Natural Resource Sector
Monitoring

FREP – WSEP REPORT #3

March 2023

Bii Wenii Kwa/Owen Creek

Watershed Status Evaluation Report

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KEY MESSAGE: Inadequate fish passage, fine sediment delivery, riparian logging, and range practices resulted in an impaired watershed function rating. Natural conditions (e.g., beetle kill, erodible soils, and beaver activity) have exacerbated conditions. A variety of opportunities exist to improve conditions by remediating key impact areas, especially related to road design and management. The watershed would benefit from a Fisheries Sensitive Watershed (FSW) designation.

1. Introduction

The Bii Wenii Kwa/Owen Creek watershed, located west of Houston B.C., supports numerous culturally and ecologically important fishes and their habitat. For millennia, the Wet'suwet'en have occupied and relied on the Morice watershed for food and resources, and the confluence of Owen Creek and Morice River is a culturally important fishing area (Wet'suwet'en 2013a). The spiritual relationship between the Wet'suwet'en and the Bii Wenii Kwa provides an intimate connection to their ancestors, and its fish values help ensure community health and overall cultural well being (Wet'suwet'en 2013b). In addition to the area's current and historical significance to the Wet'suwet'en, the watershed is the focus of a variety of industrial, agricultural, and recreational activities.

The methods used in this study follow those described in the Watershed Status Evaluation Protocol (WSEP) (e.g., Pickard et al. 2014). The WSEP was developed to understand the status (i.e., "potential-risk" or pressure, and "condition") of watersheds with significant fish values as often recognized under a Fisheries Sensitive Watershed (FSW) designation. The WSEP employs assessment methods that are repeatable and rapidly deployable, thereby effectively improving our understanding of a watershed's status and relationships among watershed components, including water quality, fish habitat connectivity, and riparian/stream-channel condition (Pickard et al. 2014; Porter et al. 2013). The protocol uses a two-tiered approach where: Tier I brings together the best available spatial information to assess the level of potential-risk associated with disturbance; and Tier II uses established provincial field assessment protocols and a probabilistic (stratified) sample design to understand the condition of a watershed's fish habitat. The WSEP also distinguishes between old vs. new, and natural vs. human-caused disturbances (see Appendix 2: WSEP – Provincial Regulatory Context).

This report provides important baseline information for the study area in 2014 and is intended to convey WSEP results and recommendations to land managers, including Wet'suwet'en Hereditary Chiefs, the provincial government, industry decision makers, and the public to help affirm and improve natural resource management practices. Section 1 provides a general overview of the watershed, including summary statistics and risk ratings for key habitat pressure indicators; Sections 2–4 outline riparian, fish passage, and sediment delivery monitoring results; Section 5 summarizes the watershed's status in 2014 and includes generalized management recommendations; and Section 6 provides references and data sources. Appendices 1 and 2 contain additional detailed information and analyses related to this report. Ultimately, the purpose of the WSEP is to encourage continued use of practices that result in the maintenance of healthy fish habitat and improve practices that are adversely impacting aquatic/fish habitat.

Figure 1. *Nadina Mountain overlooking Bii Wenii Bin (Owen Lake).*

Figure 2. *Owen Creek channel diversion and new crossing structure at its confluence with the Morice River, circa 1956. (Photo courtesy of the Office of the Wet'suwet'en.)*

The **Watershed Status Evaluation Protocol** (WSEP) is a science-based watershed monitoring tool that ties together landscape level GIS assessment with a series of existing on-the-ground sampling protocols. The WSEP is focused on legal "fisheries sensitive watersheds" and can also be used to monitor other watersheds with fish values.

FREP MISSION: Collect and communicate the best available natural resource monitoring information to inform decision making, improve resource management outcomes and provide evidence of government's commitment to environmental sustainability.

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1 WATERSHED OVERVIEW

1.1 Watershed Overview

The Owen Creek watershed occupies 216 km² and varies topographically from east to west. Nadina Mountain (2125 m) dominates the watershed's western boundary (Figure 1) while rolling hillslopes (700 to 850 m) characterize its east side. Largely underlain by erodible fine-textured soils, there is a history of slope instability (Schwab 2011). The 7-km long Owen Lake, near the watershed's upper reaches, is the origin of the 14 km Owen Creek main channel which flows north directly into the Morice River. The channel meanders through a broad floodplain with extensive oxbow back channels, wetlands, and beaver complexes.

Both anadromous and resident fish species use the watershed (Bustard 1999). Anadromous populations include steelhead, coho, pink salmon, and Pacific lamprey. Resident populations include rainbow, lake, and cutthroat trout; pygmy whitefish; burbot; Dolly Varden; longnose dace; lake chub; and several other resident species. As a well-known steelhead system, the Owen watershed contains important spawning habitat and high densities of steelhead fry (Bustard et al. 2002). Lake trout are recognized as a regionally important species and a conservation concern in Owen Lake (Tamblyn 2005; Wet'suwet'en 2013b; and Jeff Lough, pers. comm.). Traditional Indigenous Knowledge indicates the occurrence of sockeye salmon in the watershed which is now considered extirpated (Wet'suwet'en 2013a and 2013b).The basin's high fish values and sensitivities make it a good candidate for special management, and an FSW designation has been recommended (Beaudry 2011).

