

Tsable River Watershed Cumulative Effects Assessment - 2023

An application of BC's Cumulative
Effects Framework at a local
watershed scale



December 2023

**by Dave Weaver
Retired Professional Forester
Beaufort Watershed Stewards**

Statement of intent and disclaimer: The author of this report is a retired non-practicing professional forester and received no remuneration for preparing this report. The author is not a professional hydrologist and was not a practicing hydrologist during his paid working career. All the findings and conclusions presented in this report are empirically based on the data and observations, relative to the papers, publications and protocols cited in this report and are not a result of any interpretation of the data as a practicing forest hydrologist.

Credits: All the photos and images in this report were generated by the author and/or by Beaufort Watershed Stewards' volunteers.

Acknowledgement: The Beaufort Watershed Stewards would like to thank the Comox Valley Regional District for providing funding assistance to produce this report.

Published by: Beaufort Watershed Stewards, December 2023

Beaufort Watershed Stewards mission statement:

Work to promote the health and resilience of local watersheds in the Beaufort Range and to ensure the quality and quantity of fresh water for the future.

Obtain from: www.beaufortwater.org

Contact: info@beaufortwater.org



Land Acknowledgement: We respectfully acknowledge that the watersheds we depend on are on the unceded traditional territory of the K'ómoks, Pentlatch and Qualicum First Nations, the traditional keepers of this land.

Table of Contents

	Page
1.0 Executive Summary	4
2.0 Introduction	5
3.0 Objectives of the Report	6
4.0 BC's Watershed Cumulative Effects Protocol Overview	7
4.1 Cumulative Effects Protocol Assessment Model	8
5.0 Core Indicators Assessed	8
5.1 Supplemental Indicators not Assessed	9
6.0 Data Collection Methodology per Core Indicators	10
6.1 Oblique Google Earth Map of the Tsable River Watershed	10
6.2 GIS Data Collection Process and Reference Maps Produced	10
6.3 Detailed Data Collection Methods per Core Indicator	12
7.0 Results per Core Indicator	18
7.1 Data Summaries	18
7.2 Visual Comparisons of Indicator Values	18
7.3 Total Area Harvested	19
8.0 Conclusion and Discussion	21
8.1 Overall Tsable River Watershed Health Rating	21
8.2 Comparison of Watershed's Indicators Versus Water Quality	22
8.3 Suitability of the Protocol as a Cumulative Effects Tool to Assess Watershed Health	23
9.0 Recommendations	24
10.0 References	25
11.0 Appendices	26
11.1 Original Conceptual Model of the Protocol	26
11.2 Equivalent Clearcut Area (ECA) Explanation	27
11.3 Data Sheets for Core Indicator Metrics	28
11.4 GIS Maps per Core Indicator	35

Figure 1a: *The lower Tsable River (In summer, looking west)*



1.0 Executive Summary

Background:

This Tsable River Watershed Cumulative Effects (CE) Assessment is the second in a planned series of watershed health assessments undertaken by the Beaufort Watershed Stewards (BWS). The first BWS watershed assessment in 2021 involved four local watersheds ⁽⁶⁾ and overall concluded one of the four watersheds (Cowie Creek) was at high risk of elevated peak flows. Subsequently, the BWS decided to continue to assess watershed health in 2023, but with a new BC Government protocol: *Interim Assessment Protocol for Aquatic Ecosystems in British Columbia – Dec 2020*⁽³⁾ (further referred to as the “Protocol”). This is a more comprehensive procedure than was used in 2021 and includes complete thresholds for six Core Indicators of watershed health. The BWS was further motivated to continue health assessments considering the findings and recommendations of the Forest Practices Boards published special report in 2022 titled: *Forest Practices and Water - Opportunities for Action* ⁽⁸⁾. The Board identified several significant issues from this body of work, notably: “*There are no legal requirements to assess or consider cumulative effects in most watersheds in BC...and...Current forest practices contribute sediment into streams.*”

Methods:

The procedures and thresholds listed in the Protocol for the six Core Indicators metrics (listed below in the table), were followed in this Report, and were determined by using mostly Geographic Information Systems (GIS) technology, augmented with vegetation interpretation of 2022 satellite images, and finally verified with 20% ground truthing.

Results:

The following is a Summary Table, listing the six Core Indicators’ final values for this Report (High values are shown in **red**).

Six Core Indicators	Road Density	Road Density < 100 m Stream	Road Density Unstable Slopes	Stream Crossing Density	Riparian Disturbance	Peak Flow
Core Indicator Values	3.7 km/km ² HIGH	0.9 km/km ² HIGH	0.10 km/km ² LOW	1.54 #/km ² HIGH	0.05 km/km LOW	0.61 HIGH

Using the hierarchy process of the CE Protocol and the six Core indicator values identified above, the overall Tsable River watershed rating is **HIGH**. The implications and recommendations of this rating, as specified in the Protocol are the following: “*The watershed’s cumulative effects from industrial development have a **high** potential to negatively impact the natural state of hydrological processes*” and “*An adjustment to developmental activities should be considered.*”

Recommendations:

1. Encourage other community watershed groups to use this Protocol: All community watershed groups concerned about their local watersheds’ health status, are strongly encouraged to embrace this Protocol.
2. BWS will plan and perform Cumulative Effects Assessments on other watersheds using this Protocol: Due to the significant findings of this Report, it is recommended that BWS initiate additional assessments on neighboring watersheds, prioritizing those with high sediment levels and those that are > 2000 ha in overall watershed area.
3. Advocate for reform of the BC Private Managed Forest Land Act (PMFLA) - to lower the rates of harvest and advocate for full implementation of the 2014 BC Watershed Sustainability Act (WSA) watershed planning regulations: This Report clearly shows that hydrological function in the Tsable River watershed has an elevated risk of being negatively impacted by industrial development. The Tsable is managed under the PMFLA which has no restrictions on the rate of harvest and BWS is advocating restrictions be reinstated. Additionally, the WSA has the regulatory authority to mandate watershed planning and BWS is advocating government complete this empowerment by passing these regulations.

2.0 Introduction

The Tsable River Watershed Cumulative Effects (CE) Assessment project is the second in a planned series of watershed health assessment projects undertaken by the Beaufort Watershed Stewards (BWS). The first BWS watershed assessment project in 2021 involved four local watersheds ⁽⁶⁾, basically utilizing an older protocol - the 2001 BC Coastal Watershed Assessment Procedure Guidebook ⁽⁴⁾. This guidebook included clear procedures but lacked published thresholds for the health indicators. Therefore, various thresholds were borrowed from other similar published watershed assessments recently completed in BC and Alberta⁽⁶⁾.

The overall findings of the 2021 BWS report concluded that one of the four watersheds, Cowie Creek, was rated at a high risk of elevated peak flows and correlated to the highest BWS data trends for elevated sediment (turbidity levels), of the four watersheds assessed. Subsequently, the BWS decided to continue to assess watershed health of another watershed – specifically the Tsable River in 2023 - which also showed elevated turbidity readings from BWS sample data.

Fortunately, in 2022, the BWS was made aware of a new watershed assessment protocol recently published by the BC Government, titled:

Interim Assessment Protocol for Aquatic Ecosystems in British Columbia – Dec 2020⁽³⁾ (further referred to in this report as the “Protocol”).

This is a very comprehensive, made in BC Protocol, that includes complete thresholds for six core watershed health indicators. It was also designed to generate a conclusive rating for a watershed’s overall risk of negative impacts to hydrological processes, due to the cumulative effects of negative industrial development activities – which includes logging. The Protocol was designed primarily as a coarse scale GIS based assessment tool, but also recommends that finer scaled watershed specific data can be used for targeted regional applications of the thresholds, which could produce a finer resolution assessment report.

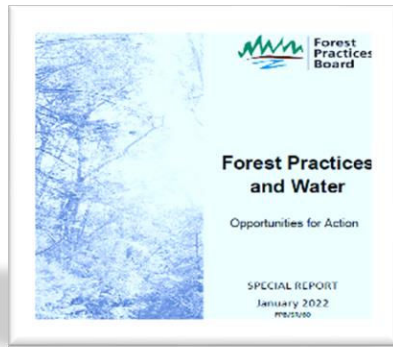
Therefore, the BWS embraced this more rigorous Protocol for this health report of the Tsable River’s aquatic and hydrological function. Also, more detailed GIS data and ground verified metrics were added in assessing the six core indicators for this report, as encouraged within the Protocol.

BWS was further motivated to continue to assess the health of other watersheds within the Beaufort Range, considering the findings and recommendations of the Forest Practices Board’s 2022 special report titled:

Forest Practices and Water - Opportunities for Action ⁽⁸⁾.

Since 2006, the Forest Practices Board (BC’s third-party internal forestry auditor) has investigated 27 complaints, published 8 special investigations, and performed 3 compliance audits that involved the interaction of forest management and water.

The Board identified 3 significant issues from this body of work:



- 1) *"There are no legal requirements to assess or consider cumulative effects of forest practices in most watersheds in BC."*
- 2) *"Current forest practices contribute sediment into streams."*
- 3) *"Historical forest practices continue to negatively affect water."*

3.0 Objectives of the Report

The prime objectives of this Tsable River Watershed CE Assessment Report (further referred to in this document as the "Report") are:

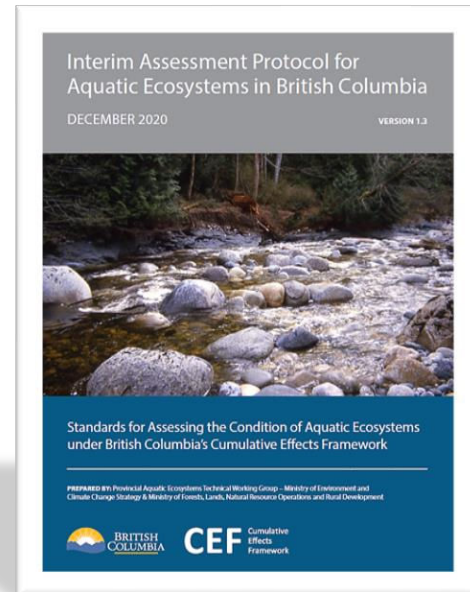
- To assess hydrological health of the Tsable River watershed and to quantify the impacts on watershed function and resilience, utilizing the most currently approved assessment methodologies contained within the 2020 CE Protocol.
- To clearly outline within this Report the methodologies and processes of the Protocol, so that other grassroots organizations can use this Report as a feasible template for assessments of their own watersheds.
- To disseminate the Report's findings to local communities and other interested parties – specifically the K'ómoks and Qualicum First Nations, local and provincial Governments, and all landowners affected and responsible for the Tsable River watershed as assessed within this Report.
- To make recommendations on how to address or further mitigate the current and future cumulative effects of industrial development within the Tsable River watershed.



