The University of Calgary

BIGHORN SHEEP USE OF AN OPEN PIT COAL MINE IN THE FOOTHILLS OF ALBERTA

by

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ABSTRACT

The purpose of this study was to obtain population data on the bighorn sheep of Cardinal River Coals Ltd.'s surface lease and to document their spatial and seasonal use of the mine site south of Hinton, Alberta. The study was conducted from September 17, 1985 to September 1, 1986. Recommendations on reclaiming an open pit coal mine to bighorn habitat were also made after it was realized that the regulations requiring reclamation of the disturbed areas did not allow for the maintenance of high walls. High walls of active or exhausted pits functioned as bighorn escape terrain on the coal mine.

Four seasonal movements for the ewes and four seasonal movements for the rams were identified which, when combined, amounted to six seasonal home ranges. Spatial patterns were analyzed for each seasonal home range. Bighorns congregated on the mine site for the pre-rut, rut and early winter. About half the ewes left to winter elsewhere for the late winter and early spring season. The remaining ewes left for lambing in the alpine in late May and did not return to graze on the mine site until late August for the pre-rut. Rams remained segregated on the mine site except during the rut. The 50-A-3 pit was used as a mineral lick by the ewes in June despite the fact that they were using the alpine zone for grazing.

A maximum of 193 sheep was counted during the pre-rut, the time when the largest numbers of sheep were present on the mine site. The lamb:100 ewe ratio (including yearling ewes)

in the fall was 49:100, indicating a healthy population. Class III and IV rams comprised 6% of the population at that time. Body weights were at the upper limit for sheep from this latitude. Lungworm levels were high and displayed heavy infection rates (>1400 LPG) during the rut and early winter. Although high lungworm output can be an expression of stress, there was no outward manifestation of pneumonia, indicating the sheep were offsetting the effects of lungworm with a healthy immune system. High walls of the active or exhausted pits were used as escape terrain, for travelling, for lambing and for security by wounded sheep. Seventy-five percent of individual sheep observations for the year occurred within 290 m of high walls. Seeps on the benched walls of the 50-A-3 pit were sought out in June by the ewes as a source of minerals. Sheep were habituated to vehicle and mining activity. Wolves did not frequent the main winter ranges within the boundaries of the mine. The reclaimed grasslands were highly productive. Crude protein values as measured by fecal nitrogen were similar to crude protein derived from native forage.

This site-specific wildlife study identified sheep habits and habitat characteristics which were used to help design the end-use reclamation during the active phase of mining. Open pit coal mining imposes constraints on how a landscape can be reclaimed. However, this study identified opportunities beneficial to bighorns that may have been otherwise overlooked.

ACKNOWLEDGEMENTS

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Gerry Acott formerly of Cardinal River Coals Ltd. was instrumental in getting this study off the ground quickly and with a minimum of bureaucracy. Many thanks go to the staff of Cardinal who helped me travel safely through the pits, graded the roads in the winter and offered me their observations. I was impressed with the concern that the employees expressed for the welfare of the sheep.

Thanks go to Kirby Smith and Bruce Treichel of Alberta Fish and Wildlife who darted and collared two ewes so that I could follow them during lambing season. Alberta Fish and Wildlife staff also supported this project by allowing me access to the laboratory in the O.S. Longman building and by freely providing survey reports on request. Brenda Kuzyk conducted analyses of fecal samples and Brenda Buchner and Debra Stevenson helped with typing and formatting the thesis. Ardys Flegel from the Faculty of Environmental Design helped me with administrative details and gave advice on Faculty and University procedures.

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Larry Sinkey reviewed my initial draft as well as my committee members. Rich Revel provided a very detailed review of my first draft which helped me focus the remainder of the writing. Max Bayer provided assistance on the interpretation of my data base and on statistics. I had several fruitful discussions with Marco Festa-Bianchet who was also a student of Val Geist.

I had never spent as many consecutive days observing any animal as I did before this study was initiated. My appreciation of the bighorn and its relationship to the environment grew as the study progressed and after it was completed I felt that I could not have called myself a biologist without having had such an opportunity.

Special thanks go to my husband Barry Godsalve who helped me through the many stages of this project.

"The earth is to be seen neither as an ecosystem to be preserved unchanged nor as a quarry to be exploited for selfish and short-range economic reasons but as a garden to be cultivated for the development of its own potentialities of the human adventure."

Rene Dubos, Symbiosis between the earth and mankind, Science, 193:462, 1976.

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1. INTRODUCTION

Habituation of the Rocky Mountain bighorn sheep (*Ovis canadensis canadensis* Shaw 1804) to human activity and use of industrial sites have a long record in North America. The negative effects of human presence and industrial activity on bighorn sheep have been documented by various authors (Buechner 1960; Northern Wild Sheep Council 1972:116). In the late nineteenth century, humans and their livestock have been identified as the cause of bighorn declines in the continental United States of America (Buechner 1960). Severe hunting, range degradation and disease introduced by domestic sheep (Goodson 1980) decimated bighorn populations, resulting in a fragmented distribution pattern. Industrial development in the form of phosphate, coal and gold mines, and the roading of wilderness areas for logging and other enterprises have all impacted on bighorn range or contributed to over-exploitation.

However, the ability of mountain sheep to habituate to human presence has been well established (Geist 1971a). The use of industrial sites by bighorn sheep is not a new phenomenon and has been documented in Alaska by Elliot (1984) and in Alberta by Morgantini and Worbets (1988). This study was initiated by Cardinal River Coals Ltd. (CRC) in response to the voluntary occupation of their mine site by bighorn sheep despite the on-going mining activity and presence of humans.

Cardinal River Coals Ltd. is an open pit coal mine situated 50 km south of the town of Hinton and 6 km west of the hamlet of Cadomin in the Alberta Foothills (Figure 1). Operations began in 1969 and reclamation in 1971. Anecdotal records communicated to the author by local residents and mine employees indicated that rams utilized old mine shafts located on the present mine site just below timberline for mineral licks prior to 1969. Reclamation and seeding of pits located adjacent to the alpine began in 1975 and soon after this time, significant numbers of ewes and juvenile sheep began using the area. In December 1977 and January 1978, 40 sheep were observed foraging on reclaimed areas (Webb 1980:23). This population continued to grow, and by 1985 numbers had become so great (200) that CRC commissioned the author to conduct a study of the bighorn use of the mine site. It was from this study that material for this Masters Degree Project was collected.

Purpose and Objectives

The purpose of this study was:

1. To obtain baseline population data on the bighorn sheep at Cardinal River Coals Ltd.

2. To document bighorn use of an active open pit coal mine by bighorn sheep.

3. To make recommendations on reclaiming an open pit coal mine to bighorn sheep habitat.

The specific objectives of this study were:

1. To conduct a bighorn sheep census on the CRC study area for one year.

2. To establish maximum numbers of each age class (Geist 1971b:54) of bighorn sheep on the study area during the year of census.

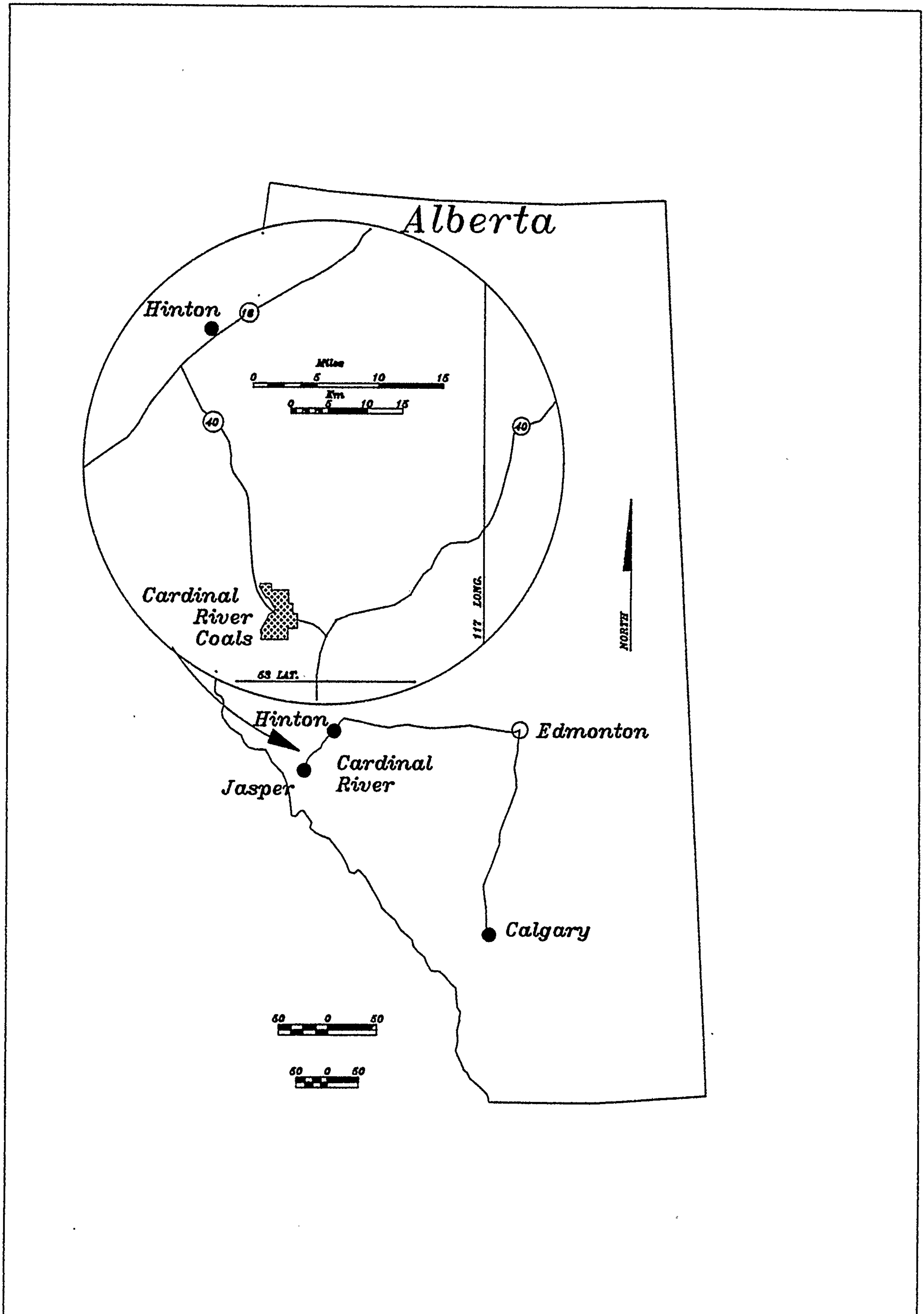


Figure 1. Location of Cardinal River Coals Ltd.

3. To record the temporal occupation patterns of the bighorn sheep for a one-year period on the study area.

4. To map the distribution of the bighorn herd on the study area throughout the year of census.

5. To examine the general health and condition of the bighorn sheep population using the study area by the measuring the following:
   : whole weight
   : body features such as chest girth, total length, etc.
   : horn length and circumference
   : skull parameters
   : parameters of productivity and mortality
   : levels of lungworm infection
   : diet quality

6. To record evidence of predators and predation of sheep on the study area.

7. To record other wildlife using the study area.

8. To describe the physical characteristics of the study area as it relates to the following bighorn habitat requirements:
   : escape terrain
   : mineral licks
   : lambing sites
   : vegetation types
   : vegetation quality as measured by fecal crude protein

Location of the Study Area

Cardinal River Coals Ltd. is situated in west central Alberta at the former townsite of Luscar at 53° 04′ north latitude and 117° 24′ west longitude. The study area is defined by CRC's Mineral Surface Lease #5972 comprising 2845.4 ha (7031 acres). It is located in Townships 47 and 48, Range 24, West of the 5th Meridian. The study area will also be referred to as the "mine site" in the text (see Appendix I for definition).

As of December 31, 1986, a total of 43.9% or 1250 ha (3,088.7 acres) of the mineral surface lease had been disturbed, of which 504.3 ha (1246.1 acres) were in some stage of reclamation (Acott et al. 1987). The Gregg River defines the west boundary of the study area, Mary Gregg Creek the north boundary, tributaries of Luscar Creek the east boundary, and the front ranges of the Rocky Mountains the south boundary. HWY 40 bisects the mineral surface lease.

Physical Characteristics

The study area is classified as subalpine (Corns and Annas 1986) and is typified by rolling topography and steep slopes of uplifted Mesozoic shales and sandstones. Elevation ranges from 1680 m to 1860 m (5512-6102 feet) a.s.l. (Acott 1981). The study area is located just below timberline at the eastern edge of the Rocky Mountains on the northeast flank of the Nikanassin range. This range extends 30 km to the northwest and 27 km to the southeast of Cadomin and presents a considerable barrier to the easterly flow of Pacific air (Root 1976). Luscar Mountain, located immediately to the southeast of the study area attains an elevation of just over 2591 m (8,500 feet).

The study area is drained by Luscar Creek, which flows in an easterly direction through the mineral surface lease to the MacLeod River, by Cabin creek which flows northward into the Gregg River, and by Mary Gregg Creek which drains the northeast boundary of the mine site and also flows into the MacLeod River. Both Luscar Creek and Cabin Creek have been diverted from their original courses to accommodate the mining process.

The Gregg River drains the western edge of the study area and also forms a common boundary between CRC and Gregg River Resources Ltd. (GRRL) - an open pit coal mine opened in 1983.

Prior to mining, the study area was almost entirely forested with a closed canopy spruce/fir forest. Forested areas are dominated by hybrid white x Engelmann spruce (Picea glauca x engelmannii), lodgepole pine (Pinus contorta), fir (Abies lasiocarpa) and black spruce (Picea mariana). Aspen (Populus tremuloides) and balsam poplar (Populus balsamifera) occur on exposed, warm, south-facing slopes. Most coniferous timber within the lease is non-merchantable, which is defined as having a height of less than 15.2 m (50 feet), a diameter at breast height of less than 20.3 cm (8 inches) and a stocking rate of less than 25 trees per hectare (10 per acre).

Soils of the study area are generally orthic gray luvisols on fine textured materials or eluviated brunisols on coarser textured parent materials (Hardy 1981).

Geology

The recoverable coal on the mine site is found in the upper beds of the Luscar Formation, which is a 457 m thick non-marine sequence of interbedded soft gray sandstones, dark gray shales and coal seams of the Cretaceous age (Cardinal River Coals 1986; Root 1976). The seam being mined is locally known as the Jewel seam and is between 10.7 - 13.7 m thick (Aiello 1973). The seam is highly folded and contains minor faulting. This folding process results in concentrations of coal at the bottom of the folds known as "pods". These "pods" of coal can range up to 61 m high on the fold axes. Open pit mining occurs where the folding process in combination with long term erosion has exposed the coal relatively close to the earth's surface.

Climate

CRC is located in an area of Cordilleran climate characterized by cold winters and cool summers (Strong and Leggat 1981). During the winter months, air that moves eastward over the Rockies periodically descends and warms adiabatically, creating the Chinooks and high temperatures that are characteristic of this area (Root 1976). Rapid removal of snow cover and desiccation of vegetation are consequences of the Chinook.

Meterological data collected at CRC from 1977 to 1987 indicate that the mean daily temperature averaged 2.4°C per year (Table 1). Total precipitation for this same period averaged 744 mm per annum, 70% of which fell during the months of May to September (Table 1).

High winds are common, being strongest near timberline on the 50-A-2 dump and on the C-baseline. Between October 1985 and March, 1986, 40 days of winds over 80 kph (50 mph) were recorded at the CRC security gate in the valley bottom at elevation 1752.6 m (5750 feet). This is similar to the three year average calculated from 1986 to 1988. Winds on the 50-A-2 dump and the C-baseline located at elevation 1828.8 m

Table 1. The average mean daily temperature (°C), total precipitation (mm), and the number of days during which the wind was greater than 80 km per hour as recorded at Cardinal River Coals Ltd., Luscar, Alberta.

Date	Mean Daily Temperature (°C) 1977-1987	Total Precipitation (mm) 1977-1987	# of Days With Wind > 80 km per hour 1985-1989
January	-6.0	16.8	8.5
February	-5.7	20.2	4.25
March	-2.3	34.8	3.5
April	1.2	48.9	1.75
May	6.2	79.4	0.75
June	10.2	130.5	1.0
July	12.7	118.0	0.25
August	11.8	104.9	0.0^
September	7.2	90.9	1.6
October	4.0	44.7	4.0
November	-4.3	25.3	6.0
December	-6.8	17.3	7.75
Annual Mean	2.4	744.0	41.0*

total precipitation = rainfall plus snow water equivalent
^ = incomplete data
* = average calculated for the 3 years 1986 - 1988

(6,000 feet) would have been of a higher velocity than those in the valley bottom.

Mining at Cardinal River Coals Ltd.

Cardinal River Coals Ltd. began mining operations at the former town site of Luscar in 1969. Prior to this time, a coal mine called Luscar Collieries Ltd. operated both underground and strip mines on the same site from 1921 to 1958. During the 1940's, no fewer than 14 mines were operating in the area of west central Alberta known as the Coal Branch (defined by a spur line of the Grand Trunk Pacific Railway connecting the mining camps that had been developed in the foothills southwest of Edson). The ready availability of other fuels (natural gas and oil), however, played a large part in shutting down activity in the Coal Branch. After 1959, limestone quarrying and logging surpassed the coal industry in importance in the area and by 1966, production had ceased entirely (Lake 1967:142).

