BIGHORN SHEEP
Cumulative Effects Assessment Report

Elk Valley, Kootenay-Boundary Region

DRAFT

Version 8

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EXECUTIVE SUMMARY

The Elk Valley in British Columbia's East Kootenay is rich in biodiversity, culture and economic wealth. Management of cumulative effects in the Elk Valley has been of increasing concern due to resource development and residential and recreational pressures as well as natural events.

Bighorn sheep are a valued component of the BC ecosystem because of their high harvest and cultural value and their importance to First Nations. The Elk Valley East and West populations are of particular significance because of their unique use of high-elevation winter range and their freedom from widespread respiratory disease. The analysis reported here is restricted to those two populations within WMU 4-23.

Spatial and non-spatial data were used to assess historic, current and potential future conditions, as well as to develop hazard maps. Three alternative future development scenarios, namely, business as usual, minimum, and maximum, and a higher natural disturbance scenario were defined to assess the response of indicators to variations in rates, spatial configurations, density or pattern of development and disturbance over the next 50 years using the ALCES Online model. Where possible, indicators of Bighorn sheep status and condition were assessed separately for each of the eight subpopulations within the two focal populations. Where lack of data makes this impossible, indicators were assessed at the population level. Four indicators were selected for assessment:

1) Amount (area) and suitability (condition) of winter range habitat;

2) Amount (area) of annual range habitat;

3) Human-caused mortality of Bighorn sheep within the Elk Valley;

4) Population trend of Bighorn sheep within the Elk Valley.

Retrospective assessment compared present-day indicator status to conditions in 1950 and attempted to identify patterns of change and their key causes. Results indicate significant loss or alteration of the most highly preferred (Rank 4) winter range habitat, which declined by 30% for the Elk Valley East population from the 1980s through the 2000s. Loss of Rank 4 habitat was especially severe in the Fording (-36%) and Ewin Creek (-41%) subpopulations, leading them to be ranked as High hazard for this indicator. Loss or alteration can be attributed to primarily

mining (Fording 22% loss, Ewin 12% loss) or habitat degradation (Fording 14% loss, Ewin 29% loss). Smaller losses for the Erickson Sheep Mt. subpopulation lead it to be ranked as Moderate hazard (8.5% from mining). Loss of Rank 4 winter range habitat is noteworthy because this habitat is effectively irreplaceable. The Elk Valley West population showed little or no change in winter range habitat, primarily because no mining activity took place in that part of the valley. There may be factors other than habitat loss leading to declines in Elk Valley West that were not assessed.

Winter range condition has declined since 1982 for 6 of the 8 sub-ranges examined, primarily because of overgrazing by ungulates (e.g. Elk, Bighorn sheep). For three sub-ranges (Imperial Ridge, Henretta/Courcelette (Gill Peak) and Ewin Ridge (Mount Banner/Long Ridge)), this decline has been significant enough to warrant a designation of "slightly at risk" (Smyth, 2014). One sub-range (Turnbull Mountain (South West)) was designated "moderately at risk"(Smyth, 2014).

Just over one-third (36%) of the annual range in Elk Valley East is the highest-quality native Rank 4 habitat, spread relatively evenly among subpopulations. Rank 4 habitat is absent in Elk Valley West only because rank scores were discounted (lowered) to reflect historically lower bighorn sheep population numbers than Elk Valley West assumed to be due to habitat quality. Annual range (rank 1-3) has increased over time in all populations surveyed. Much of this increase is due to past coal mining activity that re-created Bighorn sheep habitat in reclaimed areas.

Human-caused mortality affects a relatively small proportion of Bighorn sheep in the Elk Valley, accounting for an average of 14.5 individuals per year since 2000, and no more than 3.4% of the total population. Much of this mortality is due to hunter harvest, which claims an average of 10 rams per year (1.7% of the population) in Elk Valley East and 3 rams per year (3.2% of the population) in the West population. The latter is slightly higher than the 3% harvest benchmark recommended by the Bighorn Sheep Harvest Management Procedure (2014). Some accidental poisoning and other mine-related mortality also occurs. Road and rail strikes are relatively rare.

The estimated Bighorn sheep population in the Elk Valley East population roughly doubled between 2000 and 2010. Although the population has declined somewhat since then, it still meets the benchmark of remaining within 20% of the median population estimate from the last 5 aerial surveys. The Elk Valley West population, in contrast, has declined gradually since 2005 and no longer meets the benchmark. Lamb ratios from the past 5 surveys show a median of 35 and 41 lambs:100 ewes for the East and West populations, respectively, which is more than the minimum of 30-35 lambs:100 ewes that is generally required for stable populations.

The prospective assessment uses well validated landscape models to project how Bighorn sheep indicators might respond to alternative future development scenarios. The development scenarios used in this assessment do not result in changes to Bighorn sheep hazard, because little future disturbance is planned to winter range habitat. However, these projections include only future resource developments that are already being planned. Many undeveloped mineral leases also occur, covering a majority of Bighorn sheep winter range in Elk Valley East (Fig. 14). If leaseholders choose to develop these in the future, the impact on Bighorn sheep could be much higher than projected in this study.

Future management efforts should focus on preserving both quantity and quality of winter range habitat, as this is the most critical factor limiting Bighorn sheep populations. In the immediate future, efforts to improve the condition of at-risk winter range habitat are likely to be most effective, given that creating new winter range is difficult or impossible. Careful management of populations of both elk and Bighorn sheep may be helpful in preventing overgrazing of winter range habitat. Other habitat management programs presented in this report may also be helpful.

CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

ALCES – A Landscape Cumulative Effects Simulator
AR- Annual range
BC – British Columbia
BEC - Biogeoclimatic Ecosystem Classification
BHS - Bighorn sheep
CANFOR - Canadian Forest Products Ltd
CEA - Cumulative Effects Assessment
CEMF - Cumulative Effects Management Framework (Elk Valley)
CDC- Conservation Data Centre
DEM - Digital Elevation Model
ESSF - Engelmann Spruce-Subalpine Fir
FLNRORD – BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development
GIS – Geographic Information System
KBLUP - Kootenay-Boundary Land Use Plan
KBLUP-HLPO - Kootenay-Boundary Land Use Plan Higher Level Plan Order
KBLUP-IS - Kootenay-Boundary Land Use Plan Implementation Strategy
KNC - Ktunaxa Nation Council
LU - Landscape Unit
MS - Mountain Spruce
IMA - Interior Mountain-heather Alpine
MRVA - Multiple Resource Value Assessment
NGOs - Non-Governmental organizations
PEM - Predictive Ecosystem Mapping
RSA - Regional Study Area
TEM – Terrestrial Ecosystem Mapping
UFC - Uplands Function Checklist
UWR- Ungulate Winter Range
VCs - Valued Components
VRI - Vegetation Resources Inventory
WARS - Wildlife Accident Reporting System
WMU - Wildlife Management Unit
WR- Winter range

DOCUMENT PURPOSE

The purpose of this document is to outline the rationale, methods, and results of the Cumulative Effects Assessment (CEA) of bighorn sheep (BHS) in the Elk Valley as part of the Elk Valley Cumulative Effects Management Framework (CEMF). The various sections provide details about the existing policy framework, indicators, associated benchmarks, hazard ratings, description/interpretation of the results, and management responses including mitigation measures for Bighorn Sheep in the Elk Valley.

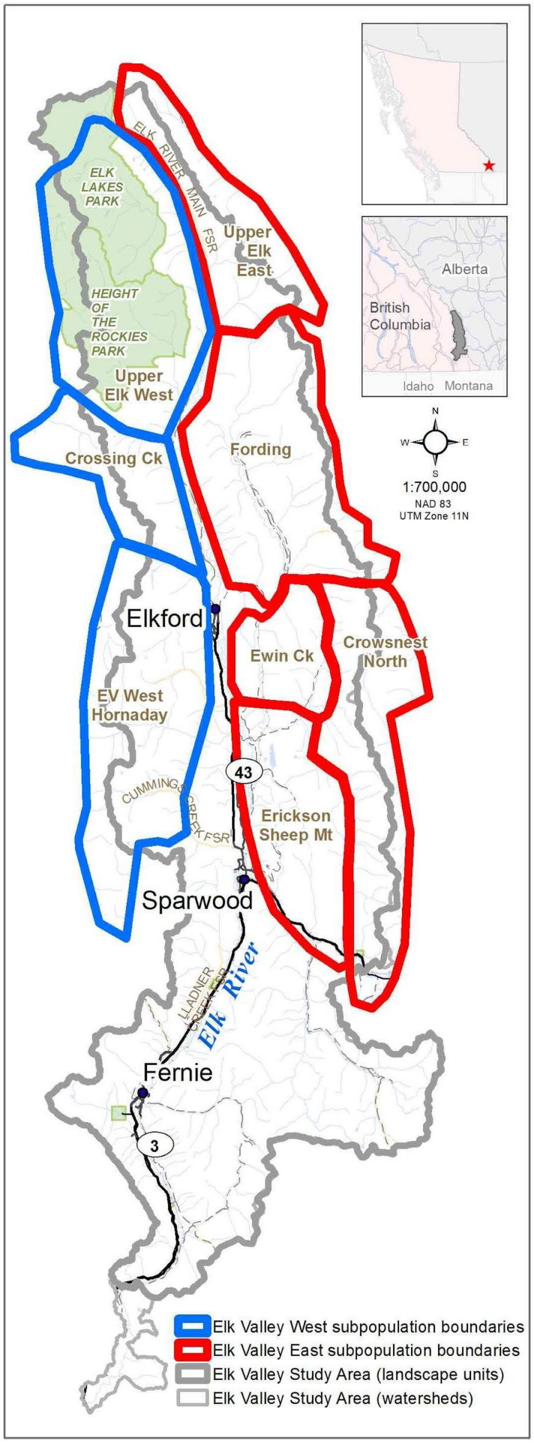
The cumulative effects assessment methods were developed by a Working Group comprised of BC government, First Nations, industry partners, environmental non-governmental organizations (NGOs), municipalities, and consultants. The BHS Expert Team refined the methods. Further review was completed by the Elk Valley CEMF Working Group and the broader stakeholders' Group (a.k.a. Workshop Group).

1.0 INTRODUCTION AND BACKGROUND

1.1 ELK VALLEY CUMULATIVE EFFECTS MANAGEMENT FRAMEWORK

The Elk Valley is located in the East Kootenay of British Columbia. The study area for the Elk Valley CEMF extends from Mount Fox in the north to Lake Koocanusa in the south (Fig. 1). The Elk Valley is an area rich in biodiversity, culture and economic wealth. Coal mining and forestry are the biggest industries in the valley, with tourism playing a smaller but growing role. Furthermore, the Ktunaxa First Nations have a deep, long-standing connection to this valley in terms of resources and spiritual value.

The management of cumulative effects in the Elk Valley has been of increasing concern due to current and ongoing resource development including open pit coal operations, timber harvesting on public and private lands, increasing recreational pressures and municipal development, all of which are contributing to stresses on the watershed. There has been growing awareness of the need for a broadly accepted, credible, and workable approach to the assessment and management of cumulative effects, both in the Elk Valley and provincially.



Developing a cumulative effects management framework is a condition in Teck Coal's Line Creek Operations Phase II EA certificate. In recognition of this, Teck Coal Ltd. and the Ktunaxa Nation Council (KNC) worked together to hold a multi-stakeholder workshop in July 2012. The Cumulative Effects Management Framework (CEMF) was launched during the initial workshop. Teck Coal Ltd. and KNC led this initiative until January 2015, when leadership was transitioned to the Ministry of Forests, Lands and Natural Resource Operations. A Working Group comprising 11 organizations (Appendix 3) oversees the CEMF business. Annual workshops have been held for broader stakeholder group (Workshop Group).

The purpose of CEMF is to develop a practical approach to assess historic, current and potential future conditions of selected valued components (VCs) and to provide a practical, workable framework that supports decisions related to assessment, mitigation and management of cumulative effects in the Elk Valley. The goal is to inform and support natural resource management decisions at appropriate levels.

The Elk Valley is a unique and challenging study area because 32% of the land is privately owned and there is extensive land use throughout. This presents some challenges with regard to the management and assessment of the values in the valley because legislation and guidelines vary between crown and private land management.

Bighorn sheep occupy core seasonal ranges that overlap with the coal lands in the valley (Fig. 1; Poole et al. 2016). For at least part of the year, sheep east of the Elk River and north of Michel Creek use lands currently under development by open pit coal mining. Through much of this sheep range the potential for ongoing coal development does exist. Influences on BHS from industrial development including mining and forestry occur within the valley.

The Elk Valley CEMF is being implemented in four stages, the details of which are provided below:

1. **Context**: includes establishing spatial and temporal boundaries and selecting valued components as the focus for the cumulative effects assessment. In general, the temporal coverage spans from 1950 to 2065.
2. **Retrospective Assessment**: includes assessing the historic and current condition of each VC using indicators of population status or quality and amount of required habitat. Additionally, benchmarks that reflect the hazard/risk to each indicator were set and VC conditions were assessed in relation to these.
3. **Prospective Assessment**: includes forecasting future conditions. Three alternative scenarios were created to assess how different rates of development may affect the valued components and their indicators into the future. In addition, two climate change scenarios, an increased natural disturbance scenario, and three mitigation options have been identified, and integrated with the future development scenarios to simulate potential future conditions.
4. **Management Action and Follow-up**: includes management recommendations and monitoring based on the results of the cumulative effects assessment.

   The first three stages have been completed and stage 4 is on-going.

1.2 Why Bighorn Sheep?

Bighorn sheep reflect a unique habitat (alpine grasslands) that is not well captured in any other VC. Bighorn sheep is a unique VC in the provincial and Elk Valley context but is not represented in the Provincial Cumulative Effects Framework, largely due to Bighorn sheep's relatively fragmented distribution within the province.

Bighorn sheep are an important and iconic species in BC. They have high harvest and cultural value and contribute to the visual quality of the landscape (Kuzyk et al. 2012). Bighorn sheep are important to First Nations, who have important cultural and spiritual values linked with the species, especially in the Elk Valley (Shackleton 1999, Demarchi et al. 2000).

Bighorn sheep in the Elk Valley are unique in their use of high elevation winter range (compared to low to mid elevation in most other populations) and their lack of documented respiratory disease outbreaks (pers. comm. Helen Schwantje). The native high elevation range provides distinct nutritional qualities, such as higher levels of important trace minerals (e.g. copper, selenium). Reclaimed land cannot duplicate this natural mineral profile (pers. comm. Helen Schwantje, FLNRO). Recently, high elevation alpine grassland communities have been red-listed in BC by the Conservation Data Center (CDC) in March 2018. These grassland communities include rough fescue-sulphur-buckwheat-thread-leaved sandwort (listed as S1; B.C. Conservation Data Centre 2018a) and Idaho fescue- sulphur buckwheat- thread-leaved sandwort (listed as S2; B.C. Conservation Data Centre 2018a). These grasslands types have a very limited distribution and according to CDC they only occur within the Elk Valley (B.C. Conservation Data Centre 2018 a,b). A study in 2009-2011 looking at the habitat use and movement of bighorn sheep in the Elk Valley showed that these grasslands were highly selected and were the highest ranked cover class (Poole et al. 2013; Poole et al. 2016).

