Comox Valley Regional District Coastal Flood Adaptation Strategy Phase 2: Flood Risk and Options Assessments

Appendix A: Risk Assessment Details

Contents

1 Introduction

The Comox Valley Regional District (CVRD) is completing a Coastal Flood Adaptation Strategy (CFAS) to assess and mitigate coastal flood hazards. In the project's Phase 1, Kerr Wood Leidal Associates (KWL) completed comprehensive coastal storm and sea level rise mapping for approximately 200 km of the CVRD coastline (floodplain mapping was also completed for the Oyster River). The methods and the GIS-based coastal flood hazard results were summarized in KWL (2021). KWL mapped a range of flood characteristics (e.g. flood extent and depth layers) using different processing methods and algorithms, depending on the intended purpose of the outputs. Given the size of the project, the available data and methods, and schedule and resources, KWL made justified assumptions and simplifications to deliver the project.

Ebbwater has been retained by the CVRD to complete Phase 2 of the CFAS, which is focused on flood risk and preliminary mitigation options assessment. The coastal flood hazard layers produced in Phase 1 are the basis for the flood risk assessment. This appendix provides background on risk assessment, which is followed by the detailed methodology used to conduct the project risk assessment.

2 Risk Assessment Background

Risk assessment describes a process where exposure, vulnerability, and hazard (and sometimes capacity) are considered to develop a risk profile for a given area or problem. The main report provides background on risk. The following sections describes indicators for risk assessments, consequence types, complementary research methods, data aggregation and scoring, and relevant guidance documents.

2.1 Indicators for Risk Assessments

Risk assessment is shaped by the types of exposed elements that are considered. And so, it is important to think about what can be measured. Given that the consequences of flood hazards are often widespread and diverse, best practice suggests that a broad spectrum of consequences should be considered. Historically, risk assessments have often focused on economic damages alone (e.g., dollar-value damages to buildings), but in a more holistic approach, social and environmental consequences should also be considered.

To summarize diverse consequences in a consistent way, consequence **indicators** are typically used. The United Nations document on indicators for disaster risk reduction (United Nations, 2016) suggests inclusion of a wide range of indicators, which include affected people, mortality, economic loss, damage to critical infrastructure, and disruption of basic services. These indicators were each based on the targets for disaster risk reduction as formulated in the Sendai Framework (UNISDR, 2015; Section 2.3). The Australian risk assessment guidelines also recommend inclusion of consequences to indicators such as the environment and cultural identity of a community (AIDR, 2015). Similarly, the BC climate risk assessment includes a holistic approach to risk management, where health, environment, and economic consequences are considered (BC MECCS, 2019). While there is a movement towards a more holistic approach, many of these indicators remain difficult to quantify (see also above section on direct/indirect and tangible/intangible consequences), and in practice, many risk assessments still tend to focus on assessing economic values alone.

In a quantitative risk assessment, where direct measures are not possible, **proxies** can be used for each indicator. A proxy is a measurable quantity which can be analyzed as part of a quantitative risk assessment (e.g., number of affected people, or buildings in a floodplain) and that is a reasonable representation of the indicator. The availability of consistent data can vary widely for different risk studies.

2.2 Consequence Types

Flood hazards may lead to direct and indirect consequences. Direct consequences describe all harm that is caused by the direct physical contact of water with people, infrastructure, or the environment (AIDR, 2015). Indirect consequences are those that our outside the direct spatial and temporal extent of the consequence. They are typically consequences that are 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. Disruption of critical infrastructure can lead to cascading consequences for many sectors (also referred to as systemic risk).

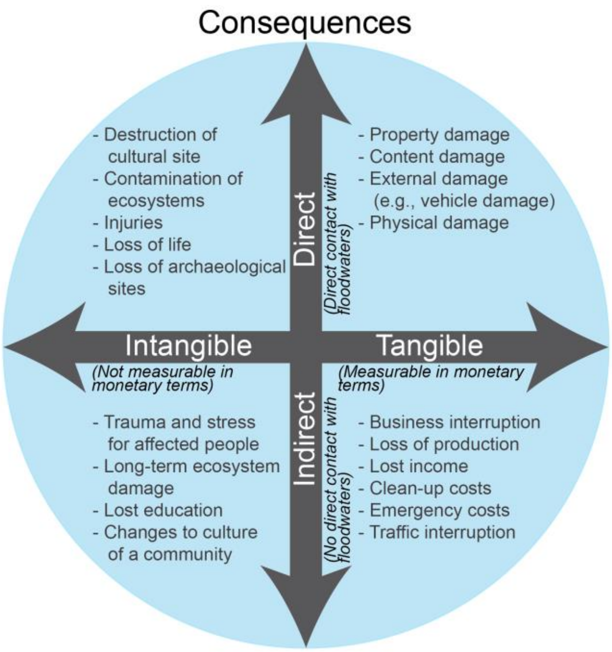

Figure 2-1: Types of consequences from flooding (Figure from Murphy et al. 2020).

The effects of a flood hazard event on the environment, human or community health, or loss of life are difficult to quantify in terms of financial values 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 et al., 2006; Murphy et al., 2020). **Error! Reference source not found.** provides examples of direct/indirect and tangible/intangible consequences. While not all consequence types are easy to estimate, they should still be considered. At a minimum, it is important to recognize what types of consequences have been included in a risk assessment and to be explicit about those that have not.