In 1986, CRC moved 2,094,054 raw short tons of coal and 14,219,574 bank cubic yards of rock (Acott et al. 1987) and produced 1.64 million clean short tons of medium volatile metallurgical coal for export to Japan. Mining operations are carried out in two 12 hour shifts, 7 days a week. At year end, manpower consisted of 241 hourly unionized employees and 73 salaried staff. Shovels with 15 and 30 cubic yard bucket capacity are employed in conjunction with 100 and 170 ton trucks to mine multiple open pits.

In 1986, two pits (50-B-5 and 51-B-3) were active (Figure 2 and 2a). Grading activities were conducted in the 50-B-6 dump #2 and pit, 50-B-5 north dump, 50-A-3 pit and 51-C-1 backfill. Regolith replacement occurred in the 50-B-5 north dump, 50-B-6 dump #1 and #2, 50-B-3 dump, 50-A-2 dump and 50-A-3 pit. Topsoil replacement occurred in the 51-C-1 and 50-B-5 dumps. A total of 73.9 hectares (182.7 a) was reseeded throughout the mine site on the 50-A-2, 51-B-2, 51-B-3 dumps and the 50-B-6 and 50-B-5 pits and on various topsoil stockpiles. A series of photographs of the mine site is included in Appendix II to help the reader associate complex place names with the physical characteristics of the study area.

Reclamation Plans and Standards

Prior to 1963 there were no reclamation standards in the province of Alberta. In 1963, the combination of public concern about industrial development and the increased rate of industrial disturbance resulted in the Surface Reclamation Act of 1963 (Bratton 1987). This Act was concerned primarily with cleanup and recontouring the land and dealt with the reclamation of well sites, pipelines, battery sites, mines and quarries.

In 1973, the Land Surface Conservation and Reclamation Act was passed. This Act provided for the planning of development so that adverse impacts would be minimized and ensured that reclamation plans, prior to construction, were completed. This change of attitude was further emphasized by the passing

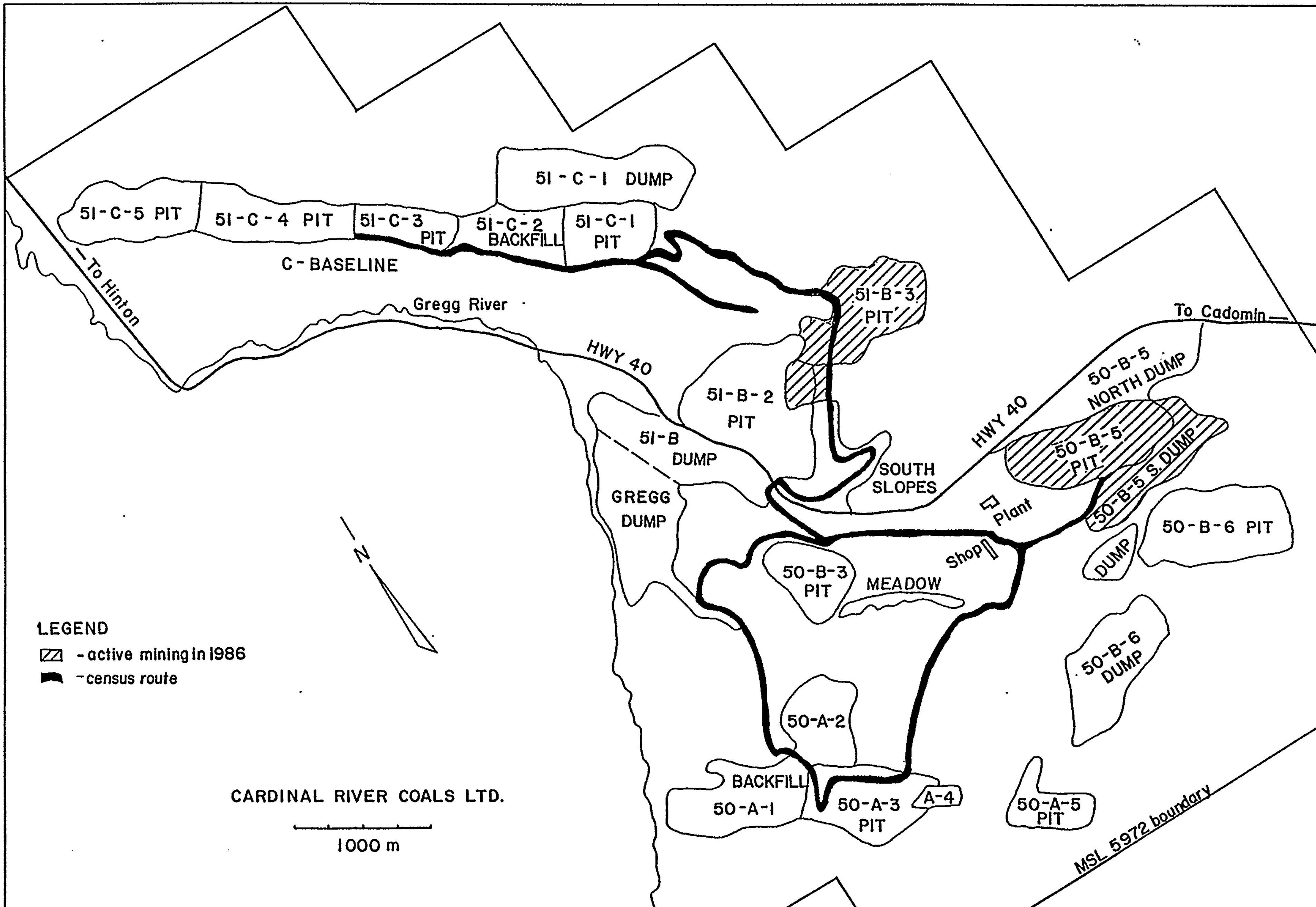


Figure 2. Study area boundary (MSL# 5972) and location of pits, dumps and backfills at Cardinal River Coals Ltd., 1986.

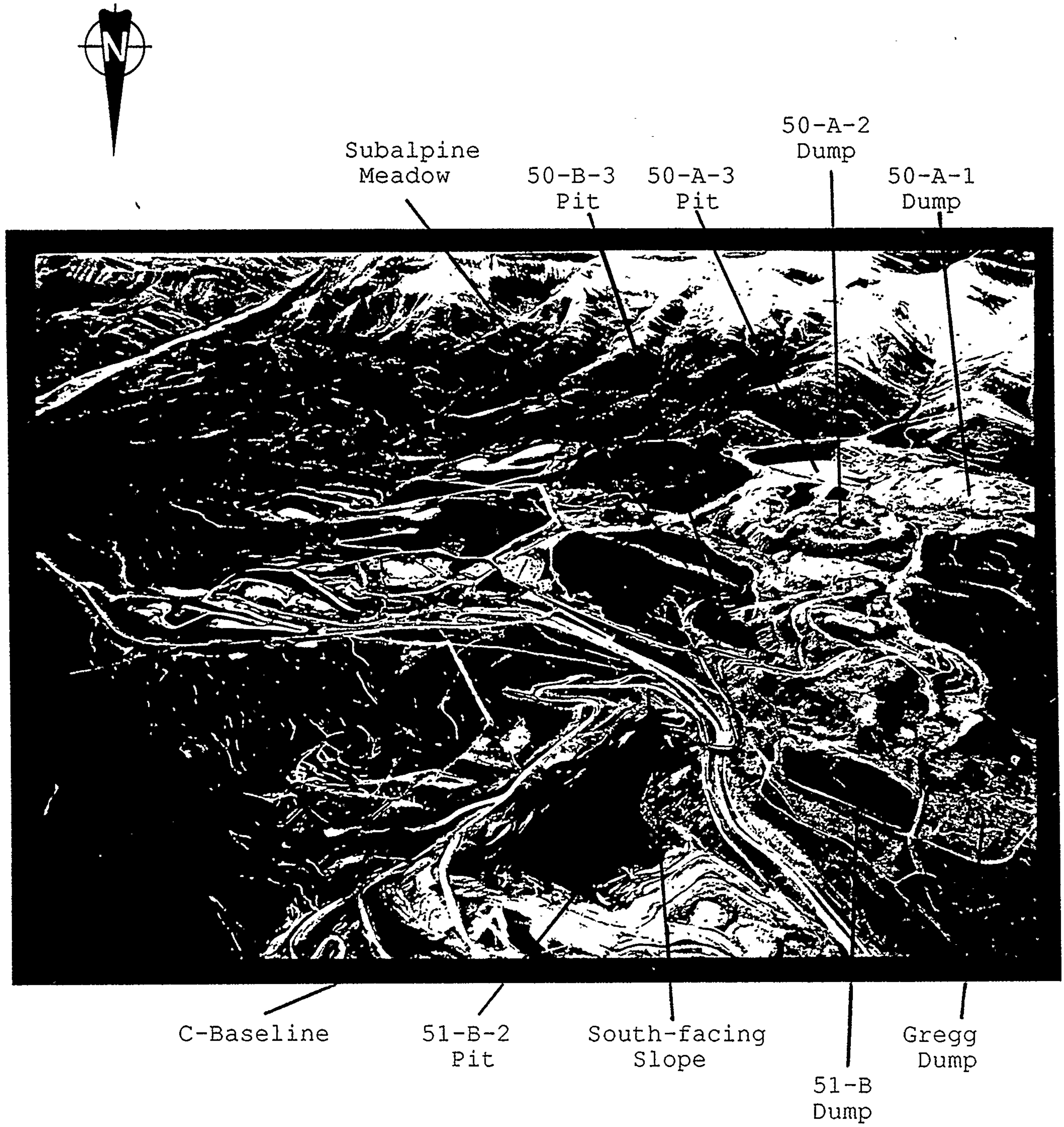


Figure 2a. Air photo of Cardinal River Coals Ltd. mine site, August 1985.

of the Regulated Coal Surface Operations Regulations in 1974, which stated that land reclamation should become an integral part of mine planning and development. In addition, a major statement on reclamation objectives was made in the Coal Development Policy (Alberta Government 1976:7). It states:

> The primary objective in land reclamation is to ensure that the mined or disturbed land will be returned to a state which will support plant and animal life or be otherwise productive or useful to man at least to the degree before it was disturbed.

Cardinal River Coals Ltd. began reclamation efforts in 1971 and by the end of 1978, 198 ha (489.2 acres) of disturbed area had been revegetated (Hardy 1981). Initial reclamation efforts used a variety of strategies and operated under two objectives:

1. To stabilize the soil surface against erosion.
2. To establish a productive and self-sustaining big game wildlife habitat.

By 1979, CRC had commissioned a study (Wallis and Wershler 1979) to develop specific guidelines for reclaiming disturbed areas to bighorn sheep, mule deer, elk and moose habitat. Objectives were refined (Acott 1983) to include:

1. A final landscape of 40% tree cover / 60% open grazing area. Under the assumption that wildlife would utilize the edge of the natural forest surrounding the mining disturbance, the amount of cover required would be correspondingly reduced.

2. Forage varieties established in the open areas would be chosen on the basis of availability, hardiness and nutritional value to wildlife.

3. Trees and shrubs planted on reforested areas would provide concealment, thermal protection and sight line interruption in addition to providing nutritious browse.

4. Travel corridors would be developed to encourage wildlife utilization of the entire reclaimed area.

By 1986, one year after initiation of the bighorn study, the emphasis on reclamation of disturbed areas was placed on bighorn habitat (Acott 1986a).

CRC also took an opportunity to diversify its primary land use objective by reclaiming the 50-B-6 pit as a lake to be used as a sport fishery. Approval by the government to go ahead with development of the lake was given in 1981.

Reclamation - Materials Handling and Vegetation Establishment

The reclamation process begins with stripping the topsoil and upper layers of the regolith prior to mining. These materials are stored in stockpiles for future use. Once the dumping and recontouring of an exhausted pit is accomplished, regolith material is replaced over the whole surface to a depth of 15 cm. Topsoil is placed only on locations selected for reforestation to a depth of 30 cm. A grass-legume mixture is then seeded directly onto the regolith by using a helicopter or hydroseeder (Acott 1986a). The resulting forage crop is composed of varying amounts of the following species: Durar Hard Fescue (Festuca ovina var. duriuscula, Arctic Red Fescue (Festuca rubra), Ruebens Canada Bluegrass (Poa compressa), Kentucky Bluegrass (Poa pratensis), Streambank Wheatgrass (Agropyron riparium), Kay Orchardgrass (Dactylis glomerata), Smooth Bromegrass (Bromus inermis), Rambler Alfalfa (Medicago spp.), Aurora Alsike Clover (Trifolium hybridum), Sainfoin

(*Onobrychis viciifolia*), Oxley Cicer Milkvetch (*Astragalus cicer*) and Sweet Clover (*Melilotus* spp.)

Reforestation with woody species is carried out on the "topsoil islands" after a nurse crop of sweet clover has been established. The following species are planted: Engelmann Spruce (*Picea engelmannii*), Lodgepole Pine (*Pinus contorta*), Green Alder (*Alnus crispa*), Swamp Birch (*Betula pumila*), Balsam Poplar (*Populus balsamifera*), Willow (*Salix* spp.), Canadian Buffaloberry (*Shepherdia canadensis*), Wolfwillow (*Eleaegnus commutata*), Wood Rose (*Rosa woodsii*) and Black Elderberry (*Sambucus melanocarpa*).

History of Bighorn Use in the Alpine Adjacent to CRC

It seems that the alpine zone immediately adjacent to the 50-A-2 dump and 50-A-3 pit must have been used by bighorn sheep prior to current mine development in 1969. An aerial survey conducted on December 10, 1963, records bighorn sheep at the nearby Luscar Lookout, and on Luscar and Leyland Mountains (Stelfox 1964). Lynch (1972), Smith and Lynch (1974) and Kosinski (1977) document the results of an Alberta Fish and Wildlife Division (AFWD) sheep collaring program for the years 1972, 1973, 1975 and 1976 which clearly identify that bighorn sheep had a tradition of traversing the mountains adjacent to CRC between the Redcap range and Jasper National Park.

Winter range surveys conducted by Cook and Hall (1978), Bibaud and Dielman (1980), Webb (1980) and Cook (1982) indicate that bighorn sheep frequented the alpine areas adjacent to CRC in the headwaters of Gregg River, Luscar Creek and drainages SE toward Leyland Mountain during the winter.

Sequence of Sheep Use of the Mine Site

Prior to the current mine development, bighorn rams were known to use old mine shafts in the vicinity of the 50-A-3 pit as mineral licks. These workings included the Big Prospect Operations which were developed on the north-facing slope of Mt. Luscar in the summer of 1950 (Cormack 1950). This development was located at about the 1828.8 m (6000 foot) level and extended east-west across the present day 50-A-3 pit and 50-A-2 backfill from an older tunnel mine known as the "Glory Hole". Tunnel mines in this area were operating between 1940 and 1945 (Van Dyke 1990).

Apparently the bighorn nursery herd did not come onto the mine site until after vegetation on the backfilled areas was established. The sequence of reclamation on the 50-A-1 and 50-A-2 backfills was: 1972 (1.2 ha), 1974 (1.2 ha), 1975 (9.3 ha), 1976 (6.5 ha), 1977 (7.7 ha), 1978 (21.9 ha) and 1979 (15.4 ha) and 1982 (0.8 ha) for a total of 64 ha. The first aerial survey to include the mine site recorded 13 sheep (11 ewes and lambs and 2 young rams) foraging on the 50-A-2 backfill on January 20, 1978 (Webb 1980:19).

By 1979, the rutting area had become established on the 50-A-1 and 50-A-2 backfills and the 50-A-3 pit (pers. comm. G. Acott). It is unknown whether the rut had taken place in adjacent alpine areas prior to this time and had simply shifted to the mine site once reclamation had progressed. In terms of occupation of the mine site as a whole, movement eastward as mining progressed must have been relatively rapid. In the central area of the mine, the 51-B-2 pit was developed between 1982 and 1984. During this time the sheep had to be chased off the area prior to blasting, indicating use of this area by 1982 and likely before. The existence of earlier reclamation on the 51-B dump south of Highway 40 (1972) and on the south-facing slopes adjacent to the 51-B-2 pit (1976) in conjunction with the development of the 50-B-3 pit in 1979 probably facilitated sheep use in this area prior to 1980.

Movement farther east by the rams onto the C-baseline was observed prior to the clearing of the 51-C-3 pit in 1980. At this time there would have been virtually no forage areas available on the north slope of the ridge. The 51-C-1 pit had been opened in 1971, however, offering at least escape terrain in the vicinity.

Bighorn Sheep Habitat Requirements

The common feature of bighorn distribution in North America is the presence of rocky escape terrain in proximity to quality forage (Wishart 1978:166). The bighorn's anti-predator strategy involves visual detection of predators at distance and response by running to escape cover (cliffs or cliff-like terrain). A long field of view unobstructed by trees or other visual impediments is therefore essential for a successful anti-predator strategy. Radio telemetry monitoring of ewes in southern Alberta showed significantly higher heart rates when these sheep were traversing forests as compared with movement on open slopes or fields (MacArthur et al. 1979).

Bighorn sheep are thus limited to foraging areas which are near to escape terrain. Most sheep use of foraging areas occurs within 0.8 km (0.5 mi) of escape terrain (Van Dyke et al. 1983:6). Stemp (1983:117) demonstrated that heart rate of ewes increased exponentially with distance from cliffs and that sheep were almost never sighted beyond 300 m from cliffs despite the presence of excellent forage and steep hills. They were never sighted beyond 500 m of cliffs.

Grasses and sedges are the preferred foods of the bighorn (Stelfox 1976). Forbs and, to a lesser extent, shrubs are also used seasonally.