1.3 Knowledge Summary

Bighorn sheep Ecology and Habitat Requirements

There are several subspecies and ecotypes of BHS in BC. The only subspecies that occurs in the East Kootenay is the Rocky Mountain bighorn sheep (Shackleton 1999, Demarchi et al. 2000). Aptly named, they live primarily in the Rocky Mountains of BC and Alberta, as well as Montana and other US jurisdictions. Within this report we use the term '*population'* to refer to a group of intermixing animals with a discrete boundary having little contact with other such groups (Caughley 1977); '*subpopulation*' to refer to groupings of sheep within a continuous distribution but with reduced interchange with individuals of adjacent subpopulations (based on distribution and known or suspected movements) (Fig. 1), and '*herd*' to identify sheep associated with particular winter ranges (Appendix 1; Poole 2013; I. Teske, FLNRO, unpubl. data).

The Elk Valley has high value BHS habitat and is home to important bighorn sheep populations which have no history of widespread disease outbreaks. Several populations of BHS occur within portions of the Elk Valley that exhibit different wintering strategies. The Elk Valley East and West populations occur within Wildlife Management Unit (WMU) 4-23, and winter on high-elevation, south and west-facing, windswept grasslands that tend to have reduced snow accumulation (Poole et al. 2016). The Mount Broadwood and Elko sheep populations occur closer to Elko in WMUs 4-02 and 4-22, spend much more of their time outside of the Elk Valley watershed, and use a more typical low to mid- (Elko) or mid to high- (Mt. Broadwood) elevation wintering strategy (Kinley 2007). Because of these differences in distribution and wintering strategies, as well as differences in how they are monitored, the BHS analysis for the Elk Valley was restricted to the Elk Valley East and West populations within WMU 4-23.

Bighorn sheep generally inhabit open to semi-open slopes in the alpine. Sheep use both man-made and natural grasslands that offer abundant forage, and typically use habitats restricted to within 400–500 m of steep escape terrain (Demarchi et al. 2000, Poole et al. 2016). Within these slopes, bighorns typically occupy four (sometimes overlapping) main ranges that vary with the seasons: spring (lambing), summer, fall (rutting), and winter, which is the most limiting to the population (Poole et al. 2016).

Spring lambing ranges are typically used from early May until June or into the beginning of July (Demarchi et al. 2000). Occasionally, lambing takes place on the winter range. These areas generally are south-facing scree slopes or rugged terrain with some vegetation that offers both predator avoidance and high quality forage. Summer range often consists of open alpine, krummholz areas or alpine and subalpine forests adjacent to grasslands. The fall rutting ranges of BHS are typically similar to the winter and lambing areas. Transitional ranges used prior to and after winter are likely important for population health. Within the Elk Valley, BHS make high use of reclaimed coal mining habitats, primarily during non-winter months, with greatest use in late summer and fall (Poole et al. 2016).

Although the adequacy of summer nutrition is seen as vital to reproductive performance of ungulates, as well as growth and development of their offspring (Cook et al. 2013), winter range is arguably the most important range of BHS in the Elk Valley. Winter is typically limiting because sheep are not adapted to forage and travel in deep snow (Dailey and Hobbs 1989). Sheep from the Elk Valley East population studied during 2009-11 generally selected winter habitats composed of native high-elevation grasslands on warmer aspects close to escape terrain (Poole et al. 2016). There are several prominent ridges in the Elk Valley that are known to be important wintering habitat for BHS.

CONSERVATION STATUS AND THREATS

Provincially, bighorn sheep are blue-listed, which means they are of Special Concern and are particularly sensitive or vulnerable to human activities or natural events (www.env.gov.bc.ca/cdc). The species has been assigned a S3? conservation status in April 2015, which notes "a stable population overall, but there have been local, substantial declines in the past. BHS have lost and continue to lose good quality habitat (especially winter range) to various types of land conversion and to forest encroachment, and the species is vulnerable to stress and stress-related diseases" (B.C. Conservation Data Centre 2015). Domestic sheep and goats on public or private lands can transmit a number of pathogens to bighorn sheep. The most significant bacterium, *Mycoplasma ovipneumoniae,* can be carried asymptomatically by domestic sheep but when transmitted, will initiate polymicrobial pneumonia epizootics in bighorn herds with up to 95% mortality (Davidson 1994, Schommer and Woolever 2008). The risk of contact with domestic livestock is reduced for wild sheep that occupy high elevation habitat, such as the Elk Valley herds. Other health issues such as bacterial pneumonia, commonly seen in bighorn sheep populations outside the Elk Valley, have not impacted Elk Valley populations, which is likely due to their isolation from domestic sheep and goats (pers. comm. Helen Schwantje).

There have been a number of causes of sheep mortality in the Elk Valley. The largest cause of anthropogenic sheep mortality in the Elk Valley is hunter harvest directed at mature rams. Sheep are also frequently killed by collisions with vehicles, but predation, lightning strikes and two incidents of nitrate toxicity on active mine sites have been documented (I. Teske, FLNRO, unpubl. data). Habitat loss due to mining often permanently alters or destroys sheep habitat, although coal mining operations can create (primarily non-winter) sheep habitat during reclamation (Poole et al. 2016). Forest encroachment can also affect sheep habitat; avoidance of conifers by BHS and use of high-visibility habitats suggest that forest encroachment would be detrimental to sheep (Wakelyn 1987). Predation is another cause of sheep mortality (Festa-Bianchet et al. 2006) and includes bears, cougars, wolves and coyotes in the Elk Valley. Non-native invasive plant species are also encroaching on native grasslands, which reduce forage quality and quantity for sheep (Demarchi 2004, Stent et al. 2013). Stress from disturbance can also be a critical factor for the sheep (Geist 1979, Schommer and Woolever 2008). Impacts from many industrial and recreational activities, such as helicopter and fixed-wing flights, backcountry skiing, all-terrain vehicles, snowmobiling, mountain biking and hiking can create stressful conditions for sheep, which can affect general immune function as well as reduce growth and overall health and fitness (Demarchi 2004; Canfield et.al. 1999).

1.4 Policy and Legal Context

Bighorn sheep are managed at the population level under the BC *Wildlife Act*, which addresses hunting regulations and licensing. Another key piece of legislation is the *Forest and Range Practices Act* (FRPA). This act establishes Ungulate Winter Ranges, Wildlife Habitat Areas, and General Wildlife Measures, as well as objectives for those areas.

Management objectives are set by Population Management Unit (PMU) and take into account the objectives described in the Big Game Harvest Management Procedure. In the Procedure, the primary management objective for all big game populations is to "maintain post-hunt numbers for each PMU at or near current levels". For bovids like bighorn sheep, the secondary population objective is to "maintain desired age structures in the harvest, and/or harvest sex ratios". It is also important to note that within the Procedure, these objectives "must consider First Nations ability to fulfil their food, social or ceremonial needs".

The Bighorn Sheep Harvest Management Procedure (2014) states that the annual allowable harvest (AAH) for rams for each population unit should not exceed 3% of the total population estimate or 8–10% of the estimated number of rams. No policy is provided on the thresholds for ewe mortality, but studies indicate that in the absence of significant predation 8–10% ewe harvest/removal is sustainable (Jorgenson et al. 1993; K. Smith, pers. comm., 5 July 2016 BHS workshop).

The Kootenay-Boundary Land Use Plan Implementation Strategy (KBLUP-IS; Kootenay Inter-Agency Management Committee 1997) provides broad ungulate winter range (UWR) management guidelines for ungulates, including sheep, which include ensuring that viable populations are maintained. Forest cover guidelines are presented for forests subject to harvest within 300 m of grassland habitat, which recommend 70% basal area retention of older, high crown closure stands. Ungulate Winter Range Order U-4-006 (2005) for the Cranbrook Timber Supply Area (TSA) provides General Wildlife Measures for forest practices carried out within the boundaries of mapped UWR polygons. These include minimum retention standards for open range and open forest, neither of which has overly direct bearing on BHS winter range in the Elk

Valley since open habitats (grasslands) are preferred and forest encroachment is a management concern. Within the identified BHS winter ranges of the Elk Valley East (but not West) populations, Order U-4-006 maps some areas of Managed Forest Wet adjacent to and on the edges of some of the identified winter range polygons. However, this habitat type targets retention of snow interception cover for moose, and therefore has little bearing on BHS. Therefore the UWR plan and order have limited effect on BHS in the Elk Valley.

2.0 Assessment Methods

2.1 Assessment Units and Reporting Units

Because of differences in distribution and wintering strategies of the sheep, as well as differences in how they are monitored, the BHS analysis for the Elk Valley was restricted to the Elk Valley East and West populations within WMU 4-23 (see Bighorn Ecology and Habitat Requirements, above). Eight BHS subpopulations (5 subpopulations for the Elk Valley East and 3 subpopulations for the Elk Valley West) were identified based on distribution and known or suspected movements (Fig. 1; Poole 2013; I. Teske, FLNRO, unpubl. data). Movement and genetic interchange among subpopulations undoubtedly occurs but is considerably less among subpopulations than within subpopulations. Reporting for the winter range and annual range indicators was summarized by the eight subpopulations because individual subpopulations overlap the smaller landscape unit and drainage scales. Reporting for human-caused mortality was summarized by subpopulations where possible but collapsed to the Elk Valley East and West populations or WMU 4-23 (both populations) depending on available data. Reporting for population trend was summed by winter range and Elk Valley East and West populations. An overview of populations, subpopulations and herds of BHS in the Elk Valley is given in Appendix 1.

2.2 Data Sources and datasets

Predictive Ecosystem Mapping (PEM, from 2015) was used for land cover, with alpine habitats updated in late 2015. Historic habitats were based on the current PEM adjusted in the disturbed areas to reflect what was there in the 1950's.

Current winter ranges were identified and mapped by Peter Holmes, Irene Teske and Peter Davidson based on survey and collar data (updated 2015). Boundaries of winter ranges encompass the outer extent of known or suspected distribution, generally covering areas used between early to mid-December to the end of April (Poole et al. 2016). Historic winter ranges (1950) from within current mine footprints were developed based on elevation, topography and open habitats present historically using a 1950s PEM, supplemented by some historic winter sheep locations pre-mining.

To assess winter range condition, a full ecological range condition assessment of 15 ranges and sub-ranges in the Elk Valley East population was conducted during 2009-10 (Smyth 2014), and the Uplands Function Checklist (UFC) Assessment Method (Fraser 2007) was applied. This winter range assessment was used to develop a 'winter range qualifier' that discounts winter range ranking based on the most recent assessment (see Tier I Indicators; winter range habitat, below).

Current annual ranges were mapped using escape terrain (open slopes ≥37°) derived from 1-m Lidar (within Teck Coal footprints) and 25-m BC Digital Elevation Model (DEM), with a 10,000 m^2 filter to remove isolated pixels (meaning a single group of escape terrain had to be 10,000 m^2 in size to be retained). Historic annual range analysis used a Digital Surface Projection Model supplied by Teck Coal, created to represent DEM in the 1950s and used to define the slope and elevation criteria.

Data for human-caused mortality were obtained from:

1. Highway/road: annual Wildlife Accident Reporting System (WARS) and FLNRO/Ministry of Transportation data on known sheep highway (road) kills that are not mine-related;
2. Hunter: annual Compulsory Inspection (CI) data (legal and illegal ram kills) for WMU 4-23 broken down by Elk Valley East and West populations;
3. Mine-related: annual mine and FLNRO data on mine-related mortalities, including road mortalities within mine properties.

FLNRORD, with financial assistance from HCTF, conducts aerial surveys (total coverage with sightability correction modelled) generally every 3-4 years for the Elk Valley East population, and slightly less frequently for the Elk Valley West population (I. Teske, FLNRORD, unpubl. data). Teck Coal annually conducts total coverage aerial surveys for all wildlife species within mine study areas (also total coverage with sightability correction modelled; K. Podrasky, Teck Coal, unpubl. data). Sightability for FLNRORD surveys was set at 0.80, until 2010 when model-derived estimates were used (2016 survey data not yet modelled; 0.80 sightability used in the interim). Studies with collared sheep in 2010 and 2011 detected 0.77-0.82 sightability (Poole 2013). Both FLNRORD and Teck Coal surveys now collect parameters needed to model sightability correction. Lamb ratios were obtained from Stent et al. (2013) with recent years obtained from FLNRORD and Teck survey data.

2.3 Indicators and Benchmarks

Values are not always measurable in their own right, and data that do measure a value directly may not always be readily available to guide decisions. Measurable indicators must be identified to assess or evaluate the status of, or threats to, the VC. For the purpose of this assessment, Tier I habitat indicators (those that could easily be represented spatially) were assessed in a GIS environment. Habitat indicators are only a proxy of population status and aren't necessarily an absolute indication of population condition. Population health indicators are included in Tier II indicators.

The following section describes the indicators used for the cumulative effects assessment of BHS and the associated benchmarks/thresholds. Each of these indicators will be assessed and summarized by subpopulation. The indicators are described with the following structure:

- Scientific Context – description of the scientific basis for the selection of the indicator;
- Management Context – what type of management decisions will be supported with this indicator;
- Indicator Overview– description of the indicator;
- Benchmarks – benchmarks identified to report the level of hazard/risk. Here we define: **Risk** = **Likelihood** of a risk event (aka **Hazard**) x **Consequence** for goals, objectives or VCs.
  Since we were not able to calculate the consequence portion of the risk equation for lack of supporting data, what we produced is a hazard map, not a risk map.
- Validation – what approaches and data have been or could be used to support or improve the indicator or benchmark levels; and
- Caveats and Data Limitations – gaps or limitations in the data.

Assessment of hazard for BHS habitat should start prior to or as close to the initiation as possible of major industrial development in the Elk Valley. Resource extraction, primarily coal mining, has altered and removed BHS habitat, and thus we assessed hazard based on 1950 PEM and DEM to properly track habitat changes and hazards to BHS. **It is important to note that where hazard is based on habitat loss, it refers to actual loss (i.e. removal due to mining) or alteration (i.e. habitat degradation, usually due to overgrazing by ungulates).**

A. Habitat Indicators

1A) WINTER RANGE HABITAT

Scientific Context

Bighorn sheep winter on high elevation grasslands and associated open habitats. These grasslands are highly selected for in winter and are critical habitat for population persistence. Winter range is rare on the landscape (~4% of merged sheep ranges based on the 2009-11 collaring study of the Elk Valley East population; Poole et al. 2016) and likely limits the demographic structure of populations. While coal mining can create some kinds of BHS range through reclamation, it is less able to create quality winter range because of the specific topographic qualities that produce reduced snow cover.

Bighorn sheep winter range habitat mapping is based on PEM mapping – site series ***capability***. Winter ranges that are overgrazed or otherwise degraded (e.g., from soil creep or invasive plants) do not produce the same amount of forage as healthy ranges (Smyth 2014), and thus have lower carrying capacity. Therefore, tracking of the ***suitability*** of winter range is an important component of the ability of winter range to support BHS, and the ranking of habitats within winter ranges should be discounted (stepped-down) when not in good health.

Management Context

To conduct a holistic and accurate assessment of winter range habitat, it is important to track both quantity and quality of BHS winter range. Winter range habitat is essential for population persistence, and range condition (quality) affects the ability of the habitat to provide sufficient forage production to sustain sheep during winter. Thus, management of winter range habitat supports objectives related to both habitat quality and quantity and those related to BHS populations within the assessment area.

Indicator Overview

- Amount of disturbed or impacted (removed or otherwise functionally altered) winter range habitat in total winter range (ha or km^2), by subpopulation.