2.3 Complementary Research Methods

Qualitative and quantitative analyses provide complementary components of a risk assessment. 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). **Error! Reference source not found.** 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 2-1: 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.

2.4 Data Aggregation and Scoring

An important goal of a risk assessment is to provide a means to compare risk (UNDRR, 2017) across spatial and temporal scales, as well as hazard types and indicators. Comparing risk can help to prioritize funding and risk reduction strategies to target locations, hazards, and indicators with the highest risk. To achieve this, datasets are typically layered in a spatially distributed risk analysis (Figure 2-2). Next, the outputs of the risk analysis are aggregated, which, considering the complexity of risk indicators, is not a straightforward process (UNDRR, 2017). Different techniques exist for risk aggregation, one of which is a index-based approach (UNDRR, 2017). Other methods include the calculation of the average annual loss for a full-statistical accounting of risk.

This project employed the higher-level, index-based, risk assessment approach. This was in response to the dual challenges of a large project area, and lack of detailed and comprehensive data. For this approach, likelihood and consequence are each represented by an index score, and risk is then calculated as the product of the two scores. Scoring is applied to each indicator, following a set of pre-determined rules that are ideally consistent across a country or region. A benefit of scoring is its simplicity for comparing risk between different indicators, hazards, and regions. Typically, the results are provided in a risk matrix of likelihood and consequence, which helps to visualize and prioritize risks (see Figure 2-2 as an example). This approach is the one used for this project, primarily in response to the challenges associated with the large project area.

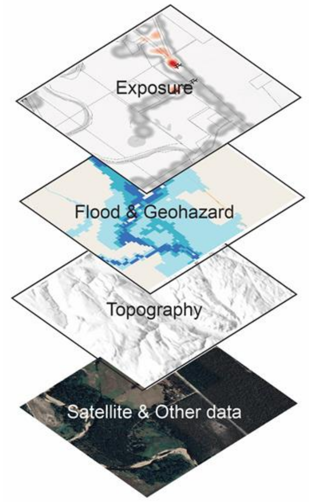

Figure 2-2: Data layering for spatially distributed risk analysis.

Index-based risk scoring approaches are intended to create consistency to compare results of several risk assessments more easily (e.g., across a country or province) to inform priority setting of resources. However, Canada does not currently have a framework to create such consistency. In the absence of a consistent framework, it is important to highlight that risk score results are strongly dependent on the method that has been used.

2.5 Relevant Guidance Documents

In the absence of Canadian regulatory or guidance documents to guide consequence and risk calculations, international guidelines may be used to inform methods. We considered guidelines developed in recent years that are based on Sendai (UN, 2016; UNDRR, 2016, 2017), and resources from the Australian Institute for Disaster Resilience (AIDR). 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[1] 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 Coastal Flood Risk Assessment Guidelines** (Murphy et al., 2020).
4. **Natural Resources Canada,** who are developing risk-based land use guidelines among other

[1] 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.

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 National Disaster Mitigation Program (NDMP)). Over time, these have evolved based on experience and data availability.

In BC, the recently enacted *Professional Governance Act* (PGA) [2021][2] provides a consistent governance framework for self-regulating professions that incorporates best practices of professional governance. One of the five professional regulators governed by the PGA, Engineers and Geoscientists of British Columbia (EGBC)[3], has developed a series of professional practice guideline documents that relate to natural hazard management, including:

- Flood Mapping in BC (EGBC, 2017)
- Legislated Flood Assessment in a Changing Climate in BC (EGBC, 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. The methods applied in this project consider the EGBC guidance, and in general exceed them by virtue of following international best practice.

2.6 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. A true risk assessment, one that looks at consequences for different likelihood scenarios over time, is an invaluable instrument for decision makers, policy makers, and planners. 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 prioritize actions and to plan for long-term financial investments into risk reduction.

[2] Weblink: https://professionalgovernancebc.ca/about/professional-governance-act/. Accessed 10 December 2020.
[3] Formerly called the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC).

3 Risk Assessment Methodology

The following sections describe the methods used to produce this project's risk results.

3.1 Approach

The risk assessment applied an index-based approach that relied on spatial processing and classification. As shown in **Error! Reference source not found.**, likelihood was determined based on three coastal flood magnitude layers. The consequences were considered based on a set of six indicators.

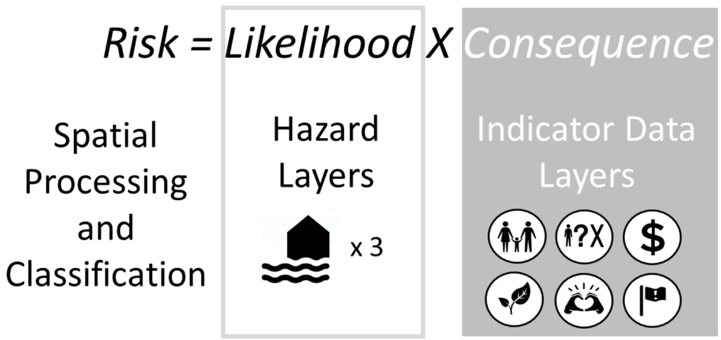

Figure 3-1. Summary of risk assessment approach.

The main report and appendix B describe the three hazard layers (planning range scenarios) that were used within the risk assessment. The following section describes the indicator data layers (data proxies) that were used. All the spatial processing and mapping was completed using QGIS.

