Appendix 13-F

MacHydro Effects Assessment

NWP COAL CROWN MOUNTAIN
Effects Assessment – Final Report

Prepared For

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1 Introduction

The Elk Valley, located in the southeast corner of British Columbia, is rich in biodiversity and culture. Coal mining, forestry, and tourism, are the biggest anthropogenic land-uses in the region, and are occurring at rates that have incited concerns over the environmental integrity of the Valley. The growing awareness of cumulative environmental effects launched the Elk Valley Cumulative Effects Management Framework (EV-CEMF) in July 2012 (Elk Valley Cumulative Effects Management Framework Working Group, 2018). The aim of the EV-CEMF is to assess historic, current, and potential future conditions of selected Valued Components (VCs) and to provide a framework that supports decisions related to the mitigation and management of these VCs in the Elk Valley.

The purpose of this work was to incorporate the EV-CEMF VCs into NWP Coal's Crown Mountain Effects Assessment. The VC's evaluated in this work include: Aquatic Ecosystems, Grizzly Bear, Old and Old/Mature (OM) Forests, and Bighorn Sheep. Each VC has a set of indicators through which hazard to the VC is assessed.

2 Methods

The NWP Coal Crown Mountain Effects Assessment used ALCES Online (online.alces.ca) to evaluate VC response to three scenarios focused on future disturbance within the context of cumulative effects. The assessment focused on the Crown Mountain Regional Study Area (RSA) over a 50-year temporal scale (Figure 1); however, EV-CEMF VC results are reported on at the scale of the Elk Valley since they were designed specifically for that region. Scenarios were run at 100 m spatial resolution and simulated at an annual time scale with outputs that correspond to current condition (year 2021), Crown Mountain maximum buildout (year 2038), and Crown Mountain post-closure (year 2055).

Future disturbance was simulated under the following scenarios: 1) The direct effects of NWP Coal's proposed development 2) Crown Mountain maximum build-out with cumulative effects, and 3) Crown Mountain maximum build-out with cumulative effects and natural disturbance. The Scenario Assumptions document outlines how the scenarios were developed and describes the assumptions that were used in the assessment (MacHydro, 2021).

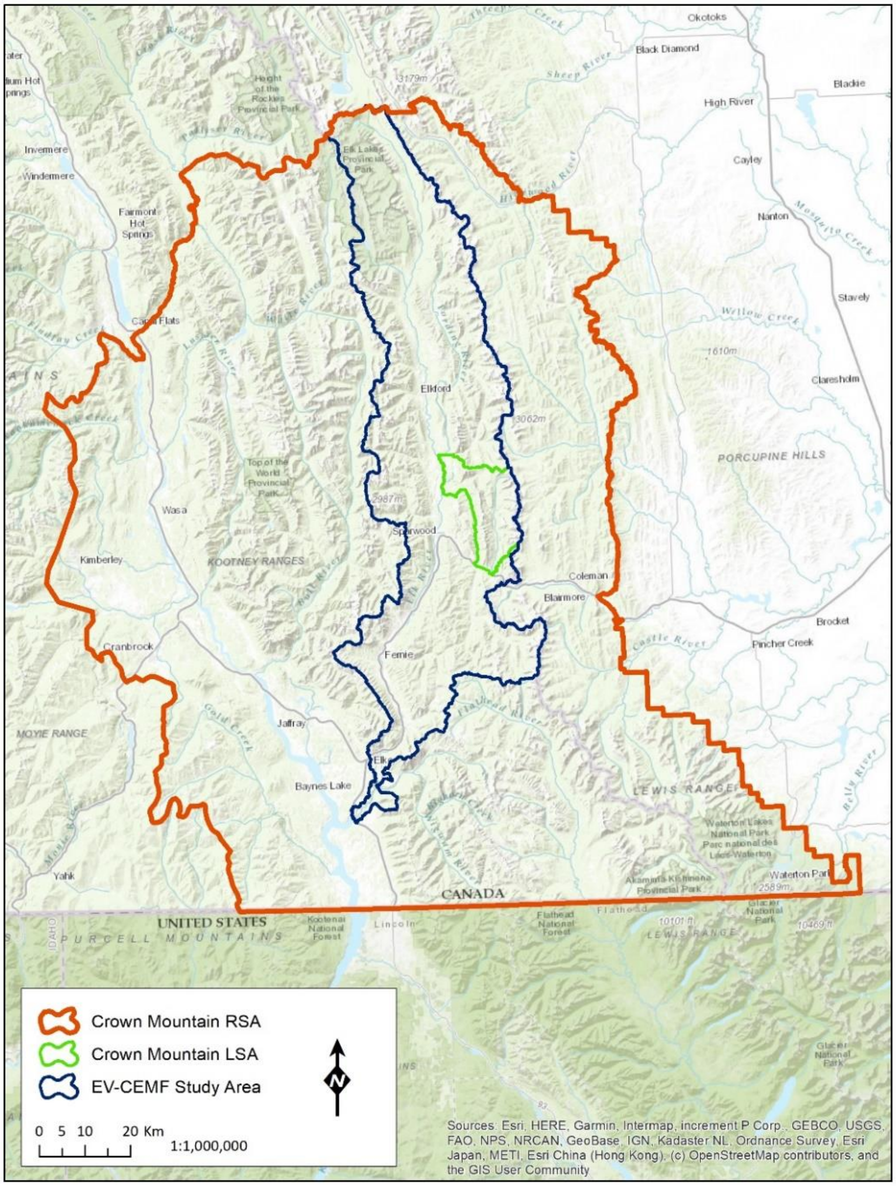
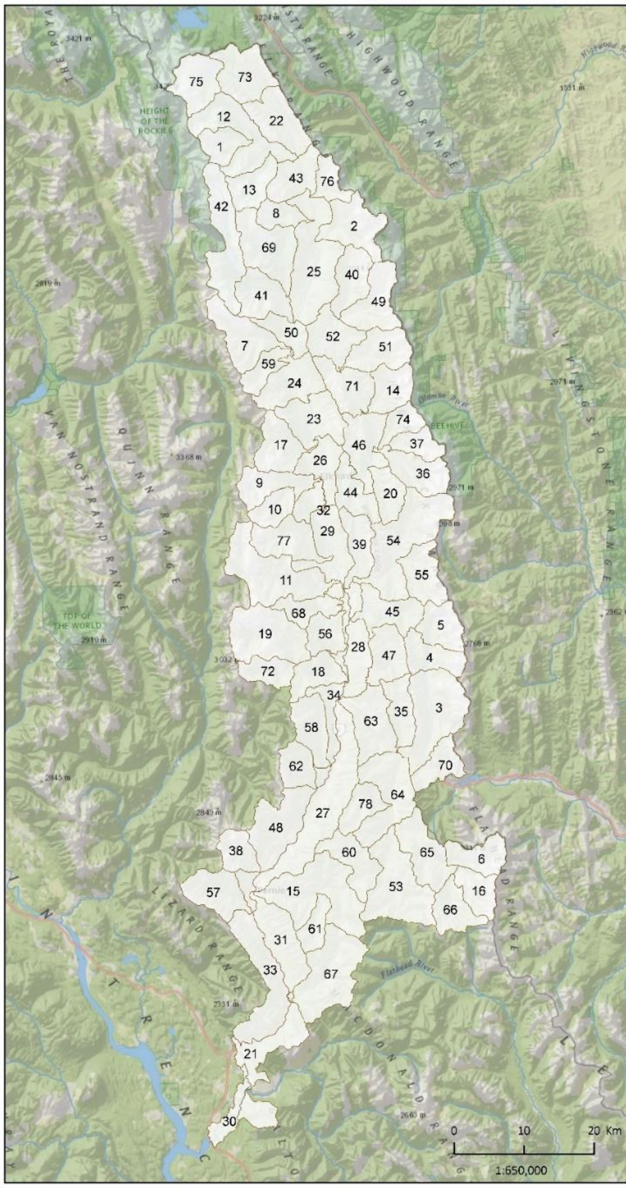


Figure 1. NWP Coal's Crown Mountain Effects Assessment Study Areas.

2.1 Assessment Units

Each EV-CEMF VC was assessed and reported on at the scale of VC-specific assessment units. Aquatic Hazard and Grizzly Bear Hazard were both assessed at the scale of the Assessment Watersheds (AWs). There are 78 AWs within the Elk Valley study area, ranging in size from 19 km^2 to 104 km^2 (Figure 2). The proposed NWP Crown Mountain mine footprint is located mostly within the Alexander Creek – Mid AW, which is of particular interest for this assessment (Figure 3).



Object ID	Assessment Watershed
1	Abruzzi Creek
2	Aldridge Creek
3	Alexander Creek - Lower
4	Alexander Creek - Mid
5	Alexander Creek - Upper
6	Andy Good Creek
7	Bingay Creek
8	Bleasdell Creek
9	Boivan Creek
10	Boivan Creek - South
11	Brule Creek
12	Cadorna Creek
13	Cadorna Creek - South
14	Chauncey Creek
15	Coal Creek
16	Corbin Creek
17	Crossing Creek
18	Cummings Creek - Lower
19	Cummings Creek - Upper
20	Dry Creek
21	Elk Face Unit - E of Elko
22	Elk Face Unit - N of Cadorna Cr
23	Elk Face Unit - N of Elkford 1
24	Elk Face Unit - N of Elkford 2
25	Elk Face Unit - N of Forsyth Cr
26	Elk Face Unit - NE of Elkford
27	Elk Face Unit - NE of Fernie
28	Elk Face Unit - NE of Sparwood
29	Elk Face Unit - S of Elkford
30	Elk Face Unit - S of Elko
31	Elk Face Unit - SE of Fernie
32	Elk Face Unit - SW of Elkford
33	Elk Face Unit - SW of Fernie
34	Elk Face Unit - SW of Sparwood
35	Erickson Creek
36	Ewin Creek
37	Ewin Creek - North
38	Fairy Creek
39	Fording River - Lower
40	Fording River - Upper
41	Forsyth Creek - Lower
42	Forsyth Creek - Upper
43	Gardner Creek
44	Grace Creek
45	Grave Creek
46	Greenhills Creek
47	Harmer Creek
48	Hartley Creek
49	Henretta Creek
50	Hornickel Creek
51	Kilmarnock Creek
52	Lake Mountain & Clode Creeks
53	Leach Creek
54	Line Creek
55	Line Creek - South
56	Littlemoor Creek
57	Lizard Creek
58	Lladnar Creek
59	Lowe Creek
60	Marten Creek
61	Matheson Creek
62	McCool Creek
63	Michel Creek - Lower
64	Michel Creek - Mid 1
65	Michel Creek - Mid 2
66	Michel Creek - Upper
67	Morrissey Creek
68	Nordstrum Creek
69	Quarrie Creek
70	Summit Creek
71	Swift Creek
72	Telford Creek
73	Tobermory Creek
74	Todhunter Creek
75	Upper Elk Lakes
76	Weary Creek
77	Weigert Creek
78	Wheeler Creek

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Figure 2. Seventy-eight Assessment Watersheds within the Elk Valley, identified by name and object ID.

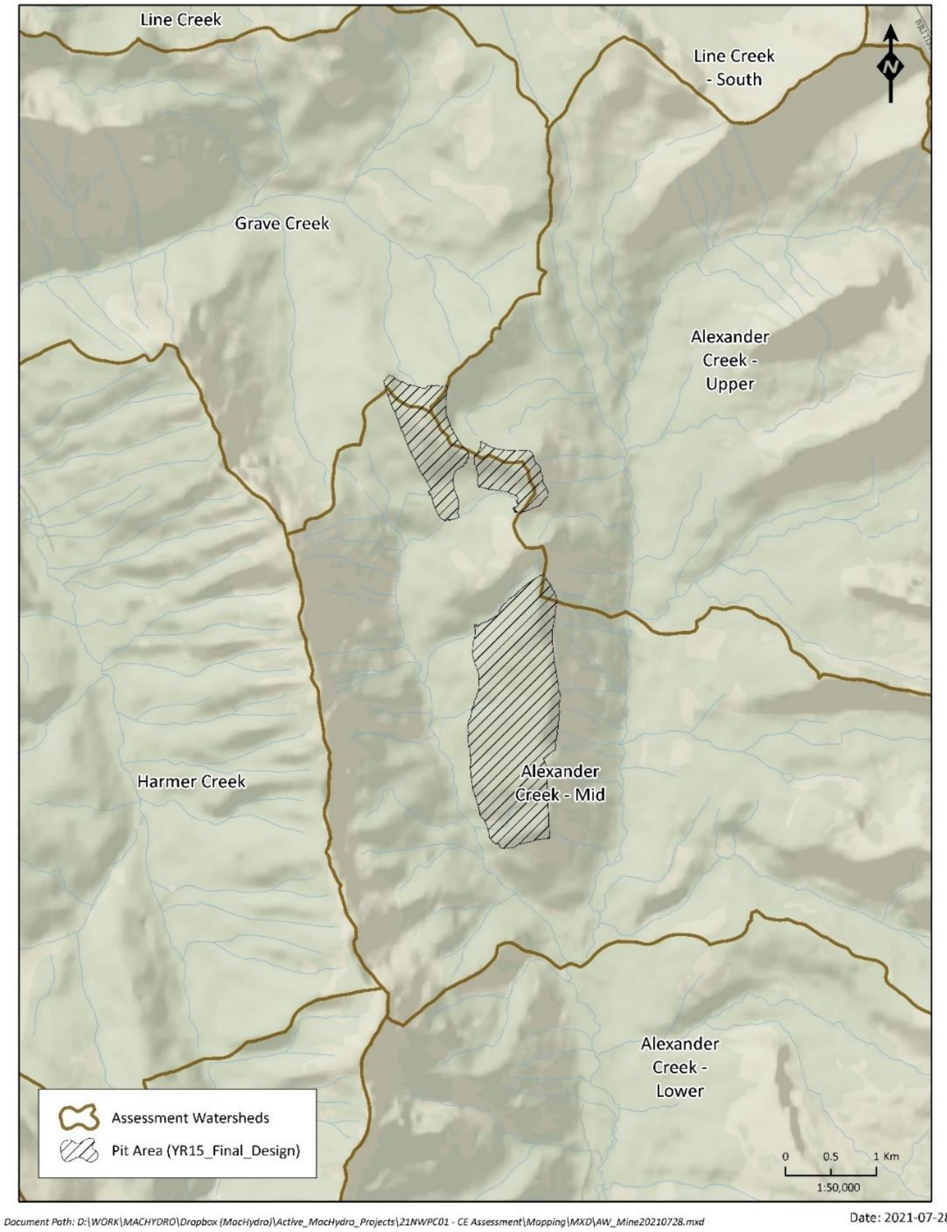

Figure 3. Location of the Crown Mountain mine area, mostly within the Alexander Creek – Mid AW.

Old Forests and Old & Mature (OM) Forests were assessed at the scale of the Biogeoclimatic (BEC) zone/subzone/variant combinations. There are five overarching BEC zones in the Elk Valley, with the Crown Mountain area intersecting the ESSF zone (Figure 4). Results for Old Forests and OM Forests are assessed and reported on separately.

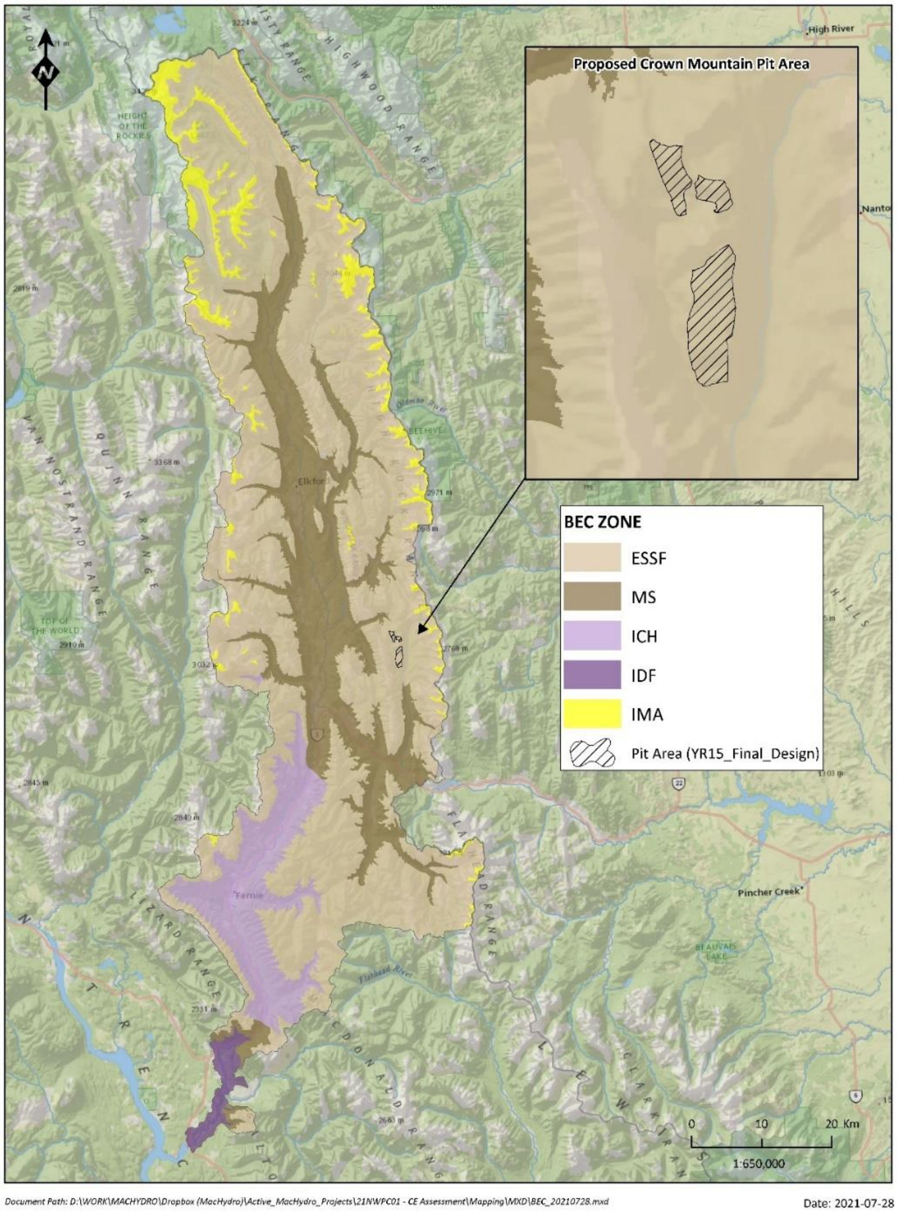

Figure 4. BEC zones in the Elk Valley, with inset showing the Crown Mountain mine within the ESSF BEC zone.

2.2 Data Sources

Cumulative effects assessments using ALCES Online require the preparation of a land cover dataset representing a continuous landscape with no overlapping layers. Multiple sources of landscape and disturbance data were integrated into a single dataset which formed the basis for the analysis. A detailed account of the data sources used in this work can be found in Appendix A of the Scenario Assumptions report (MacHydro, 2021). Landscape datasets were downloaded from open sources, specifically Earth Observation for Sustainable Development of Forests (EOSD) data for landcover and Freshwater Atlas (FWA) data for water features. Footprint datasets were retrieved from previous EV-CEMF work by FLNRORD and from NWP.

