CEF Cumulative Effects Framework

BRITISH COLUMBIA

Interim Assessment Protocol for Aquatic Ecosystems in British Columbia

Standards for British Columbia's Cumulative Effects Framework Values Foundation

Prepared by

Provincial Aquatic Ecosystems Technical Working Group – Ministries of Environment and Forests, Lands and Natural Resource Operations – for the Value Foundation Steering Committee

Approved by

Interim Approval by NRS ADMs January 2017

December 2017
Version 1.1

Note: The protocol outlined in this document is subject to change based on regional updates, as well as periodic updates to reflect continuous improvement of the protocol.

Document Control

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1.0	Jan 2017	➢ *Interim Approved by NRS ADMs*
1.1	Dec 2017	➢ *Minor Copy Edit* ➢ *Updated conceptual model.*

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Table of Contents

1.0 Introduction

Watersheds are the geographic areas that channel drainage into a river or stream system. They are defined by topographic boundaries and—depending on where they are located—might encompass complex natural ecosystems, highly urbanized landscapes, or elements of both. Watersheds have three distinct characteristics: (1) upland zones that intercept, infiltrate, and transport rain as groundwater and surface water flow, (2) riparian zones that border surface water bodies, filter surface water runoff, and provide shade that can lower water temperature, and (3) surface water bodies, such as rivers and lakes, that provide habitat, food, and water to aquatic and terrestrial species. Naturally functioning watersheds can also provide migratory corridors and habitat connectivity for birds and mammals. The term "watershed processes" refers to the dynamic suite of physical, chemical and biological interactions that form and maintain landscape functions on the scale of an entire watershed.

Human development activities have the potential to impact the natural state of hydrological processes within a watershed by, among things, altering the timing and intensity of peak flows, accelerating surface erosion, degrading the condition of riparian zones, and/or triggering mass wasting events. Impacts on hydrologic processes can influence both water quality and water quantity, and will dictate the state of aquatic habitats for fish and other biota using the watershed. Knowledge as to the state of indicators of watershed processes can inform decision-makers and serve as proxy data for assessing overall watershed condition as land development continues over time. Developing quantitative indicators with associated benchmarks of concern that can be used for evaluating the status of key hydrological processes in British Columbia's (B.C.'s) coastal and interior watersheds has been a focus of past provincial Watershed Assessment Procedure (WAP) guideline documents (B.C. Ministry Of Forests 1995a, 1995b, 1999) and this work provides the foundation for continued development of a broader set of indicators that can be used to evaluate watershed status.

The aquatic ecosystem value assessment protocol described in this document is based on a scientific understanding of watershed processes. It is intended to provide the initial foundation for a consistent approach to province-wide watershed assessments employing standardized GIS-based methodologies and consistent data sources. The subset of pressure and vulnerability indicators (so called Tier 1 indicators) described in this document represent the initial core set of what is anticipated to become a larger suite of additional geographic information systems based pressure indicators and indicators of landscape vulnerability to these pressures, and field-based watershed condition/state indicators (so called Tier 2 indicators) that together will allow increasingly better resolution of watershed status across a range of spatial scales. Further development of watershed assessment indicators beyond the core set presented in this document is a focus of the province's ongoing regional cumulative effects pilot projects.

1.1 Cumulative Effects Framework and Aquatic Ecosystems

In British Columbia's Cumulative Effects Framework (CEF), cumulative effects are defined as "changes to environmental, social, and economic values caused by the combined effect of past, present, and potential future activities and natural processes". The process for a cumulative effects assessment is predicated on a value assessment based on best-available scientific knowledge, information, and understanding. This science-based assessment relies on benchmarks to support the interpretation of the condition of the value. The desired outcome from this assessment is the long-term resilience or proper functioning of the value.

The value assessment supports the CEF's assessment of objectives set by government for the value, or for components of the value. Objectives are defined as the desired condition of a value (or a component or indicator associated with a value) as defined in legislation, policy and/or agreements with First Nations. Objectives can be broad, aspirational statements (approved or non-approved) or specific and measureable (approved).

Objectives for aquatic ecosystems were derived from various provincial legislation and regulations that provide both broad and specific direction in the form of objectives about sustaining these systems. Some of these pieces of legislation include:

- *Water Sustainability Act* (WSA) – Objectives for water quality, water quantity and aquatic ecosystems
- *Forest and Range Practices Act* (FRPA) – Fisheries sensitive watershed designations, riparian retention objectives, water quality objectives
- *Oil and Gas Activities Act* (OGAA) – Fisheries sensitive watershed designations; riparian retention objectives, water quality objectives
- *Land Act* – Important watershed designations and land use plan direction and objectives specific to components of aquatic ecosystems

Objectives for aquatic ecosystems include both broad objectives that are over-arching descriptions of desired conditions which often lack clear definitions and metrics, as well as specific objectives that have metrics directly associated with them.

