Syilx Okanagan Flood and Debris Flow Risk Assessment

Report 2 of 4: Basis of Study

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Cover Photo: Winter sunrise over Similkameen River near the mouth of Wolf Creek, March 2018.
Ebbwater Consulting Inc. image.

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This Assessment is a testament to the power of collaboration and partnership between *Syilx* and non-*Syilx* organizations, including the project team at Ebbwater Consulting Inc. (Ebbwater), and exhibits a shared concern for how water is managed and recognized in the territory.

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List of Acronyms and Abbreviations

AEP	Annual Exceedance Probability
AHRA	All-Hazards Risk Assessment
AIDR	Australian Institute for Disaster Resilience
ATV	All-terrain vehicle
BC	British Columbia
CEPF	Community Emergency Preparedness Fund
CIRNAC	Crown and Indigenous Relations and Northern Affairs
DFA	Disaster Financial Assistance
DMAF	Disaster Mitigation Adaptation Fund
DPA	Development Permit Area
EMBC	Emergency Management British Columbia
FCL	Flood Construction Level
FLNRORD	Ministry of Forests, Lands, Natural Resource Operations and Rural Development
FNESS	First Nations Emergency Services Society
FNFC	First Nations Fisheries Council
FNLC	First Nations Leadership Council
FOI	Freedom of Information
FPIC	Free, prior, and informed consent
IDF	Intensity-Duration-Frequency
INFC	Infrastructure Canada
IPCC	Intergovernmental Panel on Climate Change
ISC	Indigenous Services Canada
LSIB	Lower Similkameen Indian Band
MOTI	Ministry of Transportation and Infrastructure
NDMP	National Disaster Mitigation Program
NGO	Non-governmental Organization
OBWB	Okanagan Basin Water Board
OCP	Official Community Plan
OKIB	Okanagan Indian Band
ONA	Okanagan Nation Alliance
PIB	Penticton Indian Band
PSC	Public Safety Canada
RAAD	Remote Access Archaeology Database
RAIT	Risk Assessment Information Template
REABC	Real Estate Foundation of BC
RDCO	Regional District of Okanagan-Similkameen
RDNO	Regional District of North Okanagan
RDOS	Regional District of Okanagan-Similkameen
RGS	Regional Growth Strategy
RIBA	Royal Institute of British Architects

Sendai	Sendai Framework for Disaster Risk Reduction
TEK	Traditional Ecological Knowledge
TRC	Truth and Reconciliation Commission
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
UNDRR	United Nations Office for Disaster Risk Reduction
US	United States
USIB	Upper Similkameen Indian Band
WFN	Westbank First Nation
WSA	Water Sustainability Act

1 Introduction

This risk assessment project was initiated by the Okanagan Nation Alliance, funded by the National Disaster Mitigation Program (NDMP), and completed from September 2018 to December 2019. It is the initial phase of a multi-year flood and debris flow adaptation initiative. **The goal of this project is to understand the risk due to flood and debris flows within the Okanagan-Similkameen region and support priority-setting for future work**. This report provides background information, including on geography and geohazards of the project area, as well as the project framework and a primer on risk assessment.

The *Syilx* Okanagan people are respectfully acknowledged as a distinct and sovereign Nation – the original and enduring inhabitants of this region. The *Syilx* Okanagan Nation is a trans-boundary tribe separated at the 49th parallel by the border between Canada and the United States. The Nation is comprised of eight member communities in the southern interior of British Columbia and northern Washington State. The Okanagan Nation Alliance (ONA) represents member communities on areas of common concern with a mandate to work collectively to advance and assert *Syilx* Okanagan Nation title and rights.

Today, the Okanagan-Similkameen region is a desirable place to live and the region is home to over 360,000 people (Statistics Canada, 2016) and welcomes many visitors annually. In recent years, flood and debris flows have become an increasing concern across *Syilx* Okanagan Territory. Climate change was identified as a key driver for recent flooding in BC[1]. Furthermore, research indicates that, in addition to climate change, other cumulative pressures are making disasters, including flood and debris flows, worse. These pressures include ecological disturbance (e.g. wildfires), urban development, and industrial activities. It is well known, but perhaps not readily acknowledged, that cumulative pressures are strongly linked to human activities. In the Okanagan-Similkameen region, these human-related pressures did not exist, as we understand them today, prior to European settlement.

The project is unique in that it sees risk through the lens of Indigenous people. The Okanagan Nation Alliance is confident that by incorporating *Syilx* Okanagan values, perspectives, and processes into regional planning efforts, a new way of working with nature will emerge that is to the benefit of everyone, inclusive of the *tmixʷ*. Indeed, newcomers to the region have much to learn from those who lived on the land prior to the time when the problems arose. Furthermore, leaders in the region have a responsibility to help those who have been disproportionately impacted by recent events, particularly First Nations, as documented in the *Abbott/Chapman Report*.

In addition to this project, the Okanagan Nation Alliance is working on water and ecosystem-based management more broadly, and is exploring different approaches to risk assessment that can draw from and emphasize *Syilx* Okanagan perspectives. In line with best practice, the ONA is focusing on risk reduction by applying a planning process based on community values considering a range of hazard levels, including the effects of climate change. The project outputs will be a resource for everyone in the region

[1] Addressing the New Normal: 21st Century Disaster Management in British Columbia" (EMBC 2019, and referred to herein as the *Abbott/Chapman Report*).

to achieve mutual objectives. This report provides key background gathered from literature reviews, online research, and personal communications. It is intended to be read as a precursor to the Qualitative and Quantitative Studies, which form the core of the risk assessment.

1.1 *Syilx* Okanagan Nation

The *Syilx* Okanagan people have inhabited the interior plateau and applied knowledge systems here since the beginning of time, sharing the same land, *nsyilxcən* language, culture, and customs. *Syilx* Okanagan people are self-reliant and well provided for through ingenuity and use of the land and resources.

Archaeological records place *Syilx* Okanagan people here approximately 10,000 years ago with the last glacial retreat (Sam, 2013). The estimated number of *Syilx* Okanagan people who inhabited the territory prior to 1811 varies from approximately 2,000 to 10,000 (Sam, 2013). They travelled the breadth and depth of the territory, hunting, fishing, growing, harvesting, and trading.

The *Syilx* Okanagan Nation is a sovereign Nation which never signed treaties with European settlers and holds title and rights to the lands and waters within the territory. The *Syilx* Okanagan Nation has always governed these lands according to principles that are embedded in *captíkʷɬ* (oral stories) that derive from these diverse ecosystems. These principles carry a sacred, inherent responsibility to care for *tmixʷ* (all life forms), *tmxʷulaxʷ* (land), and *siwɬkʷ* (water).

The *Syilx* Okanagan people's way of life was dramatically disrupted with first European contact in 1811. The subsequent influx of immigrants upset the equilibrium in the region, resulting in the social marginalization of the *Syilx* Okanagan people and ongoing impacts on their sovereign territory including ecosystem degradation, severe water quality deterioration, and extreme stress on local ecologies and species loss at a scale and rate that is unprecedented.

Today the *Syilx* Okanagan people continue to assert jurisdiction and responsibility over the stewarding of these land and resources. The *nsyilxcən* language and *Syilx* Okanagan culture respectfully honour the natural laws of the *tmixʷ* – that which gives us life.

1.2 Objectives

Over the course of the project, a series of objectives evolved based on the direction from ONA and the granting agency, along with what could be accomplished within the project's timeline. Best practice dictates that adaptation to natural phenomena such as flood and debris flows be achieved through a thoughtful, risk-based planning process based on community values. Considerable effort for this project was focussed on process—it was important to embrace a diversity of perspectives and to build relationships across organizations in the region.

1. **Better understand flood and debris flows and how they impact the region.** The first aspect of this objective was to better understand these phenomena (also called natural hazards), and to analyze where they intersect with "the things that matter to people in the region" (i.e., exposed assets). The relevant analyses are included in both the Qualitative and Quantitative studies. With knowledge that hazard and risk is dynamic, a high-level literature review was conducted to provide a holistic, watershed-scale perspective of "why the hazard is increasing". This literature

review is found in Chapter 6 of this document. Addressing these pressures is an opportunity for risk reduction, and can form a more comprehensive understanding of adaptation options.

2. **Apply diverse perspectives in assessing the risk from these natural phenomena.** A wealth of understanding about the lands and waters of this territory is found in the lived experiences of *Syilx* Okanagan people and in knowledge that has been passed down through generations. Non-*Syilx* Okanagan participants in the region can benefit from understanding the *Syilx* Okanagan worldview, management practices, and ideas. This process of listening to and learning from Indigenous people is recognized globally, including through the United Nations Declaration for the Rights of Indigenous Peoples (UNDRIP). The *Syilx* perspective is found in all of this project's documents, and especially in Chapter 4 of this report, and in the Qualitative Study. Risk was assessed technically in the Quantitative Study, but a holistic view of risk was woven and presented in the Synthesis and Recommendations report.

3. **Collaborate with local governments to strengthen and align risk assessment initiatives.** This project seeks to develop a common understanding of flood and debris flow phenomena and endeavours to lay a roadmap for consistency and alignment for future, more locally-targeted, projects. As such, it aims to support the integration of the ONA's objectives and worldview in initiatives in the region for flood and debris risk reduction, as well as emergency response and recovery decision-making. The project also aims to expand the ONA's external relationships and means of communication through participation in external workshops and meetings. This objective was addressed through engagement activities documented in the Qualitative Study. Best practice and regional initiatives are presented in the main body of this report, as well as its appendices.

4. **Provide supporting information for future funding and to prioritize adaptation actions.** The ONA wishes to use the outcomes of this work to inform current and future planning efforts in the territory. This includes water and ecosystem-based management plans, official community plans, zoning bylaws, development permit areas, etc. with the objective of reducing risk over time through adaptation actions. This project seeks to develop materials to support future funding applications, including more detailed and local risk assessments, project scopes, and costings. The relevant supporting information is contained in all of this project's reports.

1.3 Project Report Structure

This Basis of Study report forms part of this project's risk assessment supporting documents (Figure 1). This report provides background information that is relevant to the Qualitative and Quantitative Studies. Those studies are complementary, and their spatial outputs are contained in the Map Book. The Synthesis and Recommendations report summarizes and builds upon the information contained in the risk assessment supporting documents. The Synthesis and Recommendations report is intended for a more general audience and policymakers.

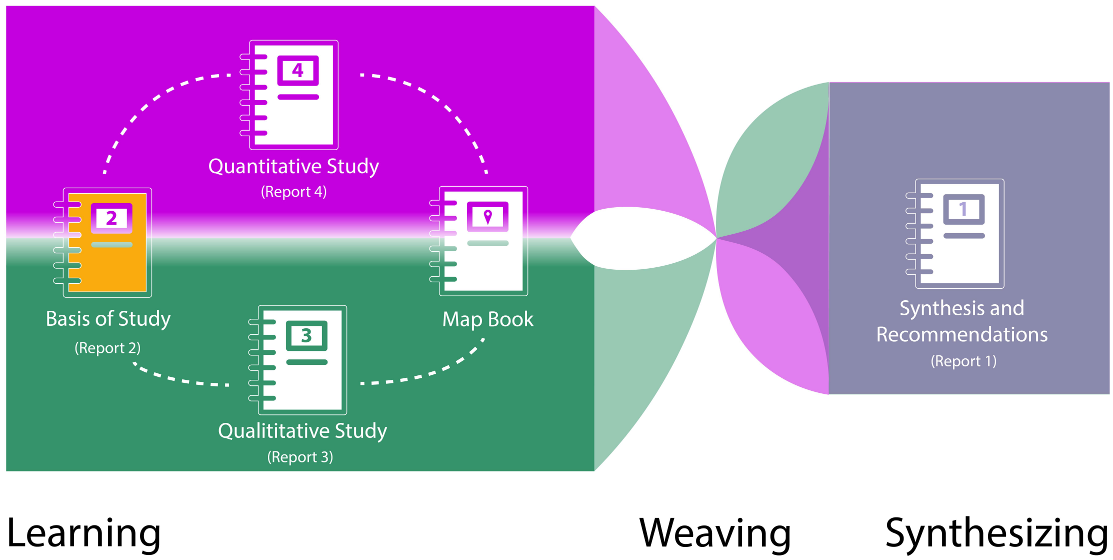

Figure 1: Project reporting diagram with the risk assessment's supporting documents (this Basis of Study report is highlighted).

This report begins by providing the project's geographic scope, including discussion on historical and recent flood and debris flow events (Chapter 2), and discussion on geohazards more broadly in the project area (Chapter 3). Next is a discussion on the project framework, including *Syilx* Okanagan perspectives within the approach taken (Chapter 4). A risk assessment primer then explains the general components of risk including hazard likelihood and consequence and other key concepts of risk and risk assessment (Chapter 5). The primer also introduces impact categories, discusses professional guidance and funding, and evolving risk assessment methods. This is followed by a literature review on the cumulative pressures on hazards to obtain a more holistic perspective of risk (Chapter 6). The next sections focus on frameworks to address the challenges explained in the previous sections, starting with best practice for disaster risk reduction (Chapter 7) and followed by governance models (Chapter 8). Chapter 9 contains this study's conclusion. Following the conclusion, a glossary of terms can be found before the references.

The appendices referenced in this report are as follows:

- Appendix A – External Steering Committee Terms of Reference: The terms that will guide the process of collaboration and sharing among participants, municipal governments, and *Syilx* Okanagan Nation participants.
- Appendix B – Updated Risk Assessment information template (RAIT): Form that is required to be filled out as part of the funding program deliverables.
- Appendix C – Climate Change Projections Science Primer: Technical background on methods used to develop climate change projections.
- Appendix D – Recently Funded Flood Initiatives: Summary and table with description, funding amounts, and progress status of publicly-funded project in the region.

- Appendix E – Review of Relevant Regional Planning-Level Initiatives: Details related to flood and debris flow hazards, and collaboration with Indigenous people scanned from regional growth strategies and watershed plans.

1.4 Language Clarification

Effort was made to decolonize the language used in this project. Importantly, this process allowed the authors to think about natural hazard risk assessment from the perspective of the *Syilx* Okanagan people. Several examples are shared below; however, it is clear that more work is required in this area with future projects.

- Names matter. "*Syilx* Okanagan community" is used rather than "Indian Band". "Non-*Syilx* Okanagan" or "settler" society is used to describe those people and areas that have been colonized largely by European descendants. "Project participant" rather than "stakeholder" was deliberately used to define those involved in the project.
- The project focused on people of the *Syilx* Okanagan Nation who live in the Okanagan-Similkameen region. The term "Indigenous" is used interchangeably with "*Syilx* Okanagan people" and also used in a broader sense when speaking about Indigenous knowledge, culture, and worldviews more generally. The worldviews of Indigenous people provide an important juxtaposition with the western worldview. However, caution is needed in recognizing the limitations of generalizing about Indigenous and western worldviews.
- The project refers to a "western" worldview, as well as western society and science. These terms are linked but distinguishing them can be confusing. For the purposes of this report, western society is understood to be settler people and their culture. Western science is the knowledge gained through the scientific process. Western science is one source of influence on the western worldview, which is manifested through western society. With this understanding, it is important to note that western science is not necessarily at odds with Indigenous knowledge.
- A number of *Syilx* Okanagan words and place names have been used throughout the reports. These words have been approved for use by *Syilx* Okanagan Elders through the community engagement process that was integral to the project.
- Floods and debris flows are referred to within this project interchangeably as "natural hazards" or, more technically specific, as "geohazards". The word "hazard" is used to remain consistent with common risk terminology. Within the typical context of risk assessments, hazards are viewed as events that have negative consequences. However, when viewed holistically these events can have positive effects on ecosystems for example (which is explained further in Section 3.3), meaning that not all hazards are bad. More neutral terms, such as "phenomenon" and "magnitude" sometimes replace risk terms such as "hazard" and "severity" which imply negative consequences.

2 Geographic Scope

This project has a broad geographic scope. The spatial study area is approximately 15,400 km^2 and includes those portions of the Okanagan and Similkameen watersheds located north of the Canada-US border (Figure 2). The study area makes up only a small part of unceded *Syilx* Okanagan territory (see Figure 2 inset). *Syilx* Okanagan territory is a large, diverse and beautiful landscape with the highest concentration of rare and threatened species in British Columbia (Okanagan Nation Alliance, n.d.)[2]. The following sections discuss the hydrography and climate, ecology, and societal setting of the project area. Past climate change trends are then discussed to set the context for historical and recent flood and debris flow events.

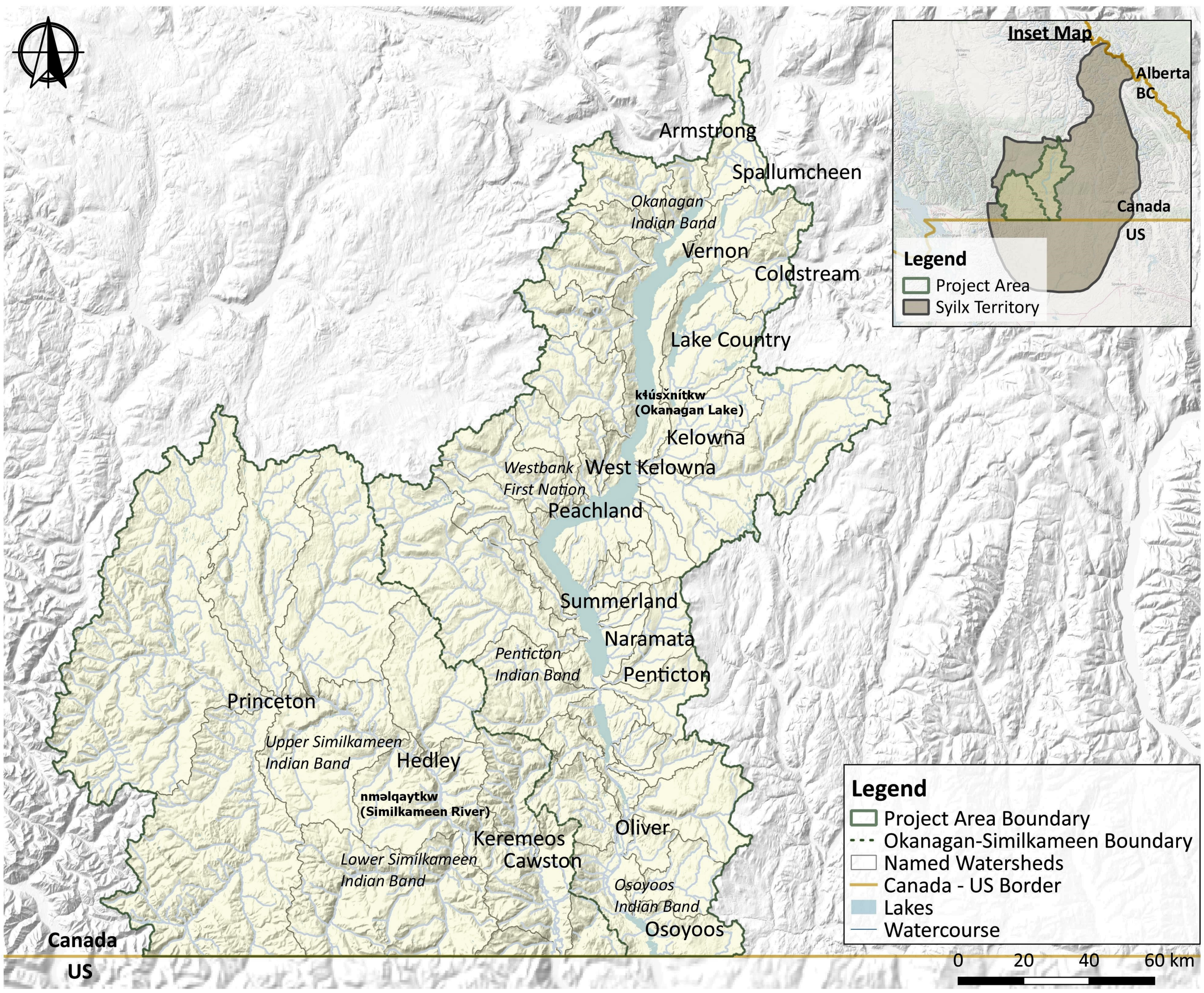

Figure 2: Project Area.

[2] *Nxwəlxwəltantət* "That Which Gives Us Life". Okanagan Nation Alliance (Book).

2.1 Hydrography and Climate

The project area includes the Okanagan River watershed including *kɬúsx̌nítkw* (Okanagan Lake) and the *nməlqaytkw* (Similkameen River) tributary watershed (Figure 2). The Similkameen is a river system, while the Okanagan is characterized by valley-bottom lakes, sides and flat valley bottoms. Elevations of the surrounding mountains vary from approximately 1600 m to 2600 m, with the highest peaks located in the southern portions of the Similkameen watershed. Each watershed consists of over 20 sub-watersheds[3] (Figure 5). Both rivers join a few kilometres south of the project area in the United States.

The region has a dry, continental climate due to its location in the rain shadow of the Coast and Cascade Mountain ranges. Precipitation is approximately distributed throughout the year with peaks around June and November (see Quantitative Study). Winter precipitation is driven by the atmospheric jet stream and summer precipitation is typically caused by surface heating of local lakes and streams. The southern extents of the study area (e.g. Keremeos, Osoyoos) are warmer and drier than more northern areas (e.g. Vernon). Precipitation also ranges depending on elevation, from just under 300 mm at lower elevations in southern regions, to approximately 770 mm in sub-alpine regions (Duke et al., 2008). Due to the region's dry conditions, water availability is sensitive to evapotranspiration loss as well as groundwater recharge and extraction[4].

Both watersheds are snowmelt-dominated, which means that the majority of annual streamflow is generated by spring snowmelt, occurring between May to July. Year-to-year flow variability reflects variations in snow accumulation and melt, precipitation, evapotranspiration, and groundwater storage patterns. As a result of these varying patterns within the project area's sub-watersheds, varying flood levels were experienced in the region in 2017 and 2018 (Section 2.6).

2.1.1 Okanagan Watershed

The Okanagan River watershed has an area of approximately 7,900 km^2. From north to south, the river flows through a series of "mainstem" lakes (Kalamalka, Wood, Okanagan, Skaha, Vaseux, and Osoyoos) whose flows are regulated to manage various services such as flood control; water supply; fisheries, aquatic, riparian, and environmental values; and recreation and tourism (Symonds, 2000). The natural lake systems are an important factor in the mainstem river's flood flows due to their attenuating effect. Flow regulation adds another layer of complexity to the attenuation effect.