PEM site series habitat classes (see Appendix 2 for descriptions) within mapped winter range (Holmes and Teske, FLNRO, 2015) were ranked from 4 to 1 based on selection and use by collared sheep in the 2009-11 telemetry study (Poole et al. 2016). Note that habitat class ranking was restricted to habitats within identified winter range polygons. Rankings ranged from Rank 4

– highly selected or highly used – through to Rank 1 – low selection or limited use, with Rank 0 being nil sheep habitat within the delineated ranges. PEM site series habitat classes by rank:

- Rank 4: ESSF Ag, ESSF Atmf, ESSF Gg, IMA_Ag, IMA Atmf
- Rank 3: ESSF AtAm, IMA AtAm, ESSF GbGg, ESSF Rt, IMA Rt, ESSF Mi, ESSF Mr, MS Mi, MS Mr, ESSF Yz
- Rank 2: ESSF Ro, IMA Ro
- Rank 1: ESSF Gb, ESSF Rz, MS Rz
- Rank 0: all other habitats not shown above.

Sheep use of Greenhills Operations reclaimed mine habitats prior to and during the sheep collaring study in 2009-11 numbered up to 30 sheep with extensive collar locations (Poole 2013, Poole et al. 2016). The highest number of sheep using the entire Greenhills area (mine site and natural habitats) was 98 in 2010. After 2011, sheep use of the Greenhills area during winter declined (FLNRO unpubl. data; Teck Coal surveys), coincidental with mining expansion. Therefore, within the Greenhills Operations footprint, Mi (mine) and Mr (mine reclaimed) site series were discounted from Rank 3 to Rank 2 habitats[1].

Furthermore, to account for both capability and suitability (range quality), winter range habitat ecological range condition assessments provide an indication of hazard status and health (condition) of the range. The ranking of the PEM site series classes was discounted (decreased in ranking) on ranges that are not in proper functioning condition (a measure of habitat quality), as assessed by Smyth (2014). The 'winter range qualifier' dictates that the ranking of PEM site series classes within at-risk winter ranges was decreased by 1 unit for ranges assessed 'slightly at risk', and by 2 units for ranges assessed 'slightly to moderately at risk' (Appendix 4). Here 'risk' is defined as ranges that are not in proper functioning condition, for example, organic material is not present, the plant community does not show good vigour, erosion is evident, and/or the

[1] Winter range mapping for the Teck Coal area was initially created in 2010/11 using GPS telemetry and inventory data. During that time existing reclamation and native winter range provided Rank 3 winter habitat. However, the landscape at GHO has changed substantially since the initial winter range mapping with the loss of native and reclaimed habitats through mine development. Therefore, the ranking was reduced to Rank 2. With continued development, a Rank 2 will likely be reduced further to Rank 1 or 0.

mineral cycle is not conducive to biological breakdown (Fraser 2007). This results in a final winter range product that gives an indication of how suitable the winter range is to support sheep in terms of both quantity and quality of habitat.

Benchmarks

No winter range hazard ranking for sheep could be found in the literature. Benchmarks for hazard rankings were created for winter range habitat using a consensus of expert opinion from the 5 July 2016 BHS workshop and informed by the concept of tiered management benchmarks and dose-response curves for the boreal caribou critical habitat model (Environment Canada 2011; Table 1; Fig. 2). This ranking system assumes a non-linear relationship between the amount (and quality) of habitat and sheep carrying capacity. Dose response curves and hazard benchmarks were adapted from the Alberta Fish Sustainability Index to characterize hazard or risk to populations and hypothesize functional relationships (MacPherson et al. 2014).

$$\text{Hazard \% difference by sub-population} = \frac{\textit{current winter range} - \textit{historical}\ (1950)\ \textit{winter range}}{\textit{historical}\ (1950)\ \textit{winter range}} \times 100$$

Table 1. Hazard benchmarks for bighorn sheep winter range (WR) in the Elk Valley. Percentages indicate amount of disturbed winter range habitat applied by subpopulation since 1950. Rankings range from Rank 4 – highly selected or highly used – to Rank 1 – low selection or limited use.

Hazard Benchmark	All WR	Rank 3-4	Rank 1-2
Very Low (1)	≤5%	≤2.5%	≤7.5%
Low (2)	5.1-15%	2.6-7.5%	7.6-22.5%
Moderate (3)	15.1-25%	7.6-12.5%	22.6-37.5%
High (4)	25.1-35%	12.6-17.5%	37.6-52.5%
Very High (5)	>35%	>17.5%	>52.5%

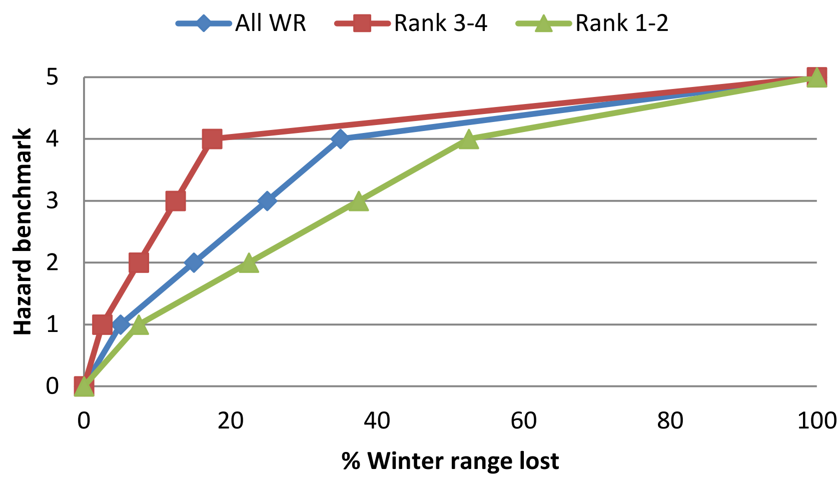


Figure 2. Proposed benchmarks (dose-response curves) for proportion of winter range lost by subpopulation in the Elk Valley. Benchmarks correspond to 0-1 very low hazard; 1-2 low hazard; 2-3 moderate hazard; 3-4 high hazard; 4-5 very high hazard; and 5 functionally extirpated (Table 1). Rankings range from Rank 4 – highly selected or highly used – to Rank 1 – low selection or limited use.

Validation

Validation of the BHS winter range habitat distribution and mapping was largely based on 2–3 decades of survey results on sheep distribution from FLNRO and Teck mine surveys, and research conducted in 2009-11 (Poole 2013, Poole et al. 2016). The ranked habitat produced a reasonable fit to the known distribution and abundance of sheep on the landscape. Field validation is required to confirm the hazard benchmarks, acknowledging that this will be challenging to accomplish.

Caveats and Data Limitations

It is important to note that dose response curves are ***hypothesized*** relationships between the proportion of winter range loss and the effect on sheep abundance. This means the relationships need to be tested and are subject to change based on results of field verification. No empirical data or reports are available for hazard ranking for bighorn sheep, for example loss of *X*% of the winter range for a population will result in a *Y*% decrease in carrying capacity and population size. In addition, specific government policy objectives are not available to provide direction. Intuitively, loss of a sufficient amount of winter range will adversely affect a population, but the shape of the response curve of the relationship is unknown. The dose response curves presented here likely result in a conservative approach to hazard assessment for BHS, compared with a sigmoidal-shaped curve (Environment Canada 2011).

1B) WINTER RANGE HABITAT QUALITY

Indicator Overview

Winter range qualifiers were also used on their own to provide an overall assessment of range condition among winter ranges for Elk Valley East. This will enable hazard assessment, benchmarks and mitigation of winter ranges independent of physical loss of winter range.

Benchmarks

Proposed benchmarks for winter range habitat qualifier by subpopulation are:

- Very low hazard (1): if <5% of winter ranges are at risk;
- Low hazard (2): if 5-15% of winter ranges are at risk;
- Moderate hazard (3): if 15-25% of winter ranges are at risk;
- High hazard (4): if 25-35% of winter ranges are at risk;
- Very high hazard (5): if >35% of winter ranges are at risk.

Validation

Direct validation of the BHS winter range habitat qualifier and discounted rankings of habitat for at risk ranges was not possible. However, field measurements during 2009-10 showed reduced forage and plant biomass production, increased presence of invasive plants, reduced ground cover, indications of multiple species use and increased evidence of soil erosion on ‘at risk sites’ when compared with ranges in proper functioning condition (Smyth 2014). Further field validation should be conducted during monitoring.

Caveats and Data Limitations

No empirical data or reports are available to validate discounting of habitat quality (and ultimately winter range carrying capacity) for bighorn sheep, but intuitively it makes sense given demonstrated reductions in forage production (Smyth 2014).

2) ANNUAL RANGE HABITAT

Scientific Context

Bighorn sheep annual range in the Elk Valley encompasses most open sub-alpine areas above about 1,600 m elevation, including many of the active mine and reclaimed areas (Poole et al. 2016). Although annual range is extensive on the landscape, large reductions in annual range availability could ultimately affect population size and health. As noted above, summer nutrition is seen as vital to reproductive performance of ungulates (Cook et al. 2013). Here we define annual range as the areas used by sheep at any time of year. Most winter ranges, which make up a small proportion of annual range, are also occupied during non-winter months.

Management Context

Annual range habitat is necessary for population persistence, and thus monitoring of annual range habitat supports decisions related to both habitat and population conservation.

Indicator Overview

The indicator is the amount of disturbed annual range habitat in total annual range (ha or km^2) by subpopulation.

Annual habitat was ranked based on the known relationship of sheep use of open habitat at distance from escape terrain (defined as open slopes ≥37°), with limited use of habitat beyond 300 m from escape terrain based on the 2009-11 collar dataset (Poole et al. 2016) and confirmed from Cadomin mine data (B. MacCallum, pers. comm., 5 July 2016 BHS workshop). This does not assume no use of habitat beyond 300 m from escape terrain but provides a reasonable boundary for which to model area of annual habitat over time. Open habitat was defined as the following site series (Appendix 2):

- ESSF Af, Ag, Ah, Am, AtAm, At, Atmf, Ro, Ro102, Rt, Sc, SkGb, Xh, Mi, Mr, Rz, Gg, Gb, GgGb, Yz;

- ESSF dkp – Vh, Vs;
- IMA Af, Ag, Ah, Am, AtAm, At, Atmf, Ro, Ro102, Rt, Sc, SkGb, Xh;
- MS Mi, Mr, Rz

Habitats were ranked based on distance to escape terrain:

- Rank 4: <=30 m from escape terrain;
- Rank 3: 30-100 m from escape terrain;
- Rank 2: 100-200 m from escape terrain;
- Rank 1: 200-300 m from escape terrain.

Elk Valley West annual range was discounted by 1 rank overall (Rank 1 retained as 1) to reflect lower overall approximate sheep numbers (~100-200) as compared with Elk Valley East estimates (~400-800).

Benchmarks

Although it is unlikely that BHS habitat loss at the annual range scale would greatly impact the amount (and quality) of habitat and sheep carrying capacity, benchmarks for hazard rankings were created for annual range habitat based on tiered management benchmarks and dose-response curves for winter range, as adapted from the boreal caribou critical habitat model (Environment Canada 2011; Table 2; Fig. 3). This ranking system assumes a non-linear relationship between the amount (and quality) of habitat and sheep carrying capacity. Dose response curves and hazard benchmarks (1-3) were adapted from the Alberta Fish Sustainability Index to characterize hazard or risk to populations and hypothesize functional relationships (MacPherson et al. 2014). Annual range is not considered to be limiting in the Elk Valley; therefore, further analysis of annual range was not completed. These benchmarks can be used as reference for future work.

$$\text{Hazard \% difference by sub-population} = \frac{current\ annual\ range - historical\ (1950)\ annual\ range}{historical\ (1950)\ annual\ range} \times 100$$

Table 2. Hazard benchmarks for bighorn sheep annual range (AR) in the Elk Valley. Percentages indicate amount of disturbed annual range habitat. Rankings range from Rank 4 – highly selected or highly used – to Rank 1 – low selection or limited use.

Hazard benchmark	All AR	Rank 3-4	Rank 1-2
Low (1)	<15%	<10%	<20%
Moderate (2)	15.1-30%	10.1-20%	20.1-40%
High (3)	>30%	>20%	>40%

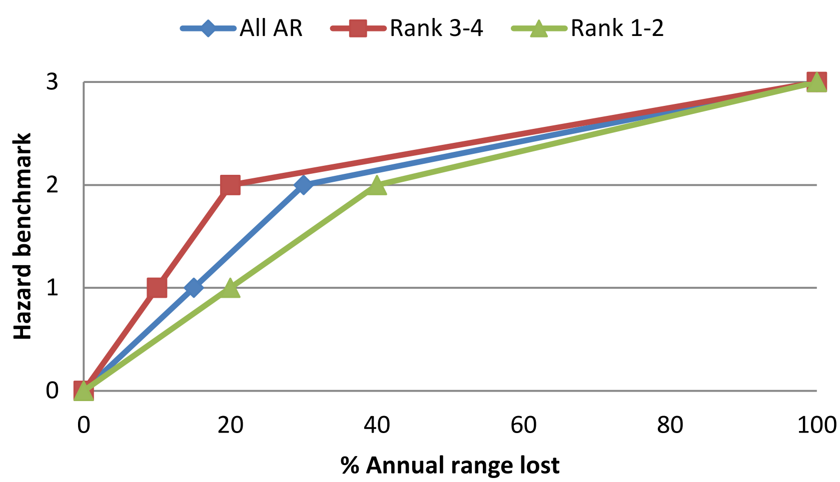


Figure 3. Proposed benchmarks (dose-response curves) for proportion of annual range lost by subpopulation in the Elk Valley. Benchmarks correspond to 0-1 low hazard; 1-2 moderate hazard; 2-3 high hazard; and 3 functionally extirpated (Table 2). Rankings range from Rank 4 – highly selected or highly used – to Rank 1 – low selection or limited use.

Validation

Validation of the BHS annual range habitat distribution and mapping was largely based on the 2009-11 collar dataset for the Elk Valley East population (Poole et al. 2016) and confirmed from Cadomin mine data (B. MacCallum, pers. comm., 5 July 2016 BHS workshop). Annual use of habitat by collared sheep reflected the mapped and ranked habitat derived from distance from escape terrain.

Caveats and Data Limitations

No empirical data or reports are available for hazard ranking for bighorn sheep (ie. loss of *X*% of annual range for a population will result in a *Y*% decrease in carrying capacity and population size). In addition, government policy objectives are not available to provide direction. Intuitively, loss of a significant portion of annual range would be required to affect a population, but this level of habitat loss and the shape of the relationship are unknown. The dose response curves presented here likely result in a conservative approach to hazard assessment for BHS, compared with a sigmoidal-shaped curve (Environment Canada 2011). Differences in topographic models between historic and current periods resulted in differences in the results, mainly attributed to mapping methodology and not actual change in the environment. This suggests there are resolution limitations that prevent quantification of real changes in annual range since 1950 (see Section 3.1).

B. TIER II INDICATORS

Most of the Tier II (population) indicators were not assessed in a GIS environment, but analysed from available field data.

3) HUMAN-CAUSED MORTALITY

Scientific Context

Minimum viable population modelling suggests that populations of native bighorn sheep below 50 are unable to resist rapid extinction (Berger 1990; although Demarchi (2004) used a minimum viable population of 125). Excessive human-caused mortality can impact sheep populations. Human-caused mortality is often additive to natural mortality and can cause a decline or slow an increase in a population. Sheep-vehicle collisions can cause high mortality in some populations, affecting all segments of the population. Hunter harvest, the largest known human-caused mortality, targets mature rams in a population. Sheep mortality at some operating coal mines in the Elk Valley occurs including vehicle collision, consumption of hazardous products, lightning strikes and predation.

Management Context

Some forms of human-caused mortality can be managed, for example harvest effort and rate on either the ram or ewe portion of a population can be changed. Management of sheep-vehicle collisions is possible through highway design and signage as well as potential over/under passes. Best management practices at mines can reduce the incidence of sheep mortalities on mine properties.