Mineral licks are sought out in the spring by both ram and ewe bands. Many reasons for this behaviour have been postulated. Weeks and Kirkpatrick (1976) postulated that white-tailed deer needed sodium in spring to compensate for an elevated intake of water and potassium. Jones and Hanson (1985: 120) indicate that licks used exclusively by bighorn sheep were enriched in calcium and magnesium. These same authors (p. 97) conclude that sulphur salts present in the bighorn licks of Alberta and Alaska must contribute importantly to the sulphur nutrition of these animals.

The other important habitat needs of a bighorn are thermal cover (provided by elevation, rock outcroppings and vegetation), rutting and lambing areas. In the southern parts of their range, water may become limiting. Bighorns may make long migrations between seasonal ranges. Rams may have up to 6 ranges and ewes up to 4 (Geist 1971b:63). Knowledge of the location of seasonal ranges is passed onto the lambs and young rams as a learned tradition.

2. METHODS

Bighorn Sheep Census

Bighorn sheep use open terrain, are active during the day, tend to concentrate on rutting/winter ranges, and can be classified by horn structure (Geist 1966; 1971b). Road access around the mine site was available for most of the year and sheep were habituated to vehicular traffic and to a lesser extent to humans. A complete census by means of direct ground counts was therefore possible.

A fixed survey route of approximately 19 km was established on the study area (Figure 3) and census counts were always made from this route. This ensured that the terrain being observed remained constant and that variations in sheep counts were not due to variations in the size of the area being censused. The route was travelled with a vehicle and on foot. Time to complete the survey varied with the season and with the number of sheep present during the census. In the fall, when maximum numbers were present, the survey took between 6 and 8 hours to complete. The rut was difficult to survey as many recounts had to be made due to sheep running through the herd and disturbing those that had already been counted. Sheep were easier to count during the winter as they interacted socially less, and were concentrated in predictable locations. In the summer, when very little sheep use occurred, the route could be surveyed in 2.5 hours. Surveys began between 0800 and 0900 and the order of the route varied

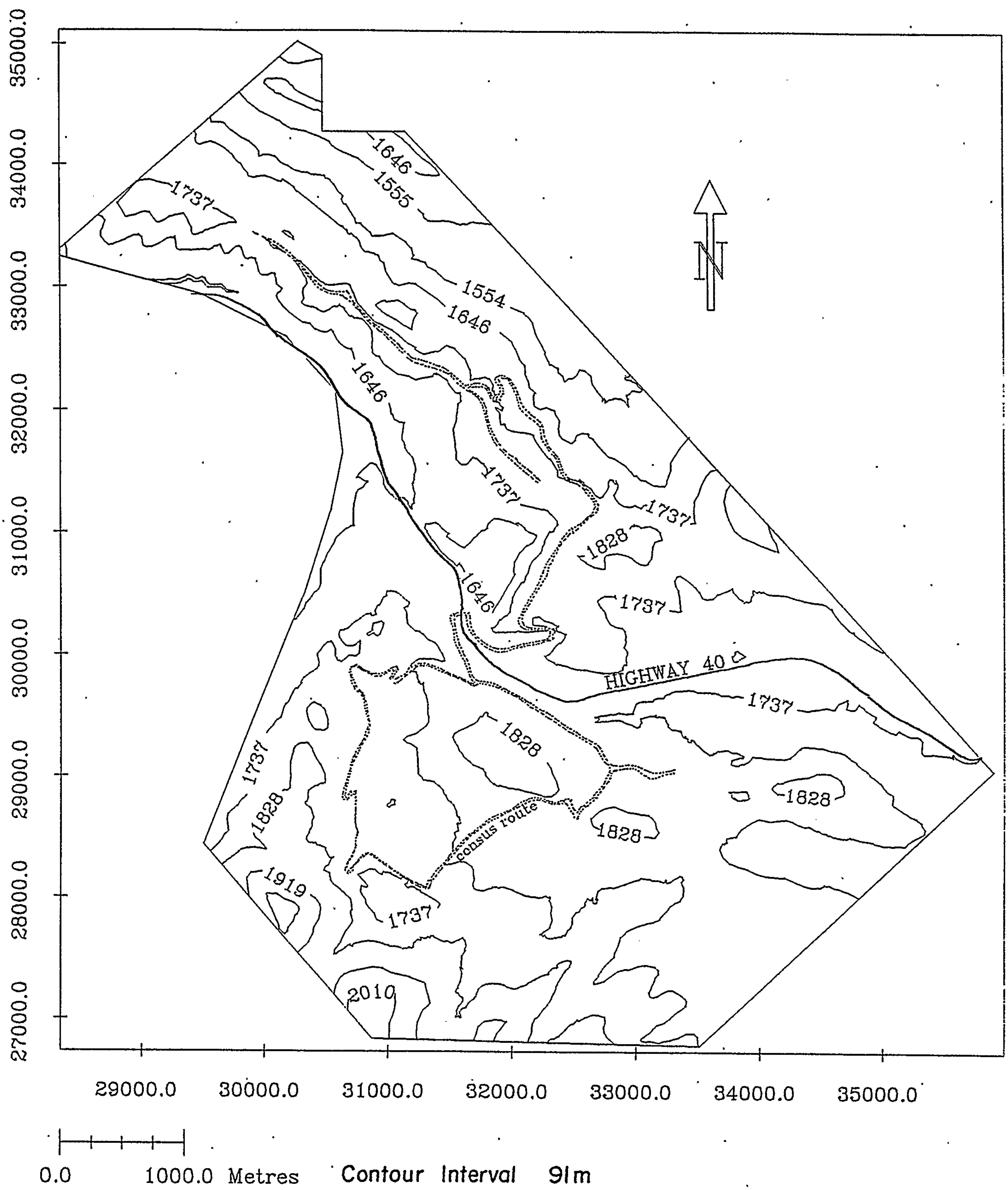


Figure 3. Base map of the study area used to plot the distribution of bighorn sheep at Cardinal River Coals Ltd.

with the location of the blast on the mine site that particular day. All sheep sighted from this survey route were counted and classified according to the eight age/sex classes identified by Geist (1971b:54).

Study Period

Observations of bighorn sheep at CRC began on September 17, 1985, and continued weekly until September 1, 1986. Three to four days per week were spent on the study area for 52 weeks. A total of 181 census counts were made during this time. Periodic observations were also made through the fall of 1986. During the summer of 1986, bighorn use of the study area was negligible. This allowed the census on the mine site to be completed quickly so that time was available for hiking in the nearby alpine areas. As a consequence, 22 alpine surveys were conducted between May 29 and August 14, 1986, in addition to the CRC sheep census. The signals from two radio-collared ewes were used to locate the herd on any particular day. Sheep were counted and classified; group locations were marked on a 1:50,000 NTS map. The drainages most frequently surveyed were those of the Gregg River, Luscar Creek and W. Jarvis Creek as these were where the nursery herd concentrated.

Temporal Occupation of Sheep on the Study Area

Movements of sheep on and off and around the study area were noted to be tied to seasonal events in the life history of the bighorn sheep. These movements were used to help define specific time periods when the sheep occupied seasonal home ranges during the annual cycle. Population characteristics and spatial use of the study area by sheep were therefore analyzed using the occupation of the seasonal home ranges as the temporal unit rather than using months or an arbitrary definition of seasons. Numerical trends were estimated by means of a maximum count for all recognizable age/sex classes and by maximum total counts for all surveys during each specific time period (Geist 1971b; Irby et al. 1988).

Distribution of Sheep on the Study Area

Animals generally use space within their home range differentially; bighorn sheep in particular are known to make seasonal movements between ranges (Geist 1971b:13) and to use certain habitats only on a seasonal basis. An understanding of the biological significance of an animals' home range requires knowledge of the intensity of use of various portions of their range (Hayne 1949). Voigt and Tinline (1980) have classified the methods used to measure home ranges as: (i) minimum area methods; (ii) centre of activity methods, and (iii) grid cell methods. This section describes the mapping techniques and the computer programs that were used to analyze the sheep use of the study area.

During each census count, the locations of sheep were plotted onto acetate overlays of a 1:4,800 base map (contour interval 1.524 m). Topographic, man-made features, and changes in vegetation were used to plot the location of each sheep or group of sheep. When a group was observed, the outline of the area they occupied was marked on the acetate overlay. The first location where a group was observed was plotted as well as subsequent movements during the observation period. In addition to plotting locations, the activity of each individual during classification was noted. Behaviour patterns used in social interactions between bighorn sheep were recorded (Appendix I) as well as behaviour that did not elicit a response from other sheep (i.e. grazing, bedding). During the study, 31 individual sheep were identified by horn and body characteristics and their presence or absence on the study area was noted during each survey. Brief descriptions of those sheep mentioned here are given in Appendix I.

Computer Mapping of Wildlife Distribution

Computer hardware (VAX 11/750, operating system BSD Unix 4.2) and mapping software developed at The Faculty of Environmental Design (EVDS) by L. Sinkey were used to enter census data, to digitize locations plotted on the 1:4,800 base map, and to analyze these data using minimum area polygon and modified grid cell techniques. These programs were written in "C" and used a graphics package developed at EVDS. Modifications to these programs were made by B. Stephens to accommodate group observations as the original software was developed for mapping individual movements and home range patterns. An earlier program dealing with the same basic concepts was written in Fortran by L. Sinkey and was used with a commercial graphics package (Bromley 1977). The following is a description of the steps required to process the data.

The location records of bighorn sheep and other wildlife were encoded with a 5-digit number. The first three digits of the identification code referred to the daily census number, while the last 2 digits identified a particular individual or group observation. This system allowed for a maximum of 999 daily census entries and 99 group observations during one census.

To enter the plotted data into the computer, a point was digitized for each individual or group location. If an area encompassing a group of sheep had been plotted, then a point representing its centre was digitized. Areas were also digitized as polygons and long distance movements were digitized as lines; however, these data were not analyzed further. Each digitized location was accompanied by a character string with the following codes:

letter	type	code	description
c	1(char)	c	contour (e.g. 1676.4 m)
p	2(pts)	r	reclaimed grasslands
l	3(lines)	c	coniferous forest
a	4(areas)	m	meadow (grassland and shrub)
		o	non-vegetated
		w	water
		p	open pit

Data collected during each census trip were entered into the computer using the program "dbi" and a 25 field header file (Table 2). Data were stored in one file called "obs" which contains information from all census counts made throughout the year (181) between September 17, 1985 and Septem-

Table 2. Header file (crcheader2) used to input bighorn sheep observation data at Cardinal River Coals Ltd.

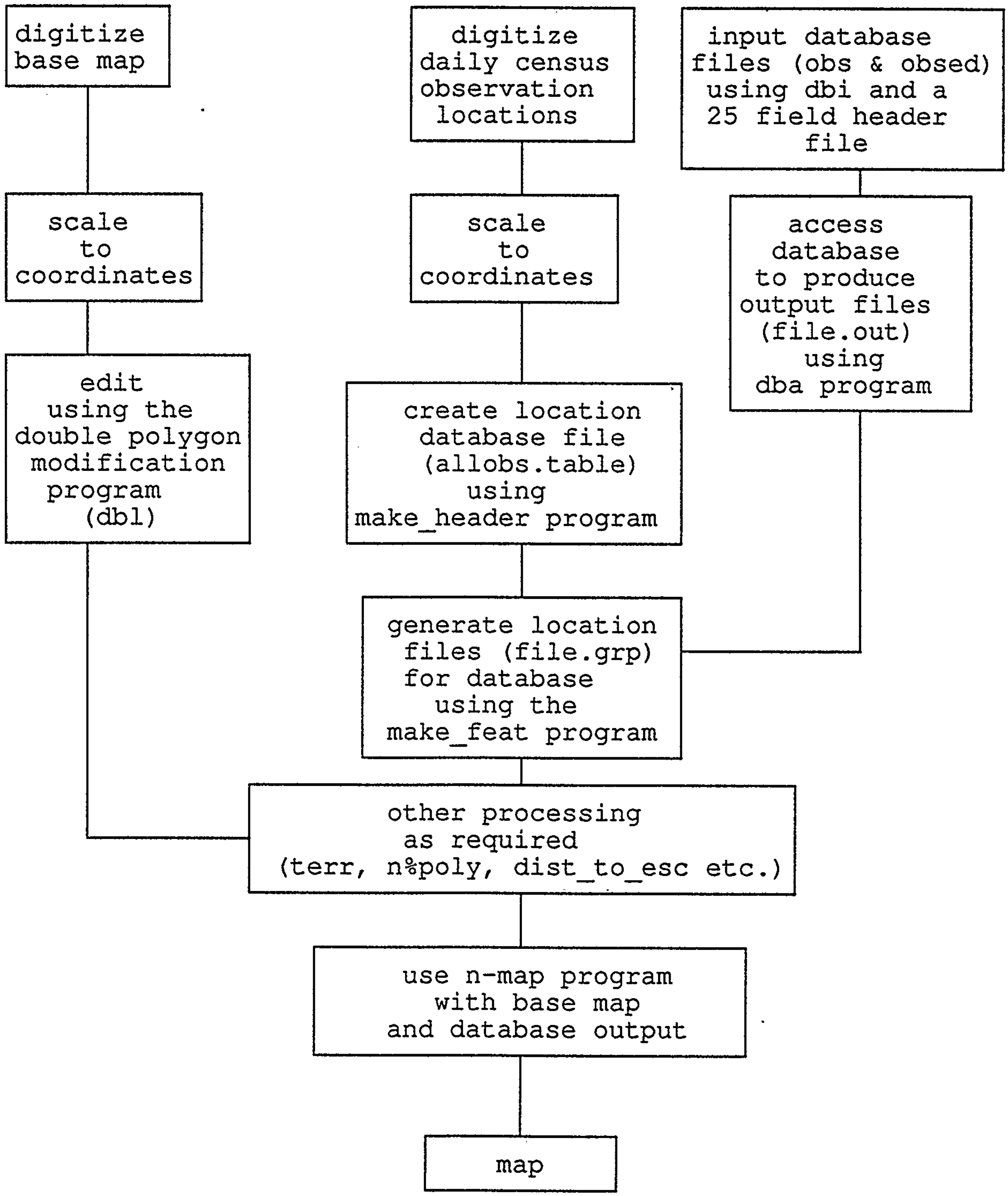
#	Letter q	Name	Number Type	Description
1.	nq	observation id	integer	5 digit
2.	nq	date	integer	year/month/day
3.	nq	group size	integer	3 digit
4.	sq	activity	multiple string text	activity codes *
5.	nq	lamb	integer	2 digit
6.	nq	ewe	integer	2 digit
7.	nq	ewey	integer	2 digit
8.	nq	ramy	integer	2 digit
9.	nq	ram1	integer	2 digit
10.	nq	ram2	integer	2 digit
11.	nq	ram3	integer	2 digit
12.	nq	ram4	integer	2 digit
13.	nq	obs type	integer	0=point, 1=area
14.	nq	obs number	integer	point # or area #
15.	nq	line number	integer	line number
16.	sq	name	multiple string text	name codes*
17.	nq	time start	integer	2400 clock
18.	nq	time end	integer	2400 clock
19.	nq	mdoe	integer	2 digit
20.	nq	mbuck	integer	2 digit
21.	nq	mfawn	integer	2 digit
22.	nq	coyote	integer	2 digit
23.	nq	grizzly	integer	2 digit
24.	nq	wolf	integer	2 digit
25.	nq	red fox	integer	2 digit

* see Appendix I

ber 1, 1986. A second file called "obsed" containing the information from 146 census counts was created from "obs" by eliminating the following: incomplete census efforts (14), the smallest count made on a day when 2 counts were conducted (18), and the first 3 counts made by an assistant in April 1986. Information on seasonal use, sex and age class and activity was retrieved from the "obs" or "obsed" files by means of a database access program (dba). Coordinates to match this information were then searched from the location file (allobs.table) by using the "make_feat" program. Output from the "make_feat" program was then run through the "nmap" program to generate an 8.5 x 11 map on the Imagen printer. The flow diagram in Figure 4 illustrates the steps required for this entire process of entering observation data, digitizing locations and printing maps.

The intensity of use of bighorn sheep on the study area was displayed using the "controlled distribution" feature of the "nmap" program (Bromley 1977:260). This is similar to a grid cell method of analyzing home range which allows determination of intensive use areas, determination of preferred areas, and identification of travel routes (Voigt and Tinline 1980). The mapping surface of the study area was divided into 17 grid lines on the horizontal axis and 20 grid lines on the vertical axis. Grid cells measured 402 x 402 m (1320 x 1320 ft) and represented 16.6 ha (40 acres). The controlled distribution permitted visual analysis of the data. In addition, a program called "terr" calculated the area of occupation of sheep on the study area in a manner similar to the minimum area

Figure 4. Steps required to input database, digitize observation locations and produce maps using the "nmap" program.



convex polygon method.

Several programs were also used to analyze various aspects of the data (Appendix I). These included: a program to measure the distance from each sheep to the nearest escape terrain; a program to calculate the area of each vegetation type on the study area, and a program to count the number of animals in each vegetation type. Area calculations were planimetric and did not account for the steep terrain. Distance from escape terrain measurements were calculated using the distance from the center of a group of sheep when it was first sighted to the nearest escape terrain. In addition, another calculation weighted each group with the number of individuals within the group.

Bighorn Population Quality

Population quality can only be determined by the characteristics of the individual which expresses the resistance of its environment through phenotypic attributes (Geist 1978; 1982. Growth in mammals is continuous in early life. Increases in linear measurements and weight are commonly used by mammalogists as indicators of age during the early life stages (DeBlase and Martin 1974). Standard body measurements are also used for comparing populations and as a measure of population quality (Geist 1971b:304-308; Shackleton 1973).

