200-year flood level), For example: the 200 year flood zone would delineate the height of the flood that statistically would occur once in 200 years. Hazard scenarios used for planning purposes should include the maximum credible event: the event which is considered extreme and yet plausible.

See the accompanying list of hazards as a guide to the community review. In general, several of the hazards from the list will be a priority for a particular community or region. Set the hazards in priority by degree of threat, and concentrate initially on the highest priority.

See the included hazard inventory community consultation process of Appendix E for details on operating the consultation process, information to capture and the method to portray information for developing the hazard assessment.

Hazard priority setting

Through an iterative process make a short list of the hazard types the community thinks are most threatening. A short list is valuable because detailed and full risk assessments for all potential hazards could be very resource intensive and derail accomplishing priority mitigations. Subject matter experts can assist the community in this process.

Hazard assessment

For each priority hazard that will be assessed for risk, the probability of a certain hazard event magnitude needs to be determined. They, like the hazard inventory for your community may already be determined. The national seismic hazard assessment is done by the Geological Survey of Canada, and that map and report's probabilistic assessment can be used directly in a risk assessment. Flood assessments were done as a program in British Columbia, though are now out of date. New ones are being developed locally (e.g. Fraser Basin Council consortium and municipalities). These assessments generally define the extent of 1 in 100 year and 1 in 200 year probable events for riverine flooding. For some hazards, it is more important to consider the intensity or severity of the maximum credible event, rather than the magnitude or intensity of a particular probability of occurrence. These considerations are best made by an expert in the assessment of the hazard of concern.

Hazard scenarios

A hazard scenario is a collection of information that describes a potential hazard event. A hazard assessment would describe how probable an event may be. The hazard scenario describes what the consequences of a hazard would be. For instance:

> The 1 in 100 year flood assessment would describe the limit of the flooded area for that probability. The flood scenario would describe how deep the water is at each site in the flooded area. It would describe how long the water level would stay. It could describe how fast the water would flow in the different parts of the flood plain and how much debris may be in the water. Each of those factors could be used to interpret what would happen to the people and structures in the area near and in the flood zone.

An earthquake scenario would provide measures of how hard the ground would shake, in what way and for how long. It could include information about how the ground may be disrupted by liquefaction, elevation changes or other breakage. It could include information about landslides that may be triggered, fires that could be ignited or noxious chemicals that could be released. The more of these factors included in a scenario, the better the estimate will be of what the hazard event would damage or harm.

Probabilistic/Deterministic assessment

Two approaches are used to assess hazards and create scenarios. The probabilistic method extrapolates from records of known or interpreted actual past events and sums the potential at any one spot of all possible events occurring. The deterministic method interprets factors that would create a single hazard event.

Appendix L: Exposure (Community Inventory)

Once the hazard threats of concern are established, the next step is to determine which community assets and citizens could be exposed to those hazards. Understanding the exposure to a hazard requires understanding the map distribution of those assets and people. Therefore the exposure inventory is a map of community assets and people. The map inventory will visually and quantitatively identify what could be harmed or damaged by a hazard event. The key categories of the community inventory are:

- Population, socio-demographic data
- Information regarding built environment and infrastructure
- Natural resources

Inventories of these three are necessary to define the existing risk from hazards. Although this is a good starting place (e.g. a snapshot in time of population and the built and natural environment), it is recommended that plans stipulating future elements in the built environment and socio-demographic projections be used to understand the risk of development proposals. This is especially important in communities and areas where significant growth is expected. The more thorough the inventory (and its vulnerability information), the more thorough the loss-estimates that can be made in the risk assessment.

Population and Socio-demographic data

- This type of data is available from Statistics Canada. It is informed practice to use the most recently available figures at the most detail available (census tracts)
- There are methods and tools for grouping and associating various socio-economic indicators (e.g. the SoVI Index: Online at University of South Carolina, Keywords “hvri, sovi”) and the modified SoVI index as adapted for use in Canada[42]
- more detailed Statistics Canada data is available through the Community Data program[43].