3.2 Indicators and Data Proxies

Based on national and international best practice (UNDRR 2015, 2016, 2017; AIDR 2015; BC MECCS 2019), we selected a set of six indicators, aimed at providing a holistic view of potential consequences (Table 2-). Note that these are not listed in order of importance.

Table 2-1: Indicators for flood consequences assessed in this report. Based on Stantec Consulting Ltd. and Ebbwater Consulting Inc. (2017); AIDR (2015); UNDRR (2016).

Indicator and Icon	Description
Affected People	This indicator portrays the number of people who are directly affected by a flood. This may include people who are injured or suffer other health effects, are evacuated or displaced, or suffer direct damages to their livelihoods (e.g., their house is damaged).
Mortality	This indicator describes the estimated number of deaths and missing persons due to a flood.
Economy	This indicator describes potential economic losses that result from a flood. This includes the exposure of public and private buildings.
Environment	This indicator includes the overflow or discharge of contamination sources into the receiving environment, in combination with damage to exposed

Indicator and Icon	Description
	environmentally sensitive areas that could be negatively affected. While flooding is an important component of many ecosystems and is a naturally occurring process, the contamination of flood waters by anthropogenic contamination sources as well as natural processes (e.g., erosion) can be detrimental to sensitive ecosystems.
Culture	This indicator is used to describe consequences to the culture of a community; this includes both Indigenous and non-Indigenous cultural sites.
Critical infrastructure	This indicator describes consequences that can potentially have more widely spread cascading effects on society, such as damage to critical infrastructure and disruption of basic services. This can include damages to health facilities, emergency response facilities, governmental facilities, transportation infrastructure, roads, electrical systems, etc.

In a quantitative risk assessment, where direct measures are not possible to characterise an indicator, **proxies** can be used. A proxy is a measurable quantity (e.g., number of affected people, or buildings in a floodplain) that is a reasonable representation of an indicator, based on a set of assumptions. The datasets used to measure each of the indicators are discussed in the sections below.

3.2.1 Affected People

The number of people in the CVRD was estimated based on census data, under the assumption that people are most affected where they live (Table 3-1). However, the smallest units in which census data is provided are dissemination areas. While dissemination areas are relatively small for urban centres (e.g., several blocks), they can be large in rural areas (spanning several small communities and including non-populated land as well). This makes the use of census data for risk assessments challenging. Therefore, in this project, a building-based method was employed. The number of affected people was mapped using the most recent (2016) Canadian Census data (applying densities based on dissemination area) in combination with residential building centroids (identified based on British Columbia Assessment data (BCA, 2020). To estimate the number of affected people, an assumption for equal number of occupants in residential buildings within the same census dissemination area was applied. Then the total number of people was calculated based on the total number of residential buildings within the hazard extent.

Table 3-1: Dataset details for the affected people indicator.

1. Affected People Indicator			
Proxy	**Quantitative Dataset**	**Assumption**	**Limitations**
Number of people	• Building centroids from the CVRD (BCA, 2020)	• People are most affected where they live, and not in their work environment	• Assumption of an even distribution of people per building. • Census data representation issues in rural areas, where people may

1. Affected People Indicator			
Proxy	**Quantitative Dataset**	**Assumption**	**Limitations**
	• Number of people assigned to each residential building based on the 2016 census (Statistics Canada, 2016)	or recreation.	not reside full time. • Does not include indirect impacts on people outside the hazard extent.

3.2.2 Mortality

Mortality describes the number of deaths and missing persons due to a natural hazard event. Mortality from flooding is relatively low in Canada (Public Safety Canada, 2019); Mortality was estimated as a fraction of the total number of affected people. The mortality fraction was based on flood events recorded in the Canadian Disaster Database (Public Safety Canada, 2019), including those events where dike breaching led to flooding. While mortality due to flooding is generally low in Canada, a dike breach can have higher mortality due to the short warning time and high flow velocity. Therefore, we assumed this estimate as a worst-case scenario. Future studies could consider warning, evacuation, and social vulnerability factors (e.g., demographics, resident versus tourist, etc.) that could affect mortality.

Table 3-2: Dataset details for the mortality indicator.

2. Mortality Indicator			
Proxy	**Quantitative Dataset**	**Assumption**	**Limitations**
Associated fraction of number of affected people	• Mortality fraction of 0.01% (Public Safety Canada, 2019)	• Fatalities can be estimated based on observed events (flooding due to structure failure).	• Does not consider individual site and event characteristics, which differ widely. • Screening-level estimate only. • Depends on affected people estimate, i.e., has similar limitations.

3.2.3 Economy

This indicator represents potential economic loss resulting from a natural hazard event. Natural hazards can damage economic assets, such as land and buildings differently. Broader economic impacts, for example to business content lost or business disruption was not within the scope of this study. A proxy for economic losses that is often used in risk assessments is property damage. Damage is typically determined using flood depth-damage curves, which relate flood depth and building characteristics (such as building material, number of floors, basement, etc.) to potential damage. However, detailed flood data, such as flood depth, is not available for this screening-level risk assessment and damage curves for Canada (NRCan, 2021) have only just been released as of March 2021. Therefore, the total value of buildings within the hazard extent was used as a proxy for flood damages (Table 3-3). It was assumed that when water recedes after a flood, most of the damage will have occurred to the building infrastructure and not to the land. The building value was considered within the consequence scoring (for flood hazard only), as indicated in Table 3-3.

