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# EAST KOOTENAY BIGHORN SHEEP ENHANCEMENT PROJECT

## - COMPLETION REPORT -

A Habitat Conservation Fund project

Peter W. Davidson[1]

Wildlife Branch
Ministry of Environment
Cranbrook, B.C.

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Wildlife Report No. R-
June 1991

[1] Present address: Ministry of Environment, Fort St. John, B.C.

## ABSTRACT

The Rocky Mountain Bighorn Sheep Enhancement Project was initiated in January 1982 to conduct prescribed burns on key winter ranges of bighorn sheep in the East Kootenay Sub-region of southeastern British Columbia. The population of Rocky Mountain bighorn sheep had declined from about 4000 in the 1920's to 2100 in 1981. Epizootic dieoffs at 18- to 24-year intervals had reduced the bighorn sheep population by 25 to 50% and full recovery of numbers had not occurred between epidemics. The 1981-1983 epizootic reduced the population of bighorns from 2100 to 1550 in 17 months. The scope of the project was broadened as a result of disease research done in 1982 and 1983 that indicated that the pneumonia epidemic may have occurred due to a compromised immune system response caused by high stress levels experienced in herds wintering adjacent to the southern Rocky Mountain Trench. Antiparasite and trace mineral treatments were initiated to prevent disease outbreaks from occurring in overpopulated herds on poor winter ranges and to promote recruitment of bighorn sheep in herds reduced through past epidemics. Harassment of bighorn sheep on winter ranges has been controlled through access management. Integrity of range has been maintained through the referral system with the Ministry of Crown Lands, Lands Branch on private land, and the Ministry of Forests on Crown range. Translocations were used to reduce population densities on land in poor condition and increase population densities on herds reduced through epizootic dieoffs.

This report will include details of all herd and habitat enhancement activities but will not include details of habitat protection and habitat mapping activities. Types of habitat enhancement techniques are described and include prescribed fire, selective logging, slashing and spacing, seeding of forage, and fertilization of range. Habitat and herd monitoring activities are described. Condition and trend of key low elevation winter ranges were determined through paired macroplots. Effects of various enhancement techniques on floristic characteristics and productivity of vegetation are described. Health and herd monitoring research included fecal lungworm larval output, fecal and blood cortisol levels, blood and tissue trace mineral levels, population structure and herd recruitment levels. Transplant monitoring included radio-telemetry follow-up of radio-collared animals after visual observation of ear-tagged animals.

## ACKNOWLEDGEMENTS

This project resulted from the efforts of many people. Although I cannot mention all those who contributed, I would like to mention some individuals and groups who deserve special credit.

First, I would like to thank R. Silver, and R. Demarchi who recognized the need for habitat enhancement work on bighorn sheep and pursued that dream through establishment of the Habitat Conservation Fund (HCF). The Habitat Conservation Fund Board has faithfully supported the Rocky Mountain Bighorn Sheep Recovery Project for 8 years under the guidance of R. Silver, R. Hunter and M. Wayne. I give special mention to L. Gansner, the local HCF representative who tirelessly defended this project and became a personal mentor.

This project was supported by several hundred people who donated time, energy, equipment and money to disease research, treatment, live capture and translocation of bighorn sheep. Several clubs deserve special mention because of continuous support: the East Kootenay Hunter's Association, the Canal Flats Wilderness Club, the Invermere Wilderness Club, and the Fernie Rod and Gun Club. Several individuals deserve special recognition for the tremendous effort expended in making the treatment, translocation, and radio-telemetry projects a success. First, D. and J. White and family have always made extensive personal sacrifices in time and energy. Guide outfitters including H. Fercho, F. Maurer, D. Anderson, K. Schmideder, Sr., K. Schmideder, Jr., and A. Cooper never missed an opportunity to trap and treat bighorn sheep. H. Kugler, M. Winger, A. and M. O'Grady spent many weeks each year baiting bighorn sheep using their own vehicles.

The Lakit Mountain Bighorn Sheep Project was initiated between the East Kootenay Hunter's Association and the Ministry of Environment to translocate, treat and follow-up radio-collared sheep moved to the Lower Wildhorse area. Radio-telemetry follow-up of collared animals was done by S. Davis, G. Johnson, D. and J. White and family, G. Ward, and A. and B. Burlingham.

Countless hours of unpaid overtime were endured by summer students hired as assistants to this project. Special mention must be made to L. Ingham who persisted through four summer seasons, and many undesirable job requests such as carcass collection, slashing of several mountain sides in 34 C heat, and range condition and trend research under searing conditions. Summer Coop students including P. Food, K. Mackenzie, and Z. Murdoch spent many hours following radio-collared bighorn sheep and assisting in range research.

Finally, I thank D. Eastman, Manager, Research and Development Section, Wildlife Branch, Ministry of Environment, who guided the write-up and assembly of this report. H. MacKenzie graciously typed several versions of this manuscript and E. Stanlake patiently edited the final copy.

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Rocky Mountain bighorn sheep (*Ovis canadensis canadensis* Shaw) in southeastern British Columbia have undergone periodic epizootic dieoffs approximately every 20 years since the mid-1920's. Dieoffs are known to have occurred in populations wintering in the East Kootenay Trench in 1924-25 (S. Engstron, H. Richardson pers. comm.); 1940 to 1942 (Cowan 1942); 1964 to 1967 (Bandy 1966; Demarchi and Demarchi 1967); and 1981 to 1983 (Davidson 1983; Schwantje 1988*a,b*). Population estimates derived from historical British Columbia Wildlife Branch (B.C.W.B.) records and reports of reliable observers revealed that following each dieoff, the subsequent recovery period was approximately 20 years. However, the overall trend in the population was downward, declining from about 4000 in the early 1920's to about 2100 in the early 1980's (Fig. 1).

The overall decline in Rocky Mountain bighorn sheep populations, and the appearance of contagious ecthyma among bighorn sheep in the Wigwam herd in January 1981, stimulated the B.C.W.B. to initiate a project under the British Columbia Habitat Conservation Fund (H.C.F.) to restore the East Kootenay Trench bighorn sheep population to at least pre-1964 dieoff levels (R. Demarchi pers. comm.).

This H.C.F. project, the East Kootenay Rocky Mountain Bighorn Sheep Enhancement Project (BSEP) began in January 1982 just as a major dieoff was underway in the Maguire bighorn sheep herd adjacent to the Wigwam herd.

In addition to the planned and budgeted enhancement activities, the reponsibility of monitoring and, if possible, preventing the spread of the epizootic was added to the BSE Project in April 1982 and the project was renamed the East Kootenay Rocky Mountain Bighorn Sheep Recovery Project (SRP).

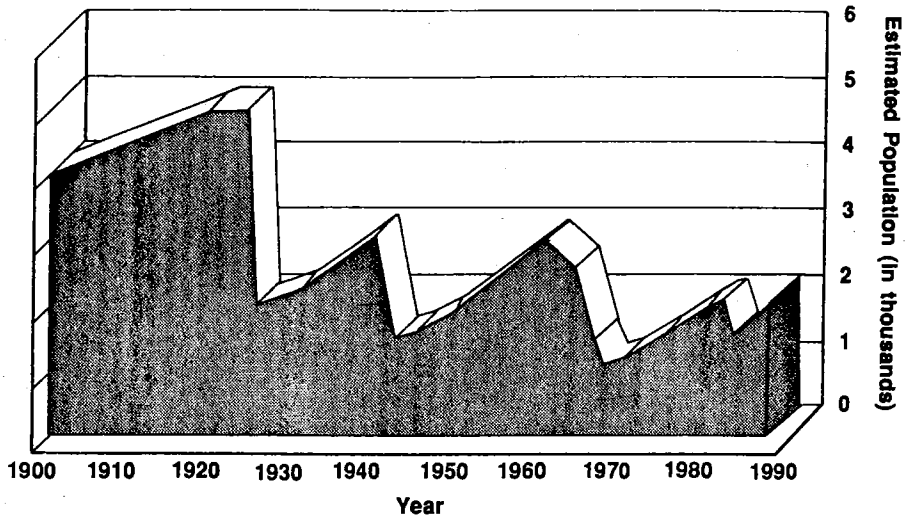



**Figure 1. Estimated population of Rocky Mountain bighorn sheep in the East Kootenay, 1900 to 1990.**

# 1. OBJECTIVES

## 1.1 Report Objectives

This report summarizes the activities of the Sheep Recovery Project from 1982 January 1 to 1988 December 31. Major topics addressed are: 1) disease research, 2) habitat enhancement techniques, 3) habitat monitoring, 4) bighorn sheep health treatments and 5) bighorn sheep translocations. This report will also provide recommendations for management of East Kootenay Rocky Mountain bighorn sheep. Habitat maps (1:20 000 scale), which were completed for bighorn sheep ranges in the Upper Elk Valley, the Galton Range and the east side of Columbia Lake, are not included but are filed in the Cranbrook office of the B.C.W.B. Project reports from summer students from the University of Victoria, British Columbia are also filed in the Cranbrook Wildlife Branch office.

## 1.2 Project Objectives

### 1.2.1 Original objective

The two major objectives of the Rocky Mountain Bighorn Sheep Enhancement Project were to:

1. Increase the population of Rocky Mountain bighorn sheep from 1550 in 1983 to 2500 by 1991.

2. Develop a management strategy for East Kootenay Rocky Mountain bighorn sheep.

### 1.2.2 Expanded purpose

A pneumonia epidemic was underway (2 weeks) when this project was initiated in the East Kootenay on 1982 January 1. Research suggests that the underlying cause for epizootic outbreaks was elevated stress levels, which compromise immune systems of bighorn sheep. This increases bighorn sheep susceptibility to bacteria and viruses (Onderka 1986; Thorne 1987). A reoccurrence of an epizootic dieoff appeared imminent; therefore, the purpose of this project was expanded to include herd monitoring and disease prevention, if possible. Stress levels among bighorn sheep were to be alleviated through habitat enhancement, habitat protection, husbandry treatment and translocations.

# 2. STUDY AREAS

## 2.1 General Description

The East Kootenay Region is a mountainous area dominated by the Purcell Range west of the East Kootenay Trench and the Rocky Mountains to the east of the Trench. A valley, 8 to 25 km wide, 400 km long with an elevation of 1000 m lies in a north-south direction between the Purcell and Rocky Mountain ranges, which have peaks up to 3600 m in height. The Columbia River is the major source of drainage for creeks and rivers located between Canal Flats and Golden, while the Kootenay River is the major source of drainage for all creeks and rivers between Canal Flats and Lake Koocanusa. A second major valley lies due west of the Front Range running between British Columbia and Alberta. The Elk River drains the watersheds that begin in Elk Lakes Park and run south to Lake Koocanusa. Open grasslands are located in the Interior Douglas-fir biogeoclimatic zone between Brisco and the American border 145 km (90 miles) south on the lower west slopes of the Rocky Mountains. These grasslands are located on the lee side of the Purcell and Selkirk Mountains with prevailing winds coming from the southwest Maritime Pacific Current. Less than 20 cm of moisture falls during the growing season near the American border and double this amount can occur 192 km north at Golden, the northern limit of bighorn sheep range.

The climate is continental with hot-dry summers and cold winters. Warm air coming from the southwest Maritime Pacific Current becomes dry as it passes over succeeding mountain ranges causing drought in summer, and bringing Chinook winds during the winter. Cold Arctic fronts flow southward during winter months and subzero weather can last for weeks at a time as this heavy air mass is trapped in valley bottoms as a result of thermal inversions. Climatic conditions are severe with temperatures ranging from -36 C for short periods during the winter to +34 C for short periods during the summer.

All months of the year can have frost but the normal frost-free growing period is about 90 days. Peak temperatures occur in July and August.

Annual precipitation is about 45 cm in the Rocky Mountain Trench and about half the moisture falls during the active growing season in April, May, June and July. Nearly 2/3 of annual precipitation falls as rain in the Trench whereas only 42% of annual precipitation falls as rain in the Upper Elk Valley. Precipitation is lowest near Canal Flats (36 cm) in the mid-section of the Trench and becomes greater as one moves north or south of this point.

Temperatures are similar throughout the Rocky Mountain Trench but a gradient from colder to warmer occurs as one moves from the northern end of sheep range at Kootenay National Park to the southern end near Grasmere (adjacent to the Galton Range). Average monthly temperatures at Fording Coal in the Upper Elk Valley are 2 to 4 C cooler than those of Cranbrook or Elko. Weather conditions at Fording Coal are believed to be similar

to those on high elevation bighorn sheep winter ranges located on the east side of the Elk Valley. Lowest temperatures occur during the months of December and January (-8 C), while peak temperatures occur in July and August (18 C). Temperatures seldom fall below -20 C at which the metabolic rate of Rocky Mountain bighorn sheep must increase to maintain homeostasis (Chappell and Hudson 1978).

Snowfall greatly impacts all large ungulates in the East Kootenay. As snow accumulates at upper elevations in the Rocky Mountains and the Purcells, deer, elk, moose and bighorn sheep (in the Rocky Mountains only) migrate to the southern Rocky Mountain Trench where lower snowfall, higher temperatures and warm Chinook winds create winter ranges with snow depths <30 cm in most years. Peak snowfall occurs in December and January although greatest snow accumulations occur in February. Between 110 and 195 cm of snow normally falls between December and February in the Rocky Mountain Trench.

During winter months, thermal inversions commonly occur in the Rocky Mountain Trench and the Elk Valley. Forage growth does not occur until late June and killing frosts occur by late August in subalpine and alpine tundra grasslands.

Bighorn sheep begin migrating in September with the first major snowfalls and virtually all have left summer ranges by the first week of October. Snow depths of 15 to 30 cm make movement difficult for bighorn sheep and depths of >60 cm provide a major barrier to movement of mature bighorn sheep (Telfer and Kelsall 1971). Bighorn sheep that winter near mountain tops totally depend on Chinook winds to create foraging areas on south-facing alpine tundra grasslands. Snow accumulations may be above normal at high elevation and less than normal in valley bottoms. Late spring snow melt and lack of Chinook winds occurred in the winter of 1983/84 and many bighorn sheep starved on the west side of the Elk Valley.

The active growing season for low elevation vegetation can begin in mid-March and last until October but the frost-free growing season is generally <90 days. The growing season of high elevation grasslands is delayed 2 to 3 weeks (Hebert 1973), and ends 2 to 3 weeks earlier than that of low elevation grasslands. Killing frosts normally occur between September 1 and the last week of May. Forage growth is largely influenced by fall precipitation before the growing season and precipitation during the growing season if temperatures are near normal in the Dry Interior Douglas-fir biogeoclimatic zone.

Fall precipitation before the 1984 growing season was about one-half normal but was near normal in 1986. Mean monthly temperatures in 1983/84 and in 1986/87 were similar to the 30-year average but precipitation during the growing season was more than twice the long-term average. Peak rainfall in the Rocky Mountain Trench occurs in June but frequent wind and high daily temperatures during summer months cause high evapotranspiration rates.

## 2.2 Key Winter Ranges

The biophysical characteristics of key bighorn sheep winter ranges studied will be discussed beginning with the Stoddart/Radium herd to the north and moving southward to the Maguire Creek herd on the Lizard Range adjacent to the southern Rocky Mountain Trench and ending with Sheep Mountain in the Upper Elk Valley (Fig. 2).

### 2.2.1 Radium Hotsprings/Stoddart Creek/ Windermere

*Topography.*— Winter range for this herd extends from Windermere Creek in the south to Radium Hotsprings, 27 km northwest. Total area of winter range is 22.9 km$^2$ (Table 1). Lower west- and southwest-facing slopes of the Rocky Mountains (between 1000 and 1500 m) are used between November and late May (Fig. 3). Topography is gently to steeply rolling slopes. Winter range occurs on alluvial fans and on colluvial slopes with 30 to 70% grade. Key winter range is located on the south-facing alluvial terraces of Canyon Meadows in Radium Hotsprings, the west-facing colluvial slopes between Dry Gulch Creek and Shuswap Creek and the west-facing slopes of Mount Swansea (Fig. 3). Topographical features of the exclosures on the winter range are given in Table 2.

*Soils.*— Soils of Canyon Meadows in Radium are primarily Orthic Eutric Brunisols of the Keeney Series (Lacelle 1976). This silty clay loam soil is derived from fluvioglacial parent material and has a layer of loess (Appendix A). Soils of the west-facing slopes between Dry Gulch Creek and Shuswap Creek are primarily Orthic Regosols of the Mayook (70%) and Keeney (30%) Series. This stony, shallow, well-drained soil is derived from colluvial parent material of limestone origin. Soils located on the alluvial fans are poorly developed brown chernozems of silty clay loam texture. Soils located on the west-facing slopes of Mount Swansea are Eutric Brunisols of the Keeney (50%) and Mud Lake (50%) Series. These are shallow silty clay loam soils derived from colluvial parent material of limestone origin.

*Climate.*— Climatic data taken from a weather station at Brisco 12 km north of Radium Hotsprings is very similar to that of Canal Flats 84 km south. Winter range for bighorn sheep located between Canal Flats and Radium Hotsprings is located in a rain shadow area <10 km due east of the Purcell Mountain Range. During summer months, hot, dry weather and frequent winds caused drought conditions and seed set in grasses on bighorn sheep winter range by mid-July. Snow seldom accumulated to >15 cm on the Radium/Windermere winter range and bare ground was common due to frequent Chinook winds.

*Vegetation.*— This winter range is located in the Dry Interior Douglas-fir biogeoclimatic zone (Utzig *et al.* 1986). Forage on alluvial terraces is characterized by a sparse stand of interior Douglas-fir[1], rabbit-brush, junegrass, needle-and-thread grass, rosy pussytoes and pasture sage. West-facing slopes are characterized by a sparse stand of interior Douglas-fir, common juniper, Rocky Mountain juniper, bluebunch wheatgrass, and pasture sage.

[1] Common and scientific names of plant species mentioned in the text are listed in Appendix B.

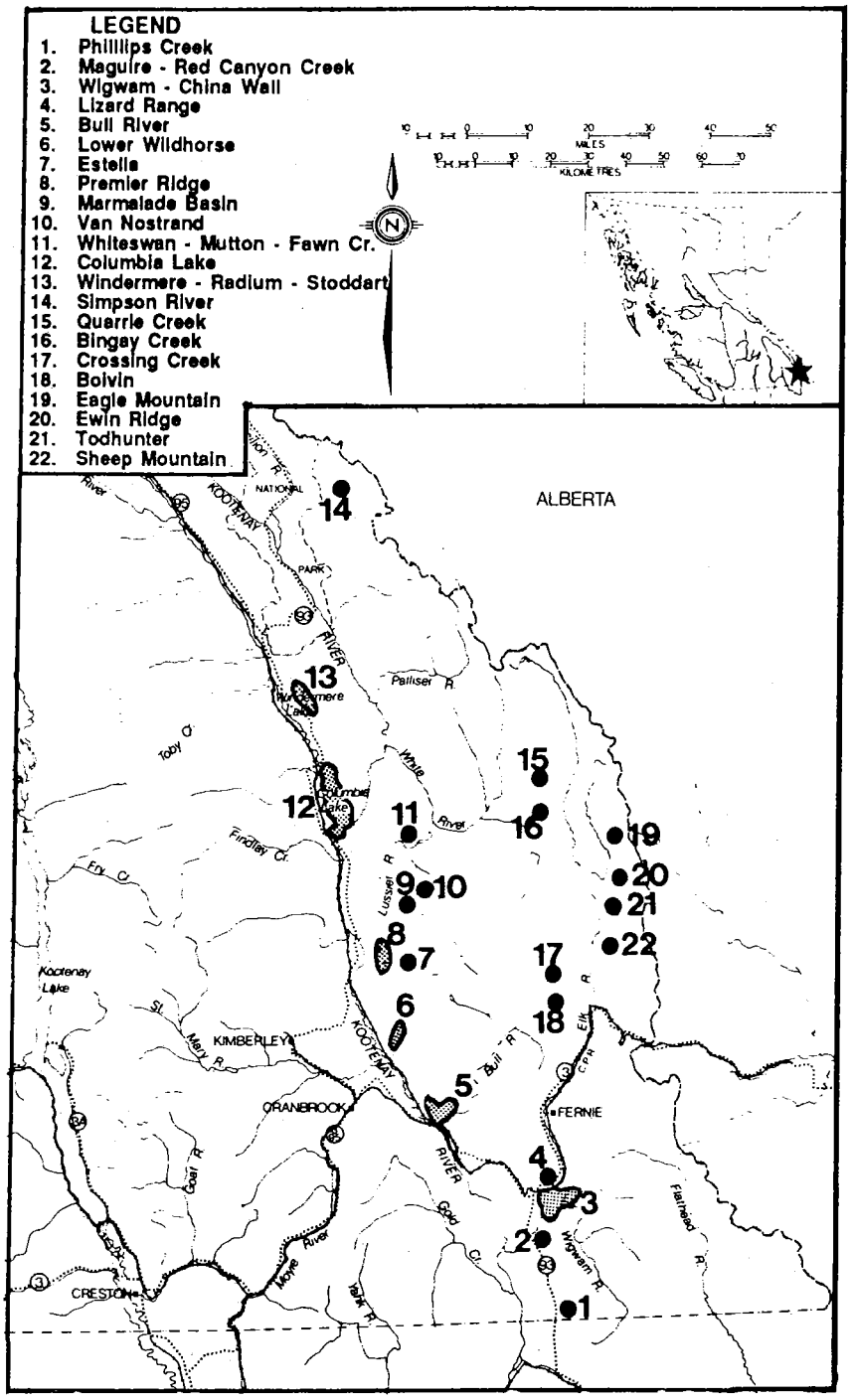



**Figure 2. East Kootenay bighorn sheep winter ranges.**

**Table 1. Ungulate biophysical capability of Rocky Mountain bighorn sheep winter ranges bordering the Rocky Mountain Trench (from Demarchi 1996).**

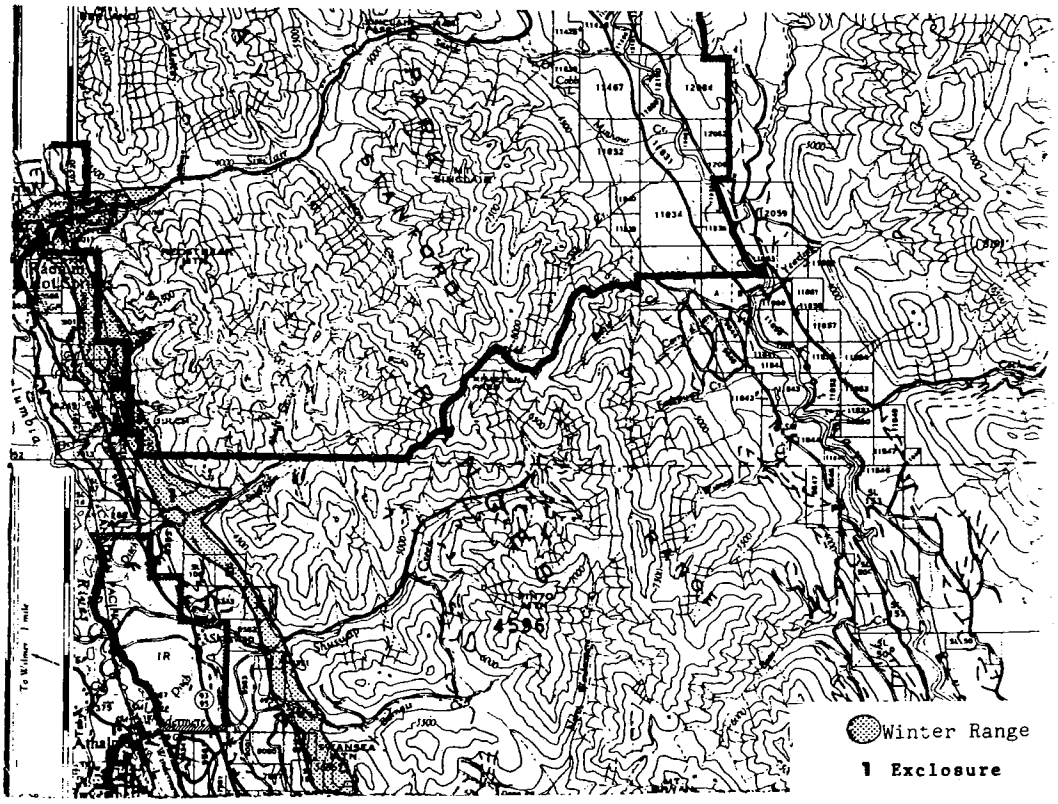
| | Winter Range ($km^2$) | | | Carrying Capacity[a] ($/km^2$) | | | Total ($km^2$) | |
|---|---|---|---|---|---|---|---|---|
| Location | I | II | III | I | II | III | Range | Carrying Capacity |
| Stoddart Creek[b] | 2.89 | 3.41 | 16.61 | 0.52 | 0.48 | 1.66 | 22.91 | 2.66 |
| Columbia Lake | 17.01 | 2.82 | 7.57 | 3.06 | 0.53 | 0.76 | 28.40 | 4.35 |
| Premier Ridge | 3.69 | 7.62 | 7.64 | 0.66 | 1.05 | 0.76 | 18.95 | 2.48 |
| Estella | 6.53 | 9.62 | 15.70 | 1.17 | 1.34 | 1.57 | 31.85 | 4.08 |
| Wildhorse | 4.34 | - | 7.44 | 0.77 | - | 0.74 | 11.78 | 1.51 |
| Bull River | 6.44 | 17.10 | 8.89 | 1.15 | 2.39 | 0.89 | 32.43 | 3.63 |
| Wigwam Flat[c] | 22.53 | 0.83 | 5.90 | 4.05 | 0.11 | 0.59 | 29.26 | 4.75 |
| Maguire Creek[d] | 1.52 | 9.04 | 8.83 | 0.27 | 1.26 | 0.88 | 19.40 | 2.23 |
| Phillips Creek | 3.32 | 0 | 12.56 | 0.60 | 0 | 1.26 | 15.88 | 1.86 |

a Carrying capacity is based on Ungulate Biophysical Capability Mapping (Demarchi 1996; see Appendix 8). Class I winter range can support 16-20 bighorn sheep/$km^2$; Class II, 12-16/$km^2$; Class III, 8-12/$km^2$).

b Stoddart Creek winter range includes Radium Hotsprings, Dry Gulch, Stoddart Creek, Shuswap Creek and Mount Swansea.

c Wigwam Flats includes Mount Broadwood, Rocky Ridge and Wigwam Flats.

d Maguire Creek includes Donald, Raymond, Maguire and Red Canyon Creek drainages.




range and grazing

**Figure 3. Location of bighorn sheep winter exclosures for Stoddart Creek.**

**Table 2. Site characteristics of grazing exclosures located on bighorn sheep winter ranges in the Rocky Mountain Trench, 1984 and 1987.**

| Location | Stoddart Creek | Columbia Lake | Premier Ridge | Bull River BR7 | Bull River BR9 | Wigwam |
|---|---|---|---|---|---|---|
| Slope (%) | 68 | 7 | 23 | 2 | 14 | 0 |
| Aspect | 210 | 270 | 290 | 343 | 190 | |
| Elevation (m) | 1052 | 862 | 1338 | 850 | 918 | 923 |
| Topography | Steep, Rolling | Gently Rolling | Gently Rolling | Flat | Gently Rolling | Flat |
| Soil Moisture Subclass | Semiarid | Semiarid | Submesic | Semiarid | Mesic | Semiarid |
| Soil Class[a] | OEB | OEB | OEB (80%) BR. GL (20%) | OEB | OEB | OEB |
| Soil Series | Mayook (70%) Keeney (30%) | Elko (60%) Myook (40%) | Keeney (80%) Flatbow (20%) | Wycliffe (60%) Saha (40%) | Wycliffe | Colin Creek |
| Soil Texture[b] | Silt-Loam | fsl gsl | fsl gsl | gsl fsl | fsl | gsil |
| Parent Mat.[c] | G1.L F1.G1 | F1.G1. G1.L. | F1.G1. Mo | Mo F1.G1 | F1.G1. | Col. |

a OEB-Orthic Eutric Brunisol; BR.GL-Brunisolic gleyed luvisol.
b fsl-fine sandy loam; gsl-gravely silt loam; gsil-gravelly silt loam.
c G1.L-Glacial lacustine; F1.G1-Fluvioglacial; Mo-Morainal; Col.-Colluvium.

### 2.2.2 Columbia Lake

*Topography.*— Bighorn sheep winter range referred to as Columbia Lake extends from the Kootenay River next to Canal Flats along the south and west slopes of Mount Sabine to the west face of the Stanford Range at Fairmont Hotsprings (Fig. 4). Total area of winter range is 28.4 km$^2$ (Table 2). Alluvial terraces and glaciolacustrine materials provide the parent material for the grasslands that border the east side of Columbia Lake (Lacelle 1976). Winter range lies between Columbia Lake at 862 m (2800 ft.) up to 1370 m (4500 ft.) in a 24-km$^2$ area. Preferred winter areas are located on the the west-facing slopes of Mount Sabine between Canal Flats and the Canal Flats Rod and Gun Beach 6 km north; the lower west-facing slopes of the Stanford Range and the alluvial terraces near Armstrong Bay; and the cliffs and glacial terraces overlooking the Columbia River 2 km south of Fairmont Hotsprings Resort. Bighorn sheep use <20% of the potential winter range because they need escape terrain near forage areas.

*Soils.*— Where bighorn sheep forage along the east side of Columbia Lake are Eutric Brunisols of three different series (Lacelle 1976, Appendix A). Soils located between Canal Flats and the T.V. Tower 3.2 km north are 60% Elko series and 40% Mayook series (Lacelle 1976; Appendix A). The Elko soil series is a shallow, fine, silt-loam developed on fluvioglacial material whereas the Mayook series is a stone-free silt loam that developed on glaciolacustrine material (Lacelle 1976). Soils located between the Canal Flats Rod and Gun beach and the T.V. Tower are well drained gravelly silt loams of the Eutric Brunisol type derived from morainal material (Lacelle 1976).

Soils of the slopes used near Armstrong Bay are Orthic Eutric Brunisols of the Rockbluff Series (Lacelle 1976) and rock outcrop (40%). This well drained gravelly silt loam soil is derived from colluvial parent material of limestone origin (Lacelle 1976).

Soils of bighorn sheep winter range located 2 km south of Fairmont are Orthic Eutric Brunisols of the Wycliffe (40%) and Rockbluff Series (40%)(Lacelle 1976, Appendix A). The Wycliffe Series are well drained gravelly silt loam soils derived from morainal parent material of limestone origin.

*Climate*.— Mean monthly temperatures at Canal Flats are similar to those at Cranbrook, and Elko but precipitation is lower, averaging 37 cm annually compared to 45 cm at Cranbrook Airport. Only 31% of the average annual precipitation or 11 cm occurs during the growing season (April to July), and evapotranspiration rates are high due to frequent hot, dry southwesterly winds. Snow rarely accumulates to >20 cm during winter months due to low average annual snowfall (140 cm) and frequent Chinook winds that generally melt snow within days of drop.

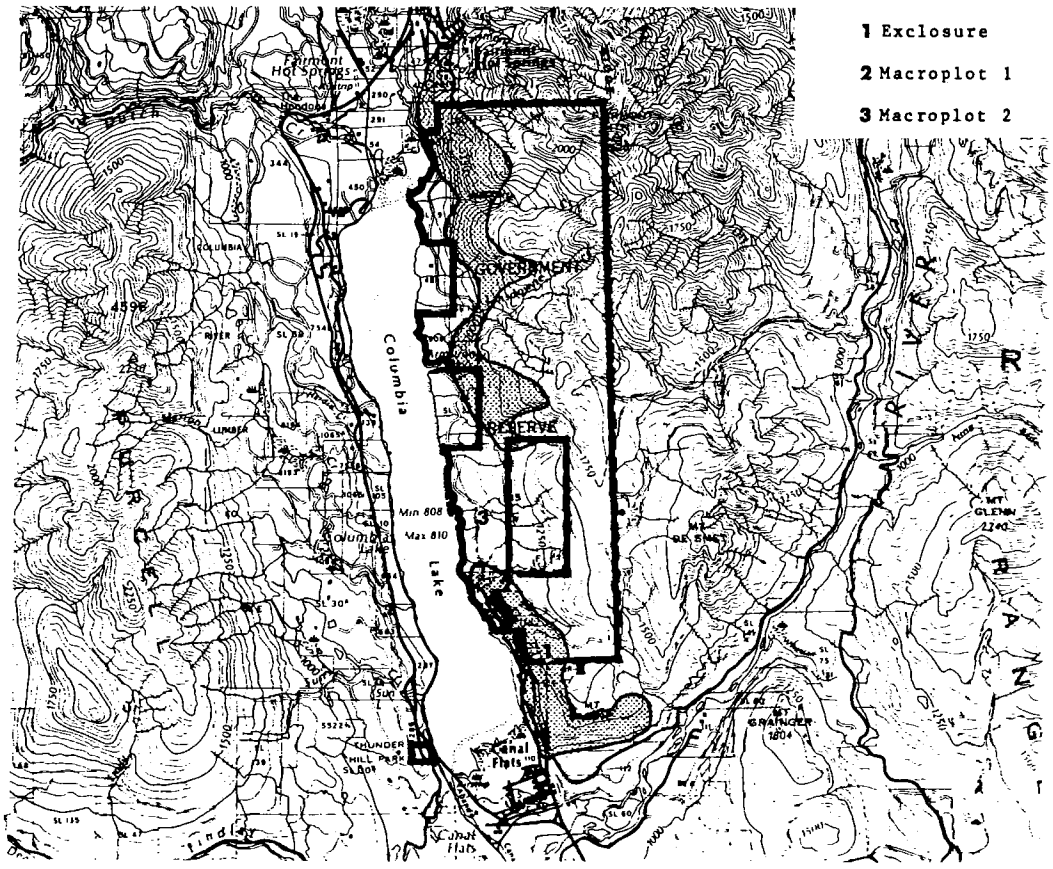



**Figure 4. Location of bighorn sheep winter ranges, grazing exclosures and fertilizer macroplots on the east side of Columbia Lake.**

*Range Vegetation.*— Junegrass and porcupine grass, pasture sage and rabbit-brush are the dominant species of vegetation on preferred foraging areas located near the T.V. repeater and Armstrong Bay. Downy wheatgrass is common beneath mature Douglas-fir, which sparsely covers the glaciofluvial benches used as winter range. Bluebunch wheatgrass is probably the climatic climax grass but is presently found only on steep slopes and beneath shrubs. The bluebunch wheatgrass - pasture sage community is the preferred forage type on west-facing slopes located above Eagle Nest Estates near Canal Flats, above Armstrong Bay and above the Columbia River near Fairmont. Rabbit-brush is the dominant shrub on alluvial fans while Rocky Mountain juniper is a codominant shrub on west-facing slopes adjacent to the alluvial fans (for more information, see Demarchi 1966).

Location of the range exclosure used to determine range condition and trend is shown in Figure 4.

### 2.2.3 Premier Ridge

*Topography.*— Winter range used by bighorn sheep on Premier Ridge lies between 1200 m and 1380 m elevation on gently to steeply rolling terrain from the cliffs of Premier and Quartz Lakes west 2 km to the west-facing slopes of Sheep Pasture and from the south end of Sheep Pasture north 3 km to the mid-section of Elk Pasture (Fig. 5). The area includes about 11.3 $km^2$ of Class I and II winter range for bighorn sheep and elk (Table 1).

*Soils.*— Soils of the Premier Ridge bighorn sheep winter range are of three series: 40% Bigfish, 40% Cervil, and 20% Flatbow (Lacelle 1976; Appendix A). Bigfish soils are rapidly drained gravelly silt loams (Lacelle 1976). The soil type is a stony acidic Orthic Eutric Brunisol overlying colluvial parent material. The Cervil Series are well drained gravelly silt loams. The soil type is Orthic Eutric Brunisol of limestone origin (Lacelle 1976). This soil is derived from morainal parent material. The Flatbow series is a well drained silt loam. The soil type is a Brunisolic Gray Luvisol derived from limestone morainal material and has a Bt horizon.

The soil moisture regime is submesic, and the soil nutrient regime is mesotrophic (Utzig *et al.* 1986).

*Vegetation history.*— Historically wild fire has occurred frequently on Premier Ridge. Most of Premier Ridge was burned in 1919 and in 1931. Extensive logging of the Ridge was done in the 1930's and 1940's and livestock grazed it for 10 months of the year. Deferred rotational grazing of livestock on Premier Ridge was initiated in 1976 following the construction of fencing and waterholes under Agricultural Rehabilitation Development Act (A.R.D.A.) funding. Forage utilization by livestock was moderate in 1984 and light or non-existent since then due to lack of water for the past 3 years and a light stocking rate by the permittee. Before 1984, forage utilization by livestock on the benchland near the top, west side of Premier Ridge had been heavy while use on west and east-facing slopes had been

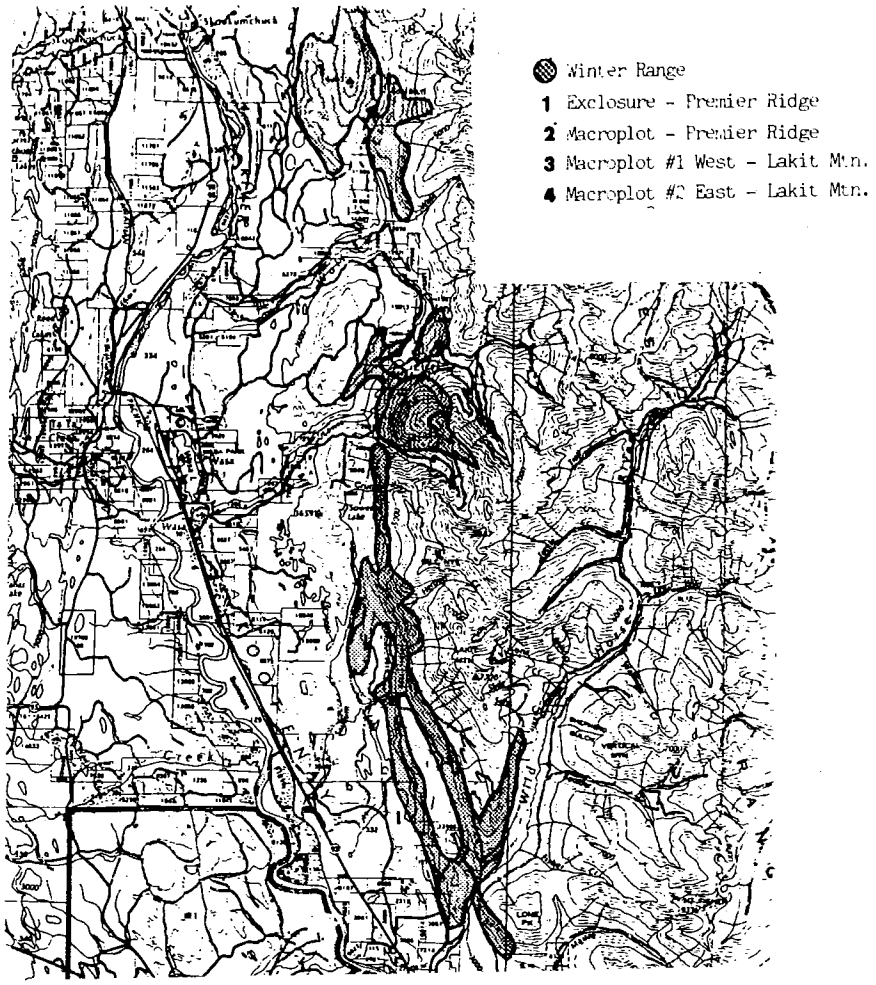



**Figure 5. Location of bighorn sheep winter ranges, grazing exclosures and selective logging macroplots on Premier Ridge, Lakit Mountain and the Lower Wildhorse.**

moderate to light. Winter and spring grazing pressure by elk and, to a lesser degree, mule deer and bighorn sheep has been heavy since 1980.

*Plant communities.*— This bighorn sheep winter range is located in the IDF3 or Kootenay Columbia Dry Cordilleran Douglas-fir biogeoclimatic variant of the Interior Douglas-fir biogeoclimatic zone (Utzig *et al.* 1986). The dominant tree is Douglas-fir, the dominant shrub is antelope-brush, and the dominant grass on west- and south-facing slopes is bluebunch wheatgrass. Heavily grazed areas on the ridge in Sheep Pasture are dominated by Canada bluegrass. The dominant shrubs in Quartz-Burnt Car Pasture where hand slashing occurred ~~are~~ were antelope-brush, saskatoon, and Rocky Mountain juniper, while the dominant grass was rough fescue. For a further description of plant communities on the bighorn sheep range, refer to Demarchi (1967). The exclosure was built in the bluebunch wheatgrass - antelope-brush plant community type on benchland located near the top of Premier Ridge. Macroplots were established due west of Quartz Lake in an area that was hand-slashed during the summer of 1987 (Fig. 5).

### 2.2.4 Wildhorse

*Topography.*— Winter range for the Wildhorse herds extends from Grundy Creek southeast 21 km to Sunk Creek (Fig. 5). A total of 11.8 km$^2$ of winter range are believed to be intensively utilized by the Wildhorse bighorn sheep herds (Table 1). Terrain of winter range located on the west-facing slopes between Horseshoe Creek and Mause Creek is gently to steeply rolling, with deeply nivated, fluvioglacial deposits at the toe of the slope (1000 m) and frequent rock outcrops above the 1200 m level. Terrain used as winter range on Lone Peak is very steep (≥60%), rocky and located between the 1200 and 1500 m level. Bighorn sheep use the steeply to gently rolling slopes of Brewery Ridge throughout the year but concentrate on the Ridge during winter months. The preferred escape terrain is the steep, rocky, southeast-facing slopes of Brewery Ridge overlooking Wildhorse Canyon whereas the preferred grazing areas are the gentle west- and south-facing slopes of Brewery Ridge. The gentle (35%) south-facing slopes of Lakit Mountain below 1500 m elevation are used from late winter throughout the summer.

*Soils.*— Soils of the Horseshoe to Mause Creek winter range are Eutric Brunisols of the Rosen Lake Series (Lacelle 1976) with frequent rock outcrops (Appendix A). This rapidly drained soil is a gravelly silt loam texture and is derived from colluvial parent material on steep slopes. Soils of Lone Peak are Eutric Brunisols of the Bigfish Series (Lacelle 1976). These stony limestone soils of gravelly silt loam texture are derived from colluvial parent material on steep slopes (Lacelle 1976). Soils of Brewery Ridge are Orthic Eutric Brunisols of the Rockbluff and Wycliff Series (Lacelle 1976). The Rockbluff Series are stony, rapidly drained, gravelly silt loam soils derived from colluvial parent material (Lacelle 1976). Wycliff soils are well drained gravelly silt loam soils derived from morainal material of limestone origin (Lacelle 1976, Appendix A). Soils of winter range located on Lakit Mountain are primarily Orthic Gray Luvisols of the Kinbasket Series (80%) and Orthic Eutric Brunisols of the Caithness Series (20%). Soils on the upper part of the Lakit winter range are Orthic Eutric Brunisols of the Rosen Lake Series. Soils of the Caithness Series are well-drained gravelly silt loams derived from colluvial parent material on steep slopes (Lacelle 1976). The Kinbasket Series are well-drained silt loam soils derived from morainal material of limestone origin.

*Climate.*— Climate of the Lower Wildhorse area is similar to that of the Cranbrook Airport, which lies 10 km west. Microclimate of the Lower Wildhorse area is believed to be slightly hotter and drier than the Cranbrook Airport area as is the bighorn sheep winter range located on the Lower Bull River (Eastman 1970).

*Vegetation.*— Winter range is located in the Dry Interior Douglas-fir biogeoclimactic zone (Utzig *et al.* 1986) where Douglas-fir is the dominant conifer with a minor component (<20%) of ponderosa pine and western larch. The dominant shrub is soopolallie on the Mause Creek and Lone Peak winter

ranges, while snowbrush and birch-leaved spirea are the codominant shrubs on Lakit Mountain. The dominant grass is bluebunch wheatgrass on Mause Creek and Lone Peak and the western slopes of Brewery Ridge while pinegrass and orchardgrass are the dominant grasses on Lakit Mountain.

### 2.2.5 Bull River

*Topography.*— Winter range for bighorn sheep extends from Fontaine Basin west 7 km to Picture Valley, and from Bull River north 4 km to Sunken Creek on the lower west-facing slopes of the Steeples Range (Fig. 6). The study area has four landforms, including the Bull River Valley, terraces adjacent to the Bull River, alluvial fans and mountain slopes (Eastman 1970). The moderate to steep slopes of the 130-m depression created by river erosion of glacial outwash are used during the rut and throughout the winter until late spring. Cliffs created by the erosive action of the Bull River (955 m) provide escape terrain and a lambing area for bighorns. Numerous natural mineral licks occur along the river breaks in alluvial clay deposits. Open grasslands and seral shrubland located on gently to steeply rolling terraces of glacial till adjacent to the Bull River are preferred grazing areas for bighorn sheep from November until

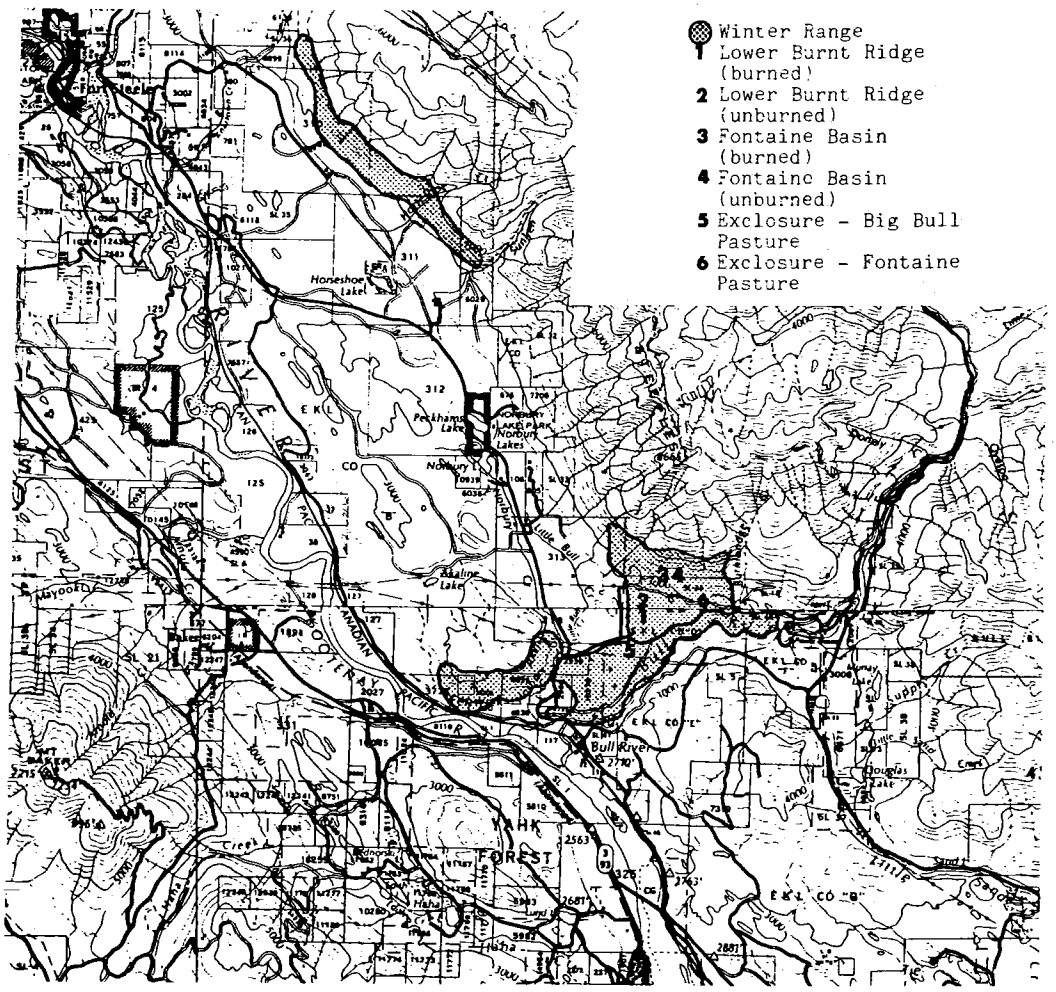



**Figure 6. Location of bighorn sheep winter ranges, grazing exclosures, and burn macroplots on the Steeples Range (Bull River).**

snow melt in late February. Open grasslands located below 1400 m on the Steeples are preferred grazing areas during late winter and spring months. Large alluvial fans have formed at the base of Petarbrook and Burntbridge Creeks (Demarchi 1966) and are lightly used by bighorn sheep due to the distance from escape terrain. Total area of winter range on the south end of the Steeples Range is estimated at 16.8 $km^2$ (Table 1).

*Soils.*— Soils of the fluvioglacial terrace deposits are well-drained Orthic Dystric Brunisols of the Saha Series (Lacelle 1976; Appendix A). These well drained grassland soils have a gravelly silt loam texture. Exclosure BR 7 in Big Bull Pasture lies on this soil type. Soils of the lower south slopes of the Steeples Range at Site BR 9 are of three Series including 40% Keeney, 40% Caithness and 20% Rosen Lake. All three series of soils are Orthic Dystric Brunisols derived from colluvium (Caithness, Rosen Lake), or fluvioglacial material (Keeney) on steep, rocky terrain.

*Climate.*— Climatic conditions at Bull River are similar to those at the Cranbrook Airport but annual precipitation is 12 cm greater at 57 cm and average temperatures are 2 C lower at Bull River (Eastman 1970). Average annual precipitation and temperatures at Aberfelde dam on the lower Bull River are similar to those of Elko and 54% higher than those of Canal Flats. Green-up occurs about 10 days later than at Canal Flats. Average precipitation during the growing season is 19 cm compared to 11 cm at Canal Flats and 14 cm at Cranbrook Airport. Average annual snowfall (138 cm) is similar to that of Canal Flats (140 cm) but lower than Cranbrook Airport (193 cm).

*Vegetation history.*— Two intense fires burned through lower Bull River in 1931 (Demarchi 1966) destroying a mature stand of interior Douglas-fir and ponderosa pine. The forest encroached very little over the past 57 years. Prescribed burns were conducted on parts of this bighorn sheep winter range in 1976, 1977, 1982 and 1985 to halt conifer encroachment and rejuvenate decadent shrubs. Most of the Crown range lying east of Highway 95A and Aberfelde dam was burned in 1976 and 1977; Fontaine Pasture was burned in 1982. Whitetail and Little Bull Pastures were burned in the spring of 1985.

*Plant communities.*— During winter, bighorn sheep prefer grazing the open grasslands on the alluvial terraces that border the Bull River or the steep southwest slopes of Bull Mountain. Sparse stands of immature Douglas-fir and ponderosa pine now cover these terraces. Antelope-brush is the dominant shrub throughout the winter range. Bluebunch wheatgrass is the dominant grass on Bull Mountain and the steep river breaks while Canada bluegrass is the dominant grass on heavily grazed slopes on lower Burntbridge Creek, where dense stands of Scouler's willow, paper birch and saskatoon also occur. For further information on this range unit, see Demarchi (1966). Vegetation on the upper Fontaine Basin on the Bull River is similar to that on Wigwam Flats, which lies in the same biogeoclimatic zone and has similar moisture conditions.

### 2.2.6 Wigwam Flats

*Topography.*— Winter range on Wigwam Flats runs from the west slopes of Mount Broadwood (also known as China Wall) west to the Elk River and from the Wigwam River in the south to the Elk River in the north (Fig. 7). Winter range covers 29.3 km$^2$ (Table 1) and has a high carrying capacity for ungulates (Demarchi 1967). The Elk and Wigwam Rivers have carved out deep canyons (150 m), which are now used as escape terrain by bighorn sheep. Three types of terrain are used as winter range: the steep south-facing colluvial slopes of China Wall; the alluvial terrace of Wigwam Flats proper; and the rolling rocky terrace west of Silver Springs Lakes (Demarchi 1976).

*Soils.*— Soils located on the lower south-facing slopes of Mount Broadwood are Orthic Dystric Brunisols of the Cooper Series (Lacelle 1976; Appendix A). This stony acidic soil has a gravelly silt loam texture and overlies limestone colluvium. Soils of Wigwam Flats proper are Orthic Dystric Brunisols of the Keeney Series derived from fluvioglacial parent material of limestone origin. This soil is shallow and well-drained with a fine silt loam texture. Parent material of the Wigwam Flats terrace is derived from glacial

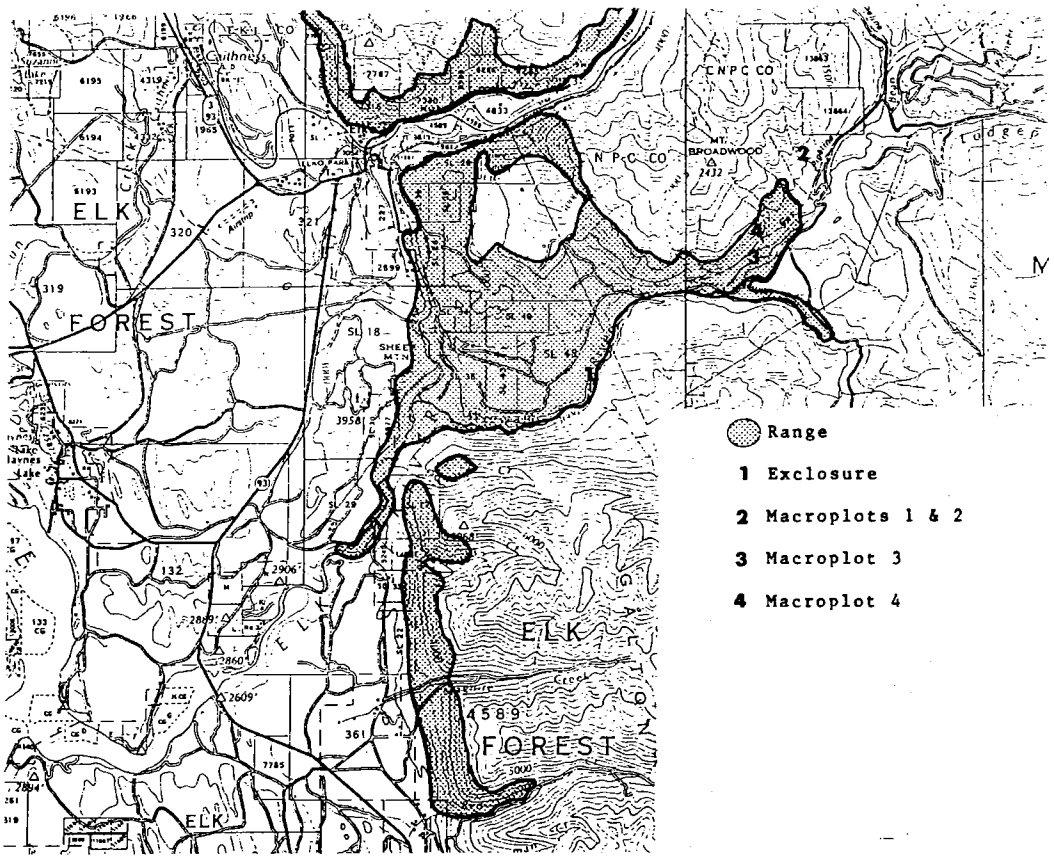



**Figure 7. Location of bighorn sheep winter ranges, grazing exclosures and fertilizer macroplots on Wigwam Flats and China Wall (Mount Broadwood).**

outwash originally located in the Silver Springs Canyon. Soils of Rocky Ridge are shallow Orthic Dystric Brunisols of the round Prairie Series (Lacelle 1976). These soils are well-drained gravelly silt loams overlying limestone colluvial parent material.

*Climate.*— Average monthly precipitation is higher at Elko near the Wigwam Flats winter range than at Canal Flats and Cranbrook Airport. During the active growing season, precipitation at Elko is nearly double that of Cranbrook Airport and Canal Flats. Moisture conditions are driest at Columbia Lake but long-term temperatures are similar on most bighorn sheep winter ranges bordering the southern Rocky Mountain Trench. Differences in precipitation may explain the fact that rough fescue is the climatic climax bunchgrass of Wigwam Flats while bluebunch wheatgrass is the climatic climax grass on bighorn sheep winter ranges located between Premier Ridge and Radium Hotsprings.

*Range vegetation.*— Winter range located on Wigwam Flats proper was covered with a dense stand of Douglas-fir until an August fire destroyed the conifer stand in 1885 (Lees and Clutterbuck 1887). Most of Wigwam Flats is now covered by a sparse stand of young to middle-aged seral forest land dominated by interior Douglas-fir and ponderosa pine. Western larch is codominant with Douglas-fir on more mesic sites located at the southern base of Rocky Ridge. The most common forage on Wigwam Flats is bluebunch wheatgrass and junegrass. Trembling aspen dominates the south-facing slopes of China Wall whereas interior Douglas-fir dominates the western slopes of Mount Broadwood. Bluebunch wheatgrass is the dominant grass on China Wall and soopolallie is the dominant shrub.

# 3. BACKGROUND INFORMATION

## 3.1. Focal Point and Spread of Disease

Sick and dying bighorn sheep were reported near the mouth of Maguire Creek (Fig. 8) on the Galton Range during the last week of December 1981. During the month of October, 1979-1981, slightly over 80 bighorn sheep had mingled with about 50 domestic sheep at the base of a ridge running between Maguire and Red Canyon Creeks. Within 2 weeks, between December 1981 and January 1982, the herd of bighorn sheep was reduced to 25 head and within 6 weeks only 14 were found alive on the winter range.

Bighorn sheep began dying on Wigwam Flats 4 km north of Maguire Creek during the last week of March 1982. Within 3 weeks, an all-age *Pasteurella* pneumonia dieoff had reduced the Wigwam Flats bighorn sheep population from about 300 to 150. During the next 3 weeks the herd

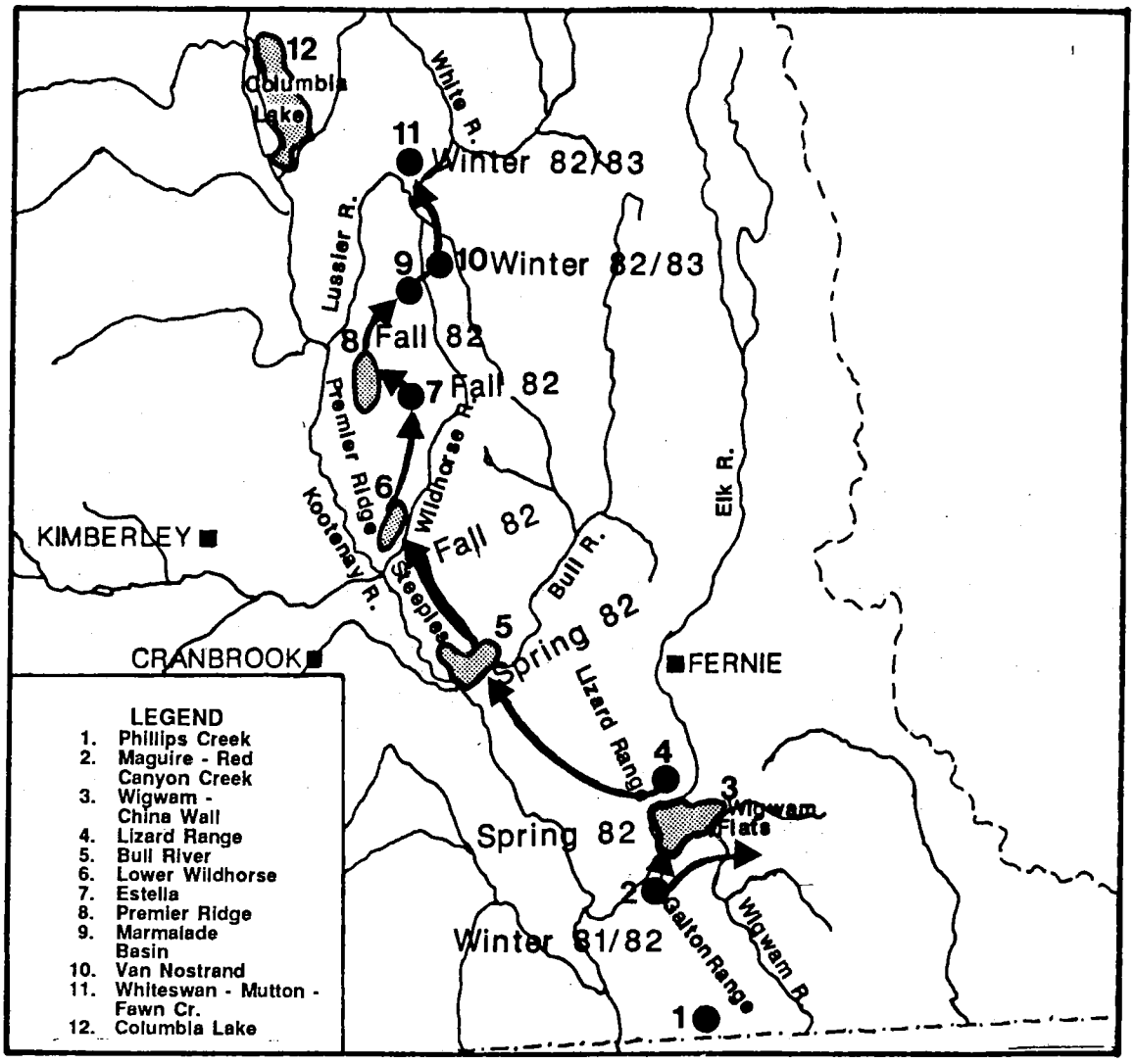



**Figure 8. East Kootenay bighorn sheep chronological order of epidemic dieoff (1981-1985).**

was reduced to 70 due to chronic *Pasteurella* pneumonia. By July 1982 sick bighorn sheep were observed on Mount Broadwood (China Wall) due east of Wigwam Flats (Fig. 8), and by September the population of bighorns using this range had dropped from 150 to 70.

A predieoff ground survey done in February 1982 recorded 267 bighorn sheep on Wigwam Flats: 55% ewes, 23% lambs and 22% rams. In February 1983 following the dieoff, 102 bighorns were observed on a thorough ground search of Wigwam Flats and Mount Broadwood: 67% were ewes, 3% lambs, and 30% rams. Only 1 breeding ram was >3-years-old during the winter of 1982-1983. In late February seven Class 2 and 3 (Geist 1971) rams appeared on Mount Broadwood after the prolonged rut was completed. None of the five Class 4 rams (Geist 1971) and only two of the 13 Class 3 rams survived the dieoff. Ninety-one carcasses were found on Wigwam Flats in April and May 1982; 85 were aged and sexed. Sex ratios of the carcasses found were 71% ewes, 5% lambs and 24% rams. Most carcasses found were between 4- and 7-years-old: 93% for ewes and 80% for rams. Mount Broadwood was not searched because carcasses collected on Wigwam Flats and sent to the Royal British Columbia Museum were not kept in B.C.

A soremouth epidemic had occurred in the Wigwam Flats herd during the winter of 1980/81, reducing the lamb crop to less than 10:100 ewes by 10 months of age. Soremouth has been related to overpopulation of bighorn sheep (Lance *et al.* 1981). The epidemic did not appear to have affected 23 Rocky Mountain bighorn sheep wintering on Sheep Mountain 6 km due south of Elko (Fig. 8), even though 85% of their cohorts had died <150 m east on Wigwam Flats directly across the Elk River Canyon.

Five of the 15 bighorn sheep translocated from Wigwam Flats to the lower Bull River in February and early March 1982 died 6 to 9 weeks after transplant - about the same time 85% of their cohorts on Wigwam Flats died. Although the transplants mixed thoroughly with the 40 to 45 bighorn sheep wintering on the lower Bull River winter range, no resident bighorns were found dead although five to ten of the resident rams were believed to have died on summer range. All the resident ewe herd apparently survived but <15% of the lambs born survived >3 months for 2 years after the ewes were exposed to disease. Half the transplants lived for 1 year and five lived for at least 3 years.

Bighorns of the Wildhorse and Estella herds were observed coughing in August and September 1982. Three sick rams from these herds were observed on summer range near Summer Lake in September 1982. Coughing ewes were observed on Lakit Mountain near the fire lookout 5 km north of the Wildhorse River in mid-September 1982. The Wildhorse herd was reduced from about 25 to 14 and the Estella herd was reduced from 70 to 55.

The epidemic affected the Premier Ridge herd on summer range overlooking the Lussier River and Diorite basin (Fig. 8) at the same time as the Wildhorse and Estella

herds. Radio-telemetry follow-up of collared transplants to the lower Wildhorse and ear-tagged animals from Premier Ridge indicated that part of the summer range was shared by these three herds. Disease was believed to have spread on this shared summer range. The Premier Ridge herd was reduced from 150 to 85 bighorns in the fall of 1982 with the death of about 20 to 25 mature rams, 15 ewes and 20 to 25 lambs. Lambs died within 3 months of birth and <10% of those born returned to fall range in October. Fourteen ewes and four lambs were captured and treated with an antiparasite drug, Ivermectin, and with selenium and Vitamins A, D and E to reduce trace mineral and vitamin deficiencies. None of the treated animals died over the next 4 months and 11 of the 14 were observed on winter range of Premier Ridge in December 1983.

Coughing bighorn sheep were observed in Marmalade Basin (Fig. 8) during the last week of November 1982. This herd wintered at high elevation (2400 m) on Mount McLean located 10 km east of Premier Ridge. Between March and May 1983, it was reduced from about 70 animals to 50. Five carcasses were found in a natural mineral lick on the Lussier River near Coyote Creek Ridge. The lick was used by this herd in February and March when deep snow on the upper slopes of Mount McLean forced evacuation of the Marmalade herd down to a clear-cut adjacent to the Lussier River located 5 km southeast of Mount McLean.

Sick rams were observed on the Van Nostrand Range in February 1982. This herd of 70 bighorns also winters at high elevation 10 km due east of Mount McLean (Fig. 8). Disease may have spread from the Marmalade herd to the Van Nostrand herd at the natural mineral lick located on the Lussier River. This lick was utilized by both the Marmalade and Van Nostrand herds. The Van Nostrand herd was reduced from 70 to 45 between March and the first week of May 1983.

The last herd affected was the Whiteswan herd, which winters at low elevation on the south-facing slopes above Whiteswan Lake (Fig. 8). This herd of 70 bighorns was reduced to 30 at the same time the Van Nostrand herd died. The disease was probably spread by rams that spent the early winter months on the Van Nostrand range located due east of Coyote Creek Ridge but moved 8 km north from Felix Basin to the Cave Creek area on Whiteswan Lake in late January when deep snow forced down-slope migration. Five ewe carcasses and a ram skull were found on the winter range located on the north side of Whiteswan Lake.

The dieoff did not proceed north of the Kootenay River even though the Columbia Lake and (north of the Kootenay River) Whiteswan herds mixed on summer/fall range located in Nine-Mile Creek and on Mount Glenn (Fig. 8).

The dieoff did not affect the Phillips Creek herd located 15 km south of the Maguire Creek herd although several ewes were observed coughing. The epidemic became evident in bighorn sheep herds of southwestern Alberta during the summer of 1982 and 60% of the Waterton Park herd

of 300 died by the spring of 1983 (J. Jorgenson pers. comm.). It was hypothesized by Alberta Wildlife personnel that the disease had spread from the Wigwam Flats/Mount Broadwood herds but movement over two mountain ranges and 90 km between these herds has never been documented. The epidemic did not spread to herds wintering on the west side of the Elk Valley despite a high probability of contact on summer range with herds from the Bull River, Wildhorse and Van Nostrand. Sick animals were observed on Mount Hornaday near Grace Creek (Fig. 8) and one lamb sacrificed from this herd was had chronic bronchial pneumonia. Bighorn sheep wintering on Sheep Mountain in the upper Elk Valley appeared sick due to delayed molt of winter pelage and heavy tick loads. Over half this herd of 75 bighorns was treated with antiparasite drugs at a bait site in March and April 1983. No carcasses were ever found and the herd has remained at 55-75 animals since then.

In summary, the dieoff affected all age classes but lambs and mature rams seemed most susceptible to acute pneumonia. Greatest herd reductions occurred near the origin of the dieoff and herds wintering adjacent to the southern Rocky Mountain Trench were most severely affected. Abnormally high post-dieoff lamb mortality occurred in all herds affected by the pneumonia epidemic and the effect lasted from 1 to 4 years depending upon the herd.

## 3.2 Cause of Deaths

Autopsy of two bighorn ewes sacrificed near the mouth of Maguire Creek indicated that verminous pneumonia may have been the cause of death (I. Thane, D.V.M., Cranbrook). We tried to assess the health status of domestic sheep near Maguire Creek but the land-owner who had initially reported dying bighorn sheep near his alfalfa field would not cooperate. The land-owner felt threatened by hunters who believed his domestic sheep were the source of disease in wild sheep without any direct evidence. Domestic sheep are known to be carriers of up to 26 different parasites and pathogens that can be transferred to wild sheep (Jessup 1985). In most cases where domestic and wild sheep have been penned in direct contact or close proximity, the bighorn sheep have died from bronchial pneumonia (Frinton 1978; Foreyt and Jessup 1982; W. Wishart pers. comm.; T. Thorne pers. comm.).

The condition of seven bighorn sheep found dead in Maguire Creek during the first week of January appeared to be excellent, judging by stored body fat, lustrous pelage and white bone marrow colour. Bighorn sheep with acute pneumonia had few outward signs of illness before death.

Bighorn sheep of Wigwam Flats began dying 3 months after those of Maguire Creek. Five ewe carcasses were collected from Wigwam Flats in early April and necropsied by Dr. G. Chalmers (D.V.M., Animal Health Division, Lethbridge Agricultural Research Station). Cause of death was determined to be "severe bronchial pneumonia" due to bacterial invasion of the lungs by *P. multocida* and *Corynebacterium pyogenes*. Little evidence

of lungworm damage was found. Three weeks later, 13 bighorn sheep carcasses from the Wigwam Flats herd were necropsied by Dr. G. Woebeser (D.V.M., Veterinary College, University of Saskatchewan, Saskatoon). All had moderate to heavy lung damage due to both *Protostrongylus stilesii* and *P. rushii* nematodes. Lungworm damage in bighorn sheep found dead was variable and not directly related to pneumonia. Two sick ewes transplanted 6 weeks earlier from Wigwam Flats to Bull River were autopsied by R. Lewis (D.V.M., Abbotsford Research Station), who found dorsal spined larvae (*Muellerius* spp.) were also present in lungs of bighorn sheep. Fecal lungworm larvae analysis of sick ewes located on Maguire Creek, Sheep Mountain, Wigwam Flats and Premier Ridge indicated that *Meullerius* infestations were widespread in herds of the East Kootenay. Both *Pasteurella multocida* and *P. hemolytica* were isolated from many of the bighorns autopsied from Wigwam Flats, Bull River and Premier Ridge. One mature ram sacrificed from the lower Wildhorse also contained *P. hemolytica* var. *nonhemolytic*. This variant of *Pasteurella* bacteria may have been present in many of the 22 bighorns collected but presence of this strain was not widely known until Drs. D. Onderka and Pantekoek were able to isolate this bacteria from bighorns sacrificed in Alberta.

Analysis of liver and kidney tissue indicated moderate to severe deficiencies in selenium and iodine with some animals showing deficiencies in copper (Appendix D). Selenium deficiencies in domestic sheep (N.R.C. Standards) reduce reproductive performance, and immune response lowering resistance to bacterial diseases and parasites (Macdonald *et al.* 1976; Van Vleet 1980; Puls 1981). Iodine deficiencies can also reduce fertility, reproductive performance, birth weight and growth rate of lambs (Puls 1981). Analysis of winter forage on Wigwam Flats (Eastman *et al.* 1971) indicated deficiencies in dietary trace minerals required by ungulates. Analysis of natural mineral licks located on winter ranges of herds that experienced the 1981/83 epizootic dieoff indicated that most were deficient in selenium, cobalt, copper, zinc and manganese (Appendix D). High levels of molybdenum, sulfur and iron in natural mineral licks may aggravate deficiencies in copper and selenium (Puls 1981). Arsenic and pthalium levels were high enough to be toxic in licks of the Lussier River and Whiteswan Lake areas (Appendix D).