Based on a review of existing direction for the management of watersheds and aquatic ecosystems, existing broad objectives can be categorized into three themes that guide the assessment procedure:

1. Sustain water quality,
2. Sustain water quantity, and
3. Sustain hydrological and aquatic ecosystem functions and processes.

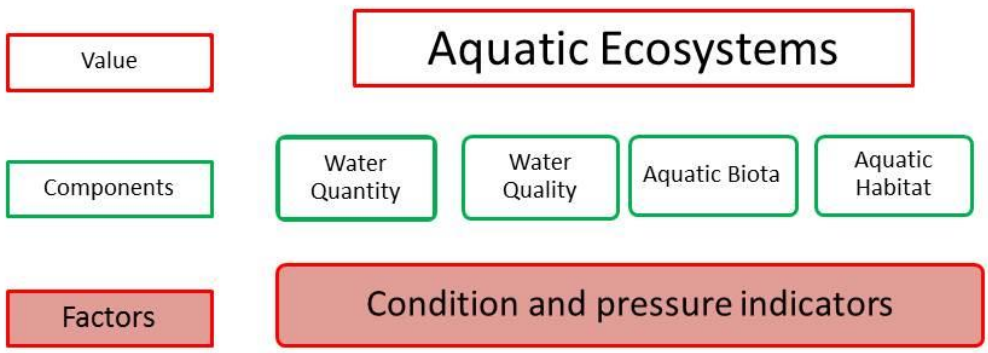
2.0 Protocol Overview

2.1 Background and Conceptual Model

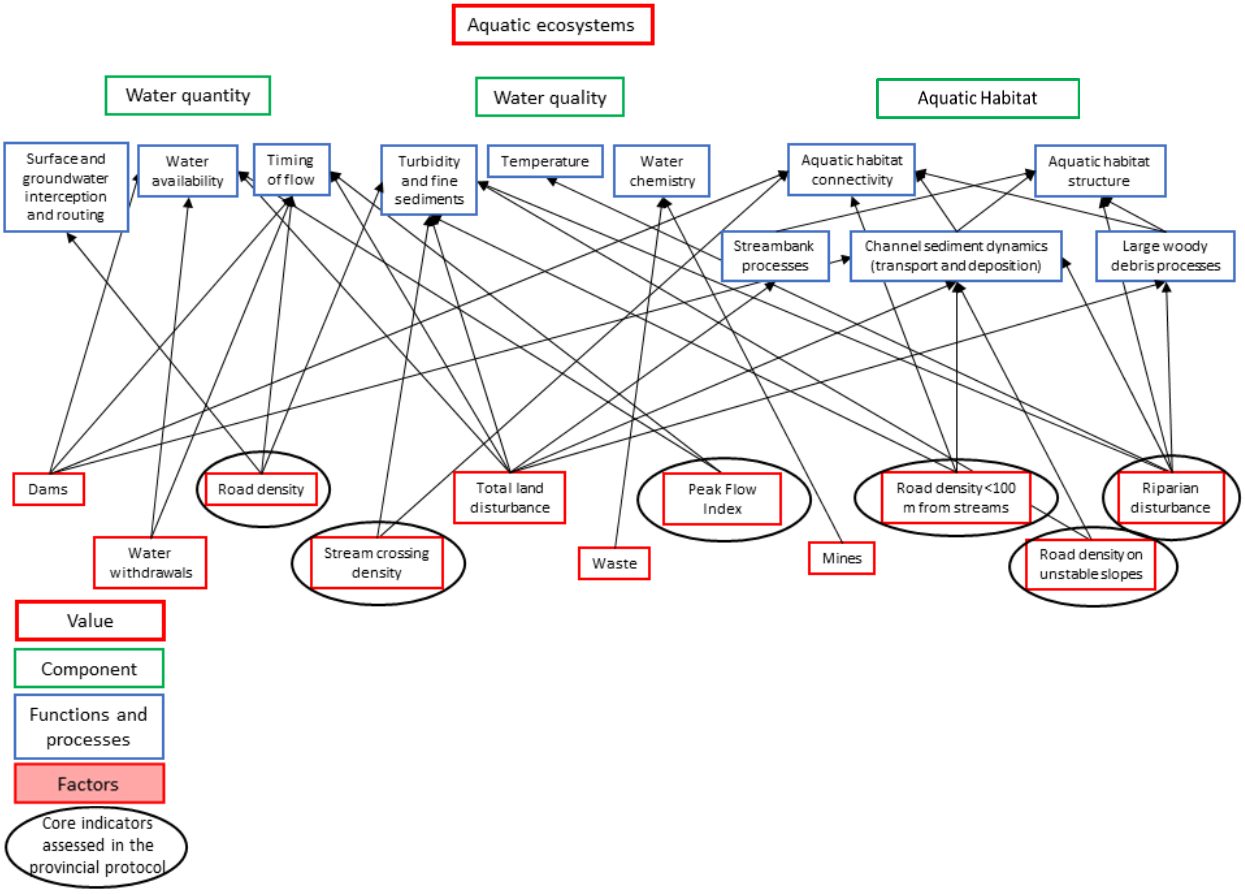
The Aquatic Ecosystems assessment protocol currently describes the derivation of a core set of watershed indicators that can be calculated consistently across the province using GIS data layers readily available from GeoBC or other ministry providers. The Aquatic