Ten ewes (4 years or older) were weighed and measured between October 3 and October 31, 1985, during the CRC nontrophy hunt. Sheep were weighed soon after being shot by hoisting them from the ground in a nylon net suspended from a spring scale which was lifted with a pulley system. The animal was weighed again after gutting but prior to being skinned. Fifteen additional ewes were weighed in the same fashion between September 28 and October 3, during the 1987 non-trophy hunt. Body measurements included total length, tail length, hind foot length, neck circumference, and heart girth. Hind foot lengths greater than 37 cm are an indication of fully grown status in Nelson's (desert) bighorn sheep (Geist 1971b:46). Neck circumferences are routinely collected for determining collar sizes. Heart girth is an indirect measure of weight (Giles 1971:81).

Growth lines caused by unequal deposition of keratinized epithelian layers due to annual hormonal changes during reproduction can be used to age members of the family Bovidae that possess horns (Caughley 1965; Geist 1966). Horn measurements made on the CRC sheep included basal circumference and total length for each horn. Length of the annual increments on each horn was also measured, although a count of the annuli is not a reliable technique for aging ewes (Geist 1966).

A minimum of 25 bighorn fecal samples was collected during the latter half of each month from October 1985 to September 1986. Samples were collected fresh and classified according to sex and age of the sheep. Larvae per gram (LPG) of the nematode parasite Protostrongylus stilesi and P. rushi were measured using the Baermann technique (Samuel and Gray

1982). Histograms of the frequency of distribution of counts of the number of larvae per gram (LPG) of dry faeces were examined for each month and were found to be skewed to the right. Therefore, all counts were transformed using a natural logarithm $\ln(x+1)$ prior to statistical analysis so that the frequency of distribution approached normality (Uhazy et al. 1973).

Other Wildlife

Observations of mule deer, wolf, coyote, fox and grizzly bear were recorded and plotted in the same fashion as for sheep. Deer were classified as doe, fawn or buck. Observations of birds were recorded throughout the year and published in the Alberta Bird Record (MacCallum 1986a, b and c). Observations of smaller mammals like hoary marmots were noted but not plotted.

Food Habits of Bighorn Sheep

Food habits of the sheep on the study area were investigated by rumen analysis and by microhistological analysis of fecal material. Ten rumen samples were collected from ewes shot during the non-trophy hunt held between September 17 and October 31, 1985, on the CRC mineral surface lease. Rumens were analyzed by the methods described by the Alberta Fish and Wildlife Division (Appendix I).

Two pellets from each of the 25 - 30 pellet groups collected monthly from the sheep on site were combined into a single sample per month. These 12 samples were sent to the

Composition Analysis Laboratory at the Colorado State University, Colorado, for microhistological analysis. Five slides per sample were prepared for analysis and 20 fields per slide were analyzed under a binocular microscope. Methods are described in Hansen et al. (undated). A complete list of plants found on the mine site and in the adjacent alpine area was supplied to the lab. Voucher specimens were collected, identified, and housed in the herbarium at the University of Calgary (UAC).

Habitat Characteristics of the Study Area

Escape terrain as used by bighorn sheep on the mine site during the year of study was identified and digitized. The program "dist_to_esc" was then used to measure the distance from each sheep or group of sheep observed to the nearest escape terrain. Distances were measured from the centre of each group observation to the nearest escape terrain. In addition, an adjustment was made to account for all individuals within the group and these distances were also reported, although this is not a common practice as a review of the literature revealed.

Home range of an animal has been defined as "the area traversed by an animal or population in its normal daily activities" (Bailey 1984:126). Bighorn sheep were not present throughout the year on the mine site, but determination of the area of occupation of the study area used by the sheep is necessary for census purposes, and for evaluating human and industrial impact on the population. Area of occupation was calculated using the "terr" and "n%poly" programs. "Terr" calculates polygon boundaries by joining outside points of sheep observations. The "n%poly" program establishes the centroid of all points (mean of x co-ordinates and the mean of y co-ordinates) and calculates the distance of each point from the centroid or arithmetic mean. Ninety-five percent of points closest to the centroid were used to establish polygon boundaries. This method assumes that random wandering by sheep from daily use sites would be eliminated from the area calculation by dropping the farthest 5% of locations where sheep were observed.

The program called the "pts_in_poly" test was used to tabulate the number of locations of individual sheep that were plotted inside the vegetation polygons.

Vegetation

An estimate of above ground biomass production during late July and early August, 1986, was obtained for the reclaimed grasslands where sheep were observed grazing at CRC during the 1985/86 year. Those reclaimed areas where sheep were not observed to be grazing were excluded from the analysis as well as areas not supporting vegetative growth due to the heat from the underground fires on the 50-A-1 and 2 dumps. The centrally located subalpine meadow was also sampled.

The area representing the reclaimed grasslands and subalpine meadow was initially divided into 9 zones depending on location, elevation and aspect. A numbered grid was placed over a map (scale 1:4,800) of the study area and 64 numbers were randomly selected in proportion to the area of each of the nine zones (62 on the reclaimed grasslands and 2 on the subalpine meadow). Each grid square represented 0.6 ha and, within each square, a 50 cm x 50 cm plot was subjectively located on the ground. All vegetative grass, forb and shrub material was clipped to ground level during July and August of 1986 within each plot to give an estimate of above ground biomass production. A total of 16 square metres was clipped within the area being sampled. Most of the above ground plant material in these plots was composed of grass and forb species. Shrub representation was almost negligible. The samples were dried at 60° Celsius, weighed on a gram scale and then were converted to kg/ha using a factor of 40.

Small exclosure cages had been previously set on 52 of the grid squares to eliminate the effects of grazing on biomass production. As the summer progressed however, it became obvious that virtually no sheep grazing occurred on the mine site during these months and that an estimate of biomass production could be obtained without the use of exclosures.

Crude Protein

Jorgenson and Wishart (1986:47) state that "significant fecal nitrogen relationships have been established with plant protein, protein intake, dry matter digestibility and body weight change". Fecal crude protein was measured from the same samples collected each month from the CRC sheep for lungworm and microhistological analysis. Nitrogen values were generated from the fecal samples analyzed by Brenda Kuzyk using the macro Kjeldahl method and converted to percent crude protein values (%N x 6.25). The fecal crude protein values thus generated provide an index for plant protein uptake by the sheep.

3. TEMPORAL AND SPATIAL USE OF CRC BY BIGHORN SHEEP

Population Size

The number of sheep observed on the study area varied seasonally during the year of observation (Figures 5 and 6). The maximum numbers occurred during the fall of 1985 and early winter of 1986. Fewer sheep were observed on CRC during the late winter and spring while the fewest occurred during the summer months of June, July and the first half of August. The highest one-day count for the year occurred on October 8, 1985 when 175 sheep (83 ewes, 45 lambs, 5 female yearlings, 3 male yearlings, 6 Class I rams, 24 Class II rams, 8 Class III rams and 1 Class IV ram) were observed.

Prior to this date, 3 ewes had been shot on September 10 and 1 on October 3, 1985, during the CRC non-trophy hunt. After October 8, an additional nine ewes were shot: 3 on October 10, 3 on October 17, 2 on October 24, and 1 on October 31. Another ewe that had been wounded offsite disappeared November 6 and was presumed dead. Two rams from the CRC herd (Class III and Class IV) were killed on or near the CRC mineral surface lease on October 23, and October 29, 1985, respectively. Population characteristics derived from daily census counts do not account for known mortality unless specified.

Seasonal Movements

During the field study, several important dates were noted regarding sheep movements on and off the study area (Table 3). These dates were used to construct home range

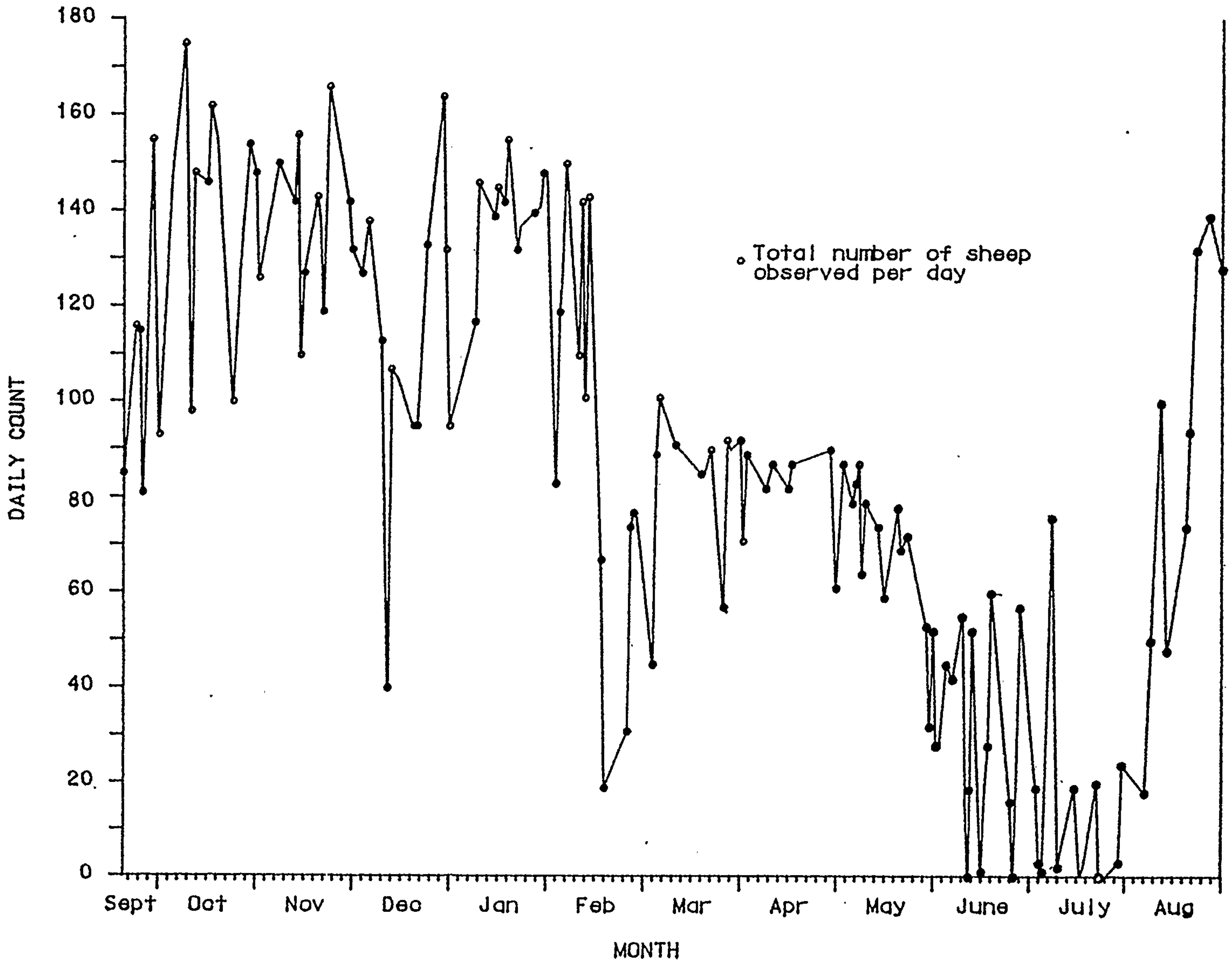


Figure 5. Census of bighorn sheep on the Cardinal River Coals Ltd. mine site for 146 days from September 19,1985 to September 1,1986.

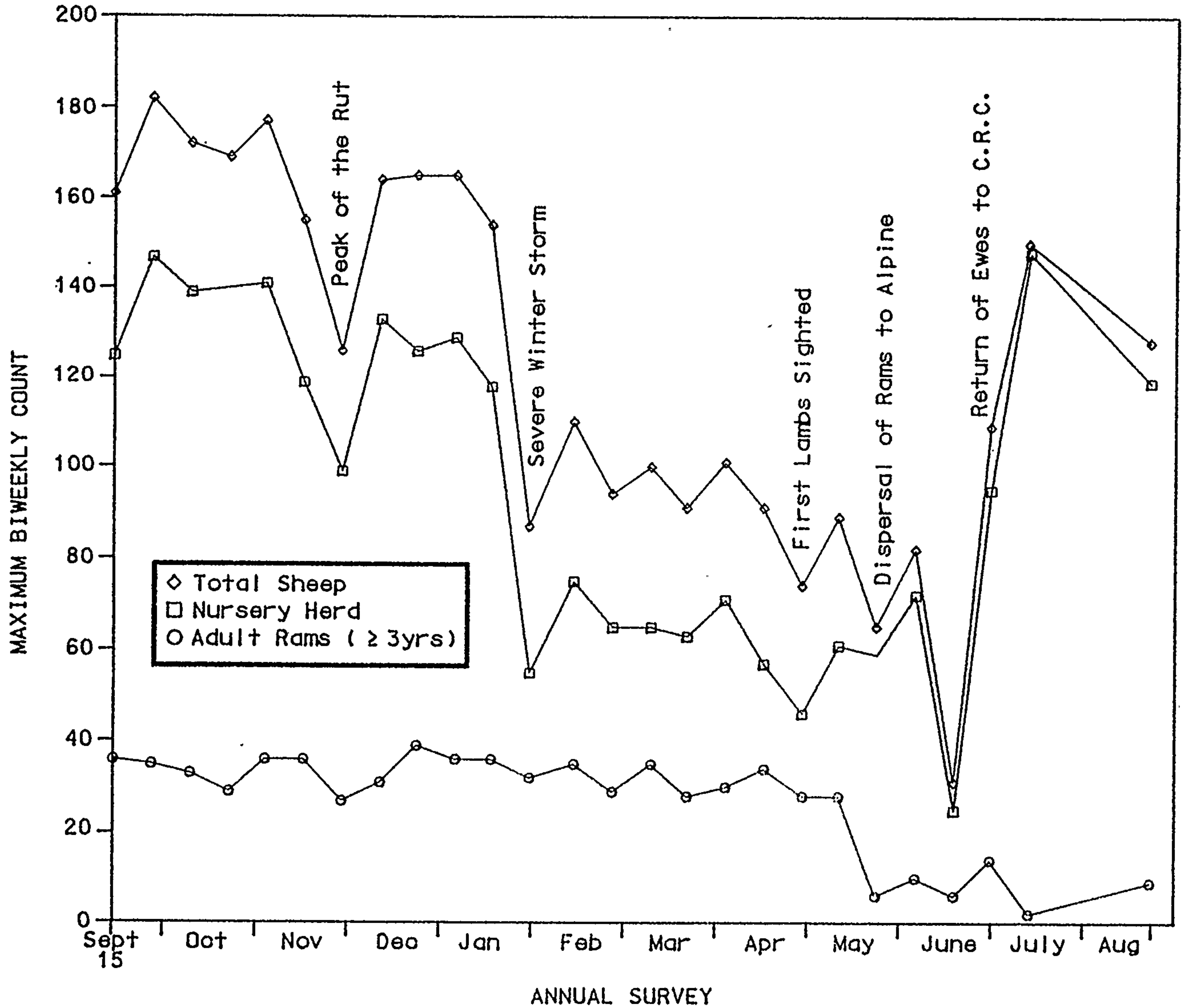


Figure 6. Maximum biweekly count of bighorn sheep on the Cardinal River Coals Ltd. mine site from September 15,1985 to September 19,1986.

Table 3. Movements of bighorn sheep on and off the Cardinal River Coals Ltd. mine site between September 17, 1985 and September 1, 1986.

Date	Sheep Movement
October 18, 1985	- ram band moves from C-baseline to benches and slopes adjacent HWY 40
October 23, 1985	- large rams leave CRC
November 7, 1985	- rams begin to congregate on 50-A-1/2 dump (ewe pre-rut range) (Figure 2)
November 15, 1985	- large rams from off the mine site join the nursery herd on the rut range
November 19, 1985	- 3 class IV rams from off the mine site join the rut
November 20, 1985	- first day mounting was observed
December 1-7, 1985	- peak of rutting activity
December 23, 1985	- last day more than 1 ewe was observed being followed and mounted by rams
December 29, 1985	- first day large rams were seen grouped together on the rut range (50-A-1/2)
January 18, 1986	- last day mounting of an old ewe (RH) was observed
February 5, 1986	- first day the adult rams were observed segregated from the nursery herd on the native slope
February 18, 1986	- least number of sheep (31) on CRC observed during the winter/spring of 1986 (January - May, inclusive)
February 26, 1986	- approximately half the nursery herd returns to CRC
May 15, 1986	- the ewe "MHL" was observed leaving nursery herd for ranges west of CRC. First day ewe "MHM" was not observed with nursery herd

Table 3 continued.

Date	Sheep Movement
May 28, 1986	- first lambs of year sighted
May 28, 1986	- a group of 12 yearlings and 3 ewes leave CRC via Luscar Creek
June 4, 1986	- large group of ewes were sighted using 50-A-3 as a mineral lick. Also the 5 ewes and lambs from 51-B-2 moved west across and off the mine site
June 25, 1986	- 95% of new lambs sighted on or near to CRC in June and early July were observed by this date (Figure 7)
August 11, 1986	- beginning of fall congregation of ewes onto CRC
August 22, 1986	- establishment of most of the nursery herd (134) on mine site for the pre-rut
September 1, 1986	- beginning of fall congregation of rams (8) onto the mine site.

occupation patterns of the nursery herd and the Class II, III and IV rams. Four major movements for the nursery herd were identified as:

1. movement onto the study area in late summer and early fall
2. movement to winter range in late winter.
3. movement to lambing sites in mid-May
4. movement into alpine drainages adjacent to CRC during the summer months.

