

April 2015

WATERSHED STATUS EVALUATION: AN ASSESSMENT OF 71 WATERSHEDS MEETING BC'S FISHERIES SENSITIVE WATERSHED CRITERIA

Prepared by:

Marc Porter, Simon Casley, Nick Ochowski, and Sam Huang

April 2015



Dala River on the north coast, photo by Lars Reese-Hansen



WATERSHED STATUS EVALUATION: AN ASSESSMENT OF 71 WATERSHEDS MEETING BC'S FISHERIES SENSITIVE WATERSHED CRITERIA

Prepared by:

Marc Porter, Simon Casley, Nick Ochoski, and Sam Huang

April 2015



The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the Government of British Columbia of any product or service to the exclusion of any others that may also be suitable. Contents of this report are presented for discussion purposes only. Funding assistance does not imply endorsement of any statements or information contained herein by the Government of British Columbia.

Management of forest and range resources is a complex process that often involves the balancing of ecological, social, and economic considerations. This evaluation report represents one facet of this process.

Citation:

M. Porter, S. Casley, N. Ochoski, and S. Huang. 2015. Watershed Status Evaluation: An Assessment of 71 Watersheds Meeting BC's Fisheries Sensitive Watershed Criteria. Victoria BC FREP Report 39.

<http://www.for.gov.bc.ca/hfp/frep/publications/index.htm>

Prepared by: Marc Porter, Simon Casley, Nick Ochoski, and Sam Huang

For more information on Forest and Range Evaluation Program publications, visit our web site at:

<http://www.for.gov.bc.ca/hfp/meta/publications.htm>

© 2015 Province of British Columbia

ACKNOWLEDGEMENTS

We would like to thank Lars Reese-Hansen, Richard Thompson, Derek Tripp, Peter Tschaplinski, and Zaid Jumeau for their continuing assistance, technical reviews, and critical feedback during the development of this report. A sincere thanks is also extended to Dirk Brinkman for his constructive review, commentary, and contributions to improving this document. Finally, we would like to recognize the members of the Watershed Status Evaluation Technical Working Group for their continued discussions and support around the use of potential remote-sensed approaches for describing and tracking watershed risks or pressures.

EXECUTIVE SUMMARY

Under British Columbia's *Forest and Range Practices Act* Government Actions Regulation, and the *Oil and Gas Activities Act* Environmental Management and Protection Regulation, watersheds with significant fish values and watershed sensitivity can be designated as Fisheries Sensitive Watersheds (FSWs). Effectiveness monitoring and assessment is critical to ensure that FSW designations succeed in achieving the intended goals of maintaining natural functions and processes to conserve healthy fish habitats and associated fish populations. Integrated GIS-based (Tier I) and field-based (Tier II) methods for assessing the habitat status of FSWs have been developed jointly by government and private partners through watershed status evaluation monitoring protocols.

This pilot project used the WSE Tier I GIS-based methods described in Porter et al. (2013) to assess the watershed indicator "risk" status of 71 watersheds across most of British Columbia's natural resource regions. Measured values for as many as nine habitat indicators within surveyed watersheds were compared to indicator benchmarks defined in Porter et al. (2013) to assess risk "status" for each FSW (i.e., GIS-derived watershed values relative to indicator benchmarks). The defined indicator benchmarks represent one of three risk levels associated with fish habitat impact: (1) low, (2) moderate, and (3) high.

The analytical proficiency of modern GIS spatial tools is easily capable of the type of analysis conducted in this WSE Tier I evaluation. The limitations to this type of analysis exist primarily with the base data. Despite the various uncertainties inherent in current databases and GIS layers supporting watershed status evaluation Tier I assessments, the survey results and interpretations presented here are a good first step toward the development of more consistent and regularly repeated evaluations of broad habitat pressures acting across provincial FSWs. This assessment has helped to identify gaps in underlying data requirements and has flagged several priority needs for improvement.

To improve the utility of future watershed status evaluation Tier I analyses, and other GIS-based forms of analysis, we make the following recommendations.

- As a high government priority, improve critical GIS data layers
- Expand the number of primary indicators
- Increase the frequency of field-based Tier II watershed condition assessments
- Adopt and improve watershed status evaluation Tier I monitoring

TABLE OF CONTENTS

Acknowledgements	iv
Executive Summary	v
1.0 Introduction	1
2.0 METHODS	2
3.0 RESULTS	7
4.0 DISCUSSION	23
4.1 GIS Data Deficiencies	23
4.2 Recommendations	25
Literature Cited	26
Appendices	27
Appendix 1. Attribute information for 71 provincial fisheries sensitive watersheds (designated, candidate, and proposed) assessed using watershed status evaluation Tier I protocols.	27
Appendix 2. Additional statistics for GIS-derived habitat indicators in 71 fisheries sensitive watersheds (designated, candidate, and proposed) across provincial management regions.	29
Appendix 3. Habitat risk ratings (green = low risk, amber = moderate risk, red = high risk) for WSE Tier I habitat indicators over 71 fisheries sensitive watersheds (designated, candidate, and proposed) in each provincial natural resource region.	32

1.0 INTRODUCTION

Over the last 10 years, the government of British Columbia has taken steps to conserve watershed-level social, ecological, and economic fisheries values in the province by way of the *Forest and Range Practices Act's* (FRPA) Government Actions Regulation (GAR), the *Oil and Gas Activities Act's* (OGAA) Environmental Management and Protection Regulation (EMPR), or other similar regulatory tools.¹ Under these two regulations, the delegated Minister (or designate) is authorized to designate a watershed with significant fish values and watershed sensitivity as a “fisheries sensitive watershed” (FSW; also referred to generically as a “watershed” in this report). This designation specifically acknowledges the considerable benefits derived from British Columbia’s fisheries resources. The designation also provides the legal framework for forest, range, and oil and gas operators to undertake practices that maintain natural watershed processes by conserving the ecological attributes necessary to protect and sustain fish and their habitat (Reese-Hansen and Parkinson 2006). These conditions and outcomes include (see Government Actions Regulation, Section 14)²:

1. conserving natural hydrological condition, stream bed dynamics, and channel integrity;
2. conserving the quality, quantity, and timing of flows; and
3. preventing cumulative effects.

Under these regulations, the Ministry of Forests, Lands, and Natural Resource Operations (MFLNRO) and Ministry of Environment (MOE) have developed policy and procedures that guide a program for evaluating and designating drainages as FSWs. Thus far, more than 36 FSWs have been legally established under the Government Actions Regulation, whereas a larger number of additional watersheds throughout the province identified as “Candidate” or “Proposed” FSWs are awaiting review before any official designation over the next several years (L. Reese-Hansen, Ministry of Forests, Lands, and Natural Resource Operations, pers. comm., February, 2013).

Effectiveness monitoring and assessment are seen as critical to evaluate potential impacts associated with cumulative effects as well as to ensure that FSW designation is successful in achieving the goals of maintaining natural functions and processes required to conserve healthy fish habitats and associated fish populations. Under the Forest and Range Evaluation Program (FREP), effectiveness monitoring protocols have been developed to evaluate fish habitat conditions in FSWs as part of the Watershed Status Evaluation (WSE) project.³ Protocols developed under this project include:

- broad-scale, Geographic Information System (computer based technology) “risk” evaluation that measures the spatial extent and intensity of development pressures on fish habitat across a watershed (referred to as “Tier I Monitoring”; see Porter et al. 2013); and
- localized, field-based monitoring of watershed fish habitat that measures the condition of a watershed (referred to as “Tier II Monitoring”; see Pickard et al. 2014).

The Tier I monitoring protocol (Porter et al. 2013) has its foundation in methods developed for assessment of watershed status under the province’s Interior and Coastal Watershed Assessment Procedures (i.e., B.C. Ministry of Forests 1995a, 1995b, 1999). Indicators and benchmarks for the protocol were selected from these procedures based on their efficacy, widespread acceptance, and the knowledge base upon which they were developed.

The FSW assessments described in this report used methods outlined in Porter et al. (2013) to generate values for Tier I habitat indicators across a subset of provincially designated FSWs, plus selected regional candidate and high-priority proposed FSWs. Measured habitat values were related to defined benchmarks of concern for each habitat indicator so as to allow evaluations of habitat pressure status (i.e., low, moderate, or high potential risk of habitat degradation) within each FSW.

The purpose of this project was to demonstrate both the application and the utility of Porter et al.’s Tier I procedure (2013). It serves as a means to establish

1 For example, Important Fisheries Watersheds as designated under the *Land Act*.

2 See *Forest and Range Practices Act*, Government Actions Regulation, B.C. Reg. 582/2004. http://www.bclaws.ca/civix/document/id/complete/statreg/582_2004#section14 (Accessed April 2015).

3 More information is available on FREP’s website, Watershed-based Fish Values Monitoring Protocol for Watersheds with High Fish Values, at: <http://www.for.gov.bc.ca/hfp/frep/values/watershed.htm>.

baseline cumulative levels of risk using currently available information, and can be used again in the future to understand any change and trend in levels of risk. This document should serve the needs of land use managers, decision makers, and those interested in watershed monitoring methods in their efforts to plan, approve, conduct, and assess land use activities while conserving aquatic and fish habitat values.

2.0 METHODS

Watersheds selected for evaluation included currently designated (i.e., as of May 2012), candidate, and proposed FSWs identified by provincial government biologists and hydrologists from most regions of the province.

Established FSWs were used in this assessment because their suitability had been demonstrated through the legal designation process. Candidate and proposed watersheds were selected based on their ability to meet the FSW technical criteria and regional ranking as a high priority. The technical criteria (or regulatory tests) are specified in regulation and require that a watershed have both significant fish values and sensitivity.

Appendix 1 contains a list of the 71 watersheds (with accompanying attributes) evaluated as part of this analysis. The map in Figure 1 shows the locations of these watersheds and indicates their regulatory status (i.e., designated, candidate, or proposed) within British Columbia's natural resource administrative regions.

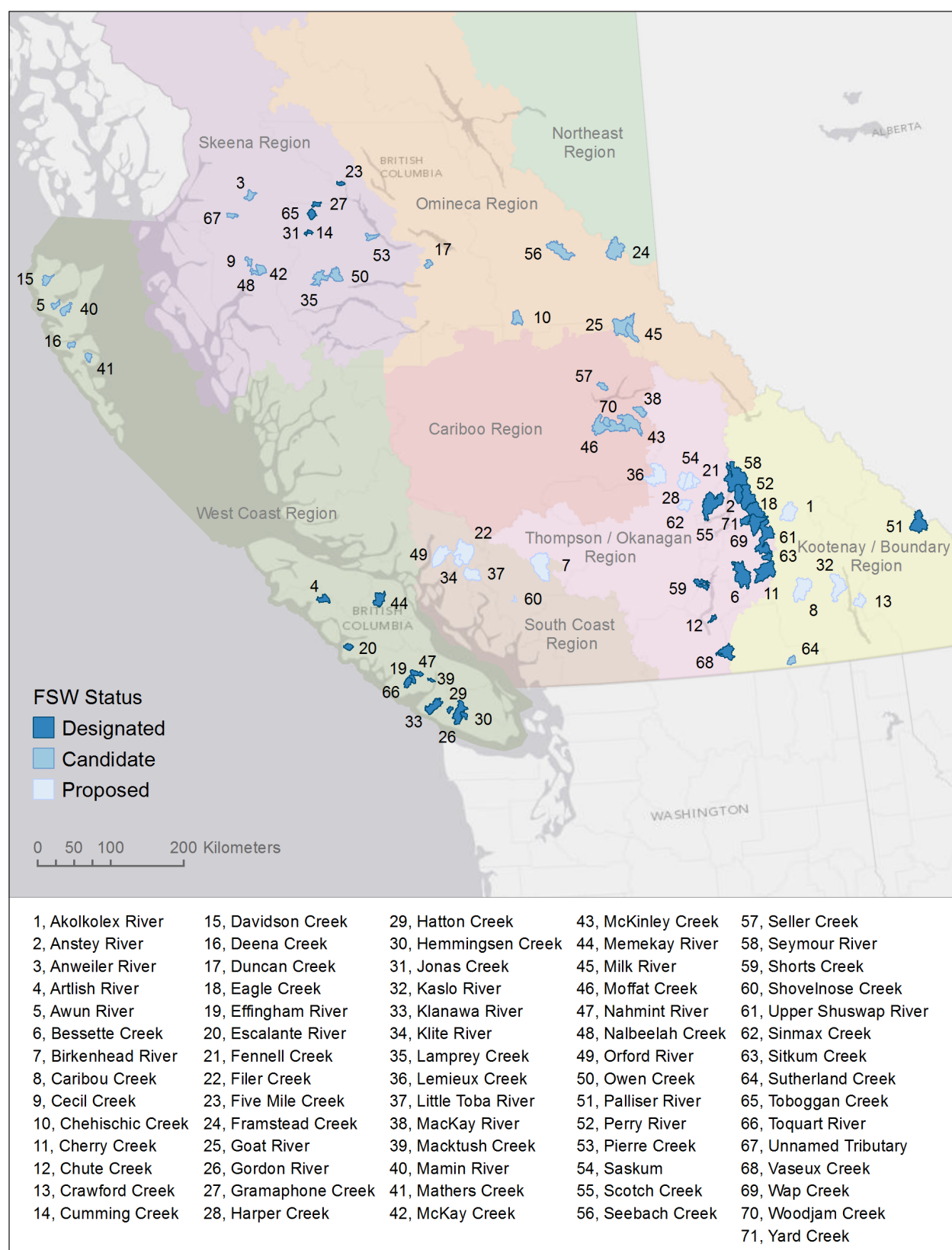


Figure 1. Location of 71 designated, candidate, and proposed fisheries sensitive watersheds within British Columbia's natural resource management regions.

Using approaches described in Porter et al. (2013), the following habitat pressure indicators were quantified for each watershed using a geographical information system (GIS). These habitat indicators are:

- Road density for the entire watershed (km/km²)
- Road density above the H₆₀ line⁴ (km/km²) (for interior watersheds only)
- Road density less than 100 m from a stream (km/km²)
- Stream crossing density (number per km²)
- Proportion of stream logged (km/km)
- Proportion of fish-bearing stream logged (km/km)
- Density of stream banks logged on slopes greater than 60% (km/km²)
- Peak flow index (unweighted; scale of 0–1)
- Road density on unstable slopes (km/km²)⁵

To assess current Tier I risk “status” for the watersheds, measured values for each of the above indicators were compared to moderate and high risk benchmarks currently defined for each indicator in Porter et al.