Time of day and Travel

- Data on travel patterns and employment location of residents is particularly useful as it indicates potential location of residents at various times of the day (to inform hazard scenarios)

[42] Journeay, J.M. 2014: Disaster Resilience by Design: A framework for integrated assessment and risk-based planning in Canada; Geological Survey of Canada, Open File 7551, 336p.
[43] Community Data website. 2015.

Built environment

- Inventories of buildings and infrastructure are used to calculate the potential damage resulting from model hazard events. This information is generally available within municipalities, as it is used for planning and budgeting.

Infrastructure information useful to collect:

- Transportation: Roads, Rail lines, Bike routes, Trails, Bridges, Overpasses, Tunnels
- Homes: Houses, detached, stratas, boats
- Schools: primary, secondary, higher
- Community facilities: Community centres, police, fire, town hall, parks, libraries
- Transmission: electrical (lines and substations), water (pipes, treatment plants, distribution centres), gas (pipes, treatment plants, distribution centres), sewer (pipes, treatment plants, distribution centres), communications (transmission receiving stations, towers) Cables (underground and above ground)
- Industry: location and hazardous materials

Data sources include:

- Statistics Canada
- BC Assessment Data (which includes parcel level information regarding: building and land values, year built, use type, square footage)
- Municipal and regional public works and engineering departments
- Local university departments studying hazard risk (Civil engineering, Planning, Earth Sciences) may have gathered information for their risk assessment research

Other general data sources:

- Integrated Cadastral Information System (federal project to map rights and interests on land.[44]
- Community Data program in BC. [45]

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[44] NRCan website. 2015. Earth Sciences, Boundary, Cadastral Management.
[45] Communitydata website. 2015.

Once you have both an understanding of relevant hazards and a community inventory, the vulnerability of the assets of the community inventory is determined.

Appendix M: Vulnerability

Vulnerability (susceptibility to harm or damage) is a complicated part of determining potential losses and risk. Quantitative vulnerability of types of North American people, structures and natural resources has been determined for a few types of hazard. Vulnerability is the potential for a life (people included) or an object (buildings, infrastructure and other things) to be harmed or damaged to some degree during a particular type of event. For example:

> What damage would a 2 story wood-frame house built under the 1990 building code in British Columbia suffer if flood water were to reach 1.5 metres above the floor of the first level and stay there for 2 days. That probable damage is the vulnerability of such a house to flood water of that type.

The data is gathered by structure types, rather than individual structures. Several key factors of damage susceptibility of a structure are important for any particular type of hazard. The engineering and social factors that govern damage susceptibility are many and varied. A few examples are given to give clearer meaning to vulnerability. It is presently out of the guide's scope to include comprehensive databases for vulnerability to a hazard (see Table M-1 for references to some vulnerability databases).

For flooding, damage susceptibility of a building is primarily a factor of water damage and siltation. Therefore, construction material susceptibility to water damage is most important. The type of flooding would govern whether flow velocity and water borne debris would cause a large percent of damage to a structure. For bridges, damage is often caused by undercutting the foundations by the force of flowing water and by water-borne debris.

For flooding, harm susceptibility of a person in a house is primarily a factor of how deep the water is in the house and how long the water stays. The deeper the water the less safe space is available to the person. Prolonged deep water requires evacuation and new shelter requirements. No access to heat, clothing, safe drinking water, sanitation and being cut off from supply sources for any length of time will harm the person's health.

For earthquakes, damage susceptibility of a building is primarily a factor of the construction to withstand shaking. Therefore, construction style and materials, and ground conditions are important factors for measuring vulnerability of a building to an earthquake. In British Columbia, building codes have evolved since the 1960s, each 5 to 10 years requiring construction that better withstands earthquake shaking induced collapse. Therefore the year of construction of a building is important in determining its vulnerability to shaking. Buildings may be built before codes (pre-code) or recently with stringent codes (high-code).