For each hazard extent, the *total* land and property values were also obtained and estimated (though these were not reported). The total property value can serve as a cost estimate for land acquisition if managed retreat is considered for risk reduction.

Table 3-3: Dataset details for the economy indicator.

3. Economy Proxy	Quantitative Dataset	Assumption	Limitations
Building value	• 2020 BCA data (BCA, 2020)	• Damage to entire building	• Does not consider other potential direct and indirect economic losses (business interruptions, emergency response costs, reconstruction costs, etc.).

3.2.4 Environment

While flood is an important component of many ecosystems and is a naturally occurring process (which is in some cases worsened through anthropogenic land cover management), the contamination of flood waters by anthropogenic contamination sources can be detrimental, if these contaminated waters affect ecologically sensitive areas. Therefore, contamination sources and sensitive ecosystems were considered within the environment indicator (Table 3-4).

Contamination Sources

Contamination sources are considered present for operations where fuel, chemicals or other toxic, persistent substances may be stored in large amounts. Contamination data were obtained from land use data from the BCA via CVRD.

There were 178 potential sources of contamination in the project area. The following sources of contamination were found to be within the long-range planning coastal flood scenario:

- Automobile paint shop, garages, etc.
- Beef
- Garbage dumps, sanitary fills, sewer lagoons, etc.
- Logging operations, including log storage
- Marine and navigational facilities (includes ferry)
- Marine facilities (marina)
- Metal fabricating industries
- Railway

The rural properties in the project area contain on-site sewerage (i.e., septic systems), which is a potential major source of contamination. However, such data were not available at the current stage. The contamination sources data that were obtained were used for consequence scoring, as shown by the blue-shaded column in Table 3-4.

Sensitive Ecosystems

We also considered the area of sensitive ecosystems within the hazard extents. The assessed datasets include the distribution of Species and Ecosystems at Risk, Conservation Lands (which include Wildlife Management Areas (WMA), provincial land, and non-governmental organization (NGO)-owned land), Ecological Reserves, Provincial Parks, Protected Areas, Recreation Areas, local and regional parks, and green spaces and they can be obtained from BC Data Catalogue (Province of British Columbia, 2020).

While flooding less sensitive green spaces might be an effective flood mitigation strategy, these areas might also contain sensitive ecosystems that are vulnerable to anthropogenic contamination sources. Further, downstream consequences of contamination sources could also lead to more widespread environmental consequences, and other indirect and intangible consequences. In the project area, there are species and ecosystems at risk, as well as ecological reserves. Sensitive ecosystems data was not used within consequence scoring, as shown by the white-coloured row in Table 3-4.

Table 3-4: Dataset details for the environment indicator.

5. Environment			
Proxy	**Quantitative Dataset**	**Assumption**	**Limitations**
Location of Contamination Sources	• 2020 BCA data (BCA, 2020)	• Contamination sources within flood hazard extents can result in spills with deleterious environmental effects.	• Not all local contamination sources were captured in the datasets (e.g., no septic tanks). • No differentiation between different contaminant types.
Area of Sensitive Ecosystems	• BC Data Catalogue (Province of British Columbia, 2020): - Species and Ecosystems at Risk Distribution - BC Parks, Ecological Reserves, and Protected Areas - Conservation Lands (incl. Wildlife Management Areas) - Non-governmental organizations (NGO) Conservation Lands - Local/Regional	• Floods can have negative effects on ecosystems due to contaminated floodwaters.	• Not all sensitive ecosystems might be captured in provincial database, especially species at risk distribution might be wider than indicated in spatial dataset. • The severities of different sources of contamination were not distinguished.

5. Environment			
Proxy	**Quantitative Dataset**	**Assumption**	**Limitations**
	Greenspaces		

3.2.5 Culture

The consequences of flood to the culture of a community can be widespread and include tangible consequences such as loss of cultural sites, but also more intangible aspects such as loss of education, and changes to the culture of a community.

As a proxy for cultural consequences, the number of cultural sites within the various hazard extents was assessed (Table 3-5). Cultural sites were selected that are likely to have high social value to a community and for which there are consistent and comprehensive datasets. This includes heritage sites, Indigenous and non-Indigenous archaeological sites, recreational sites, community centres, care centres, and educational buildings. This dataset was included within the consequence scoring (indicated by the blue-shaded row for cultural sites in Table 3-5.

Note that archaeological and traditional use sites are likely underestimated, as only sites identified in the Provincial archaeological database were assessed. The database is neither complete nor up-to-date, especially from the perspective of First Nations. This was a lesson learned and documented within the *Syilx* Okanagan Flood and Debris Flow Risk Assessment.[4]

As a part of the local culture depends on access to the outdoors, trails were also included. This includes hiking, cycling, motocross riding, snowmobiling, and skiing trails. These cultural sites can obviously only capture part of what forms the culture of a community, but they can provide an indication of potential cultural consequences of floods. Trails were not included within the consequence scoring (indicated by the white-coloured row for trails in Table 3-5).

Table 3-5: Dataset details for the culture indicator.