Figure 1b:
*The lower
Tsable
River (In
winter,
looking
east)*

4.0 BC's Watershed Cumulative Effects Protocol Overview

Interim Assessment Protocol for Aquatic Ecosystems in British Columbia – Standards for Assessing the Condition of Aquatic Ecosystems under BC's Cumulative Effects Framework. (3)



This Protocol represents an integral shift for local community watershed groups - for there is now just one document that is publicly available, developed by an extensive technical working group and science peer reviewed.

The following excerpt from the Protocol, provides the reader with an introduction to the document:

*“Human development activities have the potential to impact the natural state of hydrological processes within a watershed by altering the timing and intensity of peak flows, accelerating surface erosion, degrading the condition of riparian zones, and/or triggering mass wasting events (Sawyer and Mayhood, 1998). Impacts on hydrologic processes can influence both water quality and 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 decisionmakers and serve as proxy data for assessing overall watershed condition as land development continues over time (Gustavson and Brown 2002; Pike et al. 2010). This Protocol 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.”* (3).

4.1 Cumulative Effects Protocol Assessment Model

The Protocol describes a set of watershed indicators that can be calculated using GIS data layers. The initial set of indicators capture different aspects of watershed functions and are designed to inform watershed development and management decisions relating to mitigating the impacts. In the case of this assessment of the Tstable River watershed, industrial development has been, and continues to be, primarily privately managed forest land harvesting. There was one small coal mine (< 1 ha) in the Tstable River watershed that was active up to the 1960s and has since been decommissioned.

The Protocol's conceptual model links selected watershed indicators to identified aquatic ecosystem components, functions, processes, and factors within a nested hierarchy. A complete graphic explanation of the conceptual model hierarchy is in Appendix 11.1, from the original Protocol document (3). For this assessment, the process has been simplified graphically to reflect the targeted regional application of the Protocol to the conditions of the Tstable River and the metrics available to be assessed by BWS.

Each of the components of the conceptual model (i.e., Water Quantity, Water Quality and Ecosystem Function), are illustrated in Figure 2 below, identifying the specific Indicators and how they relate to the corresponding Components of the Protocol.

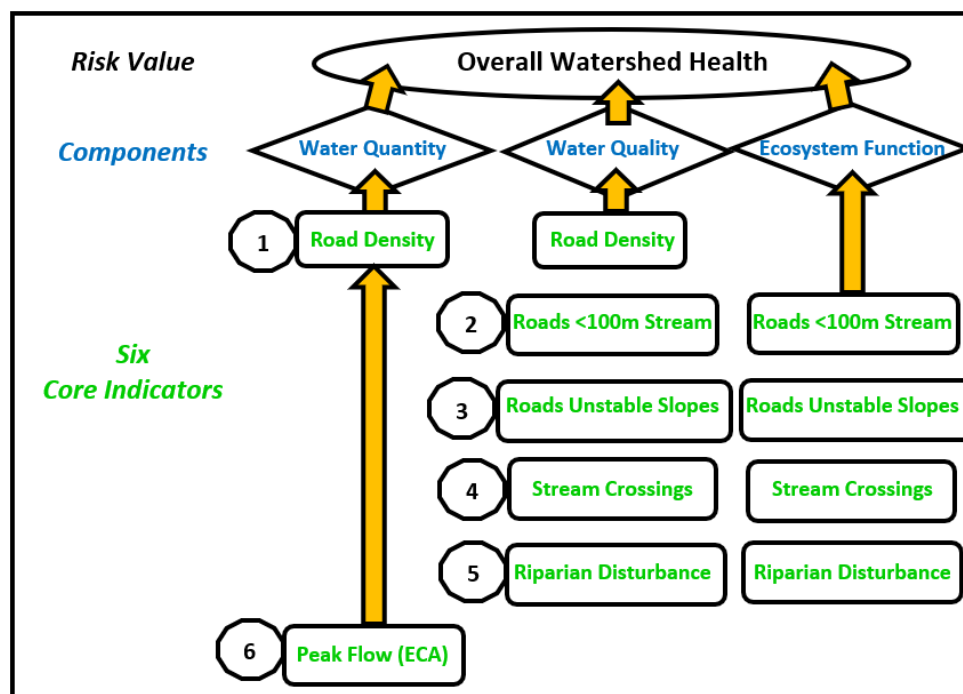


Figure 2: Simplified CE Protocol Flow Chart: Progressing upward, this figure illustrates which of the six Core Indicators determine the status of the three Watershed Components – Water Quantity, Water Quality and Ecosystem Function - and which in turn determines the Overall Watershed Health Rating at the top.

5.0 Core Indicators Assessed

The Protocol's indicators are divided into two groupings:

Six Core Indicators and **Eight Supplemental Indicators**.

Only the core indicators were assessed as these were the only indicators that have published thresholds.

Below is a list of the indicators that were assessed, and the metrics tallied. New indicators for this Report, not used in the 2021 BWS Watershed report, are in **green** font.

Core Indicators	Description	Metrics
1	Road Density	km/km ²
2	Road Density < 100 m from a stream	km/km ²
3	Road Density on potentially unstable slopes	km/km ²
4	Stream Crossing Density	#/km ²
5	Riparian Disturbance	km/km streams
6	Peak Flow – combination of three factors: a) Natural Runoff Generation Potential considers bio-geoclimatic (BEC) subzone and alpine non-forest areas. b) Surface Flow Attenuation considers drainage density ruggedness and absence of lakes and wetlands. c) Equivalent Clearcut Area (ECA) – considers the influence of forest cover disturbance (i.e., clearcuts) to changes in stream flow.	a) BEC sensitivity and % natural alpine/km² bi) Total stream length per total watershed area (km/km²), times the elevation difference and bii) Weighted average of area of lakes and wetland per lower, mid, and upper thirds of the entire watershed. c) Total ECA area (tallied by Disturbance Unit [DU] per height of trees), divided by the net area of the watershed.

Table 1: The Six Core Indicators assessed in this Report with detailed descriptions and metrics.

5.1 Supplemental Indicators Not Assessed.

The supplemental indicators were not applicable for this Report as the Protocol did not provide established benchmarks or thresholds to use in the risk ranking the health of the watershed.

List of Protocol Supplemental Indicators

- 1) Proportion of Riparian Disturbance (%) for Streams, Lakes, and Wetlands
- 2) Wetland Disturbance (%)
- 3) Total Land Disturbance (Human Disturbance/Land Use/Land Cover and Natural Disturbance combined)
- 4) Land Ownership (%)
- 5) Mines (#/Watershed).
- 6) Permitted Waste Discharge (#/Watershed).
- 7) Water Withdrawals (#/Watershed).
- 8) Dams (#/Watershed).

6.0 Data Collection Methodologies per Core Indicator

6.1 Oblique Google Earth Map of the Tsable River Watershed

Figure 3 below is an oblique Google Earth image showing the Tsable River watershed located on the east side of the Beaufort Range. The Tsable River watershed is classed as a Coastal Snow Transient Hydro-Climatology – or wet snow / rain on snow hydrology, as described by Dr Alila in his webinar presentation (2023). These are watersheds that “start at sea level and rise to over 1100 meters₍₁₎”. Their hydrology is very different to others in BC, for they rely on the input of wet snow melting from a forest canopy to recharge ground water. Alila states that “elevated removal of forest canopies can have significant impact on ground water storage and elevated peak flows₍₁₎”.

The total gross area of the watershed was accurately mapped by GIS and confirmed at **10,565 ha** or **105.65 km²**. This gross area of the watershed was truncated at the area above Highway 19, for this represented the bulk of the area impacted by industrial forest harvesting. The watershed is 100% corporate owned private forest management land.

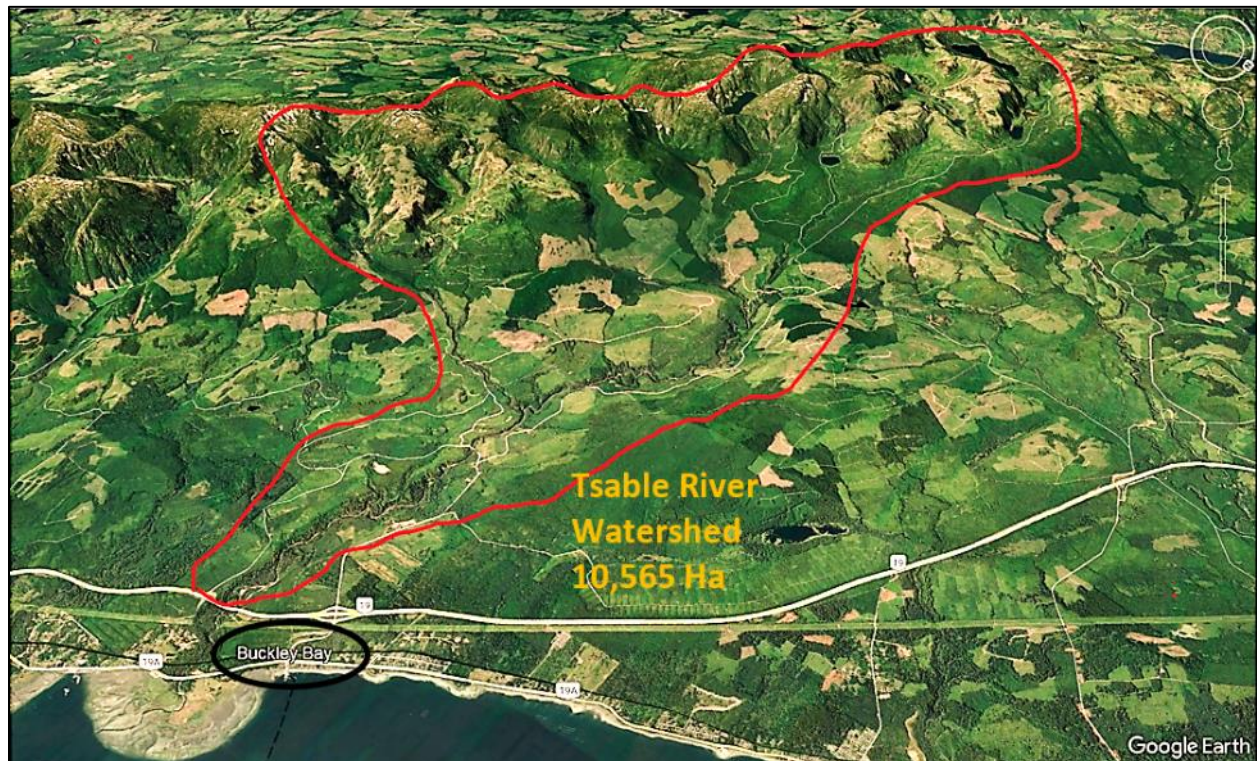


Figure 3: Oblique 2022 Google Earth image of the Tsable River Watershed. The gross area boundary above Highway 19 is in red.