Ecosystems protocol is comprised of an initial set of indicators intended to capture different aspects of watershed functioning and are designed to inform a range of watershed management decisions relating to mitigating the impacts of localized development pressures. The identified set of core indicators were considered key ones that could reflect a range of sediment production and transport processes, hydrologic processes, the composition, structure, and dynamics of upslope vegetation cover, and riparian conditions that could be affected by land management activities within a watershed. The base conceptual model for the province's aquatic ecosystem value links the selected core watershed indicators described in this protocol to identified aquatic ecosystem components, functions, processes, and factors within a nested hierarchy (Figure 1).

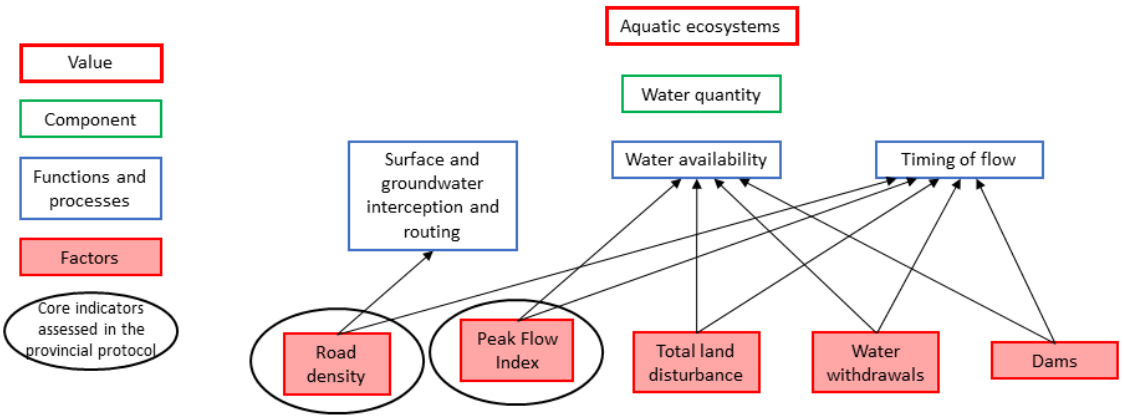
a)



b)


Aquatic ecosystems
Water quantity
Water quality
Aquatic Habitat
Surface and groundwater interception and routing
Water availability
Timing of flow
Turbidity and fine sediments
Temperature
Water chemistry
Aquatic habitat connectivity
Aquatic habitat structure
Streambank processes
Channel sediment dynamics (transport and deposition)
Large woody debris processes
Dams
Road density
Total land disturbance
Peak Flow Index
Road density <100 m from streams
Riparian disturbance
Water withdrawals
Stream crossing density
Waste
Mines
Road density on unstable slopes
Value
Component
Functions and processes
Factors
Core indicators assessed in the provincial protocol

c)


Value
Component
Functions and processes
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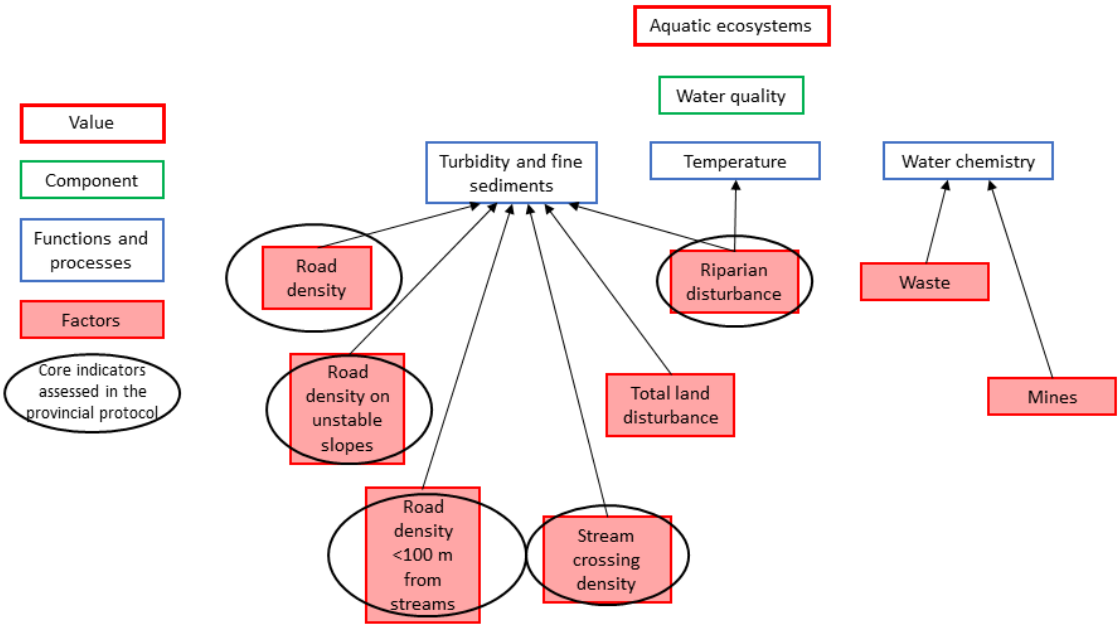
Peak Flow Index
Total land disturbance
Water withdrawals
Dams

d)



e)