About 83% of total streamflow in the watershed enters *kɬúsx̌nítkw* (Okanagan Lake), and areas downstream of the Lake (south of Penticton) generate the remaining runoff and streamflow[5].

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[3] The sub-watersheds are labelled as "Named Watersheds" in Figure 5. The small sub-watersheds surrounding lakes in the Okanagan watershed were grouped together for simplification.

[4] Approximately 80% of the region's precipitation is lost to evapotranspiration. The remaining precipitation becomes runoff or groundwater recharge. More information on the water balance specific to the Okanagan can be found here: https://www.obwb.ca/wsd/data/annual-water-balance

[5] Surface Water Hydrology. Okanagan Water Supply and Demand Project. Weblink: https://www.obwb.ca/wsd/data/surface-water-hydrology. Accessed May 15, 2019.

2.1.2 Similkameen Watershed

The nməlqaytkw (Similkameen River) watershed within the study area is approximately 7,500 km^2 in size. In contrast to the Okanagan River, the Similkameen River on the Canadian side has no dams and is unregulated. Compared to regulated flows in the Okanagan River, average annual peak yield in the Similkameen River is approximately ten times higher than flows within the Okanagan River (Table 1). This is due to the lack of attenuation from natural lakes and reservoirs with flow regulation that are present in the Okanagan. As well, the Similkameen region contains more higher-elevation areas receiving greater amounts of precipitation, which generates larger spring runoff volumes.

Table 1: Estimated peak water yield for the project watersheds.

Station Location	Flow Condition	Average Annual Peak Yield (1965-2015) ($L^3/s/km^2$)
Similkameen River at Hedley (WSC Station 08NL038)	Natural	70
Okanagan River at Oliver (WSC Station 08NM085)	Regulated	8

2.2 Ecology

> *tmixʷ*—This *nsyilxcən* word most closely translates as “ecology”. *tmixʷ* includes everything alive: the land, water, insects, people, animals, plants and medicines.

The study area lies in the interior plateau Southern Interior Ecoprovince (Demarchi, 2011), and includes Bunchgrass, Ponderosa Pine, and Interior Douglas-fir biogeoclimate zones in the valley bottoms, Montane Spruce and Engelmann Spruce-Subalpine Fir at higher elevations, and Alpine Tundra at the mountain peaks (MacKillop et al., 2018). The Ecoprovince contains a diversity of upland and aquatic habitats that vary from open grasslands to dense coniferous forests and from small ponds to large and deep lakes.

The region is a geographic link for many animals and its climate and landscape support boreal forest species such as *stunx* (Beaver), *pək’am’* (Lynx), Marten, *cr’ʔtups* (Fisher), and *skəm’xist* (American Black Bear), as well as grassland species such as the *p’ux̌ʷp’ux̌ʷəx̌ʷ* (Burrowing Owl), Long-billed Curlew, Gopher Sand Western Rattlesnake (Demarchi, 2011). The Ecoprovince has a large diversity of birds and holds 75% of all bird species known to occur in the province. Its wetlands and riparian habitats are highly biodiverse and include *aṙsikʷ* (Painted Turtles) and the *macq’ʷul’* (American Bittern).

The region’s water systems abound with anadromous fish species including Pacific Lamprey, *qwəyqwəyʕaćaʔ* (Steelhead), *ntytyix* (Chinook) and *sc'win* (Sockeye salmon), and *ćm'tus* (white sturgeon). Freshwater fish species include native and introduced *xʷminaʔ* (Rainbow trout), introduced brook trout, bull trout, mountain whitefish, lake chub, redside shiner, and northern squawk (Demarchi, 2011). From *Syilx* Okanagan perspective, other important aquatic species that need to be considered are *c'ẏy'xaʔ* (Crayfish) and *sk̓ʷuk̓ʷriṅaʔ* (Western pearlshell mussel).

2.3 Societal Setting

The study area for the project includes six *Syilx* Okanagan Nation communities (italicized below) and over 15 non-*Syilx* Okanagan local governments and communities, organized by watershed as follows:

Okanagan Watershed:

- City of Armstrong
- District of Coldstream
- Okanagan *Indian Band (OKIB)*
- Town of Oliver
- Town of Osoyoos
- *Osoyoos Indian Band (OIB)*
- City of Kelowna
- District of Lake Country
- Naramata
- District of Peachland
- City of Penticton
- *Penticton Indian Band (PIB)*
- District of Spallumcheen
- District of Summerland
- City of Vernon
- City of West Kelowna
- *Westbank First Nation (WFN)*

Similkameen Watershed:

- Cawston
- Town of Hedley
- Village of Keremeos
- *Lower Similkameen Indian Band (LSIB)*
- Town of Princeton
- *Upper Similkameen Indian Band (USIB)*
- Town of Tulameen

Non-*Syilx* Okanagan governance boundaries include three regional districts:

- Regional District of North Okanagan (RDNO)
- Regional District of Central Okanagan (RDCO)
- Regional District of Okanagan-Similkameen (RDOS)

An accurate representation of populations within the study area is difficult as census subdivisions do not match the watershed boundaries. Based on the 2016 census information and judgment, the total population in the study area likely currently exceeds 360,000, with in excess of 95% of these living in the Okanagan watershed.

2.4 Land Use

secondary land use types in the Territory include water, grassland, crops, and urban areas, based on a land use map obtained that covers the project area[6]. Agriculture is largely based on grazing and forage crops, as well as orchards and vineyards within the Okanagan Valley. The major land use type in Table 2 is dominantly forest/trees. However, the data does not contain detailed habitat fragmentation features (i.e., secondary roads, trails, and other linear infrastructure). From an ecosystem perspective, this is critical information.

In contrast to the spatial data summarized in Table 2, the habitat fragmentation data shown in Figure 3 provides a different perspective on the condition of the landscape. This is possible due to more detailed

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[6] Land Use 2010, Agriculture and Agri-Food Canada. Weblink: https://open.canada.ca/data/en/dataset/9e1efe92-e5a3-4f70-b313-68fb1283eadf. Accessed July 15, 2019.

land use information gathered with an objective that includes ecosystem health monitoring. The intact landscape is approximately 13% of the total area, which has important implications for animal habitat and ecosystem function. Note that the habitat fragmentation data is only available for the Okanagan watershed, but similar patterns could be expected for the Similkameen watershed. Section 6.2 contains further discussion on land use changes.

Table 2: Proportion of land use types in the project area (source: Agriculture and Agri-Food Canada, 2010).

Land Use Type	Area Size (Ha)	Proportion of Project Area (%)
Wetland	4,501	<1%
Roads	14,554	1%
Forest/Trees	1,339,746	86%
Crops	38,274	2%
Urban	28,601	2%
Water	54,499	4%
Other	18,377	1%
Grassland	53,028	3%

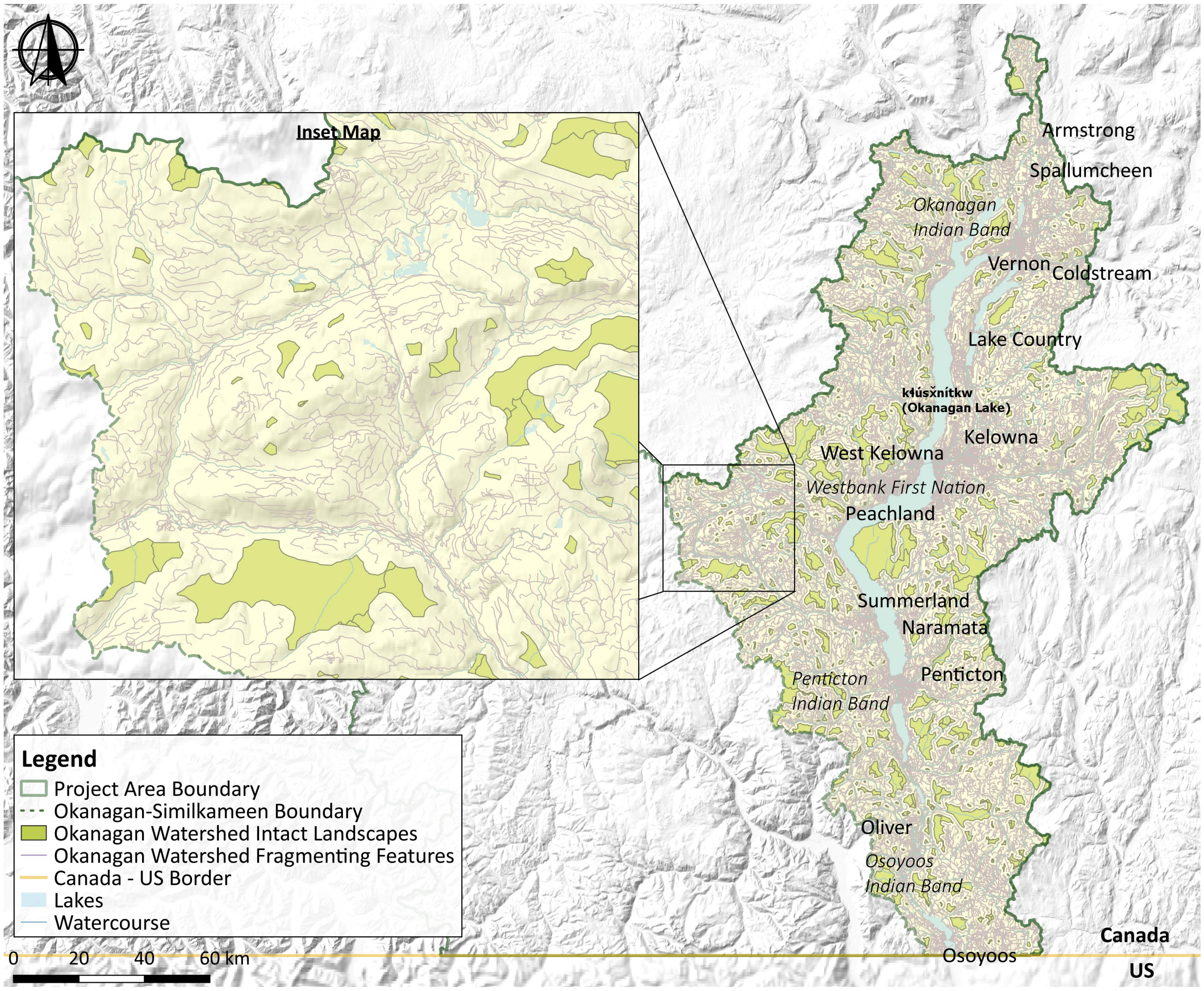

Figure 3: Okanagan watershed land use condition based on fragmenting features (Source: ONA).

2.5 Climate Change – Past Trends

Climate change is a key consideration in the project area. Historical trends show statistically significant increases in temperatures annually, and during winter and summer seasons (Ministry of Environment, 2016), as shown in Table 3. Changes in precipitation, snow, and glaciers have also been observed due primarily to the effect of rising freeze lines.

Table 3: Climate change trends for the Southern Interior Ecoprovince (adapted from Ministry of Environment, 2016).

Temperature (based on 1900-2013 data)		
Indicator	**Time Period**	**Change in °C/century**
Average	Annual	+0.9
Seasonal Average	Winter	+1.5
	Spring	Not significant[1]
	Summer	+0.6
	Fall	Not significant
Seasonal	Winter	+1.2

Temperature (based on 1900-2013 data)		
Indicator	**Time Period**	**Change in °C/century**
Minimum	Spring	+1.2
	Summer	+1.5
	Fall	+1.1
Precipitation (based on 1900-2013 data)		
Indicator	**Time Period**	**Change in %/century**
Average	Annual	+17
Seasonal Average	Winter	Not significant
	Spring	+32
	Summer	+22
	Fall	+17
Snow (based on 1950-2014 data)		
Indicator	**Time Period**	**Change in %/decade**
Snow water equivalent	Annual	-7
Snow depth	Annual	-11
Seasonal Average	Winter	Not significant
	Spring	+32
	Summer	+22
	Fall	+17
Glaciers[2]		
Indicator	**Time Period**	**Change**
Area	Annual	-45 km^2 (-12%)
Volume	Annual	-0.3 km^3/year [3]

Notes:
1: Refers to a lack of a statistical trend that is significant at the 95% confidence interval.
2: Area is based on 1985-2005, and volume is based on 1985-2000.
3: This volume of ice corresponds to approximately 400 soccer fields that are 100 m high.

Globally, a warmer atmosphere is capable of holding more water at a rate of 7% per degree Celsius (IPCC, 2013). This is leading to the intensification of the hydrologic cycle (Huntington, 2006) through a "higher energy" atmosphere, resulting in an increase in extreme precipitation and drought severity (IPCC, 2014). Climate change projections, including how these will affect climate-driven processes on the landscape, are discussed in Section 6.1 in the context of cumulative pressures on flood and debris flow hazards.

2.6 Historical and Recent Flood and Debris Flow Events

This section provides some background information to frame the extent of the problem of natural hazards in the project area, at a high level.

2.6.1 Historic Floods

The project area has a history of flood events, which were originally documented by Septer (2006). Based on summaries documented in Associated Environmental (Associated Environmental, 2016, 2017a), watercourses and lakes have flooded multiple times (with the specific number for each shown in brackets) during the period 1894 to 2015, as follows by watershed:

Okanagan Watershed:
- Okanagan Lake (12)
- Mission Creek (8)
- Mill Creek (4)
- Trout Creek (3)
- Kalamalka Lake (3)
- Vaseux (McIntyre) Creek (3)
- Penticton Creek (3)
- Shuttleworth Creek (3)
- Joe Rich Creek (2)
- McDougall Creek (2)
- Single Creek (2)
- Naramata Creek (2)

Similkameen Watershed:
- Similkameen River (17)
- Tulameen River (14)
- Hedley Creek (4)

2.6.2 2017-2018 Events

Widespread floods and debris flows were experienced in the project area in 2017 and 2018. Within the historical context, the events were exceptional. Accordingly, public discourse following the events questioned the role of climate change in their occurrence. The Government of BC's *Abbott/Chapman Report* (Abbott & Chapman, 2018), commissioned in late 2017, which also included unprecedented wildfires, suggested that, indeed, disaster management in BC needs to address a "new normal" due to climate change effects.

Figure 4: Flood and debris flow Highway 3 at Yellow Lake and Fairview Golf Course, 2018 (Source: RDOS).

In the Okanagan watershed in 2017, most areas experienced flows that approximated the 5% annual exceedance probability (AEP[7]; 20-year indicative return period)[8], but some areas such as Vernon and Penticton experienced flows that exceeded the 1% AEP (100-year indicative return period)[9]. Multiple factors played a role in flooding, with spring precipitation being central. Kelowna experienced the fourth-highest precipitation for the period of March to May, inclusive, on record. Vernon experienced the second-highest record for those three months while Penticton experienced the highest precipitation ever in that period[10].

[7] Refer to Section 4.2 for more detailed discussion on hazard likelihood, and how this is more accurately expressed as annual exceedance probability as opposed to indicative return periods.
[8] Personal communication, David Campbell, FLNRORD River Forecast Centre. March 20, 2019.
[9] What the Province learned from the flood so far. Kelowna Now. June 20, 2017. Weblink: https://www.kelownanow.com/watercooler/news/news/Kelowna/What_the_Province_learned_from_the_flood_so_far/. Accessed February 4, 2019.
[10] Personal communication, David Campbell, FLNRORD River Forecast Centre. March 20, 2019.

As a result of the high snowpack and spring precipitation, the inflows to Okanagan Lake during May 2017 were the highest on record, which caused the lake to rise to its highest level since the dam was built. Water levels were approximately 0.20 m above the estimated 0.5% AEP[11] (200-year indicative return period) (Associated Environmental, 2017). In 2018, the hazard levels were in the range of 2%-5% AEP (50 to 20-year indicative return period)[12], with impacts that included combined flood and debris flow events (Figure 4).

In the Similkameen watershed, hazard levels in 2017 were in the range of 10%-50% AEP (10 to 2-year indicative return period), which resulted in debris blockages (Figure 5). Larger events occurring downstream in the Hedley and Ashnola region. In 2018, there were hazard levels in the range of 20%-50% AEP (5 to 2-year indicative return period) in the Princeton area, and higher levels in the range of 2%-10% (50 to 10-year indicative return period) in the Hedley and Ashnola region[13].

Figure 5: Debris blockage upstream of a bridge on Princeton-Summerland Road, 2017 (Source: RDOS).

2.6.3 *Syilx* Okanagan Community Experience with Flooding 2017-2018

One of the key findings of the *Abbott/Chapman Report* was that First Nations faced disproportionate impacts across BC as a result of the 2017-2018 disaster events. All of the *Syilx* Okanagan communities were impacted by the 2017 and 2018 major flood events. Each community faced different challenges and impacts, but the shared experience paved the way for the Chiefs Executive Council (CEC) of the ONA to direct that a more proactive collective approach be taken to find ways to live more resiliently with flooding, including a comprehensive approach on how to move forward with mitigation efforts.

Upper Similkameen Indian Band experienced impacts more related to debris flows and landslides. In 2017, Okanagan Indian Band (OKIB) evacuated hundreds of homes and seasonal cabins along the lakeshore. In 2018, the impacts were mostly felt along the tributaries. As well, during the 2018 flooding, OKIB experienced significant losses to archaeology sites where erosion into Okanagan Lake caused major geomorphological impacts to the tributaries involved causing bank decay and sediment buildup. There are over 2000[14] known archaeology sites around the Okanagan lakeshore that should be reassessed after the flooding.

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[11] The 0.5% AEP is based on data that excludes recent extreme years, and does not consider climate change effects. Northwest Hydraulic Consultants Ltd. is currently revisiting the AEPs for Okanagan lake levels.

[12] Personal communication, David Campbell, FLNRORD River Forecast Centre. March 20, 2019.

[13] *Ibid.*

[14] Personal communication, Colleen Marchand, OKIB, October 19, 2018.

Syilx Okanagan communities express frustration that the current management of flooding is very reactionary. First Nations have no taxation dollars and need approval from EMBC before doing any work. It is not until the community is under flooding that EMBC can step in with a response.

Following are examples of shared experiences that draw a picture of natural hazard impacts that *Syilx* Okanagan communities have previously faced and continue to face today.

- In the months following an event, emergency response activities take priority. Since communities do not have specified emergency response staff, human resources are drained. There is lack of training to conduct emergency response adequately, and there is little or no capacity for leaders to focus on other important daily activities to keep the communities running effectively.
- During the 2017 and 2018 flood events, communities struggled to get funding dollars to manage flooding unless it was related to structural risk. This is because the National Disaster Mitigation Program requires communities to go through the process of flood mapping, a flood risk assessment, and structural and non-structural mitigation planning before funding dollars can be allocated and this includes the need for communities to collect the requisite data.
- Traditionally, *Syilx* Okanagan communities had ephemeral dwellings alongside water bodies, but these served as temporary places that were utilized for social and ceremonial reasons. During the times of year when flooding was prominent, people would leave these areas. It was due to the establishment of reserves that *Syilx* Okanagan communities were forced to live year-round in flood prone areas. Communities were also cut off from seasonal travel and use of areas beyond the allocated reserve boundaries.
- The overall experience of flood evacuation is emotionally difficult. In many cases, the direct threat to livelihood is exacerbated by the fact that flood evacuation camp settings have sensory triggers (e.g., the sound of the bells used to round people up) that can awaken intergenerational trauma from Indian residential school experiences.
- At the community level, there is a social conflict related to finding the balancing ecosystem health in times of flood (e.g., letting water go where it needs to go) while making efforts to preservation community structures and homes.
- *Syilx* Okanagan communities experience limited access and/or impacts to social uses of water during flood seasons which causes a shift in ceremonial and recreational events and capacities.

2.6.4 2017-2018 Impact Locations and Costs

The BC Ministry of Transportation and Infrastructure (MOTI) documented road infrastructure sites that were impacted by the floods in 2017 and 2018[15]. These locations appear as hotspots in Figure 6, which

[15] Personal communication, Gayle Keefe, MOTI Disaster Financial Assistance Project Manager. March 25, 2019.

represent greater concentrations of affected locations with denser colours. Figure 6 confirms that the hazard events occurred throughout the project area.

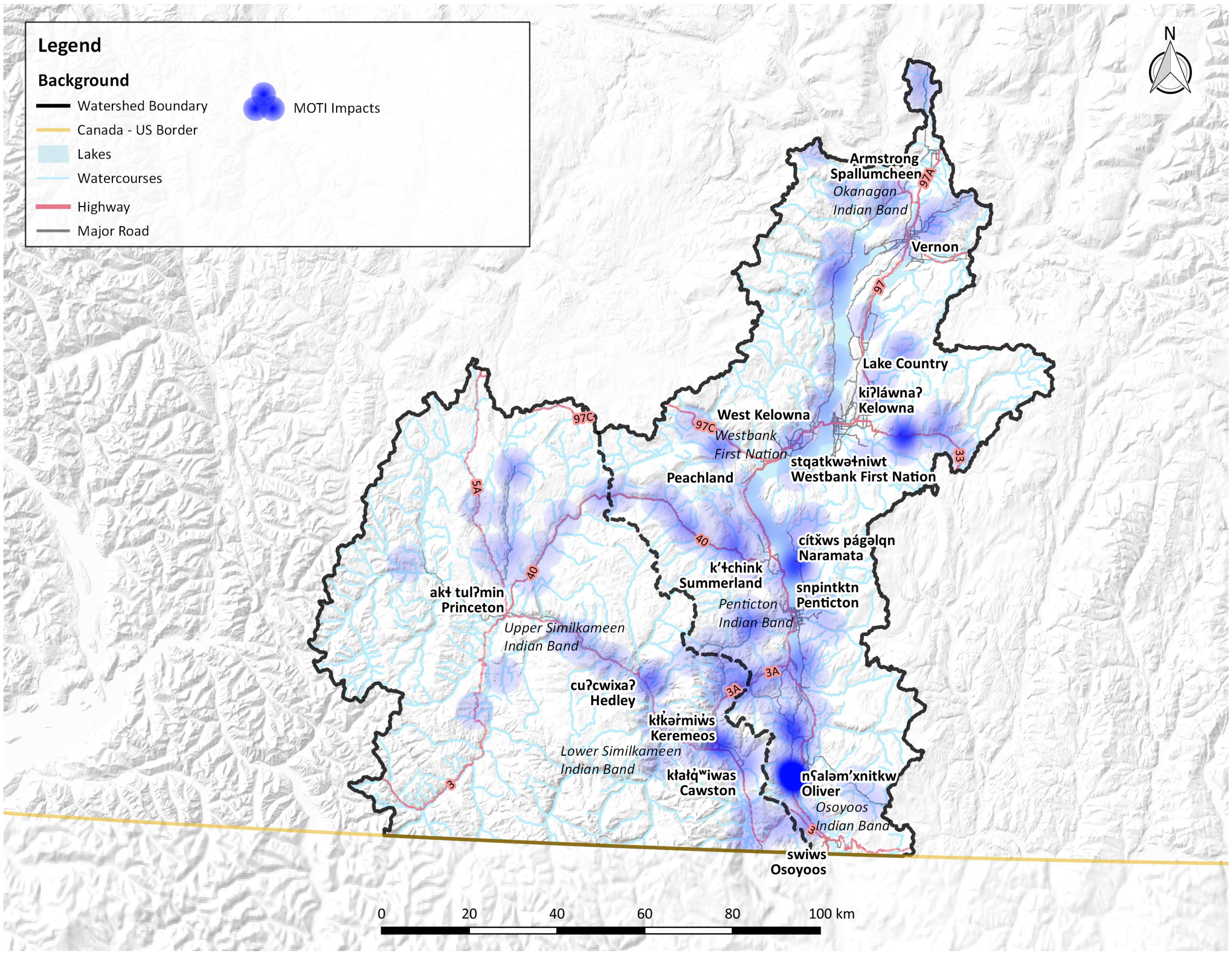

Figure 6: Hotspot map of road infrastructure sites affected by flood and debris flows in 2017-2018 for the project area (source: MOTI).