Four major movements for the Class II, III and IV rams were identified as:

1. movement onto the study area in late summer and early fall
2. movement onto the ewe pre-rut range for the rut
3. movement to winter range in early winter
4. movement into the alpine in late May and early June

The nursery herd had already congregated on the mine site when the study began on September 17, 1985, where it remained for the rut and early winter season. In mid-February, the herd left CRC in response to a severe storm event that deposited 16.2 cm of snow over 3 days (February 14 - 16) and was accompanied by -30°C temperatures. When the sheep returned, approximately half the nursery herd remained offsite, presumably to winter on traditional ranges. The portion of the herd that returned continued to use essentially the same ranges for the late winter and spring at CRC as they had for the pre-rut, rut and early winter. In mid-May, individual ewes began to leave CRC in search of lambing areas. Two ewes, (W21 and Y) had been fitted with radio collars on May 6, 1986, and were tracked into the alpine during this time. The "W21" ewe moved toward Cadomin, but by the time she was relocated, she was on her way back to the vicinity of CRC with her lamb. The "Y" ewe stayed with the nursery herd for some time and was last located in the Gregg River drainage on July 3, 1986. She was relocated on the south slopes of Sphinx Mountain on June 14, 1986, by AFWD personnel. She returned to the vicinity of CRC on August 14, 1986, with a lamb. Most lambing occurred off the mine site with the exception of 6 ewes, which lambed on the east wall of 51-B-2 pit. The ewe identified as "MHM" (see Appendix I) was one of these; she was discovered dead on the ledges of this wall. Her lamb was found dead on a ledge below her. Evidence showed that "MHM" ewe had never stood up after giving birth. There was no sign of predation. A portion of the nursery herd regrouped after lambing in the alpine meadows of the Luscar Creek drainage adjacent to the 50-A-3 pit. During the month of June, the ewes made extensive use of this pit as a mineral lick (Figure 8). Virtually no grazing took place on the mine site during this time.

The number of lambs sighted on and adjacent to CRC during the lambing and early summer seasons increased to a maximum of 36 animals on July 10 when numbers dramatically dropped (Figure 7). This drop corresponds to a movement of the nursery herd higher into the headwaters of the Gregg River and West Jarvis Creek Drainages. Few sheep were observed on CRC during the month of July. However, on August 11, one hundred sheep were observed on the mine site. This was the first movement of the herd onto CRC for the fall season. Sheep numbers

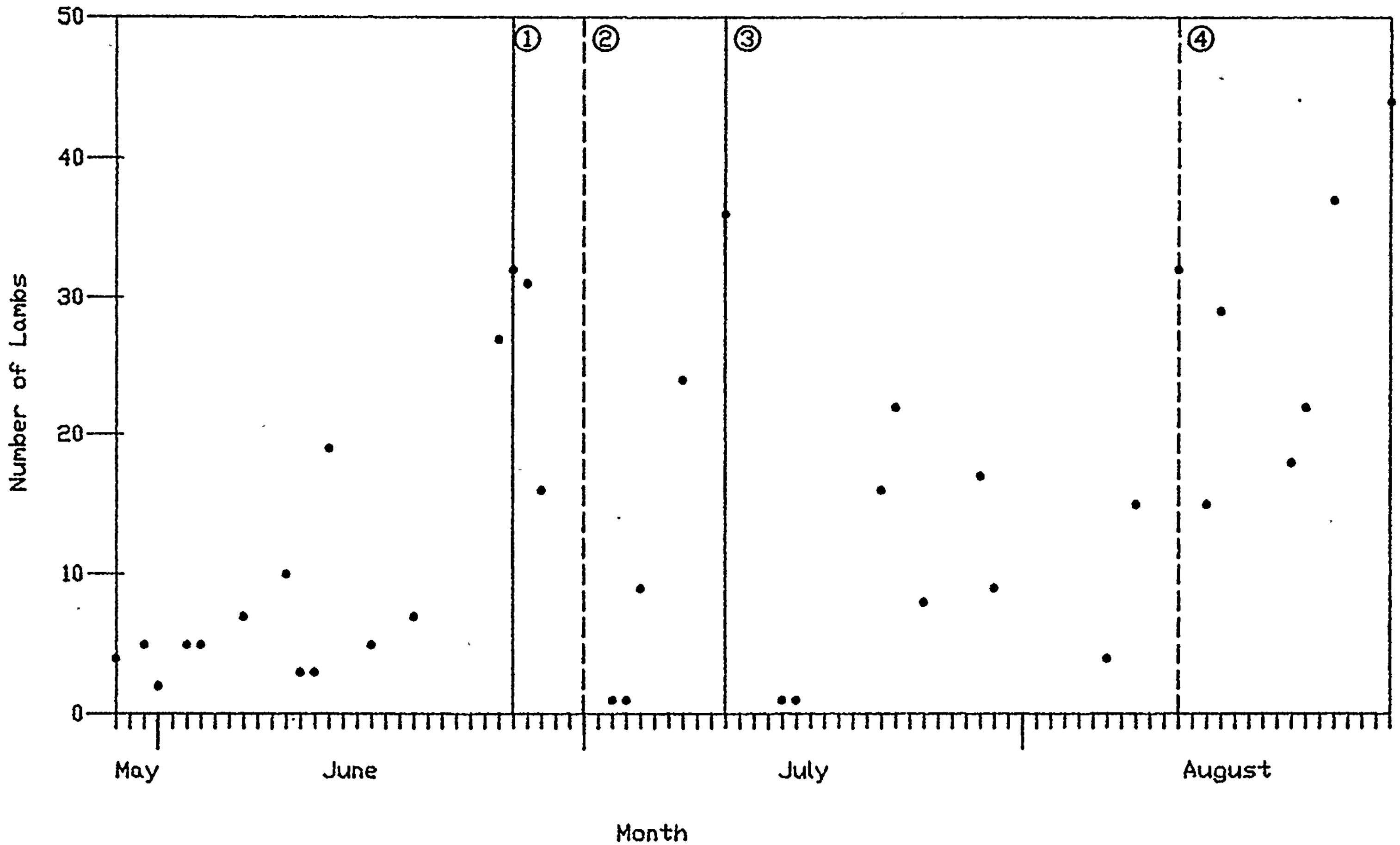


Figure 7. Total number of lambs sighted on and near Cardinal River Coals Ltd. during the lambing and summer seasons of 1986.

1. 95% of lambs observed in vicinity of Cardinal River Coals.
2. Date used to define end of lambing season.
3. 100% of lambs observed in vicinity of Cardinal River Coals.
4. Beginning of fall congregation onto Cardinal River Coals.

Figure 8. The 50-A-3 pit being used as a mineral source by ewes and lambs during June, 1986.

Figure 9. Rams on the rut range (50-A-1 and 2) November of 1985.

fluctuated until August 22, after which time consistently high numbers of sheep were observed on CRC.

The pre-rut, or fall congregation of adult rams onto CRC, had already taken place when the study began on September 17, 1985. Rams remained segregated from the nursery herd until mid October when they moved from the C-baseline to the 51-B dump south of HWY 40. This area was also used by the ewes in the pre-rut. The rams then moved onto the 50-A-1/2 dump early in November, joining the ewes for the rut (Figure 9). This dump was also part of the ewe pre-rut range. The peak of the rut occurred during the second week of December, 1985. In mid-January the adult rams segregated from the ewes, leaving them on the rut range. The rams occupied a south-facing grassland that was centrally located on the mine site. The rams alternately used this slope and the reclaimed south-facing slopes above HWY 40 throughout the winter and spring until they began to leave CRC in late May. During the summer months of June, July, and August, small groups of rams were observed travelling between various alpine ranges. Only the occasional individual or small group was observed on CRC. The adult rams returned to CRC for the fall of 1986, after September 1 and before September 29. This fall congregation was apparently later than other years when rams were sighted by CRC personnel on the mine site during the last week of August.

When the four seasonal movements for the nursery herd and the four seasonal movements for the adult rams were combined, 6 seasonal home ranges were identified. (A seasonal home range is an area to which an animal confines itself between two seasonal migrations and which it occupies at the same time in successive years (Geist 1971b:74). These were:

PRE-RUT. September 17, 1985, to November 14, 1985.
This is the period when adult rams and ewes congregate on CRC in the fall and occupy separate ranges. The bighorn herd was already present on the mineral surface lease when the study started in 1985. The nursery herd, however, began to return to CRC on August 11, 1986, during the following summer and were well established by August 22. The adult rams returned later, sometime after September 1, 1986. In most years they have been reported on the mine site the last week in August.

RUT. November 15, 1985, to January 18, 1986.
The rut was defined as the period when rams and oestrous ewes were observed together. Most rutting activity was over in December. The last day of the rut was identified as January 18, 1986, when one old ewe (RH) was observed being mounted.

WINTER. January 19, 1986, to February 14, 1986.
This was the period when the adult rams left the ewes on the rut range and wintered separately on south-facing slopes also located on CRC.

SPRING. February 15, 1986, to May 27, 1986.
This period was defined by half the nursery herd leaving CRC and wintering presumably on traditional range. Movement off the mine site was precipitated by a major storm event with only half the herd returning. Reduction in use of CRC by the nursery herd during the late winter and early spring has been observed in subsequent years. The precise dates of movement likely fluctuate from year to year depending on the weather.

LAMBING. May 28, 1986, to June 30, 1986
Lambing was defined from the first day new lambs of the year were sighted. Actual lambing dates probably occurred a few days earlier. This period encompassed the time from lambing and isolation of new lambs and ewes through to when the nursery regrouped in the alpine meadows adjacent to CRC and used the 50-A-3 pit as a mineral lick. Adult rams were not present

on CRC and were seen sporadically in the alpine during this time.

SUMMER. July 1, 1986, to August 10, 1986
This period was defined by the nursery herd movement higher into the headwaters of Gregg River and West Jarvis Creek, presumably utilizing the new forage available as snow melted at higher elevations.

Of the 11,933 individual bighorn observations made between September 17, 1985, and August 10, 1986, 73% were lambs, ewes, or yearlings of either sex, 5% were of Class I rams and 22% were of Class II, III and IV rams (Table 4). Sheep were concentrated on the study area from the pre-rut through to the beginning of lambing in the spring, a period of 254 days. In 1985, the study began on September 17, well after the date that ewes began to congregate on the mine site for the pre-rut in 1986 (August 11). These data indicate that sheep were present in significant numbers on the mine site for 291 days of that year.

Variation of Population Size Within Each Season

Using the maximum count method, the maximum number of bighorn sheep (193) on CRC occurred in the pre-rut (Table 5). Numbers fluctuated slightly just before the rut as several large rams left CRC, presumably to rut elsewhere. Also, there was some fluctuation of the numbers of ewes present on CRC at this time as several apparently left to rut elsewhere. The "C" ewe was observed in oestrous at the microwave tower located near Cadomin at the base of Leyland Mountain in December by G. Acott (pers. comm.). During the rut, several large rams from offsite joined the CRC herd. Numbers of Class IV rams

Table 4. Number of observations of bighorn sheep per seasonal home range at Cardinal River Coals Ltd. for the year 1985-1986. Numbers are not corrected for mortality. Data are from obsed file.

Season (#counts)	Lamb	Ewe	Female Yearling	Male Yearling	ClassI Ram	ClassII Ram	ClassIII Ram	ClassIV Ram	Total
Pre-rut (23)	758(25%)	1474(48%)	92(3%)	111 (4%)	96(3%)	373(12%)	117(4%)	16(1%)	3037(26%)
Rut (26)	874(27%)	1371(42%)	87(3%)	89(3%)	179(5%)	428(13%)	125(4%)	98(3%)	3251(27%)
Winter (14)	490(27%)	796(43%)	34(2%)	50(3%)	109(6%)	263(14%)	63(3%)	38(2%)	1843(16%)
Spring (38)	518(18%)	1222(42%)	3(0.1%)	92(3%)	191(7%)	608(21%)	197(7%)	75(2%)	2906(24%)

Lambing (20)	65(10%)	248(39%)	82(13%)	71(11%)	27(4%)	105(16%)	39(6%)	7(1%)	644(5%)
Summer (17)	57(23%)	111(44%)	17(7%)	28(11%)	7(3%)	26(10%)	6(2%)	0(0%)	252(2%)
Year (138)	2762(23%)	5222(44%)	315(2%)	441(4%)	609(5%)	1803(15%)	547(5%)	234(2%)	11933(100%)

------- beginning of a new year marked by the appearance of first lambs of the year. All sheep classes adjusted from this date.

Table 5. Maximum count of bighorn sheep present at Cardinal River Coals Ltd. for each seasonal home range between September 17, 1985 and August 10, 1986. Numbers are not corrected for known mortality.

Class	Pre-rut	Rut	Winter	Spring	Lambing	Summer
LAMB	47	42	39	19	11	24
EWE	83	74	70	48	37	35
F Y	7	8	5	1	11	6
M Y	8	6	5	6	8	7
I	8	10	11	8	4	3
II	28	25	25	24	17	9
III	9	9	8	10	9	2
IV	3	7	5	4	2	0
Total	193	181	168	120	99	86
# counts	23	26	14	38	20	17
Highest one day count	175	166	159	101	57	76
Date	Sep 17 to Nov 14	Nov 15 to Jan 18	Jan 19 to Feb 14	Feb 15 to May 27	May 28 to June 30	July 1 to Aug 10

Note: data are compiled for each activity period from the computer file called obsed.

F Y = female yearling
M Y = male yearling
I = Class I ram
II = Class II ram
III = Class III ram
IV = Class IV ram

were the highest that were observed for the whole year (7) at this time. The maximum number of sheep using CRC during the early winter after the rut (168) was only slightly lower than during the pre-rut (193), especially if one accounts for known mortality that occurred during the fall (12) after the maximum one day count of 175 on October 8, 1985.

A definite drop in the nursery herd numbers occurred mid-February when approximately half the numbers left to winter, presumably, on traditional range. From March 4, 1986, to May 22, 1986, total numbers of sheep on the mine were markedly consistent showing only a small decline in numbers (March 4 = 89, May 22 = 72). After this date, total numbers dropped as ewes left for lambing sites and rams dispersed into the alpine. Until this time, the total numbers of Class II, III and IV had been remarkably consistent throughout the year with the exception of the rut (Figure 6). Between June 9 and July 7, wide fluctuations of numbers of sheep (from 0 to 76) were observed on the mine, reflecting the nursery herds' periodic visits to 50-A-3 for minerals. The fewest numbers of sheep observed at CRC during the year occurred between July 9 and August 6 (minimum 0, maximum 24). Sheep at this time were to be found high in adjacent alpine drainages. Fluctuating and increasing numbers of sheep were then observed at CRC from August 8 to August 22 when large numbers of the nursery herd (total 134) appeared to have returned for the pre-rut. The first adult rams (8) appeared on September 1, 1986, for the pre-rut.

Individual Sheep Movements

The major occupation patterns and seasonal movements of the herd (Figures 5 and 6) are also reflected in the movements of individual sheep on and off the study area (Figure 10).

Two different patterns are displayed by the ewes. The ewes "C" and "MHD" were present on the mine site during the fall, interrupted by absences of greater than 10 days during the peak of the rut and the latter half of January. They then left CRC in mid-February and were not seen in the vicinity until the following fall. These two sheep were likely part of the same home range group and spent the late winter, spring, lambing, and summer seasons elsewhere. The other ewes (StHn, RH and MHL) spent most of the pre-rut, rut, winter, and spring on the mine site, then spent their summer in the alpine adjacent to CRC.