Indicator Overview

Annual trend in human-caused mortality was summed from 3 sources listed below, by subpopulation.

1. Trend in annual highway/road mortality;
2. Trend in annual hunter mortality;
3. Trend in annual mine-related mortality.

Thresholds/Benchmarks

The Bighorn Sheep Harvest Management Procedure (2014) states that the annual allowable harvest (AAH) for rams for each population unit should not exceed 3% of the total population estimate or 8–10% of the estimated number of rams. No policy is provided on the thresholds for ewe mortality, but studies indicate that in the absence of significant predation 8–10% ewe harvest/removal is sustainable. The Procedure states that "lamb and/or ewe harvest seasons should be considered [under Limited Entry Hunt seasons] where it is deemed necessary to maintain population health,…".

Validation

Validation of sustainable harvest rates for rams is based on several decades of harvest management and a full-curl rule that limits the number of rams available for harvest each year. The ewe harvest benchmark is based on Jorgenson et al. 1993, with modification from K. Smith (pers. comm., 5 July 2016 BHS workshop).

Caveats and Data Limitations

Highway wildlife mortality is generally under-reported, but greater awareness and monthly reporting by Highways staff has likely led to high reporting rates in the past 10-15 years. Most highway mortalities for the Elk Valley East populations occur along Highway 3 between

Sparwood and Crowsnest Pass. Rail-related mortalities for sheep are extremely rare, with none recorded within WMU 4-23 in the past 25 years.

4) Population Trend

Scientific Context

Many factors affect sheep population size and trend. Ewe pregnancy rates are generally high and fluctuate little, but lamb survival can be affected by a host of factors, including predation, disease, forage quantity and quality, and weather (Demarchi et al. 2000). Predation can influence both lamb and adult mortality, especially if even a handful of individual predators specialize on killing sheep (Festa-Bianchet et al. 2006). Elk Valley sheep winter at high elevation on slopes that generally do not accumulate significant depths of snow, but if snow becomes too deep or spring melts are delayed, late winter mortality from weather extremes and starvation increases (Poole et al. 2016). These winter weather-related conditions often affect rams more than ewes because rams generally enter winter in poorer condition after the rut (Demarchi et al. 2000).

Management Context

Management of sheep populations is often predicated on overall population size and trend. Winter aerial surveys provide data to estimate numbers and lamb and ram ratios. Ram harvests can be regulated to some degree through changes in hunting season type and length and minimum horn requirements (as stated in the Bighorn Sheep Harvest Management Procedure (2014)), but there are few mechanisms in place to manage ewe numbers or to enhance lamb survival. Harvesting of ewes is not embraced by most BC hunters but has occurred to reduce herd density (T. Szkorupa, FLNRO, pers. comm.) and removal for translocation purposes can be approved if appropriate for the same purpose (Demarchi et al. 2000). Lamb survival is largely driven by weather, health and predation (Portier et al. 1998). Habitat and predator management may be feasible in some situations (Demarchi 2002).

Indicator Overview

The best overall measure of current population health is the trend in population growth, which is based on estimated numbers by population (Elk Valley East and West). Data are obtained from winter surveys conducted by FLNRO (I. Teske, FLNRO, unpubl. data) and Teck Coal (K.

Podrasky, Teck Coal, unpubl. data).

Benchmarks

Maximum estimated population size may not be sustainable over the long term and may occur as a result of a period of optimal weather, habitat, and predation conditions. Following the pattern used in Alberta (K. Smith, pers. comm., 5 July 2016 BHS workshop), the benchmark objective was set to maintain populations within 20% of the median estimate as determined from the last 5 aerial surveys. Based on late winter surveys the 5-survey median for the Elk Valley East is 580 sheep, and for the Elk Valley West is 130 sheep. The current (2016; assuming 0.80 sightability) estimate for the Elk Valley East is 581 sheep, and for the Elk Valley West is 94 sheep.

Lamb ratios, commonly used as indicators of BHS population vigour (Demarchi et al. 2000) can also be obtained from aerial surveys. Stable populations generally require a minimum of 20% lambs and 35 lambs/100 ewes (>1 yr) in late winter surveys, based on a mean of multiple survey counts (K. Smith, pers. comm., 5 Jul 2016 BHS workshop). Demarchi et al. (2000) suggest population stability can be obtained with an over-winter lamb:ewe ratio of approximately 30:100.

Validation

Aerial surveys during winter should reliably track population trend over time. Although full surveys conducted by FLNRO occur less often, sheep abundance within Teck Coal survey areas can be tracked more readily and can provide strong indications of trends. Sightability of sheep during surveys and the resultant abundance estimate were generally validated using collared sheep within the Elk Valley East population during 2010 and 2011 (Poole 2013).

Caveats and Data Limitations

Aerial surveys can reliably estimate sheep numbers within alpine study areas, but estimates may be negatively biased if a significant portion of the sheep in an area are outside of the census zone (actual area covered) during the survey. Lamb ratios may be inaccurate if sex and age classification are not conducted rigorously.

C. WEIGHTING INDICATORS

There are only two habitat-based Tier I indicators proposed for BHS (winter range habitat with range condition qualifiers including an additional assessment of range condition alone, and annual range), and two broad Tier II indicators (human-caused mortality and population trend). As noted above, winter range is the most important range for BHS in the Elk Valley. Annual range is extensive on the landscape and is likely far less limiting than winter range; however, large reductions in annual range availability, especially more important shoulder season habitats, could ultimately affect population size and health. Hazard maps were not produced for annual range habitat loss, nor a total hazard map weighted between winter and annual range, since annual range is far more prevalent on the landscape and loss of winter range would more rapidly trigger management responses. Population trend and demographics (as indexed by lamb ratios) likely reflects habitat quality to some extent but can be considered complementary to habitat supply. In general, a systematic weighting of indicators was not completed due to lack of adequate data to support reasonable calculation.

2.3 Retrospective Assessment

The purpose of the retrospective assessment was to map the current and historic conditions of bighorn sheep habitat. The primary questions addressed in the retrospective assessment were:

- What did conditions look like in 1950?
- What do conditions look like now?
- What have been the patterns of change?
- What have been the key stressors or causes of change?

The completion of the retrospective assessment provided the following information for use in the Prospective Assessment:

- Current status relative to benchmarks for the condition of bighorn sheep in the Elk Valley.
- Trends observed from past data for the condition of bighorn sheep in the Elk Valley.

2.4 Prospective assessment

A prospective assessment was completed to assess how valued components may respond to the cumulative effects of future projects and actions in the regional environment (Noble 2014). The intent of the prospective assessment was not prediction, which is unattainable due to uncertainty and contingency (Peterson et al. 2003). Instead, a scenario analysis was completed to compare the consequences of multiple scenarios that differed with respect to the rate, pattern, and type of development and natural disturbance. The future condition analysis provides a mechanism to contrast the benefits and liabilities of land-use options such as management practices and development rates, and to assess the influence of uncertainties such as natural disturbance trajectories in the face of future climate conditions (Thompson et al. 2012, Duinker and Greig 2007).

To provide a holistic understanding of cumulative effects, a scenario analysis must assess the long-term consequences of multiple land uses and ecological processes to a range of Valued Components, at spatial scales that are relevant to decision making. Projecting the cumulative effects of multiple drivers over large spatial and temporal scales is aided by computer modelling. In addition to the computational advantages of computers, modelling provides a formalized process for integrating the range of information that is required for prospective assessment of cumulative effects. Further, involvement of planning participants in the modelling process can foster a common understanding of cumulative effects, thereby informing objective decision making.

The scenario analysis was completed using ALCES Online, a computer model designed for comprehensive assessment of the cumulative effects of multiple land uses and natural disturbances to ecosystems (Carlson et al. 2014). The model's ability to simulate landscape dynamics at a range of spatial extents (e.g., local, regional, provincial) and across long time frames (e.g., decades) allows scenarios to be assessed at scales that are relevant to management and policy development. A key motivation behind the development of ALCES Online was to improve the accessibility of scenario analysis to stakeholders and planners, which is achieved through an intuitive web-delivered interface. ALCES Online has been applied to inform land-use planning in multiple jurisdictions (British Columbia, Alberta, Northwest Territories, Saskatchewan, Manitoba, Ontario, western Australia, and India) and planning contexts. Examples include regional land-use planning (e.g., Carlson and Chetkiewicz 2013, Carlson et al. 2014, Carlson and Browne 2015), watershed-based planning (e.g., Donahue and MacDonald, 2015, MacDonald et al. 2015, MacDonald et al. 2017), community-based land-use planning by First Nations, and urban planning (e.g., Carlson et al. 2014).

ALCES Online operates by exposing a cell-based representation of today's landscape to user-defined scenarios that differ with respect to the rate and spatial pattern of future development and natural disturbance. The simulation engine can incorporate numerous drivers such as forestry, mining, settlements, gas exploration, agriculture, transportation networks, fire, pests, climate change, and reclamation. Scenarios are defined through a flexible set of inputs that control the rate, intensity, spatial pattern, and consequence of each driver. The simulation engine's allocation methods were applied to represent diverse spatial patterns such as outward (e.g., settlements) or dendritic (e.g., road network) growth, and disturbance events that follow user-defined size-class distributions (e.g., fire) and distribution across management units (e.g., forest harvest). As well, stochasticity was incorporated to reflect the uncertainty of future events. The flexible simulation engine and relative ease at which scenarios can be defined made it possible to explore the outcomes of numerous scenarios to develop an understanding of the range of land-use options and uncertainties that exist. Simulation outcomes in terms of changes in the abundance, location, and age of natural and anthropogenic land cover types were applied to create maps of future landscape composition and indicators of interest. Indicator relationships were implemented using a calculator that allows for simple to complex indicator relationships as represented by mathematical equations, logic statements, dose-response curves, and spatial rules (e.g., buffers or patch analyses).

In the case of bighorn sheep, equations were developed to assess the relative change over time compared to 1950, where hazard is calculated as a function of winter range habitat loss. Hazard maps were not produced for annual range habitat loss or a total hazard map weighted between winter and annual range, since annual range is far more prevalent on the landscape and loss of winter range would more rapidly trigger management responses, and since the historic topographic data did not align well with current data. Dose response curves for winter range habitat loss (Fig. 2) were implemented, allowing change over time to determine hazard conditions.

Within the prospective assessment, the following four alternative future scenarios were defined:

1) <u>Reference Scenario</u>: This scenario represents a 'business as usual' progression in development. Current rates of change in indicators were used to model future conditions.

2) <u>Minimum Scenario</u>: This scenario is meant to present a case where the intensity of human activities in the Elk Valley declines. Instead of taking the reference case and adding on to

it, this scenario takes the reference case and either subtracts from it, or substitutes activities which are assumed to be associated with fewer environmental impacts.

3) Maximum Scenario: This scenario is meant to be an 'upper bound' scenario in order to provide decision-makers with an understanding of cumulative effects from the combination of all currently proposed or projected human activities in the Elk Valley.

4) Higher Natural Disturbance Scenario: This scenario is meant to be an alternative "upper bound" scenario for the effects of human activities in combination with high rates of natural disturbance on the landscape. It is meant to provide decision-makers with an understanding of the combined cumulative effects of human activity and maximum development with increased rates of fire and pest outbreak due to climate change.

3.0 RESULTS

3.1 RETROSPECTIVE ASSESSMENT – HISTORIC & CURRENT CONDITIONS

1A) WINTER RANGE

The current area of ranked winter range habitat was summarized by subpopulation and compared with historic conditions (1950; Table 3a). Spatial results of ranked winter range are mapped for the northern and southern half of the valley (Figs. 4, 5). Winter range condition discounts were applied to the current winter range habitat (Figs. 4, 5 and 6).

Rank 3 and 2 habitats are the most prevalent within winter ranges, with the highest proportion of Rank 4 habitat within the Ewin Creek and Fording subpopulations (Table 3a, Figs. 4, 5). Greatest changes in areas of habitats occurred in the Elk Valley East populations and were associated with coal development between the early 1980s and 2000s. In particular, activities within the Fording subpopulation resulted in removal of high value native annual and winter ranges on Eagle Mountain during the 1980s, with no sheep observed after 1987 and the first use of the Greenhills area by sheep detected in 1986 (D. Martin and D. Ryder, FLNRO, pers. comm.). These habitats were replaced in some cases by reclaimed mine areas, some of which were used by wintering sheep in some years (Figs. 4, 5). High value winter range was also removed within portions of the Ewin Creek subpopulation, primarily related to development at Line Creek Operations. Reduced winter range condition within both subpopulations further contributed to effective habitat loss compared with historic conditions. There was a loss of Rank 4 habitats for Erickson-Sheep Mt. (-9%, 7 ha), Ewin Creek (-41%, 113 ha) and Fording (-36%, 486 ha) subpopulations.

For Ewin, 29% was lost due to a reduction in habitat quality (primarily related to overgrazing) and for Fording 14% was lost due to a reduction in habitat quality. Rank 4 habitat is the most highly used by BHS and is currently irreplaceable. There were increases in Rank 3 habitat in all cases, resulting in changes to combined Ranks 3 and 4 habitat of +24%, -12% and -19% for Erickson-Sheep Mt., Ewin Creek and Fording subpopulations, respectively. Little to no change in habitats occurred in the Elk Valley West population, primarily because of absence of resource development. The maps highlight the relatively small areas of winter range within the broader landscape (Figs. 4 and 5).

Table 3a. Bighorn sheep winter range area (ha) by habitat rankings by subpopulation, Elk Valley (EV). Rankings grade from Rank 4 (habitat is highly selected or highly used) to Rank 1 (habitat is less selected). Comparisons to historic values presented in parentheses; e.g., '74 (-7)' means 7 ha of Rank 4 habitat was lost (altered) between 1950 and current.

Subpopulation	**Current rank 4 ha (change from 1950)**	**Current rank 3 ha (change from 1950)**	**Current rank 2 ha (change from 1950)**	**Current rank 1 ha (change from 1950)**	**Total rank 4-1 ha (change from 1950)**
Crowsnest North	57	51	274	7	390
Erickson Sheep Mt	74 (-7)	555 (+128)	648	49 (+13)	1192 (+134)
Ewin Ck	161 (-113)	276 (+54)	198 (+29)	109 (+2)	772 (-28)
Fording	847 (-486)	713 (+114)	1252 (+628)	246 (+62)	2739 (+319)
Upper Elk East	289	328	844	113	1574
EV EAST	**1428 (-606)**	**1923 (+297)**	**3216 (+657)**	**524 (+76)**	**7091 (+425)**
Upper Elk West	72	316	781	0	1169
Crossing Ck	30	44	231	0	305
EV West Hornaday	29	171	362	7	568
EV WEST	**131**	**530**	**1375**	**7**	**2042**
EV TOTAL	**1558 (-606)**	**2453 (+297)**	**4591 (+657)**	**531 (+76)**	**9133 (+425)**

Table 3b. Bighorn sheep winter range percent change from 1950 by habitat rankings by subpopulation, Elk Valley (EV). * indicates moderate hazard. ** indicates very high hazard.