(2013) (i.e., GIS-derived watershed values relative to indicator benchmark values). These indicator benchmarks represented the levels at which fish habitat degradation is considered to be a low, moderate, or high risk.

Figure 2-A shows the areas within the 71 assessed watersheds for which Vegetation Resource Inventory (VRI) information is currently unreported (not available). Figure 2-B indicates the percentages of total watershed area in which VRI is “unreported” within each of the watersheds. (Specific values for VRI unreported are also recorded in Appendix 1.) Equivalent clearcut area (ECA) and the associated peak flow index indicator were calculated only for watersheds with more than 50% of total area represented with VRI data (56 of 71 FSWs). Thirty-two of these 56 watersheds had 100% VRI coverage. For the watersheds where VRI was lacking (i.e., with greater than 50% but less than 100% VRI reported—24 of these 56 watersheds), equivalent clearcut area (ECA) per peak flow index was calculated only for areas with reported VRI ; this calculation assumed that the results were applicable to the entire watershed. For the 15 watersheds with less than 50% VRI reported ECA and the Peak Flow Index were not calculated.

4 The H₆₀ line represents the elevation above which 60% of the watershed area lies.

5 For this indicator, slopes greater than 60% served as a coarse surrogate indicator for unstable slopes because GIS layers depicting general terrain stability at a provincial scale were lacking.

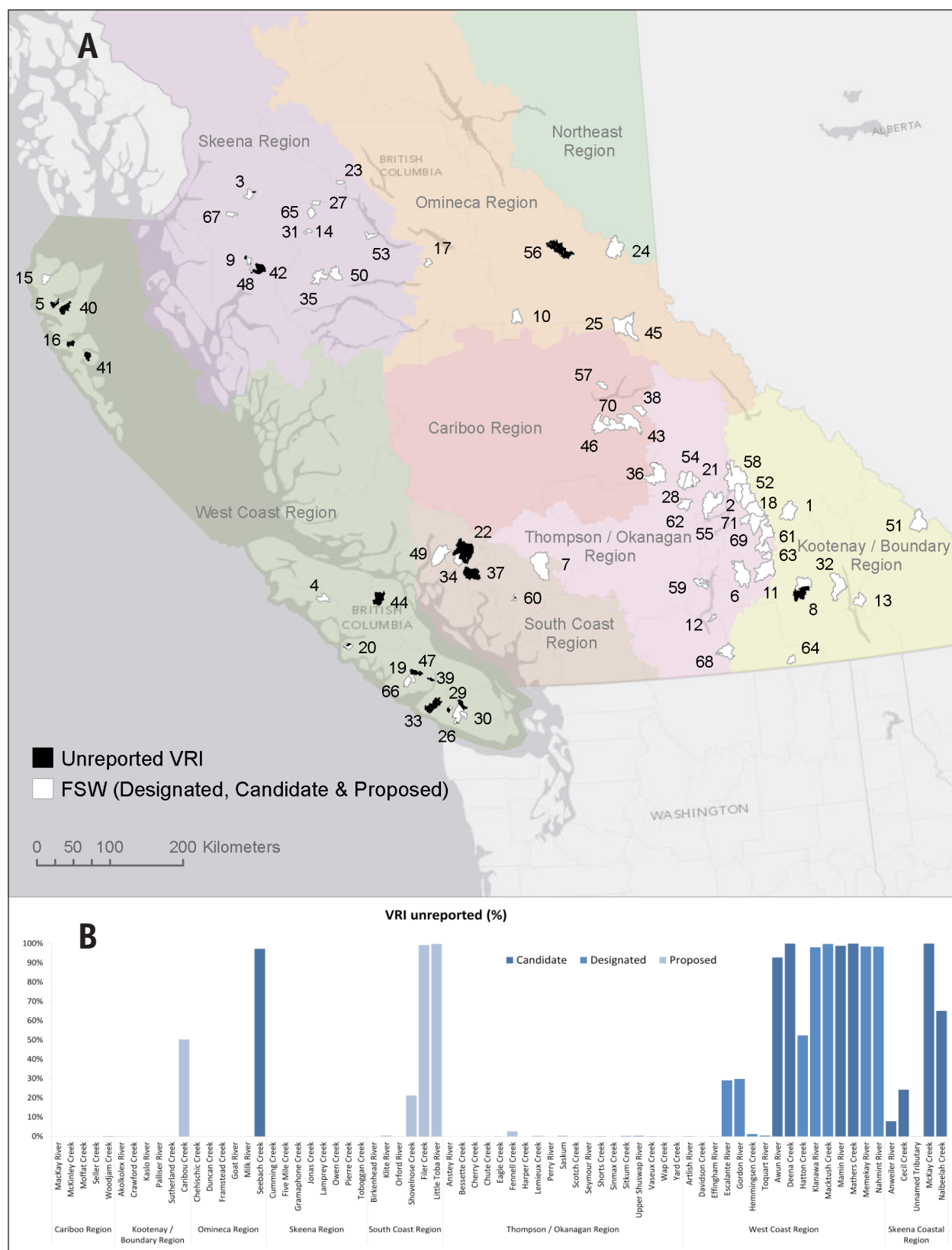


Figure 2. (A) Areas with unreported VRI land classifications within fishery sensitive watersheds (designated, candidate, and proposed FSWs combined; see Table 1 for watershed names/identifier numbers); (B) percentage VRI unreported within FSWs by region.

The analysis considered FSWs in the West and South Coast natural resource regions as “coastal” watersheds, whereas FSWs in the Omineca, Cariboo, Thompson–Okanagan, and Kootenay–Boundary natural resource regions were considered as “interior” watersheds. Watersheds within the Skeena Natural Resource Region, with its transitional biogeoclimatic conditions, were deemed either coastal or interior, depending on the ecoregion in which the watershed was located. The distinction between coast and interior conditions is based on differences in hydrological processes. Consequently, several different indicator benchmarks are used to reflect their unique hydrological characteristics (B.C. Ministry of Forests 1995a, 1995b; Porter et al. 2013).

Actual measurement units are used to illustrate benchmark break points between the three risk ratings (i.e., low, moderate, and high potential risk of habitat

degradation). Habitat indicator benchmarks are similar to those used traditionally in provincial watershed assessment procedures (B.C. Ministry of Forests 1995a, 1995b), with the exception that additional precautionary benchmark values for each indicator were added in recognition of the potential risk to inherently high fish values and sensitivity in these watersheds (Porter et al. 2013). WSE Tier I indicator benchmarks were derived from a Delphic expert-based review (Porter et al. 2013) of indicator benchmark ranges originally developed for the provincial watershed assessment procedures (B.C. Ministry of Forests 1995a, 1995b). Following the methods used to depict impact category risk scores in these procedures, normalized indicator risk matrix scores of 0.2 and 0.4 were used for moderate and high risk benchmarks, respectively (Porter et al. 2013). Table 1 shows the selected benchmark values by WSE Tier I habitat indicator.

Table 1. Habitat indicator risk rating levels

Habitat indicator	Moderate risk benchmark	High risk benchmark
Road density for entire watershed	0.6 km/km ²	1.2 km/km ²
Road density above H ₆₀ line (interior watersheds only)	0.2 km/km ²	0.4 km/km ²
Road density less than 100 m from a stream	0.08 km/km ²	0.16 km/km ²
Stream crossing density (interior watersheds)	0.16/km ²	0.32/km ²
Stream crossing density (coastal watersheds)	0.40/km ²	0.80/km ²
Portion of streams logged	0.06 km/km	0.12 km/km
Portion of fish-bearing streams logged	0.10 km/km	0.20 km/km
Stream banks logged on slopes greater than 60% (interior watersheds)	0.06 km/km ²	0.12 km/km ²
Stream banks logged on slopes greater than 60% (coastal watersheds)	0.30 km/km ²	0.60 km/km ²
Peak flow index	0.12	0.24
Road density on unstable slopes	0.06 km/km ²	0.12 km/km ²

For each of the watersheds, additional habitat indicator information was also generated, including:

- Percentage of riparian forest disturbed (%)
 - Percentage riparian disturbed by forestry (%)
 - Percentage of riparian disturbed by land alienation (%)
 - Percentage of riparian disturbed by mountain pine beetle and other forest pathogens (%)
 - Percentage of riparian disturbed by fire (%)
- Equivalent clearcut area (%)
 - From forestry (%)
 - From other forms of land development (%)

These habitat indicators provide supplemental information on types of potential habitat disturbances within the watersheds but were not incorporated into the analysis because disturbance benchmarks (i.e., low, moderate, high) are not yet defined or incorporated into the WSE Tier I risk assessment methods (Porter et al. 2013).⁶ Additional information on the disturbed riparian zones and equivalent clearcut area in the watersheds is provided in Appendix 2.

3.0 RESULTS

Values for the nine WSE Tier I habitat indicators measured in this watershed status evaluation pilot project are provided in Figures 3–13 grouped by provincial natural resource region; some indicators are presented in separate figures for coastal versus interior watersheds. In each watershed, values are presented relative to the moderate and high risk benchmarks for each habitat indicator (Porter et al. 2013). Table 2 provides a single matrix summary across all FSWs of risk “status” (low, moderate, high) for each habitat pressure indicator. Table 2 information is also depicted by natural resource region in Appendix 3.

Across the 71 watersheds, the worst performing habitat indicators (i.e., those categorized at high risk across a high proportion of the 71 watersheds) were “stream

crossing density” and “road density within 100 m of a stream.” The best performing habitat indicators (i.e., those categorized as low risk across a high proportion of the 71 watersheds) were “road density on unstable slopes,” “the portion of fish-bearing streams logged,” and “peak flow index” (for interior watersheds).

Most of the 71 watersheds evaluated had a high risk status for at least one of the measured habitat indicators. Exceptions to this were the South Coast Natural Resource Region’s Klite River, Little Toba River, Filer Creek, and Shovelnose Creek, as well as the Skeena Region’s McKay Creek and Pierre Creek, which had low risk status ratings across the full suite of eight (for coastal watersheds) or nine (for interior watersheds) habitat indicators. The Omineca Region’s Goat River also had no high risk ratings, but did have one moderate risk rating associated with “stream crossing density.” For the other watersheds, a variable mix of low, moderate, and high risk ratings occurred across the measured habitat indicators. No watersheds displayed high risk status ratings across all measured habitat indicators, but some were notable for having a significant proportion of high risk ratings (i.e., the Skeena Region’s Jonas Creek and Gramophone Creek, which had eight and nine habitat indicators rated as high risk, respectively).

On a regional basis, watersheds with the greatest number of high risk habitat indicator ratings were in the interior portion of the Skeena, Cariboo, and Thompson–Okanagan natural resource regions. Conversely, the status of watersheds in the coastal portion of the Skeena Region scored better than those in the interior, with a high proportion of low risk ratings, and a small number of moderate or high risk ratings across all habitat indicators. Watersheds in the South Coast Natural Resource Region appeared to be the least affected by habitat disturbances with a consistently high proportion of low risk ratings, and with only a limited number of moderate or high risk ratings for the “stream crossing density” and “road density near streams” indicators (see Discussion below for important contextual information to data presented here).

⁶ Total equivalent clearcut area, which includes all forms of disturbance, is incorporated directly into the peak flow index.

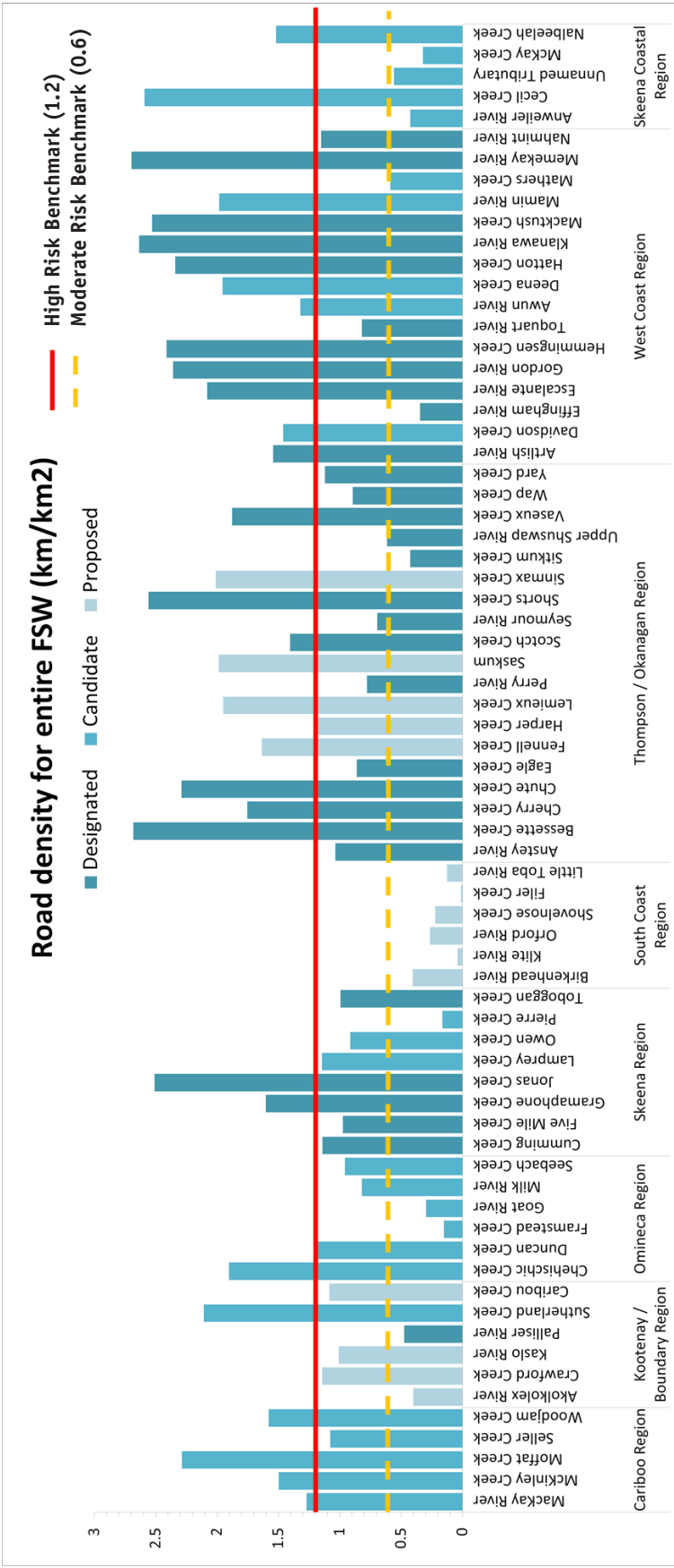


Figure 3. Road density (km/km²) for the entire watershed within British Columbia's regional fisheries sensitive watersheds (designated, candidate, and proposed).