Forest age was primarily derived from the provincial Vegetation Resource Inventory (VRI) data. Where VRI data were absent, National Aeronautics and Space Administration (NASA) satellite imagery and forest disturbance history datasets were used. For more information, refer to MacHydro (2021).

2.3 Indicators and Benchmarks

VCs response to scenarios often cannot be directly measured; therefore, indicators are used to evaluate the status of or hazards to the VC. The following section describes the indicators that were used for each VC in this work, as well as any associated benchmarks, if available. Benchmarks have been established by previous initiatives as part of the EV-CEMF that assign a level of hazard to a VC based on specific values of a measured indicator.

2.3.1 Aquatic Ecosystems

The Aquatic Hazard indicator, as used in the EV-CEMF, is described in Davidson et al. (2018) and provides an indication of the hazard present for riparian areas and Westslope Cutthroat Trout. Marcotte et al. (2021a) provide information on the detailed modelling methods and assumptions used for each component of this indicator. An overview of the components to the Aquatic Hazard indicator is presented in Figure 5 and described below.

Aquatic Hazard, as it is modelled in the EV-CEMF, is the average of the following five sub-indicators, which are scaled from 0-1 (Davidson et al., 2018):

- Stream crossing density: Stream-road intersections for all steam orders and minor roads, expressed as number of crossings per square kilometer.
- Equivalent clear-cut area (ECA): The area disturbed by anthropogenic footprint or forest disturbance, adjusted to account for hydrologic recovery.
- Riparian disturbance: ECA as a percentage of the riparian portion of the watershed.
- The density of roads near streams: The density of roads that are located within 100 m of streams.
- The density of roads on steep slopes: The density of roads that are located on slopes steeper than 60%.

The benchmarks that have been defined by the BC government for the assessment of the EV-CEMF Aquatic Hazard indicator are as follows:

- < 0.4 index = Low Hazard
- 0.4 – 0.8 index = Moderate Hazard
- > 0.8 index = High Hazard

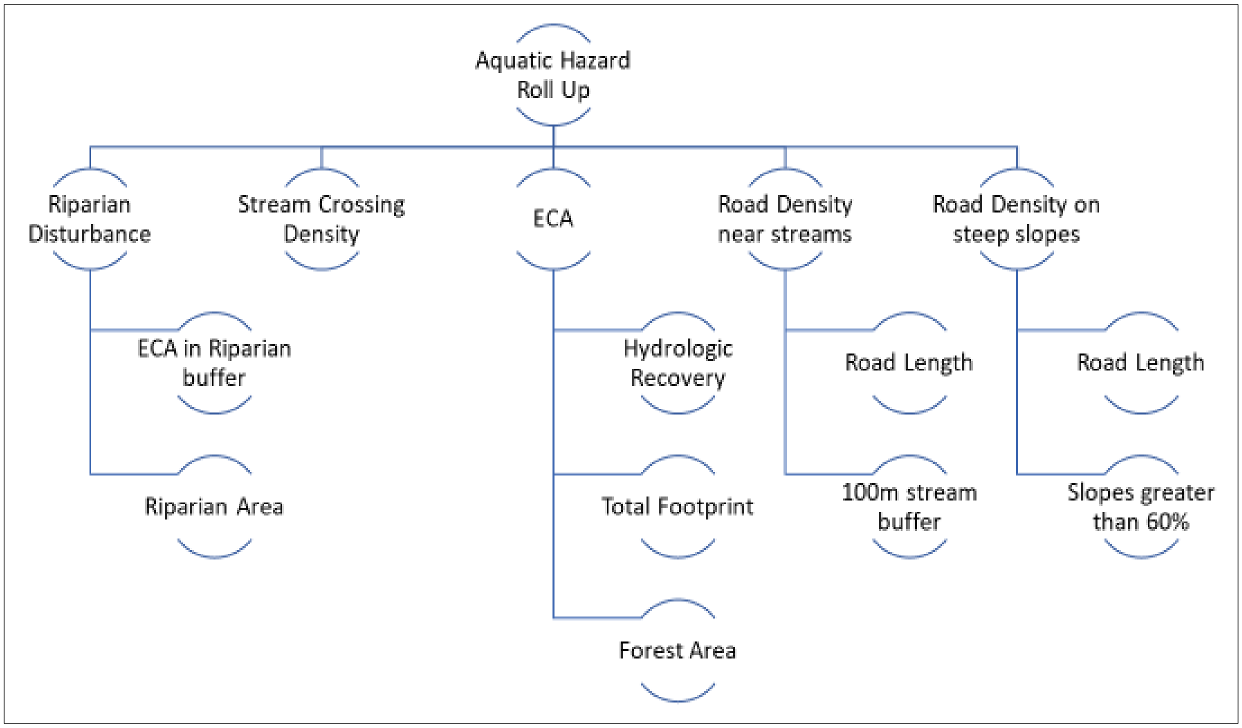

Figure 5. EV-CEMF Aquatic Hazard Model (Marcotte et al., 2021).

2.3.2 Grizzly Bear

The Grizzly Bear Hazard indicator provides an indication of the hazard present for the Grizzly Bear VC and is calculated as 1 minus habitat suitability, where suitability is dependent on habitat availability and the density of the road network. See Mowat et al (2018) and Marcotte et al (2021a) for further details on indicator and sub-indicator equations. The final Grizzly Bear Hazard score is then scaled from 0-1. Figure 6 shows the components involved in calculating Grizzly Bear Hazard. At present, benchmarks for Grizzly Bear Hazard have not been defined by the EV-CEMF.

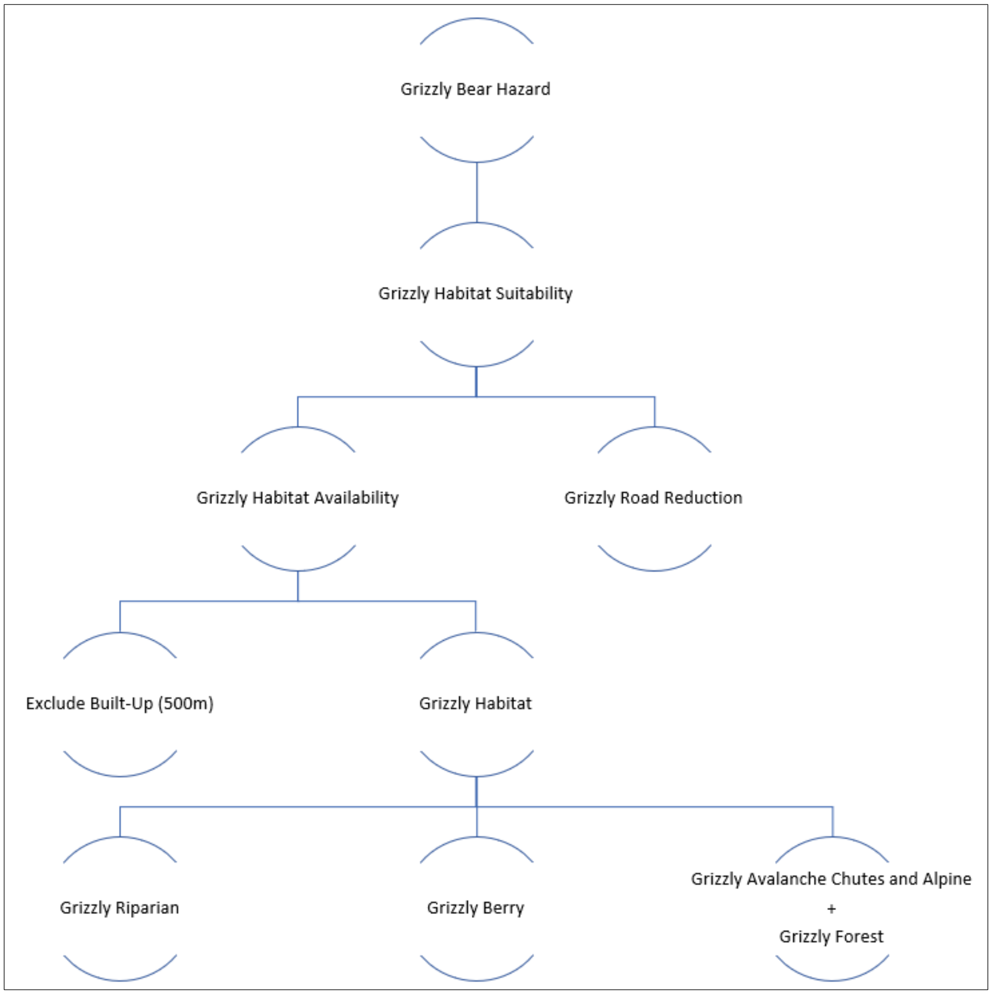

Figure 6. EV-CEMF Grizzly Bear Hazard Model (Marcotte et al., 2021).

2.3.3 Old and OM Forests

Z-Score was used as an indicator to assess change in the amount of Old and OM forests. Z-Score measures the amount of existing Old or OM forest, relative to expected Old or OM forest, and is measured as a deviation from the range of natural variability (RoNV). Figure 7 shows an example of how Z-Score is calculated for OM Forests. The existing proportion of Old or OM forest is subtracted from the expected proportion of Old or OM forest under RoNV. It is then divided by the expected standard deviation. The result is the number of standard deviations the observed value is from the expected value. Z-score was assessed at the BEC unit scale. For further details see Holmes et al (2018) and Marcotte et al (2021a).

The benchmarks, established by the BC government, for Old and OM Z-Scores are presented below:

- very low hazard = Z-Score > 0 (expected to occur 50% of the time historically)
- low hazard = 0 > Z-Score > -1 (expected to occur 34% of the time historically)

- moderate hazard = -1 > Z-Score > -2 (expected to occur 13.5% of the time historically)
- high hazard= -2 > Z-Score > -3 (expected to occur 2% of the time historically)
- very high hazard = Z-Score < -3 (expected to occur 0.5% of the time historically)

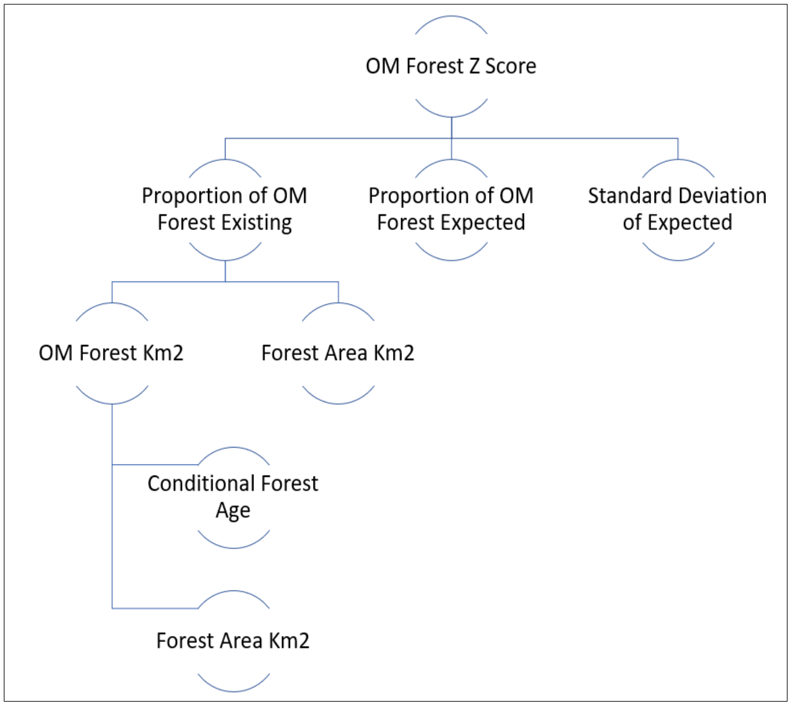

Figure 7. EV-CEMF OM Forest Z-Score Model (Marcotte et al., 2021).

Interior Forest Patch Size is used as an indicator to assess the ecological function of the Old or OM forest VC. Smaller patches are not able to provide the same services and functions as larger patches do, and larger patches are less fragmented and therefore have less edge effects. Edge effects are defined as changes in the ecological conditions (humidity, soil, plant communities) and rates of processes (predation, mortality, competition) experienced in forests adjacent to openings such as clearcuts, roads, or agricultural fields. As an example, northern goshawk are known to only use patches greater than 25 ha for breeding purposes (Stuart-Smith et al., 2012). Grizzly Bears also require large patches to sustain core habitat and facilitate bear movement. To account for edge effects, patches of interior Old or OM forest were defined by adding a 100 m buffer to the total footprint layer and subtracting that from the total size of the original Old or OM patch (Figure 8; Holmes et al., 2018).

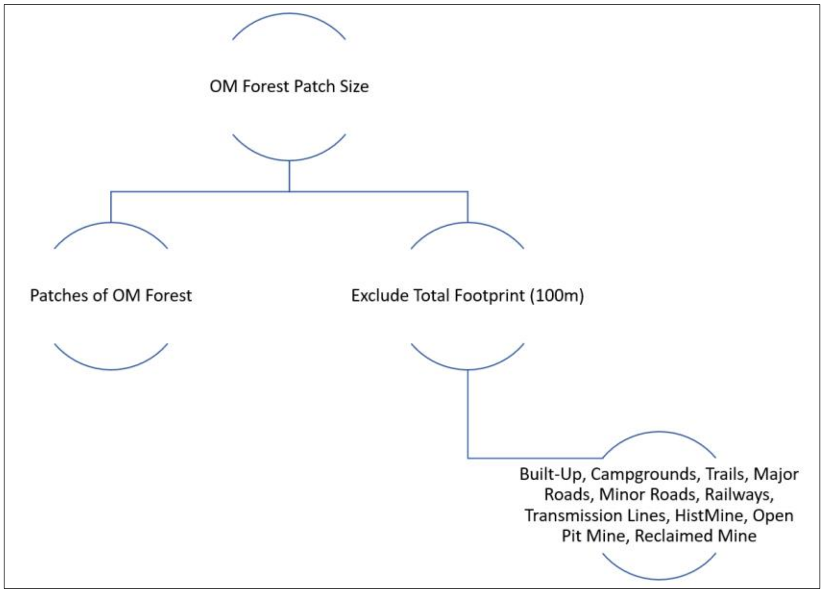

Figure 8. EV-CEMF OM Forest Patch Size Model (Marcotte et al., 2021).

2.3.4 Bighorn Sheep

The status of bighorn sheep (BHS) habitat was evaluated by assessing Rank 3 and 4 Winter Range Hazard, at the scale of each bighorn sheep subpopulation (Poole et al., 2020). Winter range habitat is considered essential for BHS population persistence during winter, and habitat ranks 3 and 4 are the most highly selected types. Rank 3 and 4 WR Hazard was therefore chosen as an indicator best suited to assess overall condition of BHS populations.

To quantify Rank 3 and 4 Winter Range Hazard, habitat was summed for ranks 3 and 4 and a percent change, relative to historic, was calculated. Hazard ratings were then assigned based on benchmarks defined below (Figure 9; Poole et al., 2018).

- Very Low Hazard (1): ≤ 2.5% change in Rank 3 and 4 Winter Range (WR)
- Low Hazard (2): 2.5 - 7.5% change in Rank 3 and 4 Winter Range
- Moderate Hazard (3): 7.5 - 12.5% change in Rank 3 and 4 Winter Range
- High Hazard (4): 12.5 - 17.5% change in Rank 3 and 4 Winter Range
- Very High Hazard (5): > 17.5% change in Rank 3 and 4 Winter Range

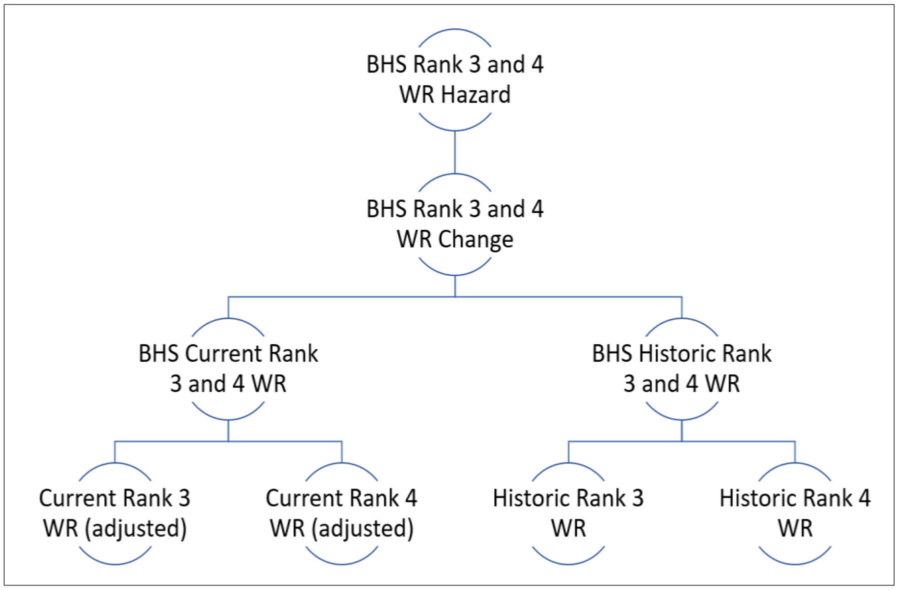

Figure 9. EV-CEMF BHS Rank 3 and 4 WR Hazard Model (Marcotte et al., 2021).

2.4 Scenarios

Scenario analysis was conducting using ALCES Online to evaluate a range of potential future landscape scenarios in the Crown Mountain RSA. Three future development scenarios were simulated and are described below. For further details on the scenario assumptions, please refer to MacHydro (2021).

- Scenario 1 – Project Case: This scenario uses data provided by NWP Coal, showing the Crown Mountain location and sequence of development over the life of mine.
- Scenario 2 – Project Case with Cumulative Effects Scenario: The same allocations and assumptions described in Scenario 1 were carried forward, and additional disturbance footprints were simulated to represent the cumulative foreseeable development within the study area.
- Scenario 3 – Project Case with Cumulative Effects and Natural Disturbance Scenario: This scenario builds off Scenario 2, while also simulating fire and insect outbreak natural disturbances.

3 Results

The following sections describe the current condition of the VCs and potential response of VCs under future conditions (Scenarios 1 through 3).

3.1 Current Condition

3.1.1 Aquatic Ecosystems

Most AWs (51, or 65%) are classified as moderate hazard, followed by 14 AWs (18%) as low hazard and the remaining 13 AWs (17%) fall under the high hazard classification (Figure 10). The highest hazards are located near the valley bottom and areas where development activities (primarily roads) are concentrated. The five highest hazard AWs are: Lake Mountain and Clode Creek, Swift Creek, Michel Creek – Lower, Greenhills Creek, and Dry Creek, from highest to lowest, respectively.