In the 1920s, settler land-use activities (e.g., forest harvesting, mining, and cattle ranching) began with the construction of an access road to Francois Lake. Now a major road through the watershed, it links forestry, mining, and ranching operations with the town of Houston and Highway 16 to the north. In the mid-1950s, the construction of the Morice West Forest Service Road (FSR) resulted in the channelization (Figure 2) of the Owen Creek mainstem (Gottesfeld et al. 2002). The watershed is popular with recreationalists who fish, hunt, camp, and hike there. Although the east side of the watershed has been predominantly managed for forestry, ranching, and some mining (Cummings 1987), the west side surrounding Nadina Mountain is largely undeveloped including a provincial/tribal park (Figure 3). In 1983, the northeast corner of the watershed was burned in the "Swiss Fire", and in the 2000s, mountain pine beetle caused high rates of lodgepole pine mortality (see Appendix Figure A2.1) in the basin (Wet'suwet'en 2013b and Wood et al. 2010).

1.2 Tier I and Tier II Watershed Synthesis

Figure 4 summarizes results from Tier I geospatial data analysis for key watershed pressure indicators. Each indicator is scored against fish-oriented risk benchmarks (Porter et al. 2013). Using 2014 data, 6 out of 9 indicators for the watershed show moderate to high levels of pressure. Specifically, both "roads close to streams" and "streams logged" scored as high. The high "roads close to streams" indicator is important in relation to the Tier II findings (e.g., Morice-Owen and Morice West FSRs) as is "streams logged" for many small streams in the watershed. Table 1 shows a synthesis of Tier II field data representing key components of watershed condition. A green checkmark here indicates a condition within an acceptable range of variability (RAV), whereas a red outcome (X) indicates that a high benchmark has been reached or exceeded, and thus the component condition is considered "impaired" (Pickard et al. 2014). Given that each component (i.e., riparian, fish passage, and sediment) and subcomponent (stratum) is independently important to watershed-level fish habitat condition, one or more red scores is sufficient to support a closer look at the watershed for specific causal factors and remedies. Each Tier II component is detailed in subsequent sections of this report.

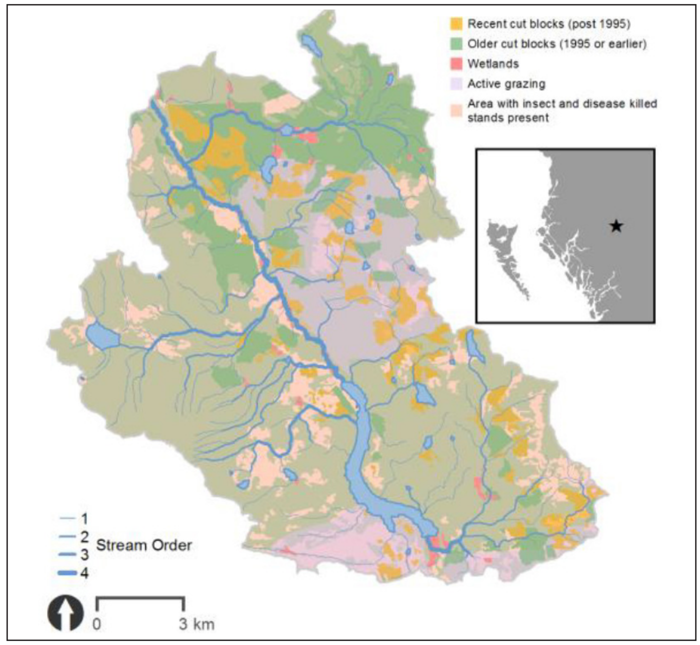

Figure 3. *Documented land use and prevalence of insects/disease in the watershed. The actual harvest area was underrepresented (see also Appendix Table A2.3).*

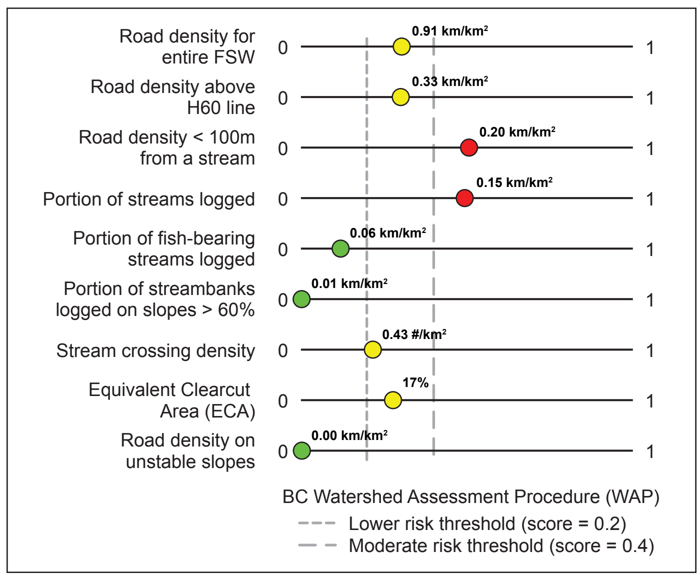

Figure 4. *2014 Tier I remotely sensed (GIS) indicators of potential risk (Porter et al. 2015). These results closely align with the Wet'suwet'en (2013b) analysis.*

Table 1. *Tier II riparian, fish passage, and fine sediment synthesis by stratum.*