6.2 GIS Data Collection Process and Reference Maps Produced.

The majority of the six Core Indicators were determined via GIS analysis, by a GIS technician hired for this project. The imagery most used for the analysis in this Report, was the July 2022 public Google Earth Pro images.

Publicly available GIS layers were then placed over these 2022 images by the GIS technician and the data in these layers were further corrected to the actual satellite images, to produce a series of maps and corresponding data tallies for the metrics of each indicator. All the data summaries and maps are contained in Appendix 11.3 and 11.4 respectfully, for reference.

The figure below is a plan view image of the Tsable River watershed, with the GIS “uncorrected” roads and waterbodies layer superimposed.

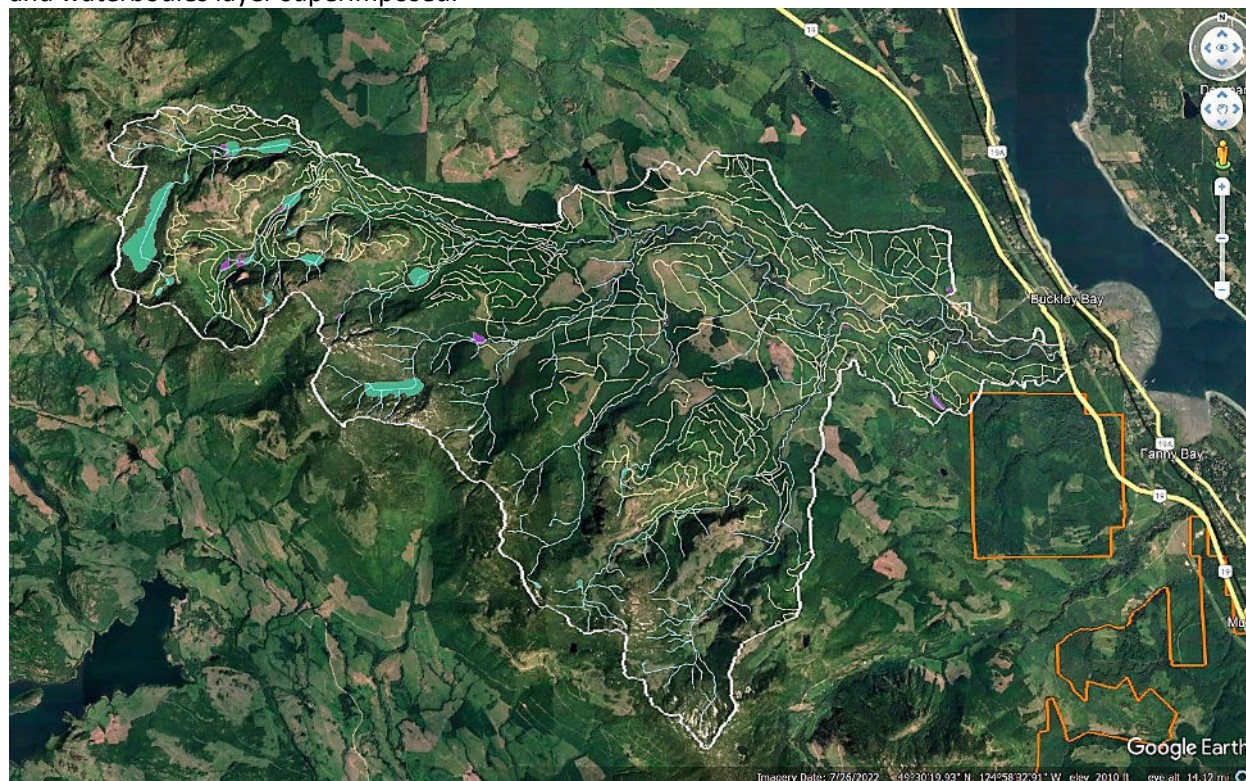


Figure 4: Google Earth image of the Table River watershed with “uncorrected” roads and streams from publicly available GIS layers. (Note, the orange lines to the southeast of the outlined Tsable River watershed, are the boundaries of public managed forest land.)

Figure 5 below shows an example of the GIS map deliverable product generated per core indicator. In this example, the map shows the outline of the Tsable River watershed, and the “corrected” Road and Stream layers superimposed on top.

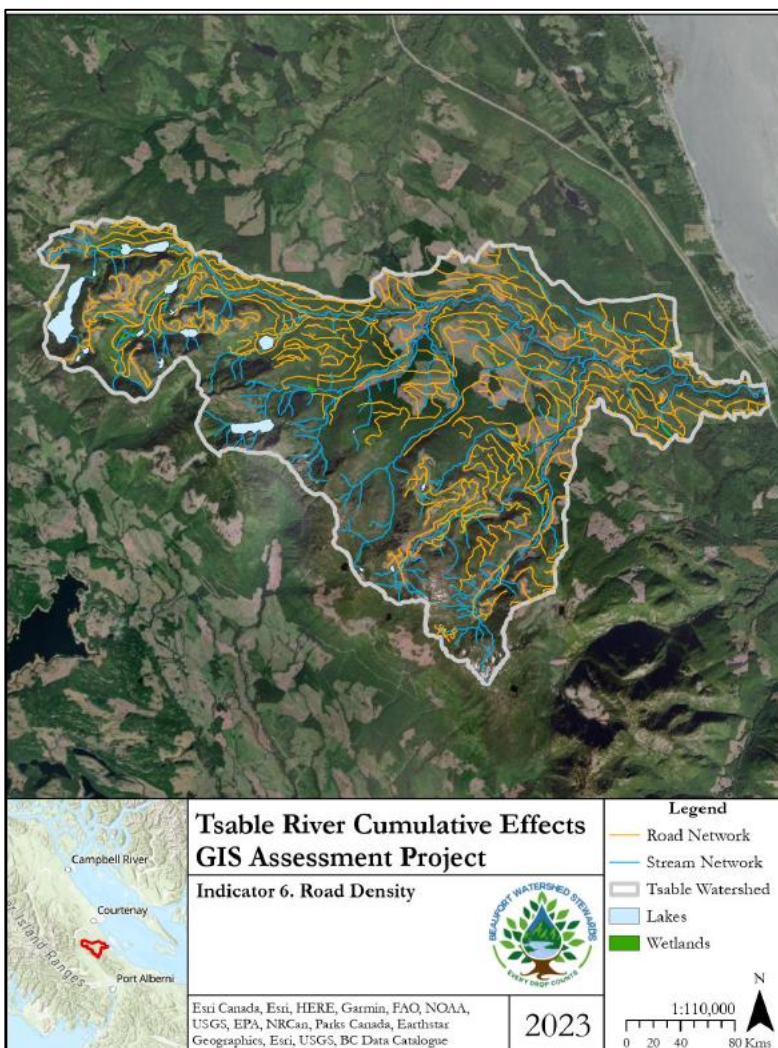


Figure 5: Example of a GIS deliverable map product with corrected and subsequently tallied metrics for several core indicators for this Report.

6.3 Detailed Data Collection Methods per Core Indicator

Below are descriptions of the methods used in this Report.

More detailed methodology information for each Indicator, are presented in Appendix 11.3.1 (primarily listed for reference for future users of this Protocol). This information in the Appendix was extracted directly from the Protocol, highlighting the Scientific Context and Thresholds₍₃₎ per Indicator.

1) Road Density (km/km²)

The total length of roads (km) was determined by GIS analysis for this Report. Then the total length of roads was divided by the net watershed area (km².)

Note: The net watershed area was calculated by subtracting the area of alpine and non-forested from the total watershed area.

2) Road Density < 100 m from a stream (km/km²)

The total length of roads < 100 meters from a stream (km) was determined by GIS analysis for this Report. Then the total length of roads was divided by the net watershed area (km².)

3) Road Density on potentially unstable slopes (km/km²)

The total length of roads on slopes > 60% slopes (km) was determined by GIS analysis for this Report. Then the total length of roads was divided by the net watershed area (km².)

One area containing a slope failure was identified within the area of > 60% slope. Below is a Google Earth image of the slide. No ground verification was performed and therefore, it was not possible to determine if the road construction caused the slide or not.

Figure 6:

Identified Slope Failure located within the identified Tsable River watershed area of > 60% slope terrain. This slide is located above Felker Lake, just east of Mount Clifton in the Beaufort Range.



4) Stream Crossing Density (#/km²)

The total number of stream crossings was determined by GIS analysis for this Report. Then the total number (#) was divided by the net watershed area (km²).

5) Riparian Disturbance (km/km) Streams – Linear Based Measurement

The total length (km) of streams with riparian disturbance within 30 m of a stream, was determined by Google Earth image interpretation and were verified on the ground where possible for this Report. The total length of streams in the watershed (km) were determined by GIS analysis. Subsequently the total riparian disturbance length was divided by the total length of streams in the watershed (km/km).

Below are two photos of Riparian Disturbance within 30 m of stream channels, identified on Google Earth and verified on the ground (both located in the upper tributary of the Tsable River). Both types of disturbances were from reserve trees along streams that blew down from wind events. This was the most common disturbance identified. Only a few upper reach unclassified streams had no riparian tree protection and were tallied as disturbed due to logging across the stream channels.



Figure 7: Ground verified Riparian Disturbance identified (the blue arrows trace the stream channel) Both of these streams have had portions of their riparian buffer trees blown down by wind events in the past. Extensive treeless clearcuts extend on both sides of these two riparian areas.

6) Peak Flow (the most complex indicator)

Below is a graphic illustrating how these complex groupings of several metrics are summed:

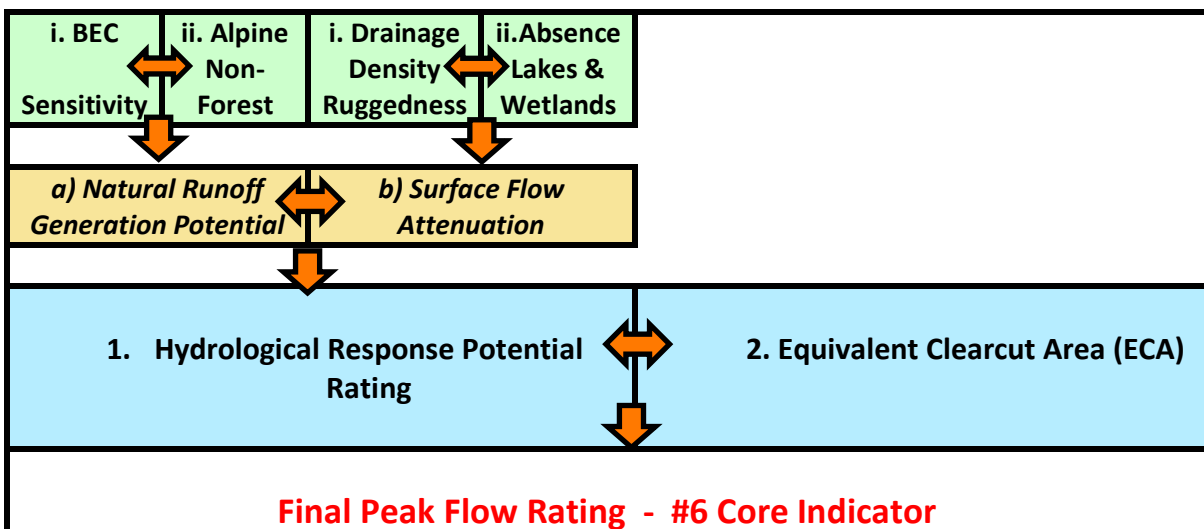


Figure 8: The Peak Flow Graphic illustrates how each micro and sub metric is summed and subsequently determines each following metric.