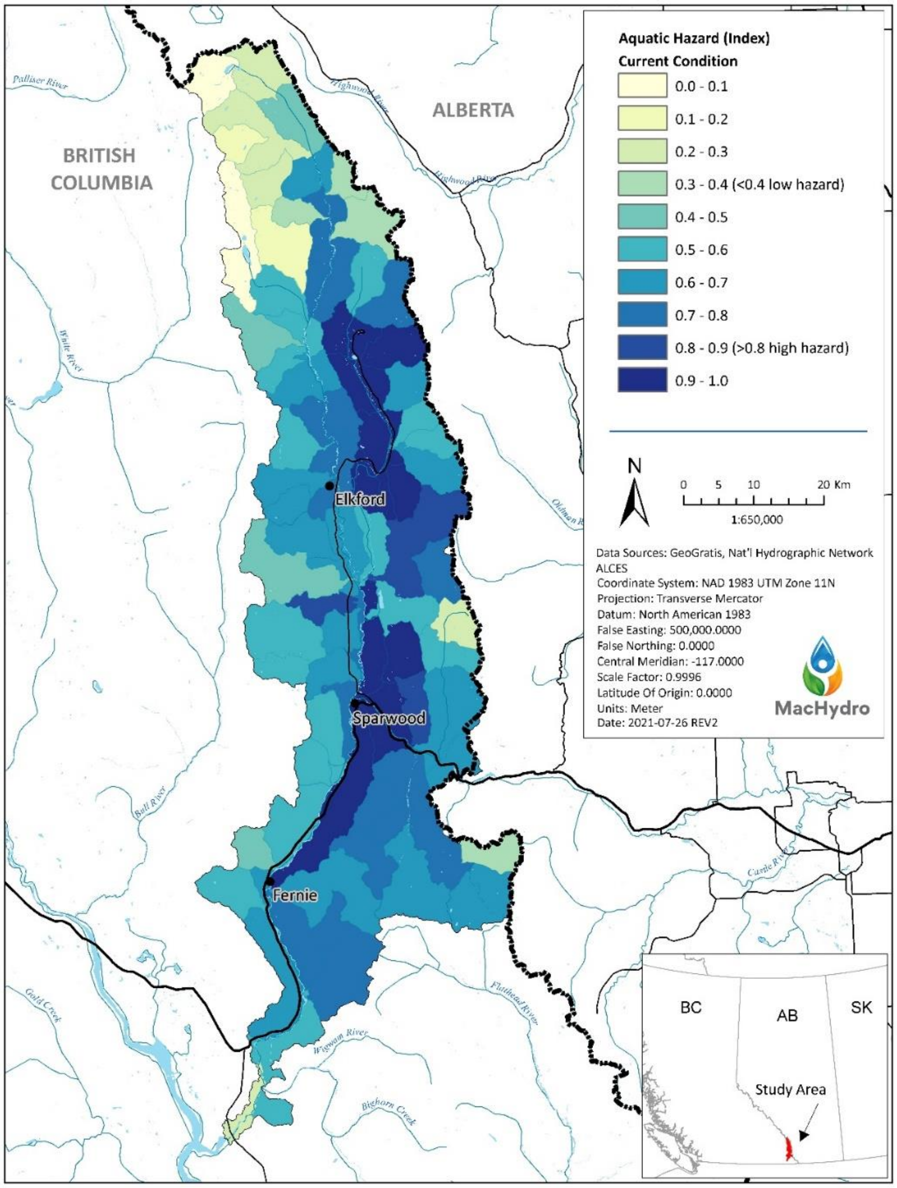

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Figure 10. Aquatic Hazard by Assessment Watershed in the Elk Valley. Aquatic Hazard is classified as low hazard where the score falls below 0.4 and high hazard where the score exceeds 0.8.

Road density near streams and stream crossings demonstrate the highest and most widespread hazards of all the Aquatic Hazard sub-indicators (Figure 11 and Figure 12). This suggests that dense road networks located near water features can have a strong influence on Aquatic Hazard. Lowest hazard AWs are almost entirely located in the northern portion of the study area, where established protected areas limit development, while highest hazard AWs are located outside of these protected areas.

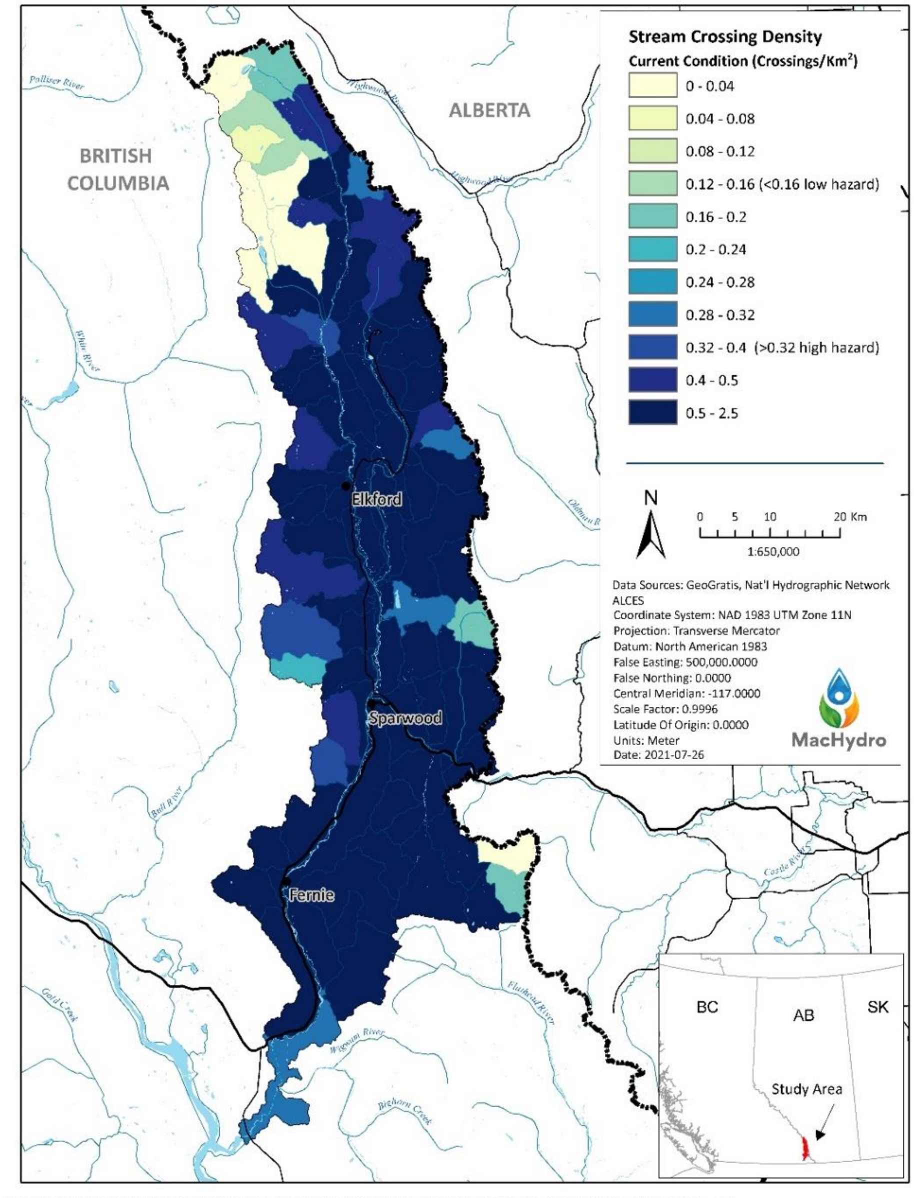

Figure 11. Stream Crossing Density summarized by AW in the Elk Valley, under current conditions.

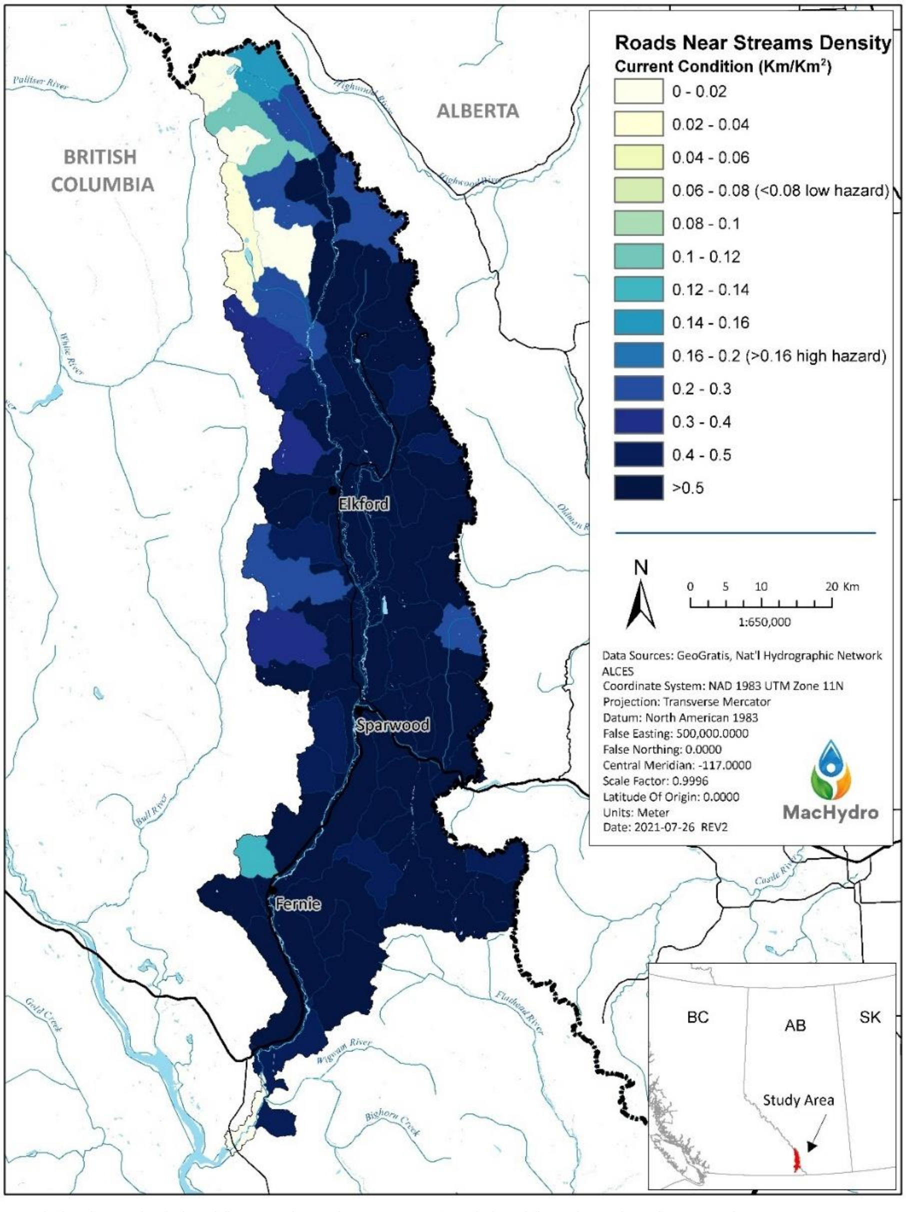

Figure 12. Road Density near Streams summarized by AW in the Elk Valley, under current conditions.

3.1.2 Grizzly Bear

Although Grizzly Bear Hazard ranges across the study area, most (50) of the AWs demonstrate a high level of hazard (score above 0.9) and the valley-wide average score reaches 0.84 (Figure 13). Grizzly Bears generally prefer natural landcover and are sensitive to high road density, as such, high hazard occurs as a combination of limited available habitat coupled with high road density. These conditions are widespread, affecting the valley bottoms and AWs with concentrated anthropogenic footprints, while high habitat availability and low road density is generally limited to the headwaters.

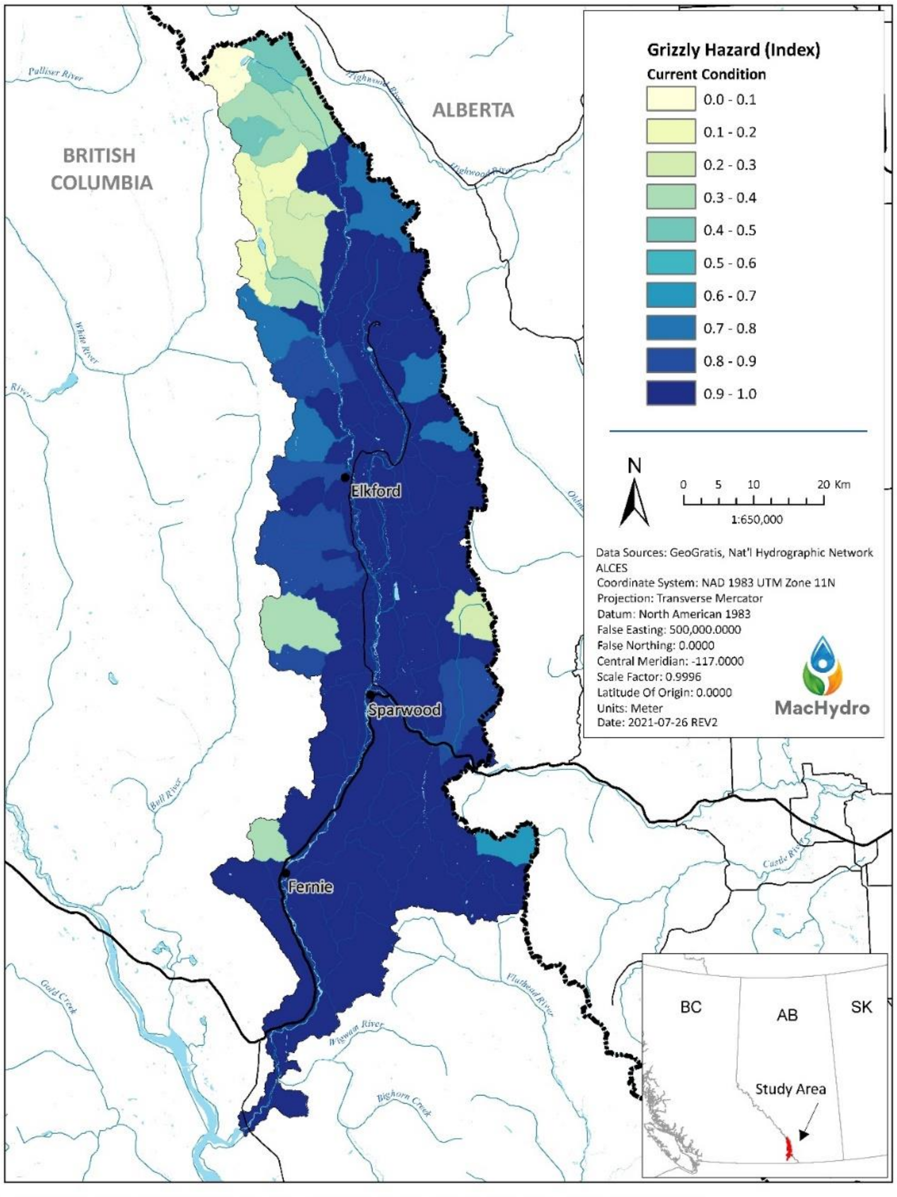

Figure 13. Grizzly Bear Hazard by AW in the Elk Valley. Darkest blue AWs indicate highest calculated hazards, while lightest blues indicate lowest hazards.

Habitat Availability ranges across the Elk Valley from 0 to 1, with an average score of 0.24 (Figure 14). AWs with notably high habitat availability occur in the northern portions of the study basin (Upper Elk Lakes and Cadorna Creek - South), while AWs with notably low habitat availability occur near areas of high mining or urban development (Michel Creek – Lower, Elk Face Unit S of Elko, and Elk Face Unit NE of Sparwood).

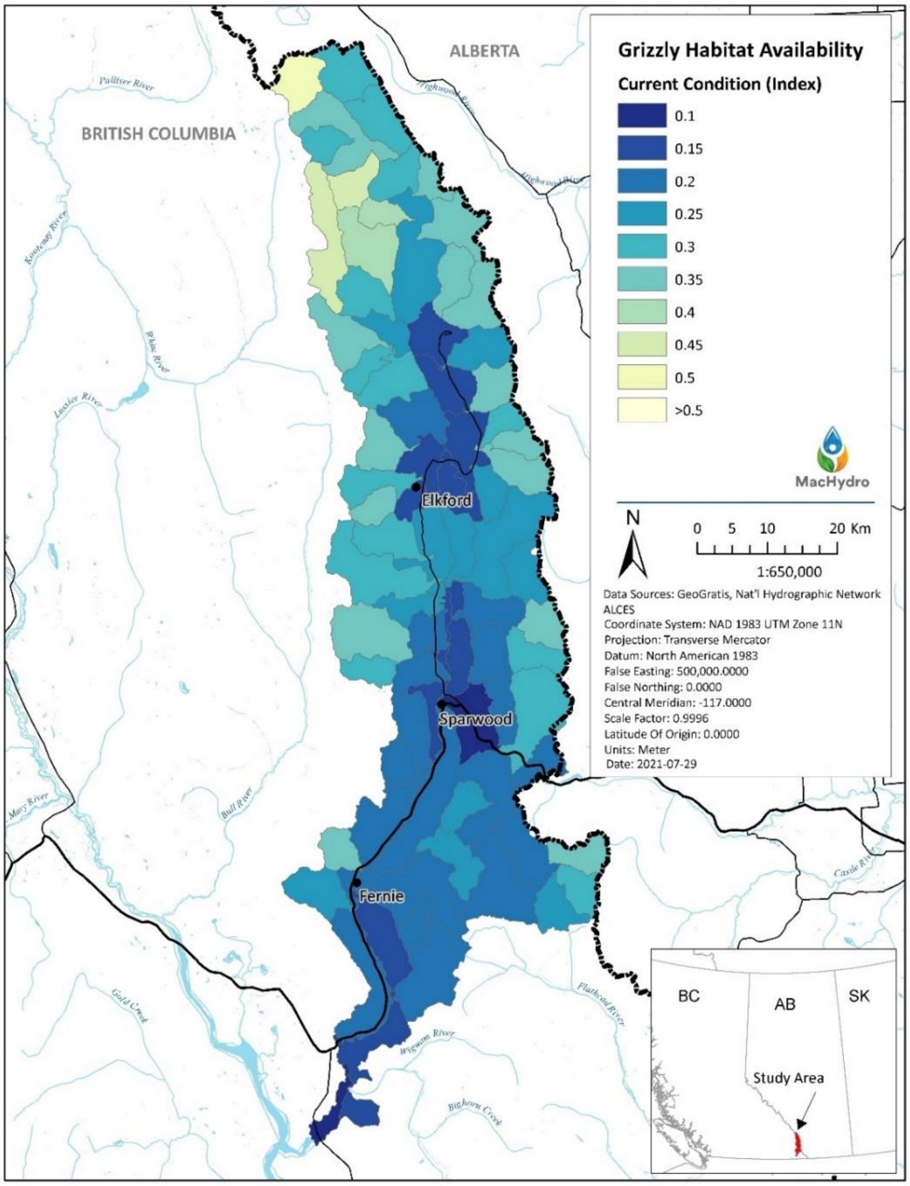

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Figure 14. Grizzly Habitat Availability by AW in the Elk Valley. Darkest blue AWs indicate lowest available habitat, while lightest blue indicates highest available habitat.

