Current Condition Report for GIS-Based Watershed Hazard in the Omineca Region

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Ministry of
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BRITISH COLUMBIA

CEF Cumulative Effects Framework

Citation

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Cover Photo Credit: Nicole Tweddle, Sowchea Creek tributary stream.

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LIST OF ACRONYMS

BC	British Columbia
BEC	Biogeoclimatic Ecosystem Classification
CEF	Cumulative Effects Framework
CCR	Current Condition Report
DMK	Mackenzie Natural Resource District
DPG	Prince George Natural Resource District
DVA	Stuart-Nechako Natural Resource District
ECA	Equivalent Clearcut Area
FRPA	*Forest and Range Practices Act*
VRI	Vegetation Resources Inventory
WAU	Watershed Assessment Unit

1 INTRODUCTION

The Province of BC has developed a Cumulative Effects Framework (CEF) to estimate potential effects of natural resource activities, large and small, on values that matter to the people of BC. The CEF aims to incorporate the combined effects of all activities and natural processes into decision making, to help avoid unintended consequences to identified economic, social and environmental values.[1] The assessment and management of cumulative effects is critical to sustainable and integrated resource management and an important foundation for addressing First Nations' rights, title, and interest. Current condition assessment forms the basis for the CEF. Assessments have been initiated for several important resource values, including grizzly bears, moose, biodiversity, aquatic ecosystems and old growth using indicators designed to demonstrate the potential cumulative effects of natural resource activities on each value.

This report (CCR) presents an overview of the current potential condition of aquatic ecosystems in the Omineca Region using GIS-based indicators. It provides a standardized relative hazard assessment across watershed assessment units (WAU) of the likelihood for changes to streamflow, sediment, and riparian zones. The report provides an overview of assessment methods and hazards at the regional and district scale. The information provided in this report can be used to compare relative hazard among WAU and their resource values. This assessment can be used to highlight those watersheds that require more detailed assessment through air photo interpretation, remote sensing analysis, and field assessment, the latter is particularly important because it can identify where models have over or underestimated conditions such as sediment generation potential and stream density.

Sowchea Creek tributary stream – Nicole Tweddle

[1] Under the BC Cumulative Effects Framework, cumulative effects are defined as changes to environmental, social and economic values caused by the combined effect of past, present and potential future human activities and natural processes.

2 REGIONAL OVERVIEW

The Omineca Region is comprised of three natural resource districts, namely Prince George, Stuart-Nechako, and Mackenzie (Figure 1). The region is over 170,000 km^2 in size and has approximately 3234 watershed assessment units. It is an ecologically diverse landscape that includes the Omineca, Cariboo, and Rocky Mountains, the upper Fraser Basin, and Nechako Plateau. The region hosts numerous large lakes including Takla and Stuart Lakes, as well as the Williston Reservoir being among the largest. Large rivers include the Upper Fraser, Nechako, McGregor, Parsnip, Stuart, and others. As a result of its diverse geography, forest types are variable and range from low elevation areas to alpine forests. The region is also home to numerous aquatic species of interest and concern including salmon, bull trout, arctic grayling, and the Nechako white sturgeon.

Figure 1. *Map of the Omineca Region showing three Natural Resource Districts and major centers.*

2.1 Watersheds and Watershed Assessment Units

Watersheds can be defined as the topographic area of land contributing water to a point along a stream network. Watersheds are nested with smaller upstream systems contributing to larger downstream units until the outlet is reached, such as the Fraser River at the Pacific Ocean. Watershed boundaries are identified upstream of a point of interest which is typically the resource value that land managers wish to afford protection such as but not limited to residences, bridges, potable supply, or fish spawning and rearing grounds. Consequently, discussions about aquatic ecosystems should follow topographic watershed boundaries. The challenge is that due to their nested hierarchy, watersheds are variable in scale and the decision of where to assign boundaries is often dependent on the resource value being managed. The provincial Cumulative Effects model (BC FLNRORD (2020)) and this regional assessment utilize WAU which are standardized areas between 2,000 and 10,000 ha (target size is 3000 ha). WAU are meant to emulate third order watersheds at a 1:50 000 scale but they follow the more detailed 1:20 000 spatial linework along outer boundaries, providing for a more accurate portrayal of the contributing basin (Carver and Gray, 2009). While these were developed to provide a continuous coverage of standardized units across the province, they vary in actual watershed order and magnitude. In addition, WAU that are located lower in a particular drainage system may not be complete watersheds as their upper catchment areas are usually captured in one or more separate WAU, as demonstrated in the following example of Blackwater Creek. This watershed is north of Mackenzie and it is composed of 4 WAU (Figure 2). The three upper WAUs along the western and southeastern area are complete topographically defined watersheds that contribute to the remaining WAU to form Blackwater Creek. This smaller northern WAU contains the outlet and is not a watershed on its own, because it receives water from the other three WAUs.

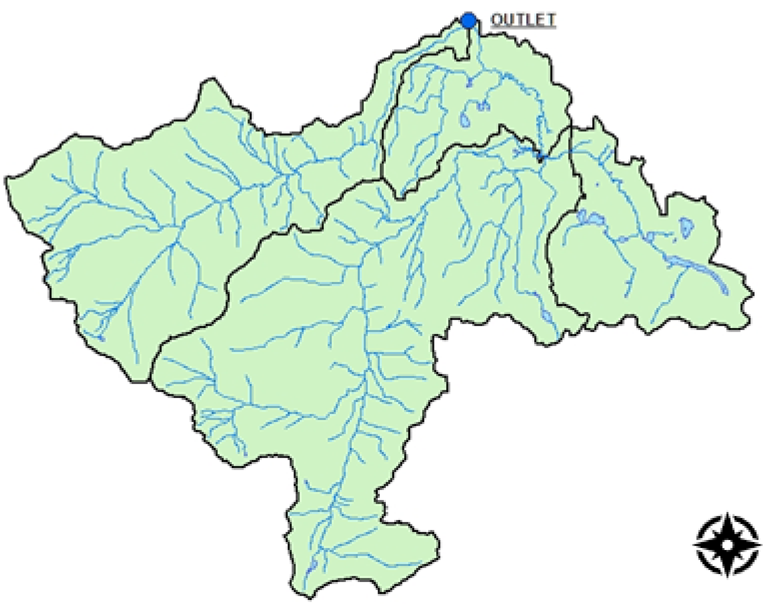

Figure 2. *Map of a watershed showing the watershed boundaries and the 4 WAU making up the watershed boundaries.*

In future, the Omineca regional approach to providing potential current condition aquatic ecosystem information will be a two-pronged approach, based upon the unit of analysis. The rationale being that indicator metrics useful for assessing development footprints can be clearly shown for the entire region using WAU while watershed-based evaluations provide a clearer picture of potential watershed hazard. This report focuses on the WAU analysis, but also provides a comparison of WAU and an analysis of stream-order based watersheds in Appendix 1. The watershed-based work is underway and will be provided in the next update to this document.

2.2 Indicators, Hazards, Risks, and Cumulative Effects

Cumulative effects are changes to environmental, social and economic values caused by the combined effect of past, present, and potential future human activities and natural processes.[2] Potential cumulative effects can be estimated using indicators that can be combined within a hazard and/or a risk assessment framework (Figure 3).

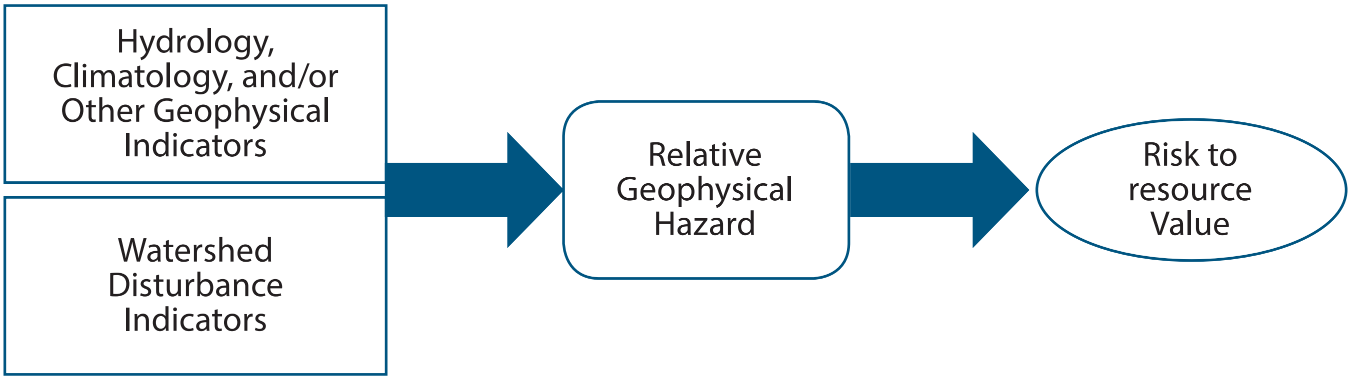

Figure 3. *Schematic clarifying the relationship between indicators, hazards, and potential risk as considered in this document.*

Indicators are defined here as measures of development or geophysical condition, e.g., equivalent clearcut area (ECA) is an indicator of forest canopy disturbance comparable to a clearcut within a WAU. Indicators are combined within a hazard assessment to identify the potential likelihood (i.e., low to high) that the geophysical features of a WAU, combined with the development footprint will result in less desirable conditions. For example, the hazard assessment for increases in peak flow combines indicators for forest canopy disturbance, such as equivalent clearcut area (ECA) with watershed indicators to estimate responsiveness. Watershed indicators include density of stream channels, road density and watershed slope because these two characteristics influence the delivery of snowmelt water or rainfall from cleared areas and roads to streams.

Risk assessment considers the hazard assessment relative to resource values. That is, if conditions change as identified in the potential hazard assessment, what is or are the consequence(s) to the value(s) of interest? If, for example, sediment transport and deposition increase within a watershed will it have a negative effect on aquatic values such as potable water supply or fish habitat?

2.3 Current Condition and Scale

It is important to understand the difference between indicators and hazard. Indicators, such as ECA, road, and stream-crossing density are area-based estimates and provide a measure of coverage across the watershed. Hazard, in contrast, is not scaled to the watershed but rather to the lowest point in the WAU. That is, if the model identifies a moderate streamflow hazard in a WAU, that means there is a moderate likelihood that the lowest portion of the WAU will experience increases to peak flow under normal conditions. It does not mean that all stream reaches above the outlet will also experience an increase in peak flow. Hazard estimates are useful for relative WAU comparison across the landscape and for highlighting those areas that may require more detailed assessment prior to further development or for restoration planning. It is also important to note here that this is a GIS-based evaluation and hazard estimates have not been field-verified – this evaluation identifies potential hazards that should be used to direct field and further office investigation.

2 Definition identified in the BC Cumulative Effects Framework: https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/cumulative-effects/cef-interimpolicy-oct_14_-2_2016_signed.pdf

3 CURRENT CONDITION ASSESSMENT METHODS

3.1 Watershed Health Project Omineca Region

The watershed health project Omineca Region (WHPOR) was initiated in 2015. It was initiated to estimate landscape condition following the mountain pine beetle (MPB) epidemic and associated salvage harvesting and to help inform decisions associated with continued development needs, such as forest harvesting and pipeline corridors. The program was developed with input from regional and district specialists across a range of disciplines from GIS, hydrology, biology, forestry, range, engineering, and others to investigate, in part, potential current and potential future effects of cumulative disturbance to watersheds.

Recognizing the size of the region and data limitations, the decision was made to follow the general GIS-based watershed evaluation seen across many jurisdictions that is somewhat like the Level 1 watershed assessment outlined in the Interior Watershed Assessment Procedure Guidebook (BC MoF, 1996, 1999). Concurrent to the Omineca project initiation, the Thompson-Okanagan Region was producing reports on their cumulative effects pilot program for watersheds. Accordingly, to ensure some consistency across regions, the approach outlined in Lewis et al., 2014 was adopted in the Omineca Region with the understanding that there may need to be some adjustments to indicator thresholds and indicators added to address regional differences. Regional threshold adjustments and additions were made following validation of this approach as identified in this document and summarized in Appendix 2.

3.2 Streamflow Hazard

Streamflow hazard reflects the relative likelihood of increased peak flow. Omineca regional watersheds have a snowmelt or nival dominated hydrologic regime, which means that they typically experience their annual peak flow event during the spring snow melt (Eaton and Moore, 2010). Consequently, spring peak flow conditions are the primary concern addressed by this hazard estimate. Data used in determination of this hazard is identified in Appendix 2.