Subpopulation	Rank 3 & 4 (%)	All Rank (%)	Rank 3 (%)	Rank 4 (%)
Crowsnest North	0	0	0	0
Erickson Sheep Mt	24	11	30	-9
Ewin Ck	-12*	-4	25	-41
Fording	-19**	12	19	-36
Upper Elk East	0	0	0	0
Upper Elk West	0	0	0	0
Crossing Ck	0	0	0	0
EV West Hornaday	0	0	0	0

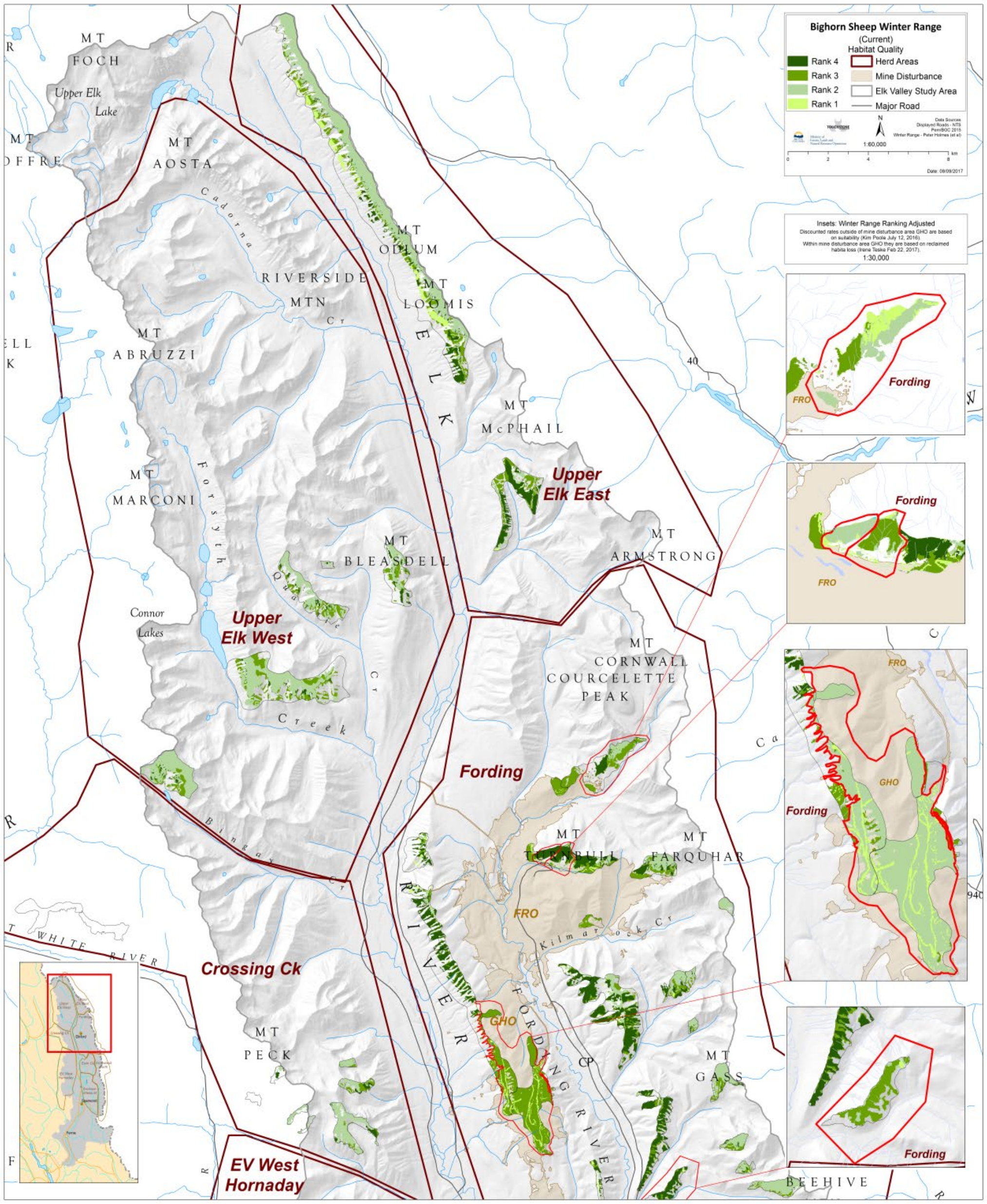


Figure 4. Bighorn sheep winter range in the northern Elk Valley ranked by habitat quality based on Predictive Ecosystem Mapping (PEM) site series data (2015). The insets show applied winter range condition qualifier discounts.

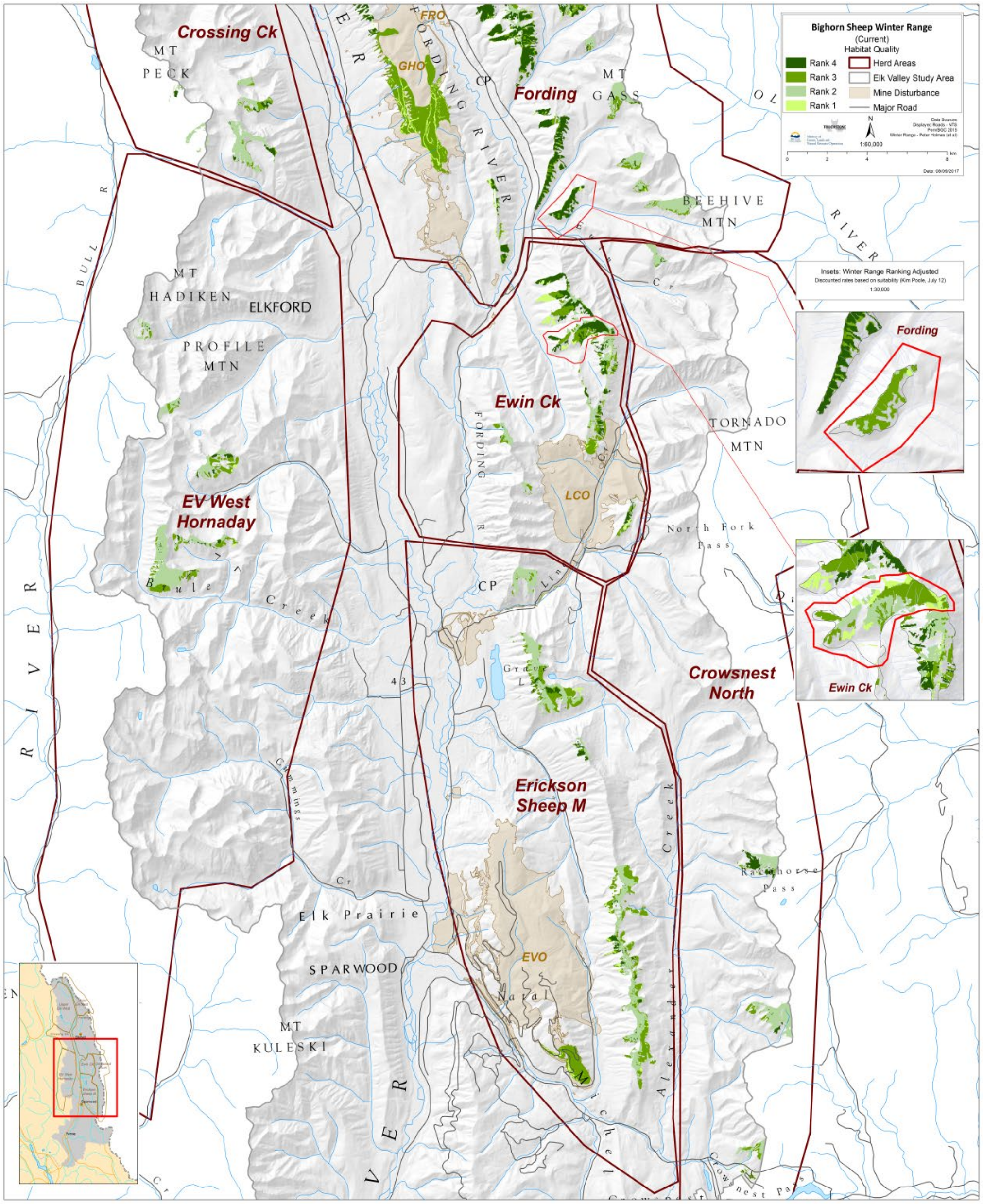


Figure 5. Bighorn sheep winter range in the southern Elk Valley ranked by habitat quality based on Predictive Ecosystem Mapping (PEM) site series data (2015). The insets show applied winter range condition qualifier discounts.

1B) WINTER RANGE QUALITY

During field work in 2009-10, 3 of the ranges were assessed as slightly at risk and 1 was assessed as slightly to moderately at risk for ecological range condition (4/15 ranges or 27% assessed at least slightly at risk; Smyth, 2014). Here risk is defined as ranges that are not in proper functioning condition (Fraser 2007). The moderately at risk area was Turnbull Mountain (South West) sub-range while the slightly at risk areas were Imperial Ridge, Henretta/ Courcelette (Gill Peak), and the Ewin Ridge (Mount Banner/Long Ridge) (Appendix 4). Most of the issues affecting ecological function are related to overgrazing (Smyth, 2014).

Historic data on range condition stretching back to 1982 were summarized to examine trends to date (C. Smyth, unpubl. data, 2016), which showed declining condition over time for 6 of the 8 sub-ranges examined (Fig. 6, Appendix 4). Declines in winter range condition can be linked primarily to overgrazing by native ungulates, resulting in poor vegetation coverage, soil creep and other factors that deteriorate the quality and function of alpine grasslands (C. Smyth, unpubl. data, 2016). Winter ranges can be efficiently assessed on a regular basis (perhaps every 3-4 years) using the UFC method, with more infrequent full ecological range assessments conducted at longer intervals (8-10 years, such as Smyth 2014).

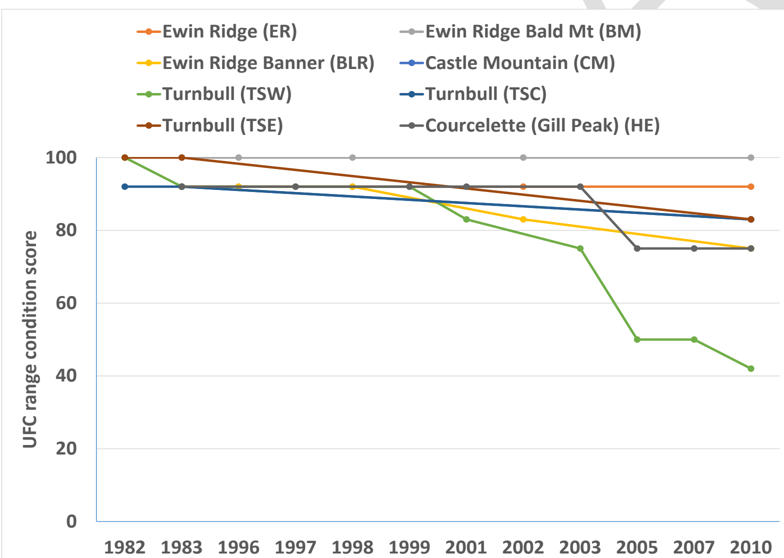


Figure 6. Trends in Uplands Function Checklist (UFC) range condition scores on Elk Valley East bighorn sheep ranges and sub-ranges, 1982 to 2010. A score of ≥80 = proper functioning condition, and <20 = non-functional.

Hazard

Hazard scores for BHS winter range were from zero (no hazard) to five (very high hazard). For Ranks 3 and 4 winter range habitats relative to historic conditions, the Ewin Creek subpopulation were ranked as Moderate hazard and Fording subpopulation as Very High hazard (Table 3a,b, Fig.9). It is important to note that rank 4 habitat is irreplaceable and therefore key when considering hazard and the loss is primarily a function of coal mining activities that have physically removed this habitat within winter range and decreased winter range condition (Fig. 6). Rank 4 habitat was lost in Ewin Creek, Erickson-Sheep Mountain and Fording subpopulations (Table 3 a, b). In both Fording and Ewin Creek, there was a loss of rank 3 and 4 winter range due to the habitat quality discount (Fig. 4, 5). Relative to 1950, there has been no negative change in Rank 1 and 2 BHS winter habitats (Table 3a); therefore, there is currently no hazard for these habitats. For the combined total winter range (all ranks), only Ewin Creek results in an overall loss of habitat and is ranked as very low hazard (Fig. 10).

A hazard score for population was also calculated. 27% of sub-ranges assessed were at least slightly at risk in Elk Valley East for winter range habitat quality resulting in high hazard (data not available for Elk Valley West).

2) Annual Range

The area of ranked annual range habitat was summarized by subpopulation (Table 4). Spatial results of ranked annual range are mapped for the northern and southern half of the valley (Figs. 7, 8). Since annual range within the Elk Valley West population was discounted to reflect relative abundance compared with the Elk Valley East population, overall weighted ranks were higher in the Elk Valley East populations (Figs. 7, 8). The alpine habitat used by Elk Valley West populations is shared with high numbers of mountain goats (>1000) (I.Teske, personal communication). Just over one-third (36%) of the BHS annual range in the Elk Valley East was Rank 4 habitat (high quality – open native habitat adjacent to escape terrain) (Table 4), spread relatively evenly among subpopulations (Figs. 7, 8). Much of the increase in annual range habitat since 1950 was related to coal mining activity that in effect created annual (primarily non-winter) range within mine footprints. Some changes over time, primarily within the Elk Valley West population, were related to differences in the digital topographic mapping between historic and current data. Differentiating 'real' change in annual range from change purely as a result of differences in topographic mapping products between 1950 and current is difficult or impossible.

Quantifying changes in annual range habitat into the future will not be affected by mapping product discrepancies.

Table 4. Bighorn sheep annual range habitat rankings (ha) by subpopulation, Elk Valley (EV). Rankings grade from Rank 4 (habitat is highly selected or highly used) to Rank 1 (habitat is less selected). Comparisons to historic values presented in parentheses; e.g., '3565 (+306)' means 306 ha of Rank 4 habitat was gained between 1950 and current.