None of the 22 nasal swabs collected from sacrificed or captured bighorn sheep were positive for virus. Fifteen blood samples were collected from captured or sacrificed bighorns and analyzed for adenovirus, bovine rhinotracheitus and parainfluenza-3 virus. Five of 16 blood sera samples taken from coughing sick ewes on Premier Ridge had a mild titre reaction to parainfluenza-3 virus. This virus is commonly associated with stress-related pneumonias in cattle and domestic sheep (Jessup 1985).

## 3.3 Post-dieoff Research

In July 1983, Dr. H Schwantje (D.V.M.) initiated a study to compare three Rocky Mountain bighorn sheep herds with

different disease histories. Health status was determined by examining the nutritional condition; microbiology, virology and serology status; pulmonary parasite loads; visual and histological lung lesions; blood chemistry; and trace mineral levels. Bighorn sheep, which had just survived an epizootic dieoff at Wigwam Flats, were compared with those from Columbia Lake, which historically should have been the next herd to experience the dieoff, and with those from Ewin Ridge in the upper Elk Valley, which had never experienced an epizootic epidemic. The three adult ewes and one juvenile ram sacrificed at Wigwam Flats had chronic pneumonia, plus secondary infections suggesting "residual effect of stressors associated with the acute dieoff in 1982" (Schwantje 1988*b*). Fatal pneumonias with little lungworm involvement in lambs were considered to be due to "... opportunistic invasion of bacteria after immunosupression of ewes and/or neonatal lambs." (Spraker and Hibler 1982; Schwantje 1988*b*). Only five lambs were observed in the Wigwam Flats herd in 1982 and 1983 and the late winter lamb:mature ewe ratios were 8:100 in January 1983; 8:100 in 1984; 16:100 in 1985; 20:100 in 1986; 55:100 in 1987 and 52:100 in 1988. The adult ewes that harboured chronic respiratory infections for at least 4 years after the dieoff were the source for further disease.

Bighorn sheep wintering on the east side of Columbia Lake had more severe lungworm infections than those of Wigwam Flats, but were in excellent body condition (Schwantje 1988*b*). Lamb:ewe ratios declined from 44:100 in 1980 to 35:100 in 1981. Necropsy and laboratory analysis indicated that both the Columbia Lake and Wigwam Flats herds had low total protein (TP), blood urea nitrogen (BUN), and fecal nitrogen (FN) levels suggesting inadequate winter range protein content (Schwantje 1988*b*). Total protein, BUN and FN values were higher on the Ewin Ridge herd where winter range productivity was high and forage quality was considered excellent (Scheurholz 1984).

## 3.4 Hypothesis of the Problem

Field research and necropsy results suggested that stress "may have contributed to death of bighorns through lowering immune response to disease" (Davidson 1982). Several potential stressors identified were poor quality winter forage; trace mineral deficiencies including selenium, iodine and copper; high winter tick (*Dermacentor albipictus*) loads in April and May 1982; cool wet spring weather (physiological stress), and a high degree of competition for forage and space with elk. The consensus at a bighorn sheep dieoff workshop held in Cranbrook in May 1983 was that "multiple stress factors appear to affect the herd disease level through individual sheep immunity or resistance to disease. A triggering factor was then able to touch off the death of sheep in the first herd ... Bacteria proliferated in the most susceptible sheep and then spread from sheep to sheep."

Common factors in the last three epizootic dieoffs were poor winter range condition, contact with domestic sheep, and severe winter or spring weather conditions. The

major conclusion of disease researchers was that managers of Rocky Mountain bighorn sheep should recognize when bighorns are entering a "zone of susceptibility" to disease and that managers must reduce stressors before the herd moves into that zone.

Many of the potential stressors affecting East Kootenay Rocky Mountain bighorn sheep can be explained by their foraging strategy as affected by past land alienations, and human land-use developments.

## 3.5 Foraging Strategy

Bighorn sheep select open grasslands and seral shrublands as winter range because they are not well adapted to cratering for forage through deep snow or for browsing. Short legs and stocky body make movement through more than 0.7 m (2 ft.) of snow difficult for bighorns (Telfer and Kelsall 1971). Narrow hooves and a relatively narrow muzzle make cratering for forage difficult in deep snow. Unlike the deer family, which use tongue and teeth to shear forage, the sheep family use only front incisors.

Grasses and forbs comprise a major part of bighorn sheep winter diets (Smith 1951; Schallenberger 1966; Constan 1967), which are of low nutrient quality (Hebert 1973). Grasses and forbs are preferred forage but shrubs may constitute a large part of the diet of bighorns (Johnson 1980; Stelfox *et al.* 1985). Grasses with fine blades, including sod grasses, needlegrass and conditioned bunchgrasses are preferred forage types (Wikeem and Pitt 1979; Johnson 1980).

Winter forage of bighorn sheep in many areas of the East Kootenay is deficient in nutrients required for body maintenance (Hebert 1973). Protein, phosphorous, iodine precursors, copper and selenium are deficient in forage and mineral licks do not supplement these deficiencies (Hebert 1973; Davidson 1983).

The winter forage strategy of several bighorn herds make them susceptible to man-made environmental disturbances. Ten of the 22 herds of Rocky Mountain bighorn sheep that are found in the East Kootenay overwinter on the lower western slopes of the Rocky Mountains where a combination of warm southwesterly winds (Chinooks), lower snowfall, and warmer temperatures create relatively snow-free grasslands and seral shrublands.

With spring green-up, herds that wintered on the lower slopes of the Rocky Mountains move up-slope taking advantage of better quality forage in early growth stages (Hebert 1973). By late June, lambing is complete and the ewe-lamb herds move to grasslands located on east and north-facing slopes of the Rocky Mountains where cooler temperatures and better moisture conditions maintain high quality forage throughout the growing season. As snow accumulates in the subalpine and alpine tundra areas in late September and early October, bighorn sheep move to pre-rut ranges located on west-facing slopes at lower elevation. With the onset of the rut, during the first week of November, most bighorn sheep have returned to winter ranges.

Hot, dry summers cause drought conditions in low elevation forage by mid-July and seed set has normally occurred in grasses by this time. Between August and March bighorn sheep utilize low elevation ranges, which have sub-maintenance levels of nutrients and energy (Hebert 1973). Although quantity of winter forage is seldom a problem to bighorn sheep wintering at low elevation in the Kootenays, requirements for nearby escape terrain (<200 m) restrict the amount of range available. Harassment by predators, competing herbivores, humans or domestic dogs reduces the distance that bighorn sheep will comfortably forage away from escape terrain (MacArthur *et al.* 1982; Stemp 1983). Proximity of these low elevation ranges to private land has placed bighorn sheep in jeopardy of exposure to at least 26 different pathogens and parasites potentially transferrable from domestic livestock (Jessup 1985). Notably, those herds that winter on the low western slopes of the Rocky Mountains have historically been most severely decimated by disease. Those herds whose winter range is most rapidly declining due to forest encroachment and land alienations are the same herds that are exposed to parasites and pathogens from domestic livestock. The low elevation open grasslands and seral shrubland sought by bighorn sheep are also preferred winter range sites for elk, mule deer and white-tailed deer. On winter ranges where elk densities exceed 30/km$^2$ such as Wigwam Flats and the east side of Columbia Lake, direct competition for forage occurs.

Bighorn sheep that winter in the middle section of the Rocky Mountains utilize south-facing alpine tundra grasslands at mid- to high elevation (2000 to 2600 m) where warm Chinook winds blow range free of snow. Herds wintering on the east and west sides of the Elk River in the upper Elk Valley must live on dried forage for 10 months of the year, but quality of freeze-dried forage is believed to be above maintenance level requirements (Johnson *et al.* 1968; Hebert 1973). Without Chinook winds, south-facing alpine tundra slopes quickly accumulate deep snow, which may lead to starvation such as occurred in the winter of 1983/84 in the Crossing and Quarrie Creek herds of the Upper Elk Valley (Fig. 2).

A third winter forage strategy is used by bighorn sheep wintering at low to mid-elevation (1700-2300 m) on the Galton Range near Grasmere (Fig. 2). Medium to low elevation open grasslands and seral shrublands located on steep south- or west-facing slopes are used until snow accumulations prevent effective foraging activity. By mid-January, bighorn sheep move beneath mature Douglas-fir - ponderosa pine stands where thermal cover and forage are provided by the shedding and shading effect of the canopy. By late March, bighorns move down to low elevation grasslands, where snow has blown off or melted. These grasslands are often located on range that has been alienated to agriculture.

A fourth foraging strategy is used by bighorn sheep herds wintering on the Van Nostand Range, Nine Mile, Mount Glenn, Marmalade and the Estella (Fig. 2). They

winter at high elevation until snow depths make foraging activity difficult and then move down to valley floors on west-facing slopes.

## 3.6 Land Alienation

Recreational, residential, industrial and agricultural developments over the last 50 years have alienated nearly 1/4 of traditional bighorn sheep winter and spring range for Rocky Mountain bighorn sheep bordering the Rocky Mountain Trench. Bighorn sheep winter range located near the town of Spillimacheen and near the mouth of Luxor and Kindersley Creeks was sold to American Christmas Tree Farm interests under Tree Farm License 13 in 1954 (Demarchi 1985). Recreational developments such as Fairmont Hotsprings, Radium Hotsprings and Eagle Nest Estates were located on key bighorn sheep winter range. Industrial developments including "Westroc" gypsum mine at Windermere, and Fording Coal and Line Creek Coal mines in the Upper Elk Valley were located on bighorn sheep range in the 1960's. Residential developments at Radium Hotsprings, Fairmont Hotsprings, Canal Flats and Elko were located on bighorn sheep winter range. Agricultural developments adjacent to the Galton Range, the Steeples Range and the Stanford Range (Canal Flats to Kootenay National Park) have disrupted traditional use of winter range by bighorn sheep and have provided a source of pathogens from domestic livestock.

## 3.7 Forest Encroachment

Forest encroachment on most of the open grassland range is occurring at a rate of 1 to 2% per year in the southern Rocky Mountain Trench. Effective control of wild fire since the late 1930's and lack of extensive logging have permitted conifer invasion of open grasslands required as winter range. Before the 1940's, wild fire occurred frequently and sometimes covered vast areas. A slash fire, which started in the Gold Creek area in 1936, burned through southeastern British Columbia to the eastern slopes of Alberta. These fires had dramatic affects upon wildlife distribution and abundance. In 1887, two English hunters named Lees and Clutterbuck (1887) bemoaned the dearth of wildlife on Wigwam Flats, which was a tangled mass of dead standing conifers following a wild fire. They quickly moved south near Tobacco Plains where game was plentiful beneath the stands of mature larch. Wigwam Flats now contains one of the most extensive open grassland ranges in the East Kootenay with high densities of game animals whereas Tobacco Plains now has a dense stand of ponderosa pine and Douglas-fir and less game than Wigwam Flats.

## 3.8 Wild Fire and Logging

Natural fire occurred every 2 to 13 years in the dry, southern end of the Rocky Mountain Trench (Dorey 1979) and every 60 to 70 years at the mesic northern end (Tande 1979). Fine fuels accumulated rapidly due to self-pruning of lodgepole pine and needle shedding of ponderosa pine. Hot summer weather created dry fuel and lightning strikes provided ignition. Fire hazards were elevated by numerous logging operations that existed in the East

Kootenay between 1898 and the late 1930's. Logging operations became active in the Kootenays to supply railroad ties for the Canadian Pacific Railroad. The extension of this railroad from Crowsnest Pass to Kootenay Lake in 1898 and the Great Northern Railroad from northern Idaho to Elko and Fernie, B.C. spawned the first logging operations in the East Kootenay. By the early 1900's over 600 men were employed in logging operations at Bull River (V. Caselman pers. comm.). By the late 1920's, more than 30 sawmills employing more than 1100 were active between Invermere and Grasmere (R. Mils pers. comm.). Also, on-site construction of railroad ties using broad-axes created large amounts of slash. Fire was used to dispose of litter but when escapes occurred, uncontrolled wild fire resulted because no equipment was available for control. When the town of Fernie was destroyed by a slash fire in 1908, the B.C. Forest Service adopted a policy of attempting to suppress all wild fires.

## 3.9 Range Condition

Wild fire and logging operations were instrumental in creating open grasslands and seral shrublands needed as winter range by bighorn sheep and mule deer. Game populations should have expanded rapidly in response to creation of vast expanses of grassland created by wild fires in the 1920's and 1930's but this did not occur. Deer populations expanded slowly until 1948 and 1955 when severe winter conditions reduced numbers (B. Petrie, R. Mills pers. comm.). Elk populations expanded slowly during the 1930's and 1940's (P. Lum pers. comm.), and rapidly during the 1950's and early 1960's (R. Demarchi pers. comm.). A game distribution map for the East Kootenay drawn by Kootenay Brown in 1928, indicated that elk could not be found west of Hosmer, B.C. or the headwaters of the Middle White River. Bighorn sheep populations expanded following wild fires in the 1920's and 1930's but populations declined dramatically in the early 1920's, 1940's, 1960's and 1980's due to lung disease. All known epidemics began in herds having a high population density on low quality overgrazed range.

Paradoxically, range condition in the Rocky Mountain Trench was poor when wild fire and logging created winter and spring range of unprecedented size. The cause of poor range condition was overgrazing by domestic cattle, sheep and horses. Cattle and domestic sheep grazed Crown land in the Rocky Mountain Trench for 10 months of the year, while thousands of wild horses roamed the Rocky Mountain Trench year-round. Horses were first brought to the Trench in the late 1700's by the Kootenay Indians who had won them in skirmishes with the Blackfoot Indians in the foothills of Alberta (Thompson Expedition 1799 to 1812 in Hopwood 1971). By the time of the Palliser Expedition in 1858,Indians had many horses(Hanic and Hanic 1979). Many horses and some cattle were imported to the East Kootenay by gold miners seeking their fortune in the Wildhorse River, Findlay Creek and Perry Creek between 1858 and 1890 (Christian 1967). In the 1880's, horses were used to haul lead, zinc and silver ore from the Sullivan and Northstar Mines located near

Kimberley, B.C. to Bummer's Flats on the Kootenay River some 48 km (30 miles) away. Logging used many horses to skid logs and railroad ties to rivers or flumes for transport to more than 30 mill yards operating in the East Kootenay. Horses were used to transport goods and supplies from northern Washington and Idaho or from the West Kootenay by the Kinbasket Trail (Christian 1967). In the 1930's, horses were used by many small business loggers operating in the Trench to skid logs to portable mills (R. Mills pers. comm.).

Most horses were abandoned on Crown range when men of the Kootenays joined the WWII war effort (R. Mills pers. comm.). By the late 1940's, between 2000 and 2500 horses roamed between Golden and the American border (Berry *et al.* 1971). Following WWII, the B.C. Forest Service declared a bounty on wild horses and sponsored roundups (R. Mills pers. comm.). By the late 1960's, professional cowboys and bounty hunters had eliminated the wild horses.

Although horse populations declined during the post-war period, cattle numbers rapidly increased as war veterans took up ranching. Between the early 1950's and the mid-1960's, cattle grazing pressure on Crown range in the Rocky Mountain Trench increased from about 30 000 AUM to over 76 000 AUM (Demarchi 1971). Over 6000 domestic sheep also grazed from Newgate to Ta Ta Creek on either side of the Kootenay River in the 1930's and 1940's (R. Mills pers. comm.).

The Grazing Act was established in 1919 by the B.C. Forest Service to regulate livestock use of Crown range. Lack of range fencing and waterholes and a 10-month grazing season meant that livestock use of Crown range was virtually uncontrolled until the late 1940's when turnout dates and stocking rates began being regulated by the B.C. Forest Service. Year-round grazing by wild horses and 8- to 10-month grazing by domestic cattle and sheep resulted in severe overgrazing and deterioration of range condition. All major bighorn sheep ranges in the Rocky Mountain Trench were in poor condition when analyzed by Ministry of Environment personnel in 1966 (D. Demarchi 1966). Overgrazing of Crown range had a disastrous effect upon bighorn sheep. Bighorn sheep that died at Bull River during the winter of 1964/65 were starving (B. Gower, L. Hansen pers. comm.). Livestock had denuded this wildlife winter range during the previous grazing season and 1 m of snow had accumulated in January (R. Demarchi pers. comm.).

Grazing pressure on Crown range was not effectively regulated until 1975 when Coordinated Resource Management Plans (C.R.M.P.'s) were required for users of Crown range. Through joint federal-provincial agreement the Agriculture Rehabilitation Development Act (A.R.D.A.) was created to fund the fences and waterholes needed to manage grazing on Crown range. Fencing and waterhole construction permitted deferred rotational grazing that have resulted in improved range condition over the past 14 years. Unfortunately, gains in productivity and quality of range made through

C.R.M.P.'s have gradually been eroded through forest encroachment and land alienations.

Joint range enhancement projects were begun by the Forest Service and the Wildlife Branch in the East Kootenay in 1976 to halt forest encroachment on open range and promote production of high quality forage. Since then, >30 000 ha of range have been treated with prescribed fire, selective logging, slashing and spacing of conifers, seeding of forage and fertilization. Since 1976, spacing projects for conifers occupied nearly half the area treated, which has little effect upon range production or quality when 800+ conifers/ha are left standing. Second-growth conifer stands are encroaching on open range at a rate of about 13 000 ha per year in the Cranbrook Timber Supply License Area (T.S.A.) alone.

Although open grasslands have diminished, demands for Crown range have increased. Most key bighorn sheep ranges are also important elk and mule deer winter ranges. The elk population increased from <7000 in 1974 to >28 000 in the East Kootenay with about two-thirds of this population wintering on Crown range in the Rocky Mountain Trench. Grazing pressure on bighorn sheep winter ranges located at Stoddart Creek, Columbia Lake and Wigwam Flats has been excessive for 25 years even though all domestic livestock have been removed.

Livestock producers have only received a 10% increase in A.U.M.'s since initiation of C.R.M.P.'s in 1975 and are demanding a better return for the $3 million that was invested on Crown range through A.R.D.A. The Forest Service has refilled all vacancies created by the Libby pondage buy-out and Wildlife Branch purchases.

## 3.10 Summary

Past dieoff research has indicated that high densities of bighorn sheep on poor quality winter range and contact with domestic livestock have led to lung disease in bighorn sheep. Alienation of Crown range, forest encroachment, suppression of wild fire, and lack of logging in the Rocky Mountain Trench have reduced the amount of open range available to wildlife and livestock. Both wildlife managers and livestock producers have increased demands upon Crown range in the Rocky Mountain Trench while the forage supply has diminished.

# 4. TRENDS IN FORAGE PRODUCTION AND CONDITION OF BIGHORN SHEEP RANGE

Forage available to bighorn sheep on winter range is related to forage production, forage use before the winter season, snow depths (Petocz 1973), and distance to escape terrain (Stemp 1983). Quality of forage available on low elevation bighorn sheep winter range in the East Kootenay is not sufficient for maintenance of body weight (Hebert 1973) and bighorn sheep may lose 12 to 25% of their body weight (Stelfox and Poll 1978). Quantity of winter forage available to bighorn sheep wintering adjacent to the southern Rocky Mountain Trench appeared to be declining due to forest encroachment and lack of logging or fire. Forage production of bighorn sheep range is shared with livestock on Premier Ridge, the lower Bull River and the lower Wildhorse areas.

Most low-elevation bighorn sheep winter ranges in the East Kootenay are also preferred winter range for elk (*Cervus elaphus nelsoni*) and mule deer (*Odocoileus hemionus hemionus*) consequently forage competition could occur. Forage competition on winter ranges is reduced through spatial separation of game species (Hudson *et al.* 1975) having different forage preferences. Competition for forage may occur between elk and Rocky Mountain bighorn sheep where little forage diversity occurs due to past overgrazing. Winter ranges located on the east side of Columbia Lake and on Wigwam Flats have had an 80 to 100 years of overgrazing by livestock and wildlife. Although all livestock were removed from these ranges by the mid-1960's (Demarchi 1966), range condition and trend on these two ranges had not improved by 1982. Elk populations had increased from 7000 in 1974 to 28 000 (R. Demarchi pers. comm.) and were reaching densities of 40/km$^2$ on the east side of Columbia Lake and Wigwam Flats. Bighorn sheep densities were 30 to 40/km$^2$ on these winter ranges before the 1981/83 dieoff. Both elk and bighorn sheep densities on winter range were similar to those which had occurred before the 1964/67 dieoff. Unless range condition and production had improved since the 1960's, winter range was unlikely to support these game densities without a deleterious effect upon bighorn sheep. An analysis of forage production, range condition and trend was therefore initiated.

## 4.1 Methods

### 4.1.1 Air photo analysis

Air photographs (1:40 000 scale) taken in 1950 to 1952 were compared with air photographs taken in the same locations at about the same scale in 1981. Bighorn sheep winter ranges adjacent to the southern Rocky Mountain Trench were compared where photographs could be obtained. The amount of forest encroachment on bighorn sheep winter range could be determined for Premier Ridge, Wildhorse, Bull River, Wigwam Flats and the Galton Range. In locations where forest encroachment or succession had occurred most slowly, it was assumed that, if suitable soil existed, the site was more arid and suitable for grassland and seral shrubland. Air photograph analysis coupled with knowledge of winter distribution of bighorn sheep and range capability from ungulate capability mapping ~~done by D.~~ (Demarchi ~~in~~ 1986) provided the basis for selection of potential habitat enhancement sites.

### 4.1.2 Floristics in 1966 and the 1980's

Range condition and trend were determined by comparing grazed and ungrazed plant communities on key bighorn sheep winter range adjacent to the southern Rocky Mountain Trench. Range exclosures of 30.8 x 15.4 m (50 x 100 ft.) were constructed in 1966 and in 1983 to exclude grazing pressure by large mammals. Range exclosures were examined at Stoddart Creek (Stelfox *et al.* 1985), the east side of Columbia Lake, Premier Ridge, the lower Bull River (2) and Wigwam Flats. Exclosures built on Premier Ridge, the east side of Columbia Lake and Estella in 1966 could not be re-examined because fencing had fallen down. Exclosures were constructed on Premier Ridge and the east side of Columbia Lake in 1983 to assess condition and trend of these important bighorn sheep winter ranges. Physical characteristics of exclosure sites are given in Table 2.

Five randomly placed 1 m by 15 m macroplots were established inside and immediately adjacent outside the exclosure using the method of Poulton and Tisdale (1961). Canopy cover, species composition, and frequency of microplots were estimated using the method of Daubenmire (1959). Microplots, 0.5 $m^2$, were placed every 2 m along the macroplot. Due to early curing of many grass and forb species, accurate plant identification was often difficult when done in July. Exclosures built and analyzed in 1966 at Wigwam Flats and Bull River were re-examined in 1984 to determine range condition and trend. Because microplot size was 0.25 m in 1984 and 0.1 m in 1966, frequency data could not be compared.

Range condition was determined by comparing plant composition as determined from macroplot analysis with that expected under climatic climax conditions (Wroe *et al.* 1972). Range condition classes were rated as follows: Excellent = 76 to 100% climax vegetation, Good = 51 to 75%, Fair = 26 to 50%, Poor = 0 to 25%. Trend in range condition was evaluated by comparing range condition at time of analysis with that of 1966.

### 4.1.3 Yields in 1984 and 1966

Production of grasses and forbs was determined by clipping at ground level and separating by type of forage. Current annual growth of shrubs including leaves was clipped and bagged. Litter was collected before forage was clipped. Samples were dried in a microwave oven at low temperature for 10 minutes. All samples were immediately weighed after drying. Forage production was determined from five 1-$m^2$ microplots randomly placed in each plant community type located on bighorn sheep winter range in 1966 (Eastman 1970).

### 4.1.4 Animal use in 1984 and 1966

Animal use of range adjacent to exclosures was estimated by counting pellet groups located within a 1 m by 15 m macroplot placed parallel above each vegetation macroplot. Pellet groups were separated by animal species. Deer and bighorn sheep pellet groups could not be separated due to the similarity in size and shape. Twenty pellets were considered to constitute one group and the defecation rate of game on winter range was assumed to be 14 times per day (Neff 1968). Pellet groups of game animals were assumed to remain intact for 4 years whereas cattle deposits were assumed to remain intact for 3 years. Animal use was determined by the following formula:

$$\text{Animal Unit Months (AUMs)/ha} = \frac{\text{Pellet piles/ha}}{(14)(4)(30)(6)}$$

An AUM is equal to the amount of forage consumed by a 454-kg cow per month. Six deer or bighorn sheep or 2.8 elk eating forage for 1 month equals 1 AUM.

Impacts of prescribed fire upon vegetation response were determined using the same method as that used in determining grazing impacts. Slope, aspect, soils and elevation of burned and adjacent unburned, or logged and adjacent unlogged macroplots were similar. The response of vegetation was determined 3 months, 15 months and 27 months after prescribed fire on 17 March 1982 on lower Fontaine pasture of the lower Bull River.

Impacts of selective logging upon vegetation were determined at two sites on lower Lakit Mountain at 15-month and 51-month intervals following completion of logging in March 1983. Both sites were burned by an intense wild fire in August 1986 so a three-way comparison between these two sites was done in July 1987.

## 4.2 Results

### 4.2.1 Stoddart Creek (includes Mount Swansea and Radium Hotsprings)

*Paired plot comparison.*— Ground cover of grasses and forbs decreased on both grazed and ungrazed range, but the decrease was more dramatic on grazed range (Fig. 9) between 1966 and 1984. Litter cover increased on both grazed and ungrazed range while the amount of bare ground decreased dramatically. Shrub cover increased on ungrazed range and remained fairly stable on grazed range (Stelfox *et al.* 1985).

Decline in forb cover on grazed and ungrazed range could largely be attributed to decline in cover of spreading dogbane (Table 3). Yellow aster, wild blue flax, and yarrow are unpalatable forb species that increase ground cover when grazed and decrease ground cover when ungrazed.

Largest shrub cover increases occurred on ungrazed range due to pasture sage and rabbit-brush. Increases in ground cover of shrubs on grazed range were largely due to rabbit-brush. Pasture sage is a preferred forage species at Stoddart Creek (Stelfox 1974) and responds as a decreaser species under heavy grazing pressure.

Litter cover and cryptogams increased between 1966 and 1984 and the amount of bare ground decreased dramatically.

Forage production on grazed range at Stoddart Creek averaged 400 kg/ha between 1967 and 1970 (Demarchi 1967), which is similar to 367 kg/ha produced on grazed range in 1984 (Stelfox *et al.* 1985). Forage production on ungrazed range was 1012 kg/ha (Stelfox *et al.* 1985) indicating that grazing pressure has reduced productivity of this range.

*Range condition and trend.*— Condition of grazed range in 1984 at Stoddart Creek remained poor to fair (Stelfox *et al.* 1985) and the trend was stable or slightly downward.

*Animal use.*— Bighorn sheep use of winter range located at Stoddart Creek was reported (Stelfox *et al.* 1985) to be 26% less in 1984 than in 1966 whereas mule deer use was 15% greater. Elk pellets were not found in 1984 but were about .04 AUM in 1966. Bighorn sheep biophysical capability is shown in Appendix C.

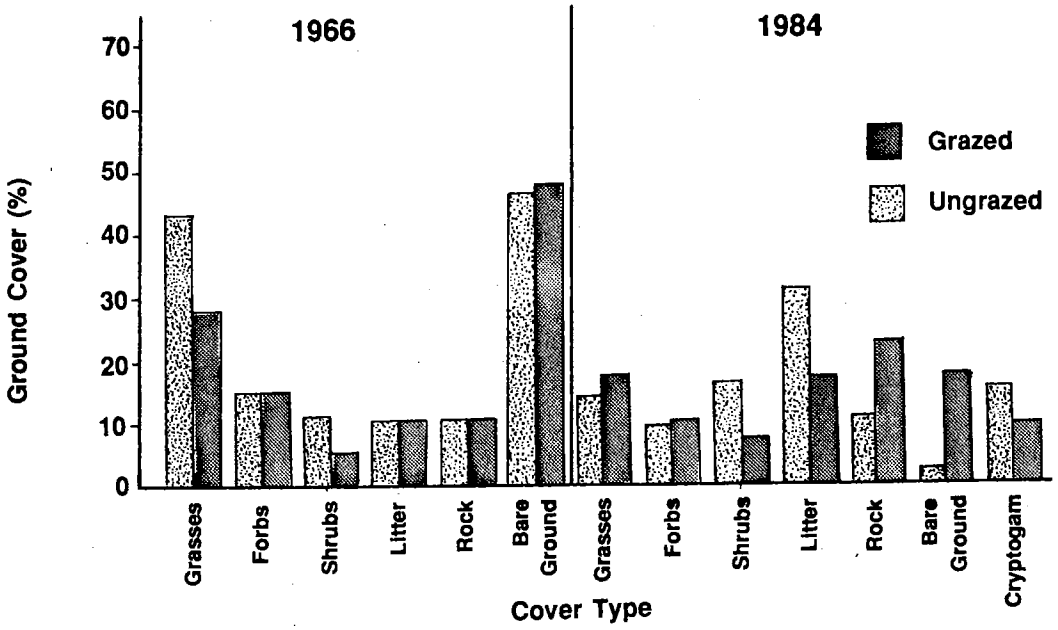



**Figure 9. Ground cover of grazed range compared to ungrazed range located near Stoddart Creek, July 1966 and 1984.**

### 4.2.2 Columbia Lake

*Paired plot comparisons of floristics, 1984.*—Ground cover forage was higher on ungrazed than grazed range due to significantly higher cover of grasses inside the exclosure (99% C.L., Fig. 10*a*, Appendix E). Frequency of grasses was also higher on ungrazed range (Table 4).

The dominant grass was porcupinegrass on ungrazed range and, after 1 year, it had significantly more ground cover inside the exclosure than outside (Table 4). Ground cover of downy wheatgrass was significantly higher inside the exclosure but this may have been due to placement of the exclosure (95% C.L.). Only 6% of 40 microplots contained downy wheatgrass

**Table 3. Ground cover of grazed range compared to ungrazed range at Stoddart Creek, July 1966 and 1984.**

| | Percent Cover[a] | | | |
|---|---|---|---|---|
| | Grazed | | Ungrazed | |
| | 1966 | 1984 | 1966 | 1984 |
| GRASSES | | | | |
| Bluebunch wheatgrass | 27.7 | 16.5 | 38.8 | 8.0 |
| Rough fescue | 0 | 0 | T | 1.5 |
| Junegrass | 0 | 1.0 | 2.4 | 4.1 |
| FORBS | | | | |
| Spreading dogbane | 10.3 | 0.6 | 3.4 | 0.6 |
| Aster | 1.2 | 2.0 | 2.6 | 2.3 |
| Hairy golden-aster | 1.2 | 2.0 | 2.6 | 2.3 |
| Spike-like goldenrod | 0.6 | 1.8 | 0 | 1.4 |
| Yarrow | 0 | 1.2 | 5.6 | 4.2 |
| Wild flax | 0.8 | 0.2 | 1.2 | T |
| SHRUBS | | | | |
| Pasture sage[b] | 2.8 | 2.6 | 13.7 | 21.2 |
| Rabbit-brush | T | 3.3 | T | 1.2 |

a Species having <1% ground cover were not included in this table.
b Pasture sage was called a shrub by Stelfox (1976) but is called a forb by the author.

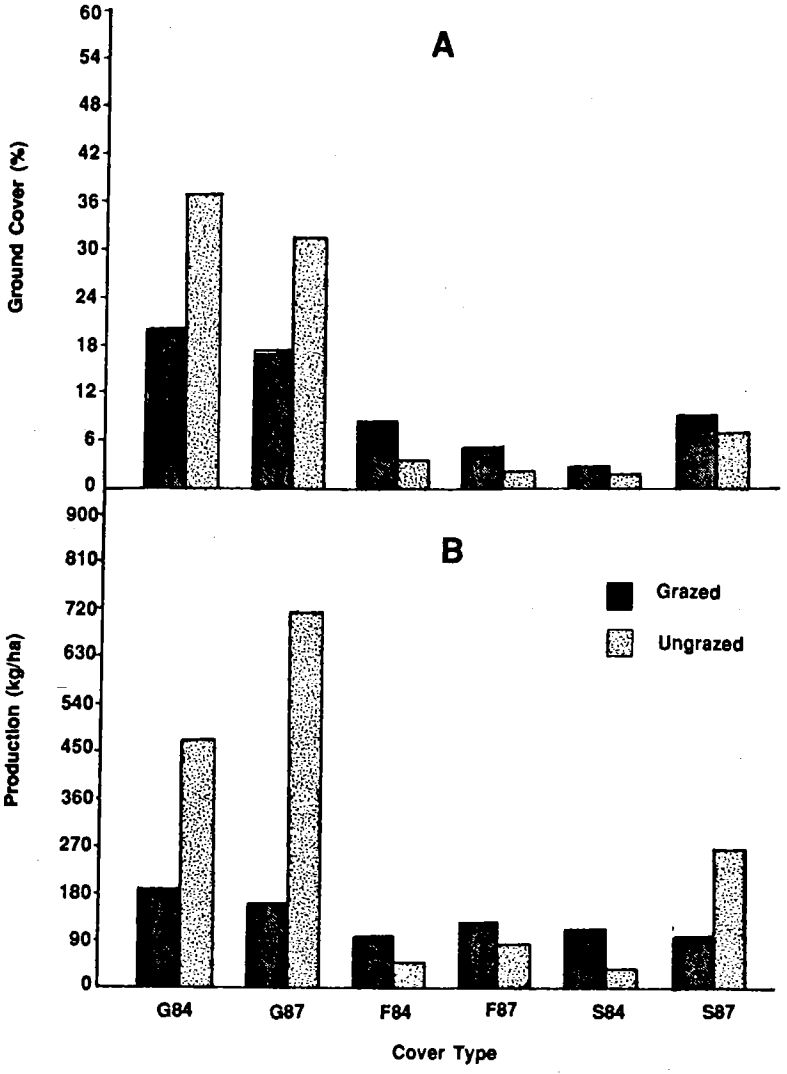



**Figure 10. Ground cover (A) and forage production (B) of grazed compared to ungrazed range near Columbia Lake, July 1984 and 1987.** (G = Grasses; F = Forbs; S = Shrubs)

outside the exclosure compared to 43% inside. In contrast, frequency of occurrence of porcupinegrass and junegrass was similar on grazed and ungrazed range. Most microplots (97%) on both grazed and ungrazed range contained porcupinegrass, and 45% contained junegrass.

Ground cover of forbs was slightly higher on grazed range than on ungrazed range (Fig. 10*a*, Appendix B). Pasture sage was the dominant forb on both (Table 4).

Shrub cover and frequency of occurrence were similar on grazed and ungrazed range but percent bare ground was significantly higher on grazed range (95% C.L., Fig. 10*a*, Appendix B).

*Forage production.*— Total forage production was significantly higher on grazed range than on ungrazed range in 1984 (90% C.L., 561:395 kg/ha, Fig. 10*b*, Appendix B). Grass production was significantly higher inside the exclosure than outside at 473 kg/ha compared to 187 kg/ha. Grasses produced 84% of total annual forage production on ungrazed range and only 43% on grazed range. Forb production was slightly higher on ungrazed range but not significantly. Forbs made up only 10% of total forage production on ungrazed range and 25% on grazed. Current annual growth of rabbit-brush (the only shrub species at this site) was significantly higher outside the exclosure although its frequency was similar on grazed and ungrazed range.

*Ungulate use.*— Pellet group counts indicated that bighorn sheep and elk used 100% of current annual growth with 69% of the grazing pressure coming from bighorn sheep at this site (Table 5).

*Paired plot floristics, 1987.*— Total forage cover was similar on grazed and ungrazed range but ground cover of grass was significantly higher on ungrazed range (99% C.L., Fig. 10*a*, Appendix B). Although frequency of occurrence of grasses was similar on grazed and

**Table 4. Ground cover and frequency of occurrence of plant species on grazed range compared to ungrazed range near Columbia Lake, July 1987.**

| Plant Species[a] | Average Cover (%) | | Frequency (%) | |
|---|---|---|---|---|
| | Grazed | Ungrazed | Grazed | Ungrazed |
| GRASSES[b] | | | | |
| Porcupinegrass | 17.4 | 26.1 | 97.5 | 80.0 |
| Junegrass | 1.9 | 9.0 | 42.5 | 60.0 |
| Downy wheatgrass | 0 | 1.8 | 0 | 57.5 |
| Sedge | 0.1 | 1.4 | 2.5 | 22.5 |
| FORBS | | | | |
| Pasture sage | 5.2 | 4.3 | 70.0 | 62.5 |
| Blue-eyed Mary | 1.3 | 0.6 | 45.0 | 15.0 |
| Fleabane | 2.6 | 0.6 | 62.5 | 17.5 |
| SHRUBS | | | | |
| Rabbit-brush | 4.7 | 2.4 | 25.0 | 55.0 |

a This table does not include species with <0.5% Seven species of grass, 15 species of forbs and 1 shrub species were present.
b Few seed heads had formed and some needlegrasses may have been stiff needlegrass and porcupinegrass.

ungrazed range, ground cover of stiff needlegrass and junegrass was higher on ungrazed range (Table 4). Ground cover of bluebunch wheatgrass was only 0.1% on both grazed and ungrazed range.

Ground cover and production of forbs were similar on grazed and ungrazed range in 1987 (Fig. 10*a*). Pasture sage, fleabane, blue-eyed Mary and Columbia bladderpod were dominant. Species diversity of forbs was higher on grazed range than on ungrazed (13:7 species). Ground cover of forbs on grazed range was significantly lower in 1987 than in 1984 but not on ungrazed range (90% C.L.).

Ground cover of shrubs was similar on grazed and ungrazed range in 1984 and 1987 (Fig. 10*a*, Appendix E). Frequency of occurrence of shrubs was higher on ungrazed range than on grazed in 1987 (Table 4).

Ground cover of litter was significantly higher on ungrazed range than on adjacent grazed range but litter weight was not significantly different. Estimated cover of bare ground was significantly higher on grazed range than on ungrazed as in 1984 (99% C.L.).

*Forage production.*— Forage production in 1987 was significantly (90% C.L.) lower on grazed range compared to adjacent ungrazed range as in 1984 (Fig. 10*b*, Appendix E). Total forage production on ungrazed range was 2.8 times greater

**Table 5. Calculated forage utilization of three bighorn sheep winter ranges based on pellet group counts, July 1984.**

| Location | Animal Unit Months Forage Use | | | | | (%) Grazed |
|---|---|---|---|---|---|---|
| | Cattle | Elk | Deers | Sheep[a] | Total | |
| Bull River | 0.53 | 0.13 | 0.25 | - | 0.91 | 44% |
| Columbia Lake | 0.5 | | | 1.10 | 1.60 | 100% |
| Wigwam Flats | 0.24 | | | 0.30 | 0.54 | 100% |

a Rocky Mountain bighorn sheep pellet groups could not reliably be distinguished from deer pellet groups, so the calculated forage use is a composite of the two game species.

on ungrazed range compared to adjacent grazed range (1064:385 kg/ha) and was 1.4 times greater in 1987 than in 1984. As in 1984, grass production was significantly (95% C.L.) higher on ungrazed range than on adjacent grazed range at 714:162 kg/ha. Forb production was similar on grazed and ungrazed range in 1987 as in 1984. Rabbit-brush was the only shrub present and produced only 99 kg/ha on grazed range compared to 265 kg/ha on adjacent ungrazed range. Shrub production in 1987 on grazed range was similar to production at the same site in 1984 but was 7.8 times greater on ungrazed range in 1987 compared to 1984 at the same site.

Animal use was not determined in 1987 at Columbia Lake.

*Floristics in 1984 compared to 1987.*— Ground cover and frequency of occurrence of vegetation on bighorn sheep winter range in 1984 could not be compared with that of 1966 because range exclosures had been destroyed.

When floristic values for 1984 and 1987 were compared, a trend in range condition was apparent. Total forage cover was higher on ungrazed range than on grazed range both in 1984 and in 1987 indicating a rapid decline in range condition due to grazing pressure(Fig. 10*a*, Appendix E).

Forage cover was similar in 1987 to that of 1984 (Fig. 10*a*). Grass and forb cover was higher on both grazed and ungrazed range in 1984 than in 1987. In contrast, shrub cover was significantly higher (95% C.L.) on both grazed and ungrazed range in 1987 than in 1984. Ground cover of litter on both grazed and ungrazed range increased significantly between 1984 and 1987 while the amount of bare ground decreased significantly (99% C.L.).

### 4.2.3 Premier Ridge

*Floristics at time of construction, July 1984.*— Ground cover of forage was similar inside and outside the exclosure on Sheep Pasture on Premier Ridge (69% and 67%, respectively, Fig. 11*a*).

Ground cover of grass was similar inside and outside the exclosure but ground cover of pinegrass was significantly greater (99%

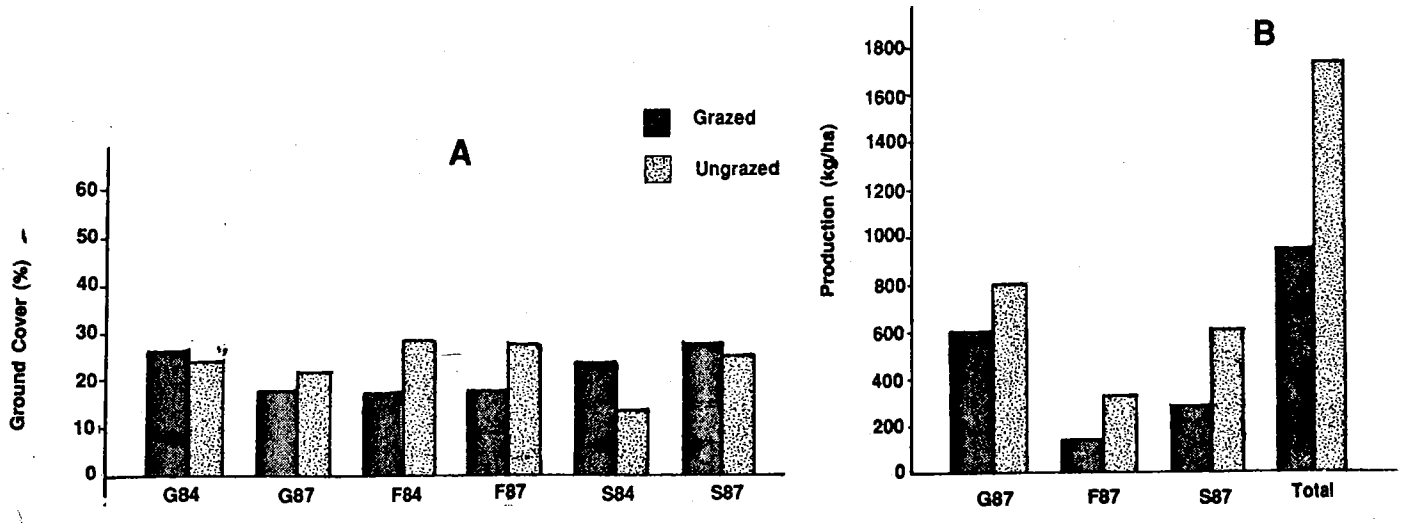



**Figure 11. Ground cover (A. July 1984 and 1987) and forage production (B. July 1987) of grazed range compared to ungrazed range on Premier Ridge.** (G = Grasses; F = Forbs; S = Shrubs).

C.L., Appendix E) outside the exclosure whereas ground cover of Canada bluegrass was significantly higher inside the exclosure (99% C.L.). Frequency of occurrence of pinegrass was higher outside the exclosure than inside (71%:39%), but frequency of occurrence of Canada bluegrass was similar on both sides of the exclosure (Table 6).

Forb cover was significantly higher inside than outside the exclosure. Mosses and lichens covered more ground area and bare ground less area on range inside the exclosure. Rosy pussytoes, asters, wild strawberries and arrow-leaved balsamroot had greater ground cover and frequency of occurrence inside the exclosure (Table 6).

Ground cover of shrubs was significantly (98% C.L.) higher outside the exclosure than on ungrazed range inside the exclosure at time of exclosure construction but was similar when analyzed 3 years later. Kinnikinnick, and antelope-brush had a greater frequency of occurrence and ground cover inside the exclosure whereas saskatoon was more abundant and covered more space outside (Table 6).

A greater diversity of forage species occurred inside the exclosure than outside (42:35).The difference was largely due to the number of forbs on ungrazed range compared to grazed range - 22:17.

Vegetation was not uniform on the site when we built the exclosure but range condition and trend can be determined using the baseline data presented.

*Paired plot comparisons, 1987.*— Analysis of the paired macroplots on Sheep Pasture, in 1987, 3 years after construction of the exclosure indicated that forage cover was higher on ungrazed range than grazed range (70%:61%) but the difference was not significant. No significant difference in grass cover was observed between grazed and ungrazed range although ungrazed grasses had higher production (Fig. 11*a*, Appendix E). Ground cover of grasses had declined on grazed and ungrazed range between 1984 and 1987, but a larger decline occurred on grazed range.

As in 1984 the frequency of pinegrass was greater inside the exclosure; however, the percent cover of pinegrass was similar on grazed and ungrazed range (Table 6). Ground cover estimates indicated that pinegrass, Canada bluegrass and rough fescue were codominant inside the exclosure even though the frequency of occurrence was similar on grazed and ungrazed range.

Grass species including narrow-spiked reedgrass, Rocky Mountain fescue, fuzzy-spiked wildrye and stiff needlegrass were only found on grazed range while Idaho fescue was found only on ungrazed range within the exclosure (Table 6).

Ground cover of forbs in 1987 compared to 1984 was significantly higher (95% C.L.) on ungrazed range than grazed range. Almost 42% of total forage cover of grazed range were forbs while 36% of ungrazed range were forbs.

More forb diversity was found within the exclosure than outside on grazed range (23:14 species). Hairy golden-aster, pussytoes, arrow-leaved balsamroot, yarrow and wild strawberry frequently occurred both inside and outside the exclosure (Table 6).

Shrub cover was similar on grazed and ungrazed range unlike 1984 when shrub cover was significantly (98% C.L.) higher outside the exclosure. Nearly 42% of total

**Table 6. Ground cover and frequency of plant species on ungrazed range (inside the exclosure) compared to ungrazed range (outside the exclosure) at Premier Ridge (PR 1), July 1984 and July 1987.**

| Vegetation Type | Cover (%) | | | | Frequency (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | Ungrazed[a] | | Grazed | | Ungrazed | | Grazed | |
| | 1984[b] | 1987 | 1984 | 1987 | 1984 | 1987 | 1984 | 1987 |
| GRASSES | | | | | | | | |
| Pinegrass | 2.3 | 8.0 | 12.3 | 7.9 | 29 | 60 | 71 | 18 |
| Canada bluegrass | 19.0 | 6.5 | 7.5 | 5.9 | 77 | 58 | 63 | 55 |
| Rough fescue | 1.7 | 5.5 | 1.3 | 1.7 | 13 | 28 | 21 | 30 |
| Junegrass | 1.5 | 0.6 | 1.4 | 1.4 | 32 | 28 | 44 | 58 |
| Bluebunch wheatgrass | 0.8 | 0.7 | 0.3 | 0.8 | 5 | 8 | 7 | 18 |
| Stiff needlegrass | 0.8 | | | | 13 | | | |
| FORBS | | | | | | | | |
| Rosy pussytoes | 5.5 | 5.7 | 0.6 | 0.9 | 52 | 73 | 19 | 25 |
| Aster | 2.7 | 4.3 | 0.8 | 2.7 | 39 | 64 | 12 | 45 |
| Hairy golden-aster | 3.6 | 5.5 | 4.5 | 4.3 | 49 | 68 | 48 | 73 |
| Wild strawberry | 4.7 | 3.5 | 1.2 | 2.6 | 61 | 73 | 20 | 45 |
| Yarrow | 2.4 | 2.2 | 3.2 | 1.8 | 67 | 60 | 65 | 68 |
| Canada goldenrod | 0.2 | 0.4 | 1.4 | 1.1 | 11 | 3 | 15 | 23 |
| Yellow penstemon | 0.8 | T | 0.1 | | 23 | | 4 | |
| Yellow hedysarum | 1.1 | 0 | 1.1 | 0.8 | 5 | 0 | 7 | 10 |
| Yellow avens | 0.8 | | 0.6 | | 19 | | 20 | |
| Arrow-leaved balsamroot | 2.2 | 3.1 | 0.9 | 0.8 | 19 | 25 | 4 | 10 |
| Perennial sow-thistle | | 0.8 | | 2.1 | | 15 | | 40 |
| Columbia bladderpod | | | | | | | | 8 |
| Yellow salsify | | | | | | | | 3 |
| SHRUBS | | | | | | | | |
| Kinnikinnick | 12.1 | 2.6 | 2.9 | 11.7 | 52 | 20 | 15 | 63 |
| Soopolallie | 5.6 | 7.3 | 5.5 | 3.9 | 15 | 23 | 9 | 10 |
| Saskatoon | 0.8 | 1.8 | 2.3 | 3.5 | 4 | 10 | 23 | 38 |
| Prairie rose | 0.7 | 1.9 | 1.3 | 3.5 | 8 | 23 | 16 | 28 |
| Rose | 0.2 | | 0.6 | | 9 | | 7 | |
| Antelope-brush | 2.4 | 3.1 | 0 | 0.6 | 4 | 8 | 0 | 8 |
| Birch-leaved spirea | 1.1 | 1.1 | 1.0 | 0.3 | 4 | 15 | 17 | 15 |
| Douglas-fir | 0.2 | 3.7 | 0.4 | 0.6 | 8 | 5 | 7 | 3 |
| CRYPTOGAMS | 13.6 | 4.3 | 7.0 | 19.3 | 49 | 23 | | |
| LITTER | 14.0 | 17.4 | 39.7 | 39.7 | 51 | 76 | | |
| ROCK | 3.6 | 3.6 | 2.1 | 2.1 | 29 | 41 | | |
| BARE GROUND | 4.1 | 8.3 | 2.4 | 2.4 | 31 | 43 | | |

a Species on ungrazed range compared to grazed range - 9:10 grasses, 14:17 forbs, 7:8 shrubs.
b Species in 1984 compared to 1987 on ungrazed range - 12:8 grasses, 20:20 forbs, 8:8 shrubs.

forage cover and 25% of total forage production were shrubs on grazed range compared to 35% ground cover and 34% of total forage production on ungrazed range (Figs. 11*a,b*). Shrub cover increased by 25% on ungrazed range and remained unchanged on grazed range between 1984 and 1987.

Kinnikinnick was the dominant shrub on grazed range and soopolallie was the dominant shrub on ungrazed range at this site. Saskatoon, prairie rose and antelope-brush were subdominant shrubs on both macroplots perhaps as a result of a past history of overgrazing (Table 6).

Ungrazed range had significantly more cryptogams and significantly less rock and bare ground than grazed range. Litter cover was higher on ungrazed range but weight of litter was similar on both.

*Paired plot comparisons, 1984-1987.*— When estimated ground cover of vegetation species in 1984 and 1987 was compared, total forage cover in 1984 was greater in both the grazed and ungrazed

macroplots (Fig. 11*a*). The largest decline in forage cover of the grazed range occurred in grasses especially pinegrass and stiff needlegrass (Table 6). In contrast, pinegrass increased from 2 to 8% of ground cover during the same period on adjacent ungrazed range. The largest declines in forage cover on ungrazed range occurred in Canada bluegrass, junegrass, and kinnikinnick. Ground cover of preferred forage species including rough fescue, saskatoon, prairie rose, and antelope-brush increased in the exclosure.

The diversity of grass species declined from 12 to 8 on ungrazed range but did not decline on grazed range between 1984 and 1987. The diversity of forbs remained similar on grazed and ungrazed range between 1984 and 1987 but species such as arrow-leaved balsamroot, perennial sow-thistle and asters showed large increases in cover and frequency of occurrence on both grazed and ungrazed range. In 1987, four species of forbs were found on grazed range that were not found in 1984. In 1984, five species of forbs were found that were not located in 1987 on grazed range (Table 6).

*Forage production.*— Total forage production in 1987 was 942 kg/ha on grazed range and 1730 kg/ha on ungrazed range (Fig. 11*b*), much higher than the 340 kg/ha reported as a 3-year average for the antelope-brush - bluegrass community between 1967 and 1969 (Eastman 1970). If current annual growth of shrubs was not included, the forage biomass estimates would be 702 kg/ha on grazed range and 1140 kg on ungrazed range in 1987 compared to an average of 340 kg/ha from 1967 to 1969. Total area of this plant community located on the west-facing slopes of Premier Ridge was calculated to be 460 ha (Eastman 1970).

Grass accounted for 823 kg/ha or 47.5% of total forage production on ungrazed range and 587 kg/ha or 62% on grazed range in 1987 (Fig. 11*b*).

Forb production was significantly higher (90% C.L.) inside the exclosure at 317 kg/ha than outside at 122 kg/ha. Only 13% of total forage production came from forbs on grazed range compared to 18% on ungrazed range. Ungrazed range had higher shrub production than grazed range (590 kg/ha: 232 kg/ha) in 1987.

### 4.2.4 Bull River, 1984

#### Big Bull Pasture (BR 7) Paired Plot Comparisons

*Floristics.*— Estimated ground cover of forage was similar on grazed and ungrazed range at this site (Fig. 12*a*). Ground cover of grasses, particularly Canada bluegrass, was significantly (90% C.L., Appendix E) greater on grazed range than on ungrazed range (Table 7). The dominant grass on both grazed and ungrazed range was Canada bluegrass; needle-and-thread grass was subdominant on both. Ground cover of rough fescue, Idaho fescue or slender wheatgrass showed little difference between grazed and ungrazed range.

Frequency of occurrence of all grass species was higher on grazed than ungrazed range (Table 7). Grasses made up 70% of ground cover of forage species on grazed range and 64% of total forage production. On ungrazed range, grasses made up 51% and 44%, respectively.

Grazed range had significantly (95% C.L., Appendix E) more ground cover and a greater frequency and diversity of forbs than ungrazed range at this site but total forb production was not significantly different (Table 7). The dominant forb on

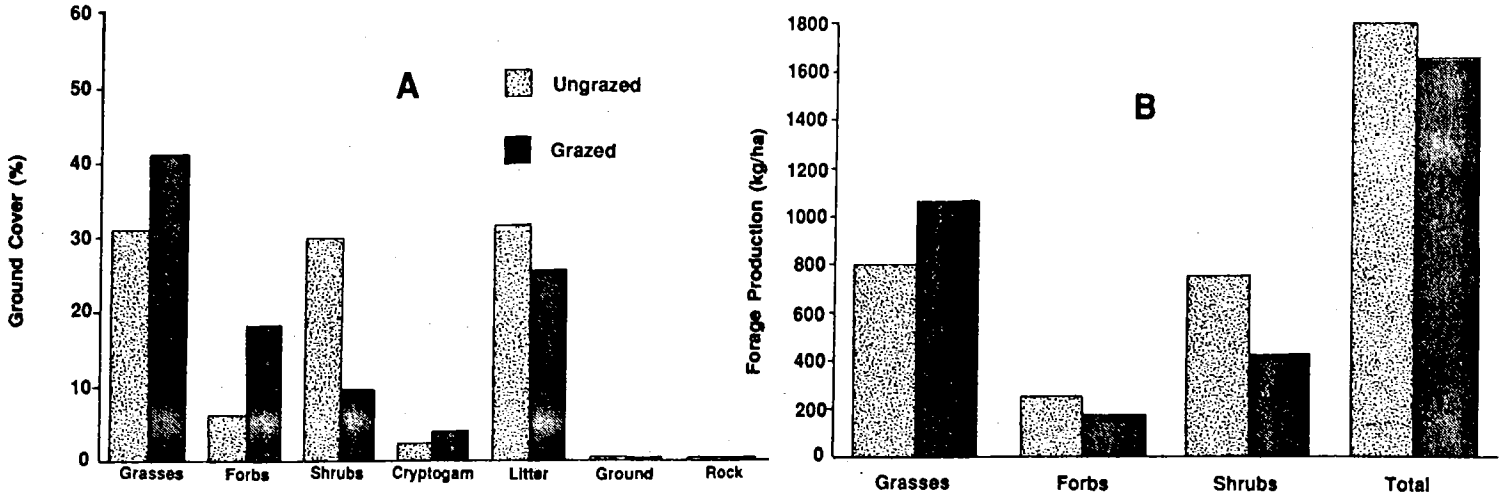



**Figure 12. Ground cover (A) and forage production (B) of grazed range compared to ungrazed range on the lower Bull River (BR 7), July 1984.**

ungrazed range was sticky cinquefoil; on grazed range, it was black medic.

Estimated ground cover and shrub production were significantly (99% C.L.) higher on ungrazed range compared to grazed (Fig. 12*b*). Antelope-brush and saskatoon had significantly higher cover on ungrazed range compared to grazed range (Table 7). Antelope-brush was dominant on both grazed and ungrazed range at this site but shrubs accounted for only 16% of forage cover on grazed range. On ungrazed range 44% of cover were shrubs.

Litter weight was higher inside the exclosure than outside but percent ground cover was not significantly different (Figs. 12*a, b*). Percent cover of rock, bare ground and cryptogams was similar on grazed and ungrazed range.

*Forage production.*— Forage production was similar on grazed and ungrazed range (Fig. 12*b*). Forage production on grazed range at 1660 kg/ha was six times greater than at Columbia Lake and five times that of Wigwam Flats.

Grass production was significantly higher on grazed range than on ungrazed range at this site (1058 kg/ha:797.9 kg/ha) and Canada bluegrass was the dominant grass (Fig. 12*b*; Table 7). Grasses were the main contributors to forage production on grazed range (64%); shrubs and grasses were the major contributors (42% and 44%, respectively) on ungrazed range.

Forb production was higher on ungrazed range than on grazed range at this site but the difference was not statistically significant. Nearly 31% of estimated forage cover was forbs on grazed range and only 9% on ungrazed range. In contrast, only 10% of total forage production was forbs on grazed range and on ungrazed range it was 14%.

Almost 24% of total forage production was shrubs on grazed range and 38% on ungrazed range. The main contributor to shrub production on both grazed and ungrazed range was antelope-brush.

*Ungulate use.*— Pellet group counts indicate that about 44% of available forage

was consumed by cattle, elk, deer and bighorn sheep (Table 5). Fifty-eight percent of forage use was by domestic cattle, 14% by elk and 28% by bighorn sheep and deer.

*Range condition and trend, 1984.*— Condition of grazed range was similar to ungrazed range in 1984 based upon the cover and productivity of grasses, forbs and shrubs. Heavy browse pressure had significantly reduced cover and production of antelope-brush and saskatoon outside the exclosure.

When ground cover estimates made inside the exclosure in 1966 were compared with those from 1984, forage cover declined from 118% to 67% and litter cover increased from 18% to 32%. Between 1966 and 1984, Kentucky bluegrass dropped from 27% to 0% of ground cover inside the exclosure (Table 8). Ground cover and frequency of downy wheatgrass, cheatgrass, pinegrass, junegrass, six-weeks fescue and Idaho fescue declined between 1966 and 1984 (Table 8, Fig. 13).

Ground cover and frequency of forbs declined on grazed and ungrazed range between 1966 and 1984 (Appendix F). Ground cover and frequency of yarrow, rosy pussytoes, yellow salsify and sticky alumroot also dropped inside and outside the exclosure between 1966 and 1984. Black medic (a weedy legume species) has invaded this area since 1966. Loss in ground cover of forbs was not as great on grazed range as on ungrazed range during this period of time (Table 8; Fig. 13).

Ground cover of shrubs declined from 31% to 9% on grazed range and remained similar on ungrazed range between 1966 and 1984 (Table 8; Fig. 13).

Range condition within the exclosure was similar in 1984 and 1966 but declined on grazed range. Condition of grazed range would have been rated fair to good in 1966 but would now be rated in the poor to fair category. The major reason for the decline in condition class rating is the reduction in cover of palatable browse species including antelope-brush and saskatoon, and the decline in cover of

(inside the exclosure) (outside the exclosure)

**Table 7. Ground cover and frequency of plant species on ungrazed range compared to ~~un~~grazed range on the lower Bull River (BR 7), July 1984.**

| Plant Species | Average Percent Cover | | | Frequency | |
|---|---|---|---|---|---|
| | Inside | Outside | Sig. Level | Inside | Outside |
| GRASSES | | | | | |
| Rough fescue | 2.5 | 0.9 | N.S. | 16 | 13 |
| Slender wheatgrass | 2.7 | 2.3 | N.S. | 28 | 36 |
| Canada bluegrass | 13.0 | 23.6 | 99% | 84 | 99 |
| Needle-and-thread | 8.4 | 9.3 | N.S. | 36 | 49 |
| Idaho fescue | 3.9 | 4.1 | N.S. | 32 | 45 |
| FORBS | | | | | |
| Cinquefoil (Sticky) | 2.0 | 1.5 | N.S. | 32 | 16 |
| Black medic | 0.1 | 6.9 | 99% | T | 36 |
| Early blue violet | 0 | 2.1 | S.D. | 0 | 36 |
| SHRUBS | | | | | |
| Antelope-brush | 26.9 | 5.3 | 99% | 65 | 23 |
| Saskatoon | 2.2 | 0 | S.D. | 7 | 0 |
| Kinnikinnick | 2.3 | 2.6 | N.S. | 5 | 13 |
| Rose | 0.7 | 1.1 | N.S. | 4 | 16 |
| CRYPTOGAMS | 2.2 | 3.9 | N.S. | 5 | 13 |
| LITTER | 21.4 | 25.5 | N.S. | 98 | 92 |
| BARE GROUND | 0.3 | 0.2 | N.S. | 3 | 5 |
| ROCK | 0.2 | 0.4 | N.S. | 3 | 1 |

**Table 8. Ground cover of forage species located at the lower Bull River exclosure (BR 7) in 1966 and 1984.**

| Species[a] | Plant Cover (%) 1966 Grazed | 1984 Grazed | 1984 Ungrazed | Type |
|---|---|---|---|---|
| GRASSES | | | | |
| Downy wheatgrass | 2.0 | - | - | Decrease |
| Slender wheatgrass | 1.0 | 2.3 | 2.7 | Decrease |
| Alpine fescue | 9.4 | - | - | Decrease |
| Soft cheatgrass | 7.2 | - | - | Increase |
| Pinegrass | 2.1 | - | - | Increase |
| Idaho fescue | - | 4.1 | 3.9 | Decrease |
| Rough fescue | - | 0.9 | 2.5 | Decrease |
| Junegrass | 7.8 | 0.3 | - | Increase |
| Canada bluegrass | 12.9 | 23.6 | 13.0 | Increase |
| Kentucky bluegrass | 27.0 | - | - | Inv. |
| Small western needlegrass | - | 9.3 | 8.4 | Increase |
| *Stipa* Sp. | - | 0.4 | - | Increase |
| FORBS[a] | | | | |
| Yarrow | 7.5 | 3.6 | 0.4 | Increase |
| Black medic | 0.1 | 6.9 | - | Decrease |
| Rosy pussytoes | 4.1 | 0.1 | 0.1 | Increase |
| Timber milk-vetch | 0.9 | - | - | Increase |
| Alpine willowherb | - | 2 | - | Decrease |
| Round-leaved alumroot | 1.3 | - | - | Increase |
| Sticky cinquefoil | - | 1.5 | 2.0 | Increase |
| Early blue violet | - | - | 2.1 | Decrease |
| Yellow salsify | 3.9 | - | - | Inv. |
| Lyall's mariposa lily | - | 0.2 | 0.1 | Increase |
| SHRUBS | | | | |
| Saskatoon | 1.2 | - | 2.2 | Decrease |
| Kinnikinnick | 2.1 | 2.6 | 2.3 | Increase |
| Antelope-brush | 27.5 | 5.2 | 26.9 | Decearse |
| Rose | T | 1.5 | 0.7 | Increase |
| Birch-leaved spirea | T | - | - | Increase |
| Snowberry | - | T | T | Increase |
| CRYPTOGAMS | 1.9 | 3.9 | 2.2 | |
| LITTER | 17.5 | 25.5 | 21.4 | |
| BARE GROUND | 3.8 | 0.2 | 0.3 | |
| ROCK | - | 0.4 | 0.2 | |

a Species of vegetation on the lower Bull River (BR7) in 1966 and 1984 on grazed range and in 1984 on ungrazed range were: 7:7:5 grasses, respectively, 7:5:5 forbs, 5:4:5 shrubs.

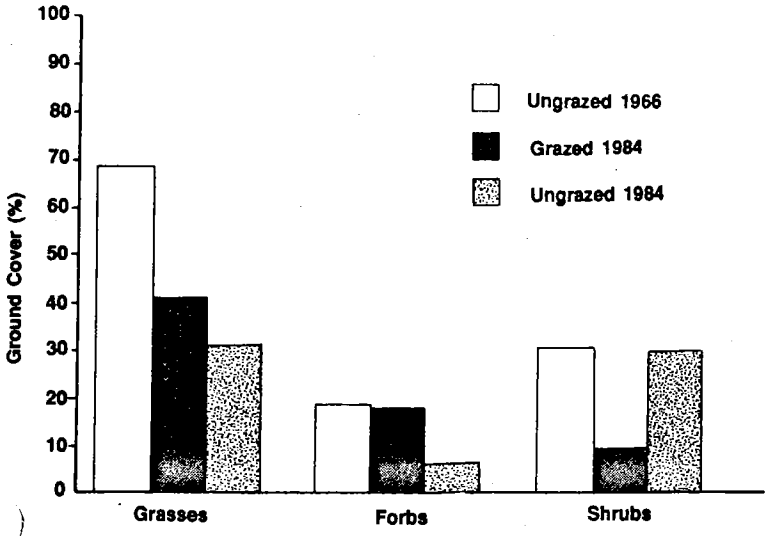



**Figure 13. Ground cover of grazed range compared to ungrazed range at lower Bull River (BR7), July 1966 and 1984.**

palatable grass species including Rocky Mountain fescue and downy wheatgrass. Palatable grass species including rough fescue and Idaho fescue have increased in cover and frequency while cover of invader species such as Kentucky bluegrass declined on grazed and ungrazed range between 1966 and 1984.

### Upper Bull River (BR9)

*Paired plot comparisons, 1984.*— Ground cover of forage was high on both grazed and ungrazed range at BR9 (86% grazed, 82% ungrazed; Fig. 14). Shrubs provided most of the forage cover, unlike the lower Bull River site where grasses were dominant. Grass cover was greater and

**Table 9. Ground cover and frequency of grazed vegetation compared to ungrazed vegetation on the upper Bull River (BR 9), July 1984.**

| Plant Species | Mean Ground Cover (%) | | Frequency (%) | |
|---|---|---|---|---|
| | Grazed | Ungrazed | Grazed | Ungrazed |
| GRASSES | | | | |
| Canada bluegrass | 11.3 | 7.3 | 93 | 81 |
| Slender wheatgrass | 4.5 | 5.0 | 64 | 55 |
| Timothy | 3.5 | 1.5 | 47 | 35 |
| Pinegrass | 0.2 | 1.8 | 4 | 20 |
| Timber oatgrass | 0.3 | 0.5 | 1 | 1 |
| Junegrass | 1.0 | 0.5 | 21 | 15 |
| FORBS[a] | | | | |
| Spreading dogbane | 0.3 | 11.5 | 4 | 49 |
| American vetch | 3.0 | 4.3 | 51 | 69 |
| Black medic | 10.0 | 2.0 | 49 | 11 |
| Yarrow | 1.3 | 1.5 | 28 | 41 |
| Aster | 1.2 | 0.7 | 19 | 12 |
| Wild strawberry | 0.4 | 0.5 | 9 | 13 |
| Peavine | 1.5 | 0.2 | 13 | 3 |
| Rosy pussytoes | 2.9 | 0.7 | 21 | 4 |
| SHRUBS | | | | |
| Saskatoon | 16.9 | 20.4 | 43 | 47 |
| Snowberry | 15.1 | 15.9 | 73 | 84 |
| Redstem ceanothus | - | 4.4 | - | 21 |
| Oregon-grape | 2.3 | 1.3 | 43 | 9 |
| Antelope-brush | 0 | 1.6 | 0 | 8 |
| Birch-leaved spirea | 1.7 | 0.8 | 28 | 12 |
| Rose | 1.0 | 0.8 | 8 | 8 |
| Kinnikinnick | T | 0.7 | 9 | 9 |
| Choke cherry | T | 1.2 | 1 | 1 |

a Forbs with <1% cover were not included in this list.

shrub cover lower on grazed range than on ungrazed range.

Grasses provided only 26% of forage cover at BR 9 on grazed range compared to 44% at BR 7. On ungrazed range, grasses provided only 17% of total forage cover at BR 9 compared to 51% at BR 7. Canada bluegrass was the dominant and slender wheatgrass the subdominant grass on both the grazed and ungrazed range at BR9 (Table 9). Frequency of all grasses was higher on grazed range outside the exclosure with the exception of pinegrass, which occurred more frequently inside the exclosure. Cover of non-native species including Canada bluegrass, timothy and black medic was greater on grazed range than on ungrazed range.

Forb cover was similar inside and outside the exclosure (26:28%). Some species, however, including yarrow, spreading dogbane and American vetch had greater cover and frequency on ungrazed range whereas other species, such as rosy

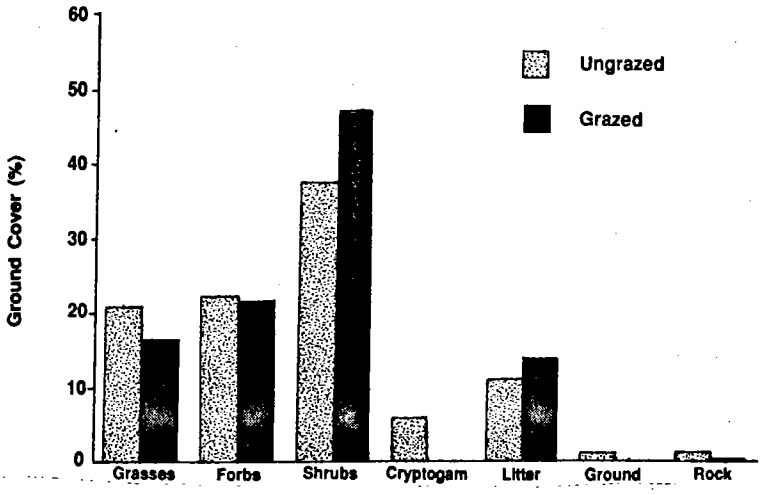



**Figure 14. Ground cover of grazed range compared to ungrazed range in the upper Bull River exclosure (BR9), July 1984.**

**Table 10. Ground cover of vegetation on the upper Bull River exclosure (BR 9) in 1966 and 1984.**

| Plant Species[a] | Mean Ground Cover (%) 1966 Grazed | 1984 Grazed | 1984 Ungrazed | Type |
|---|---|---|---|---|
| GRASSES | | | | |
| Canada bluegrass | 6.4 | 11.3 | 7.3 | Increase |
| Kentucky bluegrass | 8.0 | - | - | Inv. |
| Slender wheatgrass[b] | - | 4.5 | 5.0 | Decrease |
| Bluebunch wheatgrass | 1.2 | - | - | Decrease |
| Timothy | 4.4 | 3.5 | 1.5 | Inv. |
| Pinegrass | 4.1 | 0.2 | 1.8 | Increase |
| Soft brome | 1.0 | - | - | Increase |
| Cheatgrass | 5.2 | - | - | Increase |
| Downy wheatgrass | 1.0 | - | - | |
| Timber oatgrass | - | 0.3 | 0.5 | Increase |
| Junegrass | 2.3 | 1.0 | 0.5 | Increase |
| Sedges | 1.5 | 0 | 0 | Var. |
| FORBS[a] | | | | |
| Spreading dogbane | 4.6 | 0.3 | 11.5 | Increase |
| American vetch | - | 3.0 | 4.3 | Decrease |
| Black medic | - | 10.0 | 2.0 | Inv. |
| Yarrow | 5.3 | 1.3 | 1.5 | Increase |
| Rosy pussytoes | 1.4 | 2.9 | 0.7 | Increase |
| Asters | 14.0 | 1.2 | 0.7 | Decrease |
| Alpine willowherb | 0.7 | 0.1 | 0 | Var. |
| Wild strawberry | 2.0 | 0.4 | 0.5 | Increase |
| Early blue violet | 1.3 | 0.3 | 0.4 | Decrease |
| SHRUBS | | | | |
| Saskatoon | 23.5 | 16.9 | 20.4 | Decrease |
| Snowberry | 29.2 | 15.1 | 15.1 | Increase |
| Redstem ceanothus | 21.0 | - | 4.4 | Decrease |
| Creeping Oregon-grape | 1.1 | 2.3 | 1.3 | Var. |
| Antelope-brush | T | - | 1.6 | Decrease |
| Birch-leaved spirea | 3.9 | 1.7 | 0.8 | Increase |
| Rose | 1.0 | 1.0 | 0.8 | Var. |
| Choke cherry | - | T | 1.2 | Decrease |
| Kinnikinnick | T | T | 0.7 | Increase |
| LITTER | 17.5 | 11.1 | 15.9 | |
| ROCK | 0.6 | 1.0 | 0.5 | |
| BARE GROUND | - | - | 1.3 | |

a Species of vegetation on grazed range in 1966 and 1984 and ungrazed range in 1984 were: 11:6:6 grasses, respectively, 12:10:10 forbs and 8:7:9 shrubs.

b Slender wheatgrass may have been called bluebunch wheatgrass in 1966.

pussytoes, peavine and black medic, had greater cover and frequency of occurrence on grazed range.