The "BL" ewe reflected a modified pattern in that she left for the winter, spring, and lambing but was sighted summering adjacent to CRC with her lamb. The "BL" ewe had a badly injured left hind leg that was largely nonfunctional. She spent the fall on the slopes adjacent to the 51-B-2 east wall by herself regardless of the location of the other sheep on the mine. She moved west across the mine to join the main herd once the rut had begun and remained only a few weeks before disappearing. Her winter movement patterns may reflect

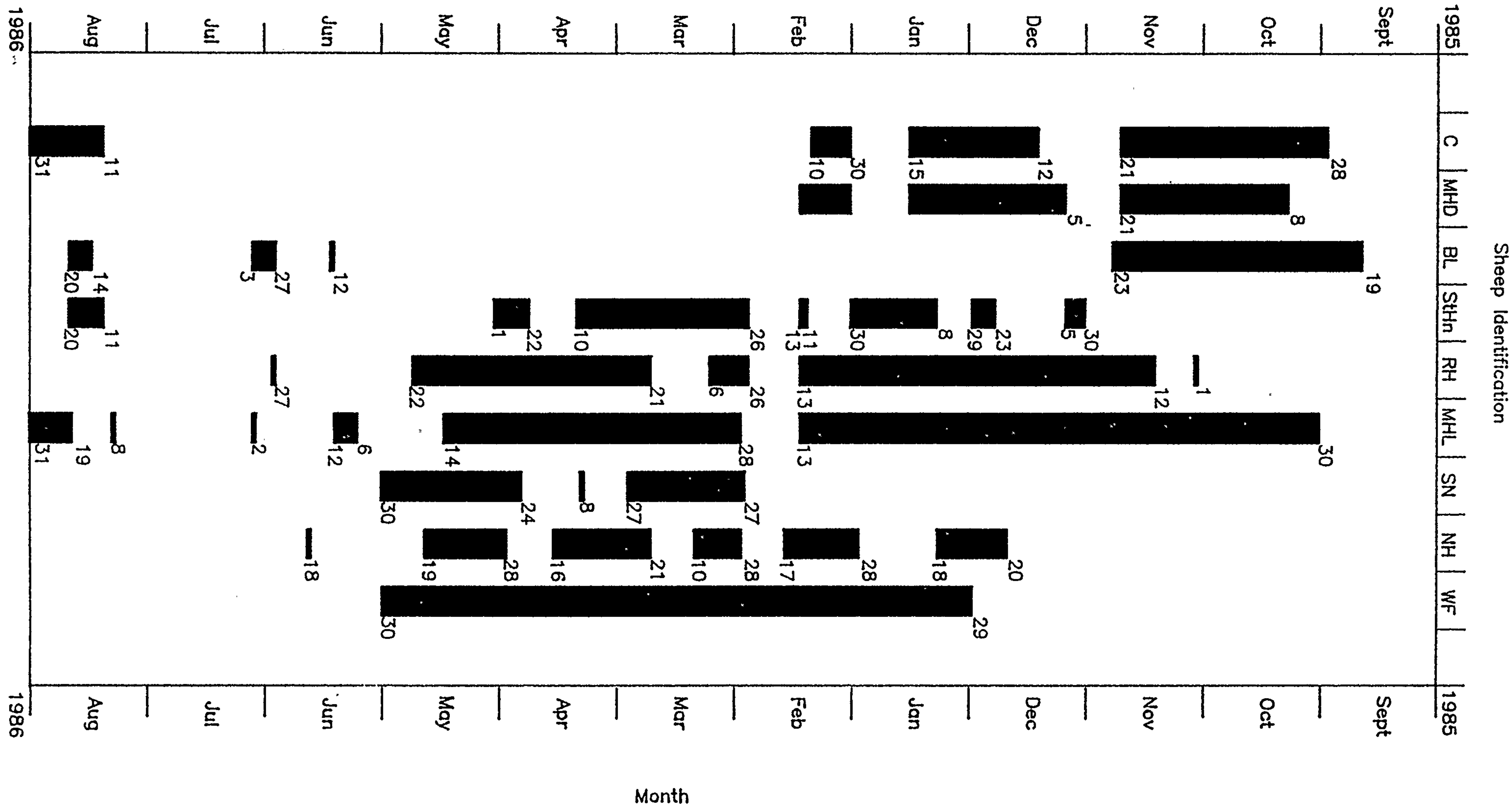


Figure 10. Annual occupation pattern of individual sheep at Cardinal River Coals Ltd. The sheep identified as C, MHD, BL, StHn, RH and MHL are ewes. The sheep identified as SN, NH, and WF are rams. Solid bars represent periods of repeated sightengs of less than 10 day intervals. Absence from the counts of 10 days or more are represented by breaks in the bars and the assumption was made that these individuals were not present on the mine site.

an adaptation to her injury and not necessarily that of other sheep.

The visibility of individual rams (SN, NH and WF) varied a great deal in the pre-rut as rams in general used smaller grasslands mixed in heavier tree cover than the ewes did at this time. Rams also moved around just before and during the rut. They spent the winter and early spring on CRC and left in late May or early June. These sheep were not sighted in the alpine adjacent to CRC in the summer months. The "SN" ram was last sighted on CRC on May 28, 1986, and was not observed again on CRC until October 25, 1986, despite intense surveys in the summer and two surveys in September. Similarly, "NH", last sighted on CRC on June 18, 1986, did not show up until October 25, 1986.

Spatial Distribution of Bighorn Sheep on CRC

Two-thirds of all sheep observations (11,933) for the year occurred on about 1.29 sq km of reclaimed grasslands on the 50-A-1/2 dumps, on the reclaimed grasslands adjacent the 51-B-2 pit and HWY 40, and on the centrally located subalpine meadow (Figure 11). These areas represented the most heavily used ranges in the pre-rut, rut, winter, and spring seasons particularly by the nursery herd. The remaining 1/3 of sheep use was scattered over 7.78 sq km of the mine site for a total use area of 9.07 sq km. These areas represent those areas that were used only seasonally for grazing, or by the much smaller ram band, or for travel purposes.

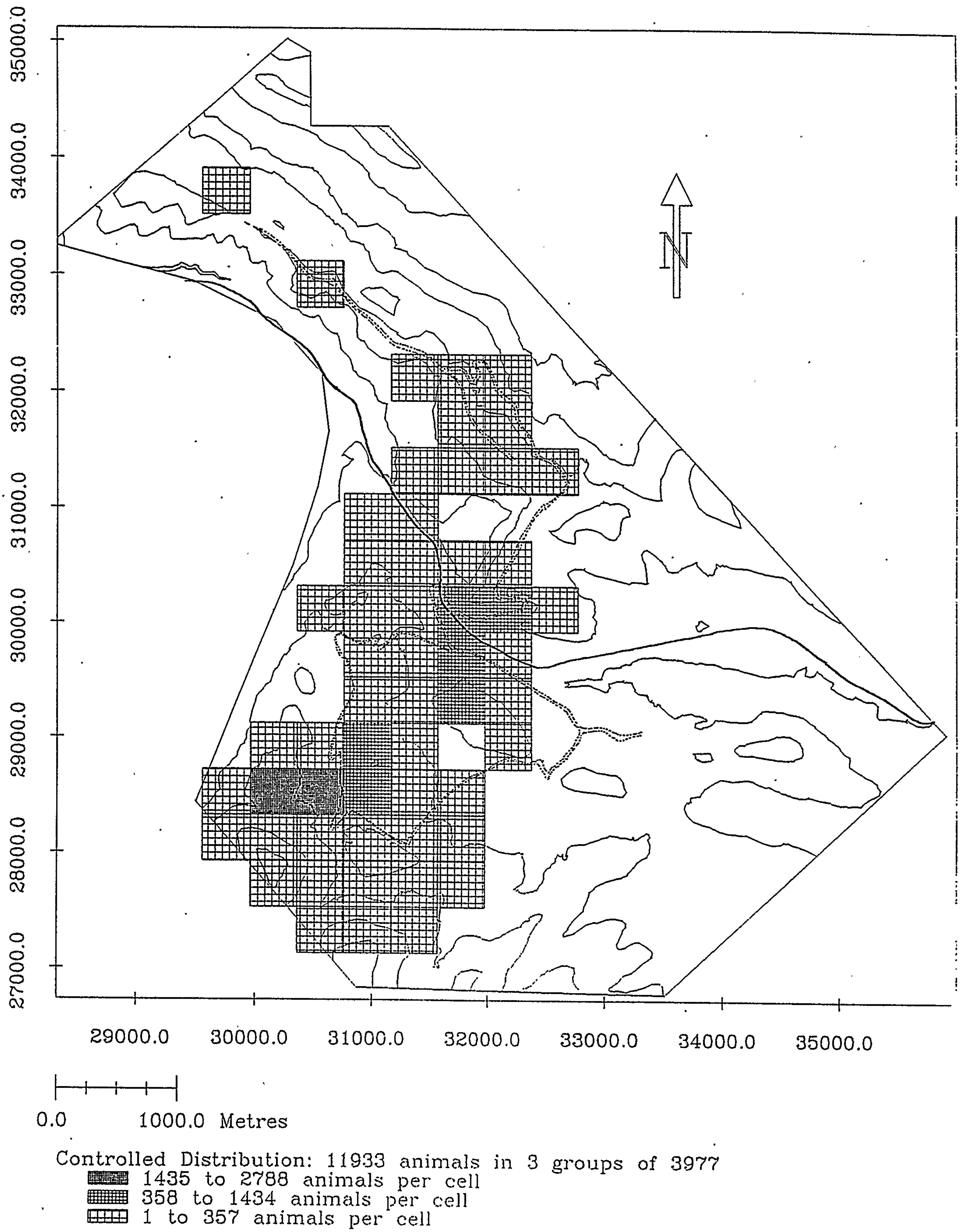


Figure 11. Intensity of use by all sheep at Cardinal River Coals Ltd. from September 17, 1985 - August 10, 1986.

Approximately 1/3 of the observations for the nursery herd (n=9,349) for the year 1985/86 were made within 32.4 ha (80 acres) of the 50-A-1 backfill (Figure 12). Another 1/3 of observations were made within an additional 32.4 ha of the 50-A-2 backfill and within 48.6 ha (120 acres) of the south slopes and valley bottom adjacent to HWY 40. This means that 2/3 of the nursery herd use was concentrated on 113.4 ha of reclaimed range (approximately 1 km^2). The last 1/3 were scattered over 696 ha (1720 acres) of the lease. The total area used by the nursery herd for grazing, security, mineral licks or travelling within the lease boundaries was 809.4 ha (2000 acres).

Ram distribution over the mine site was more widely scattered than that of the nursery herd (Figure 13). Of the 2,584 observations made of the Class II, III and IV rams, 1/3 occurred on 64.8 hectares (32.4 ha on the 50-A-1 and 50-A-2 backfills, 16.2 ha on the south-facing subalpine meadow, and 16.2 ha on the south-facing slopes above HWY 40). An additional 1/3 of observations were scattered over 113.3 ha (280 acres) located on the 50-A-2 backfill, on the slopes adjacent to HWY 40, and on a topsoil stockpile located on the C-baseline. The last 1/3 of observations were located on 696 ha (1720 acres) of the lease. The total area used by the Class II, III and IV rams was 874 ha (2160 acres).

From the above description it is apparent that the most important area used by the sheep on the study area is the 50-

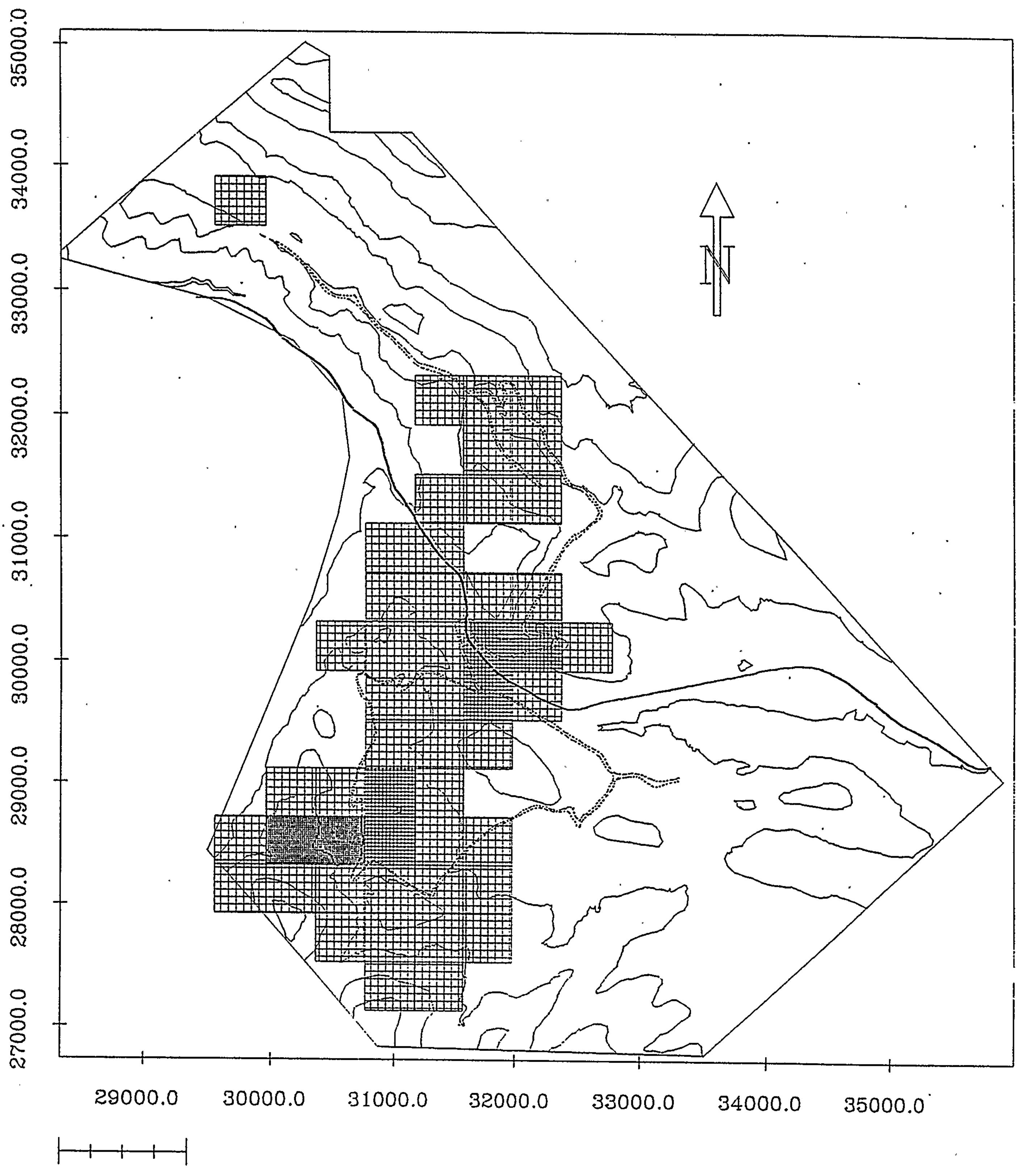
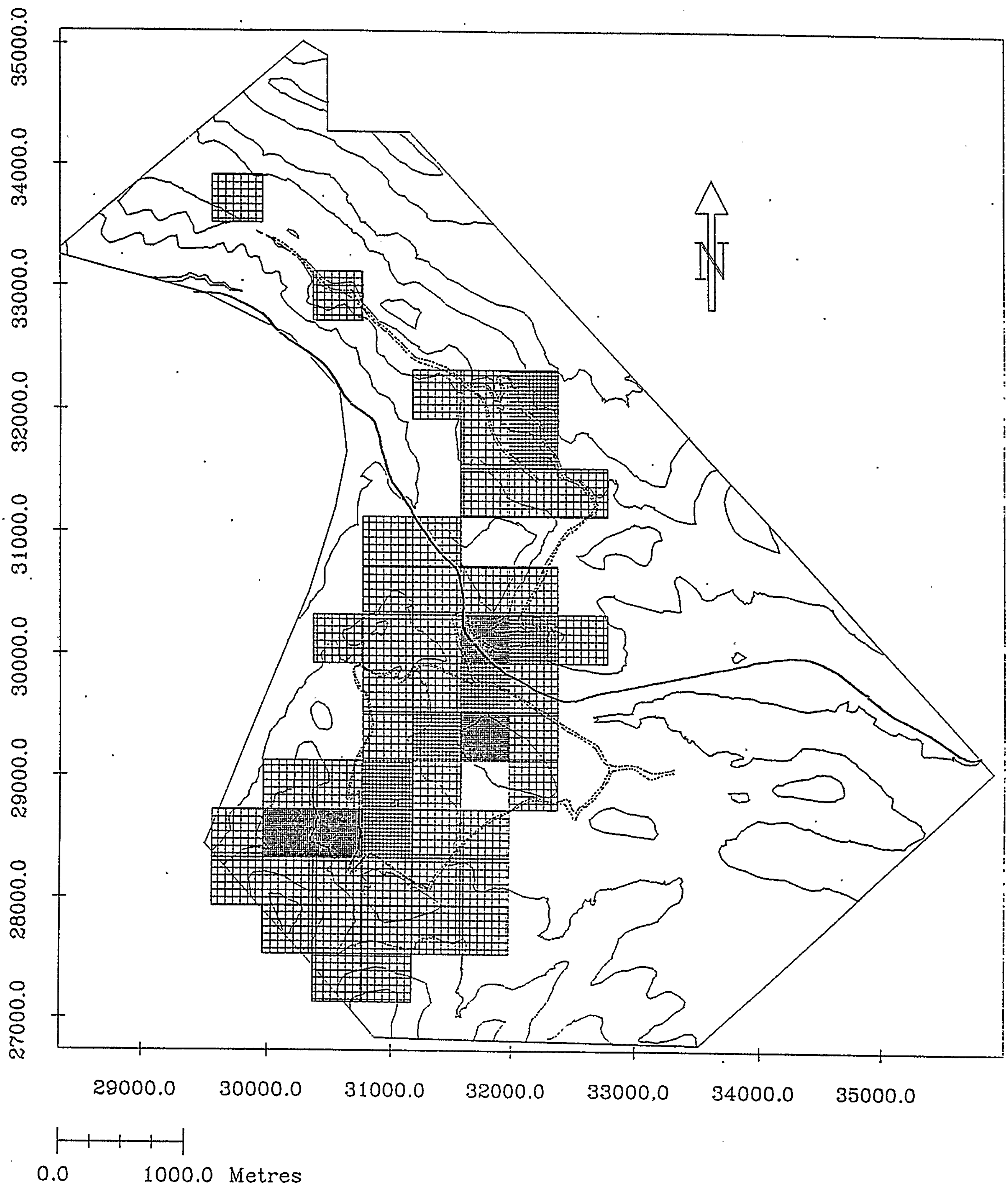


Figure 12. Intensity of use by lambs, ewes, yearlings and class I rams at Cardinal River Coals Ltd. from September 17, 1985 - August 10, 1986.



Controlled Distribution: 2584 animals in 3 groups of 861

- 170 to 363 animals per cell
- 63 to 169 animals per cell
- 1 to 62 animals per cell

Figure 13. Intensity of use by class II, III, and IV rams at Cardinal River Coals Ltd. from September 17, 1985 – August 10, 1986.