High road densities can reduce the suitability of available habitat, making it unsafe for Grizzly Bear use. Road density above 1.2 km/km^2 has the greatest negative influence on suitability in this model, while road density above 0.6 km/km^2

moderately reduces suitability, and below 0.6 km/km^2 has no impact on suitability. Across the study area, 47 of the 78 AWs demonstrate road densities above 1.2 km/km^2 and 19 AWs have densities above 0.6 km/km^2 (Figure 15). As a result, habitat suitability is lowest in the valley bottoms and highest in the headwaters of the study area, with a valley-wide average of 0.08 (Figure 16).

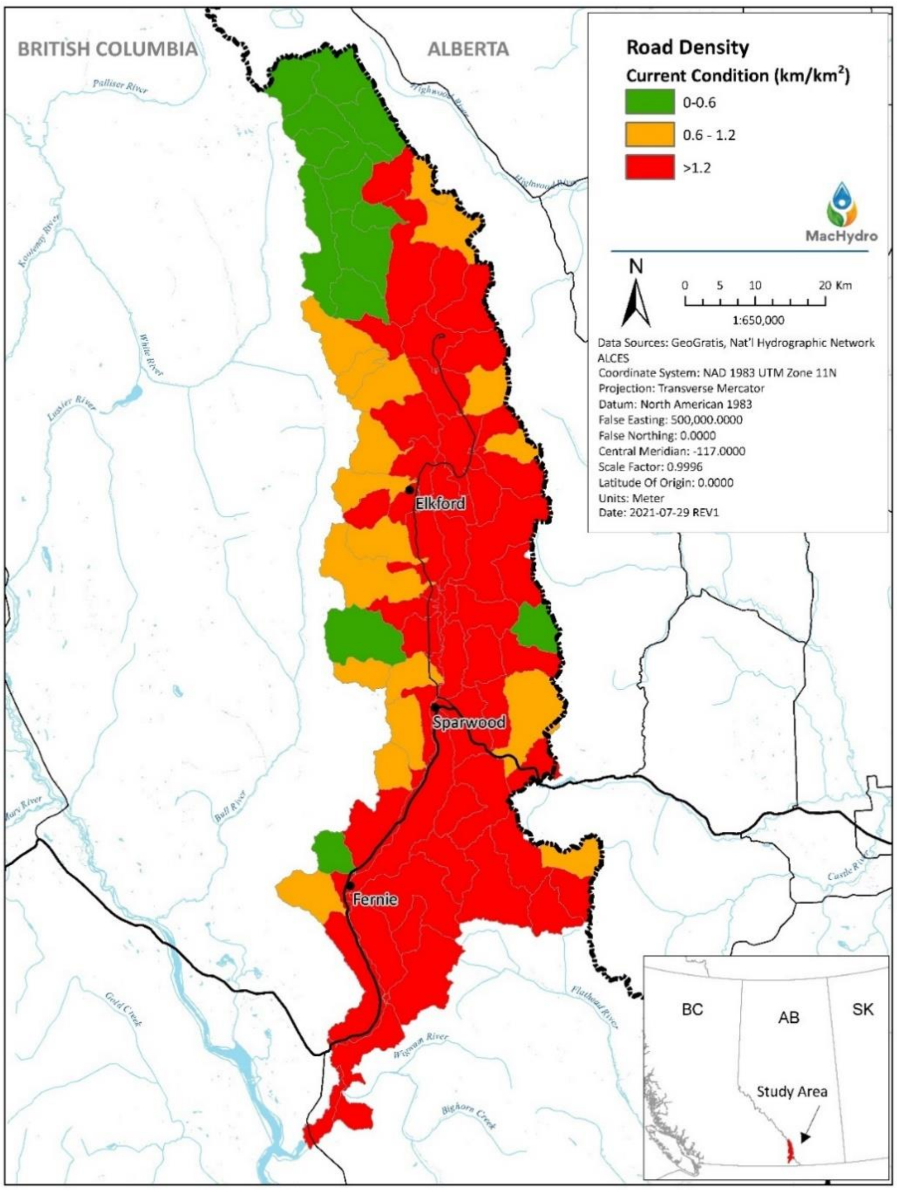

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Figure 15. Road Density (km/km^2) by AW across the Elk Valley.

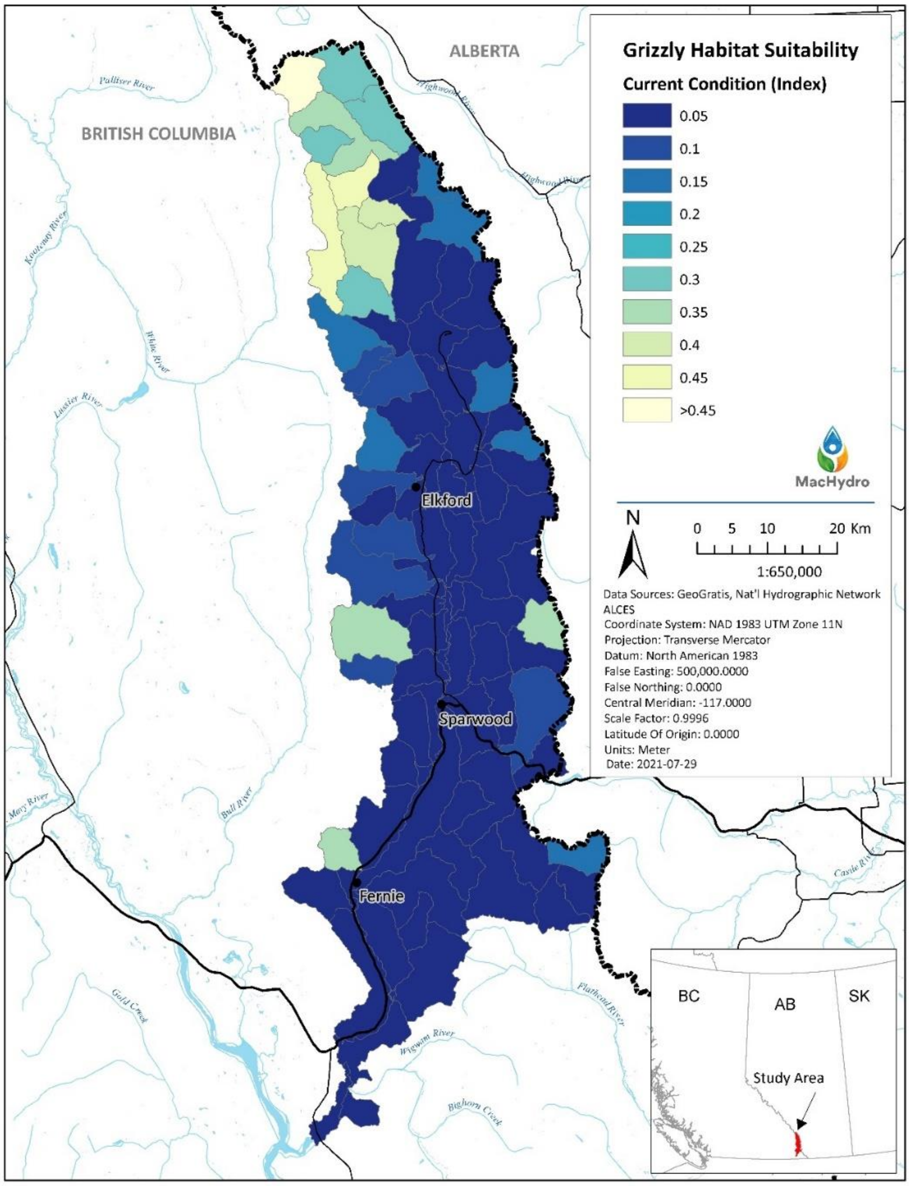

Figure 16. Grizzly Habitat Suitability by AW in the Elk Valley. Darkest blue AWs indicate lowest suitable habitat, while lightest blue indicates highest suitability.

3.1.3 Old and OM Forests

Current condition Old Forest coverage is scattered throughout the Elk Valley with a total area of 218 km^2 (Figure 17). Coverage is primarily concentrated in the ESSFdk, away from the valley-bottom. By contrast, OM Forest coverage is more prevalent with approximately 466 km^2 throughout the Elk Valley (Figure 17). OM forests are predominantly found in the ESSFdkw.

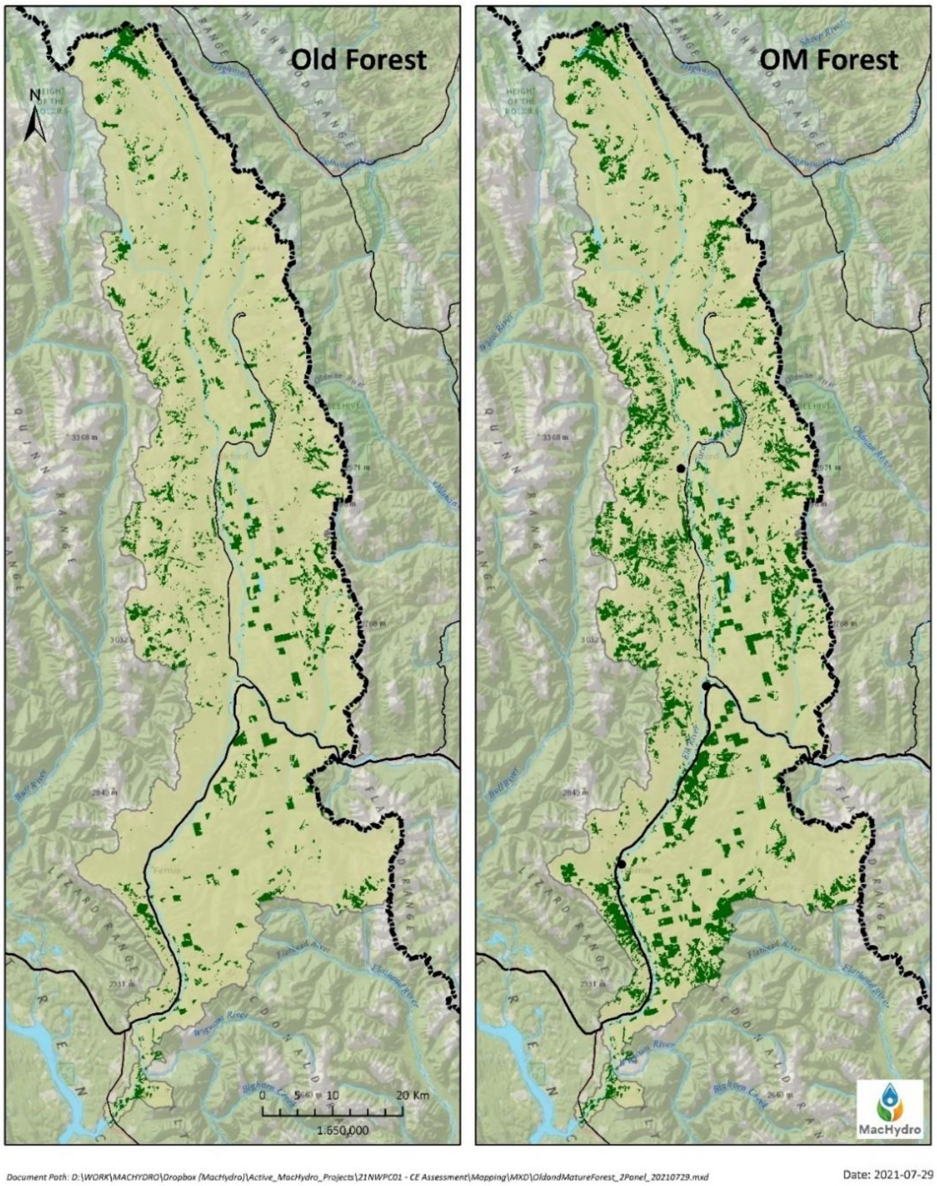

Figure 17. Current condition Old (left) and OM (right) forest coverage throughout the Elk Valley.

The current condition Old Forest Z-Score has a valley-wide average score of -1.4, corresponding to an overall hazard rating of moderate for the entire Elk Valley (Figure 18). The highest deviation from RoNV is currently found in the lower elevation BEC units of MSdw and ICHmk4, predominately found in the valley bottom portions of the study area. Z-score values closer to zero, the expected conditions, are found in the high elevation areas associated with IMAun and ESSFdkp.

The current condition OM Forest Z-Score has a valley-wide average score of -1.2, corresponding to a moderate hazard rating (Figure 18). The highest deviation from expected occurs in the MSdw and MSdk zones, whereas the smallest deviations occur in the ESSdkp and IDFdm2 zones.

Interior Old Forest patches are generally scattered throughout the Elk Valley, with an average patch size over the entire study area of 7 ha (Figure 19). OM Forest patches are more numerous, with an average size of 22 ha, and consist of a larger total area relative to Old Forest patches (Figure 19). ESSFdk hosts the largest patch sizes and the largest total patch area over the entire study area for both Old and OM patches.

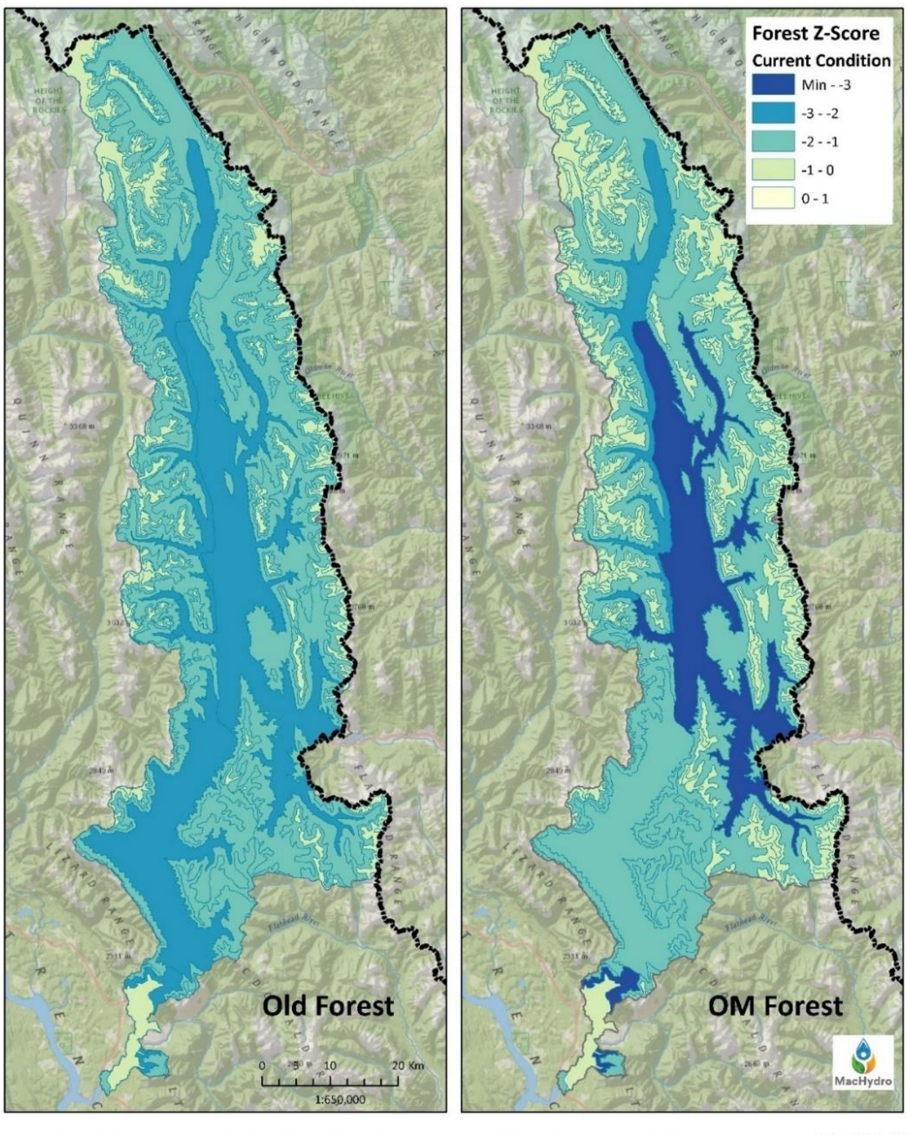

Figure 18. Current condition Old and OM Forest Z-Score by BEC unit throughout the Elk Valley. Light colors indicate low hazard classes, while darker blue colors indicate higher hazard classes.

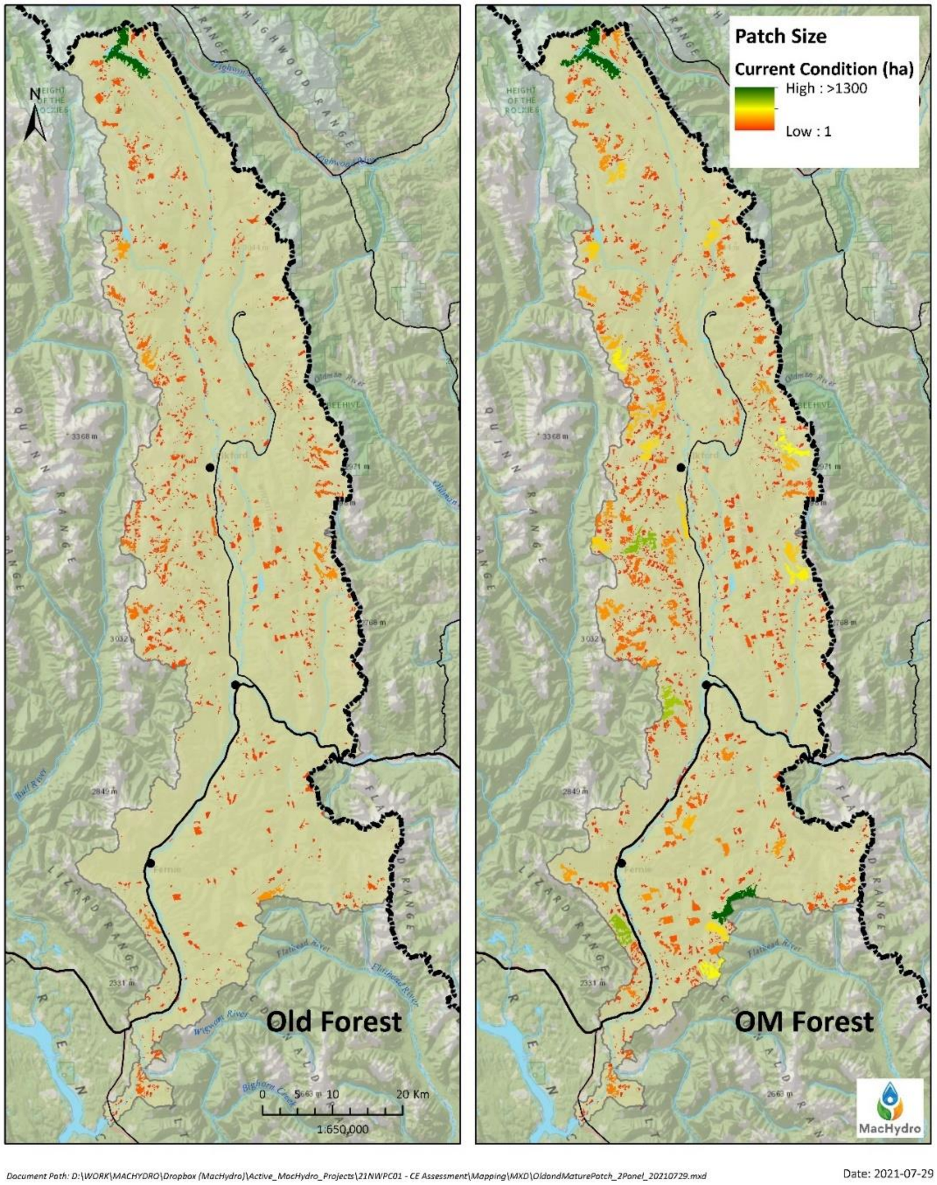

Figure 19. Interior Old and OM Forest Patches for current condition throughout the Elk Valley.