The most comprehensive vulnerability database is included with the loss-estimation tool Hazus-MH (Appendix L). It has vulnerability measures of most structures for earthquakes, floods, hurricanes and storm-surges. Hazus-MH includes a database of damage functions and fragility curves that describe the amount of damage that would occur for a particular structure exposed by some degree to a hazard event. The Hazus-MH damage function database is useful for any quantitative hazard event loss-estimate.

The nature of your vulnerability data needs will be dictated by your risk assessment tool. Qualitative tools would rely on the opinions of subject matter experts in the fields of structural damage and human harm due to hazard events. In qualitative tools, the key vulnerability measures by resource, structure or person are established in tables that permit experts to record the percentage of anticipated damage to a structure or harm to a person. These can be in part derived from quantitative vulnerability databases. Table M-1 provides examples of sources of hazard vulnerability information.

Social vulnerability data is available for some hazards through the Social Vulnerability Index[46] (SoVI). Journeay has adapted the SoV index for use locally in Canada[47]. Dunning and Durden[48] review social vulnerability tools.

Table M-1. Sample sources of vulnerability information

HAZARD	**PEOPLE; ASSETS; ENVIRONMENT; or ALL OF THE ABOVE**	**REFERENCE**	**NOTES**
Debris flow	Assets	Jakob, M., Stein, D., Ulmi, M. 2012. *Vulnerability of buildings to debris flow impact.* Natural Hazards, v. 60, no. 2, p241-261.	Debris flow vulnerability as determined from literature on debris flow losses.
Debris flow	Assets	Zhu, Z.Q., Ding, S.J., Lu, X.L. 2012. *Research on Debris Flow Damage to Transmission Lines and Corresponding Measures.* Disaster Advances, v. 5, no. 4, p1043-1045.	Debris flow vulnerability as determined from literature on debris flow losses.
Earthquake	People and Assets	FEMA. 2014. *Hazus-MH 2.1 Earthquake Technical Manual. FEMA media library webpages*	Data tables of quantitative fragility graphs for USA demographics, structures and infrastructure: includes fires triggered by the earthquake
Earthquake	Assets	Gueguen, P. 2013. *Seismic Vulnerability of Structures*. Wiley-ISTE, ISBN 978-1-84821-524-5, 368pp.	Collection of papers on international analyses

[46] Cutter, S.L. 2003. *Social vulnerability to environmental hazards*. Social Science Quarterly, vol. 84, no. 2, p242-261.
[47] Journeay, J.M. 2014. *Disaster Resilience by Design: A framework for integrated assessment and risk-based planning in Canada*; Geological Survey of Canada, Open File 7551, 336p.
[48] Dunning, C. M. and Durden, S. 2013. *Social Vulnerability Analysis: A Comparison of Tools*. US Army Corps of Engineers, Institute for Water Resources, website, 34p.