The data shown in Figure 6 presents a set of data that are specific to road infrastructure. They are a rare source of consistent empirical data that portrays impacts from flood and debris flows in 2017 and 2018 across the project area. More comprehensive analyses of impacts are presented in the Qualitative and Quantitative studies.

At the provincial scale, EMBC provided financial relief for uninsurable losses following the events through the Disaster Financial Assistance (DFA) program. As of June 27, 2019, the costs that the Government of

BC expended through EMBC associated with the 2017 and 2018 flood events in the project area were as follows[16]:

- Private sector costs paid to date: $2,691,653.
- Public sector estimated and paid: $15,638,849.

While the financial information is a useful first approximation of damages across the project area, they are not exhaustive. Collectively, the information sources such as road infrastructure and financial costs helped the project team identify data gaps that were addressed over the course of the project.

[16] Freedom of information (FOI) Request PSS-2019-93117 – "Records of flood damage estimates for the Okanagan-Similkameen region for 2017-2018. Provided by Suzanne Kardoush, Senior FOI Analyst, BC Ministry of Citizens Services. June 27, 2019.

3 Geohazards in the Project Area

Flood and debris flow hazards fall within a spectrum of geohazards. Geohazards are characterized based on the concentration of sediment that is transported (i.e. by weight and volume), as well as the flow velocity (Figure 7). Floods are characteristic of lower sediment concentration and flow velocity, and debris flows are characteristic of higher sediment concentrations and flow velocities. Both floods and debris flows are natural processes where a combination of water and surficial material move down slopes and into channels.

While there are individual definitions and classification criteria for the geohazards that span debris flow, debris flood, and clearwater floods, these events exist on a continuum, and exact differentiation of these processes can only be achieved through direct sampling. Even with direct sampling, some of the relevant thresholds can be difficult to detect. It should be kept in mind, therefore, that classification indicates the dominant process in a given watershed, not the only possible process (Jakob, 2016). Therefore, while this project refers to floods and debris flows, what was considered was the span of geohazards that is bounded by these two geohazards in Figure 7.

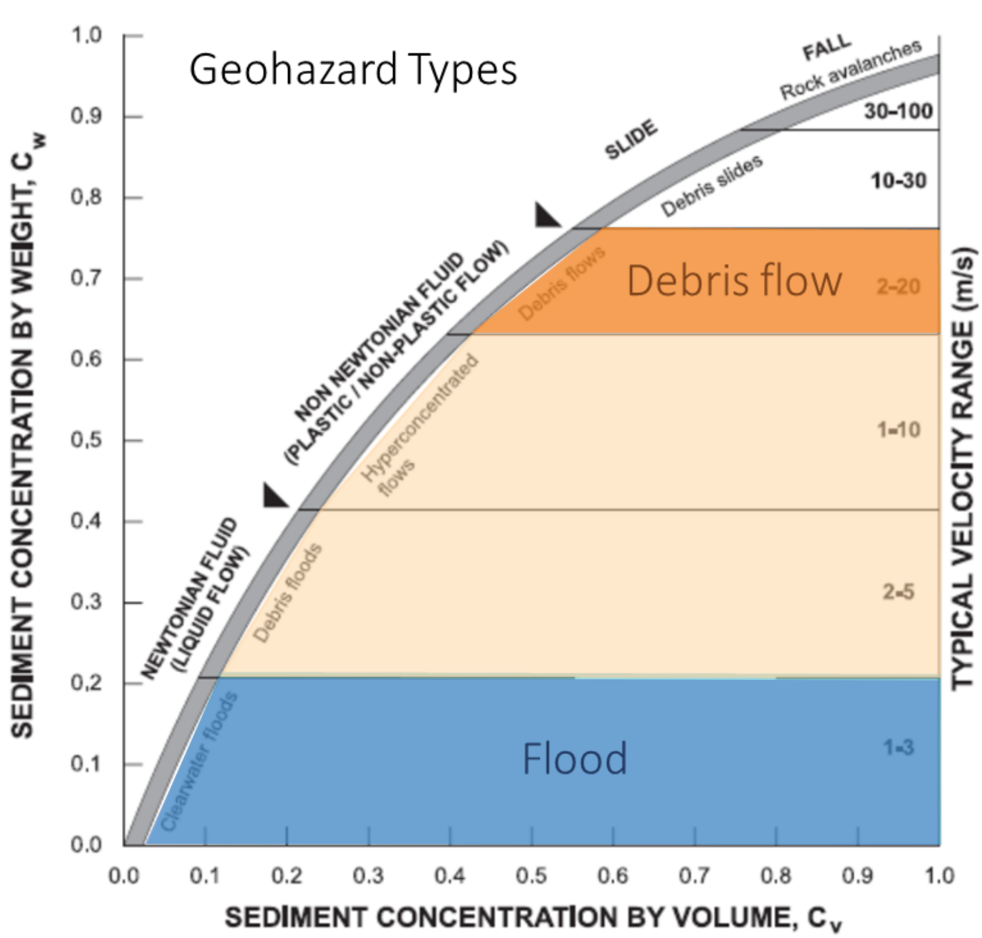

Figure 7: Geohazard types based on watershed morphometrics graph (adapted from Jakob and Jordan, 2001).

The first section below describes flood types in more detail. The second section discusses the other geohazard types including debris flows. In these sections, text boxes highlight specific geohazard conditions in the project area. The third section discusses the positive ecosystem regeneration aspects of these geohazards.

3.1 Flood Types

Floods occur when water levels are higher than normal. They are driven by climate processes that have influence on the watershed scale. The following flood types are described in the sections below: precipitation (pluvial), riverine (fluvial), dam and dike breach, rising water bodies, and high water table. In the project area, the main flood mechanisms types include heavy rain, snowmelt, and rain-on snow riverine.

3.1.1 Precipitation (Pluvial)

Pluvial floods are caused when heavy rainfall soaks an urban drainage system, or natural soils, resulting in excess overland flow (runoff). They can be very localized depending on the rainstorm path. Extreme flooding can result with a combination of warm conditions and/or rainstorms occurring during mid-winter or spring snowmelt (freshet) seasons. The warm air and/or rain leads to large volumes of snow melt, which does not infiltrate due to frozen soils—resulting in high runoff rates (Maidment, 1992). These rain-on-snow events are exacerbated when they occur rapidly and when snowpacks are deep.

3.1.2 Riverine (Fluvial)

Fluvial floods occur under a variety of conditions that cause a river to exceed its capacity and overflow onto its banks and into the floodplain (Figure 8). This can occur in small streams or large rivers, and the main driver is usually high runoff from heavy rain and snowmelt. However, other mechanisms related to channel blockages can be important factors.

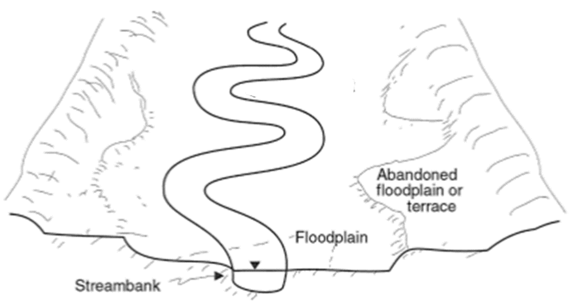

Figure 8: River channel and flood plain (Brooks et al., 2013).

Figure 9: McDougall Creek bank overtopping (Source: WFN).

Blockages can be caused by debris, ice jams, or glacial ice. The blockages cause flooding by creating backwatering conditions upstream; conversely, when the blockage is released an outburst flood occurs downstream. Ice jams occur frequently on the Similkameen River (Septer, 2006), and they start forming in the winter when slush bonds to, and accumulates below, the surface ice cover. During spring, the surface ice breaks-up into massive pieces. At river constrictions, the pieces "jam" against each other and the river banks. The prevented flow rises over the river banks and can form backwater conditions. Floods occur downstream if the jam breaks up quickly, releasing the upstream water in an outburst flood.

When one river flows into another under flood conditions, backwater effects can occur upstream in the river that has the smallest flow of the two. This condition occasionally results due to the confluence of the Okanagan and Similkameen Rivers (see Box 1).

Box 1: Backwatering Effects in Osoyoos Lake

The Okanagan and Similkameen Rivers join in the United States downstream from the project area boundary and approximately 4 km south of the outlet of Osoyoos Lake. During times of high flows in the Similkameen, backwatering effects can occur in Osoyoos Lake. The hazard increases as the lake levels rise. This condition is exacerbated during spring freshet when flow levels are high in the Okanagan River, which flows into Osoyoos Lake. While the backwatering is a naturally occurring phenomenon, managing these conditions is made more complex by the operational requirements of Zosel Dam, which is located on the Okanagan River just upstream from the confluence of the Similkameen River (Summit Environmental Consultants Inc., 2010b)

3.1.3 Dam and Dike Breach

Figure 10: Dike along the Similkameen River at Cawston (Source: Ebbwater).

Dams and dikes are human-made blockages designed to hold water behind them, creating permanent backwater conditions (Figure 10). A hazard is created in the event of their breach, when a flood wave is released downstream.

There are 349 of dams in the project area, 299 of which are classed as Active. The Ministry of Forests, Lands, and Natural Resource Operations and Rural Development (FLNRORD) conducts regular inspections and dam consequence assessments. Of the 349 dams, there are currently 6 dams rated as extreme, 29 are rated as very high, 51 are rated as high, 85 are rated as significant, and 160 are rated as low. The consequence of the remaining dams is unclassified. There are also 37 kilometres of dikes on the Similkameen River and 81 kilometres in the Okanagan watershed alone.

Flooding resultant from dam or dike failure is not a focus of this study, but could be considered in the future.

3.1.4 Rising Water Bodies

The areas around lakes and reservoirs can experience flooding resulting from high inflows combined with high waves and/or storm surge (Figure 11). This is especially the case in reservoirs when water levels are high, such as during the spring and early summer. However, managing these hazards is part of the normal operating regime by the owners of the reservoir dams.

Figure 11: High water levels on Okanagan Lake (Source: WFN).

Water bodies can also increase if large volumes of debris or sediment enter the water body. This can occur slowly following continuous erosion events[17], or suddenly following earth flows[18]. Flooding causes upland erosion, leading to sedimentation, which reduces the capacity of the lake.

3.1.5 High Water Table

The regions surrounding large rivers and lakes are generally prone to groundwater flooding, as these sections of stream reaches are generally gaining stream sections (Figure 12) (Winter et al., 1998). These areas can include fluvial deposits where evidence suggests hydraulic connections with streams and proximity to aquifers. Important aquifer systems in the Okanagan include Coldstream-Vernon and Spallumcheen, Greater Kelowna, and Vaseux Lake to Osoyoos Lake (Summit Environmental Consultants Inc., 2010a). Areas of interest in the Similkameen include valley bottoms consisting of high permeability sand and gravel aquifers (Summit Environmental Consultants Inc., 2015). Groundwater levels within the project area were generally regarded as being high in the spring of 2019 (see Box 2).

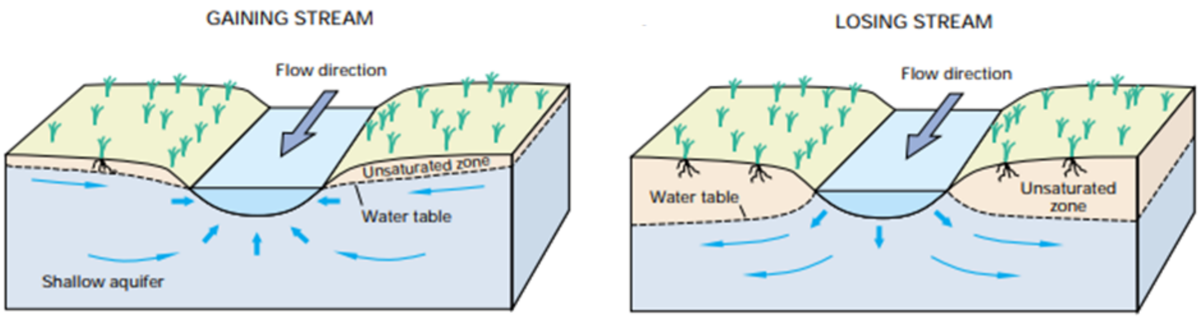

Figure 12: Gaining and losing stream reaches. Gaining streams generally have higher water tables and receive water from the groundwater system (Adapted from Winter et al. 1998).

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[17] The water level of Ellison Lake is thought to have increased in recent years due to increased sedimentation following erosion (personal communication, Matthew Salmon, Public Works Manager, District of Lake Country. May 4, 2019).

[18] Earthflows have been observed on Pinaus Lake and there is concern that a large slide into the reservoir could overtop the dam, causing a flood wave downstream (Tetra Tech, 2018).

Box 2: Groundwater Flood Potential across the Project Area

Groundwater flooding is most likely to occur in conjunction with pluvial flooding that leads to more water infiltrating into the ground (Robins & Finch, 2012), and it can persist for weeks after high river levels have receded. Based on a review of a limited number of water wells within the project area in the late winter of 2019, it was assumed that there were generally high water table conditions across the project area. This was likely due in part to groundwater recharge following flooding in 2017 and 2018.

3.2 Other Geohazard Types

Flood events can affect the landscape and increase the likelihood of other geohazards. Per Figure 7, there are three parameters that characterize these other geohazards along the spectrum, including velocity and sediment concentration. It is, however, very difficult to measure these characteristics directly and so typically other geomorphic characteristics are used for classification including the slope, watershed size, surficial material, and bedrock geology.

3.2.1 Debris Flows

Debris flows are rapid mass movements of saturated surficial material and organic debris, which can be a mixture of rock, sand, and/or soil. The high water content of debris flows allows them to flow downhill as slurry, often resembling wet concrete (Figure 13 and Figure 14). This category includes debris torrents, also known as “channelized debris flows”. Channelized debris flows commonly grow larger through entrainment of in-channel material.

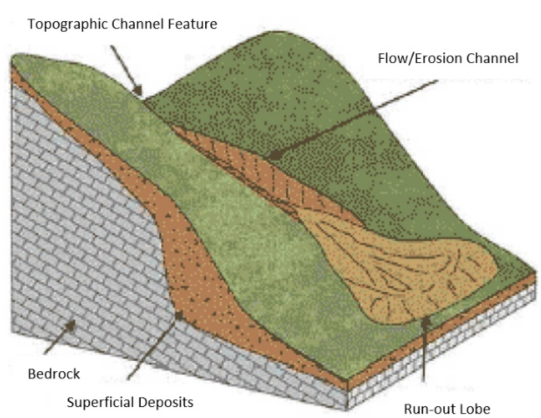

Figure 13: Channelized debris flows (Smith, 2004).

Figure 14: Debris flow near Oliver, BC in June 2010 (Globe and Mail).

Debris flows are a common hazard in the project area. They may initiate as another mass movement, such as a debris slide or rock slide, that becomes channelized by topography, and may increase in size through entrainment of surficial material, organic debris and water.

3.2.2 Debris Slides

Debris slides are rapid sliding masses of surficial material (Figure 15 and Figure 16). These typically have a shorter runout length than debris flows and move as a solid rather than a liquid or a slurry. Debris slides are common where slopes have been steepened or undercut by road building. A large debris slide occurred in 2018 in the Upper Similkameen region near Copper Mountain Mine. More information on this event is in the Qualitative Study.

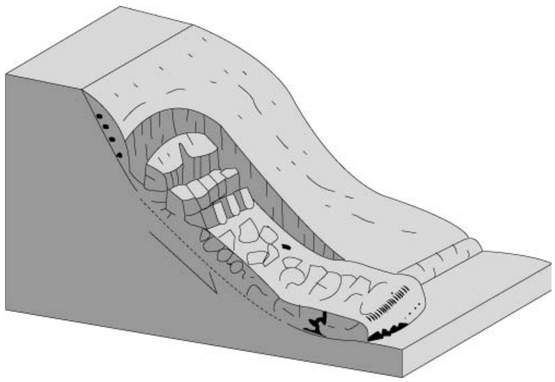

Figure 15: Debris slides (Smith, 2004).

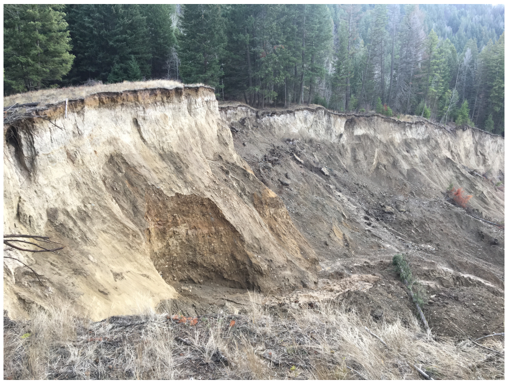

Figure 16: Debris slide near Similkameen River in July 2018 (ONA).

3.2.3 Rock Falls

Rock falls occur when detached masses of bedrock move by falling, bouncing, or rolling (Figure 17 and Figure 18). Rock falls typically have small volumes but may occur with a high frequency. These occur on steep bedrock slopes and cliffs. Rock falls occur on steep slopes and can be caused by a number of factors, such as the structure of the rock mass, weathering, ground and surface water, freeze-thaw dynamics, root wedging, and external stress. Note that rock slides were not a focus of this project, but a notable event occurred during the project (see Box 3).

Box 3: Rock Fall on Highway 97

Between January 31 and February 2, 2019, over 4,000 m^3 of rock fell onto Highway 97 between Peachland and Summerland[20]. The event affected the logistics related to conducting this project's Workshop 1. The Ministry of Transportation and Infrastructure (MOTI) reported that this rockslide was likely triggered by freeze/thaw conditions and occurred along a natural joint deep in the slope.

Figure 17: Rock fall on Highway 97 (Source: MOTI).

Figure 18: Rock fall (Smith, 2004).

3.2.4 Rock Slides

Rock slides are large disintegrating masses of bedrock moving downslope by sliding (Figure 19 and Figure 20). Rock slide volumes can vary greatly. The largest landslides in Canada are rock slides (e.g., Frank Slide in the Crowsnest Pass, AB, pictured below). Rock slides can be caused by factors such as seismic activity, external stress, as well as ground and surface water.

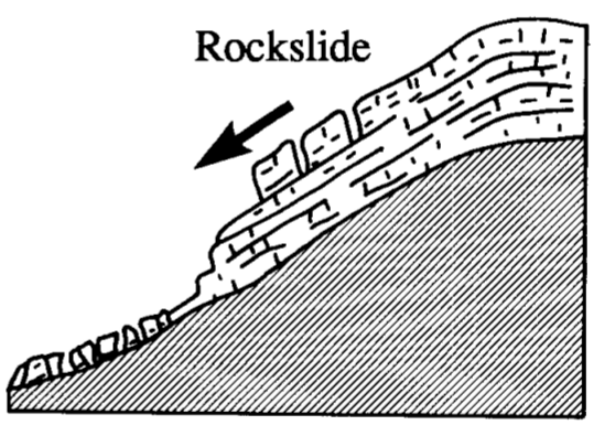

Figure 19: Rock slides (Smith, 2004).

Figure 20: Frank Slide (Lisa Cyr-Fickr, 2007).

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[19] "*Update: Ministry gives 50-50 chance of Hwy. 97 in Okanagan reopening on Wednesday*". Global News. February 5, 2019. Accessed June 23, 2019.

3.2.5 Triggering Mechanisms

Geomorphic characteristics as described in the previous sections are one indicator of the existence of geohazards in a given area. However, hydroclimatic and anthropogenic processes are extremely important in determining if and when a geohazard will be triggered. These and other watershed-scale factors are discussed in Chapter 6, in the context of cumulative pressures on hazards.

3.3 Positive Ecosystem Regeneration

> "What does it mean to 'sustain'? And if we look at the truth of what that might mean, that means that there should be no animal, or bird, or fish, or no plant that is on the endangered list, or that is on the species at-risk list." –Dr. Jeanette Armstrong, 2007[20]

Through the typical perspective of western society, flood and debris flows are referred to as natural hazards that generally cause negative impacts. For example, common flood-related discourse includes mention that it is the most frequent, impactful, and expensive natural hazard in Canada today (Office of the Parliamentary Budget Officer, 2016). While this is true, when viewed from a *Syilx* Okanagan and ecosystem perspective, it is apparent that floods also bring positive benefits (Bailey, 1991; Junk & Wantzen, 2004).

Geohazards enrich soils with nutrients that feed the landscape including riparian and aquatic ecosystems. Furthermore, the sediment, vegetation, and woody debris that ends up in these ecosystems play a role in sculpting diverse habitats (Fetherston et al., 1995). Diverse habitats support plants, macroinvertebrates, and fish during their various lifecycle stages (Trush et al., 2002). By connecting with their floodplains and through the dynamic process of habitat destruction and re-creation, riparian and aquatic ecosystems maintain their function and biodiversity[21].

[20] Native Perspectives on Sustainability: Jeannette Armstrong (Syilx), Interview by David E. Hall, Transcribed by Brianna Finney, October 21, 2007.