Peak Flow Sub-Metric Methodologies

1. **Hydrological Response Potential Rating** This sub-metric is composed of several micro-metrics. Combined, they generate an overall score for this potential rating.

a) Natural Runoff Generation Potential was calculated by using the following two micro-metrics:

- i. Biogeoclimatic Ecosystem Classification (BEC) A relative BEC unit sensitivity ranking is an indicator of average annual precipitation, average snowpack accumulation and persistence (Lewis et al., 2016; Smith et al., 2019). The BEC score is coded into 3 numerical classes for the assessment watershed:

1. LOW (0 – 0.5)
2. MODERATE ($\geq 0.5 - 1.5$)
3. HIGH (≥ 1.5)

Local BEC subzones were determined from the BC Government's BEC website maps⁽⁵⁾ for this Report. The Protocol's BEC Sensitivity Scores tab in Appendix 2 of the Protocol was used to determine the rankings as listed above.

- ii. Percent Alpine and Non-Forested Areas Natural alpine areas and associated features (ice/snow, rock/rubble, moraine) are assessed to estimate the potential for peak flow under natural conditions. The proportion of alpine and non-forested area is coded into 3 numerical classes:

1. $\geq 70\%$
2. 30-70%
3. $< 30\%$

The area of alpine and non-forested area was identified by Google Earth imagery interpretation of vegetation cover for this Report. The total area (ha) was divided by the total area of the watershed (ha) and multiplied by 100 to determine the percentage. This area of alpine and non-forested area was used to determine the net watershed area for several of the other indicators in this Report.

These two micro-metrics scores are combined to give the a) Natural Runoff Generation Potential ranking, using the following table from the Protocol below (Lewis et al, 2016):

		BEC Unit Score		
Proportion of Alpine Non-Forested Area (%)		1	2	3
	<30	Moderate	High	Very High
	31-70	Low	Moderate	High
	>70	Very Low	Low	Moderate

Table 2: Scoring matrix to derive Natural Runoff Generation Potential ranking.

b) Surface Flow Attenuation was calculated by using the following two micro-metrics:

- i. Drainage Density Ruggedness (DDR) (Melton, 1957) is the dimensionless product of drainage density (stream length per unit area – km/km²) and total elevation relief (the difference between the highest and lowest points in the watershed relative to watershed length in km) (Schumm 1956). DDR is coded into 3 numerical classes:

1. <2000 km/km²
2. 2001-4000
3. >4000 -3

The DDR was determined via GIS analysis using Google Earth for this Report.

- ii. Absence of Lakes and Wetlands are calculated using the 1:20,000 lakes and wetlands GIS layers to measure the area of lakes and wetlands within the lower 30%, mid 30% and upper 40% of each watershed. The area-weighted proportion (%) covered by lakes and wetlands is calculated by weighting the lower 30% of the area by 100%, the middle 30% by 75%, and the upper 40% by 25%. This gives greater weight to larger lakes and wetlands situated lower in a watershed, which are more likely to attenuate runoff (Lewis et al, 2016).

The proportion of lakes and wetlands and the position in the watershed, are scored and coded into 3 numerical classes:

1. >6.1 %
2. 2.1-6 %
3. 0-2 %

The lakes and wetland metric was determined via GIS analysis for this Report.

These two micro-metric scores are combined to give the b) Surface Flow Attenuation ranking, using the following table from the Protocol below (Lewis et al, 2016):

		Drainage Density Ruggedness		
Location Weighted Percent Area of Lakes/Wetlands		<2000	2001-4000	>4000
	0-2	Moderate	Low	Very Low
	2.1-6.0	High	Moderate	Low
	>6.1	Very High	High	Moderate

Table 3: Scoring matrix to derive Surface Flow Attenuation ranking₍₃₎.

Therefore, the a) Natural Runoff Generation Potential and the b) Surface Flow Attenuation resultant scores are summed to indicate the final **1. Hydrologic Response Potential Rating** (Lewis et al, 2016). These numerical scores range from 4 to 12, and are classified as follows:

VERY LOW: < 6
LOW: ≥ 6 and < 8
MODERATE: ≥ 8 and < 9
HIGH: ≥ 9 and < 11
VERY HIGH: ≥ 11

2) Equivalent Clearcut Area (ECA)

ECA is basically a “snapshot in time” of the percentage of the watershed area that is still in a hydrological clearcut state. A further detailed explanation of ECA is contained in Appendix 11.2 of this Report.

This metric is best suited for the use and interpretation of LiDAR (Light Detection And Ranging) tree height imagery data . However, for the Tsable River watershed (being 100% private forest land owned), no publicly accessible LiDAR was available. Therefore, the methods used for this Report were a combination of satellite imagery interpretation and ground height measurements. The entire net area of the watershed was first classified into seven Disturbance Units (DUs) based on the current 2022 height of regeneration - from vegetation cover interpretation using the July 2022 Goggle Earth images. Then, a representative number of DUs were ground-truthed (roughly 20%) to verify and calibrate the image interpretation. The final areas per each DU were tallied via GIS and a *hydrological recovery factor* was assigned to each DU, using the ECA tables developed by Hudson, found in the Appendix of the Protocol ⁽³⁾. The resulting ECA areas for each DU were tallied and then divided by the net watershed area x 100, to determine the final ECA % for the watershed.

Final - Peak Flow Index Rating:

The **1) Hydrologic Response Potential Rating** is combined with the **2) Proportion of ECA** in the following matrix, to result in a **Peak Flow Index Number** (consistent with Lewis et al, 2016).

		Peak Flow Index Number																			
Hydrologic Response Potential Class	VH	0.05	0.1	0.21	0.23	0.31	0.33	0.43	0.45	0.56	0.58	0.6	0.63	0.66	0.7	0.75	0.8	0.85	0.9	0.95	1
	H	0.04	0.09	0.14	0.22	0.25	0.32	0.35	0.44	0.47	0.57	0.59	0.62	0.65	0.69	0.74	0.79	0.84	0.89	0.94	0.99
	M	0.03	0.08	0.13	0.17	0.24	0.27	0.34	0.37	0.46	0.48	0.5	0.61	0.64	0.68	0.73	0.78	0.83	0.88	0.93	0.98
	L	0.02	0.07	0.12	0.16	0.19	0.26	0.29	0.36	0.39	0.41	0.49	0.52	0.54	0.67	0.72	0.77	0.82	0.87	0.92	0.97
	VL	0.01	0.06	0.11	0.15	0.18	0.2	0.28	0.3	0.38	0.4	0.42	0.51	0.53	0.55	0.71	0.76	0.81	0.86	0.91	0.96
		0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
		ECA																			

Table 4: Scoring matrix to derive Peak Flow Index Number:

These numerical scores for **Peak Flow** are classified as follows:

LOW <0.3

MODERATE 0.3-0.42

HIGH 0.42

7.0 Results per Core Indicator

7.1 Data Summaries

The following is a Summary Table listing the six Core Indicators' final values for this Report (High values are shown in **red**). An image snip from the GIS maps produced are provided at the top of the table for each indicator – for visual reference of the metric hard copy deliverable.

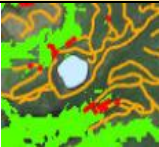
Core Indicator	Road Density	Road Density < 100 m Stream	Road Density Unstable Slopes	Stream Crossing Density	Riparian Disturbance	Peak Flow
Map Snip (Felker Lake is the circular blue image)						
Core Indicator Values	3.7 km/km ² HIGH	0.9 km/km ² HIGH	0.10 km/km ² LOW	1.54 #/km ² HIGH	0.05 km/km LOW	0.61 HIGH
Core Indicator Thresholds						
LOW	< 1.5	< 0.12	< 0.12	< 0.60	< 0.12	< 0.3
MODERATE	1.5 – 2.1	0.12 – 0.30	0.12 – 0.25	0.60 – 1.40	0.12 – 0.21	0.3 – 0.42
HIGH	> 2.1	> 0.30	> 0.25	> 1.40	> 0.21	> 0.42

Table 5: Summary Table of all Core Indicator Values with thresholds and map snips of the GIS products per indicator.

7.2 Visual Comparisons of Indicator Values

The Tsable River watershed productive forest area (net area) is roughly equal to the area of Denman and Hornby Island combined.

**Tsable River
Watershed Net Area** **8,280 ha**

**Denman and Hornby
Island** **8,100 ha**



Figure 9: Denman and Hornby Island

The following visuals below present the amount of two **HIGH** rated core indicators values, relative to the area of Denman and Hornby Island.