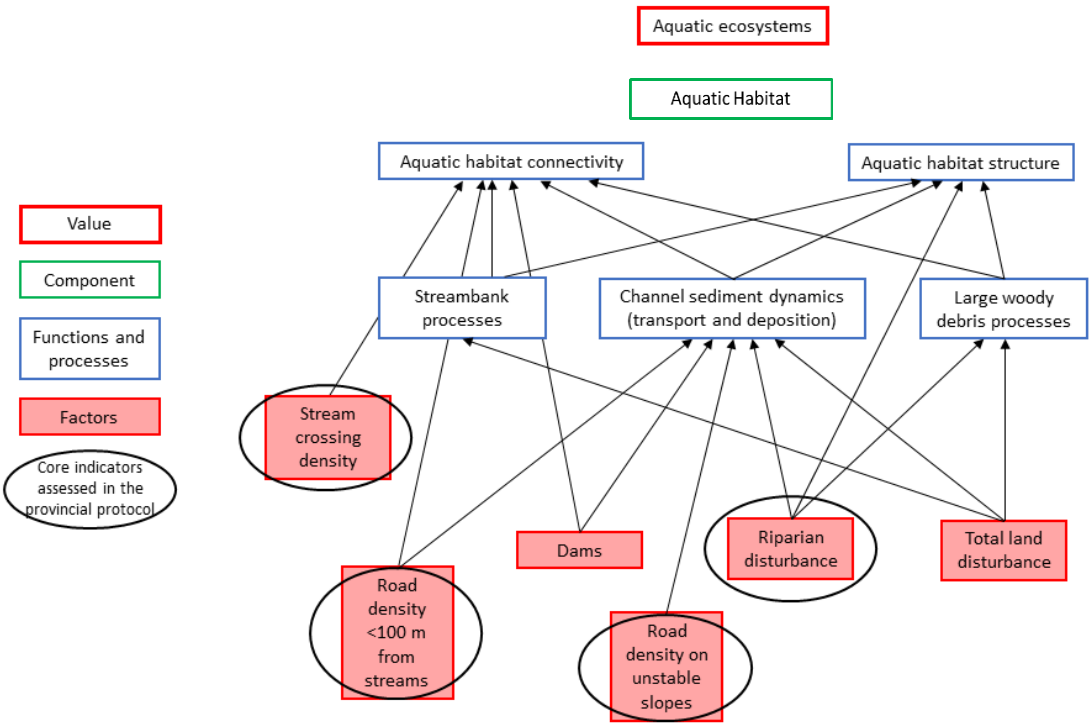


Figure 1. Conceptual model used to describe Aquatic Ecosystems. A generalised (a) and detailed (b) model was used to facilitate assessment of broad objectives for the components Water Quantity (c), Water Quality (d) and Stream-Riparian Systems (e). Indicators with benchmarks used in the provincial protocol are circled in black. Note: the component "Aquatic Biota" from the generalised conceptual model has not yet been developed.

2.2 Management Context

Identified indicators for the Aquatic Ecosystems assessment procedure will support tracking of the status of B.C.'s aquatic ecosystems and can help inform agency decisions related to:

- Government Actions Regulation, section 14
- Fisheries Sensitive Watersheds
- Forest and Range Practices Act
- Fish Protection Act
- Navigable Waters Protection Act

3.0 Aquatic Ecosystems Indicators

Each of the intended indicators is described within this document using the following structure:

- Scientific Context - An overview of the scientific basis for the indicator
- Indicator – A general description of the indicator and an outline of methods for its generation with examples and data sources
- Components Supported by Indicator – Key linkages within the province's aquatic ecosystem value conceptual model supported by the indicators;
- Data Sources – The core geographic information system layers that inform derivation and quantification of the indicator, and any particular data assumptions of note in regards to indicator derivation
- Reporting Strata – The intended default spatial scale/organization for provincial-scale reporting on the indicator
- Benchmarks[1] – Low and high reference points based on best available scientific information that will be used to identify the differential state of aquatic ecosystem and habitat degradation in relation to indicator values, and
- Validation – Approaches that could be used (e.g. analyses, models, field-based projects) to improve indicator derivation or better define associated risk flags/thresholds

Details of geographic information based derivation methods (data inputs, data outputs) for each assessment indicator are presented in Appendices I – IV.