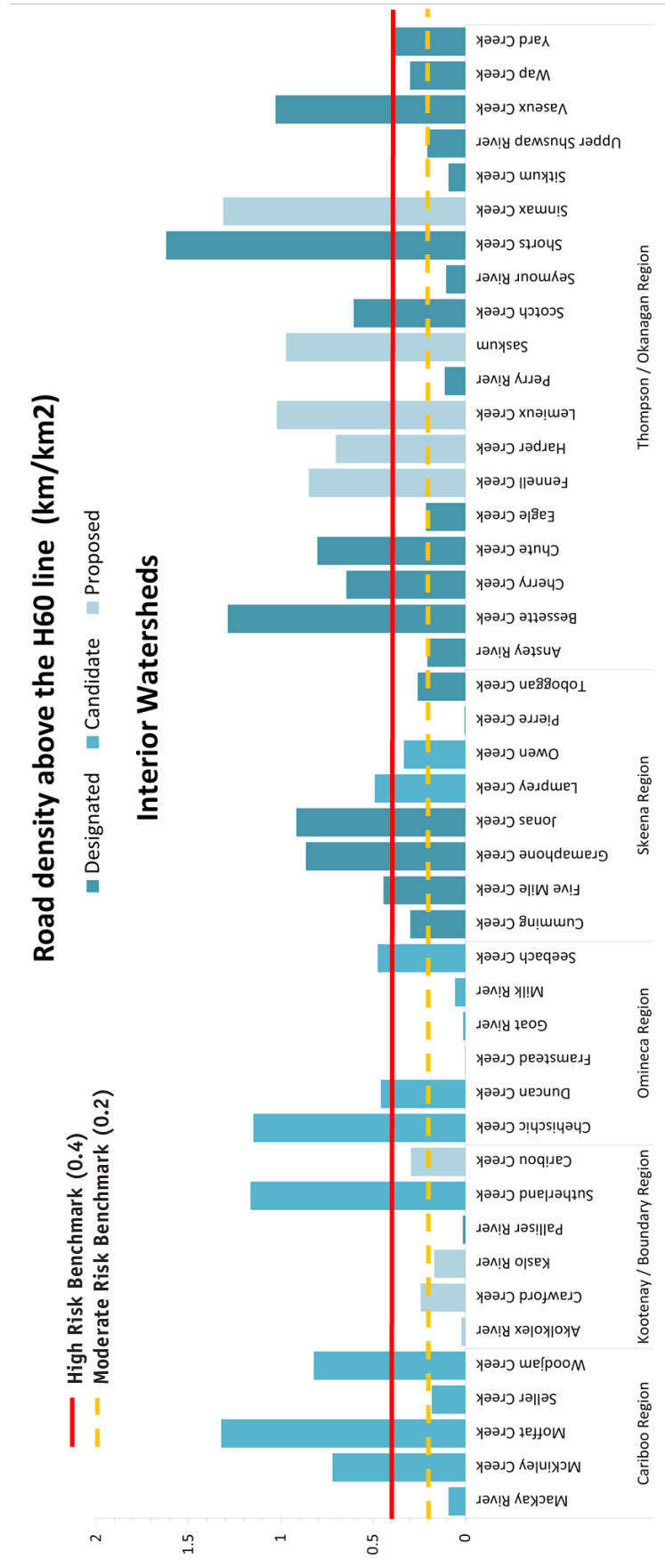


Figure 4. Road density (km/km²) above the H₆₀ line for fisheries sensitive watersheds (designated, candidate, and proposed) in British Columbia's interior natural resource regions. Note that this indicator/associated risk benchmark is not applicable to coastal watersheds.

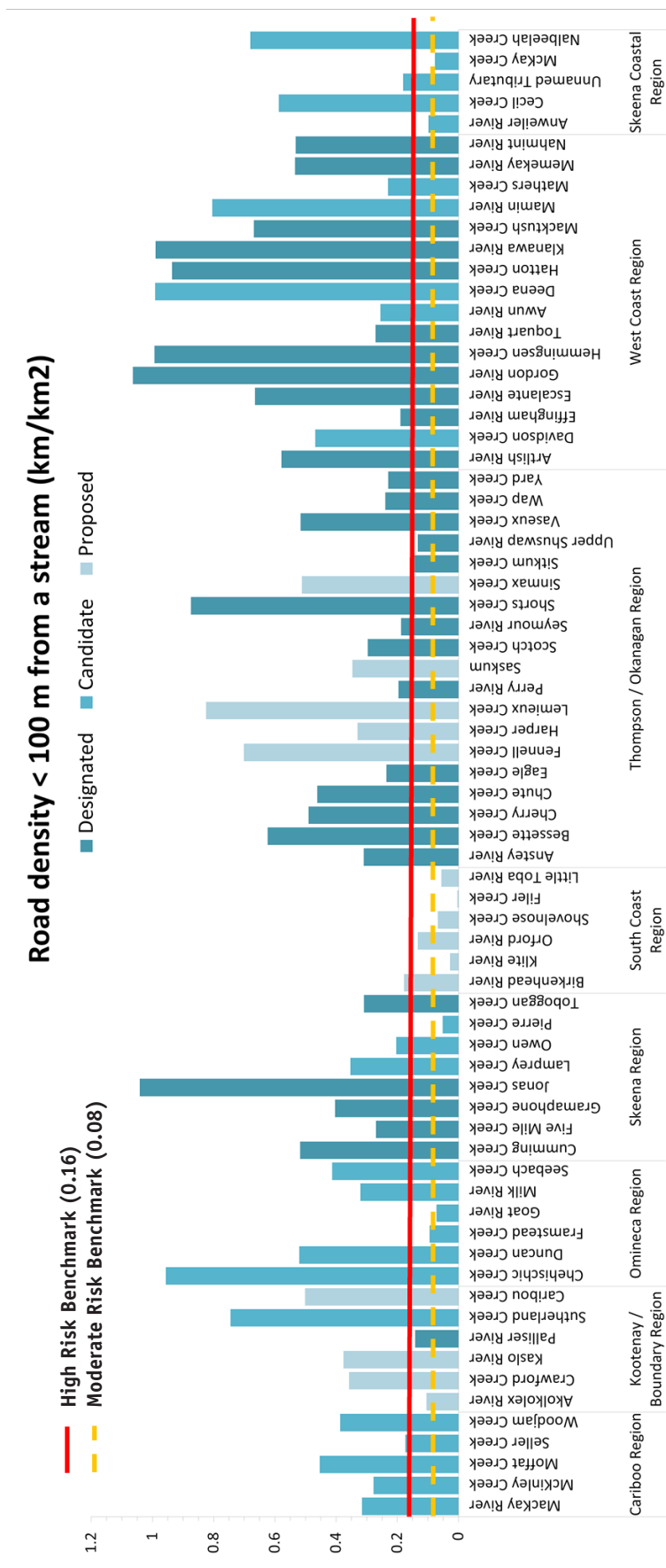


Figure 5. Road density (km/km²) less than 100 m from a stream for British Columbia's fisheries sensitive watersheds (designated, candidate, and proposed).

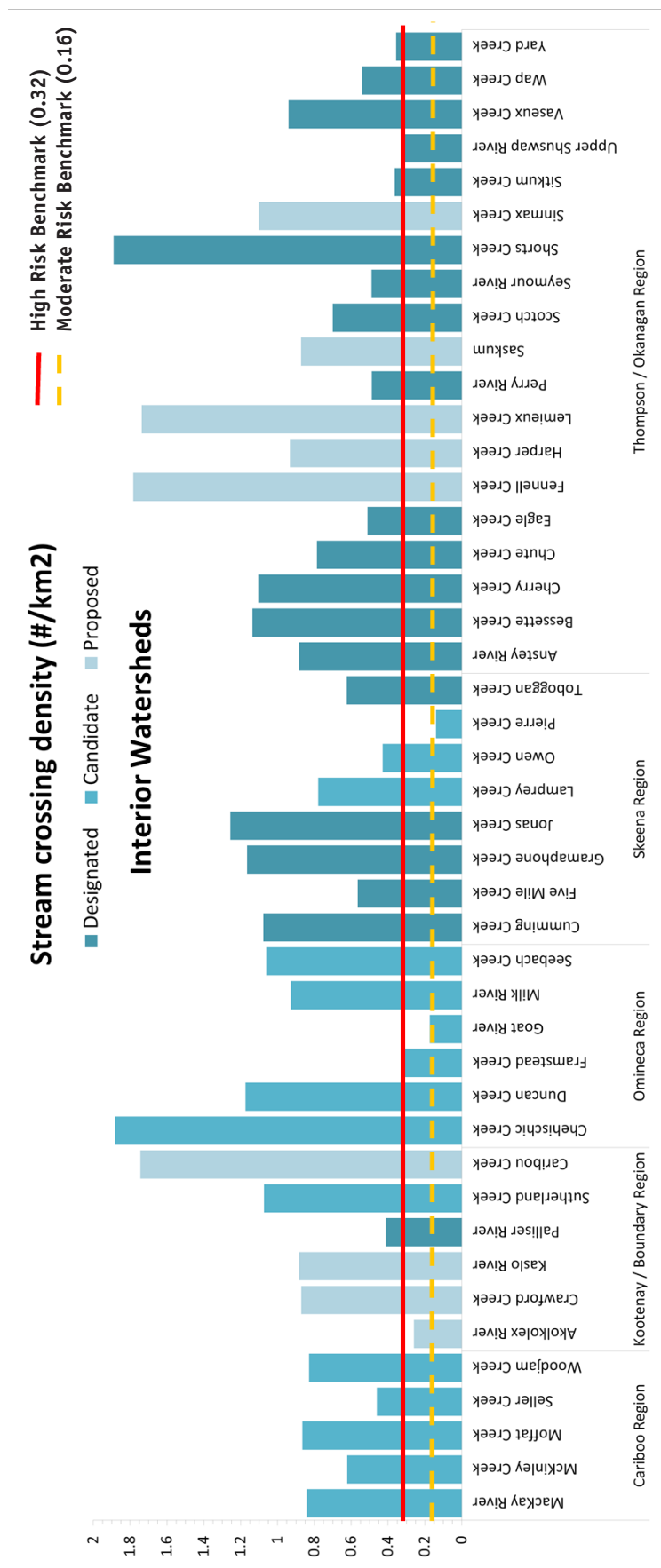


Figure 6. Stream crossing density (number per km²) for fisheries sensitive watersheds (designated, candidate, and proposed) in British Columbia's interior natural resource regions.

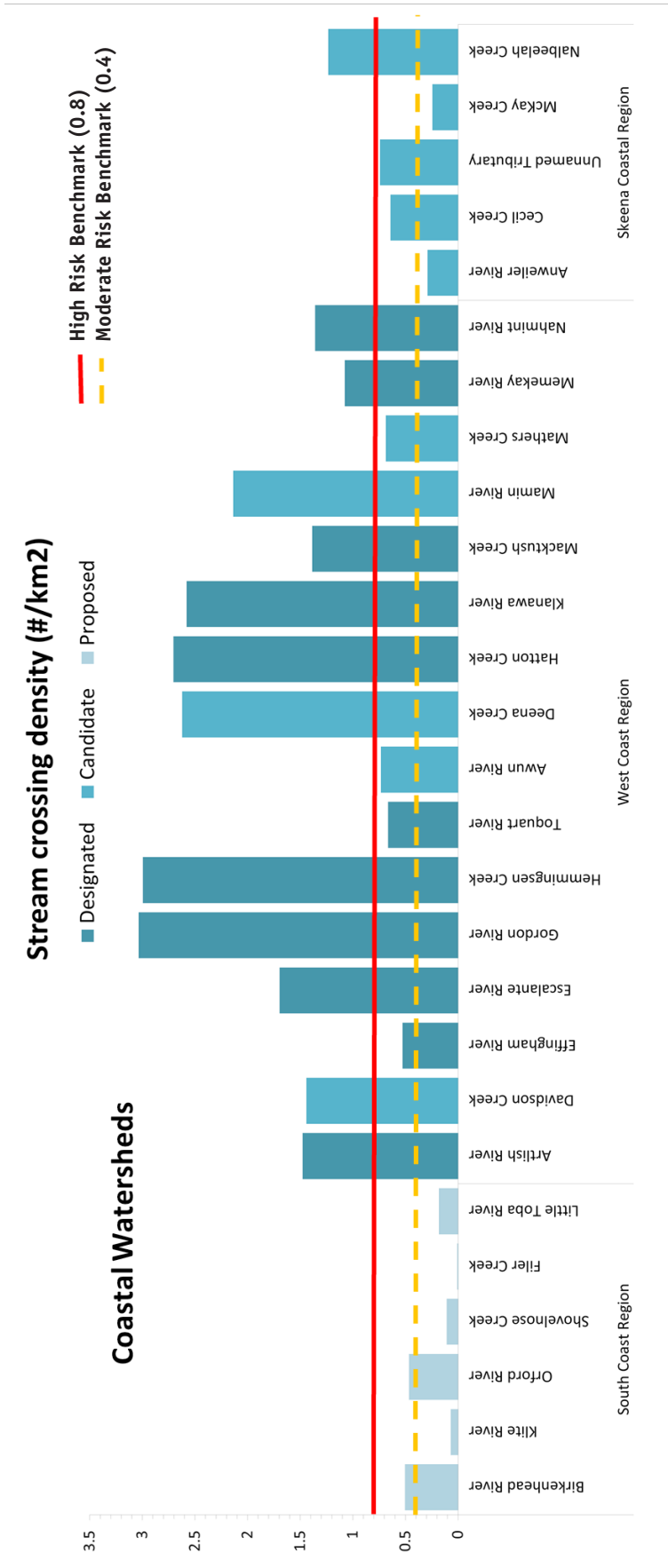


Figure 7. Stream crossing density (number per km²) for fisheries sensitive watersheds (designated, candidate, and proposed) in British Columbia's coastal natural resource regions.