A-1 and 50-A-2 backfill. This area was reclaimed in 1977, 1978, and 1979, and is used for grazing by the nursery herd during the pre-rut, rut, winter, and spring seasons (Appendix IV Figures 34, 35, 36 and 37). Rams congregated here to rut, during which time the high walls of the adjacent 50-A-3 pit were used heavily by ewes escaping rams and by rams attending receptive females. The benched walls of this pit were used as escape sites, bedding areas, and in May and June, the seeps from the walls were used as mineral licks (Appendix IV Figure 38) by the nursery group that used the Luscar Creek valley immediately west of the lease. This daily movement was interpreted as a response to the need for minerals as virtually no grazing took place on the mine at this season.

The sheep also made moderate to heavy use of the south-facing subalpine meadow that is centrally located on the study area. This area was used primarily by rams during the winter and spring period (Appendix IV Figures 42 and 43) when they had segregated from the nursery herd. Heaviest use of this hill was on the NW corner which lies adjacent to the 50-B-3 benched pit wall. This slope and pit wall were used by the nursery herd chiefly as a travel route connecting the 50-A-2 backfill with the HWY 40 area.

The nursery herd used the south-facing slopes and valley bottoms adjacent to HWY 40 heavily during the pre-rut and winter seasons (Appendix IV Figures 34 and 36), while the rams used this area heavily in the winter and spring (Appendix IV

Figures 42 and 43). This area was seeded in 1976. The east wall of the nearby 51-B-2 pit was used as escape terrain by the sheep when they frequented this area. In May of 1985, and 1986, 6 and 5 ewes, respectively, lambed on this wall. In 1986, these lambing sites were within a few hundred metres of an active dump site. Most lambing, however, took place off the study area in the alpine region.

Moderate use of the large bench and slopes of a portion of the Gregg dump was made by the nursery herd during the pre-rut. This part of the Gregg dump was reclaimed in 1972 and 1979/80.

Rams also used a topsoil dump located on the C-baseline. This area received heavy use during the pre-rut (Appendix IV Figure 40). A powerline located on the C-baseline was reclaimed in 1978, while the topsoil island was reclaimed in 1983. Rams have been observed on the C-baseline by mine personnel since 1980.

Distribution in the Summer

During this period (May 29 - August 14, 1986), part of the nursery herd from the CRC bighorn population was most frequently sighted in the alpine drainages adjacent to CRC rather than on CRC itself. Use of the mine site at this time was restricted to the 50-A-3 pit (Appendix IV Figure 39) which was used as a mineral lick particularly in June. Minimal grazing by sheep occurred on CRC during the summer months (June 1 - August 11).

In June and early July the nursery herd concentrated their foraging activities in the Luscar Creek area (Figure 14 and Table 6). As the summer progressed, the sheep gradually moved higher into the headwaters of the Gregg River and West Jarvis Creek, presumably exploiting the new growth available at these elevations. Bighorns are seasonal migrants and are believed to follow an altitudinal gradient to take advantage of new-growth forage (Shackleton 1973; Hoefs and Cowan 1979). This appeared to be what the CRC herd was responding to. It should be noted that the rams, on the other hand, were seen at intervals travelling through the area in small groups.

Several individually recognizable ewes (Y, MHL, W21) were identified as part of the sheep herd using alpine drainages adjacent to CRC throughout the summer (Table 7). Other ewes such as "C", "StHn" and "MRH" obviously summered elsewhere and were not seen on or near the mine site until the late summer or early fall of 1986 when sheep began to congregate for the pre-rut. Ewe "C" was collared in 1977 by the AFWD on Cadomin Mountain, so it is probable that she summered on the Redcap range.

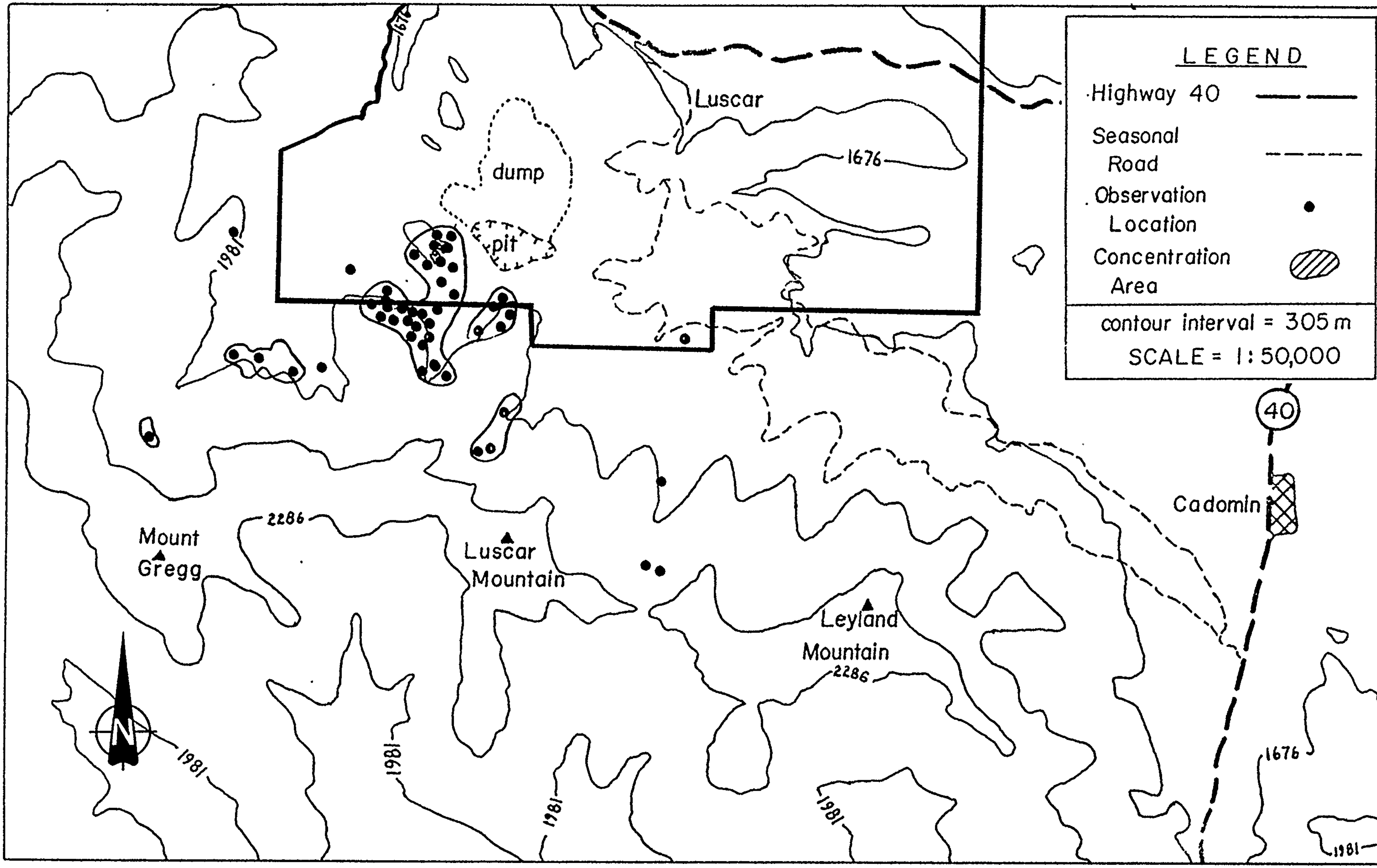


Figure 14. Distribution of bighorn sheep during the summer of 1986 adjacent to Cardinal River Coals Ltd.

Table 6. Number of bighorn sheep observed in the alpine drainages adjacent to Cardinal River Coals Ltd. from May 29 to August 14, 1986.

Date	Gregg River	Luscar Creek	West Jarvis Creek	East Jarvis Creek D4	East Jarvis Creek D3-D1	CRC
May 29	3	12				32
May 31		4				-
June 1						28
June 4				6	1	45
June 11		30				0
June 12	4	39				52
June 15		21				1
June 24		94				16
June 25	95	4				0
June 26	13	65				24
June 27		38				57
July 3	63					3
July 10	66	18				2
July 12		77				-
July 15	6	8				9
July 21		15	38			20
July 22	56					0
July 24	25					0
July 28		15	33			3
July 29			31			24
Aug 6		8				18
Aug 14	46					51
Cumulative Frequency	377	447	72	6	1	404

Note: West and East Jarvis Creek areas were not surveyed with the same intensity as CRC, Luscar Creek or Gregg River.

Table 7. Summer occupation patterns of individual sheep observed on Cardinal River Coals Ltd. and in the adjacent alpine drainages from May 29 to September 1, 1986. All sheep are ewes.

	Sheep Label							
Date	C	StHn	RH	BL	W21	MHL	Y	MRH
May 29		Luscar						CRC
June 1								CRC
3							CRC	
4							CRC	CRC
6						CRC		CRC
9						CRC	CRC	
10							CRC	
11					Luscar	Luscar		Luscar
12				CRC		CRC		
15								Luscar
16								CRC
18							CRC	
24					CRC			
25				GRR	GRR	GRR	GRR	GRR
27			CRC	CRC				
July 2						CRC		
3			GRR	CRC	GRR	GRR		
10					GRR			
14							Sphinx	
21					Luscar			
22					GRR			
28				WJC			WJC	
29				WJC			WJC	
Aug. 8		CRC				CRC		
11	CRC	CRC	CRC		CRC			
13	CRC	CRC			CRC			
14	CRC	CRC		CRC	CRC		CRC	
19	CRC			CRC	CRC	CRC		
20	CRC	CRC		CRC	CRC	CRC	CRC	CRC
22	CRC				CRC	CRC		CRC
26	CRC				CRC	CRC	CRC	CRC
Sept. 1	CRC			CRC	CRC	CRC	CRC	

Luscar = Luscar Creek
GRR = headwaters of Gregg River
WJC = West Jarvis Creek
Sphinx = south slopes of Sphinx Mountain; location established during an AFWD aerial survey for goats.

4. POPULATION QUALITY OF BIGHORN SHEEP

"Individual and population quality appears to be a function of how well individuals grow, which in turn is determined by the nutritional regime of the pregnant and lactating females" (Geist 1971b:281). Population quality is therefore related to body and horn size, age at sexual maturation, behavioural vigour, life expectancy, reproductive success, and survival rates of the young. Factors such as parasitism, harassment, and predation cause an animal to expend energy that otherwise could be used for growth, reproduction, or maintenance (Festa-Bianchet 1987; Stemp 1983). Body size, horn size, lungworm loads, nutritional quality of forage, harassment, and predation as factors affecting population quality are discussed below.

Body Size

"The most common indices of general animal condition are measures of body size, usually body weight, or measures of body-fat reserves" (Bailey 1984:318). Weight has been used as a useful index of the recent nutritional status of ruminants (Thorne et al. 1979:74). Body weight used in conjunction with a linear body measure (such as total length) can provide an index that is better related to physical condition than that provided by body weight alone (Bailey 1984:319).

Mean live weights for the 25 ewes measured at CRC was 73.34 kg (161.68 lb), mean heart girth was 101.58 cm, and total length averaged 152.56 cm (Table 8).

Table 8. Weights (kg) and body measurements (cm) from ewes greater than 4 years taken during the Cardinal River Coals Ltd. non-trophy hunt September 10 to October 31, 1985 and September 28 to October 16, 1987.

measurement	n	mean	range	SD
whole weight	25	73.3	58.5 - 85.7	6.7
gutted weight	18	52.7	41.3 - 62.1	5.2
heart girth	25	101.6	91.5 -108.0	3.8
total length	25	152.6	133.0 -174.0	10.2
tail length	25	13.1	7.0 - 18.0	3.6
neck circumference	15	35.3	31.5 - 41.0	2.8
hindfoot length	17	41.0	38.5 - 44.0	1.5

whole weight = weighed immediately after having being killed using a Salter 400 lb spring scale and net.

gutted weight = weighed after being gutted and before being skinned

heart girth = measured around the circumference of the body immediately behind the forelegs.

total length = measured along the dorsal contour from the tip of the nose to the tip of the tail vertebrae with the animal fully extended.

tail length = measured from the base of the tail to the tip of the tail vertebrae.

neck circumference = measured around the circumference of the neck immediately below the head.

hindfoot = measured from the joint of the hock to the tip of the nail.

Most data published for body measurements focus on the spring or summer period when sheep would be in poorer body condition than in the fall when the CRC data were collected. Direct comparisons are not possible as body weights would be near maximum in the fall after the summer feeding period. Mean weights for ewes 4 years or older from Alberta populations (Table 9) vary from 72.1 kg (159 lbs) measured in Waterton during April and May 1973 to 70.3 kg (155 lbs) in Sheep River and 65.8 kg (145 lbs) in Jasper measured at various times of the year (Blood et al. 1970). Weights of 20 "adult" ewes measured in June and July of 1975 and 1976 at Cadomin (Kosinski 1977) averaged 57.65 kg (127.1 lb), which is significantly different from the CRC mean weight of 73.34 kg ($t=6.73$ $df=36$ $P<0.0001$) measured 2 to 3 months later. Jorgenson and Wishart (1984) calculated summer (June, July and August) growth rates in older ewes on Ram Mountain to be linear. Linear growth rates of 0.17, 0.18 and 0.19 kg/day for 3, 4 and 5 year old ewes respectively, were calculated. Using 0.19 kg and multiplying by 60 (days), the average weight of Cadomin sheep (mostly Redcap range residents) by the first of September would be 69.05 kg, still considerably less than the CRC sheep, but not significantly different ($t=1.84$ $df=36$ $P>0.05$). A direct comparison, however, would necessitate data being collected during the same time period on sheep from both sites.

Weights of ewes 4 years and older from Ram Mountain were

Table 9. Weights of ewes from various locations and dates in Alberta.

Location	Date	n	Age	Weight (kg)	Range (kg)	Source
Waterton	April/May	65	>4	72.1	54.4-90.7	Blood et al 1970
Sheep R	all year	24	>4	70.3	65.3-82.5	Blood et al 1970
Jasper	all year	12	>4	65.8	53.1-82.5	Blood et al 1970
Cadomin	June/July	20	adult	57.6	43.1-69.9	Kosinkski 1976
Ram Mtn	Sept/Oct	21	>4	68.1	53.6-78.0	Jorgenson 1978-1989
CRC	Sept/Oct	25	>4	73.3	58.5-85.7	MacCallum this study

made available by J. Jorgenson (Alberta Fish and Wildlife) for use in this study. Live sheep were measured in September and October between the years 1978 and 1989. The average weight was 68.09 kg, significantly less ($t=2.79$ $df=44$ $P<0.0078$) than the CRC sheep average weight of 73.3 kg.

The weights of CRC sheep in the fall are similar to those of ewes in Waterton measured in the spring, but are greater than those recorded for Jasper ewes taken at various times throughout the year. Bighorns of southern Alberta attain a larger size than those of northern Alberta (Blood et al. 1970). Wishart (1969) attributed these differences to an optimum combination of climate, soil and vegetation present in southern Alberta. Weights of the CRC ewes in fall are likely to be at the high end for sheep in northern Alberta.

Horn Size

High quality expanding bighorn populations are characterized by individuals of high weights, large horns, high birth rates, and short life span, while low quality, stable or declining populations are characterized by individuals of lower weights, smaller horns, low birth rates, and long life span. Horn size has been used to note differences in population quality in bighorns (Geist 1971b:280; Shackleton 1973). In addition, a number of skull characters have been demonstrated to provide a good measure of population quality (Wishart and Brochu 1982). Horns for ewes greater than 3 years of age were measured in the field for total length and circumference of the base to the nearest half cm. Skulls were sent to the AFWD lab in Edmonton and horn increments and skull measurements were done by AFWD personnel.

Mean horn length of ewes > 3 years was 21.8 cm for the right horn and 21.9 cm for the left horn (Table 10). No significant difference was found between the two. The annual increment length was longer the second year than during the first and third years (Table 11). There was no significant difference between the horn length of the first and third increments of the right horn. Wishart and Brochu (1982), however, noted longer growth in the first year's annual increment as compared with the third year increment for bighorns from southern Alberta. Bighorns from northern Alberta displayed a reversed growth pattern (longer growth in the third year as compared with the first year). A similar trend was identified by Shackleton (1973:62) for high and low quality populations. CRC sheep appear to reflect an intermediate growth form with no difference between the first and third year annual increments.

Mean basal circumference measured from ewes at CRC was 13.0 cm for the right horn and 13.0 cm for the left. No difference was found between them. The mean horn basal circumference of ewes from southern Alberta (x=13.3, sd=0.953, range=11.5-15.1, n=19) is larger than for ewes from northern Alberta (x=12.9, sd=1.057, range=10.8-14.6, n=27) as reported by Wishart and Brochu (1982). However, these authors found

Table 10. Length and base circumference (cm) of horns of ewes greater than 3 years at Cardinal River Coals Ltd. measured during the non-trophy hunts in 1985 and 1987.

Ewes	n	Mean	Range	SD
length				
L	24	21.9	18.0 - 28.8	2.628
R	24	21.8	16.0 - 28.0	2.754
base circumference				
L	24	13.0	11.5 - 14.5	0.702
R	24	13.0	12.0 - 14.3	0.670

Table 11. Mean lengths (cm) of the first three annual increments of ewe horns from Cardinal River Coals Ltd., 1981 to 1986 as measured by Alberta Fish & Wildlife Division personnel at the Edmonton laboratory.