HAZARD	PEOPLE; ASSETS; ENVIRONMENT; or ALL OF THE ABOVE	REFERENCE	NOTES
Earthquake and Hurricane	Assets (bridges)	Kameshwar, S., Padgett, J.E. 2014. *Multi-hazard risk assessment of highway bridges subjected to earthquake and hurricane hazards.* Engineering Structures, v. 78, p154-166.	Damage functions for bridges exposed to earthquakes and hurricanes.
Explosion	Assets	Luccioni, B.M., Ambrosini, R.D., Danesi, R.F. 2005. *Analysing explosive damage in an urban environment.* Proceedings of the Institution of Civil Engineers – Structures and Buildings, v. 158, no. 1, p1-12.	Compilation of damage characteristics of explosions on some types of buildings in a dense urban environment
Flood	Assets	FEMA. 2014. *Hazus-MH 2.1 Flood Technical Manual. FEMA media library webpages*	Data tables of quantitative damage functions for USA structures, infrastructure and agriculture
Hurricane	Assets, People	FEMA. 2014. *Hazus-MH 2.1 Hurricane Technical Manual. FEMA media library webpages*	Data tables of quantitative damage functions for USA demographics, structures and infrastructure
Oil spill	People	D'Andrea, M.A., Reddy, G.K. 2014. *Health Risks Associated with Crude Oil Spill Exposure.*Americal Journal of Medicine, v. 127, no. 9. p886.e9–886.e13.	Single case study of the physical result on people who assisted with an oil spill clean-up.
Storm-surge	Assets	FEMA. 2014. *Hazus-MH 2.1 Hurricane Technical Manual. FEMA media library webpages*	Data tables of quantitative damage functions for USA structures and infrastructure
Tsunami	Assets	FEMA. 2015. *Hazus Tsunami Technical Manual.* In preparation.	Data tables of quantitative damage functions for USA structures and infrastructure
Tsunami	Assets (Port Business)	Hsieh, C.-H. 2014. *Disaster risk assessment of ports based on the perspective of vulnerability.* Natural Hazards, v. 74, no. 2, p851-864.	Pilot data analysis of post-disaster business continuity of a port facility. Hazus provides this type of analysis for the immediate effects of earthquakes, floods and hurricanes.
All hazard	People	Dunning, C. M. and Durden, S. (2013). *Social Vulnerability Analysis: A Comparison of Tools.* US Army Corps of Engineers, Institute for Water Resources, website, 34p.	
All hazard	People	Journeay, J.M. (2014) *Disaster Resilience by Design: A framework for integrated assessment and risk-based planning in Canada.* Geological Survey of Canada Open File, in review.	

Appendix N: Risk Mitigation

At this stage, results of a risk assessment are in hand. That risk assessment resulted in a local catalogue of hazards, and their threat to humans and the natural and built environment. The actual risk will have been compared to the community's preferred level of risk, and where the actual risk to unacceptable; a decision would have been made to determine how to reduce it to acceptable levels (how to mitigate the risk). How then to evaluate actions that would most effectively and efficiently reduce the risk to tolerable and acceptable levels? In practical terms, how can the risk be reduced the most for the least cost.

First, the community must understand its risk management objective. Commonly the primary objective is to save lives. Other objectives can be broadly classified as reducing economic losses, social disruption and environmental degradation. The community's choice of objectives should be reflected in the community's risk tolerance criteria (Appendix F).

Establish Mitigation options and priorities for risk reduction

Risk mitigation can be considered for each of the three components of risk: 1) hazard, 2) exposure and 3) vulnerability. Primarily safe land-use decisions mitigate exposure to the hazard, and may require mitigation of the hazard. Mitigation of the vulnerability is the realm of structural codes and social supports. Table N-1 provides examples of risk mitigation types to guide thinking about mitigation options.

Table N-1. A sample of the categories of risk mitigation and their cultural categories

RISK CATEGORY	MITIGATION EXAMPLE	CULTURAL DECISION CATEGORY	MITIGATION TOOL[49]
Hazard	Dikes to hold back flood water (riverine or coastal flood)	Land use	Dyking legislation, by-laws, regulations, and management authorities
Hazard	Nets to capture debris from flood water (debris flood)	Land use	By-law and management authority
Hazard	Bolts to hold rock slabs on a rock face (landslide)	Land use	By-law and management authority
Hazard	Secure containment of toxic and explosive chemicals (industrial accident)	Chemical Management Plan Social code[50]	Legislation, regulations, management authority

[49] Research for mitigation improvement is universal to this section and is not repeated for each case.
[50] A social code is used here to denote behaviour management rules such as seat-belt laws, smoking controls, helmet laws, driving licences, access rules.