3.1 Road density (km/km^2)

<u>Scientific Context</u>

Increasing road density increases exposed surface materials to erosion while peak flows may be magnified as road density increases because roads act as surface drainage

[1] A subset of indicators calculated did not have defined benchmarks associated with them due to uncertainty in available research, absence in research, or uncertainty in subject matter expert opinion. These indicators are considered and presented as supporting context for the core indicators with defined benchmarks.

networks that increase runoff. During heavy precipitation or snow melting events, roads increase flow concentrations into streams. For example, ditches intercept sub-surface and surface flows, and roads reduce infiltration and transfer flows to the ditches, which then are rapidly transported to nearby stream channels. Road density can also influence low flow and water temperature by increasing surface runoff and modifying subsurface flows. Roads may also increase coarse and fine sediment delivery to streams depending on surficial geology and terrain stability.

Indicator

- Total length of roads divided by the total watershed area (km/km^2)

Components Supported by Indicator

- Water Quantity; Water Quality

Data Sources

- B.C. Consolidated Roads layer: representing a composite from DRA, FTEN, TRIM, OGC, and RESULTS
    - ***Data Assumptions***: Includes in-block roads

Reporting strata

- B.C. Freshwater Atlas Assessment Units

Benchmarks

- < 0.6 km/km^2 (low)
- 0.6 – 1.2 km/km^2 (moderate)
- > 1.2 km/km^2 (high)

Validation

- To be determined

Map Classification

- Up to 1.2 km/km^2 increase scale in increments by 0.2 km/km^2
- Above 1.2 km/km^2, increase scale by each whole number to >5 km/km^2

3.2 Road density ≤ 100 m from a stream (km/km^2)

Scientific Context

High road density in close proximity to streams may contribute significant amounts of sediment to streams, affecting water quality, stream bed morphology and biota. Erosion and transport processes depend on precipitation, soil texture, road construction and maintenance practices.

Indicator

- Total length of roads within 100m of a stream, divided by the total watershed area (km/km^2)

Components Supported by Indicator

- Water Quality; Stream & Riparian Systems

Data Sources

- B.C. Consolidated Roads layer: representing a composite from DRA, FTEN, TRIM, OGC, and RESULTS; FWA stream network and double line rivers
    - ***Data Assumptions*:** use of a 100m riparian buffer (i) captures possible discrepancies in resolution of spatial data, (ii) is supported by literature on spatial extent of riparian buffer functions. All FWA streams are used for analysis, including intermittent and indefinite streams (for now). Consistency and confidence in these classifications may vary across the province, thus cannot be reliably separated at this point.

Reporting strata

- B.C. FWA Assessment Units

Benchmarks

- < 0.08 km/km^2 (low)
- 0.08 – 0.16 km/km^2 (moderate)
- > 0.16 km/km^2 (high)

Validation

- To be determined

Map Classification

- Up to 0.16 km/km^2 increase scale in increments by 0.02 km/km^2
- Above 0.16 km/km^2, increase scale by 0.1 km/km^2 starting at 0.2 km/km^2 to >0.5 km/km^2

3.3 Road density on unstable slopes (km/km^2)

Scientific Context

Roads on unstable terrain increase the chance of mass wasting by undermining or loading slopes, by saturating soils and by reducing soil root networks. Roads can alter surface drainage patterns and divert subsurface flow to the surface increasing the chance of soil saturation and gulley erosion. Clearings associated with roads reduce the root network that provides structural support to soil; they increase the chance of soil saturation by reducing rainfall interception and increasing snowmelt rates.

Mapping of terrain stability is, however, currently available only at local scales for a limited number of watersheds. However, several methodologies suggest that unstable terrain can be defined (as a default) as slopes > 60%. This criterion has traditionally been used in B.C., although with recognition that the potential impacts in regards to slope will likely be different on the coast versus the interior. Until provincial scale terrain stability maps become available for broad use, road densities on slopes >60% can represent a surrogate threshold in relation to landslide risk on unstable soils.

Fans, gullies, and gentle over steep terrain are other important types of unstable terrain, but are not considered at the general scale of the watershed assessment protocol.

Indicator

- Total length of roads found on steep slopes (> 60%), divided by the total watershed area (km/km^2)

Components Supported by Indicator

- Water Quality; Stream & Riparian Systems

Data Sources

- B.C. Consolidated Roads layer: representing a composite from DRA, FTEN, TRIM, OGC, and RESULTS; Digital Elevation Model (DEM)
    - ***Data Assumptions*:** DEM used to define areas with slope > 60%; Future iterations may consider refining by incorporating a coupled stream restriction

Reporting Strata

- B.C. FWA Assessment Units

Benchmarks

- < 0.06 km/km^2 (low)
- 0.06 – 0.12 km/km^2 (moderate)
- > 0.12 km/km^2 (high)

Validation

- To be determined

Map Classification

- Up to 0.12 km/km^2 increase scale in increments by 0.02 km/km^2
- Above 0.12 km/km^2, increase scale by 0.1 km/km^2 starting at 0.2 km/km^2 to >0.5 km/km^2

3.4 Stream crossing density (#/km^2)

Scientific Context

Stream crossings (i.e. roads, utility lines, other linear developments) represent a potential focal point for local sediment and intercepted flow delivery, as well as representing a potential physical impediment to connectivity of fish populations (i.e. aquatic ecosystem connectivity including fish populations). A higher density of stream crossings in a watershed is generally indicative of greater risks of fine sediment inputs, although these risks will be dependent on the construction type (i.e. open box versus closed box culverts), as well as the condition of stream crossing structures.