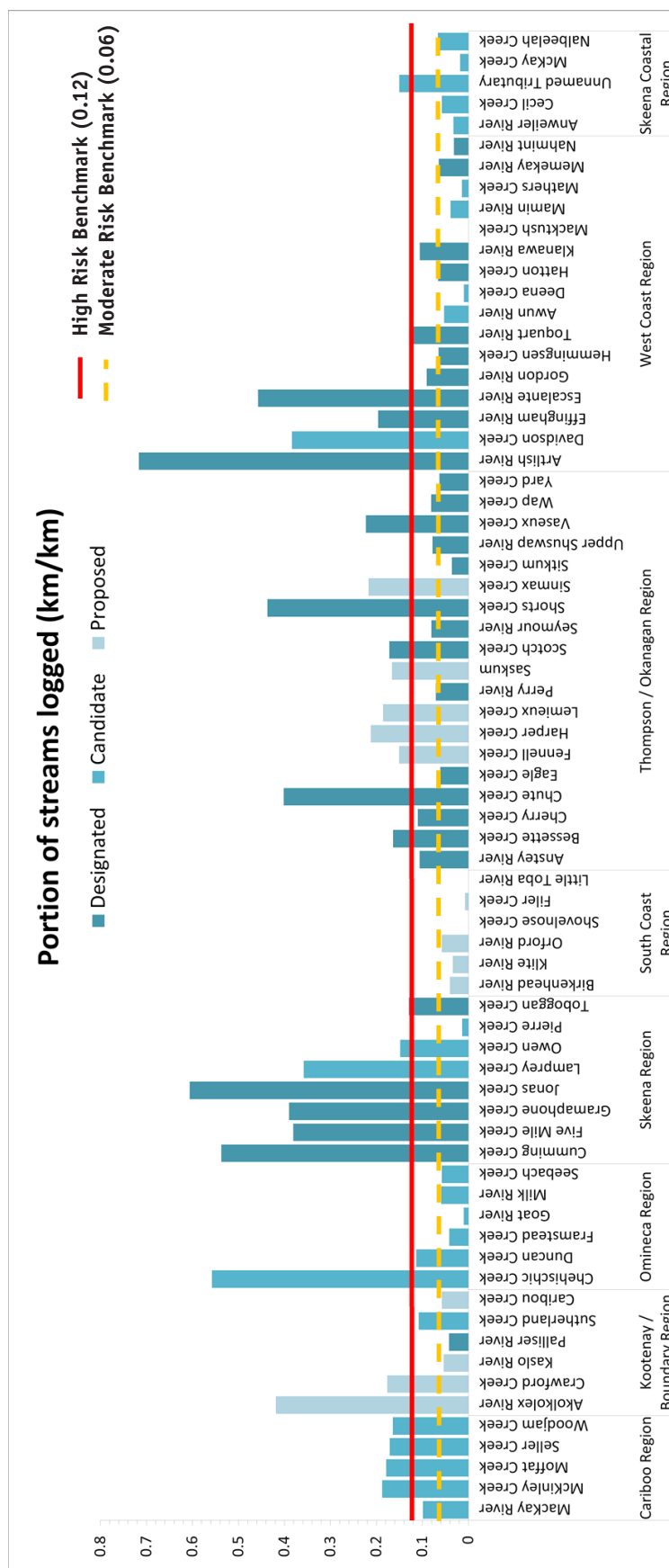


Figure 8. Portion of streams logged (km/km) for British Columbia's regional fisheries sensitive watersheds (designated, candidate, and proposed).⁷

⁷ Because of currency and spatial coverage limitations of provincial GIS vegetation resource inventory data, some watersheds in this figure are depicted at a lower risk level than may be the case. This issue is addressed in Section 4.

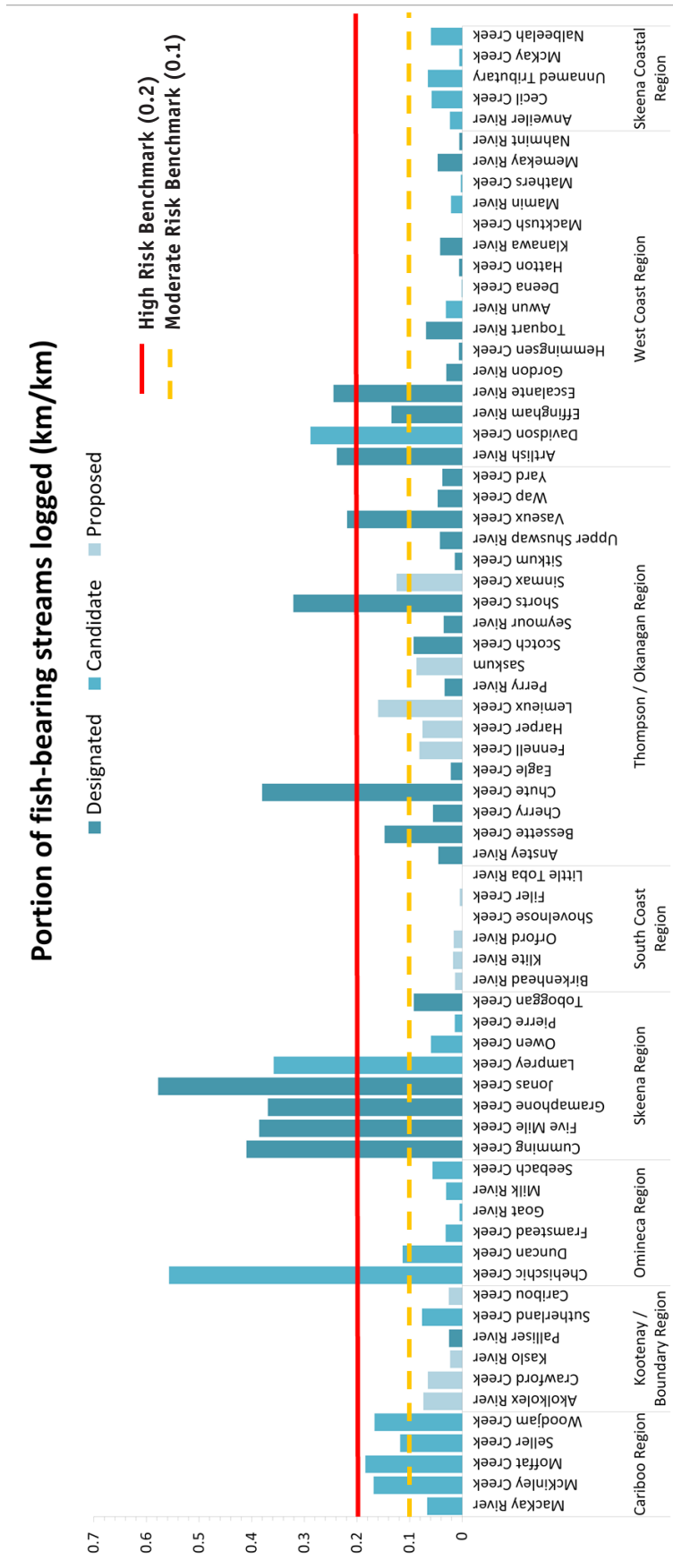


Figure 9. Portion of fish-bearing streams logged (km/km) for British Columbia's regional fisheries sensitive watersheds (designated, candidate, and proposed). Fish-bearing status (observed and inferred) was determined for the analysis using the province's modelled fish habitat GIS layer (Mount et al. 2011).⁸

8 Because of currency and spatial coverage limitations of provincial GIS vegetation resource inventory data, some watersheds in this figure are depicted at a lower risk level than may be the case. This issue is addressed in Section 4.

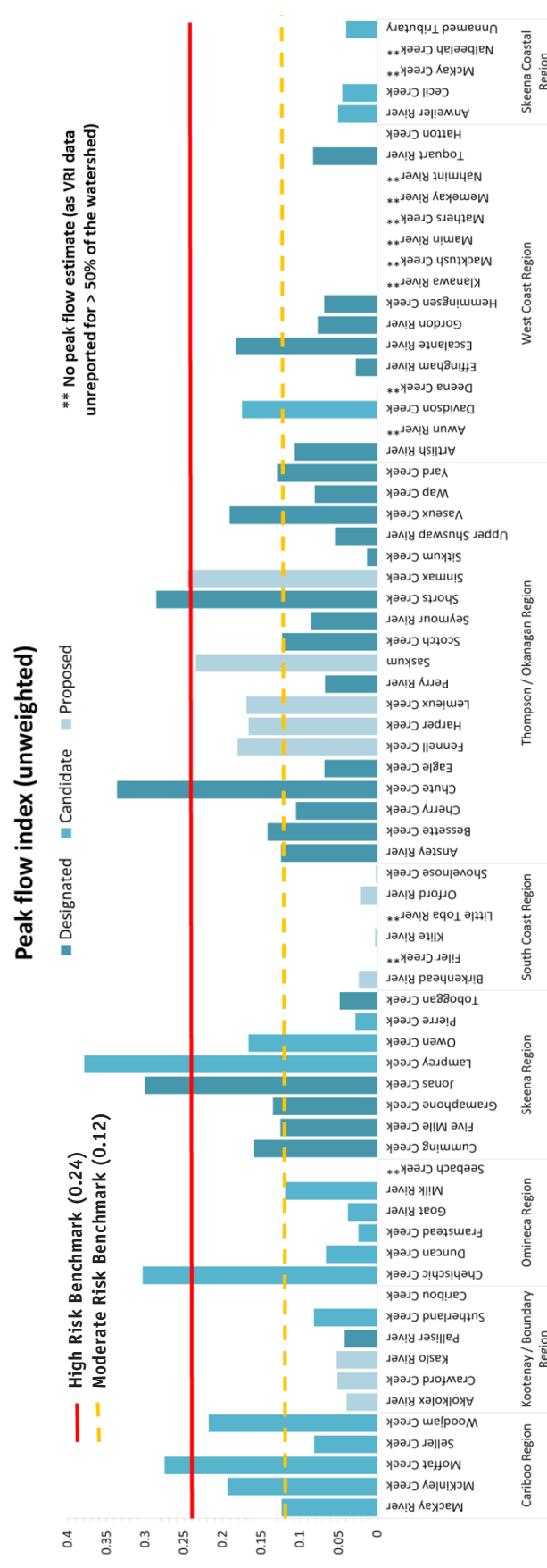


Figure 10. Peak flow index values (0–1) for British Columbia's regional fisheries sensitive watersheds (designated, candidate, and proposed).

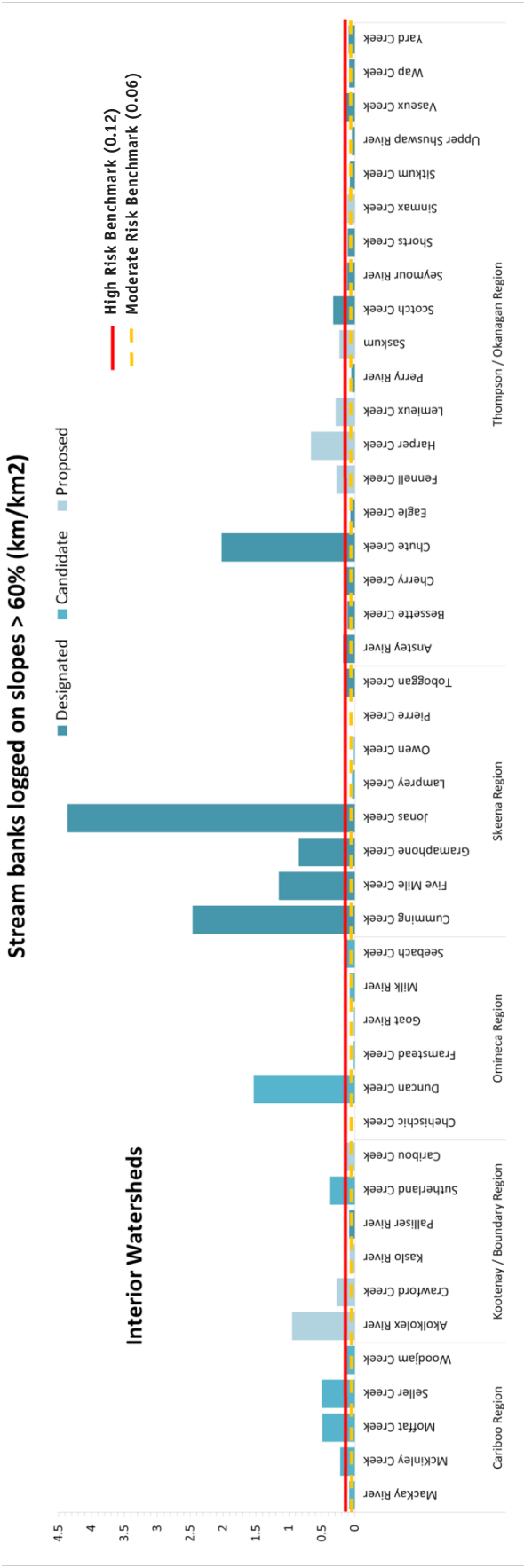


Figure 11. Stream banks logged (km/km²) on slopes greater than 60% for fisheries sensitive watersheds (designated, candidate, and proposed) in British Columbia's interior natural resource regions.