6. Culture			
Proxy	**Quantitative Dataset**	**Assumption**	**Limitations**
Non-indigenous archaeological sites	• BC Data Catalogue (Province of British Columbia, 2020): - Civic Facilities (museums, community halls, recreation centres, pools, arena, etc.)	• Cultural sites can indicate consequences to the culture of a community.	• Proxies for cultural consequences cannot capture intangible consequences of cultural impacts. • Not all local cultural sites may be captured.

[4] See Report 2: Qualitative Study. Weblink: https://www.syilx.org/wp/wp-content/uploads/2020/07/R3_ONA_QualitativeStudy_31Dec2019medres.pdf. Accessed 5 May 2021.

6. Culture			
Proxy	**Quantitative Dataset**	**Assumption**	**Limitations**
	- Child Care - Education (schools K12, post-secondary) • Archaeological and Heritage Sites (MFLNRORD, 2020): - Heritage Sites - Indigenous archaeological sites - Indigenous traditional use sites.		• Archaeological data is not complete. • Many more cultural impacts likely exist which are not captured.
Trails	• Provincial Road Atlas (Province of British Columbia, 2020): - Trails	• Damaged sites can lead to negative consequences for the culture of a community.	• Dataset was not included in consequence scoring.

3.2.6 Critical Infrastructure

Critical infrastructure encompasses a range of assets, which we categorized in terms of facilities and basic services. While the assets could be categorized in a variety of ways, the categorization used suited the purposes of the risk assessment (Table 3-6).

Critical Infrastructure Facilities

Critical infrastructure facilities include emergency response and first responder facilities (i.e., fire hall, police, and ambulance stations), hospitals, local government offices (which typically support emergency response efforts), as well as transportation hubs (airports and ports), and food banks. To identify the location of such facilities, spatial data from the BC Data Catalogue were used (Province of British Columbia, 2020). This category was included within the consequence scoring (indicated by the blue-shaded relevant row in Table 3-6).

Disruption of Basic Services

Disruption of basic and critical services, such as electricity, telecommunication, and road and train access can also lead to wide-spread cascading effects on a society. Using data from the Integrated Cadastral Information (ICI) Society (ICI, 2020), the number of overhead electrical distribution poles and transmission structures in the hazard extent was determined (Table 3-6). Especially wooden poles are susceptible to damage during long-duration flood events, and all overhead electrical structures are susceptible to damage from geohazards. No damage to underground structures was assumed. The number of telecommunication facilities in the various hazard extents was also determined, based on ICI data. The length of roads and railway tracks in the hazard extent was determined based on BC Data catalogue information.

Table 3-6: Dataset details for the critical infrastructure indicator.

4. Critical Infrastructure and Disruption of Basic Services			
Proxy	**Quantitative Dataset**	**Assumption**	**Limitations**
Location of critical facilities	• BC Data Catalogue (Province of British Columbia, 2020): - First Responders - Local Government Offices - Hospitals - Airports - Port Terminals - Food Banks • ICI Society Data (ICI, 2020): - BC Hydro Substations	• Flood and geohazard damage to critical facilities.	• Some local critical facilities might not be captured. • It was not possible to include water and wastewater treatment plants, as no consistent dataset existed.
Location of line/point features of basic services	• BC Data Catalogue (Province of British Columbia, 2020): - Road Atlas - Railway Tracks • ICI Society Data (ICI, 2020): - BC Hydro and Fortis distribution poles - BC Hydro and Fortis transmission structures - Telus and Shaw telecommunication facilities (pedestals)	• Damage or interruption of use to roads and railways. • Damage to overhead electrical poles (underground features assumed to not be affected).	• Damage to overhead electrical poles might be limited due to clearwater flooding but is included for a conservative approach.

3.2.7 Consequence Confidence Ratings

Given the uncertainties in data proxies and in determining the consequences for many of the indicators, a consequence confidence rating (Table 3-7) was assigned for each indicator. The consequence confidence rating describes the data availability for each indicator, and how well the proxy data can capture the tangible and intangible consequences associated with the indicator (Table 3-8). The rating table was broadly based on AIDR (2015), but adjusted for the purposes of this project. Especially for culture and environment indicators, many intangible consequences exist, which cannot be quantified.

Table 3-7: Consequence confidence rating descriptions and criteria (based on AIDR (2015), adjusted).

Consequence Confidence Rating	Description	Criteria
5	Very High	Proxy data can well capture all tangible and intangible consequences for an indicator and is reliably available at local scale.
4	High	Proxy data can relatively well capture consequences for an indicator and is available at local scale.
3	Moderate	Proxy data can capture most consequences for an indicator. But while available at local scale, some data uncertainties/inconsistencies exist, or not all local assets may be captured.
2	Low	Proxy data can capture some consequences for an indicator, but some assets might be missing, or not all tangible/intangible consequences might be captured.
1	Very Low	Only limited data and methods exist, and proxy data can only capture a small part of the consequences of an indicator, or the method to determine the proxy data is very uncertain.

Table 3-8: Assigned consequence confidence ratings for each indicator and rationale for this project.

Indicator	Assigned Consequence Confidence Rating	Rationale
1. Affected People	Moderate	Sub-regional to local data (which can capture primary consequences) is available, but some uncertainties/ inconsistencies exist in the data, especially for rural sites.
2. Mortality	Very low	Only a very uncertain method exists to estimate mortality, as no detailed hazard or vulnerability data are available.
3. Economy	High	A detailed local and up to date (2020) dataset exists, which captures the primary economic consequences, albeit not all direct and indirect consequences.
4. Environment	Low	While available contamination sources data is relatively reliable, not all contamination sources are included. Further, many more tangible and intangible consequences may exist.
5. Culture	Very low	While provincial cultural sites datasets exist, these likely do not capture all local sites. Further, this proxy can only capture a small part of the tangible/intangible consequences to the culture of a community.
6. Critical Infrastructure	Moderate	Relatively reliable data exists, which can indicate the primary critical infrastructure consequences. However, local critical infrastructure aspects may not be captured.