Subpopulation	current rank 4 ha (change from 1950	current rank 3 ha (change from 1950)	current rank 2 ha (change from 1950)	current rank 1 ha(change from 1950)	Total annual range (change from 1950)
Crowsnest North	3565 (+306)	2447 (+52)	1683 (-81)	682 (-140)	8377 (+137)
Erickson Sheep Mt	1957 (+430)	1187 (+324)	875 (+507)	548 (+441)	4568 (+1702)
Ewin Ck	1540 (+386)	1122 (+276)	882 (+389)	426 (+252)	3969 (+1302)
Fording	4059 (+682)	3791 (+705)	3820 (+1128)	2289 (+908)	13959 (+3423)
Upper Elk East	1614 (+297)	1290 (+48)	1121 (-31)	598 (-99)	4623 (+215)
EV EAST	12735 (+2102)	9837 (+1404)	8381 (+1912)	4543 (+1361)	35496 (+6779)
Upper Elk West		6983 (+487)	4653 (+101)	5951 (-195)	17587 (+393)
Crossing Ck		1932 (+46)	1007 (+3)	707 (-44)	3646 (+6)
EV West Hornaday		7359 (+267)	3428 (-63)	2643 (-131)	13430 (+73)
EV WEST	0	16274 (+800)	9088 (+42)	9301 (-370)	34663 (+472)
EV TOTAL	12735 (+2102)	26111 (+2204)	17469 (+1954)	13844 (+991)	70159 (+7251)

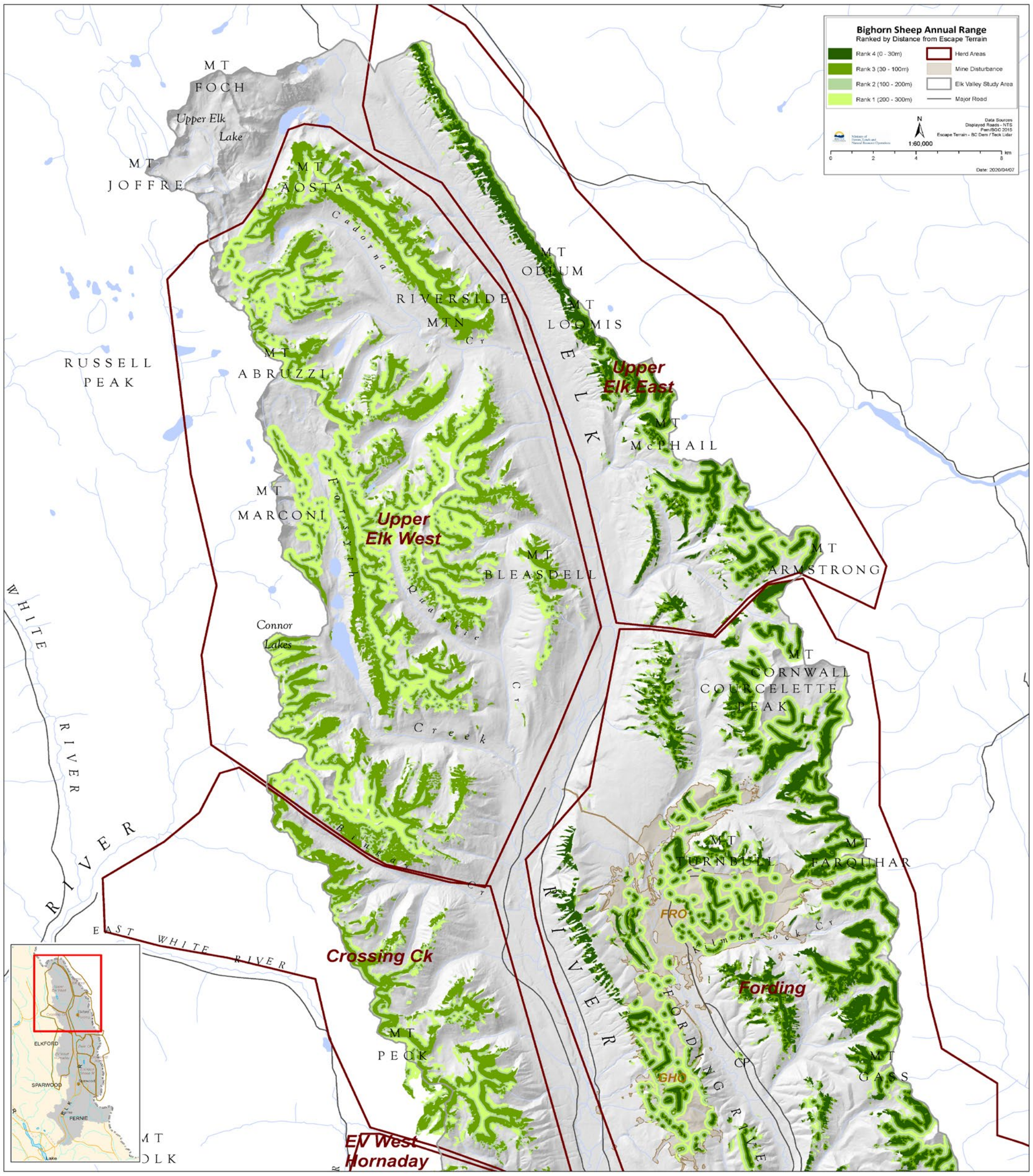


Figure 7. Bighorn sheep annual range in the northern Elk Valley ranked by habitat quality based on Predictive Ecosystem Mapping (PEM) site series data (2015).

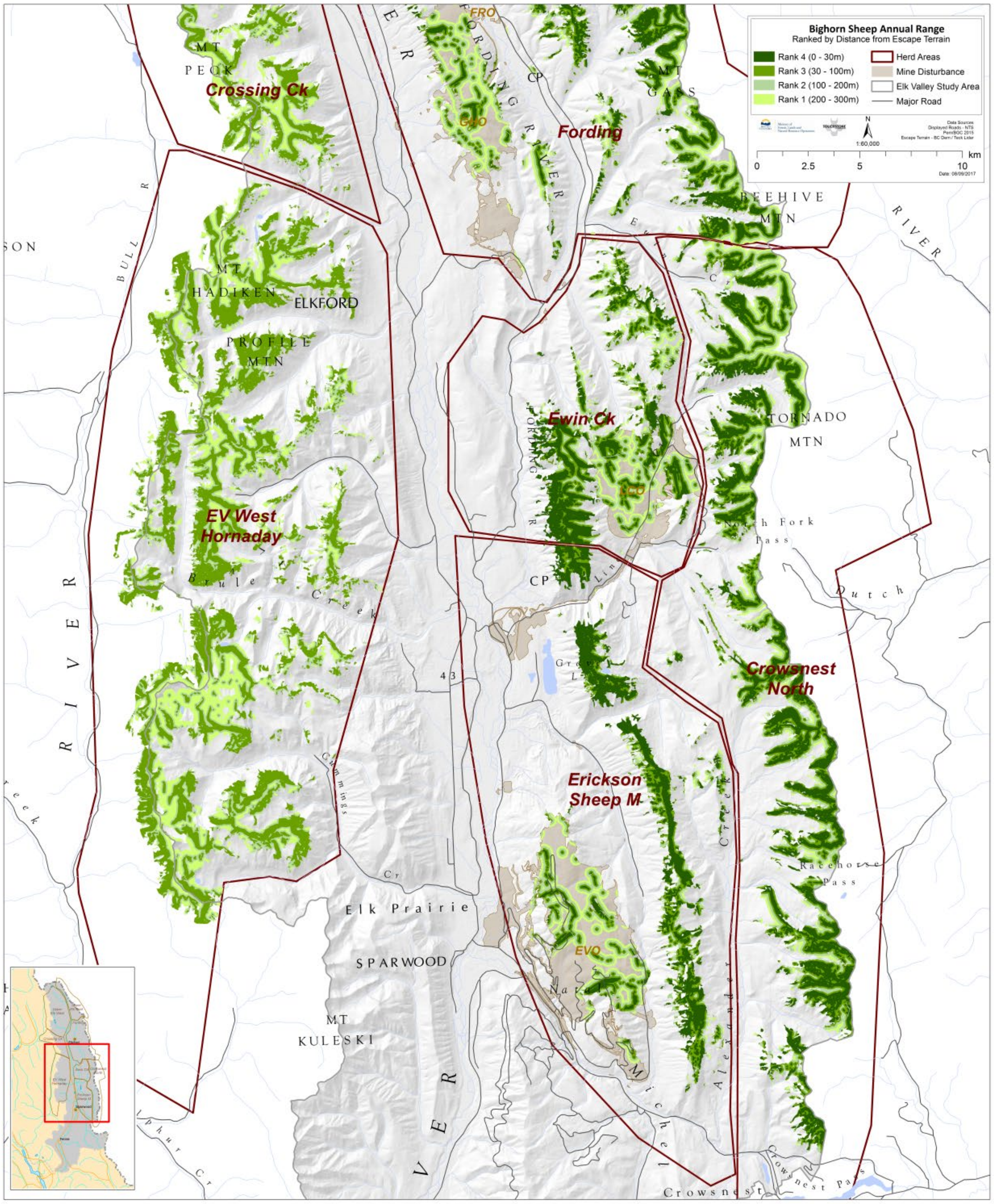


Figure 8. Bighorn sheep annual range in the southern Elk Valley ranked by habitat quality based on Predictive Ecosystem Mapping (PEM) site series data (2015).

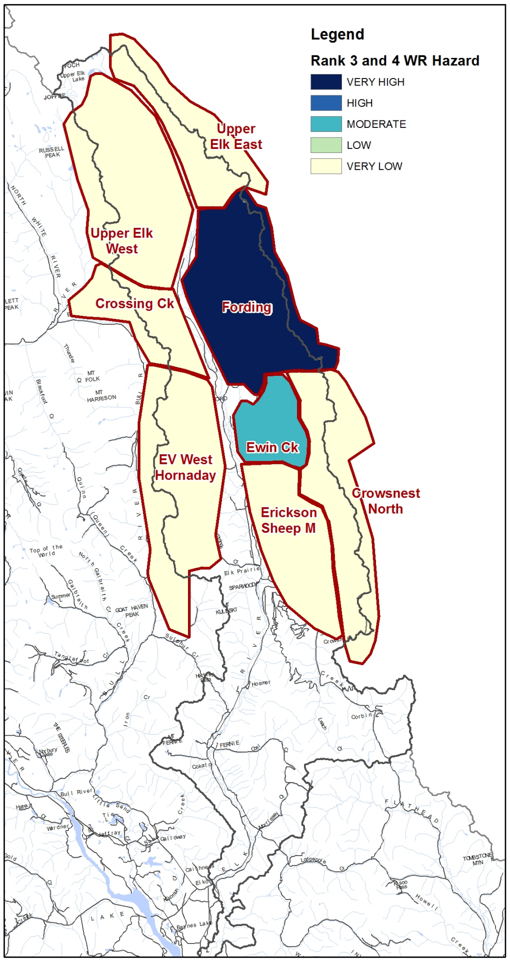


Figure 9. Ranks 3 and 4 (above) winter range (WR) hazard for each of the Elk Valley BHS subpopulations.

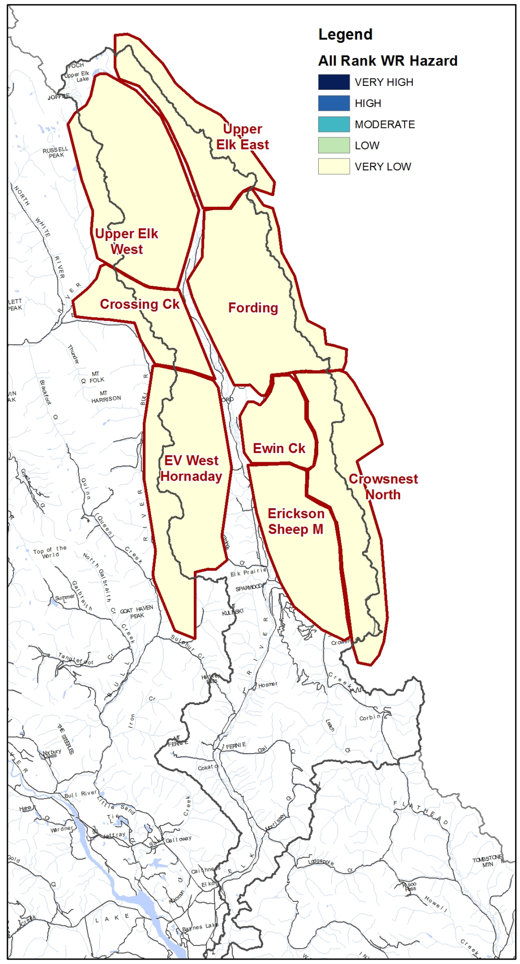


Figure 10. All winter range (WR) Ranks hazard for each of the Elk Valley BHS subpopulations.

3) HUMAN-CAUSED MORTALITY

Known human-caused mortalities of bighorn sheep have fluctuated over time, with an average of

14.5 individuals per year since 2000 (Fig. 11). Several incidences of accidental poisoning on mine properties have occurred since 2010. The recent maximum overall annual mortality is approximately 3.4% of the bighorn sheep estimate for both populations in WMU 4-23. The average annual ram harvest from 2011-15 for the Elk Valley East population was 10.0 rams (roughly 1.7% of the total estimate) and for the West population (including rams from the West population harvested in WMU 4-22) was 3.0 rams (roughly 3.2% of the total estimate). Thus the ram harvest in the Elk Valley West population appears to be slightly higher than the 3% recommended in the Bighorn Sheep Harvest Management Procedure (2014). There is no indication that thresholds for ewe mortality are being exceeded, although monitoring of this parameter is challenging. Monitoring of ram mortality is conducted on an annual basis by FLNRORD.

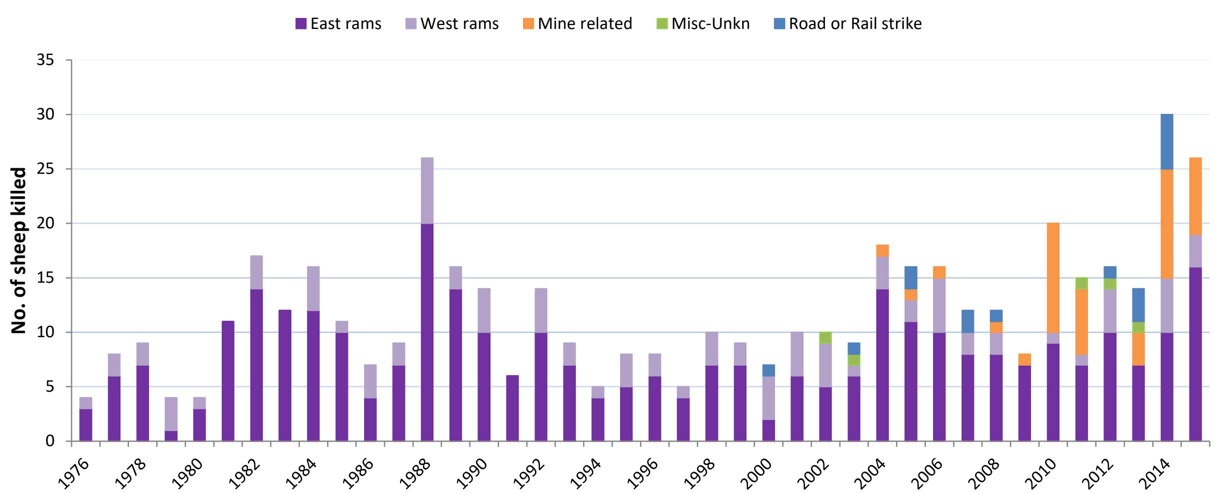


Figure 11. Human-caused mortality of bighorn sheep for the Elk Valley East and West populations. Ram harvest was obtained from Wildlife Management Unit 4-23 compulsory inspection data, with the other data from FLNRO (unpubl. data) and pertaining primarily to the Elk Valley East population. Prior to 2000, the cause of mortality was not recorded and mortality may have been related to mine or road/rail strikes.

4) Population trend

The estimated number of BHS in the Elk Valley East population increased between the year 2000 and 2010, and subsequently declined (Fig. 12). Estimated number of BHS in the Elk Valley West population declined since 2005. Several factors affect sheep abundance, including weather (primarily snow depths and forage conditions) and changes in predation risk that affect both reproduction and survival (Demarchi et al. 2000). Winters leading up to 2010 were generally not severe, which may have contributed to the peak numbers during 2010 in the Elk Valley East population. While the Elk Valley East population is within the benchmark of 20% of the median estimate as determined from the last 5 aerial surveys, the Elk Valley West population appears to have dropped below this level.