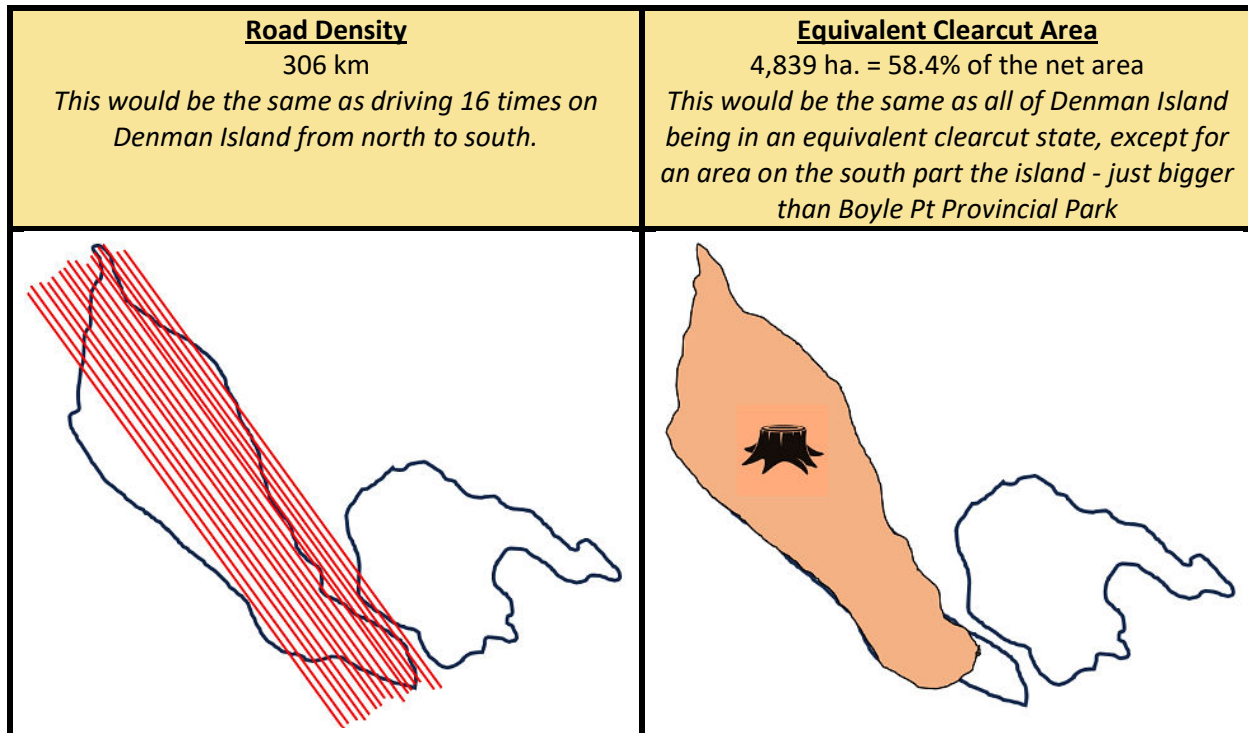


Figure 10: Road Density and ECA compared to area of Denman and Hornby Island.

7.3 Total Area Harvested

The Tsable River watershed's accessible 1st growth forests were completely harvested via extensive clearcuts in the 1930s and 1940s (the only patches left are a few narrow steep gullies and high elevations patches). This metric of *Total Area Harvested*, is not a metric of the Protocol's core indicators, and no credible source is available in the literature to demonstrate what threshold level of harvest rate would be acceptable or unacceptable for BC coastal harvesting practices.

However, for the purposes of comparing the Tsable River watershed harvest rate since the 1990's to the previous four watersheds assessed in 2021 by BWS, the following percentage of harvesting rate was calculated for the Tsable River - by dividing the area of second growth harvested since the 1990's (up to July 2022), by the net forest area.

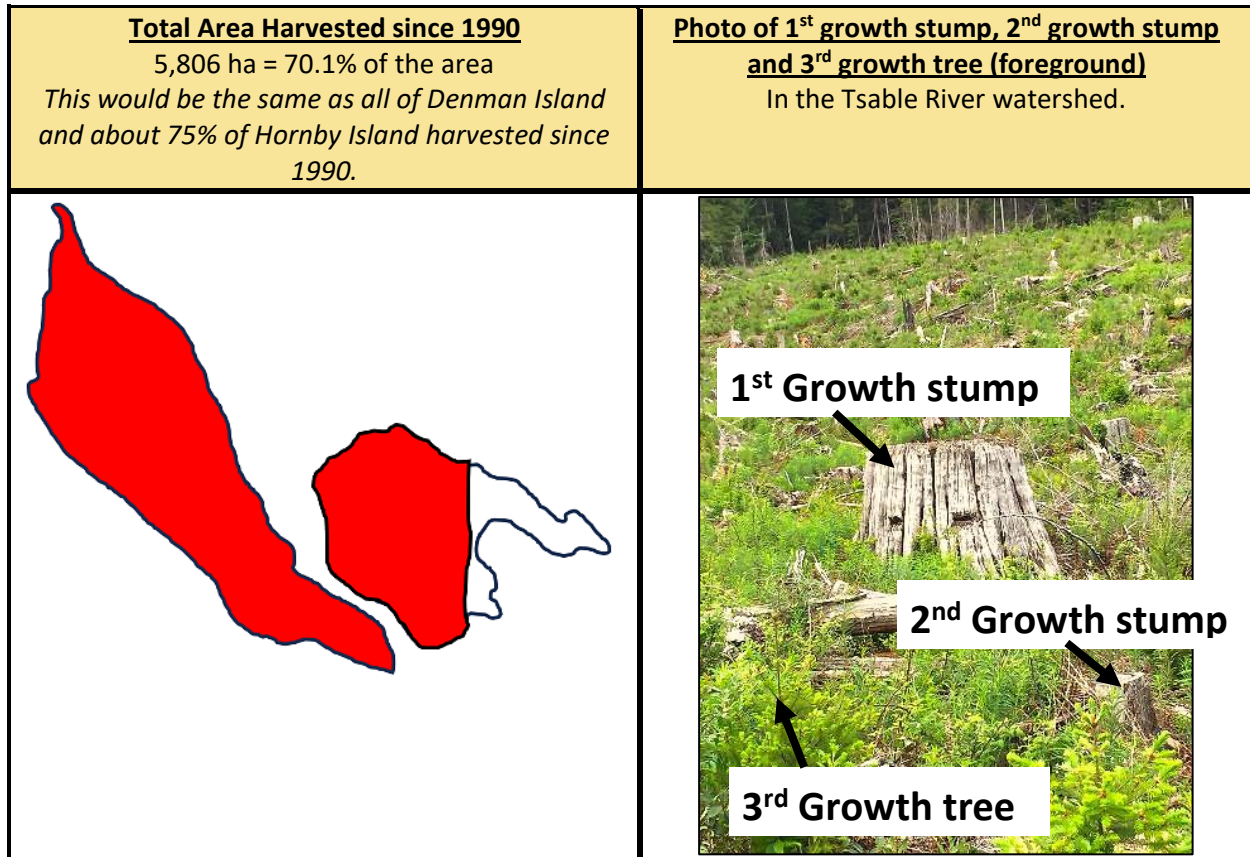


Figure 11: Total Harvested Area of the Tsable Watershed compared to Denman and Hornby Island. Including a photo illustrating 3 generations of trees on the landscape.

8.0 Conclusion and Discussion

8.1 Overall Tsable River Watershed Health Ratings

The following figure summarizes how the Overall Watershed Health rating was determined by the Core Indicator's ratings, as defined in the hierarchy of the Protocol₍₃₎.

Within the Indicators that impact the watershed Components – *Water Quality*, *Water Quantity* and *Ecosystem Function* – the highest rating of the Indicators determines the rating for that Component. Likewise, the highest rating of all the Components determines the Overall rating for the watershed.

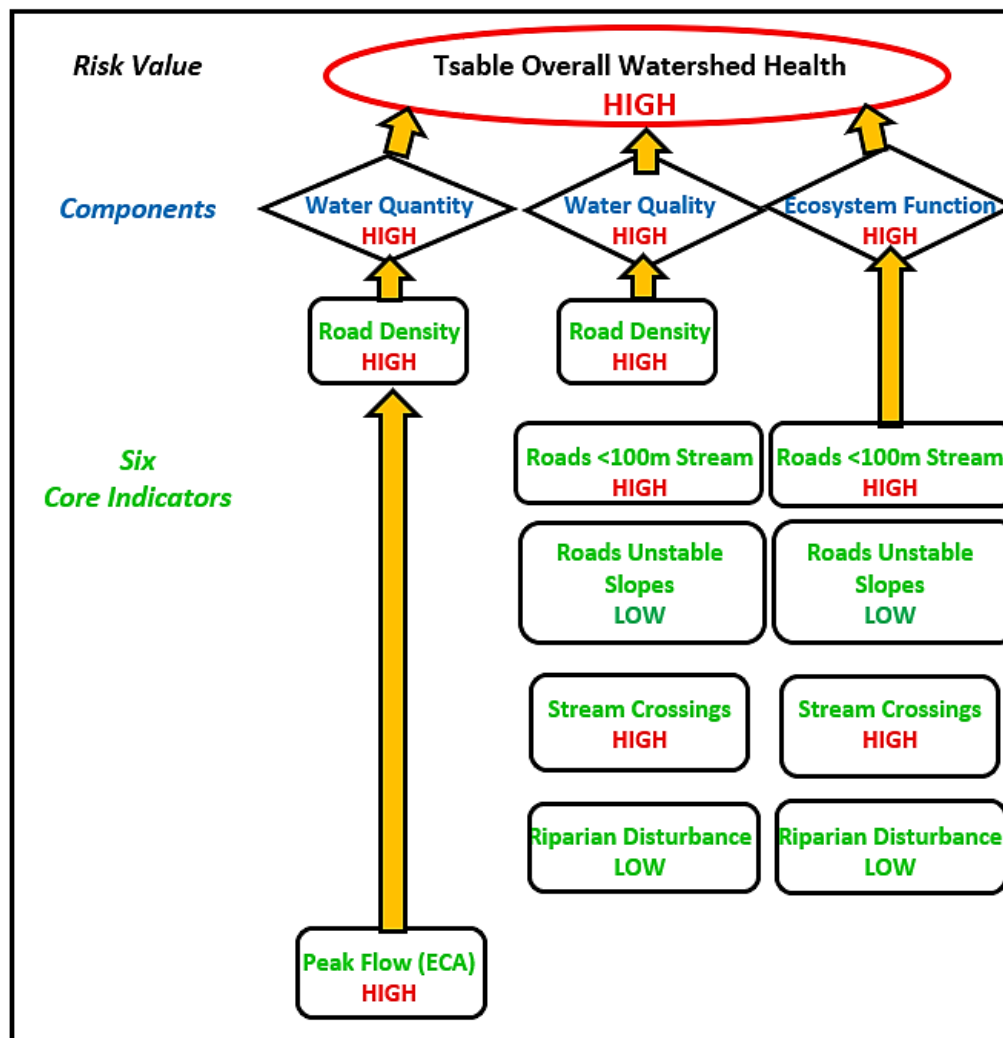


Figure 12: How the Overall Watershed Ratings are determined as per the Protocol model.

The following quotation from the Protocol summarizes the implications and recommendations of the Overall Tsable River watershed's **HIGH** rating:

"The watersheds cumulative effects from industrial development have a **high** potential to negatively impact the natural state of hydrological processes."

"An adjustment of developmental activities should be considered."

8.2 Comparison of Watersheds' Indicators Versus Water Quality

Due to the high ratings of the Tsable River watershed within the results of this Report, Figure 13 below was assembled to compare several compatible indicators determined for the Tsable River and four other Beaufort Range watersheds that were assessed in 2021 (Specifically Mud Bay, Waterloo, Wilfred, and Cowie Creek watersheds).