[21] Understanding Rivers through the Lens of Ecohydrology. Presentation by Dr. Mark Lorang. Environmental Flow Needs Conference. Kelowna, BC. October 2018.

4 Project Framework

In early-phase project discussions with the ONA and individuals from its member communities, it was directed that this project be led by *Syilx* Okanagan perspectives. The ONA sought to disrupt western society's path dependency whereby decision-makers remain "locked in" to past policies and actions that favour engineered (e.g., structural mitigation) approaches to flood management (Parsons et al., 2019). This path dependency stands in the way of efforts to address changing hazard risks linked to climate change and other cumulative pressures. The *Syilx* Okanagan Nation maintains that existing institutional arrangements and frameworks do not adequately facilitate the implementation of wise environmental management that supports Indigenous communities to adapt to changing natural phenomena. In response, a new perspective and approach more closely aligned with a *Syilx* Okanagan worldview was adopted to guide this project.

4.1 *Syilx* Okanagan Perspective

"If people can't understand that we *are* water; they have missed the point."
– Arnie Baptiste, *Syilx* Representative

The *Syilx* Okanagan worldview is complex and diverges from the western science worldview. It cannot be fully summarized in this report format; however, in the community discussions and engagement that laid the foundation for this project, a number of themes emerged that have been employed in this report as ways of increasing the alignment of this project with *Syilx* Okanagan perspectives. These themes are:

1) Uphold Water Responsibilities.
2) Apply *Syilx* Okanagan knowledge.
3) Connect to place.
4) Value *tmix*^{w} (all living things).
5) Collaborate and develop water partnerships.

An overarching understanding that ties all these themes together is: "Water is connection".

4.1.1 Uphold Water Responsibilities

Syilx Okanagan communities have a deep intrinsic connection to *siwɫk*^{w} (water). Maintaining the integrity of *siwɫk*^{w} and respecting its relationship to all life is essential to *Syilx* Okanagan identity and is entrenched in responsibility to the *tmx*^{w}*ulax*^{w} (land).

Syilx Okanagan community members and ONA staff repeated throughout this project that water is "the most important thing and gives us life". The *Syilx* Okanagan perspective respects the power of water and recognizes that "water will go where it needs to go". Within this understanding, there is also a recognition that not all flooding is bad, and that there are positive regenerative aspects of natural phenomena such as flood and debris flows. These phenomena are an intrinsic part of *tmx*^{w}*ulax*^{w} (land) and are connected to *tmix*^{w} (all living things, sacred life forces).

Syilx Okanagan water laws and values related to *siwɬkʷ* are outlined in the *Syilx* Okanagan Water Declaration[22], which was endorsed by the ONA Chiefs Executive Council in July 2014. The Water Declaration communicates not only water responsibilities that *Syilx* Okanagan people carry, but also water-supporting activities that everyone residing in *Syilx* Okanagan territory can implement in their daily lives.

4.1.2 Apply *Syilx* Okanagan Knowledge

The *Syilx* Okanagan people have a manifest reverence for Elders and Traditional Ecological Knowledge Keepers who carry a deep responsibility to teach future generations about environmental conditions of the past and present. Elders also offer reminders of historical events that have set the stage for the challenges of today. The history of colonization and settlement patterns of immigrants since 1811 have affected hazards, exposure and vulnerability in palpable ways for everyone in the region.

Over the generations, the *Syilx* Okanagan have passed down teachings through oral literature such as *captíkʷɬ*. These *captíkʷɬ* contain a collection of laws, customs, values, and principles that reveal truths about the meaning of being *Syilx* Okanagan. Taken together, the *captíkʷɬ* define and inform *Syilx* Okanagan rights and responsibilities to the *siwɬkʷ, to the* land, and to one another. *captíkʷɬ* stories hold teachings on how we all can relate to and live on this land. They serve as reminder of natural laws and protocols that need to be followed in order for all the future generations to survive in harmony with the *tmixʷ*.

4.1.3 Connect to Place

From a *Syilx* Okanagan perspective, in order to effectively engage in watershed planning, it is important for researchers, Elders, community members, and decision makers to venture out into the watershed and observe it from the headwaters to the valley bottoms. This has always been an important part of the sacred responsibilities that *Syilx* communities and families have to their local watersheds. For several years now, the ONA has been implementing watershed tours in support of *Syilx* Okanagan watershed responsibility processes. Watershed tours can range in size from a single creek to the Columbia River. They consist of getting out into a watershed with *Syilx* Okanagan community members or Elders who have intergenerational knowledge of those systems. On the watershed tours, *Syilx* Okanagan community members share not only important knowledge about the water itself but also about the surrounding ecosystem.

4.1.4 Value *tmixʷ* (All Living Things)

tmixʷ is the *nsyilxcən* word that most closely translates as "ecology". The *Syilx* Okanagan understanding is that *siwɬkʷ*, *tmxʷulaxʷ* (land), and all living things are all part of *tmixʷ* and are all intricately connected. What we do to one of them, we do to them all. *Syilx* Okanagan responsibilities extend beyond fellow human beings to include everything within the ecosystem: water, plants, animals, land. With the word *tmixʷ*, the *Syilx* Okanagan responsibility to honour the natural laws of that which gives us life is embedded within the *nsyilxcən* language itself.

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[22] *siwɬkʷ* Water Declaration. Okanagan Nation Alliance. Weblink: https://www.*sylix*Okanagan.org/about-us/*Syilx*Okanagan-nation/water-declaration/. Accessed October 15, 2018.

As is stated in the *Syilx siwɬkʷ* (Water) Declaration: "The Okanagan Nation has accepted the unique responsibility bestowed upon us by the Creator to serve for all time as protectors of the lands and waters in our territories, so that all living things return to us regenerated. When we take care of the land and water, the land and water takes care of us. This is our law."

Throughout this project, *Syilx* Okanagan knowledge, the *Syilx siwɬkʷ* (Water) Declaration, *captíkʷɬ*, and watershed tours were integrated into the risk assessment. The Okanagan Nation is confident that by incorporating *Syilx* Okanagan values, perspectives, and processes into regional planning efforts, a new way of working with nature will emerge that is to the benefit of everyone, inclusive of the *tmixʷ*.

4.1.5 Collaborate and Develop Water Partnerships

The *Syilx* Okanagan Nation is committed to continued efforts of building relationships and collaborative initiatives towards respecting the shared responsibility for the health of *siwɬkʷ* and aquatic ecosystems. For example, ONA hosts an annual Water Forum for both *Syilx* and non-*Syilx* participants to build a collective knowledge around *siwɬkʷ* based on principles from *Syilx* Okanagan natural law. Participants come from a range of backgrounds including all levels of government, academia, industry and non-governmental organizations (NGOs).

At the Environmental Flow Needs Conference held in Kelowna in October 2018, Grand Chief Stewart Phillip spoke of the relationship between the *Syilx* Okanagan people and the settlers in the region. He explained that the relationship is now entering a phase where climate change is causing widespread havoc on the land. The resulting impacts are creating complexities and interconnections. Responding to these requires a non-linear and systems thinking approaches to innovation. This is resulting in non-*Syilx* people, governments, and organizations looking for guidance and insight from *Syilx* Okanagan and other Indigenous Nations whose knowledge systems are holistic, "spiral," and ecosystem-based.

A diversity of perspectives must be coordinated to create more resilient and dynamic planning and responses to care for *siwɬkʷ.* The Grand Chief said that the *Syilx* Okanagan people are up for the challenge and welcome collaboration with others to address these issues.

4.2 Approach

Discussions about strategies to meet the need of both *Syilx* and non-*Syilx* participants in developing a collective approach to flood response were part of the initial groundwork of *Syilx* Okanagan community engagement and coordination with non-*Syilx* partners.

While *Syilx* Okanagan means of knowledge transmission rely heavily on oral traditions, land-based learning, and storytelling, western science relies on analytical thinking and the written form. The project adopted a number of strategies to address the discrepancies between the *Syilx* Okanagan and western science approaches, always with the objective of meaningfully integrating *Syilx* perspectives into this risk assessment. These strategies included having an Internal Steering Committee comprised of *Syilx* Okanagan Nation members, conducting watershed tours with Traditional Ecological Knowledge (TEK) Keepers, and recognizing multiple perspectives in alignment with the *Syilx* Okanagan *nʕawqnwixʷ* model of decision-making.

One important lesson that was shared by *Syilx* Okanagan Traditional Ecological Knowledge Keeper Richard Armstrong is that while the two worldviews often appear to be far apart, there are also many ways in which *Syilx* Traditional Ecological Knowledge *is* multi-disciplinary western science. This is demonstrated through a comparison of best practice for flood management (see Section 4.1 of the Qualitative Study), whereby the *siwɬkʷ* (water) Declaration is compared with the 10 golden rules of for flood management. The convergence of the two worldviews is also demonstrated in the development of ecosystem-based ideas to guide adaptation (see Section 3.4 of the Synthesis and Recommendations report), whereby respect for water and recognition of cumulative pressures are discussed.

4.2.1 Steering Committees

Several different steering bodies were set up in order to create capacity and guide the project.

Internal Committee: This included members of the *Syilx* Okanagan Nation communities and Ebbwater staff. Starting in July 2018, this group held monthly phone meetings. In October and September 2018, a number of focused learning sessions (discussed in the Qualitative Study) were held with this group.

External Committee: Some members of the Internal Committee also participated in the project's External Committee (officially called the *Syilx* Flood Adaptation Initiative Steering Committee), which also included political and technical representatives from a range of regional project partners including local governments and agencies. The External Committee participated in the project's kick-off meeting held in December 2018. At that meeting, the following Terms of Reference for the External Committee's principles of engagement was adopted (see Appendix A for the full document):

- Recognition and respect. Acknowledging that the world views and values held by *Syilx* (Okanagan) Nation and Regional Districts are each unique
- Having consistent, meaningful dialogue about activities from the earliest stage of projects (the point of conceptualization) and iteratively through to implementation
- Working together to achieve mutual objectives to maximize the outcomes of the *Syilx* Flood Risk Assessment
- Commit to work together for consensus decision-making to find solutions that everyone actively supports, or to support the common goal.

4.2.2 Watershed Tours

In addition to community engagement sessions, watershed tours were conducted to give all project participants the opportunity to fully experience the land through their senses and to provide space for them to connect to different ecosystems. The tours were led by *Syilx* Okanagan Elders who decided which locations would be visited and the topics that would be discussed. The objectives of the tours were to build knowledge, capacity, and appreciation among project participants, as well as to strengthen relationships between them.

4.2.3 Decision-Making with Diverse Perspectives

There is growing recognition of the importance of reconciling the use of western methods with Indigenous knowledge in order to realize the beneficial outcomes that are possible when multiple perspectives are considered. An example of this is the use by scholars of Mi'kmaw Elder Albert Marshall's principle of Two-Eyed Seeing as a framework for integrating western and Indigenous perspectives.[23]

In the *Syilx* Okanagan worldview, *nʕawqnwixʷ* offers a means of incorporating both Indigenous and western knowledge and ways of knowing into dialogue and decision-making. This uniquely *Syilx* decision-making model was applied in completing the Qualitative Study and was also used to inform decisions made throughout the Quantitative Study. One area where it was applied was in helping non-*Syilx* Okanagan participants become more aware of the impacts of colonization on *Syilx* Okanagan peoples and their lands and waters. This risk assessment project aimed to shift more typical western qualitative research paradigms toward a process that was relevant, reciprocal, respectful, and responsible (Peltier, 2018).

Syilx Okanagan scholar and author Dr. Jeannette Armstrong has outlined the *nʕawqnwixʷ* model for decision-making as it relates to land and water use. *nʕawqnwixʷ* considers principles and knowledge that are contained within the *captikwɬ* "How Food Was Given," which is also known as the story of the Four Food Chiefs. The Four Food Chiefs came together in order to make a plan to feed *st'lsqilxʷ* (the people to be). This central question is resolved through the combined perspectives of the Four Chiefs: *skmxist* (Black Bear), *siya* (Saskatoon Berry), *spiƛ̓əm* (Bitter Root), and *ntityix* (King Salmon).

Each of the Food Chiefs represents a different perspective and in the *nʕawqnwixʷ* approach, each of these perspectives must be included when making decisions (Figure 21). Within the framework of *nʕawqnwixʷ*, collective input helps build a broader perspective. Collective dialogue helps to clarify the question and reveals information, actions, and solutions to move forward, all based on the dynamic inputs of multiple perspectives.

Syilx Okanagan scholar Dr. Bill Cohen describes *nʕawqnwixʷ* as follows:

> "*Enowkinwixw* was used traditionally to address and resolve issues of serious concern to the community. It is not based upon conflict or debate: it is, rather, a clarifying, strategic planning, and unifying process, an organizational model. The challenge is not to convince others of your position. The challenges and the responsibilities are to contribute understanding to the collective and to consider and include the feelings and viewpoints of all others, and as a group come to the best possible solutions for the whole community, and the future generations."[24]

nʕawqnwixʷ is a powerful model that can be used for decision-making with respect to *Syilx* Okanagan land and water use. Principles include a commitment to balance, reciprocity, sustainability, ongoing use,

[23]Two-Eyed Seeing. Institute for Integrative Science and Health. Weblink: http://www.integrativescience.ca/Principles/TwoEyedSeeing/. Accessed June 24, 2019.

[24] Dr. Bill Cohen, 2010.

ecological integrity, inclusivity, collective contributions, rights/responsibility, respect, and inter-relatedness.

The *nʕawqnwixʷ* process teaches that:

- With complex issues (i.e. climate change), it is important to step out of our comfort zone and truly listen to other perspectives.
- Solutions will be multi-faceted and holistic and consider social, cultural, scientific, economic, and governance values.
- As well as communicating with others who have different perspectives, it is also required to listen and see issues from different perspectives.
- It's important to allow space for the diverse perspectives from all participants to be voiced and understood from all angles and different worldviews.
- Every voice, even those with differing points of view, need to be heard in dialogue for good decision making.
- It is necessary to work in collaboration to build a collective knowledge base that is multi-disciplinary.
- There is a collective approach that includes all different perspectives and will only occur after fair dialogue in which all voices are heard.
- There are voices beyond the human kind that also need a space to be heard and recognized, such as species, species habitats, and spiritual locations/landforms.

Figure 21: The perspectives of the Four Food Chiefs (source: ONA).

4.2.4 Complementary Research Methods

Qualitative and quantitative studies were developed as complementary components of the risk assessment in order to enhance the application throughout the project of *Syilx* Okanagan knowledge, including the *nʕawqnwixʷ* process. Qualitative research studies subjects in their natural setting and attempts to interpret phenomena in terms of the meaning people bring to them. Quantitative research is rooted in things that can be measured through numerical analysis (McLeod, 2017). Table 4 outlines the advantages and disadvantages of the two research methods. The purpose of applying these complimentary methods was to enrich the project, where possible, with the advantages of both methods as listed in the first row of the table.

Table 4: Advantages and disadvantages of qualitative and quantitative research methods (adapted from McLeod, 2017).

	Qualitative studies	Quantitative studies
Advantages	• Direct involvement by project participants allows subtleties and complexities to be identified and articulated. • Descriptions can be used to articulate possible relationships, causes, effects and dynamic processes. • Allows for ambiguities and contradictions in the data, which are a reflection of social reality. • Based on narrative style, which allows people to examine all forms of knowledge.	• Numerical interpretation is regarded as scientifically objective and rational. • Useful for testing and validating existing theories. • Can use sophisticated software and computers to efficiently process large datasets. • Measured values can be checked by others because results are less open to interpretation.
Disadvantages	• Because of time and costs involved, the information does not draw from large numbers of people or data sets, and more time is required. • The validity or reliability of the information is questioned as it is difficult to apply conventional standards to address these issues. • It is difficult to replicate studies, as they depend on the specific people that were involved. • It is difficult to extend findings to a wider context with confidence.	• Does not easily allow participants to explain choices or meaning. • Poor knowledge of data and its use may negatively affect analysis and interpretation. • Large sample sizes are needed for more accurate analysis, and more data are required to obtain and manage large study areas. • Researchers might miss evidence of new theories because of a focus on hypothesis-testing.

Figure 22 illustrates some examples of qualitative and quantitative research activities that were carried out within the project. Activities that were more qualitative in nature are located on the left side of the diagram, and those that are more quantitative are located on the right side. Many activities, such as those located in the middle of the diagram, involved a mix of qualitative and quantitative research methods. For example, the two workshop events and impacts mapping exercises were important activities that bridged the two research methods. The bottom of the diagram (in the grey-shaded area) represents the process of synthesizing the information gathered during the risk assessment supporting activities to inform priority-setting for adaptation.

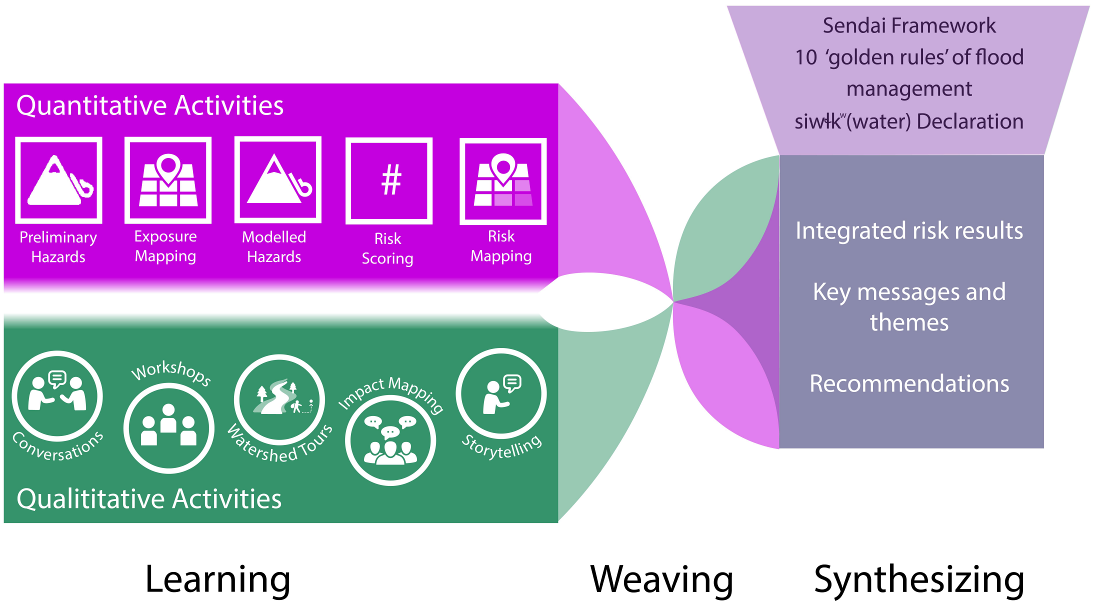


Figure 22: Example qualitative and quantitative activities that were integrated through weaving and synthesizing processes, using *Syilx* and non-*Syilx* frameworks.

Note that risk-related terms such as “hazard” and “exposure” in the boxes of Figure 22 are described in the next chapter.

4.3 Limitations

Given the information, timing, and resources available to complete this project, there were limitations to the work completed in this phase.

1. **Geographic scope and approach.** The project area consists of two large watersheds, each with their own sub-watersheds with varying hydroclimates, topography, ecology, and over 20 communities. This project also considers two hazards that, while they are interrelated, are triggered by unique processes in nature. A desire to view the issues holistically, and to consider positive as well as negative impacts of hazards, required at least equal emphasis be placed on qualitative versus quantitative approaches and results. The success of this experimental approach remains to be seen.
2. **Project input.** This project sought to understand flood and debris flow hazard exposure as completely and richly as possible. This was mostly achieved through direct engagement with project participants during three learning sessions, two workshops, three watershed tours, and numerous email and telephone communications. The information collected through these sources is limited to the knowledge and input from those who participated; there are potentially some flood and debris flow hazard vulnerabilities and impacts that were not identified because a given group or individual was not able to participate.
3. **Timeframe.** The majority of the work was conducted within a timeframe of 6 months. This was a challenge in terms of gathering information, completing analyses, and obtaining feedback. The non-*Syilx* Okanagan project participants, including the Ebbwater team, had a steep learning curve

in terms of understanding the *Syilx* Okanagan perspective. The learning goes much deeper than the scope of this project. Decolonizing the non-*Syilx* Okanagan understanding of history takes time, and this process was compromised by the timeframe.

4. **Data and results.** The flood and debris flow hazard data for this project was produced by separate desktop studies. The exposure and vulnerability used for risk assessment was sourced for the Qualitative Study through the process described above, and for the Quantitative Study through the ONA, regional partners, and open data sources. While the results are presented at relatively detailed resolutions, the approach was necessarily simplistic. Therefore, at the highest resolutions, results should be considered with caution for planning purposes, and are not suitable for engineering design purposes.
5. **Actions and next steps.** The goal of this work was to understand the risk due to flood and debris flows within the project area in order to support priority-setting of future work for adaptation. It purposely did not seek to provide engineering designs at this stage; pre-determining a solution before fully understanding the problem will often lead to failure. Further, the technical information required to develop and assess some flood and debris flow adaptation options (especially structural works) was not available at this time. The recommendations are therefore focused on quick-wins and adaptation actions to reduce risk and increase resilience over time.

5 Risk Assessment Primer

This chapter outlines the components of natural hazard risk, then provides detail on hazard likelihood, key concepts, and impact categories. The chapter includes a discussion on professional guidance and the funding context. The chapter ends with a discussion on evolving methods based on our learnings from applying unique perspectives to this risk assessment.

The non-numerical aspects of the risk assessment, including hazards and exposure are found in the Qualitative Study. The technical analyses are found in the Quantitative Study.

5.1 General Components

A solid grounding in the understanding of the terms *hazard* and *risk* are key to understanding the components of a risk assessment. Figure 23 shows how *risk* is a function of both the *likelihood* of an event occurring, and the *consequences* (impacts) if that event occurs. C*onsequence* is defined as a function of the *hazard* (where and how big is the event?), *exposure* (what's in the way), and *vulnerability (*how susceptible is it?).