Indicator

- Total length of stream crossings divided by the total watershed area (#/km^2)

Components Supported by Indicator

- Water Quality; Stream & Riparian Systems

Data Sources

- B.C. Consolidated Roads layer: representing a composite from DRA, FTEN, TRIM, OGC, and RESULTS; FWA stream network, Ecological Aquatic Units of B.C. (EAUBC) Ecoregions used for delineation of coastal versus interior areas
    - ***Data Assumptions:*** Coastal considered to be EAUBC FRESHWATER_ECOREGION = 'North Pacific Coastal'. All other areas in B.C. are considered to be Interior.

Benchmarks

Interior watersheds

- < 0.16/km^2 – (low)
- 0.16 - 0.32/km^2 – (moderate)
- > 0.32/km^2 – (high)

Coastal watersheds

- < 0.40/km^2 – (low)
- 0.40 - 0.80/km^2 – (moderate)
- > 0.80/km^2 – (high)

Reporting Strata

- B.C. FWA Assessment Units

Validation

- To be determined

Map Classification

Interior

- Up to 0.32/km^2 increase scale in increments by 0.04/km^2
- Above 0.32/km^2, increase scale by 0.1 km/km^2 starting at 0.4/km^2 to >0.5/km^2

Coastal

- Up to 0.8/km^2 increase scale in increments by 0.2/km^2
- Above 0.8/km^2, increase scale by 0.1 km/km^2 starting at 0.9/km^2 to >1.0/km^2

3.5 Riparian disturbance (%)

Scientific Context

Riparian areas are intimately connected with stream ecosystems, providing a wide variety of ecological services and functions. Riparian areas can affect channel morphology and aquatic habitats through the provision of large wood. Riparian areas also influence water quality, provide shade, and are sources of food and nutrients to aquatic ecosystems. The maintenance of these functions and services depends upon intact riparian areas. As the portion of streams that are disturbed (by various factors) increases, so does the risk of surface erosion and mass-transport of sediment during heavy precipitation events. When riparian vegetation is lost, stream channels are weakened due to the lack of root structures, and intensified surface erosion and mass-wasting are common outcomes.

Indicator

- Total length of stream riparian disturbed divided by the total length of streams (%)

Components Supported by Indicator

- Water Quality; Stream & Riparian Systems

Data Sources

- FWA stream network; Fire perimeters - current and historic (Wildfire Management Branch); Custom 'Development' data from various sources including Tantalis, OGC, and BTM (Baseline Thematic Mapping); FAIB Consolidated Cut blocks; VRI (for insect disturbance)
    - ***Data Assumptions:*** Riparian related disturbance is defined as that occurring within 30m of a stream. Total disturbance includes human disturbance since 1995 (rail, transmission, major rights of way, harvesting, mining, oil & gas, seismic, agriculture, and urban activity), historical logging (pre-1995), natural fire and insect disturbance.

Reporting Strata

- B.C. FWA Assessment Units

Benchmarks

- < 0.10 km/km (< 10%) (low)
- 0.10 – 0.20 km/km (10 -20%) (moderate)
- > 0.20 km/km (> 20%) (high)

> **Note:** This is a preliminary risk categorization. Further review of riparian thresholds based on literature and expert opinion is required.

Validation

- To be determined

Map Classification

- Up to 0.2 km/km increase scale in increments by 0.05 km/km
- Above 0.2 km/km, increase scale by 0.1 km/km^2 starting at 0.3 km/km to >0.5 km/km

3.6 Peak Flow Index (% of watershed area)

Scientific Context

Peak Flow Index for the purpose of this version of the protocol is the assessment unit-area normalized score calculated from Equivalent Clear cut Area (ECA). Equivalent clear cut area (ECA) is a modeled metric that attempts to relate the influence of forest cover disturbance (e.g., clear cuts) to changes in stream flow. ECA includes the area of land that has been harvested, cleared or burned, with consideration given to the silvicultural system, regeneration growth, and location within the watershed. It expresses the relative hydrologic impacts of disturbed forests compared to mature intact forest canopy, and

reflects complex changes in flows resulting from changes in canopy precipitation interception, evapotranspiration, snow melt dynamics and runoff.