Riparian		***Fish passage***		***Fine sediment***	
Non-fish habitat	✘	Stream order 1 & 2	✘	Spur roads	✔
Fish habitat – 1st & 2nd order	✘	Stream order 3	✘	Branch roads	✔
Fish habitat – ≥ 3rd order	✘	Stream order ≥ 4	✘	Mainline roads	✘

2.1 Riparian Survey

Figure 5 shows the locations of 38 riparian sample sites. Field data collection followed a WSEP-adapted (Pickard et al. 2014) version of FREP's Riparian Management Evaluation Protocol (Tripp et al. 2009), which uses 15 distinct questions to assess the relative health and "functioning condition" of a stream and its riparian area. Sites were selected using a spatially balanced stratified random sample design (Pickard et al. 2014). Riparian monitoring results were also analyzed to understand impacts (i.e., "No" answers – see Appendix Table A2.1; and causal factors – see Appendix Table A2.2) (Tripp 2019a).

2.2 Key Riparian Survey Results

Table 2 depicts riparian functioning condition ratings across sample sites within three habitat strata. Thirty-nine percent (n=15) of the 38 riparian reaches assessed were "functioning at high risk" or "not properly functioning". Twenty-three sites were dropped because they were non-classified drainages, wetlands, or inaccessible. Consistent with fine sediment delivery findings from the Owen-Morice FSR (Section 4), most (86%) mainstem sample sites (n=7) failed riparian question #8, indicating elevated fine sediment deposition impacts (Figure 6). An important impact observed in sample reach #166, where Owen Creek meets the Morice River, was a channel diversion used to accommodate a road crossing structure (Figure 2) resulting in the loss of a significant quantity of productive main channel habitat. At a landscape level, riparian samples indicated impacts follow land development patterns with improving scores from east to west. Forests surrounding Nadina Mountain Provincial Park on the watershed's western side have not been harvested and sampling here showed streams generally in "properly functioning condition" (Figure 7) despite elevated mortality among riparian conifers (Engelmann spruce and subalpine fir). Overall, causal factor analysis (Tripp 2019a) showed natural factors accounted for 45% of all impacts, including beetle kill, beaver activity, flooding, fire, wind, and (naturally) high background fine sediment levels. Logging impacts, which accounted for 21% of the causal factors, are primarily related to pre-1995 falling and yarding practices across streams and low riparian forest retention. The next two most significant impacts were attributed to range activities (e.g., overgrazing, trampling, pasture development) or unknown upstream factors (logging, natural impacts, livestock, roads), and together accounted for 14% of impacts. Roads (largely FSRs) accounted for 6% of the impacts in all sample reaches.

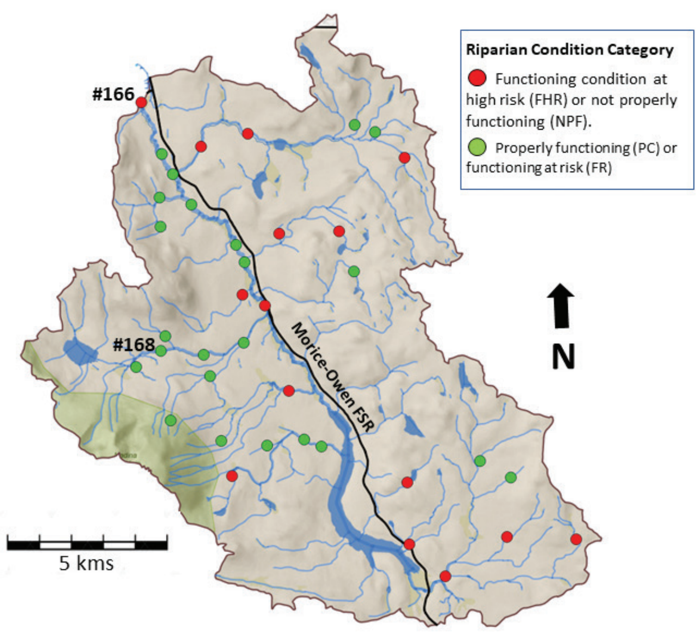

Figure 5. *Riparian survey locations showing functioning condition ratings.*

Table 2. *Distribution of riparian survey sample results. Each number in the table represents the number of surveys (sites) receiving a "No" answer (x axis) by strata (y axis). Coloured columns represent functioning condition categories. (Condition abbreviations: PF = Properly functioning; FR = functioning but at risk; FHR = functioning but at high risk; and NPF = not properly functioning.)*

STRATA	PF			FR		FHR		NPF				*n*
# No answers:	0	1	2	3	4	5	6	7	8	9	10	
NFH		2	1	3	1		1	1	1			10
FH 1&2		2	2	1	2	3	1	1			1	12
FH ≥3		1	2	2	5	1	2		1	1		15

Figure 6. *Site #166 — beaver dams, like this one on the right bank located along the lower Owen Creek mainstem, store and release large quantities of accumulated fine sediments when they breach.*

Figure 7. *Site #168 — an example of a properly functioning stream reach. Riparian area retention and conservation of functioning streams should be a priority while impacted areas recover.*

KEY RIPARIAN FINDINGS — A significant proportion of riparian samples were not functioning or at high risk, particularly on the east side of the watershed. Channelization has resulted in the loss of important high quality fish habitat at the watershed's Morice River confluence.

MANAGEMENT OPPORTUNITIES — To improve fish habitat conditions, management of fine sediments generated from FSRs, the reintroduction of Owen Creek into its historic channel, and retaining functional riparian areas, along with promoting recovery of impacted riparian areas through restoration, should be prioritized.