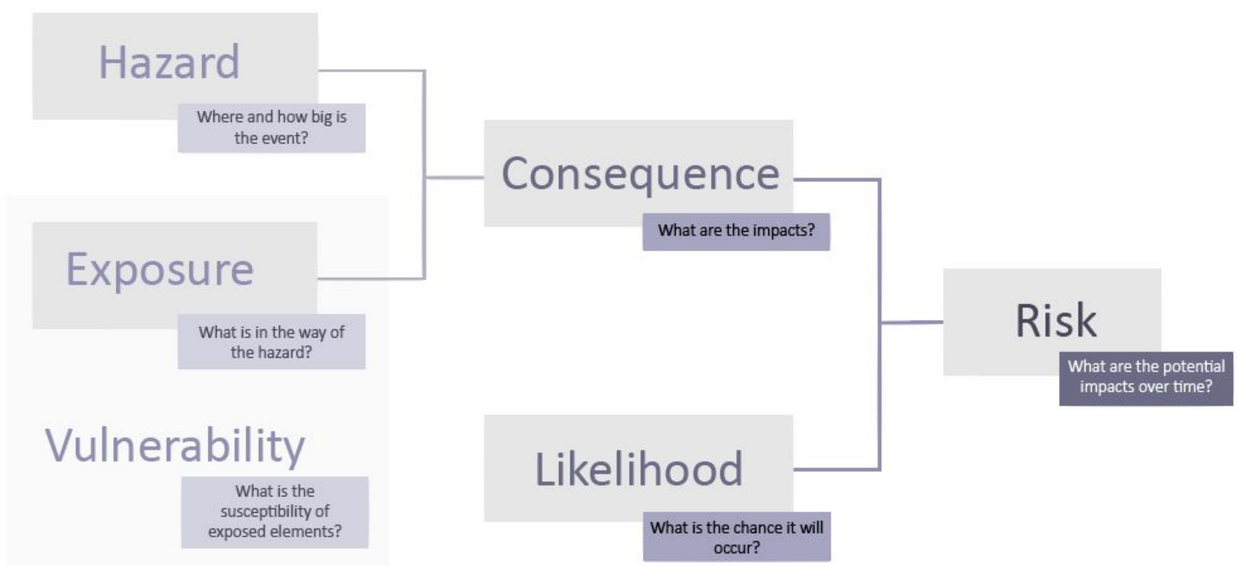


Figure 23: Risk as a function of consequence and likelihood (simplified).

Disaster risk is the result of the interaction between a hazard and the characteristics that make people and places exposed and vulnerable. In this sense, **disasters** do not exist by themselves, but disasters often follow natural hazard events. This is because the effect of human activities on hazards, and the ways in which humans interact with those hazards, are what leads to disasters. Therefore, a community's ability to affect and adapt to natural hazards heavily influences the ensuing disaster risk.

5.2 More About Hazard Likelihood

The likelihood (or frequency, or probability) of a hazard occurring is a key component of understanding the hazard. Likelihood is expressed as an Annual Exceedance Probability (AEP), which is the percentage probability of a hazard event occurring in any year. For example, an extreme flood that has a calculated probability of 0.2% of occurring in this or any given year is described as the 0.2% AEP flood hazard[25]. This same event is also commonly referred to as the 1 in 500-year event, which generally ends up incorrectly leading readers to thinking that the event only occurs once every 500 years.

Flood hazard event likelihoods can be quantified more easily compared to debris flow events. This is due to the higher frequency of flood events, and the availability of monitoring data. For this reason, the likelihood of debris flow events within the project area are not well known.

5.2.1 Encounter Probabilities

Another way to think about hazard likelihood is through the use of asset encounter probabilities, where it is possible to calculate the likelihood of encountering an event of a given size over a defined time period—for example, the length of an average mortgage (25 years) or the average lifespan of a human (75 years). Table 5 shows that for a 1% AEP event there is a 22% chance that an event of this size or greater will occur over a 25-year period. Understanding the likelihood of an event as well as the encounter probability of an event can support decisions related to flood and debris flow hazard management. This project considered multiple likelihood scenarios, and reported them all using the AEP terminology.

Table 5: Encounter probabilities for various likelihoods.

Annual Exceedance Probability (AEP)	Indicative Return Period	Encounter Probability of Occurrence in 25 years	Encounter Probability of Occurrence in 50 years	Encounter Probability of Occurrence in 75 years	Encounter Probability of Occurrence in 100 years
100%	Annual	100%	100%	100%	100%
30%	Once every three years	100%	100%	100%	100%
10%	Once every 10 years	93%	99%	100%	100%
3%	Once every 33 years	53%	78%	90%	95%
1%	Once every 100 years	22%	39%	53%	63%
0.1%	Once every 1000 years	2%	5%	7%	10%

[25] It is emerging best practice to represent hazard likelihoods with an AEP. In the past, hazard likelihood was commonly represented as an X-year return period. However, this tends to cause confusion regarding the frequency of an event with the lay public. For example, it is commonly believed that if a 100-year event has occurred, it will not re-occur for another 99 years, which is incorrect.

5.3 More About Hazard Consequence

Hazard likelihood and magnitude are inversely related—the lower the likelihood of an event occurring, the higher the magnitude (i.e. in the case of flood, this generally means higher and faster water). In the context of natural hazard risk, the higher the magnitude, the higher the consequence. In western society, the consequences are generally viewed as undesirable. As such, “severity” is often used to both qualify the magnitude of a hazard event, as well as imply its undesirable consequences. However, it is important to acknowledge that the consequence of an event may be either desirable or undesirable (Sayers et al., 2013).

This project refrained from using the term “severity”, as it is not entirely accurate when considering the consequences of flood and debris flow hazards from an ecosystem and *Syilx* Okanagan perspective (Section 3.3 and Section 4.1, respectively). Instead, the term “magnitude” is used to qualify the size of the flood hazard, while implying a neutral consequence (i.e. either positive or negative). Indicative flood magnitudes of “High”, “Moderate”, and “Low”, were assigned based on a high-level understanding of likelihoods expressed as annual exceedance probabilities (AEPs). Details of this approach are in the Quantitative Study.

5.4 Key Risk Concepts

Given that *risk* is the combination of the likelihood of an event and its consequences, a *risk assessment* is essentially a methodology to determine the nature and extent of *risk*. This is done by analyzing potential *hazards* and evaluating conditions of *exposure* that together could potentially harm people, property, services, livelihoods, and the environment on which they depend. Risk assessment requires an understanding of the range of risks, as well as their cumulative, spatial, and dynamic aspects. These concepts will be explained in the following sections. Two methods to characterize risk (i.e., scenario and probabilistic) will then be explained, to introduce how the concepts can be applied in a risk assessment.

5.4.1 Range of Risk by Hazard

Different geohazards have different combinations of likelihood and consequence, and therefore, risk. Flood events can range from nuisance (i.e. high likelihood, low consequence) to catastrophic (low likelihood, high consequence). These events could fall as a bubble in many places in Figure 24, which is focused on coastal zone hazards. In contrast to floods, debris flows are generally considered to be low likelihood, high consequence events. This is similar to earthquakes or tsunamis; however, debris flows are much smaller in scale.

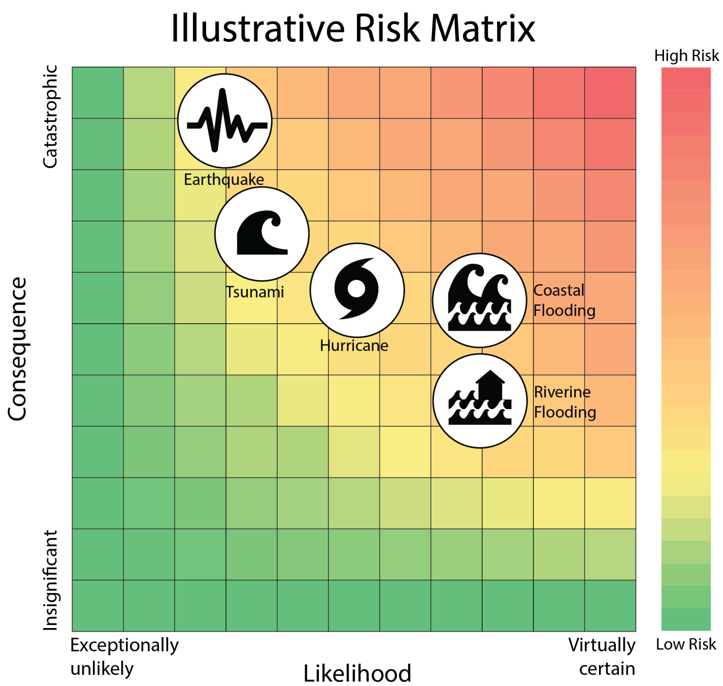


Figure 24: Consequence and likelihood of various natural and human-induced hazards (National Research Council, 2020)**.**

5.4.2 Cumulative Risk

In looking across time-horizons, a virtually certain but insignificant event can have the same risk as a catastrophic but rare event. For example, a nuisance hazard that occurs annually over several decades and accumulates losses, may in fact be more impactful than a catastrophic hazard that occurs just once (Figure 25). A risk assessment can be used to compare both the impacts and the potential benefits of adaptation options for the whole spectrum of nuisance to catastrophic events. This provides a useful tool to make informed investment and planning decisions.

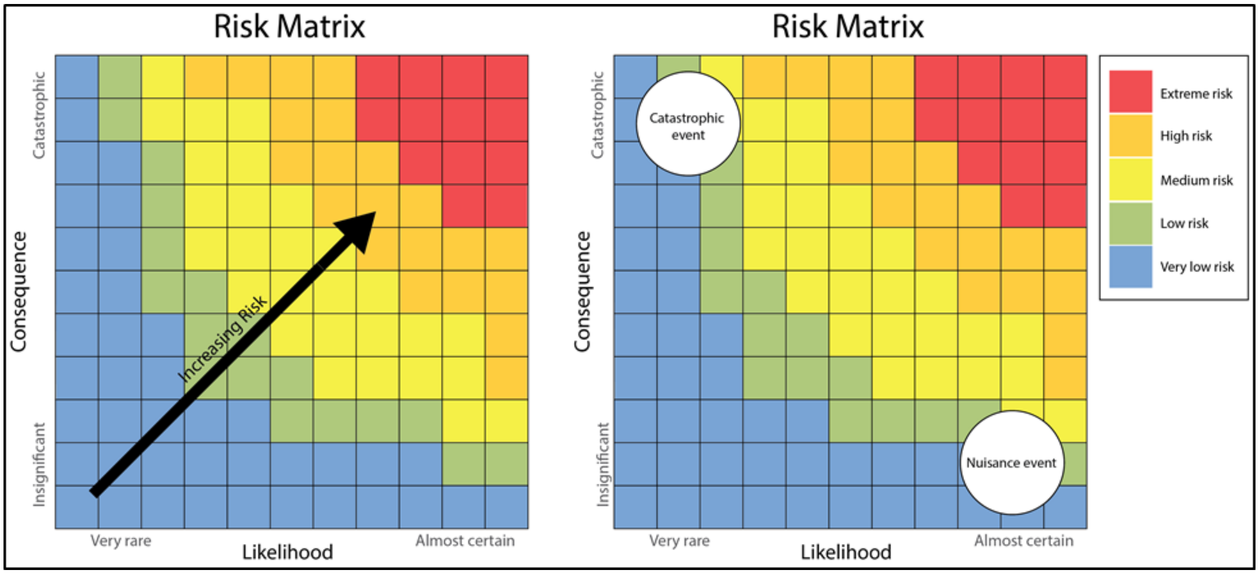


Figure 25: Risk as a function of likelihood and consequence – nuisance and catastrophic risk.

A further temporal consideration of flood and debris flow hazards is the event onset. Floods may have a slow onset or can be quite sudden. In contrast, debris flows are generally considered to be sudden, which has considerable implications to warning times and response capacity. Understanding the temporal considerations of each hazard within a risk assessment framework is key to planning for mitigation, management, and response.

While risk assessments are typically conducted as a “snapshot in time”, the historical context is important to consider. The *Syilx* Okanagan people did not exercise self-determination in deciding the location of their present-day settlements. This and other events of the past affects the exposure and vulnerability of these people in terms of flood and debris flow risk.

5.4.3 Spatial Risk

The information required to complete a risk assessment must be tailored to fit the project scale and the data and resources available. Different levels of effort are used to achieve different objectives, and more resources are required to conduct detailed analyses at large spatial scales. For example, the national all-hazards risk assessment (AHRA) is a tool that will help identify, analyze, and prioritize a full range of potential threats based on a high-level analysis (Public Safety Canada, 2012). This type of tool can be developed relatively quickly and inexpensively at a national scale and is invaluable for prioritization exercises. However, to make decisions to reduce risk locally, in particular through the use of land-use policy, a more robust methodology is required—ideally a fine-scale risk assessment (see Figure 26). A fine-scale risk assessment is one that includes measurable, objective *hazard*, *exposure (*including *vulnerability),* and *likelihood* (magnitude) to calculate *risk* and loss. The quantification of *risk*, although at times cumbersome, provides invaluable information for risk reduction through the provision of robust, transparent data for planning and decision-making.

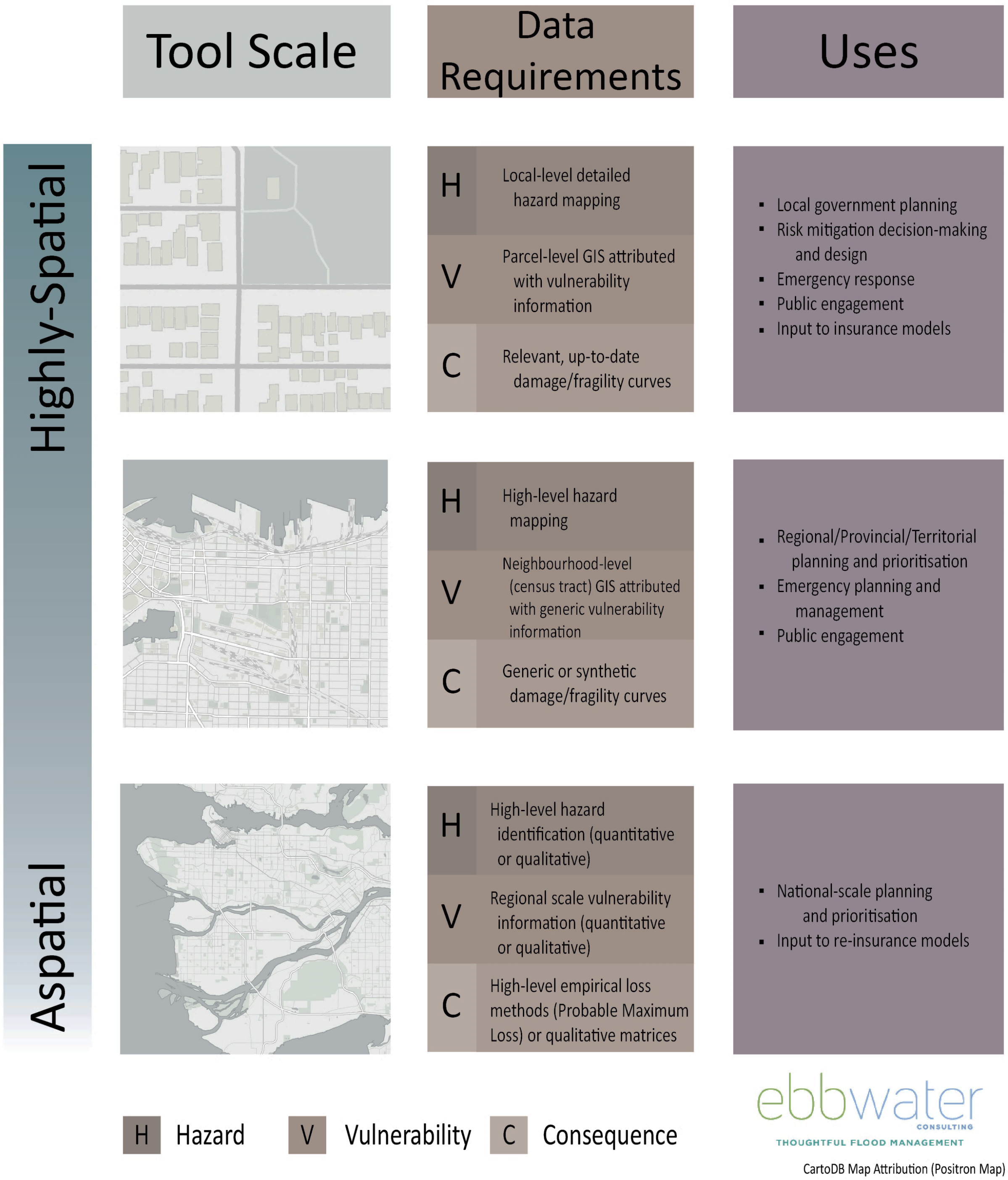


Figure 26: Spatial scales of risk assessment.

Due to the size of the area studied, this project's risk assessment spatial scale lies somewhere in the middle of the aspatial and highly-spatial spectrum. This balance was necessary to acquire relevant data for the 15,400 km^2 area, including obtaining input from participants representing over 20 local governments, groups, and agencies.

5.4.4 Dynamic Risk

Risk is not static. The components of risk (i.e., hazard likelihood and severity, exposure, and vulnerability) are all prone to change over time. These changes are a result of issues that range from global to local contexts related to climate change, land use, and governance (Chapter 8); Figure 27 demonstrates schematically how risk can increase with time. For example, for flood and debris flow hazards, climate change is likely to continue to increase the likelihood of occurrence (it may also increase the magnitude and therefore the consequences), shifting risk from the left to the right in the graphic in Figure 27.

Risk can also increase by changing the consequences of the hazard occurring, through other pressures such as allowing increases in urban development (see Chapter 6). In this case, the risk shifts from the bottom to the top of the graphic in Figure 27. As climate change and other pressures are cumulative, the increased likelihood combined with the increased consequences are likely to result in dramatically increased risk (as illustrated in the top right of the graphic in Figure 27).

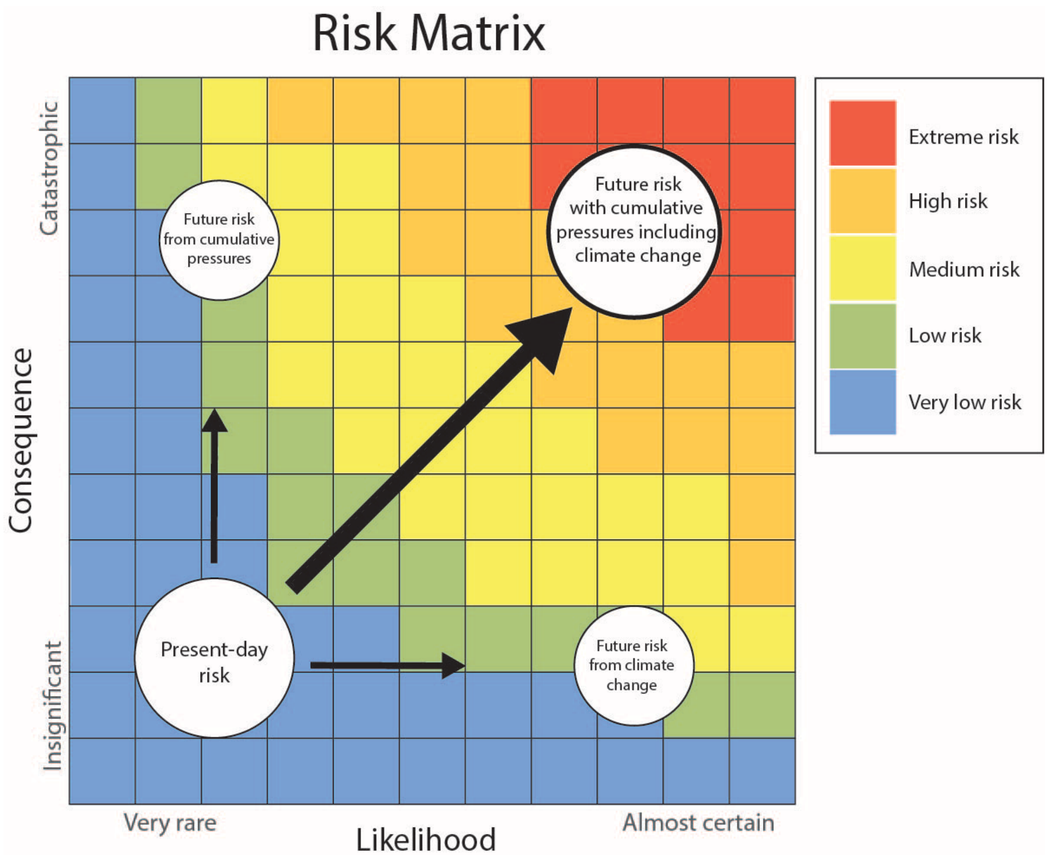


Figure 27: Dynamic risk with climate change and watershed-scale pressures.

Given that risk is dynamic, it is important to consider both present-day and future risk, especially when seeking means to maintain or reduce risk over time. Cumulative pressures are discussed further in Chapter 6.

5.4.5 Scenario and Probabilistic Risk

Risk as a function of likelihood and consequence can be characterized in different ways. Two approaches with different levels of effort and outcomes that serve different purposes are outlined below.

Scenario-based Risk

If a single event likelihood (e.g., an extreme event) is used to calculate damages and losses, this is called a risk *scenario*. This is the most common type of assessment completed in Canada, as it is relatively straightforward and requires only one hazard event be calculated and mapped. Scenarios are commonly used for emergency response planning, where large probable maximum events are used for exercises on the assumption that a plan for a catastrophic event will also be valid for smaller events. Scenarios have also traditionally been used to support hazard mitigation decisions because this simple standards-based approach is relatively straightforward to calculate.

Probability-based Risk

A probabilistic assessment is one that considers a range of hazard events and damage outcomes. The area under a curve (with likelihood and consequence as the axes) is integrated to give a full picture of risk. This approach is rarely used at present, but is quickly being considered best practice, as it provides an understanding of the impacts of frequent small events, as well as infrequent large events. Probabilistic assessments can be resource intense; however, updates in technology and methods are slowly reducing the relative effort to conduct them.

Scenario versus Probability-based Risk

Scenario approaches are the most commonly used—primarily because of the relative effort. However, probabilistic approaches are becoming more common and are generally considered best practice. This is especially true with climate change, as some smaller and medium events become more common. Decisions can be affected by the approach taken (Lyle, 2016), and it is therefore important to choose an appropriate approach given the available resources, data, and time. For this project, the quantitative debris flow risk assessment is scenario-based. Given the spatial scale of the project area, considerable effort was required to delineate debris flow prone areas without consideration for probabilities of occurrence. The quantitative flood risk assessment resembles a probabilistic-based approach. However, the definition of the likelihood of events is semi-quantitative (see the Quantitative Study for further details).

