Cumulative Effects Framework

British Columbia

Guide to Using Cumulative Effects Framework Assessments in Support of Natural Resource Activities: Aquatic Ecosystems

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Acronyms

CE	Cumulative Effects
CEF	Cumulative Effects Framework
ECA	Equivalent Clearcut Area
GIS	Geographic Information System
QEP	Qualified Environmental Professional
SARA	Species at Risk Act
SDM	Statutory Decision Maker
WAU	Watershed Assessment Unit

Glossary

Activity footprint: The total geographical area that will be directly disturbed, occupied, or altered during the construction and operation of the proposed activity, including land clearing, excavation, access routes, and work camps.

Consequence: The effect on human well-being, property, the environment, or other things of value. Consequence reflects "what is at stake" by assessing the ecological, economic, or social importance of elements at risk. More valuable or sensitive elements generally correspond to higher potential consequences.

Cumulative effects: The changes to environmental, social, and economic values caused by the combined effect of past, present, and potential future activities and natural processes.

Elements at risk (elements): Specific features, resources, assets, or values that may be affected by a hazard. These may include ecological components, economic assets, cultural resources, or social values.

Hazards: A source of harm or potential to cause harm. The data from individual indicators are combined to assess specific categories of hazards and produce hazard ratings.

Hazard rating: Describes the likelihood of hazard occurrence (a harmful event or condition).

Hydrologic connectivity: The linkage among water systems (streams, wetlands, lakes, and groundwater) within a watershed, creating pathways through which upstream disturbances can influence downstream conditions and values.

Indicators: GIS based metrics used to measure and report on the condition and trend of a value. Indicators quantify pressures on aquatic ecosystems from human activities and natural disturbances within a watershed. Indicators are the foundational data for cumulative effects assessments.

Management strategies: Actionable measures to avoid, mitigate, manage, or further investigate cumulative effects identified through the assessment. They are informed by hazard and risk ratings and aim to reduce adverse impacts.

Natural resource activity (activity): The proposed work, project, or action. An activity may require multiple authorizations, including permits, tenures, and licenses. An example of an activity would be developing a sand and gravel mine, which may require authorizations such as a mining permit, licence of occupation, water licence, forestry licence to cut, explosive blasting permit, among others, depending on the nature and location of the activity.

Receiving watershed assessment unit: The downstream boundary or watershed assessment unit at which the effects of upstream activities are evaluated.

Risk: The probability of loss, defined as a measure of the likelihood and consequence of an adverse effect to health, property, the environment, or other things of value[1]. Risk can be analyzed using the following equation: risk = hazard likelihood x consequence.

Study area: The geographic area over which cumulative effects on a value will be examined. It consists of one or more assessment units used in the Cumulative Effects Framework assessment and represents the broader area over which the impacts of the proposed activity may combine with other impacts to affect the value.

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[1] Adapted from Canadian Standards Association (CSA). 1997. Risk management: Guideline for decision-makers. CAN/CSA-Q850-97 (R2009).

Purpose of this guide

This guide was developed as part of B.C.'s Cumulative Effects Framework (CEF). It is intended for users who are planning a natural resource activity and want to understand cumulative effects on aquatic ecosystems. This guide can be applied to operational activities of all sizes and across various sectors, from simple permit applications (e.g., forest harvesting) to complex major developments (e.g., major projects).

This guide supports the interpretation and application of spatial cumulative effects assessment data for the **Aquatic Ecosystems value** (hereafter referred to as the "CEF assessment"), enabling users to understand risks to aquatic ecosystems. It provides step-by-step instructions on how to understand, interpret, and use cumulative effects assessment resultant data in the context of:

- **Locating and accessing the data** through the BC Data Catalogue
- **Characterizing the current condition and risk** to aquatic ecosystems and identifying the land use or natural factors that are driving those conditions
- **Describing the activity's contribution to risk and determining actions and recommendations** to mitigate potential cumulative effects

There are two main objectives of this guide:

1. To develop an understanding of the Aquatic Ecosystem CEF assessment data
2. To learn how to apply this information to a proposed activity and address cumulative effects on aquatic ecosystems appropriately and to the extent possible

Once the foundational knowledge is established, cumulative effects can be considered and integrated in the early stages of planning and design of the proposed activity.

User guide primer

- This guide is designed to be applicable across all natural resource sectors in BC and for a broad scope and scale of operational activities, from routine permits to major projects. Given the broad range of users, it doesn't detail the specific administrative procedures for individual sectors/permit types

- Information and application requirements differ depending on the type of activity being proposed. Users should consult with the appropriate regulating agency for specific requirements and expectations

- This guide is to be used alongside the 2020 Aquatic Ecosystem CEF assessment (which utilizes 2018/2019 data) and the associated Protocol. Links for regional assessments can be found in Step 1 of this guide

- This guide provides a roadmap for how to consider the CEF assessment. It is not a complete guide on how to manage impacts to the value and should be used alongside other relevant information. Professional[2] judgement is required to integrate value and activity specific considerations

- Cumulative effects information and benchmarks[3] should not be interpreted as development capacity targets or ecological or hydrological thresholds. Instead, cumulative effects data are intended to provide context for understanding potential risks associated with development

- This guide is intended as a living document. Updates and revisions will occur as the supporting protocol and practices continue to develop

- The Cumulative Effects Framework welcomes feedback and recommendations. Please direct comments to CumulativeEffects@gov.bc.ca

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[2] The term "professional" used through out this guide refers to those educated and working in the natural resource field and is not exclusive to regulated professionals (i.e. "Qualified Environmental Professionals," or "QEPs"), unless specifically noted.

[3] Government of B.C. 2026. "Benchmarks in Cumulative Effects Framework (CEF) Assessments. Available at: https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/cumulative-effects/guidance/cef_benchmarks_and_thresholds_march_2026.pdf

Assessment assumptions and data limitations

Prior to working with the Aquatic Ecosystem CEF assessment results data, please review and understand the following considerations and limitations. Further documentation of assumptions and limitations can be found in the Interim Assessment Protocol for Aquatic Ecosystems in British Columbia[4] (Protocol).

Assessment scale: CEF assessment results are derived from Geographic Information System (GIS) analysis and designed to be a coarse approach to estimate conditions at a watershed scale. These assessments are intended to support, not replace, the detailed analysis and advice provided by professional subject matter experts.

Indicators: The data provides results for indicators that have been demonstrated to affect the condition and function of aquatic ecosystems and related elements. These are **pressure indicators** rather than **state indicators**.

For example, to understand where suspended sediment concentration may negatively affect aquatic ecosystems, reliance is placed on GIS pressure indicators, such as road density near streams, which can be calculated across the watershed. In contrast, data to report on state indicators such as total suspended solids may only exist for specific streams.

The indicators and hazard categories in the CEF assessment were selected based on the availability of publicly available datasets, at a provincial scale, as well as known, relevant ecological benchmarks. The assumptions and limitations of individual indicators are discussed in detail in the Protocol.

Input data: The CEF assessment is run periodically using publicly available data at a provincial extent. There are a few notable considerations regarding input data.

- Data vintage – additional disturbance may have occurred in the study area since the CEF assessment was completed
- Variability – inherent in the datasets, such as missing information regarding disturbance history

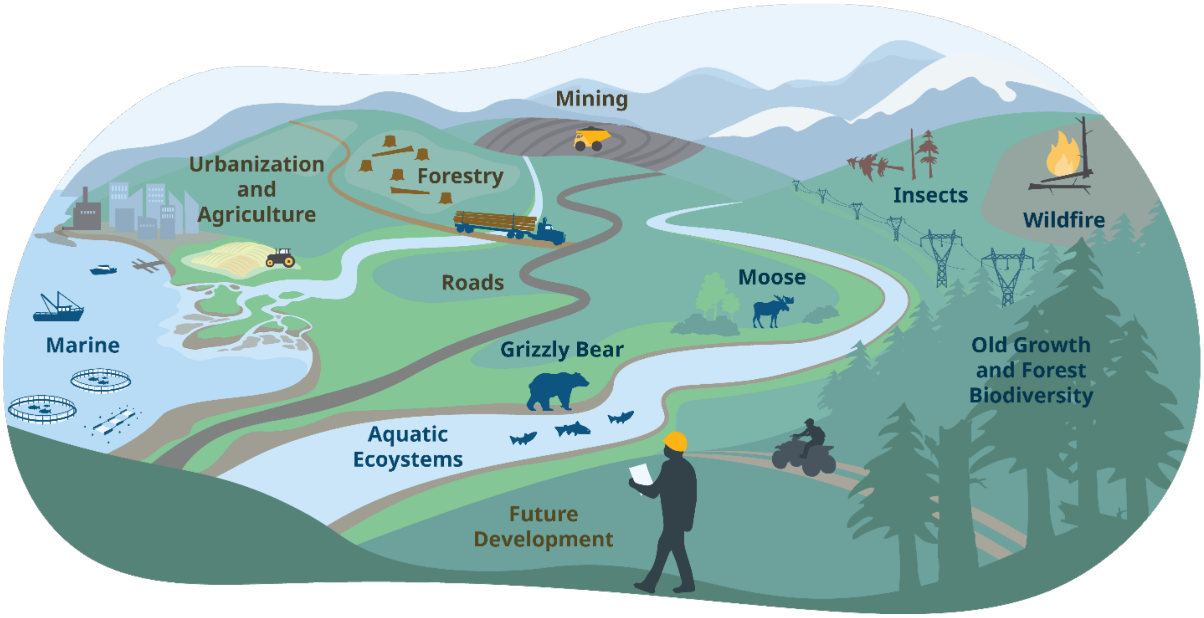
[4] The Protocol provides the methods for assessing and reporting on the condition and trends of aquatic ecosystems and is available at: https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/cumulative-effects/protocols/cef-aquatic-ecosystems-protocol-dec2020.pdf

- Uncertainty – in how the data reflects the current condition of the land base. For example, road datasets may include roads that were tenured but never built or built but since decommissioned

Watershed assessment units (WAU): Some inconsistencies exist where small tributaries empty into large lakes, large rivers, or the ocean, and where lower portions of larger watersheds are designed as separate units to maintain complete upstream catchments

Cumulative Effects Framework (CEF)

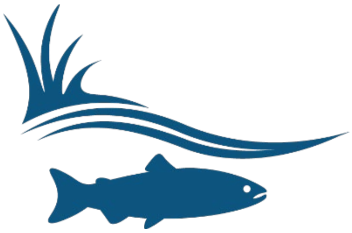
The Cumulative Effects Framework (CEF) identifies and assesses cumulative effects to values across the province. **Cumulative effects** are the changes to values caused by the combined effect of past, present, and potential future activities and natural processes. While individual land use activities may have relatively small residual impacts, the cumulative impact of those activities can add up over time and result in unintended, unexpected, and possibly significant effects on values.



Cumulative effects assessments form the basis for the CEF and report on the current condition of individual CEF values. The assessments use indicators to demonstrate the cumulative effects of multiple natural and human-caused disturbances on each value. Results from CEF assessments are incorporated into decision-making processes to help maintain or improve the condition of values over time.

Assessing and managing cumulative effects on values is a key part of sustainable and integrated resource management. Consistent cumulative effects management will provide a level of certainty required for long-term investment, support achieving objectives set by government, and enhance transparency and accountability in resource development.

Aquatic ecosystems



Aquatic ecosystems are the dynamic interactions between biotic communities of plants, animals, and the microorganisms and abiotic components such as water, sediment, nutrients, and temperature, within freshwater environments including rivers, lakes, wetlands, and riparian zones. These ecosystems provide essential functions such as nutrient cycling, flood mitigation, water quality improvement, and temperature regulation. They also play a role in supporting many human needs, including providing drinking water, recreation, and cultural value.

Human and natural disturbances, such as land development, resource extraction, and extreme weather events, can alter the natural state of hydrological processes, leading to changes in peak flow timing and intensity, increased surface erosion and landslide events, and degradation of riparian habitats. These impacts can intensify flooding, reduce water quality, and degrade habitat, directly affecting aquatic ecosystems and other values.

Understanding the Aquatic Ecosystem CEF assessment

The Aquatic Ecosystem CEF assessment uses a standardized, computer-based methodology for evaluating the current condition of aquatic ecosystems across the province. It leverages GIS data, primarily sourced from the BC Data Catalogue. The assessment uses indicators that can be consistently applied at a provincial scale and are supported by scientifically defensible benchmarks. The methodology for the assessment is described in the Protocol.

The process begins by identifying a value, listing associated pressures, and developing a cause-effect conceptual model using a pathway-of-effects approach. Indicators within each pathway represent the likelihood of harmful events or conditions and are grouped into three primary hazard categories: sediment, riparian, and peak flow.

While based on the Protocol, this guide implements alternative methods to combine indicators to better align the assessment with an operational context. Specifically, the road density indicator has been removed from the peak flow hazard, and the riparian hazard is now based solely on the riparian disturbance indicator. Indicators no longer included in hazards may still provide useful contextual information but should be deprioritized relative to those shown in Figure 1. Detailed descriptions of the indicators within each hazard category are provided in the Step 5 tables.