Development and natural disturbance influence on peak flow is primarily related to removal of the forest canopy. As forest canopy is removed, more snow and precipitation reach the ground and can enter stream channels which increases stream flow (Macdonald et al., 2003; Schelker et al., 2013). The combination of increased snowpack in forest cover openings, increased solar radiation from lost canopy and subsequent altered energy balance can influence melt and lead to increased spring peak flows (Bosch and Hewlett, 1982; Winkler et al., 2005, 2010, 2015). Disturbance of forest canopy is estimated here through the indicator ECA.

ECA identifies the proportion of a watershed that is like an area that has been recently harvested or experienced forest removal through wildfire or other disturbances. When a forested stand is cleared its ECA value is 100%. As that forest grows back and canopy cover increases, ECA values decrease from 100% back to zero once the disturbed forest stand has reached canopy closure that is the same as the original cleared mature forest stand (Zhang and Wei, 2012; Winkler, 2017). Therefore, a watershed that has an estimated 20% ECA may be one that has recently cleared areas totalling 20% of the watershed, or older development across a larger proportion that has some re-growth. ECA considers canopy disturbance from beetle infestation, fires, forest harvesting, roads and right of ways, villages and towns, private property, and reserve lands. Fire guards have not yet been included but will be incorporated into future versions like the provincial CEF approach. Runoff potential and ECA metrics combine to estimate runoff generation potential.

To assess the relative hazard of increased peak flow in snowmelt-dominated watersheds, it is necessary to have some estimate of how much snow the watershed receives and the forest cover that is available for disturbance. These are identified in the workflow as runoff potential (Figure 4) with Biogeoclimatic Ecosystem Classification (BEC) zone identifying relative snow levels and vegetation resources inventory (VRI) identifying forest cover of the watershed. A watershed with few coniferous stands and a low snow load is likely to yield a lower peak flow compared to one with a forest harvesting with a high snow load and coniferous cover.

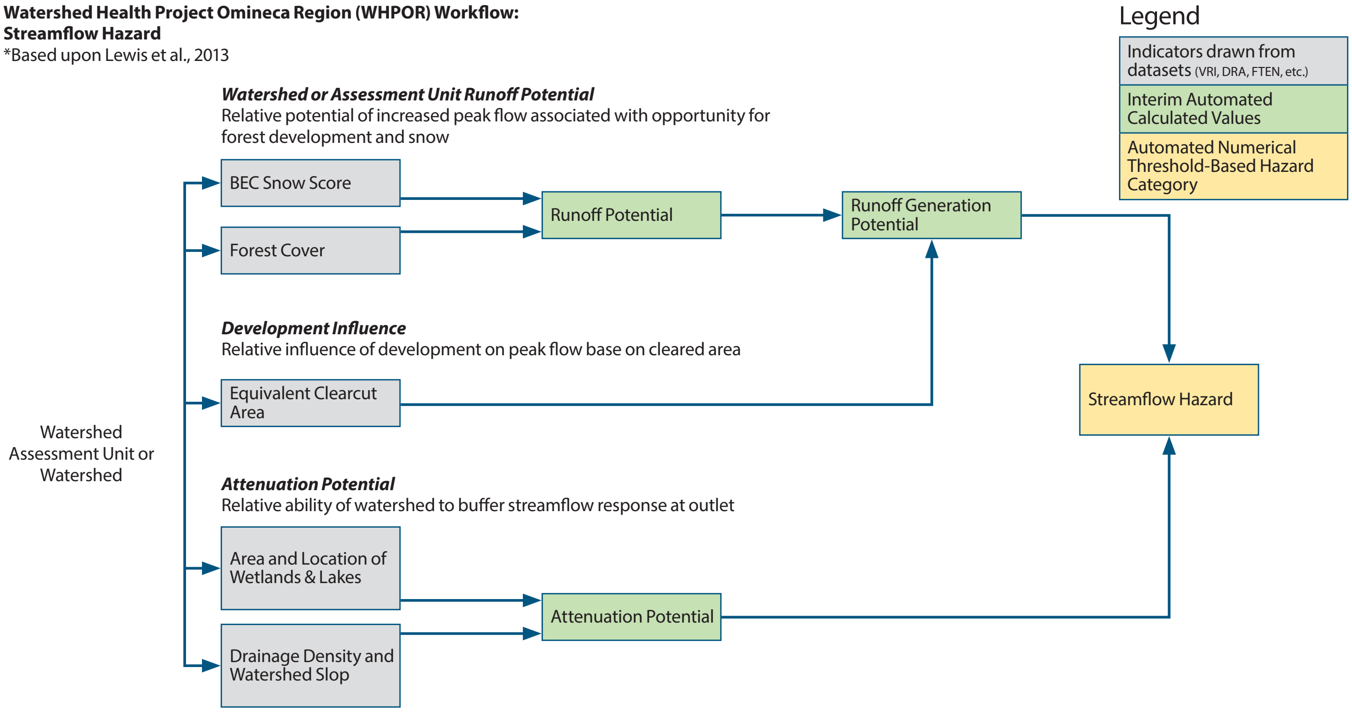

Figure 4. *Workflow of streamflow hazard assessment used in the Omineca Region current condition evaluation.*

The ability of a watershed to convey water to the outlet will also influence the likelihood a change in peak flow. Three watershed characteristics that were readily available from the data warehouse and are known to influence runoff delivery to the mainstem are the area and location of wetlands and lakes, as well as drainage density, and watershed slope. These indicators were combined to estimate the attenuation potential of the watershed. For example, a steep well drained watershed with few to no wetlands or lakes has less ability to detain and store melt water upstream of its outlet compared to a relatively flat poorly drained watershed with lakes and wetlands in its lower reaches.

To determine streamflow hazard, the attenuation potential and runoff generation potential are combined as shown in Table 1. Those assessment units with high attenuation potential and low runoff generation potential are at lowest hazard while those with little attenuation potential and high runoff generation potential have the highest stream flow hazard estimates.

Table 1. *Stream flow hazard determination as identified by combining categorical determination of runoff generation potential and attenuation (from Lewis et al., 2015).*

		Attenuation Potential				
		Very High	High	Mod	Low	Very Low
Runoff Generation Potential	Very Low	V. Low	V. Low	Low	Low	Mod
	Low	V. Low	Low	Low	Mod	High
	Mod	Low	Low	Mod	High	High
	High	Low	Mod	High	High	V. High
	Very High	Mod	High	High	V. High	V. High

3.3 Sediment Hazard

Sediment hazard reflects the relative likelihood of increased sediment generation and delivery of sediment to streams within the analysis unit. This hazard speaks to the relative hazard of increasing the fine sediment load which may be suspended during high flow periods and settle as flow decreases. Data source, metrics, and threshold information is provided in Appendix 2.

To assess the relative hazard of increased sediment generation and delivery to streams, it is necessary to consider natural sediment generation and delivery potential within the WAU. This is identified by determining areas of erodible soils along steep coupled slopes, which are defined as those having >50% slope terminating within 50m of a stream (Figure 5). British Columbia does not have continuous soil cover mapping throughout the region, so the provincial 1:250,000 Quaternary Deposit layer was used to identify sensitive soils considered to be glacio-fluvial sedimentary deposits, which tend to lack cohesion and are prone to erosion (i.e., silty textured soils) (Lewis *et al*., 2014). These indicators were combined to identify the erosion potential of the WAU.

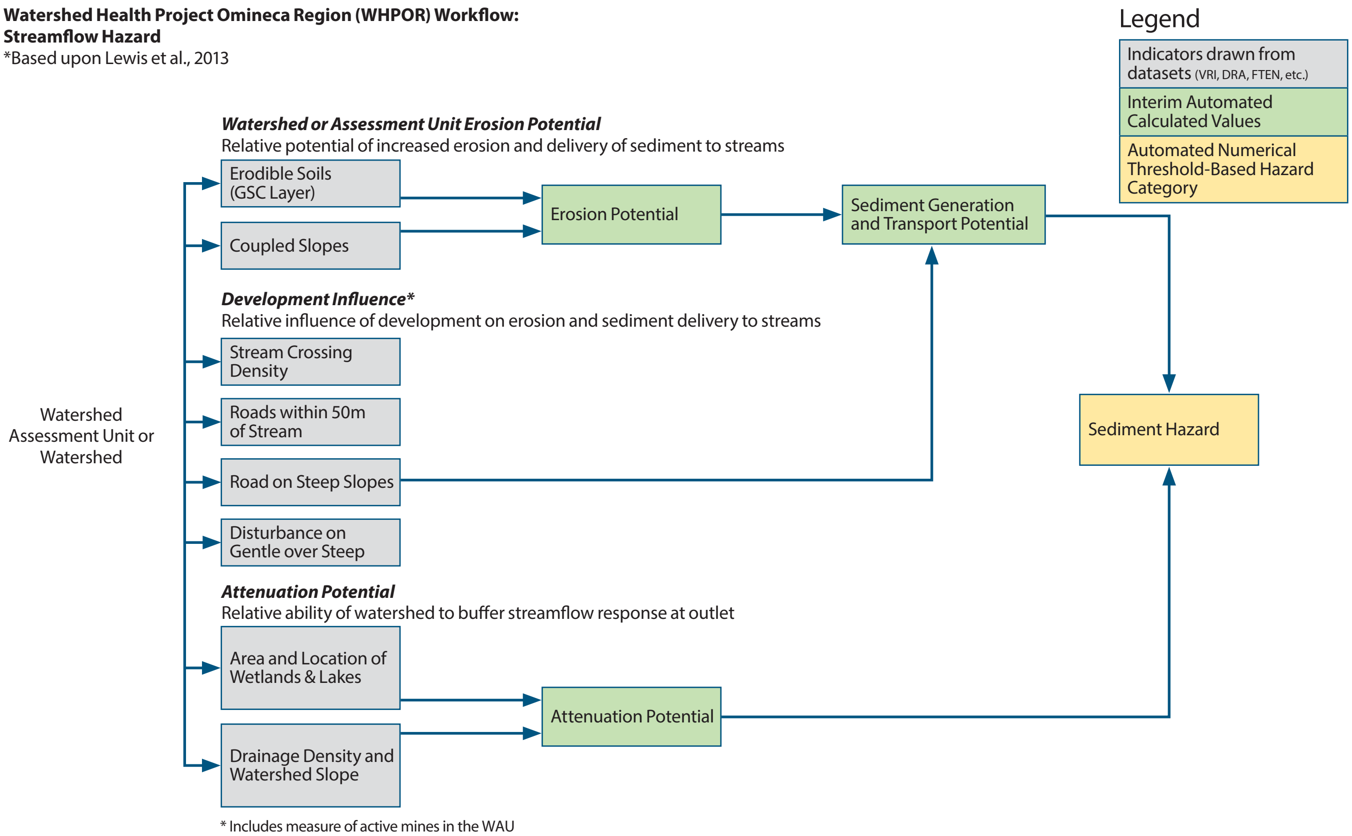

Figure 5. *Workflow of sediment hazard assessment used in the Omineca Region current condition evaluation.*

Sediment generation and transport potential was determined by considering the erosion potential of the analysis unit and development influence. In assessing development influences on resource activities, the focus here is roads because they are well documented as being the most prominent source of sediment production and delivery to streams (Gucinski, 2001; Luce, 2002; Rex and Carmichael, 2002). The provincial Forest and Range Evaluation Program identified that approximately 29% of crossings inventoried across the province and roughly 41% of those in the Omineca were at moderate hazard or higher, indicating they could be contributing 1m^3 or more sediment to streams annually (Carson and Maloney, 2021).

While roads can contribute sediments to streams at crossings, site and design variability will influence the amount of sediment entering streams. The variability in sediment delivery to streams from roads in the assessment units cannot be quantified using this GIS approach. Instead, each road-related indicator is assessed through comparison to recognized thresholds from previous watershed assessment procedural guidebooks (BC MoF, 1996 and 1999). In addition to the road indicators, this approach also looks at gentle over steep terrain, which is identified as areas where harvesting occurred on a slope < 50% that is directly coupled to a slope > 50%. Although the issue identified by this indicator may be more prominent in the Kootenay region where the supporting research originated, there are locations within the Omineca where this condition occurs, so the indicator was retained (Figure 6). Finally, placer and coal leases were also included from the original Lewis et al. (2014) approach but are rare through the Omineca and not currently found to have a significant influence on sediment hazard at the scale of analysis and so were not included in the workflow provided in Figure 5.