3 FISH PASSAGE MONITORING

3.1 Fish Passage Survey

Eighteen crossings were evaluated in the watershed, of which 78% (n=14) were assessed as either barriers or potential barriers to fish passage. Figure 9 illustrates factors associated with impediments impacting fish passage. The most common problems observed were insufficient embedment and channel constriction (stream width ratio). Table 3 summarizes results by stream size and class. The single most significant fish passage concern observed was MCR #59 on the Morice-Owen FSR south of Owen Lake (Figure 10). This crossing prevents access to the Riddeck Creek sub-basin (above Owen Lake) with important S3 and S4 fish habitat. A crossing on the Nadina Mountain trailhead road (MCR #85) is at risk of failing, impacting downstream fish habitat and compromising access to a provincial park. While habitat values are currently low at crossing MCR #27, prior to Owen Creek's 1950s diversion (Figure 2), the channel at this formerly S2 mid-reach site offered close to 2 kms of additional high value main channel habitat. Restoring fish passage at this site would be part of a much larger restoration effort [see Appendix 7 (iii)].

3.2 Fish Passage Survey Results

Figure 8 shows the locations where stream crossings were assessed for fish passage in the Owen Creek watershed. Field data collection followed the Ministry of Environment's Field Assessment for Fish Passage Determination of Closed Bottom Structures protocol (MOE 2011) and a census of all roads crossing fish streams was completed. The protocol uses five characteristics to determine the likelihood that a closed-bottomed culvert will provide safe fish passage (i.e., cumulative scoring for culvert length, slope, embedment, stream width ratio, and outlet drop). Sites assessed were predetermined using a fish habitat model (BCMOE n.d. and Mount et al. 2011) and a current GIS road layer.

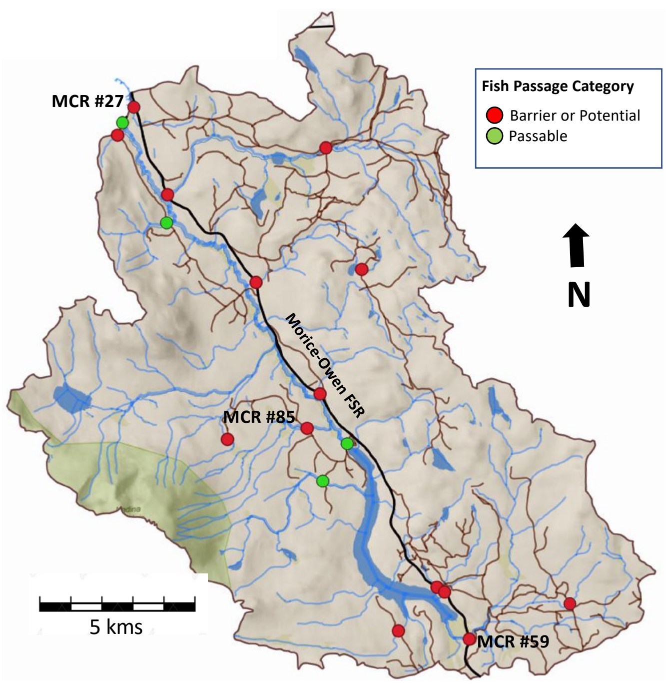

Figure 8. Fish passage survey locations in the Owen Creek watershed with passage ratings. "My Crossing Reference" (MCR) # indicates sites with priority fish passage or fish habitat concern. Crossing #P1 is also a barrier worth prioritizing for restoration but does not influence the restoration priority of (downstream) crossing MCR #59 (Irvine 2021).

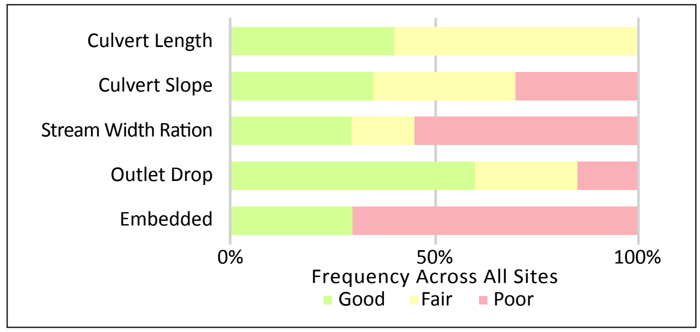

***Figure 9.** Cumulative characteristics affecting fish passage across the watershed.*

***Figure 10.** Located on the southern end of the Morice-Owen FSR (MCR #59), this 1.2 m culvert was deemed to be a significant barrier due to the following factors: channel constriction, length, absence of natural stream bed, and outlet drop, all of which restrict or prevent fish access to several kms of high value upstream habitat (Irvine 2021).*

***Table 3.** Table depicting results of fish passage surveys in the Owen Creek watershed.*

Stream size & class	*n*	Passable	Potential barrier	Barrier
> 4th order	3	2	1	0
3rd order	6	2	0	4
1st & 2nd order	9	0	1	8
Total	**18**	**4**	**2**	**12**
S2	6	4	1	1
S3	5	0	0	5
S4	7	0	1	6
Total	**18**	**4**	**2**	**12**

KEY FISH PASSAGE FINDINGS — Several culverts completely prevent access to important upstream fish habitat; over 50% of structures constrict the channel and put them at high risk of failing to pass fish in the future.