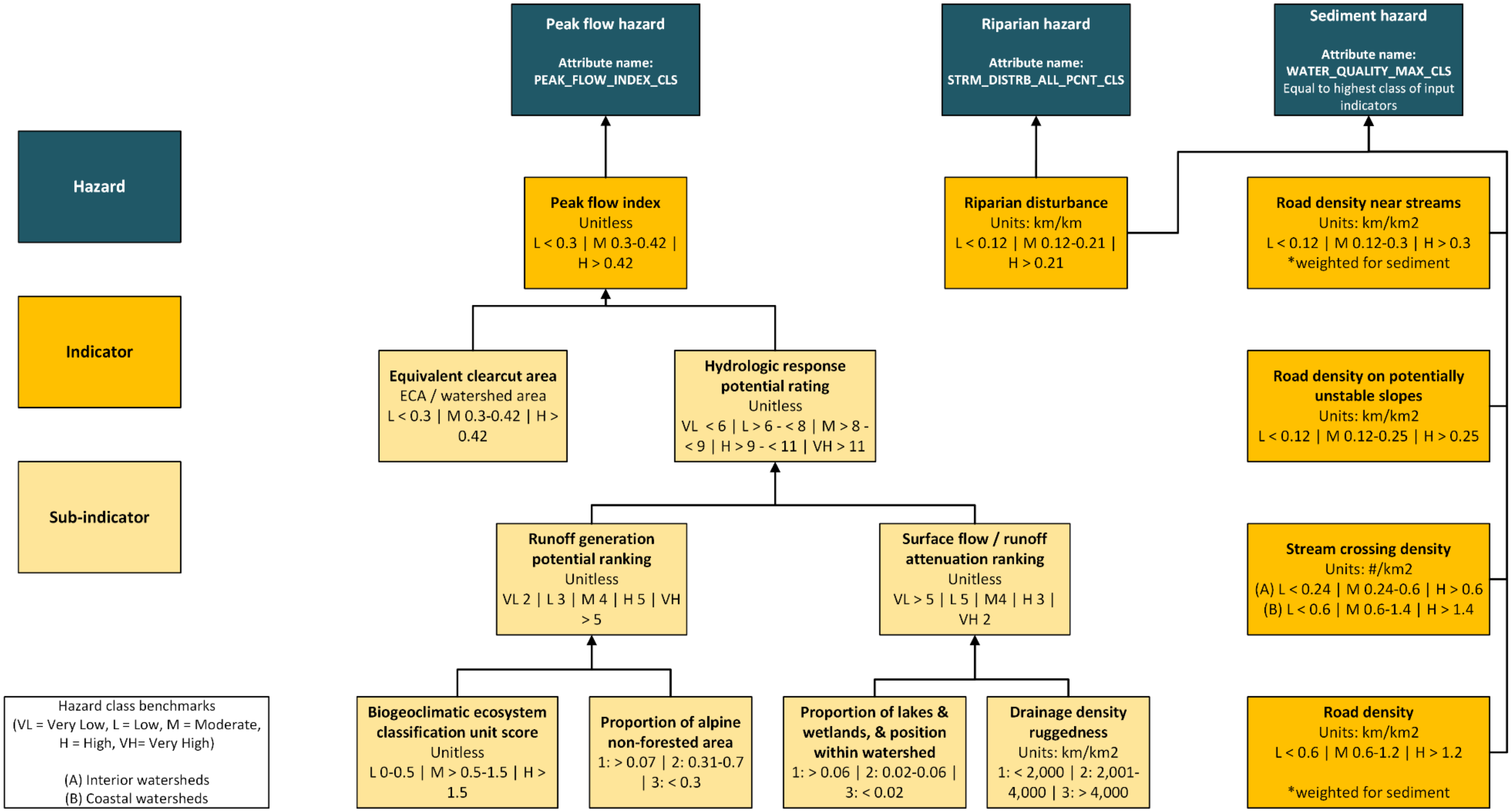


Figure 1: Recommended Aquatic Ecosystem CEF assessment hazard roll-up. An alternative plain text version is available in Appendix 6.

Hazard categories

Riparian hazard

Assesses the likelihood of reduced riparian function, which can negatively impact aquatic habitat, stream shading, bank stability, upland sediment filtration, and large woody debris input.

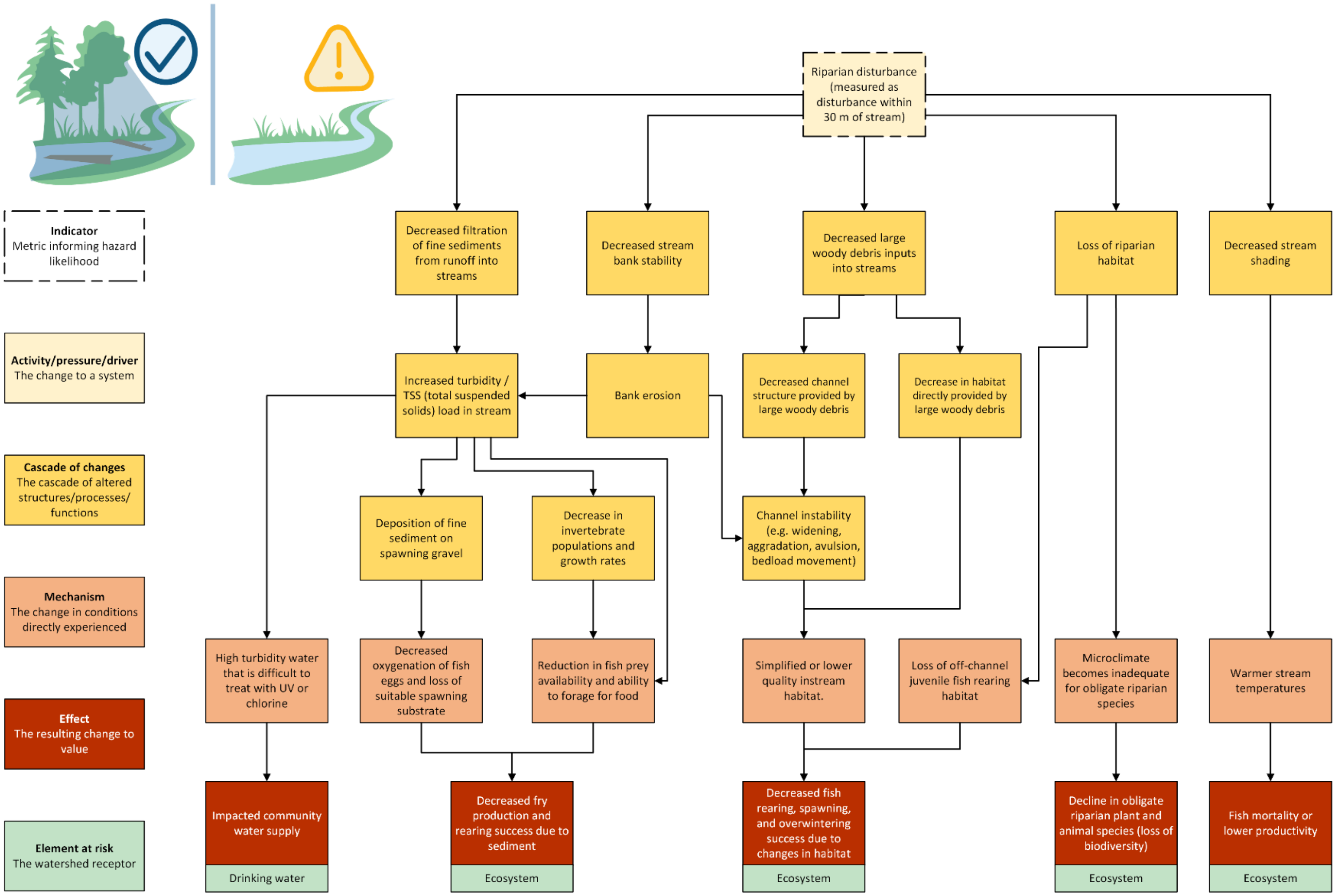


Figure 2: Riparian hazard definition and pathway of effects. An alternative plain text version is available in Appendix 6.

Sediment hazard

Assesses the likelihood of increased suspended sediment concentrations and mass sediment delivery (e.g., landslides) into streams. This analysis considers the impact of roads, crossings, and other human disturbances.

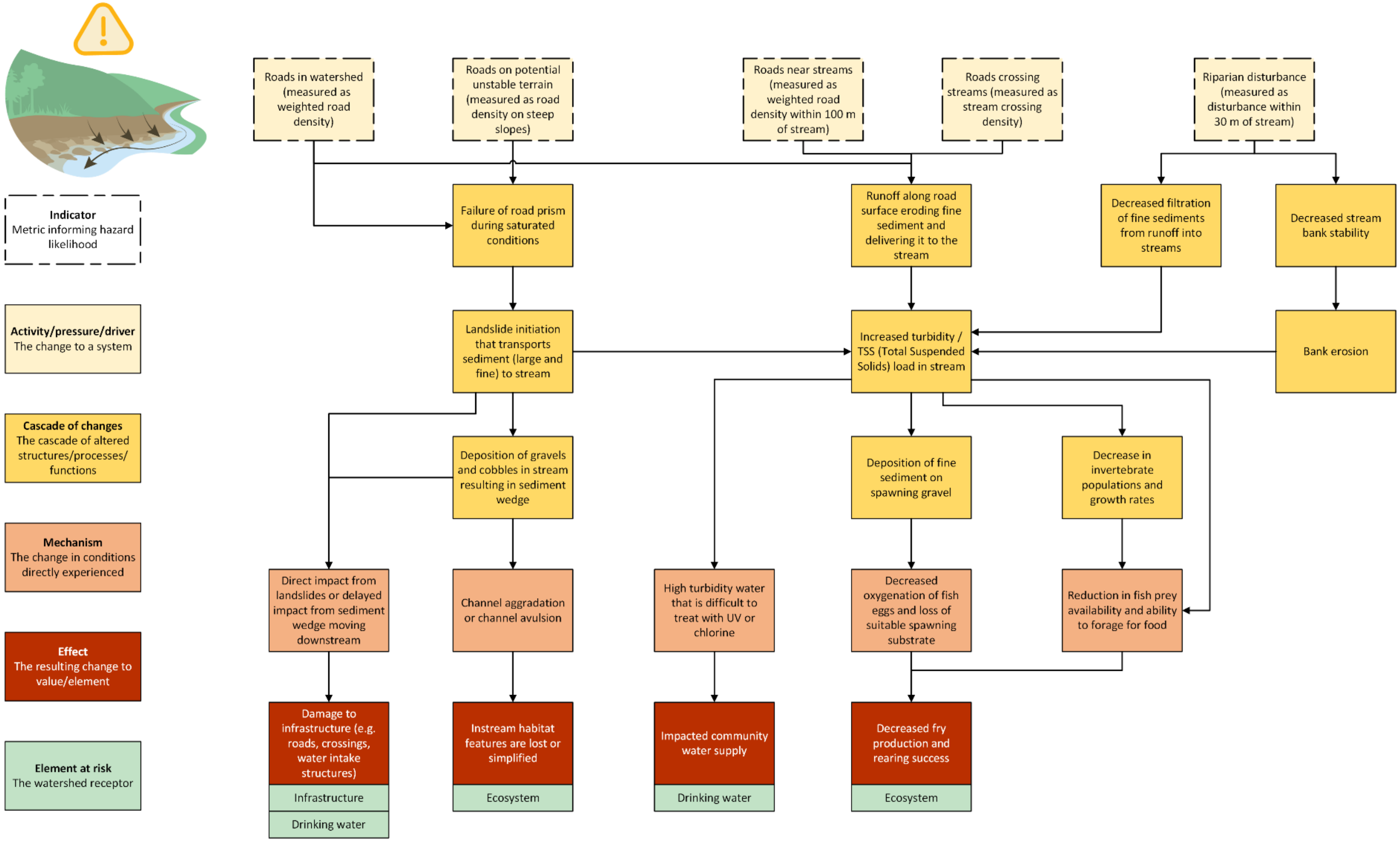


Figure 3: Sediment hazard definition and pathway of effects. An alternative plain text version is available in Appendix 6.

Peak flow hazard

Assesses the likelihood of increased frequency and magnitude of peak flow events, which may lead to harmful hydro-geomorphic outcomes including floods, bank erosion, channel instability, debris flood, and debris flows