Shrub cover at BR9 was higher (47:37%) on ungrazed range than on grazed (Fig. 14). Snowberry was the dominant and saskatoon the subdominant shrub on grazed and ungrazed range (Table 9). Browse pressure from ungulates had removed the very palatable shrub species redstem ceanothus and antelope-brush outside the exclosure and increased the cover of less palatable species such as Oregon-grape and birch-leaved spirea.

*Range condition and trend.*— When ground cover in 1966 was compared with 1984, total forage cover declined dramatically on grazed and ungrazed range. Ground cover of forage declined from 132% in 1966 on grazed range to 78% on grazed range in 1984 and 85% on ungrazed range (Table 10). Between 1966 and 1984, Kentucky bluegrass, bluebunch wheatgrass, and soft brome grass disappeared from the exclosure while timber oatgrass moved onto grazed and ungrazed range at BR 9 (Table 9).

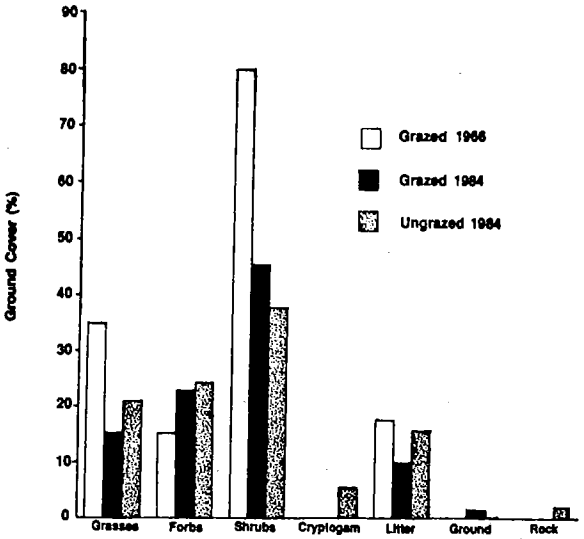



**Figure 15. Ground cover of grazed range compared to ungrazed range on the upper Bull River (BR 9), July 1966 and 1984.**

Forb cover increased slightly between 1966 and 1984 on grazed and ungrazed range. On grazed range, decreases in ground cover of spreading dogbane, yarrow, asters and wild strawberry occurred between 1966 and 1984. Large increases in ground cover occurred in black medic and American vetch on grazed range between 1966 and 1984 on grazed range (Table 10).

Ground cover of shrubs decreased from 80% in 1966 to 37% on grazed range and 46% on ungrazed range in 1984 (Fig. 15). Large declines occurred in cover and frequency of redstem ceanothus, saskatoon and birch-leaved spirea on grazed and ungrazed range between 1966 and 1984. Estimated ground cover of litter and rock changed little.

### 4.2.5 Wigwam Flats, 1984

*Paired plot comparisons of floristics.*— Total forage cover was greater on ungrazed range than grazed range 18 years after exclosure construction (Fig. 16*a*). Grass cover was significantly greater (95% C.L., Appendix [illegible]) inside the exclosure located at Purple Canyon (PCE) than outside. Rough fescue was the dominant grass inside the exclosure (35%) while bluebunch wheatgrass was the dominant grass outside (12%), although frequency of occurrence was equal on grazed and ungrazed range (Table 11, Appendix [illegible]). Bluebunch wheatgrass was subdominant inside the exclosure and junegrass was subdominant outside.

Frequency of occurrence of junegrass was similar inside and outside the exclosure but ground cover was 5% outside compared to 2% inside. Both bluebunch wheatgrass and junegrass responded as increaser species under grazing pressure.

Forb cover and frequency was similar inside and outside the exclosure (Fig. 16*a*) except for rosy pussytoes, few-flowered shootingstar, and yellowish paintbrush, which had significantly more cover inside the exclosure. Yarrow, wild bergamot and yellow salsify were more abundant and vigorous outside (Table 11). Forb diversity was higher inside the exclosure than outside (21:14 species).

Shrub cover was significantly higher inside the exclosure than outside but production was not significantly different (Appendix [illegible]). Ground cover of prairie rose and birch-leaved spirea was higher inside the exclosure than outside.

Low growing cryptogams (mosses and lichens) covered significantly more ground on grazed range than on ungrazed range (Fig. 16*a*).

Ground cover estimates of litter were almost three times greater on ungrazed range than on adjacent grazed range.

Summer grazing pressure before clipping probably did not significantly reduce forage production in unprotected macroplots. No significant differences in forage production were observed among

**Table 11. Ground cover and frequency of plant species on grazed range compared to ungrazed range on Wigwam Flats (PCE), July 1984.**

| Plant Species | Average Cover (%) | | Frequency (%) | |
|---|---|---|---|---|
| | Inside | Outside | Inside | Outside |
| GRASSES | | | | |
| Rough fescue | 34.8 | 1.7 | 36 | 37 |
| Bluebunch wheatgrass | 13.3 | 11.3 | 64 | 61 |
| Junegrass | 2.2 | 5.4 | 58 | 55 |
| FORBS[a] | | | | |
| Wild bergamot | 4.0 | 4.7 | 70 | 63 |
| Yarrow | 0.2 | 0.6 | 5 | 40 |
| Cut-Leaved Anemone | 0.7 | 0.3 | 7 | 8 |
| Hood's phlox | 2.4 | 2.3 | 60 | 48 |
| Rosy pussytoes | 2.2 | 0.2 | 1 | 1 |
| Paintbrush, yellowish | 0.2 | 1.5 | 22 | 17 |
| Chickweed | 1.4 | 1.2 | 45 | 39 |
| Yellow penstemon | 1.4 | 0 | 5 | 1 |
| Long-leaved starwort | 1.4 | 1.2 | 45 | 39 |
| Yellow salsify | 0 | 3.0 | 0 | 1 |
| Early blue violet | 1.0 | 0 | 5 | 0 |
| Lyall's mariposa lily | 0.5 | 0.1 | 21 | 3 |
| Few-flowered shootingstar | 2.1 | 0 | 1 | 0 |
| SHRUBS | | | | |
| Rose | 3.3 | 0.4 | 8 | 8 |
| Birch-leaveed spirea | T | 0.5 | 7 | 9 |
| Pin cherry | 1.5 | 0 | 1 | 0 |
| CRYPTOGAMS | 74.4 | 53.7 | | |
| LITTER | 10.6 | 3.7 | | |
| BARE GROUND | 5.5 | 4.2 | | |
| ROCK | 0.6 | 2.1 | | |

a Species having <0.5% cover were not included in this table. Comparing grazed to ungrazed range, there were 5:5 grass species, 14:20 forb species and 3:4 shrub species.

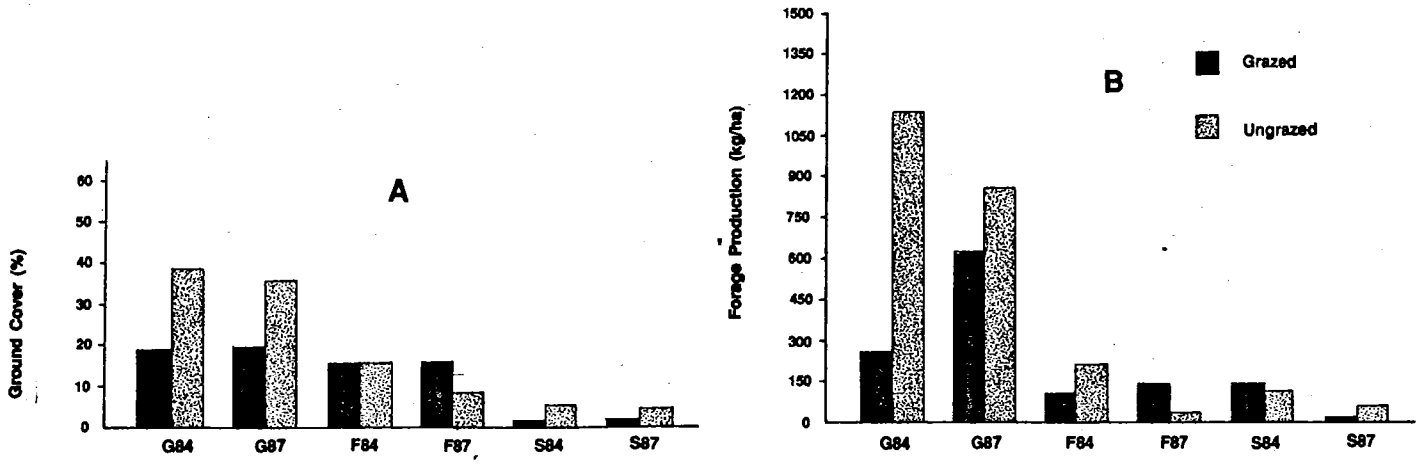



**Figure 16. Ground cover (A) and forage production (B) of grazed range compared to ungrazed range on Wigwam Flats, July 1984 and 1987.** (G = Grasses; F = Forbs; S = Shrubs)

ten 1-$m^2$ exclosed plots and adjacent grazed 1-$m^2$ plots.

*Forage production.*— Total forage production was nearly three times greater on ungrazed range than on grazed range near Purple Canyon in 1984 (1457:515 kg/ha; Fig. 16*b*). Forage production on grazed range of Wigwam Flats was slightly less that of Columbia Lake (366:380 kg/ha on 2-year average) and five times less that of the lower Bull River or Premier Ridge.

Grasses made up 78% of total forage production and 51% of estimated ground cover inside the exclosure compared to 36% and 19%, respectively, outside. Production of grass was significantly higher (99% C.L.) inside the exclosure at 1140 kg/ha than outside at 259 kg/ha confirming the importance of high quality bunchgrasses in increased forage production.

Forb production on ungrazed range was almost double that of grazed range in 1984 (204:112 kg/ha), but the difference was not statistically significant due to the crudeness of the comparison. Forbs made up 22% of total forage production on grazed range and 14% of total forage production on ungrazed range.

Shrub production was similar on grazed and ungrazed range, making up 28% of total forage production on grazed range and 8% of total forage production on ungrazed range.

Litter weight was significantly greater (99% C.L.) inside the exclosure than outside (5126:2810 kg/ha).

*Ungulate use.*— Pellet group counts indicated that all available forage had been grazed near Purple Canyon during the previous winter season (Table 5). Forty-four percent of use was by elk and 54% was by bighorn sheep and/or mule deer.

*Range condition and trend.*— When ground cover estimates inside the Purple Canyon exclosure in 1984 were compared with those made in 1966, total forage cover increased from 35% to 59% (Fig. 17). Ground cover of grazed forage was similar to cover 18 years previously (36%:35%). Ground cover of grasses increased from 23% to 38% inside the exclosure but decreased from 23% to 19% outside the exclosure between 1966 and 1984. Bluebunch wheatgrass had increased from <1% ground cover inside the exclosure in 1966 to 13% of ground cover in 1984 (Table 12). On ungrazed range,ground cover of rough fescue increased from a trace in 1966 to 35% in 1984. Junegrass, six-weeks fescue, alpine fescue, and Idaho fescue declined in cover values since 1966 while rough fescue, Canada bluegrass and sedges increased in cover on ungrazed range.

Forb cover increased from 7% to 16% of ground cover inside the exclosure between 1966 and 1984 whereas shrub cover changed little. Between 1966 and 1984,

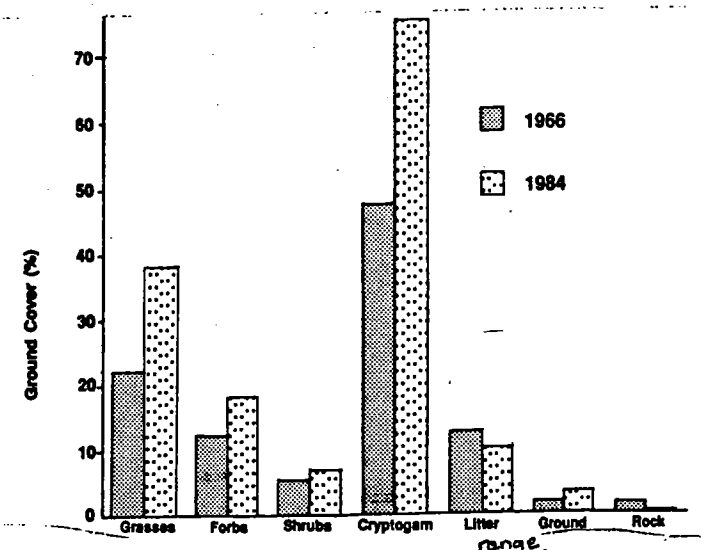



**Figure 17. Ground cover of grazed vegetation at Wigwam Flats compared to the same site in 1984.**

cover values of 10 species of forbs increased inside the exclosure, five species invaded and 12 species found in 1966 were not found in 1984 (Table 12). Few-flowered shootingstar, wild bergamot, yellow penstemon, Hood's phlox and chickweed had the largest increases in forb cover. The largest decrease in forb cover was by large-fruited desert-parsley because it dries and cures by the fourth week of July when it disintegrates and blows away.

Shrub cover changed little between 1966 and 1984 (Fig. 17), but species diversity increased inside the exclosure.

Ground cover of cryptogams decreased from 49% in 1966 to 24% in 1984 and the amount of exposed rock increased by 2% (Table 12).

*Paired plot comparisons, 1987.*— Total forage cover was higher on ungrazed range in 1987 than on grazed range as in 1984 but was 12% lower than it had been in 1984. Total grass cover was significantly higher (90% C.L.) inside the exclosure than outside as in 1984 (Fig. 16*a*). As in 1984, rough fescue was the dominant grass inside the exclosure (34% in 1987:35% in 1984) and bluebunch wheatgrass was the dominant grass outside (13% in 1987:13% in 1984). As in 1984, frequency of occurrence of grasses closely paralleled cover estimates with the notable exception of rough fescue that occurred in 65% of grazed plots but had only 3% ground cover (Table 13, Appendix E). As in 1984, estimated ground cover of rough fescue was much higher on ungrazed range than grazed range indicating that game animals selected this species.

Forb cover was significantly higher on grazed range than on ungrazed in 1987 at Purple Canyon and diversity of forb

**Table 12. Ground cover of plant species at Wigwam Flats (PCE) in 1966 and 1984.**

| Plant Species | Type | Plant Cover 1966 | Plant Cover 1984 | | Difference |
|---|---|---|---|---|---|
| GRASSES | | | | | |
| Bluebunch wheatgrass | Decreaser | 0.55 | 13.33 | ±0.51 | +12.8 |
| Pinegrass | Increaser | - | 0.2 | ±0.3 | +0.2 |
| Alpine fescue | Decreaser | 1.79 | | - | -1.79 |
| Idaho fescue | Increaser | 1.01 | | - | -1.01 |
| Six-weeks fescue | Decreaser | t | | - | t |
| Rough fescue | Decreaser | - | 34.83 | +11.91 | +34.93 |
| Junegrass | Increaser | 6.48 | 2.20 | ±0.62 | -4.28 |
| FORBS | | | | | |
| Nodding onion | Increaser | 0.67 | | 0.20 | -0.47 |
| Western pasqueflower | Increaser | t | 0.73 | ±0.85 | +0.73 |
| Rosy pussytoes | Increaser | t | 2.17 | ±1.82 | +2.17 |
| Lyall's mariposa lily | Increaser | - | 0.51 | ±0.35 | +0.51 |
| Large-flowered collomia | Increaser | 0.63 | | - | 0.63 |
| Few-flowered shooting star | Increaser | - | 2.13 | +1.31 | +2.13 |
| Large fruited desert-parsley | Increaser | 6.7 | 0.95 | +1.08 | |
| Wild bergamot | Increaser | 2.6 | 3.97 | +1.8 | +0.37 |
| Yellow penstemon | Decreaser | - | 1.4 | +0.13 | +1.4 |
| Hord phlox | Increaser | 0.84 | 2.39 | +2.76 | 1.55 |
| Long-leaved starwort | Increaser | - | 1.43 | +1.18 | +1.43 |
| SHRUBS | | | | | |
| Pin cherry | Decreaser | - | 1.51 | +1.33 | +1.51 |
| Rose | Increaser | 4.69 | 3.32 | +1.14 | -1.37 |
| BARE GROUND | | 1.9 | 5.51 | | -4.41 |
| LITTER | | 11.9 | 10.59 | | -1.31 |
| ROCK | | 2.5 | 0.57 | | 1.93 |
| CRYPTOGAMS | | 48.8 | 74.41 | | 24.39 |

**Table 13. Ground cover and frequency of plant species on grazed range compared to ungrazed range on Wigwam Flats (PCE), July 1987.**

| Plant Species | Average Cover (%) | | Frequency (%) | |
|---|---|---|---|---|
| | Inside | Outside | Inside | Outside |
| GRASSES | | | | |
| Rough fescue | 33.6 | 3.0 | 100 | 65 |
| Bluebunch wheatgrass | 0.9 | 12.5 | 20 | 95 |
| Junegrass | 1.6 | 5.4 | 57.5 | 90 |
| FORBS[a] | | | | |
| Wild bergamot | 1.9 | 6.0 | 45 | 72.5 |
| Yarrow | 0.1 | 1.3 | 7.5 | 45 |
| Cut-leaved anemone | 0.6 | 0.4 | 2.5 | 30 |
| Hood's phlox | 2.3 | 3.4 | 67.5 | 85 |
| Large-fruited desert-parsley | 1.1 | 1.6 | 50 | 55 |
| Pearly everlasting | 0.1 | 0.5 | 2.5 | 30 |
| Owl clover | 0 | 0.8 | 0 | 45 |
| Long-leaved starwort | 0.8 | 0.9 | 45 | 52.5 |
| SHRUBS | | | | |
| Pin cherry | 1.7 | 0 | 7.5 | 0 |
| Wood's rose | 2.0 | 0.7 | 35 | 17.5 |
| Birch-leaved spirea | 0.2 | 1.0 | 2.5 | 22.5 |
| CRYPTOGAMS | 35.0 | 36.2 | | |
| LITTER | 22.1 | 22.3 | | |
| BARE GROUND | 1.2 | 1.8 | | |
| ROCK | 2.5 | 2.9 | | |

a Species having <0.5% cover were not included in this table. Comparing grazed to ungrazed range, there were 4:5 grass species, 22:14 forb species and 4:4 shrub species.

species was greater (Table 13; Fig. 16*a*). Also, ground cover of yarrow, wild bergamot, and western pasqueflower greatly increased on grazed range.

No significant difference in ground cover or shrub production was observed between grazed and ungrazed range in 1987 and values were similar to 1984. Saskatoon and birch-leaved spirea were more abundant on grazed range; pin cherry and rose were more abundant on ungrazed range (Table 13).

Ground cover values of cryptogams, litter, bare ground and rock were similar on grazed and ungrazed range in 1987, but cryptogam cover had declined significantly from 1984 and litter cover had increased significantly on grazed range.

*Forage production.*— Total forage production was higher on both grazed and ungrazed range in 1987 than in 1984. On grazed range, total forage production in 1984 was only 515 kg/ha compared to 793 kg/ha in 1987. The average forage production on grazed range in 1984 and 1987 was 654 kg/ha, 1.3 times greater than on the same range in 1966 (Eastman 1970). Although moisture conditions and temperatures during the growing season were similar in 1984 and 1987, forage production increased by 54% on grazed range and declined by 35% on ungrazed.

Grasses produced nearly four-fifths of total forage production in 1984 and 1987 on both grazed and ungrazed range except for 1984 when only 50% of total forage production on grazed range was due to grasses. On ungrazed range total forage production was 1457 kg/ha in 1984 and 945 kg/ha in 1987. As in 1984 grass production on grazed range was lower than on ungrazed range (631:854 kg/ha). Forb production was higher on grazed range than on adjacent ungrazed range both in 1984 and 1987. Forb production accounted for 22% of total forage production in 1984 and only 18% in 1987.

As in 1984 litter weight was significantly (99% C.L.) greater inside the exclosure

than outside but total litter weight had declined significantly since 1984 (1987: 2810 kg/ha inside:1639 outside; 5126 kg/ha inside in 1984:2810 outside).

## 4.3 Forest Encroachment

Paired aerial photographs indicate that forest encroachment occurred at a rate of 0.5 to 2%/year on low elevation winter ranges since the major wild fires of the 1930's. On dry, well-drained low-elevation winter ranges, the rate of forest encroachment is slowed by climatic conditions, but on ranges where moisture conditions during the growing season are better, forest encroachment is approaching 2%/year. The loss of open winter range has been most rapid on the lower Bull River, Wigwam Flats/China and Galton ranges. The rate of forest encroachment and ingrowth has been more rapid on spring-fall range than on low-elevation winter ranges due to better moisture conditions, and less heat. Forest encroachment on intermediate range between lambing and rutting ranges is believed to cause extended use of low-elevation winter ranges by bighorn sheep. Telemetry follow-up of radio-collared bighorn sheep indicated that little time is spent (<3 days) on intermediate range on the Stanford Range east of Columbia Lake. Long-time residents of Canal Flats believe that bighorn sheep arrive on the winter range 1 month earlier than 20 to 40 years ago and leave 2 to 3 weeks later in the spring. Most ewe bands at Columbia Lake, Wigwam Flats, the lower Wildhorse and the Lizard Range do not leave winter range until several days before lambing in late May and early June and usually return to winter range by early September.

Little forest encroachment has occurred on west-facing slopes of Premier Ridge since 1952, but forests are rapidly encroaching on the east-facing slopes above Quartz and Premier Lakes. Prescribed fires in 1977 and 1983, conducted by the Ministry of Environment on the upper west-facing slopes of Sheep Pasture, have slowed the rate of forest ingrowth on Premier Ridge. The east-facing slope of Premier Ridge in Quartz-Burnt Car pastures was burned in 1983. The east-facing slopes above Quartz Lake located within Premier Lake Provincial Park were slashed in 1987. Extensive Christmas tree cutting has occurred on the south-facing slopes of Premier Ridge.

Forest ingrowth is estimated to have reduced semi-open winter range located on the lower Wildhorse by about 40% since 1952. Selective logging in the 1940's and 1960's on Brewery Ridge and the lower west-facing slopes of Lakit Mountain maintained small openings (<1 ha) where bunchgrass was available during winter months. Before selective logging on Brewery Ridge and lower Lakit Mountain in 1982 and 1983, <170 ha of open winter range located between Horseshoe Creek and Lone Peak was available to bighorn sheep in the Wildhorse drainage. This forest encroachment is believed to be the major cause of elk migration to open cultivated fields and the Bummer's Flats slough area where winter forage could be obtained. Creation of 230 ha of open winter range through selective logging of the lower southwestern slopes of Lakit Mountain and Brewery Ridge virtually ended elk depredation of hay fields in the vicinity.

Forest encroachment has been dramatic on the lower Bull River winter range probably approaching 2%/year (Fig. 18). Open winter range for bighorn sheep located on the lower western slopes of Bull Mountain has been reduced by at least 50% since 1952. Traditional elk winter range located

in Pickering Hills (Fig. 18) had few conifers in 1952 (21 years after two major wild fires) and is now 60% overgrown with conifers. This forest encroachment may explain a change in winter distribution of elk coming from the Bull River drainage. Before 1965, virtually all elk migrating from Bull River drainage would winter in Pickering Hills and adjacent range to the south. Since then, about 1/3 of the Bull River elk population migrates across Bull Mountain to winter on the lower western slopes of the Steeples Range and the Picture Valley hills and Kootenay River bottom.

Forest encroachment in the Wigwam Flats-Mount Broadwood-Sheep Mountain area has reduced open grassland and seral shrubland range by about 50%. Sheep Mountain located due west of the Elk River had <30 ha of trees in 1952 and is now 50% overgrown with conifers. Conifer encroachment has been delayed on Wigwam Flats by a prescribed fire in 1977. Few hectares of open winter range can now be found on the western slopes of Mount Broadwood and little Baldy due east of Silver Springs Lakes and few bighorn sheep now winter in this area. Conifer encroachment south of the Wigwam and Lodgepole Rivers and adjacent to Mount Broadwood has left little open range and snow accumulations on the alluvial terraces now force elk to migrate north across the Wigwam River to winter on the open south-facing slopes of Mount Broadwood or on the open grasslands of Wigwam Flats and Rocky Ridge. Grazing pressure on traditional sheep range of Wigwam Flats has not been due solely to population increases in elk. Elk populations wintering on Wigwam Flats have changed from <200 in 1974 to nearly 800 in 1982 and 350 to 400 now. Winter densities of elk on Wigwam Flats-Mount Broadwood-Sheep Mountain have also been influenced by hunting pressure especially on cows and calves, snow depths on traditional fall ranges and forest encroachment on traditional winter range.

## 4.4 Conclusions and Discussion

### 4.4.1 Stoddart Creek-Radium Hotsprings

Range condition and trend has not improved on several key bighorn sheep winter ranges adjacent to the southern Rocky Mountain Trench despite removal of all domestic livestock since the mid-1960's. Range condition near exclosures has remained in poor or fair condition between Stoddart Creek and Radium Hotsprings, the east side of Columbia Lake and Wigwam Flats due to grazing pressure from elk, bighorn sheep and deer. Condition of winter range located between Radium Hotsprings-Stoddart Creek was poor to fair in 1984 and the trend in range condition was stable or gradually declining (Stelfox *et al.* 1985). With roughly three-quarters of the grazing pressure coming from bighorn sheep in 1984 one can assume that population densities on this winter range are high enough to prevent recovery of range condition and productivity. Forage production was slightly lower in 1984 than in 1966 at Stoddart Creek (367:400 kg/ha; Stelfox *et al.* 1985) but could have been due to less optimum moisture conditions.

Estimated carrying capacity of this 19.6-$km^2$ winter range for bighorn sheep based upon Ungulate Biophysical Capability mapping (Demarchi 1986) is 166 (Table 1) and the known population now exceeds that number between Mount Swansea and Radium Hotsprings.

Population counts by the author during the winter of 1984/85 exceeded the peak

population of bighorn sheep counted between Radium Hotsprings and Stoddart Creek. Over 160 bighorn sheep were observed between Radium Hotsprings and Stoddart Creek (which was baited) in one day. This count did not include the mature ram band nor 55 bighorn sheep that wintered between Mount Swansea (near Windermere and Stoddart Creek). Bighorn sheep tagged and neck-collared at Mount Swansea near Windermere have frequently been observed at Stoddart Creek and Radium Hotsprings. The author's estimate of bighorn sheep using this winter range was 250 but included a wider area than censused by Stelfox *et al.* (1985) who claimed that a minimum population of 114 bighorn sheep were found in the Radium Hotsprings-Stoddart Creek area. Bait site counts of bighorn sheep normally result in 50-100% higher numbers of bighorn sheep counted through ground or aerial surveys. Bighorn sheep densities on 8.5 $km^2$ of Class I and II winter range (Demarchi 1986) located between Mount Swansea and Radium Hotsprings were 29 $km^2$, which is higher than range in poor condition should support.

Eighty-two bighorn sheep were translocated from these herds by the Wildlife Branch between 1986 and 1988. An average of two rams have been harvested annually from the Mount Swansea-Stoddart herd since 1985 but the population of sheep has only declined by about 30 and the population density still averages 25 $km^2$ on this winter range.

### 4.4.2 Columbia Lake

Grazing pressure by elk and bighorn sheep has kept this winter range in poor condition since removal of all livestock in 1961. Since 1980, 150 to 200 bighorn sheep and 150 to 300 elk are estimated to have wintered on 1230 ha of Class I and II winter range (Table 1) located along the east side of Columbia Lake. Although the average density of bighorn sheep is 16 /$km^2$, only 18% of the potential winter range is utilized as forage areas.

Bighorn sheep populations wintering on the east side of Columbia Lake have not declined even though an average of 14% of the estimated population have been removed annually. Between 1984 and 1989, 129 bighorn sheep were translocated from the east side of Columbia Lake. An average annual harvest of five rams has occurred since 1985 and three ewes since 1987. The growth rate of this herd must be at least 14%/year after natural mortality including predation. Herd recruitment has been stimulated through winter bait site treatment with high quality feed, trace mineral supplements and antiparasite treatment, which has elevated recruitment levels.

The estimated carrying capacity for bighorn sheep on this 28.4-$km^2$ winter range based upon Ungulate Biophysical Mapping (Demarchi 1986) is 435 (Table 1) but the long history of overgrazing by livestock has resulted in disclimax vegetation of low growth form and low productivity as at Stoddart Creek. Little bluebunch wheatgrass remains on alluvial fans preferred as grazing areas. Forb and shrub diversity are low and forage production is a fraction of the site potential. Drought conditions due to low levels of moisture during the growing season, hot summers and frequent dry winds will make the recovery of range condition and productivity a slow process under optimal grazing pressure. Forest encroachment and land alienation near Canal Flats and Fairmont Hotsprings are rapidly reducing the quantity of winter range while forest encroachment on spring-fall range has resulted in extended

use of winter range. The lack of litter, high amount of bare ground, low forage cover and production, and 100% forage utilization as indicated by pellet group counts suggest that condition of part of this winter range will continue to degenerate unless grazing pressure is reduced dramatically or forage production is expanded.

### 4.4.3 Premier Ridge

Ground cover of climatic climax vegetation located on Premier Ridge indicates that range on the upper western slope is in poor to fair condition. A good diversity of grasses, forbs and shrubs and high forage production (932 kg/ha) at this site indicate that this range may be recovering from a long history of overgrazing. In 1984 and 1987, nearly 2/3 of forage production on grazed range came from grasses and production was double that of 1967-1969 in the same vegetative community. Shrub production accounted for 25% of total forage production on grazed range in 1987 giving this range the capability of supporting game animals during periods of deep snow accumulation. Total forage production on grazed range was 2.5 times that of Columbia Lake and Stoddart Creek giving this range a much higher capability of supporting game animals although in a similar condition class. The excellent productivity of this winter range and high species diversity of forage make Premier Ridge an excellent winter range. The segregation of preferred grazing areas between elk, white-tailed deer, mule deer and bighorn sheep (Hudson *et al.* 1975) permits heavy grazing pressure without competition for forage and space. The estimated carrying capacity of this 19-km$^2$ winter range based upon Ungulate Biophysical Capability Mapping (Demarchi 1986) is 188. The 1960's dieoff occurred when the total population was between 200 and 250 and the population has yet to recover to that level.

### 4.4.4 Bull River

*Big Bull Pasture (BR 7).*— Range condition in 1984 inside the exclosure was similar to that of 1966 but had declined one condition class to poor to fair on grazed range. The drop in condition of grazed range is due to declines in cover of palatable shrubs including the antelope-brush - bluegrass community. Forage production was 556 kg/ha (Eastman 1970), which is only one-third the forage production found in this community in 1984. If shrub production was not included in production estimates from 1967 to 1970, production was 46% of that in 1984. The difference in forage production may be attributed to the decrease in cover and frequency of antelope-brush and the increase in cover, frequency and production of Canada bluegrass on grazed range since 1966. Canada bluegrass communities are productive (Harper 1969) and preferred by bighorn sheep (Wikeem and Pitt 1979). Antelope-brush is not considered a weedy species because it is a productive forage species heavily utilized by mule deer and elk in the East Kootenay (Quaedvlieg 1969). The increased productivity of the antelope-brush - bluegrass community on terraces bordering the Bull River Canyon is highly desirable for bighorn sheep but may be undesirable for deer and elk, which depend more heavily on browse production. Forage production was 4.3 times that of Columbia Lake (1660:385 kg/ha) and 1.8 times that of grazed range located at Premier Ridge giving this range a high capability of supporting wintering game animals. Forage production of ungrazed range was similar to that of ungrazed range at Premier Ridge (1798:1730 kg/ha) and 3.2 times that of

Columbia Lake. Carrying capacity of this range is much greater than that of Columbia Lake and Stoddart-Radium Hotsprings though similar in condition class and biophysical rating (Appendix B).

*Fontaine Pasture (BR 9).*— Condition of grazed range has declined by one class since 1966 due to browse pressure causing the disappearance of redstem ceanothus by 1984 when it had constituted 58% of forage cover in 1966. The decline in highly palatable browse species indicated that browse pressure was excessive and reduced the ability of this range to support elk and deer, which depend heavily on browse. Since 1966, ground cover and frequency of Canada bluegrass increased on grazed range while Kentucky bluegrass disappeared as at Big Bull pasture. Forage production was not assessed due to time constraints but is believed to be similar to that of BR 7.

Estimated carrying capacity for bighorn sheep on this 32.4-km$^2$ winter range is 390 (Table 1) based on Ungulate Biophysical Capability Mapping (Demarchi 1986). The estimated population of 130 bighorn sheep is only one-third the potential of this range under ideal range conditions and grazing regimes. The actual carrying capacity for bighorn sheep is probably two-thirds the potential due to land alienations and fair/good range condition rating.

### 4.4.5 Wigwam Flats

Range condition near Purple Canyon on Wigwam Flats would be rated as poor to fair on the grazed section and good on ungrazed range. Condition of ungrazed range has not improved since removal of all livestock in the mid-1960's assuming that bluebunch wheatgrass is the climatic climax. However, the dominant grass inside the exclosure built in 1966 is now rough fescue and the condition class rose from poor/fair to good. Heavy grazing pressure by elk and, to a lesser degree, mule deer and bighorn sheep maintained this winter range in poor condition and thus low forage production. As at Columbia Lake, heavy grazing pressure during spring months when grasses are relying on root reserves for growth probably caused continuous poor range condition. Before the dieoff on Wigwam Flats in 1982, high densities of elk, mule deer and bighorn sheep (60, 40, 30/km$^2$, respectively) removed virtually all forage production. Following the pneumonia epidemic in bighorn sheep and reduction in elk numbers through Limited Entry Hunting of cows and calves, densities of bighorn sheep were reduced to 6/km$^2$ and elk were reduced to 30/km$^2$. Mule deer densities have not changed since 1980.

The estimated carrying capacity for bighorn sheep on this 29.3-km$^2$ area (including Mount Broadwood, Table 1) based upon Ungulate Biophysical Capability Mapping (Demarchi 1986) is 448. This level was probably exceeded before the 1982 pneuomonia epidemic. Although grazing pressure declined significantly between 1982 and 1987, condition class had not changed. Forage production had increased 1.3 times on grazed range between 1966 and 1987 indicating that some range recovery is occurring. Semi-arid soil moisture regimes, thin soils, low precipitation, coupled with a short growing season, and frequent winds ensure that range condition will recover slowly even under optimal grazing pressure. Uncontrolled forest encroachment and increasing populations following the 1982 dieoff of bighorn sheep will add grazing pressure to the bluebunch wheatgrass plant community that occupies 890 ha (Eastman 1970) on the alluvial terraces of Wigwam Flats.

# 5. HABITAT ENHANCEMENT

Condition of major winter ranges for bighorn sheep bordering the Rocky Mountain Trench had not improved since the mid-1960's although Coordinated Resource Management Plans (CRMP) were implemented to regulate livestock grazing pressure and, after 1982, extensive harvest of cow and calf elk through Limited Entry Hunting controlled elk grazing pressure. Loss of winter range to forest encroachment and land alienation was more than offsetting the gains made by managing livestock and wildlife more intensively. A program was needed to maintain open range for wildlife because wild fires were being effectively controlled, and little logging was completed or planned for bighorn sheep range. Budgets allotted to manage wildlife in British Columbia did not, and still do not, include maintaining critical range.

Recognizing the need for a range enhancement program, a joint prescribed burning program was initiated between the Ministry of Forests and the Ministry of Environment in 1975. More than 1500 ha of wildlife winter range at Bull River, Wigwam Flats and Premier Ridge were burned between 1975 and 1978 but static budgets and increasing costs for game inventory, regulations and protection meant that enhancement activities could not be maintained without outside funding.

The Habitat Conservation Fund (HCF) was established in 1982 to provide funds for habitat enhancement and land acquisition. A voluntary surcharge on hunting, trapping, guiding and fishing licenses provided the source of funds, which were to be administered by the Ministry of Environment. The East Kootenay Habitat Enhancement Project for Rocky Mountain bighorn sheep was initiated in 1982 using HCF funding. This project enhanced winter and spring range for bighorn sheep through prescribed burns, selective logging, slashing and spacing and seeding of forage on sites disturbed through logging.

Almost all bighorn sheep winter ranges in the East Kootenay are also important ranges for elk and mule deer. Enhancement prescriptions should address the needs of the major users of the winter range being treated.

## 5.1 Objective of Habitat Enhancement

The primary objective of habitat enhancement work was to maintain and create open grasslands and seral shrublands traditionally used as winter range by bighorn sheep. Habitat enhancements were also used to stimulate grass, forb and shrub production and rejuvenate decadent forage plants.

## 5.2 Methods for Enhancement

### 5.2.1 Choosing habitat enhancement technique

The technique used to enhance range depended upon many factors including:

1. the objectives of habitat enhancement activity;
2. the physical characteristics of the site including slope, aspect, soil depth and type, and soil moisture regime;
3. type of vegetative community present, i.e., what seral type and stage;
4. the cost of treatment per hectare;
5. type of access and ease of performing the enhancement activity.

Prescribed burns were the preferred enhancement technique for preventing forest encroachment on open grasslands

and seral shrublands due to the low cost of treatment and effectiveness in rejuvenating decadent shrubs and bunchgrasses while maintaining winter range in an early seral stage (Premier Ridge, lower Bull River, Fig. 2). Costs of planning and implementing range burns varied between $3 to $50/ha depending upon proximity to private land, and difficulty in controlling the burn. The time, effort and cost increased dramatically with the need to protect private holdings. In addition to maintaining open grasslands and seral shrublands, prescribed fire was also used on uneven age conifer stands to prevent rapid ingrowth of adjacent open grasslands. Slash created through building of 30-m wide fire guards at Wolf Creek and the Estella (Fig. 2) was supposed to generate enough heat following gel-gas ignition to create a crown fire. The purpose of crown fires was to remove immature lodgepole pine and interior Douglas-fir that were encroaching open winter range. Prescribed fire was proposed for slash abatement after the cutting of trembling aspen on Mount Broadwood and Whiteswan Lake (Fig. 2).

Guidelines used to select sites for prescribed fire were:

1. use as winter range by bighorn sheep;
2. high capability to support bighorn sheep;
3. high potential for desired vegetative response based upon soil, terrain and vegetation present;
4. proximity to private land;
5. difficulty in light up and control of fire;
6. type and amount of fuel present;
7. difficulty of access;
8. past fire and grazing history.

A 5-year prescribed burning plan was developed and priorities given for bighorn sheep winter and spring ranges bordering the Rocky Mountain Trench using the guidelines mentioned above.

Most bighorn sheep winter ranges could not be burned effectively in the East Kootenay due to physical characteristics of the site, lack of continuous suitable fuels and presence of private land. Physical characteristics including shallow or rocky soil preclude a successful burn. Few conifers >5 m high were killed with prescribed fire.

Guidelines used in selecting other enhancement techniques were:

1. Selective logging was used where adequate mature wood was present for an economical harvest and where slopes were <70%, thus permitting random downhill skidding by small caterpillar or F.M.C. (tracked vehicle). Random downhill skidding minimized soil damage and permitted rapid revegetation because <5% of cut-block areas were disturbed by skid roads and sidecast vs 15 to 45% through traditional rubber-tired skid road construction.

2. Slashing and spacing of conifers were completed on winter range where prescribed fire could not be conducted due to high risk of escape, or lack of continuous fine fuels needed to carry a fire. These methods of enhancement were effective on winter ranges with high ungulate biophysical capability and a low to moderate wood fibre capability that made selective logging uneconomical. These sites had more advanced seral stages than those selected for prescribed fire. These techniques were more expensive than prescribed fire ranging from $200 to $700/ha.

3. Forage seeding was used where soil had been disturbed through selective logging to produce high quality winter forage and prevent noxious weed invasion.

4. Fertilization of bighorn sheep winter ranges was not conducted because this technique was found to be uneconomical.

### 5.2.2 Conducting enhancements

*Prescribed burns.*— Prescribed burns were conducted in spring or fall when fine

fuels or grasses, shrubs and small dead wooden material were dry, ambient air temperatures were >20 C, relative humidity was <35%, winds were <15 km/h and heavy fuels (slash) fuel moisture was <20%. Normally at least three warm, dry days were required following snow melt to achieve appropriate fuel moisture conditions. Natural and man-made fire guards were used to control spread of the fire after light-up occurred.

Light-up was accomplished by an auto-incendiary device (AID) mounted to a helicopter. The AID machine injected ethylene glycol (antifreeze) into ping pong balls containing potassium permanganate and ejected these from the helicopter through a hopper-loaded chute. Spontaneous combustion of the ping pong balls occurred 30 seconds to 1 minute after ejection. This machine had several advantages over hand-operated drip torches including rapid light-up, control of light-up pattern and safety of personnel involved in prescribed fires.

Where fuels were discontinuous or a crown fire was desired, light-up with a heli-torch containing 60% diesel fuel, 40% gas and a gelling agent called "Surefire" was most effective. Hand-held drip torches were used to create fire guards and fill in areas missed through helicopter light-up. Rapid spring green-up and large elevational differences on winter ranges located on the western edge of the Rocky Mountains created a narrow burn window and sometimes needed two-stage burning.

*Other enhancement methods.*— The design for selective logging cut-blocks was initially addressed through Timber Supply Area (TSA) Plans developed by the Ministry of Environment for different biogeoclimatic zones of the Province. If the Ministry of Forests approved cut-block development for the benefit of bighorn sheep and a logging contractor had obtained cutting rights, a preharvest silviculture plan (PHSP) was developed with input from the Ministry of Environment, the Ministry of Forests and the contractor. This plan addressed: location; standards and management of access to the cut-block; engineering requirements including culverts, road drainage, and road lay-out; period of time and season the block was to be harvested; and prescription of tree harvest. The Wildlife Branch could voice its concerns over any aspect of the development of a cut-block.

Selective logging on bighorn sheep winter range attempted to create openings ≥4 ha in the Interior Dougas-fir biogeoclimatic zone, which includes virtually all winter ranges in the Rocky Mountain Trench. Large patch-cuts were preferred to promote growth of palatable species of grass, forbs and shrubs. On areas selectively logged for bighorn sheep, about 10% mature timber was to be left on ridge tops and natural bedding areas used as thermal and hiding cover. On bighorn sheep winter range located between Maguire and Red Canyon Creeks on the Galton Range, mature timber was left on a lateral moraine at 1400 m and on adjacent lower west-facing slopes that were used as bedding and escape terrain. In timber stands that remained, <400 stems/ha of immature timber were left. Where winter range capability for mule deer was high in the contiguous area, immature Douglas-fir thickets at least 100 m in diameter as well as timber on north-facing slopes and creek bottoms were left as thermal and hiding cover. Loggers and hand-slash crews were directed to leave dead, standing snags for small mammals, woodpeckers and raptors. This directive usually meant that timber could not be cut within two tree lengths of

the snag to comply with Worker's Compensation Board Regulations. Selective logging and slashing were avoided near natural mineral licks, major migration trails and creek beds. On the dry, south- and west-facing slopes of Lakit Mountain (lower Wildhorse) and the Galton Range, random down-hill skid trails were seeded with a grass-legume mix within 2 weeks of final use. When seeded this way, the forage mix germinated and survived better than areas built by small caterpillar for rubber-tired skidders where little revegetation occurred. Traditional skid trail construction removed the upper soil horizons and exposed the non-fertile B and C soil horizons to the surface. Compaction of exposed, sterile soils was high using this skidding method so revegetating with forage species or trees was difficult.

Winter ranges treated by slashing conifers were Premier Ridge, the east side of Columbia Lake and Mount Swansea. Patches of immature conifers were clear-cut and mature conifers with >15 cm dbh were spaced to 400 to 600 stems/ha. Openings of at least 10 ha were preferred for bighorn sheep but they were often larger to discourage potential competitors such as elk. Vehicular access to the work site had to be good and slopes moderate so the Workers' Compensation Board would permit workers to enter the site. Slash had to be burned.

This method of enhancement was expensive ($500 to $700/ha) and depended on outside funding. Federal and provincial employment abridgement and welfare assistance programs were used to complete spacing and slashing projects for the Sheep Enhancement Project.

Hand and mechanical slashing of trembling aspen was done on 130 ha of bighorn sheep, elk and mule deer winter range located on the south-facing slopes of Mount Broadwood. The purpose of the slash work was to reduce the height of the canopy cover and promote aspen root suckering, thereby providing an abundant available food source for wintering game animals and preventing conifer encroachment on this important winter range. Mechanical slashing was done on 15 ha of slope <15% while the ground was frozen in January 1984.

Seeding of grasses and legumes on skid roads and landings disturbed by logging was effective in creating high quality winter forage and preventing surface erosion, and knapweed invasion.

Fertilization trials were attempted on bighorn sheep winter ranges on the east side of Columbia Lake and on Wigwam Flats to evaluate the cost-benefit of this technique.

## 5.3 Accomplishments of the Habitat Enhancement Program

Habitat enhancement treatments were completed on 1953 ha of bighorn sheep winter and spring range between 1982 and 1988: prescribed fires, 775 ha; selective logging, 540 ha; slashing, 380 ha; spacing, 110 ha; grass-legume mix, 130 ha; and, fertilization, 18 ha (Table 14).

Monitoring plots were estabished on bighorn sheep winter range to determine how effective various enhancement techniques were. Enhancement techniques monitored were prescribed fire, selective logging, mechanical and hand slashing, wild fire and fertilization. The effects of wild fire on vegetation were included because the Lakit Mountain fire of August 1986 occurred in an area already being monitored because it had been selectively logged in 1982 and 1983.

**Table 14. Habitat enhancement projects completed under the Rocky Mountain Bighorn Sheep Enhancement Project.**

| Location | Date Treated | Treatment (area in ha) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Prescribed Burning | Selective Logging | Slashing | Juvenile Spacing | Forage Seeding | Fertilized |
| Fontaine Basin | March 1982 | 350 | | | | | |
| Premier Ridge (Sheep Pasture) | April 1983 | 100 | | | | | |
| Premier Ridge (Quartz Pasture) | April 1983 | 110 | | | | | |
| Maguire Creek | April 1983 | 140 | | | | | |
| | April 1983/October 1984 | | 150 | | | | |
| | Spring 1984 | | | | | 25 | |
| | Spring 1985 | | | | | 15 | |
| | Spring 1986 | | | | | 15 | |
| | Fall 1987 | | | | | 15 | |
| Whiteswan Lake | September 1984 | 10 | | | | | |
| | March 1984 | | | 10 | | | |
| Wolf Creek | September 1984 | 20 | | | | | |
| Bull River (near Placid Oil) | April 1986 | 30 | | | | | |
| Estella | May 1988 | 15 | | | | | |
| Lakit Mt./Brewery Ridge | March 1982/March 1984 | | 180 | | | | |
| | July 1984/September 1984 | | | | 100 | | |
| | Spring 1984 | | | | | 25 | |
| | Spring 1988 | | | | | 35 | |
| Red Canyon Creek | May 1985 | | 150 | | | | |
| Horseshoe Creek | May 1987/May 1988 | | 60 | | | | |
| Mt. Broadwood | December 1983/February 1984 | | | 130 | | | |
| Columbia Lake | February 1987/December 1987 | | | 180 | | | |
| | February 1987/December 1987 | | | | 10 | | |
| | May 1982 | | | | | | 6 |
| Mt. Swansea | June 1987/November 1987 | | | 60 | | | |
| Wigwam Flats | May 1982 | | | | | | 12 |
| TOTAL AREA TREATED | | 775 | 540 | 380 | 110 | 130 | 18 |

## 5.4 Evaluation of Monitoring Plots

Monitoring plots were established in Fontaine Pasture in April 1982 after a prescribed fire 1982 March 17 (Fig. 6). This pasture had previously been burned in April 1977. Fuel loads in the lower Fontaine and Burntbridge Basin area (lower Bull River) were estimated to be about 25.8 tonnes/ha (Fischer 1981) on the seral shrubland and sparse interior Douglas-fir, ponderosa pine, western larch stand. Fire intensity was low as demonstrated by maximum flame heights of 5 m and rate of spread <2 m/second. Physical characteristics of burned and adjacent unburned macroplots are given in Table 15.

### 5.4.1 Methods

*Prescribed fire.*— Six macroplots were established in July 1982 to monitor the effects of prescribed fire on vegetation but only four of these were paired and later re-examined in July 1983 and 1984. Macroplots I and II were established on an alluvial fan near Burntbridge Creek with vegetation typical of the benches next to the lower Bull River. This fan had a long history of heavy grazing pressure (Smith 1955) by wildlife and cattle. Macroplots V and VI were established on the lower south-facing slopes of Bull Mountain commonly used by bighorn sheep and mule deer in winter. Five randomly placed transects, 1 m by 15 m, were established on the treated and untreated macroplots using the method of Poulton and Tisdale (1961). Canopy cover and species composition of vegetation were estimated in 0.25-$m^2$ microplots placed every 2 m along each transect. Stem densities of each shrub species were counted in each transect on treated and untreated areas. Physical characteristics of the plots are presented in Table 15.

*Selective logging.*— The lower Wildhorse had not burned for more than 100 years, consequently nearly all traditional winter ranges had grown in with conifers. About 100 ha were selectively logged on the lower south-facing slopes of Lakit Mountain in February and March 1983 using random, down-hill skidding. In June 1983,all skid trails and landings were seeded at 10 to 12 kg/ha with a grass-legume mix containing 30% orchardgrass, 20% creeping red fescue, 20% perennial ryegrass, 10% alsike clover, and 20% intermediate wheatgrass.

Four macroplots were established on Lakit Mountain in July 1984 to monitor the effects of selective logging on vegetation. Plot size and method of analysis was identical to that described for prescribed fire on the Lower Bull River. Physical characteristics of the logged and adjacent unlogged macroplots are presented in Table 16.

All macroplots were analyzed in July of 1984, 1986 and 1987. The analysis in 1986 occurred <2 weeks before an intense wild fire. This fire burned through 400 ha of timber on the lower Wildhorse including the monitoring plots.

*Slashing.*— Four macroplots were established on Mount Broadwood in August 1985 to determine the effect of hand- and caterpillar-slashing of trembling aspen on forage. Macroplot I had a 5-m radius, and macroplots II, III and IV had 2.5-m radii. The circular plots were divided into quadrats using the cardinal directions of the compass and canopy cover, composition and stem density (shrubs only) were recorded for each quadrat. Physical characteristics of slashed and adjacent unslashed macroplots are given in Table 17.

**Table 15. Site characteristics of burned and unburned macroplots on Fontaine Pasture ~~on the~~ (lower Bull River).**

| Macroplot | Slope (%) | Aspect (°) | Elevation (m) | Terrain | Soil Characteristic | |
|---|---|---|---|---|---|---|
| | | | | | Type | Moisture |
| I. Burned | 0 | 154 | 870 | Level | Wycliff Dark Brown Chernozem | Semi-arid |
| II. Unburned | 0 | 87 | 835 | Level | Wycliff Dark Brown Chernozem | Semi-arid |
| V. Burned | 26 | 154 | 970 | Steep Rolling | 60% Wycliff DBC 40% Saha Orthic Dystric Brunisol | Sub-humid |
| VI. Unburned | 23 | 152 | 950 | Steep Rolling | 60% Wycliff DBC 40% Saha ODB | Sub-humid |

**Table 16. Site characteristics of macroplots on Lakit Mountain, Quartz Lake and Columbia Lake.**

| Location | Lakit Mountain | | Quartz Lake | Columbia Lake |
|---|---|---|---|---|
| | I | II | | |
| Slope (%) | 30 | 10 | 32 | 8 |
| Aspect (°)) | 84 | 52 | 110 | 272 |
| Elevation (m) | 1010 | 1020 | 1072 | 902 |
| Topography | Gently Rolling | Gently Rolling | Steeply Rolling | Gently Rolling |
| Soil Moisture Subclass | Subxeric | Subxeric | Subxeric | Xeric |
| Soil Class[a] | OEB | OEB | OEB | OEB |
| Soil Series | Rosen (80%) Caithness (20%) | Keeney (80%) Caithness (20%) | Kenney (80%) Flatbow (20%) | Maycock |
| Soil Texture[b] | gsil | fsl/gsl/gsil | fsl/gsl/sil | sil |
| Parent Mat. | colluvium | fluviogl. colluvium | fluviogl. morainal | glaciola. |

a OEB Orthic Eutric Brunisol

b gsil-gravelly silt loam; fsl-fine sandy loam; fsl-fine sandy loam; gsl-gravelly sandy loam.

**Table 17. Site characteristics of vegetation macroplots on Mount Broadwood (China Wall).**

| | Plot Number | | | |
|---|---|---|---|---|
| | I | II | III | IV |
| Location | | | | |
| Flight L. | 81103 | 81103 | 81103 | 81103 |
| Photo Number | 171 | 171 | 171 | 171 |
| Slope (%) | 23 - 24 | 23 - 24 | 7 - 10 | 14 - 23 |
| Aspect (°) | 149 | 149 | 180 | 170 |
| Elevation (m) | 1038 | 1032 | 937 | 965 |
| Position | middle | middle | lower | lower |
| Topography | flat | flat | rolling | rolling |
| Soils | | | | |
| Moisture Subclass | semi-arid | semi-arid | subhumid | subhumid |
| Drainage | rapid | rapid | rapid | rapid |
| Type | Orthic Dystric Brunisols, Copper Series, gravelly silt-loam texture[a] | | | |
| Parent Material | limestone | colluvium | | |
| Succession | | | | |
| Status | young seral | young seral | young seal | young seal |
| rate | normal | normal | normal | normal |
| Expected Climax | D-f[b] | D-f | D-f | D-f |
| Factors Affecting Stand Estimate | wind, rapidly drying slope | wind, rapidly drying slope | receiving area | course p.m. rapidly drying |

b Lacelle 1976

b Douglas-fir

Habitat Conservation Fund monitoring guidelines were used to determine the effects of hand-slashing activities in Premier Lake Provincial Park and on the east side of Columbia Lake.

These guidelines record many physical and biological attributes of the site including location, slope, aspect, elevation, slope position, microtopography, surface substrate, ecological moisture regime, ecological nutrient regime, soil classification and description, and bedrock geology. Some of the physical characteristics of these sites are presented in Table 16. Macroplots had a 5.6-m radius for an area of 0.01 ha. Canopy cover and distribution of trees, tall shrubs (2-10 m), low shrubs, grasses and forbs, mosses and liverworts, lichens, and tree seedlings were recorded.

*Fertilization.*— The feasibility of fertilizer application on native bighorn sheep range was evaluated through a cost-benefit analysis. Cost was determined as the capital cost of buying fertilizer and the labour and equipment cost in application. Benefit was determined to be the open market value of the increased forage production due to fertilization of range. Plots were 10 m by 10 m. Sixteen different types of fertilizer treatments were tested in a non-random block design and each treatment was replicated four times. The design of fertilizer treatments is illustrated below.

| | | Phosphorous (kg/ha) | | | |
|---|---|---|---|---|---|
| | | 1(0) | 2(100) | 3(200) | 4(400) |
| Nitrogen (kg/ha) | A(0) | 0,0 | 0,100 | 0,200 | 0,400 |
| | B(50) | 50,0 | 50,100 | 50,200 | 50,400 |
| | C(100) | 100,0 | 100,100 | 100,200 | 100,400 |
| | D(200) | 200,0 | 200,100 | 200,200 | 200,400 |

Test sites were not exclosed from grazing animals but the effect of grazing pressure was estimated by comparing forage production within five 1-$m^2$ plots with forage production of adjacent unprotected range at each site. Six ha of alluvial fan were fertilized on the east side of Columbia Lake and 12 ha of till plain were fertilized on Wigwam Flats adjacent to the Wigwam River. Rates of fertilizer used were 100 kg/ha of 20-0-0 mixed with 50 kg/ha 11-55-0. Application was completed with a truck-mounted rotary spreader in late May 1982.

## 5.5 Observations

### 5.5.1 Prescribed fire

*Lower Burntbridge Basin.*— Three months following a low intensity spring burn on the semi-arid, well drained alluvial fans of lower Fontaine Basin, total forage cover was significantly higher on unburned range than on burned range (Table 18, Fig. 19*a*). The cover of grasses increased during the first growing season after prescribed fire, whereas the ground cover of forbs and shrubs declined. Ground cover of grasses, forbs and shrubs increased on burned range at this site in 1983 and 1984 (Fig. 19*a*). On unburned range, grass cover increased significantly (99% C.L.) in 1983 over cover in 1982 and was similar to cover of adjacent burned range. By the third growing season following prescribed fire, grass cover was significantly higher on burned range than adjacent unburned range. Ground cover of Canada bluegrass, spreading needlegrass and Idaho fescue responded best to prescribed fire at this site (Table 18).

Ground cover of forbs decreased during the first growing season following prescribed fire and then increased during the following two growing seasons (Fig. 19*a*). Sticky cinquefoil was the dominant forb on burned range and spreading dogbane was dominant on unburned range

**Table 18. Ground cover and frequency of burned vegetation (BR 1) compared to unburned vegetation (BR 2) on lower Burntbridge Basin, July 1982, 1983 and 1984.**

| Vegetation Species | Estimated Cover (%) | | | | | | Frequency (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1982 | | 1983 | | 1984 | | 1982 | | 1983 | | 1984 | |
| | B[a] | UB | B | UB | B | UB | B | UB | B | UB | B | UB |
| GRASSES AND SEDGES | | | | | | | | | | | | |
| Canada bluegrass | 20.6 | 17.1 | 38.1 | 38.4 | 26.7 | 24.9 | 85 | 97.5 | 95 | 82.5 | 95 | 9 |
| spreading needlegrass | 2.6 | 0.8 | 4.7 | 1.4 | | | 24.4 | 2.5 | 32.5 | 7.5 | | |
| Idaho fescue | 1.8 | | | | | | | | | | | |
| six-weeks fescue | | | 0.5 | | | | 22.0 | | | | | |
| needle-and-thread grass | | | | | | 1.0 | | | 15.0 | | 40 | 5 |
| FORBS | | | | | | | | | | | | |
| spreading dogbane | 0.1 | 4.4 | 0.1 | 1.3 | | 2.6* | 7.3 | 52.5 | 2.5 | 52.5 | | 38* |
| sticky cinquefoil | 1.7 | 1.5 | 2.6 | 2.1 | 2.8 | 1.5 | 46.3 | 35.0 | 40.0 | | 4- | 28 |
| pearly everlasting | T | 1.7 | | | | | 2.4 | 30.0 | | | | |
| black medic | 1.3 | | 1.5 | | 3.1 | 0.5* | 34.0 | | 30.0 | | 40 | 8* |
| wavy-leaved thistle | 0.5 | T | | | | | 9.8 | 2.5 | | | | |
| early blue violet | | | 0.9 | 0.2 | | | | | 12.5 | 10.0 | | |
| pussytoes | | | | | 0.2 | 2.6 | | | | | 5 | 38 |
| SHRUBS | | | | | | | | | | | | |
| antelope-brush | 0.6 | 8.6 | 1.0 | 8.4 | 2.8 | 10.4 | 4.9 | 35.0 | 15.0 | 35.0 | 15 | 40 |
| snowberry | T | 1.5 | 0.4 | 1.0 | 2.9 | 2.1 | 2.4 | 12.5 | 2.5 | 25.0 | 13 | 40 |
| saskatoon | 0.3 | 13.2 | 1.0 | 8.5 | 1.8 | 14.1 | 4.9 | 55.0 | 7.5 | 37.5 | 8 | 58* |
| kinnikinnick | 4.1 | 0.3 | 4.3 | 1.3 | 3.8 | 0.2 | 14.6 | 7.5 | 27.5 | 10.0 | 25 | 8 |
| LITTER | 64.6 | 47.8 | 42.8 | 21.0 | 35.5 | 31.7 | 100.0 | 97.5 | 95.0 | 57.5 | 95 | 100 |
| MOSS | | | 1.7 | 16.3 | | | | | 7.5 | 35.0 | | |
| ROCK | | | 2.4 | | | | | | 7.5 | | | |
| CRYPTOGAMS | | | | | 0.1 | 4.5* | | | | | 3 | 3 |
| BARE GROUNG | | | | | 5.5 | 0* | | | | | 45 | 0* |

[a]B = Burned vegetation; UB = Unburned vegetation; * significant difference

(Table 18). Some undesirable invading forb species such as black medic and wavy-leaved thistle increased in frequency and cover after this spring burn (Table 18). Canada bluegrass was the dominant grass at this site.

Shrub cover was significantly (90% C.L.) reduced by prescribed fire (Fig. 19*a*, Appendix [illegible]). Browse Condition Class (Aldous 1944) improved with spring burning (Davidson 1983). Most saskatoon shrubs had a history of heavy browse pressure while browse pressure on antelope-brush appeared to be light to moderate. Had time not been a constraint browse production on burned range would have been compared with adjacent unburned range. Because the Condition Class (Aldous 1944) and availability of browse had improved with burning, total available forage may not have declined even though cover and stem density of preferred browse species had declined. Ground cover and frequency of antelope-brush, saskatoon and spreading dogbane were most greatly reduced by prescribed fire (Table 18, Appendix [illegible]). Kinnikinnick was the dominant shrub on burned range at this site and antelope-brush and saskatoon were codominant on unburned range at lower Burntbridge Basin.

Stem densities of antelope-brush and saskatoon were significantly (90% and 99% C.L.) reduced by this prescribed fire, whereas stem densities of rose, redstem ceanothus and Scouler's willow increased (Table 19). These differences in stem density remained during the second growing season.

In 1982, mosses and lichens had significantly higher ground cover (66% of the total) on burned range than on unburned range at this site (Fig. 19). The prescribed burn did not consume duff and litter layers except under some shrubs where the fuel load was heavy.

*Fontaine Basin.*— Total forage cover was significantly (95% C.L., Appendix [illegible]) higher on unburned range than on adjacent burned range at upper Fontaine Basin for two growing seasons following prescribed fire but by the third growing season forage cover values were similar (Fig. 19*b*, Appendix [illegible]).

Cover of grasses increased significantly (99% C.L.) in response to fire whereas

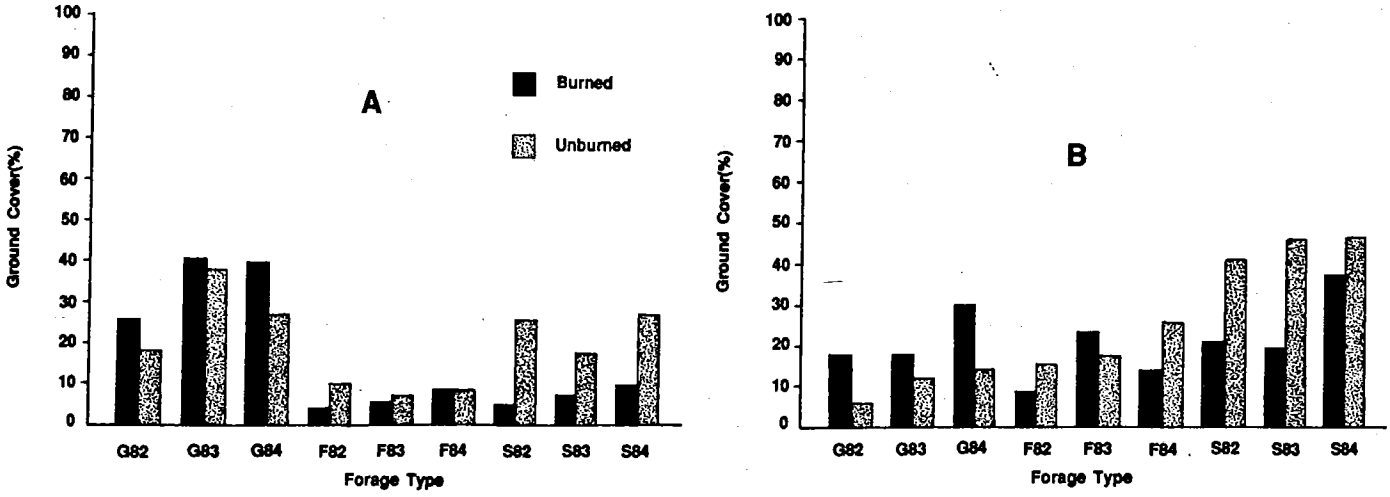



**Figure 19. Ground cover of burned range compared to unburned range, July 1982-1984. A. lower Burntbridge Basin. B. Fontaine Basin.** (G = Grasses; F = Forbs; S = Shrubs)

**Table 19. Stem densities of burned shrubs compared to those of unburned shrubs on lower Burntbridge Basin, Bull River, July 1982 and 1983.**

| Shrub Species | Mean Stem Density / 15m$^2$ | | | |
|---|---|---|---|---|
| | 1982 | | 1983 | |
| | Burned | Unburned | Burned | Unburned |
| Saskatoon | 16.0 | 98.2[a] | 17.6 | 131.0[b] |
| Antelope-brush | 3.4 | 9.0[c] | 2.6 | 5.3[d] |
| Snowberry[e] | 0.8 | 11.6 | 23.0 | 0 |
| Rose | 2.6 | 3.0 | 0.6 | 0 |
| Balsam poplar | 0.2 | 0 | 0.2 | 0 |

a Sig. difference at 99% level - burned vs unburned.
b Sig. difference at 98% level - burned vs unburned.
c Sig. difference at 90% level - burned vs unburned.
d Sig. difference at 95% level - burned vs unburned.
e Sig. difference between both burned and unburned; and 1982 and 1983.

cover of shrubs declined significantly (98% C.L.) as at the drier site on lower Burntbridge Basin (Fig. 19*b*). Grass cover on burned range increased significantly (99% C.L.) by the third growing season following prescribed fire and was double that of adjacent unburned range.

The dominant grass on this site was timber oatgrass; pinegrass and Canada bluegrass were subdominant on burned range; and cheatgrass was codominant with timber oatgrass on the unburned range (Table 20). Grasses that increased most dramatically in cover and frequency of occurrence after burning were timber oatgrass, Canada bluegrass and pinegrass.

The cover of forbs decreased with burning (Fig.19*b*). Spreading dogbane and pussytoes had the greatest decreases in cover and frequency of occurrence (Table 20). Forb cover and frequency increased dramatically on the burned site during the second growing season following fire but declined in cover to preburn levels by the third growing season. An introduced legume, black medic, was the only forb to show a major increase in cover and frequency in response to fire during the first growing season (Table 20, Appendix 1[illegible]). By the second growing season, diversity of forbs on the burned site was equal to that of the adjacent unburned site (14) and the vigour of most species was better.

The dominant forbs in the burned area at Fontaine Basin were sticky cinquefoil and black medic; the dominant forbs in the adjacent unburned area were sticky cinquefoil and spreading dogbane (Table 20).

Cover of shrubs was significantly reduced (98% C.L.) by prescribed fire for two growing seasons but by the third growing season no significant differences were observed (Fig. 19*b*, Appendix [illegible]). Unlike the response at the lower Burntbridge Basin, in Fontaine Basin, antelope-brush and saskatoon showed the greatest declines in cover and frequency (Table 20) and snowberry increased in cover and frequency. Burning may have also stimulated growth of choke cherry and rose (three species). The dominant shrub on burned range was snowberry; on unburned range, antelope-brush dominated. Saskatoon and snowberry were subdominant on unburned range at Fontaine Basin.

**Table 20. Ground cover and frequency of burned vegetation (BR 4) compared to unburned vegetation (BR 5) on Fontaine Basin, July 1982-1984.**
(Bull River)

| Vegetation Species | Estimated Cover (%) | | | | | | Frequency (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1982 | | 1983 | | 1984 | | 1982 | | 1983 | | 1984 | |
| | B[a] | UB | B | UB | B | UB | B | UB | B | UB | B | UB |
| GRASSES AND SEDGES | | | | | | | | | | | | |
| timber oatgrass | 8.3 | 2.9 | 2.7 | 2.4 | 16.4 | 6.6 | 70.0 | 10.0 | 32.5 | 42.5 | 73 | 45 |
| pinegrass | 3.2 | | 2.1 | 0.9 | 5.7 | 0.2* | 25.0 | | 25.0 | 5.0 | 33 | 5 |
| cheatgrass | 0.3 | 2.9 | | 7.2 | 0.1 | 5.8* | 7.5 | 65.0 | | 80.0 | 73 | 5 |
| Canada bluegrass | 4.8 | 0.1 | 8.4 | 1.7 | 8.6 | 1.0* | 65.0 | 2.5 | 67.5 | 17.5 | 5 | 78 |
| small western needlegrass | 0.6 | | | | | | 12.5 | | | | | |
| slender wheatgrass | | | 2.5 | 0.3 | | | | | 67.5 | 22.5 | | |
| timothy | | | 0.5 | T | | | | | 17.5 | 2.5 | | |
| sedge | | | 0.9 | 0.4 | | | | | 30.0 | 10.0 | | |
| FORBS | | | | | | | | | | | | |
| sticky cinquefoil | 3.0 | 1.9 | 0.2 | 4.4 | 4.9 | 4.5 | 52.5 | 40.0 | 5.0 | 75.0 | 60 | 60 |
| aster | 0.9 | 0.5 | 2.9 | 0.4 | | | 25.0 | 15.0 | 62.5 | 12.5 | | |
| woolly mullein | 1.1 | 0.5 | 0.2 | 0.5 | | | 25.0 | 15.0 | 5.0 | 5.0 | | |
| yarrow | 1.3 | 1.4 | 1.4 | 1.2 | 3.7 | 2.7 | 40.0 | 50.0 | 47.5 | 47.5 | 55 | 50 |
| spreading dogbane | | 5.1 | | 6.3 | 0 | 9.9* | | 50.0 | | 50.0 | 0 | 70 |
| wild bergamot | | 1.4 | 1.5 | 0.3 | | | | 12.5 | 5.0 | 7.5 | | |
| small-flowered willowherb | T | 1.5 | 0.1 | 1.9 | 1.7 | 3.1 | 7.5 | 35.0 | 5.0 | 75.0 | 45 | 78 |
| lemonweed | 0.6 | 1.5 | 0.7 | 0.5 | | | 12.5 | 10.0 | 12.5 | 12.5 | | |
| pussytoes | | | 1.9 | 0.3 | | | | | 30.0 | 22.5 | | |
| American vetch | | | 1.7 | | | | | | 60.0 | | | |
| wild strawberry | | | 0.7 | 0.3 | | | | | 47.5 | 2.5 | | |
| black medic | | | 0.8 | | | | | | 15.0 | | | |
| harebell | | | 1.5 | | | | | | 5.0 | | | |
| pearly everlasting | | | 0.8 | | | | | | 5.0 | | | |
| peavine | | | 0.7 | | | | | | 15.0 | | | |
| rosy owl-clover | | | | 1.5 | | | | | | 62.5 | | |
| SHRUBS | | | | | | | | | | | | |
| antelope-brush | 2.0 | 26.7 | 0.8 | 28.3 | 12.0 | 30.6* | 30.0 | 60.0 | 5.0 | 75.0 | 48 | 75 |
| snowberry | 16.3 | 5.1 | 10.3 | 0.2 | 22.6 | 7.8* | 70.0 | 35.0 | 72.5 | 32.5 | 83 | 50 |
| saskatoon | | 7.4 | 5.1 | 11.9 | 0.6 | 8.7* | | 37.5 | 12.5 | 25.0 | 5 | 33 |
| choke cherry | 2.3 | | | | | | 7.5 | | | | | |
| kinnikinnick | 1.3 | 1.3 | | | | | 2.5 | 10.0 | | | | |
| Oregon-grape | 1.3 | | | | | | 2.5 | | | | | |
| rose | 0.5 | | 0.5 | | | | 12.5 | | 12.5 | | | |
| birch-leaved spirea | | | 0.6 | | | | | | 27.5 | | | |
| Scouler's willow | | | 2.3 | | | | | | 2.5 | | | |
| LITTER | 40.7 | 33.3 | 32.9 | 14.2 | 11.0 | 22.0* | 97.5 | 97.5 | 92.5 | 87.5 | 58 | 75 |
| CRYPTOGRAMS | 2.3 | | 0.7 | | 1.0 | 0.1* | 15.0 | | 5.0 | | 10 | 3 |
| ROCK | 4.1 | 1.3 | 6.4 | 7.1 | 5.7 | 5.7 | 45.0 | 27.5 | 70.0 | 37.5 | 60 | 38 |
| BAREGROUND | 4.8 | 5.6 | 0.7 | 3.2 | 2.0 | 3.3 | 25.0 | 27.5 | 5.0 | 37.5 | 25 | 18 |

[a]B - burned; UB - unburned; * Indicates significant difference between burned and unburned in 1984.