Indicator

- Equivalent Clear cut Area (ECA) within a watershed divided by the total watershed area (%)

Components Supported by Indicator

- Water Quantity

Data Sources

- VRI updated with additional harvesting from FAIB Consolidated Cut blocks and RESULTS (including height info if available); Private Land (FOWN); Human Development layers (various)
    - ***Data Assumptions:*** ECA is based on forest stand height and additional disturbance assumptions (i.e., human development areas considered as 100% ECA; private forests considered as 75% disturbed). Stand recovery is based on height as per 1999 Watershed Assessment Guidebook table 8-1 with full recovery at 12 m. Where height is not available (e.g., for recent harvesting) age is used as a surrogate: 1-10 years = 100%, 11-20 = 75%, and 21-40 = 25% ECA. Where >50% of watershed has VRI Unreported, ECA is recorded as 9999 (insufficient data).

Reporting Strata

- B.C. FWA Assessment Units

Benchmarks

- < 25% (low)
- 25-45% (moderate)
- > 45% (high)

> **Note:** This is a preliminary risk categorization based on the variable parameter ECA. This indicator assessment should be supported with localized watershed knowledge.

Validation

- To be determined

Map Classification

- Increase scale in increments of 5% to >50%.

3.7 Total land disturbance (human disturbance/land use/land cover and natural disturbance combined) (%)

Scientific Context

Total disturbance represents the sum of all potential cumulative impacts on key watershed processes such as altered hydrologic flows, sediment generation, contaminants, etc. that can affect aquatic habitats.

Indicator
Area in watershed disturbed (human or natural processes) divided by the total watershed area (%)

Components Supported by Indicator
- Water Quantity; Water Quality; Stream & Riparian Systems

Data Sources
- Custom 'Development' data from various sources, including Tantalis, OGC, and BTM (Baseline Thematic Mapping); FAIB Consolidated Cut blocks; Fire perimeters - current and historic (Wildfire Management Branch); VRI (for insect disturbance)
    - ***Data Assumptions:*** Disturbance types are reported separately, as well as grouped into disturbance categories. Human disturbance/land use/land cover is reported for 100% of the watershed assessment unit (i.e., with no overlaps.) Where there are overlapping activities, a hierarchy is applied where certain activities take precedence. Reporting elements are unique disturbance/land cover type; current human disturbance (within 20 years), historic harvesting (pre 1995), total human disturbance (current and historic), total fire, total insect, total fire and insect (avoiding duplication), net fire and insect (not covered by human disturbance), total non-disturbed (not affected by human or natural disturbance)

Reporting Strata
- B.C. FWA Assessment Units

Benchmarks
- No benchmarks have been defined yet for this indicator. Further review of potential benchmarks based on literature and expert opinion is required.

Validation
- To be determined

Map Classification
- Reported qualitatively as mapped polygons for each parameter examined

3.8 Mines (#/watershed)

Scientific Context
Mines can pose a potentially significant threat to aquatic ecosystems. Fuel and oil spills are a risk at all mine sites where equipment is used. Mine sites can in some cases produce high volumes of highly acidic, toxic tailings. Tailings pond failure poses a low probability, but high consequence risk. Toxic chemicals affect water quality and can kill fish and their invertebrate food supply. Historic placer mining has also been known to be a significant source of water quality impairment. More recent activity can still pose a threat to channel bank, fan and floodplain stability where not undertaken properly.

Indicator
- The total number of mines (of all types) occurring within a watershed (#/watershed)

Components Supported by Indicator

- Water Quality

Data Sources

- MinFile Points: WHSE_MINERAL_TENURE.MINFIL_MINERAL_FILE
    - ***Data Assumptions:*** Mine type categories included in assessment are producer, past producer, and developed prospect

Reporting Strata

- B.C. FWA Assessment Units

Benchmarks

- No benchmarks have been defined yet for this indicator. Requires further review of potential benchmarks based on literature, expert opinion.

Validation

- To be determined

Map Classification

- Reported qualitatively as mapped point sources

3.9 Permitted waste discharge (#/watershed)

Scientific Context

High levels of wastewater discharge from municipal and industrial sources could impact the water quality of salmonid habitats either through excessive nutrient enrichment or chemical contamination. Some industrial waste products can directly injure or kill aquatic life even at low concentration while excessive nutrient levels can result in depletion of the dissolved oxygen in streams and lakes, starving fish and other aquatic life.

Indicator

- The total number of wastewater discharge sites (of all types of discharge) occurring within a watershed (#/watershed)

Components Supported by Indicator

- Water Quality

Data Sources

- MOE Authorizations Database
    - ***Data Assumptions:*** Only active wastewater discharge sites are included in the assessment

Reporting Strata

- B.C. FWA Assessment Units

Benchmarks

- No benchmarks have been defined yet for this indicator. Further review of potential benchmarks based on literature and expert opinion is required.