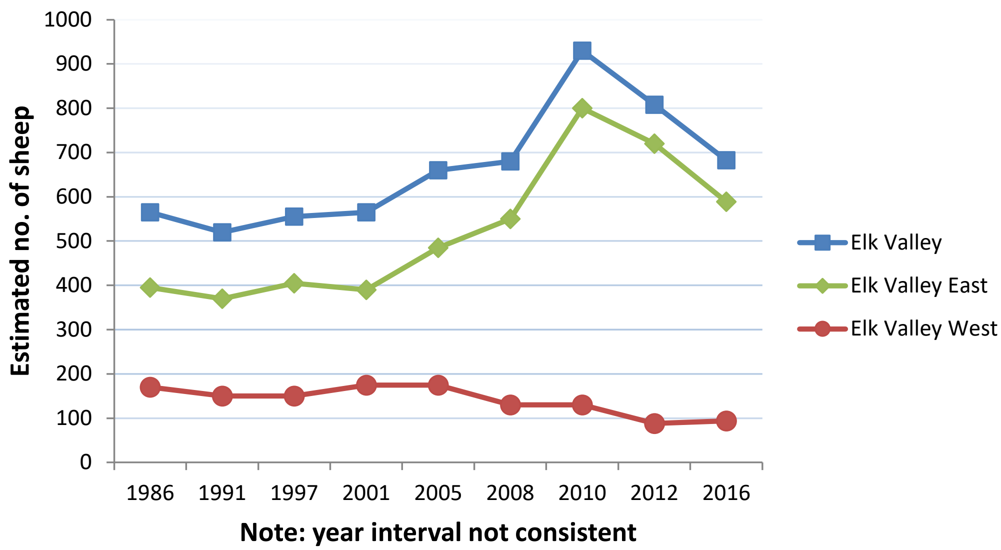


Figure 12. Trends in estimated number of bighorn sheep in the Elk Valley East and West populations.

The Elk Valley East lamb ratio declined slightly over the past 15-20 years, while the ratio in the West population was stable except for the most recent survey (Fig. 13). The median lamb ratios for the East and West populations over the past 5 surveys were 35 and 41 lambs:100 ewes, respectively. Stable populations generally require a minimum of 20% lambs and 30–35 lambs/100 ewes (>1 yr) in late winter surveys (Demarchi et al. 2000), based on a mean of multiple survey counts.

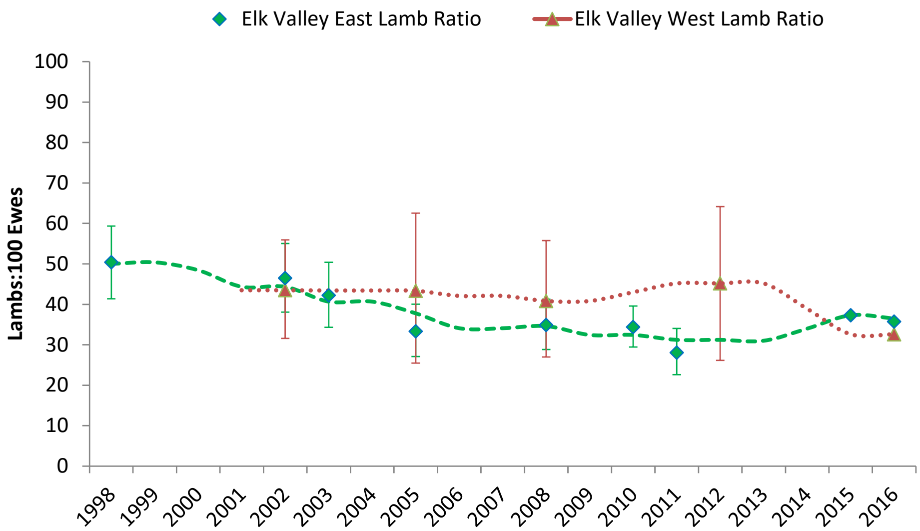


Figure 13. Trends in bighorn sheep lamb ratios in the Elk Valley East and West populations. Data from FLNRO sheep surveys, except for 2015 and 2016 data from Teck mine surveys.

The number of sheep observed during surveys on individual or adjacent groups of winter ranges within the Elk Valley East is shown in Table 5. Ewin Ridge stands out as consistently having the largest number of wintering sheep, approximately 25-30% of the population. Chauncey, Todhunter, Imperial Ridge, and Sheep Mountain consistently have relatively stable sheep numbers. Greenhills Range encompasses native grasslands on the middle to north end of Greenhills Ridge, as well as sheep that began wintering on reclaimed habitats within Greenhills Operations in the mid-1980s. Sheep winter use of these reclaimed habitats appears to have been reduced after 2011 concurrent with mining expansion.

Table 5. Bighorn sheep observed on winter ranges within the Elk Valley East population during aerial surveys, 1975 to 2016. Herd numbers from digital FLNRO data (I. Teske, FLNRO, unpubl. data) except for 2015 and 2016, which were from Teck mine survey data (except for 2016 Deadman Pass, Chauncey, and Tobermory-Aldridge). Blank values signify no survey of that area conducted. Totals may not be comparable among years.

Date	Tobermory, Aldridge	Brownie, Turnbull, Henretta	Greenhills Range	Chauncey, Todhunter, Imperial Ridge	Ewin Ridge, Line Creek	Sheep Mountain	Erickson Ridge-EVO	Deadman Pass	Crowsnest Pass	Total
Mar-75				7	109	44				160
Mar-76				21	87	53				161
Mar-79				24	72	14				110
Mar-81		20		70	179	74				343
Feb-83				25	144	62				231
Mar-85		19		76	100	18				213
Mar-86		17		28	89	31				165
Jan-87		14		40	95	47				196
Mar-88		16		14	52	26				108
Mar-90		19		30	69	40				158
Mar-91		10		36	92	28				166
Feb-98		41	26	32	62	53	11	27	1	253
Feb-02	29	58	18	44	74	46	27	5	26	327
Feb-03	30	70	29	43	63	33	13	7	20	308
Feb-05	28	69	48	44	91	52	11	10	23	376
Feb-08	50	65	77	47	110	43	20			412
Feb-10		118	98	57	154	59	45	8	57	596
Feb-11	27 (Aldridge)	59	63	92	128	46	39			454
Mar-15	7 (Aldridge)	51	60	41	108	48	28			343
Feb-16	17	47	61	57	127	46	44	1		400

3.2 Prospective Assessment – Potential Future Conditions

In the prospective assessment, models were developed based on the retrospective assessment and local expertise. The models were used to predict how indicators may respond to future conditions and changes in the landscape. These changes are due to a combination of natural and human-induced phenomena.

The outcome of the prospective assessment allows us to assess how BHS indicators respond to alternative future development, different mitigation options and an increased natural disturbance scenario related to climate change. The development scenarios presented here do not result in changes in BHS hazard as only 2% of the winter range habitat is disturbed into the future. Mining activity between 1950 and 2015 is responsible for the clear majority of BHS winter range habitat loss compared with current projections 30 years into the future. However, future mining development only considers the reasonable foreseeable future in terms of expansion using planned expansion information (Fig. 14 (red)). This projection also only extends out 30 years, until 2045 (compared to 50 years for other development assumptions) and does not account for all potential development in the Elk Valley. The mineral tenures occupy an area that is much larger than the current extent of the mining scenarios used in this analysis and cover a majority of the BHS winter ranges in Elk Valley East population (Fig. 14 (orange)). In general, we don't have clear, long term (i.e. 50 years), planning information for mining and mineral development, and therefore the development and resulting impact could be much higher than levels considered in this report. Future development of coal mining beyond that already being planned could pose a potential risk to BHS winter range. Future work should evaluate where likely coal development could occur and subsequent BHS hazard. Additionally, future potential conditions do not model changes in habitat quality, which can also lead to changes in hazard.

It is expected that the application of CEMF to planned future development on BHS winter range is an important consideration for this VC and for resource managers and development proponents. Ideally, the application of CEMF would occur early in the planning stage for a development to ensure adequate time to clearly understand the potential impacts and to evaluate management or mitigation opportunities to offset impacts. It is important to note that mitigation opportunities to offset impacts may not exist for rank 4 habitat types. Future updates to the CEMF prospective assessments should ensure that the most current mine development information (which is at a scale of resolution that can support CEMF) is included in the modelling, and mitigation/management responses.

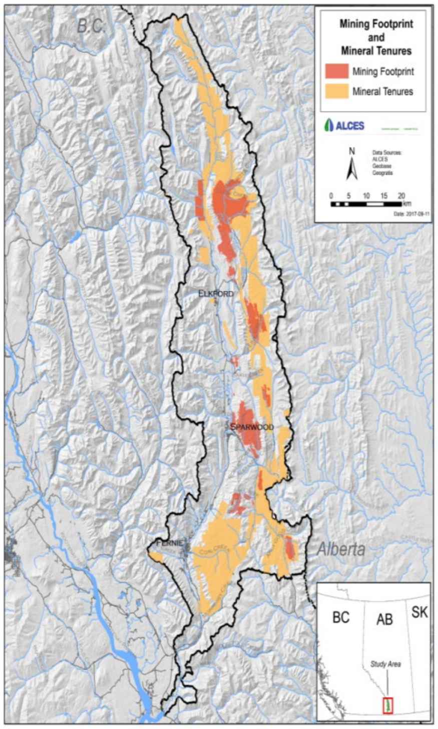


Figure 14. Current and foreseeable mining expansion polygons (red) and mineral tenure polygons (orange).

4.0 Mitigation and Management Recommendations

The Cumulative Effects Framework (CEF) Interim Policy (BC Natural Resource Board, 2016) defines management responses as considerations, actions, decisions or measures proposed or approved based on consistent principles and applied through coordinated management across the natural resource sector. The Policy identifies three levels of management responses:

Operational Responses *– consideration of site-level guidance or implementation of measures to mitigate the effects of projects or activities, typically undertaken by proponents.*

***Tactical Responses** – processes to improve consistency and/or coordination in applying current policy direction, or to seek further information, that may be undertaken by government, stakeholders, proponents and/or First Nations.*

***Strategic Responses** – measures to define or establish strategic direction for the management of land and/or resource values, typically led or coordinated by government.*

Management responses are developed for bighorn sheep (BHS) in the Elk Valley based on present results, expert opinion, and past experiences from the valley and elsewhere. The key driver for proposing management responses for bighorn sheep (BHS) is the observed winter range condition, particularly rank 4 winter range. The proposed management responses are not prioritized at this stage, so prioritization should be considered when developing the implementation plan for the Elk Valley. In addition, further description of the recommended management responses (e.g., exact location and required resources for the proposed structures) should be addressed by the implementation plan.

4.1 Extent of Current Mitigation Practices

Apart from the creation of escape terrain and use of reclamation prescriptions designed for BHS and other ungulates on reclaimed mine areas within Teck operations, active mitigation is not currently being conducted on BHS habitat. Teck has a Sustainability Strategy in place that includes development of biodiversity management plans and associated mitigation plans to manage potential impacts on 'Ecosystem and Biodiversity Elements', including some at the species level, to achieve a Net Positive Impact (NPI) on biodiversity. Teck has completed Habitat Suitability Index (HSI) models on back-casted or pre-existing ecosystem conditions to quantify BHS habitat quantity and quality to determine baseline for Teck's management of BHS as an ecosystem and biodiversity element. The biodiversity management plans will be the central management program to show how mitigation is employed to achieve NPI with regard to BHS, notable through comparing historical HSI results to actual and planned conditions.

Potential mitigation practices for habitat and population management are provided below (not in order of priority of expected effect).

4.2 Mitigation scenarios

Table 6 summarizes mitigation scenarios that have been considered for bighorn sheep (BHS) in the Elk Valley. The intensity of mitigation can be adjusted based on future monitoring data.

Table 6. Mitigation scenarios for bighorn sheep (BHS) in the Elk Valley.[1] Mitigations modelled in ALCES are highlighted in **bold** font.

Indicator	Business as usual (current mitigation)	Moderate mitigation	Intensive mitigation
Winter range habitat	None	**Avoid development in the best (Ranks 3 and 4) BHS winter range;** Avoid impacts to Ranks 3 and 4 winter range through project design;	**Avoid development in all BHS winter range;** Avoid impacts to all winter range through project design; If opportunities exist, increase winter range size in windswept habitats above 1,800 m by setting back forest ingrowth or creating new open habitats through the use of mechanical or hand cutting of trees and shrubs; Reduce access and habitat loss by deactivating roads in and near winter range; Secure habitat offsets within winter range;
Winter range condition	None	Improve range condition by one step in moderately and highly impacted winter ranges using revegetation, fertilizing, over-seeding; Reduce presence of invasive species;	Improve winter range condition in all ranges to proper functioning condition using revegetation, fertilizing, over-seeding; Manage BHS and elk population numbers and distribution through relocation or population reduction programs on Crown and Teck lands; Establish temporary exclusion fencing to recover vegetation in highly impacted winter ranges;
Annual range habitat	Creation of escape terrain and use of reclamation prescriptions on reclaimed mine areas within Teck operations	Protect natural mineral licks; Use silvicultural prescriptions designed for sheep; Minimize disturbance to primary migration routes and seasonal movement corridors;	Create escape terrain near foraging areas; Use prescribed burns to rehabilitate habitat; Conduct mechanical or hand cutting to reduce forest/shrub ingrowth in annual range (especially transitional ranges); Avoid disturbance to primary inter-mountain migration routes and seasonal movement corridors; Avoid impacts to key transitional habitats (spring, late fall/early winter) by project

Indicator	Business as usual (current mitigation)	Moderate mitigation	Intensive mitigation
			design; Secure habitat offsets within winter range;
Highway/ road mortality	Signage, speed limits	Reduce and enforce speed limits; Avoid attractants (e.g., salts, agronomic seed mixes in road cuts); Implement awareness campaigns with public;	Construct wildlife over/under passes on highway 3; Establish exclusion fencing along highways;
Hunter mortality	Current harvest mgmt. (GOS full curl rams);	Reduce access through access management (maintains opportunity); Reclaim roads that lead to winter or annual ranges;	Implement Limited Entry Hunting; Implement low success hunting opportunities (e.g., bow hunting only);
Mine-related mortality	Current mine best mgmt. practises; Maintain operator awareness programs (training, signage, awareness notifications); Maintain speed management;	Review and revise mine best mgmt. practises; Minimize exposure opportunities to chemicals and dangerous substances; Avoid attractants (e.g., salts) near problem areas; Establish crossings or movement management in known high use areas (e.g., direction fencing); Seek alternative access routes to separate people and sheep; Increase operator education and awareness;	Eliminate potential for chemical interaction (e.g., physically through barriers [e.g., fence sheep out of high risk areas] and through alternative products); Install crossings where known traditional movement corridors present high risk of impacts; Install grounding rods in areas of known lightning impacts; Consider predator management (specifically coyote management);
Population trend	Regular inventories	Review and revise harvest program mgmt.;	Enhance predator mgmt.; Implement Limited Entry Hunting; Manage BHS and elk population numbers and distribution through relocation or population reduction programs;

[1] Business as usual: current mitigation practices regarding development and current mitigation practices;
Moderate mitigation: improved mitigation on future developments, or restoration on past developments (e.g., no net loss);
Intensive mitigation: forward management and mitigation of development, and retrospective reclamation.

4.3 Operational Management responses

Operational management responses include site or project-level implementation of measures to mitigate the effects of projects or activities, typically undertaken by proponents. These include the mitigation measures described in section 4.2 above. Management levers directed at BHS winter range habitat (and to a lesser extent, annual range) can address habitat availability (area) and quality (suitability/range condition). Preventing future loss of winter range is critical, especially rank 4 winter range. Given difficulties in creating new winter range, most effective efforts in the immediate future might best be focused on increasing winter range condition in at-risk winter ranges. Levers directed at management of human-caused mortality and populations trend address harvest and predator management and measures to reduce vehicle-sheep collisions and accidents on mine property.

Over-abundance of both sheep and elk on BHS winter ranges can affect winter range habitat quality and condition. While the reduction of elk can be a valid management option, the removal of ewes (often unpalatable with the public but common in other jurisdictions and has been used in BC before) only makes sense if substantial habitat loss occurs in a subpopulation. Management of these situations is challenging because many of the winter ranges are on or require access through Teck Coal properties, with related safety concerns.