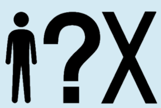
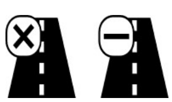
5.5 Exposure Indicators

The ONA has several objectives in terms of framing this risk assessment. There is an interest in developing a better understanding of the exposure and risk generally throughout the project area to flood and debris flow phenomena.

The use of exposure indicators presents a considerable limitation with the objective of incorporating the *Syilx* Okanagan perspective for this project. Impacts and consequences are diverse and interconnected, which is not easily considered within the exposure indicator "boxes" that have been defined. (As described in Section 4.2, the risk assessment method deliberately has been developed with complimentary qualitative and quantitative studies to partially address this issue). The issue has also been partially addressed through implicit re-prioritizing of the exposure indicator discussions, which was more in-line with the ONA's view.

Risk assessment is shaped by the types of exposed elements that are considered; however, it is important to think about what can be measured. Given that the impacts of flood and debris flow hazards are often widespread and diverse, best practice suggests that a broad spectrum of impacts should be considered. One approach is to base impacts on the recently released UN document on indicators for disaster risk reduction (United Nations, 2016), which itself is based on the Sendai Framework indicators (UNISDR, 2015). These base indicators are currently being used by federal agencies in Canada to support various disaster risk and risk reduction programs. They are described in Table 6, and where otherwise noted, they were applied to the risk assessment using separate methods within the Qualitative and Quantitative Analyses.

Table 6: Risk assessment impact category descriptions.

Impact Category		What Is Described
Environment		Impacts to environmentally sensitive areas that are directly exposed, and the effects of contaminants that are released into the area when hazardous sites are affected.
Culture		Impacts to sites of cultural significance including harvesting, sacred, and recreational areas.
Mortality		People that go missing or die as a result of the event. *Not used in the qualitative analysis.*
Affected People		People impacted because they have had their homes, schools, businesses, and/or other services lost.
Economy		Direct losses, which primarily includes damage and reconstruction costs to public and private structures. This also can include the cost of response.
Disruption		Describes the potentially more widely spread impacts that can result (e.g., when a road is cut off or a public amenity is damaged).

The impact categories in Table 6 are not a complete list of impacts, but they provide a good starting point for review and discussion. For example, the categories do not fully cover indirect impacts (e.g., long-term health) or intangible impacts (e.g., human stress and livelihood). However, given that most indirect and intangible impacts are difficult to quantify and to monetize, the above provides a good foundation for a risk assessment. The categories outlined above also fully meet the needs of Public Safety Canada's current Risk Assessment Information Template (RAIT) form.

5.5.1 Other Impact Types

Beyond the gross indicators for risk mentioned above, there are many ways to categorize and consider impacts. As described below, not all of these impact types are easy to estimate, but that does not mean they should not be considered. At a minimum, it is important to recognize what types of impacts have been considered in a risk assessment and to be explicit about those that have not. While the quantitative Study included little consideration for direct and indirect impacts, and impact tangibility, the methods applied in the Qualitative Study allowed some consideration of these.

Direct and Indirect Impacts (or Consequences)

Impacts can also be grouped into direct and indirect impacts. **Direct** impacts describe all harm that relates to the immediate physical contact of water and debris to people, infrastructure, and the environment (i.e., elements at risk, or assets). Examples include damage to buildings, impacts on building contents and other assets, damage to the environment, and loss of human life. **Indirect** impacts are those caused by the disruption of the physical and economic links in the region, as well as the costs associated with the emergency response to a hazard. For example, business losses because of interruption of normal activities, or costs associated with traffic disruption when roads are impassable.

Impacts (or Consequences) by Tangibility

The effect of a flood and debris flow hazard event on the environment, human or community health, or loss of life are difficult to quantify, and are therefore considered to be **intangible** impacts. On the other hand, the **tangible** dollar losses from a damaged building or ruined infrastructure are more easily calculated. This does not mean that tangible losses are more important than the intangibles, just that they are easier to quantify and assess. The inclusion of intangible impacts is desirable for the development of a robust risk assessment (Messner & Meyer, 2006). Table 7 provides examples of direct/indirect and tangible/intangible impact typologies.

Table 7: Examples of hazard impact typologies.

Hazard Impact	Tangible	Intangible
Direct	• Building damage • Infrastructure damage	• Loss of life • Health effects • Loss of habitat and environment
Indirect	• Loss of business • Traffic disruption • Emergency response costs	• Inconvenience of event recovery • Increased vulnerability of survivors

5.6 Guidance and Funding

There are currently no regulated Canadian guidance documents on how consequences from natural hazards should be estimated and on how risk should be calculated. There are, however, international documents on practices that can be used to inform methods. In particular, consideration was given to Sendai (UNISDR, 2015) and further guidelines developed in recent years which are based on the Sendai

Framework for Disaster Risk Reduction (Sendai, further explained in Chapter 7) (UNISDR, 2009, 2016, 2017). Resources from the Australian Institute for Disaster Resilience (AIDR) were also considered. The AIDR provides insight into the use of stakeholder knowledge and expert elicitation to support the estimation of intangible and indirect impacts, as well as discussion of consequence scoring methods (AIDR, 2015).

The methods applied also consider forthcoming guidance on natural hazard risk assessment being developed by various agencies[26] in Canada. Specifically:

1. **Defence Research and Development Canada/Public Safety Canada**, who are developing a "Methodological Approach to Canada's National Risk Profile".
2. **Natural Resources Canada/Public Safety Canada***,* who are developing flood risk assessment guidelines as part of the Federal Flood Mapping Framework initiative.
3. **National Research Council,** who are developing coastal flood risk assessment guidelines.
4. **Natural Resources Canada***,* who are developing risk-based land use guidelines among other documents.

Each of the above are on different timelines, but all follow the basic frameworks for natural hazard risk assessment described in the international documents. Finally, methods were derived from recent experience completing natural hazard risk assessments for other communities in Canada (also under the NDMP). Over time, these have evolved based on experience and data availability.

In BC, there is a general trend to rely on qualified professionals, as opposed to rigid regulatory standards, in the natural resources field—this includes natural hazard management. In order to provide guidance to clients and professionals, the Engineers and Geoscientists of British Columbia (EGBC)[27] have developed a series of professional practice guideline documents, including:

- Flood Mapping in BC (APEGBC, 2017)
- Legislated Flood Assessment in a Changing Climate in BC (Church et al., 2018)
- Legislated Landslide Assessments for Proposed Residential Developments in British Columbia (APEGBC, 2010).

While these guidelines provide useful information to help practitioners think about the information required to study natural hazards, none of them reference current international best practice for natural hazard risk assessment and risk reduction.

5.6.1 Flood Management Funding Context

The regulatory context described in 8.2 shows that natural hazard management is primarily a local government responsibility. However, natural hazard mitigation, especially structural flood and debris flow hazard mitigation projects, are generally far more expensive than local government budgets can stretch.

[26] Ebbwater is involved either as an author, advisor, or reviewer for each of the above guidelines. There may be other initiatives that are not yet public, and therefore not included in this list.

[27] Formerly called the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC).

In recent years, the provincial and federal governments have developed grant funding programs to support natural hazard mitigation planning, as well as to implement management solutions; these are summarized in Table 8.

Table 8: Summary of available funding programs for flood and debris flow hazard risk reduction.

Program	Owner	Comments
National Disaster Mitigation Program (NDMP)	Public Safety Canada (PSC)/Emergency Management British Columbia (EMBC)	This is a 5-year program (currently in its last cycle) designed to support hazard mitigation through the funding of foundational research and planning (hazard risk assessments, hazard mapping, hazard mitigation plans). This project was funded through the NDMP. This funding source will sunset in 2020; no replacement for this program was announced in Budget 2019. *The ONA received approximately $350,000 from this grant program for this risk assessment project.*
Community Emergency Preparedness Fund (CEPF)	Union of BC Municipalities (with funding from EMBC)	This is a 2-year program (currently in its last cycle) that, in part, mirrors the NDMP. There are also additional funding streams for structural mitigation works and for emergency management/response and emergency social services.
Built Environments Grant	Real Estate Foundation of BC (REABC)	This program funds projects that advance sustainable land use and real estate practices. *The ONA received $20,000 through the grant program for this risk assessment project.*
FN Adapt	Crown and Indigenous Relations and Northern Affairs (CIRNAC)	The program funds projects to assess and respond to climate change impacts on community infrastructure and emergency management. *The ONA did not receive funding from this program for this Stream 1 Project. However, the OBWB received $75,000 in 2018/19 to integrate the ONA into floodplain mapping activities.*
Disaster Mitigation and Adaptation Fund (DMAF)	Infrastructure Canada (INFC)	This is a 10-year program that has just had its first intake. This was envisioned as a complementary program to the NDMP, where foundational work, including proposed mitigation options, is realized through DMAF funding. This program supports all-hazards (as opposed to the flood-focused NDMP and CEPF) and has a basement funding allocation of $20M. Further, this program has a strong focus on green infrastructure and low-carbon resilience (as opposed to structural mitigation).

The funding program criteria/requirements have variations on the following need for both planning and structural mitigation projects to demonstrate:

- Hazard risk (either historic or based on a risk assessment) and a plan to reduce risk.
- Commitment to preparedness, planning, and mitigation.
- Contribution to or grounding in a comprehensive, cooperative, and regional mitigation plan.
- Consideration of climate change (both mitigation of greenhouse gases and adaptation to climate futures).
- Good value for money.

These criteria, along with the overall mandates for these programs, show a clear directional shift in senior government funding for natural hazards. Namely, that senior government is shifting away from reactionary funding and from a focus on structural measures towards investing in long-term resilience based on comprehensive risk-based plans. In order for the ONA to leverage these funds in the future, they need to invest in the development of comprehensive natural hazard management planning. This current project lays the foundation for this type of work and should put the ONA in good stead for senior level government funding in the future.

Appendix B contains a review of recent and ongoing flood management projects in the study area.

5.7 Evolving Methods

Globally, risk assessment practice is evolving quickly. This means that new data and tools need to be incorporated both qualitatively and quantitatively, and some key issues are discussed in the following sections. As with many global issues with overlapping environmental, social, and economic components, tailoring needs to the local context is critical. How can risk reduction be approached more holistically and consider alternative worldviews? This question is discussed in Chapter 7.

5.7.1 Quantitative Data Needs

Although widely accepted as best practice for natural hazards management, risk-based planning and the requisite risk assessments are a relatively new concept in Canada. Traditionally, natural hazards have been managed based on specific hazard standards (e.g., a 0.5% AEP flood event or a factor-of-safety on engineered designs in flood and debris flow hazard areas). In the transition from a factor-of-safety approach for natural hazards to more detailed risk assessment methods, there is a need to develop new methods to understand the interactions between the hazards and the assets at risk. Methods for this type of detailed assessment are in their infancy, and require a range hazard likelihood data, and exposure data (including vulnerability) Hazard likelihoods require the development of modern flood (and other geohazards, as applicable) maps, which require field monitoring data for hydraulic model calibration and development. Diverse exposure data, including vulnerability metrics such as population demographics and related proxies is also required on a watershed basis.

5.7.2 Incorporation of Qualitative Information

The impacts of flood and debris flow hazards are widespread, and affect people, infrastructure, the economy, culture, and the environment. Damage estimation, however, has traditionally been the domain of engineers, and, as such, has focused on economic valuation of infrastructure and building losses, leaving a large gap in knowledge regarding intangible impacts (Messner & Meyer, 2006). This gap has increasingly been acknowledged, but there is still very limited validated research available, and tools to look at intangible impacts are largely undeveloped. It is known that when damages are monetized, buildings become priorities for hazard mitigation, whereas when damage is expressed as the number of people affected by an event (through stress or inconvenience), road damage and associated disruption become a mitigation priority (Veldhuis, 2011). The metrics chosen for assessing damage can deeply affect subsequent planning decisions. In effect, the non-inclusion of intangible impacts can affect priorities.

5.8 Summary

Risk assessment for natural hazards is a challenging and evolving field. The level of effort it takes to conduct a risk assessment is very dependent on the use of the information, but also on the available data and resources. Detailed quantitative methods for all-hazard risk in particular are in their infancy in Canada (Lyle & Hund, 2017).

It should be noted that much of this work, including the spatial scale and Indigenous perspective, is leading-edge and therefore required significant innovation. It is anticipated that these methods will be refined and improved over time by risk management professionals. The qualitative and quantitative risk assessments provided in the Qualitative and Quantitative studies meets and exceeds current best practice and is suitable for input into risk assessment templates required by various funding agencies. The results also provide foundational information that can be used to support future adaptation planning.

In summary, a true risk assessment, one that looks at consequences over time, is an invaluable instrument for decision makers, policy makers, and planners. From the Indigenous perspective, the causes of harm and the elements at risk need to be considered holistically. Such a risk assessment can be used to understand and to mitigate present and future damages and to create risk management strategies that are cost-effective and supported by all communities in a region. As such, they can be used to help plan for long-term financial investments into adaptation and risk reduction.

6 Cumulative Pressures on Hazards

Considering risk reduction holistically requires a better understanding of the complex and interrelated factors that are contributing to increasing hazard within the project area. Climate change is an overarching pressure with effects on all the others, which are summarized as follows for this project: land use change, ecological disturbance, industrial activity, flood defence structures, urban development, and surface-subsurface interactions (Figure 28). While these pressures are not necessarily comprehensive, they address key factors to consider when assessing how flood and debris flow hazards are likely to change in the project area going into the future.

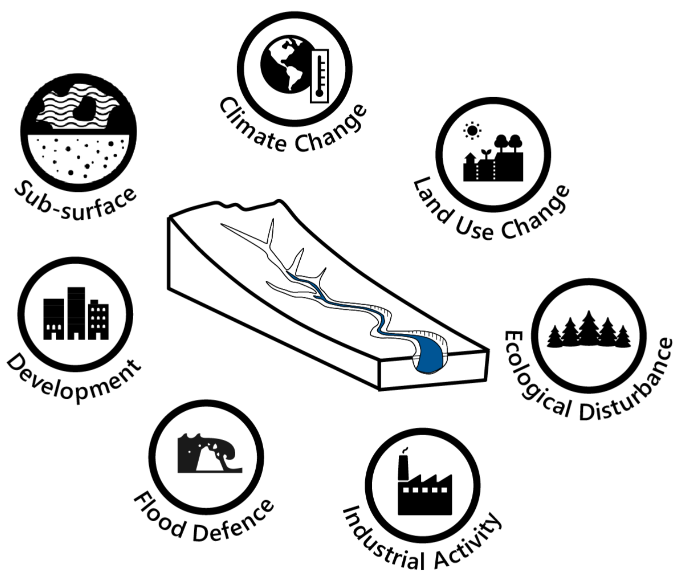


Figure 28: Watershed-scale cumulative pressures on flood and debris flow.

Considered even more broadly, cumulative pressures are degrading watersheds and affecting water quality, water security, human health, ecosystem functions, *Syilx* Okanagan livelihoods, and fish and fish habitat (Polis Project on Ecological Governance, 2019). Therefore, an understanding of the cumulative pressures that relate directly to flood and debris flow hazard is an important step in identifying holistic adaptation solutions, with wide-ranging co-benefits at the watershed scale. The following sections include a review of information that demonstrates how the various pressures affect flood and debris flow hazards. The discussion also includes high-level references to how some pressures negatively affect water quality; flood waters can transport contaminants toward receptors with important consequences.

6.1 Climate Change

The climatic changes that have been observed in the region in the past (see Table 3) are likely to continue and to become more pronounced in the future[28]. Table 9 shows projections for key climate indicators for

[28] Summary of Climate Change for Okanagan-Similkameen in the 2050s. Plan2Adapt Tool. Pacific Climate Impacts Consortium. Weblink: http://www.plan2adapt.ca/tools/planners?pr=21&ts=8&toy=16. Accessed February 9, 2019.

the 30-year period centred on the 2050s, relative to the 1961-1990 period, for the Okanagan-Similkameen region. Appendix C contains additional information on the science of climate change projections.

Table 9: Temperature, precipitation, and snowfall projections for the 2050s, based on 1961-1990 baseline (Adapted from PCIC Plan2Adapt Tool).

Indicator	Time Period	Ensemble Median	Range[1]
Mean Temperature	Annual	+1.9°C	+1.1 to +2.7
Precipitation	Annual	+6%	-2% to +10%
	Summer	-13%	-26% to +3%
	Winter	+6%	-4% to +16%
Snowfall[2]	Winter	-14%	-25% to -3%
	Spring	-56%	-75% to -13%

Notes:

1: The range represents the 10th to 90th percentile.

2: Derived from temperature and precipitation.

In the project area, mean temperature is likely to increase by approximately 2°C. Although temperature increases of a few degrees may seem small, they are associated with important physical and biological changes[29]. The uncertainty in temperature projections is smaller compared to the projections for precipitation and snowfall (Table 9). However, it is generally understood that warmer temperatures are likely to lead to more precipitation falling as rain rather than snow, with less overall snowfall (Table 9), less snowpack accumulation, and reduced spring runoff (Larson et al., 2011).

The sections below focus on how specific climate-driven processes are likely to affect flood and debris flow hazards.

6.1.1 Hydrogeomorphic Desiccation

Temperature increases are likely to lead to more frequent drought conditions. Dry soils become water-repellent, which reduces their infiltration capacity (Gimbel et al., 2016) and increases runoff under extreme rain (see Section 6.2). The effect of hydrophobic soils on the likelihood of debris flows is discussed in Section 6.3.1. The conditions that develop during prolonged dry periods and areas burned by wildfire with a moderate to high severity can increase surface runoff and cause significant erosion, increasing the likelihood of debris flows or debris floods (Hope et al., 2015).

6.1.2 Hydrologic Regime Shift

Increased warming and precipitation in winter (Table 9) could lead to an increase in ice jam floods due to the incidence of mid-winter thaws. Warming is likely to continue to shift hydrologic regimes from being snowmelt-dominant to rainfall-dominant, resulting in a shorter and earlier spring runoff (freshet) period (Berghuijs et al., 2014). While average freshet flows are likely to decrease, spring flooding resulting from

[29] Combined with the temperature increases that occurred for the period 1900-2013 (Table 2), the region will experience a rise in average temperature of approximately 2.5°C by 2050. For comparison, a rise in temperature of about 5°C, which occurred approximately 10,000 years ago, was enough to melt the ice sheets that covered much of North America (Ministry of Environment, 2016).

rain-on-snow events will still be possible (Surfleet & Tullos, 2013). Increasing winter precipitation (Table 9) is likely to result in increased flooding during that season (Buttle et al., 2016).

The movement of high moisture air masses from the Pacific Ocean to inland areas is one extreme precipitation mechanism experienced in the project area. These events, known as atmospheric rivers, are projected to double in the region for the 2050s during fall and winter (Pinna Sustainability, 2014).

Debris flow occurrence is linked to runoff and flooding (Dunne & Leopold, 1978; Hungr et al., 2001); therefore, the hydrologic changes discussed above are likely to increase debris flow hazard as well.

6.1.3 Precipitation Intensity Increase

It is the intensity of extreme precipitation events that leads to overland flow (runoff) and flooding, as soils exceed their infiltration capacities (Maidment, 1992). Precipitation under different intensity-duration-frequency (IDF) combinations are projected to increase in Canada (Cannon & Innocenti, 2018). Changes specific to the project were obtained from the research authors (Alex Cannon, Environment Canada, personal communication, March 22, 2019). Results in Table 10 show that, relative to other combinations, the IDF increases are projected to be largest for events of lower frequency (greater severity) and shorter durations. Therefore, rainfall conditions that lead to flooding are projected to become more severe in the project area. The projections show the percent increase in precipitation *per degree of warming*; therefore, the projections may be associated with likely future time periods based on forthcoming climate warming projections for the Okanagan region that are scheduled for completion in February 2020 by the Pacific Climate Impacts Consortium.

Table 10: Future change in precipitation amount per degree celsius of warming in project area (extracted and provided by the authors of Cannon and Innocenti (2018)).

Duration	Percent Increase (50^{th} percentile)	Percent Increase (25^{th} percentile)	Percent Increase (75^{th} percentile)
10% AEP (10-year indicative return period)			
0.25-hr	8.4	5.2	12.2
1-hr	8.1	5.5	11.1
24-hr	7.3	4.7	10.1
2% AEP (50-year indicative return period)			
0.25-hr	8.8	5.2	13.1
1-hr	8.5	5.5	11.9
24-hr	7.8	4.8	11.0

Short and intense rainfall is one of two dominant weather processes that affects the likelihood of debris flow events, along with the antecedent moisture conditions (Jakob & Lambert, 2009). Guthrie (2009) noted that a critical threshold for landslides on Vancouver Island is 80–100 mm in a 24-hour period, and that this threshold is likely to be exceeded more frequently under climate change. Landslide triggering precipitation thresholds are unknown for the project area; however, based on the IDF for Kelowna

Airport[30], and the projections in Table 3 and Table 10, precipitation intensity is likely to remain below the threshold that is theorized for Vancouver Island. This is largely due to the much dryer conditions experienced in the Okanagan compared to Vancouver Island. However, increased intensity of precipitation, especially associated with convective storms, is still likely to result in an increase in debris flow frequency.

6.2 Land Use Change

Water is stored naturally in catchments within natural or traditional ecosystem vegetation such as forests and wetlands, river channels and flood plains, and the sub-surface. Land use change typically reduces the ability of water to infiltrate into the sub-surface and to be taken up by vegetation (Maidment, 1992), increasing flood frequency and severity (Tollan, 2002). Land use change in the project area has primarily occurred through the conversion of land for food production, but it has also occurred from deforestation (Section 6.3) industrial activity (Section 6.4) and urbanization (Section 6.6). Many ecosystems have been reduced by as much as 90% compared to the year 1800 (Lea, 2005).

6.2.1 Loss of Wetlands and Riparian Areas

Wetland areas are distinct ecosystems that support vegetation and aquatic plants that are adapted to permanently high water tables (i.e. flooded areas). Riparian areas occur at the interface between land and streams, and support diverse habitats. Together, wetland and riparian areas have important ecosystem functions, including buffering environmental effects related to water quality and quantity caused by humans (Ecoscape Environmental Consultants, 2017). Wetlands and riparian areas are critical to flood management; they store flood water volumes and reduce water velocities, attenuating flood waves (Maidment, 1992; Anderson, Rutherford and Western, 2006). Riparian areas maintain channel conveyance (Dadson et al., 2017).

Wetlands and riparian habitats have been reduced by 85% in the Okanagan-Similkameen region[31]. This has been due to the other pressures discussed in this Chapter, with the predominant ones being grazing, agriculture and forestry activity, recreational use, urban development, and invasive species (Ecoscape Environmental Consultants, 2017).