3.1.4 Bighorn Sheep

Currently, the highest hazard to BHS Rank 3 and 4 Winter Range is found in the Fording subpopulation, with a hazard rating of High. The Ewin subpopulation currently has a Moderate hazard rating, and all other herds were classified as Low or Very Low hazard (Figure 20). These results are lower than past EV-CEMF results because the current condition mine footprints were not clipped out of the existing WR mapping products received from the government.

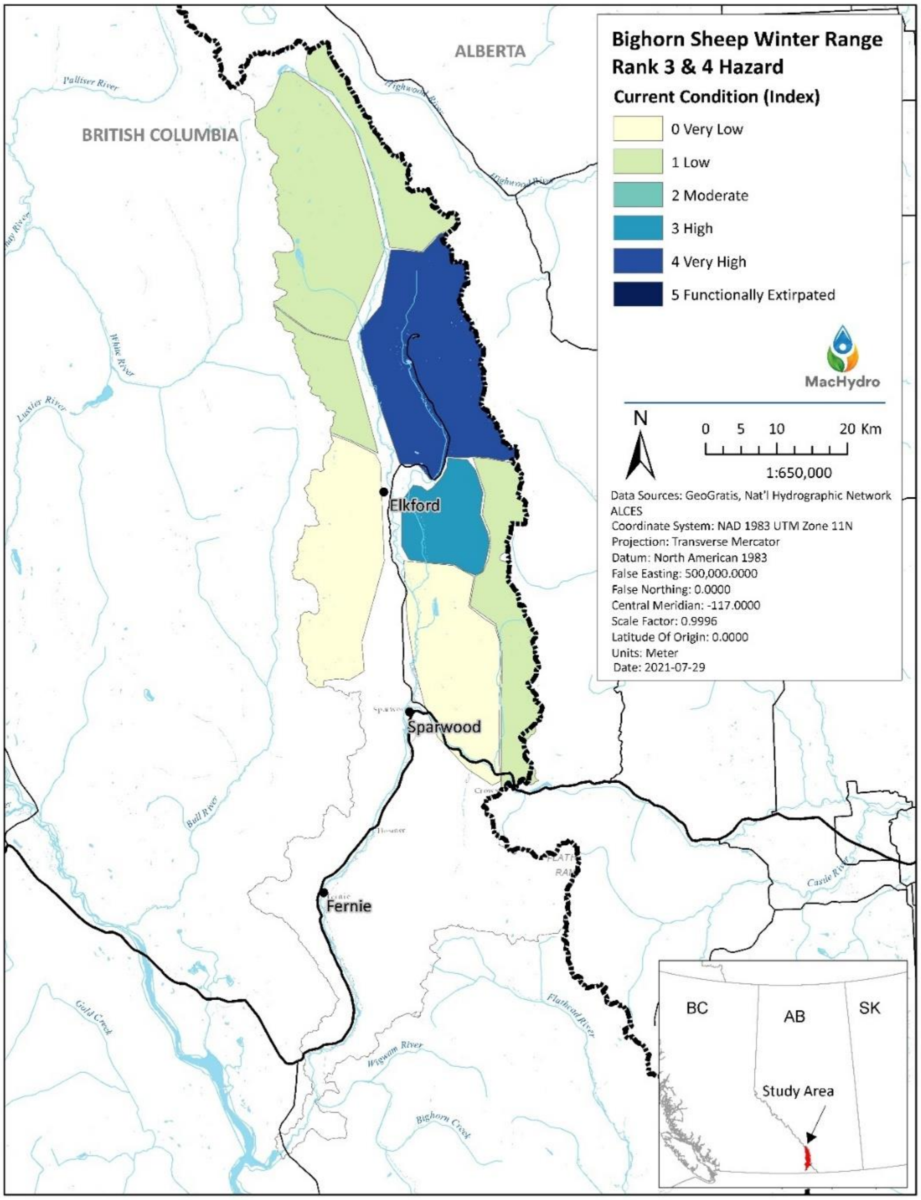

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Figure 20. Current Condition Bighorn Sheep Rank 3 and 4 Winter Range Hazard by sheep sub population in the Elk Valley.

3.2 Prospective Assessments

The following section explores the response of the CEMF VC indicators to the simulated future scenarios described in section 2.4.

3.2.1 Aquatic Ecosystems

At peak mine development, in year 2038, Scenario 1 shows 53 AWs at moderate hazard, followed by 14 AWs with low hazard. The remaining 11 AWs are considered high hazard (Figure 21). Scenario 2, which incorporates the cumulative effects of other development in the valley, shows 52 AWs at moderate, 14 at low, and 12 at high hazard. Scenario 3, which further considers the effects of natural disturbance, demonstrates 56 AWs at moderate, 8 at low, and 14 at high hazard. Elk Valley wide average Aquatic Hazard at 2038 is 0.60, 0.60, and 0.65, for Scenarios 1, 2, and 3, respectively (Figure 21). At 2055, these average hazard indices reach 0.57, 0.55, and 0.61, respectively, suggesting that reclamation of mine footprint can help to reduce Aquatic Hazard, through removal of roads and mine footprint (Figure 22).

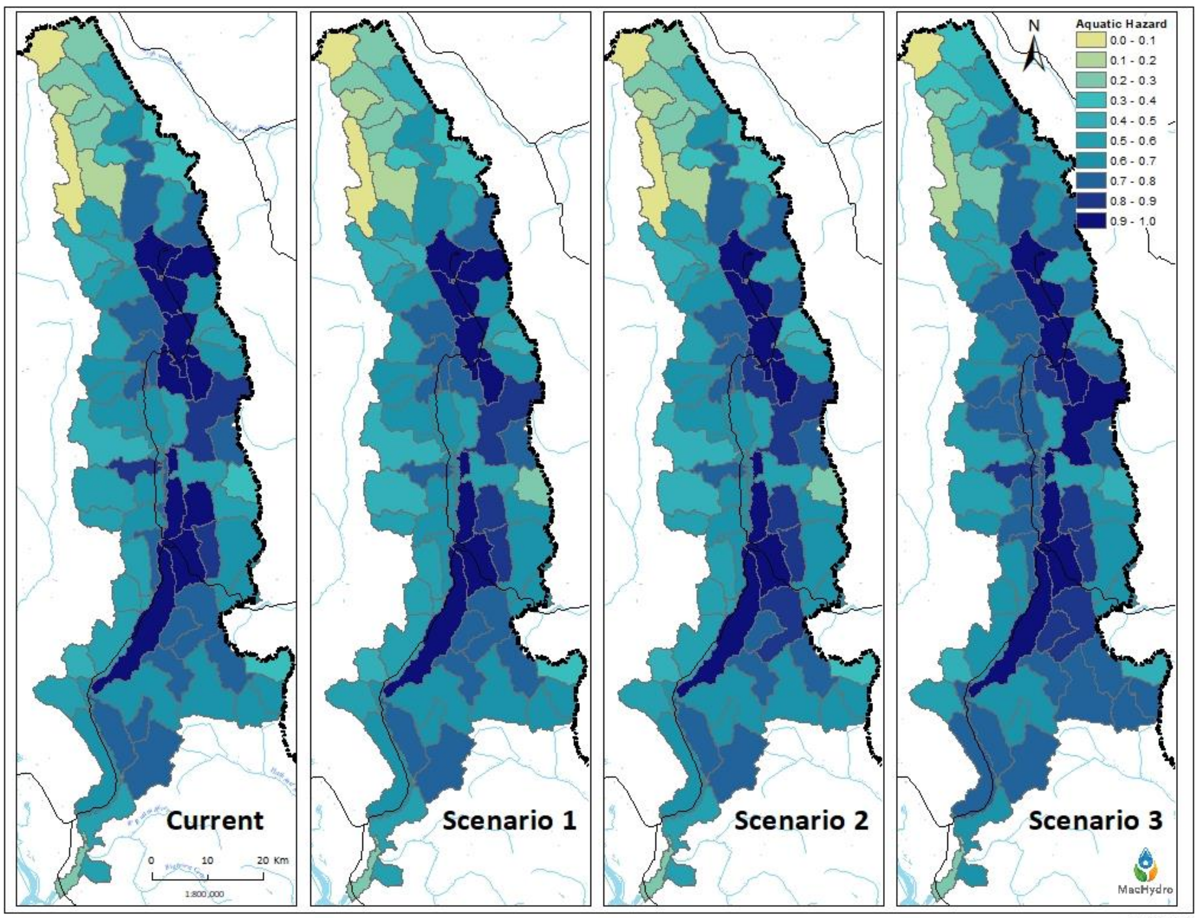

Figure 21. Aquatic Hazard index at current condition and at 2038 under Scenarios 1, 2, and 3.

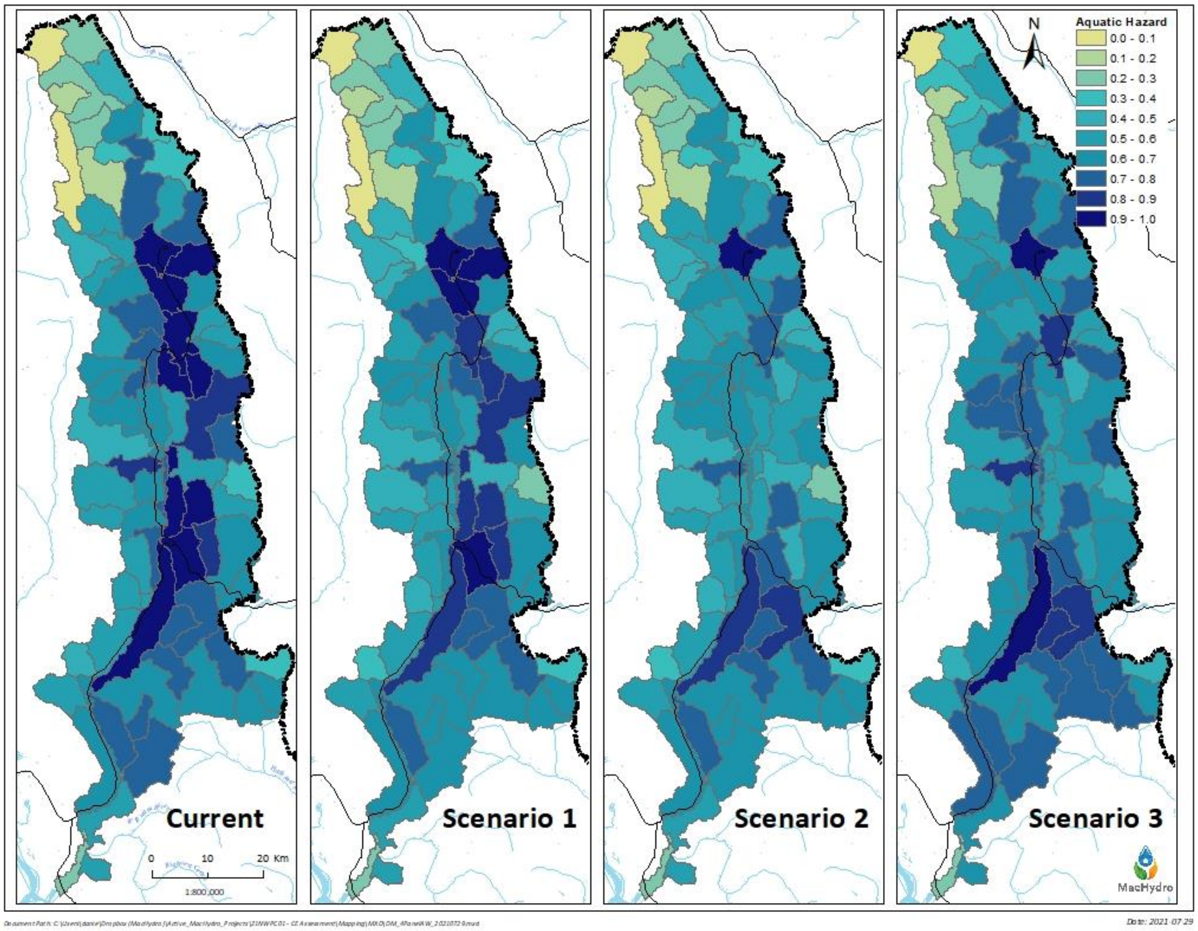

Figure 22. Aquatic Hazard index at current condition and at 2055 under Scenarios 1, 2, and 3.

The projected increase in Aquatic Hazard in Scenario 3, relative to Scenario 1 and 2, is related to a younger forest age overall from natural disturbance activities in the scenario. The minimal difference between Scenario 1 and Scenario 2 is because of roads; although Scenario 2 simulates more overall development, much of this effect is diluted by the removal of roads at mine sites (mines grow overtop of roads). Roads are a strong driver of Aquatic Hazard, and the effect of removing roads to develop mine sites acts to decrease Aquatic Hazard and counter any negative effects of additional developments. This is an artefact of the way the Aquatic Hazard VC equation is set up and should be considered upon interpretation of results.

Table 1 shows Aquatic Hazard indices for the Alexander Creek – Mid AW, associated with the Crown Mountain project, for current condition and year 2038 and 2055 under all scenarios. In Scenario 1, hazard increases at peak mining (at 2038) and decreases with mine reclamation (at 2055). Compared to an aging forest alone, Aquatic Hazard would have reached 0.58 at 2038; therefore, mining acts to increase hazard in this AW by 0.04 index points. Reclamation of the mine footprint by 2055 reduces the

Aquatic Hazard score, yet not enough to bring it into a Low hazard rating. The same pattern is demonstrated in Scenario 2, yet hazard scores reach slightly higher levels by 2055. This is because of the additional cutblocks and road development co-occurring in this AW in Scenario 2, relative to Scenario 1. In Scenario 3, by 2038, Aquatic Hazard is projected to reach the highest levels, and in 2055 the hazard does not decrease to the same extent as observed in other scenarios. This is because natural disturbances; insect outbreak and wildfire, act to decrease the age of the forest and therefore increase the ECA and Riparian Disturbance components of the Aquatic Hazard VC.

Table 1. Aquatic Hazard Indices for Alexander Creek Mid AW, under current condition, scenario 1, 2, and 3.

		Aquatic Hazard Index (Hazard Rating)						
AW	**Associated Proposed Development**	**Current Condition**	**Scenario 1**		**Scenario 2**		**Scenario 3**	
		2021	**2038**	**2055**	**2038**	**2055**	**2038**	**2055**
Alexander Creek – Mid	Crown	0.57 (Mod)	0.61 (Mod)	0.51 (Mod)	0.61 (Mod)	0.53 (Mod)	0.68 (Mod)	0.65 (Mod)

3.2.2 Grizzly Bear

In this model, forest age is a primary driver of habitat availability, with young forests aged < 20 years preferred by Grizzly bears, and intermediate forests aged 20-80 years not preferred. Berry habitat is also linked to forest age, with young open canopy forests having higher value based on their optimal conditions for berry growth. Another driver of habitat availability is the presence of naturalized landscapes vs anthropogenic footprint, such as mine development which removes natural landcovers.

At the scale of the Elk Valley, Habitat Availability changes by approximately -6%, -6%, and +4%, in Scenarios 1, 2, and 3, respectively by 2038, and by -11%, -3%, and -9% by 2055 (Figure 23 and Figure 24). In Scenario 1, Habitat Availability decreases at both 2038 and 2055 because peak mine development for Crown Mountain in 2038 removes available habitat from the landscape, and subsequently at 2055 mine reclamation at Crown Mountain only converts 1.8 km^2 of mine footprint into young forest, which isn't enough to counteract the natural aging of other young forests into unfavorable intermediate age classes elsewhere in the valley. In Scenario 2, Habitat Availability decreases similarly in 2038, yet increases in 2055 due to further conversion of mine footprint from reclamation at other mine sites, as well as simulation of cutblocks to increase young favorable forests. Scenario 3 demonstrates an increase in available habitat by year 2038 due to large insect outbreaks in the first decade of the simulation, creating a high proportion of forests aged less than 20 years old. Scenario 3 subsequently demonstrates a decrease in available habitat by

2055 because the same insect outbreaks that were once favorable in 2038, are now aged greater than 20 years and no longer considered preferred habitat.