Figure 6. *Gentle over steep terrain and harvesting in the Anzac watershed north of Prince George (Photo Credit (August 2020): Alex Bevington, Research Hydrologist Omineca Region).*

Although it is recognized that sediment response to development activities within an assessment unit is influenced by weather and vehicle traffic on roads, this analysis does not model sediment and erosion with precipitation. That type of analysis is better addressed using a universal soil loss equation approach. Instead, this approach identifies the likelihood of sediment reaching the outlet by considering the area and location of wetlands and lakes as well as the drainage density and slope of a watershed. For example, a steep watershed with few to no wetlands or lakes has less ability to delay streamflow and allow settling of transported sediment than a lower profile system with lakes and wetlands in its lower reaches that can slow delivery of water and suspended sediment to the outlet. While this settling can decrease the geophysical hazard at the outlet, it is important to recognize that the settled sediment may have environmental consequences for those lakes and wetlands where the sediment has deposited (Donohue and Molinos, 2009.).

To determine sediment hazard, the attenuation potential and sediment generation and transport potential are combined as shown in Table 2. Those assessment units with high attenuation potential and low sediment generation and transport potential are at lowest hazard, while those with little attenuation potential and high sediment generation and transport potential have the highest sediment hazard estimates.

Table 2. *Sediment hazard determination as identified by combining categorical determination of sediment generation and transport potential as well as attenuation (from Lewis et al., 2015).*

		Attenuation Potential				
		Very High	High	Mod	Low	Very Low
Sediment Generation and Transport Potential	Very Low	V. Low	V. Low	Low	Low	Mod
	Low	V. Low	Low	Low	Mod	High
	Mod	Low	Low	Mod	High	High
	High	Low	Mod	High	High	V. High
	Very High	Mod	High	High	V. High	V. High

3.4 Riparian Hazard

Riparian hazard reflects the likelihood that disturbance within the riparian zone will alter the freshwater and terrestrial attributes that make this area one that holds some of the highest biodiversity values across the landscape (Bunnell and Dupuis, 1993; Olson et al., 2007). Data source, metrics, and threshold information is provided in Appendix 2.

Riparian hazard differs slightly in its approach compared to streamflow and sediment hazard in that rather than the correlative process used there relating disturbance indicators to hazard, riparian hazard provides a direct measure of intrusion into the riparian zone. The three land use types considered are forest disturbance as identified by cutblock or wildfire burn area boundaries, range tenures identified by polygon boundaries and presence of cattle, and private land parcels (Figure 7).

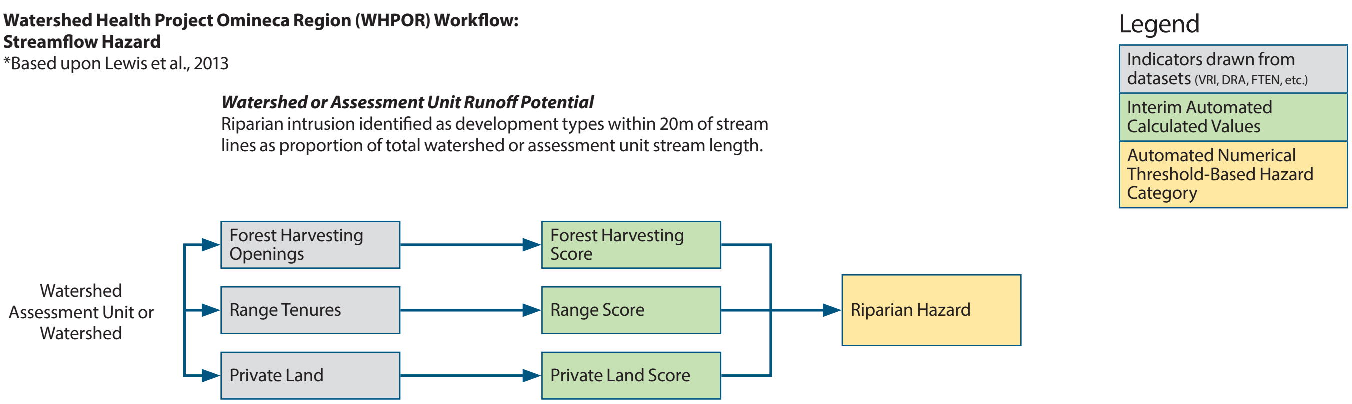

Figure 7. *Workflow of riparian hazard assessment used in the Omineca Region current condition evaluation.*

Where any of these disturbance boundaries lay within 20m of the stream edge, that length of intrusion was measured and summed across the watershed to identify the proportion of riparian zone encroachment across the entire watershed. Rex et al., (2011) suggest that small streams that do not currently have reserve zones would benefit from a 10 m reserve to maintain stream function in north central BC. Data accuracy for riparian disturbance is 20m so that was selected as the threshold because finer resolution was not possible. Larger streams having intrusion within 20m will also be identified but expectations are that forest disturbance since FPC into large stream riparian zones will not occur because they have reserves of 20m and greater (or in the case of S1-A streams a floodplain > 100m). Although this assessment includes three tenure types, most areas of the Omineca Region have only one tenure type with regularity, namely forest harvesting. As initially designed, riparian hazard is estimated by summing all three tenure types and requires moderate or higher score on two or more to reach a moderate or high hazard (Lewis et al., 2014). This approach was not followed in the Omineca Region, because vast areas of the region are only exposed to forest harvesting and may accordingly never reach moderate or higher hazard regardless of forest disturbance levels. Although we do consider all three types of development, to ensure forest disturbance influences were not diluted by the absence of other land tenure types, a threshold of 30% riparian disturbance for forestry was deemed to be a high hazard. This threshold is based on local research that identified in-stream response of invertebrates and stream process when the proportion of riparian areas upstream surpassed that level (Nordin et al., 2009). Watersheds having 20-30% or more riparian disturbance were considered moderate hazard.

3.5 Caveats

The assessment provided here uses WAU which is useful for a cumulative effects assessment because it shows the development footprint as well as the related hazard and provides for a coarse-level comparison among many watersheds. It does not provide an estimate of the impact of development or risk to resource values. It provides a district and regional overview of current condition that can be reviewed annually to identify broad development and hazard trends. Although useful for identifying annual trends, it does not provide information on all regional watersheds. This is because, as discussed earlier, watersheds are nested systems that can be drawn with respect to specific characteristics, such as stream order (e.g., a 4th order watershed), or a downstream value of interest, such as potable supply. The next iteration of this assessment will present both WAU and watershed-based metrics. Watersheds that will be presented then will be 3rd to 5th order systems that are tributaries to 6th order and higher mainstem rivers as outlined in Appendix 1.

The procedure outlined in this report will evolve as knowledge is improved by research findings and local fieldwork, generated by the provincial program or identified in literature. For example, prior to recent research by Winkler and Boon (2015) harvested sites were considered 90% hydrologically recovered from an ECA perspective when trees reached 9m, but these recent findings indicate recovery is between 60-65% of mature stand height which is more variable than a 9m target (Winkler and Boone, 2015). The mountain pine beetle ECA approach used in this assessment (Lewis and Huggard, 2010) has not been integrated into the new Winkler and Boone recovery curves but will be for the next version. Hazard thresholds may also change as and where research identifies the need for a shift. If changes occur, they will be identified within procedural descriptions of future assessments.

4 CURRENT CONDITIONS

4.1 Stream Flow Hazard

Forest cover disturbance information to 2019 shows a clear concentration of forest canopy loss in the southern Stuart-Nechako (DVA) and western Prince George (DPG) resource management districts. These areas were significantly affected by MPB, salvage harvesting, and fires over the last 15-20 years (Figure 8). Fires and forest development have also increased ECA values in areas of the Mackenzie (DMK) as well as central Stuart-Nechako (DVA). The Robson Valley, which is the south eastern arm of DPG shows ECA concentration primarily along the Fraser mainstem and highway corridor.

Despite having some high and very high ECA levels throughout most of the DVA and DPG, streamflow hazard estimates are lower than might be expected looking at ECA alone (Figure 9). At the WAU level, this is due to the attenuating influence of wetlands and lakes, as well as lower runoff potential due to relatively low snowpack levels estimated for the area (Figure 9). In contrast, higher slope areas of the DMK and Robson Valley in the DPG are well forested and have high projected snowpack levels and consequently have moderate projected streamflow hazards despite low ECA levels. This identifies that these areas may be particularly responsive to forest canopy disturbance and that hazard may increase disproportionately to relative level of disturbance depending upon their responsiveness. Given the current spruce beetle outbreak in the DMK and DPG and related potential for salvage operations, there should be consideration of the synergistic influence of development and beetle disturbance on hydrologic shifts, particularly in those watersheds that may be more responsive to disturbance and increased runoff.

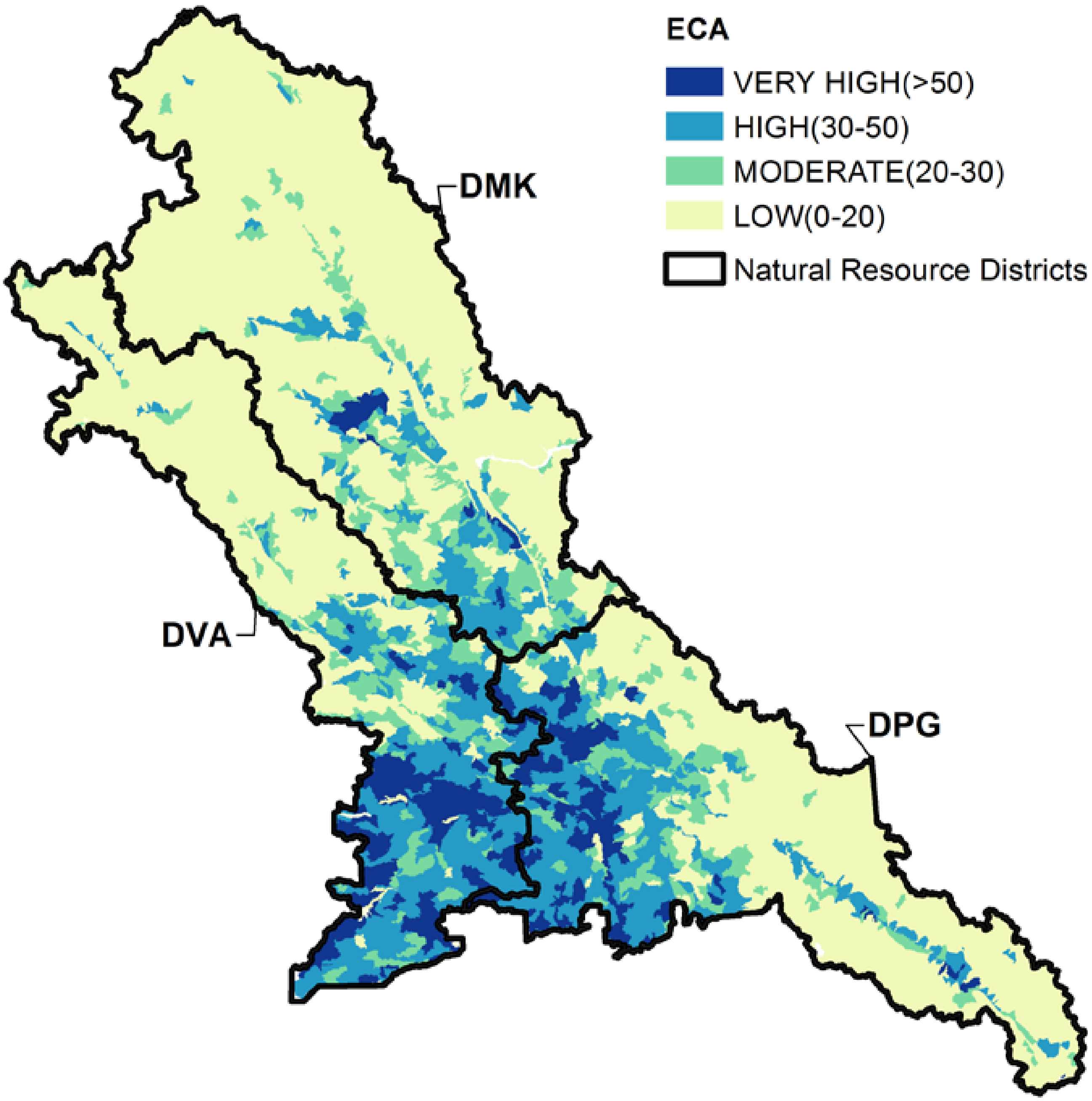

Figure 8. *Equivalent clearcut estimates for the Omineca Region based upon forest disturbance data to 2019.*

On a regional level, approximately 60% of WAU have low ECA levels below 18 and 74% are below 30 (Figure 10). Of the 26% of WAU that exceed an ECA of 30, most are in the southern DVA and western DPG which were heavily affected by the MPB infestation, subsequent salvage harvesting, and have large areas with private land holdings that have been cleared (Figure 8, Table 3). The concentration of these forest disturbance events and differences in land use activities is reflected in the district breakdown shown in Table 3 which indicates that of the three districts, Prince George and Stuart-Nechako exhibit the highest relative levels of disturbance with approximately 45 and 51% of their WAU in the moderate and higher ECA categories respectively (Table 3). Although the Prince George district had ~34% of its watersheds in high to very high ECA, approximately 20% are in the high streamflow hazard condition. In Stuart- Nechako, ~40% of the watersheds are high to very high ECA but only approximately 15% of WAU are in the high streamflow hazard due to WAU buffering capability (Table 4).