At the top of the figure under the names of the watersheds, are listed their % private forest land ownership. In the 2021 BWS report ⁽⁶⁾, BWS observed that land ownership was associated with different health indicator outcomes. This is believed to be primarily the result of legislation mandating lower rates of harvest rates on public land, compared to no mandate to control harvest rates on private land. As well, at the top of figure, are listed the size of the net forest area in each watershed. Alila ⁽¹⁾ has found that *"as the size of a watershed increases, the potential impact on a watershed from industrial development increases as well"*. This is evident in the figure below, as the graph value increases to the right along with the size of the watersheds.

Included at the bottom of figure are recently available water quality BWS data points per watershed, for the maximum turbidity values observed for rainfall events days, of over 10 mm of rain per day.

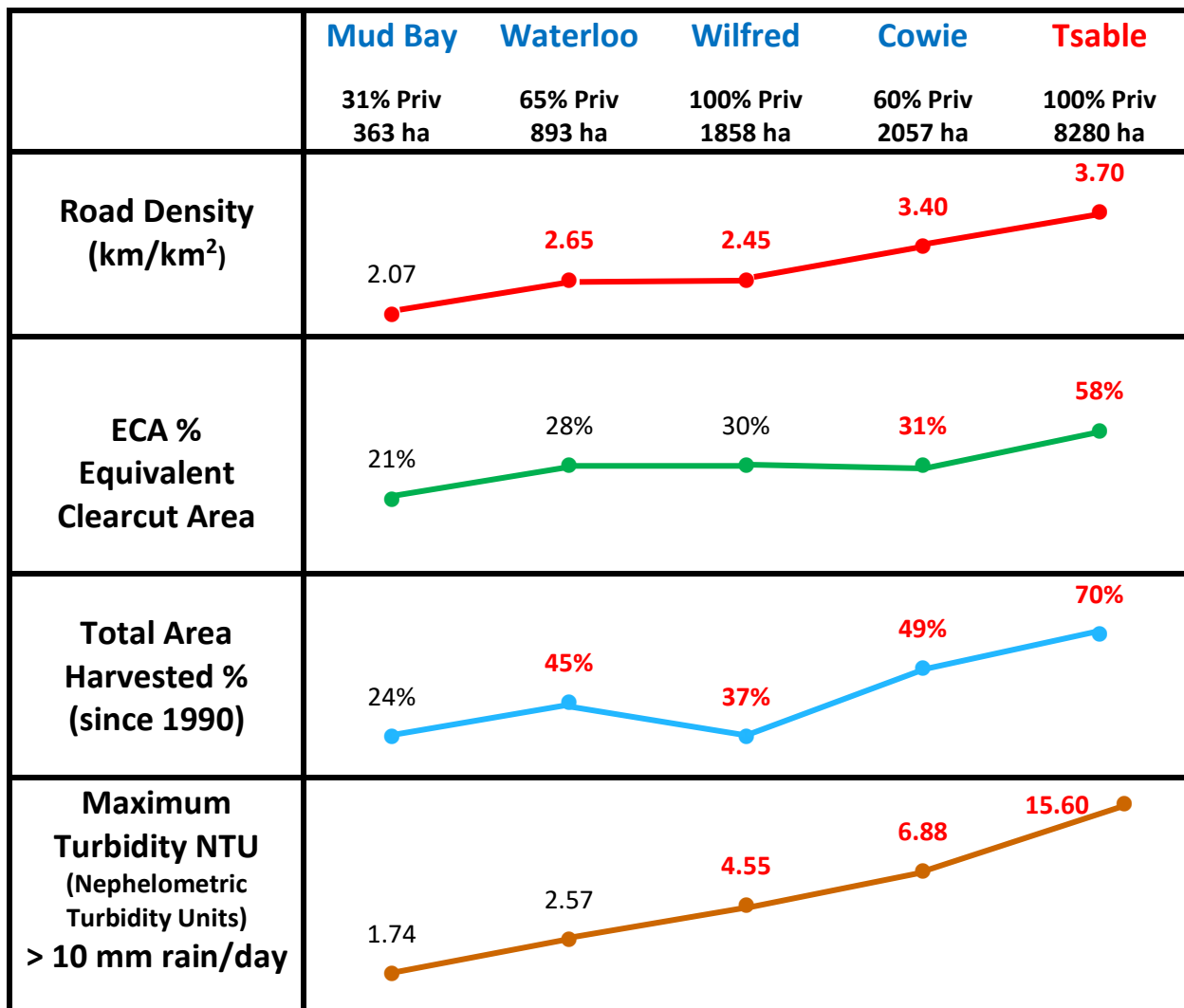


Figure 13: Comparison of Watershed Indicators between the Tsable River and other Beaufort Range watersheds versus Maximum Turbidity⁽⁶⁾

In reviewing this comparison above in Figure 13, the Tsable River is leading all watersheds with the highest indicator values for Road Density, ECA and Total Area Harvested since 1990. It is the largest watershed of the five, and therefore supports Alila's theory of *"as watershed size increases, so can the potential for industrial development impact"*. However, he clearly states that *"it is not just size that drives impacts, rather that the geomorphological shapes (physical features) can have a strong influence on the degree of impact as well"*.

However, the BWS water quality data at the bottom of the figure shows that during peak flow events, the Tsable River has the highest maximum turbidity at 15.60 NTUs. What is causing elevated sediment events in the Tsable River is ultimately unknown. Given the limited data and expert recommendations, the Tsable River can just be highlighted as having elevated risk of negative impacts to hydrological function, due to industrial development cumulative effects.

Figure 14: Tsable River at peak flow showing high turbidity (located by the Highway 19A bridge).



8.3 Suitability of the Protocol as a Cumulative Effects Tool to Assess Watershed Health

Overall, the procedures within the Protocol were relatively straight forward to deploy and produced meaningful rankings of watershed health. The Protocol is designed primarily for a digital - GIS and LiDAR data-based assessment. However, even without LiDAR data, BWS volunteers with forestry experience were able to assess metrics for a few of the LiDAR dependent core indicators by using information interpreted from Google Earth Pro imagery and were then ground verified. BWS also found that publicly available GIS layers could be corrected via a GIS technician using the same imagery in a reasonable timeframe and resulted in an improved final product.

The original conceptual model within the Protocol is complex, particularly when interpreting how micro-metrics influence sub-metrics and then ultimately define a core indicator value. BWS found that simplifying the diagrams into steps and processes (crafted in this Report by BWS) aided in interpreting the values and defining the overall rating of the watershed.

In conclusion, BWS has found this Protocol to be a feasible watershed health assessment tool at the community group level.

9.0 Recommendations

1. **Encourage other community watershed groups to use this Protocol:** All community watershed groups concerned about their local watersheds' health status, are strongly encouraged to embrace this Protocol, and be empowered to perform an assessment such as this Report. BWS is willing to mentor and assist watershed groups to perform these assessments and to aid in presenting their findings.
2. **BWS will plan and perform Cumulative Effects Assessments on other watersheds using this Protocol:** Due to the significant findings of this Report, it is recommended that BWS initiate additional assessments on neighboring watersheds currently being monitored for water quality and quantity. Watersheds targeted for health assessments should be prioritized considering the following criteria: 1) those showing high sediment levels in their measurements and 2) those that are > 2000 ha in overall watershed area⁽¹⁾.
3. **Advocate for reform of the BC Private Managed Forest Land Act (PMFLA), to lower the rates of harvest, and advocate for full implementation of the 2014 BC Watershed Sustainability Act (WSA), watershed planning regulations:** This Report clearly shows that hydrological function in the Tsable River has a high risk of being negatively impacted by industrial development – primarily elevated rates of logging. The Tsable River is managed under the PMFLA which has no legal restrictions on the rate of harvest. BWS is encouraging all interested parties to advocate to the BC Government to bring this requirement back to this act immediately, which was in fact removed in 2003.

The WSA has the capability to implement regulations for landscape planning necessary for the protection of ecosystem function in BC – even on private forest land watersheds like the Tsable. However, to date this WSA planning regulation has not been enacted. BC hydrologists are strongly advocating that BC forest management shift to the landscape scale – away from the current forest stand scale. Specifically, they are recommending that landscape management units should be the watershed boundaries and not the entire tenure area for forest companies (Alila ⁽²⁾). Likewise, BWS is encouraging all interested parties to advocate to the BC Government to immediately enact all the watershed planning regulations proposed in the WSA.



Figure 15: *Tsable River at peak flow in November (looking west of the highway 19A bridge).*

10.0 References

1. Alila Y. 2023. Forests and Water: New science for a Changing Climate. Webinar sponsored by Oregon Shores Conservation Coalition
<https://healthywatershed.org/video-replays/>
2. Alila Y., Johnson R. 2023. Nonstationary stochastic paired watershed approach: Investigating Forest harvesting effects on floods in two large, nested, and snow-dominated watersheds in British Columbia, Canada. 625 Journal of Hydrology.
3. B.C. Ministry of Environment and Climate Change Strategy and Ministry of Forests, Lands and Natural Resource Operations and Rural Development 2020. Interim Assessment Protocol for Aquatic Ecosystems in British Columbia – Standards for Assessing the Condition of Aquatic Ecosystems under British Columbia’s Cumulative Effects Framework. Version 1.3 Prepared by the Provincial Aquatic Ecosystems Technical Working Group
<https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/cumulative-effects/protocols/cef-aquatic-ecosystems-protocol-dec2020.pdf>
4. B.C. Ministry of Forests. 2001. Coastal Watershed Assessment Procedure guidebook. 2nd ed., Version 2.1. Forest Practices. Branch., Min. For., Victoria, B.C. Forest Practices Code of British Columbia Guidebook.
https://www.crownpub.bc.ca/Product/Details/7680001634_S
5. B.C. Ministry of Forests, Research Branch. 2023. Biogeoclimatic Classification Program – Website. Victoria, B.C., V8W 3E7
<https://www.for.gov.bc.ca/hre/becweb/>
6. Beaufort Watershed Stewards. 2021. Hydrological Health Report Card on Four Watersheds
<https://beaufortwater.org/wp-content/uploads/simple-file-list/Watershed-Report-Card/BWS-Watershed-Health-Project-4-Nov-2021.pdf>
7. Costanza, R., Mageau, M. 1999. What is a healthy ecosystem. Aquatic Ecology 33, 105–115.
8. Forest Practice Board. 2022. Forest Practices and Water - Opportunities for Action Forest Practices Board, Victoria, BC.
<https://www.bcfpb.ca/wp-content/uploads/2022/01/SR60-Forest-Practices-and-Water-Ops-for-Action.pdf>
9. Pike R.G., Redding T.E., Moore R.D., Winkler R.D., and K.D Bladon. 2010. Compendium of Forest Hydrology and Geomorphology in British Columbia, Volume 1 of 2. Land Management Handbook 66, Forest Science Program BC Forest Service / FORREX, Prov. B.C., Victoria, B.C.
https://www.for.gov.bc.ca/hfd/pubs/docs/lmh/lmh66/lmh66_volume1of2.pdf