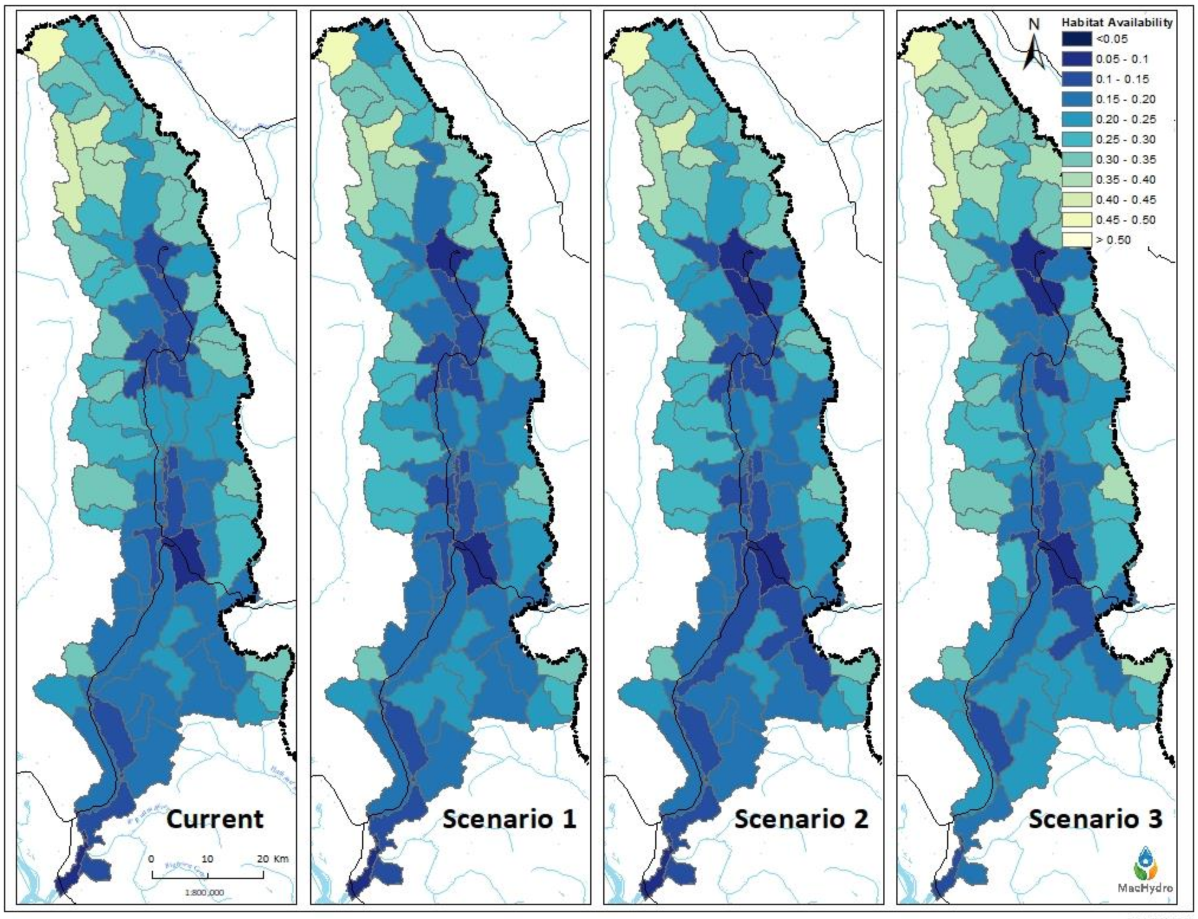

Figure 23. Grizzly Habitat Availability by AW in the Elk Valley under Current condition, and at 2038 under Scenarios 1, 2, and 3.

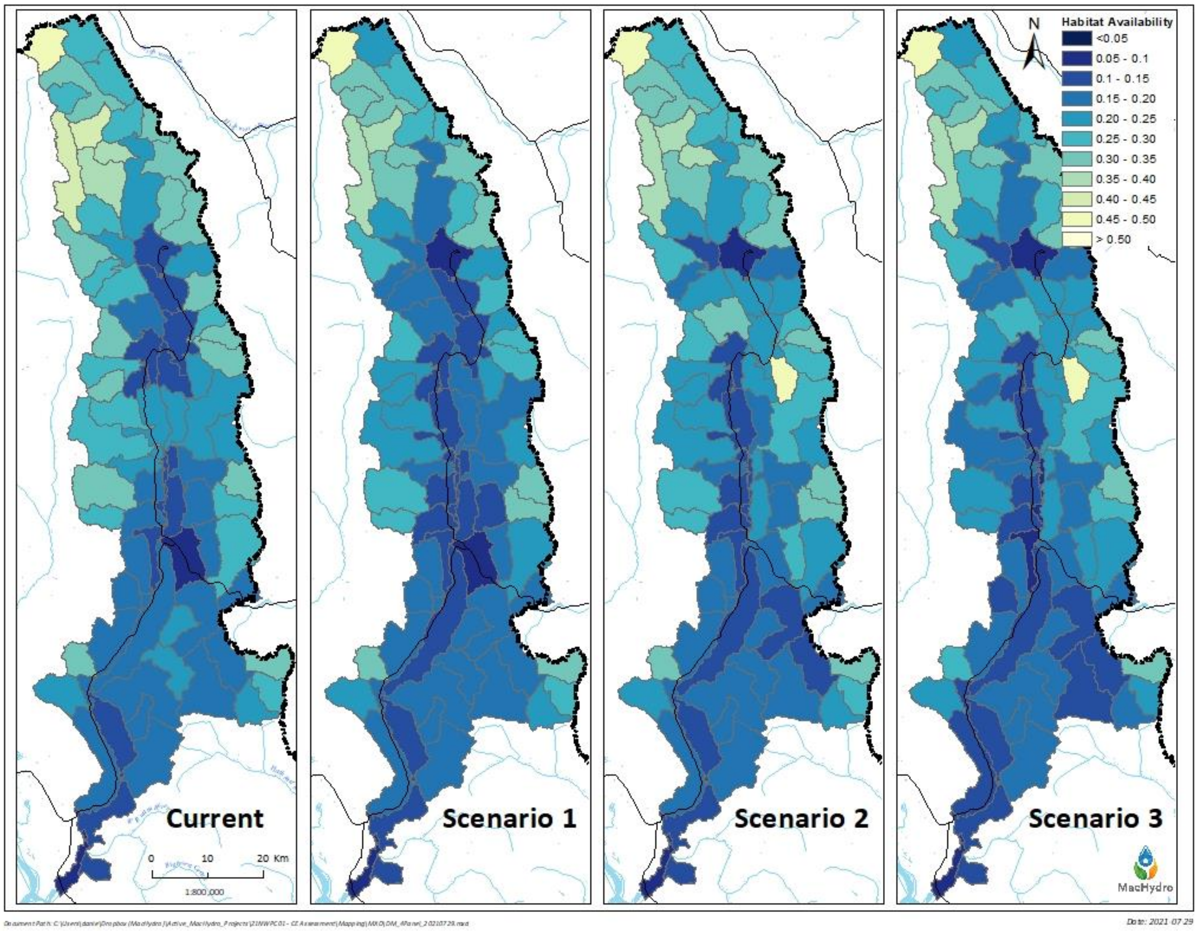

Figure 24. Grizzly Habitat Availability by AW in the Elk Valley under Current condition, and at 2055 under Scenarios 1, 2, and 3.

The Alexander Creek – Mid AW, associated with the proposed Crown Mountain mine, shows a decrease in available habitat at 2038 relative to current condition, with a subsequent increase at 2055, in both Scenarios 1 and 2 (Table 2). This is because the proposed mining development removes available habitat from the AW at 2038, and converts planned areas for mine reclamation into young forest at 2055. Scenario 1 demonstrates an increase in habitat at 2055, rather than the decrease seen at the scale of the Elk Valley. This is because at the local scale of the Alexander Creek – Mid AW alone, mine reclamation is enough to outbalance aging forests elsewhere in the AW. There is effectively no decrease in available habitat under Scenario 3, since increased rates of natural disturbance act to increase young open-canopy forests for Grizzly.

Table 2. Grizzly Habitat Availability Indices for Alexander Creek Mid AW, under current condition, scenario 1, 2, and 3.

		Grizzly Habitat Availability						
AW	**Associated Proposed Development**	**Current Condition**	**Scenario 1**		**Scenario 2**		**Scenario 3**	
		2021	**2038**	**2055**	**2038**	**2055**	**2038**	**2055**
Alexander Creek – Mid	Crown	0.29	0.25	0.31	0.26	0.32	0.30	0.29

The Grizzly Habitat Suitability indicator, and hence the final Grizzly Bear Hazard indicator, build off Habitat Availability, but are also strongly linked to road density. Figure 25 demonstrates the high levels of road density in all scenarios, at 2055, with many AWs exceeding the density benchmarks. Combined with the distribution of available grizzly habitat, this results in high levels of Grizzly Bear Hazard across most of the Elk Valley, in all scenarios at 2055 (Figure 26).

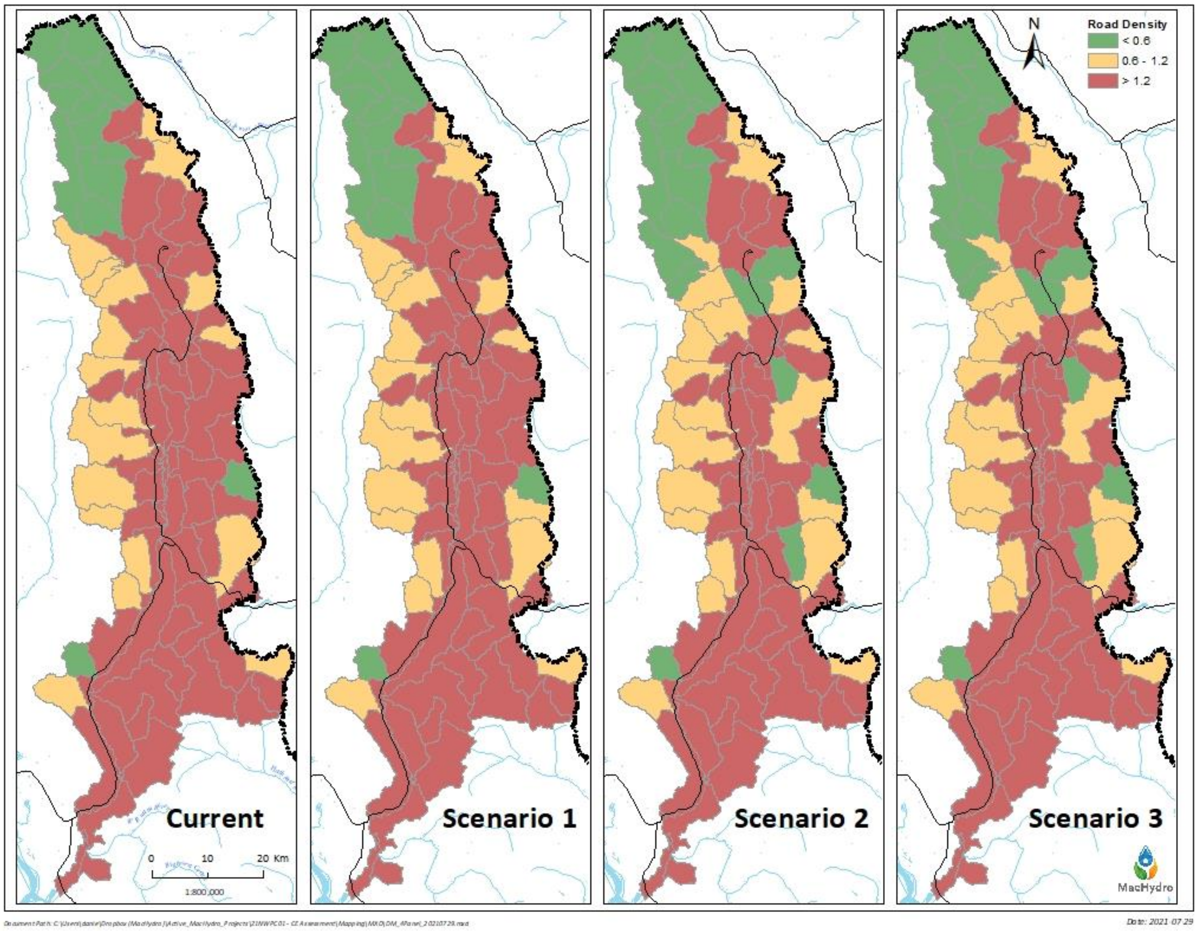

Figure 25. Current road density (km/km^2) by AW in the Elk Valley (far left), and at 2055 under Scenarios 1, 2, and 3 (left to right).

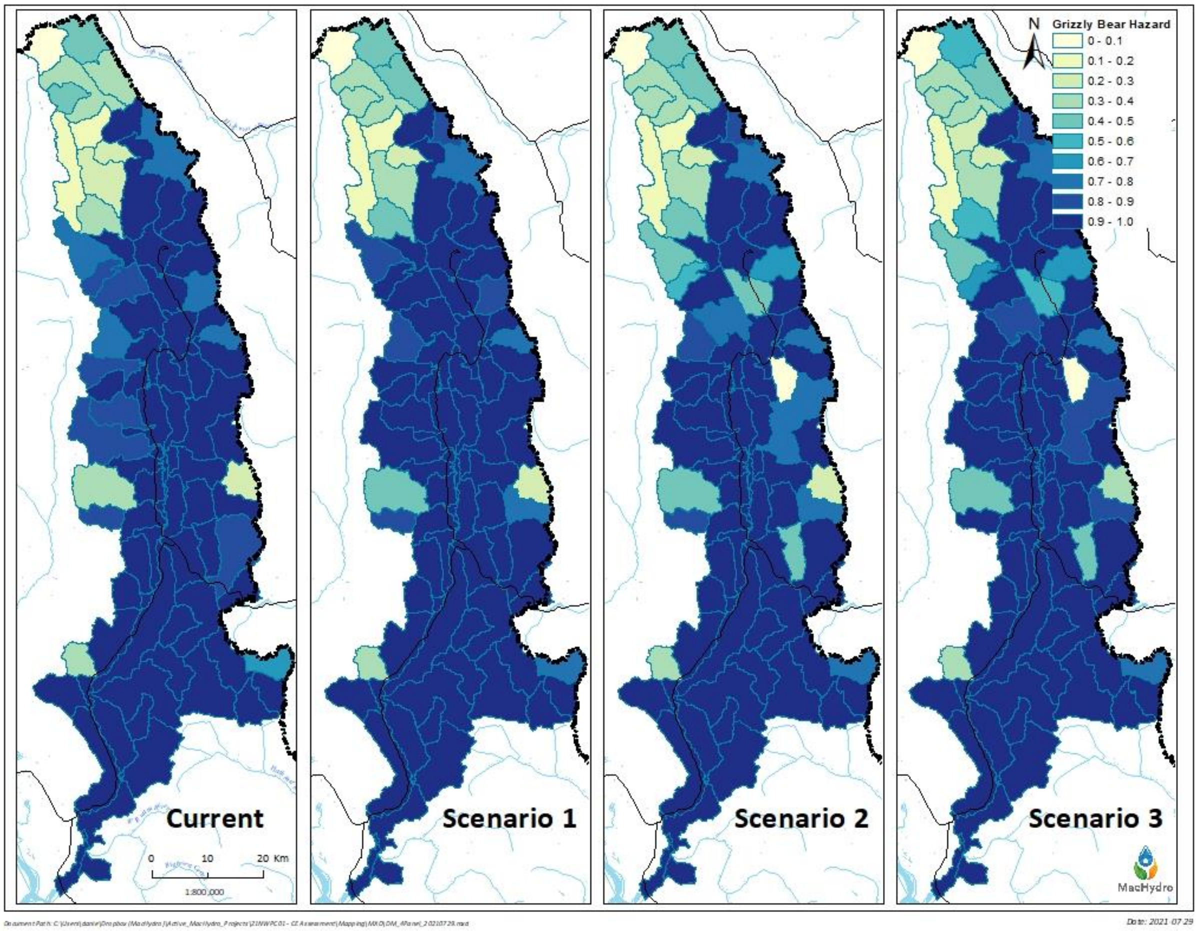

Figure 26. Current Grizzly Bear Hazard (index) by AW in the Elk Valley (far left), and at 2055 under Scenarios 1, 2, and 3 (left to right).

Interestingly, the increases in Grizzly Habitat Availability that were previously seen in Scenario 3 from increased natural disturbance, are not detectable at the level of Grizzly Bear Hazard, due to the strong negative effect of roads in AWs where road densities are high. Furthermore counter-intuitive results can occur at local scales, with some AWs subject to mine development exhibiting decreased Grizzly Bear Hazard upon peak mining. The Alexander Creek - Mid AW specifically, shows a decrease in Grizzly Bear Hazard upon peak mining at 2038 under all scenarios (Table 3). This is because, although habitat availability does in fact decrease, the development of mine footprint leads to the removal of roads in some locations, which drives down the overall road density at the scale of the AW. If the road density is moved below the thresholds of 1.2 km/km^2 or 0.6 km/km^2, more habitat will be deemed suitable, and therefore the final hazard index will decrease. This dynamic is seen in the Alexander Creek – Mid AW, as well as other AWs that host proposed mining developments, and highlights the unequal importance of roads relative to mine footprint in the VC equation. By 2055, further decreases in Grizzly Hazard can be seen in Scenarios 1 and 2 due to planned reclamation activities on mine sites.

Table 3. Grizzly Bear Hazard Indices for Alexander Creek Mid AW, under current condition, scenario 1, 2, and 3.

		Grizzly Bear Hazard						
AW	**Associated Proposed Development**	**Current Condition**	**Scenario 1**		**Scenario 2**		**Scenario 3**	
		2021	**2038**	**2055**	**2038**	**2055**	**2038**	**2055**
Alexander Creek – Mid	Crown	0.99	0.88	0.76	0.87	0.75	0.79	0.80

3.2.3 Old and OM Forests

The Elk Valley demonstrates an overall increase in total Old Forest coverage (relative to current condition) of approximately 79 km^2, 73 km^2, and -6 km^2 by 2038 in Scenarios 1, 2, and 3, respectively, and 187 km^2, 167 km^2, and 61 km^2, by 2055 (Figure 27). Old forest loss is expected to occur by 2038 in Scenario 3, due to the large areas of insect outbreak that are simulated to occur in the first decade of this simulation. Both Scenarios 1 and 2 show increases in Old Forest coverage in the absence of large-scale natural disturbance events, and Scenario 1 shows a greater increase relative to Scenario 2, due to the absence of incorporating cumulative anthropogenic developments.

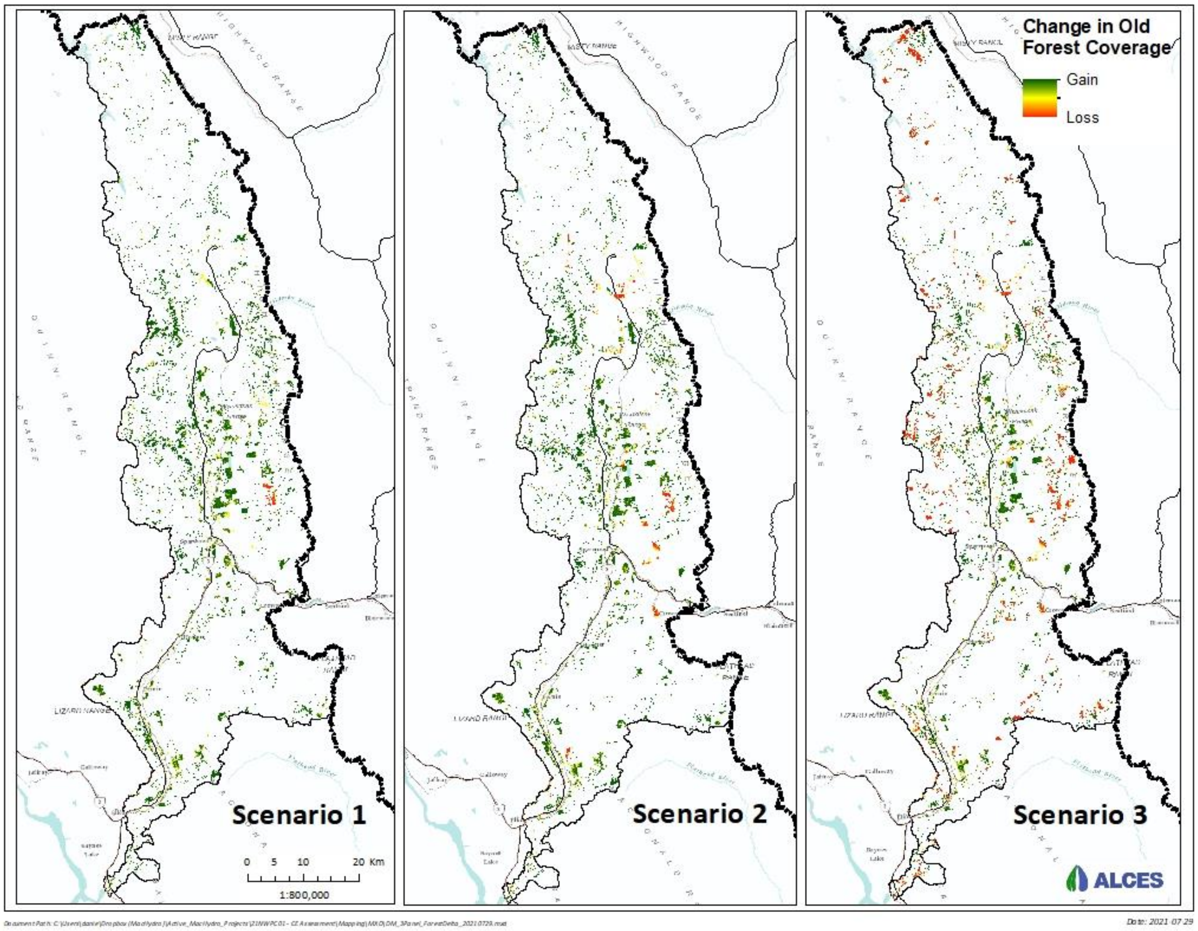

Figure 27. Change from current condition to 2055 in Old Forest coverage under Scenario 1, 2, and 3. Yellow to green scale indicates areas where Old Forests are gained by the year 2055, while orange to red scale indicates areas where Old Forest is lost.