Validation

- To be determined

Map Classification

- Reported qualitatively as mapped point sources

3.10 Water withdrawals (#/watershed)

Scientific Context

Heavy use of both surface and hydraulically connected subsurface water for human purposes can affect salmonid habitats at critical times of year by reducing instream flows to levels that could constrain physical access to spawning and rearing habitats or potentially dewater salmon spawning nests (i.e. redds). Reductions in both surface water and ground water supplies can also increase water temperatures with resultant impacts on all salmonid life stages.

Indicator

- The total number of provincial water license points of diversion occurring within a watershed (#/watershed)

Components Supported by Indicator

- Water Quantity

Data Sources

- B.C. Points of Diversion: WHSE_WATER_MANAGEMENT.WLS_POD_LICENCE_SP
    - ***Data Assumptions:*** Water licenses represent only the amount of water allocated through provincial permitting processes, not actual use (i.e. monitoring of water use and compliance with water license conditions does not generally occur). Only water licenses identified as Active or Applications are to be used in the assessment. Additionally, information describing water licenses (long-term use) does not account for water allocated through temporary water permits (short-term use) which is a regulatory tool used in the oil and gas sector and is currently difficult to track.

Reporting Strata

- B.C. FWA Assessment Units

Benchmarks

- No benchmarks have been defined yet for this indicator. Further review of potential benchmarks based on literature and expert opinion is required.

Validation

- To be determined

Map Classification

- Reported qualitatively as mapped point sources

3.11 Dams (#/watershed)

Scientific Context

Dams can affect flows and overall stream network connectivity, while dams located along fish migration routes could potentially block passage (or at least impede or delay passage (dependent on dam design and seasonal water levels) to spawning streams and/or lakes with consequent impacts to fish survival and productivity.

Indicator

The total number of dams occurring within a watershed (#/watershed)

Components Supported by Indicator

- Water Quantity; Stream & Riparian Systems

Data Sources

- Dam Lines: WHSE_WATER_MANAGEMENT.WRIS_DAMS_PUBLIC_SVW
    - ***Data Assumptions:*** all dam types are included in the assessment

Reporting Strata

- B.C. FWA Assessment Units

Flags

- No benchmarks have been defined yet for this indicator. Further review of potential benchmarks based on literature and expert opinion is required.

Validation

- To be determined

Map Classification

- Reported qualitatively as mapped point sources

4.0 Assessment Method

4.1 Value Roll Up

The watershed unit value roll-up follows a similar procedure to that of the Watershed Assessment Procedure Guidebook (BC MOF 1999). Each raw, calculated indicator value is translated into a normalized score between 0 and 1 (Table 1). All values within the lowest classification receive a normalized score of 0 while the remainder of the calculated values are divided into equal interval classifications (from 0.1-1.0) with an identified upper value serving as the highest classification 1.0. Indicator values are assigned a score based on its corresponding interval. The classification represents the normalized score for the assessment unit indicator (Table 1). Each assessment watershed will therefore receive a single normalized score for each of the six benchmarked indicators assessed.

Once indicator scores are calculated, the average of the six scores for each assessment watershed is calculated resulting in a single, comprehensive watershed score for each unit assessed. For coastal assessment watersheds, those that receive a value <0.3 are scored low, those that receive a value >0.7 are scored high while those in between are scored moderate.

For interior assessment watersheds, those that receive a value <0.4 are scored low, those that receive a value >0.8 are scored high while those in between are scored moderate.

Map Classification

- Increase scale in increments of 0.1 to a maximum value of 1.0.

4.2 Component Roll-Up

The same procedure as above (Value Roll Up) is used to determine the component roll up score for water quality, water quantity, and stream riparian systems however, the average assessment watershed score is calculated from only the relevant benchmarked indicators in the conceptual model for the respective component (refer to Figure 1).

Map Classification

- Increase scale in increments of 0.1 to a maximum value of 1.0.

Table 1. Indicator value score classification table. Values within a cell represent a range bounded by it and the number in the cell immediately to its right.

Indicators	Score										
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Road Density	0	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	>3.0
Road Density near Streams	0	0.04	0.08	0.12	0.16	0.20	0.25	0.30	0.35	0.40	>0.45
Road Density on Unstable Slopes	0	0.03	0.06	0.09	0.12	0.15	0.20	0.25	0.30	0.35	>0.40
Stream Crossing Density (Coastal)	0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	>2.0
Stream Crossing Density (Interior)	0	0.08	0.16	0.24	0.32	0.40	0.50	0.60	0.70	0.80	>0.90
Riparian Disturbance	0	0.03	0.06	0.09	0.12	0.15	0.18	0.21	0.24	0.27	>0.30
Peak Flow Index	0	0.06	0.12	0.18	0.24	0.30	0.36	0.42	0.48	0.54	>0.60

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Appendix

Indicator definitions, data inputs, output field description, ownership, and development pseudo-base thematic mapping for Aquatic Ecosystems assessment indicators (these data will be subject to be periodic updating).

See accompanying spreadsheet:
"Aquatic_Protocol_Appendix_GIS_Indicators_Inputs_DataDict_20160818.xlsx".