Additional recommendations:

- Developments should seek to avoid impacts to BHS winter ranges, especially Rank 3 and 4, through project design, including activity or development buffers around designated winter range or other critical habitat features to avoid degradation of the habitat along this interface by, for example, blast rock, debris or erosion.
- Provincial government should cooperate with landowners and proponents to restore/improve and enhance BHS winter ranges using prescribed burning, intensive restoration or habitat enhancement activities (spacing and commercial thinning, revegetating, over-seeding, invasive plant management), or reductions in ungulate populations.
- Provincial government and proponents should manage invasive species and control their spread and impacts on winter ranges. Revegetation of disturbed sites in sheep habitat

should consider appropriate seed mixes that provide forage for BHS and are rated as free of invasive species as possible. To avoid introducing disease, managers must not use domestic sheep and goats for invasive plant control in areas of sheep habitat.

- Provincial government and proponents should cooperate with landowners and proponents to consider methods to improve forage and range condition on adjacent shoulder/transitional habitats to reduce pressure on core winter habitats outside of critical winter periods.
- Provincial government should cooperate with landowners and proponents to manage BHS population numbers and distribution through relocation or population reduction programs if required.
- Provincial government should cooperate with landowners and proponents to consider temporary fencing of key portions of winter range to improve habitat.
- Provincial government should cooperate with landowners and proponents to develop or coordinate programs to set back forest ingrowth in windswept habitats above 1,800 m using mechanical or hand cutting of trees and shrubs. Intensive mitigation may provide for a slight increase in winter range and likely larger increase in transitional range size by setting back forest ingrowth or creating new open habitats.
- Developers and new developments should mitigate losses to winter habitat and important habitat features through project design and engineering or reclamation.
- Proponents should conduct offset mitigation on habitats within the herd or subpopulation to offset the residual impact of any loss due to predicted degradation of winter range.
- Provincial government should cooperate with landowners and proponents to manage ungulate species overlap on BHS winter ranges to improve range suitability. If it is shown that high elk numbers may be impacting range condition, a targeted harvest of elk may be required, prioritizing areas where elk have high residency time on at-risk and non-fully functioning BHS winter ranges, many of which are on mine property.
- Provincial government should manage population demographics through harvest based program management.
- Provincial government should manage ewe and lamb ratios and survival through defined management programs.
- Provincial government should seek to reduce vehicle-sheep collisions through highway design (e.g., exclusion fencing, wildlife overpasses), signage and traffic management programs (e.g., reduce and enforce speed limits).

- Developments should minimize the occurrence of new roads in or near high quality BHS winter range that could enhance access for predators to core ranges.
- Proponents should deactivate or reclaim existing unused roads and trails in or near core BHS winter range.
- Proponents should avoid disturbance to primary inter-mountain migration routes and seasonal movement corridors;
- Proponents should avoid impacts to key transitional habitats (spring, late fall/early winter) by project design;
- Proponents should review and revise mine best management practices to reduce mine-related mortality.

4.4 Tactical Management responses

Tactical management responses include processes to improve consistency and/or coordination in applying current policy direction, or to seek further information, that may be undertaken by government, proponents, stakeholders and/or First Nations. These may include assessment, monitoring, evaluation, research, coordination, collaboration, guidelines, management plans, etc. Timelines for tactical response are difficult to propose, but to be effective should occur within 5 years.

- Provincial government should conduct research to define the location of primary inter-mountain migration routes.
- Provincial government should encourage participation in habitat restoration programs through the development of a ‘banking approach’ to allow proponents to invest upfront in habitat services mitigation and to draw on those ‘banked units’ if/when required or apply the credits in other ways that offer mutual benefit.
- Provincial government should verify BHS annual range for the Elk Valley West population and update Elk Valley East and Elk Valley West BHS population estimates every 3–4 years.
- Provincial government should update winter range mapping every 4 years based on Teck mine surveys and FLNRORD surveys; more frequent updates of winter range mapping on Teck mine property may be required depending on expanding development of mines. A 4 year cycle allows for at least one FLNRORD valley-wide survey and multiple annual Teck surveys to be conducted. Teck and other coal mine proponents should provide

  orthophotos, when updated, to FLNRORD to track changes in habitat due to development.
  - Provincial government is planning a bighorn sheep inventory for East Side Elk Valley for winter 2018-19
  - Recommend that Province conducts West side inventory in 2020 and East side in 2022
  - Recommend that Teck continue to conduct wildlife inventories annually or every 2 years.

- Provincial government should amalgamate and update annually the Teck mine BHS data since 2004 to examine trends in numbers and lamb ratios observed/estimated. These data should be summarized by main BHS winter ranges and at the subpopulation scale.
- Provincial government should monitor general BHS health including measures of animal stress (using recent techniques) and demographics on an annual basis to assess risk. These include opportunistic collection of samples from mortalities (road kills and others). A healthy herd is defined as: all age classes appear healthy (good body condition and no clinical signs of disease) and are present in expected proportions, with lamb:ewe ratios >20 lambs:100 ewes and population numbers stable or increasing (WAFWA Wildlife Health Committee 2014).
- Provincial government should cooperate with landowners and proponents to assess winter range condition/health every 3–4 years using the Uplands Function Checklist (UFC) Assessment Method (Fraser 2007), with more infrequent full ecological range assessments (such as Smyth 2014) conducted at longer intervals (8-10 years). The effectiveness of restoration measures can be assessed during winter range condition assessments. (Note: the last UFC assessment, covering about 75% of the main winter ranges, was conducted in 2010).
- Proponents should conduct research into developing functional winter ranges on used mine property that provides similar function to native winter ranges.

4.5 Strategic Management Responses

Strategic management responses include measures to define or establish strategic direction for the management of land and/or resource values, typically led or coordinated by government. This may include new objectives for valued components, new acts and/or regulations.

- To best inform management responses, clear objectives are needed. No explicit objectives for BHS habitat or population size are available. To this effect, FLNRORD should develop specific habitat and population objectives within 3 years. Below are **proposed** initial strategic management objectives for habitat and population that may help guide management responses in the future:
  - A. Habitat objective: To ensure sufficient BHS habitat (especially winter range) on the landscape to maintain healthy numbers of BHS within each subpopulation. Definition of 'sufficient' winter range will be challenging, but to retain hazard benchmarks at or below low hazard, habitat loss in any subpopulation should be maintained ≤15% of all winter ranges or ≤7.5 % Rank 3 and 4 (Table 1, Fig. 2).
  - B. Population objective: To maintain each subpopulation within 20% of the median subpopulation size from the years 2005 to 2016 (600 sheep) and with >30–35 lambs:100 ewes as determined from the last 5 aerial surveys. This objective should be re-evaluated at least every 10 years.
    - Surveys from 2005 to 2016 show a range of recent moderate to high populations.
- FLNRORD should consider developing an Elk Valley watershed habitat management strategy that includes BHS habitat to address the risk to critical habitat.
- Provincial government in consultation with First Nations, proponents and stakeholders should consider establishing protected areas in Rank 4 winter range when/if required especially due to Red Listed ranking of high elevation grasslands.
- In future CE assessments, habitat loss/alteration should be presented separately for mining loss versus loss of habitat quality (e.g. discounting of rank due to overgrazing or encroachment).

ACKNOWLEDGEMENTS

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APPENDIX 1. POPULATIONS, SUBPOPULATIONS, AND HERDS OF BIGHORN SHEEP IN THE ELK VALLEY.

Population	Subpopulation	Main Herds
Elk Valley East	Crowsnest North	Crowsnest Pass
		Deadman Pass
	Erickson – Sheep Mt	Erickson Ridge
		South Pit EVO
		Sheep Mt
		Line Ck Canyon
	Ewin Ck	LCO – Wisukitsak Ridge
		Ewin Ridge
	Fording	Imperial Ridge
		Todhunter
		Chauncey
		Beehive Mt
		Continental Divide
		Burnt Ridge Extension
		Greenhills - GHO
		Greenhills Ridge North
		Turnbull
		Brownie

		Henretta
		Gill Peak
	Upper Elk East	Aldridge
		Tobermory
Elk Valley West	Upper Elk West	Mt Bleasdell
		Quarry Ck
		Forsyth Ck
		Bingay Ck
	Crossing Ck	Crossing Ck
	EV West Hornaday	Brule Ck
		Boivin Ck

APPENDIX 2. PREDICTIVE ECOSYSTEM MAPPING (PEM) SITE SERIES CLASSES CONSIDERED FOR BIGHORN SHEEP HABITAT MAPPING IN THE ELK VALLEY.

Biogeoclimatic (BEC) Zones

- IMA: Interior Mountain-heather Alpine
- ESSF: Engelmann Spruce – Subalpine Fir; dkp: Dry Cool Parkland variant.
- MS: Montane Spruce

PEM site series

Acronym	Name and Description
Af	Alpine Fellfield: Ecosystems of winter wind-exposed sites where the dynamics of soil freeze and thaw cycles and of wind give rise to characteristic sparse, low plant cover in a rocky or scree matrix.
Ag	Alpine Grassland: Well-vegetated and grass dominated ecosystems of dry, cold climates with low but significant snow load and well-developed soils.
Ah	Alpine Heath: Mountain-heather dominated snowbed ecosystems that are widespread and common throughout B.C. in snow accumulating sites and stable substrates.
Am	Alpine Meadow: Well-vegetated and forb dominated ecosystems of sub-alpine and alpine elevations.
At	Alpine Tundra: Well-vegetated ecosystems of mixed composition commonly with an abundance of dwarf woody plants.
AtAm	Alpine Tundra / Alpine Meadow: Lump code for Alpine Tundra and Alpine Meadow. Well-vegetated ecosystems of mixed composition commonly with an abundance of dwarf woody plants; well-vegetated and forb dominated ecosystems of sub-alpine and alpine elevations.
Atmf	Alpine Tundra /Alpine Fellfield / Alpine Meadow: Undifferentiated complex of numerous Alpine ecosystems. May contain dwarf woody plants, cushion plants, and forb dominated ecosystems.
Gb	Brushland: Shrub ecosystems of very dry sites dominated (>10%) by drought tolerant woody shrubs of moderate stature.
Gg	Grassland: Well-vegetated and grass dominated ecosystems of dry, cold climates with low but significant snow load and well-developed soils.
GbGg	Brushland / Grassland: Complex of very dry sites dominated by either (>10%) drought tolerant woody shrubs of moderate stature or grasses. For this variant; Gb comes first to reflect brushlands are more common that grasslands.
Mi	Mine
Mr	Mine reclaimed
Ro	Rock Outcrop: A gentle to steep, bedrock escarpment or outcropping, with little soil development and sparse vegetative cover.
Ro102	Rock Outcrop/BlLa – Grouseberry: Bedrock escarpment or outcropping with little soil

	development and sparse vegetative cover lumped with trees on rock (shallow soils, warm aspects).
Rt	Talus: Active and inactive talus (large rocks) and active scree (smaller rocks and more soil) ecosystems.
Rz	Road Surface
Sc	Subalpine Shrubland: Low deciduous, shrub-dominated ecosystem that develops on frost-prone sites with dry to very moist soils. Subalpine shrublands are widespread at the treeline in cold, dry climates, but they also occur in frost-prone hollows at lower elevations.
SkGb	Krummholz / Brushland: Lump code for mixture of stunted, krummholz trees and brushlands at high elevation.
Vh	Avalanche Herb: Forb, dwarf shrub- or grass-dominated ecosystems in avalanche tracks.
Vs	Avalanche Shrub: Shrub-dominated ecosystems in avalanche tracks.
Xh	Disclimax Herb: Lush forb-dominated ecosystems that occur at lower elevations in areas where site conditions or stand age cannot explain lack of tree cover.
Yz	Alpine Tundra /Alpine Fellfield / Alpine Meadow / Krummholz: Undifferentiated complex of open meadow, stunted tree growth, and unclassified woodland forest. Covers a relatively small area of the PEM.

APPENDIX 3. LIST OF CURRENT CEMF WORKING GROUP MEMBERS

#	Name	Organization
1	Taye Ayele	Chair, FLNRO
2	Marcin Haladaj	FLNRO
3	Lyle Saigeon	FLNRO
4	Cassidy van Rensen	FLNRO
5	Bill Green	KNC
6	Alison Burton	KNC
7	Warn Franklin	Teck Coal Ltd.
8	Steve Hilts	Teck Coal Ltd.
9	Kevin Podrasky	Teck Coal Ltd.
10	Lee-Anne Walker	Elk River Alliance
11	Kari Stuart-Smith	CANFOR
12	Terry Melcer/ Scott Beeching	District of Sparwood/Elkford
13	Brian Dureski	CanWel Building Materials Group Ltd.
14	Mark Hall	MoE
15	Darin Welch	MoTI
16	Mark Vendrig	CanAUS Coal Ltd
17	John Pumphrey	CanAUS Coal Ltd
18	Jeff Berdusco	CanAUS Coal Ltd
19	Art Palm	Jameson Resources Crown Mountain Project
20	Michael Keefer	Jameson Resources Crown Mountain Project
VC TEAM LEADS		
1	Peter Holmes	Old & Mature Forest, FLNRO
2	Herb Tepper	Westslope Cutthroat Trout, FLNRO
3	Alan Davidson	Riparian Habitat. FLNRO
4	Kim Poole	Bighorn Sheep, Aurora Wildlife Research
5	Garth Mowat	Grizzly bear, FLNRO
TECHNICAL SUPPORT		
1	William Burt	FLNRO
2	Rhian Davies	FLNRO
3	Ryan MacDonald	ALCES Group
3	Kathleen McGuinness	Touchstone GIS Services Inc.

APPENDIX 4. ECOLOGICAL RANGE CONDITION

The Uplands Function Checklist Assessment Method (UFC) was used to score each sub-range (Fraser, 2007).

Uplands Function Checklist (UFC)	
Proper functioning condition	≥80
Slightly at risk	61-79
Moderately at risk	41-60
Highly at risk	20-40
Non-functional	<20

Results from Smyth (2014) on ecological range condition from 1982-2010. Note that years are not continuous.

Range	**Sub-range**	**UFC Range Condition from 1982-2010**											
		1982	1983	1996	1997	1998	1999	2001	2002	2003	2005	2007	2010
Ewin Ridge	Ewin Ridge (ER)	-	92	92	-	92	-	-	92	-	-	-	92
	Bald Mountain (BM)	-	100	100	-	100	-	-	100	-	-	-	100
	Banner-Long Ridge (BLR)	-	92	92	-	92	-	-	83	-	-	-	75
	Castle Mountain (CM)	-	92	-	-	-	-	-	-	-	-	-	83

Turnbull	Southwest (TSW)	100	92	-	92	-	92	83	-	75	50	50	42
	South Central (TSC)	92	92	-	-	-	-	-	-	-	-	-	83
	South East (TSE)	100	100	-	-	-	-	-	-	-	-	-	83
Henretta	Courcelette (Gill Peak) (HE)	-	92	-	92	-	92	92	-	92	75	75	75
	Sheep Mt (SMA, SMB)	-	-	-	-	-	-	-	-	-	-	-	83
	Imperial Ridge (IR)	-	-	-	-	-	-	-	-	-	-	-	66
	Todhunter (THR)	-	-	-	-	-	-	-	-	-	-	-	83
	Burnt Ridge Ext (BRE)	-	-	-	-	-	-	-	-	-	-	-	83
	Chauncey Ridge (CHR)	-	-	-	-	-	-	-	-	-	-	-	83
	Brownie Ridge (BR[BRA, BRB])	-	-	-	-	-	-	-	-	-	-	-	83
	Greenhills Range (GR [GRN, GRS])	-	-	-	-	-	-	-	-	-	-	-	83