6.2.2 Conversion to Agriculture and Ranching Lands

When traditional land use is changed from its natural state for the purpose of food plant or animal production, the hydrologic regime changes. Typically, this leads to soil erosion and increased runoff, especially where lands are compacted by cattle and heavy machinery[32]. Ditches and diversions also change water flow paths, increasing flood potential. Fertilizer use degrades water quality (Kanianska, 2016).

[30] IDF data obtained from Environment and Climate Change Canada. Weblink: ftp://client_climate@ftp.tor.ec.gc.ca/Pub/Engineering_Climate_Dataset/IDF/. Accessed June 20, 2019.
[31] https://www.osstewardship.ca/wetlands-riparian-areas. Accessed June 6, 2019.
[32] Careless Farming Adding to Floods. BBC News, Science and Environment, 7 March, 2014. Weblink: https://www.bbc.com/news/science-environment-26466653. Accessed December 4, 2019.

6.3 Ecological Disturbances

Many ecological disturbances have occurred in the project area since European settlement. The disturbances are linked to a variety of sources and activities. Key disturbances that affect flood and debris flows are wildfire, infestations and invasive species, animal and habitat removal, and recreational land use.

6.3.1 Wildfire

Wildfires leave ground cover barren and unable to absorb or slow water infiltration and runoff. This is due to the removal of vegetation and changes to soil properties that make them water-repellent (hydrophobic) (Doerr et al., 2009; Hope et al., 2015), which increases runoff. Hydrophobic soils develop in conjunction with prolonged dry periods and areas burned by wildfire. Where these conditions are severe, surface runoff can cause significant erosion, increasing the likelihood of debris flows or debris floods (Nyman et al., 2019).

Debris, ash, and sediment that remain on the ground post-fire can be picked up by runoff during ensuing rainstorms, which can increase the hazard impacts. Elevated hazard conditions remain until vegetation can be restored, which can take up to five years[33]. A number of debris flows, debris floods, and debris slides occurred during rainstorms following the 2003 extreme fire season in the southern Okanagan (Jordan & Covert, 2009).

In Canada, large wildfires have been getting larger over the last 50 years (Little et al., 2018), and wildfires are likely to increase in the future due to climate change (Wotton et al., 2017). However, wildfires are critical components of our ecosystems as they rejuvenate forests and promote biodiversity. Without wildfires, ecosystems are more susceptible to large damaging fires and infestation[34][35].

6.3.2 Infestations and Invasive Species

Infestations can change vegetation patterns, with resulting effects at a watershed scale. The Mountain Pine Beetle is an example infestation that has impacted forests within the project area, with important consequences to hydrologic regimes resulting from forest canopy removal (Redding et al., 2008). In large dead pine forests across the central interior of BC, research suggests that water yield, peak flows, and flood timing were affected (Forest Practices Board, 2007; Schnorbus, 2011). Warmer minimum temperatures in winter, resulting from climate change (Table 3) contributed to the beetle population's expansion into BC (Carroll et al., 2003).

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[33] Flood After Fire Factsheet. Weblink: https://www.ready.gov/sites/default/files/Flood_After_Fire_Fact_Sheet.pdf. Accessed June 12, 2019.

[34] We created B.C.'s wildfire problem – and we can fix it. Globe and Mail. 13 July 2017. Weblink: https://www.theglobeandmail.com/opinion/we-created-bcs-wildfire-problem-and-we-can-fix-it/article35686104/. Accessed 12 June, 2019.

[35] For a Warming World, A New Strategy for Protecting Watersheds. Yale Environment 360. Weblink: https://e360.yale.edu/features/why-restoring-watersheds-is-a-new-priority-in-a-warming-world. Accessed June 18, 2019.

Watershed studies conducted worldwide have shown that changes in dominant plant species result in changes in surface runoff and groundwater discharge (Le Maitre et al., 2015). As discussed in Section 6.2, the project area has undergone significant changes to its natural vegetative cover. The specific impacts of invasive cheatgrass on watershed hydrology in the project area are not well known; however, its spread may be linked to the spread of wildfires in the region based on research in other areas. Cheatgrass is commonly found in recently burned rangeland, winter crops, abandoned fields, eroded areas and heavily grazed grasslands[36]. The fine-textured leaves of this plant are prone to ignition, increasing the rate of spread of wildfires (Blank et al., 1995).

6.3.3 Animal and Habitat Removal

Beaver behaviour can have significant impacts on hydrology and ecosystems[37], and they inhabit mountain wetland habitats in Canada (Morrison et al., 2015). Based on research in the United Kingdom, beaver dams increase water storage, reduce the mean velocity and discharge downstream of dams (Dadson et al., 2017; Puttock et al., 2017). Beaver dams also maintain stream and riparian habitats (Maenhout, 2013), with concomitant flood management benefits as discussed in Section 6.2. Beaver activities can also potentially help manage wildfires[38]. The removal of beavers in British Columbia[39] and their wetland habitats has likely led to a reduction in these flood management benefits in the project area.

6.3.4 Recreational Land Use

The creation of trail networks and lodges to support activities such as all-terrain vehicle (ATV) use, skiing, and mountain biking results in flood impacts from the removal of trees that are smaller in scale but similar to those explained in Section 6.4.2. Fossil-fuel powered vehicles used in these activities are also potential sources of contamination.

6.4 Industrial Activity

Industrial activity that can lead to effects on hydrology include non-renewable resource extraction and logging. These types of activities require road access, the construction and operation of which can lead to increased surface runoff during precipitation events, leading to increased erosion (Dunne & Leopold, 1978) and debris flow frequency (R. Guthrie, 2005)[40]. Some of the impacts on hydrology from road infrastructure also occur due to other linear infrastructure such as electrical, telecommunications, and pipeline right-of-ways (Martz & Campbell, 1980; Raiter et al., 2018).

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[36] Invasive Species Council of BC. Weed of the Week: Cheatgrass. Weblink: https://bcinvasives.ca/news-events/media/articles/weed-of-the-week-cheatgrass

[37] Beavers are dam important for the ecosystem. CBC News. May 18, 2017. Weblink: https://www.cbc.ca/news/canada/why-beavers-matter-1.4121550. Accessed June 18, 2019.

[38] Beavers and wildfires video. Weblink: https://twitter.com/EmilyFairfax/status/1097195169131024384/video/1. Accessed 15 May, 2019.

[39] Furbearer Management Guidelines, British Columbia. Weblink: http://www.env.gov.bc.ca/fw/wildlife/trapping/docs/beaver.pd. Accessed June 12, 2019.

[40] Weblink: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5336032.pdf

6.4.1 Non-renewable Resource Extraction

Mines can disrupt hydrological regimes during all phases of activity starting with land clearing and diversion construction. During operation, mine facilities such as tailings dams and surface pits can provide water storage; however, this benefit is impermanent and is not the primary purpose of these facilities. When dam breaches occur, there can be significant water quality, erosion, and downstream flood impacts (Kossoff et al., 2014; Rico et al., 2008)[41]. Mining activities can also impact groundwater quality and quantity through seepage from underground works and facilities such as waste rock piles (Celebi & Ozdemir, 2014; Jhariya & Khan, 2016). Water contamination resulting from pollutants such as heavy metals, acid rock drainage, and others is a major concern; tailings dam breaches or seepage can permanently affect ecosystems[42].

Mine reclamation activities do not usually return hydrological regimes to their pre-mining state, and the flood hazard on the landscape generally increases (Ferrari et al., 2009).

6.4.2 Logging

Clearcut areas accumulate approximately 40% more snow compared to undisturbed areas. Removal of the forest canopy affects hydrology in four ways: 1) snowfall interception and transpiration decreases, which increases the amount of snow and water on the ground[43], and 2) there is less shade and more wind, which increases snowmelt rates (Forest Practices Board, 2007). These conditions contribute to the potential for more extreme flood events (Winkler et al., 2010). In other areas of BC, logging activities have been linked with a 10-fold increase in landslide frequency compared to undisturbed land (R. H. Guthrie, 2002).

6.5 Flood Defence Structures

Flood defence infrastructure such as dams and dikes are designed to hold water under specific conditions. However, dams also create issues that can contribute to flooding. Dike construction can result in elevated flood levels in neighbouring areas[44] and transfer flood flows downstream (Pinter et al., 2008). Dikes also lead to faster-moving and higher-energy flow conditions (Entwistle et al., 2018). If and when a dike or dam fails or is overtopped, flood waters usually flow to high exposure areas. The control of dam reservoir outflows to manage water supply and ecosystem needs can also play a role in flooding.

Flood defence structures are common in the study area and are mapped within the large-size maps within the map tool, as part of the Quantitative Study outputs. In portions of the project area, dikes have

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[41] CBC News. Mount Polley mine disaster: 3 years later concerns still remain. Weblink: https://www.cbc.ca/news/canada/british-columbia/mount-polley-mining-fears-1.4235913. Accessed June 13, 2019.

[42] Mine Water Pollution in Canada: Are Waters & Fish Habitat Protected? Response to The Canada's Commissioner on Environment & Sustainable Development's (CESD) Audit released on April 2, 2019. Weblink: https://miningwatch.ca/sites/default/files/2019-04-05-miningwatchcanada-cesdreport_7_0.pdf. Accessed December 2, 2019.

[43] Clearcut areas accumulate approximately 40% more snow compared to undisturbed areas. Sprawling clearcuts among reasons for B.C.'s monster spring floods. The Narwhal. March 13, 2019

[44] How "levee wars" are making floods worse. Weblink: https://www.youtube.com/watch?v=LTv6RkFnelM

eliminated the ability of flood waters to overtop natural meandering river channel banks[45] and into low-lying areas. Compared to pre-dike conditions, there is less water infiltration into the ground in the areas behind the dikes, and reduced maintenance of floodplain ecosystems that move water away from the surface through evapotranspiration.

6.6 Urban Development

In a developed watershed, precipitation falls on the surface and reaches streams more quickly, resulting in an increased likelihood of more frequent and severe flooding[46]. This results from the conversion of permeable surfaces to impermeable surfaces, which leads to less evapotranspiration and infiltration, and more surface runoff (Figure 29).

The original development of non-*Syilx* Okanagan communities in the project area generally occurred near watercourses and lakes due to these locations with desirable views. These low-lying areas are on or near flood plains and debris flow paths and receive flood flows from upper watershed areas.

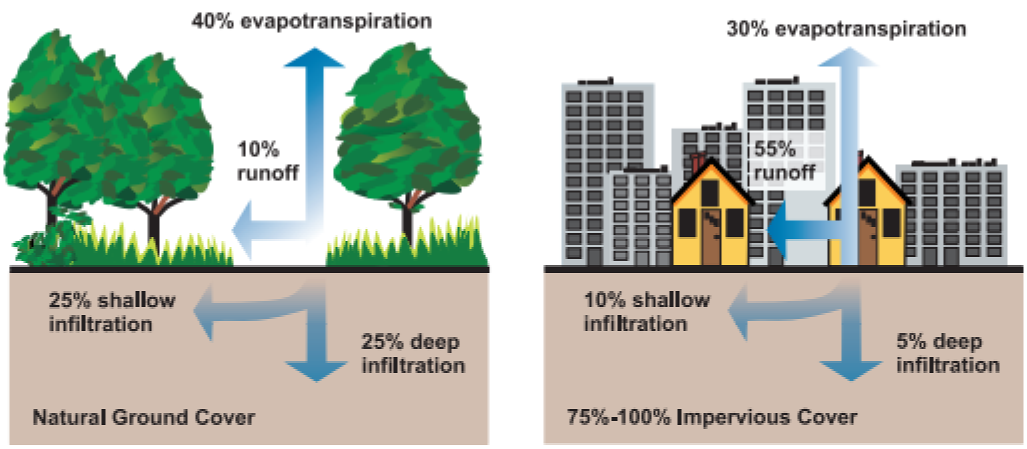


Figure 29: Relationship between ground cover and surface runoff (US EPA, 2003).

6.7 Surface-Subsurface Interactions

The changing interaction of natural and human-made subsurface conditions could affect groundwater flood hazard. For example, engineered environments can alter groundwater flow paths through dewatering and drainage works, and flood defences (British Geological Survey, 2010).

Projecting changes in groundwater in BC is challenging, as detailed hydrogeology data required are sparse and the modelling uncertainty stemming from global climate, to hydrologic, and to groundwater models

[45] Okanagan River Restoration Initiative. *Syilx* Okanagan Nation Natural Resources Department and Collaborators. Weblink: https://www.Syilx.org/projects/Okanagan-river-restoration-initiative-re-meander-reconnection/. Accessed June 21, 2019.
46 United States Geological Survey. Impervious Surfaces and Flooding. Weblink: https://www.usgs.gov/special-topic/water-science-school/science/impervious-surfaces-and-flooding?qt-science_center_objects=0#qt-science_center_objects, accessed May 23, 2019.

is high[47]. On one hand, there is a potential for groundwater levels to decline in the future due to greater evapotranspiration, less infiltration, and more extraction. On the other hand, increases in climate variability could lead to higher-than-normal groundwater conditions in some years (British Geological Survey, 2010), as observed in the spring of 2019. Therefore, it is possible that groundwater flooding could decrease in severity in average hydrologic years but increase in severity during or following extreme hydrologic years.

6.8 Future Hazard Change

This section summarizes the previous sections in terms of projecting future flood and debris flow hazard. The climate-driven processes described in Section 6.1 alone are likely to increase flood and debris flow hazard in the future. This is due to the increasing variability of extreme climate conditions that drive these processes. Climate variability is increasing as natural variability (occurring on multiple timescales including years) and climate change (occurring over a longer-term timescale) are combined (Figure 30).

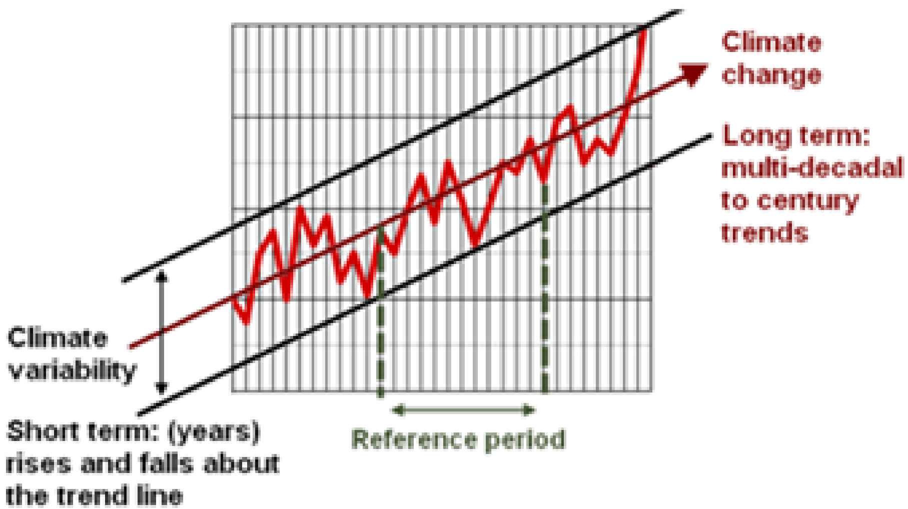


Figure 30: The interaction of natural variability and climate change and increasing extreme conditions (Source: pacificclimatefutures.net).

The climate-driven processes are likely to exacerbate the other watershed-scale pressures stemming from land use change, ecological disturbance, industrial activity, flood defences structures, urban development, and surface-subsurface interactions. Many of the pressures are likely to continue to increase due to regional population growth.

Within the above generalized assumption, it should be noted that important feedback loops may exist within the complex interrelations between the cumulative pressures and the earth system. One example is the effect of atmospheric aerosols from forest fire smoke on regional climate (Robock, 1991; Tosca et al., 2013).

47 Impacts of Climate Change on Groundwater in BC. Innovation. May/June 2009. Weblink: https://www.obwb.ca/fileadmin/docs/impacts_of_climate_change_groundwater_bc.pdf. Accessed 19 June, 2019.

In addition, there are important gaps in knowledge and nuances related to how the pressures could affect hazard likelihood and magnitude. One example relates to the change in likelihood and magnitude of debris flow hazards in watersheds where the supply of material is limited. In these watersheds, if the likelihood of debris flow events increases, as suggested by Jakob and Lambert (Jakob & Lambert, (2009) for elsewhere in BC, the magnitude of events could decrease over time. This will occur due to the "flushing" of sediment as material is more frequently wasted off the surface. It is important to note in this case that the decrease in hazard magnitude will occur over a long period of time (on a geologic scale).

7 Disaster Risk Reduction

This chapter starts to explore solutions to the problems that have been described in earlier chapters. Disaster risk has been previously defined as the result of the interaction between a hazard and the characteristics that make the environment, people, and assets exposed and vulnerable. This chapter presents the Sendai Framework for Disaster Risk Reduction (Sendai) [48], which is the global blueprint for reducing disaster risk and increasing community resilience.

Sendai is supported by the United Nations and is promoted through four priorities for action:

1. Understanding disaster risk.
2. Strengthening disaster risk governance.
3. Investing in disaster risk reduction for resilience.
4. Enhancing disaster preparedness.

Sendai provides a framework to support all levels of government, from national to local, to adapt to future hazards. The framework also identifies the need for a broader and a more people-centred approach to disaster risk, including engagement of Indigenous people. This is reflected in three of the four Sendai Framework priorities for action (Table 11).

Table 11: Sendai actions related to Indigenous People.

Priority	Description of Action
1	To ensure the use of traditional, Indigenous and local knowledge and practices, as appropriate, to complement scientific knowledge in disaster risk assessment and the development and implementation of policies, strategies, plans and programmes of specific sectors, with a cross-sectoral approach, which should be tailored to localities and to the context.
2	To empower local authorities, as appropriate, through regulatory and financial means to work and coordinate with civil society, communities and indigenous peoples and migrants in disaster risk management at the local level.
4	Indigenous peoples, through their experience and traditional knowledge, provide an important contribution to the development and implementation of plans and mechanisms, including for early warning.

Furthermore, the Words Into Action Guidelines for National Disaster Risk Assessment (UNISDR, 2017) states that "knowledge held by indigenous groups can provide alternative ideas for disaster risk reduction. Integrating traditional knowledge within the administrative frameworks of a city or region must be done with a full understanding of how each will enhance or detract from the other."

[48] Sendai Framework for Disaster Risk Reduction 2015-2030. United Nations. Weblink: https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf

7.1 Planning Process

Adaptation planning is the process by which best practice is considered to provide a path to disaster risk reduction. Ebbwater has developed an 8-step planning process to guide communities with this objective (Figure 31); this process is not meant to be prescriptive but to provide general guidance, it broadly follows other fundamental planning and adaptation process. This process takes a community from the acknowledgement of the hazard through to an implementation plan, with specific timelines, budgets and monitoring of measures of success. The results of this project, along with other projects in the region, provides the foundation for regional partners to move forward in this process. The Qualitative Study evaluates the degree to which the ONA and its partners in the region are along this process.

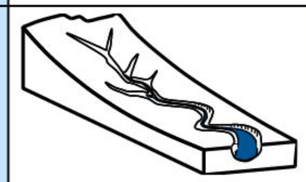
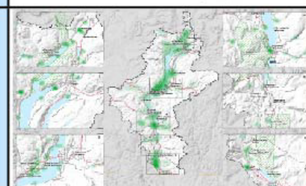
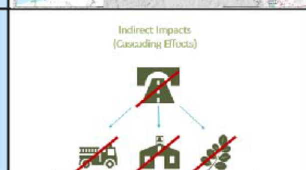
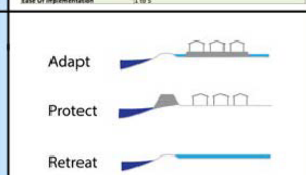
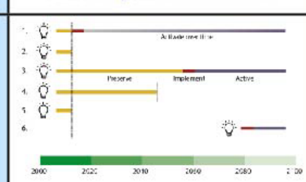
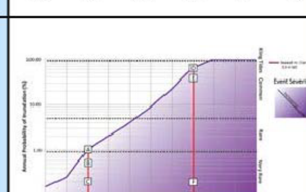
Step	Relevant Questions	Ideas	Explanation
1 Acknowledge Problem and Set the Stage	What is the governance model? What is the planning timeline?		A clear governance model needs to reconcile jurisdictional challenges to manage cumulative pressures equitably. This understanding will feed planning objectives and timelines.
2 Identify Natural Phenomena	Where, when, and how are flood/debris flows etc. occurring? What is the role of these phenomena in terms of biodiversity?		Understanding the changing nature of natural phenomena is complex. Modelling approaches need to explicitly consider all the cumulative pressures, and the effects on changing likelihood and magnitude of events.
3 Identify Exposure and Vulnerability	What is in the way of destructive events? Who is disproportionately impacted? How and why?		This step involves in-depth analysis and cataloguing of assets, infrastructure, communities, and ecosystems. Engagement is key.
4 Identify Consequences, Opportunities, and Risk	What are the potential impacts (positive and negative) of flood/debris flows etc? Where are the risk areas?		Good decisions are made with a full accounting of risks. This means understanding cascading infrastructure effects (e.g. road closures), as well as ecosystems and culture (e.g. access to fishing and other critical sites.
5 Establish Objectives and Measures of Success	What do we want to achieve? Safe, resilient community? Healthy ecosystem? How can we measure our objectives?		Measures need to be developed that reflect community values. Engagement with the public and professionals is required to explore how adaptation scenarios will be explored.
6 Identify Options	What adaptation options are suited to the problem?		Many options are available. None is a silver bullet and most can work in tandem. Examples fall into categories such as reverse or modify (human activities), restore (ecosystems), and adapt, protect, and retreat.
7 Implement Preferred Options	What are the best options to achieve success? When will these need to be implemented?		A strong decision process and a risk-based approach will ensure that options are suited to the community and the values established earlier in the process.
8 Develop Adaptive Management Plan	What are the priorities for adaptation? How could projects improve with better information?		An adapting community defines specific actions and priorities based on timelines. This involves monitoring and evaluation and consideration of new information as it becomes available.

Figure 31: 8-Step Adaptation Planning Process for disaster risk reduction.

7.2 Sendai in Canada

The Federal Government is a signatory to Sendai to adapt to climate change and achieve sustainable development. Public Safety Canada is the Federal Government's lead agency to implement Sendai[49]. The agency recognizes that disaster risk is increasing due to negative climate change impacts, and that it is negatively impacting development achievements including economic growth.