3.3 Data Aggregation and Risk Scoring Steps

The aggregation of risk assessment results provides important means to compare risk across spatial and temporal scales, as well as hazard types and indicator categories (UNDRR, 2017). We used an approach applying index-based scoring classifications. A consequence score was assigned for each indicator and hazard type, based on the exposure (i.e., spatial data within hazard extent). Similarly, a likelihood score was assigned for the hazard layers. The risk score was then calculated as the product of the consequence score and the likelihood score. The following sub-sections further describe the classification and scoring process.

3.3.1 Consequence Scoring

The consequence scoring rules were drawn from national and international best practice approaches (Public Safety Canada, Natural Resources Canada, National Research Council) (AIDR, 2015; Stantec Consulting Ltd. & Ebbwater Consulting Inc., 2017) and are summarized in Table 3-9. For each indicator, a score from 1 to 5 was assigned, where 1 demonstrates insignificant consequences and 5 demonstrates catastrophic consequences. Note that we used absolute consequence scoring for all indicators, including affected people and economy.

A limitation of absolute scoring is that it can diminish the consequence score for project areas with relatively small populations (such as this project). For example, the consequence score of 100 affected people is larger if it is compared in absolute terms to a total number of 1,000 people, but it is smaller when compared to a total number of 1,000,000 people. This is important to consider for this project, which has a relatively small population.

Table 3-9: Consequence scores and criteria.

Consequence Score	Description	Criteria
Affected People *(# people)*		
5	Catastrophic	Number of affected people > 10,000
4	Major	Number of affected people > 1,000 and ≤ 10,000
3	Moderate	Number of affected people > 100 and ≤ 1,000
2	Minor	Number of affected people > 10 and ≤ 100
1	Insignificant	Number of affected people ≤ 10
Mortality *(# people)*		
5	Catastrophic	Mortality estimate > 1,000
4	Major	Mortality estimate > 100 and ≤ 1,000
3	Moderate	Mortality estimate > 10 and ≤ 100
2	Minor	Mortality estimate > 1 and ≤ 10
1	Insignificant	Mortality estimate ≤ 1
Economy *(in million $)*		
5	Catastrophic	Exposed building value ≤ 100,000
4	Major	Exposed building value > 1,000 and ≤ 10,000
3	Moderate	Exposed building value > 100 and ≤ 1,000
2	Minor	Exposed building value > 10 and ≤ 100

Consequence Score	Description	Criteria
1	Insignificant	Exposed building value ≤ 10
Environment *(# sources)*		
5	Catastrophic	> 100 exposed environmental contamination sources
4	Major	> 10 to ≤ 100 exposed environmental contamination sources
3	Moderate	>1 to ≤ 10 exposed environmental contamination sources
2	Minor	1 exposed environmental contamination sources
1	Insignificant	No exposed environmental contamination sources
Culture *(# sites)*		
5	Catastrophic	> 100 exposed cultural sites
4	Major	> 10 to ≤ 100 exposed cultural sites
3	Moderate	>1 to ≤ 10 exposed cultural sites
2	Minor	1 exposed cultural site
1	Insignificant	No exposed cultural sites
Critical Infrastructure *(# facilities)*		
5	Catastrophic	> 100 exposed Critical Infrastructure (CI) facilities
4	Major	> 10 to ≤ 100 exposed CI facilities
3	Moderate	>1 to ≤ 10 CI exposed facilities
2	Minor	1 CI exposed facility
1	Insignificant	No exposed CI facility

3.3.2 Likelihood Scoring

The likelihood of a hazard occurring is a key input to risk assessment. Likelihoods for the flood layers were assigned using high-level approaches and have very high associated uncertainty. The three flood scenarios that were used included both frequent low magnitude events (short-term planning range scenario), as well as rare, high magnitude events (mid- and long-range planning scenarios). Although the mid- and long-range planning scenarios included sea level rise, this component was not factored into the likelihood score. Table 3-10 describes the three coastal flood hazard scenarios used in the analysis.

Table 3-10: Flood hazard layers likelihood ranges.

Planning Range Scenario	Annual Exceedance Probability (AEP)[1]	Relative Sea Level Rise
Short-term	10%	0 m
Mid-term	0.5%	0.5 m
Long-term	0.5%	1.0 m

Note 1 – The 10% AEP flood has indicative return period of 10 years; the 0.5% AEP flood has an indicative return period of 200 years.

Error! Reference source not found. assigns a likelihood score to each coastal flood scenario based on their AEP. The 5-point likelihood score scale is logarithmic. This is generally believed to appropriately represent the extreme value statistics associated with natural hazard events (Verga, 2013; Williamson, 2015). This type of scale of hazard likelihood is being used by several federal agencies, and is generally replacing the non-logarithmic likelihood scoring (Stantec Consulting Ltd. & Ebbwater Consulting Inc., 2017) presented in the current NDMP Risk Assessment Information Template (RAIT).