MANAGEMENT OPPORTUNITIES — Remediate priority fish passage locations commencing with the Riddeck Creek culvert on the Morice-Owen FSR mainline (Site #59).

4 FINE SEDIMENT DELIVERY MONITORING

4.1 Fine Sediment Survey

Figure 11 shows the 57 sites where fine sediment surveys were completed. Field data collection followed FREP's Water Quality Effectiveness Evaluation Protocol or WQEE (Carson et al. 2009). Randomly selected survey sites (Pickard et al. 2014) were sampled to assess the extent and nature of fine sediment generation from roads affecting streams. A cumulative fine sediment, fish and habitat impact analysis using hydrographic, life-stage vulnerability, and WQEE data was also conducted (Pickard et al., *in press*).

4.2 Fine Sediment Survey Results

Most spur and branch roads generated and delivered low volumes of sediment at crossings or inter-drainage sites (Figure 12). Although there are records of mass wasting events in the Owen Creek watershed (Schwab 2011), within the sampled road network only one such site was observed (Carson 2014). Thirty-three percent of all sites sampled (n=19) delivered moderate to high volumes of fine sediment to streams (Table 4); most of these sites were located on mainline forest service roads (FSRs). Throughout the watershed, FSRs are in close proximity to high value fish habitat. FSR road locations and road surface materials make it difficult to manage road surface sediment generation and delivery to fish habitat (Figure 13). Sample sites (n=12) along FSRs adjacent to Owen Creek delivered sediment loads averaging 2.4m^3 per site (Carson 2014). An estimate of the mean fine sediment delivery concentrations from roads during coho or steelhead egg incubation periods in Owen Creek (downstream of Owen Lake), indicate potential for chronic impacts (above natural background levels) during egg to fry life stages for both species (Tripp 2019b).

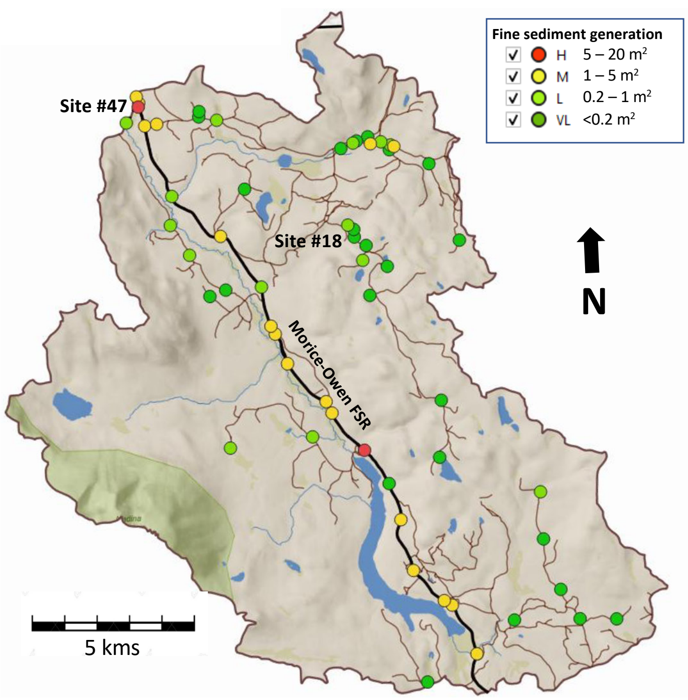

Figure 11. *Fine sediment survey locations within the sub-basins showing the volume of fine sediment generation delivery by category at each site and photo site location. Higher sediment generation categories occurred predominantly along the Morice-Owen and Morice West FSRs.*

Figure 12. *Site #18 is characteristic of a network of lightly used branch roads throughout the watershed. Their impact on water quality, quantity, and timings of flow are often minimized as vegetation reclaims and armors the road surface and increases soil infiltration along the road right-of-way. Lightly used roads like Site 18 and deactivated roads most often generate "very low" volumes of fine sediment.*

Figure 13. *Site #47 – where the Morice-Owen FSR runs immediately adjacent to the Owen Creek historic channel. Frequent berm ruptures as depicted here were observed along FSRs, often delivering high volumes of fine sediment to important fish habitat.*

Table 4. *On average, lightly used roads delivered very low concentrations of fine sediment to streams compared to exponentially higher concentrations along mainline FSRs (Carson 2014).*

Road Use	# of sites evaluated	Range of WQ values (m^3)	Average WQ value within road use class (m^3)	# of Very Low	# of Low	# of Mod	# of High
Mainline (Heavy)	21	0 to 6	2.41	2	2	15	2
Branch (Moderate)	7	0.09 to 2.76	0.9	1	4	2	0
Spur (Light)	17	0 to 0.5	0.11	13	4	0	0
Deactivated	12	0 to .75	0.06	11	1	0	0
All uses	57	0–6	1.04	27	11	17	2

KEY FISH SEDIMENT DELIVERY FINDING — Secondary roads delivered low volumes of sediment; however, the FSRs are a major contributor of fine sediment, impacting important valley bottom fish-bearing streams and off-channel habitat.

MANAGEMENT OPPORTUNITIES — Implement sediment management practices (e.g., grader-berm management), especially along FSRs. Harden FSR road surfaces as required to prevent fine sediment generation and delivery to stream channels.