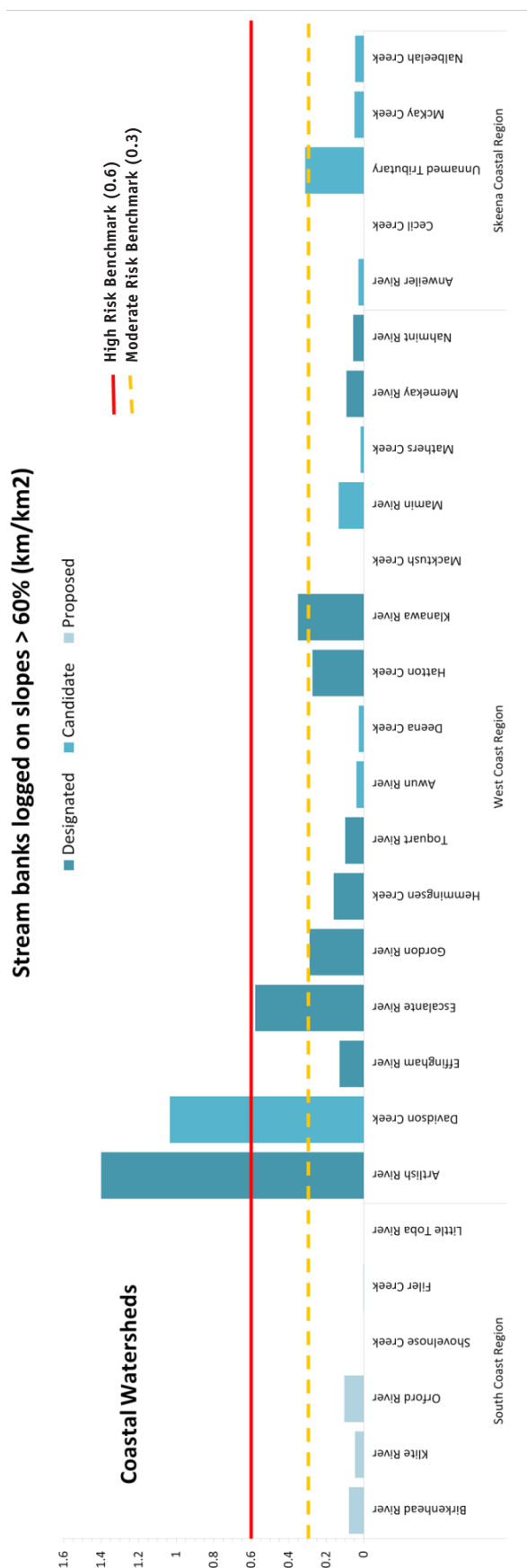


Figure 12. Stream banks logged (km/km²) on slopes greater than 60% for fisheries sensitive watersheds (designated, candidate, and proposed) in British Columbia's coastal natural resource regions.

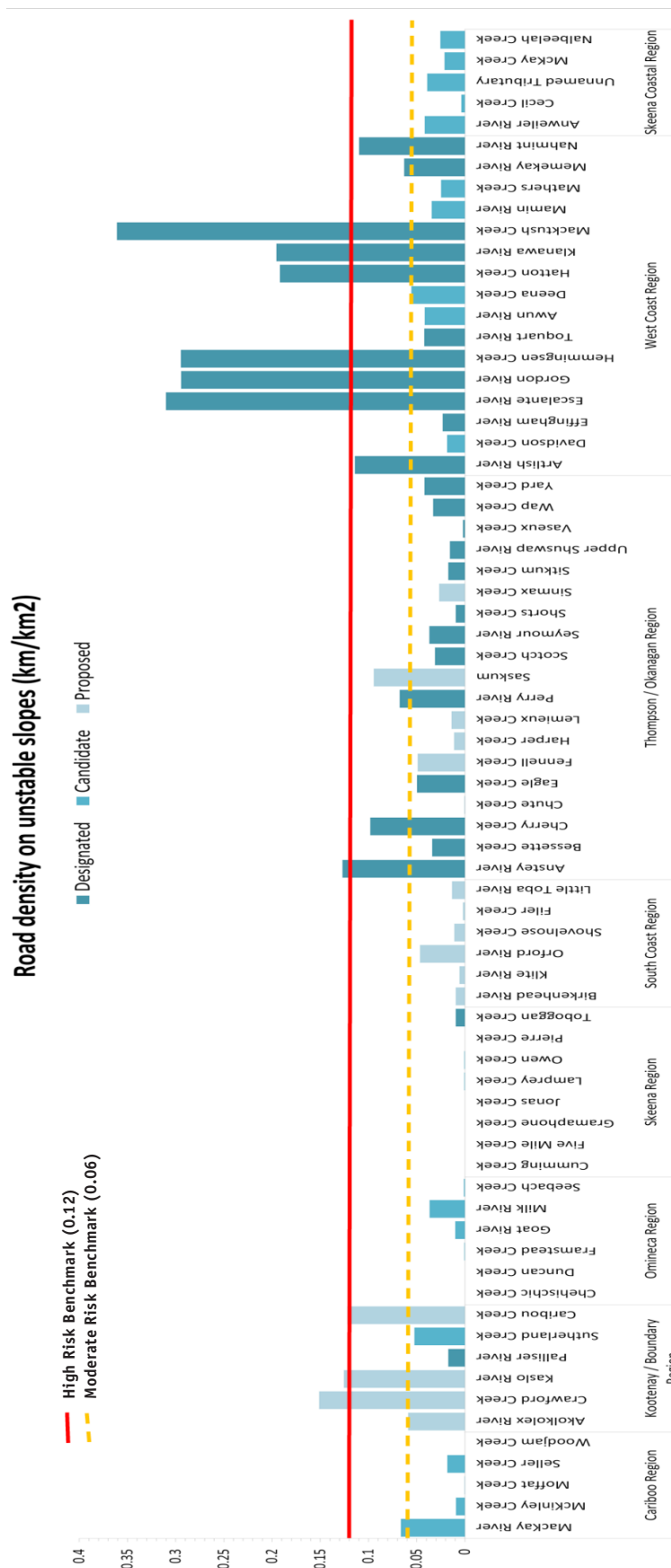


Figure 13. Road density (km/km²) on unstable slopes for fisheries sensitive watersheds (designated, candidate, and proposed). Note that a coarse surrogate for unstable slopes is used in this analysis (i.e., slopes > 60% are used to represent unstable slopes) in the absence of any current provincial-scale GIS layer directly depicting slope stability.

Table 2. Habitat risk status ratings (green = low risk, amber = moderate risk, red = high risk) for WSE Tier I habitat indicators measured in 71 provincial fisheries sensitive watersheds (designated, candidate, and proposed). Benchmark values used for assigning status of each habitat indicator are defined in the watershed status evaluation Tier I protocol (Porter et al. 2013). Benchmark values for some habitat indicators vary by region (i.e., coastal vs. interior watersheds). Note that a peak flow index (unweighted) value was not calculated if more than 50% of the watershed area lacked Vegetation Resource Inventory reporting (indicated by "null").⁹

Watershed name	Status	Region	Road density for entire FSW (km/km ²)	Road density above H ₆₀ line (km/km ²)	Road density < 100 m from stream (km/km ²)	Stream crossing density (#/km ²)	Portion of streams logged (km/km)	Portion of fish-bearing streams logged (km/km)	Stream banks logged on slopes > 60% (km/km ²)	Peak flow index (unweighted)	Road density on unstable slopes (km/km ²)
Akoklex River	Proposed	Kootenay-Boundary	0.40	0.02	0.10	0.26	0.42	0.07	0.95	0.04	0.06
Anstey River	Designated	Thompson-Okanagan	1.04	0.21	0.31	0.88	0.11	0.05	0.18	0.12	0.13
Anweiler River	Candidate	Skeena Coastal	0.43	NA	0.10	0.29	0.03	0.02	0.03	0.05	0.04
Artish River	Designated	West Coast	1.54	NA	0.58	1.48	0.72	0.24	1.40	0.11	0.11
Awun River	Candidate	West Coast	1.32	NA	0.26	0.73	0.05	0.03	0.04	null	0.04
Bessette Creek	Designated	Thompson-Okanagan	2.68	1.29	0.62	1.14	0.16	0.15	0.11	0.14	0.03
Birkenhead River	Proposed	South Coast	0.41	NA	0.18	0.50	0.04	0.01	0.08	0.02	0.01
Caribou Creek	Proposed	Kootenay-Boundary	1.08	0.29	0.50	1.74	0.06	0.03	0.13	null	0.12
Cecil Creek	Candidate	Skeena Coastal	2.59	NA	0.59	0.64	0.06	0.06	0.00	0.05	0.00
Chehischic Creek	Candidate	Omineca	1.90	1.15	0.96	1.88	0.56	0.56	0.00	0.30	0.00
Cherry Creek	Designated	Thompson-Okanagan	1.75	0.64	0.49	1.11	0.11	0.06	0.16	0.11	0.10
Chute Creek	Designated	Thompson-Okanagan	2.29	0.80	0.46	0.79	0.40	0.38	2.02	0.34	0.00
Crawford Creek	Proposed	Kootenay-Boundary	1.14	0.24	0.36	0.87	0.18	0.07	0.27	0.05	0.15
Cumming Creek	Designated	Skeena	1.14	0.30	0.52	1.08	0.54	0.41	2.46	0.16	0.00
Davidson Creek	Candidate	West Coast	1.46	NA	0.47	1.44	0.38	0.29	1.03	0.17	0.02

⁹ See Appendix 3 for a regional breakdown of the information in this table.

Watershed name	Status	Region	Road density for entire FSW (km/km ²)	Road density above H ₆₀ line (km/km ²)	Road density < 100 m from stream (km/km ²)	Stream crossing density (#/km ²)	Portion of streams logged (km/km)	Portion of fish-bearing streams logged (km/km)	Stream banks logged on slopes > 60% (km/km ²)	Peak flow index (unweighted)	Road density on unstable slopes (km/km ²)
Deena Creek	Candidate	West Coast	1.96	NA	0.99	2.62	0.01	0.00	0.03	null	0.06
Duncan Creek	Candidate	Omineca	1.20	0.46	0.52	1.17	0.11	0.11	1.53	0.07	0.00
Eagle Creek	Designated	Thompson-Okanagan	0.86	0.21	0.24	0.51	0.06	0.02	0.07	0.07	0.05
Effingham River	Designated	West Coast	0.35	NA	0.19	0.53	0.20	0.13	0.13	0.03	0.02
Escalante River	Designated	West Coast	2.08	NA	0.67	1.70	0.46	0.24	0.58	0.18	0.31
Fennell Creek	Proposed	Thompson-Okanagan	1.63	0.85	0.70	1.78	0.15	0.08	0.28	0.18	0.05
Filer Creek	Proposed	South Coast	0.01	NA	0.00	0.01	0.01	0.00	0.00	null	0.00
Five Mile Creek	Designated	Skeena	0.97	0.44	0.27	0.57	0.38	0.39	1.15	0.13	0.00
Framstead Creek	Candidate	Omineca	0.15	0.00	0.09	0.33	0.04	0.03	0.02	0.02	0.00
Goat River	Candidate	Omineca	0.30	0.01	0.07	0.17	0.01	0.01	0.01	0.04	0.01
Gordon River	Designated	West Coast	2.36	NA	1.06	3.04	0.09	0.03	0.29	0.08	0.29
Gramophone Creek	Designated	Skeena	1.60	0.86	0.40	1.17	0.39	0.37	0.85	0.13	0.00
Harper Creek	Proposed	Thompson-Okanagan	1.18	0.70	0.33	0.93	0.21	0.08	0.66	0.17	0.01
Hatton Creek	Designated	West Coast	2.34	NA	0.94	2.70	0.07	0.01	0.27	null	0.19
Hemmingsen Creek	Designated	West Coast	2.41	NA	0.99	3.00	0.06	0.01	0.16	0.07	0.29
Jonas Creek	Designated	Skeena	2.51	0.92	1.04	1.26	0.61	0.58	4.36	0.30	0.00
Kaslo River	Proposed	Kootenay-Boundary	1.01	0.17	0.38	0.88	0.05	0.02	0.08	0.05	0.13
Klanawa River	Designated	West Coast	2.64	NA	0.99	2.58	0.11	0.04	0.35	null	0.20
Klite River	Proposed	South Coast	0.04	NA	0.03	0.07	0.03	0.02	0.05	0.00	0.01
Lamprey Creek	Candidate	Skeena	1.14	0.49	0.35	0.78	0.36	0.36	0.04	0.38	0.00
Lemieux Creek	Proposed	Thompson-Okanagan	1.95	1.02	0.82	1.74	0.19	0.16	0.29	0.17	0.01
Little Toba River	Proposed	South Coast	0.13	NA	0.06	0.18	0.00	0.00	0.00	null	0.01
Mackay River	Candidate	Cariboo	1.27	0.09	0.32	0.84	0.10	0.07	0.09	0.12	0.07