Table 3-11: Coastal flood hazard likelihood scoring, based on Stantec Consulting Ltd. and Ebbwater Consulting Inc. (2017); Verga (2013); AIDR (2015)).

Planning Range Scenario	Likelihood Qualifier	Score
-	Almost certain	5.0
Short-term	Likely	4.0
Mid-term	Unlikely	3.0
Long-term	Unlikely	3.0
-	Rare	2.0
-	Very rare	1.0

3.3.3 Risk Scoring

Once likelihood and consequence scores were determined for each of the scenarios, the risk score was calculated as the product of likelihood and consequence. The resulting risk scores were described as 'very low' to 'extreme' (Table 3-12) and were represented graphically in a risk matrix for communication. In the main report, flood risk results are presented spatially as mapping, numerically in tabular form (for the affected people indicator only), and graphically as matrices. The full quantitative risk results are provided to the CVRD in spreadsheet format.

Table 3-12: Risk score descriptions.

Risk Score	Description
> 15	**Extreme risk**
> 9 and ≤ 15	**High risk**
> 4 and ≤ 9	**Medium risk**
> 2 and ≤ 4	**Low risk**
≤ 2	**Very low risk**

3.4 Risk Confidence Ratings

A risk confidence rating was assigned for each indicator and hazard. It indicates how reliable the risk score is, and is based on a combination of the hazard and the consequence confidence rating as shown in Table 3-13, based on AIDR (2015). The purpose of identifying confidence ratings is two-fold. First, the confidence ratings can be valuable in guiding prioritization of future data collection efforts in the region (i.e., efforts can be made to improve low confidence data sources). Second, confidence ratings provide important qualitative information that can be considered in risk score comparisons. For example, if a particular risk score for an exposure indicator, hazard, or electoral area appears to be lower or higher than expected, confidence ratings can be considered as a potential source for discrepancies.

The consequence confidence ratings were discussed in Section 3.2.7. In this project, a confidence rating of “high” was assigned to all three hazard layers as they were produced within a detailed process (KWL, 2021). Based on the aforementioned consequence and hazard confidence ratings, and AIDR ratings matrix in Table 3-13, most of the consequence indicators have a risk confidence rating of “moderate”. The exception is that the economy indicator has a risk confidence rating of “high”.

Table 3-13: Risk confidence rating, as combination of consequence confidence rating and likelihood confidence rating (AIDR, 2015).

		Consequence Confidence Rating				
		Very low	Low	Moderate	High	Very high
Hazard Confidence Rating	**Very high**	Moderate	Moderate	High	Very high	Very high
	High	Moderate	Moderate	Moderate	High	Very high
	Moderate	Low	Moderate	Moderate	Moderate	High
	Low	Very low	Low	Moderate	Moderate	Moderate
	Very low	Very low	Very low	Low	Moderate	Moderate

3.5 Summary

A variety of quantitative data gathering activities were conducted to understand the consequence and risk associated with flood in a fulsome manner. All of the spatial layers used within the risk assessment are listed in Attachment 1, and are included within the data package.

4 Conclusion

This document provided background information on risk assessment, and accompanying details on the methods used to complete the risk assessment for this project. This included a summary of the risk assessment approach and details on the quantitative methods. The main report contains the risk assessment results, which is based on the consequence and likelihood scores described in this document.

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Attachment 1: Data Summary Sheet

Table 1 provides a list of data used to support the analyses presented in the risk assessment. All the spatial data listed has been provided to the CVRD.

Legend

Hazard Data
Exposure Data
Risk Data

Table 1: Summary of data used for the coastal flood risk assessment.

DATA CATEGORY	DATA DESCRIPTION	FILE NAME	Data Purpose	DATA TYPE	SOURCE	CONFIDENCE SCORE	INCLUDED IN DATA PACKAGE
Modelled Floodplain	Hydraulic Model Results	*185_Flood_Extent_XXYYY*	Hazard used as the basis for the flood risk assessment	Shape file	Ebbwater	High	Yes
Buildings	Polygons showing building footprints	*185_CVRD_Residential_Buildings.shp*	Mortality and Affected People assessments	Shape file	Building Footprints obtained via CVRD, 2016 Census of Population	Moderate	Yes
Roads	Database of roads in BC	*185_Roads_Merged.shp*	Critical Infrastructure assessment	Shape file	BC Data Catalogue	Moderate	Yes
Rail	Database of railway in BC	*185_Railway_Merged.shp*	Critical Infrastructure assessment	Shape file	BC Data Catalogue	Moderate	Yes
Telecommunications	Database of telecommunications	*185_Telcom_Facilities.shp*	Critical Infrastructure assessment	Shape file	ICI Data Catalogue	Moderate	Yes
Electrical Utility Structures	BC Hydro Distribution Poles and Transmission Structures	*185_Electrical_Utility_Structures.shp*	Critical Infrastructure assessment	Shape file	ICI Data Catalogue	Moderate	Yes
CI buildings and facilities	Critical Infrastructure Facilities	*185_CI_Facilities.shp*	Critical Infrastructure assessment	Shape file	BC Data Catalogue	Moderate	Yes
Contamination Sources	Contaminating land uses from BC Assessment	*185_Land_Parcels_Contamination_Sources.shp*	Environment assessment	Shape file	BC Assessment Authority and compiled property boundaries	Low	Yes
Environment	Species and Ecosystems at Risk	*185_Species_at_Risk_Merged.shp*	Environment assessment	Shape file	BC Data Catalogue	Low	Yes
Environment	BC Parks, Ecological Reserves, and Protected Are	*185_EcoReserves.shp*	Environment assessment	Shape file	BC Data Catalogue	Low	Yes
Environment	Conservation Lands	*185_Conservation_Lands.shp*	Environment assessment	Shape file	BC Data Catalogue	Low	Yes
Environment	Local and Regional Greenspaces	*185_Greenspaces.shp*	Environment assessment	Shape file	BC Data Catalogue	Low	Yes
CVRD Archaeology	Archaeology and historic sites	*185_Archaeological_Sites.shp*	Culture assessment	Shape file	BC Archaeology Branch	Very Low	Yes