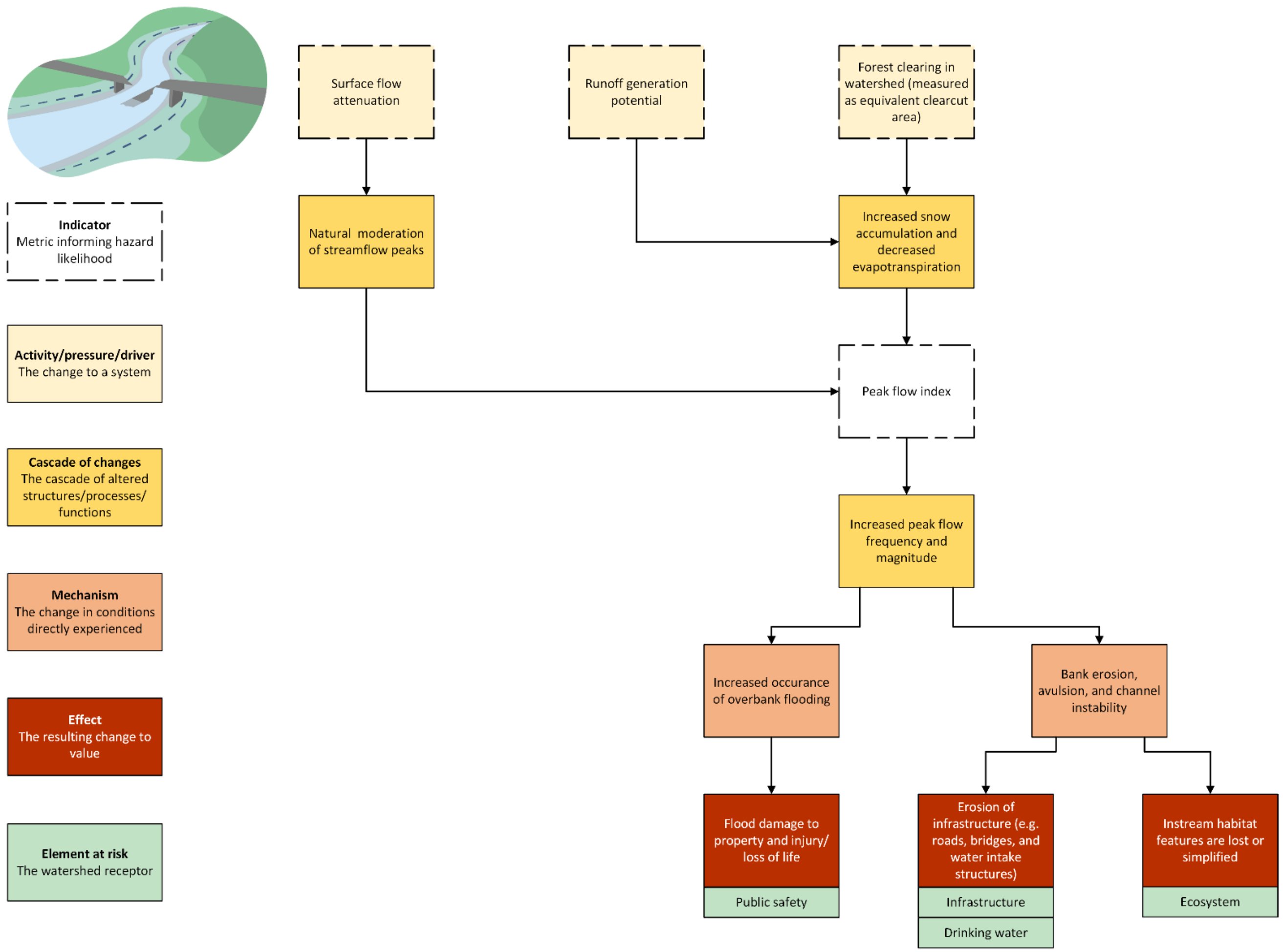


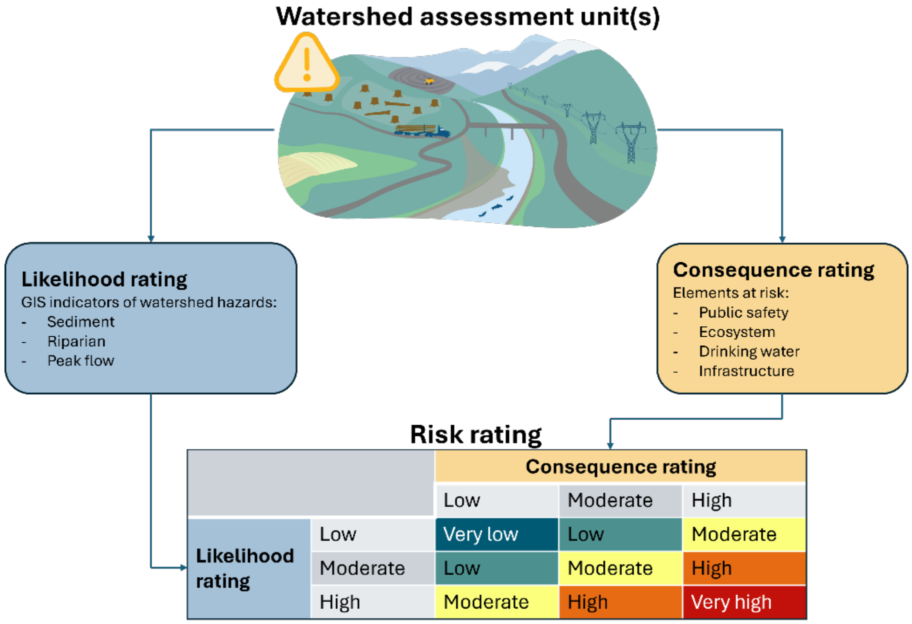
Figure 4: Peak flow hazard definition and pathway of effects. An alternative plain text version is available in Appendix 6.

Risk management framework

This guide utilizes a risk-based approach aligned with the Canadian Standards Association. Risk is the probability of harm or loss arising from hazardous events or conditions and has two components:

- Likelihood: the probability that a hazard will occur
- Consequence: the severity of impact should the hazard occur

Risk is determined by combining likelihood and consequence in a risk matrix to produce an overall rating.



		Consequence rating		
		Low	Moderate	High
Likelihood rating	Low	Very low	Low	Moderate
	Moderate	Low	Moderate	High
	High	Moderate	High	Very high

Figure 5: Diagram showing how likelihood and consequence combine in a risk matrix, adapted from Lewis et al.[5]. An alternative plain text version is available in Appendix 6.

The CEF assessment provides likelihood ratings, while users are responsible for assessing the consequences and applying the resulting risk rating to inform management strategies that reduce the proposed activity's contribution to cumulative effects.

[5] Lewis, D., Grainger, B., & Milne, M. 2016. A GIS indicator-based watershed assessment procedure for assessing cumulative watershed effects. Province of British Columbia. https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/cumulative-effects/watershed_assessment_procedure_final.pdf

User guide workflow

The following is an overview of the recommended workflow for users to access and interpret CEF assessment information for aquatic ecosystems. This workflow emphasizes not only the technical steps but also guides users through the interpretation of assessment results within the context necessary for considering cumulative effects associated with natural resource activities.

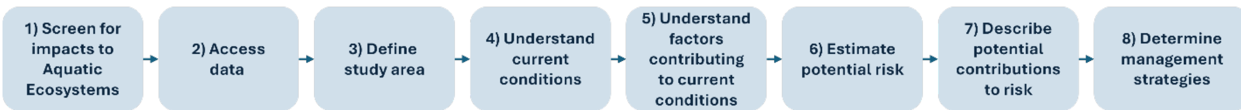


Figure 6: Recommended workflow for using the Aquatic Ecosystem CEF assessment. Steps are summarized in Table 1 below.

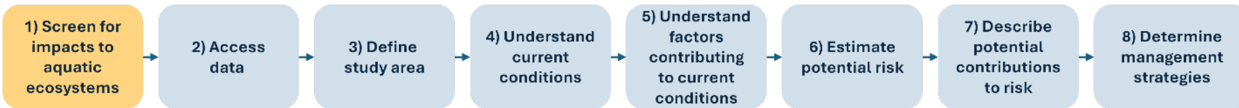
Each step reflects a progressive layering of information: hazards identify potential problems, indicators explain the underlying causes, consequences reveal the significance, and risk informs the level of concern and appropriate management response.

Table 1: Workflow steps for using the Aquatic Ecosystem CEF assessment

Step	User action	Purpose
1) Screen for impacts to Aquatic Ecosystems	Answer screening questions	Determine whether the CEF assessment for Aquatic Ecosystems is applicable to the proposed activity
2) Access data	Download the Aquatic Ecosystem CEF assessment data	Equip users with required data to use this guide
3) Define study area	Identify downstream elements at risk and delineate upstream drainage	Define the spatial extent within which cumulative effects will be assessed

Step	User action	Purpose
4) Understand current conditions	Record and interpret hazard ratings	Understand the watershed hazards within the study area
5) Understand factors contributing to current conditions	Record and interpret indicator ratings	Identify and understand key drivers of watershed hazards to guide targeted mitigations
6) Estimate potential risk	Assess consequences and combine with hazard likelihood	Determine potential risk ratings for each element and/or the overall aquatic ecosystem
7) Describe potential contributions to risk	Identify and record project impacts that may contribute to cumulative effects	Consider how the project could interact with the indicators used in the CEF assessment
8) Determine management strategies	Identify mitigations to reduce contribution to cumulative effects	Use the risk ratings along with hazard and indicator interpretations to inform management strategies

Step 1: Screen for impacts to Aquatic Ecosystems



This step provides direction for screening proposed activities to determine whether they may contribute to cumulative effects assessed through the CEF. The screening process identifies whether the CEF assessment for Aquatic Ecosystems is applicable based on the proposed activity's contribution to cumulative effects.

This guidance focuses exclusively on the hazards and indicators included in the 2020 CEF assessment. There may be additional hazards, such as pollution or low flow, that should be considered where appropriate or required by permitting agencies, and when defensible and reliable data sources are available to support their inclusion.

Screening is conducted using the questions in Table 2. Each question highlights potential pathways through which an activity may influence sediment, riparian, or peak flow hazards. The questions are not exhaustive; professional judgement must be applied when determining whether an activity contributes to applicable watershed hazards. Answering "yes" to any of the questions indicates consideration of the CEF assessment would be appropriate.

When use of the CEF assessment is warranted, evaluating all watershed hazards is strongly recommended to provide context on existing stressors. For instance, an activity contributing solely to peak flow hazard may be of greater concern in a watershed already experiencing high riparian pressures.

Table 2: Aquatic Ecosystem CEF assessment screening questions

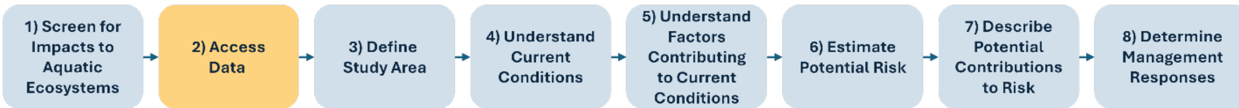
Screening question	Yes	No	Applicable hazards
Does the activity involve road construction within 100 m of a stream, lake, or wetland?	☐	☐	Sediment
Does the activity involve road construction on potentially unstable slopes?	☐	☐	Sediment
Does the activity involve new stream crossings?	☐	☐	Sediment
Does the activity disturb soil or clear vegetation within 30 m of a stream, lake, or wetland?	☐	☐	Riparian, Sediment
Does the activity involve forest clearing?	☐	☐	Peak Flow

Actions:

1.1 Answer the screening questions in Table 2 and apply professional judgement to determine whether the CEF assessment for the Aquatic Ecosystem value is applicable to the proposed activity:

- If the activity does **not** appear to contribute to any watershed hazards (all screening questions were answered "no"), use of the CEF assessment for Aquatic Ecosystems is **not recommended**. Provide a brief written rationale documenting why the CEF assessment is not being used
- If the activity appears to contribute to **one or more** watershed hazards (any screening question was answered "yes"), using and considering the CEF assessment for Aquatic Ecosystems **is recommended**

Step 2: Access data



All datasets used in and produced by the assessment are publicly available for download from the BC Data Catalogue. The assessment data, protocol, and current condition reports are available on the CEF Aquatic Ecosystem Value webpage. All future CEF assessments will be available through the BC Data Catalogue.

Internal government users can access CEF assessment data on internal network drives to avoid the need for downloading large datasets. Refer to the CEF SharePoint Resources site for details.

The assessment is provided as a geodatabase that can be opened using GIS software. The key elements of the assessment are spatial polygon features linked to an attribute table containing detailed information for each feature. Additional CEF resources available on the BC Data Catalogue to be used alongside the assessment include:

- Aquatic Ecosystem CEF assessment data dictionary: Outlines the indicators, data sources, and output fields for the 2020 Aquatic Ecosystem CEF assessment
- Human disturbance data: A consolidated human disturbance footprint dataset to support cumulative effects assessment and analysis. Refer to the methodology document for a full description how this data was developed
- Integrated Roads Data: A consolidated road dataset that represents both built roads and road tenures to support cumulative effects assessment and analysis

Regional watershed assessments

There are locations within the province where Aquatic Ecosystem assessments are provided through a regional variant. These assessments evaluate watershed hazards using local landscape conditions and region-specific information. Available variants include those for the Cariboo, Thompson Okanagan, Omineca, and Skeena regions. Table 4 provides links to available regional assessments.

Table 3: Links to CEF assessment data and resources

Description	Data Name[6]	Data Link
Aquatic Ecosystem CEF assessment data	**Geodatabase:** BCCE_Watershed_Assmnt_2020.gdb **Feature class:** BCCE_AQUATICS_ASSESSMT_2020	Data is available for download through the BC Data Catalogue as an ArcGIS file geodatabase (gdb), along with the data dictionary (xlsx): https://catalogue.data.gov.bc.ca/dataset/83ba263f-6ca1-42c3-8a56-71b7f594b1ac
Human disturbance data	**Geodatabase:** Human_Disturbance_*YEAR*.gdb **Feature Class:** Human_Disturb_BTM_*YEAR*	Data is available for download through the BC Data Catalogue as an ArcGIS file geodatabase (gdb), along with input data list (xlsx), and methodology document (PDF): https://catalogue.data.gov.bc.ca/dataset/7d61ff12-b85f-4aeb-ac8b-7b10e84b046c
CEF integrated roads data	**Geodatabase:** BC_CEF_Integrated_Roads_*YEAR*.gdb **Feature Class:** Integrated_roads_*YEAR*	Data is available for download through the BC Data Catalogue as an ArcGIS file geodatabase (gdb), along with an input data list (xlsx) and methodology document (PDF): https://catalogue.data.gov.bc.ca/dataset/a489bc6a-f676-4503-8cd7-dcf0bdf2ae99

[6] *YEAR* indicates the year the assessment was completed or the dataset was created.

Table 4: Links to regional Aquatic Ecosystem cumulative effects assessments

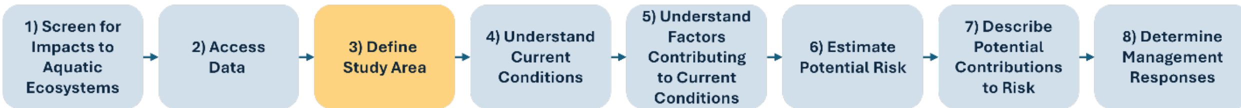
Region	Link
Omineca	• https://catalogue.data.gov.bc.ca/dataset/91eb5598-83c1-4754-ae5c-60fd9856dd26
Cariboo & Thompson Okanagan	• https://catalogue.data.gov.bc.ca/dataset/dfa8eb9d-ca89-4166-a728-8e0f73768fc4
Skeena	• https://catalogue.data.gov.bc.ca/dataset/d6dcbd90-2c68-4230-93b4-8b9a64f67226

Actions:

2.1 Download the BCCE_Watershed_Assmnt_2020.gdb dataset from the BC Data Catalogue as referenced in Table 3

2.2 Load the BCCE_AQUATICS_ASSESSMT_2020 feature class to view the attribute table

Step 3: Define study area



This step defines the spatial extent needed to evaluate cumulative effects, referred to as the study area. For Aquatic Ecosystem assessments, watersheds provide natural spatial boundaries, with the Watershed Assessment Unit (WAU) serving as the foundational unit of analysis. While a single WAU represents the minimum scale of assessment, multiple WAUs are typically aggregated to adequately capture cumulative effects.