11.0 Appendices

11.1 Original Conceptual Model of the Protocol

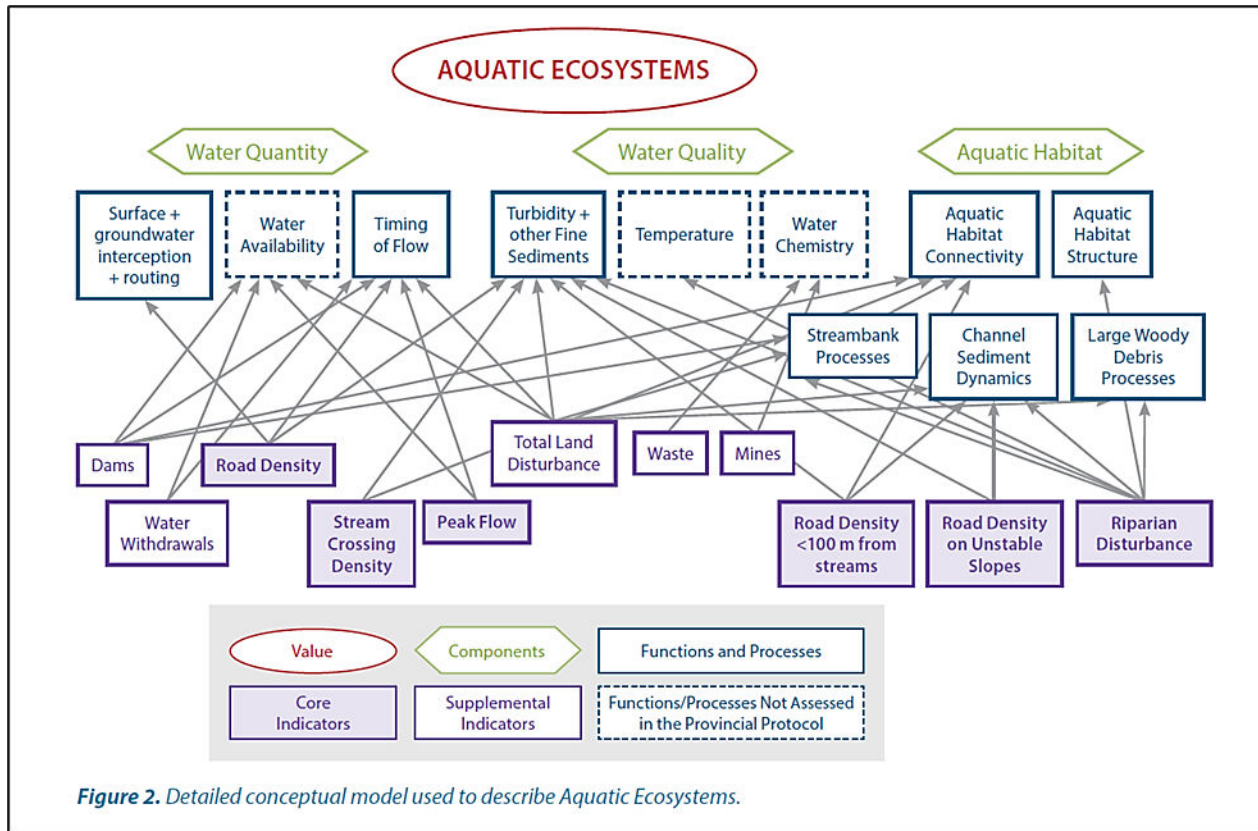


Figure 2. Detailed conceptual model used to describe Aquatic Ecosystems.

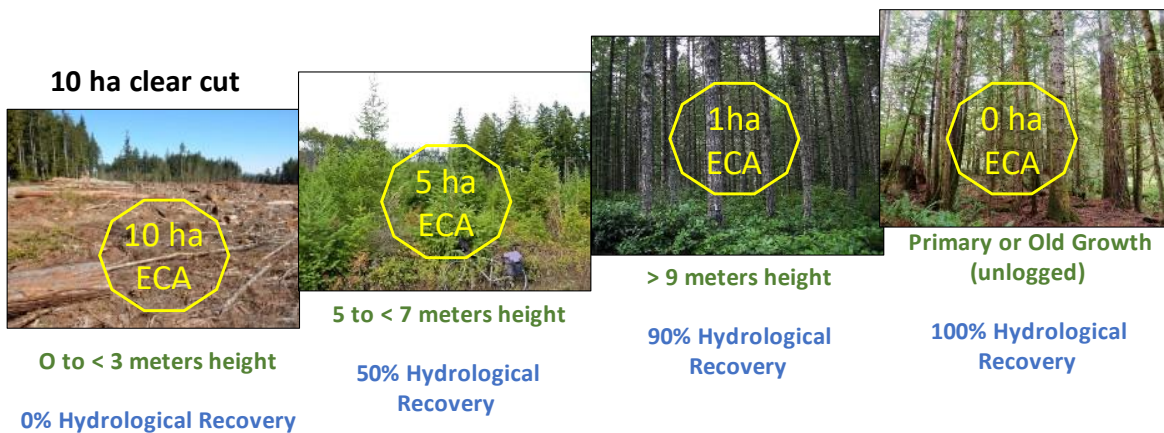
11.2 Equivalent Clearcut Area (ECA) Explanation

What is **ECA** and Hydrological recovery?

- **Equivalent Clearcut Area (ECA)** is basically a “snap shot in time” of the percentage of the watershed area still in a *hydrological “clearcut state”*
- **Clearcut State** is all disturbed / denuded / clearcut harvested forest areas, that have had the *vegetation cover removed* and the resultant regenerating vegetation has *not yet achieved hydrological recovery*
- **Hydrological Recovery** is defined as achieving an ability to intercept precipitation to the same rate prior to the disturbance – this is usually a certain *height and crown closure* of regenerated plantations in managed forests



Height of Trees = % Hydrological Recovery +/- best match



11.3 Data Sheets for Core Indicator Metrics

11.3.1 Detailed Methodology Per Core Indicator – Scientific Context and Thresholds₍₃₎

1) Road Density (km/km²)

Scientific Context

As road densities increase, more surface materials are exposed to erosion, which can result in an increase in the mobilization of sediment to nearby waterways (Meehan 1991).

Peak flows within a watershed may be magnified as road density increases because the compact nature of roads resists water infiltration and facilitates surface water runoff (Smith & Redding 2012). Road density can also influence low flow and water temperature by decreasing infiltration capacity, thus modifying subsurface flows (Meehan 1991).

Ditch lines that run perpendicular to slopes intercept sub-surface and surface flows as well as collect runoff from roads, all of which are then rapidly transported to nearby stream channels (Forman and Alexander 1998; Gustavson and Brown 2002). During heavy precipitation and/or snow melting events, these processes are exacerbated as high levels of water and sediments are diverted to streams via roads and ditch lines.

Threshold Benchmarks

- < 1.5 km/km² (LOW)
- 1.5 – 2.1 km/km² (MODERATE)
- > 2.1 km/km² (HIGH)

2) Road Density < 100 m from a stream (km/km²)

Scientific Context

High road density near streams may contribute significant amounts of sediment to streams, affecting water quality, stream bed morphology and biota (Carson *et al.* 2009). Erosion and transport processes are dependent on precipitation, soil texture, road construction and maintenance practices (Gucinski *et al.* 2001; Carson *et al.* 2009).

Threshold Benchmarks

- < 0.12 km/km² (LOW)
- 0.12 – 0.30 km/km² (MODERATE)
- > 0.30 km/km² (HIGH)

3) Road Density on potentially unstable slopes (km/km²)

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 (Sawyer and Mayhood 1998; Gustavson and Brown 2002; Jordan 2002; Jordan *et al.* 2010). Roads can alter surface drainage patterns and divert subsurface flow to the surface increasing the chance of soil saturation and gulley erosion (Pike *et al.* 2007).

Clearings associated with roads reduce the root network that provides structural support to soil, and they increase the chance of soil saturation by reducing rainfall interception and increasing snowmelt rates (Smith and Redding 2012).

Mapping of terrain stability is only available at local scales for a limited number of watersheds. However, several methodologies suggest that potentially unstable terrain can be defined (as a default) as slopes > 60% (Sawyer and Mayhood 1998; Gustavson and Brown 2002) or >50% on Haida Gwaii (B. Floyd, pers. comm.).

Threshold Benchmarks

- < 0.12 km/km² (**LOW**)
- 0.12 – 0.25 km/km² (**MODERATE**)
- > 0.25 km/km² (**HIGH**)

4) Stream Crossing Density (#/km²)Scientific Context

Stream crossings (i.e., roads, utility lines, other linear developments) represent a potential focal point for local sediment and flow delivery (Reid and Dunne 1984; Anderson 1996; Haskins and Mayhood 1997; Anderson et al. 1998; Brown 1999; Reid and Anderson 1999). Crossing structures can be a barrier to upstream fish passage, thereby restricting habitat and potentially fragmenting populations (Marshall 1996; Harper and Quigley 2000; BC MOF 2002).

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 (MOF 1995a, b; Smith and Redding 2012).

Threshold Benchmarks

- < 0.60 /km² (**LOW**)
- 0.60 – 1.40 /km² (**MODERATE**)
- > 1.40 /km² (**HIGH**)

5) Riparian Disturbance (km/km) Streams – Linear Based MeasurementScientific Context

Riparian areas can regulate channel morphology and contribute to 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 the intactness of riparian areas (Meehan 1991; Gustavson and Brown 2002).

As the proportion of disturbed streams increases within a watershed, so does the risk of surface erosion and mass-transport of sediment during heavy precipitation events (MOF 1995a, b). 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.

Riparian disturbance is limited to human causes as natural events such as fires or insect damage will retain large wood and provide a measure of other riparian functions until the forest regenerates.

Threshold Benchmarks

- 0.12 km/km (<12%) (**LOW**)
- 0.12 – 0.21 km/km (12 -21%) (**MODERATE**)
- > 0.21 km/km (>21%) (**HIGH**)

6) Peak Flow – a combination of several metricsScientific Context

The peak flow indicator is an estimate of the likelihood that harmful changes in streamflow will result from current land use activities. A large proportion (up to 80%) of total annual water yield is discharged in the peak flow period. Peak flows are of considerable management concern as they can result in channel forming events, important when considering the design of stream crossings, instream structures or the effects of flooding on downstream values. An increase in peak flow frequency and magnitude may result in harmful hydro-geomorphic events such as floods, bank erosion, channel instability, debris floods, and debris flows.