Watershed name	Status	Region	Road density for entire FSW (km/km ²)	Road density above H ₆₀ line (km/km ²)	Road density < 100 m from stream (km/km ²)	Stream crossing density (#/km ²)	Portion of streams logged (km/km)	Portion of fish-bearing streams logged (km/km)	Stream banks logged on slopes > 60% (km/km ²)	Peak flow index (unweighted)	Road density on unstable slopes (km/km ²)
Macktush Creek	Designated	West Coast	2.53	NA	0.67	1.39	0.00	0.00	0.00	null	0.36
Mamin River	Candidate	West Coast	1.98	NA	0.80	2.14	0.04	0.02	0.13	null	0.03
Mathers Creek	Candidate	West Coast	0.59	NA	0.23	0.69	0.01	0.00	0.02	null	0.02
McKay Creek	Candidate	Skeena Coastal	0.32	NA	0.08	0.24	0.02	0.01	0.05	null	0.02
McKinley Creek	Candidate	Cariboo	1.50	0.72	0.28	0.62	0.19	0.17	0.22	0.19	0.01
Memekay River	Designated	West Coast	2.70	NA	0.53	1.08	0.06	0.05	0.09	null	0.06
Milk River	Candidate	Omineca	0.82	0.06	0.32	0.93	0.06	0.03	0.08	0.12	0.04
Moffat Creek	Candidate	Cariboo	2.29	1.32	0.45	0.86	0.18	0.18	0.49	0.28	0.00
Nahmint River	Designated	West Coast	1.15	NA	0.53	1.36	0.03	0.01	0.06	null	0.11
Nalbeelah Creek	Candidate	Skeena Coastal	1.52	NA	0.68	1.23	0.07	0.06	0.05	null	0.03
Orford River	Proposed	South Coast	0.27	NA	0.13	0.47	0.06	0.02	0.10	0.02	0.05
Owen Creek	Candidate	Skeena	0.91	0.33	0.20	0.43	0.15	0.06	0.01	0.17	0.00
Palliser River	Designated	Kootenay-Boundary	0.47	0.01	0.14	0.41	0.04	0.03	0.08	0.04	0.02
Perry River	Designated	Thompson-Okanagan	0.78	0.11	0.20	0.49	0.07	0.03	0.05	0.07	0.07
Pierre Creek	Candidate	Skeena	0.16	0.01	0.05	0.14	0.01	0.01	0.00	0.03	0.00
Saskum	Proposed	Thompson-Okanagan	1.99	0.97	0.35	0.87	0.17	0.09	0.23	0.23	0.09
Scotch Creek	Designated	Thompson-Okanagan	1.41	0.61	0.30	0.70	0.17	0.09	0.33	0.12	0.03
Seebach Creek	Candidate	Omineca	0.96	0.47	0.41	1.06	0.06	0.06	0.14	null	0.00
Seller Creek	Candidate	Cariboo	1.08	0.18	0.17	0.46	0.17	0.12	0.50	0.08	0.02
Seymour River	Designated	Thompson-Okanagan	0.69	0.10	0.19	0.49	0.08	0.04	0.12	0.09	0.04
Shorts Creek	Designated	Thompson-Okanagan	2.56	1.62	0.87	1.89	0.44	0.32	0.11	0.29	0.01
Shovelnose Creek	Proposed	South Coast	0.22	NA	0.07	0.11	0.00	0.00	0.00	0.00	0.01
Sinmax Creek	Proposed	Thompson-Okanagan	2.01	1.31	0.51	1.10	0.22	0.12	0.11	0.25	0.03

Watershed name	Status	Region	Road density for entire FSW (km/km ²)	Road density above H ₆₀ line (km/km ²)	Road density < 100 m from stream (km/km ²)	Stream crossing density (#/km ²)	Portion of streams logged (km/km)	Portion of fish-bearing streams logged (km/km)	Stream banks logged on slopes > 60% (km/km ²)	Peak flow index (unweighted)	Road density on unstable slopes (km/km ²)
Sitkum Creek	Designated	Thompson-Okanagan	0.42	0.09	0.14	0.36	0.04	0.01	0.07	0.01	0.02
Sutherland Creek	Candidate	Kootenay-Boundary	2.11	1.16	0.75	1.07	0.11	0.08	0.37	0.08	0.05
Toboggan Creek	Designated	Skeena	0.99	0.26	0.31	0.62	0.13	0.09	0.16	0.05	0.01
Toquart River	Designated	West Coast	0.82	NA	0.27	0.67	0.13	0.07	0.10	0.08	0.04
Unnamed Tributary	Candidate	Skeena Coastal	0.56	NA	0.18	0.74	0.15	0.07	0.31	0.04	0.04
Upper Shuswap River	Designated	Thompson-Okanagan	0.62	0.21	0.13	0.31	0.08	0.04	0.04	0.05	0.02
Vaseux Creek	Designated	Thompson-Okanagan	1.88	1.03	0.52	0.94	0.22	0.22	0.14	0.19	0.00
Wap Creek	Designated	Thompson-Okanagan	0.89	0.30	0.24	0.54	0.08	0.05	0.09	0.08	0.03
Woodjam Creek	Candidate	Cariboo	1.58	0.82	0.39	0.83	0.16	0.17	0.14	0.22	0.00
Yard Creek	Designated	Thompson-Okanagan	1.12	0.39	0.23	0.36	0.06	0.04	0.09	0.13	0.04

4.0 DISCUSSION

Application of the Tier I risk evaluation protocol (Porter et al. 2013) described here represents a broad-scale, GIS-based assessment procedure used to evaluate the status of 71 British Columbia watersheds with significant fish values and sensitivity. The results from this study show that varying levels of human development activities and, in some cases, compounding natural disturbances, represent a wide range of risk levels to fish and fish habitat in these watersheds. Additionally, the application of this protocol demonstrates the utility and benefits that can be derived from such analysis as a natural resource management tool. The protocol, and information derived from it, can be used to help:

- consolidate essential geographic information from various sources in a way that clearly provides indications of relative levels of risk;
- make quick cross-comparisons between and within watersheds;
- prioritize and realize cost efficiencies by identifying watersheds that require further on-the-ground monitoring activities, research, or restoration opportunities; and
- conduct risk-related trend monitoring using a consistent and repeatable method.

Information of this nature, presented in the format used here, is beneficial to several audiences and users. For example, such information can help inform sound natural resource decisions at appropriate spatial scales. Resource managers may consider this information during resource allocation, mitigation, or offsetting discussions related to management activities in various types of watersheds (i.e., via a scan of indicator results), or as part of a program of long-term trend monitoring to better understand change. In addition, this method of GIS-based monitoring is of benefit to policy makers, First Nations, industry, and the public as a user-friendly approach to data presentation, by helping to serve as a basis for understanding watershed risk, policy strengths or deficiencies, and to stimulate further discussion, engagement, and future work.

While the WSE Tier I methods (Porter et al. 2013) used to generate habitat indicator metrics rely on the best currently available, broad-scale GIS data sourced from provincial and federal agencies, various uncertainties associated with this data may affect the quality and reliability of the derived habitat indicator risk information. Consequently, certain analytical caveats should be considered when interpreting habitat risk ratings. These caveats are related to spatial and temporal inaccuracies in current GIS base data and subsequent representations of the watershed characteristics used to summarize habitat risk indicator information. Examples of these data deficiencies are discussed below.

4.1 GIS Data Deficiencies

Several WSE Tier I habitat indicators rely on accurate mapping of roads, streams, and forest cover (i.e., road density for the entire FSW, road density above the H_{60} line, road density less than 100 m from a stream, stream crossing density, portion of streams logged, portion of fish-bearing streams logged, road density on unstable slopes). Although the methods used for this analysis consolidated all broadly available provincial road data into a single composite roads layer, initial field assessments suggest that a variable and uncertain amount of both new and older (e.g., abandoned or decommissioned) roads have likely not been identified and therefore not quantified across surveyed watersheds (L. Reese-Hansen, Habitat Management Branch, B.C. Ministry of Forests, Lands and Natural Resource Operations, pers. comm., February, 2013). Furthermore, the spatial depictions of roads between data sources relative to their actual location on-the-ground may vary significantly, affecting important indicators such as road density less than 100 m from a stream. Ongoing work by GeoBC staff should eliminate most of these data issues (Ogborne and Hlasny 2014).

Mapped representations of streams in the FSWs were based on the hydrology GIS layer in the province's 1:20 000 *Freshwater Atlas*.¹⁰ Although this source provides the most comprehensive and accurate depiction of stream networks in British Columbia, many smaller streams are not captured even within this GIS layer. An example of the significance of this deficiency is its effect on estimates of potential fish passage constraints using stream crossing

10 See <http://geobc.gov.bc.ca/base-mapping/atlas/fwa/index.html>.

densities along the fluvial margins of large streams, where important small fish streams are not captured by the provincial *Freshwater Atlas* and thus will not be captured using this GIS layer. This will result in an underestimate of the fish passage constraints. Consequently, the full extent of unquantified stream densities in our analyses is unknown and likely varies by topographic form and region.

Several WSE Tier I habitat indicators rely on data sets that depict the extent and location of past logging activities in a watershed (i.e., portion of streams logged, portion of fish-bearing streams logged, stream banks logged on slopes greater than 60%, and peak flow index). The Porter et al. (2013) methodology used for this analysis involves an amalgamation of all provincial government forestry information available at the time of analysis (i.e., Vegetation Resource Inventory, RESULTS, Forest Tenures Roads layers). Even with this amalgamation of forestry information, several field assessments have shown it to under-represent the total extent of harvesting within some tenures (e.g., Tree Farm Licensees) and historic harvesting generally, especially with increasing age (L. Reese-Hansen, Habitat Management Branch, B.C. Ministry of Forests, Lands and Natural Resource Operations, pers. comm. February, 2013).

Although a significant improvement to the Vegetation Resource Inventory-based information used in the current WSE Tier I protocol, these shortcomings also apply to the province's newly available Consolidated Cut Blocks GIS layer, which brings together the same VRI, RESULTS, and FTEN information used in the current WSE Tier I protocol, but also supplements these data with LANDSAT satellite imagery analysis identifying additional logging activities outside the currently defined cutblock boundaries. This layer provides a more accurate base for future assessments of logging-related Tier I habitat indicators, but the supplemental information from the LANDSAT imagery analysis only extends back to 2000 (Ann Morrison, Forest Inventory and Analysis Branch, B.C. Ministry of Forests, Lands and Natural Resource Operations, pers. comm., May 2014). An initial review of this layer indicates that in some watersheds a considerable amount of historic logging occurred before 2000 and therefore remains unidentified (L. Reese-Hansen, Habitat Management Branch, B.C. Ministry of Forests, Lands and Natural Resource Operations, pers. comm., May 2014).

Road-related mass wasting can have a significant impact on fish habitat. Because provincial-scale mapping of terrain stability is not currently available, unstable slopes

within our analyses (i.e., for calculating the habitat indicator "road density on unstable slopes") were defined using a coarse surrogate of terrain stability (i.e., slopes > 60%). Consequently, an inherent amount of uncertainty exists in the assessment of this indicator and it serves only as a coarse indication of road-related mass wasting risk.

Given the broad-brush nature of our analysis, the peak flow index indicator was determined by employing an unweighted equivalent clearcut area calculation across all watersheds. This provides a quick, repeatable index that may be further refined locally if forest alteration in various elevational zones (e.g., rain-on-snow zones) was determined to have a greater influence on peak flows. Watersheds that are contained entirely or partially within tree farm licence areas presented data challenges because VRI information is either not currently available or exists for only a portion of these watersheds. If VRI data was available across at least 50% of a watershed's total area, an assessment of an unweighted equivalent clearcut area and peak flow index was conducted based on the existing VRI data. Extrapolation from a subset of VRI data to an entire watershed introduces greater uncertainty to the calculation of a final peak flow index. Improving the currency and completion of a contiguous provincial VRI coverage to avoid "work-arounds" of this type will improve the accuracy of future peak flow calculations.

The analytical proficiency of modern GIS spatial tools is easily capable of the type of analysis conducted in this WSE Tier I evaluation. The limitations to this type of analysis exist primarily with the base data. Despite the various uncertainties inherent in current databases and GIS layers supporting watershed status evaluation Tier I assessments, the survey results and interpretations presented here are a good first step toward the development of more consistent and regularly repeated evaluations of broad habitat pressures acting across provincial FSWs. This assessment has helped to identify gaps in underlying data requirements and has flagged several priority needs for improvement.

Although known or suspected inaccuracies in Tier I indicator results are associated with the supporting GIS base data, this form of analysis still provides important and useful information to managers, decision makers, and other analysts. For example, an under-representation of many indicators (e.g., stream crossing, road density, or extent of logging) likely results in a lower risk rating than is warranted. Therefore, the watersheds identified

with habitat indicators categorized with a high risk rating are potentially at an even higher risk. More problematic, however, is that watersheds in the low-risk category may face more severe habitat pressures than is reflected through the currently available data. This outcome is not unique to this type of analysis and is an important factor in any analysis using the GIS data sets discussed above.

4.2 Recommendations

To improve the utility of future watershed status evaluation Tier I assessment, and other GIS-based forms of analysis, we make the following recommendations.

1. As a high government priority, improve critical GIS data layers

Given the accelerating pace of development in various parts of the province, and the utility of the methods described here, we recommend that provincial resource management agencies place a high priority on improving the accuracy, comprehensiveness, and reporting frequency of the underlying data sets and GIS-based information needed to inform WSE Tier I watershed monitoring indicators.

2. Expand the number of primary indicators

Consistent with the legacy of the province's original watershed assessment procedures (B.C. Ministry of Forests 1995a, 1995b), the focus of the current WSE

Tier I monitoring protocol is on forestry-related impacts within watersheds. Although many of these indicators are suitable for "cumulative effects" analysis, we recommend an expansion of the current list of measured indicators to include more possible stressors to fish habitat and water values.

3. Increase the frequency of field-based Tier II watershed condition assessments

A GIS analysis of watershed indicators can yield useful information about potential pressures or risks linked to development activities. Nevertheless, not all roads are built equally—a single kilometre of poorly built road may have a higher impact on fish habitat than many kilometres of well-built road. Accordingly, GIS measures alone do not reveal information about current, on-the-ground conditions. We therefore recommend the use of WSE Tier I monitoring as an overview analysis that will help highlight those areas in need of field-based Tier II analysis.

4. Adopt and improve watershed status evaluation Tier I monitoring

Regardless of the deficiencies discussed here, WSE Tier I risk analysis provides useful information about risks to watershed condition. We recommend the continued use of the current WSE Tier I protocol as a tool for the efficient and repeatable monitoring of watersheds across British Columbia.

LITERATURE CITED

B.C. Ministry of Forests. 1995a. Interior watershed assessment procedure guidebook. Forest Practices Code of British Columbia guidebook. <http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/iwap/iwap-toc.htm> (Accessed April 2015).

_____. 1995b. Coastal watershed assessment procedure guidebook (CWAP). Forest Practices Code of British Columbia guidebook. <http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/iwap/iwap-toc.htm> (Accessed April 2015).

_____. 1999. Watershed assessment procedure guidebook. 2nd ed., Version 2.1. Forest Practices Branch, Victoria, B.C. Forest Practices Code of British Columbia guidebook. <https://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/wap/WAPGdbk-Web.pdf> (Accessed April 2015).

Mount, C., S. Norris, R. Thompson, and D. Tesch. 2011. GIS modelling of fish habitat and road crossings for prioritizing of culvert assessment and remediation. Streamline Watershed Management Bulletin 14(2):7–13. http://www.forrex.org/sites/default/files/publications/articles/Streamline_Vol14_No2_art2.pdf (Accessed April 2015).