Stem densities of antelope-brush were reduced significantly (90% C.L., Table 21, Appendix F) on burned range compared to adjacent unburned range at Fontaine Basin. Stem densities of saskatoon increased after burning even though ground cover of this shrub had declined. The apparent anomalies could be due to a past history of heavy browse pressure before burning resulting in poor vigour. Above-ground growth was killed by fire but root suckering was stimulated resulting in more shoots, but covering less area. Stem densities of snowberry were similar on burned and adjacent unburned range at Upper Fontaine even though cover and frequency of occurrence of snowberry was significantly higher on burned range (Tables 20, 21). Cover and frequency of occurrence of snowberry were greater on burned range at this site even though stem densities were similar. An even distribution and better vigour of snowberry on burned range compared to adjacent unburned range may explain this observation. Antelope-brush appeared susceptible to fire, with the cover, frequency of occurrence and stem densities reduced by this low intensity spring fire.

Shrub cover remained significantly (99% C.L., Appendix F) higher on unburned

**Table 21. Stem densities of burned shrubs compared to those of unburned shrubs on upper Fontaine Basin , Bull River, July 1982 and 1983.**

| Shrub Species | Mean Stem Density / 15m$^2$ | | | |
|---|---|---|---|---|
| | 1982 | | 1983 | |
| | Burned | Unburned | Burned | Unburned |
| Saskatoon | 72.0 | 58.8 | 54.0 | 88.4[a] |
| Antelope-brush | 1.4 | 6.4[a] | 1.6 | 15.8 |
| Snowberry[c] | 55.2 | 52.8 | 186.2[b] | 78.0[c] |
| Rose | 2.4 | | 3.2 | |
| Choke cherry | | 11.8 | | 10.0 |
| Birch-leaved spirea | 2.8 | 0 | 15.8 | 5.2 |
| Redstem ceanothus | 0 | 1.2 | 3.0 | 0.6 |
| Scouler's willow | | | 34.0 | 0 |
| Douglas maple | | | 0 | 0.6 |

a Sig. difference at 90% level - burned vs unburned.
b Sig. difference at 95% level - burned vs unburned.
c Sig. difference at 98% level - 1982 vs 1983.

range than adjacent burned range in 1983 but by the third growing season no significant differences were observed (Fig. 19*b*). Qualitative differences remained for the three growing seasons that the site was analyzed. Cover of antelope-brush and saskatoon remained significantly (99% C.L.) higher on unburned range and cover of snowberry remained significantly lower (99% C.L., Table 20). Stem densities of saskatoon and antelope-brush remained significantly higher on unburned range during the second growing season while stem densities of snowberry and rose were higher on burned range at Upper Fontaine Basin (Table 21).

Litter cover was significantly higher (95% C.L.) in 1982 than in 1983 on both burned and unburned range but this difference was not observed in 1983 and 1984 (Appendix [illegible]). No significant changes occurred in cover of cryptogams, rock or bare ground after burning.

### 5.5.2 Selective logging

#### Macroplot 1 (West), Lakit Mountain - July 1984

*Canopy closure and stem density.*— Crown closure at both macroplots examined on Lakit Mountain was estimated to be 70% before logging in February and March 1983. Selective logging reduced canopy closure to <5% at both sites. Composition of the canopy at Macroplot I (West) was 95% interior Douglas-fir and 5% ponderosa pine whereas at Macroplot II (Middle Site) composition was 23% lodgepole pine, 19% ponderosa pine and 62% interior Douglas-fir. Average height of 10 trees was 11 m (35 feet) and average age of trees was 61 years at Macroplot I; average height of trees at Macroplot II was 15 m (50 feet).

*Ground cover, composition and frequency.*— Fifteen months and two growing seasons after completion of selective logging on Lakit Mountain, the cover of grasses, forbs and shrubs had increased significantly (99% C.L.) over that of adjacent unlogged range (Fig. 20, Appendix [illegible]). Total forage cover was 56% on logged range compared to 9% on adjacent unlogged range with the change in grass cover contributing most to the observed difference. Pinegrass constituted 42% of the cover on logged range and only 6% of adjacent unlogged cover (Table 22). An increase in ground cover of

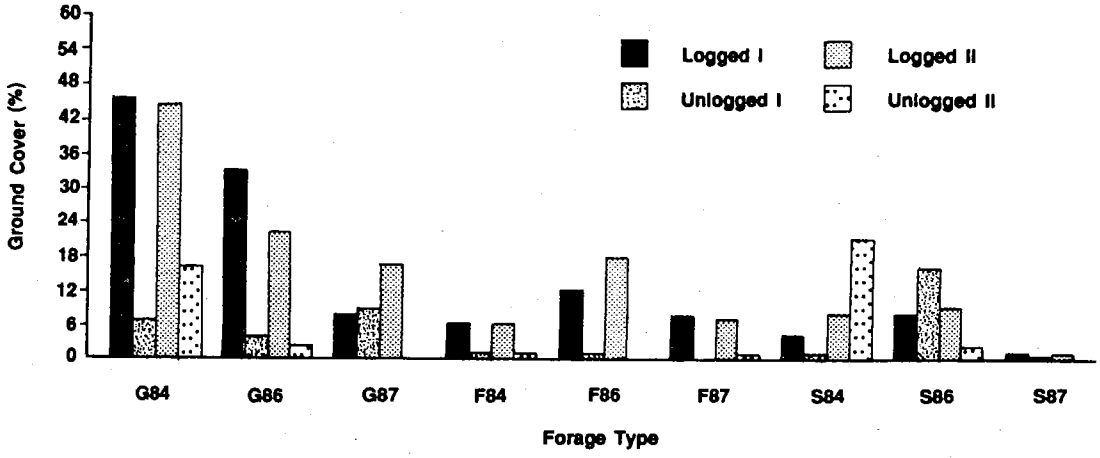



**Figure 20. Ground cover of forage on logged range compared to unlogged range on Lakit Mountain, July 1984, 1986 and 1987.**

rough fescue from a trace in the entire unlogged area to 3% of ground cover 1.3 years after logging (Table 22) will mean that more palatable, high quality grass is available to wintering ungulates. This grass was not observed under cover of conifers before logging but was observed in small openings nearby.

Forbs made up 6% of ground cover and shrubs covered 4% on the logged area compared to 0.7% and 1.1%, respectively, on unlogged range (Table 22). Ground cover of at least three species of aster, rosy pussytoes and creamy peavine were stimulated by logging.

Logging increased the cover of shrubs from 1% to 4% (Table 22) with birch-leaved spirea, creeping juniper and rose species showing the greatest increase in ground cover.

Diversity of vegetation was much greater on logged range than unlogged range. Three species of grass, 15 species of forbs and 5 species of shrubs were observed on logged range compared to 1 species of grass, 1 of forbs and 3 of shrubs on unlogged range (Table 22).

Logging significantly reduced the cover of cryptogams, and litter and increased the amount of bare ground at this site (Appendix G).

### Changes in ground cover: 1984, 1986 and 1987

*Macroplot I (West).*-- Total forage cover of logged range changed little between the 1984 and 1986 growing seasons remaining at 56% of ground cover (Fig. 20). At the same time, ground cover on unlogged range was significantly lower (99% C.L.), ranging between 9% and 22% of ground cover. The difference in forage cover was primarily due to the increase in cover and frequency of pinegrass (Table 22), although forbs contributed significantly to the observed differences in cover.

One growing season following the wild fire (1987), grasses no longer had significantly higher cover on logged range compared to adjacent unlogged range at Macroplot I (Fig. 20, Appendix G). Cover and frequency of occurrence of grasses on logged range was severely reduced by the wild fire, but ground cover of grasses on unlogged range increased.

**Table 22. Ground cover and frequency of vegetation on logged range compared to unlogged range on Lakit Mountain Macroplot I (West), July 1984, 1986 and 1987.**

| Plant Species | Ground Cover (%) | | | | | | Frequency (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1984 | | 1986 | | 1987 | | 1984 | | 1986 | | 1987 | |
| | L[a] | UL | L | UL | L | UL | L | UL | L | UL | L | UL |
| GRASSES AND SEDGES | | | | | | | | | | | | |
| pinegrass | 42.2 | 6.4 | 32.1 | 2.7 | 7.1 | 0.6 | 37 | 58 | 98 | 50 | 75 | 20 |
| rough fescue | 3.0 | 0 | | | | | 1 | 0 | | | | |
| sedges | 1.8 | 0 | | | | | 2 | 0 | | | | |
| orchardgrass | | | | | 0.4 | 6.0 | | | | | 15 | 70 |
| FORBS | | | | | | | | | | | | |
| rosy pussytoes | 1.1 | 0.1 | | | | | 6 | 1 | | | | |
| asters | 1.3 | 0 | 0.6 | 0.3 | | | 6 | 1 | 10 | 3 | 27.5 | 0 |
| creamy peavine | 0.6 | 0 | | | 1.0 | 0 | 1 | 0 | | | | |
| yarrow | | | 4.6 | | | | | | 8 | | | |
| yellow penstemon | | | 3.2 | | | | | | 11 | | | |
| small-flowered willowherb | | | 3.2 | 0.1 | 2.1 | 0.1 | | | 80 | 3 | 40 | 2.5 |
| woolly pussytoes | | | 2.2 | | 0.6 | 0 | | | 15 | | 17.5 | 0 |
| sow-thistle | | | 1.8 | T | | | | | 58 | 13 | | |
| Canada thistle | | | 0.7 | | | | | | 3 | | | |
| Canada goldenrod | | | | | 0.8 | 0 | | | | | 12.5 | 0 |
| fleabane | | | | | 0.6 | 0 | | | | | 10 | 0 |
| wild strawberry | | | | | 0.5 | 0 | | | | | 5 | 0 |
| SHRUBS | | | | | | | | | | | | |
| birch-leaved spirea | 3.0 | 0.8 | 5.9 | 2.8 | 0.8 | 0.4 | 1.7 | 14 | 48 | 63 | 12.5 | 35 |
| Oregon-grape | 1.1 | 1.0 | 0 | 8.5 | | | 1 | 1 | 0 | 45 | | |
| creeping juniper | 1.0 | 0 | | | | | 3 | 0 | | | | |
| roses | 0.7 | 0 | | | | | 1 | 0 | | | | |
| wnowberry | | | 1.5 | 0.9 | | | | | 13 | 26 | | |
| Rocky Mountain juniper | | | 0.4 | 2.8 | | | | | 3 | 5 | | |
| common juniper | | | 0.1 | 1.8 | | | | | 3 | 10 | | |
| saskatoon | | | 0.3 | 0.6 | | | | | 8 | 8 | | |
| redstem ceanothus | | | | | 0.3 | 0.4 | | | | | 17.5 | 12.5 |
| CRYPTOGAMS | 4.3 | 19.0 | 0.1 | | | | 9 | 25 | 3 | | | |
| LITTER | 34.4 | 71.4 | 46.0 | 79.3 | | | 40 | 40 | 100 | 100 | | |
| BARE GROUND | 4.3 | 0 | 0 | 0 | | | 40 | 0 | 0 | 3 | | |
| ROCK | 0.5 | 2.3 | 0.3 | 0.1 | | | 4 | 14 | | 13 | | |

[a]L - logged; UL - unlogged

In 1986, forb cover and frequency of occurrence was significantly higher on logged range at Macroplot I than adjacent unlogged range (Fig. 20, Appendix G) and did not change greatly despite an intense wild fire that occurred in 1987. The wild fire did not reduce the diversity of grasses found on logged and unlogged range but did reduce the diversity of forbs and shrubs on unlogged range and the diversity of shrubs on logged range.

Shrub cover was 16% on unlogged range compared to 8% on adjacent logged range at this site in 1986 (Fig. 20). Following wild fire, shrub cover was significantly reduced (99% C.L.) on both logged and unlogged range to about 1% ground cover.

Seven of nine shrub species were eradicated by fire on logged range; five of six shrub species were eradicated on unlogged range. Redstem ceanothus became the dominant shrub on unlogged range following the wild fire although it had not been observed in the macroplot before but had been observed 200 m north. Shrub diversity had been reduced from six species on logged range and seven species on unlogged range to two species following wild fire. Only redstem ceanothus and birch-leaved spirea remained following fire (Table 22).

Stem densities of all shrubs were severely reduced by intense fire but birch-leaved spirea cover and stem densities were most affected on logged range and creeping Oregon-grape cover and stem densities were most reduced on unlogged range at this site (Table 23). Snowberry was eradicated by wild fire on both the logged and unlogged macroplots where it had been a subdominant shrub with 11 200 stems/ha on logged range and 6000 stems/ha on unlogged range (Table 23).

Cover of litter was significantly higher (99% C.L.) on unlogged range compared to adjacent logged range between 1984 and 1986 (Fig. 20). The intense wild fire significantly (99% C.L.) reduced litter cover of both logged and unlogged range. Litter cover was reduced from 46% to 21% on logged range and from 79% to 15% on unlogged range. Following fire no significant difference in litter cover was found between logged and adjacent unlogged macroplots.

Ground cover of cryptogams was significantly higher (95% C.L.) on unlogged range than logged range in 1984 and 1987 with few being observed in 1986 due to the dry, hot summer (Appendix G). The fire did not have an observable effect on cryptogam cover.

**Table 23. Stem densities of logged range compared to unlogged range on Lakit Mountain Macroplot I (West), July 1986 and 1987.**

| Shrub Species | Stem density / ha | | | |
|---|---|---|---|---|
| | Logged | | Unlogged | |
| | 1986 | 1987 | 1986 | 1987 |
| birch-leaved spirea | 41,066 | 11,333 | 27,732 | 8,400 |
| snowberry | 11,200 | 0 | 6,000 | |
| saskatoon | 4,533 | 0 | 1,865 | |
| redstem ceanothus | 400 | 4,533 | | 10,666 |
| roses | 267 | 133 | 2,135 | |
| Rocky Mountain juniper | 133 | 0 | | |
| common juniper | 133 | 0 | 135 | |
| Lapland rosebay | | | 135 | |
| creeping Oregon-grape | 533 | 0 | 82,265 | |
| TOTAL | 58,265 | 15,999 | 120,267 | 19,066 |

No significant differences in bare ground were found between logged and unlogged range before wild fire but a large and significant increase in bare ground occurred on both logged and unlogged range following wild fire (Fig. 20, Appendix ~~H~~). Cover of bare ground increased from 0.3% on logged range in 1986 before the fire to 45% in 1987 following the fire. A similar trend occurred on unlogged range.

### Changes in forage production resulting from logging and wild fire

Total forage production was significantly higher (99% C.L.) on logged range than on unlogged range in 1986 at 1224:82 kg/ha (Table 24). ~~Appendix H).~~ The 1986 wild fire significantly reduced forage production of logged range from 1224 kg/ha to 597 kg/ha (51%) whereas forage production on unlogged increased from 82 kg/ha to 248 kg/ha.

In 1986, grasses constituted 74% of total forage production on logged range compared to 31% on adjacent unlogged range. Following wild fire, grasses constituted 80% of total forage production on logged range and 65% of total forage production on adjacent unlogged range. Before the wild fire, grass production was significantly higher (99% C.L.) ~~Appendix H)~~ on logged range at 906 kg/ha than on adjacent unlogged range at 26 kg/ha (Table 24). During the first growing season following wild fire, production of grasses on logged range was reduced by half (906 to 478 kg/ha) and that of grasses on unlogged range increased six-fold to 160 kg/ha. Although logged range produced three times the grass biomass/ha than unlogged range, the difference was no longer statistically significant at this level of sampling(Table 24).

Forb production was 170 kg/ha on logged range compared to 17 kg/ha on adjacent unlogged range in 1986 before wild fire. Following wild fire, forb production was reduced by 44% to 96 kg/ha on logged range, but increased five times to 85 kg/ha on unlogged range. Shrub production was 3.8 times more in 1986 on logged range compared to unlogged (Table 24).

The intense heat of the 1986 wild fire significantly (99% C.L.) reduced shrub production on logged range from 148 kg/ha in 1986 to 23 kg/ha in 1987. Although shrub production of unlogged range was reduced from 39 to 3 kg/ha this difference was not statistically significant due to small sample size.

**Table 24. Forage production of logged range compared to unlogged range in July 1986 before fire on Lakit Mountain and in 1987 after wild fire.**

| Location | | Year | Vegetation Production (kg /ha) | | | Total |
|---|---|---|---|---|---|---|
| | | | Grass | Forbs | Shrubs | |
| Lakit 1 | logged | 1986 | 906 | 170 | 148 | 1,224 |
| Lakit 1 | unlogged | 1986 | 26 [a] | 17 | 39 | 82 [a] |
| Lakit 1 | logged | 1987 | 478 | 96 | 23 | 597 |
| Likit 1 | unlogged | 1987 | 160 | 85 | 3 | 248 |
| Lakit 2[b] | logged | 1986 | 591 | 401 | 55 | 1,047 |
| Lakit 2[c] | unlogged | 1986 | | | | |

a Indicates significant difference at 99% level between logged and unlogged.
b Due to time constraints Lakit 2 was not clipped in 1987.
c Cattle had bedded here making a legitimate comparison impossible.

*Macroplot II, Lakit Mountain, July 1984-1987.*— Ground cover values of forage were similar between Macroplot II (East) and Macroplot I (West) with the exception of shrub cover (Fig. 20, Appendix ). Total forage cover of logged range was also similar at both sites (56% West:59% East). Ground cover of forage on logged range remained significantly higher than that of unlogged range between 1984 and 1987 (Fig. 20). Wild fire significantly (99% C.L.) reduced total forage cover on both logged and unlogged range (Appendix ).

Ground cover of grasses was significantly (99% C.L.) higher on logged range than on unlogged between 1984 and 1987 (Fig. 20, Appendix ). Frequency of occurrence of pinegrass was similar on logged and unlogged range at both sites, but ground cover was from 4 to 7 times greater on logged range due to better vigour.

Ground cover of forbs was higher on logged range than unlogged between 1984 and 1987 (Fig. 20, Appendix ). Ground cover of forbs increased significantly (90% C.L.) between 1984 and 1986 on logged range but not on adjacent unlogged range. The 1986 wild fire significantly (90% C.L.) reduced forb ground cover on logged range, but increased it on unlogged range.

Ground cover of shrubs was higher on unlogged than on adjacent logged range in 1984 but not in 1986 or 1987 (Fig. 20). Ground cover of creeping Oregon-grape was much higher on unlogged range than on adjacent logged range in 1984 (Table 25). The 1986 wild fire created more (99% C.L.) shrub cover on logged range - from 9% to 0.7% - but had less effect on unlogged range (Appendix ).

Before wild fire, logged range contained 21 plant species and unlogged range contained only 10 species with the major difference due to forb diversity (Table 25). Following wild fire, plant diversity was reduced to four species with the greatest effect being on forbs and shrubs.

Stem densities of birch-leaved spirea were reduced from 41 066 to 10 000 on logged range but were not affected on unlogged range. This result may have been due to cattle that had bedded in the unlogged conifer stand in the early summer of 1986. Snowberry was eradicated at both logged and unlogged sites by the fire of 1986, while saskatoon was greatly reduced in stem density. Creeping Oregon-grape and common juniper were eradicated from the unlogged macroplot by the wild fire. Redstem ceanothus was stimulated to germinate and became the codominant shrub where it had not been observed previously on the unlogged macroplot. Snowbrush became the codominant shrub on the logged macroplot where it had not been observed previously. Total stem density of unlogged range did not decline at this site but stem density of shrubs on logged range declined from 55 065 to 14 800 as a result of intense heat.

Ground cover of litter on unlogged range was significantly (99% C.L.) higher than that of adjacent logged range before and after fire at Macroplot II (Fig. 20, Appendix ). The fire, however, significantly (99% C.L.) reduced ground cover of litter on both logged and unlogged range.

Ground cover of cryptogams was significantly (95% C.L., Appendix ) higher on unlogged range than on logged range until the wild fire of 1986 reduced cryptogam cover on unlogged range. Cryptogam cover changed little on logged range and in fact was higher after the fire.

**Table 25. Ground cover of logged range compared to unlogged range at Lakit Mountain Macroplot II (East), July 1984, 1986 and 1987.**

| Cover Type | Estimated Ground Cover (%) | | | | | |
|---|---|---|---|---|---|---|
| | 1984 | | 1986 | | 1987 | |
| | L | UL | L | UL | L | UL |
| Grass | 44.6 a | 16.2 a,b | 21.7 | 2.7 b | 16.9 | 0.1 b |
| Forbs | 6.4 | 0.7 | 17.5 c | 0.1 b | 7.1 | 1.1 b |
| Shrubs | 8.2 b | 21.2 a,b | 8.9 d | 2.5 | 0.7 | 0.2 |
| Total forage | 59.2 e | 38.1 a | 48.1 e | 5.3 | 24.7 | 1.4 |

a 1984 > 1986 and 1987, 99% C.L.
b Significant difference between logged and unlogged.
c 1986 > 1984 and 1987, 90% C.L.
d 1984 and 1986 > 1987, 95% C.L.
e 1984 and 1986 > 1987, 99% C.L.

Bare ground cover was similar on logged and adjacent unlogged range before and after fire but increased significantly (99% C.L.) from 3% to 33% on logged range and from <0.1% to 29% on unlogged range following wild fire (Fig. 20, Appendix G).

The amount of surface rock was low before wild fire on both logged and unlogged sites but this level increased significantly (99% C.L.) because intense heat burned down to mineral soil (Fig. 20, Appendix G).

### 5.5.3 Effects of slashing and spacing

*Mount Broadwood, Macroplots I and II.*— The aspen stand on Mount Broadwood, which was slashed in December 1983 and January and February 1984, produced leaves during the spring of 1985. Warm, late winter weather conditions may have stimulated an early movement of sap from the roots to the buds of trembling aspen. The stem density of live trembling aspen of Macroplot I, calculated from a 12.5-m radius plot was 2201 stems/ha. The average breast diameter was 20.8 cm and the estimated tree height was 10.5 m. Hand slashing with power saws completely removed the aspen overstory, estimated to have a 70% canopy cover when in leaf. The result was a dramatic increase in shrub cover and a decrease in grass and forb cover (Fig. 21). The stem density of trembling aspen increased more than 10-fold to 26 400/ha by the second growing season after slashing and the stand was 1.25 to 1.75 m

**Table 26. Stem densities of logged range compared to unlogged range on Lakit Mountain Macroplot II (East), July 1986 and 1987.**

DATA MISSING

high. Stem density of all shrubs except saskatoon increased dramatically when the trembling aspen canopy cover was removed although ground cover of shrubs decreased. Snowberry, rose and birch-leaved spirea stem density responded most dramatically to removal of the aspen overstory (Table 27). Pinegrass cover was reduced by opening the canopy cover of aspen.

Ground cover and diversity of forbs were reduced for two growing seasons after hand slashing (Fig. 21). Aster, yellow penstemon and peavine were the most reduced in cover (Table 27). Ground cover of litter was not affected.

*Mount Broadwood Macroplots III and IV.*— Macroplot III was not paired because the entire area had been mechanically slashed by bulldozer, but Macroplot IV was unslashed and was located within 200 m of Macroplot III on a similar slope having similar soil, aspect, elevation, and edatropic characteristics (Table 17).

Stem density of mature trembling aspen was reduced from 8 400/ha before dozing by the caterpillar to 0 following dozing. Mean dbh of the aspen ($n$ = 30) was 19.8 cm, average height was estimated to be 10.2 m and average age of aspen was 36 years. Canopy closure was estimated to be 70% when the aspen had leaves.

When ground cover, species composition and stem density are compared between Macroplot III, which was dozed, and Macroplot IV, which was not dozed, mechanical slashing appeared to increase the cover of forbs and shrubs, but had little effect upon grasses (Fig. 21). Shade-tolerant forbs and shrubs (including thimbleberry, blue clematis, twistedstalk, false Solomon's seal, baneberry, creeping Oregon-grape and Pacific rhododendron) decreased in ground cover following mechanical clearing of the area (Table 28).

Stem density of trembling aspen increased to 26 400 or three times above the pre-slash density by the second growing season following dozing. Stem densities of birch-leaved spirea and rose also increased in response to opening of the canopy cover. Stem densities of creeping Oregon-grape, soopolallie and Pacific rhododendron were dramatically reduced (Table 30).

Diversity of forbs was greater (10:4) beneath the unslashed aspen but diversity of grasses and shrubs was not affected by slashing 3 years after treatment.

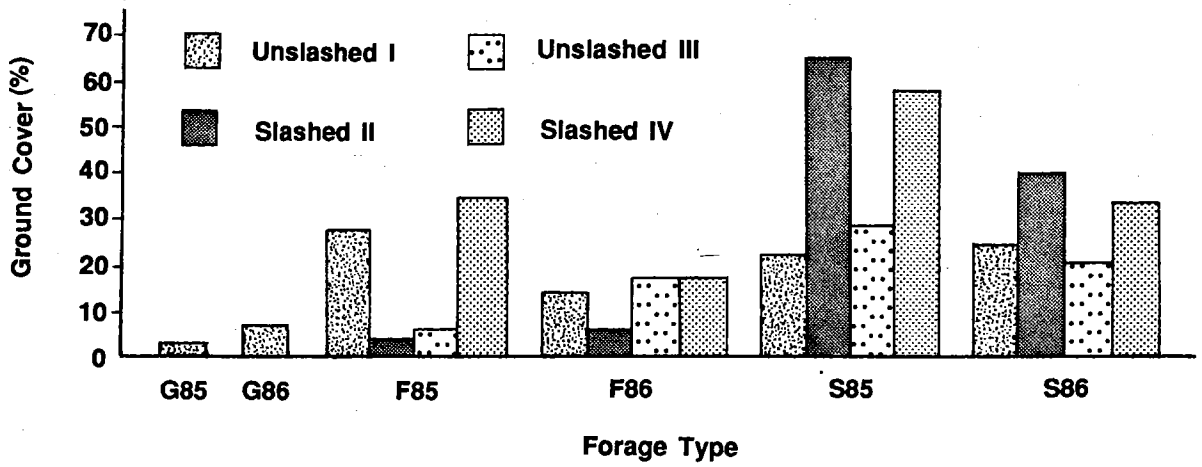



**Figure 21. Forage cover of unslashed aspen compared to slashed aspen macroplots on Mount Broadwood, August 1985 and 1986.**

**Table 27. Ground cover of vegetation on unslashed range in Macroplot I compared to hand-slashed range in Macroplot II, Mount Broadwood, 1985 and 1986.**

| Plant Species | | Estimated Ground Cover (%) of Macroplots | | | |
|---|---|---|---|---|---|
| | | 1985 | | 1986 | |
| | | Mac I | Mac II | Mac I | Mac II |
| Grasses | | | | | |
| | pinegrass | 2.8 | T | 6.5 | 1.0 |
| | northern wheatgrass | T | T | | |
| Forbs | | | | | |
| | asters | 17.8 | 1.4 | 7.1 | 3.0 |
| | yellow penstemon | 3.0 | | | |
| | spreading dogbane | 3.8 | 2.0 | 1.8 | 2.5 |
| | peavine | 2.0 | 0.1 | 1.0 | |
| | yarrow | 1.8 | 0.8 | | |
| | American vetch | 1.5 | | | |
| | chickweed | T | | | |
| | wild bergamot | 0.5 | | | |
| | paintbrush | 0.8 | | | |
| | black medic | T | | | |
| | Total | 26.4 | 3.5 | 13.5 | 5.5 |
| Shrubs | | | | | |
| | snowberry | 13.8 | 11.3 | 7.5 | 6.5 |
| | roses | 3.0 | 11.3 | 10.5 | 8.5 |
| | Oregon-grape | 1.3 | 10.5 | 2.5 | 1.5 |
| | redstem ceanothus | 0.8 | 0.3 | 2.0 | |
| | birch-leaved spirea | 2.0 | 1.8 | 1.3 | 2.5 |
| | saskatoon | T | 0 | | |
| | Douglas maple | T | T | | |
| | trembling aspen | 38.3 | 18.0 | | |
| | soopallallie | 2.0 | | | |
| | Total | 20.9 | 64.2 | 23.8 | 39.0 |
| Trees | | | | | |
| | trembling aspen | 45.0 | 48.0 | | |
| Cryptogam | | 2.0 | | | |
| Litter | | 53.5 | 55.0 | 98.0 | 100.0 |
| Rock | | 1.0 | | | |
| Ground | | 0.8 | | | |

**Table 28. Ground cover of vegetation on slashed range in Macroplot III compared to Macroplot IV, Mount Broadwood, August 1985 and 1986.** unslashed range in

| Plant Species | Estimated Ground Cover (%) | | | |
|---|---|---|---|---|
| | Unslashed | | Slashed | |
| | 1985 | 1986 | 1985 | 1986 |
| GRASSES | | | | |
| downy wheatgrass | T | T | T | T |
| orchardgrass | T | | | 0.3 |
| pinegrass | | | | |
| FORBS | | | | |
| Spreading dogbane | 2.8 | 1.5 | 17.3 | 10.3 |
| baneberry | | 4.0 | | |
| peavine | 1.0 | 1.8 | 1.5 | 1.0 |
| aster | 1.6 | 1.3 | 6.8 | 2.3 |
| American vetch | T | 1.0 | 7.0 | 2.5 |
| wintergreen | T | 0.1 | | |
| blue clematis | T | 0.5 | | |
| twistedstalk | T | 0.3 | | |
| fireweed | T | 0.3 | | |
| false Solomon's-seal | 0.3 | | | |
| yarrow | | | 1.3 | 0.8 |
| wild bergamot | | | 0.3 | |
| TOTAL | 5.4 | 15.6 | 34.1 | 16.9 |
| SHRUBS | | | | |
| common snowberry | 11.8 | 7.3 | 19.3 | 10.8 |
| soopolallie | 7.0 | 7.0 | 3.8 | 0.5 |
| creeping Oregon-grape | 2.5 | 1.5 | 1.6 | 0.3 |
| saskatoon | 3.3 | | 1.0 | 0.8 |
| thimbleberry | | 5.8 | | |
| Douglas maple | 2.0 | | 2.1 | 0.5 |
| rose | 1.0 | 1.3 | 3.5 | 1.3 |
| birch-leaved spirea | 0.5 | 0.8 | 7.5 | 1.8 |
| pin cherry | T | 0.3 | | |
| Lapland rosebay | T | 0.1 | | |
| balsam poplar | | | 2.8 | 3.0 |
| trembling aspen | | | 15.0 | 14.5 |
| TOTAL | 28.3 | 19.3 | 56.6 | 33.5 |
| TREES | | | | |
| trembling aspen | 48.0 | 48.0 | | |
| CRYPTOGAMS | | 0.3 | N.R. | 0.3 |
| LITTER | 58.8 | 92.2 | N.R. | 95.2 |
| ROCK | 2.0 | 8.0 | N.R. | 5.5 |

*Quartz Lake (Premier Ridge).*— Forage species were not expected to respond to treatment for at least one growing season but ground cover and frequency of vegetation on slashed and unslashed range were compared to indicate vegetative changes caused by the treatment.

Ground cover of shrubs on unslashed range was 10% higher than that of slashed range (Table 29). Ground cover of grasses and forbs was similar on treated and untreated areas with pinegrass dominant and bluebunch wheatgrass subdominant. Ground cover of trees was 22% on unslashed range and 13% on slashed range. Hand slashing removed 12% of the canopy cover of conifers <10 m high.

*Columbia Lake.*— Ground cover of grasses, forbs and shrubs was similar between slashed and non-slashed areas because they were compared during the same growing season when habitat treatment had been conducted. Hand slashing reduced the cover of trees by 2.3% because Rocky Mountain juniper was completely removed (Table 30). Although not demonstrated using the HCF Monitoring Guidelines, several hundred stems/ha of interior Douglas-fir were slashed. Spacing reduced the canopy cover of interior Douglas-fir by 1.3% at this site.

### 5.5.4 Cost-benefit of fertilization

*Columbia Lake.*— Forage production

**Table 29. Ground cover of vegetation at Quartz Lake (Premier Ridge) before and after hand-slashing, July 1987.**

| Plant Species | Mean Cover (%) | |
|---|---|---|
| | Slash | Unslash |
| GRASSES | | |
| pinegrass | 8 | 11 |
| rough fescue | 2 | 1.5 |
| bluebunch wheatgrass | 6 | 7.5 |
| junegrass | 0.3 | T |
| TOTAL | 16.3 | 20.0 |
| FORBS | | |
| aster | 2 | 1 |
| goldenrod | T | T |
| yellow hedysarum | T | |
| yarrow | T | 0.5 |
| black medic | T | T |
| pussytoes | | T |
| arrow-leaved Balsamroot | | 0.5 |
| TOTAL | 3.0 | 2.5 |
| SHRUBS | | |
| common snowberry | 2 | 2 |
| rose | 1.5 | |
| soopolallie | 1 | 3 |
| saskatoon | 3 | 7.5 |
| flat-topped meadowsweet | 1.5 | 0.5 |
| antelope-brush | 0.5 | 0.5 |
| rocky Mountain juniper | T | T |
| kinnikinnick | 3.5 | 7.5 |
| creeping Oregon-grape | | 2 |
| TOTAL | 13.0 | 23.0 |
| TREES | | |
| Douglas-fir >10 m | 12.5 | 10.0 |
| Douglas-fir 2 - 10 m | | 10.0 |
| Douglas-fir < 2 m | | 2.0 |
| Lodgepole pine 2 - 10 m | 0.5 | |
| TOTAL TREES | 13.0 | 22.0 |
| Decaying Wood | 2 | 3.5 |
| Bed Rock | 5 | 1 |
| Cobbles | 4 | 12.5 |
| Mineral Soil | 3 | 8 |
| Organic Matter | 25 | 32.5 |
| Snags (Weathered) | Rare | Rare |

**Table 30. Ground cover of vegetation at Columbia Lake before and after hand slashing, August 1987.**

| Plant Species | Mean Cover (%) | |
|---|---|---|
| | Unslash | Slash |
| GRASSES | | |
| junegrass | 2.3 | 1.5 |
| porcupinegrass | 1.0 | T |
| downy wheatgrass | 0.8 | 2.5 |
| slender wheatgras | 2.0 | |
| TOTAL GRASSES | 6.4 | 4.0 |
| FORBS | | |
| hairy golden-aster | 1.8 | 0.5 |
| commandra (pall) | 0.5 | |
| lemonweed | 0.5 | 0.3 |
| goatsbeard | 0.3 | |
| fleabane | 0.5 | |
| goldenrod | 1.0 | 1.0 |
| western pasqueflower | T | T |
| hodding onion | T | T |
| wild blue flax | | T |
| pussytoes | T | |
| horthern bedstraw | | 0.3 |
| TOTAL | 5.09 | 3.0 |
| SHRUBS | | |
| rabbit-brush | 2.5 | 4 |
| snowberry | T | T |
| saskatoon | T | |
| rose | T | |
| common juniper | | T |
| TOTAL | 3.0 | 4.5 |
| TREES | | |
| Douglas-fir > 10 m | 7.0 | 8.0 |
| Douglas-fir 2 - 10 m | 1.8 | 0.5 |
| Douglas-fir < 2 m | | 0.5 |
| Rocky Mountain juniper < 2 m | 0.5 | |
| TOTAL TREES | 11.3 | 9.0 |
| Decaying Wood | 3.0 | 1.0 |
| Mineral Soil | 12.0 | 35.0 |
| Organic Matter | 50.5 | 25.5 |

decreased from 622 kg/ha to 463 kg/ha with increasing rates of nitrogen application at Site 1 (Columbia Lake) and was not affected by increasing levels of nitrogen at Site 2 near Armstrong Bay. Forage production increased from 453 kg/ha with no phosphorous fertilization at Site 2 (Appendix 3).

*Wigwam Flats.*— Forage production declined from 1258 kg/ha to 979 kg/ha with increasing levels of nitrogen fertilizer but increased from 1150 kg/ha to 1406 kg/ha with increasing levels of phosphorous fertilizer (Appendix 3).

## 5.6 Conclusions

### 5.6.1 Prescribed fire

Changes in forage production and quality are related to the physical characteristics of the site burned (Wright 1974; Davidson 1982; Demarchi 1985), season of burn (A. Bailey pers. comm.), climactic conditions (Wright 1974), and species of plant burned (Davidson 1982; Demarchi 1985). Range burns of low to moderate intensity may first reduce the vigour of bunchgrasses but within several years bunchgrass productivity usually exceeds preburn levels (A. Bailey pers. comm.), as does antelope-brush (Quadvlieg 1969). Cover (Davidson 1983) and quality (D.Demarchi 1985) of preferred shrubs such as saskatoon and choke cherry can increase with a moderately intense prescribed fire.

The vegetative response to prescribed fire is largely dictated by the fire intensity and duration (P. Woodard pers. comm.), which increase as the fuel loading, especially heavy fuel (>3 cm) loading, increases. Fire intensity is influenced by the dryness of

fuels especially heavy fuels, relative humidity at time of burning, ambient air temperature and wind speed. The intensity of fire on lower Fontaine and Burntbridge Basin was low due to light fuel loads, short duration of fire and low flame heights (<5 m). Intense fires, such as those in June 1985 and August 1986 in the East Kootenay, leave many areas with exposed mineral soil, which is subject to erosion. Nutrient pools, soil tilth and seed sources may be lost with the loss of the duff layer.

For a successful burn on seral shrubland located on the lower western edge of the Rocky Mountains, fine fuels should have <10% moisture, heavy fuels <20% moisture; temperature, 18 to 25 C; relative humidity, 15 to 35%; and, wind speeds, <15 km/hr.

In March 1982, a cool, spring prescribed fire on a semi-arid seral shrubland on the lower Bull River increased ground cover of grasses but caused a large decline in ground cover and stem densities of shrubs. Grasses including Canada bluegrass and spreading needlegrass increased in ground cover after prescribed fire. Ground cover and stem densities of antelope-brush and saskatoon were reduced by fire. The effect lasted for at least three growing seasons. The decline in browse would not be suitable for wintering game species such as deer, elk and moose but would be suitable for bighorn sheep, which rely primarily on grasses and forbs (Quaedvlieg 1969; Johnson 1980). Ground cover of most forb species was also reduced by this cool spring burn and the effect lasted for at least 3 years. Ground cover of spreading dogbane and pearly everlasting was reduced by fire; ground cover of black medic and sticky cinquefoil increased.

Better moisture conditions resulted in a more rapid vegetative response to prescribed fire at Fontaine Basin compared to Burntbridge Basin. Ground cover of most browse species except antelope-brush was stimulated by a cool spring burn on this sub-hygric site, in contrast to the shrub response on the semi-arid alluvial terrace of Burntbridge Basin. Condition Class (Aldous 1944) of all browse species improved after burning and available browse production appeared to have improved. As on the semi-arid site, ground cover of grasses increased after prescribed fire but cover of forbs declined. Grasses that responded positively to prescribed fire at the mesic site were timber oatgrass, Canada bluegrass and pinegrass. By the second growing season, ground cover of forbs equalled that of adjacent unburned range, and by the third growing season ground cover of grasses was double that of adjacent unburned range.

This spring burn had little effect on the duff and litter layer and probably had little effect on the forage nutrient pool.

Antelope-brush was very susceptible to prescribed fire, thus in locations where it was used as a prime winter food source for deer and elk, prescribed fire may not be a suitable enhancement technique.

On mesic or moister sites with suitable soil in the Dry Interior Douglas-fir biogeoclimatic zone, prescribed fire can be used to stimulate forage production for many ungulate species.

### 5.6.2 Selective logging

Selective logging on a semi-arid site on Lakit Mountain dramatically increased ground cover and production of forage species by reducing canopy cover of interior Douglas-fir from 70% to <5%. The cover, frequency of occurrence and production of grasses, especially pinegrass,

increased dramatically with selective logging due to better light, more soil heat, and lack of competition from other grasses. Forage production increased nearly 15 times over that of unlogged range 2 years after logging with pinegrass increasing most. Logging had little effect upon cover, composition and frequency of occurrence of shrubs 4 years later. In time, differences may have been observed but a wild fire changed the entire microclimate of the area in 1986.

Selective logging improved species diversity of grasses and forbs (5:23) and stimulated growth of palatable forage species such as rough fescue, junegrass, fireweed and aster. Scarification of the ground surface during logging probably created a suitable seed-bed for annual invaders, such as some of the asters, wavy-leaved thistle and fireweed, and better light, greater soil heat and less competition may have stimulated dormant grass seed to germinate. The cover and frequency of cryptogams and litter were significantly higher on unlogged range probably because conifers provided a cooler, moister environment.

The cover and frequency of occurrence of bare ground and rock was similar on logged and adjacent unlogged range, which suggests that winter logging had little effect on the duff layer.

An intense wild fire on Lakit Mountain in August 1986 dramatically reduced the ground cover and production of forage on logged range but increased the ground cover and production of forage on adjacent unlogged range. The large differences in forage cover and production between logged and unlogged range were no longer observed after wild fire. The heavy canopy cover of unlogged range was removed by wild fire permitting better forage growth although plant species diversity and litter levels were reduced and the amount of exposed mineral soil increased.

The ground cover of grasses was most reduced by wild fire (45%-8%) but the diversity of grass species was not affected. In contrast, the cover of forbs was reduced in half but the diversity of forb species was reduced from 15 to 2. Shallow rooting systems of most forbs observed on Lakit Mountain made them susceptible to fire, whereas more deeply rooted grasses were not as severely affected.

Ground cover and stem densities of shrubs were significantly reduced by wild fire with birch-leaved spirea being most affected on logged range and creeping Oregon-grape on unlogged range. Five of the seven shrub species present were temporarily eradicated by intense heat but redstem ceanothus was observed on macroplots where it had not been observed previously.

Prescribed fire and selective logging were more effective than wild fire in producing open range with high species diversity and productivity. The undesirable effects of the intense wild fire demonstrate the need to conduct prescribed burns during the appropriate time on forested sites where fuel build-up is not excessive. The appropriate time is determined by fire weather conditions, fuel load, fuel type, fuel moisture, and the objectives of the land manager (P. Woodard pers. comm.)

### 5.6.3 Slashing

Hand slashing of forested habitat is labour intensive and expensive for the increase in forage production achieved. Costs for slashing conifers varied between $580 and $790/ha and the cost of slashing aspen averaged $792/ha. Both mechanical and

hand-slashing of aspen produced a dramatic increase in suckering of aspen that increased stem densities from 3 to 10 times. These suckers would be available to wintering game animals as forage for at least three growing seasons because they are <2.5 m. high and therefore browseable. Other species of shrubs responding rapidly to the opening of the canopy cover included rose, birch-leaved spirea and balsam poplar. Shade-tolerant forbs including American vetch peavine, thimbleberry, wintergreen, twistedstalk, baneberry and false Solomon's-seal declined in cover after slashing. Most forbs were generally not available as winter forage due to dispersal of brittle dried leaves in the wind.

The increase in cover and stem density of preferred browse species such as trembling aspen, balsam poplar and rose far outweighed the relatively small declines in cover of some less desirable browse species such as Oregon-grape.

In provincial parks such as Premier Lake, where prescribed fire is not yet condoned, hand-slashing of conifers was effective in achieving the objectives of the B.C Parks Branch and the Wildlife Branch of the Ministry of Environment to maintain natural looking, productive winter range.

On winter ranges that lack suitable conditions for prescribed fire such as the east side of Columbia Lake, hand slashing of trees may be the only feasible method of enhancement. This method has temporarily halted forest encroachment. For 12 years, forest encroachment has accelerated due to frequent cool-wet summers and warm-dry winters. Without this type of project, Rocky Mountain bighorn sheep would lose a large part of the unalienated winter range remaining between Canal Flats and Radium Hotsprings 64 km north.

### 5.6.4 Fertilization

The increase in forage production achieved by using fertilizer at Columbia Lake and Wigwam Flats did not warrant the cost of purchase and application (Table 31).

Fertilizer application on the alluvial fans of Columbia Lake and the glacial till plain of Wigwam Flats was not economically feasible. Both sites were located on semi-arid Eutric Brunisol soils in the Dry Interior Douglas-fir biogeoclimatic zone (Utzig *et al.* 1986) where annual moisture is <45 cm. Winter range located along the east side of Columbia Lake is the least productive of all ranges examined and in most need of an increase because of heavy densities of elk and bighorn sheep and insufficient winter range for these populations elsewhere.

**Table 31. Market value of increased forage production versus the cost of fertilizer treatment.**

| Location | Rate P205 (kg/ha) | Production Increase (kg/ha) | Market Value ($) | Cost Fert. ($) | Cost Appl. ($) | Total Cost ($) |
|---|---|---|---|---|---|---|
| Columbia Lake (1) | 100 | 44 | 3.70 | 45.70 | 2.00 | 47.70 |
| | 200 | 83 | 7.05 | 91.40 | 2.00 | 93.40 |
| | 400 | 162 | 13.73 | 182.80 | 2.00 | 184.80 |
| Wigwam Flats | 100 | 17 | 1.44 | 45.70 | 2.00 | 47.70 |
| | 200 | 16 | 1.19 | 91.40 | 2.00 | 93.40 |
| | 400 | 326 | 27.70 | 182.80 | 2.00 | 184.80 |

# 6. HUSBANDRY TREATMENTS

Biologists and veterinary pathologists agreed that additive stressors make bighorn sheep vulnerable to disease (Rocky Mountain Disease Research Conference, Cranbrook, May 1983). Potential stressors identified from the 1981-83 epizootic dieoff in bighorn sheep were: trace mineral deficiencies including selenium, iodine and copper (Davidson 1983; Schwantje 1988*b*), poor nutrition (Eastman *et al.* 1971; Schwantje 1988*b*), moderate to high lungworm loads (Davidson 1983; Schwantje 1988*b*), high winter tick loads (Davidson 1982), cool wet early spring weather (Davidson 1983), competition with elk for forage and space (Davidson 1982) and harassment by dogs (Davidson 1982).

An outbreak of soremouth (contagious ecthyma) in bighorn sheep wintering on Wigwam Flats during the winter of 1981/82 indicated that cell-mediated immunity in bighorn sheep was already seriously compromised (Zarnke *et al.* 1983; Schwantje 1988*a*). Poor nutrition may have impaired development of the thymus and spleen in lambs (Hudson *et al.* 1974) thereby impairing the ability of the immune system to suppress pathogenic organisms. The formation and response of lymphocytes may be suppressed both by malnutrition and by corticosteroids secreted in response to stress (Hudson *et al.* 1974). Vitamin deficiencies are common in dried, cured winter forage, which may also have reduced the effectiveness of the immunosuppressive system (Hudson *et al.* 1974). Copper, iodine and selenium deficiencies may have suppressed the immune response of bighorn sheep and reduced reproductive success and growth (Chandra 1983; MacDonald *et al.* 1976). Cool, wet spring weather may also have compromised the immune system of bighorn sheep in the late winters of 1981 and 1982. Harassment from dogs, helicopters or any negative conditioning will elevate corticosteroid output and under chronic or acute stress conditions (MacArthur *et al.* 1982; Stemp 1983; Harlow *et al.* 1987).

Lungworm parasites especially *Protostrongylus stilesii* caused extensive tissue damage in some of the bighorn sheep necropsied during the dieoff (G. Woebeser, R. Lewis - Veterinary Pathology Reports 1982, Cranbrook), which in turn may have impaired the reactivity of the immune system (Hudson *et al.* 1974).

## 6.1 Methods

### 6.1.1 Treatments

Not all stressors affecting bighorn sheep could be alleviated but we tried to reduce nutritional deficiencies, parasitic loads and harassment. Nutritional stress was reduced by increasing the quantity and quality of bighorn sheep winter ranges bordering the Rocky Mountain Trench through habitat enhancement projects and bait-site treatments with second-cut alfalfa hay (14-18% crude protein) and fermented apple mash.

The nutritional status of between 250 and 450 bighorn was improved through annual treatment at bait sites during January and February. Antiparasite drugs were placed in the fermented apple mash bait when a consistent number of bighorn sheep responded to the call for feeding. An antiparasite drug, Ivermectin, was first tried on bighorn sheep being baited at Premier Ridge in February 1983. This drug proved to be unpalatable to bighorn sheep so another drug, Fenbendazole, was used

at bait sites in 1984. This antiparasite drug proved to be very palatable and had a wide tolerance level. The dosage of Fenbendazole used per bighorn sheep averaged 7 ml of 100 mg/ml concentration placed in 1 kg of apple mash/sheep. The recommended dosage for domestic sheep was 2.5-5 ml/50 kg body weight. The body weight of bighorn ewes was assumed to be about 65 kg, lambs 30 kg, and mature rams 110 to 120 kg.

A trace mineral mix was administered by free choice at bait site troughs. The mix contained 150 ppm selenium, 12.4% phosphorous, 17.2% sodium, 1.2% magnesium, 8000 mg/kg zinc, 3900 mg/kg manganese, 4000 mg/kg copper, 1000 mg/kg iodine, 70 mg/kg cobalt, 46 500 IU/kg Vitamin A, 46 500 IU/kg Vitamin D and 3375 IU/kg Vitamin E. Table 32 presents the location and number of bighorn sheep treated at bait sites from 1984 to 1989.

### 6.1.2 Evaluating treatments

The effectiveness of antiparasite treatments was evaluated through Von Baermann lungworm larval analysis of feces collected on the range before medicinal treatment and an analysis of feces collected from the same herd 7 to 10 days following treatment or directly from the animal during capture. The effectiveness of trace mineral treatments could not be evaluated because capturing the same animal within 1 month was difficult. The effect of better winter feed, antiparasite and trace mineral treatment on blood cortisol levels could not be evaluated for the same reason - difficulty recapturing within a short time. Herd structure, herd size and horn growth of harvested rams before and after bait site treatments were used as an indicator of the effects of husbandry treatments. The effect that mild winters have had on herd structure and growth was evaluated by comparing treated with untreated herds, with full knowledge that not all factors were equal.

## 6.2 Observations

Bait site treatment with Fenbendazole was effective in reducing lungworm larval loads but the effects were short-lived (Table 33).

Bait site treatment did not eliminate lungworm larval output at Columbia Lake even though most of the herd had been treated annually since 1984. Reinfection must have occurred rapidly because lungworm larval output has returned to 200-800 larvae/g (lpg) (low) 11 months after being almost eliminated through treatment. Lungworm larval levels of 0-400 lpg are considered low, 400-800 lpg moderate, 800-1000+ lpg high (Bill Samuels

**Table 32. Location and number of bighorn sheep treated at bait sites in the Rocky Mountain Trench from 1984-1989.**

| Location | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|
| Stoddart Creek[a] | | | 47 | 17 | | 37 |
| Mt. Swansea | 15 | 45 | 55 | 55 | 55 | - |
| Columbia Lake | 130 | 150 | 160 | 170 | 130 | 150 |
| Premier Ridge | 85 | 90 | 105 | 120 | 135 | - |
| Bull River[b] | - | 35 | 45 | 35 | 55 | 110 |
| Wildhorse | - | - | - | 45 | - | - |
| TOTAL | 230 | 320 | 412 | 443 | 375 | 314 |

a Bighorn sheep captured at Stoddart Creek were treated only at time of capture.
b Bighorn sheep located on the lower Bull River would not consistently take apple mash until 1989 but did utilize the trace mineral mix.

**Table 33. Effect of Fenbendazole treatment on lungworm larval loads of East Kootenay bighorn sheep, 1984 - 1988[a].**

| Location | Date | Type Sample | Number of Samples | Average larvae/g[b] |
|---|---|---|---|---|
| Columbia Lake | November 1983 | Pre-treat | 7 | 734 |
| Columbia Lake | February/March 1984 | Post-treat | 28 | 34 |
| Columbia Lake | November/December 1984 | Pre-treat | 9 | 539 |
| Columbia Lake | March 1985 | Post-treat | 19 | 0 |
| Mount Swansea | December 1984 | Pre-treat | 6 | 390 |
| Mount Swansea | March 1985 | Post-treat | 11 | 0 |
| Mount Swansea | December 1985 | Pre-treat | 9 | 22 |
| Columbia Lake | January 1987 | Pre-treat | 22 | 856 |
| Columbia Lake | January 1987 | Post-treat | 20 | 269 |
| Premier Ridge[c] | February 1987 | Post-treat | 10 | 7 |
| Lizard Range | March 1987 | Untreated | 10 | 615 |
| Columbia Lake | January 1988 | Pre-treat | 21 | 134 |
| Columbia Lake | January 1988 | Post-treat | 15 | 3 |
| Columbia Lake | February 1988 | Transplant treated | 12 | 384 |
| Mount Swansea | January 1988 | Pre-treat | 15 | 205 |
| Mount Swansea | February 1988 | Post-treat | 10 | 2 |
| Stoddart Creek | February 1988 | Untreated transplant | 18 | 2,028 |
| Bull River | January 1988 | Pre-treat | 15 | 209 |
| Bull River | February 1988 | Post-treat | 15 | 8 |
| Premier Ridge | January 1988 | Pre-treat | 14 | 246 |
| Premier Ridge | February 1988 | Post-treat | 15 | 24 |
| Lizard Range | January 1988 | Untreated transplant | 10 | 265 |
| Arrow Lake | January 1988 | Untreated transplant | 11 | 269 |

a Fecal lungworm larval analysis was completed before and after the dieoff on Wigwam Flats, Bull River and Premier Ridge but the results from Abbotsford are suspect and are therefore not included. Lungworm larval analysis was done by the Provincial Wildlife Laboratory at Edmonton, Alberta.

b Lungworm larval levels of 0-400 larvae/g (lpg) are considered low, 400-800 lpg moderate, 800-1000 lpg high (W. Samuels pers. comm.).

c No pre-treatment samples were collected.

pers. comm.). Lungworm larval output increased to an average of only 22 lpg in December 1985 after being eliminated in March 1985 in the Mount Swansea herd (~~Appendix 1~~ Table 33). This level was considerably lower than the average of 529 lpg observed in bighorn sheep of Columbia Lake treated and re-sampled during the same period.

Lungworm larval output taken from feces collected directly from the animal was dangerously high (2038 lpg) in bighorn sheep translocated from Stoddart Creek to Wigwam Flats in 1987. These animals were given an oral drench of antiparasite drug at time of capture, which eliminated most lungworm. The average lungworm larval output of 10 samples collected on the Stoddart Creek range within days of this transplant contained only 230 lpg, suggesting that fecal samples collected from the range may not be an accurate indicator of lungworm larval output.

Lungworm larvae treatment of the Stoddart Creek herd was not completed because Parks Canada requested we not treat this herd. This agreement was developed between Parks Canada and the provincial Wildlife Branch so translocation of shared bighorn sheep could occur.

Lungworm larval output may be related to herd densities and/or range condition. Lungworm larval output from bighorn sheep translocated from Columbia Lake to the Lizard Range and Arrow Lakes was lower than that of the source herd 2 to 3 years after treatment (Table 33).

Blood cortisol levels did not appear to be related to lungworm larval output. Untreated Stoddart Creek bighorn sheep with extremely high lungworm larval output had blood cortisol levels below that of the Bull River herd and only slightly higher than that of the Columbia Lake herd, which were both treated for parasites. Blood cortisol analysis done on samples collected in February 1985 from 16 bighorn sheep captured at Columbia Lake averaged 5.27 ug/kl, which was considered high (T. Spraker, file note to Cranbrook Wildlife Branch, 1985). These bighorn sheep had been treated annually with antiparasite drugs and trace minerals at winter bait stations. Blood cortisol levels of 11 bighorn sheep captured near Columbia Lake on 1988 February 7 averaged 5.03 ± 0.90 ug/dl (Table 34), which was lower than 1985 but still in the high range. Forty-five bighorn sheep had

**Table 34. Blood corticosteroid levels in captured bighorn sheep in the East Kootenay 1988 and 1989.**

| Location | Tag. No. | Sex | Age | Corticosteroid Level (mg/dl) |
|---|---|---|---|---|
| Columbia Lake | | | | |
| February 7, 1988 | 34 | F | 0.5 | 3.4 |
| | 35 | F | 4.5 | 5.1 |
| | 38 | M | 3.5 | 4.7 |
| | 39 | M | 3.5 | 4.7 |
| | 40 | F | 1.5 | 5.5 |
| | 41 | M | 2.5 | 4.0 |
| | 42 | M | 5.5 | 5.0 |
| | 44 | M | 1.5 | 5.5 |
| | 45 | F | 4.6 | 6.1 |
| | 46 | M | 2.5 | 4.7 |
| | 47 | F | 6.5 | 6.6 |
| Average, Both Sexes: 5.03 ± .90 mg/dl (n = 11). Average Ewes: 5.83 (n = 4) mg/dl. Average Rams: 4.77 mg/dl (n = 6). One Lamb: 3.4 mg/dl. | | | | |
| Bull River | | | | |
| January 28, 1989 | 70 | M | 3.5 | 4.7 |
| | 71 | F | 1.5 | 3.8 |
| | 72 | M | 0.5 | 5.2 |
| | 73 | M | 0.5 | 6.8 |
| | 74 | F | 4.5 | 7.4 |
| | 75 | F | 2.5 | 5.1 |
| | 126 | M | 1.5 | 4.5 |
| | 128 | F | 3.5 | 5.8 |
| | 129 | F | 4.5 | 5.6 |
| | 131 | F | 5.5 | 6.7 |
| | 132 | M | 0.5 | 6.6 |
| | 133 | F | 2.5 | 8.2 |
| | 134 | F | 1.5 | 4.5 |
| | 135 | F | 3.5 | 7.3 |
| | 138 | M | 4.5 | 4.4 |
| | 139 | F | 4.5 | 5.4 |
| Average corticosteroid level of 16 bighorns sampled was 5.75 ±1.28 mg/dl. Average corticosteroid level of: 10 Ewes was 5.98 mg/dl., of 3 Rams was 4.53 mg/dl., and of 3 Lambs was 6.2 mg/dl. | | | | |
| Stoddart to Wigwam | | | | |
| February 11, 1989 | 66 | F | 7.5 | 5.6 |
| | 107 | F | 3.5 | 6.1 |
| | 110 | F | 4.5 | 5.4 |
| | 111 | F | 4.5 | 6.5 |
| | 113 | F | 4.5 | 4.2 |
| | 114 | F | 1.5 | 4.1 |
| | 121 | F | 2.5 | 5.4 |
| | 122 | F | 3.5 | 5.8 |
| | 124 | F | 8.5 | 6.2 |
| | 125 | F | 3.5 | 4.5 |
| Average corticosteroid level of 10 bighorn ewes sampled was 5.38 ± 84 mg/dl. | | | | |

been translocated from this herd between February 1985 and February 1987, which should have reduced the stress level.

The average cortisol level of 11 blood samples collected from bighorn sheep captured at Bull River on 1989 January 28 was 5.75 ± 1.28 ug/dl (Table 34). This herd had just recuperated from a soremouth epidemic. Since 1984, about one-half of this herd was annually treated with antiparasite drugs and trace minerals.

Average blood cortisol levels of 10 bighorn sheep captured at Stoddart Creek on 1989 February 11 was 5.38 ± 0.84 ug/dl. Between 1986 and time of sampling, the Stoddart Creek herd had not received bait site treatment, but 64 bighorn sheep had been removed through hunter kills. Ewes and lambs had the highest blood cortisol levels in all herds sampled while rams had the lowest levels (Table 34).

Bait site treatment improved lamb recruitment over those of untreated herds. The Premier Ridge herd was treated annually between 1984 and 1988, the Estella herd wintering <6 km south of Premier Ridge was not treated. The estimated population of bighorn sheep increased from 85 to 165 on Premier Ridge, whereas that of Estella increased from 45 to 75 during the same time. The Bull River herd increased from an estimated population of 35 in 1983 to at least 128 (counted) in 1989. Herd structure, population counts and estimated populations are given in Table 35.

The Estella band did not succumb to the 1982/83 epizootic dieoff, which affected the Bull River and Premier Ridge herds. Sex ratios did not really indicate the change in recruitment because non-productive yearling ewes were included. In rapidly expanding populations such as Bull River and Premier Ridge, yearling ewes represent 1/4 to 1/6 of the ewe population. For example, in 1986 the lamb:ewe ratio at Bull River was 33:49 or 67%, but the lamb:mature ewe ratio was 89%. Between 1985 and 1988, recruitment averaged 92% for lamb:mature ewes on

**Table 35. Population counts, herd structure and herd estimates of the Premier Ridge, Estella and Bull River bighorn sheep herds, 1982-1987.**

| | | Population | | Sex Ratios (%) | | |
|---|---|---|---|---|---|---|
| Herd | Date | Count | Estimated | Ewes: | Lambs: | Rams: |
| Premier | March 1982 | 71 | 130 | 42: | 24: | 34 |
| Premier | February 1983 | 80 | 90 | 64: | 21: | 15 |
| Premier | March 1984 | 73 | 90 | 70: | 23: | 16 |
| Premier | January 1985 | 62 | 100 | 61: | 11: | 28 |
| Premier | February 1986 | 73 | 110 | 55: | 27: | 18 |
| Premier | February 1987 | 123 | 135 | 48: | 26: | 26 |
| Premier | February 1988 | 134 | 150 | 54: | 26: | 20 |
| Estella | March 1982 | 18 | 45 | 56: | 28: | 17 |
| Estella | February 1983 | 35 | 45 | 63: | 26: | 11 |
| Estella | March 1984 | 16 | 45 | 50: | 38: | 12 |
| Estella | March 1985 | 33 | 45 | 67: | 24: | 9 |
| Estella | March 1986 | 55 | 65 | 53: | 31: | 16 |
| Estella | March 1987 | 40 | 70 | 55: | 33: | 12 |
| Estella | March 1988 | 52 | 75 | 67: | 25: | 9 |
| Bull R. | March 1982 | 35 | 45 | 54: | 37: | 19 |
| Bull R. | February 1983 | 11 | 35 | 64: | 9: | 27 |
| Bull R. | March 1984 | 38 | 50 | 50: | 29: | 21 |
| Bull R. | February 1985 | 45 | 65 | 56: | 18: | 26 |
| Bull R. | February 1986 | 49 | 70 | 49: | 33: | 18 |
| Bull R. | January 1987 | 50 | 80 | 42: | 28: | 30 |
| Bull R. | February 1988 | N.R. | | | | |

the Bull River and 58% on Premier Ridge. The Bull River and Premier Ridge herds have rapidly expanded since 1985 while the Estella herd has increased more slowly. The difference may be due to bait site treatment with antiparasite drugs and trace minerals, which has stimulated recruitment.

Ram horn growth has been compared by Wildlife Management Units (WMU) from 1975 when compulsory inspection began to 1987. Two WMUs with the highest harvest rates were compared to assess the impact of herd treatment on horn growth. Average horn lengths by age of bighorn rams harvested in the Elk Valley (WMU 4-23) were compared with those harvested in WMU 4-25 (Columbia Lake, Stoddart Creek, Simpson River) in the Rocky Mountain Trench. Body weights and horn curl characteristics were similar between these areas although foraging strategies differed (Schwantje 1988*b*). These WMU's were used because the number of rams harvested was high, and the chance of intermingling was extremely remote. Average age, horn size and days required to harvest a ram were compared for 1985 and 1987, assuming that the effect of bait site treatments took 3 to 4 years to have an effect on harvestable rams. From compulsory return data, the average horn size was larger and average age of harvested rams nearly 2 years younger in WMU 4-25 than in 4-23 with similar numbers of rams harvested annually (Table 36). The average number of days required to harvest a ram was 6.9 in WMU 4-25 compared to 10.2 days in the Elk Valley. Better quality rams were obtained in WMU 4-25 even though horn curl requirements were only full curl or 8 years of age compared to mature full curl (above the bridge of the nose) requirements in the Elk Valley during this time.

## 6.3 Conclusions

Bait site antiparasite treatments significantly reduced lungworm larval output but did not influence blood cortisol levels. Stress levels in bighorn sheep (based upon peak cortisol levels), treated at Columbia Lake and Bull River, remained high despite virtual elimination of lungworm shortly after administration of antiparasite drugs. Bait site treatments with antiparasite drugs, trace minerals, and high quality forage has stimulated recruitment and caused a rapid population expansion in the Bull River, and Premier Ridge herds. Untreated herds such as the Estella band have also expanded since exposure to pneumonia in 1982/83 but the rate of expansion has not been as rapid as that of treated herds.

**Table 36. Characteristics of rams harvested in WMU 4-23 (Elk Valley) compared to those of WMU 4-25 (Upper Columbia), 1985-1987.**

| | | | Base (mm) | | Circu. (mm) | |
|---|---|---|---|---|---|---|
| Years | No. | Age (Years) | Left | Right | Left | Right |
| W.M.U. 4 - 23 | | | | | | |
| 1985 | 10 | 9.3 | 380.7 | 382.9 | 877.0 | 905.7 |
| 1986 | 8 | 9.3 | 381.4 | 381.0 | 800.5 | 893.5 |
| 1987 | 9 | 8.5 | 388.7 | 385.4 | 911.8 | 907.7 |
| MEAN | 9 | 8.98 | 383.6 | 383.1 | 889.8 | 902.3 |
| W.M.U. 4 - 25 | | | | | | |
| 1985 | 7 | 8.2 | 391.3 | 390.9 | 921.7 | 941.0 |
| 1986 | 11 | 6.6 | 388.0 | 387.1 | 897.6 | 897.6 |
| 1987 | 12 | 6.5 | 400.2 | 400.1 | 930.8 | 930.8 |
| MEAN | 10 | 6.5 | 393.2 | 392.7 | 916.5 | 929.7 |

The Wigwam Flats and the Lower Wildhorse herds, which did experience an epizootic dieoff in 1982 (as did the lower Bull River and Premier Ridge), would not have expanded within 6 years if translocations had not been conducted.

Rapid expansion of treated herds could not be discerned through change in sex or ewe:lamb ratios because high survival of lambs to yearling age meant that 1/4 to 1/6th of the ewe population were non-breeders.

Herd treatment apparently improved horn quality of rams over that of an untreated herd. Horn growth of rams may be used to indicate the efficacy of husbandry treatments because the level of nutrition obtained during pregnancy and lactation has an effect upon horn growth of rams for the duration of their lives (Shackleton 1973; Horesji 1976). High quality second-cut alfalfa hay, fermented apple mash and supplementation of free choice trace mineralized salt at winter bait stations improved the level of nutrition during mid- to late winter months when quality of native range is at its lowest level and physiological demands upon pregnant ewes are at a peak.

The level of nutrition obtained during winter months before spring green-up has a direct effect upon overwinter weight loss in bighorn sheep (Stelfox 1974; Jorgenson and Wishart 1986), birth weights of lambs (Shackleton 1973), and milk production in lactating ewes (Shackleton 1973; Horesji 1976). After development of the rumen at 3 weeks of age, it is the length of the active growing season (Shackleton 1973; and Wishart Jorgenson 1986), forage strategy of the ewe band (Hebert 1973; Petocz 1973), habitat diversity (Johnson 1980), quality of forage and minerals available to rams (Hebert 1973) and herd status (Shackleton 1973) that influence the rate of horn growth in rams.

## 7. TRANSLOCATIONS OF BIGHORN SHEEP

Translocations have proved effective in re-establishing many bighorn sheep populations extirpated through excessive hunting and disease in the western United States. Only those translocations that were done without considering habitat requirements of Rocky Mountain bighorn sheep have failed. In Utah and Colorado several bighorn sheep transplants also failed because traditional winter range was impacted by residential and recreational development (T. Spraker pers. comm.).

The Kootenay Region of southeastern British Columbia provided an excellent opportunity for translocation of bighorn sheep because several herds had reached dangerously low population levels (<20) due to periodic epidemic dieoffs. By the 1980's, low-elevation winter ranges used by bighorn sheep along the lower western slopes of the Rocky Mountains were isolated islands of open grassland and seral shrubland in a sea of coniferous forest. Small, isolated populations of bighorn sheep were vulnerable to extinction due to disease and predation (Risenhoover *et al.* 1988). Historically, periodic wild fires had maintained open range with preferred forage, an unobstructed view and low accumulations of snow required by bighorn sheep. Following the 1964-67 lungworm-pneumonia epidemic in bighorn sheep, several herds were almost extirpated. The lower Bull River herd was reduced from about 250 to 8 bighorn sheep (R. Demarchi pers. comm.; B. Gower pers. comm.). The Lizard Range had provided habitat for nearly 200 bighorn sheep until a combination of human developments virtually extirpated the herd in the early 1920's. The epidemic dieoff of 1964/65 ended the spring/fall migration to and from Wigwam Flats in the remnant bighorn sheep herd.

Human developments that affected spring and fall movement to and from Wigwam Flats included:

1. The construction of the townsite of Elko at its present site near the turn of the century;
2. The realignment of the Canadian Pacific Railroad in the 1920's;
3. The construction of the Elk River Power dam near the townsite of Elko in 1924, which raised the water level and increased the width of open water that had to be crossed in spring and fall months;
4. The development of Highway 3 in its present location on the north side of the Elk River in the 1940's;
5. The construction of the Elk River log haul road on the south side of the Elk River parallel to Highway 3.

Traditional winter range for the Maguire Creek herd on the lower western slopes of the Galton Range was alienated by agriculture in the late 1800's. Winter range located further upslope had grown in with conifers since the massive wild fires of 1936. The bighorn sheep population was 85 before the 1981/82 epidemic dieoff and only 14 bighorn sheep survived.

Bighorn sheep on Wigwam Flats experienced epidemic dieoffs in 1964/65 and 1982. The latter dieoff reduced the estimated population from 450 to 130 during the spring and summer of 1982. Post-dieoff pneumonia in lambs (Schwantje 1988*b*) kept recruitment levels at <10% for 2 years and at <20% for 2 more years. The estimated population continued to decline and it was feared that many older ewes that had survived the dieoff would no longer be able to reproduce.

Epidemic lung disease in 1940-42 reduced the Wildhorse herd to <40, and a dieoff in

1982 further reduced this herd to <20 bighorn sheep. Accounts by long-time residents (B. Kotine, A. Rosicky pers. comm.) indicate that 130-150 bighorn sheep utilized the lower Wildhorse area as winter range before the 1940's. The huge wild fires that occurred in most of the Rocky Mountain Trench in the 1920's and 1930's did not occur in the lower Wildhorse and only about 170 ha of open grassland and seral shrubland remained by the early 1980's. This winter range was shared with elk, mule deer, white-tailed deer and cattle.

South-facing slopes between the Keenleyside Power dam and Tulip Creek on Lower Arrow Lake near Castlegar were identified as a suitable site for bighorn sheep in the early 1970's by V. Geist and in 1984 by D. Hebert and the author. The reservoir created by damming the Columbia River had modified the surrounding climate resulting in low snow accumulations for 500 m above the water surface. A combination of steep rocky terrain bordered by small bluebunch wheatgrass meadows and low snow accumulations provided suitable winter range for bighorn sheep. Competition for forage was expected to be low due to low numbers of elk and mule deer and the absence of livestock on this Crown range.

## 7.1 Objectives

The objectives of the transplant program of Rocky Mountain bighorns were to:

1. restock traditional ranges where populations had been severely reduced or extirpated including Bull River, the Lizard Range, the lower Wildhorse, Maguire Creek, and Wigwam Flats;

2. reduce the potential for epidemic outbreak through reduction of high density herds on poor quality range;

3. complete a bighorn sheep transplant to non-traditional habitat that had been modified by man and now appeared to be suitable - Lower Arrow Lake.