5 BII WENII KWA/OWEN CREEK WATERSHED STATUS — SUMMARY

5.1 Watershed Status and Recommendations

RIPARIAN — At the watershed and site level, protect all functional riparian habitat and recover/restore reaches where there are riparian and channel impacts.

FISH PASSAGE & CONNECTIVITY — Restore access to important fish habitats at all identified (priority) sites.

SEDIMENT DELIVERY — Minimize fine sediment delivery from roads with better grader-berm management and/or hardening of road surfaces.

FSW STATUS — Designate the Bii Wenii Kwa/Owen Creek watershed as an FSW.

Application of the WSEP to the Bii Wenii Kwa/Owen Creek watershed showed that important benchmarks indicating healthy fish habitat conditions were exceeded (Pickard et al. 2014) (Table 5). Analyses of Tier I indicators suggest high potential risk to watershed condition associated with road proximity to streams, riparian harvesting, and equivalent clearcut areas. Several high-risk rated Tier I indicators (Figure 4) correlate with field-based Tier II condition assessments (e.g., roads adjacent to streams and fine sediment deposition in stream channels). Although all Tier II components performed poorly (i.e., riparian, fish passage, and fine sediment), most impacts were concentrated in the eastern half of the watershed. Fifteen percent of the watershed has documented presence of insect/beetle kill (see Appendix Figure A2.1) and field observations made during surveys suggest this number is likely higher. Mountain pine beetle infestation, common in the watershed in recent decades, has been widely attributed to climate change (Woods et al. 2010), and the high incidence of fir and spruce bark beetle observed in the area may be similarly related. Analysis of casual factors (Tripp 2019a) show that a significant portion of impacts were natural (45%), human factors accounted for 41% (logging, ranching, and roads), and unknown upstream factors accounted for 14% (see Appendix Table A2.2). Human factors in order of importance were low riparian retention, cross-stream falling and yarding from old logging, excessive grazing and trampling by livestock, and erosion of fine sediments at road stream crossings. Natural impacts were attributed primarily to beetle-killed trees, beavers, high background sediment levels, windthrow, floods, and fire. Both old and recent logging activities have impacted riparian areas and many of these would benefit from application of various process-based restoration techniques (e.g., Wheaton et al. 2019). Many fish passage sites were found to be problematic (78%) and addressing this issue at key locations (especially MCR #59) is essential to restoring access to important isolated fish habitat. Mass wasting was determined to be well within limits of concern, as was fine sediment generation and delivery on most secondary, tertiary, and spur roads. However, this was not the case where FSRs closely paralleled Owen Creek and delivered an average of 2.4m^3 at both crossing and proximity sites (an amount almost two and half times greater than recommended for FSWs), impacting habitat and likely salmonids during early life stages (Tripp 2019b). Finally, the complete reintroduction of Owen Creek into its original confluence channel, and subsequent recovery of important main-channel habitat (MCR #27), should be considered a priority. The recommendations highlighted above are further detailed in Appendix 1. To allow recovery of conditions important to fish and fish habitat, special management is required to enable coordinated planning and management of activities throughout the watershed to prevent compounding past, current and future impacts. As the data for this report was collected in 2014, another WSEP application should be considered in the near future to compare changes in the watershed's status. Given the findings of this evaluation, the watershed's high fish values and geomorphic sensitivities (Beaudry 2011), the area would benefit from an FSW designation.

Table 5. *Survey results by habitat category for three assessment components (riparian, fish passage, and fine sediment). Using categories described in the WSEP (Pickard et al. 2014), a green outcome indicates the condition of a sub-component is within an acceptable range of variability (ARV), an amber outcome (would) indicate the condition marginally exceeds ARV and is of moderate concern, and a red outcome indicates that the outcome exceeds the ARV and is of high concern. See also Table 2 for distribution of "No" answers by stratum for the riparian assessment component.*

Riparian	**Non-fish habitat (*n = 10*)**	**Fish habitat 1st & 2nd order (*n = 12*)**	**Fish habitat ≥ 3rd order (*n = 15*)**
Total stream length	127 kms	80 kms	28 kms
Are there enough PC & FR sites?	No – 30% *(Benchmark >80%)*	No – 50% *(Benchmark >85%)*	No – 67% *(Benchmark >90%)*
Are NPF & FHR sites low?	No – 50% *(Benchmark <25%)*	No – 50% *(Benchmark <20%)*	No – 33% *(Benchmark <25%)*
Are NPF sites low?	No – 20% *(Benchmark <10%)*	No – 17% *(Benchmark <5%)*	No – 13% *(Benchmark <0%)*
Watershed score	✘	✘	✘
Fish passage	**Stream order 1 & 2 (*n = 9*)**	**Stream order 3 (*n = 6*)**	**Stream order ≥ 4 (*n = 3*)**
Barrier/potential barrier	100%	67%	33%
Passable	0%	33%	67%
Watershed score	✘	✘	✘
Find sediment production benchmarks	**Spur & deactivated (*n = 29*)**	**Branch (*n = 7*)**	**Mainline (*n = 21*)**
Total road length by road type	130 kms	37 kms	35 kms
Did more than 60% of the sites sampled have **very low or low** sediment production ratings	Yes (100%)	Yes (71%)	No (19%)
Did less than 25% of the sites sampled have **moderate** sediment production ratings	Yes (0%)	No (29%)	No (71%)
Did less than 3% of the sites sampled have **high or very high** sediment production ratings	Yes (0%)	Yes (0%)	No (10%)
Watershed score	✔	✘	✘