Ogborne, C. and B. Hlasny. 2014. The BC Resource Roads Integration Program: Adding ‘missing resource roads’ to the provincial corporate database. In: Resource roads

in British Columbia: Environmental challenges at the landscape level. Columbia Mountain Institute of Applied Biology, Revelstoke, B.C. pp. 102–109. http://cmiae.org/wp-content/uploads/Resource-Roads-conference-2014-summary_FINAL_3.pdf (Accessed April 2015).

Pickard, D., M. Porter, L. Reese-Hansen, R. Thompson, D. Tripp, B. Carson, P. Tschaplinski, T. Larden, and S. Casley. 2014. Fish values: Watershed status evaluation. B.C. Ministry of Forests, Lands and Natural Resource Operations and B.C. Ministry of the Environment, Victoria, B.C. Draft Version 1.0. https://www.for.gov.bc.ca/hfp/frep/values/watersheds/140402%20WSE%20Protocol%20April%2002_14.pdf (Accessed April 2015).

Porter, M., S. Casley, Darcy Pickard, E. Snead, and K. Wieckowski. 2013. Tier I watershed status evaluation protocol. B.C. Ministry of Forests, Lands and Natural Resource Operations and B.C. Ministry of the Environment, Victoria, B.C. Draft Version 3.1. https://www.for.gov.bc.ca/hfp/frep/values/watersheds/Tier%201%20watershed%20values%20monitoring%20protocol_V3.2_May24_2013.pdf (Accessed April 2015).

Reese-Hansen, L. and E. Parkinson. 2006. Evaluating and designating Fisheries Sensitive Watersheds: An overview of B.C.’s new FSW procedure. B.C. Ministry of Environment, Victoria, B.C. Draft. <http://www.env.gov.bc.ca/wld/documents/fsw/FSW%202006%20Information%20Paper%20v1.1.pdf> (Accessed April 2015).

APPENDICES

Appendix 1. Attribute information for 71 provincial fisheries sensitive watersheds (designated, candidate, and proposed) assessed using watershed status evaluation Tier I protocols.^{11,12}

Watershed name	Watershed identifier #	Area (km ²)	Natural resource region	Regulatory status
MacKay River	38	143.7	Cariboo	Candidate
McKinley Creek	43	453.5	Cariboo	Candidate
Moffat Creek	46	552.6	Cariboo	Candidate
Seller Creek	57	89.0	Cariboo	Candidate
Woodjam Creek	70	91.7	Cariboo	Candidate
Akolkolex River	1	390.1	Kootenay–Boundary	Proposed
Caribou Creek	8	529.1	Kootenay–Boundary	Proposed
Crawford Creek	13	187.2	Kootenay–Boundary	Proposed
Kaslo River	32	450.8	Kootenay–Boundary	Proposed
Palliser River	51	428.1	Kootenay–Boundary	Designated
Sutherland Creek	64	93.2	Kootenay–Boundary	Candidate
Chehischic Creek	10	193.5	Omineca	Candidate
Duncan Creek	17	77.5	Omineca	Candidate
Framstead Creek	24	465.6	Omineca	Candidate
Seebach Creek	56	414.8	Omineca	Candidate
Goat River	25	472.6	Omineca	Candidate
Milk River	45	189.6	Omineca	Candidate
Anweiler River	3	116.6	Skeena (coastal)	Candidate
Cecil Creek	9	66.9	Skeena (coastal)	Candidate
Cumming Creek	14	30.7	Skeena (interior)	Designated
Five Mile Creek	23	44.2	Skeena (interior)	Designated
Gramophone Creek	27	60.9	Skeena (interior)	Designated
Jonas Creek	31	13.5	Skeena (interior)	Designated
Lamprey Creek	35	240.2	Skeena (interior)	Candidate
McKay Creek	42	139.9	Skeena (coastal)	Candidate
Nalbeelah Creek	48	51.8	Skeena (coastal)	Candidate
Owen Creek	50	212.4	Skeena (interior)	Candidate
Pierre Creek	53	93.1	Skeena (interior)	Candidate
Toboggan Creek	65	110.5	Skeena (interior)	Designated
Unnamed Tributary	67	72.7	Skeena (coastal)	Candidate
Birkenhead River	7	685.2	South Coast	Proposed
Filer Creek	22	565.5	South Coast	Proposed

11 This list represents watersheds that are either currently designated as fisheries sensitive watersheds, candidates for designation, or are known high-priority “proposed” watersheds with the requisite fish values and sensitivity. This list does not represent a complete list of all potential FSWs in the province.

12 For this analysis, FSWs in the Skeena Natural Resource Region have been separated into coastal versus interior watersheds based on their location; this reflects the markedly different biogeoclimatic zones across this region.

Watershed name	Watershed identifier #	Area (km ²)	Natural resource region	Regulatory status
Klite River	34	128.4	South Coast	Proposed
Little Toba River	37	306.5	South Coast	Proposed
Orford River	49	423.0	South Coast	Proposed
Shovelnose Creek	60	18.6	South Coast	Proposed
Anstey River	2	232.1	Thompson–Okanagan	Designated
Bessette Creek	6	554.5	Thompson–Okanagan	Designated
Cherry Creek	11	508.4	Thompson–Okanagan	Designated
Chute Creek	12	47.1	Thompson–Okanagan	Designated
Eagle Creek	18	344.3	Thompson–Okanagan	Designated
Fennell Creek	21	111.6	Thompson–Okanagan	Proposed
Harper Creek	28	185.6	Thompson–Okanagan	Proposed
Lemieux Creek	36	537.2	Thompson–Okanagan	Proposed
Perry River	52	436.3	Thompson–Okanagan	Designated
Saskum	54	215.5	Thompson–Okanagan	Proposed
Scotch Creek	55	588.1	Thompson–Okanagan	Designated
Seymour River	58	709.5	Thompson–Okanagan	Designated
Shorts Creek	59	155.6	Thompson–Okanagan	Designated
Upper Shuswap River	61	597.6	Thompson–Okanagan	Designated
Sinmax Creek	62	193.2	Thompson–Okanagan	Proposed
Sitkum Creek	63	101.7	Thompson–Okanagan	Designated
Vaseux Creek	68	280.7	Thompson–Okanagan	Designated
Wap Creek	69	357.9	Thompson–Okanagan	Designated
Yard Creek	71	120.6	Thompson–Okanagan	Designated
Artlish River	4	124.5	West Coast	Designated
Awun River	5	72.2	West Coast	Candidate
Davidson Creek	15	118.6	West Coast	Candidate
Deena Creek	16	67.5	West Coast	Candidate
Effingham River	19	60.5	West Coast	Designated
Escalante River	20	79.0	West Coast	Designated
Gordon River	26	307.7	West Coast	Designated
Hatton Creek	29	42.1	West Coast	Designated
Hemmingsen Creek	30	62.8	West Coast	Designated
Klanawa River	33	242.3	West Coast	Designated
Macktush Creek	39	28.1	West Coast	Designated
Mamin River	40	145.5	West Coast	Candidate
Mathers Creek	41	80.0	West Coast	Candidate
Memekay River	44	214.4	West Coast	Designated
Nahmint River	47	94.2	West Coast	Designated
Toquart River	66	102.1	West Coast	Designated

Appendix 2. Additional statistics for GIS-derived habitat indicators in 71 fisheries sensitive watersheds (designated, candidate, and proposed) across provincial management regions.¹³

Watershed name	Status	Region code	Region	Vegetation Resource Inventory unreported (%)	Riparian forest disturbed (%)	Forestry disturbed riparian (%)	Alienated disturbed riparian (%)	MPB (Beetle) disturbed riparian (%)	Fire disturbed riparian (%)	Total equivalent clearcut area (%)	Equivalent clearcut area from developed land (%)	Equivalent clearcut area from forestry (%)
Akolkolex River	Proposed	2	Kootenay–Boundary	0.04	43.09	42.30	0.16	0.00	0.63	3.97	0.24	3.73
Anstey River	Designated	6	Thompson–Okanagan	0.00	12.07	5.74	0.71	1.02	4.60	14.45	4.22	10.23
Anweiler River	Candidate	4	Skeena Coastal	7.89	3.15	2.89	0.23	0.00	0.03	5.10	0.37	4.32
Artlish River	Designated	7	West Coast	0.15	76.33	75.05	1.28	0.00	0.00	10.71	1.27	9.43
Awun River	Candidate	7	West Coast	92.76	4.46	4.07	0.39	0.00	0.00	null	null	2.75
Bessette Creek	Designated	6	Thompson–Okanagan	0.00	36.60	11.04	2.72	19.51	3.34	14.22	2.72	11.50
Birkenhead River	Proposed	5	South Coast	0.00	10.87	0.54	0.40	6.36	3.56	2.39	0.44	1.96
Caribou Creek	Proposed	2	Kootenay–Boundary	50.25	17.57	2.21	0.71	8.54	6.11	null	null	5.35
Cecil Creek	Candidate	4	Skeena Coastal	24.25	3.82	0.00	1.94	0.27	1.61	4.55	2.51	0.93
Chehischic Creek	Candidate	3	Omineca	0.00	71.65	32.41	1.81	36.32	1.11	30.40	1.77	28.63
Cherry Creek	Designated	6	Thompson–Okanagan	0.10	24.02	2.57	1.34	14.81	5.29	10.53	1.53	8.99
Chute Creek	Designated	6	Thompson–Okanagan	0.00	69.81	3.42	2.20	5.24	58.95	33.76	1.91	31.84
Crawford Creek	Proposed	2	Kootenay–Boundary	0.00	12.23	0.00	1.14	3.71	7.38	5.17	1.08	4.10
Cumming Creek	Designated	4	Skeena	0.00	23.58	4.86	0.89	17.83	0.00	15.93	0.98	14.95
Davidson Creek	Candidate	7	West Coast	0.00	8.56	7.82	0.74	0.00	0.00	17.53	0.86	16.67
Deena Creek	Candidate	7	West Coast	99.97	4.48	1.48	1.51	0.00	1.49	null	null	0.19
Duncan Creek	Candidate	3	Omineca	0.00	46.43	0.75	1.10	37.81	6.76	6.66	1.06	5.60
Eagle Creek	Designated	6	Thompson–Okanagan	0.01	12.16	1.53	1.17	0.08	9.37	8.15	2.77	5.38
Effingham River	Designated	7	West Coast	0.09	1.83	1.46	0.36	0.00	0.00	2.78	0.27	2.51
Escalante River	Designated	7	West Coast	29.08	17.74	14.98	1.81	0.00	0.95	18.32	1.68	11.31
Fennell Creek	Proposed	6	Thompson–Okanagan	2.64	46.53	5.12	1.33	22.52	17.55	19.40	4.43	14.46
Filer Creek	Proposed	5	South Coast	99.21	2.01	0.62	0.01	0.00	1.38	null	null	0.00
Five Mile Creek	Designated	4	Skeena	0.00	35.74	3.60	0.81	8.82	22.51	12.53	0.99	11.54

¹³ Yellow highlights represent FSWs with a large proportion (> 50%) of total area lacking Vegetation Resource Inventory reporting and for which equivalent clearcut area was not calculated (indicated by “null”).

Watershed name	Status	Region code	Region	Vegetation Resource Inventory unreported (%)	Riparian forest disturbed (%)	Forestry disturbed riparian (%)	Alienated disturbed riparian (%)	MPB (Beetle) disturbed riparian (%)	Fire disturbed riparian (%)	Total equivalent clearcut area (%)	Equivalent clearcut area from developed land (%)	Equivalent clearcut area from forestry (%)
Framstead Creek	Candidate	3	Omineca	0.00	5.54	4.91	0.13	0.13	0.38	2.45	0.09	2.35
Goat River	Candidate	3	Omineca	0.00	4.58	0.12	0.39	0.44	3.63	3.91	0.78	3.13
Gordon River	Designated	7	West Coast	29.80	19.06	2.11	2.34	0.00	14.61	8.10	2.52	3.16
Gramophone Creek	Designated	4	Skeena	0.00	41.84	11.17	0.97	29.71	0.00	13.52	1.28	12.24
Harper Creek	Proposed	6	Thompson–Okanagan	0.00	36.21	1.31	0.86	1.07	32.96	16.92	1.65	15.26
Hatton Creek	Designated	7	West Coast	52.38	7.74	6.10	1.64	0.00	0.00	null	null	7.02
Hemmingsen Creek	Designated	7	West Coast	1.20	9.76	5.18	1.73	0.00	2.85	14.75	10.46	4.11
Jonas Creek	Designated	4	Skeena	0.00	36.65	15.08	2.11	16.87	2.59	30.14	2.00	28.14
Kaslo River	Proposed	2	Kootenay–Boundary	0.00	25.08	0.79	1.04	3.48	19.77	5.27	0.97	4.30
Klanawa River	Designated	7	West Coast	98.06	12.42	11.18	1.24	0.00	0.00	null	null	3.84
Klute River	Proposed	5	South Coast	0.51	20.36	0.00	0.06	0.00	20.30	0.30	0.04	0.26
Lamprey Creek	Candidate	4	Skeena	0.00	57.99	15.98	1.05	39.03	1.93	37.91	1.01	36.90
Lemieux Creek	Proposed	6	Thompson–Okanagan	0.40	64.93	11.04	2.37	50.94	0.58	16.94	2.24	14.63
Little Toba River	Proposed	5	South Coast	99.83	1.41	0.00	0.13	0.00	1.28	null	null	10.40
Mackay River	Candidate	1	Cariboo	0.00	12.25	1.28	0.78	9.95	0.25	12.38	1.16	11.23
Macktush Creek	Designated	7	West Coast	99.82	4.13	0.11	1.85	0.00	2.17	null	null	25.72
Mamin River	Candidate	7	West Coast	98.81	4.99	3.36	1.64	0.00	0.00	null	null	0.90
Mathers Creek	Candidate	7	West Coast	100.00	2.09	1.70	0.38	0.00	0.00	null	null	17.58
McKay Creek	Candidate	4	Skeena Coastal	100.00	4.51	4.38	0.13	0.00	0.00	null	null	0.00
McKinley Creek	Candidate	1	Cariboo	0.00	35.75	4.53	0.92	21.42	8.88	19.88	2.30	17.58
Memekay River	Designated	7	West Coast	98.51	10.32	8.64	1.44	0.00	0.23	null	null	1.95
Milk River	Candidate	3	Omineca	0.00	4.52	0.79	1.93	0.00	1.80	11.92	1.52	10.40
Moffat Creek	Candidate	1	Cariboo	0.00	64.28	14.47	1.20	46.60	2.01	27.73	2.01	25.72
Nahmint River	Designated	7	West Coast	98.42	3.22	2.60	0.62	0.00	0.00	null	null	15.44
Nalbeelah Creek	Candidate	4	Skeena Coastal	65.13	5.01	1.92	1.28	0.00	1.82	null	null	21.10
Orford River	Proposed	5	South Coast	0.09	6.17	0.63	0.37	0.00	5.16	2.23	0.28	1.95
Owen Creek	Candidate	4	Skeena	0.00	55.58	2.81	1.81	38.03	12.93	16.68	1.24	15.44
Palliser River	Designated	2	Kootenay–Boundary	0.00	19.66	1.36	0.27	15.03	3.01	4.21	0.37	3.84
Perry River	Designated	6	Thompson–Okanagan	0.00	26.52	1.47	0.52	0.00	24.53	6.96	2.41	4.55
Pierre Creek	Candidate	4	Skeena	0.00	45.17	1.16	0.08	14.93	29.01	2.87	0.13	2.75