DATA CATEGORY	DATA DESCRIPTION	FILE NAME	Data Purpose	DATA TYPE	SOURCE	CONFIDENCE SCORE	INCLUDED IN DATA PACKAGE
Cultural Buildings	Buildings with a high social of cultural value from BC Assessment land use data	*185_Land_Parcels_Culture_Buildings.shp*	Culture assessment	Shape file	BC Assessment Authority and compiled property boundaries	Very Low	Yes
Civic Facilities & Education	Additional Culture Buildings for BC Data Catalogue	*185_DataBC_Culture_Buildings.shp*	Culture assessment	Shape file	BC Data Catalogue	Very Low	Yes
Recreation Trails	Recreation trail including hiking, horse riding, cycling, winter sports, and motor sports	*185_Trails_Merged.shp*	Culture assessment	Shape file	BC Data Catalogue (road atlas)	Very Low	Yes
Building and Land Values	Total and improved land values	*185_Land_Parcels_with_BC_Assessment.shp*	Economy assessment	Shape file	BC Assessment Authority and compiled property boundaries	High	Yes
Buildings	Polygons showing building footprints	*185_CVRD_Residential_Buildings_10005.shp*	Mortality and Affected People assessments	Shape file	Building Footprints obtained via CVRD, 2016 Census of Population	Moderate	Yes
Roads	Database of roads in BC	*185_Roads_Merged_10005.shp*	Critical Infrastructure assessment	Shape file	BC Data Catalogue	Moderate	Yes
Rail	Database of railway in BC	*185_Railway_Merged_10005.shp*	Critical Infrastructure assessment	Shape file	BC Data Catalogue	Moderate	Yes
Telecommunications	Database of telecommunications	*185_Telcom_Facilities_10005.shp*	Critical Infrastructure assessment	Shape file	ICI Data Catalogue	Moderate	Yes
Electrical Utility Structures	BC Hydro Distribution Poles and Transmission Structures	*185_Electrical_Utility_Structures_10005.shp*	Critical Infrastructure assessment	Shape file	ICI Data Catalogue	Moderate	Yes
CI buildings and facilities	Critical Infrastructure Facilities	*185_CI_Facilities_10005.shp*	Critical Infrastructure assessment	Shape file	BC Data Catalogue	Moderate	Yes
Contamination Sources	Contaminating land uses from BC Assessment	*185_Land_Parcels_Contamination_Sources_10005.shp*	Environment assessment	Shape file	BC Assessment Authority and compiled property boundaries	Moderate	Yes

DATA CATEGORY	DATA DESCRIPTION	FILE NAME	Data Purpose	DATA TYPE	SOURCE	CONFIDENCE SCORE	INCLUDED IN DATA PACKAGE
Environment	Species and Ecosystems at Risk	*185_Species_at_Risk_Merged_10005.shp*	Environment assessment	Shape file	BC Data Catalogue	Moderate	Yes
Environment	BC Parks, Ecological Reserves, and Protected Are	*185_EcoReserves_10005.shp*	Environment assessment	Shape file	BC Data Catalogue	Moderate	Yes
Environment	Conservation Lands	*185_Conservation_Lands_10005.shp*	Environment assessment	Shape file	BC Data Catalogue	Moderate	Yes
Environment	Local and Regional Greenspaces	*185_Greenspaces_10005.shp*	Environment assessment	Shape file	BC Data Catalogue	Moderate	Yes
CVRD Archaeology	Archaeology and historic sites	*185_Archaeological_Sites_10005.shp*	Culture assessment	Shape file	BC Archaeology Branch	Moderate	Yes
Cultural Buildings	Buildings with a high social of cultural value from BC Assessment land use data	*185_Land_Parcels_Culture_Buildings_10005.shp*	Culture assessment	Shape file	BC Assessment Authority and compiled property boundaries	Moderate	Yes
Civic Facilities & Education*	Additional Culture Buildings for BC Data Catalogue	-	Culture assessment	Shape file	BC Data Catalogue	Moderate	No[1]
Recreation Trails	Recreation trail including hiking, horse riding, cycling, winter sports, and motor sports	*185_Trails_Merged_10005.shp*	Culture assessment	Shape file	BC Data Catalogue (road atlas)	Moderate	Yes
Building and Land Values	Total and improved land values	*185_Land_Parcels_with_BC_Assessment_10005.shp*	Economy assessment	Shape file	BC Assessment Authority and compiled property boundaries	High	Yes

Note 1: The exposure data layer was not present within any of the coastal flood planning range scenario extents; therefore, the data are not included within the data package.