Figure 14. *Data collection crew preparing to access a nearby riparian site (pictured: Darcy Pickard, Dallas Nikal, and Gary Michell).*

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6.2 Tier I and Tier II Data Sources

	Indicators (Data source)	(1)	(2)	(3)	(4)	(5)	(6)
GIS derived indicators							
Tier I	Watershed road density	✓					
Tier I	Road density above H60	✓		✓	✓		
Tier I	Road density < 100m from stream	✓					
Tier I	Streams logged		✓		✓		
Tier I	Fish streams logged		✓			✓	
Tier I	Stream crossing density	✓			✓		
Tier I	ECA		✓				
Field data							
Tier II	Riparian				✓	✓	✓
Tier II	Fish passage					✓	✓
Tier II	Sediment delivery						✓

Data sources: (1) Digital Roads Atlas & Forest Tenures Roads, (2) consolidated cutblocks (cut within last 100 years), (3) Digital Elevation Model; (4) Freshwater Stream Atlas stream network, (5) Ministry of Environment fish habitat distribution model (Version 2011), and (6) field collected data (available from L. Reese-Hansen). For detailed information on data sources used for Tier I indicators, please refer to WSEP Tier I protocol (Porter et al. 2013 and Porter et al. 2015).

APPENDIX 1. DETAILED WATERSHED RECOMMENDATIONS

(i) Riparian management – Riparian areas have been extensively impacted by natural factors (e.g., beetle mortality), old logging (e.g., harvesting to stream edge and cross channel yard and falling), and new logging (e.g., blowdown). While disturbed areas recover, protecting remaining undisturbed riparian forests (i.e., riparian buffers on all class S4, S5, and S6 streams) should be the ongoing priority across the watershed (Tschaplinski 2010; Tschaplinski and Tripp 2017). In some parts of the watershed, range (cattle) management practices should emphasise prevention of impacts to stream banks and riparian vegetation.

There are opportunities to accelerate long-term recovery of riparian function along disturbed streams (i.e., riparian restoration within suitable areas) using low-tech, process-based restoration techniques (e.g., Wheaton et al. 2019). Retention and recovery of streamside shade will also help moderate late summer stream temperatures (Bustard 1999).

(ii) Fish passage – Several stream crossing structures have been identified that significantly limit access to high value fish habitat. Replacing these structures should be a high priority activity, commencing with the Riddeck Creek crossing on the Morice-Owen FSR culvert (MCR #59). This structure blocks fish access to a large sub-basin and extensive high-value fish habitat (Irvine 2021a) at the south end of Owen Lake. Fish passage recommendations in Irvine (2021b) should also be prioritized for restoration.

(iii) Channel restoration – The channelization and placement of a hard crossing structure on Owen Creek at the confluence with the Morice River in the mid 1950s (Gottesfeld et al. 2002) saw the loss of important high-value main channel fish habitat. The FSR and bridge have also been problematic from a maintenance perspective as the Morice River migrates toward it. Reintroducing Owen Creek in its entirety back into its original channel is seen as a priority and would result in the recovery of several kilometers of (additional) main channel fish habitat. This work should be integrated with the relocation of the FSR to a stable location that would put the new road location and Owen Creek crossing above the apex of the Owen Creek alluvial fan (several hundred meters south of its current location).

(iv) Fine sediment – Along locations where FSRs parallel Owen Creek, high levels of fine sediment delivery were impacting important main channel habitat and adjacent wetlands. Consistent with Tamblyn (2005), improved sediment management practices that minimize fine sediment generation and delivery at road crossings and proximity sites is a priority, including FSR road surface hardening techniques to prevent this from happening. Additional opportunities to minimize sediment delivery include a variety of improved grader and grader-berm management techniques along FSRs (see Carson 2014).

(v) Watershed management – Given the findings of this evaluation, the basin's high fish values, and geomorphic sensitivities to disturbance, a Fisheries Sensitive Watershed designation (Beaudry 2011) under FRPA and OGAA is warranted.

Analysis of Riparian "No" Answers

Riparian question (indicator) category	Non-fish habitat (*n = 10*)	Fish habitat 1st & 2nd order (*n = 12*)	Fish habitat > 3rd order (*n = 16*)	All strata (*n = 38*)
1. Channel bed disturbance	0% (0)	0% (0)	6% (1)	3% (1)
2. Channel bank disturbance	10% (1)	25% (3)	63% (10)	37% (14)
3. Large woody debris (LWD) characteristics	20% (2)	8% (1)	44% (7)	26% (10)
4. Channel morphology	30% (3)	33% (4)	6% (1)	21% (8)
5. Aquatic connectivity	60% (6)	67% (8)	56% (9)	61% (23)
6. Fish cover diversity	0% (0)	25% (3)	6% (1)	11% (4)
7. Channel stability (moss abundance/condition)	10% (1)	33% (4)	50% (8)	34% (13)
8. Fine sediment introduction	80% (8)	58% (7)	69% (11)	68% (26)
9. Aquatic invertebrate diversity	0% (0)	17% (2)	0% (0)	5% (2)
10. Windthrow frequency	50% (5)	25% (3)	56% (9)	45% (17)
11. Riparian soil disturbance/bare ground	30% (3)	8% (1)	13% (2)	16% (6)
12. LWD supply/root network	30% (3)	33% (4)	38% (6)	34% (13)
13. Shade and riparian microclimate	30% (3)	17% (2)	6% (1)	16% (6)
14. Disturbance-increaser plants, noxious weeds, & invasive plants	10% (1)	8% (1)	6% (1)	8% (3)
15. Vegetation form, vigour, and structure (buffer condition)	20% (2)	50% (6)	38% (6)	37% (14)