RISK CATEGORY	MITIGATION EXAMPLE	CULTURAL DECISION CATEGORY	MITIGATION TOOL[49]
Hazard	Clear ground fuel sources from forests and reduce vegetation routes for fire (interface fire)	Land use	By-law, Development Permit Area, management authority
Hazard	Use antibiotics only when absolutely necessary, and ensure it fully kills the infectious agent (Infectious diseases)	Social code	Health management authority
Hazard	Drain sloped areas susceptible to sliding when supersaturated (debris-flow)	Land use	By-law, Development Permit Area, management authority
Exposure	Keep riverine flood plains for the use of the river and do not build permanent structures on them (riverine flood)	Land use	Development Permit Area, Official Community Plan, Regional planning authority[51]
Exposure	On a riverine flood plain, build a permanent structure so its critical functions are above the highest flood water level (e.g. mounds, stilts, sacrificial lower levels, floating homes)	Building codes[52] Land use	Legislation, by-law, regulation, Development Permit Area
Exposure	Evacuation system that includes: warning, escape routes, public transportation (includes support for mobility impaired), emergency support services (shelter, food, water, clothing, psycho-social) (multi-hazard, e.g. tsunami, hurricane, debris-flow)	Land use Social code	Legislation, by-law, regulation, Emergency Management Authority,
Exposure	Require property setbacks from railway lines (derailment)	Land use	Legislation, by-law, Guidelines for New Development in Proximity to Railway Operations[53], management authority
Exposure	Wash your hands when they are exposed to foreign objects and quarantine yourself when you are ill (infectious diseases)	Social code	Health management authority
Exposure	Restrict construction in high probability landslide runout areas (landslide)	Land use	Legislation, by-law, regulation, Development Permit Area
Vulnerability	Use water proof construction material and sealed connections (flood)	Building code	Legislation, by-law, regulation, building authority
Vulnerability	Structural elements that maintain a building's structural integrity through strong shaking (earthquake)	Building code	Legislation, regulations, building authority

[51] An example is the Toronto and Regional Conservation Authority that manages land use within the region's flood prone areas: www.trca.on.ca
[52] Building codes are used here to refer to all codes used to control the construction of structures (Building, Fire, Electrical, Plumbing)
[53] FCM and RAC. 2013. Guidelines for new development in proximity to railway operations. Federation of Canadian Municipalities and the Railway Association of Canada, 122p.

RISK CATEGORY	MITIGATION EXAMPLE	CULTURAL DECISION CATEGORY	MITIGATION TOOL[49]
Vulnerability	Foundational pilings that penetrate liquefiable soil (earthquake)	Building code	Legislation, regulations, building authority
Vulnerability	Multistory building designed with lower floors that have collapsible walls (tsunami)	Building code	Legislation, regulations, building authority
Vulnerability	Increase immune system with vaccines and healthy living habits (infectious diseases)	Social code	Health management authority
Vulnerability	Fire retardant cladding on roofs and siding of buildings (wildfire interface)	Building code Land use	Legislation, by-law, management authority, Development Permit Area, Official Community Plan

It is presently beyond the guide's scope to include a comprehensive list and description of land-use mitigation options for all hazard types and magnitudes. Baxter et al.[54] provide a list of some mitigation options and references to other FEMA sources with options and descriptive background (see also FEMA[55]).

It is important to include mitigation strategy into long-range plans, including Official Community Plans and capital plans. Include the operational component of the strategy in on-going municipal management systems.

Armed with the measures of hazard risk and the risk tolerance criteria; options for achieving acceptable risk can be evaluated using a standardized model for cost-benefit analysis. The most effective way to evaluate a mitigation option is to re-run the risk assessment for the community where it includes the potential mitigation.[56,57] Then compare the amount of existing risk to the mitigated risk to measure the risk reduction achieved for the cost of the mitigation. Such runs are most efficient for quantitative risk assessment methods.

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[54] Baxter et al. 2013. Mitigation ideas: A resource for reducing risk to natural hazards. United States of America, Federal Emergency Management Agency, 88p.