## 7.2 Methods

### 7.2.1 Site selection

The source herds used for translocations were selected for the following reasons:

1. Winter and/or spring range was in poor condition;

2. Herd densities were high, often exceeding 30/km$^2$;

3. Competition with elk was high on traditional winter range;

4. Harassment by dogs and man was high on winter range;

5. Access to winter range was convenient.

The Wigwam Flats herd was considered a prime source for transplants in 1982 for all the above stated reasons. During the previous winter, an outbreak of soremouth had reduced lamb survival by more than 20%. The rate of horn growth in rams appeared to have declined from that of the mid-1970's when the population was rapidly expanding. The outbreak of soremouth was taken as an indicator that high stress levels in bighorn sheep had compromised the immune system and made them susceptible to a pox virus lying dormant as spores on this range since the era of livestock ranching (from the early 1900's until 1965). The Wigwam Flats and Mount Broadwood area had been declared a Game Reserve in 1926, but this status was ended in 1965 because elk and deer populations required control through hunter harvest. During this time, only bighorn sheep and mountain goats were hunted. Elk and bighorn sheep populations had grown rapidly in the late 1950's and early

1960's and were similar to those in the 1980's before the bighorn sheep epidemic. Through consultation with the Colorado Game and Fish Branch, herd reduction through translocations was considered advisable to prevent a dieoff.

Bighorn sheep from the east side of Columbia Lake were selected as a source for transplants because herd densities were high (30+/km$^2$) during mid-winter months, range condition was poor (see Chapter 4 on range conditions and trends), lungworm larval loads were high (Davidson 1983; Schwantje 1988*b*), and harassment from dogs was frequent. Husbandry treatments were initiated on this herd in January 1984 to insure that bighorn sheep intended for translocation were healthy.

The Stoddart Creek herd was selected as a source herd because herd densities were approaching those present before 1966/67 when an epidemic reduced this herd by 50% (Eastman *et al.* 1971; Stelfox *et al.* 1985). Range condition had been assessed as poor to fair and in no better condition than in 1965 when all livestock was removed (Stelfox *et al.* 1985).

Release sites were selected using the following guidelines:

1. Bighorn sheep had traditionally used this range;
2. Essential habitat components required for year-round residency were present;
3. Competition with other ruminants would be minimal;
4. Impacts upon other resource users would be minimal;
5. The biophysical potential to support a viable population was high.

### 7.2.2 Capture method

Bighorn sheep were captured at bait sites using an 80 x 80 ft. Wyoming drop net (Davidson 1983). The site selected for capture was one that was accessible by 4 x 4 truck in any winter conditions, lying on relatively flat ground having few rocks and near escape terrain. In most cases, bighorns had been treated two or three times at weekly intervals with Fenbendazole to reduce the parasite load of translocated animals to a minimum before transplant.

The net was dropped when 20 to 30 bighorns were lured under with fermented apple mash used as bait. Each volunteer was given a blindfold and a hog-tie before net-drop and 30 to 50 volunteers or two per captured animal were generally on site. Blindfolds were made of pantlegs cut off at the level of the upper and mid-part of the thigh. These fabric pieces were about 1 foot long and had a string or Velcro attached at the wide end so that the blindfold could easily be secured. Hog-ties were made of soft cotton rope about 2.5 m (8 ft.) long. All volunteers were transported to the bait site in three or four open-box 4 x 4 pick-ups and were encouraged to keep noise and movement to an absolute minimum.

During the day of capture, baiting was done by the same person in the same way, after which the pick-up was driven to outside the perimeter of the drop net. As baiting was being done, other pick-ups drove to the outside perimeter of the lower corners of the drop-net and one truck (usually the author's) drove with the hood latch ajar to the lead wire end leading to the dynamite caps. The person baiting gave a pre-arranged hand signal when all people and bighorn sheep were clear of the net edges and enough bighorn were under the net. The dynamite caps were then detonated by touching the lead ends to the truck battery posts.

### 7.2.3 Treatment following capture

Two volunteers were assigned to each sheep, one to restrain the animal and the other to blindfold and then hog-tie the animal. All captured bighorns were taken out of the net as quickly as possible and placed with the head upslope to prevent a build-up of rumen gas. Each bighorn was ear-tagged with a coloured and numbered medium size Rototag for future identification and the number, age and sex of the captured animal were recorded.

Each bighorn then received a drench of Fenbendazole, a long-lasting antibiotic (Tetracyline), selenium citrate and Vitamins A, D and E. Fecal samples were collected for lungworm larval analysis. A 5- to 10-cc sample of blood was collected from the jugular vein using an 18-gauge needle and vacutube. These samples were kept from freezing and taken to a veterinary laboratory where they were centrifuged to separate hemoglobin from serum. The serum was then sent for corticosteroid analysis as an indirect measure of stress (Harlow *et al.* 1987).

Ewes >7-years-old and rams >3-years-old were released at the capture site because these age groups would wander widely in search of home range. Transplants were moved with a horse trailer that had been roofed over at the 4-foot level for darkness. Blindfolds and hog-ties were removed when transplants were loaded into the horse trailer for transport. No more than 30 bighorns were transported at one time in a 6-horse trailer and the move was completed the same day as capture.

Bighorns were released during daylight hours to escape terrain in habitat similar to their original range.

### 7.2.4 Monitoring transplants

One or more young ewes (<5-years-old), in any major transplant group were radio-collared so that the movement, habitat use and herd status could be determined at the release site. Location, number and status of radio-collars are given in Table 37.

The first transplant to the lower Bull River in 1982 contained ear-tagged animals but no radio-collars. Transplants to the Lizard Range, Maguire Creek, Arrow Lakes, Wigwam Flats and the lower Wildhorse all contained radio-collared bighorn sheep. Only transplants to the lower Wildhorse and Arrow Lakes were followed consistently. A lack of tracking equipment initially and a lack of funding and personnel limited tracking elsewhere.

Monitoring of radio-collared animals was completed largely through the efforts of volunteers and summer students. We especially tried to record movements after departure from winter range until the sheep returned about 4 months later. Funding required to follow bighorn sheep on the Lizard Range never materialized. The information obtained from radio-telemetry follow-up of collared bighorn sheep released near Elko was largely due to the efforts of one local volunteer and the author on ground surveys. Radio-telemetry monitoring of bighorn sheep trapped and released at Columbia Lake was accomplished by two volunteers and one summer student.

Radio-telemetry follow-up of bighorn sheep translocated to the lower Wildhorse was completed by volunteers from the East Kootenay Hunter's Association and the author representing the Ministry of Environment. The East Kootenay Hunter's Association obtained funding for the Lakit

**Table 37. Destination, date and status of radio-collars on translocated bighorn sheep in the East Kootenay.**

| Destination | Date | Sex | Age (Years) | Collar Lifespan (Months) |
|---|---|---|---|---|
| Lizard Range | 31/01/84 | M | 1.5 | 30 |
| | | F | 3.5 | 54 |
| | | (Died) | | |
| Maguaire Creek | 29/02/84 | F | 2.5 | 18 |
| Arrow Lake | 09/02/85 | F | 0.5 | 3 |
| | | F | 6.5 | 3 |
| | | F | 7.5 | 3 |
| Columbia Lake | 06/02/85 | F | 3.5 | 18 |
| | | | 3.5 | 38 |
| Columbia Lake | 25/01/86 | F | 6.5 | 12 |
| Wildhorse | 25/01/86 | F | 2.5 | 4 |
| | | M | 2.5 | 6 |
| Columbia Lake | 25/01/86 | F | 5.5 | 24 |
| Wigwam Flats | 16/02/86 | F | 4.5 | 4 |
| | | (Died) | | |
| Arrow Lakes | 24/01/87 | F | 2.5 | Unknown |
| Wildhorse | 07/02/87 | F | 3.5 | 22 |
| | | (Died) | | |
| | | F | 3.5 | 10 |
| | | (Died) | | |
| | | F | 3.5 | 4 |
| | | F | 4.5 | Ongoing |
| Wildhorse | 07/02/88 | F | 4.5 | Ongoing |
| | | F | 4.5 | 6 |
| Wigwam | 14/02/88 | F | 3.5 | Ongoing |
| | | F | 2.5 | 5 |
| | | (Died) | | |
| Columbia Lake | 14/02/88 | M | 2.5 | Ongoing |

Mountain Project (lower Wildhorse) through the North Carolina Chapter of Safari Club International in 1986.

Attempts to capture and radio-collar bighorn sheep on the lower Wildhorse were stymied due to infrequent sightings, difficult terrain, and difficulty in capture. During the winter of 1985/86 an alternate plan was developed to assess the status of the lower Wildhorse herd.

A small herd (5) of bighorn sheep was translocated to the lower Wildhorse from Columbia Lake. Two of the transplants were radio-collared. We believed that this small herd would probably join the resident Wildhorse herd and, through radio-collared transplants, herd movement and habitat use of the resident herd could be determined. The information gained would permit assessment of size and capability of winter range for the Wildhorse herd, which was largely unknown. The two ewes, two lambs and one yearling ram were tracked at least once per week on foot or by air primarily through the efforts of volunteers of the East Kootenay Hunter's Association. Unfortunately, radio-collar signals became weak by 1986 May 15 only 3 months after attachment so herd movements from winter range could not be determined.

## 7.3 Observations

### 7.3.1 Bull River transplant

Sixteen bighorn sheep including 12 ewes, 3 rams and 1 male lamb were translocated to the lower Bull River from Wigwam Flats between 1982 January and March 16. Within a week of translocation, the 16 bighorn sheep mixed with the local herd. Six weeks after translocation, one lamb was observed coughing and sick. By the eighth week following transplant, 8 of the 16 transplants had died of *Pasteurella* pneumonia (R. Lewis pers. comm.). Although the transplants had no indication of illness at time of capture, the

pneumonia epizootic must have been underway. The first dead animals on the Wigwam were observed on Rocky Ridge <10 days after the Bull River transplant was completed on 1982 March 16. None of the local Bull River sheep were found dead but rams from this herd were observed coughing on summer range. Five of the transplants were observed on winter range on the lower Bull River in December 1983, and three including two ewes and a ram are known to have lived at least 3 years.

### 7.3.2 The Lizard Range

*Herd structure.*— Twenty-eight bighorns were captured on winter range located along the east side of Columbia Lake and released on the Lizard Range 2 miles east of Elko between 1984 January 31 and March 5 (Fig. 22*a*). Table 38 shows details of the bighorns translocated.

All fourteen ewes gave birth in May 1984 and 12 survived to yearling age. Thirteen of the 14 mature ewes gave birth in 1985 and 10 of these are believed to have survived to yearling age. Table 39 gives the population structure of the Lizard Range transplant from 1984 through 1986.

Ten more bighorns were transplanted from Columbia Lake to the Lizard Range on 1985 January 25. These included 6 ewes, 4 rams, and 1 lamb (Appendix 9). This herd was released north of Elko 1.6 km (1 mi.) behind the bark mill and about 4.6 km (3 mi.) west of the first set of transplants.

The Lizard Range transplants had an unexpected boost in population between March and May 1986 because 18 of the 47 bighorn sheep translocated to Wigwam Flats in February 1986 emigrated. These sheep had been translocated from Stoddart Creek to Wigwam Flats to stimulate

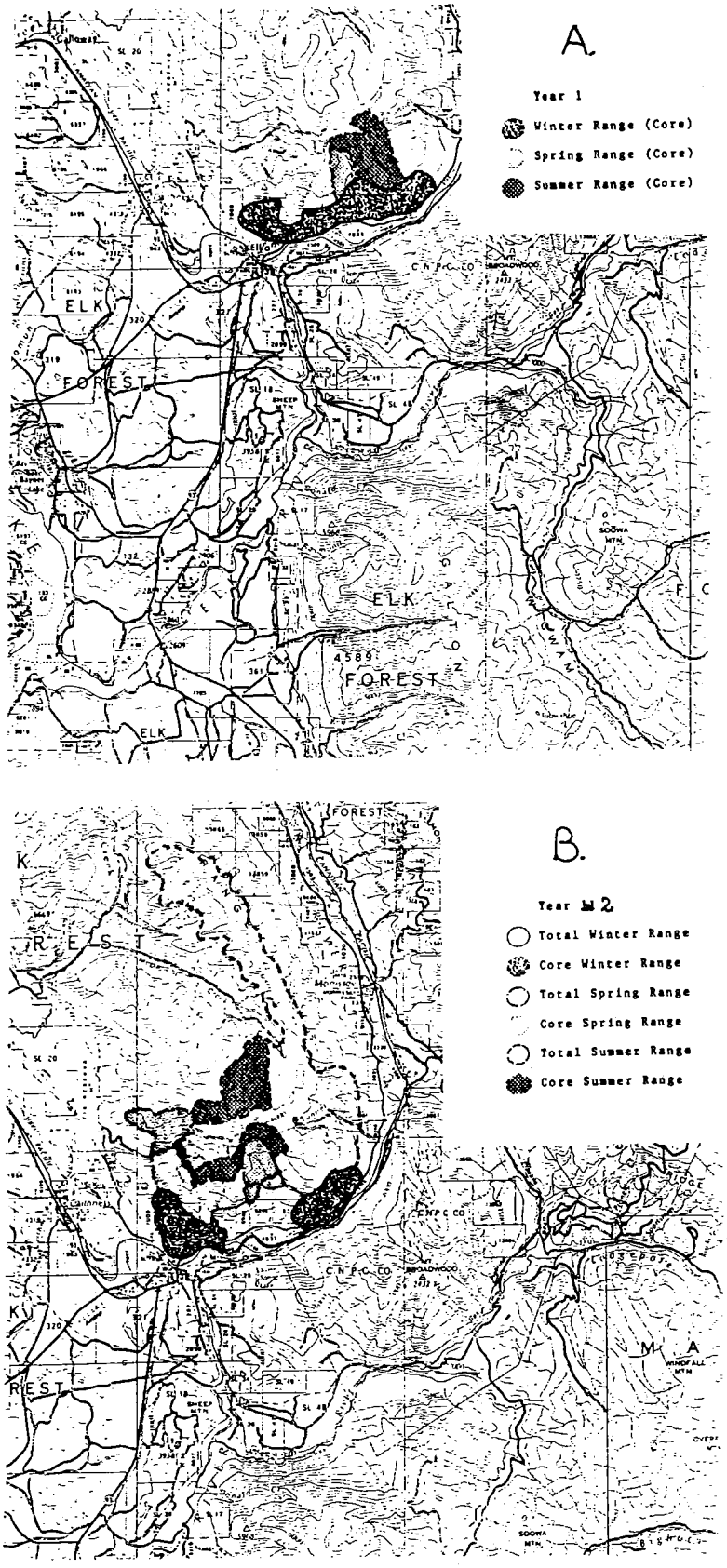



**Figure 22. Distribution of bighorn sheep translocated to the Lizard Range in 1984. A. Year 1 - February 1984 to March 1985. B. Year 2 - March 1985 - April 1986.**

**Table 38. Population structure of bighorn sheep translocated from Columbia Lake to the Lizard Range in 1984[a].**

| Date Moved | Ewes | Lambs (Sex) | Rams (Age) | Total |
|---|---|---|---|---|
| January 31, 1984 | 3 | 2 (M)( | 1 (1.5) | 6 |
| February 1, 1984 | 2 | 3 (2M, 1F) | 3 (2(1.5) 1(2.5) | 8 |
| February 11, 1984 | 4 | 2 (1F, 1M) | | 6 |
| March 5, 1984 | 5 | 2 (M) | 1 (2.5) | 8 |
| TOTAL MOVED | 14 | 9 (6M, 3F) | 5 (2(1.5) 2(2.5) | 28 |

a For further details concerinng the transplants consult Appendix E.

**Table 39. Population dynamics of the Lizard Range transplant herd from 1984-1986.**

| Year | Ewes (Type) | Lambs | Rams (Type) | Total |
|---|---|---|---|---|
| 1984 - 1985 | 14 (Mature) | 14 - - - 12 [a] | 10 (5 Yearling) | 36 |
| 1985 - 1986 | 20 (6 Yearling) | 13 - - - 10 | 16 (6 Yearling) | 49 |
| 1986 - 1987 | 24 (5 Yearling) | 22 - - - 18 [b] | 21 (5 Yearling) | 67 |

a Two ewes and 1 lamb were killed by vehicles on Highway 3, 3 miles east of Elko in 1984.
b One ewe and 1 ram were killed by vehicles on Highway 3 east of Elko in 1986.

recruitment of the local herd.

The source herd for the Wigwam Flats transplant had been habituated to people, human residences and dogs in Radium Hotsprings, thus Highway 3, the Elk River, the town of Elko and the resident dogs did not provide an impenetrable barrier to these sheep. They simply walked across the Elk River bridge, grazed on lawns of Elko residents, then headed north for summer range as they had done at Radium Hotsprings. These transplants did not migrate back to Wigwam Flats in the fall as expected, but remained on the Lizard Range due north of Elko.

*Seasonal distribution and movement.*— Distribution of transplants was limited during the year, extending <4 km west or north of the release site on Mack Creek (Fig. 22*a*). Following release on the power line on Mack Creek, the transplants moved upslope 500 m or east 1 km to the canyon where they remained throughout the winter. The winter season was assumed to be from the time of heavy snow accumulation until early May when sheep moved to the spring lambing range. Heavy snowfall usually occurred at the end of November or the first week of December in alpine and subalpine areas of the East Kootenay.

The functional spring season for bighorn extended from early May until late June when ewes and newborn lambs departed for summer range in alpine and subalpine biogeoclimatic zones. Lambing occurred on Highway 3, 5 km east of Elko, and on the upper western edge of the Dry Creek (Mack Creek) drainage. The first lamb was observed on May 18 in the Canyon and the entire ewe herd had lambed by 1984 June 7.

Summer and fall seasons were classified together because radio-telemetry research on five different bighorn sheep herds indicated that movement by the ewe herd from summer range occurred in early September with almost no time spent upon intermediate range between summer and winter range. Fall rut range was located on, or immediately adjacent, to winter range. Most of the transplants spent the summer season on the head wall of Mack Creek <5 km from the release site (Fig. 22*a*). Total range used was 2.01 km$^2$ (Table 40). The number of sightings on each of the seasonal ranges is presented in Appendix G.

During the second winter some dispersal

**Table 40. Size of seasonal range used by bighorn sheep translocated to the Lizard Range and the lower Wildhorse, 1984-1988.**

| Location | Season | Seasonal Range ($km^2$) | | Percent | |
|---|---|---|---|---|---|
| | | Core | Total | Core | Total |
| Lizard Range | | | | | |
| Year 1 | winter | 4.76 | 4.76 | 46 | 46 |
| | spring | 3.63 | 3.63 | 35 | 35 |
| | summer/fall | 2.01 | 2.01 | 19 | 19 |
| Total | | 10.40 | 10.40 | 100 | 100 |
| Year 2 | winter | 7.93 | 7.93 | 45 | 22 |
| | spring | 5.60 | 7.04 | 32 | 20 |
| | summer/fall | 4.22 | 20.90 | 23 | 58 |
| Total | | 17.75 | 35.93 | 100 | 100 |
| Wildhorse Range (Forestbauera) | winter | 4.34 | 11.76 | 18 | 19 |
| | spring | 9.40 | 24.02 | 38 | 37 |
| | summer/fall | 10.67 | 28.40 | 44 | 44 |
| Total | | 24.42 | 64.18 | 100 | 100 |

occurred with bighorn sheep moving along the lower south-facing slopes of the Lizard Range between the tunnel on Highway 3 and the ridge due north of Elko (Fig.22 *a*). Winter range expanded from <1 $km^2$ during the first winter to 4.76 $km^2$ by the second winter (Table 40). Total range used during the first 13 months following transplant was only 104 $km^2$.

Spring range expanded from 3.5 $km^2$ in 1984 to 5.6 $km^2$ in 1985 and included the south-facing slopes of Burton Creek (Fig. 22*b*). Part of the herd that had wintered near Elko in 1984/85 moved north to the Burton Creek drainage during early May 1985.

Core summer range more than doubled in size in 1985 and included the ridge top between No Name Draw and Burton Creek, as well as the headwaters of Tunnel, Burton and McDermid creeks (Fig. 22*b*). One herd of five ewes and lambs ranged 13 km north of 1984 summer range into the headwaters of Liphart Creek. Core summer range was only 4.2 $km^2$ in 1985 but total summer range used was 20.9 $km^2$ (Table 40).

By the summer/fall of 1987, bighorn sheep had dispersed as far north as the headwaters of Iron Creek, as far east as the Fernie ski hill, and as far north as Sulphur Springs on the Upper Bull River and the Aberfelde Power dam on the lower Bull River. All bighorn sheep ranges that had been utilized historically were now reoccupied. Annual herd movement between Wigwam Flats and the Lizard Range now occurs. Mature rams frequently move from Wigwam Flats to the Lizard Range during summer months and return during late fall. Part of the Lizard Range ewe herd was observed lambing near Silver Springs on Wigwam Flats in 1987. (A complete list of sightings on seasonal range is given in Appendix G)

The total Lizard Range bighorn sheep herd is presently >100, and traditional migrations to and from Wigwam Flats were re-established by part of the herd.

*Mortality.*— Herd mortality was minimal the first 2 years after translocation with the greatest mortality coming from vehicle collisions (5). Salt applied to Highway 3 near the Elk River, and lush forage on the shoulders of the highway attract bighorn sheep and thus create a hazard to motorists on sharp corners in the canyon located between 5 and 12 km east of Elko. Salt licks were created above the

western edge of the Canyon to draw bighorns away from Highway 3. This practice aggravated the problem by encouraging more bighorns to come to the area and to spend more time grazing lush forage along the highway. The problem has largely (but not completely) been controlled by creating mineral licks 5 km west of this area and 1.6 km north of the highway. Ten bighorn sheep were killed on Highway 3 between Elko and Fernie between 1984 and 1988.

Predators including coyotes and cougars did not affect the Lizard Range transplants until 1986. Lamb recruitment was 89 and 91% during the first 2 years following transplant and fell to 55% during the third year probably due to predation. Cougars and coyotes were observed stalking transplants and two coyote kills were found north of Elko. Residents of Elko reported harassment of bighorn sheep and mule deer by dogs near natural licks located within 1 km of Elko.

A hunting season for mature rams was declared in the fall of 1988 and three mature full curl rams were harvested. At least 28 rams aged 3+ are now found on the Lizard Range indicating a good potential for future hunting and viewing.

### 7.3.3 Maguire Creek

*Herd structure.*— Seven bighorn ewe were translocated to Maguire Creek from Armstrong Bay (Columbia Lake) on 1984 February 20 (Appendix G). One ewe had a radio-collar attached (Table 37).

On 1985 February 6, 10 more bighorn sheep were translocated to Maguire Creek from Columbia Lake. These included 7 ewes and 3 lambs (2 F, 1 M). No radio-collars were attached to this group.

*Herd distribution and movement.*— This herd was tracked infrequently due to the shortage of time and lack of local volunteer help. The herd translocated in 1984 was observed daily by a logger on the west face of Maguire Creek until May when the herd moved up to lamb. Spring and summer range during 1984 is unknown. Winter range was located on the north side of Limestone Lookout at the north end of the Galton Range (Fig. 23). This herd returned to the west face of Maguire Creek on 1985 April 4 where they were observed daily until 1985 May 16. Lack of time to radio-track again prevented spring and summer range being assessed. Fall range in 1985 was similar to winter range of 1984. The last sighting of the radio-collared ewe was on 1985 November 17 near the mouth of Phillips Creek 30 km south of her last sighting 3 weeks earlier near Limestone Lookout.

Six of the seven ewes and lambs translocated to Maguire Creek in 1985 were observed at km 34 on the Ram Creek Road between 1985 September 10 and October 15. This group was never relocated.

### 7.3.4 Arrow Lakes transplant

On 1985 February 9, 20 bighorn sheep were translocated from the east side of Columbia Lake to Tulip Creek on the Lower Arrow Lakes about 6 km west of the Keenleyside power dam. The herd included 11 ewes, 5 lambs (3 F, 2 M) and 4 rams (Appendix G). Radio-collars (Austec) were attached to three young ewes, but all stopped functioning within 4 months. Survival and recruitment of translocated bighorn sheep were reported (G. Woods pers. comm.) to be high in 1984 and 1985 so 18 more bighorn sheep were translocated from Stoddart Creek to

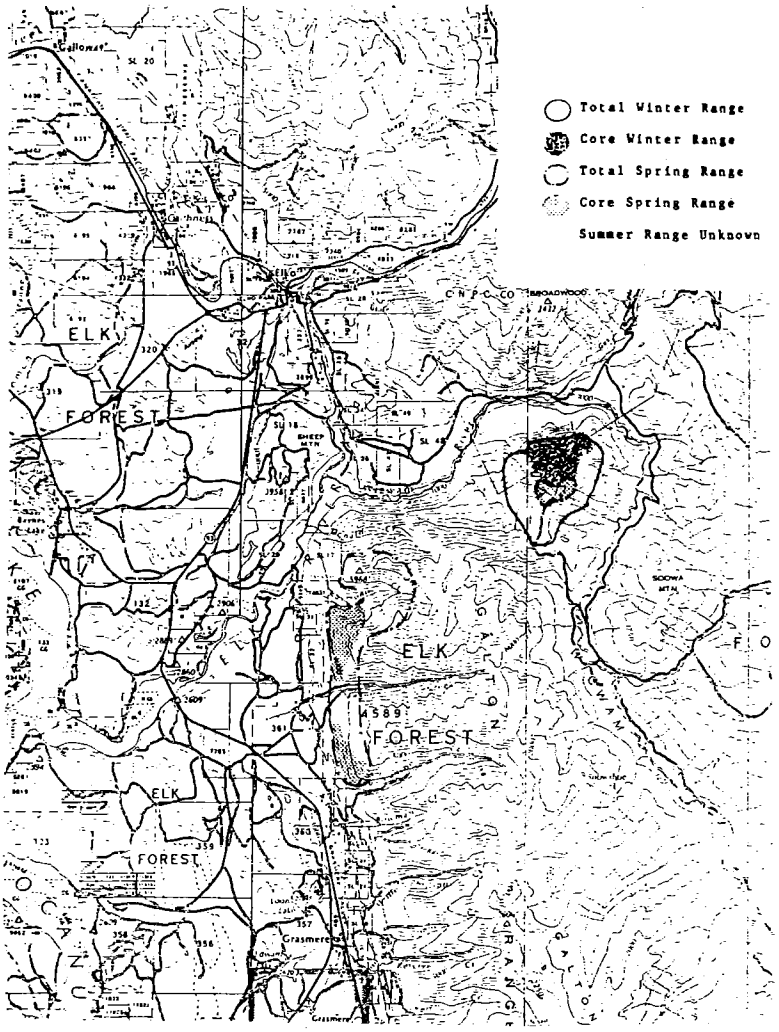



**Figure 23. Distribution of bighorn sheep translocated to Maguire Creek - 1984 February 11 to September 1986.**

Tulip Creek on 1987 February 24. These included 11 ewes, 3 lambs and 4 rams. D. Miller (Wildlife Branch, Nelson, B.C.) has been monitoring this herd since the last transplant. The herd now numbers over 60 but growth is slow due to cougar predation that began in 1987.

### 7.3.5 Wildhorse transplants

*Herd structure.*— Five bighorn sheep were translocated from Columbia Lake to the lower Wildhorse on 1986 January 25. These included two ewes, two lambs and one yearling ram. One 2.5-year-old ewe and the yearling ram were radio-collared.

*Herd movement and distribution.*— The translocated sheep moved south to Lone Peak from Wildhorse Canyon where they remained until the first week of March. As snow melt occurred in early March, the ram joined a local group of seven rams and moved up the Mause Creek drainage (Fig. 24). The ram group remained in the Mause Creek drainage until May when the group was observed 6.5 km from the Sunken Creek drainage. The radio-collared ewe and six transplants moved southeast 5 km on the lower west-facing slopes of the Mause Creek/Sunken Creek Ridge (Fig. 24). During the first week of May, as the time to lamb approached, the group moved to the south-facing slopes of Horseshoe Creek. Signals from both radio-collars became very weak by mid-May and no further radio-telemetry locations were made.

*Initial conclusions.*— The lower west face of the ridge running between Horseshoe Creek and Mause Creek was used as winter range by bighorn sheep observed in the Wildhorse Canyon. A preliminary estimate of carrying capacity based upon size of open range and composition of forage indicated that 150 bighorn sheep could winter along this slope for 5 months of the year. Potential competition with deer and elk appeared to be low due to the low density of potential competitors on the rocky west-facing slopes between Sunken Creek and Mause Creek used as winter range by the translocated bighorn sheep as well as part of the indigenous Wildhorse herd.

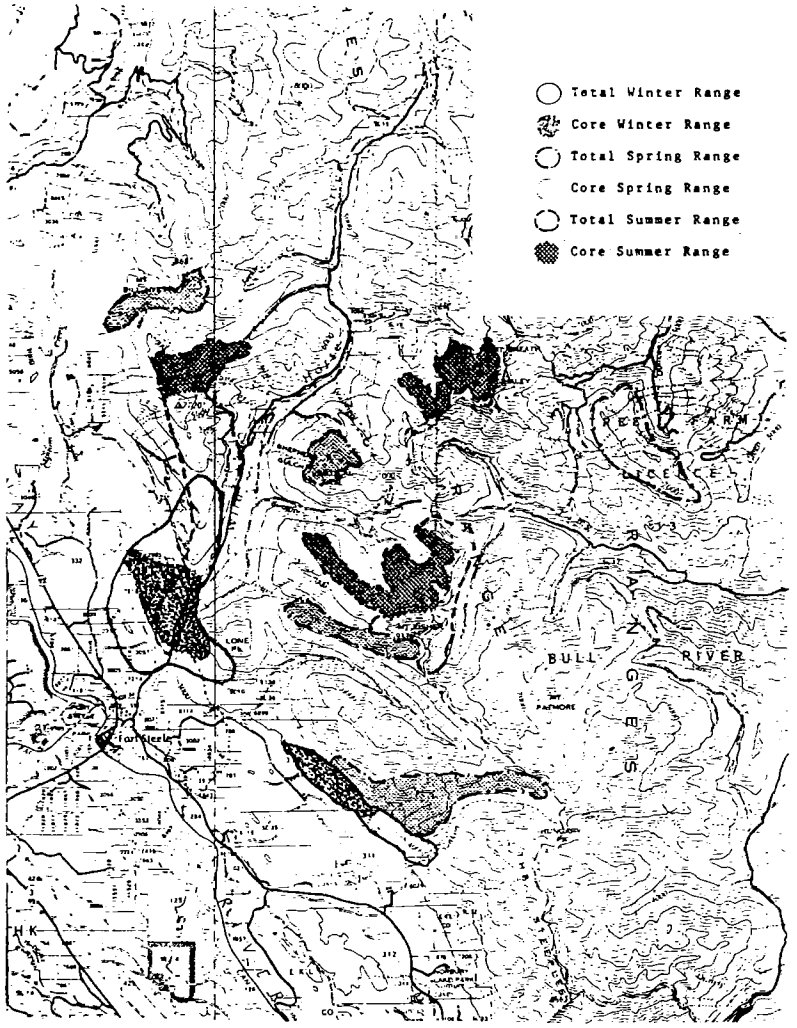



**Figure 24. Distribution of bighorn sheep translocated to the lower Wildhorse - February 1987 to December 1988.**

*Herd structure.*— Total number of bighorn sheep moved to the lower Wildhorse between 1986 and 1988 were 24 ewes, 16 lambs and 11 rams. Details of age, sex, tag number, and radio-collar frequencies used are given in Appendix G. Fifteen bighorn sheep were released on the north side of the Wildhorse River on Brewery Ridge or Lakit Lake. These included six ewes, eight lambs and one ram. Thirty-six bighorn sheep were released south of the Wildhorse River near the Forestbauer Ranch. These included 18 ewes, 8 lambs and 10 rams. Seasonal range use and size was determined from visual and tracked locations of translocated bighorn sheep.

*Herd distribution and movement - Forestbauer transplants, 1987 and 1988.*— Radio-telemetry follow-up indicated that winter range for bighorn sheep released near the Forestbauer Ranch lies between Sunken Creek and Brewery Ridge (Fig. 24). Translocated bighorn sheep released south of the Wildhorse remained within 2 km of the release site until the early May, when the ewe groups moved upslope to lamb and the ram groups moved up Mause Creek. This transplant used 3.8 km$^2$ of winter range but concentrated on 1.2 km$^2$ near the Forestbauer Ranch.

By the second winter, ewe groups spent most time on Brewery Ridge due north of the Wildhorse River in a 3.2-km$^2$ area. As snow melt occurred in February, bighorn sheep moved southeast 5 km to the west-facing grass slopes located between Horseshoe Creek and Mause Creek. Winter range for the Lakit Lake transplant was located between Lakit Lake and Hebert Creek and was <1.5 km$^2$ in area (Fig. 24). Core (highly used) winter range was 18% of total core range or 7% of all range used (Table 40).

Early spring range for the Forestbauer transplants was located on Horseshoe Creek as ewe herds moved upslope with snow melt in early May (Fig. 24). Early spring range for the Lakit Mountain transplant was located on the lower south-facing slopes of Mount Bill Nye while lambing range was located near the

ridge top of this mountain. Pre-lambing ranges for the Forestbauer transplants were located on a ridge between Duncan and Clay Creeks and on a ridge and cirque north of Fisher Peak. Lambing range was located on Vertical Mountain and the cirque north of Fisher Peak. Core spring range was 38% of all core range used or 15% of all range used (Table 40).

Summer/fall range for the Forestbauer transplant was located in the east fork of the Wildhorse, the south-facing slopes of Mount Patmore, the headwaters of Boulder and Victoria creeks (Fig. 24). Movement between summer range at the headwaters of Boulder Creek south of the Wildhorse River and Victoria Creek north of Wildhorse Creek occurred. Core summer/fall range was 44% of core range used or 17% of total range used (Table 40). Summer/fall range for the Lakit Lake transplant was located between Diorite Creek and the Lussier River up to 40 km from spring range.The pattern habitat use by resident Lakit Lake bighorn sheep is unknown because the batteries of the Austec radio-collar lasted only 5 months and because only two bighorn sheep were sighted on the summer range.

### 7.3.6 Wigwam Flats

*Herd structure.*— In February 1986, 47 bighorn sheep were translocated to Wigwam Flats from Stoddart Creek. These included 28 ewes, 12 lambs (7F, 5M), and 7 rams. One 4.5-year-old ewe was radio-collared (Appendix G).

On 1988 February 14, 17 more bighorn sheep were moved to Wigwam Flats including 11 ewes, 2 lambs (F) and 4 rams (3 yearling, one 2-year-old) (Appendix G). A 3.5-year-old ewe and a 2.5-year-old ewe were radio-collared.

*Herd movement and seasonal distribution.*— The transplant herd of 1986 was released near Purple Canyon. In late March 1986, nine of the transplanted bighorn sheep had moved north 6 km from the release site to No Name Draw due north of Elko on the Lizard Range. Sightings of tagged animals in April and May 1986 indicated that more than half of the Wigwam transplants moved north to the Lizard Range, surmounting such barriers as the Elk River, the Elko townsite, the River haul road, the railroad and Highway 3. These transplants were habituated to people, highway traffic and dogs in Kootenay National Park. Some of these transplants are believed to have returned to the south slopes of Mount Broadwood in late fall 1988.

The radio-collared ewe and seven other bighorn sheep wintered on the upper west slopes of Mount Broadwood. By mid-May, this group moved north 3 km to the Lizard Range in the Highway 3 tunnel area, presumably in search of a suitable lambing area. During the lambing season, 2 weeks later, the radio-collared ewe was tracked to the north slopes of the Galton Range near Limestone Lookout, >10 km south of the previous sighting. Her collar later failed but was retrieved by a hunter 1.5 years later on the north slopes of Mount Broadwood.

The two radio-collared ewes released with 17 transplants in 1988 did not move far from the release site by mid-summer. During the first week of June 1987 the 2.5-year-old ewe had died. The location of the carcass near the rock face of China Wall suggested predation may have been the cause.

The translocated bighorn sheep apparently were utilizing all range used by the resident bighorn sheep within 2 years.

*Population status of Wigwam transplants.*— All mature transplanted ewes (39) appeared to be pregnant in 1987 and average lamb recruitment to 10 months of age was 55%. Lamb recruitment in 1988 was not recorded due to time constraints. A ground count of the Wigwam Flats herd in March 1989 revealed 191 bighorn sheep with 111 ewes, 48 lambs and 32 rams. Ten ewes were yearlings so the lamb to mature ewe ratio was 48:100.

## 7.4 Summary of Captures and Translocations

A total of 340 Rocky Mountain bighorn sheep were captured and 232 translocated between March 1982 and February 1989. These included 138 ewes (59%), 52 lambs (22%) and 59 (18%) rams (Appendix 41). The total increase in bighorn sheep populations attributed to the transplant program was 400 including at least 330 in the East Kootenay as well as 65-70 in the West Kootenay. The transplant population is expected to double within the next 10 to 15 years, providing epidemic disease is avoided. No deaths were caused by capture or translocation.

At least 31 bighorn sheep transplants are known to have died due to vehicular collisions (13), hunter harvest (3), predation (5), disease (8) and unknown (4). Five of the 18 (28%) radio-collared bighorn sheep were believed to have been killed by predators. About 2% of the Lizard Range transplants have been killed by vehicles annually. One ankle break and one tibia diplasia occurred in ewes during capture, but both were alive 2 years later.

## 7.5 Response of Donor Herds to Translocations

Bighorn sheep wintering on the east side of Columbia Lake were used as the donor herd between 1984 and 1989 because population densities were high, lungworm larval loads were moderate to high, lungworm damage to lungs was high (Schwantje 1988*b*), and blood urea nitrogen levels were low suggesting submaintenance level digestible protein intake. The population wintering along the east side of Columbia Lake was estimated to be 200 to 220 in 1984 and that estimate remained at 180 to 200 in 1988 even though 145 bighorn sheep were translocated (Appendix 41) from this herd between 1984 and 1989. These included 75 (52%) ewes, 48 (33%) lambs, and 22 (15%) rams. Between 1984 and 1988, 18 rams were harvested and, since 1987, seven ewes were harvested under Limited Entry Hunting permits. Thus, since 1984, 30 bighorn sheep (15%) have been removed annually but the population has remained stable and healthy.

Before translocations from Columbia Lake, sex ratios averaged 55% ewes, 20% lambs and 25% rams between 1982 and 1984 (Table 41). Between 1984 and 1988, sex ratios at Columbia Lake averaged 47% ewes, 25% lambs, 29% rams. Between 1982 and 1984, the lamb:ewe ratio averaged 36%, and the ram:ewe ratio averaged 45%. Following translocation, the lamb:ewe ratio averaged 53% and the ram:ewe ratio averaged 62%.

Eighty bighorn sheep were translocated from the Stoddart Creek herd between 1986 and 1989. These included 55 ewes, 16 lambs and 12 rams. From 1982-1986, sex ratios of bighorn sheep translocated from Stoddart Creek averaged 47% ewes, 22% lambs and 31% rams. Sex ratios after translocations in 1986 and 1988 were 52% ewes, 22% lambs, and 26% rams. The lamb:ewe ratios were 46% and ram:ewe ratio 66% before translocation of 64

**Table 41. Population status of bighorn sheep herds on the east side of Columbia Lake and Stoddart Creek, 1983-1988.**

| | Columbia Lake | | | | | | Stoddart Creek | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
| Actual Counts | | | | | | | | | | | | | | |
| Ewes | 43(52)[a] | 62(58) | 81(56) | 52(49) | 47(41) | 53(48) | 79(49) | 39(50) | 24(39) | 29(43) | 75(46) | 110(57) | c | 96(52) |
| Lambs | 18(22) | 23(21) | 23(16) | 20(19) | 40(35) | 20(18) | 43(26) | 18(23) | 11(18) | 15(22) | 35(22) | 50(26) | | 41(22) |
| Rams | 21(26) | 22(21) | 40(28) | 35(32) | 27(24) | 36(33) | 43(26) | 21(27) | 17(44) | 24(35) | 52(32) | 34(18) | | 49(26) |
| Total | 82 | 107 | 144 | 107 | 114 | 110 | 162 | 78 | 62 | 68 | 162 | 194 | | 186 |
| Estimated Total | 200 | 299 | 210 | 190[b] | 200 | 190 | 200 | 180 | 190 | 205 | 230 | 240 | | 230 |

[a] % of total count in parentheses.
[b] Before 1985, sex ratios were based on annual air surveys done by helicopter. From 1985 - 1988, sex ratios were determined from bait site counts of bighorn sheep between 7 January and 7 March.
[c] Missed.

bighorn from this herd. After transplant of 47 bighorn sheep in 1986, the lamb:ewe ratio was 42% and the ram:ewe ratio 50%.

Lungworm larval output of untreated bighorn sheep at Stoddart Creek declined dramatically when densities were reduced through translocation. Lungworm larval output from the Stoddart Creek herd in February 1985 before translocations, averaged 2032 lpg in ewes ($n$ = 11), 2081 lpg in lambs ($n$ = 11), and 1146 in rams ($n$ = 12)(Stelfox *et al.* 1985). The average lungworm larval load of fecal samples taken from five ewes, five lambs and five rams sampled in January and February 1988, 2 years following translocation of 47 bighorn sheep was 449 lpg for ewes, 540 lpg for lambs and 314 lpg for rams (Kootenay National Park files, 1988). The translocation of 47 bighorn sheep from this herd in February 1986 is believed to have reduced the lungworm loads of all remaining bighorn sheep dramatically with the largest declines in ewes and lambs.

Lungworm larval output could not be compared before and after translocation at Columbia Lake because this herd was treated for parasites before capture.

Corticosteroid levels of blood sera taken from captured bighorn sheep located at Columbia Lake, Stoddart Creek and the lower Bull River were generally high (T. Spraker, letter to Cranbrook Wildlife Branch Files 1985; Table 34) and did not relate directly to fecal lungworm larvae loads. The average blood cortisol level of 10 samples taken from ewes captured in February 1989 at Stoddart Creek was 5.38 g/ml, which was similar to the levels of treated bighorn sheep located on the east side of Columbia Lake and the lower Bull River (Table 34). Cortisol levels of 6.0 g/ml were reported to have preceded an all age dieoff of bighorn sheep in

Colorado (Spraker *et al.* 1985). The average lungworm larval load of untreated bighorn sheep wintering at Stoddart Creek in February 1988 was 434 lpg, whereas the average lungworm larval load ($n$ = 11 from treated bighorn sheep at Columbia Lake in February 1988 was 0.8 lpg.

## 7.6 Discussion and Conclusions

Translocation of bighorns to traditional range may be one of the most efficient methods of increasing bighorn sheep populations, providing that all necessary habitat components remain, and the source herd is free of disease. The Bull River transplant failed because bighorn sheep used for transplant were diseased, and the symptoms were not recognized. Translocations from high density herds such as those wintering on the east side of Columbia Lake and Stoddart Creek were effective in preventing disease outbreak, stimulating better recruitment, and improving sex ratios in the donor herd.

Traditional bighorn sheep range with low densities due to periodic epizootic dieoffs have proved to be suitable recipient areas for translocations. The Lizard Range transplant herd has been characterized by excellent pregnancy rates (94% to 100%), high rates of lamb survival (55% to 91%) to yearling age and rapid colonization of traditional habitat. By the third year following translocation bighorn sheep had dispersed widely and were sighted as far north as Island Lake more than 18 km from the release site.

Predators appear to require 1.5 to 2 years to utilize the new type of food source (transplants) on ranges not previously having bighorn sheep, such as the north side of Arrow Lakes and the Lizard Range. The drop in lamb survival from about 90% during the first 2 years to 55% thereafter and observed predation in the Lizard Range herd strongly suggest that predators are harvesting about 35% of these herds annually. Transplants to ranges having a resident population of bighorn sheep (Bull River, lower Wildhorse, Maguire Creek) are treated as a food source immediately, thus herd expansion is not as rapid as that of herds on previously non-colonized range. Herd expansion on Maguire Creek and the lower Wildhorse has been slower than that of the lower Bull River due to more intense predation, less suitable winter and spring range, and lack of bait site treatment following transplant.

The translocation of bighorn sheep to the lower Arrow Lake area has demonstrated that bighorn sheep can colonize non-traditional range providing all habitat requirements are present. A change in microclimate induced by the warming effect of impounded water from the Keenleyside dam created ideal winter range for bighorn sheep.

Translocations have reduced lungworm larval loads of the donor herd but appear to have had little effect on blood cortisol levels. Blood corticosteroid levels were high in all herds examined indicating that suppression of the immune response may be occurring (Hudson *et al.* 1974). A comparison of blood cortisol levels of the Stoddart Creek bighorn sheep herd before and after translocations could not be achieved because blood samples were destroyed in transport. High lungworm larval output in untreated bighorn sheep located at Stoddart Creek may indicate that the immunosuppresive ability of the host has been compromised (Hudson 1973; D.K. Onderka pers. comm.).

# 8. DISCUSSION

## 8.1 General Response of Bighorn Sheep

Bighorn sheep populations of the East Kootenay increased from 1550 in 1983 to 2350 by 1988. The increase in population occurred in herds wintering in, or adjacent to, the Rocky Mountain Trench and did not occur in herds wintering in the Elk Valley (Fig. 25). Populations of bighorn sheep wintering in the Elk Valley declined slightly between 1983 and 1988 indicating that the past 12 years of mild winter weather were not directly correlated with population levels. Bighorn sheep populations wintering along the western slopes of the Rocky Mountains have been reduced in number by 25% to 50% in 18- to 24-year epizootic lung disease cycles since the 1920's, whereas those of the Elk Valley have not been affected. Historically, bighorn sheep wintering adjacent to the Rocky Mountain Trench have not regained former population levels before another disease cycle occurred. The Sheep Recovery Program increased the Rocky Mountain Trench (and vicinity) populations from 800 to 1600 in 5 years and, by 1988, the total population of East Kootenay bighorn sheep exceeded pre-dieoff levels.

Ram horn growth rate and size were better in herds that were managed intensively. The number of trophy rams increased dramatically with at least 14 rams harvested in 1987 and 1988 that qualified for the North American Boone and Crockett Record Book. Long-term residents report that ram horn quality is now similar to that found in the East Kootenays 40 years ago. During the 1988 hunting season, 63 rams were harvested in the East Kootenays, well above the long-term (14-year average of 38 developed since 1975 when compulsory inspection was initiated).

Hunting opportunities for bighorn sheep increased in the East Kootenay since this project was started. Limited Entry ewe-lamb seasons were initiated in 1986 to control population densities on crowded range and to adjust sex ratios (1983 Regional Wildlife Plan). Twenty-four L.E.H. ewe/lamb permits were issued in the East Kootenay in 1986 and, by 1989, 193 permits were issued. Non-trophy success rates have averaged about 12%.

The Sheep Recovery Project was instrumental in preventing spread of lung disease by reducing herd sizes, enhancing habitat, treating bait sites, and managing access on key winter ranges. By reducing stress levels in bighorn sheep, or maintaining the stress level below a vulnerability zone (G. Woebeser pers. comm.), we prevented disease spread in herds, such as those located on the east side of Columbia Lake and Stoddart Creek, that had historically succumbed to lung disease .

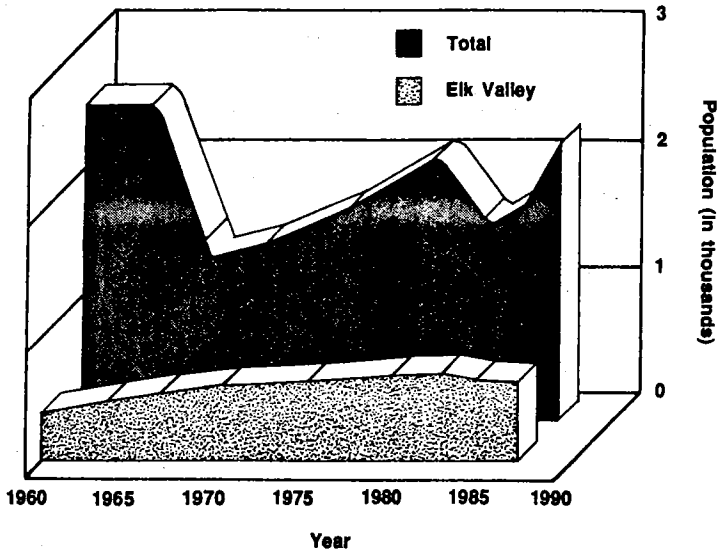



**Figure 25. Estimated bighorn sheep population in the East Kootenay - 1967 to 1987.**

By managing vehicle access on key winter ranges, harassment of bighorn sheep, range damage and the spread of noxious weeds were reduced. Seasonal and year-round Area Closures under Section 111 of the Wildlife Act prevented the spread of noxious weeds especialy spotted and diffuse knapweed (*Centaura maculosa, C. diffusa*). Vehicle access closures when noxious weeds have set seed, coupled with an ongoing annual herbicide spray program by the provincial Forest Service and the Kootenay Livestock Association, have effectively prevented knapweed from destroying key wildlife winter ranges. Biological control of knapweed is not feasible in the East Kootenay because only spot infestations occur and these would not permit overwinter survival of parasitic insects. Biological control of large infestations in the Kootenay Lake area 100 km west has not been effective due to the number of agents (12) required to control knapweed effectively and the poor overwinter survival of most of the imported agents. With huge sources of noxious weed due west and due south of the East Kootenay, wildlife ranges must be constantly watched to control infestations. The Rocky Mountain Sheep Recovery project has contributed an amount equal to the annual cost of herbicide used to control knapweed on bighorn sheep winter range on Mount Broadwood and Wigwam Flats.

## 8.2 Range Responses

### 8.2.1 Prescribed fire

Low intensity spring burns done on xeric to subhygric sites such as those found at Bull River may stimulate increased cover and frequency of forbs and shrubs, especially antelope-brush. Although stem density of palatable shrubs such as saskatoon, choke cherry and antelope-brush was initially reduced by low intensity spring burning, leader growth was exceptional and dead woody stems acting as a barrier to browsing were removed. The effect of prescribed fire on forage production and leader growth in various plant communities was not determined due to time constraints but this information would more adequately reflect the response of shrubs to fire than stem density and ground cover. Weather stations capable of storing 1 month's data are now being used to determine when prescribed burning would achieve management objectives such as retarding conifer encroachment, and promoting greater production of high quality forage.

The effect of low intensity fire on soils, and plant community response in various biogeoclimatic zones is largely unknown in the East Kootenay. D. Demarchi (1983) determined the effect of prescribed fire on the macronutrient quality and production of several shrub species in response to spring burning in the Rocky Mountain Trench. Thompson and Feller (1988) compared the response of several plant communities in the Rocky Mountain Trench to spring and fall burning, but only a few of the plant communities affected by prescribed fire on a few soil types were examined. The relationship of fuel load, fuel type and fire intensity has been developed for various forested communities in Montana (Fischer 1981) but has not been developed for seral shrublands similar to those found in southeastern British Columbia.

In summary, the information base needed to predict the vegetative response to prescribed fire in major ecosystems of the East Kootenay is incomplete, and requires many years of research to become more scientific and objective.

### 8.2.2 Wild fire

The intense heat of a wild fire on Lakit Mountain in August 1986 greatly reduced the ground cover, species diversity, frequency of occurrence and production of grasses and forbs on both logged and unlogged range in semi-arid soil conditions in the Dry Interior Douglas-fir biogeoclimatic zone. Wild fire greatly increased the ground cover of rock and bare ground and dramatically reduced litter and duff. Differences in ground cover, and production of forage between logged and adjacent unlogged area were eliminated by wild fire. Although the lower Lakit Mountain wild fire was intense, seed and root stock of grasses, forbs and shrubs survived to regrow in the year following the burn. Wild fire returned thousands of hectares of forested land to an early seral grass-forb community in the East Kootenay in 1985 and 1986. Wild fire on subalpine bighorn sheep range in the Lussier, Coyote and Wildhorse drainages stimulated plant growth of plant communities preferred by bighorn sheep. Bighorn sheep populations that were static or declining, such as those of Marmalade Basin and Van Nostand Range, are now increasing. Populations are estimated to have grown from 45 to 75 on McLean Peak and Marmalade Basin, and from 35 to 75 on the Van Nostand Range since the dieoff in 1983. Most of this increase occurred since the wild fires of 1985.

### 8.2.3 Selective logging

Selective logging on sub-xeric mountain slopes in the Dry Interior Douglas-fir biogeoclimatic zone increased the species diversity of grasses and forbs and promoted growth of forage species with high nutrient quality such as rough fescue, junegrass, fireweed and aster. The ground cover, frequency of occurrence and production of grasses increased dramatically with selective logging. Random down-hill skidding by small caterpiller left semi-arid surface soils intact and permitted rapid (<1 year) revegetation following seeding of grasses and a legume.

The amount of soil damage done in random down-hill skidding was 20% of that done by traditional rubber-tired skidders or small caterpiller on steep mountain slopes with skid roads at 50- to 150-m intervals. This method of logging is more costly to the logger, but has much greater long-term benefits to forage and forest production when done on dry sites. Without a financial incentive, this aesthetically pleasing and environmentally sound method of logging will soon disappear in the East Kootenay. An analysis of 1:15 000 maps of drainages indicates that 25% to 45% of the land surface was disturbed by skid roads and side cast. In contrast selective logging with random down-hill skidding on the Galton Range and Lakit Mountain disturbed <5% of the land surface, which was easily reclaimed because soil horizons had not been greatly disturbed.

### 8.2.4 Slashing

Hand- and mechanical-slashing was effective in halting conifer and aspen invasion of shrublands and grasslands, but at high cost. Hand-slashing of aspen stimulated a 10-fold increase in aspen suckers by changing apical dominance in a 35-year-old stand. Slashing of aspen caused small declines in cover, frequency and stem density of shade-tolerant shrub species such as Pacific rhododendron and Oregon-grape, but caused large increases in stem density of preferred browse species including trembling aspen, balsam poplar and rose.

Hand-slashing has been effective in preventing conifer encroachment on winter ranges where other enhancement techniques could not be used. Prescribed fire, selective logging and spacing have not been approved in most provincial parks as a means of maintaining wildlife habitat. Hand-slashing, piling and burning of conifers was approved in Premier Lake Provincial Park and proved effective in re-opening conifer stands to maintain habitat preferred for bighorn sheep, mule deer and elk.

Hand-slashing was the only feasible means of enhancing many of the bighorn sheep ranges in the Rocky Mountain Trench. Scattered fuels, rocky slopes, and poor quality timber made prescribed burning and selective logging impossible options on most bighorn sheep winter ranges bordering the Trench. Without federally and provincially funded job-training or employment assistance programs, hand-slashing is prohibitively expensive. Employment assistance and job training programs were used to hire slash crews to enhance bighorn sheep winter range located on Mount Swansea, the east side of Columbia Lake, Brewery Creek and Mount Broadwood. The cost of hand-slashing and piling varied between $580 and $792/ha.

### 8.2.5 Fertilization

Fertilization was not economical on semi-arid soils of bighorn sheep winter ranges located on the east side of Columbia Lake or on Wigwam Flats. The major reasons for low forage production on bighorn sheep winter ranges are limited moisture during the growing season and a long history of overgrazing, thus fertilization is unlikely to be an economical option on any of the Rocky Mountain Trench winter ranges.

## 8.3 Herd Treatment

Bait site treatment of bighorn sheep on winter ranges bordering the Rocky Mountain Trench effectively reduced lungworm larval output of treated animals and prevented disease outbreaks in herds vulnerable to lung disease. Bait site treatment also effectively limited the spread of soremouth in bighorn sheep. During the winter of 1988/89, two bighorn sheep herds with soremouth were treated with antiparasite drugs and trace minerals at winter bait stations. After discussion with Dr. P. Rice (DVM), we chose treatment at winter bait stations as the best way to build up host immunity and prevent the spread of the disease. Several bighorn sheep were observed with bleeding, swollen lips on the lower Bull River winter range in October. Two months later about 20% of the population of 130 bighorn sheep appeared to be infected. At the same time, about 1/4 of the lower Wildhorse bighorn sheep herd (50) appeared to have an active infection of soremouth. Two weeks after the start of bait-site treatment, all lesions disappeared and no more active cases were observed in these two herds. A small herd of bighorn sheep located near Premier Lake also had lip lesions symptomatic of soremouth at the same time and were not treated. In contrast to treated herds, active lip lesions were reported in this herd over 3 months after initial sightings. The outbreak of soremouth in bighorn sheep populations that are well below carrying capacity of range (Table 1) and the presence of several elk with soremouth on Premier Ridge in October may indicate that the disease was attained at a natural lick. The outbreak of soremouth in the Bull River herd (known to have high blood cortisol levels) and the alleviation of soremouth through winter bait site treatment indicated that the

Resource values lost in land alienations are seldom (if ever) adequately evaluated before approval because:

1. All resource values are not considered;
2. Adequate measures do not exist to determine value of many resources;
3. The time scale, money and manpower allotted to developing adequate resource evaluations seldom occur before major land alienations;
4. Long-term impacts to other resources are seldom considered.

Some past land sales have alienated critical winter and spring range for game animals and in turn has resulted in crop depredation and disease. Land alienations and resource agreements to private enterprise resulted from our inability to manage habitat for the benefit of wildlife - a public resource. As I drive by the Columbia River near Fairmont Hotsprings, I recognize the loss of a marvellous heritage - the annual 1200-km salmon run, replaced by non-compromising artifacts of modern recreational man. No longer does the river run red with sockeye salmon as recorded 100 years ago (Baillie-Grohman 1900). A few scattered artifacts near smoke pits in rock ledges near the Columbia River stand as mute testament to a culture that no longer exists.

### 8.5.2 Lack of appropriate management

Presently, the B.C. Ministry of Forests (MOF) has the mandate to manage over 85% of the provincial land base. The budget allotted for range management, water management and recreation by the MOF is <5% of their total budget, miniscule compared to the silviculture budget. This bias toward wood fibre management has had a major detrimental impact upon other resource values. Forest encroachment on high capability wildlife winter ranges has reduced the carrying capacity for these animals.

Most of the bighorn sheep winter ranges in the Rocky Mountain Trench continue to be overgrazed because the MOF has not adequately covered the cost of maintaining range, nor accurately assessed the existing carrying capacity of range. About 3/4 of the Rocky Mountain Trench south of Invermere has been included in CRMP's, because livestock producers were promised an increase in A.U.M. grazing as range conditions improved. Most livestock producers doubt the effectiveness of CRMP's, or blame wildlife because the promised increase in AUM grazing has not occurred. The cause has not been the method of operational planning, nor the allocation of the range resource between livestock and wildlife, but the commitment by the Wildlife Branch and the MOF to employ a land-use strategy that would maintain and enhance Crown range through appropriate funding and staff.

### 8.5.3 Lack of appropriate enhancement systems

The process of initiating habitat enhancement activities is far too cumbersome to be effective in controlling forest encroachment. Initial approval for prescribed burns must be obtained from the Ministry of Environment, the Ministry of Forests, the Board of Directors of HCF and the Waste Management Branch, Ministry of Environment. Each body may overrule the burn at any time. Small business logging on bighorn sheep range must fit into the local MOF guidelines assuring regional equity, and projects must usually be completed in 2 to 3 years. Because of these restrictions and small quotas given individual loggers, <35 ha can normally be logged on one site. If further sales are permitted nearby, the bid

system is used for the small business sale, thus one mountain can be logged by several different companies. As a result, the Ministry of Environment has little control on quality or quantity of logging done for wildlife. This project has had no success in directing big business toward logging for wildlife.

### 8.5.4 Lack of long-term commitment to enhancement

Planning and implementing the Rocky Mountain Sheep Recovery project has always been hampered by lack of long-term commitment to funding. Plans for enhancement activities on Crown range managed by the MOF must be submitted several months or years in advance. Five-year enhancement plans by the Wildlife Branch for Crown range are now being required. The spring burning season for prescribed fire normally occurs during the latter part of March and April. The fiscal year for HCF ends on March 31 during the peak of the prescribed burning period and budgets are not officially committed until the third or fourth week of April, when the burn season is essentially over.

The HCF Board has established rating criteria that prefer wildlife projects that are short-term (1 year), aimed at one species of game animal, and require no annual maintenance. Forest encroachment and habitat disruption of bighorn sheep ranges is a continuous ongoing process in the East Kootenay, which will require continuous input to maintain. Nearly all important bighorn sheep winter ranges are also important winter ranges for elk and mule deer, and enhancement activities have been designed to accommodate major species.

# 9. MANAGEMENT RECOMMENDATIONS

## 9.1 Management Objectives

### 9.1.1 Development of a land-use strategy

The Rocky Mountain Sheep Recovery Project has demonstrated that a rapid recovery in population levels can be achieved with management of both habitat and herds. The entire project may have been done in vain unless a commitment is made to develop and follow a long-term land-use strategy. This strategy should involve all major participants on Crown range in the development of a land-use plan. This plan would describe the best uses of Crown range based on the biophysical capability and methods required to maintain renewable resource capability. By adopting a land-use plan, land alienations could be regulated, damage to other resources limited, and management activities on Crown range could be controlled.

The Trench Resource Management Plan (TRMP) is a land-use plan being developed in the East Kootenay by the MOF and the MOE to resolve the divergent demands for Crown range. Land with moderate to high capability for growing forest will be managed primarily for wood production and game species such as white-tailed deer and elk that prefer dense canopy cover. Land with high capability for range and low capability for tree production will be managed for grassland and seral shrubland with <20% forest canopy cover. This open range is preferred by mule deer, bighorn sheep and cattle. Land having moderate capability for wood fibre production and high capability for grassland will be managed for both range and timber values with 20-60% canopy cover. The habitat enhancement technique required to manage each biophysical unit appropriately has been identified. The effect of this land-use plan on wood fibre production in the future has now been assessed at the request of private industry. This land-use plan has identified sensitive wildlife range such as mineral licks, migration routes, and birthing areas. Other values such as watershed, recreation, and Christmas tree potential were also recognized.

A political commitment to this type of land-use plan is required by government agencies and industry involved with Crown land,otherwise future options for range, wildlife, watershed, recreation, and preservation of past cultural history may be lost.

### 9.1.2 Land repatriation

Presently, the East Kootenay contains about 35 880 ha or 358.8 $km^2$ of winter range used by bighorn sheep. This total is comprised of about 106.5 $km^2$ of Class I (Ungulate Biophysical Potential, Demarchi 1986), 77.6 $km^2$ of Class II and 174.7 $km^2$ of Class III winter range (Table 1; Appendix C). Wherever possible, critical bighorn sheep winter range should be repatriated to the Crown, and management rights should be obtained by the MOE. Approximately 5101 ha of land should be purchased soon and 4902 ha over the long term. The locations, priority, size, ungulate biophysical capability and legal description of parcels that should be purchased are given in Appendix H. Priority of purchase was listed as high (1), medium (2) or low (3) using the need of the land purchase for the long-term viability of individual herds as a base. At least 22 parcels of alienated bighorn sheep winter range in the Rocky Mountain Trench should be repatriated to the Crown within 10 years. The Stoddart

**Table 42. Actual bighorn sheep populations in the Rocky Mountain Trench compared to biophysical potential and suggested methods for approaching that potential.**

| Location | Number Bighorn Sheep | | Method of Increase | |
|---|---|---|---|---|
| | Potential | Actual | Range | Herd |
| Stoddart Creek | 270 | 200 | Slash and Burn | Prevent Disease |
| Columbia Lake | 440 | 200 | Selective Log<br>Seed Range | Prevent Disease |
| Premier Ridge | 250 | 160 | Pr. Burn<br>Slash | Husbandry Treatment |
| Estella | 410 | 75 | Pr. Burn<br>Slash | Husbandry Treatment |
| Wildhorse | 150 | 50 | Selection Logging<br>Slash, Pr. Burn | Husbandry Treatment Transplant |
| Bull River | 360 | 135 | Pr. Burn | Husbandry Treatment |
| Lizard Range | 200 | 100 | Pr. Burn | Treat Min. Licks |
| Wigwam Flats | 475 | 170 | Pr. Burn, Slash<br>Selective Log | Treat Min. Licks |
| Maguire Creek | 220 | 60 | Selection Logging<br>Pr. Burn | Treat Min. Licks |
| Phillips Creek | 185 | 70 | Selection Logging<br>Seed | Treat Min. Licks |
| Total | 2,960 | | | |

Creek, and lower Bull River winter ranges now have 25% of winter range alienated and large portions of the remaining winter range will not be functional unless undeveloped corridors to these fragmented ranges are left in a natural state.

### 9.1.3 Assuring appropriate grazing pressure

Population densities of bighorn sheep should be kept below maximum carrying capacity of existing range. Potential carrying capacity of range for bighorn sheep wintering in the Rocky Mountain Trench is nearly 3000, excluding range north of Radium Hotsprings. Actual bighorn sheep numbers wintering in the Rocky Mountain Trench are now 1250. Through range enhancement and animal husbandry, herd numbers could be raised to 2200 or 80% of the potential carrying capacity in the Rocky Mountain Trench without endangering the entire population (Table 42).

## 9.2 Enhancement

1. Habitat enhancement projects should have priorities assigned, based on detailed land-use plans such as the Trench Resource Management Plan. Habitat Conservation Funds could then be committed to the process of enhancement based on a land-use plan rather than a species enhancement plan at a particular time. Since forest encroachment is ongoing on East Kootenay wildlife range, this approach would more adequately assess the need for continuous orderly commitment to enhancement of wildlife habitat.

2. The land-use plan should identify the need for enhancement by comparing potential ungulate biophysical capability with actual carrying capacity.

3. A thorough inventory of actual range carrying capacity in the Rocky Mountain Trench is required to adjust livestock and wildlife populations to prevent overgrazing and overbrowsing that would nullify the value of enhancement activities.

4. Enhancement of bighorn sheep and mule deer winter range should continue to prevent development of small islands of winter range within which bighorn sheep are vulnerable to predation and harassment.

5. Habitat enhancement techniques employed should depend on a cost-benefit analysis as well as feasiblity as determined by the physical and biological characteristics of each site.

6. Wherever possible, prescribed fire should be used due to the low cost and excellent results achieved with this method of enhancement. Frequency of prescribed fire on rangeland should be determined by the type of vegetation community desired and the intensity of the burn. Spring or fall burns on seral shrublands in the Rocky Mountain Trench are normally of low intensity, leaving most of the duff layer intact. Under these conditions, in the Dry Interior Douglas-fir biogeoclimatic zone, prescribed fire should be repeated every 7 to 15 years to prevent conifer encroachment and to regenerate decadent shrubs. When traditional bighorn sheep winter range has been cleared of conifers through selective logging, clear-cut logging or slashing, prescribed fire should be used to maintain open grasslands and seral shrublands.

7. Other enhancement techniques must be considered in locations where prescribed fire is not feasible or desirable. Situations where prescribed fire is not feasible include: areas of high risk due to heavy fuels, proximity of private land, high timber values, and difficult access. Steep slopes, shallow soils, discontinuous fuel loads and other resource values such as large snags and high quality timber may preclude prescribed fire.

8. Selective logging is second in efficiency to prescribed fire in habitat enhancement, but its use is limited by the presence of sufficient mature timber to make logging profitable, and the willingness of timber companies to consider other resource values. Sites chosen for logging should have remnant stands of preferred forage species, otherwise logging may produce more undesired plant species with little opportunity for change due to lack of seed or root source.

9. Some monetary incentives, such as reduced stumpage rate, should be given to logging companies that sacrifice logging efficiency to accommodate other resource values including wildlife, watershed, aesthetics and recreation. This practise is common in the United States and has effectively maintained the productivity of critical wildlife winter ranges. Subsidized helicopter logging in Idaho has permitted range enhancement in locations where traditional logging methods would not have been feasible or viable. Reclamation of disturbed sites to natural forest and/or range regeneration should be effected via preharvest silvicultural prescription plans (PHSP) with the actual work funded from an adequate portion of the stumpage fee.

10. Hand- and mechanical-slashing of conifers should be considered where prescribed fire and selective logging are not feasible, and outside funding can be obtained. The high cost/ha makes this technique questionable except where forests are rapidly encroaching on critical winter range.

11. Seeding of grass-legume forage mixes on soils disturbed through logging is recommended to produce high quality winter forage and prevent invasion of noxious weeds.

    Seeding of ranges in severe disclimax states due to a lengthy history of overgrazing should be considered if feasible and effective. In locations such as the upper Columbia, where poor range and drought conditions are coupled with high demand by game species, seeding of domestic forage species on fringe areas of winter range is suggested to permit core areas time to rehabilitate. Interseeding of core range areas to native forage species may be necessary because few climatic bunchgrass species naturally occur.

12. Fertilization is not an economical method of habitat enhancement on semi-arid bighorn sheep winter ranges of the Rocky Mountain Trench and should not be considered as an effective enhancement tool.

13. Guidelines used by the HCF Board for project evaluation should reflect provincial, regional and local wildlife management strategies. For example, if the provincial, regional and local wildlife strategy is to increase the East Kootenay bighorn sheep population from 1550 in 1983 to 2100 by 1991, then a 7-year funding commitment should be made based on an annual review of the technical merits of the project. This commitment would permit appropriate planning, staffing, and interagency approval time to achieve major results.

14. Budget approval or denial should come at the end of the year when habitat enhancement work is minimal. Because funding comes from a surcharge on hunting, fishing, guiding and trapping licenses that are sold throughout the year, this demand should not cause a major inconvenience to fund administrators.

15. The process for approving habitat enhancement projects should be streamlined to capitalize on narrow burn windows.

### 9.2.1 Herd enhancement and protection

Epizootic dieoffs are one of the greatest threats to bighorn sheep survival in the East Kootenay. Detection and management of elevated stress levels must immediately become an integral part of bighorn sheep management in the East Kootenay. By carefully managing grazing pressure on bighorn sheep winter ranges, avoiding direct contact between bighorn sheep and domestic livestock, maintaining high quality winter forage and mineral licks, limiting competition for winter forage, and reducing harrassment through access management, epizootic dieoffs may be avoided. Periodic treatment at winter bait sites may be required to prevent disease if herds appear to be under high stress. Translocations of bighorn sheep are required to control population densities of bighorn sheep. Transplants control population densities of bighorn sheep more effectively than L.E.H. non-trophy seasons because low density ranges can be completely restocked and harassment on winter ranges by hunters seeking non-trophy animals can be avoided.

## 9.3 Monitoring Systems

### 9.3.1 Herd

A combination of factors should be assessed to determine the health status of bighorn sheep herds. Stress levels of herds subject to periodic dieoffs should be assessed annually if population densities are approaching carrying capacity. Blood cortisol levels during peak excitement have not proved to be a sensitive indicator of stress, but may be useful in generalizing the stress category of a herd (e.g., low, medium and high). Lungworm larval output should be determined annually in herds having high density and located on poor quality range. Fecal samples should be collected during winter months when lungworm larval output is highest (Stelfox *et al.* 1985; W. Samuels pers. comm.). The change in lungworm larval output during the same period in successive years can be used as an indicator of host control of larval output (D.K. Onderka pers. comm.). Nutritional stress may be assessed through analysis of digestible energy of forage consumed, fecal nitrogen levels (Hebert 1973), and diaminopimiellic acid (DAPA) of fecal material.

Population dynamics of herds wintering in the Rocky Mountain Trench should be determined to detect changes in herd structure that indicate an increasing, stable, or declining population (Jorgenson and Wishart 1986). Population structure may be used to indicate potential disease outbreak when population dynamics are known (Jorgenson and Wishart 1986). A high proportion of ewes, especially non-productive ewes, low lamb recruitment and low proportion of rams may indicate a stable or declining population that has exceeded a safe carrying capacity for existing range.

A protocol should be established between the MOE and the Ministry of Agriculture to sample livestock or wildlife when either is suspected of causing disease outbreak.

## 9.4 Habitat Protection

The first priority in habitat protection must be to prevent further alienation of Crown range. This can be accomplished by legislation over critical wildlife range on Crown land such as the Wildlife Management Area legislation, by legislation restricting development on key game ranges, and by purchase of key parcels as recommended above.

The second priority in habitat protection must be the adoption of land-use plans, which recognize the value of Crown range and the wildlife resource, and the implementation of operation plans, such as CRMP's, by users of Crown range. Land-use plans such as the Trench Resource Management Plan will protect bighorn sheep habitat from incompatible uses such as timber or Christmas tree production through an unbiased evaluation of the biophysical capability of the land base. CRMP's should address the method to maintain the values identified in the land-use plan.