Watersheds exist at multiple scales or orders. For instance, the Dunsmuir Creek watershed is nested within the South Nanaimo River watershed, which in turn sits within the Nanaimo River watershed. While Dunsmuir Creek constitutes a single WAU, the South Nanaimo River is composed of five WAUs. For guidance on scaling between watershed orders, refer to Appendix 1: Understanding watershed assessment units.

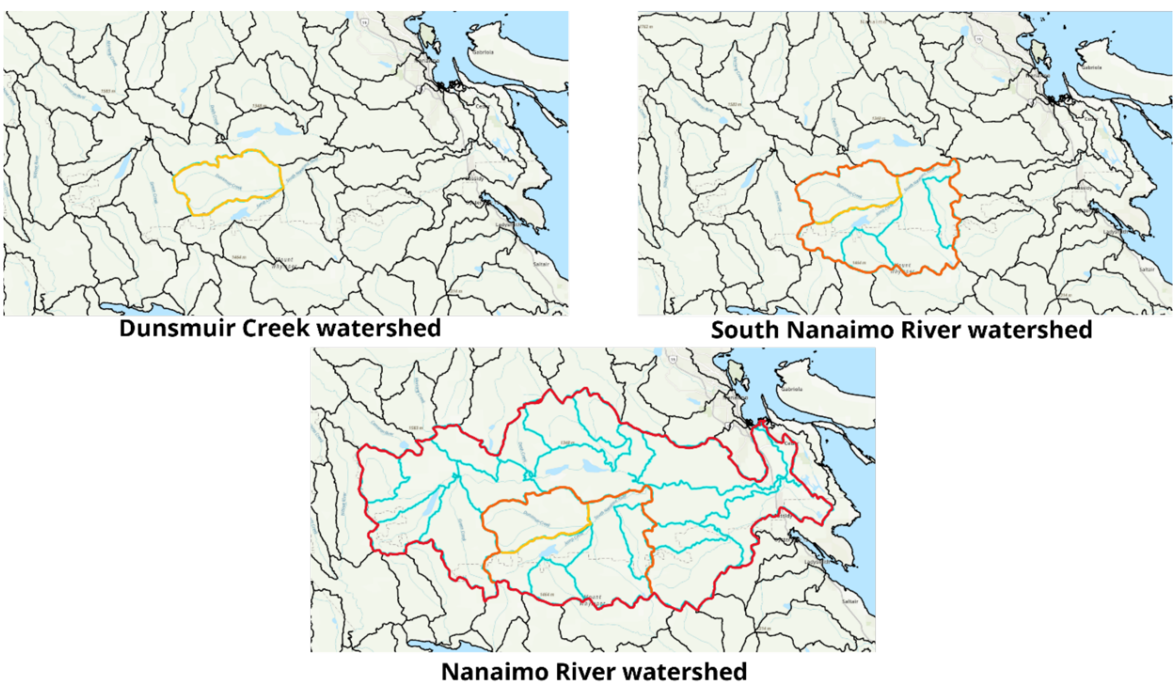


Figure 7: Example of the nested watersheds within the Nanaimo River Watershed.

To define the study area, identify the **receiving WAU** then delineate the drainage area upstream of it. There are two methods for identifying the receiving WAU:

A. Using the location of the element(s) at risk: the receiving WAU is determined by the WAUs the elements are situated in
B. Identifying the buffering point: The receiving WAU is identified by the point where upstream impacts would be substantially attenuated or buffered. This typically corresponds to a significant hydrologic transition, such as the outlet of a watershed into a large lake, or the confluence with a major receiving river

Upstream boundary: In general, the upstream extent of influence is defined by the entire drainage area contributing to the downstream value. For example, conditions at a point on a river reflect all activities occurring throughout its upstream basin, regardless of its size.

In practice, there may be valid reasons to define more limited boundaries. In such cases, professional judgement should be applied to select a boundary that neither overemphasizes nor underemphasizes the scale of project impacts. It is recommended that the assessment area does not exceed the size of a watershed group, a unit within the BC Freshwater Atlas[7]. Administrative considerations may also shape boundary decisions, for example, where streams cross into or originate from outside the province.

Identifying elements at risk

Within the aquatic ecosystem, elements at risk are specific receptors that may be affected by watershed hazards. These elements may be ecological, cultural, related to human health and wellbeing, or associated with infrastructure. Table 5 provides examples of common watershed elements and criteria; it is not an exhaustive list.

[7] Guidance on the BC Freshwater Atlas is available at: Province of British Columbia. 2010. Freshwater Atlas user guide. https://www2.gov.bc.ca/assets/gov/data/geographic/topography/fwa/fwa_user_guide.pdf

Table 5: Examples of common watershed elements

Element at risk	Description	Example criteria
Public safety	Human life and property	Dwellings and critical facilities located within floodplains
Ecosystem component	Specific populations or habitat features	Fish spawning habitat, riparian habitat for species of concern, and wetlands
Drinking water	Drinking water sources and intakes	Surface water domestic licenses and waterworks licenses
Infrastructure	Physical assets required for community function	Highways, bridges, railways, pipelines, telecommunications, and transmission lines located within floodplains

Elements are typically identified through local knowledge. Engagement and other consultative steps within the application process can provide valuable opportunities to understand what matters most to local communities and First Nations.

The Watershed Characterization Resource[8] offers an additional tool for this task. It compiles publicly available information and contextual data that helps users identify and locate valuable ecological and social components.

Multiple elements and scales

Elements are often aggregated within the same WAU. However, elements located in different WAUs may require separate study areas corresponding to different watershed orders. For example, a community drinking water intake may be

[8] Reid, D., Pike, R., & Lamhonwah, D. 2024. Desktop watershed characterization resources and methods for British Columbia (Water Science Series No. WSS2024-04). https://a100.gov.bc.ca/pub/acat/documents/r63110/DesktopWatershedCharacterizationReport_1726766574373_6368B54ED4.pdf

located in the headwaters, while critical fish spawning habitat is situated in the valley bottom. In this situation, each element would require its own watershed context: the drinking water intake would have a relatively small upstream drainage area, and therefore a smaller study area, whereas the valley bottom habitat would be part of a higher-order watershed, and would require a larger study area.

Notes:

- Focusing solely on the WAU overlapping the activity footprint may overlook cumulative effects from upstream activities or downstream contributions to cumulative effects
- The study area is not dependent on the size of the activity footprint
- Regional variants can differ in their use of nested watersheds

Actions:

3.1 If not readily available, map the boundary of the proposed activity, including the primary development area and any ancillary components such as access roads, transmission lines, and work camps. The mapped boundary defines the activity footprint

3.2 Identify the WAU(s) that intersect the activity footprint. Record the Assessment Unit Source ID **(ASSESSMENT_UNIT_SOURCE_ID)**, this is how WAUs will be identified. Additional useful reference fields include Assessment Unit Name **(ASSESSMENT_UNIT_NAME)** and Local Watershed Code **(LOCAL_WATERSHED_CODE)**

3.3 Determine the receiving WAU using one of the following approaches:
Element approach: Identify downstream elements that could be affected by watershed hazards originating from the activity WAU(s). Use local knowledge, engagement feedback, and input from regulatory agencies to identify important downstream elements. Assign each element to the WAU in which it is located. Exact coordinates of elements are not required. The WAU(s) containing these elements are considered the receiving WAU(s).
Hydrologic transition approach: Identify the receiving WAU by locating the downstream point where potential upstream impacts are expected to be

substantially reduced or buffered. This is typically a major hydrologic transition, such as where a watershed drains into a large lake or joins a major river

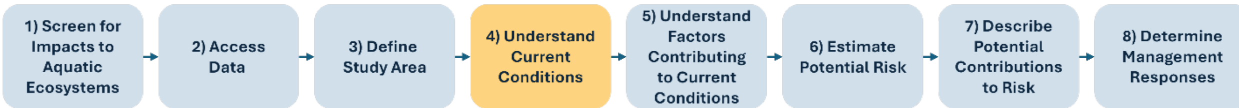
3.4 Define the drainage area upstream of the receiving WAU using the steps outlined in “Appendix 1: Understanding Watershed Assessment Units”, or manually if the watershed boundary is known

3.5 Verify that all selected WAUs are hydrologically connected and contribute flow to the receiving WAU. Exclude any internal basins without outlets or adjacent units that do not contribute flow

3.6 Compile the final set of WAUs that form the study area into a table and produce a map of the study area

Suggested outputs: Table of downstream elements, table of WAU(s) comprising the study area, map of study area.

Step 4: Understand current conditions



Understanding the current condition requires reviewing the watershed hazards within the study area. The CEF assessment assigns hazard ratings (low, moderate, or high) to each WAU using provincial-scale GIS indicators. These hazard ratings represent the likelihood of hazard occurrence (see Figures 2-4 for hazard definitions and pathway diagrams).

By examining the distribution of hazard ratings across WAUs within the study area an understanding of the cumulative pressures from past and present activities on downstream aquatic elements can be gained. This understanding of current conditions informs which hazards should be prioritized for mitigation, and where additional investigation is needed.

Actions:

4.1 Open the attribute table, then for each WAU in the study area, locate and record the hazard ratings from the following fields:

- Sediment Hazard: **WATER_QUALITY_MAX _CLS**
- Riparian Hazard: **STRM_DISTRB_ALL_PCNT_CLS**
- Peak Flow Hazard: **PEAK_FLOW_INDEX_CLS**

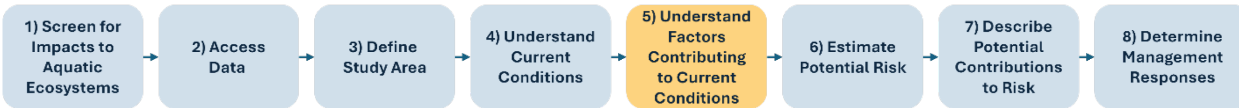
4.2 Create a table summarizing the hazard ratings for all WAUs. Optionally, include a map depicting hazard ratings to help readers visualize their spatial distribution. When mapping, symbolize the data based on the hazard classes as follows:
- **WATER_QUALITY_MAX_CLS**: High, Moderate, Low
- **STRM_DISTRB_ALL_PCNT_CLS**: High, Moderate, Low, Insufficient Data
- **PEAK_FLOW_INDEX_CLS**: High, Moderate, Low

4.3 Prepare a summary describing the current watershed condition. Focus on the distribution of hazard ratings and explain what these conditions mean for any elements and the proposed activity.

Example: "Sediment hazard is high across 7 of 8 WAUs. Riparian hazard is moderate and widespread. Peak flow hazard is low. These conditions suggest that sediment mitigation and road stream management will be key priorities."

Suggested outputs: Table of hazard ratings, maps of hazard ratings (optional), summary of current condition of watershed.

Step 5: Understand factors contributing to current conditions



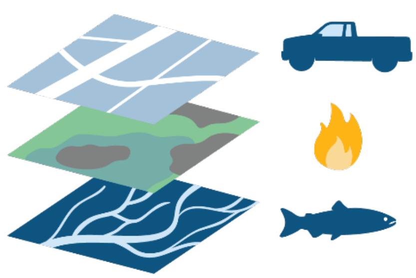
To understand the drivers behind watershed hazards it is important to examine the underlying indicators. This step helps pinpoint specific pressures within the study area and informs more targeted recommendations.

While hazard ratings reflect the condition of the watershed, they do not explain why a rating is what it is. By analyzing the indicators contributing to each hazard (e.g. road density, stream crossings, forest cover), the primary drivers of those hazards can be identified. A thorough review of the indicators ensures that recommendations are targeted and effective.

At this step, consider whether any significant natural or human-caused disturbances have occurred since the assessment that could materially alter watershed conditions. In most cases, users should rely on the existing data and routine CEF assessment reruns to capture incremental change. This check is intended only to flag major events or substantial land use changes that may affect key indicators and hazard likelihood. For example, a recent wildfire may significantly increase ECA, thereby influencing peak flow hazard.

Indicators

Indicators are organized into a tiered system, categorized as core, additional, or supplemental. An indicator can be classified as core or additional depending on the specific hazard being assessed.



Core indicators are the most reliable measures of pressures or stressors affecting a specific value. They directly represent the primary factors influencing hazard level in the watershed. These indicators are essential for assessing the root causes of hazards and should be prioritized in the analysis.

Additional indicators provide supporting context to the core indicators. While they are valuable for understanding the broader context, they are often secondary to core indicators in terms of their direct relevance to hazard assessment. Additional indicators may be removed from assessments as more accurate indicators are developed.

Sub-indicators are components that each measure a specific aspect or condition, that together make up a higher-level indicator.

Table 6: Sediment hazard indicators

Hazard Category	Type	Indicator	Attribute Field Name	Benchmark	Description
Sediment	Core	Road Density within 100 m of a Stream Weighted (km/km^2)	RD_STRM_BUFF_100_DENS_WGHTD_CLS	L<0.12, M=0.12-0.3, H>0.3	The proximity of roads to waterways increases the likelihood of direct sediment transport into streams.
		Stream Crossing Density (#/km^2)	RD_STRM_XING_DENS_CLS	(Interior) L<0.24, M=0.24-0.6, H >0.6 (Coastal) L<0.6, M=0.6-1.4, H>1.4	Stream crossings provide direct access for sediment from roads to be delivered into streams.
		Road Density on Potentially Unstable Slopes (km/km^2)	RD_STEEP_SLOPE_DENS_CLS	L<0.12, M=0.12-0.25, H>0.25	Roads located on steep potentially unstable slopes provide opportunities for road prism failure that results in landslides and delivery of sediment to streams.
		Riparian Disturbance (km/km)	STRM_DISTRB_ALL_PCNT_CLS	L<12%, M=12-21%, H>21%	Disturbance to riparian areas impacts sediment hazard through bank stability, which can accelerate bank erosion, and by reducing vegetation cover that would help filter sediment.
		Road Density Weighted (km/km^2)	RD_DENS_WGHTD_CLS	L<0.6, M=0.6-1.2, H>1.2	Measures the concentration of roads within a watershed. By applying weights based on factors that influence sediment generation potential, this indicator provides a more accurate representation than road density alone.