Table A2.1. *Summary of each channel and riparian question used in the riparian reach surveys by category and for the entire watershed. Increasing numbers indicate a higher frequency of recorded impacts related to each riparian question/category. Frequency is presented as a percentage and number of "No" answers by stratum/strata and for the entire watershed.*

Causal Factor Analysis of Riparian Surveys

Impact category (activity/factor)	Harvest condition/era			
	Unlogged (*n=18*)	Pre-code (*n=13*)	Post-code (*n=7*)	All (*n=38*)
Logging (harvesting)	0 (0.0)	32 (1.5)	39 (1.6)	21 (0.9)
Natural factors	70 (2.3)	26 (1.4)	41 (1.7)	45 (1.9)
Ranching	0 (0.0)	28 (1.5)	7 (0.3)	14 (0.6)
Roads	5 (0.2)	7 (0.4)	2 (0.1)	6 (0.2)
Other human related	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Upstream factors	25 (0.8)	7 (0.4)	8 (0.3)	14 (0.6)
All	100 (3.2)	100 (5.4)	100 (4.1)	100 (4.1)

Table A2.2. *Percent of "No" answers to the 15 main riparian protocol questions caused by broadly defined activities or factors at randomly selected sites in the Owen Creek watershed. Numbers in parentheses are the mean number of "No" answers per site attributed to each cause. Pre-code (old) and post-code (new) logging refers to pre and post 1995 harvesting (adapted from Tripp 2019a).*

Insect/Beetle Kill

Figure A2.1. *Beetle-killed (pine and spruce) trees are prevalent throughout the Owen Creek watershed (Site #168). The image depicts a root rot fungal infection (tomentosus) that may interact with beetles in a primary-secondary relationship causing widespread tree mortality.*

Descriptive Landscape and Disturbance Indicators

Table A2.3. *Various descriptive landscape and disturbance indicators for the Owen Creek watershed in 2014. These results are similar to, and corroborated by, Wet'suwet'en (2013b).*

Vegetation resources inventory data	
Reported	216.30 km^2 (100%)
Unreported	0 km^2 (0%)
Watershed area	216.30 km^2
Consolidated harvesting history	
Post-1995 cutblocks	16.69 km^2 (7.7%)
Pre-1996 cutblocks (old)	36.66 km^2 (16.9%)
Remaining	159.00 km^2 (73.5%)
Active grazing area	
Active Grazing Area	44.69 km^2 (21.0%)
Insect and disease killed stands	
Presence of beetle kill or disease	31.45 km^2 (14.8%)
Area weighted average % killed	12.41%

WSEP – Provincial Regulatory Context

In British Columbia, regulations under statutes, such as the *Forest and Range Practices Act* (FRPA), *Oil and Gas Activities Act* (OGAA), and the *Land Act*, can be used to augment standard regulatory requirements emphasising additional conservation requirements in the management of watersheds with fish and fish habitat values. For example, under FRPA and OGAA, the provincial government can legally designate an area as a Fisheries Sensitive Watershed (FSW) if it has significant fish values and sensitivity to disturbance (Reese-Hansen et al. 2017) As part of the designation, and consistent with the watershed's values and sensitivities, land-use management objectives are established to protect fish habitat in the FSW by requiring operators to prevent (cumulative) impacts to fish habitat arising from their activities. Assessing watershed status is critical to conserving fish habitat and other associated values, and for continually improving both the ecological condition and management practices within these watersheds.

Working with a range of partners, the provincial government developed the Watershed Status Evaluation Protocol (WSEP). It is used to collect monitoring data to help understand the pressures and conditions in watersheds with important fish values. The WSEP employs assessment methods that are repeatable and rapidly deployable, thereby cost-effectively improving our understanding of a watershed's status and relationships among watershed components (Pickard et al., in press and Porter et al., in press). The protocol uses a two-tiered approach where: Tier I brings together the best available spatial information to assess the level of potential risk associated with disturbance; and Tier II applies existing field-based protocols via a spatially balanced probabilistic sample design to understand a watershed's fish habitat condition. The WSEP also distinguishes between old (e.g., pre-1995) and new impacts (post 1995 — the year when regulatory requirements were strengthened requiring forest management operations to better protect fish habitat). Pre- and post-1995 disturbance is often referred to as "old" or "new logging" (e.g., Tripp 2019a).

The FREP WSEP methods used in this assessment are aligned with government's Cumulative Effects Framework (CEF) Assessment of Aquatic Ecosystems. While the CEF assessment is an analysis of all watersheds across the province (using predefined standardized "assessment units"), the WSEP is a targeted analysis (i.e., targets FSWs or watersheds with fish values of interest) of both risk (Tier I) and condition (Tier II) used to understand the status of a specific watershed, including the influence of cumulative disturbances (natural and human) on fish habitat. WSEP Tier II analysis can also be used to inform the condition of CEF assessment units.

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