Thirdly, Timber Supply Area Plans (TSA) and preharvest silviculture prescription plans (PHSP) completed before cut-block development on Crown range will include the needs of wildlife before logging. This system requires random on-site inspection of company work, legislation describing penalties for companies that ignore TSA and PHSP plans, and legislated enforcement authority within the Forest Service to enforce contracts.

Fourthly, the Wildlife Act and the mandate given the provincial Wildlife Branch will continue to be used to protect wildlife range and manage bighorn sheep and other game populations so that viable populations continue to exist. Access management through the Wildlife Act will continue on key wildlife ranges even though the plans are being developed by the MOF.

The B.C. Wildlife Branch, MOE, Cranbrook, has effectively managed grazing pressure by wildlife on Crown range in the Rocky Mountain Trench through input into CRMP's and design of hunting regulations. Range quality must be protected by determining a suitable carrying capacity for multiple species of game animals on shared winter ranges. Bighorn sheep populations should be given the highest priority on key winter ranges because of their scarcity and importance. Bighorn sheep are limited to 12 narrowly defined winter ranges in the Rocky Mountain Trench whereas elk and deer winter in most of the Trench.

## 9.5 Future Research Needs

### 9.5.1 Developing methods to monitor health status

The first objective of management should be disease prevention rather than disease treatment. Practical methods of monitoring the health status of bighorn sheep herds are required. Outward visual appearances are not always good indicators of vulnerability to disease. Potential stressors can be deduced from environmental and physical conditions, but sensitive measures of the degree of vulnerability to disease are not known.

As a beginning, blood titres of major herds wintering in the Rocky Mountain Trench should be evaluated periodically for exposure to bacteria and viruses. Fecal nitrogen levels and DAPA levels can indicate nutritional stress on herds tested, but do not indicate the many nutritional stressors such as low levels of digestible energy, phosphorous, trace mineral levels and water soluble vitamins that can affect nutritional status of the herd.

Blood cortisol levels can give some idea of individual reaction to the stress of capture. However, bighorn sheep may not develop adrenal exhaustion or hypersensitivity under chronic stress (Harlow *et al.* 1987), therefore the relationship of blood cortisol levels to stress when taken once cannot be

determined. The trend in cortisol and lungworm larval levels of an individual herd over several years when assessed at a similar time of year is a more sensitive indicator of herd health than a single assessment.

Although the level of lungworm larval output increases under stress (D.K. Onderka pers. comm.), the absolute level cannot be used to predict epizootic dieoffs. Stelfox (1974) predicted a dieoff would be most probable in Jasper National Park and least probable in Waterton National Park in Alberta based upon lungworm larval outputs, overwinter weight loss of bighorn sheep, and range condition. In fact, the Waterton Lake herd was the first to die. Normally bighorn sheep in good condition could present a strong reaction to lungworm larval output but the masking effects of L1 larval proteins may reduce or eliminate host detection and antigen reaction (Hudson *et al.* 1974).

Remote monitoring of cardiac response may be the most sensitive predictor of adrenal function (corticosteroid reaction) of bighorn sheep and potential compromise of the immune system (Harlow *et al.* 1987), but is not feasible for most herds under present budget restraints.

Successful treatment of soremouth at winter bait sites in 1989 has tentatively indicated that, by reducing several of the potential stressors affecting bighorn sheep, the immune system of the host can control and prevent the disease. Treatment with better quality feed, trace minerals and antiparasite drugs at winter bait stations apparently prevented lung disease and reduced the spread of soremouth. This hypothesis requires testing in a controlled laboratory environment and further examination in the field.

Assuming that the pox virus causing soremouth occurs on all bighorn sheep ranges in the Rocky Mountain Trench due to a long history of livestock grazing, outbreaks of soremouth may be taken as an indication that immune systems of bighorn sheep are compromised. A soremouth outbreak preceded the 1981/1983 epidemic lung disease outbreak in bighorn sheep of the East Kootenay.

Research should be conducted to determine whether resistance to disease is genetically inherited and/or largely influenced by the environment in which the bighorn sheep must live. Epizootic lung disease has not occurred in California bighorn sheep of British Columbia, except in a confined artificial environment (Frinton 1978), but has occurred in most low elevation Rocky Mountain bighorn sheep herds. Rocky Mountain bighorn sheep translocated to Spences Bridge in 1926/27 from Banff, Alberta have not experienced periodic dieoffs although the donor herd has since that time (D. Lowe pers. comm.; Stelfox 1970). Knowledge of the mechanism of disease resistance will permit better management decisions for future disease prevention.

### 9.5.2 Mortality research

Recruitment levels of lambs could be a good indicator of herd health status if predation and other mortality factors are well understood. Mortality in bighorn sheep of the East Kootenay, especially that due to predation, is poorly understood (as in most herds of North America) and needs study. Numerous research projects on the California bighorn sheep herd at Vaseaux Lake have demonstrated that mortality factors in bighorn sheep are poorly understood. Cougar and coyote predation on the California bighorn sheep on the Chilcotin Junction are presently

being evaluated (Scott 1988, unpubl. M.Sc. Thesis). The prey base for predators is limited to two major game species (California bighorn sheep and mule deer) unlike the East Kootenay where at least six game species are available for predation. Little predator research has been undertaken directly on bighorn sheep in the East Kootenay. Some research by Sheurholtz (1984) and Wielgus (1989) on cougar predation in the upper Elk Valley indicated that bighorn sheep are not an important part of cougar diets.

Recruitment in translocated bighorn sheep on the Lizard Range near Elko and on the Arrow Lakes near Castlegar indicate that predators take 1.5 to 2 years to develop a strategy on translocated bighorn sheep. The effect of predation on various bighorn sheep herds and upon various sex and age classes of sheep herds is largely unknown. Bighorn sheep herds at Wildhorse appear to have a high rate of predation (50%), whereas the herd located at Bull River <8 km south has a low predation level (<10%). Herds located at Columbia Lake and Windermere appear to have high predation levels on rams, whereas that of Stoddart Creek <8 km north of Mount Swansea appears to have had high predation on lambs in some years. Mortality that might be attributed to predation may be due to poor nutrition. Treated herds have an average of 20% better lamb survival than untreated herds, no matter what the predation level on the herd. A predator study on a recently translocated herd might be most effective in understanding the impact of predation on bighorn sheep populations.

### 9.5.3 Foraging behavior and diet selection

Research is needed to determine the effect of foraging strategies (especially of the ewe herd) on lamb survival, and ram horn growth characteristics.

Food habits, diet selection and the effect of diets on lamb recruitment are not understood in the East Kootenay. Nutrient level of important forage species and seasonal diets of bighorn sheep, mule deer and elk are largely unknown. Shrubs were an important component of bighorn sheep diets throughout the year in the Stoddart Creek band with willow and soopolallie being the species most commonly found in diets (Stelfox *et al.*1985). Grasses were an important dietary component in winter and spring months with bluegrasses and fescues being the most commonly selected (Stelfox *et al.*1985). Shrubs were found to have adequate phosphorous and nitrogen levels for body maintenance (Davidson 1982; Demarchi 1985) whereas grasses and forbs have sub-maintenance levels (Eastman *et al.* 1971). Herds that utilize mostly shrubs during winter months such as the Stoddart Creek band may have a distinct nutritional and hence immunological advantage over herds where little opportunity for shrub selection exists due to a long history of overuse - e.g., the Wigwam Flats and Columbia Lake ranges. Management may be attempting to produce more coarse cured bluebunch wheatgrass on bighorn sheep winter ranges when finer bladed grasses, such as the bluegrasses and fescues, and junegrass are preferred (Wikeem and Pitt 1979).

The dietary overlap between bighorn sheep and other wild ungulates and livestock should be evaluated to determine the level of ungulate management needed to produce population objectives.

### 9.5.4 Effects of habitat enhancement activities

Further research is required on prescribed fire to determine short- and long-term responses of soil and vegetation in major plant community types to prescribed fire done at various heat intensities. The effect of spring versus fall burning in major plant communities of the East Kootenay should also be evaluated.

Further research is also required to understand the effect of canopy closure in the major forest ecotypes on forage quality and productivity. The effect of logging and slashing of conifers on forage quality and productivity in major forest ecotypes needs further research.

### 9.5.5 Radio-telemetry research

More detailed radio-telemetry research is required on herds that will be disrupted through development of other resources. Winter range and migration routes of bighorn sheep on Eagle Mountain in the upper Elk Valley are being severely disrupted through open pit coal mining with virtually no knowledge of the long-term impact on the herd. Radio-telemetry research on the Line Creek herd between 1981 and 1983 (Schuerholz 1984) has permitted mine development and reclamation to minimize damage to this herd. Bighorn sheep herds wintering at Stoddart Creek and the lower Bull River face fragmentation of critical range through land alienations with little knowledge of potential impacts.

The impacts of major industrial, residential and recreational developments on population dynamics, health status and immune systems of bighorn sheep herds should be determined.

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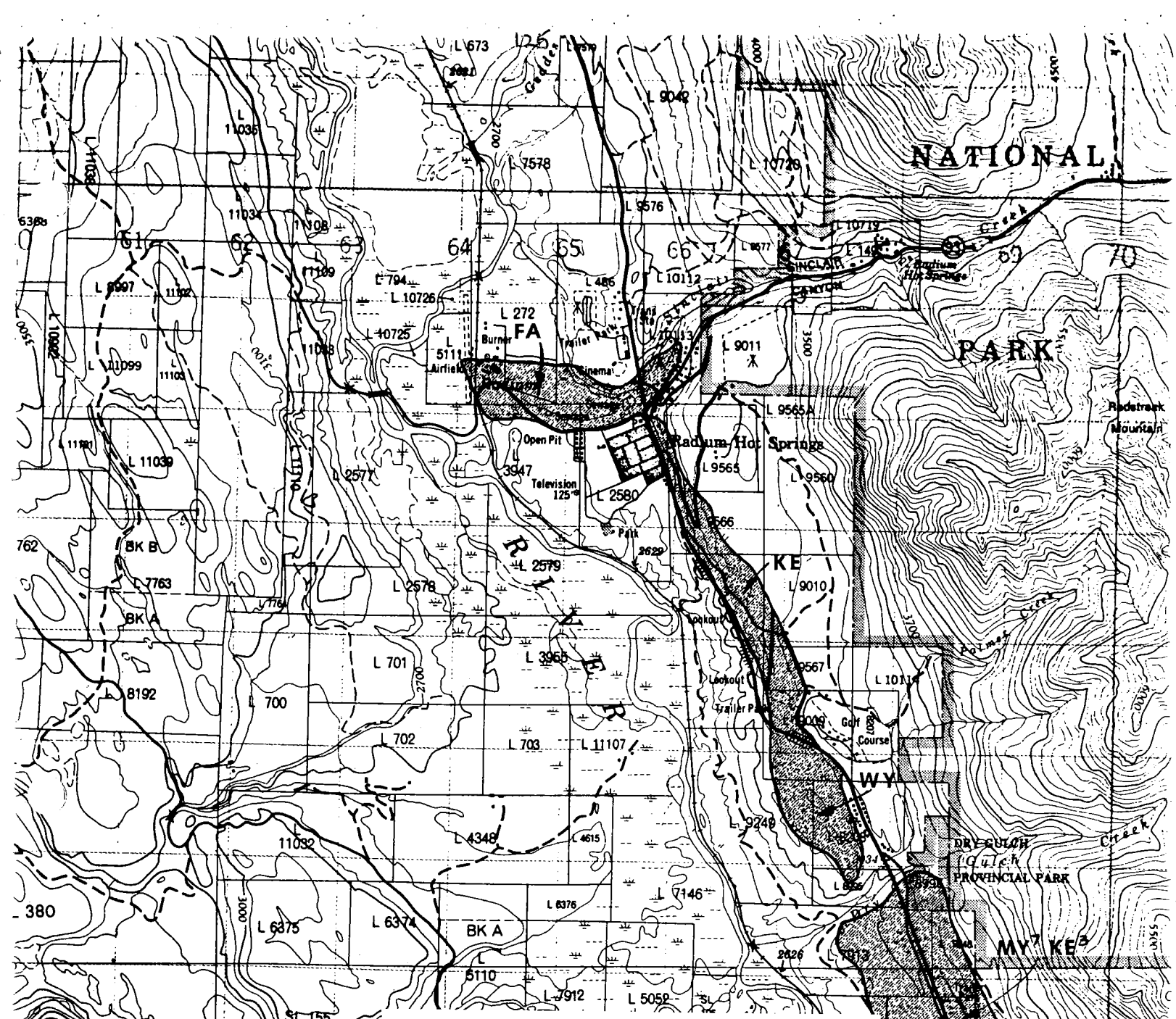
APPENDICES (pages 125-183)


NATIONAL
PARK
Radium Hot Springs
Radium Hot Springs
Golf Course
Open Pit
Television 125
Trailer Park
Lookout
Lookout
Trailer Park
Airfield
Cinema
Burner
Dry Gulch
PROVINCIAL PARK
Redstreak Mountain
Paint Creek
Dry Gulch Creek
Ditch
Ditch
Ditch
SINCLAIR CANYON
SHUSWAP
INDIAN
Shuswap Creek
Lake Enid
Creek
KE
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WY
BK A
BK B
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RIVER
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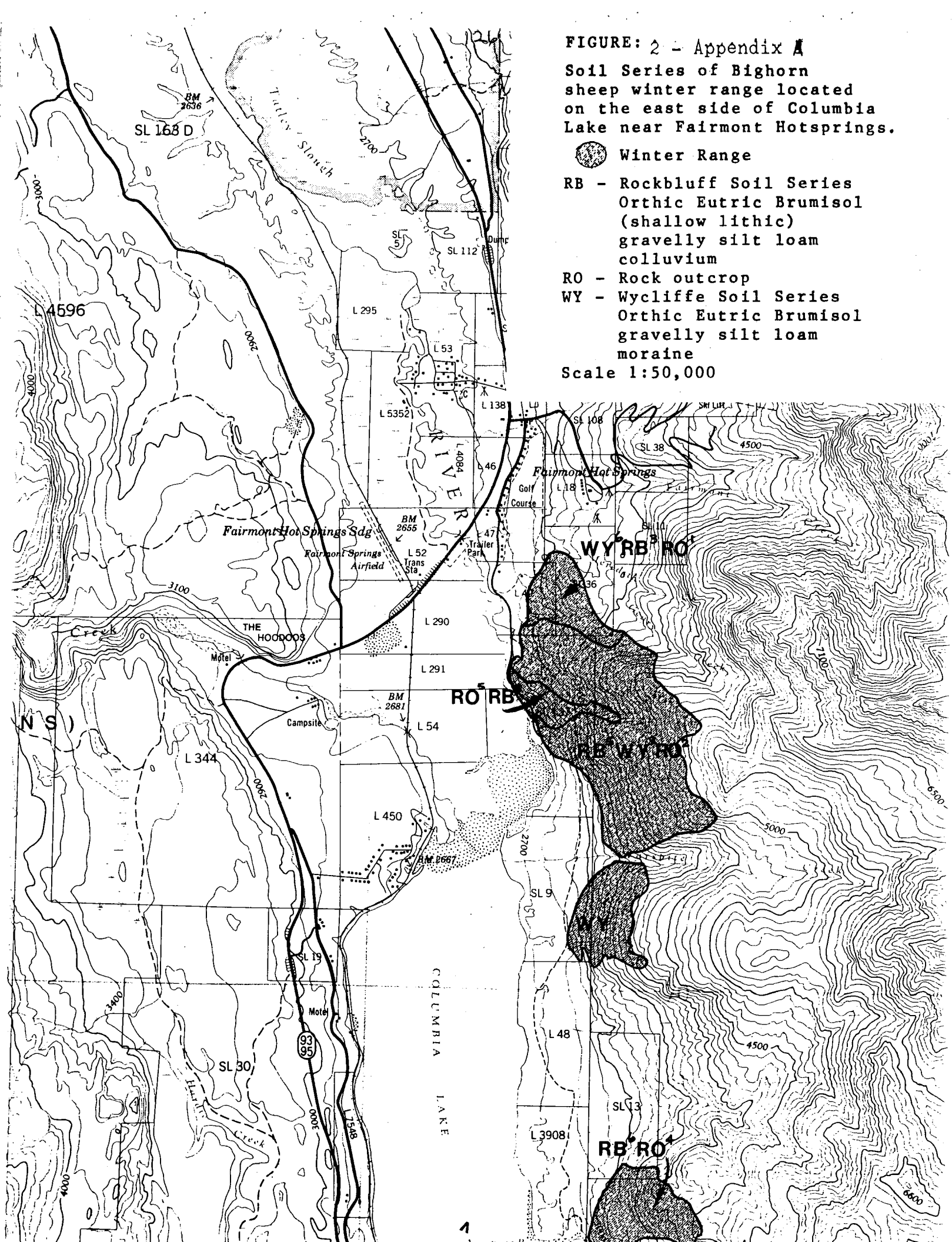



**FIGURE:** 2 - Appendix A

**Soil Series of Bighorn sheep winter range located on the east side of Columbia Lake near Fairmont Hotsprings.**

Winter Range

RB - Rockbluff Soil Series
Orthic Eutric Brumisol
(shallow lithic)
gravelly silt loam
colluvium

RO - Rock outcrop

WY - Wycliffe Soil Series
Orthic Eutric Brumisol
gravelly silt loam
moraine

Scale 1:50,000

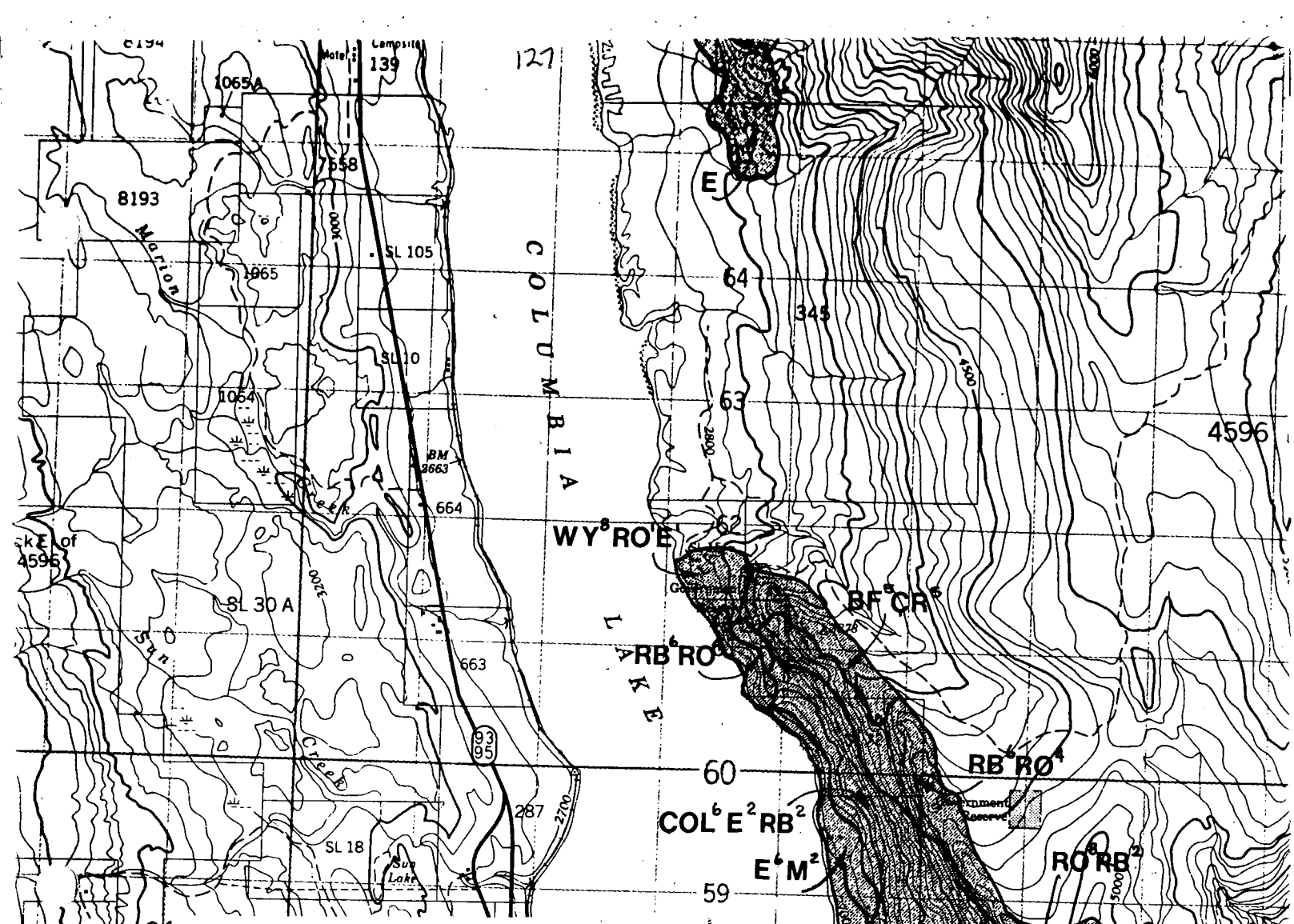



FIGURE: 2a - Appendix A

Soil Series of Bighorn sheep winter range located on the east side of Columbia Lake near Canal Flats.

Winter Range

COL- Colin Creek Soil Series
Orthic Eutric Brunisol
gravelly silt loam
colluvium

E - Elko Soil Series
Orthic Eutric Brunisol
fine / gravelly sandy loam
fluvioglacial

M - Mayook Soil Series
Orthic Eutric Brunisol
silt loam
glaciolacustrine

RB - Rockbluff Soil Series
Orthic Eutric Brunisol
gravelly silt loam
colluvium

RO - Rock outcrop

WY - Wycliffe Soil Series
Orthic Eutric Brunisol
gravelly silt loam
moraine

Scale 1:50,000

**FIGURE:** 3 - Appendix A

Soil Series of Bighorn sheep winter range located at Premier Ridge.

Winter Range

BF - Big Fish Soil Series
Orthic Eutric Brunisol
gravelly silt loam
colluvium

CR - Cervic Soil Series
Orthic Eutric Bruisol
gravelly silt loam
colluvium

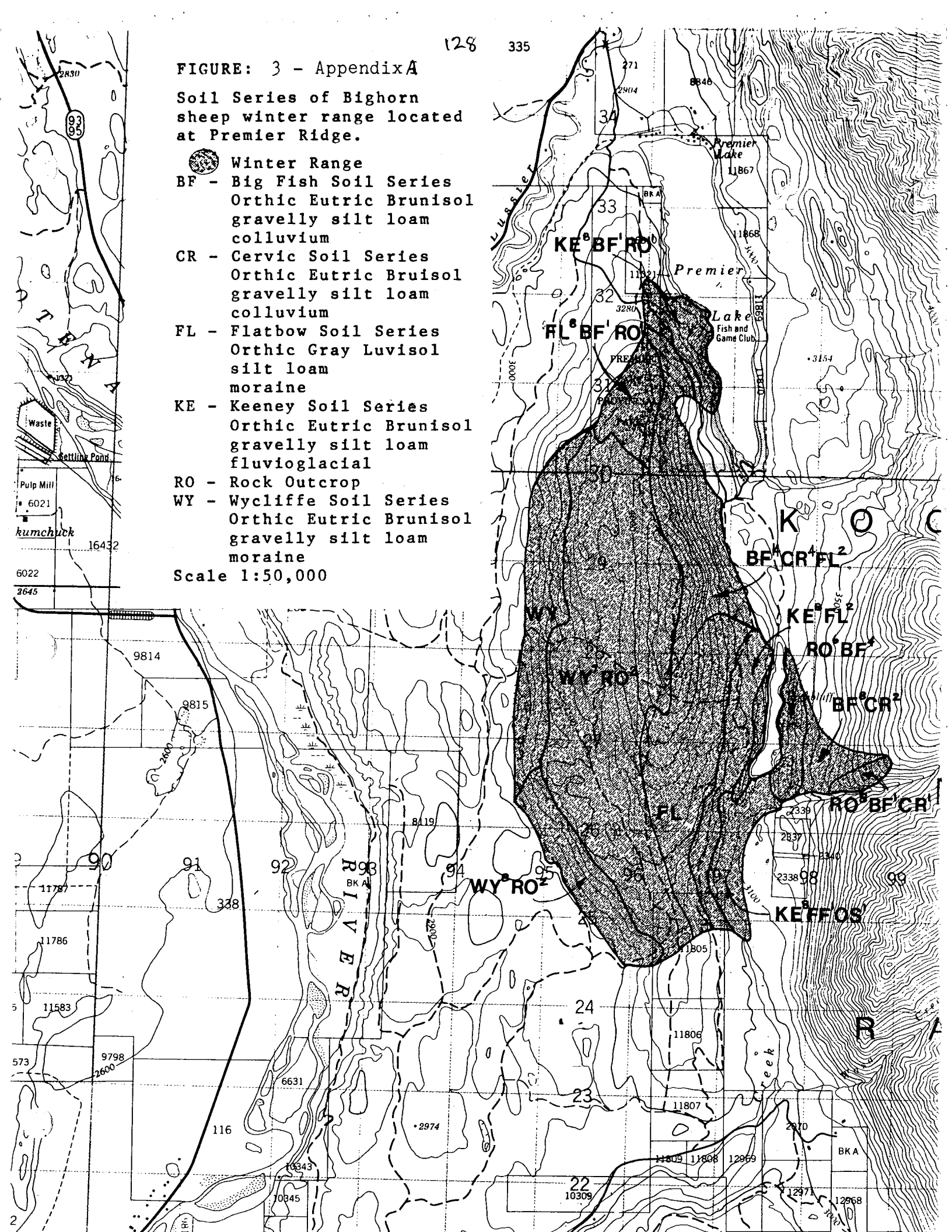
FL - Flatbow Soil Series
Orthic Gray Luvisol
silt loam
moraine

KE - Keeney Soil Series
Orthic Eutric Brunisol
gravelly silt loam
fluvioglacial

RO - Rock Outcrop

WY - Wycliffe Soil Series
Orthic Eutric Brunisol
gravelly silt loam
moraine

Scale 1:50,000



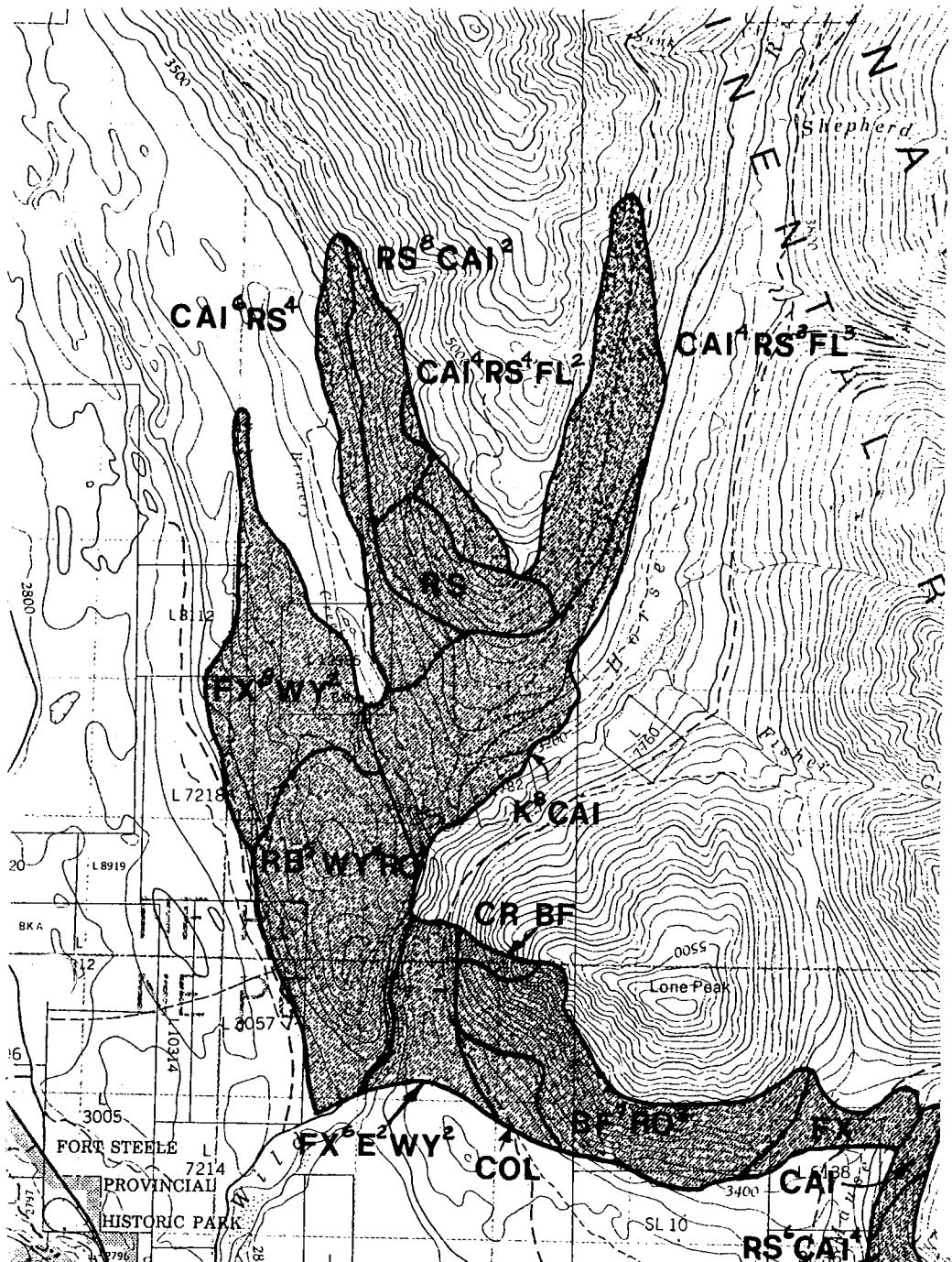



FIGURE: 4/5 - Appendix A

Soil Series of Bighorn sheep winter range located on the Lower Wildhorse.

Winter Range

BF - Big Fish Soil Series
Orthic Eutric Brunisol
gravelly silt loam
colluvium

CAI- Cathiness Soil Series
Orthic Eutric Brunisol
gravelly silt loam
colluvium

COL- Colin Creek Soil Series
Orthic Eutric Brunisol
gravelly silt loam
colluvium

FL - Flatbow Soil Series
Brunisolic Gray Luvisol
silt loam
moraine

FX - Fishertown Soil Series
Orthic Eutric Brunisol
gravelly sandy loam
fluvioglacial

RB - Rockbluff Soil Series
Orthic Eutric Brunisol
gravelly silt loam
colluvium

RO - Rock outcrop

RS - Rosen Lake Soil Series
Orthic Eutric Brunisol
gravelly silt loam
moraine

WY - Wycliffe Soil Series
Orthic Eutric Brunisol
gravelly silt loam
moraine

Scale 1:50,000

**FIGURE: 5/4 - Appendix A**

**Soil Series of Bighorn sheep winter range located on the Lower Bull River.**

Winter Range

CAI- Caithness Soil Series
Orthic Eutric Brunisol
gravelly silt loam
colluvium

E - Elko Soil Series
Orthic Eutric Brunisol
fine / gravelly sandy loam

FF - Fireweed Soil Series
Cumulic Regosol
(calcareous)
gravelly sandy loam
fluvial

KE - Keeney Soil Series
Orthic Eutric Brunisol
Fine / gravelly sandy loam
fluvioglacial

MD - Marmalade Soli Series
Orthic Eutric Brunisol
gravelly silt loam
moraine

RB - Rockbluff Soil Series
Orthic Eutric Brunisol
gravelly silt loam
colluvium

RO - Rock outcrop

SA - Saha Soil Series
Orthic Dystric Brunisol
fluvioglacial

Scale 1:50,000

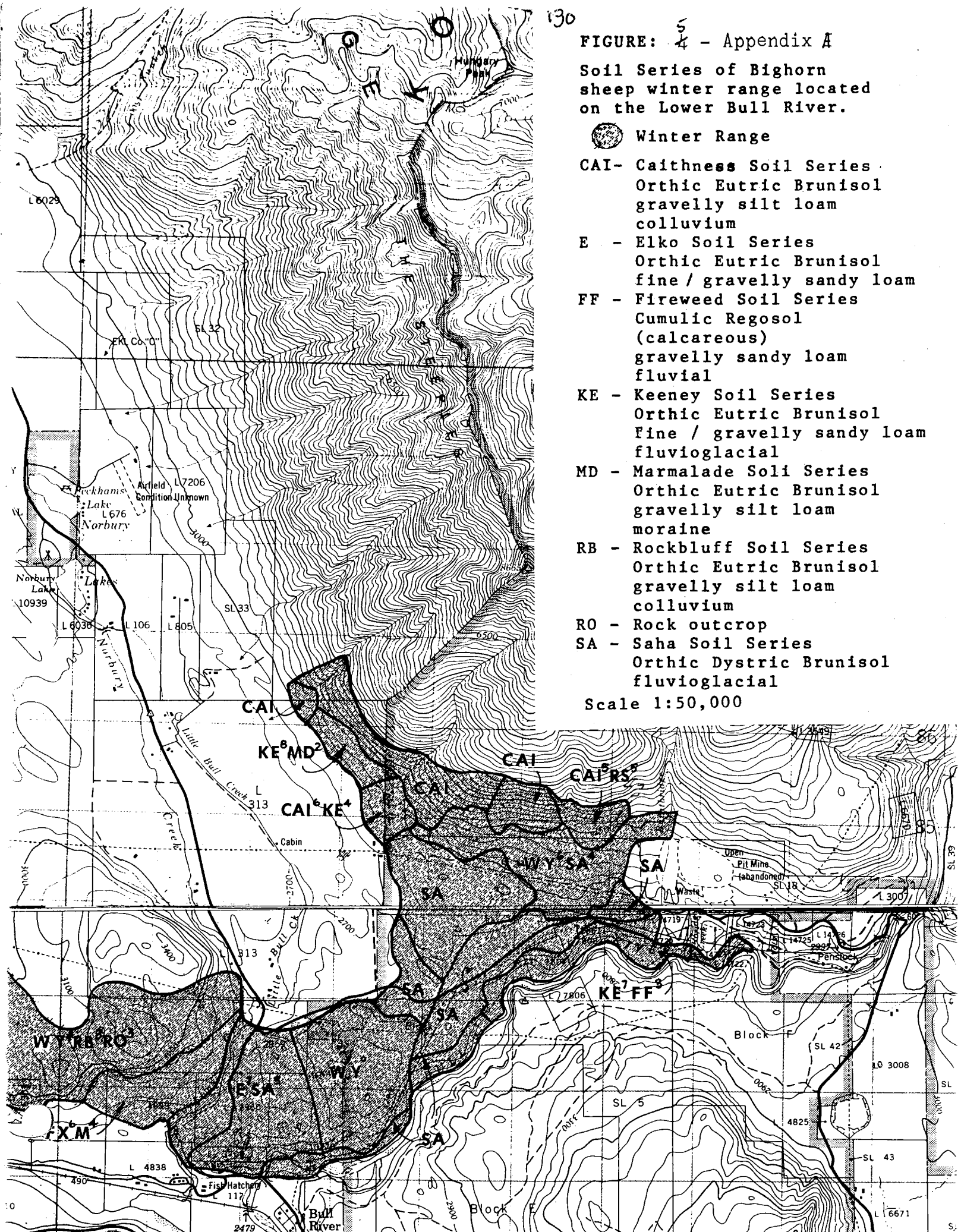


**FIGURE:** 6 - Appendix A

**Soil Series of Bighorn sheep winter range located between Wigwam River and Burton Creek.**

Winter Range

BF - Bigfish Soil Series
Orthic Eutric Brunisol
gravelly silt loam
colluvium

CAI- Caithiness Soil Series
Orthic Eutric Brunisol
gravelly silt loam
colluvium

CG - Cummings Soil Series
Orthic Dystric Brunisol
gravelly sandy loam

FL - Flatbow Soil Series
Brunisolic Gray Luvisol
silt loam
moraine

KE - Keeney Soil Series
Orthic Eutric Brunisol
fine / gravelly sandy loam
fluvioglacial

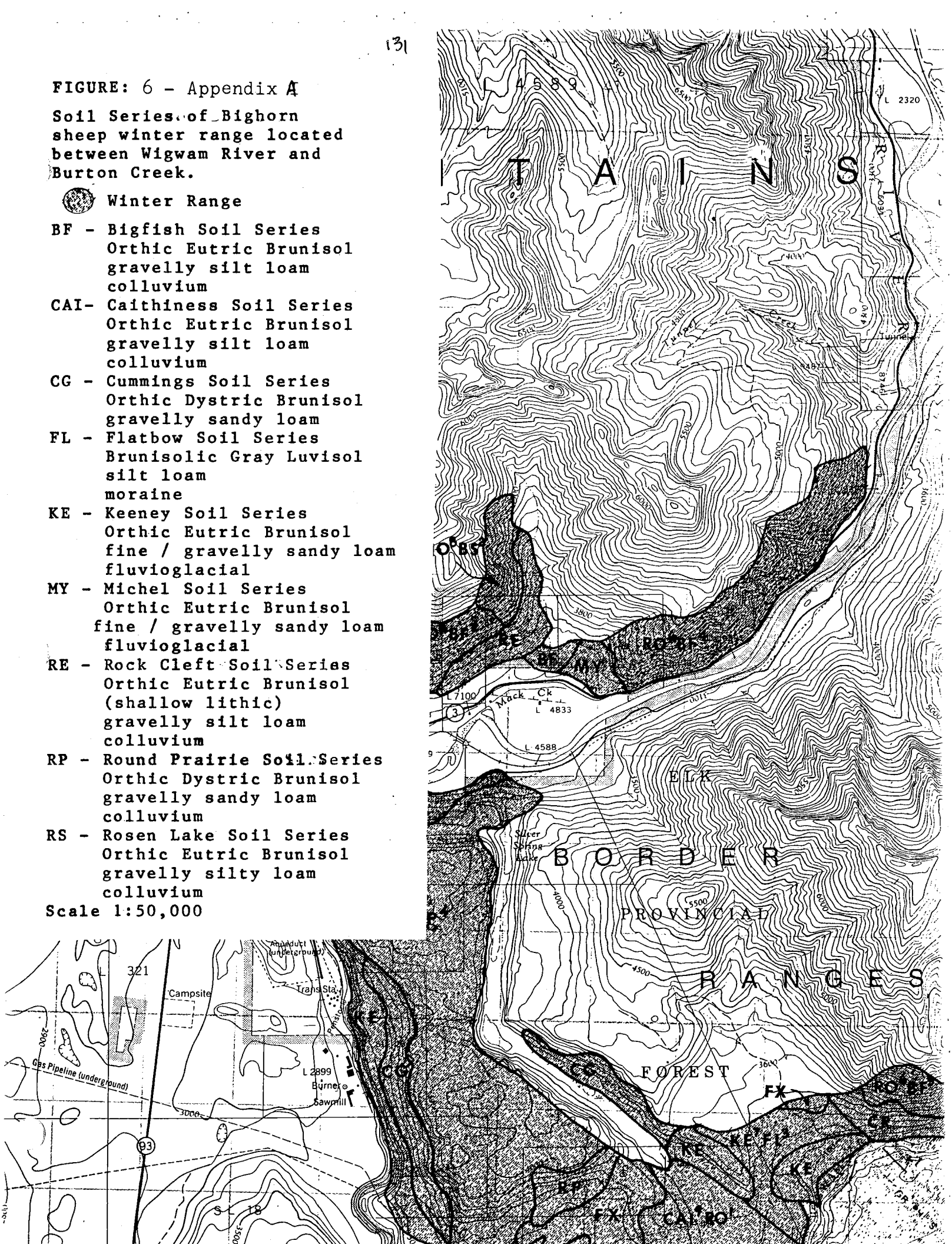
MY - Michel Soil Series
Orthic Eutric Brunisol
fine / gravelly sandy loam
fluvioglacial

RE - Rock Cleft Soil Series
Orthic Eutric Brunisol
(shallow lithic)
gravelly silt loam
colluvium

RP - Round Prairie Soil Series
Orthic Dystric Brunisol
gravelly sandy loam
colluvium

RS - Rosen Lake Soil Series
Orthic Eutric Brunisol
gravelly silty loam
colluvium

Scale 1:50,000



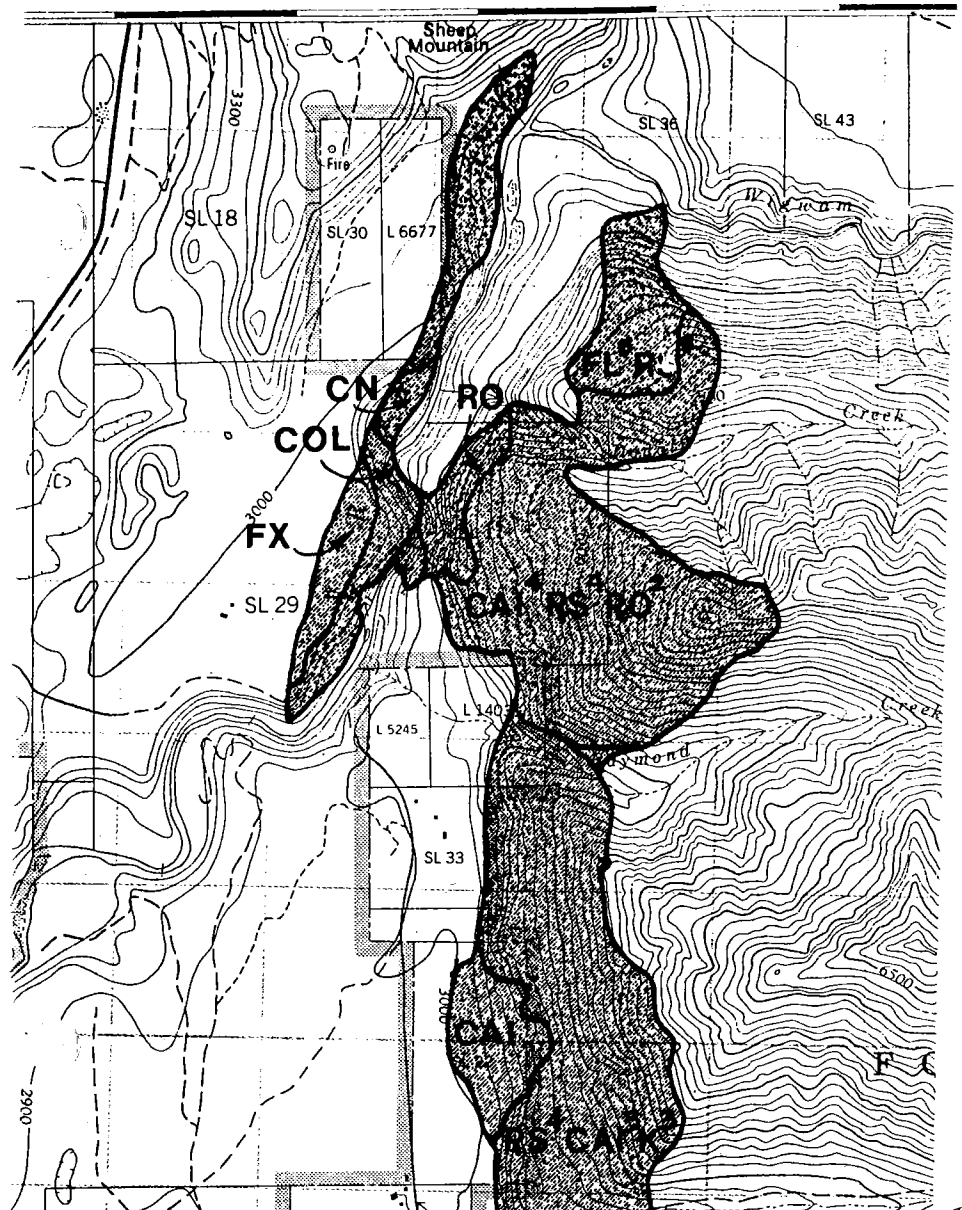



**FIGURE:** 7 - Appendix A

**Soil Series of Bighorn sheep winter range located between Wigwam Flats ~~and~~ - Red Canyon Creek.**

Winter Range

CAI- Caithness Soil Series
Orthic Eutric Brunisol
gravelly silt loam
colluvium

CN - Crowsnest Soil Series
Cumulic Regosol
(calcareous)
gravelly / sandy loam
fluvial

COL- Colin Creek Soil Series
Orthic Eutric Brunisol
gravelly silt loam
colluvium

FL - Flatbow Soil Series
Brunisolic Gray Luvisol
silt loam
moraine

K - Kinbasket Soil Series
Orthic Gray Luvisol
silt loam
moraine

RO - Rock outcrop

RS - Rosen Lake Soil Series
Orthic Eutric Brunisol
(shallow lithic)
gravelly silt loam
colluvium

Scale 1:50,000

Appendix B. Common[1] and scientific names of plant species mentioned in text.

## GRASSES

| | |
|---|---|
| alpine fescue | *Festuca brachyphylla* |
| bluebunch wheatgrass | *Agropyron spicatum* |
| bluegrass, Canada | *Poa compressa* |
| Cusick's | *Poa cusickii* |
| Kentucky | *Poa pratensis* |
| Sandberg's | *Poa sandbergii* |
| bluejoint | *Calamagrostis canadensis* |
| brome, downy | see cheatgrass |
| smooth | *Bromus inermis* |
| soft | *Bromus mollis* |
| Canada bluegrass | *Poa compressa* |
| cheatgrass | *Bromus tectorum* |
| Cusick's bluegrass | *Poa cusickii* |
| downy brome | see cheatgrass |
| downy wheatgrass | *Agropyron dasystachyum* |
| fescue, alpine | *Festuca brachyphylla* |
| Idaho | *Festuca idahoensis* |
| red | *Festuca rubra* |
| Rocky Mountain | *Festuca saximontana* |
| rough | *Festuca scabrella* |
| six-weeks | *Vulpia octoflora* |
| fuzzy-spiked wildrye | *Elymus innovatus* |
| giant wildrye | *Elymus cinereus* |
| Hooker's spike-oat | *Avenochloa hookeri* |
| Idaho fescue | *Festuca idahoensis* |
| intermediate wheatgrass | *Agropyron intermedium* |
| junegrass | *Koeleria macrantha* |
| Kentucky bluegrass | *Poa pratensis* |
| muttongrass | *Poa fendleriana* |
| needle-and-thread grass | *Stipa comata* |
| needlegrass, small western | *Stipa occidentalis* var. *minor* |
| spreading | *Stipa richardsonii* |
| stiff | *Stipa occidentalis* |
| oatgrass, poverty | *Danthonia spicata* |
| timber | *Danthonia intermedia* |
| orchardgrass | *Dactylis glomerata* |
| pinegrass | *Calamagrostis rubescens* |
| porcupinegrass | *Stipa spartea* |
| poverty oatgrass | *Danthonia spicata* |
| red fescue | *Festuca rubra* |
| Rocky Mountain fescue | *Festuca saximontana* |
| rough fescue | *Festuca scabrella* |
| Sandberg's bluegrass | *Poa sandbergii* |
| six-weeks fescue | *Vulpia octoflora* |
| slender wheatgrass | *Agropyron trachycaulum* |
| small western needlegrass | *Stipa columbiana* var. *minor* |
| smooth brome | *Bromus inermis* |
| soft brome | *Bromus mollis* |
| spike-oat, Hooker's | *Avenochloa hookeri* |
| spreading needlegrass | *Stipa richardsonii* |
| stiff needlegrass | *Stipa occidentalis* |
| timber oatgrass | *Danthonia intermedia* |
| timothy | *Phleum pratense* |
| wheatgrass, bluebunch | *Agropyron spicatum* |
| downy | *Agropyron dasystachyum* |
| intermediate | *Agropyron intermedium* |
| slender | *Agropyron trachycaulum* |
| wildrye, fuzzy-spiked | *Elymus innovatus* |
| giant | *Elymus cinereus* |

## FORBS

| | |
|---|---|
| agoseris, pale | *Agoseris glauca* |
| alpine aster | *Aster alpinus* |
| alpine hedysarum | *Hedysarum alpinum* |
| alpine meadowrue | *Thalictrum alpinum* |
| alpine willowherb | *Epilobium anagallidifolium* |
| alsike clover | *Trifolium hybridum* |
| alumroot, round-leaved | *Heuchera cylindrica* |
| American vetch | *Vicia americana* |
| anemone, cut-leaved | *Anemone multifida* |
| annual hawksbeard | *Crepis tectorum* |
| arnica, cut-leaved | *Arnica cordifolia* |
| arrow-leaved balsamroot | *Balsamorhiza sagittata* |
| aster, alpine | *Aster alpinus* |
| showy | *Aster conspicuus* |
| smooth | *Aster laevis* |
| tufted white prairie | *Aster pansus* |
| avens, yellow | *Geum aleppicum* |
| balsamroot, arrow-leaved | *Balsamorhiza sagittata* |
| baneberry | *Actaea rubra* |
| bedstraw, northern | *Galium boreale* |
| bergamot, wild | *Monarda fistulosa* var. *mollis* |
| black elderberry | *Sambucus racemosa* var. *melanocarpa* |
| black medic | *Medicago lupulina* |
| bladderpod, Columbia | *Lesquerella douglasii* |
| blue elderberry | *Sambucus cerulea* |
| blue-eyed grass, northern | *Sisyrinchium septentriorale* |
| blue-eyed Mary | *Collinsia parviflora* |
| broad-leaved willowherb | *Epilobium latifolium* |
| bull thistle | *Cirsium vulgare* |
| campion, moss | *Silene acaulis* |
| Canada goldenrod | *Solidago canadensis* |
| Canada thistle | *Cirsium arvense* |

[1] Common names from Meidinger, D. 1987. Recommended vernacular names for common plants of British Columbia. Res. Rep. B.C. Ministry of For. and Lands, Victoria.

chickweed *Cerastium* sp.
cinquefoil, graceful *Potentilla gracilis*
shrubby *Potentilla fruticosa*
sticky *Potentilla glandulosa*
clover, alsike *Trifolium hybridum*
white *Trifolium repens*
collomia, large-flowered *Collomia grandiflora*
Columbia bladderpod *Lesquerella douglasii*
common dandelion *Taraxacum officinale*
creamy peavine *Lathyrus ochroleucus*
cut-leaved anemone *Anemone multifida*
dalmatian toadflax *Linaria dalmatica*
dandelion, common *Taraxacum officinale*
death-camas, meadow *Zigadenus venenosus*
mountain *Zigadenus elegans*
desert-parsley,
large-fruited *Lomatium macrocarpum*
narrow-leaved *Lomatium triternatum*
dock *Rumex* spp.
dogbane, spreading *Apocynum androsaemifolium*
elderberry, black *Sambucus racemosa* var. *melanocarpa*
blue *Sambucus cerulea*
red *Sambucus racemosa*
early blue violet *Viola adunca*
false Solomon's-seal *Smilacina racemosa*
false Solomon's-seal,
star-flowered *Smilacina stellata*
three-leaved *Smilacina trifolia*
few-flowered
shootingstar *Dodecatheon pulchellum*
field pussytoes *Antennaria neglecta*
fireweed *Epilobium angustifolium*
flax, wild blue *Linum lewisii*
fleabane *Erigeron* spp.
fringed grass-of-
Parnassus *Parnassia fimbriata*
geranium, sticky *Geranium viscosissimum*
Geyer's onion *Allium geyeri*
globeflower *Trollius laxus*
goatsbeard *Aruncus dioicus*
golden-aster, hairy *Heterotheca villosa*
goldenrod, Canada *Solidago canadensis*
graceful cinquefoil *Potentilla gracilis*
grass-of-Parnassus,
fringed *Parnassia fimbriata*
green wintergreen *Pyrola chlorantha*
groundsel, western *Senecio integerrimus*
gumweed *Grindelia* sp.
hairy golden-aster *Heterotheca villosa*
harebell *Campanula* spp.
hawksbeard, annual *Crepis tectorum*
heart-leaved arnica *Arnica cordifolia*
hedysarum, yellow *Hedysarum sulphurescens*
alpine *H e d y s a r u m alpinum*
Holboell's rockcress *Arabis holboellii*
Hood's phlox *Phlox hoodii*
Jacob's-ladder, showy *Polemonium pulcherrimum*
lance-leaved stonecrop *Sedum lanceolata*
large-flowered collomia *Collomia grandiflora*
large-fruited desert-
parsley *Lomatium macrocarpum*
large-leaved avens *Geum macrophyllum*
lemonweed *Lithospermum ruderale*
locoweed, stalked-pod *Oxytropis podocarpa*
long-leaved starwort *Stellaria longifolia*
long-stalked starwort *Stellaria longipes*
lupine, silky *Lupinus sericeus*
Lyall's mariposa lily *Calochortus lyalli*
mariposa lily, Lyall's *Calochortus lyalli*
threespot *Calochortus apiculatus*
marsh valerian *Valeriana dioica*
meadow death-camas *Zigadenus venenosus*
milk-vetch, timber *Astragalus miser*
moss campion *Silene acaulis*
mountain death-camas *Zigadenus elegans*
mullein, woolly *Verbascum thapsus*
mustard, wormseed *Erysimum cheiranthoides*
narrow-leaved desert-
parsley *Lomatium triternatum*
nodding onion *Allium cernuum*
nodding thistle *Carduus nutans*
northern bedstraw *Galium boreale*
northern blue-eyed grass *Sisyrinchium septentriorale*
northern starwort *Stellaria calycantha*
northern wormwood *Artemisia campestris*
Nuttall's pussytoes *Antennaria parviflora*
old man's whiskers *Geum triflorum*
onion, Geyer's *Allium geyeri*
nodding *Allium cernuum*
prairie *Allium textile*
owl-clover, rosy *Orthocarpus bracteosus*
yellow *Orthocarpus luteus*
paintbrush, yellowish *Castilleja lutescens*
pale agoseris *Agoseris glauca*
pasqueflower, western *Pulsatilla occidentalis*
pasture sage *Artemisia frigida*
pearly everlasting *Anaphalis margaritacea*
peavine *Lathyrus* spp.
peavine, creamy *Lathyrus ochroleucus*
penstemon, yellow *Penstemon confertus*
perennial sow-thistle *Sonchus arvensis*
phacelia, thread-leaved *Phacelia linearis*
phlox, Hood's *Phlox hoodii*
prairie crocus *Pulsatilla patens* ssp. *multifida*
prairie onion *Allium textile*
pussytoes, field *Antennaria neglecta*
Nuttall's *Antennaria parvifolia*
racemose *Antennaria racemosa*
rosy *Antennaria microphylla*

| | |
|---|---|
| umber | *Antennaria umbrinella* |
| woolly | *Antennaria lanata* |
| racemose pussytoes | *Antennaria racemosa* |
| rattlesnake-plantain | *Goodyera oblongifolia* |
| red elderberry | *Sambucus racemosa* |
| rockcress, Holboell's | *Arabis holboellii* |
| rosy owl-clover | *Orthocarpus bracteosus* |
| rosy pussytoes | *Antennaria microphylla* |
| round-leaved alumroot | *Heuchera cylindrica* |
| sage, pasture | *Artemisia frigida* |
| salsify, yellow | *Tragopogon dubius* |
| shepherd's purse | *Capsella bursa-pastoris* |
| shootingstar, few-flowered | *Dodecatheon pulchellum* |
| slimpod | *Dodecatheon conjugens* |
| showy aster | *Aster conspicuus* |
| showy Jacob's-ladder | *Polemonium pulcherrimum* |
| shrubby cinquefoil | *Potentilla fruticosa* |
| silky lupine | *Lupinus sericeus* |
| silverweed | *Potentilla anserina* |
| slender speedwell | *Veronica filiformis* |
| slimpod shootingstar | *Dodecatheon conjugens* |
| small-flowered willowherb | *Epilobium minutum* |
| small twistedstalk | *Streptopus streptopoides* |
| smooth aster | *Aster laevis* |
| sow-thistle, perennial | *Sonchus arvensis* |
| speedwell, slender | *Veronica filiformis* |
| spreading dogbane | *Apocynum androsaemifolium* |
| stalked-pod locoweed | *Oxytropis podocarpa* |
| star-flowered false Solomon's-seal | *Smilacina stellata* |
| starwort, long-leaved | *Stellaria longifolia* |
| long-stalked | *Stellaria longipes* |
| northern | *Stellaria calycantha* |
| sticky cinquefoil | *Potentilla glandulosa* |
| sticky geranium | *Geranium viscosissimum* |
| stonecrop, lance-leaved | *Sedum lanceolatum* |
| strawberry-blite | *Chenopodium capitatum* |
| strawberry, wild | *Fragaria virginiana* |
| wood | *Fragaria vesca* |
| sunflower | *Helianthus* spp. |
| tall tumble-mustard | *Sisymbrium altissimum* |
| thistle, bull | *Cirsium vulgare* |
| Canada | *Cirsium arvense* |
| nodding | *Carduus nutans* |
| wavy-leaved | *Cirsium undulatum* |
| thread-leaved phacelia | *Phacelia linearis* |
| three-leaved false Solomon's-seal | *Smilacina trifolia* |
| threespot mariposa lily | *Calochortus apiculatus* |
| timber milk-vetch | *Astragalus miser* |
| toadflax, dalmatian | *Linaria dalmatica* |
| tufted white prairie aster | *Aster pansus* |
| tumble-mustard, tall | *Sisymbrium altissimum* |
| twistedstalk, small | *Streptopus streptopoides* |
| umber pussytoes | *Antennaria umbrinella* |
| valerian, marsh | *Valeriana dioica* |
| vetch, American | *Vicia americana* |
| violet, early blue | *Viola adunca* |
| yellow montane | *Viola nuttallii* ssp. *praemorsa* |
| wavy-leaved thistle | *Cirsium undulatum* |
| western groundsel | *Senecio integerrimus* |
| western pasqueflower | *Pulsatilla occidentalis* |
| white clover | *Trifolium repens* |
| wild bergamot | *Monarda fistulosa* var. *mollis* |
| wild blue flax | *Linum lewisii* |
| wild strawberry | *Fragaria virginiana* |
| willowherb, alpine | *Epilobium anagallidifolium* |
| broad-leaved | *Epilobium latifolium* |
| small-flowered | *Epilobium minutum* |
| wintergreen | *Pyrola* spp. |
| wintergreen, green | *Pyrola chlorantha* |
| wood strawberry | *Fragaria vesca* |
| woolly mullein | *Verbascum thapsus* |
| woolly pussytoes | *Antennaria lanata* |
| wormseed mustard | *Erysimum cheiranthoides* |
| wormwood, northern | *Artemisia campestris* |
| yarrow | *Achillea millefolium* |
| yellow avens | *Geum aleppicum* |
| yellow hedysarum | *Hedysarum sulphurescens* |
| yellow montane violet | *Viola nuttalli* ssp. *praemorsa* |
| yellow owl-clover | *Orthocarpus luteus* |
| yellow penstemon | *Penstemon confertus* |
| yellow salsify | *Tragopogon dubius* |
| yellowish paintbrush | *Castilleja lutescens* |

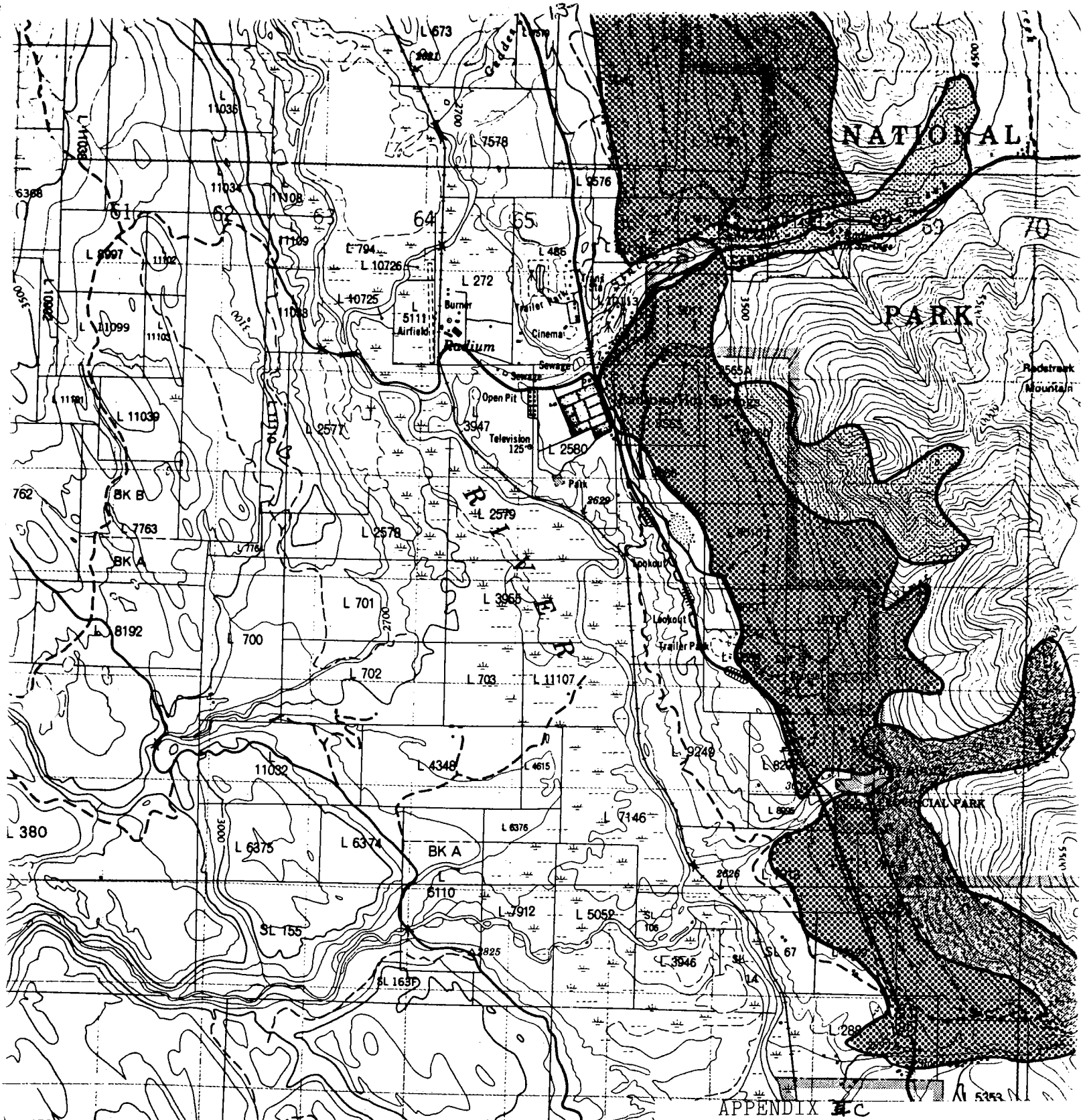
**SHRUBS**

| | |
|---|---|
| alpine bog-laurel | *Kalmia microphylla* ssp. *microphylla* |
| antelope-brush | *Purshia tridentata* |
| azalea, false | *Menziesia ferruginea* |
| balsam poplar | *Populus balsamifera* ssp. *balsamifera* |
| birch-leaved spirea | *Spiraea betulifolia* |
| bitterbrush | see antelope-brush |
| black gooseberry | *Ribes lacustre* |
| black huckleberry | *Vaccinium membranaceum* |
| blueberry, oval-leaved | *Vaccinium ovalifolium* |
| velvet-leaved | *Vaccinium myrtilloides* |
| blue clematis– | *Clematis occidentalis* |
| bog-laurel, alpine | *Kalmia microphylla* ssp. *microphylla* |
| ceanothus, redstem | *Ceanothus sanguineus* |
| cherry, choke | *Prunus virginiana* |
| pin | *Prunus pensylvanica* |
| choke cherry | *Prunus virginiana* |
| clematis, blue | *Clematis occidentalis* |
| common juniper | *Juniperus communis* |

| | |
|---|---|
| common snowberry | *Symphoricarpos albus* |
| creeping juniper | *Juniperus horizontalis* |
| creeping Oregon-grape | *Mahonia repens* |
| currant, red swamp | *Ribes triste* |
| sticky | *Ribes viscosissimum* |
| Douglas maple | *Acer glabrum* |
| false azalea | *Menziesia ferruginea* |
| gooseberry, black | *Ribes lacustre* |
| northern | *Ribes oxyacanthoides* |
| grouseberry | *Vaccinium scoparium* |
| huckleberry, black | *Vaccinium membranaceum* |
| red | *Vaccinium parvifolium* |
| juniper, common | *Juniperus communis* |
| creeping | *Juniperus horizontalis* |
| Rocky Mountain | *Juniperus scopulorum* |
| kinnikinnick | *Arctostaphylos uva-ursi* |
| Lapland rosebay | *Rhododendron lapponicum* |
| maple, Douglas | *Acer glabrum* |
| mock-orange | *Philadelphus lewisii* |
| mountain-heather, white | *Cassiope mertensiana* |
| northern gooseberry | *Ribes oxyacanthoides* |
| ocean-spray | *Holodiscus discolor* |
| Oregon-grape, creeping | *Mahonia repens* |
| oval-leaved blueberry | *Vaccinium ovalifolium* |
| Pacific rhododendron | *Rhododendron macrophyllum* |
| pin cherry | *Prunus pensylvanica* |
| poplar, balsam | *Populus balsamifera* ssp. *balsamifera* |
| prairie rose | *Rosa woodsii* |
| prickly rose | *Rosa acicularis* |
| rabbit-brush | *Chrysothamnus nauseosus* |
| red huckleberry | *Vaccinium parvifolium* |
| redstem ceanothus | *Ceanothus sanguineus* |
| red swamp currant | *Ribes triste* |
| rhododendron, Pacific | *Rhododendron macrophyllum* |
| white-flowered | *Rhododendron albiflorum* |
| Rocky Mountain juniper | *Juniperus scopulorum* |
| rose, prairie | *Rosa woodsii* |
| prickly | *Rosa acicularis* |
| rosebay, Lapland | *Rhododendron lapponicum* |
| saskatoon | *Amelanchier alnifolia* |
| Scouler's willow | *Salix scouleriana* |
| snowbrush | *Ceanothus velutinus* |
| snowberry, common | *Symphoricarpos albus* |
| western | *Symphoricarpos occidentalis* |
| soopolallie | *Shepherdia canadensis* |
| spirea, birch-leaved | *Spiraea betulifolia* |
| sticky currant | *Ribes viscosissimum* |
| thimbleberry | *Rubus parviflorus* |
| velvet-leaved blueberry | *Vaccinium myrtilloides* |
| western snowberry | *Symphoricarpos occidentalis* |
| white-flowered rhododendron | *Rhododendron albiflorum* |
| white mountain-heather | *Cassiope mertensiana* |
| willow, Scouler's | *Salix scouleriana* |

**TREES**

| | |
|---|---|
| alpine larch | *Larix lyallii* |
| aspen, trembling | *Populus tremuloides* |
| Douglas-fir, interior | *Pseudotsuga menziesii* var. *glauca* |
| Engelmann spruce | *Picea engelmannii* |
| fir, subalpine | *Abies lasiocarpa* |
| interior Douglas-fir | *Pseudotsuga menziesii* var. *glauca* |
| larch, alpine | *Larix lyallii* |
| western | *Larix occidentalis* |
| lodgepole pine | *Pinus contorta* |
| pine, lodgepole | *Pinus contorta* |
| ponderosa | *Pinus ponderosa* |
| ponderosa pine | *Pinus ponderosa* |
| spruce, Engelmann | *Picea engelmannii* |
| subalpine fir | *Abies lasiocarpa* |
| trembling aspen | *Populus tremuloides* |
| western larch | *Larix occidentalis* |




APPENDIX C

**FIGURE:** 1

**Ungulate biophysical capabilities for the Stoddart Creek Bighorn sheep winter ranges.**

- **Class 1 - may support 12-24** B.H. Sheep /km 2
- **Class 2 - may support 8-12** B.H. Sheep /km 2
- **Class 3 - may support 4-8** B.H. Sheep /km 2

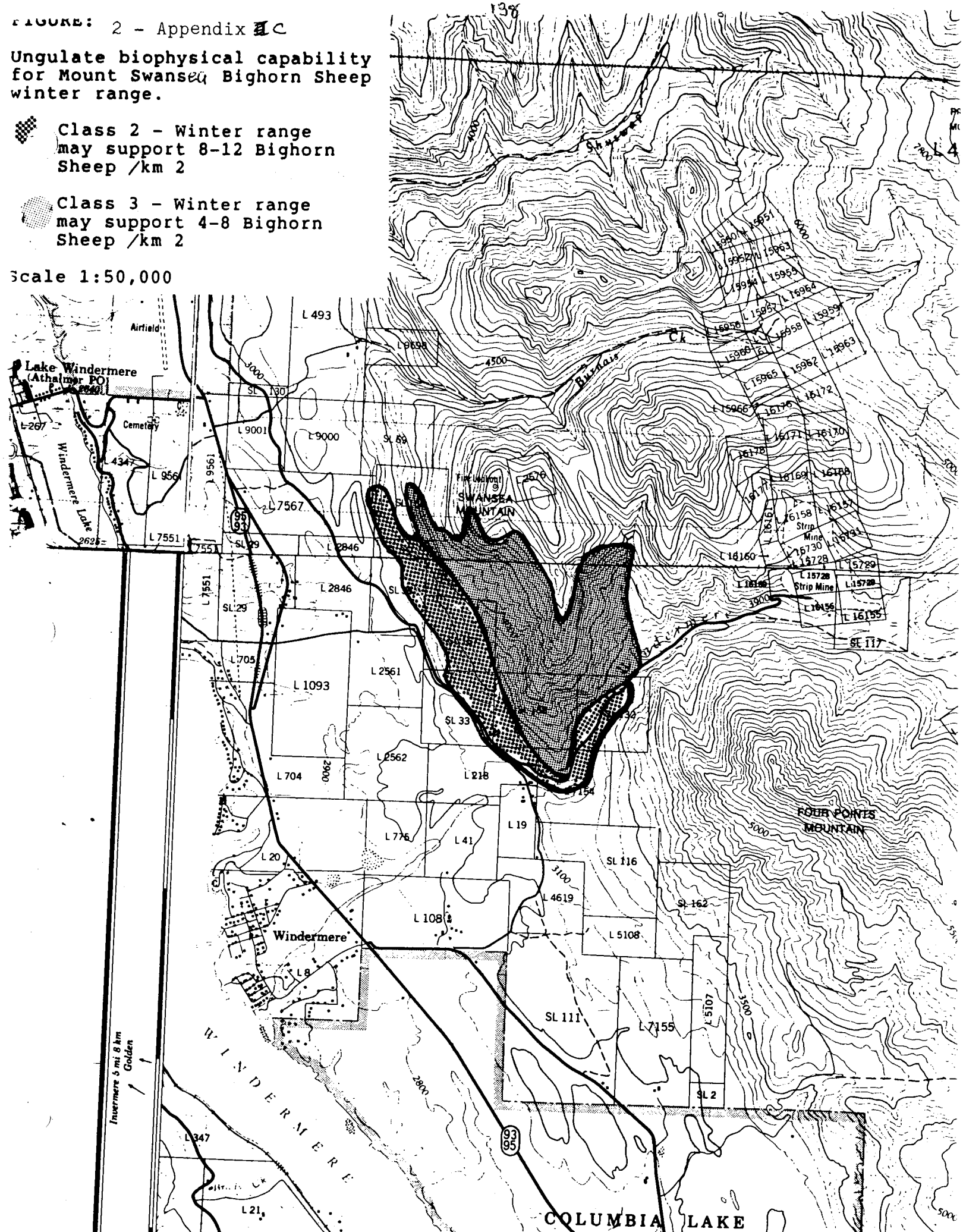
FIGURE: 2 - Appendix IC

Ungulate biophysical capability for Mount Swansea Bighorn Sheep winter range.