Table 7: Riparian hazard indicators

Hazard Category	Type	Indicator	Attribute Field Name	Benchmark	Description
Riparian	Core	Riparian Disturbance (km/km)	STRM_DISTRB_ALL_PCNT_CLS	L<12%, M=12-21%, H=21%	Measures the extent of human disturbance occurring within 30 m of a stream. This indicator is prioritized because it measures all human disturbances within the zone where the majority of riparian functions are generated or maintained (shading, temperature regulation, bank stability, nutrient filtering, large woody debris recruitment, floodplain connectivity, and habitat provision).
	Additional	Stream Crossing Density (#/km^2)	RD_STRM_XING_DENS_CLS	(Interior) L<0.24, M=0.24-0.6, H >0.6 (Coastal) L<0.6, M=0.6-1.4, H>1.4	Construction and maintenance of stream crossings contribute to riparian impacts. Considered an additional indicator as it captures only one form of riparian disturbance among numerous potential impacts.
		Road Density on Potentially Unstable Slopes (km/km^2)	RD_STEEP_SLOPE_DENS_CLS	L<0.12, M=0.12-0.25, H>0.25	The likelihood that landslides triggered by road failures may extend to waterways and impair riparian function. Considered an additional indicator as it represents one form of riparian disturbance among numerous potential impacts.
		Road Density within 100 m of a Stream (km/km^2)	RD_STRM_BUFF_100_DENS_CLS	Low<0.12, M=0.12-0.3, H>0.3	Roads located close to watercourses have a high potential to disrupt or impair key riparian functions by altering hydrology, modifying plant community structure, and fragmenting habitat.

Table 8: Peak flow hazard indicators

Hazard Category	Type	Indicator	Attribute Field Name	Benchmark	Description
Peak Flow	Core	Peak Flow Index	PEAK_FLOW_INDEX_CLS	L<0.3, M=0.31-0.42, H>0.42	A composite indicator based on multiple sub-indicators that capture forest disturbance and various watershed characteristics that influence peak flow event magnitude and frequency.
	Sub-Indicator	Hydrologic Response Potential	HYDROLOGIC_RESP_ POT_CLS	VL<6, L=6-7, M=8-9, H=9-11, VH=>11	Derived from the Runoff Generation Potential and Runoff Attenuation ratings (see Protocol) and provides an estimate of how sensitive a watershed may be to forest removal, in terms of increasing the frequency and magnitude of peak flow events.
		Equivalent Clearcut Area (%)	ECA_FINAL_PCNT	% of AU, 9999 where >50% of VRI unreported L<0.3, M=0.3-0.42, H>0.42	Equivalent Clearcut Area (ECA) is a measure of the total amount of disturbance (forest cleared) in a watershed and considers natural (i.e. fire, insect) and human (i.e. forest harvest, agriculture) disturbance. The ECA is defined as the area of disturbed forest that is hydrologically equal to a clearcut of the same size. The calculations account for the rate of forest regrowth over time, such that a newly cleared area will have a much higher ECA value than an equal size area that was harvested years ago and has since regrown.
	Additional	Road Density	RD_DENS_CLS (sensitive or mountainous watersheds) RD_DENS_WAP_CLS (other watersheds)	L<0.6, M=0.6-1.2, H>1.2 L<0.15, M=1.5-2.1, H>2.1	Roads intercept shallow groundwater at cut slopes and route that water along with road surface runoff, to the stream network, contributing to increased magnitude of high flow events.

Actions:

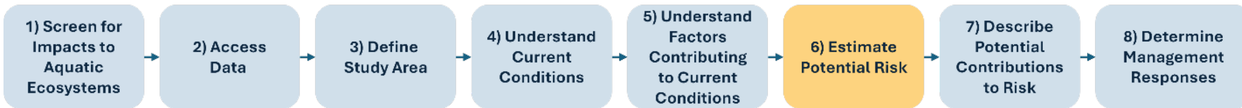
5.1 For each WAU in the study area, review the attribute table and record the indicator ratings associated with moderate or high hazards. Use Tables 6-8 to identify which indicators correspond to each hazard category and to confirm correct field names. Indicators underlying low hazards are typically low and may be omitted

5.2 Review each indicator according to its relevance to the specific hazard. An indicator may function as a core indicator for one hazard category while serving as an additional indicator for another. Consider the mechanism by which each indicator contributes to the hazard and the relative strength of that contribution
Example: Stream crossing density is a core indicator for sediment hazard, as road-stream intersections are a primary pathway for sediment delivery to watercourses. However, the same indicator is an additional indicator for riparian hazard, as stream crossings represent only one of many potential riparian disturbances

5.3 Provide a clear interpretation explaining the key factors driving watershed hazards across the study area. Connect hazard ratings to underlying indicators and describe how land use activities, natural landscape characteristics, or existing disturbances contribute to current conditions.
Example: “High sediment hazard in the upper basin is driven by steep terrain combined with an extensive road network. Riparian hazard remains low throughout the watershed. Peak flow hazard is moderate, driven by moderate ECA within watersheds with moderate hydrologic response potential

Suggested output: Table of indicators and summary of key factors driving watershed hazards.

Step 6: Estimate potential risk



To estimate risk, the potential consequences of hazards within the area of assessment must first be determined. The purpose of the consequence rating is to provide a quick and transparent overview of what is at stake. The resulting risk rating reflects a balance between likelihood and consequence.

Traditional engineering risk analysis incorporates multiple consequence factors. This GIS-based approach simplifies the process by making targeted assumptions and focusing on the relative importance of elements to ecological, social, cultural, and economic systems. The goal is to gain a watershed scale understanding of potential consequences without the need for extensive field surveys or site-specific investigations. Key assumptions:

- Consequence ratings represent the potential impact if an element were completely lost or severely compromised. While individual events may not cause total loss, sustained high risk conditions can eventually result in degradation or elimination of elements
- Exposure is treated as being held constant, identified elements should exist within the stream or adjacent floodplain, where they are directly subject to watershed hazards originating from upstream activities

Guiding principles for rating consequence

- Use a 3-tier rating system (low, moderate, and high) to avoid unnecessary complexity
- Use accessible data: Base ratings on publicly available information such as species presence, road networks, water licence points of diversion, utility maps, and floodplain data
- Leverage existing frameworks: Certain natural resource regions have developed specific consequence or sensitivity scoring systems for fish and/or infrastructure. Where such systems exist and are supported by more detailed local data, use those frameworks instead of the more generalized approach provided here

- Apply transparent criteria: Use clear, plain language standards:
    - High consequence: Legally protected resources or essential services
    - Moderate consequence: Regionally important resources or secondary services
    - Low consequence: Common, widespread resources or services with minimal impact
- Work at a coarse resolution: It is sufficient to know which assessment unit an element resides in, not the precise location. This can also protect sensitive information

Table 9 provides an example of a consequence rating framework. This is one possible model; users can adapt or develop their own framework. For major or controversial projects building a consensus around how consequences are defined can improve clarity, trust, and defensibility. However, straightforward locations and activities may require less intensive consideration.

Table 9: Example consequence rating framework

Consequence rating	Description	Rating criteria
High	Loss would have provincial or national repercussions, loss of life / serious injury, or threaten critical habitat or species	• Primary and inter-provincial highways • National railways, transmission lines, and pipelines • Community waterworks and domestic water intakes • Legally protected species and critical habitat • Permanent residents or critical facilities within 1-in-200-year floodplain
Moderate	Important at the regional scale, disruption causes	• Secondary highways and major roads

	noticeable but manageable impacts	• Sport fish, regionally significant species • Agricultural, commercial, and industrial water intakes • Structures without permanent occupancy within 1-in-200-year floodplain
Low	Local value only, loss is easily repairable or naturally redundant	• Local and resource roads • Short term use water licences • Common species

Pairing elements to hazards

Different elements are vulnerable to different types of hazards. For example, stream crossing infrastructure such as a highway or pipeline may be highly susceptible to peak flow hazards but largely unaffected by sediment or riparian hazards. Refer to Table 10 to identify which hazards apply to each element and assess the corresponding risk levels.

Table 10: Element and hazard pairings.

		Hazard		
		Sediment	**Riparian**	**Peak Flow**
Element	**Ecosystem**	⚑	⚑	⚑
	Infrastructure	-	-	⚑
	Public safety	-	-	⚑
	Drinking water	⚑	⚑	⚑

Determine risk ratings

Apply the risk matrix to determine the overall risk rating for each identified element by combining the likelihood and consequence ratings. The risk rating is a balance between likelihood and consequence. A hazard with moderate likelihood but high consequence may still present high risk. Conversely, a hazard with a high likelihood but low consequence may be considered an acceptable risk.

Table 11: Risk rating matrix

		Consequence rating		
		Low	Moderate	High
Hazard likelihood rating	Low	Very low	Low	Moderate
	Moderate	Low	Moderate	High
	High	Moderate	High	Very high

Risk manifests as an accumulation of pressures due to human and natural disturbances, whether from increased sediment, altered flows, or degraded riparian areas. While these pressures do increase the risk of single catastrophic events, the chronic exposure to stressors is equally important.

Using drinking water as an example, a landslide upstream of a community drinking water intake could have devastating impacts. However, a gradual increase in the frequency and magnitude of sediment mobilization may be just as consequential, leading to more frequent boil water advisories and higher costs associated with treatment, maintenance, and filtration that accumulate over time.

Actions:

6.1 Develop or apply a transparent consequence rating framework based on publicly available data sources. Apply the framework to assign a consequence rating to each identified element at risk. Ensure that every rating is supported by a clear rationale. Compile the results in a table that lists each element, its consequence rating, and the supporting rationale. For example, the drinking water element might receive a high consequence rating if a water licence within the study area supplies a large population

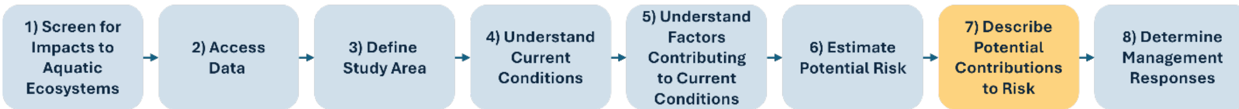
6.2 Determine which hazard categories are relevant to each element at risk. Not all elements will be sensitive to all hazards. For example, infrastructure within a floodplain may be vulnerable to peak flow hazards, but not to sediment hazards

6.3 Use the risk matrix in Table 11 to combine the hazard likelihood ratings with consequence ratings and assign a risk rating (very low to very high) for each hazard-element pairing

6.4 Summarize the risk analysis results in a table that presents, for each element at risk: the applicable hazard, the hazard likelihood rating, the consequence rating, and the resulting risk rating

Suggested output: Consequence rating framework used, table of consequence ratings and rationales, and table summarizing risk analysis results.

Step 7: Describe potential contributions to risk



In this step, consider the scale and nature of the proposed activity and how it may contribute to risk through cumulative effects. This will help determine whether the existing CEF assessment data is sufficient or whether additional analysis is needed to understand the activity's contribution to cumulative effects.

Minor or incremental contributions

For most activities with small, incremental impacts, **do not recalculate indicator ratings**. Instead, focus on understanding existing cumulative effects and the current level of risk to the value. CEF assessment reruns are intended to capture the "nibbling effect" of the gradual repetitive impacts that accumulate over time.

When additional analysis is required

If an activity could substantially change the condition of an indicator, its impact should be evaluated through additional analysis. The scope and complexity of this analysis may vary, ranging from a simple estimate of change (e.g., approximately 12 km of new road near streams) to a more complex quantitative or spatial analysis (e.g., recalculation of peak flow index using CEF methods). Note that substantial change in risk can occur even when the overall risk rating remains the same. Use professional judgement to determine if additional analysis is required and document the outcome of this consideration.

Major projects

Major projects undergoing an environmental assessment may need to quantify the contributions of the project along with other reasonably foreseeable future activities to cumulative effects. In these cases, the methodology and approaches used in the CEF assessment should be considered to complete that analysis.

Actions

7.1 Determine if additional analysis (recalculation of any aspect of the CEF assessment) is needed by asking whether the proposed activity:

- Could substantially move the condition of an indicator?
- Occurs within a special management area?
- Raised concerns during consultation or engagement?

If none of these conditions apply, the existing risk analysis results are considered adequate to support management decision-making, and no further refinement of indicators, hazards, or risk ratings is necessary.

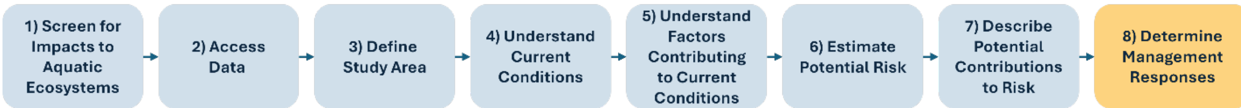
7.2 Where additional analysis is warranted, complete the appropriate level of assessment and document any changes to indicators, hazards, or risk ratings. Confirm the scope and approach with the SDM or relevant agency

7.3 Summarize how the proposed activity is expected to influence risk ratings (increase, decrease, or no change), even where categorical ratings remain unchanged.

For example, risk to aquatic ecosystems from riparian hazard is currently rated as moderate. The proposed activity is expected to increase riparian pressure; however, risk is expected to remain moderate.

Suggested output: Additional analysis results (if required), summary of the proposed activity's contribution to risk.

Step 8: Determine management strategies



This step translates risk findings into appropriate management strategies. Building on the CEF assessment, users are expected to use the best available and most current information, consider additional local context, and apply professional judgement to ensure risks to aquatic ecosystems are accurately understood and mitigated. Management strategies should be proportionate to the level of risk, with the objectives of minimizing the activity's contribution to cumulative effects and, where feasible, supporting broader risk reduction across the watershed.

Refine potential risk using additional information

Before identifying management strategies, consider all information gathered to this point and evaluate whether additional context or new information may influence risk to aquatic ecosystems in ways not captured in the CEF assessment. The review does not replace or re-run the CEF assessment, rather, it supports professional interpretation of whether the initial risk rating remains appropriate when additional information and local context are considered.