In October 2019, the BC announced its plans to modernize its emergency management legislation, which includes launching a public engagement process lasting until January 31, 2020. With the modernization of the act, BC became the first province in Canada to officially adopt Sendai, which it is using as a cornerstone of the process.

7.3 Risk Reduction and First Nations

Following the *Abbott/Chapman Report*, the BC Government released the *Government's Action Plan: Responding to wildfire and flood risks (Action Plan)* (EMBC, 2018). This report is focused on disaster recovery and emergency management; adaptation measures are said to be addressed within the Provincial Adaptation Strategy, which is to be released in 2020.

One of the outcomes of the *Action Plan* is the development of an integrated disaster recovery framework. This framework is being led by Provincial agencies to coordinate recovery activity across provincial government agencies and reflect the important roles of First Nations and other partners.

Guidance to implement key priorities and principles of the *Action Plan* is inclusive of First Nations, including:

- Planning must include partners and must contribute to reconciliation with First Nations.
- Implementation must be integrated with all partners and across all program areas and must contribute to reconciliation with First Nations.
- Action must take a holistic view and balance multiple values, such as environmental, economic (e.g. tourism), cultural (e.g. First Nations values), and risk mitigation.
- Local and traditional knowledge must be respected and utilized.
- While all phases of emergency management are essential (planning, mitigation, response, and recovery), particular attention must be paid to improvements in mitigation and recovery.

The Province, in conjunction with Indigenous Services Canada (ISC), is seeking input from First Nations leadership and communities on the most productive mechanism to purse the *Action Plan*. Avenues for discussion include the First Nations Leadership Council (FNLC), EMBC First Nations Emergency Partnership Tables, and First Nations Emergency Services Society (FNESS).

[49] Sendai Framework for Disaster Risk Reduction 2015-2030. Public Safety Canada. Weblink: https://www.publicsafety.gc.ca/cnt/mrgnc-mngmnt/dsstr-prvntn-mtgtn/pltfrm-dsstr-rsk-rdctn/snd-frmwrk-en.aspx. Accessed July 4, 2019.

Federal, provincial, and local government actions related to disaster risk reduction and Sendai are an opportunity to disrupt path dependency and can lead to tangible and viable adaptation solutions.

8 Governance

The legal systems of Indigenous peoples have existed since time immemorial. Many are founded on the common spiritual principle that existence is a gift from the Creator. With this gift comes a stewardship responsibility toward all inanimate and animate beings on Earth, along with their intricate interconnections. These inherent rights and responsibilities cannot be changed or dismissed by anybody, not even by Indigenous peoples themselves (FNFC, 2018).

No government-to-government agreement or Crown or local government decision can extinguish Indigenous rights and responsibilities (FNFC, 2018). Therefore, the solutions to environmental management challenges need to address systemic issues related to authority, responsibility, knowledge, and accountability (Polis Project on Ecological Governance, 2019). As an example, in the project area governance processes should respect Indigenous water law and stewardship principles such as the *Syilx* Okanagan Water Declaration (Section 4.1.1) and the *Syilx* Okanagan Water Strategy (under development).

8.1 Supporting Indigenous Governance

Increasingly, First Nations are being empowered by a changing regulatory landscape. One key driver has been the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP). In Canada and BC, other key drivers include the Tsilqot'in decision [2014], and BC's *Water Sustainability Act* [2016].

8.1.1 UNDRIP

UNDRIP is the most comprehensive international instrument on the rights of Indigenous Peoples. It establishes a universal framework for minimum standards for the survival, dignity, and well-being of the Indigenous peoples of the world and it elaborates on existing human rights standards and fundamental freedoms as they apply to the specific situation of Indigenous Peoples. A tenet of UNDRIP is the duty for government to obtain free, prior, and informed consent (FPIC) from Indigenous People on issues that might affect their interest.

In 2016, New Democratic Party Member of Parliament Romeo Saganash introduced Bill C-262 calling for UNDRIP to become federal legislature, however after three senate readings, it was left to die in the summer of 2019.In late 2019, BC became one of the first jurisdictions in the world to table legislation, Bill 41, to implement UNDRIP and uphold the rights of Indigenous Peoples[50]. An adaptable and sustainable path is forged for all when Indigenous Peoples are recognized as decision makers who have stewarded their territories for millennia and who have inherent jurisdiction with indigenous natural laws.

8.1.2 Section 35 of Constitution Act

In Canada, Indigenous People have a constitutional relationship with the Crown based on Section 35 of the *Constitution Act* [1982]. This relationship includes existing Aboriginal and treaty rights. In 2014, the Tsilqot'in decision by the Supreme Court of Canada clarified that First Nations must be involved in decisions (i.e., at all government levels) that affect their territory; natural hazard adaptation planning falls

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[50] West Coast Environmental Law. "Bill 41: A new law to uphold Indigenous rights in BC" from https://www.wcel.org/blog/bill-41-new-law-uphold-indigenous-rights-in-bc

into this category. The decision also clarified that Aboriginal rights and title exist on a territorial basis, and it recognized ownership rights to Indigenous peoples, including rights related to land use and economic benefits.

8.1.3 Water Sustainability Act

Though water management continues to be a provincial responsibility under the *Water Sustainability Act* [2016], the Act envisions delegating aspects of watershed governance to bodies other than the Government of British Columbia. For example, Section 115 of the Act refers to the establishment of Advisory Boards consisting of local groups or entities to provide local expertise and input into statutory decision-making. Local groups could provide recommendations on the appointment of Advisory Board members and developing terms of reference (Polis Project on Ecological Governance, 2019). The *Act* represents improvements with regard to Indigenous participation in water management compared to its predecessor. However, it has been criticized for the limited consultation process that was used in its development (Joe et al., 2017), and its disregard for the "unextinguished" water rights of Indigenous People (Gullason, 2018).

8.1.4 Provincial Guidance on Relationships with Indigenous People

The tabling of Bill 41, in late 2019, to implement UNDRIP is a significant driver for First Nations governance in this province. Other drivers include the mandate letters for every cabinet minister in the Government of British Columbia. The letters stipulate that each minister is responsible for moving forward on Truth and Reconciliation Commission (TRC) Calls to Action[51]. The Province of BC also has draft principles that guide the Province of BC's relationship with Indigenous Peoples[52].

The draft principles are as follows:

1. All relations with Indigenous peoples need to be based on the recognition and implementation of their right to self-determination, including the inherent right of self-government.
2. Reconciliation is a fundamental purpose of section 35 of the Constitution Act, 1982.
3. The honour of the Crown guides the conduct of the Crown in all of its dealings with Indigenous peoples.
4. Indigenous self-government is part of Canada's evolving system of cooperative federalism and distinct orders of government.
5. Treaties, agreements, and other constructive arrangements between Indigenous peoples and the Crown have been and are intended to be acts of reconciliation based on mutual recognition and respect.
6. Meaningful engagement with Indigenous peoples aims to secure their free, prior and informed consent when B.C. proposes to take actions which impact them and their rights, including their lands, territories and resources.

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[51] The Truth and Reconciliation Commission was created to preserve the memory of Canada's Residential School system and legacy. One of the outputs was the 94 "Calls to Action", including those grouped under "Equity for Aboriginal People in the Legal System". Weblink: http://trc.ca/assets/pdf/Calls_to_Action_English2.pdf

[52] Weblink: https://www2.gov.bc.ca/assets/gov/careers/about-the-bc-public-service/diversity-inclusion-respect/draft_principles.pdf

7. Respecting and implementing rights is essential and that any infringement of Section 35 rights must by law meet a high threshold of justification which includes Indigenous perspectives and satisfies the Crown's fiduciary obligations.
8. Reconciliation and self-government require a renewed fiscal relationship, developed in collaboration with the federal government and Indigenous nations that promotes a mutually supportive climate for economic partnership and resource development
9. Reconciliation is an ongoing process that occurs in the context of evolving Crown-Indigenous relationships.
10. Distinctions-based approach is needed to ensure that the unique rights, interests and circumstances of Indigenous peoples in B.C. are acknowledged, affirmed, and implemented.

8.2 BC Legislative Framework

In BC, the *Local Government Act* and *Land Title Act* apply to non-*Syilx* settlements in the project area. Therefore, their application is separate from the governance mechanisms discussed in the previous sections. The acts apply to parts of the risk assessment work conducted as part of this project (but by no means to all), and they are discussed here within this context.

The *Local Government Act* and *Land Title Act* were amended in 2003 and 2004 to remove the role of the Minister of Environment from floodplain designation and approving administration, shifting the authority to local governments. Due to this change, local governments have an increasingly important role to play in the management of flood hazards and gain this authority from the Provincial legislation—the *Community Charter* and the *Local Government Act*.

8.2.1 Community Charter

The *Community Charter* [2003] provides the statutory framework for local governments within the province of BC; it sets out areas of authority and procedures. Of relevance to flood management are the provisions with Division 8 of the *Charter* that set out the authority of local government to have a Chief Building Inspector permit buildings and occupancy of structures, and to require certification of a *qualified professional*[53] that "land may be safely used" in areas subject to flood (and other hazards).

The use of the *Community Charter* generally requires base information from flood mapping (either extents or extents and flood depths or FCLs) to support the Chief Building Inspector and qualified professionals to determine if a site and/or building is safe for intended use. In the absence of an approved flood map, this statute still provides a local government's Chief Building Inspector with the ability to require a geotechnical report to be prepared by a qualified professional for new buildings and for structural alteration or addition to an existing building or structure. The qualified professional may also determine an FCL for new construction on parcels that are or may be subject to sea level rise (i.e., likely to be subject to flooding) [Section 56].

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[53] In the case of the *Community Charter*, a *qualified professional*, is defined as "(a) a professional engineer, or (b) a professional geoscientist with experience or training in geotechnical study and geohazard assessments".

8.2.2 Local Government Act

Where flood mapping is available, this statute provides both policy and regulatory provisions that can be implemented as stand-alone provisions or collectively to form a framework to effectively manage flood hazard areas. Specific tools available under the *Local Government Act* [2004] relevant to natural hazard management are:

1. **Regional Growth Strategy (RGS) Bylaw:** Is a strategic plan that defines a regional vision for sustainable growth. Policies can be incorporated into an RGS to prepare for climate change by supporting adaptation strategies and by allowing for sea level rise to the year 2200 and beyond. Appendix C contains a review of these and watershed-scale initiatives in the project area, as they relate to flood management and Indigenous perspectives.

2. **Official Community Plan (OCP) Bylaw:** Is a guiding policy document used to inform land use decision. OCPs can include policies in support of climate adaptation and strategies to mitigate sea level rise. Where coastal flood mapping studies have been completed, these findings and results should be reflected in an OCP.

3. **Development Permit Areas (DPAs):** Are designated areas requiring special treatment. An Official Community Plan may designate DPAs for specified purposes, including the protection of development from hazardous conditions like coastal flooding [Section 488]. Hazard DPAs are generally triggered by alterations to the land associated with development activities. DPAs must include contributions or objectives that justify the designation and must also provide guidelines for developers and homeowners to meet the requirements of the DPA.

4. **Flood Bylaw**: If a local government considers that flooding may occur on land, the local government may adopt a bylaw to designate a floodplain area and specify flood levels for it, establish setbacks and construction elevations for habitable space for new buildings and structures, and for landfill within the flood hazard area [Section 524]. Most often, applications for building permits trigger flood bylaw requirements.

5. **Zoning Bylaw:** Land use zoning bylaws are used to regulate the use of individual parcels of land, including parcel configuration, the density of the land use, and siting and standards of buildings and structures [Section 479]. These bylaws have been used historically for flood hazard areas to ensure public safety is maintained by limiting the types of uses associated with those lands.

6. **Subdivision Bylaw:** Standards for subdivision design that take into consideration sea level rise can be established by local governments (within the *Provincial Guidelines)*. In the case of Regional Districts, the Approving Authority for subdivision is the Ministry of Transportation and Infrastructure, who is required to consider the *Provincial Guidelines* to determine the conditions for subdivision approval.

7. **Local Building Bylaw:** There is also provision under [Section 694] of the *Local Government Act* for a local building bylaw or permit process to require floodproofing. Generally, these are no longer used as the updated BC Building Code has some provisions for floodproofing and any additional conditions can also be integrated into a flood bylaw. It should also be noted that the National Research Council of Canada and partners are working to incorporate new floodproofing standards into future iterations of the Canadian Building Code.

The *Local Government Act* provides provisions that enable local governments to manage development in relation to lands prone to flooding. In doing so, the local government must consider the Provincial Flood Hazard Area Land Use Management Guidelines (the *Provincial Guidelines*). The guidelines are intended to minimize injury and property damage resulting from flooding and are linked to the Provincial Compensation and Disaster Financial Assistance Regulation. Together, the Provincial Regulation and Guidelines are used to determine if property has been adequately protected and whether a local government is eligible for financial assistance following a flood event.

9 Conclusion

This Basis of Study report provided the foundation upon which the remaining risk assessment supporting documents (i.e., the Qualitative and Quantitative Studies, as well as the Map Book) are based. This report presented the project's geographic scope, including discussion on historical and recent flood and debris flow events and discussion on geohazards more broadly in the project area. This was followed by a discussion on the project framework, including incorporating the *Syilx* Okanagan perspective. The basic components of risk assessment, including key concepts, were explained. To achieve the objective of completing a risk assessment that is holistic, a full chapter was dedicated to a literature review on the cumulative pressures on hazards. Best practices for disaster risk reduction were then discussed as well as governance drivers and guidance.

Readers are invited to move from this report to the Qualitative Study and the Quantitative Study in a complementary fashion. The three reports are summarized within the Synthesis and Recommendations report.

10 Glossary

The following table is meant to be a comprehensive glossary of terms used throughout the risk assessment supporting documents, including the Qualitative and Quantitative studies. Key sources are provided for reference and where these are deemed important due to potential variances in definitions.

Term	Definition	Source
All Hazards	Referring to the entire spectrum of hazards, whether they are natural or human-induced. Note: For example, hazards can stem from geological events, industrial accidents, national security events, or cyber events.	Public Safety Canada (PSC)
All-Hazards Approach	An emergency management approach that recognizes that the actions required to mitigate the effects of emergencies are essentially the same, irrespective of the nature of the incident, thereby permitting an optimization of planning, response, and support resources.	PSC
Annual Exceedance Probability (AEP)	It is emerging best practice to represent hazard likelihoods with an AEP. In the past, hazard likelihood was commonly represented as an X-year return period. However, this tends to cause confusion regarding the frequency of an event with the lay public. For example, it is commonly believed that if a 100-year event has occurred, it will not re-occur for another 99 years, which is incorrect.	
Asset	Also referred to as “assets-at-risk”, those things that may be harmed by a hazard (e.g., people, houses, buildings, or the environment). In this project, assets were grouped according to exposure indicators.	Royal Institute of British Architects (RIBA)
captíkwł	*nsyilxcən* word meaning “a collection of teachings about *Syilx* Okanagan laws, customs, values, governance structures and principles that, together, define and inform *Syilx* Okanagan rights and responsibilities to the land and to our culture”.	ONA
Climate Change	A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.	Intergovernmental Panel on Climate Change (IPCC)
Consequence	In this project, the *quantitative* description of how natural hazards/phenomena affect assets (organized by exposure indicators). Levels are calculated based on geospatial analyses, aggregation of information, and scoring tables.	
Critical Infrastructure (CI)	Processes, systems, facilities, technologies, networks, assets, and services essential to the health, safety,	PSC

Term	Definition	Source
	security, or economic well-being of Canadians and the effective functioning of government. The ten CI sectors in Canada are: Health; Food; Finance; Water; Information and Communication Technology; Safety; Energy and Utilities; Manufacturing; Government; Transportation.	
Debris Flow	Debris flows are rapid mass movements of saturated surficial material and organic debris, which can be a mixture of rock, sand, and/or soil.	
(Asset) Encounter Probability	The probability that an asset will be affected by a hazard of a given magnitude in a given time period.	
nʕawqnwixʷ	*Syilx* decision-making model based on the four-food chief *captíkwł.* Premised on that all voices in a community need to be heard to reach best sustainable solutions.	ONA and Dr. Jeannette Armstrong
Exposure	A measure of the amount of a structure, life, or other asset-at-risk that could be impacted by a potential hazard. Example: parts or all of houses, schools, and livestock in a flood and debris flow hazard area are exposed to a potential flood and debris flow hazard.	
Exposure Indicator	Describes groupings of generalized assets (e.g., environment, culture, affected people, economy, and disruption). Provides a means of assessing impacts (qualitative) and consequences (quantitative) by specifying the information used.	
Flood	Overflowing of water onto land that is normally dry. It may be caused by overtopping or breach of banks or defenses, inadequate or slow drainage of rainfall, underlying groundwater levels, or blocked drains and sewers. It presents a risk only when people and human assets are present in the area where it floods.	RIBA
Frequency	The number of occurrences of an event in a defined period of time.	PSC
Geohazard	A hazard of natural geological or meteorological origin (i.e., this does not include biological hazards).	
Hazard	A potentially damaging physical event, phenomenon, or human activity that may cause the loss of life, injury, property damage, social and economic disruption, or environmental degradation. Hazards can be single, sequential, or combined in their origin and effects. Hazards are characterized by their location, intensity, frequency, and probability.	UNDRR

Term	Definition	Source
	Hazards may be natural, anthropogenic (caused by humans), or socionatural (associated with a combination of natural and anthropogenic factors)	
Hazard Assessment	Acquiring knowledge of the nature, extent, intensity, frequency, and probability of a hazard occurring. In this project, separate hazard assessments were completed for flood and debris flows.	
(Natural) Hazard	Natural process or phenomenon that may cause loss of life, injury, other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.	UNDRR
Impact	In this project, the *qualitative* description of how natural hazards/phenomena affect assets.	
k̓ʷuləncútn	*nsyilxcən* word for "The Creator".	ONA
Likelihood	A general concept relating to the chance of an event occurring. Likelihood is generally expressed as a probability or a frequency of a hazard of a given magnitude or severity occurring or being exceeded in any given year. It is based on the average frequency estimated, measured, or extrapolated from records over a large number of years, and is usually expressed as the chance of a particular hazard magnitude being exceeded in any one year.	RIBA
Magnitude	Refers to the size or extent of an event. In this project, it relates to the likelihood of a flood. A flood event with small likelihood will have a large magnitude, and vice versa.	
Map Book	Electronic compilation of maps. For this project, they contain relevant information relevant to the risk assessment outputs at various scales and they are hyperlinked for ease of use.	
Melton Ratios	A metric based on watershed area and relief used to differentiate watersheds prone to clearwater flooding from those subject to debris flows and floods.	
Mitigation	This report was written primarily with a disaster risk reduction lens and has adopted standard terminology from this field. Mitigation, in this case, relates to strategies or measures that are used to directly reduce natural hazard impacts or risk. Whereas, mitigation is often used in climate adaptation literature to refer to local or global efforts to reduce greenhouse gas emissions.	
Morphometrics	Morphometrics describes measures of the shape or form of the watershed.	
nsyilxcən	Language of the Syilx Okanagan people.	ONA

Term	Definition	Source
Okanagan Nation Alliance	Formed in 1981 as the inaugural First Nations government in the Okanagan which represents the 8 member communities including; Okanagan Indian Band, Upper Nicola Band, Westbank First Nation, Penticton Indian Band, Osoyoos Indian Band and Lower and Upper Similkameen Indian Bands and the Colville Confederated Tribes on areas of common concern. Each community is represented through the Chiefs Executive Council (CEC) by their Chief or Chairman.	ONA
Probability	In statistics, a measure of the chance of an event or an incident happening. This is directly related to *likelihood*.	PSC
Qualitative Study	Research that relies on subjective information obtained from direct communication or various means of input by people. In the case of a risk assessment, that part of the study that uses project participants' input to frame the issues, as well as depth of understanding.	
Quantitative Study	Research that relies primarily on numerical information. In the case of a risk assessment, that part of the study that primarily makes use of the data to calculate risk.	
Resilience	The ability of a system, community, or society exposed to hazards to resist, absorb, accommodate, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.	UNDRR
Risk	The combination of the probability of an event and its negative consequences.	UNDRR
Risk Assessment	A methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods, and the environment on which they depend. Risk assessments (and associated risk mapping) include: a review of the technical characteristics of hazards, such as their location, intensity, frequency, and probability; the analysis of exposure and vulnerability, including the physical, social, health, economic, and environmental dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities, with respect to likely risk scenarios. This series of activities is sometimes known as a risk analysis process.	UNDRR

Term	Definition	Source
Settler	A person who has migrated with a group to an area and established a permanent residence there, often to colonize the area. Settlers are generally from a sedentary culture, which comes with different concepts of land ownership not traditionally held in the settled area.	
Scenario	The definition of an event being modelled or assessed, based on different parameters. In this project, relates to flood magnitudes, which are loosely attributed to likelihoods and associated scores.	
siwɬkʷ	*nsyilxcən* word for water. The meaning comes from (siw) and (ɬkʷ): • The (siw) from siwst-to drink (human) • The (ɬkʷ) from ɬkʷitkʷ-to lap (animal) • Together the two parts identify the Syilx ethic that the right to water is equal for animals and humans. • silwɬkʷ is sacred as the source of all life on the tmxʷulaxʷ.	ONA
***Syilx* Okanagan People**	The Indigenous people of the interior plateau, as defined by the *Syilx* Nation	
ṫiḱt	*nsyilxcən* word for flood.	ONA
tmixw	*nsyilxcən* word for “all living things, sacred life forces”.	ONA
tmxʷulaxʷ	*nsyilxcən* word for “our land”.	ONA
Traditional Ecological Knowledge (TEK) Keepers	*Syilx* Elders who are dedicated to the teachings of the land, and sharing them with people.	
Vulnerability	The characteristics and circumstances of a community, system, or asset that make it susceptible to the damaging effects of a hazard.	UNDRR
Water Balance	Describes the flow of water in and out of an environmental system, such as a watershed, in terms of precipitation, evapotranspiration, streamflow, and groundwater storage.	

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Appendix A External Steering Committee Terms of Reference

All appendices for this report are packaged as a separate document.

Appendix B Updated Risk Assessment information template (RAIT)

All appendices for this report are packaged as a separate document.

Appendix C Climate Change Projections Science Primer

All appendices for this report are packaged as a separate document.

Appendix D Recently Funded Flood Initiatives

All appendices for this report are packaged as a separate document.

Appendix E Review of Relevant Regional Planning-Level Initiatives

All appendices for this report are packaged as a separate document.