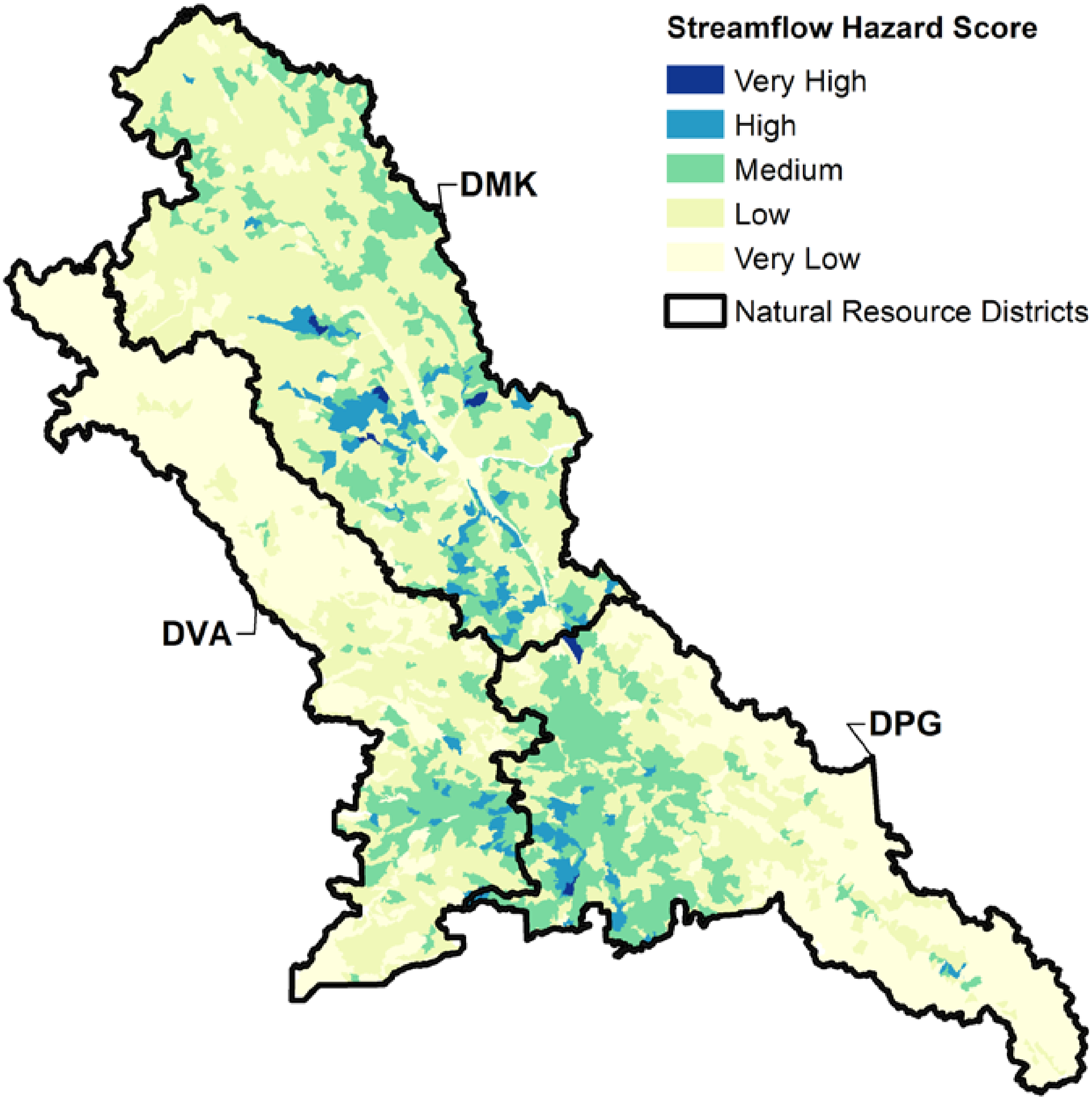

Figure 9. *Streamflow hazard estimates for the Omineca Region based upon 2019 forest disturbance information.*

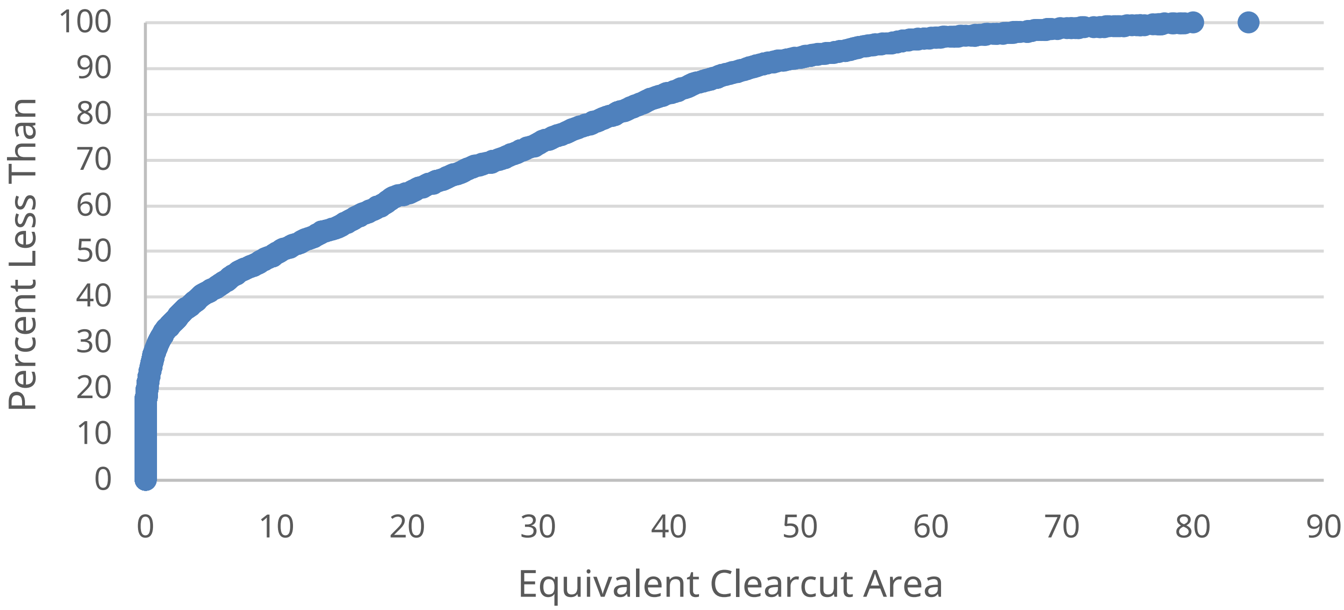

Figure 10. *Workflow of riparian hazard assessment used in the Omineca Region current condition evaluation.*

Table 3. *Categorical ECA values for WAU in each of the three districts within the Omineca region.*

	Mackenzie	Prince George	Stuart-Nechako
Low	79.1	54.6	48.8
Moderate	10.4	11.1	10.8
High	9.1	24.2	26.5
Very High	1.4	10.1	13.9

Table 4. *Categorical streamflow hazard values for each of the three districts within the Omineca region.*

	Mackenzie	Prince George	Stuart-Nechako
Very Low	7.0	5.1	10.8
Low	67.4	44.8	57.4
Moderate	19.6	29.8	16.6
High	5.6	20.1	15.2
Very High	0.5	0.2	0

4.2 Sediment Hazard

Approximately 40% of the WAU units in the Omineca region have one or more kilometer of road per square kilometer of watershed area (Figure 11). As a result of the extensive road network through the region, approximately 38% of regional WAU have stream crossing densities exceeding 0.6/km^2 placing them in the high to very high category. The highest concentration of crossings was found to be in the DVA and DPG with approximately 40 and 56% of respective WAU having high densities (Table 5). One caveat to the numbers provided here is that decommissioned roads are not well documented, so the numbers presented for both road density and crossings may be higher than they should be where road sections have been decommissioned and restored. Road and crossing density are higher in the central portion of the region which has been the concentrated area of forest development including private lands and highways (Figure 12).

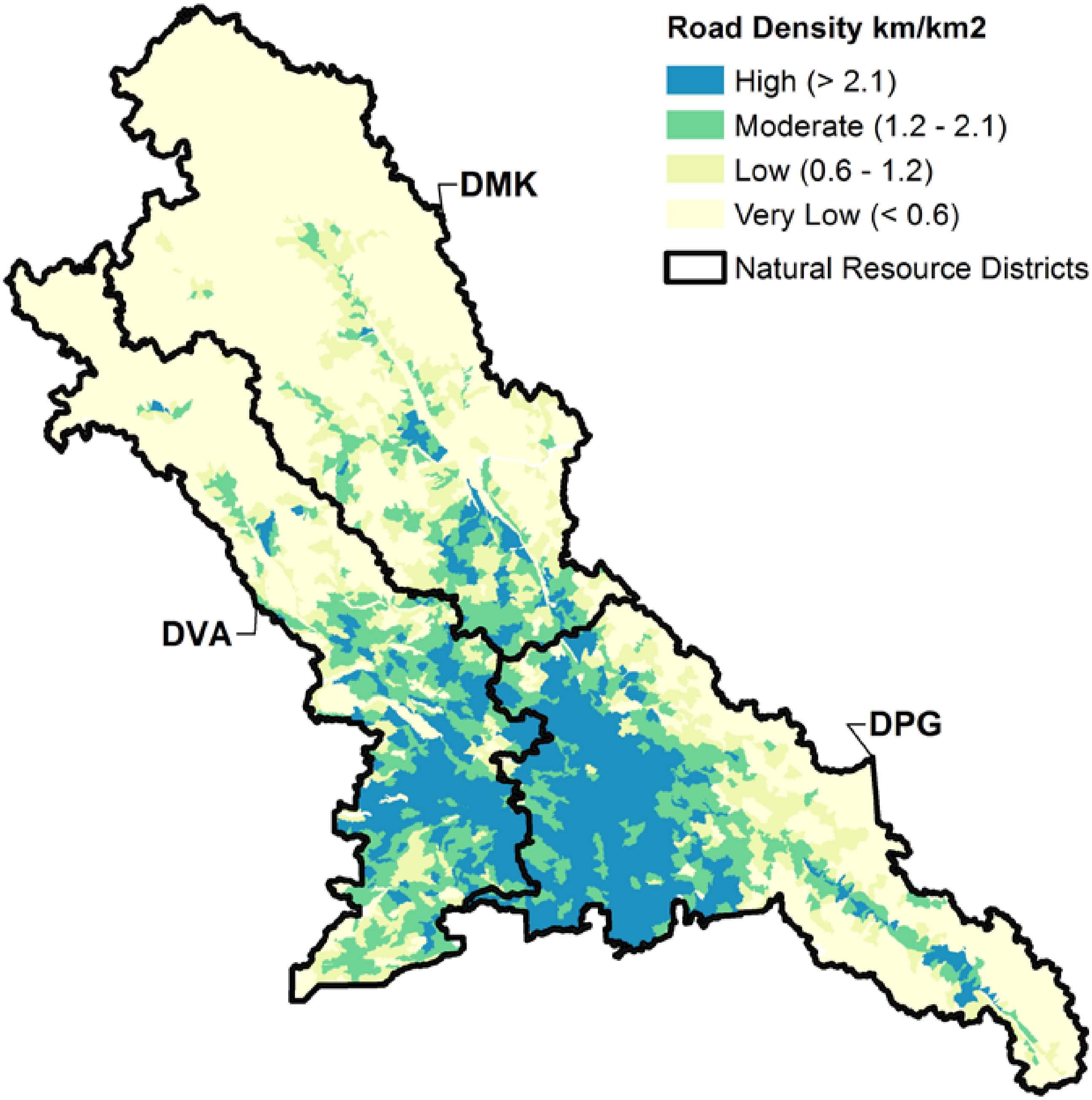

Figure 11. *Road density for WAU in the Omineca Region to 2019 (very low <0.3 km/km², Low 0.3-1.5 km/km², moderate 1.5-1.94 km/km², moderate 1.94-2.38 km/km², high >2.38 km/km²).*

Table 5. *Categorical stream crossing classes for WAU in each of the three districts within the Omineca region.*

	Mackenzie	Prince George	Stuart-Nechako
Low	74.2	36.3	47.3
Moderate	8.7	7.2	11.8
High	17.1	56.6	40.9