The following questions provide a starting point; however, professional judgement should be used to identify other relevant information sources or local context:

(a) Are there additional watershed characteristics or stressors (e.g. drought, pollution sources, elevated water temperatures) not captured in the CEF assessment that could interact with the value?

(b) Is there local or regionally specific information on climate change trends that may influence future hydrologic or geomorphic processes (e.g. peak or low flow regimes, landslide frequency)?

(c) Are there broad objectives or considerations that may be relevant, such as legal, policy, or planning objectives (e.g. Fisheries Sensitive Watersheds, Community Watersheds, Wildlife Habitat Areas, Land Use Plans, Water Sustainability Plans)? If not considered, these may influence consequence ratings.

(d) Are there concerns or information raised through consultation with First Nations or engagement with the public?

Propose management strategies based on risk

Management strategies describe the combination of decisions, conditions, and actions used to manage identified risks to aquatic ecosystems. They guide how, where, and under what constraints an activity may proceed, and may include avoidance, modification, mitigation, monitoring, or further investigation.

Management strategies should be proportionate to the level of risk and aligned with relevant government objectives for the value, as well as existing plans, policies, or agreements (e.g., Treaty 8 Planning and Mitigation Measures), to ensure an appropriate and consistent approach. However, government objectives do not always articulate the desired condition for a value or the watershed. In addition, best management practices and minimum default, site-level requirements may not be sufficient to adequately manage risk, even in low-risk situations. Given this, professional judgement needs to be applied to consider these aspects when identifying management strategies.

Low risk: These situations generally require minimal management beyond applying and enforcing standard best management practices and regulatory requirements. An exception may occur when a single activity is of such a magnitude that it can significantly shift the risk level, at which time further analysis to verify risk (e.g., ECA analysis) and identify additional mitigation may be required.

Moderate risk: Additional measures may be required to prevent further degradation. Management strategies may include enhanced or tailored mitigations, such as increased buffers, stricter erosion and sediment control, optimized alignment or sitting, and reduced footprint.

High risk: Avoidance should be prioritized. Where avoidance is not feasible, further investigation or action may be required to address specific risks before proceeding.

Note: There may be situations where it is not possible to mitigate incremental risk from an activity to the degree necessary to meet objectives for aquatic ecosystems. In this case, the appropriate management strategy may be to identify alternative approaches to the design or location of the activity as originally proposed. Early consideration of cumulative effects information will help to identify these situations and inform activity planning and design to avoid impacts to values that are inconsistent with objectives.

Triggering further professional investigation

Further professional investigation is used to reduce uncertainty and inform management decisions when a coarse watershed-level CEF assessment identifies moderate to high risk. These investigations evaluate risk mechanisms and management options at an appropriate scale and level of detail prior to proceeding with activities that may contribute to cumulative effects.

Further professional investigation itself is not a mitigation; rather, it provides a technical basis to determine whether activities should proceed, under what conditions, and with what measures. Investigations should be completed by Qualified Environmental Professionals (QEPs) and follow recognized professional practice standards, where applicable.

Examples of further professional investigations:

Peak flow hazard: A watershed assessment for hydrologic and geomorphic risk, conducted in accordance with the joint professional practice guidelines[9]. This assessment evaluates how land use changes affect peak flow generation and channel stability, identifying areas where increased runoff may lead to flooding, erosion, or infrastructure damage.

Sediment hazard: A watershed-level road risk assessment that identifies the road segments and drainage features that pose the greatest risk of sediment delivery to streams, supporting prioritization for maintenance, upgrades, deactivation, or other corrective actions.

Riparian hazard: A riparian restoration or management plan that identifies priority sites for protection or restoration, and outlines management strategies to maintain or improve riparian function and connectivity.

Actions:

8.1 Review additional information not captured in the CEF assessment, including additional stressors, climate trends, legal and policy objectives, and concerns from First Nations or public engagement. Use professional judgement to determine if this information influences risk

[9] Engineers and Geoscientists British Columbia and Association of British Columbia Forest Professionals. 2020. Watershed Assessment and Management of Hydrologic and Geomorphic Risk in the Forest Sector. Version 1.0. https://www.egbc.ca/getmedia/8742bd3b-14d0-47e2-b64d-9ee81c53a81f/EGBC-ABCFP-Watershed-Assessment-V1-0.pdf

8.2 Use the outcome of the risk analysis to inform management strategies (e.g. best management practices, tailored mitigations, and/or further professional investigation) to reduce the activity's contribution to cumulative effects on aquatic ecosystems. Document proposed management strategies in a table organized by hazard type

Suggested output: Table of proposed management strategies.

Summary of outputs

The following summarizes the recommended outputs. Refer to the case study for illustrative examples:

- Table of downstream elements at risk
- Map of the assessment area(s)
- Table of WAUs that form the assessment areas(s)
- Table summarizing hazard ratings with interpretation
- Table summarizing indicators with interpretation
- The consequence rating framework utilized
- Table of consequence ratings and rationale
- Table summarizing risk ratings
- Written documentation of contribution to cumulative effects and rationale for whether additional analysis is warranted
- Table of proposed management strategies

Case study

Project: Made-Up-Quarry

Location: Within Watershed Assessment Unit 300-698419-426421, approximately 11 km upstream of Arrow Lake.

Regulatory Context: Kuskanax Creek Community Watershed under the Forest and Range Practices Act.

Other Information: Village of Nakusp Water Operations Report 2024

Disclaimer: The activities and impacts in this case study are fictional. Consequence and risk ratings were developed using simplified, high-level assumptions and have not been verified. The case study should not be relied upon for any purpose other than demonstrating application of the Aquatic Ecosystem CEF assessment.

Step 1: Screen for impacts to Aquatic Ecosystems

The proposed quarry includes new access infrastructure and localized ground disturbance. Screening questions were completed to determine whether application of the Aquatic Ecosystem CEF assessment is appropriate.

The activity intersects multiple sediment and riparian hazard pathways, including road construction near streams and disturbance within the riparian zone.

Consistent with Step 1 guidance, the presence of one or more “yes” responses indicates that consideration of cumulative effects on Aquatic Ecosystems is appropriate. All three watershed hazards are considered to provide full watershed context, even when direct contributions are limited.

Table 12: Screening questions for impacts to Aquatic Ecosystems

Screening question	Yes	No	Applicable hazards
Does the activity involve road construction within 100 m of a stream, lake, or wetland?	☒	☐	Sediment
Does the activity involve road construction on potentially unstable slopes?	☐	☒	Sediment
Does the activity involve new stream crossings?	☐	☒	Sediment
Does the activity disturb soil or clear vegetation within 30 m of a stream, lake, or wetland?	☒	☐	Riparian, Sediment
Does the activity involve forest clearing?	☐	☒	Peak flow

Step 2: Access data

The "BCCE_Watershed_Assmnt_2020.gdb" dataset was downloaded from the BC Data Catalogue and reviewed using GIS software.

Step 3: Define study area

The activity footprint is situated within **ASSESSMENT_UNIT_SOURCE_ID** 17356 (**LOCAL_WATERSHED_CODE** 300-698419-426421). Downstream elements at risk were identified using publicly available information.

Table 13: Downstream elements at risk

Element	Description
Public safety	Village of Nakusp at the Kuskanax Creek mouth (alluvial fan).
Ecosystem	Bull trout (species of special concern). Other regionally important species include Kokanee, Rainbow trout, and Mountain whitefish.
Infrastructure	Highway 23 crossing over Kuskanax Creek (secondary highway).
Drinking water	Designated Community Watershed. Intake on Kuskanax Creek used as backup to a groundwater supply.

Arrow Lake provides a natural boundary at **ASSESSMENT_UNIT_SOURCE_ID** 17351, and all identified elements are located within this WAU, which serves as the receiving WAU.

Using the method from Appendix 1, nine WAUs were identified. One adjacent WAU was excluded after confirming that it drains directly to Upper Arrow Lake and is not hydrologically connected to the elements identified in Kuskanax Creek. The final study area consists of eight WAUs.

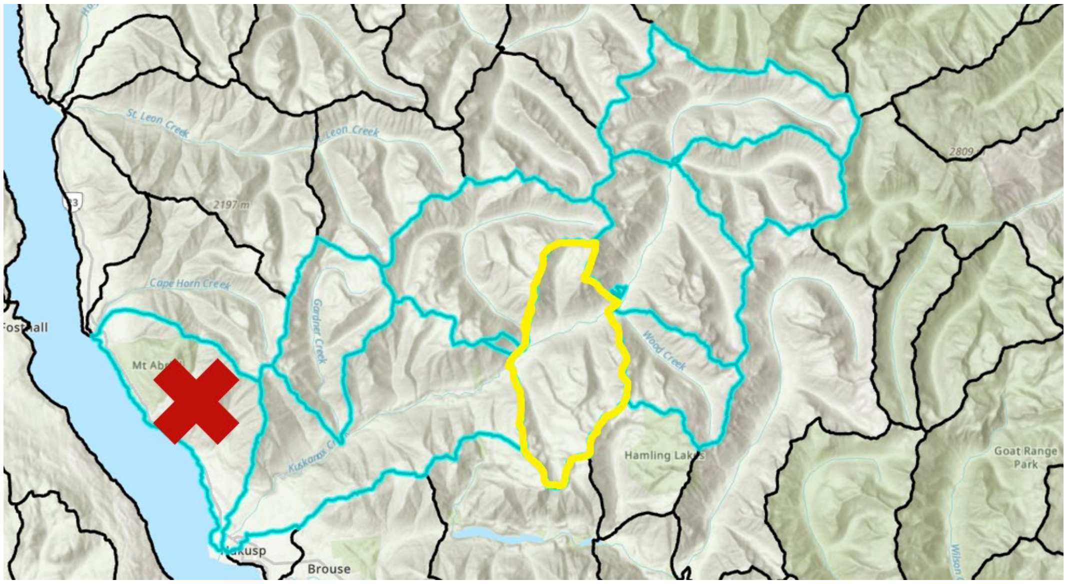


Figure 8: Study area showing eight included WAUs and one excluded due to lack of hydrologic connectivity to elements at risk. The activity WAU is outlined in yellow.

Table 14: WAUs that form the study area

ASSESSMENT_UNIT_NAME	ASSESSMENT_UNIT_SOURCE_ID	LOCAL_WATERSHED_CODE
Kuskanax Creek	17351	300-698419-000000
Gardner Creek	17352	300-698419-214855
No name	17353	300-698419-449423
Wood Creek	17354	300-698419-557306
Kuskanax Creek 2 (Activity WAU)	17356	300-698419-426421
Kuskanax Creek 3	17357	300-698419-557603
Rogers Creek	17355	300-698419-735354
Kuskanax Creek 4	17358	300-698419-735354

Step 4: Understand current conditions

Hazard ratings for all WAUs within the study area were compiled and reviewed.

Table 15: Summary of hazard ratings

ASSESSMENT_UNIT_SOURCE_ID (ASSESSMENT_UNIT_NAME)	Sediment hazard (WATER_QUALITY_MAX_CLS)	Riparian hazard (STRM_DISTRB_ALL_PCNT_CLS)	Peak flow hazard (PEAK_FLOW_INDEX_CLS)
17351 (Kuskanax Creek)	High	High	Low
17352 (Gardner Creek)	High	High	Low
17353 (No Name)	High	Moderate	Low
17354 (Wood Creek)	Low	Low	Low
17356 (Kuskanax Creek 2)	High	Moderate	Low
17357 (Kuskanax Creek 3)	High	Moderate	Low
17355 (Rogers Creek)	High	Moderate	Low
17358 (Kuskanax Creek 4)	Moderate	Low	Low

Interpretation

Sediment hazard is elevated across most of the study area, with Wood Creek as the exception. Riparian hazard is generally moderate, indicating notable near stream disturbance. Peak flow hazard is uniformly low, suggesting intact cover and naturally attenuating hydrology.

These results indicate that cumulative effects concerns are primarily driven by sediment-related pressures, with riparian condition functioning as an important contributing stressor.

Step 5: Understand factors contributing to current conditions

Table 16: Summary of indicators

Indicator	Published field name	Kuskanax	Gardner	No Name	Wood	Kuskanax 2	Kuskanax 3	Rogers	Kuskanax 4
Road density weighted (Sediment hazard only)	RD_DENS_WGHTD_CLS	Moderate	Moderate	Low	Low	Moderate	Low	Low	Low
Road density	RD_DENS_CLS	High	Moderate	Low	Low	Moderate	Low	Low	Low
Road density WAP (Peak flow hazard only)	RD_DENS_WAP_CLS	High	Moderate	Low	Low	Moderate	Low	Low	Low
Stream crossing density	RD_STRM_XING_DENS_CLS	High	High	High	Low	High	High	High	Moderate
Road density near streams weighted	RD_STRM_BUFF_100_DENS_WGHTD_CLS	Moderate	High	Moderate	Low	Moderate	Moderate	Moderate	Moderate
Road density near streams	RD_STRM_BUFF_DENS_CLS	High	High	Moderate	Low	High	Low	High	Moderate
Road density on potentially unstable slopes	RD_STEEP_SLOPES_DENS_CLS	Low	Low	Low	Low	Low	Low	Low	Low
Proportion of equivalent clearcut area	ECA_FINAL_PCNT	Low	Low	Low	Low	Low	Low	Low	Low
Hydrologic response potential	HYDROLOGIC_RESP_POT_CLS	Low	Low	Low	Low	Low	Low	Low	Low

Interpretation

Sediment pressures are primarily associated with road-stream proximity, particularly road density near streams and the density of stream crossings. Road density on potentially unstable slopes is low throughout the study area, suggesting that landslide driven sediment delivery is not a dominant mechanism. Peak flow hazard is low across all WAUs and was not further assessed, as the underlying indicators are likely to be low. Overall, the findings support prioritizing mitigation related to road siting and design, stream crossings, and protection of riparian areas.