Watershed name	Status	Region code	Region	Vegetation Resource Inventory unreported (%)	Riparian forest disturbed (%)	Forestry disturbed riparian (%)	Alienated disturbed riparian (%)	MPB (Beetle) disturbed riparian (%)	Fire disturbed riparian (%)	Total equivalent clearcut area (%)	Equivalent clearcut area from developed land (%)	Equivalent clearcut area from forestry (%)
Saskum	Proposed	6	Thompson–Okanagan	0.44	40.81	4.61	0.96	11.33	23.92	23.94	2.73	21.10
Scotch Creek	Designated	6	Thompson–Okanagan	0.00	27.47	4.05	1.13	1.53	20.76	12.31	1.28	11.03
Seebach Creek	Candidate	3	Omineca	97.27	3.42	2.18	0.78	0.01	0.45	null	null	4.55
Seller Creek	Candidate	1	Cariboo	0.00	61.40	2.23	0.62	58.53	0.03	8.17	0.96	7.20
Seymour River	Designated	6	Thompson–Okanagan	0.00	14.00	2.44	0.63	0.05	10.89	9.21	1.48	7.73
Shorts Creek	Designated	6	Thompson–Okanagan	0.12	54.93	18.42	2.17	22.98	11.36	28.60	2.02	26.55
Shovelnose Creek	Proposed	5	South Coast	21.22	0.65	0.44	0.21	0.00	0.00	0.20	0.16	0.00
Sinmax Creek	Proposed	6	Thompson–Okanagan	0.00	36.08	7.16	2.28	18.28	8.36	24.59	2.37	22.22
Sitkum Creek	Designated	6	Thompson–Okanagan	0.25	53.65	0.00	0.27	0.22	53.16	1.33	0.31	1.02
Sutherland Creek	Candidate	2	Kootenay–Boundary	0.00	49.64	3.63	4.83	22.02	19.15	8.20	2.76	5.43
Toboggan Creek	Designated	4	Skeena	0.00	18.99	2.34	0.85	3.93	11.87	4.88	1.01	3.87
Toquart River	Designated	7	West Coast	0.51	3.81	3.30	0.51	0.00	0.00	8.31	0.59	7.68
Unnamed Tributary	Candidate	4	Skeena Coastal	0.05	3.52	3.08	0.44	0.00	0.00	4.04	0.48	3.56
Upper Shuswap River	Designated	6	Thompson–Okanagan	0.31	22.86	1.62	0.35	0.65	20.25	5.49	0.46	5.01
Vaseux Creek	Designated	6	Thompson–Okanagan	0.14	85.77	9.43	2.33	0.91	73.11	19.11	1.73	17.35
Wap Creek	Designated	6	Thompson–Okanagan	0.05	8.46	1.69	0.64	0.97	5.16	9.50	2.88	6.61
Woodjam Creek	Candidate	1	Cariboo	0.12	73.71	8.89	0.98	61.71	2.12	25.26	7.44	17.79

Appendix 3. Habitat risk ratings (green = low risk, amber = moderate risk, red = high risk) for WSE Tier I habitat indicators over 71 fisheries sensitive watersheds (designated, candidate, and proposed) in each provincial natural resource region.¹⁴

Cariboo Natural Resource Region

Watershed name	Status	Road density for entire FSW (km/km ²)	Road density above H ₆₀ line (km/km ²)	Road density < 100 m from stream (km/km ²)	Stream crossing density (#/km ²)	Portion of streams logged (km/km)	Portion of fish-bearing streams logged (km/km)	Stream banks logged on slopes > 60% (km/km ²)	Peak flow index (unweighted)	Road density on unstable slopes (km/km ²)
MacKay River	Candidate	1.27	0.09	0.32	0.84	0.10	0.07	0.09	0.12	0.07
McKinley Creek	Candidate	1.50	0.72	0.28	0.62	0.19	0.17	0.22	0.19	0.01
Moffat Creek	Candidate	2.29	1.32	0.45	0.86	0.18	0.18	0.49	0.28	0.00
Seller Creek	Candidate	1.08	0.18	0.17	0.46	0.17	0.12	0.50	0.08	0.02
Woodjam Creek	Candidate	1.58	0.82	0.39	0.83	0.16	0.17	0.14	0.22	0.00

Kootenay–Boundary Natural Resource Region

Watershed name	Status	Road density for entire FSW (km/km ²)	Road density above H ₆₀ line (km/km ²)	Road density < 100 m from stream (km/km ²)	Stream crossing density (#/km ²)	Portion of streams logged (km/km)	Portion of fish-bearing streams logged (km/km)	Stream banks logged on slopes > 60% (km/km ²)	Peak flow index (unweighted)	Road density on unstable slopes (km/km ²)
Akolkolex River	Proposed	0.40	0.02	0.10	0.26	0.42	0.07	0.95	0.04	0.06
Caribou Creek	Proposed	1.08	0.29	0.50	1.74	0.06	0.03	0.13	null	0.12
Crawford Creek	Proposed	1.14	0.24	0.36	0.87	0.18	0.07	0.27	0.05	0.15
Kaslo River	Proposed	1.01	0.17	0.38	0.88	0.05	0.02	0.08	0.05	0.13
Palliser River	Designated	0.47	0.01	0.14	0.41	0.04	0.03	0.08	0.04	0.02
Sutherland Creek	Candidate	2.11	1.16	0.75	1.07	0.11	0.08	0.37	0.08	0.05

¹⁴ See Porter et al. (2013) for benchmark values used to assign status of each habitat indicator. Benchmark values for some habitat indicators vary by region (i.e., coastal vs. interior watersheds). A peak flow index (unweighted) value was not calculated if more than 50% of the watershed area lacked Vegetation Resource Inventory reporting (indicated by “null”).

Skeena Natural Resource Region (coastal watersheds)

Watershed name	Status	Road density for entire FSW (km/km ²)	Road density above H ₅₀ line (km/km ²)	Road density < 100 m from stream (km/km ²)	Stream crossing density (#/km ²)	Portion of streams logged (km/km)	Portion of fish-bearing streams logged (km/km)	Stream banks logged on slopes > 60% (km/km ²)	Peak flow index (unweighted)	Road density on unstable slopes (km/km ²)
Anweiler River	Candidate	0.43	NA	0.10	0.29	0.03	0.02	0.03	0.05	0.04
Cecil Creek	Candidate	2.59	NA	0.59	0.64	0.06	0.06	0.00	0.05	0.00
McKay Creek	Candidate	0.32	NA	0.08	0.24	0.02	0.01	0.05	null	0.02
Nalbeelah Creek	Candidate	1.52	NA	0.68	1.23	0.07	0.06	0.05	null	0.03
Unnamed Tributary	Candidate	0.56	NA	0.18	0.74	0.15	0.07	0.31	0.04	0.04

South Coast Natural Resource Region

Watershed name	Status	Road density for entire FSW (km/km ²)	Road density above H ₅₀ line (km/km ²)	Road density < 100 m from stream (km/km ²)	Stream crossing density (#/km ²)	Portion of streams logged (km/km)	Portion of fish-bearing streams logged (km/km)	Stream banks logged on slopes > 60% (km/km ²)	Peak flow index (unweighted)	Road density on unstable slopes (km/km ²)
Birkenhead River	Proposed	0.41	NA	0.18	0.50	0.04	0.01	0.08	0.02	0.01
Filer Creek	Proposed	0.01	NA	0.00	0.01	0.01	0.00	0.00	null	0.00
Klite River	Proposed	0.04	NA	0.03	0.07	0.03	0.02	0.05	0.00	0.01
Little Toba River	Proposed	0.13	NA	0.06	0.18	0.00	0.00	0.00	null	0.01
Orford River	Proposed	0.27	NA	0.13	0.47	0.06	0.02	0.10	0.02	0.05
Shovelnose Creek	Proposed	0.22	NA	0.07	0.11	0.00	0.00	0.00	0.00	0.01

Thompson–Okanagan Natural Resource Region

Watershed name	Status	Road density for entire FSW (km/km ²)	Road density above H ₅₀ line (km/km ²)	Road density < 100 m from stream (km/km ²)	Stream crossing density (#/km ²)	Portion of streams logged (km/km)	Portion of fish-bearing streams logged (km/km)	Stream banks logged on slopes > 60% (km/km ²)	Peak flow index (unweighted)	Road density on unstable slopes (km/km ²)
Anstey River	Designated	1.04	0.21	0.31	0.88	0.11	0.05	0.18	0.12	0.13
Bessette Creek	Designated	2.68	1.29	0.62	1.14	0.16	0.15	0.11	0.14	0.03
Cherry Creek	Designated	1.75	0.64	0.49	1.11	0.11	0.06	0.16	0.11	0.10
Chute Creek	Designated	2.29	0.80	0.46	0.79	0.40	0.38	2.02	0.34	0.00
Eagle Creek	Designated	0.86	0.21	0.24	0.51	0.06	0.02	0.07	0.07	0.05
Fennell Creek	Proposed	1.63	0.85	0.70	1.78	0.15	0.08	0.28	0.18	0.05
Harper Creek	Proposed	1.18	0.70	0.33	0.93	0.21	0.08	0.66	0.17	0.01
Lemieux Creek	Proposed	1.95	1.02	0.82	1.74	0.19	0.16	0.29	0.17	0.01
Perry River	Designated	0.78	0.11	0.20	0.49	0.07	0.03	0.05	0.07	0.07
Saskum	Proposed	1.99	0.97	0.35	0.87	0.17	0.09	0.23	0.23	0.09
Scotch Creek	Designated	1.41	0.61	0.30	0.70	0.17	0.09	0.33	0.12	0.03
Seymour River	Designated	0.69	0.10	0.19	0.49	0.08	0.04	0.12	0.09	0.04
Shorts Creek	Designated	2.56	1.62	0.87	1.89	0.44	0.32	0.11	0.29	0.01
Sinmax Creek	Proposed	2.01	1.31	0.51	1.10	0.22	0.12	0.11	0.25	0.03
Sitkum Creek	Designated	0.42	0.09	0.14	0.36	0.04	0.01	0.07	0.01	0.02
Upper Shuswap River	Designated	0.62	0.21	0.13	0.31	0.08	0.04	0.04	0.05	0.02
Vaseux Creek	Designated	1.88	1.03	0.52	0.94	0.22	0.22	0.14	0.19	0.00
Wap Creek	Designated	0.89	0.30	0.24	0.54	0.08	0.05	0.09	0.08	0.03
Yard Creek	Designated	1.12	0.39	0.23	0.36	0.06	0.04	0.09	0.13	0.04

West Coast Natural Resource Region

Watershed name	Status	Road density for entire FSW (km/km ²)	Road density above H ₅₀ line (km/km ²)	Road density < 100 m from stream (km/km ²)	Stream crossing density (#/km ²)	Portion of streams logged (km/km)	Portion of fish-bearing streams logged (km/km)	Stream banks logged on slopes > 60% (km/km ²)	Peak flow index (unweighted)	Road density on unstable slopes (km/km ²)
Artlish River	Designated	1.54	NA	0.58	1.48	0.72	0.24	1.40	0.11	0.11
Awun River	Candidate	1.32	NA	0.26	0.73	0.05	0.03	0.04	null	0.04
Davidson Creek	Candidate	1.46	NA	0.47	1.44	0.38	0.29	1.03	0.17	0.02
Deena Creek	Candidate	1.96	NA	0.99	2.62	0.01	0.00	0.03	null	0.06
Effingham River	Designated	0.35	NA	0.19	0.53	0.20	0.13	0.13	0.03	0.02
Escalante River	Designated	2.08	NA	0.67	1.70	0.46	0.24	0.58	0.18	0.31
Gordon River	Designated	2.36	NA	1.06	3.04	0.09	0.03	0.29	0.08	0.29
Hatton Creek	Designated	2.34	NA	0.94	2.70	0.07	0.01	0.27	null	0.19
Hemmingsen Creek	Designated	2.41	NA	0.99	3.00	0.06	0.01	0.16	0.07	0.29
Klanawa River	Designated	2.64	NA	0.99	2.58	0.11	0.04	0.35	null	0.20
Macktush Creek	Designated	2.53	NA	0.67	1.39	0.00	0.00	0.00	null	0.36
Mamin River	Candidate	1.98	NA	0.80	2.14	0.04	0.02	0.13	null	0.03
Mathers Creek	Candidate	0.59	NA	0.23	0.69	0.01	0.00	0.02	null	0.02
Memekay River	Designated	2.70	NA	0.53	1.08	0.06	0.05	0.09	null	0.06
Nahmint River	Designated	1.15	NA	0.53	1.36	0.03	0.01	0.06	null	0.11
Toquart River	Designated	0.82	NA	0.27	0.67	0.13	0.07	0.10	0.08	0.04