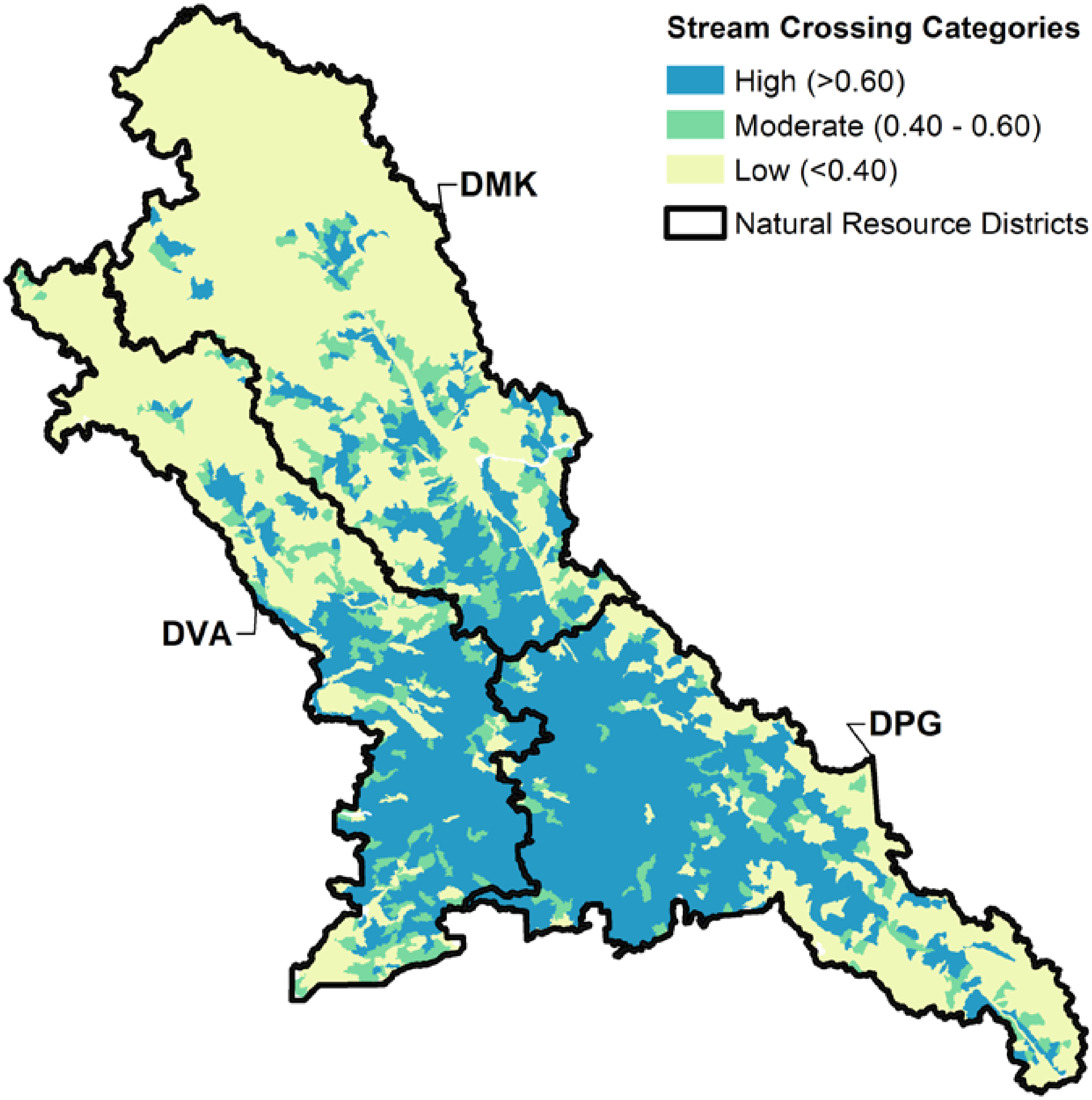

Figure 12. *Stream crossing density for the Omineca Region based upon 2019 information (Low (<0.4 /km^2), Moderate (0.4- 0.6/km^2), High (>0.6/km^2)).*

Roads near streams can influence sediment transport in watersheds. The DPG and DVA have upwards of 45% or 20% respectively of WAU with roads near streams (Table 6). Roads on steep slopes and gentle over steep terrain are site specific concerns not broadly seen across the region, but rather within pockets of certain resource districts (Tables 7 and 8). Prince George has the highest concentration of WAU with roads on steep slopes with approximately 14% being moderate and higher, followed by the Mackenzie and Stuart-Nechako districts. Although included in the assessment, gentle over steep development areas were found to be rare in the region, with 1.5% of WAU in the Mackenzie district at moderate or higher levels followed by Prince George at 1% (Table 8). Gentle over steep development areas are relatively rare currently but as forest harvesting efforts focus on spruce beetle affected areas in steeper areas of the Mackenzie and Prince George District the frequency of gentle over steep may increase and best management practices developed in the southern interior where this issue was first described should be considered to minimize landslide risk (Jordan, 2001).

Table 6. *Categorical roads near stream classes for WAU within each of the Omineca Region districts.*

	Mackenzie	Prince George	Stuart-Nechako
Low	91	54.4	70.8
Moderate	7.8	24.4	20.2
High	1.2	21.2	9

Table 7. *Categorical roads on steep slope classes for WAU within each of the Omineca Region districts.*

	Mackenzie	Prince George	Stuart-Nechako
Low	93.9	85.7	99
Moderate	6	13.6	1.0
High	0.1	0.7	0

Table 8. *Categorical gentle over steep classes for WAU within each of the Omineca Region districts.*

	Mackenzie	Prince George	Stuart-Nechako
Low	98.5	99	100
Moderate	1.3	0.9	0
High	0.2	0.1	0

Determination of sediment hazard for each WAU includes the development indicators described above, as well as WAU generation and attenuation potential. Accordingly, development indicator values such as road information are less variable than sediment hazard rating. Some WAU with high road densities can have a lower sediment hazard than those with lower road densities owing to watershed soil and slope conditions and level of road use relative to surfacing quality.

Substantial portions of the DPG are identified as having high to very high sediment hazard (Table 9, Figure 13). These hazard levels are being driven in some areas by stream crossing density and others by watershed conditions, such as steep coupled slopes and erodibility (Figure 14). Further, higher drainage densities and lack of lake and wetland buffering for many WAU in the Robson Valley is contributing to higher hazard levels. Forest development in areas with steep coupled slopes and limited attenuation or buffering capacity should be paired with monitoring to ensure erosion and sediment control measures minimize sediment erosion and delivery to waterbodies.

Table 9. *Sediment hazard for WAU in the Omineca Region across resource districts.*

	Mackenzie	Prince George	Stuart-Nechako
Very Low	70.6	35.7	78.7
Low	9.8	15.8	12.1
Moderate	7.3	11.8	5.6
High	5.6	12.9	3.0
Very High	6.7	23.8	0.6

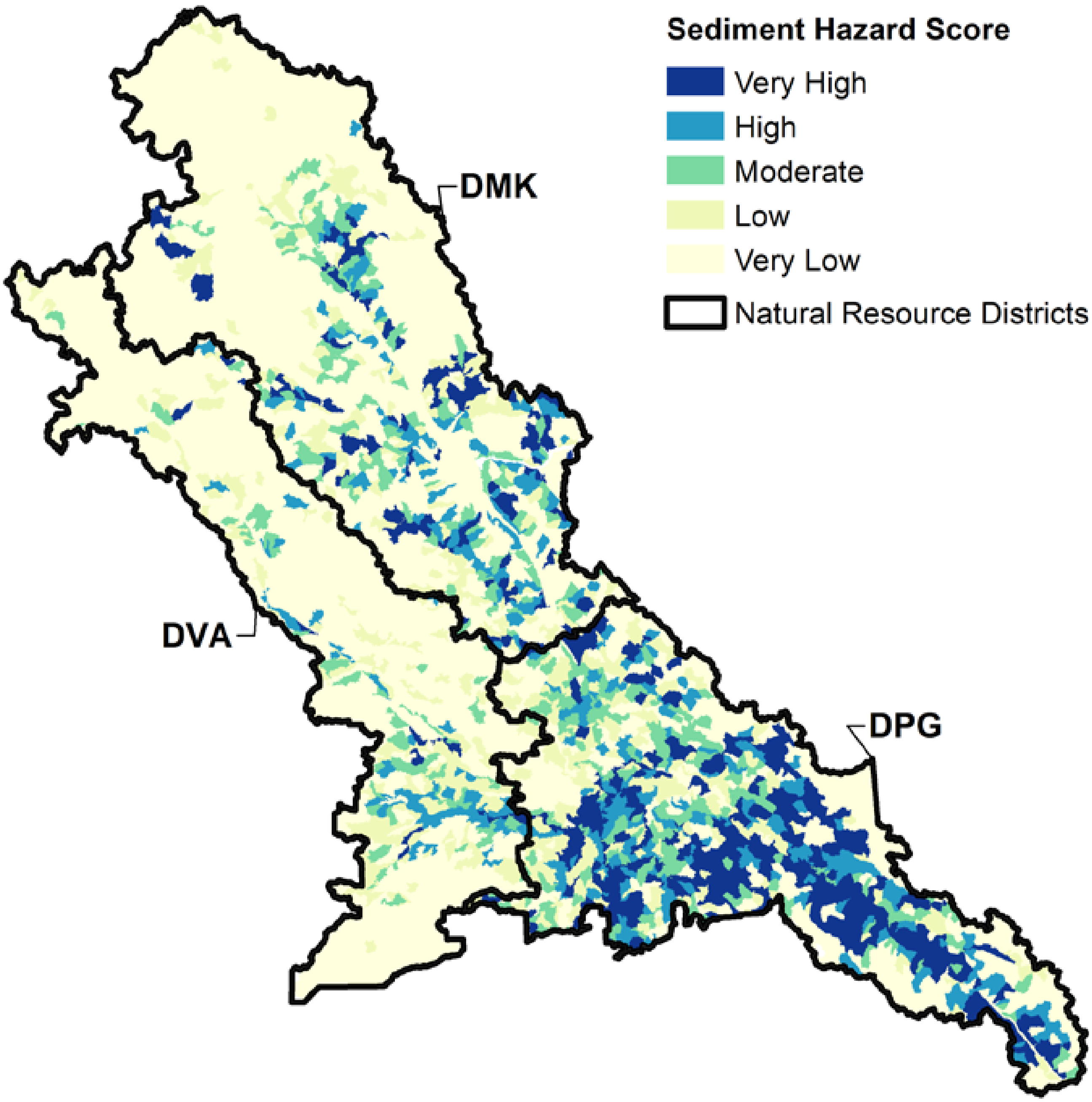

Figure 13. *Sediment hazard for Omineca Region based upon 2019 information.*

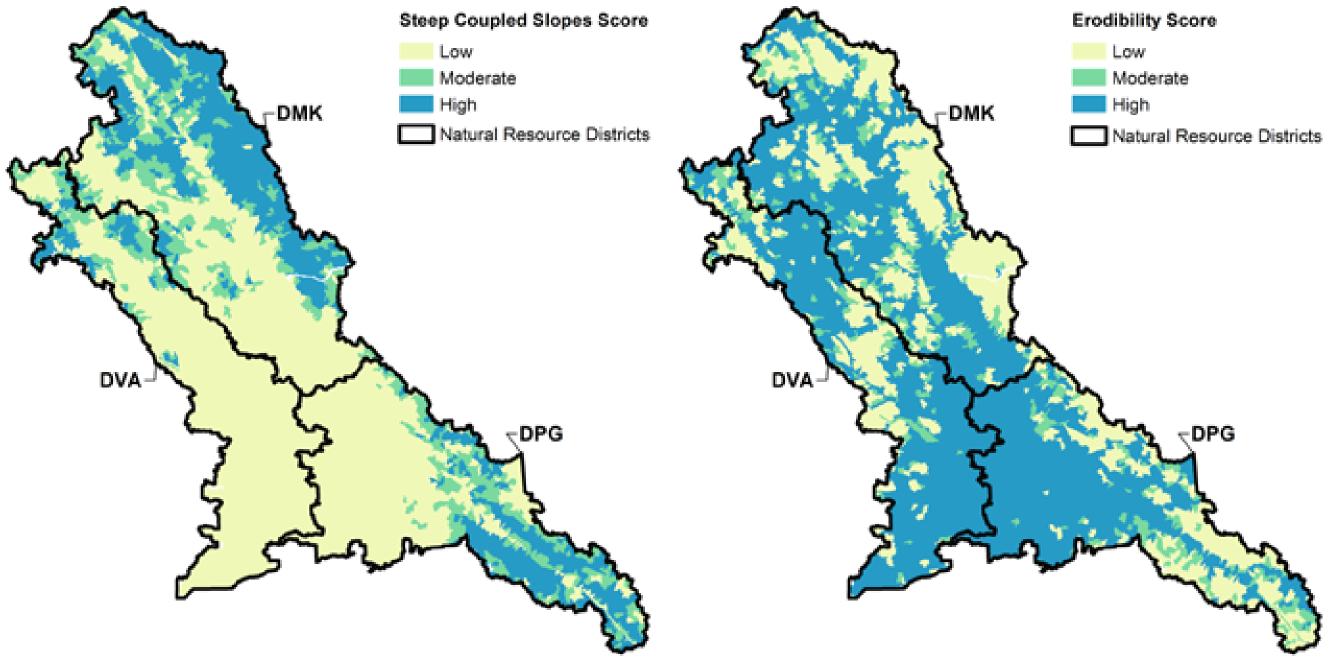

Figure 14. *Omineca regional steep coupled slope (left) and soil erodibility indicator (right) scores.*