Step 6: Estimate potential risk

Consequence ratings were assigned using the example framework provided in the guide and informed by local context. The ecosystem element received a high consequence rating due to the presence of Bull Trout, a species of special concern. Drinking water was rated as moderate due to source redundancy; this rating would be high if surface water were the community's primary source. Public safety was rated as moderate, as there are no permanent residences within the floodplain, although some commercial or industrial structures are present. Infrastructure was rated moderate, reflecting the role of the highway to surrounding communities.

Table 17: Consequence ratings and rationale

Element at risk	Consequence	Rationale
Public safety	Moderate	No permanent residents within inundation zone; some industrial & commercial activity.
Ecosystems	High	Presence of Bull Trout, a species of special concern.
Infrastructure	Moderate	Highway 23 is a secondary highway.
Drinking water	Moderate	Surface water source used as backup to groundwater supply.

The risk rating matrix was used to combine the hazard likelihood and consequence ratings.

Table 18: Risk matrix

		Consequence Rating		
		Low	Moderate	High
Likelihood Rating	Low	Very Low	Low	Moderate
	Moderate	Low	Moderate	High
	High	Moderate	High	Very High

Table 19: Summary of potential risk ratings

Element	Consequence rating	Likelihood rating	Potential Risk rating
Public safety	Moderate	Peak Flow - Low	Low
Ecosystems	High	Sediment – High	Very High
		Riparian – Moderate	High
		Peak Flow - Low	Moderate
Infrastructure	Moderate	Peak Flow - Low	Low
Drinking water	Moderate	Sediment – High	High

Overall, sediment and riparian pressures pose a very high to high risk to aquatic ecosystems, while sediment-related pressures present a high risk to drinking water.

Step 7: Describe potential contributions to risk

The proposed quarry involves new infrastructure, including 6.2 km of new road segments, of which 0.55 km are located within 100 m of a stream. Riparian disturbance is estimated at 100 m. The proposed activity is expected to increase potential risk to ecosystem and drinking water elements.

Potential to substantially move the condition of an indicator

While these additions increase existing pressures, they are not expected to substantially alter watershed-scale indicators such as road density, road density near streams, or riparian disturbance.

Location in a special management area

The activity is located within the Kuskanax Creek Community Watershed, which elevates sensitivity. However, based on the 2024 Village of Nakusp Water Operations Report (2024), the surface water intake on Kuskanax Creek is not the primary source.

Based on the absence of substantial change to key indicators, additional quantitative analysis is not necessary and using the current condition results from the CEF assessment are sufficient.

Step 8: Determine management strategies

Management strategies are scaled to the level of risk and focus on the primary drivers of cumulative effects identified in the CEF assessment. Given the very high sediment risk and high riparian related risk to aquatic ecosystems, management responses extend beyond best management practices.

Sediment delivery from existing and proposed road infrastructure is the primary driver of sediment related risk. To address uncertainty related to sediment generation, a watershed-level road risk assessment completed by a QEP is recommended. This assessment should evaluate the condition and risk profile of existing roads, with particular focus on haul routes, and prescribe site-specific mitigation measures.

To further reduce sediment related risk, the use of existing roads and stream crossings should be prioritized, and new roads should maintain a minimum 100 m setback from streams where feasible. Based on review of the sediment hazard indicators, roads located on potentially unstable slopes do not appear to be a concern within the study area.

Riparian management focuses on avoiding new disturbance within 30 m of streams; where this is achieved, no restoration or offsetting is recommended. The proposed activity is not expected to materially alter forest cover or hydrologic response.

Table 20: Proposed management strategies

Hazard	Management strategies
Sediment	• A watershed-level road risk assessment and management plan completed by a QEP to evaluate existing road networks, with a focus on haul roads. Permitting should be conditional upon remediation of identified problem segments and implementation of recommended upgrades to reduce sediment generation. • Prioritize use of existing roads and stream crossings. • Maintain a 100 m setback from streams for all new roads.
Riparian	• Maintain a 30 m no disturbance buffer.
Peak Flow	• Not applicable

Appendices

Appendix 1: Understanding watershed assessment units

Watersheds are used as the assessment units because hydrological processes are the key drivers of cumulative effects in aquatic ecosystems. Disturbance impacts accumulate from headwaters to valley bottoms in the same way that water flows and collects within a watershed. Watershed assessment units (WAU) were designed as per Carver and Grey[10] and represent standardized catchments with target areas of 3,000 to 5,000 hectares. This was an automated process following a set of logical rules intended to emulate 1:50k watersheds, but with 1:20k detail. Although the priority was to create topographically complete watersheds to the greatest extent possible, there are inconsistencies where small tributaries empty into lakes, large rivers, or the ocean. Additionally, lower portions of larger watersheds may be designated as separate units to maintain a greater number of complete catchments upstream. The WAUs have the same watershed codes as the Fresh Water Atlas allowing for streamlined GIS processes.

Watersheds have a hierarchical order, and in most cases, a watershed higher in order than that of an assessment unit will need to be assessed. To view data for a higher-order watershed, data must be manually aggregated from all individual watershed assessment units contained within it. Defining higher order watersheds can be done using the Watershed Code Local. Each six-digit segment represents a watershed order. To move up the hierarchy, remove the last six-digit segment.

Example:

Starting Local Watershed Code Local (assessment unit):

300-625474-020842-232716-246231-598080

To move up one order (sub-basin):

300-625474-020842-232716-246231-000000

Repeat the process to continue moving up the hierarchy.

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[10] Carver, M., & Gray, M. 2009. Assessment watersheds for regional level applications. Province of British Columbia. https://www2.gov.bc.ca/assets/gov/data/geographic/topography/fwa/fwa_overview_of_assessment_watersheds.pdf

1. Using the **Map** tab > **Selection** group > **Select by Attributes**.

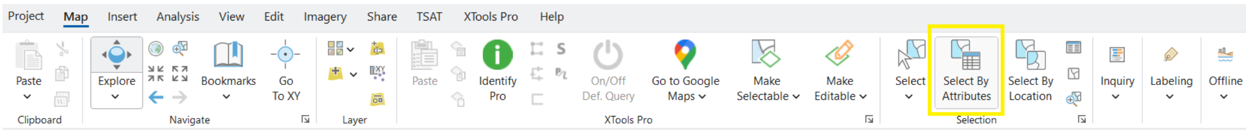

Figure 9: Location of Select by Attributes on the map tab in ArcGIS Pro

2. Build a logic statement to select the appropriate watershed. Write an expression: Where "Watershed Code Local" "begins with" then start with the Watershed Code Local of the WUA and remove six digits at a time until at the desired watershed level.

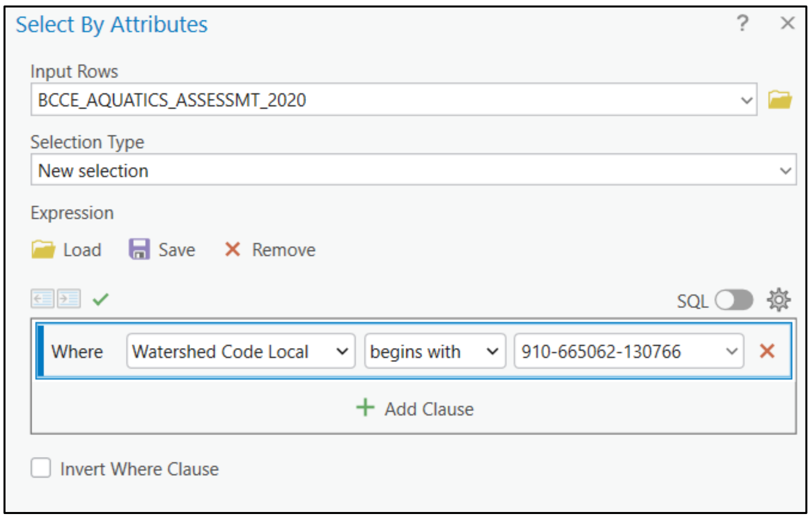

Figure 10: Select by Attributes window showing an example expression used to select a higher-order watershed

3. If a WAU needs to be removed, select **Selection Type** > **Remove from the current selection**, then use the expression: Where "Assessment Unit Source ID" "is equal to" the ID of the WAU to be remove.

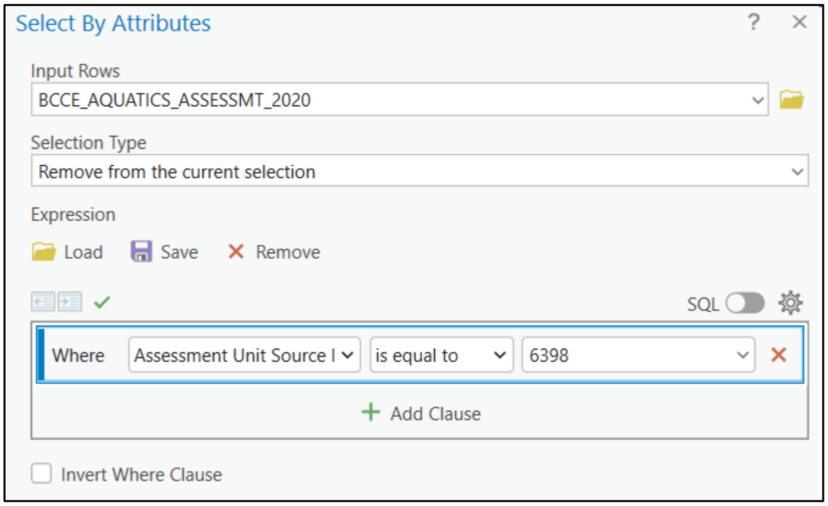

Figure 11: Select by Attributes window showing an example expression for how to remove a WAU from the selection

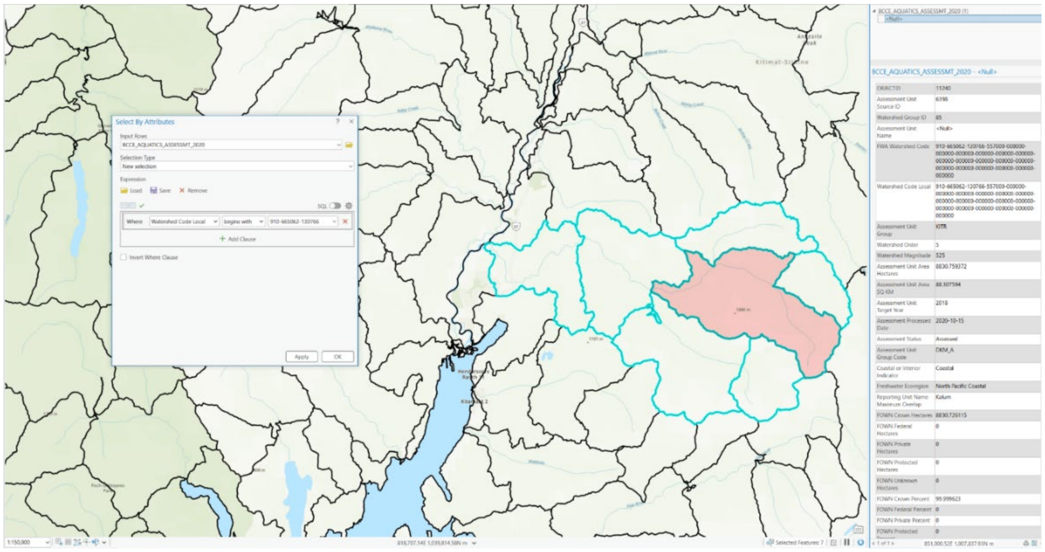

Figure 12: Example map showing Select by Attributes method of defining a higher-order watershed.

Appendix 2: Resource library

Resource	Link
CEF webpage	https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/cumulative-effects-framework
CEF Aquatic Ecosystem protocol	https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/cumulative-effects/protocols/cef-aquatic-ecosystems-protocol-dec2020.pdf
CEF assessment portal	https://experience.arcgis.com/experience/c90fc8a412d84aa09425244ef2db671e/page/Introduction
Human disturbance	https://catalogue.data.gov.bc.ca/dataset/7d61ff12-b85f-4aeb-ac8b-7b10e84b046c
CEF integrated roads	https://catalogue.data.gov.bc.ca/dataset/a489bc6a-f676-4503-8cd7-dcf0bdf2ae99
Land use plans & legal direction by region	https://www2.gov.bc.ca/gov/content/industry/crown-land-water/land-use-planning/regions
Environmental mitigation policy for B.C.	https://www2.gov.bc.ca/gov/content?id=5E84522AFC644511A5DC2AF36B897A9D
BC drought information portal	https://droughtportal.gov.bc.ca/
PCIC climate analysis tool	https://www.pacificclimate.org/analysis-tools
Current wildfire fire perimeters	https://catalogue.data.gov.bc.ca/dataset/cdfc2d7b-c046-4bf0-90ac-4897232619e1
Historical wildfire fire perimeters	https://catalogue.data.gov.bc.ca/dataset/22c7cb44-1463-48f7-8e47-88857f207702

Element at risk resource	Link
Desktop Watershed Characterization Resource	https://a100.gov.bc.ca/pub/acat/documents/r63110/DesktopWatershedCharacterizationReport_1726766574373_6368B54ED4.pdf
Species presence data	https://maps.gov.bc.ca/ess/hm/habwiz/
Fisheries sensitive watersheds	https://catalogue.data.gov.bc.ca/dataset/1a560a12-9be1-49a4-971a-dbc80875a0d7
Community watersheds	https://catalogue.data.gov.bc.ca/dataset/bc57faf7-23e4-43fe-918a-e999936dbafa
Drinking water sources	https://catalogue.data.gov.bc.ca/dataset/2ed101db-f2aa-4487-aa20-8f4c412e69b2
Water rights	https://catalogue.data.gov.bc.ca/dataset/5549cae0-c2b1-4b96-9777-529d9720803c
Flood study explorer	https://climatereadybc.gov.bc.ca/pages/flood-study-explorer
B.C. highway functional classification	https://www2.gov.bc.ca/assets/gov/driving-and-transportation/transportation-infrastructure/planning/inventories/bc_numbered_hwy_functional_classes.pdf