Class 2 - Winter range may support 8-12 Bighorn Sheep /km 2

Class 3 - Winter range may support 4-8 Bighorn Sheep /km 2

Scale 1:50,000



Appendix 再C

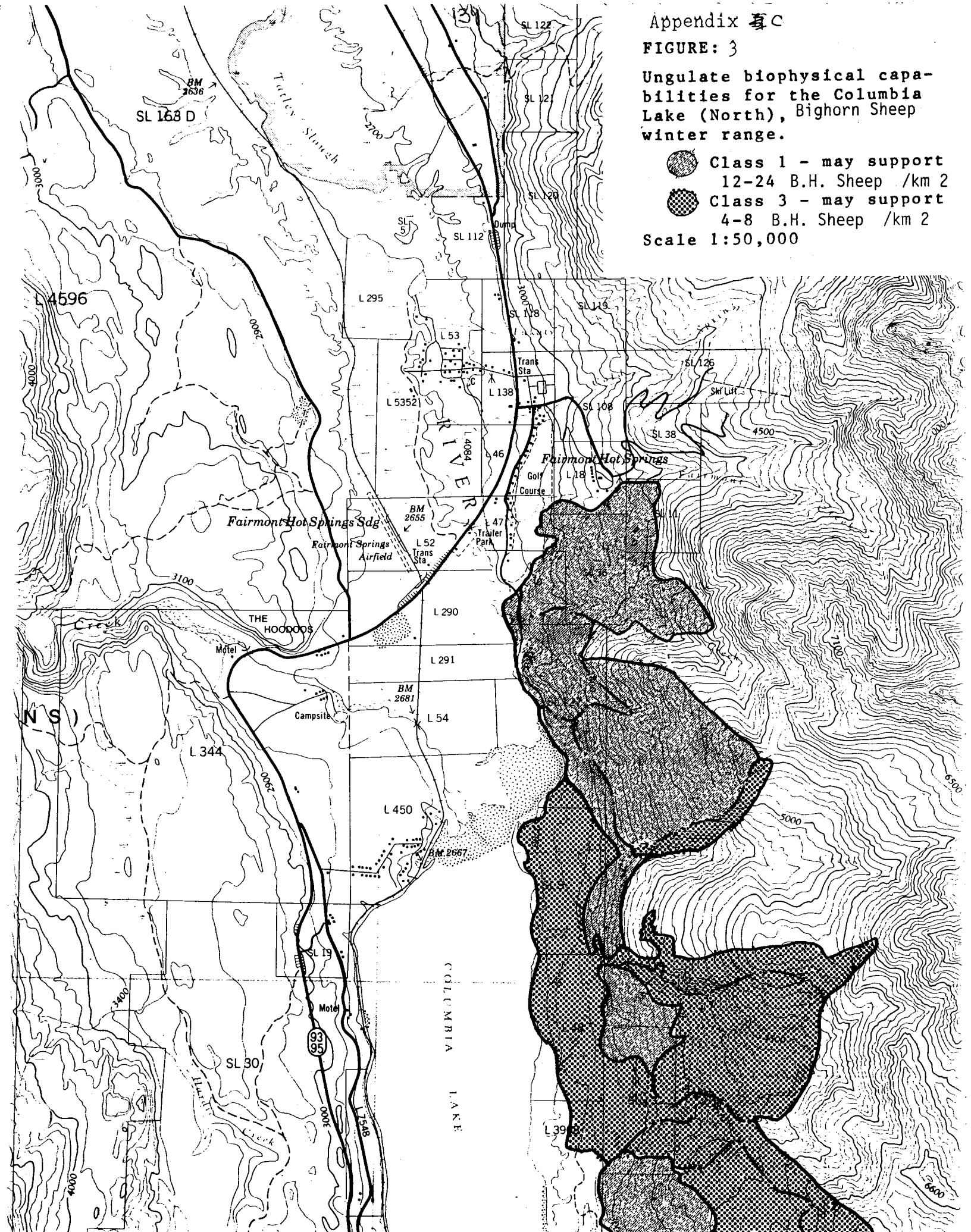
**FIGURE: 3**

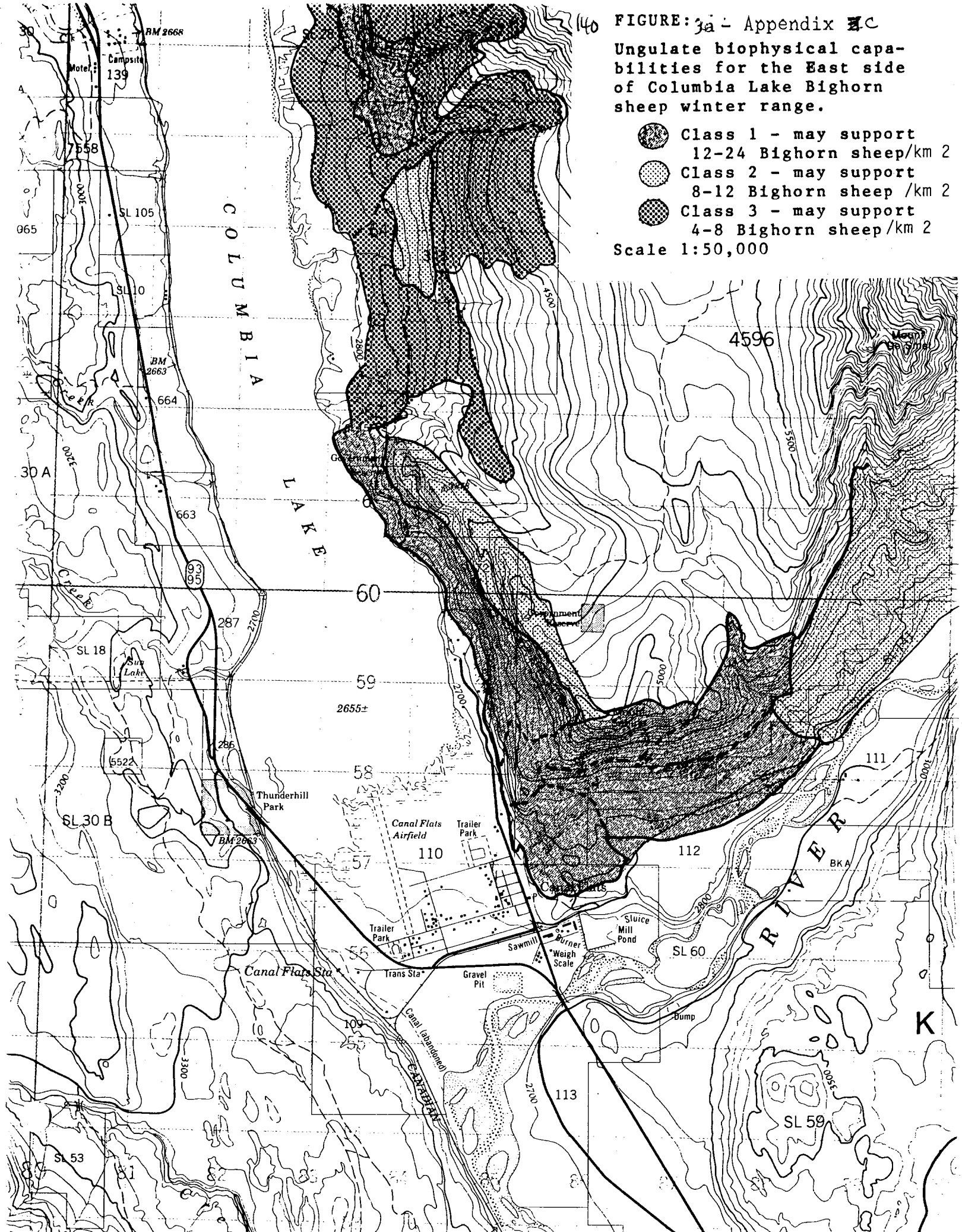
**Ungulate biophysical capabilities for the Columbia Lake (North), Bighorn Sheep winter range.**

**Class 1 - may support 12-24 B.H. Sheep /km 2**

**Class 3 - may support 4-8 B.H. Sheep /km 2**

**Scale 1:50,000**




140
FIGURE: 3a - Appendix C
Ungulate biophysical capabilities for the East side of Columbia Lake Bighorn sheep winter range.
Class 1 - may support 12-24 Bighorn sheep/km 2
Class 2 - may support 8-12 Bighorn sheep /km 2
Class 3 - may support 4-8 Bighorn sheep/km 2
Scale 1:50,000
COLUMBIA LAKE
RIVER
Thunderhill Park
Canal Flats Airfield
Trailer Park
Canal Flats
Canal Flats Sta
Trans Sta
Gravel Pit
Sawmill
Burner
Weigh Scale
Sluice
Mill Pond
Dump
Canal (abandoned)
CANADIAN
Government Reserve
Mount De Smet
Campsite
Motel
BM 2668
BM 2663
SL 105
SL 10
SL 18
SL 30 B
SL 60
SL 59
SL 53
4596
2655±
60
59
58
57
110
111
112
113
109
30 A
K

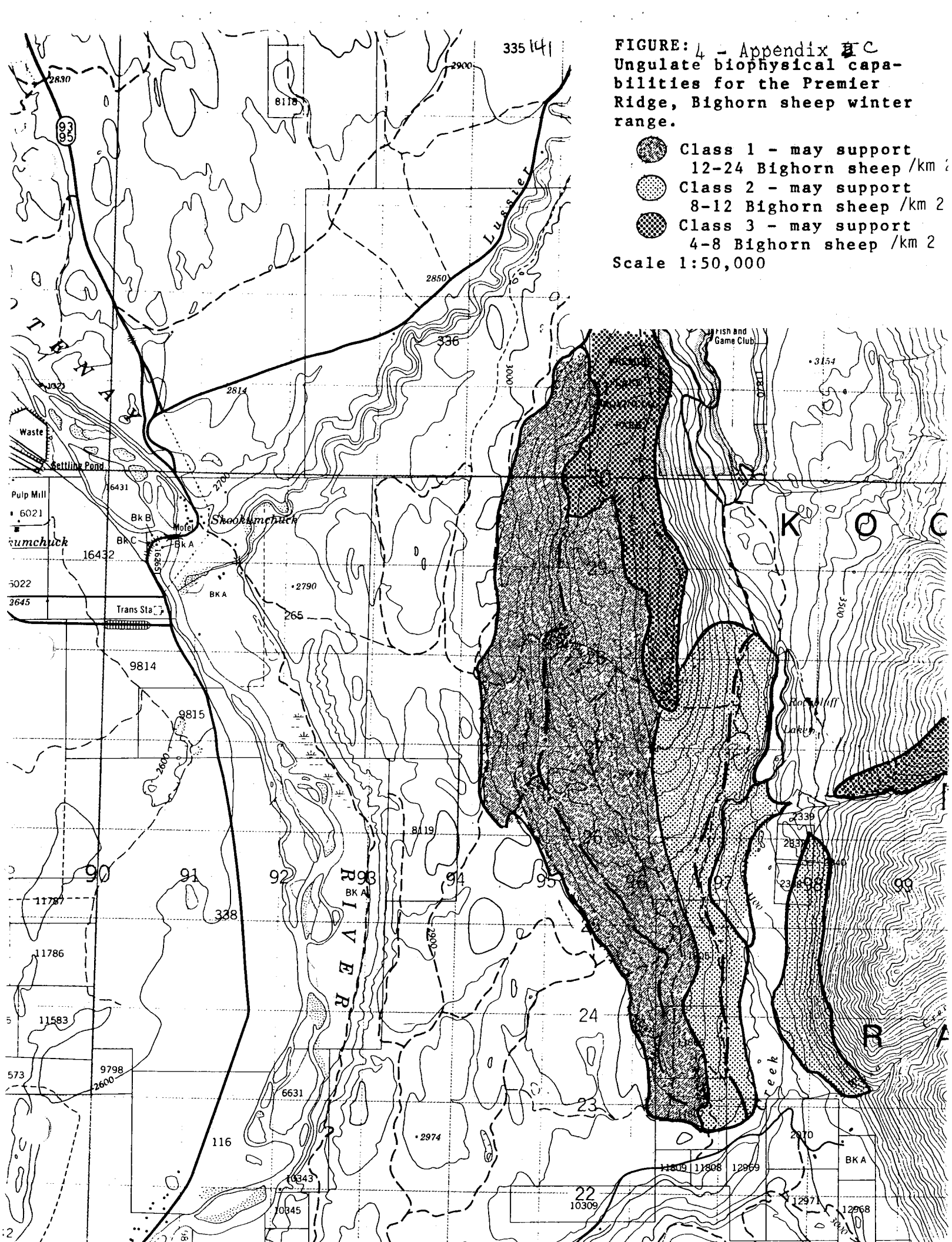



FIGURE: 4 - Appendix C
Ungulate biophysical capabilities for the Premier Ridge, Bighorn sheep winter range.

Class 1 - may support 12-24 Bighorn sheep /km 2

Class 2 - may support 8-12 Bighorn sheep /km 2

Class 3 - may support 4-8 Bighorn sheep /km 2

Scale 1:50,000

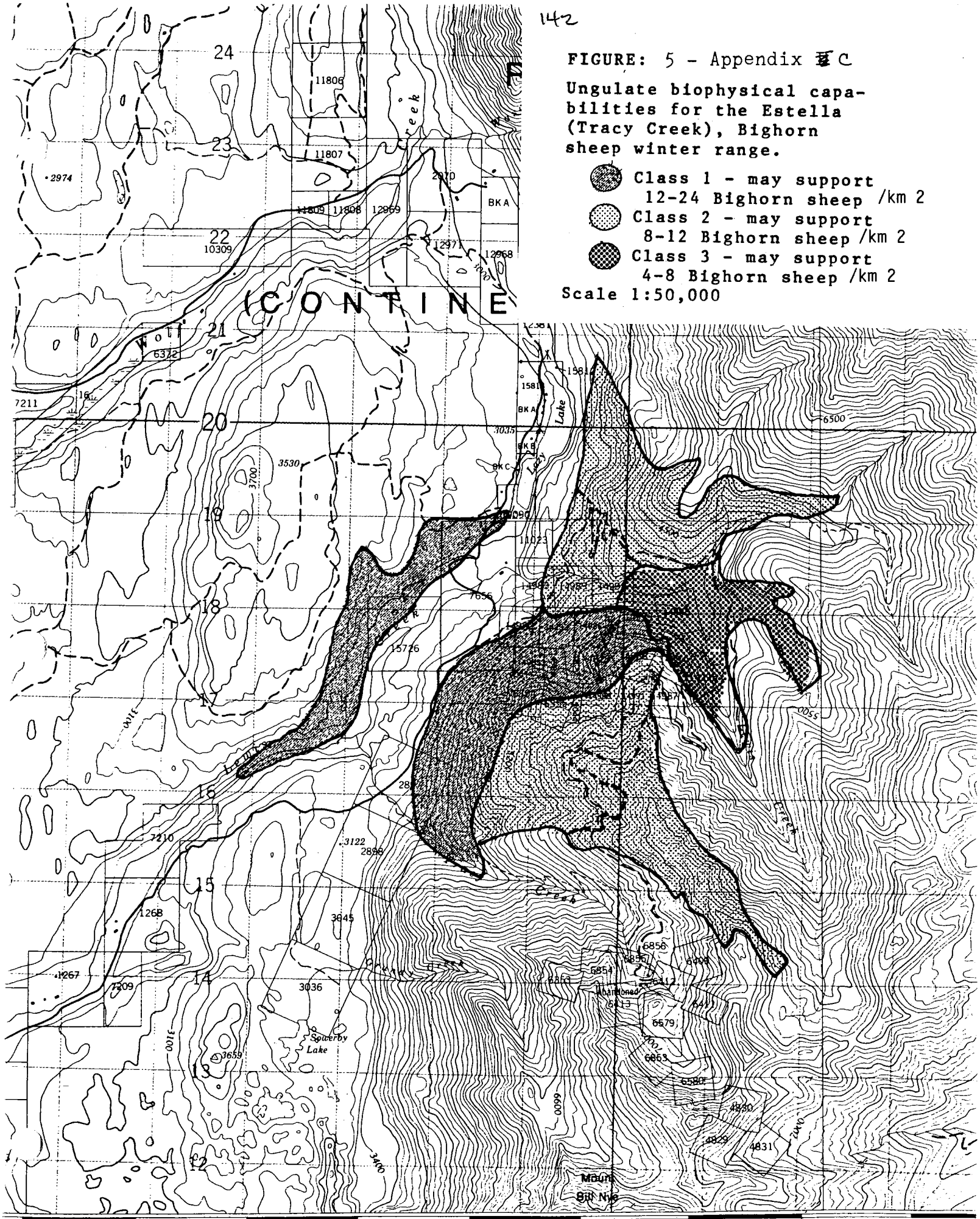



**FIGURE:** 5 - Appendix C

**Ungulate biophysical capabilities for the Estella (Tracy Creek), Bighorn sheep winter range.**

- Class 1 - may support 12-24 Bighorn sheep /km 2
- Class 2 - may support 8-12 Bighorn sheep /km 2
- Class 3 - may support 4-8 Bighorn sheep /km 2

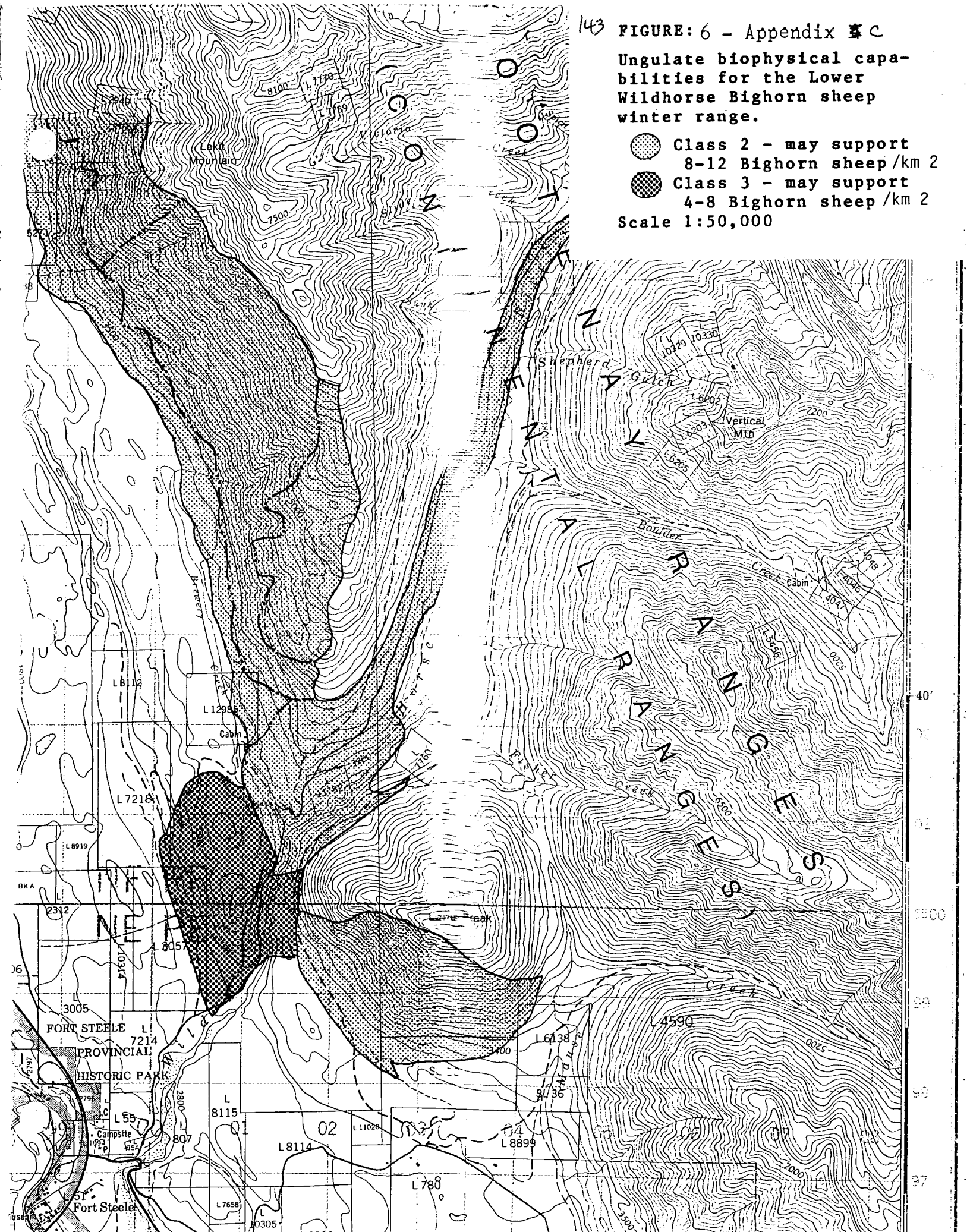
Scale 1:50,000

**FIGURE:** 6 - Appendix C

**Ungulate biophysical capabilities for the Lower Wildhorse Bighorn sheep winter range.**

- Class 2 - may support 8-12 Bighorn sheep/km 2
- Class 3 - may support 4-8 Bighorn sheep/km 2

Scale 1:50,000



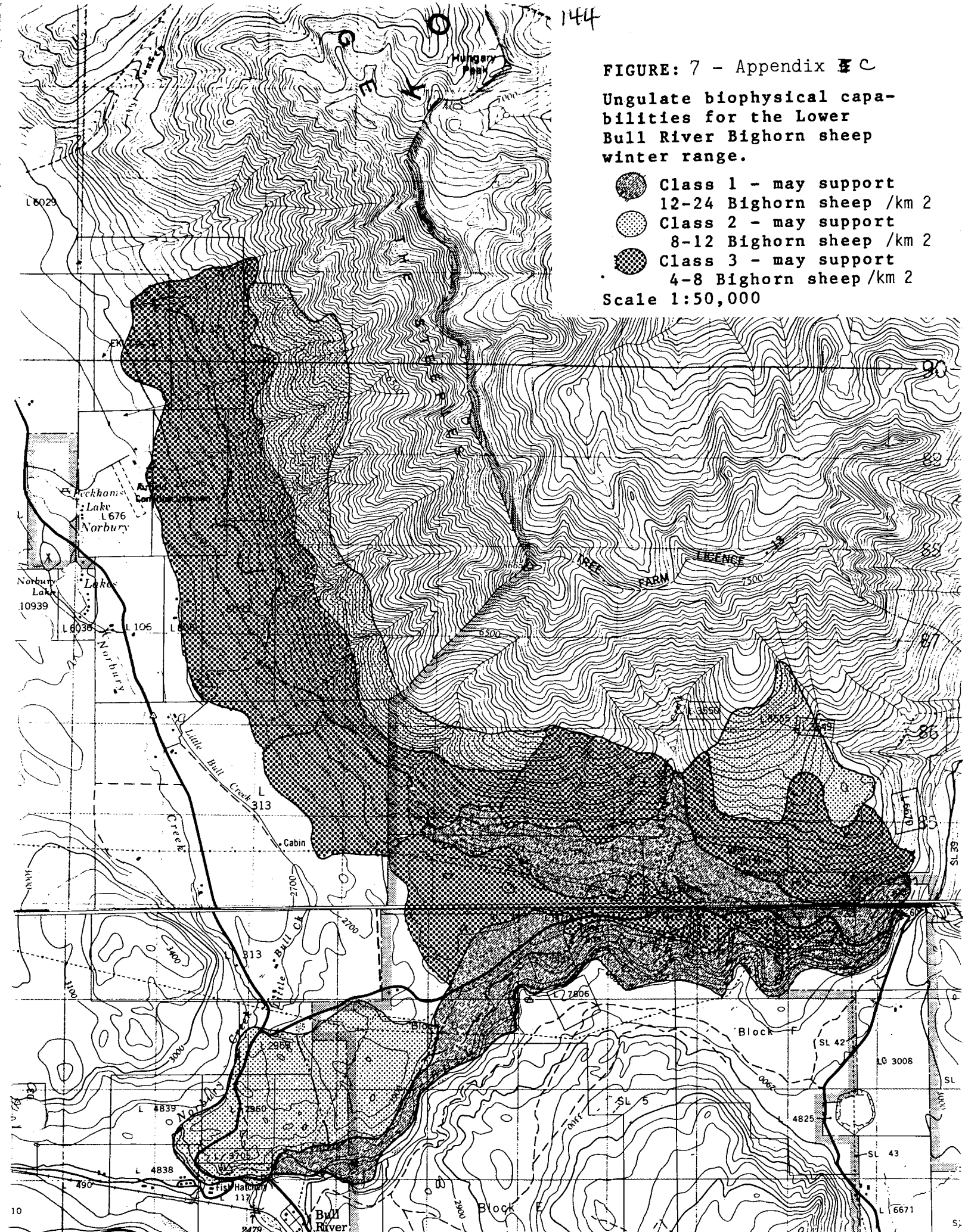



**FIGURE:** 7 - Appendix ~~B~~ C

**Ungulate biophysical capabilities for the Lower Bull River Bighorn sheep winter range.**

- Class 1 - may support 12-24 Bighorn sheep /km 2
- Class 2 - may support 8-12 Bighorn sheep /km 2
- Class 3 - may support 4-8 Bighorn sheep /km 2

Scale 1:50,000

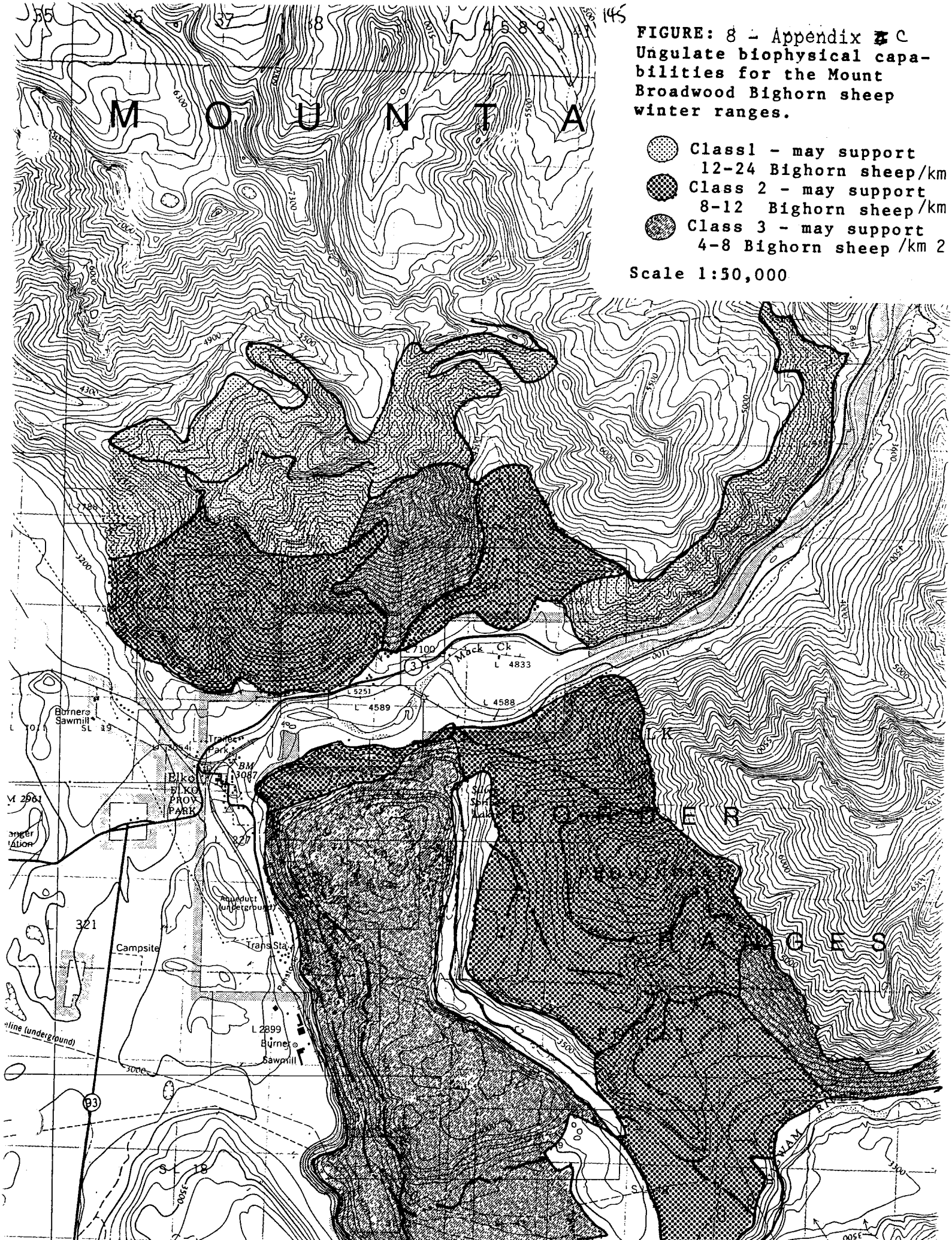



**FIGURE:** 8 - Appendix C
Ungulate biophysical capabilities for the Mount Broadwood Bighorn sheep winter ranges.

- Class1 - may support 12-24 Bighorn sheep/km 2
- Class 2 - may support 8-12 Bighorn sheep/km 2
- Class 3 - may support 4-8 Bighorn sheep /km 2

Scale 1:50,000

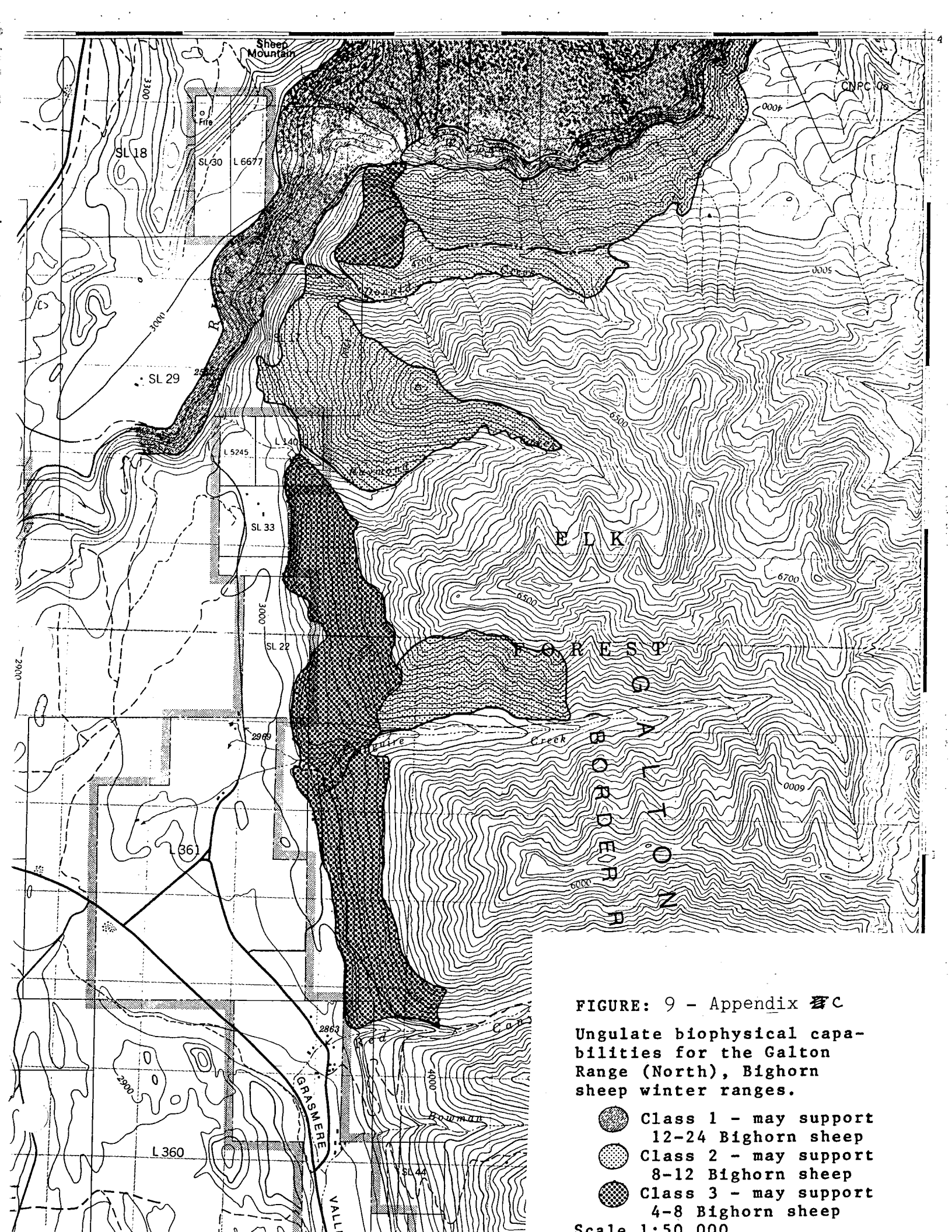



**FIGURE:** 9 - Appendix ~~B~~ C

**Ungulate biophysical capabilities for the Galton Range (North), Bighorn sheep winter ranges.**

- Class 1 - may support 12-24 Bighorn sheep
- Class 2 - may support 8-12 Bighorn sheep
- Class 3 - may support 4-8 Bighorn sheep

Scale 1:50 000

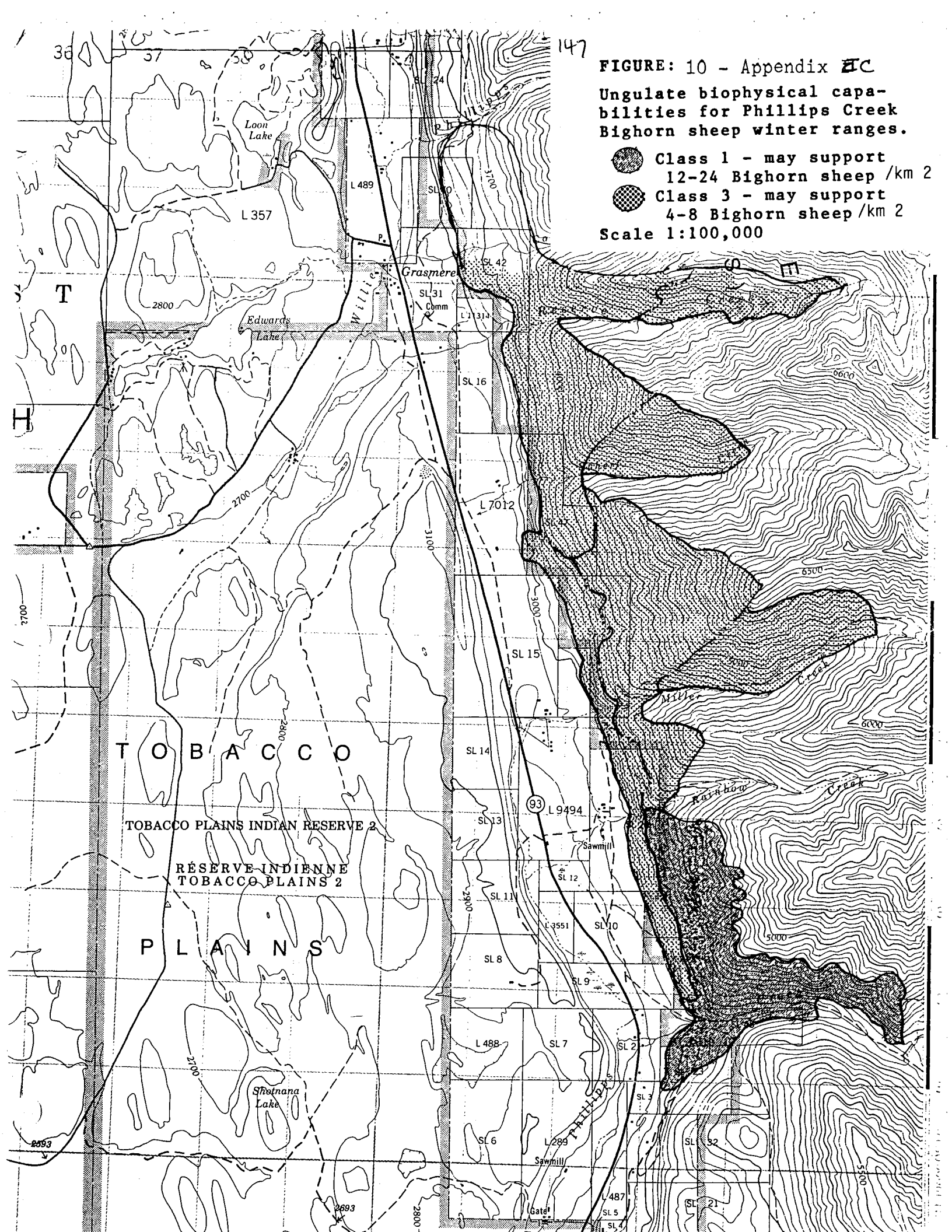
147

**FIGURE:** 10 - Appendix 4C

**Ungulate biophysical capabilities for Phillips Creek Bighorn sheep winter ranges.**

- Class 1 - may support 12-24 Bighorn sheep /km 2
- Class 3 - may support 4-8 Bighorn sheep /km 2

**Scale 1:100,000**



Appendix D. Table 1. Trace mineral level of natural mineral licks used by bighorn sheep of the East Kootenay.

| Location and Lick No. | Macronutrients (%) | | | | | Micronutrients (ppm) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | S | Ca | Fe | Cu | Mn | Zn | B | Mg | Se |
| China Wall | | | | | | | | | | | | |
| 1 | 0.07 | 0.09 | 1.09 | 0.36 | 4.61 | 18 950 | 18 | 403 | 78 | 26 | 8 | 0.8 |
| 2 | 0.97 | 0.08 | 1.11 | 0.16 | 5.32 | 15 586 | 15 | 348 | 71 | 26 | 3 | 0.371 |
| East Wigwam | | | | | | | | | | | | |
| 3 | 0.15 | 0.06 | 1.02 | 0.18 | 3.54 | 20 728 | 15 | 421 | 54 | 20 | 8 | 0.5 |
| West Wigwam | | | | | | | | | | | | |
| 4 | 0.06 | 0.09 | 1.32 | 0.39 | 5.00 | 21 133 | 20 | 506 | 84 | 31 | 9 | 0.099 |
| Lussier Hotspring | | | | | | | | | | | | |
| 1 | 0.06 | 0.03 | 1.10 | 0.59 | 8.97 | 19 267 | 18 | 221 | 49 | 10 | 9 | 0.057 |
| 2 | 0.07 | 0.04 | 0.74 | 0.02 | 9.88 | 20 822 | 17 | 334 | 43 | 10 | 6 | 0.083 |
| 3 | 0.07 | 0.04 | 1.26 | 0.31 | 10.46 | 725 000 | 21 | 232 | 49 | <1 | 9 | 0.074 |
| 4 | 0.09 | 0.05 | 1.20 | 0.22 | 11.02 | 725 000 | 17 | 298 | 46 | <1 | 9 | 0.050 |
| Whiteswan | | | | | | | | | | | | |
| 1 | 0.47 | 0.06 | 0.08 | 4.87 | 15.70 | 1 273 | 6 | 121 | 5 | 26 | <2 | 0.106 |
| 2 | 0.10 | 0.03 | 0.16 | 2.88 | 18.63 | 3 816 | 6 | 165 | 10 | 12 | 3 | 0.060 |
| 3 | 0.13 | 0.03 | 0.16 | 2.88 | 18.63 | 3 274 | 6 | 110 | 10 | 12 | 3 | 0.114 |
| 4 | 0.15 | 0.05 | 0.89 | 0.01 | 16.93 | 4 770 | 7 | 268 | 21 | 15 | 6 | 0.155 |
| 5 | 0.07 | 0.05 | 0.93 | 0.64 | 18.15 | 11 761 | 9 | 152 | 25 | 15 | 6 | 0.088 |
| $\bar{x}$ | 0.12 | 0.054 | 0.84 | 0.89 | 11.50 | 142 154 | 13.5 | 275.3 | 41.9 | 15.8 | 6.2 | 0.197 |
| SD | 0.11 | 0.021 | 0.443 | 1.41 | 6.06 | 8 677.7 | 5.8 | 123.6 | 26.3 | 9.6 | 2.7 | 0.225 |

Appendix D. Table 2. Trace mineral levels of bighorn sheep in the Rocky Mountain Trench, 1982.

| Location | Date | Sex and Age | Tissue Type | Level of Trace Mineral (ppm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Se | Cu | Zn | Fe | Mn | Ca | Mg | P | I |
| Wigwam | April | F 3 yr. | Liver | <0.07 | | | | | | | | |
| 30/82 | | F 4 yr. | | 0.12 | | | | | | | | |
| Bull R. | May | F 3 yr. | Liver | 0.33 | 54.1 | 243 | 286 | 3.6 | | | | 2.0 |
| 13/82 | | F 5 yr. | | 0.26 | 19.9 | 193 | 242 | 4.8 | | | | 2.5 |
| | | F #79 | Kidney | - | 5.0 | 54 | 66 | 1.2 | | | | - |
| | | F #82 | | - | 3.8 | 42 | 57 | 1.0 | | | | - |
| | | F #79 | Serum | 0.092 | 1.85 | 0.89 | | | 92 | 188 | 58 | |
| | | F #82 | | 0.098 | 2.42 | 0.70 | | | 96 | 229 | 61 | |
| China | Oct. | F | Liver | 0.12 | 32 | 30 | 62 | 1.7 | | | | |
| Wall | 13/82 | 5.5 yr. | Kidney | - | 4.6 | 27 | 49 | 1.1 | | | | |
| | | | Serum | 0.03 | 1.27 | 0.94 | | | 91 | 312 | - | 3.0 |
| Alexander | Oct. | M | Liver | 0.12 | 114 | 41 | 74 | 25 | | | | |
| Creek | 22/82 | 10 yr. | | | | | | | | | | |
| Cross R. | Oct. | M | Liver | 0.34 | 90 | 32 | 171 | 2.4 | | | | |
| 22/82 | | 5.5 yr. | | | | | | | | | | |
| | | | | | | | | | **Lead** | | | |
| Lower | Nov. | M | Liver | 0.07 | 11.6 | 139 | 141 | 2.5 | | 0.5 | | |
| Wildhorse | 10/82 | 6.5 yr. | Kidney | - | 3.1 | 59 | 50 | 0.9 | | 0.5 | | |
| | | | Serum | 0.014 | | | | | | | 120 | 1.5 |
| Wigwam | Dec. | F | Serum | 0.095 | 0.93 | | | | 100 | 279 | 20 | 1.5 |
| Healthy | 15/82 | 5.5 yr. | | | | | | | | | | |
| Ft.Collins | Dec. | $n$ = 32 | Serum | 0.10 $\bar{x}$ | | | | | | | | |
| Colo. | /82 | | Range = 0.04 - 0.4 | | | | | | | | | |
| Sheep R., | 1982 | $n$ = 3 | Serum | 0.066 | 0.66 | 2.3 | | | | | | <1 |
| Alta. | | | | 0.026 | 0.69 | 2.7 | | | | | | 1 |
| | | | | 0.048 | 0.73 | 1.9 | | | | | | 2 |
| Ram R., | | $n$ = 2 | Serum | 0.026 | 1.17 | 1.4 | | | | | | 2.5 |
| Alta. | | | | 0.021 | - | - | | | | | | 2.5 |

Appendix D. Table 3. Trace mineral levels of domestic sheep.

| Mineral Levels | Tissue Type | Level of Trace Mineral (ppm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Se | Cu | Zn | Fe | Mn | Ca | Mg | P | I |
| Deficient[a] | Serum | 0.006-0.03 | 0.1-0.6 | 0.22-0.45 | | | 0.01-0.02- | 0.5-1.5 | | 2.5 |
| | Liver | 0.005-0.100 | 0.5-4.0 | - | | | 1.0-2.1 | | | |
| | Kidney | - | - | - | 13-25 | | 1.0- | | | |
| | Diet | | | 1-20 | <40 | 2.0 6.0 | | | | <0.08 |
| Marginal | Serum | 0.03-0.05 | 0.4-0.8 | 0.40-0.80 | | | 0.012-0.014 | | | 3.0-4.0 |
| | Liver | 0.150-0.250 | 5.0-20 | 30.0-75 | 45-300 | | | | | |
| | Kidney | 0.70-1.10 | | | | | 0.5-1.2 | | | |
| | Diet[b] | 0.1 | | 30.-50 | 30-50 | 8-20 | | | | 0.1-0.4 |
| Toxic | Serum | 3.0 20 | 3.3-50 | 30.-0.80 | 0.40- | | | 30 000 | | 4 000.- |
| | Liver | 15.0-30.0 | 250.-1000 | | | | 5.0-10.0 | | | |
| | Kidney | 6.0-15.0 | 18.0-120.6 | | | | 5.0+ | | | |
| | Diet | | | 2000 | 4000 | 1000 | | 10 000 | 30 000. | 4 000. |

[a] Puls 1981

[b] MacDonald *et al.* 1976 or 0.0007 mg Se/kg body weight.

**Appendix E. Part 1. Ground cover and forage production on major bighorn sheep winter ranges in the Rocky Mountain Trench.**

| Cover type | Ground cover (%) | | | | Forage production (kg/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | Grazed | | Ungrazed | | Grazed | | Ungrazed | |
| | 1984 | 1987 | 1984 | 1987 | 1984 | 1987 | 1984 | 1987 |
| **GRASSES** | | | | | | | | |
| Columbia Lake | 20.0 ± 5.3[a] | 17.3 ± 1.8 | 37.1 ± 6.4* | 31.5 ± 4.9* | 187[b] | 162 ± 24.3 | 473* | 714 ± 417.6* |
| Premier Ridge | 26.1 ± 3.1 | 18.5 ± 2.0** | 25.3 ± 3.0 | 21.8 ± 3.7 | | 587 ± 315 | | 823 ± 425 |
| Bull River (BR 7) | 40.9 ± 4.4 | | 31.0 ± 7.4* | | 1058 | | 798 | |
| Bull River (BR 9) | 16.3 | | 21.2 | | | | | |
| Wigwam Flats (PCE) | | | | | 259 | 631 | 1130* | 854 |
| **FORBS** | | | | | | | | |
| Columbia Lake | 8.7 ± 3.2 | 5.3 ± 1.1** | 3.5 ± 2.5 | 2.1 ± 2.2* | 97 | 125 ± 56.4 | 53* | 85 ± 32.4 |
| Premier Ridge | 17.5 ± 4.5 | 18.1 ± 5.4 | 29.0 ± 6.8* | 27.9 ± 4.9* | | 2 ± 75 | | 317 ± 144* |
| Bull River (BR 7) | 18.0 | | 6.2* | | 174 | | 250 | |
| Bull River (BR 9) | 22.2 | | 22.7 | | | | | |
| Wigwam Flats (PCE) | | | | | 112 | 141 | 204 | 34* |
| **SHRUBS** | | | | | | | | |
| Columbia Lake | 3.0 ± 2.4 | 9.6 ± 3.2 | 1.7 ± 1.4 | 6.6 ± 3.1** | 112 | 99 ± 73.4 | 34* | 265 ± 299.5 |
| Premier Ridge | 23.6 ± 5.4 | 27.6 ± 21.2 | 14.6 ± 4.9* | 25.9 ± 24.8 | | 232 ± 256 | | 590 ± 716 |
| Bull River (BR 7) | 9.6 | | 29.8* | | 428 | | 750* | |
| Bull River (BR 9) | 47.0 | | 37.0 | | | | | |
| Wigwam Flats (PCE) | | | | | 144 | 22 | 114 | 58* |
| **TOTAL FORAGE** | | | | | | | | |
| Columbia Lake | 31.7 | 32.2 | 42.3 | 40.2 | 396 | 386 ± 93.3 | 560* | 1064 ± 617.8* |
| Premier Ridge | 67.2 ± 8.6 | 60.7 ± 8.8 | 69.0 ± 6.2 | 70.2 ± 10.2 | | 941 ± 434[c] | | 1730 ± 1064 |
| Bull River (BR 7) | 68.5 | | 67.0 | | 1660 | | 1798 | |
| Bull River (BR 9) | 85.5 | | 80.9 | | | | | |
| Wigwam Flats (PCE) | | | | | 515 | 793 | 1457* | 945 |
| **CRYPTOGAMS** | | | | | | | | |
| Columbia Lake | 0 | 0 | 0.3 | 0 | | | | |
| Premier Ridge | 7.0 ± 6.2 | 4.3 ± 2.8 | 13.6 ± 7.5* | 19.3 ± 10.3* | | | | |
| Bull River (BR 7) | 3.9 ± 4.8 | | 2.3 ± 3.9 | | | | | |
| Bull River (BR 9) | 0 | | 6.1 | | | | | |
| **LITTER** | | | | | | | | |
| Columbia Lake | 3.2 ± 1.2 | 6.7 ± 0.9** | 2.4 ± 1.5 | 16.4 ± 4.39*** | 289 | 718 ± 323.3 | 318 | 734 ± 694.8 |
| Premier Ridge | 27.5 ± 4.4 | 27.5 ± 4.6** | 14.0 ± 10.1 | 39.7 ± 10.9*** | 1078 | | 1030 | |
| Bull River (BR 7) | | | | | 393 | | 681 | |
| Bull River (BR 9) | 11.1 | | 15.9 | | | | | |
| Wigwam Flats (PCE) | | | | | 2810 | 1639 | 5126* | 4515 |

**Appendix E, Part 1, continued**

| Cover type | Ground cover (%) | | | | Forage production (kg/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | Grazed | | Ungrazed | | Grazed | | Ungrazed | |
| | 1984 | 1987 | 1984 | 1987 | 1984 | 1987 | 1984 | 1987 |
| **BARE GROUND** | | | | | | | | |
| Columbia Lake | 69.1 ± 3.9 | 58.1 ± 5.5** | 58.7 ± 5.2* | 11.9 ± 3.8*** | | | | |
| Premier Ridge | 8.3 ± 4.3 | 8.8 ± 5.2 | 4.1 ± 1.7* | 2.4 ± 1.5* | | | | |
| Bull River (BR 7) | 0.2 | | 0.3 | | | | | |
| Bull River (BR 9) | 0 | | 1.0 | | | | | |
| **ROCK** | | | | | | | | |
| Columbia Lake | 0.1 | 0 | 0.8 ± 0.6 | 1.3 ± 1.3 | | | | |
| Premier Ridge | 2.6 ± 0.9 | 4.1 ± 1.4 | 3.6 ± 2.1 | 2.1 ± 1.0* | | | | |
| Bull River (BR 7) | 0.4 | | 0.2 | | | | | |
| Bull River (BR 9) | 0.5 | | 1.6 | | | | | |

[a] ± SD
[b] Original data for 1984 were lost so SD could not be produced
[c] If kinnikinnick included as a shrub, production was 1692 kg/ha
* Significant difference between grazed and ungrazed; ** Significant difference between years; *** Significant difference between grazed and ungrazed and between years.

**Appendix E, Part 2. Ground cover and frequency of plant species on grazed range compared to ungrazed range in the Rocky Mountain Trench.**

**Stoddart Creek, 1966 and 1984**

| Cover type | Ground cover (%) | | | |
|---|---|---|---|---|
| | Grazed | | Ungrazed | |
| | 1966 | 1984 | 1966 | 1984 |
| Grasses | 27.7 | 17.5 | 43.5 | 13.9 |
| Forbs | 14.7 | 9.5 | 15.1 | 9.9 |
| Shrubs | 5.0 | 6.6 | 11.3 | 16.7 |
| Total forage | 47.4 | 33.6 | 69.9 | 40.5 |
| Litter | 10.6 | 16.4 | 10.6 | 31.5 |
| Rock | 10.0 | 22.6 | 10.0 | 10.8 |
| Bare ground | 46.9 | 16.7 | 46.9 | 2.7 |
| Cryptogams | | 9.4 | | 15.6 |

**Columbia Lake, July 1984 and 1987**

| Plant Species | Cover (%) | | | | Frequency (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | Ungrazed | | Grazed | | Ungrazed | | Grazed | |
| | 1984[a] | 1987 | 1984 | 1987 | 1984 | 1987 | 1984 | 1987 |
| **GRASSES** | | | | | | | | |
| porcupinegrass | 26.2 | 26.1 | 14.7 | 17.4 | 100 | 80 | 97 | 97.5 |
| junegrass | 2.2 | 9.0 | 0.1 | 1.9 | 43 | 60 | 45 | 42.5 |
| downy wheatgrass | 2.8 | 1.8 | 2.4 | 0 | 43 | 57.5 | 5 | 0 |
| timber oatgrass | | 0.4 | | 0.3 | | 10 | | 17.5 |
| bluebunch wheatgrass | | 0.1 | | 0.1 | | 2.5 | | 2.5 |
| sedges | | 1.4 | | 0.1 | | 22.5 | | 2.5 |
| giant wildrye | | T | | 0 | | 2.5 | | 0 |
| **Total** | | 38.8 | | 18.8 | | | | |
| **FORBS** | | | | | | | | |
| pasture dage | 0.9 | 4.3 | 1.8 | 5.2 | 29 | 62.5 | 41 | 70.0 |
| pussytoes | | 0.4 | | 0.5 | | 5.0 | | 2.5 |
| blue-eyed Mary | | 0.6 | | 1.3 | | 15.0 | | 45.0 |
| fleabane | | 0.6 | | 2.6 | | 17.5 | | 62.5 |
| wild blue flax | | 0.4 | | 0.3 | | 15.0 | | 17.5 |
| nodding onion | | T | | 0 | | 2.5 | | 0 |
| cut-leaved anemone | | 0 | | 0.3 | | 0 | | 7.5 |
| northern wormwood | | 0 | | T | | 0 | | 2.5 |
| mariposa lily | | 0 | | T | | 0 | | 2.5 |
| gumweed | | T | | 0 | | 2.5 | | 0 |
| desert-parsley | | 0 | | 0.1 | | 0 | | 7.5 |
| Columbia bladderpod | 0.7 | 0 | 1.0 | 0.3 | 63 | 5.0 | 71 | 52.5 |
| dalmatian toadflax | | 0 | | 0.2 | | 0 | | 7.5 |
| alsike clover | | o | | T | | 0 | | 7.5 |
| unknown | | 0 | | T | | 0 | | 2.5 |
| **Total** | | 6.3 | | 10.8 | | | | |
| **SHRUBS** | | | | | | | | |
| rabbit-brush | | 2.4 | | 4.7 | | 55.0 | | 25.0 |
| **BARE GROUND** | 58.7 | | 69.1 | | 100 | | 97 | |
| **LITTER** | 2.4 | | 3.2 | | 56 | | 69 | |

[a] Species list for 1984 is incomplete because original data were lost.

**Premier Ridge (PR 1), July 1984 and 1987**

| Plant Species | Cover (%) | | | | Frequency (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | Ungrazed | | Grazed | | Ungrazed | | Grazed | |
| | 1984[a] | 1987 | 1984 | 1987 | 1984 | 1987 | 1984 | 1987 |
| **GRASSES** | | | | | | | | |
| pinegrass | 2.3 | 8.0 | 12.1 | 7.9 | 39 | 60 | 71 | 18 |
| Canada bluegrass | 19.0 | 6.5 | 7.5 | 5.9 | 77 | 58 | 63 | 55 |
| rough fescue | 1.7 | 5.5 | 1.3 | 1.7 | 13 | 28 | 21 | 30 |
| junegrass | 1.5 | 0.6 | 1.4 | 1.4 | 32 | 3 | 44 | 58 |
| bluebunch wheatgrass | 0.8 | 0.7 | 0.3 | 0.8 | 5 | 8 | 7 | 18 |
| sedges | T | 0.2 | 0.2 | 0.2 | 1 | 8 | 9 | 13 |
| slender wheatgrass | T | 0.2 | 0.2 | 0.1 | 1 | 3 | 11 | 3 |
| sm. western needlegrass | 0.2 | | 0 | 0.2 | 5 | | 0 | 3 |
| Idaho fescue | 0.1 | 0.1 | 0 | 0 | 4 | 3 | 0 | 0 |
| hairy wildrye | | | | 0.1 | | | | 3 |
| alpine fescue | | | | 0.1 | | | | 3 |
| downy wheatgrass | | | | 0.1 | | | | 3 |
| porcupinegrass | 0 | | 0.1 | | 0 | | 1 | |
| intermediate wheatgrass | T | | T | | 1 | | 1 | |
| **Total** | 25.3 | 21.8 | 26.1 | 18.5 | | | | |
| **FORBS** | | | | | | | | |
| rosy pussytoes | 5.5 | 5.7 | 0.6 | 0.9 | 52 | 73 | 19 | 25 |
| aster | 2.7 | 4.3 | 0.8 | 2.7 | 39 | 64 | 12 | 45 |
| hairy golden-aster | 3.6 | 5.5 | 4.5 | 4.3 | 49 | 68 | 48 | 73 |
| wild strawberry | 4.7 | 3.5 | 1.2 | 2.6 | 61 | 73 | 20 | 45 |
| yarrow | 2.4 | 2.2 | 3.2 | 1.8 | 67 | 60 | 65 | 68 |
| Canada goldenrod | 0.2 | 0.4 | 1.4 | 1.1 | 11 | 3 | 15 | 23 |
| yellow penstemon | 0.8 | T | 0.1 | 0 | 23 | 5 | 4 | 3 |
| yellow hedysarum | 0.2 | 0 | 1.1 | 0.8 | 5 | 0 | 7 | 10 |
| Lyall's mariposa lily | 0.2 | 0.1 | 0.3 | 0 | 8 | 5 | 10 | 3 |
| dandelion | 0.1 | 0.2 | 1.2 | 0.3 | 8 | 13 | 43 | 3 |
| yellow avens | 0.8 | 0 | 0.6 | 0.3 | 19 | | 20 | 18 |
| lemonweed | 0.2 | 0.3 | 0 | | 4 | 8 | 0 | 0 |
| pearly everlasting | | 0 | | 0.1 | | | | 5 |
| field pussytoes | | T | | 0 | | 3 | | 0 |
| globeflower | 0.1 | 0.1 | 0 | 0.2 | 7 | 5 | 0 | 3 |
| arrow-lvd. balsamroot | 2.2 | | 0.9 | | 19 | | 4 | |
| heart-lvd. arnica | | 0.4 | | | 3 | 3 | | |
| fleabane | | 0.3 | | | | 8 | | |
| gumweed | | 0.1 | | | | 3 | | |
| march valerian | | 0.3 | | | | 10 | | |
| nodding onion | | 0.1 | | | | 3 | | |
| prairie onion | | T | | | | 3 | | |
| perennial sow-thistle | | 0.8 | | 2.1 | | 15 | | 40 |
| goatsbeard | | | | | | | | 3 |
| Columbia bladderpod | | | | | | | | 8 |
| sunflower | | 3.1 | | 0.8 | | 25 | | 10 |
| racemose pussytoes | T | | | | 3 | | 3 | |
| violet | | 0.1 | T | | | 3 | | |
| shepherd's purse | 0 | | | | 0 | | 2 | |
| wormseed mustard | 0.2 | | T | | 4 | | 0 | |
| round-lvd. alumroot | 0.3 | | 0 | | 3 | | 0 | |
| harebell | T | | 0 | | 1 | | 0 | |
| unknown | | 0.4 | 0 | 0.1 | | 3 | | 3 |
| **Total** | 29.0 | 27.9 | 17.5 | 18.1 | | | | |
| **SHRUBS** | | | | | | | | |
| kinnikinnick | 12.1 | 2.6 | 2.9 | 11.7 | 52 | 20 | 15 | 63 |
| soopolallie | 5.6 | 7.3 | 5.5 | 3.9 | 15 | 23 | 9 | 10 |
| saskatoon | 0.8 | 1.8 | 2.3 | 3.5 | 4 | 10 | 23 | 38 |
| prairie rose | 0.7 | 1.9 | 1.3 | 3.5 | 8 | 23 | 16 | 28 |
| rose | 0.2 | | 0.6 | | 9 | | 7 | |
| antelope-brush | 2.4 | 3.1 | 0 | 0.6 | 4 | 8 | 0 | 8 |
| birch-leaved spirea | 1.1 | 1.1 | 1.0 | 0.3 | 4 | 15 | 17 | 15 |
| interior Douglas-fir | 0.2 | 2.7 | 0.4 | 0.6 | 8 | 5 | 7 | 3 |
| **Total** | 23.1 | 20.5 | 14.6 | 24.1 | | | | |
| **Total Forage** | | 70.2 | | 60.7 | | | | |
| **CRYPTOGAMS** | 13.6 | 4.3 | 7.0 | 19.3 | | | | |
| **LITTER** | 27.5 | 27.5 | 39.7 | 39.7 | | | | |
| **ROCK** | 4.1 | 4.1 | 2.1 | 2.1 | | | | |
| **BARE GROUND** | 8.8 | 8.8 | 2.4 | 2.4 | | | | |

**Lower Bull River (BR 7), 1966 and 1984.**

| Plant species | Type | Plant cover (%) | |
|---|---|---|---|
| | | 1966 | 1984 |
| **GRASSES** | | | |
| downy wheatgrass | Dec | 2.0 | 0 |
| slender wheatgrass | Dec | 1.0 | 2.7 |
| rough fescue | Dec | 0 | 2.5 |
| Idaho fescue | Dec | 0 | 3.9 |
| alpine fescue | Dec | 9.4 | 0 |
| small western needlegrass | Inc | 0 | 8.4 |
| cheatgrass | Inc | 7.2 | 0 |
| pinegrass | Inc | 2.1 | 0 |
| junegass | Inc | 7.8 | 0.3 |
| Kentucky bluegrass | Inc | 27.0 | 0 |
| unknown needlegrass | Inc | 0 | T |
| **Total** | | 69.2 | 30.9 |
| **FORBS** | | | |
| yarrow | Inc | 7.5 | 0.4 |
| rosy pussytoes | Inc | 4.1 | 0.1 |
| timber milk-vetch | Dec | 0.9 | 0 |
| alpine willowherb | Inc | 1.2 | 0 |
| round-leaved alumroot | Inc | 1.3 | 0 |
| goatsbeard | Inc | 3.9 | 0 |
| Lyall's mariposa lily | Inc | 0 | 0.2 |
| nodding onion | Inc | T | 0 |
| cut-leaved anemone | Inc | T | 0 |
| Holboell's rockcress | Inc | T | 0 |
| aster | Dec | T | T |
| wavy-leaved thistle | Inc | T | 0.1 |
| large-flowered collomia | Inc | T | 0 |
| fireweed | Dec | 0 | 0.1 |
| fleabane | Inc | T | 0 |
| yellow avens | Inc | T | 0 |
| old man's whiskers | Inc | 0 | 0.5 |
| lemonweed | Inc | T | 0.2 |
| black medic | Inc | T | 0.1 |
| yellow penstemon | Inc | T | 0 |
| graceful cinquefoil | Inc | T | 0 |
| northern starwort | Inc | 0 | 0.1 |
| woolly mullein | Inc | 0 | T |
| **Total** | | 18.9 | 3.7 |
| **SHRUBS** | | | |
| antelope-brush | Dec | 27.5 | 26.9 |
| saskatoon | Dec | 1.2 | 2.2 |
| kinnikinnick | Inc | 2.1 | 2.3 |
| prickly rose | Inc | T | 0.7 |
| birch-leaved spirea | Inc | T | 0 |
| common snowberry | Inc | 0 | 0.1 |
| **CRYPTOGAMS** | | 1.9 | 2.3 |
| **LITTER** | | 17.5 | 31.5 |
| **BARE GROUND** | | 3.8 | 0.3 |
| **ROCK** | | 0 | 0.2 |

**Upper Bull River (BR 9), 1966 and 1984.**

| Plant species[a] | Type | Ground cover (%) | | | Frequency (%) | |
|---|---|---|---|---|---|---|
| | | Grazed | | Ungrazed 1984 | Grazed 1984 | Ungrazed 1984 |
| | | 1966 | 1984 | | | |
| **GRASSES** | | | | | | |
| Canada bluegrass | Inc | 6.4 | 11.3 | 7.3 | 93 | 81 |
| Kentucky bluegrass | Inv | 8.0 | | | | |
| slender wheatgrass[b] | Dec | | 4.5 | 5.0 | 64 | 55 |
| bluebunch wheatgrass | Dec | 1.2 | | | | |
| timothy | Inv | 4.4 | 3.5 | 1.5 | 47 | 35 |
| pinegrass | Inc | 4.1 | 0.2 | 1.8 | 4 | 20 |
| soft brome | Inc | 1.0 | | | | |
| cheatgrass | Inc | 5.2 | | | | |
| downy wheatgrass | | 1.0 | | | | |
| timber oatgrass | Inc | | 0.3 | 0.5 | 1 | 1 |
| poverty oatgrass | Inc | T | | | | |
| junegrass | Inc | 2.3 | 1.0 | 0.5 | 21 | 15 |
| sedge | Var | 1.5 | | | | |
| **Total** | | 35.1 | 20.8 | 16.6 | | |
| **FORBS** | | | | | | |
| spreading dogbane | Inc | 4.6 | 0.3 | 11.5 | 4 | 49 |
| American vetch | Dec | | 3.0 | 4.3 | 51 | 69 |
| black medic | Inv | | 10.0 | 2.0 | 49 | 11 |
| yarrow | Inc | 5.3 | 1.3 | 1.5 | 28 | 41 |
| cut-leaved anemone | Dec | | 0.2 | | | 2 |
| rosy pussytoes | Inc | 1.4 | 2.9 | 0.7 | 21 | 4 |
| aster | Dec | 1.4 | 1.2 | 0.7 | 19 | 12 |
| wild strawberry | Inc | 2.0 | 0.4 | 0.5 | 9 | 13 |
| peavine | Inc | | 1.5 | 0.2 | 13 | 3 |
| early blue violet | Dec | 1.3 | 0.3 | 0.4 | 12 | 9 |
| alpine willowherb | Var | 0.7 | 0.1 | | 2 | |
| Holboell's rockcress | Inc | | | T | | |
| wavy-leaved thistle | Inc | T | | | | |
| blue-eyed Mary | Inc | T | | | | |
| creamy peavine | Inc | | | 0.2 | | |
| yellow penstemon | Var | T | | | | |
| goatsbeard | Inv | T | | | | |
| white clover | Inv | T | | | | |
| **Total** | | 16.7 | 21.2 | 22.0 | | |
| **SHRUBS** | | | | | | |
| saskatoon | Dec | 23.5 | 16.9 | 20.4 | 43 | 47 |
| common snowberry | Inc | 29.2 | 15.1 | 15.1 | 73 | 84 |
| redstem ceanothus | Dec | 21.0 | | 4.4 | | 21 |
| Oregon-grape | Var | 1.1 | 2.3 | 1.3 | 43 | 9 |
| antelope-brush | Dec | T | | 1.6 | | 8 |
| birch-leaved spirea | Inc | 3.9 | 1.7 | 0.8 | 28 | 12 |
| rose | Var | 1.0 | 1.0 | 0.8 | 8 | 8 |
| kinnikinnick | Inc | T | T | 0.7 | 9 | 9 |
| chole cherry | Dec | | T | 1.2 | 1 | 1 |
| **Total** | | 79.7 | 37.0 | 46.3 | | |
| **LITTER** | | 17.5 | 11.1 | 15.9 | | |
| **CRYPTOGAMS** | | 0.6 | | 6.1 | | |
| **ROCK** | | | 1.0 | 1.6 | | |
| **BARE GROUND** | | | | 1.0 | | |

[a] Plant species on grazed range in 1966 and 1984 and ungrazed range in 1984 were 11:6:6 grasses, respectively; 12:10:10 forbs and 8:7:9 shrubs.

[b] Slender wheatgrass may have been called bluebunch wheatgrass in 1966.

**Wigwam Flats, July 1984 and 1987.**

| Plant Species[a] | Cover (%) | | | | Frequency (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | Ungrazed | | Grazed | | Ungrazed | | Grazed | |
| | 1984 | 1987 | 1984 | 1987 | 1984 | 1987 | 1984 | 1987 |
| **GRASSES** | | | | | | | | |
| rough fescue | 34.8 | 33.6 | 1.7 | 3.0 | 36 | 100 | 37 | 65 |
| bluebunch wheatgrass | 13.3 | 0.9 | 11.3 | 12.5 | 64 | 20 | 61 | 95 |
| junegrass | 2.2 | 1.6 | 5.4 | 5.4 | 58 | 57 | 55 | 90 |
| sedge | 0.2 | 0.1 | T | 0 | 2 | 5 | 1 | 0 |
| Canada bluegrass | 0.3 | | 0.2 | | 1 | | 1 | |
| Sandberg's bluegrass | | 0 | | 0 | | 0 | | 3 |
| muttongrass | | T | | T | | 3 | | 3 |
| **Total** | 50.8 | 36.2 | 18.6 | 20.9 | | | | |
| **FORBS** | | | | | | | | |
| wild bergamot | 4.0 | 1.9 | 4.7 | 6.0 | 70 | 45 | 63 | 73 |
| yarrow | 0.2 | 0.1 | 0.6 | 1.3 | 5 | 7 | 40 | 45 |
| cut-leaved anemone | 0.7 | 0.6 | 0.3 | 0.4 | 7 | 3 | 8 | 30 |
| Hood's phlox | 2.4 | 2.3 | 2.3 | 3.4 | 60 | 67 | 48 | 85 |
| desert-parsley | 0.4 | 1.1 | 0 | 1.6 | 1 | 50 | 0 | 55 |
| rosy pussytoes | 2.2 | 0 | 0.2 | T | 1 | 0 | 1 | 3 |
| field pussytoes | 0.2 | | 0 | | 1 | | 0 | |
| aster | T | 0 | 0.2 | 0.2 | 0 | 0 | 1 | 7 |
| yellowish paintbrush | 0.2 | 0 | 1.5 | 0.1 | 22 | 0 | 17 | 3 |
| blue-eyed Mary | 0.2 | 0 | 0.1 | 0 | 1 | 3 | 5 | 0 |
| chickweed | 1.4 | T | 1.2 | 0 | 45 | 5 | 39 | 0 |
| yellow penstemon | 1.4 | 0 | 0 | T | 5 | 0 | 1 | 3 |
| long-leaved starwort | 1.4 | 0.8 | 1.2 | 0.9 | 45 | 45 | 39 | 53 |
| yellow salsify | 0 | | 3.0 | | 0 | | 1 | |
| early blue violet | 1.0 | 0 | 0 | T | 5 | 3 | 0 | 3 |
| nodding onion | 0.2 | 0 | 0.2 | T | 1 | 0 | 1 | 3 |
| Lyall's mariposa lily | 0.5 | | 0.1 | | 21 | | 3 | |
| shootingstar | 2.1 | | 0 | | 1 | | 0 | |
| alpine willowherb | 0.1 | | 0 | | 1 | | 0 | |
| fleabane | 0 | | 0.4 | | 0 | | 13 | |
| northern bedstraw | 0.3 | | 0 | | 1 | | 0 | |
| yellow hedysarum | T | | 0 | | 1 | | 0 | |
| round-leaved alumroot | T | | 0 | | 1 | | 0 | |
| pearly everlasting | | 0.1 | | 0.5 | | 3 | | 30 |
| Nuttall's pussytoes | | 0.2 | | 0 | | 10 | | 0 |
| unclass. pussytoes | | 0.2 | | 0.4 | | 7 | | 8 |
| showy Jacob's-ladder | | 0.2 | | 0 | | 5 | | 0 |
| harebell | | 0.2 | | T | | 7 | | 3 |
| old man's whiskers | | 0 | | T | | 0 | | 3 |
| alpine hedysarum | | 0 | | T | | 0 | | 3 |
| owl-clover | | 0 | | 0.8 | | 0 | | 45 |
| sticky cinquefoil | | 0 | | 0.1 | | 0 | | 5 |
| Canada goldenrod | | 0.2 | | 0.2 | | 15 | | 10 |
| perennial sow-thistle | | 0 | | T | | 0 | | 3 |
| dandelion | | 0 | | 0 | | 0 | | 5 |
| goatsbeard | | T | | 0.1 | | 3 | | 3 |
| **Total** | 18.9 | 8.9 | 16.0 | 16.0 | | | | |
| **SHRUBS** | | | | | | | | |
| prairie rose | 3.3 | 2.0 | 0.4 | 0.7 | 8 | 35 | 8 | 17 |
| birch-leaved spirea | T | | 0.5 | | 7 | | 9 | |
| pin cherry | 1.5 | 1.7 | 0 | 0 | 1 | 7 | 0 | 0 |
| choke cherry | 0.3 | 0.2 | 0.2 | 0.1 | 1 | 5 | 1 | 3 |
| saskatoon | | 0 | | 0.1 | | 0 | | 3 |
| **Total** | 5.1 | 3.9 | 1.1 | 1.0 | | | | |
| **CRYPTOGAMS** | 74.4 | 35.0 | 53.7 | 36.2 | | | | |
| **LITTER** | 10.6 | 22.1 | 3.7 | 22.3 | | | | |
| **BARE GROUND** | 5.5 | 1.2 | 4.2 | 1.8 | | | | |
| **ROCK** | 0.6 | 2.5 | 2.1 | 2.9 | | | | |

[a] Plant species present on grazed compared to ungrazed were 5:5, grasses, respectively; 14:21, forbs; 3:4 shrubs.