4.3 Riparian Hazard

Crown land forest development is the most expansive type of land development activity in the region and accordingly it has the greatest level of intrusion into riparian zones (Table 10). The greatest proportion of WAU with moderate or higher levels of overlap between riparian zones and block boundaries occurs in the DPG and DVA districts at 50% and 41% respectively. The DVA and DPG have the highest human populations, agricultural areas, and cities so they consequently have the highest proportion of private land intrusion on riparian zones at 11.6% and 7.8% respectively. Range tenure occurs in concentrated areas, but across the region is relatively low in comparison to crown land forestry and private land holdings. Prince George and Mackenzie had the highest level of range tenure overlap at 2.5% and 1.2% respectively. At the regional level, range influence is limited, but in those areas with concentrated usage, cattle can have a significant effect on stream condition (FPB, 2002; Carson and Maloney, 2021). It is relevant to note here that the combination of private land and range in the southern portion of the Stuart-Nechako district around Vanderhoof is an area with high density cattle operations that is diluted at the district scale due to the large size of the DVA.

Table 10. *Land tenure intrusion on WAU riparian zones by resource district and relative disturbance level.*

	Logged Riparian			Range Tenure			Private Land		
	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
Mackenzie	79	17.9	3.2	97.4	2.1	0.5	100		
Prince George	49.9	30.9	19.2	97.5	2.3	0.2	88.5	7.3	4.3
Stuart-Nechako	58.7	34.3	7.0	98.8	1.1	0.1	92.2	4.6	3.2

The Prince George and Stuart-Nechako districts have the highest levels of riparian hazard at roughly 28% and 13% of the WAU being moderate or higher. The higher levels of riparian hazard in these districts are associated with pine beetle salvage, private land, and range values. Given the current spruce beetle outbreak in northern Prince George and southern Mackenzie districts, riparian hazard levels may continue to increase depending upon riparian management practices.

Table 11. *Riparian hazard values by resource district in the Omineca region.*

	Very Low	Low	Moderate	High	Very High
Mackenzie	76.4	20	3.6	0	0
Prince George	44.1	27.8	24.6	3.1	0.4
Stuart-Nechako	55.4	30.4	12.5	1.7	

4.4 Summary

The assessment provided here clearly shows that the MPB epidemic and subsequent pine beetle salvage operations had a significant influence on WAU of the Prince George resource district as it has the highest proportions of WAU in moderate and higher hazard categories (Table 12). The disturbance footprint is much higher than the predicted streamflow hazard in the Stuart-Nechako district due to tempered streamflow response owing to its comparatively gentle landscape and higher proportion of wetlands and lakes in lower reaches of district WAU. The response is slightly more variable in the Prince George district which has some steeper sloped WAU leading to areas with relatively little disturbance having moderate streamflow hazard as noted for the Robson Valley. This pattern is also observed for some Mackenzie watersheds. Where these more responsive watersheds intersect with spruce beetle infestation it should be recognized that there is an elevated baseline streamflow hazard and best management practices, such as those outlined in the Omineca Region Guidelines for Watershed Planning (BC Gov, 2017) should be considered. As identified in the introduction of this report, the results of this assessment are best considered in combination with more detailed field assessments as well as air photo interpretation and other remote sensing analyses.

Table 12. *Summary table of the three hazard types across resource districts in the Omineca region.*

District	Hazard	Very Low	Low	Moderate	High	Very High
Mackenzie	Streamflow	7	67.4	19.6	5.6	0.4
	Sediment	70.6	9.8	7.3	5.5	6.7
	Riparian	76.4	20	3.6		
Prince George	Streamflow	5.1	44.8	29.8	20.1	0.2
	Sediment	35.7	15.8	11.8	12.9	23.8
	Riparian	44.1	27.8	24.6	3.1	0.4
Stuart-Nechako	Streamflow	10.8	57.4	16.6	15.2	
	Sediment	78.7	12.1	5.6	3	0.6
	Riparian	55.4	30.4	12.5	1.7	

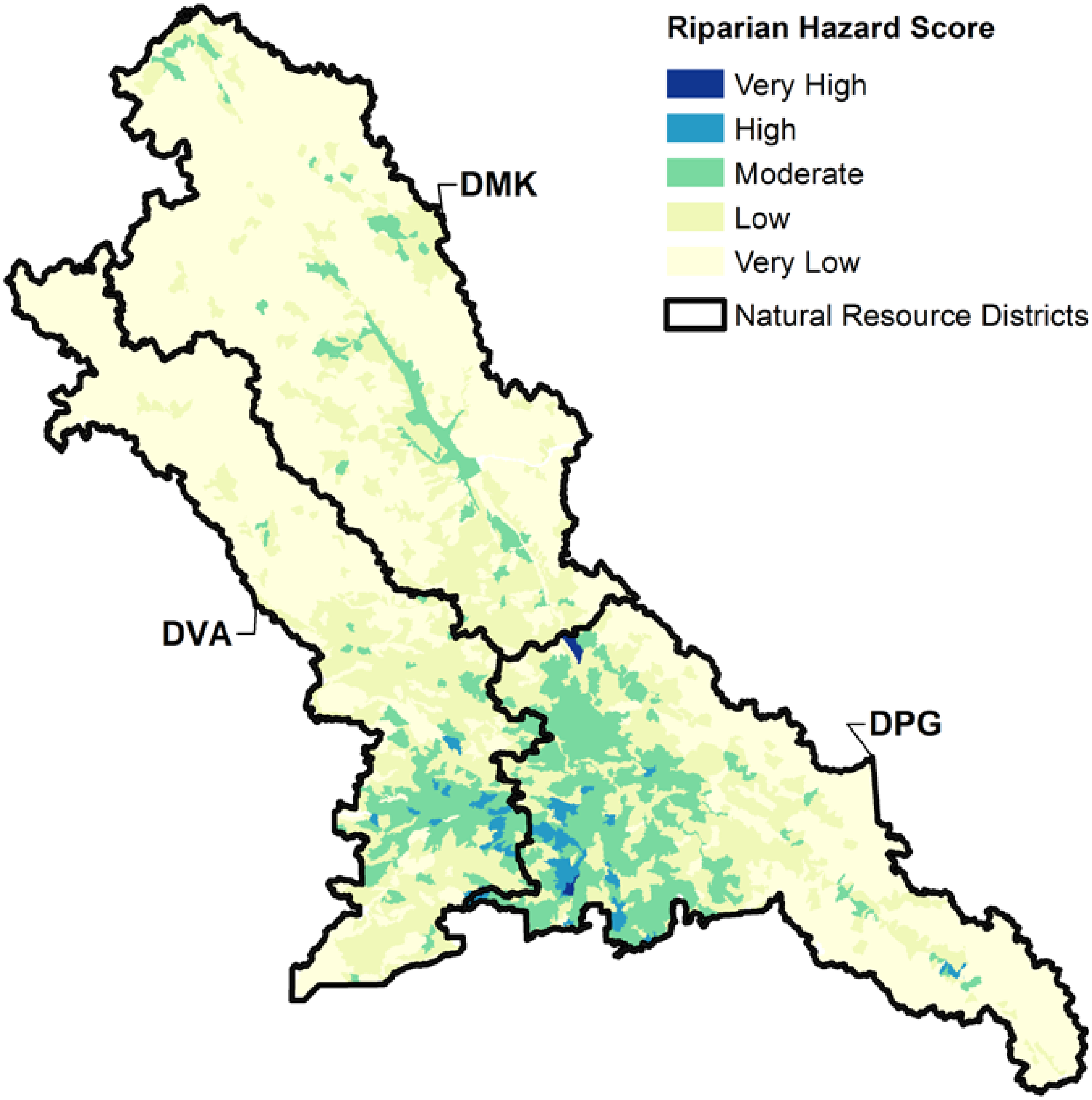

Figure 15. *Riparian hazard for Omineca Region based upon 2019 information.*

Sediment hazard conditions are moderate or higher for more than 48% of the WAU in the Prince George district. This relatively high proportion of sites is due to a combination of erodible soils, historical harvesting and MPB salvage, as well as steep coupled slopes along the Robson Valley where pockets of development occur in catchments with high stream-crossing density and limited sediment attenuation capability. Most of the Stuart-Nechako and Prince George districts were classified as having erodible soils and some of these areas are comprised of WAU with steep coupled slopes. Both indicators suggest these WAU to be potentially quite responsive to existing and new road construction. In those areas with moderate and higher baseline hazard, roads may have a larger than anticipated effect on erosion and sediment transport processes. Consequently, it is recommended that findings from the provincial FREP water quality program (Carson and Maloney, 2021) and erosion and sediment control for forest roads and stream crossings from FP Innovations (FP Innovations, 2007) be considered.

Riparian hazard conditions were highest in the Prince George and Stuart-Nechako districts owing to historical harvesting, as well as recent salvage harvesting associated with the MPB, and higher levels of private land ownership. Logging was the primary form of riparian disturbance followed by riparian clearing on private lands. Provincial FREP findings indicate that larger stream systems, particularly those with buffers (S1-S3) have better outcomes than smaller systems and/or those without buffers (S4-S6) (Nordin et al., 2016). Where streams are encountered during industrial or private development, retention of riparian buffers can decrease environmental impact and maintain stream function. Regional research identified the need for maintaining the first 10m around small streams (Rex et al., 2010) while provincially it was found that small streams with a minimum of 10 m of retention on either side were in better and properly functioning or in low-risk condition compared to those that had less retention (Nordin et al., 2016). Where possible, co-location of wildlife tree patches or other reserves with small un-buffered streams contained will help to temper riparian disturbance in forest development blocks.

Reviewing specific hazards at the WAU level has value as does considering the combination of hazards within each unit. Given the summary nature of this report, we provide the number of hazards within each WAU that are moderate or higher. Moderate was chosen as a threshold because it assumes that disturbance levels beyond current levels will increase the degree within the moderate category or into higher levels. Looking across districts it is seen that Prince George has approximately 43% of its WAU with two or more moderate hazards followed by Stuart-Nechako and Mackenzie at approximately 15 and 10% respectively (Table 13). In the Prince George District, the number of WAU with two or more hazards above moderate are generally associated with historical harvesting, fires, as well as MPB and salvage-harvesting, private lands, and in steeper terrain where sediment and stream flow hazard are naturally higher (Figure 16). Stuart-Nechako WAU in private land areas as well as that associated with MPB-related salvage harvesting appear to have a higher number of moderate hazards while in Mackenzie WAU with natural hazard conditions or those where disturbance occurs and may exacerbate natural hazards have two or more moderate hazard scores (Figure 16).