Appendix 3: Checklist

Step	Description	Completed	N/A	Notes
1.1	Answer screening questions	☐	☐	
2.1	Download CEF assessment data from the BC Data Catalogue	☐	☐	
2.2	Load feature class to view attribute table	☐	☐	
3.1	Map activity footprint	☐	☐	
3.2	Identify activity WAU(s) and record relevant fields	☐	☐	
3.3	Identify receiving WAU(s) using the element or hydrologic transition approach	☐	☐	
3.4	Delineate upstream drainage area the to receiving WAU(s)	☐	☐	
3.5	Confirm hydrologic connectivity of all included WAUs	☐	☐	
3.6	Produce table of WAUs defining the study area and a map	☐	☐	
4.1	Locate and record hazard ratings	☐	☐	
4.2	Display hazard ratings in a table or visually with maps	☐	☐	
4.3	Summarize current watershed conditions	☐	☐	

Step	Description	Completed	N/A	Notes
5.1	Locate and record indicator benchmarks	☐	☐	
5.2	Review indicator-hazard relationships using Tables 6-8	☐	☐	
5.3	Summarize key drivers of watershed hazards	☐	☐	
6.1	Establish a consequence rating framework and rate each element	☐	☐	
6.2	Identify hazard-element pairings	☐	☐	
6.3	Apply risk matrix to assign risk ratings	☐	☐	
6.4	Summarize risk analysis results	☐	☐	
7.1	Determine whether additional analysis is required (recalculation of indicators)	☐	☐	
7.2	If required, complete additional analysis and document changes to indicators and hazards	☐	☐	
7.3	Summarize how the proposed activity may impact hazard ratings	☐	☐	
8.1	Validate potential risk	☐	☐	
8.2	Document proposed management strategies or further investigation by hazard	☐	☐	

Appendix 4: Data Template

Hazard / indicator	Published field name	WAU 1	WAU 2	WAU 3	WAU 4	WAU 5	WAU 6	WAU 7	WAU 8
Sediment hazard	WATER_QUALITY_MAX_CLS								
Riparian hazard (Riparian disturbance)	STRM_DISTRB_ALL_PCNT_CLS								
Peak Flow Hazard (Peak flow index)	PEAK_FLOW_INDEX_CLS								
Road density weighted (Sediment hazard only)	RD_DENS_WGHTD_CLS								
Road density	RD_DENS_CLS								
Road density WAP (Peak flow hazard only)	RD_DENS_WAP_CLS								
Stream crossing density	RD_STRM_XING_DENS_CLS								
Road density near streams weighted	RD_STRM_BUFF_100_DENS_WGHTD_CLS								
Road density near streams	RD_STRM_BUFF_DENS_CLS								
Road density on potentially unstable slopes	RD_STEEP_SLOPES_DENS_CLS								
Proportion of equivalent clearcut area	ECA_FINAL_PCNT								
Hydrologic response potential	HYDROLOGIC_RESP_POT_CLS								

Appendix 5: Alternative plain text version for figures

Figure 1: Recommended Aquatic Ecosystem CEF assessment hazard roll-up

The figure presents how indicators are combined to produce the three watershed hazard ratings: peak flow hazard, riparian hazard, and sediment hazard.

Along the left side of the figure is a legend that visually distinguishes hazards, indicators, and sub-indicators by colour. Each indicator in the figure is also labeled with its unit type and benchmark; detailed definitions and benchmarks are provided in Tables 6 through 8.

The indicators are arranged to show how sub-indicators are combined into indicators and then combined again to form hazard ratings. The figure is read from the bottom upward and from left to right.

At the sub-indicator level, the biogeoclimatic ecosystem classification unit score and proportion of alpine non-forested area combine to form the runoff generation potential ranking.

Also at the sub-indicator level, the proportion of lakes and wetlands, and position within watershed, and drainage density ruggedness combine to form the surface flow and runoff attenuation ranking.

The runoff generation potential ranking and the surface flow and runoff attenuation ranking combine to form the hydrologic response potential rating. The hydrologic response potential rating is then combined with equivalent clearcut area to form the peak flow index. The peak flow hazard is defined by the peak flow index and has the attribute name peak_flow_index_cls.

The riparian hazard has the attribute name strm_distrb_all_pcnt_cls and is defined by the riparian disturbance indicator alone.

The sediment hazard is defined as the highest class of the following indicators: riparian disturbance, weighted road density near streams, road density on potentially unstable slopes, stream crossing density, and weighted road density. The sediment hazard has the attribute name water_quality_max_cls.

Figure 2: Riparian hazard definition and pathway of effects

This figure presents a pathway of effects diagram for the riparian hazard. The diagram shows how landscape indicators and human activities contribute to reduced riparian function and resulting impacts on drinking water and ecosystems.

In the top left, the diagram defines riparian hazard as the likelihood of reduced riparian function, which can negatively impact aquatic habitat, stream shading, bank stability, upland sediment filtration, and large woody debris input. Below the definition is a decorative illustration comparing an intact riparian area with trees, shade, and woody debris to a disturbed riparian area lacking these features.

Along the left side of the diagram, the pathway components are listed and visually distinguished by colour. These components include indicator, defined as a metric informing hazard likelihood; activity, pressure, or driver, defined as a change to the system; cascade of changes, defined as altered structures, processes, or functions; mechanism, defined as changes in conditions directly experienced; effect, defined as a change to a value; and element at risk, defined as the watershed receptor.

The main pathway of effects is shown in the centre of the diagram and is read from the upper left to the lower right.

Riparian disturbance, measured as disturbance within 30 metres of a stream, is identified as both an indicator and an activity, pressure, or driver. Riparian disturbance leads to five cascades of change.

The first cascade of change is decreased filtration of fine sediments from runoff into streams. This leads to increased turbidity and total suspended solid load in the stream.

The second cascade of change is decreased stream bank stability. This leads to bank erosion, which also results in increased turbidity and total suspended solid load in the stream.

Increased turbidity and total suspended solid load lead to mechanism of high-turbidity water that is difficult to treat with ultraviolet or chlorine disinfection. The resulting effect is impact to community water supply, affecting the drinking water element of risk.

Increased turbidity and total suspended solid load also lead to two additional cascades of change. The first is deposition of fine sediment on spawning gravels, which leads to the mechanism of decreased oxygenation of fish eggs and loss of suitable spawning substrate. The resulting effect is decreased fry production and rearing success due to sediment, affecting the ecosystem element at risk.

The second additional cascade is a decrease in invertebrate populations and growth rates. This leads to the mechanism of reduced fish prey availability and reduced ability to forage for food. The resulting effect is also decreased fry production and rearing success due to sediment, affecting the ecosystem element at risk.

The third cascade of change from riparian disturbance is decreased large woody debris input to streams. This leads to decreased channel structure provided by large woody debris and decreased habitat directly provided by large woody debris. Decreased channel structure and bank erosion together lead to channel instability, including widening, aggradation, avulsion, and increased bedload movement. Channel instability and reduced habitat directly provided by large woody debris lead to the mechanism of simplified or lower-quality instream habitat. The resulting effect is decreased fish rearing, spawning, and overwintering success due to habitat changes, affecting the ecosystem element at risk.

The fourth cascade of change is loss of riparian habitat. This leads to the mechanism of inadequate microclimate conditions for obligate riparian species. The resulting effect is a decline in obligate riparian plant and animal species, representing a loss of biodiversity, affecting the ecosystem element at risk. Loss of riparian habitat also leads to the mechanism of loss of off-channel juvenile fish habitat, which results in decreased fish rearing, spawning, and overwintering success due to habitat changes, affecting the ecosystem element at risk.

The fifth cascade of change is decreased stream shading. This leads to the mechanism of warmer stream temperatures, which results in increased fish mortality and lower productivity, affecting the ecosystem element at risk.

Figure 3: Sediment hazard definition and pathway of effects

This figure presents a pathway of effects diagram for the sediment hazard. The diagram shows how landscape indicators and human activities contribute to increased sediment events and resulting impacts on infrastructure, ecosystems, and drinking water.

In the top left, the diagram defines sediment hazard as the likelihood of increased suspended sediment concentrations and mass sediment delivery (e.g., landslides) into streams. This analysis considers the impact of roads, crossings, and other human disturbances. A decorative illustration of sediment entering a stream from an eroding stream bank appears below this definition.

Along the left side of the diagram, the pathway components are listed and visually distinguished by colour. The components include, indicator defined as a metric informing hazard likelihood; activity, pressure, or driver, defined as a change to the system; cascade of changes, defined as altered structures, processes, or functions; mechanism, defined as changes in conditions directly experienced; effect, defined as a change to a value; and element at risk, defined as the watershed receptor.

The main pathway of effects is shown in the centre of the diagram and is read from the upper left to the lower right.

Roads in watershed, measured as weighted road density is identified as both an indicator and an activity, pressure, or driver. This leads to the cascade of change of failure of the road prism during saturated conditions.

Roads on potential unstable terrain, measured as road density on steep slopes is identified as both an indicator and an activity, pressure, or driver. This also leads to failure of the road prism during saturated conditions, which then leads to the cascade of change of landslide initiation that transports large and fine sediment to streams.

Landslide initiation that transports sediment to streams leads to the mechanism of direct impacts from landslides or delayed impacts from a sediment wedge moving downstream. The resulting effect is damage to infrastructure, including roads, stream crossings, and water intake structures, affecting the infrastructure and drinking water elements at risk.

Landslide initiation that transports sediment to streams also leads to the cascade of change of deposition of gravels and cobbles in the stream, forming a sediment wedge. This leads to the mechanism of channel aggradation or channel avulsion. The resulting effect is loss or simplification of instream habitat features, affecting the ecosystem element at risk.

Roads near streams, measured as weighted road density within 100 metres of a stream, and roads crossing streams, measured as stream crossing density, are identified as indicators and as activities, pressures, or drivers. These, together with weighted road density, lead to the cascade of change of runoff along road surface eroding fine sediment and delivering it to streams. This results in the cascade of change of increased turbidity and total suspended solid load in streams.

The previously mentioned cascade of change of landslide initiation that transports sediment to streams also contributes to increased turbidity and total suspended solid load in streams.

Riparian disturbance, measured as distance within 30 metres of a stream, is identified as both an indicator and an activity, pressure, or driver. This leads to two cascades of change: decreased filtration of fine sediments from runoff into streams, and decreased stream bank stability. Decreased stream bank stability leads to bank erosion. Bank erosion, together with decreased filtration of fine sediments, leads to increased turbidity and total suspended solid load in streams.

Increased turbidity and total suspended solid load in streams lead to one mechanism and two cascades of change. The mechanism is high turbidity water that is difficult to treat using ultraviolet light or chlorine disinfection. The resulting effect is impacts to community water supply, affecting the drinking water element at risk.

The first additional cascade of change is deposition of fine sediment on spawning gravels. This leads to the mechanism of decreased oxygenation of fish eggs and loss of suitable spawning substrate. The resulting effect is decreased fry production and rearing success, affecting the ecosystem element at risk.

The second additional cascade of change is decreased invertebrate populations and growth rates. This leads to the mechanism of reduced fish prey availability and reduced ability to forage for food. Increased turbidity and total suspended solid load in streams also directly contribute to reduced prey availability and foraging ability. The resulting effect is decreased fry production and rearing success, affecting the ecosystem element at risk.

Figure 4: Peak flow hazard definition and pathway of effects

This figure presents a pathway of effects diagram for the peak flow hazard. The diagram shows how landscape indicators and human activities contribute to increased peak flow events and their impacts on people, infrastructure, and ecosystems.

In the top left, the diagram defines peak flow hazard as the likelihood of increased frequency and magnitude of peak flow events, which may lead to harmful hydro-geomorphic outcomes including floods, bank erosion, channel instability, debris floods, and debris flows. A decorative illustration of a flooding stream damaging a crossing appears below this definition.

Along the left side, the diagram lists the components of the pathway of effects, which are visually distinguished by colour. The components include, indicator defined as a measurable feature; activity, pressure, or driver, defined as a change to the system; cascade of changes, defined as altered structures, processes, or functions; mechanism, defined as changes in conditions directly experienced; effect, defined as a change to a value; and element at risk, defined as the receptor of effect.

The main pathway of effects is shown in the centre of the diagram and is read from the upper left to the lower right.

Surface flow attenuation is identified as both an indicator and an activity, pressure, or driver. This leads to the cascade of change of natural moderation of streamflow peaks, which contributes to the peak flow index indicator.

Runoff generation potential and forest clearing in the watershed, measured as equivalent clearcut area, are also identified as indicators and activities, pressures, or drivers. Both lead to the same cascade of change, increased snow accumulation and decreased evapotranspiration, which contributes to the peak flow index indicator.

The peak flow index indicator leads to the cascade of change of increased peak flow frequency and magnitude. This cascade of change leads to two mechanisms. The first mechanism is increased occurrence of overbank flooding. The second mechanism is increased bank erosion, avulsion, and channel instability.

Increased overbank flooding results in the effect of flood damage to property and injury or loss of life, which impacts the public safety element at risk.

Increased bank erosion, avulsion, and channel instability results in two effects. The first is erosion of infrastructure, such as roads, bridges, and water intake structures, affecting infrastructure and drinking water elements at risk. The second is loss or simplification of instream habitat features, impacting the ecosystem element at risk.

Figure 5: Risk matrix illustrates how hazard likelihood ratings can be used with consequence ratings to inform potential risk. Adapted from Lewis et al., 2015.

At the top of the figure is Watershed assessment unit(s), illustrated by a stream affected by human activities such as logging, a stream crossing, and sediment entering the water from roads.

Two branches extend downstream from the watershed assessment unit. The left branch is hazard likelihood rating, defined as GIS indicators of watershed hazards, including sediment, riparian, and peak flow. The right branch is consequence rating, defined as elements at risk, including public safety, ecosystem, drinking water, and infrastructure.

Both branches lead to a potential risk rating matrix. In the matrix, hazard likelihood ratings of low, moderate, and high are shown along the vertical axis. Consequence ratings of low, moderate, and high are shown along the horizontal, or x-axis at the top.

Risk increases diagonally across the matrix from very low in the top left corner to very high in the bottom right corner.