It can be more insightful to look at Old Forest coverage at smaller units, such as at the scale of the AW, or even the mine footprint itself. Table 4 shows total Old Forest coverage summarized at the scale of the Alexander Creek – Mid AW. Old Forest coverage continually declines throughout all scenarios. Scenario 1 and Scenario 2 demonstrates identical results, suggesting that any other anthropogenic development in Scenario 2 does not intersect Old Forest coverage. Scenario 3 demonstrates the largest rate of decline relative to the others, due to the simulated cumulative anthropogenic developments as well as natural disturbance. Within the Crown Mine footprint itself, the project directly results in the loss of 1.16 km^2 of Old Forest, representing approximately 0.5% of the total existing Old Forest in the Elk Valley.

Table 4. Current and projected amounts of total Old Forest (km^2) for Alexander Creek – Mid AW, associated with the Crown Mountain project

		Total Old Forest (km^2)						
AW	**Associated Proposed Development**	**Current Condition**	**Scenario 1**		**Scenario 2**		**Scenario 3**	
		2021	**2038**	**2055**	**2038**	**2055**	**2038**	**2055**
Alexander Creek – Mid	Crown	5.9	5.3	4.5	5.3	4.5	3.3	2.7

Similarly at the scale of the Elk Valley, total OM Forest coverage is expected to increase at both 2038 and 2055, in all scenarios, with increases of approximately 196.5 km^2, 178.2 km^2, and 15.3 km^2 at 2038 under Scenario 1, 2, and 3, respectively, and 613.5 km^2, 553.5 km^2, and 331.5 km^2 at 2055 (Figure 28). OM Forest gain is expected to occur at all timesteps under all scenarios, although to a lesser degree under Scenario 3, which simulates large-scale natural disturbance events. OM Forests will gain at a greater rate than Old Forests due to the substantially lower age cutoff for classification to the mature age class (100 or 120 years old depending on BEC zone vs 140 or 250 years depending on BEC zone).

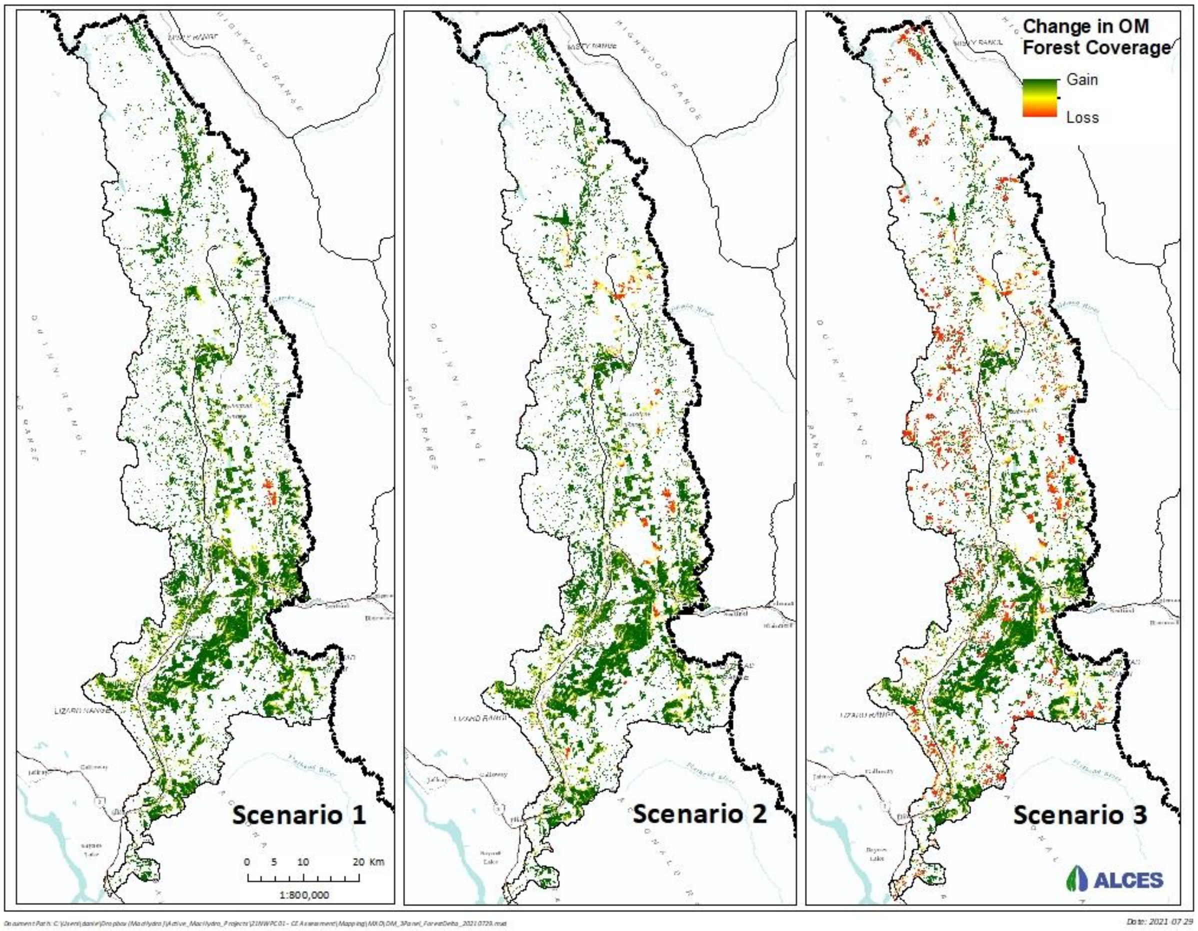

Figure 28. Change from current condition to 2055 in OM Forest coverage under Scenario 1, 2, and 3. Yellow to green scale indicates areas where OM Forests are gained by the year 2055, while orange to red scale indicates areas where OM Forest is lost.

Table 5 demonstrates that in the Alexander Creek – Mid AW, OM Forest coverage declines upon peak mining at 2038, and then increases due to natural aging and recruitment by 2055, under all scenarios. Scenario 2 see's slightly less OM Forest by the end of 2055, relative to Scenario 1, and this is due to a few small active cutblocks in the OM Forest landbase in the years 2030 and 2040. Scenario 3 demonstrates the largest decline in OM Forest coverage by 2038 due to the large insect outbreaks in the first decade of that simulation. Within the Crown Mountain mine footprint itself, the project is expected to result in the loss of 1.9 km^2 of OM Forest, representing only 0.4% of the total existing OM Forest coverage in the Elk Valley.

Table 5. Current and projected amounts of total OM Forest (km²) for Alexander Creek – Mid AW associated with the Crown Mountain project.

		Total OM Forest (km²)						
AW	**Associated Proposed Development**	**Current Condition**	**Scenario 1**		**Scenario 2**		**Scenario 3**	
		2021	**2038**	**2055**	**2038**	**2055**	**2038**	**2055**
Alexander Creek – Mid	Crown	8.2	7.1	9.9	7.1	9.7	4.7	5.7

The prospective assessment results (Figure 29 and Figure 30; Table 6 and Table 7) suggest that mining alone doesn't have a large effect on Z-score, unlike larger scale disturbances such as fire, insect outbreak, or timber harvest. Scenario 1 shows improvements in both Old and OM Z-Score through both 2038 and 2055; these are expected results since Scenario 1 only simulates the Crown Mountain mine development disturbance. Scenario 2 does in fact simulate an estimated amount of timber harvest; however, most cutblocks were randomly located outside the Elk Valley, therefore the effect of forestry on Z-Score is negligible. As a result, Z-Score for both Old and OM Forests improve steadily through 2038 and 2055 in Scenario 2. Finally, insect disturbance drives most of the Z-Score response in Scenario 3, since most fire is randomly simulated outside the Elk Valley. Most of the insect outbreaks occur within the BEC zones of ESSFdkw and ESSFdk2, and these BEC zones show a worsening of Old and OM Z-Scores by 2038 (Table 6 and Table 7). Insect disturbance is not simulated past the first decade so Z-Score subsequently improves again by 2055.

Table 6. Current and projected Old Forest Z-Score for BEC units associated with the Crown Mountain project.

BEC Zone	Associated Proposed Development	Old Forest Z-Score (index)						
		Current Condition	Scenario 1		Scenario 2		Scenario 3	
		2021	2038	2055	2038	2055	2038	2055
ESSFdk1	Crown	-1.97 (Mod)	-1.72 (Mod)	-1.34 (Mod)	-1.67 (Mod)	-1.50 (Mod)	-1.95 (Mod)	-1.86 (Mod)
ESSFdkw	Crown	-1.61 (Mod)	-1.49 (Mod)	-1.31 (Mod)	-1.46 (Mod)	-1.32 (Mod)	-1.65 (Mod)	-1.57 (Mod)
MSdw	Crown	-2.74 (High)	-2.39 (High)	-1.74 (Mod)	-2.33 (High)	-1.85 (Mod)	-2.44 (High)	-2.05 (High)
ESSFdk2	NA	-1.88 (Mod)	-1.58 (Mod)	-1.26 (Mod)	-1.57 (Mod)	-1.26 (Mod)	-2.02 (High)	-1.83 (Mod)
ICHmk4	NA	-2.10 (High)	-1.73 (Mod)	-1.31 (Mod)	-1.75 (Mod)	-1.34 (Mod)	-1.93 (Mod)	-1.59 (Mod)

Table 7. Current and projected OM Forest Z-Scores for BEC Units associated with the Crown Mountain project.

BEC Zone	Associated Proposed Dev.	OM Forest Z-Score (index)						
		Current Condition	Scenario 1		Scenario 2		Scenario 3	
		2021	2038	2055	2038	2055	2038	2055
ESSFdk1	Crown	-1.85 (Mod)	-1.50 (Mod)	0.00 (V. Low)	-1.45 (Mod)	-0.27 (Low)	-1.84 (Mod)	-0.84 (Low)
ESSFdkw	Crown	-0.69 (Low)	-0.42 (Low)	0.30 (V. Low)	-0.42 (Low)	0.20 (V. Low)	-0.98 (Low)	-0.45 (Low)
MSdw	Crown	-3.14 (V. High)	-2.50 (High)	0.00 (V. Low)	-2.43 (High)	-0.33 (Low)	-2.65 (High)	-0.84 (Low)
ESSFdk2	NA	-1.86 (Mod)	-1.52 (Mod)	-0.97 (Low)	-1.53 (Mod)	-1.01 (Mod)	-2.14 (High)	-1.77 (Mod)
ICHmk4	NA	-1.34 (Mod)	0.60 (V. Low)	1.67 (V. Low)	0.56 (V. Low)	1.57 (V. Low)	-0.10 (Low)	0.71 (V. Low)

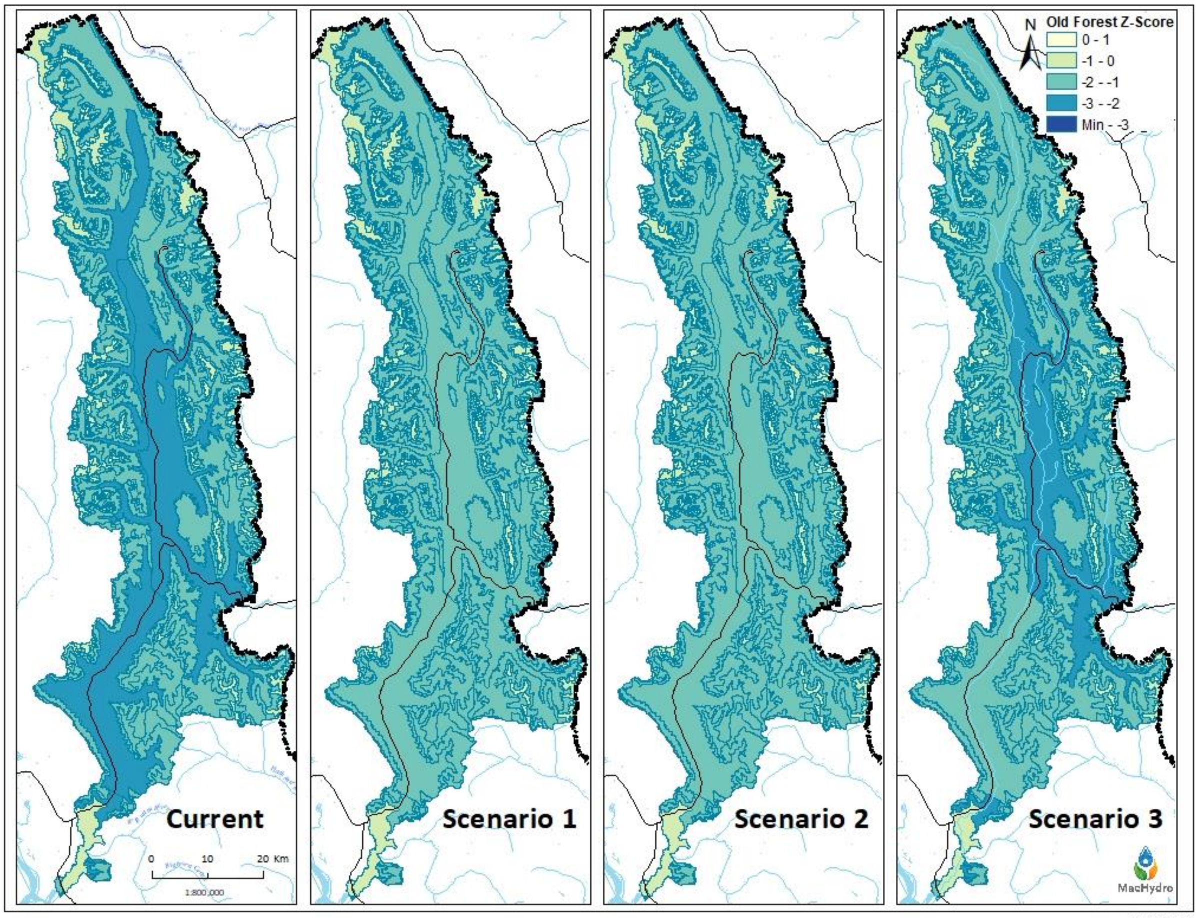

Figure 29. Old Forest Z-Score by BEC in the Elk Valley, under current conditions, and at 2055 under Scenario 1, 2, and 3.

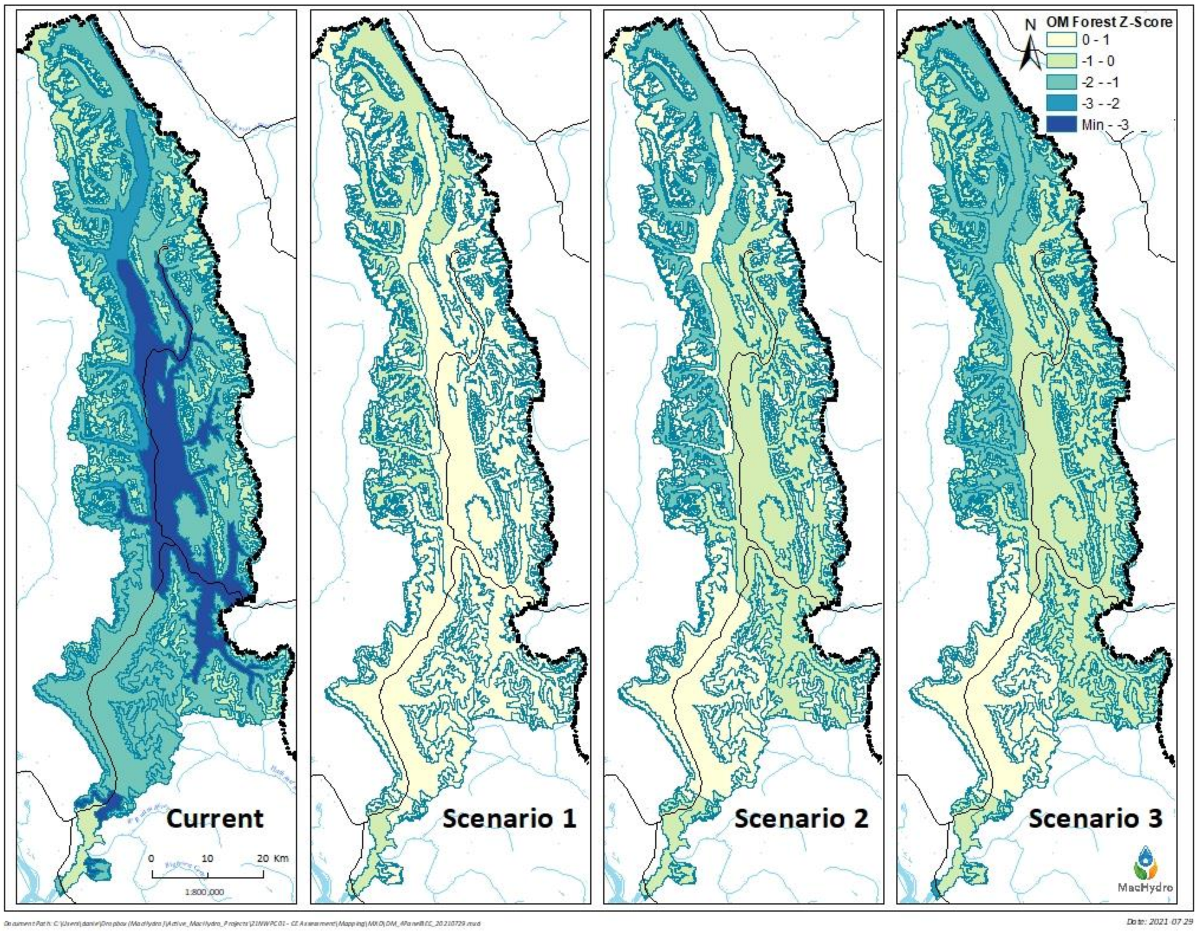

Figure 30. OM Forest Z-Score by BEC in the Elk Valley, under current conditions, and at 2055 under Scenario 1, 2, and 3.