Table 13. *Proportion of WAU with moderate hazard scores for each of the three districts in the Omineca Region.*

	0	1	2	3
Mackenzie	62.3	27.4	9.4	0.9
Prince George	30.9	26.2	28.1	14.7
Stuart-Nechako	63.7	21.1	10.3	4.9

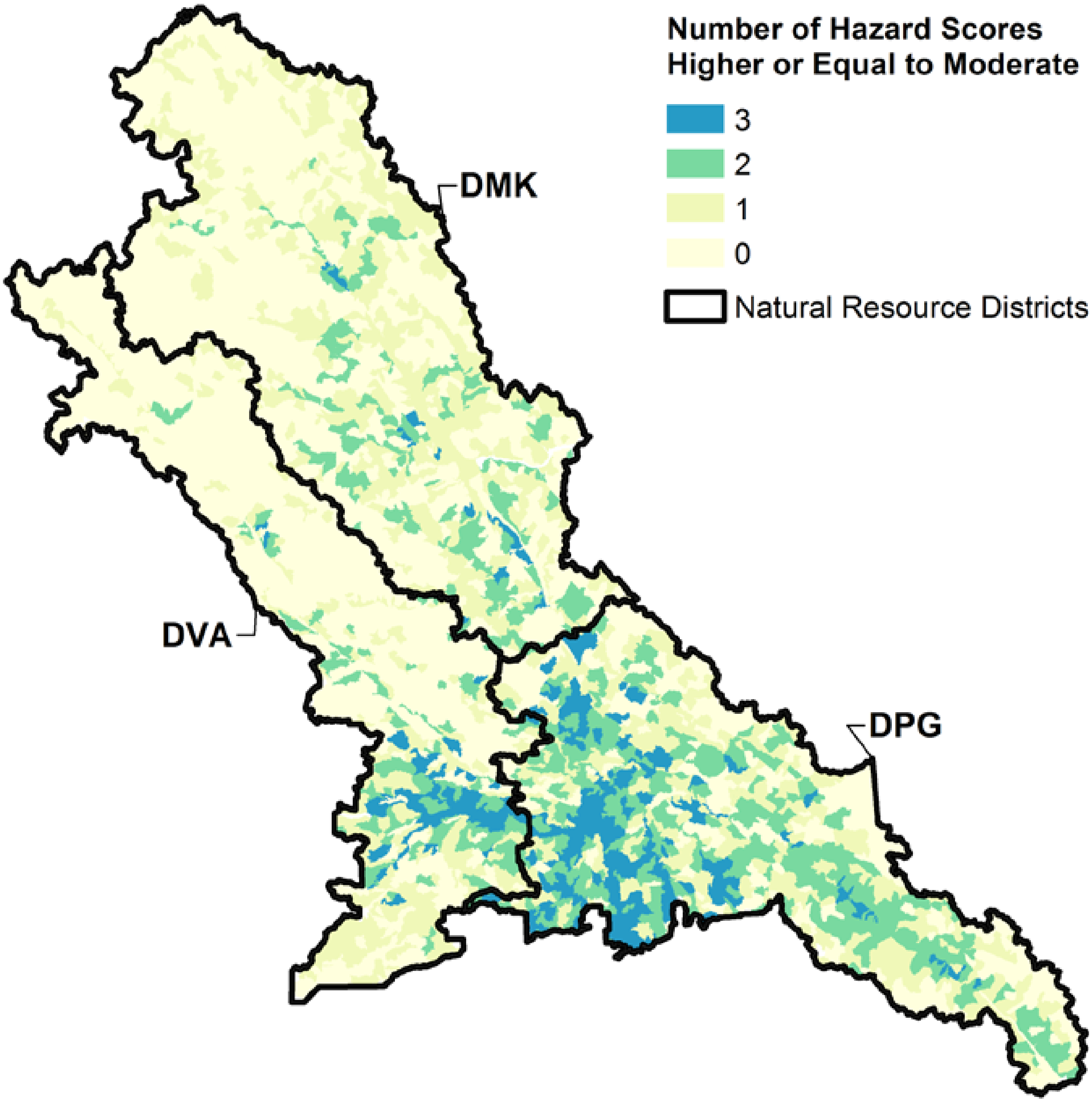

Figure 16. *Omineca regional WAU with moderate hazards based on analysis using 2019 data.*

5 FUTURE REPORTS

This is the initial report for the Omineca Region, and it is expected that this report will be updated as disturbance and vegetation resource inventory databases are updated. It is expected that there will be changes in the way data is presented and that other hazard metrics will be incorporated as data and research/field verification allows. Due to the size of the region, it is recognized that the scale of the maps provided in this document are not useful for planning purposes at the watershed or site level, so this report is provided as a thematic overview of current conditions and where the data is required to support planning and development purposes, it can be provided upon request. Future editions of the report and the data upon which it is written will be made available on the provincial cumulative effects and regional websites.

As identified in the document, some of the changes expected in the next report include:

- Development of a regional watershed layer that will separate tributary and mainstem topographically defined watersheds. Presenting the WAU layer as provided here provides complete regional coverage while the mainstem and tributary analysis allows for watershed -specific overviews (Appendix 1).
- Current hydrological hazard focus is on the increase in peak flows owing to public safety and aquatic habitat concerns. Anticipated climate change effects on precipitation patterns may increase drought frequency with implications for summer low stream flows. Consequently, future version of this document will employ a measure of drought hazard at the WAU and watershed level using the stand-level drought risk assessment tool (Foord et al., 2017; Griesbauer et al., 2021).
- Equivalent clearcut area estimates will be improved for the next version through current research into development of recovery curves for historical wildfire areas and integration of the MPB ECA metrics with the Winkler and Boone (2015) recovery curves.
- Riparian disturbance metrics for logging should identify where enhanced reserves occur particularly for small streams.
- Remote sensing related metrics on disturbance patterns such as riparian intrusion, development rate, burned vegetation, and forest regrowth will be added to support/validate GIS-based indicators.

In addition to the metrics provided by this process, it is anticipated that discussions and application of this data will provide the opportunity for enhanced collaboration with First Nations, industry, and communities. These discussions have been initiated regionally through the Environmental Stewardship Initiative and community-based watershed restoration within the Nechako Basin. Collaboration regionally and with provincial counterparts will both inform and improve the current process and potentially broaden and enhance the application of the information contained in this and future reports.

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APPENDICES

Appendix 1 - WAU and Watershed Evaluation Scales

The objective of this section of the report is to explain the value of considering varying scales of watersheds as well as the watershed assessment units (WAU) for identifying regional conditions, development or disturbance effects, and restoration planning. The next version of this document will subdivide the region into mainstem rivers identified as being of 6th order and larger watersheds, followed by the 3rd to 5th order component tributary basins to mainstems, as well as WAU as presented in this report.

By looking at 6th order and larger basins such as the Chilako River (Figure 1) the reviewer can identify relative hazard conditions of these systems throughout the entire watershed. Where large systems such as these indicate moderate and higher hazard there should be further investigation because it might generally be expected that the larger size of these watersheds could lower geophysical hazard estimate due to size (i.e., averaging of hazards based on a larger land base. To clarify the need for looking at these scales, we present two fictitiously important fish habitat sites located in the Chilako that are candidates for some potential restoration work to address sediment generation and transport (Figure 1).

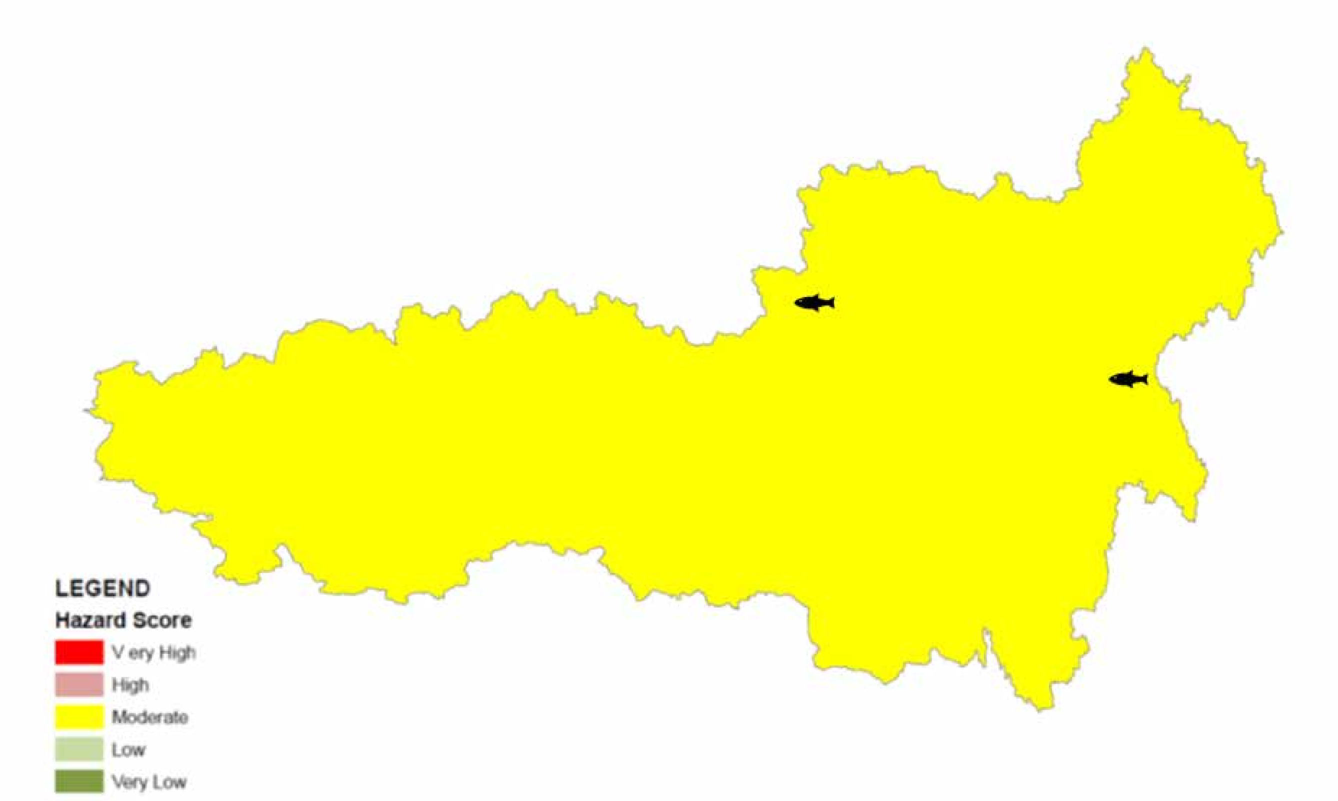

Figure A1. *The Chilako River watershed sediment hazard rating for the entire system is identified here as a moderate hazard. The watershed is over 3400 square kilometers and a moderate ranking over that area indicates that either much of the basin is at moderate hazard and/or the proportion of low and high hazard areas are relatively equal. For demonstration purposes the two fish markers are intended to indicate areas important to fish and candidates for restoration work if needed.*

Once the component 3rd to 5th order tributary watersheds to the mainstem are drawn a couple of things become obvious (Figure 2). First, there are areas within the watershed that are not identified (white polygons). These have not been identified because they are not at minimum third order watersheds. Also, we see there is considerable variability among the tributary basins with much of the watershed in a low to very low sediment hazard condition but approximately 15 of the direct tributary watersheds are in a high hazard condition. The two fisheries areas being considered for restoration work are in watersheds with different hazard conditions with the western site being in a low hazard system while the eastern site is in the lower end of a high hazard watershed.

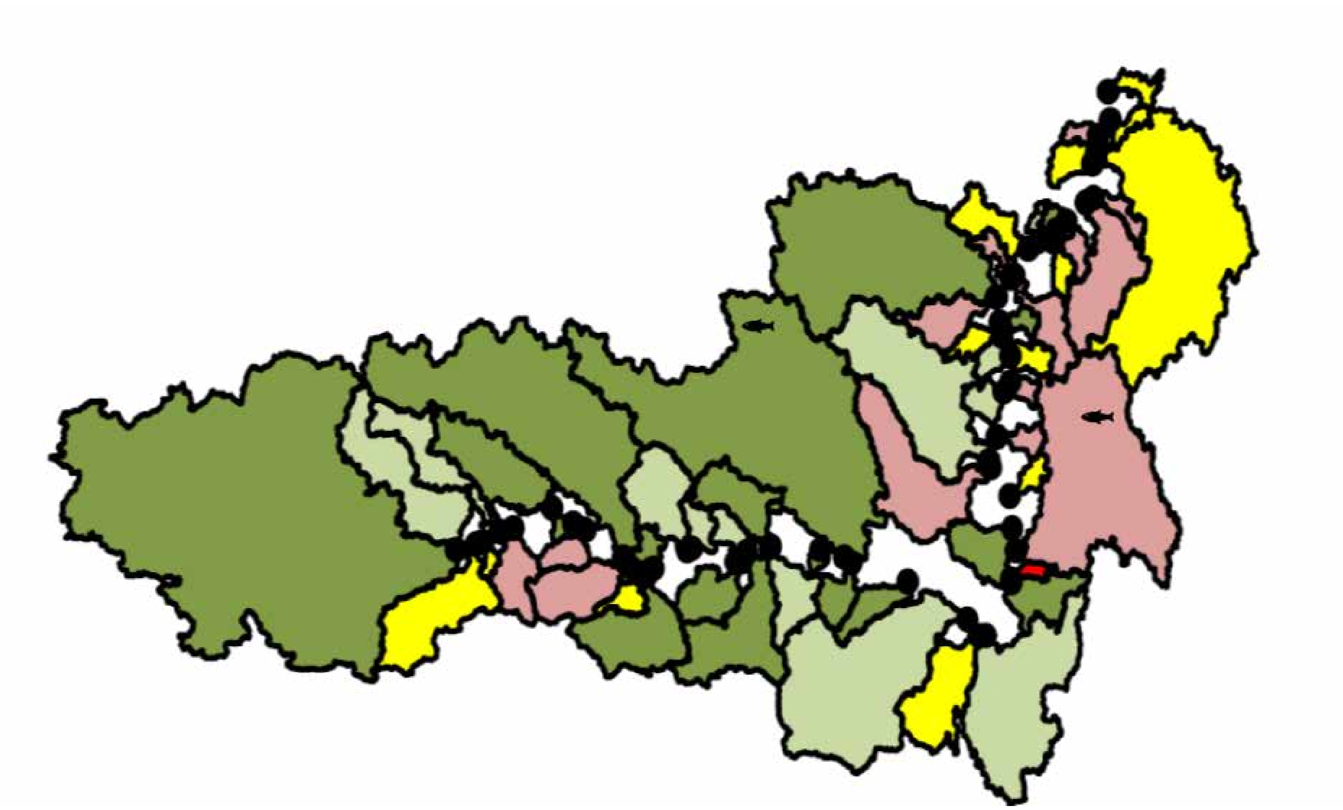

Figure A2. *The Chilako River watershed sediment hazard rating for 3rd-5th order direct tributary watersheds. The Chilako flows from the west (left) along the dots and then north (top) to its outlet to the Nechako. For demonstration purposes the two fish markers are intended to indicate areas important to fish and candidates for restoration work where needed.*