Peak flows are regulated by a combination of factors, including those that are linked to *natural runoff generation potential, surface flow attenuation, and equivalent clearcut area (ECA)*. It is the combination of these factors that control the magnitude, timing, and duration of peak flows.

Natural runoff generation potential considers *bio-geoclimatic (BEC) subzone and alpine non-forested areas*. It accounts for the degree of change in peak flows resulting from development using the assumption that watersheds grouped in specific sub-zone clusters with varying degrees of natural non-forested areas will generate different degrees of additional runoff after forest canopy loss or alteration (Winkler et al. 2010a).

Surface flow attenuation refers to how efficiently hillslope and stream runoff is slowed, captured and stored as it is routed through the watershed, and is represented by *drainage density ruggedness* and *absence of lakes and wetlands*. *Drainage density ruggedness* indicates the potential for rapid runoff delivery to and through streams, which may contribute to harmful flood events (Patton and Baker, 1976). The absence of lakes and wetlands and man-made reservoirs in a watershed can have an influence on peak flow discharges because lakes and wetlands are shown to mitigate peak flows (Acreman and Holden 2013, Woltenmade and Potter 1994, Taylor, and Pierson 1985). The size and placement of wetlands within a watershed has also shown to influence attenuation, with larger lakes and wetlands located on the main-stem channel lower in a watershed being more effective at reducing downstream flooding (Acreman and Holden 2013, Delaney 1995, Ogawa and Male 1986).

Equivalent Clearcut Area (ECA) is a modeled metric that relates the influence of forest cover disturbance (e.g., clearcuts) to changes in stream flow (MOF 2001; Smith and Redding 2012). ECA includes the area of land that has been harvested or otherwise cleared. Natural disturbance is included in ECA calculations to account for increases in surface water runoff due to changes in forest structure and function.

Hydrologic recovery curves reflecting changes in flows resulting from the regenerating forest are used to modify the ECA values (Sawyer and Mayhood 1998; Hudson and Horel 2007; Winkler and Boon 2015). A further detailed explanation of ECA is contained in Appendix 11.2 of this Report.

Overall Peak Flow Threshold Benchmarks

< 0.3 (LOW)

0.3 – 0.42 (MODERATE)

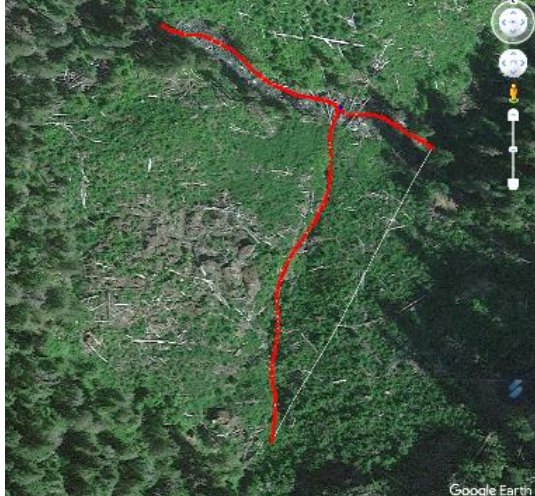
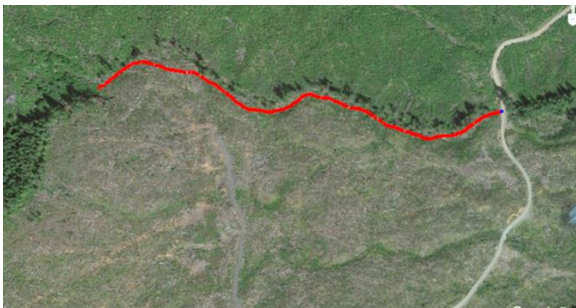
> 0.42 (HIGH)

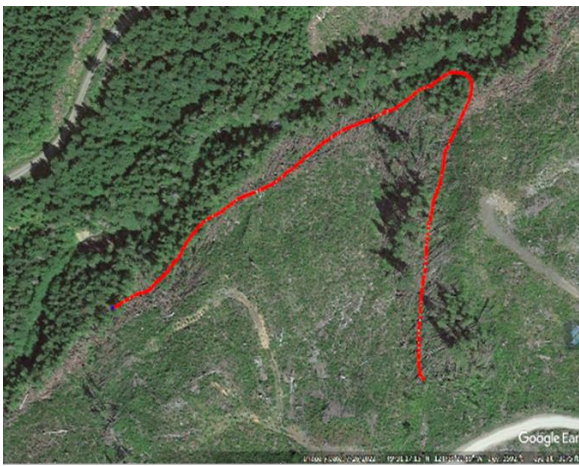
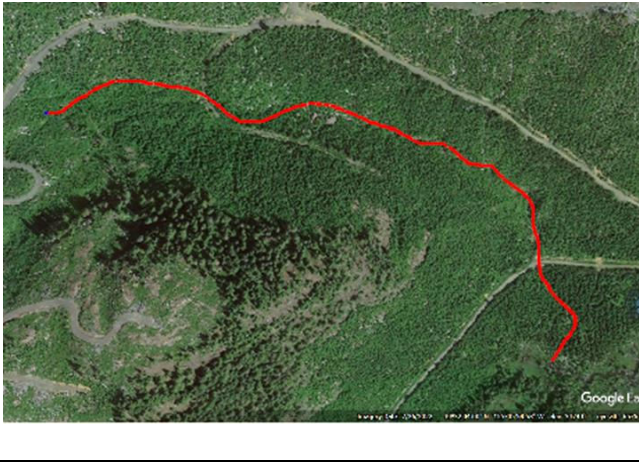
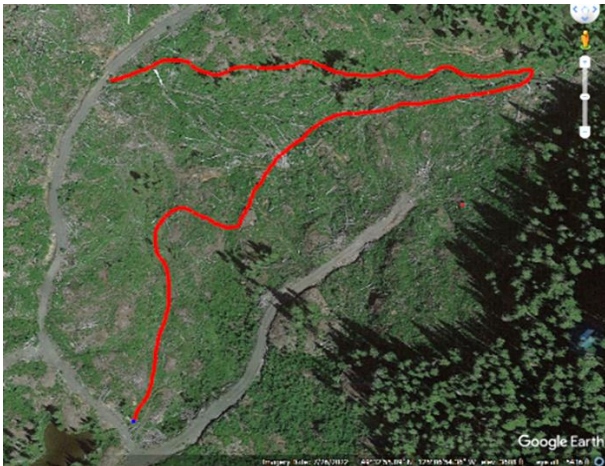
11.3.2 GIS Deliverables Data Sheet

Data and /or Metric	Value	Context Description
1. Date of satellite imagery used	July 2022	Averaged date – used mostly for Disturbance Units and stream assessment – other images used for complete analysis was the 2021 imagery.
2. Watershed Area	10,565 ha Gross Area 105.65 km ²	
3. Area of Alpine and Non- Forested	2,086 ha	
4. Areas of Wetlands and Lakes	Wetlands (W) 23.5 ha Lakes(L) 175.0 ha Total 198.5 ha:	
5. Areas of Wetlands and Lakes at 3 elevation levels (lower 30%, middle 30% and upper 40%)	4.9 ha – 0.15 % (all W) in lower 30% watershed (3169.5 ha) 0.3 ha – 0.01 % (all W) in mid 30% watershed (3169.5 ha) 193.3 ha - 4.57 % (175 ha L, 18.3 ha W) in upper 40% watershed (4226 ha) Final Weighted Average 1.3% value	
6. Net Forested Area	8,280.5 ha Net Area 82.805 km ²	Total area minus area of alpine and non-forested.
7. Length of the watershed in km	13.93 km	
8. Area of >60% slope	2075 ha	
9. Length in km of all streams and river	107.1 km	
10. Road density	306 km	
11. Road density located <100 m from a stream	77 km	
12. Road density on potentially unstable terrain	8.4 km	
13. Number of stream crossings	127	
14. Riparian disturbance	5.36 km	All documented in Riparian Disturbance Measurements and Images section below.

11.3.3 Riparian Disturbance Measurements and Images

All documented by Stream and estimated Stream class (S-Classes from by the Forest Range Practices Act).

Upper North Tumblewater Creek No riparian protection (S6) – 0.15 km 	Mid Tumblewater Creek Debris Torrent (S6) – 0.10 km 
South Tumblewater Creek no protection (S6) : 0.17 km 	South Tumblewater Creek no protection and logging debris in S6 – 0.44km 
North Beaufort Creek Blowdown along stream – 0.56 km 	South Beaufort Creek Blowdown – 0.18 km 

Mainstream Beaufort Creek blowdown – 0.5 km 	Further south mainstream Beaufort Creek blowdown – 0.35 km 
South Beaufort Creek area S6 blowdown – 0.32 km 	Upper Tsable River S6 with no riparian protection – 1.15 km 
Upper Tsable River S6 with no riparian protection – 0.57 km 	Upper Tsable River S6 creek/wetland not protected – 0.87 km. 

11.3.4 Disturbance Units (DU) Classes and ECA Determinations

- Grouped tree height classes are relative to the interpreted cover “colours” from the 2022 Google Earth images (ground-truthed in the field in 2003 with 131 estimates and measurements).
- Averaged Hydrological Recovery Factors are from the Protocols 2020 Excel descriptions (reference Hudson 2007 from the Protocol).

<i>DU Colour Class</i>	<i>Tree Height Range (Meters)</i>	<i>Hydrological Recovery Factor (HRF)</i>	<i>Area (Ha)</i>	<i>ECA Ha (HRF x Area)</i>
Brown	0 - <3 m	1.0	1562.2	1562.2
V Light Green	3 - <5 m	0.86	1223.6	979.0
Light Green	5 - <7 m	0.75	1080.3	810.0
D Green	7 - <9 m	0.63	1939.6	1222.0
V Dark Green	9 - <20 m	0.25	297.0	74.0
	≥20 m 2 nd Growth	0.10	1923.8	192.0
	Old Growth	0.0	252.0	0.0
			TOTAL	4839.2
			ECA % (4,839.2 ha ECA/ 8,280.5 ha Net Area)	58.4%

11.3.5 Table of 2023 Maximum Turbidity (NTU) of the Tsable River and other streams in the Beaufort Range

- Values in **red** are over the 5 NTU threshold for impact on fish habitat (Tripp 2020)₍₆₎.

2023	Sept 22	Sept 25	Sept 26	Sept 27	Oct 24	Nov 3	Nov 10	Dec 5	Dec 26
Wilfred	0.79	3.53	1.47	0.97	1.50				3.02
Cowie	0.48	5.02	2.27	2.17	1.74			2.29	6.44
Tsable		8.25		3.09	0.73	3.26	6.71	11.2	15.6

11.4 GIS Maps per Core Indicator