Results suggest that ongoing hazards for Old Forests are likely to persist at the scale of all BECs under Scenario 3. OM Forest Z-Score is projected to move into the low hazard category by 2055 in all BECs associated with Crown development. The largest improvement is expected to occur in the MSdw BEC, suggesting either that current disturbances disproportionately affect that zone, or simulated disturbances are disproportionately located outside of that zone.

Overall, interior Old Patch size shifts towards a greater number of small patches (1-5 ha) under all scenarios (Figure 31). This effect is most noticeable in Scenario 3 due to natural disturbance. Interior OM Patch size behaved similarly, demonstrating a shift towards smaller patches by 2055 (Figure 32). These results suggest that under simulated rates of fire and insect outbreak (alongside cumulative anthropogenic effects) large patches of Old and OM Forest are projected to be less numerous in the Elk Valley.

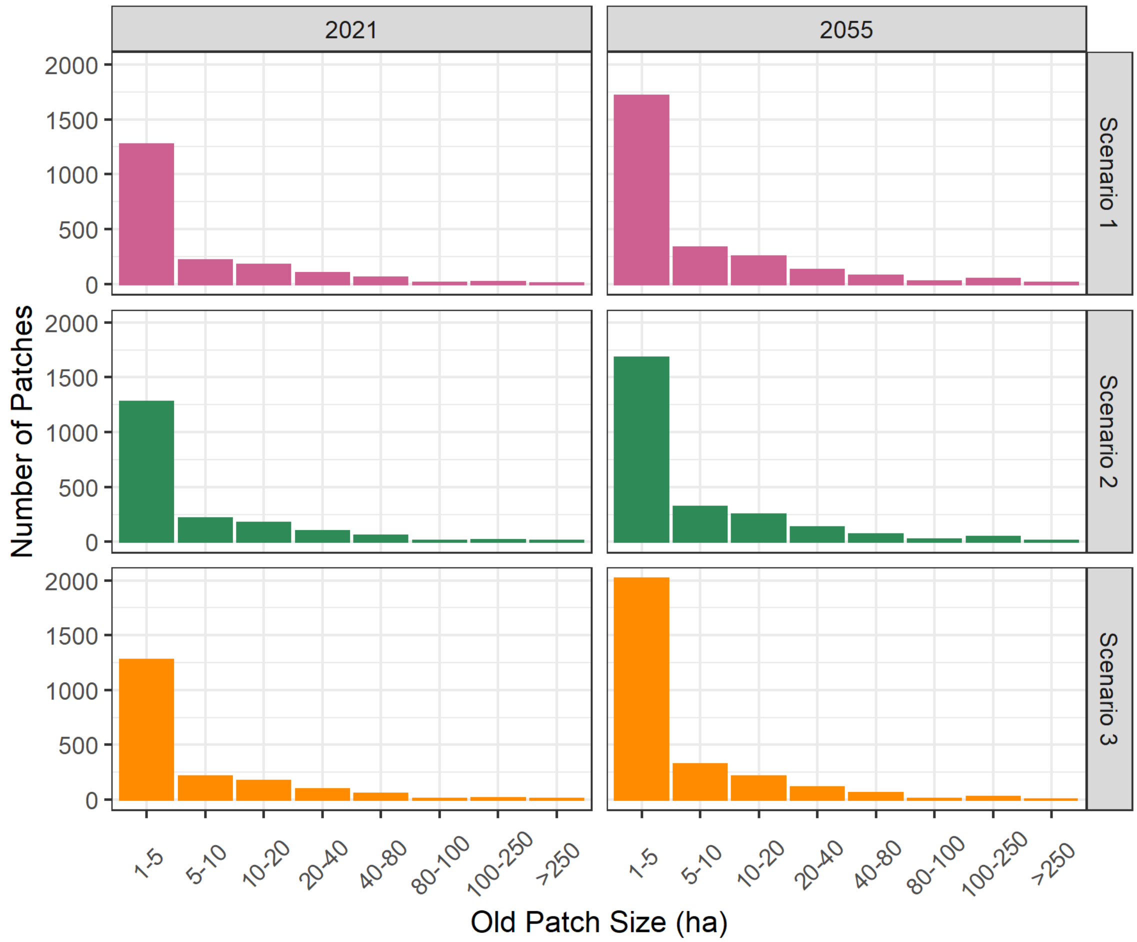

Figure 31. Old Forest histogram of patch size distribution from current to 2055 under Scenario 1, 2, and 3.

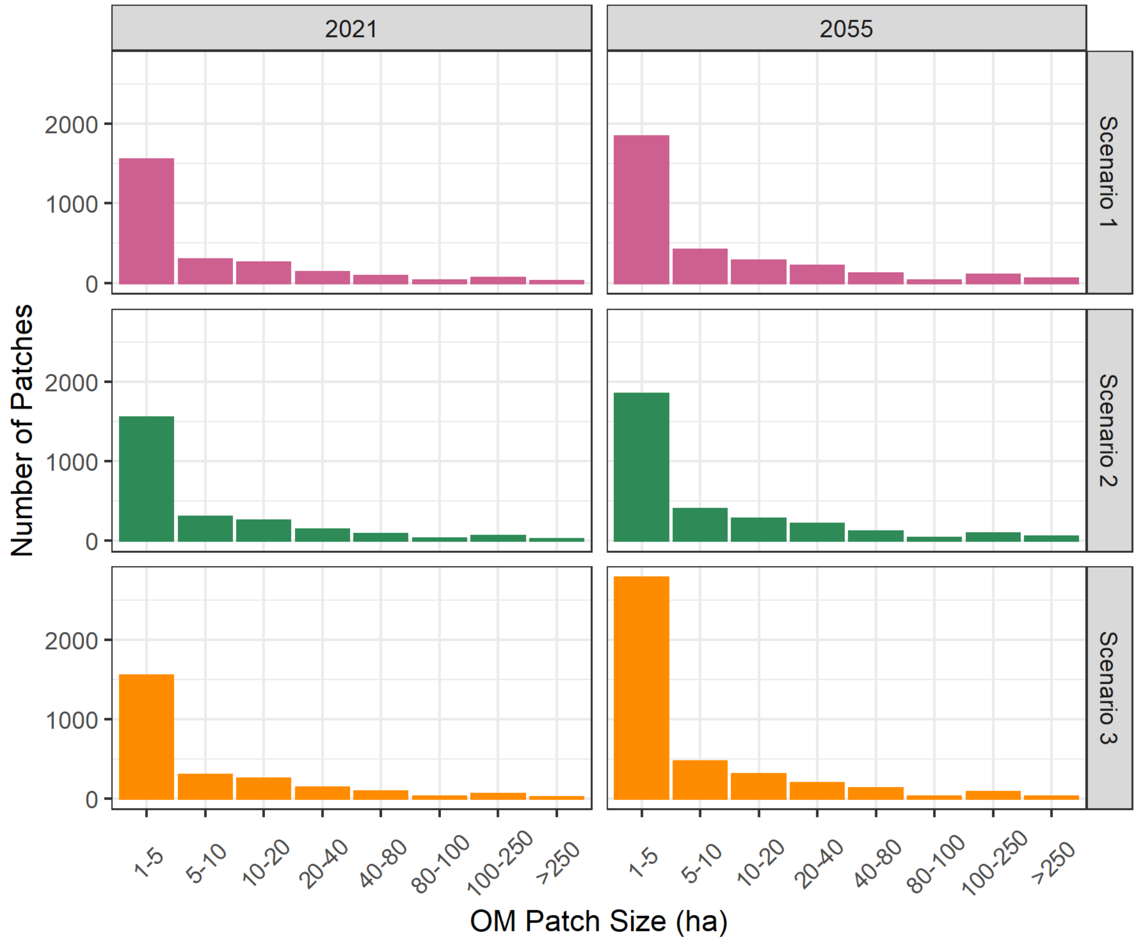

Figure 32. OM Forest histogram of patch size distribution from current to 2055 under Scenario 1, 2, and 3.

3.2.4 Bighorn Sheep

The prospective assessment scenarios result in an increase in hazard for the Fording sub-population upon further mine development in Scenario 2 and 3, pushing hazard level for Fording above 4.0 and into a Very High class (Table 8 and Figure 33). These results suggest that the Crown Mountain project does not impose an effect on BHS Rank 3 and 4 WR Hazard in the Erickson sub-population as it is currently modelled. This is because the area of planned mining development does not intersect with any existing Rank 3 or 4 WR. Results also suggest that the effect of other mining activities, simulated in Scenario 2 and 3, have a negative influence on the Fording sub-population alone and does not intersect with any Rank 3 or 4 WR in other sub-populations.

Table 8. BHS Rank 3 and 4 WR Hazard indices for Sheep subpopulations in the Elk Valley, under current conditions, Scenario 1, 2, and 3.

		Rank 3 and 4 WR Hazard (index)						
Sub-Pop.	**Associated Proposed Dev.**	**Current Cond.**	**Scenario 1**		**Scenario 2**		**Scenario 3**	
		2021	**2038**	**2055**	**2038**	**2055**	**2038**	**2055**
Erickson	Crown	0.00 (V. Low)	0.00 (V. Low)	0.00 (V. Low)	0.00 (V. Low)	0.00 (V. Low)	0.00 (V. Low)	0.00 (V. Low)
Fording		3.98 (High)	3.98 (High)	3.98 (High)	4.25 (V. High)	4.25 (V. High)	4.25 (V. High)	4.25 (V. High)
Ewin		2.90 (Mod)	2.90 (Mod)	2.90 (Mod)	2.90 (Mod)	2.90 (Mod)	2.90 (Mod)	2.90 (Mod)
Crowsnest N.		0.03 (V. Low)	0.03 (V. Low)	0.03 (V. Low)	0.03 (V. Low)	0.03 (V. Low)	0.03 (V. Low)	0.03 (V. Low)
Upper Elk E.		0.02 (V. Low)	0.02 (V. Low)	0.02 (V. Low)	0.02 (V. Low)	0.02 (V. Low)	0.02 (V. Low)	0.02 (V. Low)
Upper Elk W.		0.13 (V. Low)	0.13 (V. Low)	0.13 (V. Low)	0.13 (V. Low)	0.13 (V. Low)	0.13 (V. Low)	0.13 (V. Low)
Crossing Ck		0.06 (V. Low)	0.06 (V. Low)	0.06 (V. Low)	0.06 (V. Low)	0.06 (V. Low)	0.06 (V. Low)	0.06 (V. Low)
EV West Hornaday		0.00 (V. Low)	0.00 (V. Low)	0.00 (V. Low)	0.00 (V. Low)	0.00 (V. Low)	0.00 (V. Low)	0.00 (V. Low)

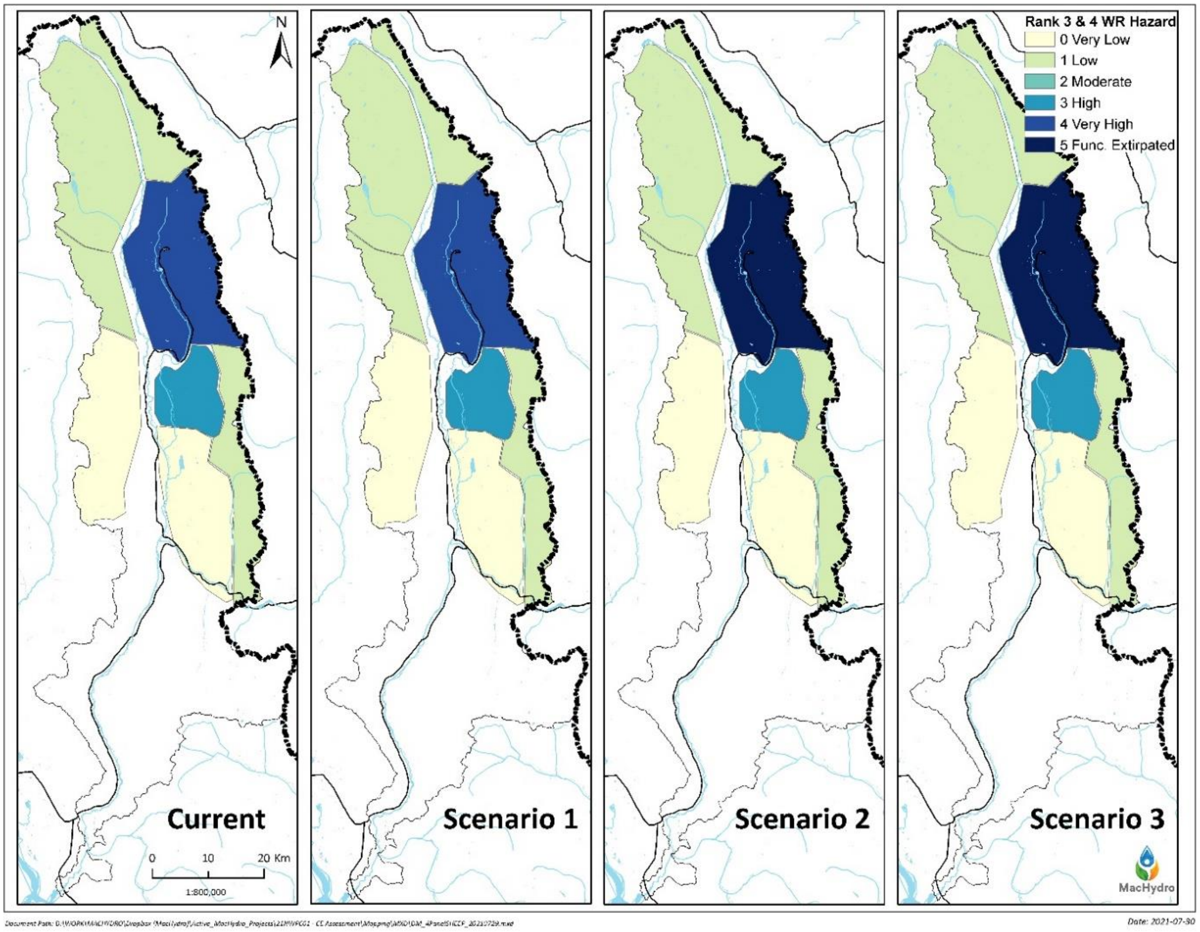

Figure 33. Bighorn Sheep Rank 3 and 4 Winter Range Hazard, by Sheep sub population in the Elk Valley, under current conditions, and at 2055 under Scenario 1, 2, and 3.

4 Discussion

4.1 Aquatic Ecosystems

The results from this assessment suggests that hazard to aquatic ecosystems is highest in the valley bottom and most intense in areas heavily affected by human development, such as mining and dense road networks. Changes in hazard into the future are generally highest under Scenario 3 in response to simulated fire and insect disturbances, and at peak mine development at 2038. Simulations also suggest that mine reclamation at 2055 has the potential to mitigate some of the effect on the aquatic VC, yet generally does not bring hazard to a lower rating class.

The only caveat to this is that if mine development results in the removal of pre-existing roads, Aquatic Hazard scores could decrease (rather than increase upon peak mining) since they are strongly linked to road densities. This is a limitation to the EV-CEMF VC equation and should be addressed. This analysis also highlights other area for potential improvements in the Aquatic Hazard CEMF VC equation. As an example, mining development related to Crown Mountain is expected to disturb a large portion of West Alexander Creek, representing approximately 10% of the AW by area. Yet simulations suggest that mining activity in this AW only accounts for an increase in hazard of 0.04 index points. This comparison suggests that the VC is not sensitive to the spatial scale of the disturbance – a more intuitive modelling approach may be more useful moving forward for future assessments.

4.2 Grizzly Bear

Grizzly Habitat Availability is largely dependent on the abundance of young, open-canopy forests that can provide preferred forests as well as optimal conditions for berry growth. As such, developments on the landscape such as mining reclamation, forest harvest, or large-scale natural disturbances, can drive changes in available habitat for Grizzly. The timing of these developments and events is paramount, since forests continue to age and eventually move from young preferred ages into intermediate unfavored ages. For example, insect outbreaks that are simulated in the first decade of Scenario 3, eventually act to decrease habitat availability by 2055, because they increase the relative proportion of intermediate aged forests on the landscape.

Grizzly Bear Hazard is not only linked to amount of available habitat, but also very strongly linked to the density of the local road network. Saturated road networks can mask potential increases in available habitat. Conversely, decreases in road density from other anthropogenic developments (i.e., mine development) may be reflected in the model as a benefit to Grizzly, whereas that may not be the case. This is a key model limitation and should be addressed in future provincial CEMF efforts.

4.3 Old and OM Forests

Current condition results suggest that observed amounts of Old Forest are lower than what would be expected in the Elk Valley, with the biggest hazards occurring in the MSdw, and ICHmk4 zones. Similar results for OM Forest Z-Score suggest lower amounts than expected valley-wide (although less hazardous relative to Old Z-Score), with high hazards occurring in the MS zone. The most conservative and realistic scenario, Scenario 3, demonstrates little improvement in valley wide Z-Score and no change in hazard rating for Old Forests, suggesting that hazard for the Old Forest VC is unlikely to improve moving forward.

The shift toward smaller Old Forest patches seen in Scenario 3 suggests that Old Forest stands are highly fragmented when incorporating cumulative effects and natural disturbance. This can translate to high hazard for VCs that require large patches of functional forest, and may require that Old Forest conservation or management efforts be implemented.

Although mining development can remove Old and OM Forests from the landbase and fragment existing Old and OM patches, at the scale of the Elk Valley and the BEC zone, natural disturbance (and forest harvest) is the primary driver of changes in Z-Score and Patch Size. Natural disturbance resilience strategies (fire breaks, insect trap trees, etc..) can provide opportunities for improving Old Forest conditions in the Elk Valley.

4.4 Bighorn Sheep

Hazard to the BHS VC is related to presence of Rank 3 and Rank 4 Winter Range relative to historic coverage. As such, avoiding overlap with existing rank 3 and 4 winter range in the mine planning stages is the most effective way of minimizing further hazards to BHS. In this work, current mine areas were not removed from existing winter range datasets. This approach was taken because BHS herds have been shown to actively use mine sites for overwintering, based on telemetry data and anecdotal evidence. A similar approach may be considered for any EV-CEMF BHS model updates. Currently the EV-CEMF model does not allow for creation or rehabilitation of rank 3 or 4 winter range. Future work on EV-CEMF model equations could evaluate whether reclamation should be used as a form of winter range rehabilitation.

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6 Appendices