The WAU provide complete coverage for the Chilako River watershed (Figure 3). Focussing on the two watersheds of interest (Figure 3) the western watershed is seen to be composed of 7 WAU and one of these headwater polygons is in moderate sediment hazard condition which should be considered during future development decisions as it contributes water and sediment to downstream reaches over time where the fish habitat value of interest is located. The eastern watershed is composed of four WAU and the lower portion containing the valued fish habitat area is the receiving polygon of the two upstream moderate and a single very high hazard WAU because these units drain north into the Chilako mainstem (Figure 3). Armed with this information the restoration planner may choose to focus on the eastern watershed and conduct more intensive reviews of these three WAU starting with the highest hazard system using remote sensing tools such as historical photos and satellite imagery to identify natural and development induced sediment sources as well as channel morphology changes followed by field visitation for drone flights as well and road/crossing inspection.

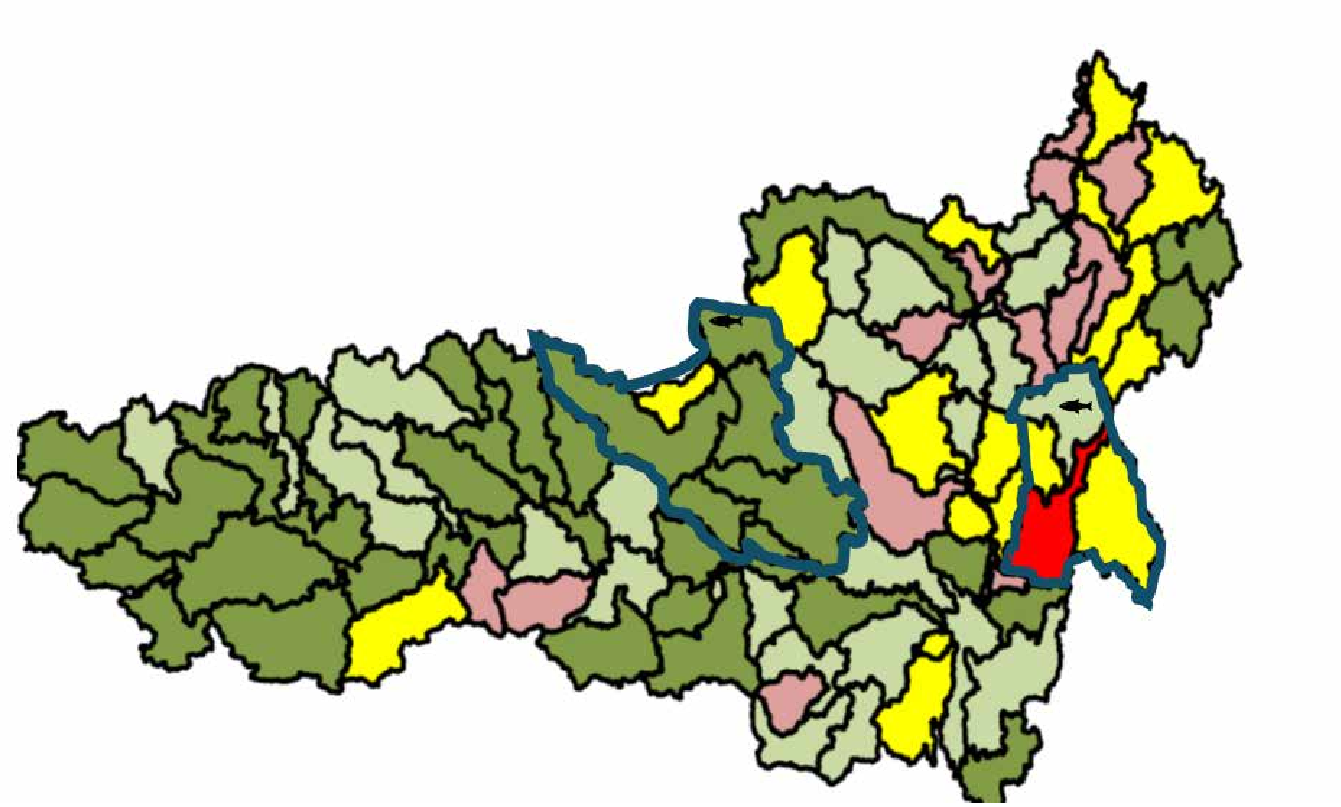

Figure A3. *The Chilako River watershed sediment hazard rating for all WAU within the watershed. The Chilako flows from the west along the dots and then north to its outlet to the Nechako. For demonstration purposes the two fish markers are intended to indicate areas important to fish and candidates for restoration work where needed.*

This exercise identifies the value in looking across the range of watershed to WAU scales to identify focus for restoration efforts. These data could be similarly used to identify potential implications of disturbance associated with development pressure and or natural disturbance from fires or pests. For the sediment focussed restoration planning example WAU provide a more reasonable unit for work planning. It would also work well for riparian restoration planning based upon riparian hazard metrics.

Appendix 2 WHPOR Indicator and Hazard Metrics Source Data and Thresholds

Two tables to follow of i) source data and ii) thresholds

Table A1. *Description of Watershed Indicator Scores - Thompson Okanagan Region.*

This is revised from the original analysis prepared by Forsite Consultants 2012. Data inputs, and in some cases analysis assumptions, have been revised.

Prepared by Kamloops GeoSpatial Services (Sasha Lees, Graham MacGregor, Gail Smith)

Further revisions have been made to this document to reflect the Watershed Health Project - Omineca Region (by Sean Barry and Noelle Bouvier): Including formatting and the ECA calculation description.

Indicator	Field Name	Measurement	Data Source
Alpine Non-forested area	**ALPINE_NF_PERCENT**	Percentage of reporting unit covered by Alpine or Alpine Forest types.	WHSE_FOREST_VEGETATION.VEG_COMP_LYR_R1_POLY
BEC zone	**BEC_Score**	Proportion of watershed by BEC variant category. Score is the sum of BEC snow accumulation scores (0 – 3) times their areas.	WHSE_FOREST_VEGETATION.BEC_BIOGEOCLIMATIC_POLY
ECA (forest cover disturbance)	**ECA_Score**	Equivalent clearcut area (ECA) as per Winkler and Boon (2015) with Snow Recovery (%) =100*(1-EXP(-0.24*(height-2)))^2.909 and recovery expected at approximately 65% of mature stand height. Mountain Pine Beetle effects were derived from the VRI attributes for STAND_PERCENTAGE_DEAD (where IBM) for pine stands, and years since attack for Dry vs Wet/Moist BEC subzones.	VRI updated with additional harvesting from FTEN and RESULTS BEC Subzones
Drainage density ruggedness (DDR)	**DDR_Score** **(DDR_Length_km)**	Stream density as a function of relief.	WHSE_BASEMAPPING.FWA_STREAM_NETWORKS_SP Relief (max elevation - min elevation in the unit) derived from DEM
Absence of lakes / wetlands	**Lake_wetland_Abscence** **(Lake_wetland_adjust_ha)**	Percent of the watershed in open water (lake/wetland). Large lakes in lower portion of reporting unit have the greatest affect.	WHSE_BASEMAPPING.FWA_LAKES_POLY WHSE_BASEMAPPING.FWA_WETLANDS_POLY WHSE_BASEMAPPING.FWA_MANMADE_WATERBODIES_POLY
Terrain stability	**Terrain_stability_percent**	Percent of reporting unit area containing slopes >60%	Slopes derived from DEM
Soil erodibility	**GSC_Score**	Percentage of the reporting unit in high erosion potential geological units – GSC quaternary deposits	WHSE_MINERAL_TENURE.GEOL_QUATERNARY_POLY

Indicator	Field Name	Measurement	Data Source
Steep coupled slopes	**Percent_steep_ coupled**	Proportion of the reporting unit located in steep (>50%) coupled slopes. Coupled slopes have less then 50m of gentle terrain between the steep slope and stream. Steep coupled area derived through GIS analysis – area directly upslope of intersection between 50m buffer on streams and 50% slope coverage.	Slopes derived from DEM
Extent of roading	**Rds_Extent**	Density of roads per square kilometer	Roads built from a combination of DRA, FTEN, and TRIM
Roads close to water	**RdsStrmB_Ext_KM2**	Total length of roads within 50 m of a stream by rep unit	Roads and Streams as above
Roads on steep coupled slopes	**RdsSlps_Ext_KM2**	Density of roads located on steep coupled slope areas.	Roads and Slopes as above
Disturbance on gentle over steep (GOS)	**GOS_Score_Percent**	Proportion of the reporting unit that is harvested with gentle (<50%) slope upslope (within 300m) of steep coupled slope areas. Include all harvesting in the last 75 years.	VRI updated with additional harvesting from FTEN and RESULTS. GOS derived from DEM analysis.
Logged riparian area	**Logged_PCNT**	Percentage of the total stream length within or adjacent to cutblocks. Summarized/weighted by stream order classes, with higher order streams receiving a greater weighting.	Harvesting and Streams as above
Cattle / range use	**Range_PCNT**	Percentage of total stream length within active range unit (km/km). Summarized/weighted by stream order classes, with higher order streams receiving a greater weighting.	WHSE_FOREST_TENURE.FTEN_RANGE_ POLY_SVW WHSE_TANTALIS.TA_CROWN_TENURES_ SVW
Private Land and Indian Reserves	**PrivateIR_PCNT**	Percentage of total stream length within or adjacent to private land and IR (km/ km). Private and IR land buffered by 20m to capture areas "adjacent to" streams. Summarized/weighted by stream order classes, with higher order streams receiving a greater weighting.	WHSE_CADASTRE.CBM_INTGD_ CADASTRAL_FABRIC_SVW WHSE_ADMIN_BOUNDARIES.CLAB_ INDIAN_RESERVES
Placer mining	**Placer_Score**	Proportion of area occupied by placer mine tenures adjacent to streams (ha/ ha). Summarized/weighted by stream order classes, with higher order streams receiving a greater weighting.	WHSE_MINERAL_TENURE.MTA_ACQUIRED_ TENURE_SVW
Coal Leases	**Coal_Lease_PCNT**	Proportion of reporting unit occupied by Coal Lease.	WHSE_MINERAL_TENURE.MTA_ACQUIRED_ TENURE_SVW

Table A2. *Indicator thresholds.*

	Low	Moderate	High
ECA	< 20%	20-30%	>30%[1]
Roads on Steep Slopes	0	0-0.1 km	>0.1 km[2]
Roads Near Streams	< 0.2 km	0.2-0.4 km	> 0.6 km
Gentle Over Steep	< 5%	5-10%	>10%[3]
Stream Crossing Density	< 0.4	0.4-0.6	>0.62
Private Land Riparian Intrusion	< 10%	10-30%	> 30%[3]
Forestry Riparian Intrusion	< 10%	10-30%	> 30%[4]
Range Riparian Intrusion	< 30%	30-60%	>60%[3]

1 Consideration of IWAP and Winkler and Boon, 2017
2 Identified with consideration of IWAP thresholds
3 Identified with consideration of Lewis et al., 2014 thresholds
4 Based on Nordin et al. (2009) and consideration of Lewis et al. 2014 thresholds

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CEF Cumulative Effects Framework