[55] FEMA. 2013. Local Mitigation Planning Handbook; US Federal Emergency Management Agency (FEMA). - See Chapter 6.

[56] Wein, A.M., Journeay, M. & Bernknopf, R.L. 2007. Scenario-Based Risk Analysis within an Analytic-Deliberative Framework for Regional Risk Reduction Planning. In Oxley, L. and Kulasiri, D. (eds) MODSIM 2007 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2007, p 1688-1695. MSSANZ website as Document "Scenario-Based_s32_Wein_.pdf"

[57] Journeay, J.M. 2014: Disaster Resilience by Design: A framework for integrated assessment and risk-based planning in Canada; Geological Survey of Canada, Open File 7551, 336p.

Appendix O: Development Decision-Making

Building permits, development permits and subdivision approval in this region are all granted by the Approving Officer (AO) of the local authority. This is a critical decision-making role and the person fulfilling it should work closely with a team of staff to ensure that due consideration is given to hazard risk and ***community*** resilience in every project proposal. If each site is assessed as 'safe for use intended' without considering cumulative impacts and effects of risk transfer, then risks will build up over time to unacceptable levels.

- Most of the development occurring in this region is through the development permitting process, as opposed to subdivision
- Since 2004, the AO is also responsible for approving development in the floodplain (such proposals had been previously considered by the province)
- The AO has the authority to require reports from the project proponents, such as environmental assessments, or hazard studies, that help determine site suitability.
- AO's can approve, reject or allow with covenant the proposed project
- Covenants are used for site-specific control, and are registered against title of the land (e.g. runs with the land), they can be used for subdivision or building permits

Subdivision approvals

To incorporate risk reduction in the subdivision approval process, the following are key concerns:

- Do subdivision regulations restrict subdivision of land within or adjacent to hazard areas?
- Do regulations provide for cluster subdivisions in order to conserve protective systems where appropriate?
- Do regulations allow for transfer of density (TOD) where hazards exist?

Development permit review

A risk management approach to development review requires that a proposed project be examined from a systems perspective and taking into account cumulative effects. For example:

- how does the proposed project fit into the neighbourhood or community as it changes over the projected life-cycle?
- what are the effects of a proposed development on surrounding properties?
- what kind of increased runoff can be expected and, what effects will this have for stormwater management?
- what are the impacts on the transportation network and evacuation routing/capacity?

In weighing the costs and benefits of development proposals informed practices suggest the following:

- include the human/social, physical/built environment, and economic
- use a reference to costs of past events as benchmark and examine a portfolio of hazard scenarios
- multiple accounting valuation, full-cost accounting
- include a way to account for caring for the land (as opposed to just accounting for negative impacts on the land)
- **Transfer of Density**: market-based technique that encourages voluntary transfer of growth from places where a community would like to see less development (sending area) to places where a community would like to see more development (receiving area). Sending areas would be environmentally-sensitive or high-hazard lands. Receiving areas are places where the community has agreed to increased development, because of proximity to jobs, shopping, transportation and other amenity.

Sometimes the only way to preserve high hazard lands is to buy property rights. Example from Salt Spring Official Community Plan:

> "The Local Trust Committee should consider rezoning applications from property owners who wish to transfer their development potential from areas identified on Maps 13 and 14 as subject to natural hazards. Specific areas should be considered "Development Potential Donor Areas", even if they are in a Designation that is a Development Potential Receiving Area. Applications should meet the guidelines in Appendix 4. The LTC should consider preparing new mapping of areas subject to natural hazards and refine "Development Potential Donor Areas"."

Real estate and developers

- Municipalities have greater authority to reduce or waive development cost charges (DCCs) as a result of Bill 27 (Green Communities)

Building codes

Building codes complement land-use guidelines and are often more effective when used together. The building code is adopted by the province of BC. It is one of the few tools that works at addressing renovations and retrofits in the existing built environment. The Building Code is adopted by municipalities, who can modify it to suit their interests, and cannot undermine it.