F.

**Appendix F. Part 1. Ground cover and frequency of plant species on treated range compared to untreated range in the Rocky Mountain Trench. Lower Burntbridge Basin**

| Plant species | Ground cover (%)[a] | | | | | | Frequency (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Burned (BR 1) | | | Unburned (BR 2) | | | Burned (BR 1) | | | Unburned (BR 2) | | |
| | 1982 | 1983 | 1984 | 1982 | 1983 | 1984 | 1982 | 1983 | 1984 | 1982 | 1983 | 1984 |
| **GRASSES** | | | | | | | | | | | | |
| Canada bluegrass | 20.6 | 38.1 | 26.7 | 17.1 | 38.4 | 24.9 | 85.0 | 95.0 | 95 | 97.5 | 82.5 | 9 |
| junegrass | 0.1 | 0.4 | | 0.2 | | | 7.3 | 12.5 | | 5.0 | | |
| slender wheatgrass | 0.2 | 0.2 | | 0.1 | 0.2 | | 12.2 | 10.0 | | 2.5 | 5.0 | |
| timothy | 0.1 | 0.1 | | 0.1 | 0.1 | | 2.4 | 2.5 | | 2.5 | 5.0 | |
| spreading needlegrass | 2.6 | 4.7 | | 0.8 | 1.4 | | 24.4 | 32.5 | | 2.5 | 7.5 | |
| Idaho fescue | 1.8 | 0.1 | | | | | 22.0 | 2.5 | | | | |
| sm. western needlegrass | 0.2 | 0.3 | | | | | 14.6 | 5.0 | | | | |
| bluebunch wheatgrass | 0.1 | | | | 0.1 | | 2.5 | | | | 2.5 | |
| sedge | T | | | | 0.3 | | 2.5 | | | | 5.0 | |
| six-weeks fescue | | 0.5 | | | | | | 15.0 | | | | |
| porcupinegrass | | 0.1 | | | | | | 2.5 | | | | |
| intermed. wheatgrass | | 0.1 | | | | | | 2.5 | | | | |
| rough fescue | | 0.1 | | | | | | 2.5 | | | | |
| needle-and-thread grass | | | 8.0 | | | 1.0 | | | 40 | | | 5 |
| **Total** | 25.7 | 44.7 | 34.7 | 18.3 | 40.5 | 25.9 | | | | | | |
| **FORBS** | | | | | | | | | | | | |
| spreading dogbane | 0.1 | 0.1 | 0 | 4.4 | 1.3 | 2.6 | 7.3 | 2.5 | 0 | 52.5 | 52.5 | 38 |
| sticky cinquefoil | 1.7 | 2.6 | 2.8 | 1.5 | 2.1 | 1.5 | 46.3 | 40.0 | 40 | 35.0 | 35.0 | 28 |
| pearly everlasting | T | | | 1.7 | | | 2.4 | | | 30.0 | | |
| black medic | 1.3 | 1.5 | 0.5 | | | 0.5* | 34.0 | 30.0 | | | | |
| aster | 0.1 | 0.3 | | 0.3 | 0.3 | | 7.3 | 5.0 | 40 | 2.5 | 2.5 | 8 |
| yellow penstemon | | 0.1 | | 0.4 | 0.2 | | | 5.0 | | 7.5 | 15.0 | |
| wavy-leaved thistle | 0.5 | 0.1 | | T | 0.1 | | 9.8 | 2.5 | | 2.5 | 5.0 | |
| early blue violet | 0.2 | 0.9 | | 0.2 | 0.2 | | 9.8 | 12.5 | | 12.5 | 10.0 | |
| woolly mullein | 0.1 | 0.1 | | 0.3 | 0.1 | | 2.4 | 2.5 | | 7.5 | 2.5 | |
| Canada thistle | 0.2 | | | | | | 2.4 | | | | | |
| yarrow | T | 0.1 | | 0.1 | 0.1 | | 2.4 | 2.5 | | 5.0 | 5.0 | |
| pussytoes | T | 0.1 | 0.2 | 0.2 | 2.0 | 2.6 | 2.4 | 2.5 | 5 | 10.0 | 32.5 | 38 |
| pasture sage | | | | 0.1 | | | | | | 2.5 | | |
| round-leaved alumroot | T | 0.1 | | | 0.1 | | 2.4 | 2.5 | | | 2.5 | |
| goatsbeard | T | 0.2 | | | | | | 5.0 | | | | |
| prairie onion | T | | | | | | 7.3 | | | | | |
| wild strawberry | | 0.1 | | | 0.1 | | | 2.5 | | | 7.5 | |
| western pasqueflower | | 0.1 | | | | | | 2.5 | | | | |
| Holboell's rockcress | | T | | | | | | 2.5 | | | | |
| owl-clover | | T | | | T | | | 2.5 | | | 2.5 | |
| gumweed | | | | | 0.2 | | | | | | 2.5 | |
| yellowish paintbrush | | | | | 0.1 | | | | | | 2.5 | |
| harebell | | | | | T | | | | | | 2.5 | |
| **Total** | 4.2 | 6.4 | 3.5 | 9.5 | 6.9 | 7.2 | | | | | | |

**Appendix E, Part 1, lower Burntbridge Basin, continued**

| Plant species | Ground cover (%)[a] | | | | | | Frequency (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Burned (BR 1) | | | Unburned (BR 2) | | | Burned (BR 1) | | | Unburned (BR 2) | | |
| | 1982 | 1983 | 1984 | 1982 | 1983 | 1984 | 1982 | 1983 | 1984 | 1982 | 1983 | 1984 |
| **SHRUBS** | | | | | | | | | | | | |
| antelope-brush | 0.6 | 1.0 | 2.8 | 8.6 | 8.4 | 10.4 | 4.9 | 15.0 | 15 | 35.0 | 35.0 | 40 |
| common snowberry | T | 0.4 | 2.9 | 1.5 | 1.0 | 2.1 | 2.4 | 2.5 | 13 | 12.5 | 25.0 | 40 |
| saskatoon | 0.3 | 1.0 | 1.8 | 13.2 | 8.5 | 14.1* | 4.9 | 7.5 | 8 | 55.0 | 37.5 | 58 |
| kinnikinnick | 4.1 | 4.3 | 3.8 | 0.3 | 1.3 | 0.2 | 14.6 | 27.5 | 25 | 7.5 | 10.0 | 8 |
| rose | 0.1 | 0.2 | | 0.1 | | | 4.9 | 5.0 | | 2.5 | | |
| **Total** | 5.1 | 6.9 | 11.3 | 23.7 | 19.2 | 26.8 | | | | | | |
| **LITTER** | 64.6 | 42.8 | 35.5 | 47.8 | 21.0 | 31.7 | 100.0 | 95.0 | 95 | 97.5 | 57.5 | 100 |
| **CRYPTOGAMS** | | 1.7 | 0.1 | | 16.3 | 4.5* | | 7.5 | 3 | | 35.0 | 3 |
| **ROCK** | | 2.4 | | | | | | 7.5 | | | | |
| **BARE GROUND** | | | 5.5 | | | 0* | | | 45 | | | 0 |

[a] On burned range compared to unburned range, there were in 1982, 9:5 species of grasses, 14:11 s pecies of forbs and 5:5 species of shrubs; in 1983, 11:6 - grasses, 16:15 - forbs, 5:4 - shrubs; in 1984, 2:2 - grasses; 4:4 - forbs, 4:4 - shrubs.

* significant difference between burned and unburned in 1984

| Plant species | Ground cover (%)[a] | | | | | | Frequency (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Burned (BR 1) | | | Unburned (BR 2) | | | Burned (BR 1) | | | Unburned (BR 2) | | |
| | 1982 | 1983 | 1984 | 1982 | 1983 | 1984 | 1982 | 1983 | 1984 | 1982 | 1983 | 1984 |
| **GRASSES** | | | | | | | | | | | | |
| oatgrass | 8.3 | 2.7 | 16.4 | 2.9 | 2.4 | 6.6 | 70.0 | 32.5 | 73 | 10.0 | 42.5 | 45 |
| pinegrass | 3.2 | 2.1 | 5.7 | | 0.9 | 0.2* | 25.0 | 25.0 | 33 | | 5.0 | 5 |
| cheatgrass | 0.3 | | 0.1 | 2.9 | 7.2 | 5.8* | 7.5 | | 5 | 65.0 | 80.0 | 78 |
| Canada bluegrass | 4.8 | 8.4 | 8.6 | 0.1 | 1.7 | 1.0* | 65.0 | 67.5 | 73 | 2.5 | 17.5 | 5 |
| sm. western needlegrass | 0.6 | | | | | | 12.5 | | | | | |
| slender wheatgrass | 0.1 | 2.5 | | 0.3 | 0.3 | | 2.5 | 67.5 | | 10.0 | 22.5 | |
| junegrass | 0.8 | 0.3 | | 0.1 | | | 12.5 | 10.0 | | 2.5 | | |
| sedge | 0.1 | 0.9 | | 0.2 | 0.4 | | 2.5 | 30.0 | | 2.5 | 10.0 | |
| timothy | | 0.5 | | | T | | | 17.5 | | | 2.5 | |
| bluebunch wheatgrass | | 0.1 | | | | | | 2.5 | | | | |
| **Total** | 18.2 | 17.5 | 30.8 | 6.5 | 12.9 | 13.6 | | | | | | |
| **FORBS** | | | | | | | | | | | | |
| sticky cinquefoil | 3.0 | 0.2 | 4.9 | 1.9 | 4.4 | 4.5 | 52.5 | 5.0 | 60 | 40.0 | 75.0 | 60 |
| aster | 0.9 | 2.9 | | 0.5 | 0.4 | | 25.0 | 62.5 | | 15.0 | 12.5 | |
| woolly mullein | 1.1 | 0.2 | | 0.5 | 0.5 | | 25.0 | 5.0 | | 15.0 | 5.0 | |
| yarrow | 1.3 | 1.4 | 3.7 | 1.4 | 1.2 | 2.7 | 40.0 | 47.5 | 55 | 50.0 | 47.5 | 50 |
| spreading dogbane | | | 0 | 5.1 | 6.3 | 9.9* | | | 0 | 50.0 | 50.0 | 70 |
| wild bergamot | | 1.5 | | 1.4 | 0.3 | | | 5.0 | | 12.5 | 7.5 | |
| small-flowered willowherb | T | 0.1 | 1.7 | 1.5 | 1.9 | 3.1 | 7.5 | 5.0 | 45 | 35.0 | 75.0 | 78 |
| lemonweed | 0.6 | 0.7 | | 1.5 | 0.5 | | 12.5 | 12.5 | | 10.0 | 12.5 | |
| pussytoes | 0.2 | 1.9 | | T | 0.3 | | 7.5 | 30.0 | | 2.5 | 22.5 | |
| American vetch | | 1.7 | | | | | | 60.0 | | | | |
| early blue violet | 0.1 | | | T | | | 5.0 | | | 2.5 | | |
| wild strawberry | T | 0.7 | | 0.2 | 0.3 | | 2.5 | 47.5 | | 12.5 | 2.5 | |
| harebell | | 1.5 | | 0.2 | | | | 5.0 | | 7.5 | | |
| black medic | T | 0.8 | | | | | 2.5 | 15.0 | | | | |
| pearly everlasting | | 0.8 | | | | | | 5.0 | | | | |
| peavine | | 0.7 | | | | | | 15.0 | | | | |
| rosy owl-clover | | | | | 1.5 | | | | | | 62.5 | |
| chickweed | | | | | 0.3 | | | | | | 17.5 | |
| long-stalked starwort | | | | | T | | | | | | 2.5 | |
| yellow penstemon | | | | | 0.1 | | | | | | 2.5 | |
| Solomon's-seal | | | | 0.1 | | | | | | 2.5 | | |
| grouseberry | | | | 0.1 | | | | | | 2.5 | | |
| pasture sage | | | | 0.1 | | | | | | 2.5 | | |
| unknown | | | | 0.2 | | | | | | 10.0 | | |
| **Total** | 7.2 | 23.1 | 10.3 | 14.7 | 18.0 | 20.2 | | | | | | |
| **SHRUBS** | | | | | | | | | | | | |
| antelope-brush | 2.0 | 0.8 | 12.0 | 26.7 | 28.3 | 30.6* | 30.0 | 5.0 | 48 | 60.0 | 75.0 | 75 |
| snowberry | 16.3 | 10.3 | 22.6 | 5.1 | 0.2 | 7.8* | 70.0 | 72.5 | 83 | 35.0 | 32.5 | 50 |
| saskatoon | | 5.1 | 0.6 | 7.4 | 11.9 | 8.7* | | 12.5 | 5 | 37.5 | 25.0 | 33 |
| choke cherry | 2.3 | 0.1 | | | | | 7.5 | 2.5 | | | | |
| kinnikinnick | 0.3 | T | | 1.3 | | | 2.5 | 2.5 | | 10.0 | | |
| creeping Oregon-grape | 1.3 | 0.2 | | | | | 2.5 | 5.0 | | | | |
| rose | 0.5 | 0.5 | | | | | 12.5 | 12.5 | | | | |
| birch-leaved spirea | | 0.6 | | | | | | 27.5 | | | | |
| Scouler's willow | | 2.3 | | | | | | 2.5 | | | | |
| redstem ceanothus | | 0.1 | | | 0.3 | | | 2.5 | | | 0.5 | |
| **Total** | 22.7 | 20.0 | 35.2 | 40.5 | 40.7 | 47.1 | | | | | | |

**Appendix E, Part 1, upper Fontaine Basin, continued**

| Plant species | Ground cover (%)* | | | | | | Frequency (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Burned (BR 1) | | | Unburned (BR 2) | | | Burned (BR 1) | | | Unburned (BR 2) | | |
| | 1982 | 1983 | 1984 | 1982 | 1983 | 1984 | 1982 | 1983 | 1984 | 1982 | 1983 | 1984 |
| **LITTER** | 40.7 | 32.9 | 11.0 | 33.3 | 14.2 | 22.0* | 97.5 | 92.5 | 58 | 97.5 | 87.5 | 75 |
| **CRYPTOGAMS** | 2.3 | 0.7 | 1.0 | | | 0.1* | 15.0 | 5.0 | 10 | | | 3 |
| **ROCK** | 4.1 | 6.4 | 5.7 | 1.3 | 7.1 | 5.7 | 45.0 | 70.0 | 60 | 27.5 | 37.5 | 38 |
| **BARE GROUND** | 4.8 | 0.7 | 2.0 | 5.6 | 3.2 | 3.3 | 25.0 | 5.0 | 25 | 27.5 | 37.5 | 18 |

* significant difference between burned and unburned in 1984.

**Appendix E. Part 1. Lakit Mountain I.**

| Plant species | Ground cover (%) | | | | | | Frequency (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Logged | | | Unlogged | | | Logged | | | Unlogged | | |
| | 1984 | 1986 | 1987 | 1984 | 1986 | 1987 | 1984 | 1986 | 1987 | 1984 | 1986 | 1987 |
| **GRASSES** | | | | | | | | | | | | |
| pinegrass | 42.2 | 32.1 | 7.1 | 6.4 | 2.7 | 0.6 | 37 | 98 | 75 | 58 | 50 | 20 |
| bluebunch wheatgrass | 0 | | | 0.1 | | | 0 | | | 1 | | |
| rough fescue | 3.0 | 0.1 | 0.2 | 0 | | 0 | 1 | 8 | 5 | 0 | | 0 |
| sedge | 1.8 | | T | 0 | | 0.4 | 2 | | 3 | 0 | | 30 |
| intermediate wheatgrass | | 0.3 | | | | | | 3 | | | | |
| junegrass | | 0.1 | | | | | | 3 | | | | |
| **Total** | 47.0 | 32.6 | 7.7 | 6.5 | 2.7 | 7.1 | | | | | | |
| **FORBS** | | | | | | | | | | | | |
| rosy pussytoes | 1.1 | | 0.1 | 0.1 | | 0 | 6 | | 3 | 1 | | 0 |
| asters | 1.3 | 0.6 | 0.5 | 0 | 0.3 | 0 | 6 | 10 | 15 | 1 | 3 | 0 |
| small-flowered willowherb | 0.4 | 3.2 | 2.1 | 0 | 0.1 | 0.1 | 7 | 80 | 40 | 0 | 3 | 3 |
| Canada thistle | 0.3 | 0.7 | | | 0 | | 1 | 3 | | 0 | | |
| annual hawksbeard | 0.3 | 0.1 | | 0 | | | 1 | 3 | | 0 | | |
| arrow-leaved balsamroot | 0.2 | | | 0 | | | 3 | | 0 | | | |
| chickweed | 0.3 | | | 0 | | | 3 | | | 0 | | |
| nodding onion | 0.1 | 0.1 | | 0 | | | 1 | 3 | | 0 | | |
| western pasqueflower | 0.1 | | | 0 | | | 1 | | | 0 | | |
| yellow owl-clover | T | | | 0 | | | 1 | | | 0 | | |
| shootingstar | T | | | 0 | | | 1 | | | 0 | | |
| wild strawberry | 0.3 | 0.1 | 0.5 | 0 | | 0 | 2 | 3 | 5 | 0 | | 0 |
| creamy peavine | 0.6 | | 1.0 | 0 | | 0 | 1 | | 27 | 0 | | 0 |
| yellow penstemon | 0.1 | 3.2 | | 0 | | | 1 | 11 | | 0 | | 0 |
| dandelion | 0.1 | 0.2 | | 0 | | | 2 | 5 | | 0 | | |
| yarrow | | 4.6 | 0.4 | | | 0 | | 8 | 7 | | | 0 |
| woolly pussytoes | | 2.2 | 0.6 | | | 0 | | 15 | 17 | | | 0 |
| perennial sow-thistle | | 1.8 | | | T | | | 58 | | | 13 | |
| pearly everlasting | | 0.4 | | | | | | 5 | | | | |
| wavy-leaved thistle | | 0.3 | T | | 0.1 | 0 | | 18 | 3 | | 10 | 0 |
| goatsbeard | | 0.2 | 0.1 | | | 0 | | 5 | 3 | | | 0 |
| early blue violet | | | 0.1 | | 0.2 | 0 | | 3 | 3 | | 8 | 0 |
| dock | | 0.2 | | | | | | 5 | | | | |
| alsike clover | | | T | | 0.1 | 0 | | 0 | 3 | | 5 | 0 |
| Canada goldenrod | | T | 0.8 | | | 0 | | 3 | 13 | | | 0 |
| fireweed | | | 0 | | | 0.1 | | | 0 | | | 3 |
| fleabane | | | 0.6 | | | | | | 10 | | | 0 |
| woolly mullein | | | T | | | 0 | | | 3 | | | 0 |
| unknown | | 0.1 | T | | | 0 | | 5 | 3 | | | 0 |
| **Total** | 5.2 | 18.1 | 6.8 | 0.1 | 0.9 | 0.2 | | | | | | |
| **SHRUBS** | | | | | | | | | | | | |
| birch-leaved spirea | 3.0 | 5.9 | 0.8 | 0.8 | 2.8 | 0.4 | 17 | 48 | 17 | 14 | 63 | 13 |
| creeping Oregon-grape | 1.1 | | | 1.0 | 8.5 | | 1 | 0 | | 1 | 45 | |
| creeping juniper | 1.0 | | | 0 | | | 3 | | | 0 | | |
| redstem ceanothus | 0.1 | 0.1 | 0.3 | 0 | | 0.4 | 2 | 3 | 13 | 0 | | 35 |
| kinnikinnick | | 0.1 | | | | | | 3 | | | | |
| rose | 0.7 | | | 0 | 0.1 | | 1 | | | 0 | 3 | |
| saskatoon | | 0.3 | | | 0.6 | | | 8 | | | 8 | |
| common snowberry | 0 | 1.5 | | 0.2 | | | 0 | 13 | | 2 | 26 | |

Appendix E. Part 1, Lakit Mountain I, continued

| Plant species | Ground cover (%) | | | | | | Frequency (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Logged | | | Unlogged | | | Logged | | | Unlogged | | |
| | 1984 | 1986 | 1987 | 1984 | 1986 | 1987 | 1984 | 1986 | 1987 | 1984 | 1986 | 1987 |
| Rocky Mt. juniper | | 0.4 | | | | 2.8 | | | 3 | | 5 | |
| common juniper | | 0.1 | | | 1.8 | | | 3 | | | 10 | |
| Total | 5.9 | 8.4 | 1.1 | 2.0 | 17.5 | 0.8 | | | | | | |
| **CRYPTOGAMS** | 4.3 | | | 19.0 | | | 9 | 3 | | 25 | 0 | |
| **LITTER** | 0.1 | | | | | | | | | | | |
| **BARE GROUND** | 34.4 | 46.0 | | 71.4 | 79.3 | | 40 | 100 | | 40 | 100 | |
| **ROCK** | 4.3 | 0 | | 0 | 0 | | 40 | 0 | | 0 | 3 | |
| | 0.5 | 0.3 | | 2.3 | 0.1 | | 4 | | | 14 | 13 | |

**Appendix E. Part 1, Lakit Mountain II.**

| Plant species | Ground cover (%) | | | | | | Frequency (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Logged | | | Unlogged | | | Logged | | | Unlogged | | |
| | 1984 | 1986 | 1987 | 1984 | 1986 | 1987 | 1984 | 1986 | 1987 | 1984 | 1986 | 1987 |
| **GRASSES** | | | | | | | | | | | | |
| pinegrass | 42.7 | 20.7 | 5.0 | 15.0 | 2.7 | 0.1 | 37 | 93 | 60 | 38 | 25 | 3 |
| rough fescue | 0.5 | 0.7 | | | | | 2 | 13 | | | | |
| sedge | | | T | | | T | | | 3 | | | 0 |
| junegrass | | | | 0.1 | | | | | | 2 | | |
| Idaho fescue | | 0.1 | | | | | 3 | | | | | |
| orchardgrass | | 0.1 | 11.7 | | | 0.1 | | 3 | 75 | | | 3 |
| cheatgrass | | | 0.1 | | | 0 | | | 3 | | | 0 |
| Kentucky bluegrass | | | 0.1 | | | 0 | | | 3 | | | 0 |
| **Total** | 43.2 | 21.6 | 16.9 | 15.1 | 2.7 | 0.2 | | | | | | |
| **FORBS** | | | | | | | | | | | | |
| rosy pussytoes | 0.3 | 0.6 | | 0.1 | | | 2 | 10 | | 1 | | |
| asters | 0.3 | 3.5 | | 0.1 | | | | 40 | | | | |
| small-flowered willowherb | 0.1 | 9.2 | | | | | 1 | 83 | | | | |
| Canada thistle | 0.9 | 0.3 | | 0.9 | | | 1 | 3 | | 1 | | |
| annual hawksbeard | | 0.1 | | | | | | 3 | | | | |
| arrow-leaved balsamroot | 0.9 | 0.2 | 0 | | | T | 3 | 3 | 0 | | | 3 |
| chickweed | 0.2 | 0.2 | | | | | 4 | 5 | | | | |
| wild strawberry | 0.1 | 0.6 | | 0.3 | | | 1 | 10 | | 5 | | |
| creamy peavine | | | 5.7 | | | 0.7 | | | 53 | | | 20 |
| yellow penstemon | 0.1 | 0.1 | | | | | 10 | 3 | | | | |
| dandelion | 0.1 | | 0.2 | 0.1 | | 0 | 1 | | 5 | 1 | | 0 |
| yarrow | 0.3 | 1.3 | | | | | 2 | 10 | | 1 | | |
| woolly pussytoes | | 0.4 | 0.2 | | | 0 | | 18 | 7 | | | 0 |
| perennial sow-thistle | | 1.0 | | | | | | 28 | | | | |
| pearly everlasting | | T | | | T | | | 3 | | | 3 | |
| wavy-leaved thistle | 0.2 | | 0 | | 0.3 | | 2 | 0 | | | 5 | |
| goatsbeard | | 0.2 | | | | | | 5 | | | | |
| early blue violet | | T | T | | T | 0 | | 3 | 3 | | 3 | 0 |
| alsike clover | | | 0.2 | | | T | | | 10 | | | 5 |
| Canada goldenrod | | 0.1 | | | | | | 3 | | | | |
| woolly mullein | | T | | | | | | 3 | | | | |
| spreading dogbane | 0.1 | | | | | | 1 | | | | | |
| harebell | 0.1 | | | 0.2 | | | 1 | | | 4 | | |
| wild bergamot | 0.3 | | | | | | 4 | | | | | |
| alpine willowherb | 0.5 | | | | | | 6 | | | | | |
| bull thistle | | 0.1 | | | | | | 3 | | | | |
| rattlesnake-plantain | | | | | T | | | | | | 3 | |
| desert-parsley | | | 0.8 | | | 0.1 | | | 43 | | | 3 |
| round-leaved alumroot | | T | | | | | | 3 | | | | |
| unknown | | | T | | | 0 | | | 3 | | | 0 |
| **Total** | 4.5 | 17.9 | 7.3 | 1.7 | T | 1.1 | | | | | | |
| **SHRUBS** | 5.4 | 3.8 | 0.2 | 1.2 | 0.9 | 0.1 | 12 | 50 | 3 | 12 | 15 | 0 |
| birch-leaved spirea | | | | | | | | | | | | |
| creeping Oregon-grape | | | 0 | 10.5 | | 0.1 | | | 0 | 19 | | 3 |
| creeping juniper | 0.9 | | | 1.8 | | | 1 | | | 4 | | |
| redstem ceanothus | | 1.1 | | | | | | 3 | | | | |
| rose | | 0.4 | | | | | | 1 | | | | |
| saskatoon | 0.4 | 0.2 | | 1.2 | | | 2 | | | 12 | | |

**Appendix E. Part 1, Lakit Mountain II, continued**

| Plant species | Ground cover (%) | | | | | | Frequency (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Logged | | | Unlogged | | | Logged | | | Unlogged | | |
| | 1984 | 1986 | 1987 | 1984 | 1986 | 1987 | 1984 | 1986 | 1987 | 1984 | 1986 | 1987 |
| common snowberry | 3.3 | 0.1 | | 1.6 | 0.6 | | 19 | 3 | | 7 | 18 | |
| Rocky Mt. juniper | | 1.3 | | | | | | 3 | | | | |
| common juniper | | 2.0 | | | | | | 3 | | | | |
| Douglas-fir | | 0.2 | | 2.1 | 0.4 | | | | | 21 | | |
| lodgepole pine | | | 0.1 | | | 0 | | | 3 | | | 0 |
| white-flwrd. rhododendron | | | T | | | 0 | | | 7 | | | 0 |
| **Total** | 10.0 | 9.1 | 0.3 | 18.4 | 1.9 | 0.2 | | | | | | |
| **CRYPTOGAMS** | 1.7 | | | 6.9 | | | 6 | | | 13 | | |
| **LITTER** | 35.4 | 47.6 | | 5.1 | 83.0 | | 36 | | | 4 | | |
| **BARE GROUND** | 4.5 | 3.1 | | | 0.3 | | 8 | | | | | |
| **ROCK** | 0.3 | 0.8 | | 0.1 | 2.5 | | 4 | | | 5 | | |

**Appendix F Part 1. Ground cover (%) at Mount Broadwood, Macroplot I (unslashed) and Macroplot II (slashed), 1985 and 1986.**

| Plant species | Unslashed (Macroplot I) | | Slashed (Macroplot II) | |
|---|---|---|---|---|
| | 1985 | 1986 | 1985 | 1986 |
| **GRASSES** | | | | |
| Pinegrass | 2.8 | 6.5 | T | 1.0 |
| downy wheatgrass | | | T | T |
| **Total** | 2.8 | 6.5 | T | 1.0 |
| **FORBS** | | | | |
| Asters | 17.8 | 7.1 | 1.4 | 3.0 |
| yellow penstemon | 3.0 | | | |
| spreading dogbane | 3.8 | 1.8 | 2.0 | 2.5 |
| peavine | 2.0 | 1.0 | 0.1 | |
| yarrow | 1.8 | 0.8 | | |
| American vetch | | | 1.5 | |
| chickweed | | T | | |
| wild bergamot | | 0.5 | | |
| paintbrush | | 0.8 | | |
| black medic | | | T | |
| **Total** | 28.4 | 12.0 | 5.0 | 5.5 |
| **SHRUBS** | | | | |
| common snowberry | 13.8 | 7.5 | 11.3 | 5.5 |
| rose | 3.0 | 10.5 | 11.3 | 8.5 |
| creeping Oregon-grape | 1.3 | 2.5 | 10.5 | 1.5 |
| redstem ceanthus | 0.8 | 2.0 | .3 | |
| birch-leaved spirea | 2.0 | 1.3 | 1.8 | 2.5 |
| saskatoon | T | | 0 | |
| Douglas maple | | T | T | |
| trembling aspen | | | 38.3 | 18.3 |
| soopolallie | | | | 2.0 |
| **Total** | 20.9 | 23.8 | 73.5 | 39.0 |
| **TREES** | | 48.0 | | |
| trembling aspen | 45.0 | | | |
| | | | | 2.0 |
| **CRYPTOGAMS** | | | | |
| **LITTER** | 53.5 | 98.0 | 55.0 | 100.0 |
| **ROCK** | | | 1.0 | |
| **BARE GROUND** | | | 0.8 | |

**Appendix F. Part 2. Ground cover, stem densities and forage production on treated vs. untreated range in the Rocky Mountain Trench.**

**Ground cover (%) at Bull River treatment sites, July 1982, 1983 and 1984.**

| Cover type | Lower Burntbridge Basin | | | | | | Upper Fontaine Basin | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Burned | | | Unburned | | | Burned | | | Unburned | | |
| | 1982 | 1983 | 1984 | 1982 | 1983 | 1984 | 1982 | 1983 | 1984 | 1982 | 1983 | 1984 |
| Grasses | 25.9 (14.4)[a] | 40.5 (10.5) | 39.8[*] (4.0) | 18.3 (1.8) | 37.9[**] (7.7) | 27.4[+] (8.9) | 18.4[*] (3.0) | 17.7 (3.0) | 30.1[*++] (8.0) | 6.2 (0.8) | 12.9[*] (2.7) | 14.1[+] (1.9) |
| Forbs | 4.3 (1.7) | 6.0 (1.1) | 8.6[+] (2.5) | 9.6 (6.6) | 6.6 (3.2) | 8.9 (2.0) | 9.2 (1.7) | 23.1[**] (3.9) | 14.1[***+] (1.9) | 14.7 (6.6) | 17.6 (4.9) | 25.4[++++] (2.0) |
| Shrubs | 5.3 (4.5) | 7.2 (5.1) | 9.9 (11.1) | 24.8 (11.5) | 17.4[+] (6.9) | 26.7[+] (11.5) | 21.4 (5.4) | 19.9 (7.7) | 37.3[*+] (8.0) | 40.4[+++] (7.7) | 46.2[+++] (8.7) | 45.8 (13.6) |
| Total forage | 35.5 (6.7) | 43.7 | 58.3[***] (10.1) | 52.7[++] (9.7) | 61.9 | 63.7 (6.2) | 46.5 (4.8) | 60.7 (10.0) | 81.4[*+] (10.1) | 61.3[+++] (10.4) | 76.7[+++] (6.2) | 85.5[+] (6.6) |
| Cryptogams | 64.6[*] (5.9) | 1.7 | 0.1 | 47.4 (9.8) | 16.3 (7.6) | 4.4 (2.8) | 2.3[*] (2.4) | 0.8 (0.9) | 1.0 | 0 | 2.0[+++] | 0.5 |
| Litter | | 42.8[*] (9.7) | 34.4 (8.4) | | 21.0 (11.8) | 31.7 (5.1) | 40.7[**] (2.5) | 32.9[*] (12.3) | 11.1 (3.6) | 33.3[***] (8.1) | 14.0 (4.9) | 22.0 (13.3) |
| Rock | | 2.5 | 5.5 (3.4) | | | 0.4 | 4.1 (3.8) | 6.4 (6.2) | 5.7 (1.0) | 1.3 (1.8) | 7.1 (6.0) | 5.7 (5.4) |
| Bare Ground | | | | | | | 4.8 (7.0) | 0.7 | 2.0 (1.5) | 5.6 (5.8) | 6.6 (8.5) | 3.3 (4.2) |

[a] Standard deviation in parentheses.
[*] Burned significantly greater than unburned
[**] 1983 results significantly greater than 1982 and 1984
[***] 1983 results significantly greater than 1984
[+] 1984 results significantly greater than 1982
[++] 1984 results significantly greater than 1982 and 1983
[+++] Unburned significantly greater than burned
[*] 1984 results significantly greater than 1983
[**] 1982 results significantly greater than 1984
[***] 1982 results significantly greater than 1983

**Stem densities/15 m² at Bull River treatment areas.**

| Shrub species | Lower Burntbridge Basin | | | | Upper Fontaine Basin | | | |
|---|---|---|---|---|---|---|---|---|
| | Burned | | Unburned | | Burned | | Unburned | |
| | 1982 | 1983 | 1982 | 1983 | 1982 | 1983 | 1982 | 1983 |
| Saskatoon | 16.0 (14.3)[a] | 17.6 (21.0) | 98.2* (36.8) | 131.0 (28.5) | 72.0 (54.3) | 54.0 (21.0) | 58.8 (24.6) | 88.4 (28.5) |
| Antelope-brush | 3.4 (2.7) | 2.6 (0.2) | 9.0* (4.6) | 5.3 (1.7) | 1.4 (1.1) | 1.6 0.9 | 6.4* (4.2) | 15.8* (11.7) |
| Common snowberry | 0.8 | 23.0** | 11.6 (14.3) | 0 | 55.2 (52.7) | 186.2** (61.7) | 52.8 (49.9) | 78.0 (61.1) |
| Rose | 2.6 (2.9) | 3.0 | 0.6 | 0 | 2.4 (2.9) | 3.2 (2.9) | | |
| Balsam poplar | 0.2 | 0.2 | 0 | 0 | | | | |
| Choke cherry | | | | | 0 | 0 | 11.8 (11.9) | 10.0 (10.6) |
| Birch-leaved spirea | | | | | 2.8 | 15.8 (21.2) | 0 | 5.2 (4.3) |
| Redstem ceanthus | | | | | 0 | 3.0 (3.0) | 1.2 | 0.6 |
| Scouler's willow | | | | | | 30.4 | | 0 |
| Douglas maple | | | | | | 0 | | 0.6 |

[a] Standard deviation in parentheses
* Unburned significantly greater than burned
** 1983 results significantly greater than 1982

**Ground cover (%) on treated ranges at Lakit Mountain, July 1984, 1986 and 1987.**

| Cover type | Macroplot I | | | | | | Macroplot II | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Logged | | | Unlogged | | | Logged | | | Unlogged | | |
| | 1984 | 1986 | 1987 | 1984 | 1986 | 1987 | 1984 | 1986 | 1987 | 1984 | 1986 | 1987 |
| Grasses | 45.4[*+] (8.0) | 33.2[+] (5.0) | 7.6 (3.0) | 6.8 (3.0) | 3.5 (5.6) | 9.0 (3.2) | 44.6[**] (8.3) | 21.7[+] (9.2) | 16.9 (6.1) | 16.2[++**] (7.0) | 2.7 (1.3) | 0.1 (0.4) |
| Forbs | 6.3 (3.2) | 12.3 (4.4) | 7.7[+] (3.5) | 0.7 | 0.7 (0.7) | 0.1 (0.1) | 6.4 (6.7) | 17.5[***] (6.5) | 7.1[+] (5.1) | 0.7 (0.3) | 0.1 | 1.1[*] (0.3) |
| Shrubs | 4.2[*] (3.8) | 8.1[**] (6.2) | 0.9 (0.5) | 1.1 (0.5) | 16.0 (7.3) | 0.7 (0.5) | 8.2[*] (3.8) | 8.9 (6.2) | 0.7 (0.5) | 21.2[*++] (7.9) | 2.5 (2.9) | 0.2 (0.3) |
| Total forage | 55.9[*+] (6.6) | 55.6[+] (3.3) | 16.2 (6.8) | 8.5[*+] (2.4) | 21.5 (12.2) | 9.9 (3.8) | 59.1[*+] (10.2) | 48.2 (3.5) | 24.3[+] (10.7) | 38.1[*] (15.0) | 5.3 (3.9) | 1.4 (1.4) |
| Litter | 34.4[*] (3.7) | 46.0[**] (4.0) | 21.3 (9.6) | 71.5[*++] (7.9) | 79.3[++] (10.6) | 15.4 (1.0) | 35.4 (12.3) | 47.6[***] (2.1) | 35.2 (10.3) | 55.1[++] (14.4) | 83.0[++] (12.3) | 61.6[++] (15.8) |
| Cryptogams | 4.3[***] (7.4) | 0.3 | 3.8 (2.5) | 17.0[++**] (6.6) | 0 | 10.7 (4.7) | 0.9 | 0.6 | 1.2[*] (0.1) | 6.9[*++] (4.1) | 12.4 (9.2) | 0.1 (1.7) |
| Bare Ground | 4.3 (2.8) | 0.3 | 44.5 (8.3) | 2.2 (0.5) | 0.2 | 42.5[*] (5.8) | 4.5 (5.4) | 3.1 (2.2) | 32.8[*] (11.5) | 0 | 0.3 (0.3) | 28.7[*] (13.6) |
| Rock | 0.9 (1.1) | 0.3 | 14.0[*] (3.1) | 0 | 0.7 | 22.6[*++] (5.5) | 0.3 | 0.8 (0.8) | 7.8 (3.1) | 0 | 2.5 (0.8) | 8.3 (2.7) |

[*] Standard deviation in parentheses.
[*] 1984 and 1986 results significantly greater than 1987
[**] 1986 results significantly greater than 1987
[***] 1984 and 1987 results significantly greater than 1986
[+] Logged significantly greater than unlogged
[++] Unlogged significantly greater than logged
[+++] 1986 results significantly greater than 1984
[*] 1987 results significantly greater than 1984 and 1986
[**] 1984 results significantly greater than 1986 and 1987
[***] 1986 results significantly greater than 1984 and 1987

**Appendix E. Part 2. Forage response (kg/ha) to various rates of fertilization at Columbia Lake (2 sites) and Wigwam Flats, 1982.**

| P205 (kg/ha) / N (kg/ha) | 0 | | | 100 | | | 200 | | | 400 | | | Mean | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Columbia L. | | Wigwam Flats | Columbia L. | | Wigwam Flats | Columbia L. | | Wigwam Flats | Columbia L. | | Wigwam Flats | Columbia L. | | Wigwam Flats |
| | 1 | 2 | | 1 | 2 | | 1 | 2 | | 1 | 2 | | 1 | 2 | |
| 0 | 664 | 420 | 1127 | 472 | 405 | 1364 | 634 | 308 | 1111 | 730 | 554 | 1431 | 622 | 422 | 1258 |
| 50 | 491 | 401 | 1496 | 652 | 461 | 988 | 548 | 398 | 1295 | 956 | 387 | 1576 | 612 | 412 | 1339 |
| 100 | 415 | 481 | 974 | 406 | 543 | 1077 | 688 | 313 | 1141 | 578 | 402 | 1316 | 522 | 435 | 1127 |
| 200 | 241 | 529 | 1001 | 454 | 396 | 837 | 458 | 324 | 775 | 698 | 380 | 1303 | 463 | 408 | 979 |
| Mean | 453 | 458 | 1150 | 496 | 451 | 1067 | 579 | 336 | 1081 | 741 | 420 | 1406 | | | |

Appendix G. Table 1. Source, destination, number, age and sex, and tag number of Rocky Mountain bighorn sheep in the East Kootenays, 1982-1989.

| Date | Source - Destination | Sex | Age | Tag No. | Tag Colour[a] | Collar Freq. |
|---|---|---|---|---|---|---|
| Feb. March 1982 | Wigwam Flats - Bull River | M | 0.5 | 87 | Y | |
| | | M | 2.5 | 80 | Y | |
| | | M | 2.5 | 82 | Y | |
| | | M | 3.5 | 84 | Y | |
| | | F | 3.5 | 79 | Y | |
| | | F | 3.5 | 88 | Y | |
| | | F | 3.5 | 90 | Y | |
| | | F | 3.5 | 94 | Y | |
| | | F | 4.5 | 83 | Y | |
| | | F | 4.5 | 85 | Y | |
| | | F | 4.5 | 86 | Y | |
| | | F | 4.5 | 89 | Y | |
| | | F | 4.5 | 91 | Y | |
| | | F | 4.5 | 92 | Y | |
| | | F | 4.5 | 93 | Y | |
| | | F | 5.5 | 81 | Y | |
| | **Total translocated = 16: 12 ewes, 3 rams, 1 lamb (M)** | | | | | |
| 26 Jan 1989 | Premier Ridge - released | F | 0.5 | 10 | Y | |
| | | F | 1.5 | 8 | Y | |
| | | F | 2.5 | 11 | Y | |
| | | F | 3.5 | 12 | Y | |
| | | F | 5.5 | 9 | Y | |
| 29 Jan 1983 | Premier Ridge - released | F | 4.5 | 3 | Y | |
| | | F | 5.5 | 4 | Y | |
| 06 Mar 1983 | Premier Ridge - released | F | 0.5 | 5 | Y | |
| | | F | 0.5 | 13 | Y | |
| | | F | 0.5 | 14 | Y | |
| | | F | 1.5 | 17 | Y | |
| | | F | 3.5 | 27 | Y | |
| | | F | 3.5 | 6 | Y | |
| | | F | 3.5 | 15 | Y | |
| | | F | 3.5 | 16 | Y | |
| | | F | 3.5 | 21 | Y | |
| | | F | 4.5 | 18 | Y | |
| | | F | 5.5 | 4 | Y(retrap) | |
| | **Total trapped = 18: 14 ewes, 4 lambs (F)** | | | | | |
| 31 Jan 1984 | TV Tower Columbia Lake - Lizard Range | M | 0.5 | 4 | Y | |
| | | M | 0.5 | 6 | Y | |
| | | M | 1.5 | 5 | Y | 151.419 |
| | | F | 3.5 | 3 | Y | |
| | | F | 3.5 | 2 | Y | |
| | | F | 4.5 | 1 | Y | 151.023 |
| | **Total translocated = 6: 3 ewes, 1 ram, 2 lambs (M)** | | | | | |

Appendix E. Table 1, continued

| | | | | | | |
|---|---|---|---|---|---|---|
| 01 Feb 1984 | TV Tower Columbia Lake - Lizard Range | F | 0.5 | 15 | Y | |
| | | M | 0.5 | 16 | Y | |
| | | M | 0.5 | 17 | Y | |
| | | M | 2.5 | 23 | Y | |
| | | F | 3.5 | 20 | Y | |
| | | F | 4.5 | 21 | Y | |
| | | F | 4.5 | 24 | Y | |
| | | M | 4.5 | 18 | Y | |
| | **Total translocated = 8: 2 ewes, 3 lambs (2M, 1F), 3 rams** | | | | | |
| 11 Feb 1984 | Armstrong Bay, Columbia Lake - Lizard Range | F | 0.5 | 10 | Y | |
| | | M | 0.5 | 22 | Y | |
| | | F | 2.5 | 14 | Y | |
| | | F | 3.5 | 13 | Y | |
| | | F | 4.5 | 12 | Y | |
| | | F | 4.5 | 11 | Y | |
| | **Total translocated = 6: 4 ewes, 2 lambs (1M, 1F)** | | | | | |
| 20 Feb 1984 | Armstrong Bay, Columbia Lake - Maguire Creek | F | 2.5 | 1 | Y | |
| | | F | 2.5 | 4 | Y | 151.037 |
| | | F | 2.5 | 7 | Y | |
| | | F | 3.5 | 5 | Y | |
| | | F | 4.5 | 3 | Y | |
| | | F | 4.5 | 6 | Y | |
| | | F | 6.5 | 2 | Y | |
| | **Total translocated = 7 ewes** | | | | | |
| 29 Feb 1984 | TV Tower, Columbia Lake - release | F | 0.5 | 9 | B | |
| | | M | 0.5 | 4 | B | |
| | | M | 1.5 | 2 | B | |
| | | F | 2.5 | 7 | B | |
| | | F | 3.5 | 5 | B | |
| | | F | 3.5 | 6 | B | |
| | | F | 4.5 | 3 | B | |
| | | F | 4.5 | 8 | B | |
| | | F | 6.5 | 1 | B | |
| | **Total trapped and released = 9: 6 ewes, 1 ram, 2 lambs (M,F)** | | | | | |
| 02 Mar 1984 | Mount Swansea - release | M | 2.5 | 12 | R | |
| | | F | 2.5 | 19 | R | |
| | | F | 2.5 | 20 | R | |
| | | F | 3.5 | 13 | R | |
| | | F | 3.5 | 14 | R | |
| | | F | 3.5 | 19 | R | |
| | | M | 3.5 | 16 | R | |
| | | M | 4.5 | 11 | R | |
| | | M | 4.5 | 15 | R | |
| | | M | 4.5 | 18 | R | |
| | | M | 4.5 | 21 | R | |
| | **Total trapped and released = 11: 5 ewes, 6 rams** | | | | | |

Appendix E. Table 1, continued

| | | | | | | |
|---|---|---|---|---|---|---|
| 05 Mar 1984 | Columbia Lake - Lizard Range | M | 0.5 | 14 | B | |
| | | M | 0.5 | 17 | B | |
| | | F | 2.5 | 12 | B | |
| | | M | 2.5 | 18 | B | |
| | | F | 3.5 | 11 | B | |
| | | F | 6.5 | 13 | B | |
| | | F | 6.5 | 10 | B | |
| | | F | 7.5 | 16 | B | |
| | **Total translocated = 8: 5 ewes, 2 lambs (M), 1 ram** | | | | | |
| 07 Mar 1984 | Columbia Lake - released | F | 0.5 | 5 | Y | |
| | | M | 0.5 | 6 | Y | |
| | | F | 1.5 | 1 | Y | |
| | | M | 1.5 | 1 | Y | |
| | | F | 2.5 | 3 | Y | |
| | | M | 2.5 | 2 | Y | |
| | | F | 3.5 | 6 | Y | |
| | | F | 4.5 | 4 | Y | |
| | | F | 5.5 | 2 | Y | |
| | | F | 6.5 | 1 | W | |
| | **Total trapped and released = 9: 6 ewes, 2 lambs (M,F), 1 ram** | | | | | |
| **1984 Summary** | **Captured = 64: 38 ewes, 13 lambs (9M, 4F), 13 rams**<br>**Translocated = 37: 21 ewes, 11 lambs (7M, 4F), 5 rams**<br>**Translocated to the Lizard Range = 28: 14 ewes, 9 lambs (7M, 2F), 5 rams** | | | | | |
| 09 Feb 1985 | Armstrong Bay - Tulip Creek, Arrow Lake | M | 0.5 | 6 | W | |
| | | M | 0.5 | 14 | W | |
| | | F | 0.5 | 15 | W | 151.148 |
| | | F | 0.5 | 16 | W | |
| | | F | 0.5 | 21 | W | |
| | | M | 1.5 | 19 | W | |
| | | M | 2.5 | 9 | W | |
| | | F | 3.5 | 3 | W | |
| | | M | 3.5 | 7 | W | |
| | | M | 3.5 | 17 | W | |
| | | F | 4.5 | 2 | W | |
| | | F | 4.5 | 8 | W | |
| | | F | 4.5 | 12 | W | |
| | | F | 4.5 | 13 | W | |
| | | F | 5.5 | 4 | W | |
| | | F | 5.5 | 10 | W | |
| | | F | 6.5 | 5 | W | 151.023 |
| | | F | 6.5 | 11 | W | |
| | | F | 7.5 | 18 | W | |
| | | F | 8.5 | 20 | W | |
| | | F (released) | 8.5 | 1 | W | 153.371 |
| | **Total translocated = 20: 11 ewes, 5 lambs (3F, 2M), 4 rams** | | | | | |

Appendix G. Table 1, continued

| | | | | | | |
|---|---|---|---|---|---|---|
| 16 Feb 1985 | TV Tower - Maguire | F | O.5 | 27 | B | |
| | | F | 0.5 | 35 | B | |
| | | M | 0.5 | 33 | B | |
| | | F | 1.5 | 31 | B | |
| | | F | 2.5 | 34 | B | |
| | | F | 2.5 | 38 | B | |
| | | F | 3.5 | 32 | B | |
| | | F | 3.5 | 39 | B | |
| | | F | 4.5 | 36 | B | |
| | | F | 5.5 | 37 | B | |
| | **Total translocated = 10: 7 ewes, 3 lambs (2F, 1M)** | | | | | |
| 16 Feb 1985 | TV Tower - released | M | 0.5 | 26 | B | |
| | | F | 0.5 | 28 | B | |
| | | F | 1.5 | 40 | B | |
| | | F | 1.5 | 10 | B | |
| | | M | 1.5 | 12 | B | |
| | | M | 1.5 | 14 | B | |
| | | F | 3.5 | 29 | B | |
| | | F | 3.5 | 30 | B | 151.148 |
| | | M | 3.5 | 11 | B | |
| | | M | 3.5 | 13 | B | 151.040 |
| | **Total captured and released = 10: 4 ewes, 2 lambs (M, F), 4 rams** | | | | | |

**1985 Summary** **Total captured = 40: 22 ewes, 10 lambs (5M, 5F), 8 rams**
**Total translocated = 30: 18 ewes, 8 lambs (3M, 5F), 4 rams**

| | | | | | | |
|---|---|---|---|---|---|---|
| 25 Jan 1986 | TV Tower - Lizard Range | F | 0.5 | 51 | B | |
| | | M | 1.5 | 55 | B | |
| | | M | 1.5 | 56 | B | |
| | | M | 2.5 | 52 | B | |
| | | M | 2.5 | 60 | B | |
| | | F | 2.5 | 62 | B | |
| | | F | 2.5 | 53 | B | |
| | | F | 5.5 | 50 | B | |
| | | F | 6.5 | 54 | B | |
| | | F | 7.5 | 57 | B | |
| | | F | 7.5 | 61 | B | |
| | **Total translocated = 11: 6 ewes, 1 lamb (F), 4 rams** | | | | | |
| 25 Jan 1986 | TV Tower - released | F | 4.5 | 59 | B | |
| | | Leg broken | | | | |
| | | M | 5.5 | 53 | B | |
| | | F | 6.5 | 58 | B | 151.037 |
| 25 Jan 1986 | Armstrong Bay - Wildhorse | F | 0.5 | 53 | Y | |
| | | M | 0.5 | 57 | Y | |
| | | F | 2.5 | 54 | Y | 151.600 |
| | | M | 2.5 | 56 | Y | 151.400 |
| | | F | 5.5 | 58 | Y | |
| | **Total translocated = 5: 2 ewes, 2 lambs (M, F), 1 ram** | | | | | |

Appendix G. Table 1, continued

| | | | | | | |
|---|---|---|---|---|---|---|
| 25 Jan 1986 | Armstrong Bay - released | M | 2.5 | 51 | Y | |
| | | F | 3.5 | 50 | Y | |
| | | M | 3.5 | 55 | Y | |
| | | F | 5.5 | 52 | Y | |
| | **Total trapped and released = 4: 2 ewes, 2 rams** | | | | | |
| 16 Feb 1986 | Stoddart Creek - Wigwam Flats (Purple Canyon) | F | 0.5 | 27 | R | |
| | | F | 0.5 | 32 | R | |
| | | F | 0.5 | 34 | R | |
| | | F | 0.5 | 38 | R | |
| | | F | 0.5 | 39 | R | |
| | | F | 0.5 | 60 | Y | |
| | | M | 0.5 | 65 | Y | |
| | | F | 1.5 | 61 | Y | |
| | | F | 1.5 | 62 | Y | |
| | | F | 1.5 | 64 | Y | |
| | | M | 1.5 | 33 | R | |
| | | M | 1.5 | 37 | R | |
| | | M | 1.5 | 40 | R | |
| | | M | 1.5 | 41 | R | |
| | | M | 1.5 | 42 | R | |
| | | F | 2.5 | 28 | R | |
| | | F | 2.5 | 31 | R | |
| | | F | 2.5 | 45 | R | |
| | | F | 2.5 | 66 | Y | |
| | | F | 2.5 | 67 | Y | |
| | | M | 2.5 | 30 | R | |
| | | F | 3.5 | 25 | R | |
| | | F | 3.5 | 26 | R | |
| | | F | 3.5 | 29 | R | |
| | | F | 3.5 | 35 | R | |
| | | F | 3.5 | 44 | R | |
| | | F | 3.5 | 59 | Y | |
| | | F | 4.5 | 36 | R | 151.000 |
| | | F | 4.5 | 43 | R | |
| | | F | 4.5 | 63 | Y | |
| | | F | 4.5 | 68 | Y | |
| | **Total translocated = 31: 18 ewes, 7 lambs (6F, 1M), 6 rams** | | | | | |
| 24 Feb 1986 | Stoddart Creek - Wigwam Flats | F | 0.5 | 36 | B | |
| | | M | 0.5 | 29 | B | |
| | | M | 0.5 | 34 | B | |
| | | M | 0.5 | 28 | B | |
| | | M | 0.5 | 37 | B | |
| | | M | 1.5 | 33 | B | |
| | | F | 2.5 | 31 | B | |
| | | F | 3.5 | 48 | B | |
| | | F | 4.5 | 43 | B | |
| | | F | 4.5 | 44 | B | |
| | | F | 4.5 | 45 | B | |
| | | F | 5.5 | 32 | B | |
| | | F | 5.5 | 42 | B | |
| | | F | 5.5 | 46 | B | |
| | | F | 5.5 | 49 | B | |
| | | F | 6.5 | 47 | B | |
| | **Total translocated = 16: 10 ewes, 5 lambs (4M, 1F), 1 ram** | | | | | |

**1986 Summary** **Total translocated = 63: 36 ewes, 15 lambs (9F, 6M), 12 rams**
**Total translocated to Wigwam Flats = 47: 28 ewes, 12 lambs (7F, 5M), 7 rams**

Appendix G. Table 1, continued

| | | | | | |
|---|---|---|---|---|---|
| 24 Jan 1987 | Stoddart Creek - Arrow Lakes | F | 0.5 | 18 | O |
| | | M | 0.5 | 13 | O |
| | | M | 0.5 | 4 | O |
| | | M | 1.5 | 3 | O |
| | | M | 1.5 | 5 | O |
| | | M | 1.5 | 17 | O |
| | | F | 1.5 | 15 | O |
| | | F | 2.5 | 2 | O |
| | | M | 2.5 | 12 | O |
| | | F | 3.5 | 11 | O |
| | | F | 3.5 | 16 | O |
| | | F | 5.5 | 8 | O |
| | | F | 5.5 | 10 | O |
| | | F | 5.5 | 14 | O |
| | | F | 6.5 | 1 | O |
| | | F | 7.5 | 6 | O |
| | | F | 7.5 | 7 | O |
| | | F | 7.5 | 9 | O |
| | **Total translocated = 18: 11 ewes, 3 lambs (2M, 1F), 4 rams** | | | | |
| 31 Jan 1987 | Armstrong Bay - released | M | 2.5 | 19 | O |
| | | M | 4.5 | 20 | O |
| 01 Feb 1987 | TV Tower - released | F | 3.5 | 1 | O |
| | | F | 3.5 | 2 | O |
| | | M | 6.5 | 53 | B |
| 07 Feb 1987 | Columbia Lake - Wildhorse | M | 0.5 | 15 | O |
| | | M | 0.5 | 17 | O |
| | | F | 0.5 | 21 | O |
| | | F | 0.5 | 23 | O |
| | | F | 2.5 | 20 | O |
| | | F | 3.5 | 2 | O |
| | | M | 3.5 | 13 | O |
| | | F | 4.5 | 18 | O |
| | | F | 4.5 | 19 | O |
| | | F | 4.5 | 40 | O |
| | | F | 5.5 | 22 | O |
| | | F | 6.5 | 16 | O |
| | **Total translocated to Wildhorse (Forestbauer Ranch) = 12: 7 ewes, 1 ram, 4 lambs (2M, 2F)** | | | | |
| 07 Feb 1987 | Columbia Lake - released | M | 4.5 | 50 | Y |
| | | M | 5.5 | 5 | O |
| | | F | 8.5 | 14 | O |

Appendix E. Table 1, continued

| | | | | | | |
|---|---|---|---|---|---|---|
| 07 Feb 1987 | Columbia Lake - Lakit | M | 0.5 | 6 | O | |
| | | M | 0.5 | 8 | O | |
| | | M | 0.5 | 11 | O | |
| | | F | 0.5 | 9 | O | |
| | | F | 0.5 | 10 | O | |
| | | F | 0.5 | 12 | O | |
| | | F | 3.5 | 1 | O | 151.040 |
| | | F | 3.5 | 2 | O | 151.675 |
| | | F | 3.5 | 4 | O | |
| | | F | 3.5 | 7 | O | 150.840 |
| | | F | 5.5 | 3 | O | |
| | **Total translocated = 11: 5 ewes, 6 lambs (3M, 3F)** | | | | | |
| 07 Feb 1987 | Armstrong Bay - Mause Creek | F | 0.5 | 23 | O | |
| | | F | 0.5 | 25 | O | |
| | | M | 0.5 | 15 | O | |
| | | M | 0.5 | 21 | O | |
| | | M | 0.5 | 26 | O | |
| | | M | 2.5 | 27 | O | |
| | | F | 2.5 | 20 | O | |
| | | F | 3.5 | 51 | Y | |
| | | M | 3.5 | 13 | O | |
| | | M | 3.5 | 29 | O | |
| | | F | 4.5 | 18 | O | |
| | | F | 4.5 | 19 | O | |
| | | F | 4.5 | 40 | Y | 151.739 |
| | | F | 5.5 | 22 | O | |
| | | F | 5.5 | 24 | O | |
| | | F | 5.5 | 28 | O | |
| | | F | 6.5 | 16 | O | |
| | **Total translocated = 17: 9 ewes, 5 lambs (3M, 2F), 3 rams** | | | | | |
| **1987 Summary** | **Total captured = 66: 35 ewes, 18 lambs (10M, 8F), 13 rams**<br>**Total translocated = 58: 32 ewes, 18 lambs (10M, 8F), 8 rams**<br>**Total translocated to the Wildhorse = 40: 21 ewes, 15 lambs (8M, 7F), 4 rams** | | | | | |
| 07 Feb 1988 | Columbia Lake - Wildhorse | F | 0.5 | 34 | O | |
| | | F | 1.5 | 40 | O | |
| | | M | 1.5 | 44 | O | |
| | | M | 2.5 | 41 | O | |
| | | M | 2.5 | 46 | O | |
| | | M | 3.5 | 39 | O | |
| | | F | 4.5 | 35 | O | 150.667 |
| | | F | 4.5 | 45 | O | 153.101 |
| | | F | 6.5 | 47 | O | |
| | **Total translocated = 9: 4 ewes, 1 lamb (F), 4 rams** | | | | | |
| 07 Feb 1988 | Columbia Lake - released | M | 3.5 | 38 | O | |
| | | M | 5.5 | 42 | O | |

Appendix G. Table 1, continued

| | | | | | | |
|---|---|---|---|---|---|---|
| 14 Feb 1988 | Stoddart Creek - Wigwam | F | 0.5 | 54 | Y | |
| | | F | 0.5 | 64 | Y | |
| | | M | 1.5 | 55 | Y | |
| | | M | 1.5 | 60 | Y | |
| | | M | 1.5 | 61 | Y | |
| | | F | 2.5 | 56 | Y | |
| | | F | 2.5 | 69 | Y | 150.680 |
| | | M | 2.5 | 67 | Y | |
| | | F | 3.5 | 55 | Y | |
| | | F | 3.5 | 59 | Y | 150.705 |
| | | F | 4.5 | 62 | Y | |
| | | F | 6.5 | 53 | Y | |
| | | F | 6.5 | 57 | Y | |
| | | F | 6.5 | 63 | Y | |
| | | F | 7.5 | 51 | Y | |
| | | F | 7.5 | 52 | Y | |
| | | F | 7.5 | 68 | Y | |
| | **Total translocated = 17: 11 ewes, 2 lambs (F), 4 rams** | | | | | |
| 14 Feb 1988 | Stoddart Creek - released | F | 7.5 | 66 | Y | |
| | | F | 8.5 | 65 | Y | |
| **1988 Summary** | **Total captured = 30: 17 ewes, 3 lambs (F), 10 rams**<br>**Total translocated = 26: 15 ewes, 3 lambs (F), 8 rams** | | | | | |
| 28 Jan 1989 | Bull River - released | F | 0.5 | 71 | Y | |
| | | F | 0.5 | 136 | Y | |
| | | M | 0.5 | 72 | Y | |
| | | M | 0.5 | 73 | Y | |
| | | M | 0.5 | 132 | Y | |
| | | M | 0.5 | 137 | Y | |
| | | M | 1.5 | 126 | Y | |
| | | F | 1.5 | 127 | Y | |
| | | F | 1.5 | 134 | Y | |
| | | F | 2.5 | 75 | Y | |
| | | F | 2.5 | 133 | Y | |
| | | F | 3.5 | 128 | Y | 151.036 |
| | | F | 3.5 | 130 | Y | |
| | | F | 3.5 | 135 | Y | |
| | | M | 3.5 | 138 | Y | |
| | | M | 3.5 | 70 | Y | |
| | | F | 5.5 | 74 | Y | |
| | | F | 5.5 | 129 | Y | |
| | | F | 5.5 | 139 | Y | 151.671 |
| | | F | 6.5 | 131 | Y | |
| | **Total captured and released = 20: 11 ewes, 6 lambs (4M, 2F), 3 rams** | | | | | |
| 28 Feb 1989 | Stoddart Creek - Maguire Creek | F | 0.5 | 108 | O | |
| | | F | 0.5 | 112 | O | |
| | | M | 1.5 | 120 | O | |
| | | F | 1.5 | 114 | O | |
| | | F | 2.5 | 106 | O | |
| | | F | 2.5 | 117 | O | |
| | | F | 2.5 | 121 | O | |
| | | F | 3.5 | 105 | O | |
| | | F | 3.5 | 109 | O | |

Appendix G. Table 1, continued

| | | | | |
|---|---|---|---|---|
| F | 3.5 | 115 | O | |
| F | 3.5 | 116 | O | |
| F | 3.5 | 116 | O | |
| F | 3.5 | 122 | O | 150.675 |
| F | 3.5 | 125 | O | |
| F | 4.5 | 110 | O | |
| F | 4.5 | 111 | O | |
| F | 4.5 | 113 | O | |
| F | 4.5 | 119 | O | |
| F | 4.5 | 123 | O | |

**Total translocated = 19: 16 ewes, 2 lanbs (F), 1 ram**

**1989 Summary** **Total captured = 39: 27 ewes, 8 lambs (4M, 4F), 4 rams**

**1982-1988** **Total captured = 346: 206 ewes, 74 lambs (32M, 42F), 66 rams**

**1982-1989** **Total translocated = 249: 150 ewes, 58 lambs (33F, 25M), 41 rams**

**Total translocated to the Bull River = 16: 12 ewes, 1 lamb (M), 3 rams**
**Total translocated to the Lizard Range = 39: 20 ewes, 10 lambs (7M, 3F), 9 rams**
**Total translocated to Maguire Creek = 36: 30 ewes, 5 lambs (4F, 1M), 1 ram**
**Total translocated to the Arrow Lakes = 38: 22 ewes, 8 lambs (4M, 4F), 8 rams**
**Total translocated to Wigwam Flats = 64: 39 ewes, 14 lambs (9F, 5M), 11 rams**
**Total translocated to lower Wildhorse = 54: 27 ewes, 18 lambs (9M, 9F), 9 rams**

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* Tag colour abbreviations: B - blue, O - orange, R - red, Y - yellow

Appendix G. Table 2. Sightings or locations on seasonal range of bighorn sheep translocated to the Lizard Range and the lower Wildhorse.

| Location | Sightings | | | |
|---|---|---|---|---|
| | Winter | Spring | Summer | Fall |
| **Lizard Range - year 1, 1984-1985** | | | | |
| Mack Creek | 35 | 18 | 3 | 8 |
| Tunnel | 18 | 9 | 2 | 7 |
| No Name Draw | | 3 | | |
| **Lizard Range - year 2, 1985-1986** | | | | |
| Tunnel | 15 | 7 | 2 | 7 |
| Mack Creek | | 12 | 7 | 3 |
| No Name Draw | 5 | 3 | 2 | |
| Bark Mill | 6 | | | 5 |
| Burton Creek | 5 | | 9 | 5 |
| Tunnel Creek | | | 7 | 5 |
| **Lower Wildhorse, 1987-1988** | | | | |
| Mause-Horseshoe | 18 | 5 | | 7 |
| Brewery Ridge | 12 | 7 | 3 | 5 |
| Sunken Creek, Horseshoe Creek (Headwaters | | 5 | 3 | 3 |
| Mt. Fisher area | | 9 | 5 | 3 |
| Vertical Mt. - Boulder Creek | | 7 | 2 | |
| Clay Creek | | 3 | | |
| East Fork, Wildhorse R. | | 3 | 2 | |
| Cliff Lake | | | 3 | |
| Dibble Glacier | | | | |
| Hebert Creek - Tracy Creek | | 9 | 2 | |

H

Appendix F. Size (ha) and priority of bighorn sheep winter range that should be repatriated to the Crown.

| Location | Size (ha) | Capability Rating | Priority of Purchase |
|---|---|---|---|
| **Radium Hotsprings** | | | |
| D.L. 10719 | 34.11 | 1W | 1 |
| D.L. 9577 | 16.19 | 1W | 1 |
| D.L.10113 | 70.42 | 1W | 1 |
| D.L. 9576 | 25.54 | 3W | 3 |
| D.L. 272 | 129.5 | 3W | 3 |
| D.L. 486 | 129.1 | 3W | 3 |
| **Radium - Dry Gulch** | | | |
| D.L. 9011 | 64.75 | 3W | 3 |
| D.L. 9565 | 64.75 | 3W | 3 |
| D.L. 9566 | 46.88 | 3W | 3 |
| D.L. 9010 | 46.75 | 2W | 1 |
| D.L. 9567 | 32.38 | 2W | 3 |
| D.L. 10114 | 48.56 | 2W | 1 |
| D.L. 8207 | 32.38 | 2W | 1 |
| D.L. 9248 | 32.38 | 1W | 1 |
| **Stoddart Creek** | | | |
| D.L. 288 | 129.9 | 1W | 3 |
| D.L. 5353 | 133.54 | 1W | 1 |
| D.L. 5343 | 129.5 | 3W | 2 |
| S.L. 76 D.L. 4596 | 64.0 | 1W | 1 |
| S.L. 100 D.L. 4596 | 64.0 | 1W | 1 |
| Reverted to Crown | | | |
| S.L. 68 D.L. 4596 | 63.2 | | 1 |
| Reverted to Crown | | | |
| **Shuswap Creek** | | | |
| D.L. 4351 | 33.9 | 2W | 1 |
| D.L. 9562 | 64.62 | 2W | 3 |
| D.L. 493 | 129.5 | 2W | 3 |
| D.L. 9698 | 35.2 | 1W | 1 |
| **Windermere Creek** | | | |
| D.L. 5108 | 35.21 | 3W | 3 |
| D.L. 5107 | 35.21 | 1W | 1 |
| S.L. 33 D.L. 4596 | 16.66 | 1W | 1 |
| S.L. 35 D.L. 4596 | 60.78 | 1W | 1 |
| S.L. 69 D.L. 4596 | 56.88 | 2W | 2 |
| S.L. 132 D.L. 4596 | 64.75 | 3W | 2 |
| S.L. 157 D.L. 4596 | 64.75 | 1W | 1 |
| Has reverted to Crown | | | |
| **Madius Creek** | | | |
| D.L. 9245 | 64.75 | 2W | 2 |
| S.L. 115 D.L. 4596 | | 1W | 2 |
| **Fairmont Hotsprings** | | | |
| D.L. 18 | 64.75 | 3W | 3 |
| D.L. 40 | 64.75 | 1W | 1 |
| D.L. 47 | 61.51 | 2W | 3 |
| D.L. 48 | 127.48 | 3W | 1 |
| D.L. 108 | 129.5 | 3W | 1 |
| S.L. 11 D.L. 4596 | 64.75 | 3W | 1 |
| S.L. 36 D.L. 4596 | 83.2 | 1W | 1 |
| S.L. 38 D.L. 4596 | 64.75 | 2W | 3 |
| D.L. 345 | 934.83 | 3W | 2 |
| D.L. 110 | 900.43 | 1W | 1 |

Appendix F, continued

| | | | |
|---|---|---|---|
| D.L. 111 | 143.66 | 3W | 3 |
| D.L. 112 | | 1W | 1 |
| **Lewis Creek - Wildhorse** | | | |
| D.L. 2898 | | 2W | 2 |
| D.L. 8845 | 64.75 | 3W | 2 |
| D.L. 8106 | 64.75 | 3W | 2 |
| D.L. 12985 | | 3W | 2 |
| **Wildhorse R. - Bull R.** | | | |
| D.L. 310 | 1036.0 | 1W | 1 |
| Except S.L.'s 4, 9, 10, 15 and 16, 323.8 ha have reverted to the Crown | | | |
| D.L. 311 | 1036.0 | 1W | 1 |
| Except S.L.'s 2-6, 1014 ha have reverted to the Crown | | | |
| D.L. 313 | 1036.0 | 2W | 2 |
| All but S.L.'s 14-16 have reverted to the Crown | | | |
| D.L. 312 | 129.6 SW<br>189.9 E | 3W | 2 |
| S.L. 10 D.L. 4590 | | 3W | 3 |
| S.L. 36 D.L. 4590 | | 3W | 3 |
| S.L. 18 D.L. 4590 | 182.8 | 2W | 3 |
| S.L. 33 D.L. 4590 | 154.0 | 2W | 3 |
| S.L. 34 D.L. 4590 | 228.4 | 1W | |
| Reverted to Crown | | | |
| **Peckham's Lake - Bull R.** | | | |
| D.L. 10278 | 104.73 | 1W | 2 |
| D.L. 10278 | 64.75 Acquired by Parks Branch in 1981 | | |
| D.L. 2960 | 64.75 | 3W | 2 |
| D.L. 4839 | 72.84 | 1W | 1 |
| D.L. 3005 | | 1W | 3 |
| S.L. 40 D.L. 4590 | | 1W | 1 |
| S.L. 76 D.L. 4590 | | | |
| **Sand Creek - Elko** | | | |
| D.L. 8904 | 58.3 | 1W | 1 |
| D.L. 7340 | 118.6 | 1W | 1 |
| D.L. 7316 | 139.2 | 1W | |
| Reverted to Crown | | | |
| D.L. 7008 | 143.3 | 2W | |
| Reverted to Crown | | | |
| D.L. 7788 | 16.2 | 3W | |
| D.L. 8285 | 107.0 | 1W | |
| Reverted to Crown | | | |
| D.L. 8286 | 64.8 | 3W | |
| **Wigwam Flats - Sheep Mountain** | | | |
| D.L. 2899 | | | |
| **Crestbrook Mill Site** | | | |
| S.L. 35 | | | |
| **Mount Broadwood** | | | |
| **Crowsnest Resources Ltd., Calgary, Alberta** | | | |

Appendix F, continued

| | | | |
|---|---|---|---|
| **Raymond Creek** | | | |
| D.L. 14031 | 64.8 | 1W | 1 |
| S.L. 33 D.L. 4589 | 64.8 | 3W | 3 |
| S.L. 22 D.L. 4589 | 129.6 | 2W | 1 |
| **Rainbow - Phillips Creek** | | | |
| S.L. 20 D.L. 4589 | 129.6 | 1W | 3 |
| S.L. 45 D.L. 4589 | 64.8 | 1W | |
| Reverted to Crown | | | |
| S.L. 46 D.L. 4589 | 43.5 | 1W | 1 |
| S.L. 23 D.L. 4589 | 64.5 | 1W | 1 |
| S.L. 32 D.L. 4589 | 130.0 | 2W | 2 |
| S.L. 21 D.L. 4589 | 130.0 | 3W | 3 |