Sample Policy Goals and Their Measures with an Economic Emphasis[58]

SUSTAINABILITY INDEX	POLICY GOAL	INDICATOR	INDICATOR MEASURE
Social	Social strength	Exposure	probability of exposure of a person in time and space to a hazard
		Agency	percentage of self-independence based on numbers of people with certain personal income, education level, shelter expenses/income and ethnicity
		Coping capacity	percentage based on age, education, gender, language and family structure
	Public safety	Casualties	number of deaths and injuries
		Displaced people	number of people displaced from their homes
		Shelter needs	number of people needing emergency shelter
Economic	Physical strength	Direct damage	percent of structures damaged
		Levels of protection	losses avoided minus costs of mitigation
		Induced damage	loss of employment and income
	Economic security	Capital loss	cost of percent damage of buildings and infrastructure, inventory loss
		Income loss	Dollar value of lost income during recovery time
		Probable loss	monetary value of all losses of a probable disaster scenario
	System functionality	Resistance	percent of structures that resist damage from a hazard event
		Disaster debris	tons of debris
		Recovery time	percent deviation from planned disaster recovery time
Environment	Environmental safety	Quality	percent change in life sustaining quality of air, water, flora and fauna
		Casualties	percent loss of flora and fauna
		Habitat	percent loss of habitat

[58] Adapted from Journeay, J.M. (2011) *Extending the Capabilities of Hazus for Disaster Mitigation and Comprehensive Land Use Planning. Seattle: Hazus Users Conference Proceedings.*

Appendix P: Monitoring and Evaluating

Monitoring and evaluation helps ensure learning and operational improvements, which translate into cost savings over time. Monitoring should assist in understanding the impacts of development on hazard risk and vice versa. Creating a culture of monitoring and evaluation in your community requires setting clear indicators and targets (e.g. a range of activities to be measured). The monitoring culture can be built through community engagement. Such community participation can provide many "eyes on the ground" for public structures and infrastructure. Another mechanism may be more useful for monitoring the ongoing hazard risk changes of private structures, where personal interests could interfere with objectivity.

Compliance monitoring: building and site

Informed practices:

- monitoring/maintenance schedule for drainage, foundations, containment walls etc. (monitoring based on design objectives)
- assessing condition/strength of infrastructure (e.g. overpass, bridges)
- building health assessments
- review of extended impact factors
- time of sale of property could be an intervention point for monitoring, requiring retrofit/alteration of parcel?

Coordinating development permitting and strategic planning

Informed practices:

- at the municipal level, to have planners take turns in both the strategic planning role and the development permitting role so that there is synthesis between short term decision making and long term objectives
- monitoring and evaluation relates back to and informs the development approval process, and development permit areas

Data management

Ongoing updates of:

- plans and bylaws (digital repository)
- data: socio-demographic (Stats Can, other analyses, as included in OCP)
- data: built environment (critical infrastructure/facilities, building data)

- hazard info: as updated, commissioned reports or external sources (e.g. other levels of government), climate change projections

Repetitive Loss Avoidance Accounting

Calculate the losses avoided through implementation of the risk mitigation. The calculation provides a measure of the value of the benefit for the cost of the mitigation. The calculation is done using the same technique for determining the model risk of a mitigation for various options of development. That technique calculates the risk for each proposed development and compares the difference in risk. FEMA[59] and Journeay[60] describe the technique. Calculation of the actual loss avoidance compares the actual losses of a hazard event to those that may have occurred if high risk development proposals had been accepted (non-mitigated).

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[59] FEMA 2009. Loss Avoidance Study, Riverine Methodology Report.

[60] Journeay, J.M. 2014: Disaster Resilience by Design: A framework for integrated assessment and risk-based planning in Canada; Geological Survey of Canada, Open File 7551, 336p.

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