Increment	n	Mean	Range	SD
1st				
L	11	4.99	2.00 - 7.70	1.662
R	11	4.98	1.50 - 9.50	2.218
2nd				
L	13	9.95	6.90 - 13.50	1.988
R	12	9.96	7.50 - 13.00	1.796
3rd				
L	13	4.45	3.20 - 6.00	0.886
R	13	4.76	2.60 - 6.50	1.189

L = left horn
R = right horn

significant difference (P>0.05) between the two. The mean horn basal circumference of ewes from CRC falls between the measurements from northern and southern sheep, although the standard deviation is much smaller for the CRC sheep (Table 10) than for either the northern or southern populations.

Skull Characters

Of the five skull characters identified by Wishart and Brochu (1982) as good indicators of population quality, mean values measured for the CRC sheep (Table 12) for lower molar length (83.2 mm) occiput - frontal length (121.1) and naso-cranial length (199.8) were similar to those published by Wishart and Brochu (1982) for ewes from populations in the northern Rockies in Alberta (82.4, 121.2, and 198.2 mm respectively). The upper molar length of the CRC ewes (83.2 mm) was less than that for southern (85.2 mm) and greater than that for northern (81.9 mm) populations. Basisphenoid crown height for the CRC sheep (82.8 mm) was less than both southern (92.9) and northern (88.1) populations.

Population Characteristics

Management of a population of any big game species requires knowledge of productivity, mortality, and numbers or density (Gilbert 1978:297). These measures are generally estimated due to the expense and difficulty in obtaining actual values.

Using figures corrected for known mortality and the maximum count method, the maximum numbers of bighorn sheep on

Table 12. Skull, rostral and cranial measurements (mm) of bighorn ewes 3 years and older from Cardinal River Coals Ltd. mine site 1981 to 1986.

Measurement	n	Mean	Range	SD
Upper molar length	18	83.2	76.6 - 89.0	2.86
Lower molar length	13	82.8	77.0 - 88.0	3.28
Basisphenoid-crown height	18	82.8	74.0 - 93.1	5.43
Occiput-frontal length	18	121.1	111.5 - 125.0	3.20
Naso-cranial length	14	199.8	1860. - 229.2	10.33

definition of skull measurements from Wishart and Brochu (1982):

L Upper molar (length) series or upper tooth row = greatest alveolar length of combined upper molars and premolars.

M Lower molar (length) series or lower tooth row = greatest alveolar length of combined lower molars and premolars.

W Basisphenoid-crown height = greatest distance between the highest point of the crown between the horn cores, and the point on the basisphenoid near its junction with the presphenoid.

X Occiput-frontal length = least distance between the superior lip of the foramen magnum and the centre of the frontals in line with the two frontal foramina.

Z Naso-cranial length = least distance between the midline of the anterior end of the nasals and the depression of the parieta parietals in adult males or to the parietal crest in female and juveniles.

(see Appendix I Figure 25 for diagram of skull measurements) the study area during the pre-rut was: 198 (47 lambs, 88 ewes, 7 female yearlings, 8 male yearlings, 8 Class I rams, 28 Class II rams, 9 Class III rams and 3 Class IV rams). It should be noted that mortality does not affect the counts of seasons other than the pre-rut (unless mortality is carried over into the next season). Population ratios calculated from these data for the pre-rut (September 17 to November 14, 1985) are as follows:

lamb:100 ewes (ewes 2.5 years and older)	53:100
lamb:100 ewes and female yearlings	49:100
yearling:100 ewes (ewes 2.5 years and older)	17:100
yearling:100 sheep (rams & ewes 2.5+ years)	11:100
yearling male:yearling female	53:47
Class I II III & IV rams:ewes (2.5+ years)	35:65

During the fall of 1986, a maximum of 32 yearlings were counted in 11 counts indicating that 68% of the 47 lambs counted during the fall of 1985 survived their first year.

Lungworm Loads

Infection of bighorn sheep by nematode parasites, Protostrongylus stilesi and P. rushi, has been related to reduced efficiency of the immune system (Festa-Bianchet 1987) and has been associated with epizootic events of pneumonia-related die-offs. Although the term "lungworm pneumonia complex" is used to describe these events, there has been little evidence in the literature for a direct causative relationship between the presence of increased amounts of lungworm and outbreaks of pneumonia (Foreyt and Jessup 1982; Spraker et al. 1984; Onderka and Wishart 1984; Samson et al. 1987). Some evidence has been presented to indicate that in some circumstances lungworm infection in bighorn sheep acts as a predisposing factor to bacterial pneumonia (Forrester and Senger 1964; Spraker and Hibler 1982). Other stress factors that reduce the immunity or resistance level of individual sheep, and thus making a population susceptible to epidemic disease include: loss or deterioration of range, inclement weather, crowding, deep snow, poor nutrition, and parasite levels (Spraker and Hibler 1982; Schwantje 1986). Pneumonia die-offs in sheep with many etiological agents has been recently termed "respiratory disease complex of bighorn sheep" (Onderka and Wishart 1984). Another manifestation of long term low level stress condition is the presence of contagious ecthyma in sheep (Lance 1980).

The rate of lungworm larval output in a population can be detected by the number of first stage larvae shed per gram (LPG) of dry feces (Uhazy et al. 1973). These authors suggest that when large numbers of samples can be obtained from a herd, a useful index to the proportion of heavily infected animals in that herd may be obtained. They suggested LPG counts of greater than 1400 represent heavy output.

Larval output from the CRC sheep rose during each month during the fall of 1985 (Figure 15) and peaked in December after which a decline occurred. Larval output during the summer months May to September were very low compared to the winter months.

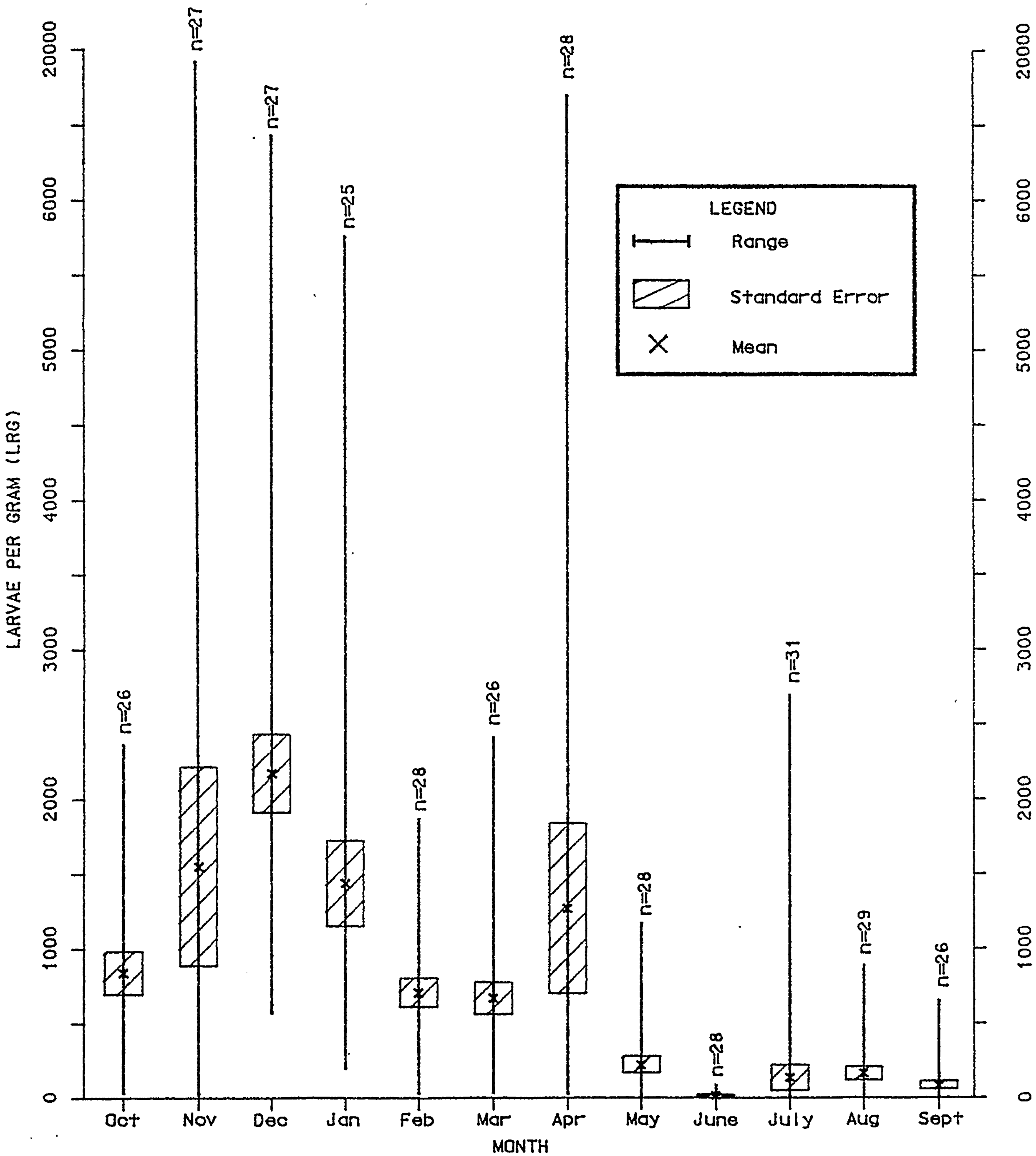


Figure 15. Descriptive statistics for measurement of Protostrongylus spp. larvae per gram (LPG) of dry feces for the bighorn sheep of Cardinal River Coals Ltd. October 1985 to September 1986

A oneway analysis of variance was performed on the transformed log(x+1) LPG data for the twelve months and it was found that there was a significant difference between the 12 means ($F=46.36$ $P<0.05$). A two sample-t test performed on transformed LPG values for ewes 2 years and older and rams 3 years and older indicates that there was a significance difference between the means in winter ($t=-2.23$ $df=70$ $P<0.03$) but not in summer. The means of the transformed LPG data were higher in winter for the rams than for the ewes (Table 13). Seasonal variation in the numbers of larvae per gram of dry feces in bighorn sheep has been described by other authors (Uhazy et al. 1973; Festa-Bianchet 1987; Jorgenson and Wishart 1983). LPG data for the CRC bighorns showed seasonal variation between winter and summer months as well. The highest rate of larval output (>1400 LPG) for the year occurred in December and January (60% and 36% respectively). High larval output during the summer months was virtually nonexistent (Figure 16). High larval output (>1400 LPG) in rams greater than 3 years occurred in the fall and early winter months. No heavy output in rams was noted between the months of March and September. High levels of larval output in ewes peaked in December, declined, then showed a secondary peak in March and April.

The CRC herd displayed high rates of larval output during the rut and early winter period. Despite these levels, there has been no outward manifestation of pneumonia to indicate

Table 13. Transformed log(x+1) LPG values for ewes (> 2 years) and rams (> 3 years) for the winter and summer months 1985 to 1986.

Summer (May - September 1986)						
	Transformed Larval Counts					LPG
n		Mean	SD	Min.	Max.	Mean
Ewes	64	1.594	0.804	0.000	2.952	140.4
Rams	32	1.496	0.832	0.000	3.066	111.8

Winter (October 1985 - April 1986)						
	Transformed Larval Counts					LPG
n		Mean	SD	Min.	Max.	Mean
Ewes	90	2.8253	0.4959	1.3010	4.1533	1195
Rams	40	3.0482	0.5388	1.5682	4.2595	2155

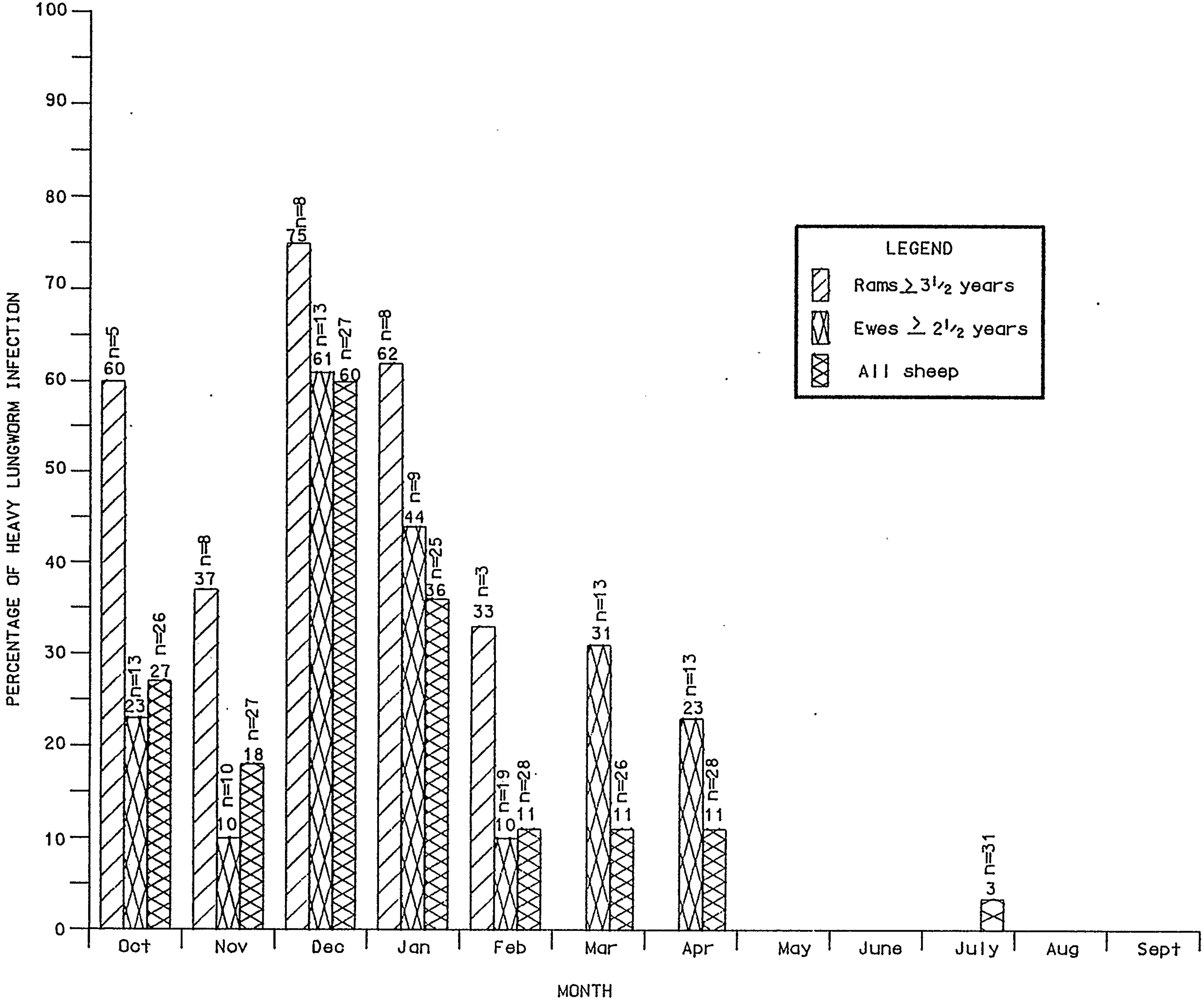


Figure 16. Percentage of heavy (>1400 LPG) lungworm infection in Cardinal River Coals Ltd. bighorn sheep for each month between October 1985 and September 1986.

that multiple stressors are reducing the resistance of the herd to disease. It is possible that the stress of the rut on rams in the fall and the stress of late winter on the ewes is reflected in the heavy (>1400 LPG) larval output during these times of the year (Figure 16).

A comparison of LPG from fecal samples collected from bighorns on the Redcap range (data made available from K. Smith, Alberta Fish and Wildlife Division) and from those on CRC for the month of March, 1986, shows a significant difference ($t=3.02$ $df=29$ $P<0.05$). The LPG levels from Redcap sheep are much higher ($n=21$, $x=1499.1$, $SD=1155.6$, range=54-3744) than those from CRC sheep ($n=26$, $x=673$, $SD=540$, range=36-2380).

Diet

Fifty percent by weight of rumen material consisted of grass. Timothy (Phleum pratense), wheatgrass (Agropyron spp.), bluegrass (Poa spp.) and fescue (Festuca spp.) were the most common species identified and consisted of 43% of grass material. It is likely that most of the bluegrass, fescue and wheatgrass represent the agronomic species present on the mine site. Only a trace of a "native" species, foxtail barley (Hordeum jubatum), was present, representing 1.4% of the grass component. Fifty-five percent of grass material was unidentified.

Legume species comprised 28% of the contents of the rumen by weight. Cicer milkvetch (Astragalus cicer) pods made up

27% of this legume material while another 27% consisted of cicer milkvetch leaves, clover (Trifolium spp.) and alfalfa (Medicago spp.). The remaining 46% of legume material was unidentifiable to the genus level.

Small amounts of forbs (7%), roots (5%) and moss were found in the rumen samples. Willow (Salix spp.) leaves, birch (Betula spp.) leaves and woody stems (3%) comprised the remainder of identifiable material by weight of rumen samples. Six percent of the total contents of the rumens were unidentifiable.

Agronomic species comprised 37% of the identifiable contents of the 10 rumens collected at CRC September 17 - October 31, 1985. Much of the grass and legume material was identifiable only as inflorescence, stem or leaf parts. If the assumption was made that most of this material was composed of agronomic species (most of what is present on CRC), then agronomic grasses and legumes would make up about 76% of the bighorn's diet during these two months.

Microhistological analysis results were grouped into grass, sedge, forb, shrub and tree categories (Table 14). Grass and sedge genera comprised 67% and 7% of the annual diet of bighorn sheep using the mine site, while forbs comprised 15%, shrubs 5% and coniferous trees 6%. Grass components of the diet were highest from October to December (82-92%) and lowest in June and July (31 and 37%). Sedge consumption on the other hand was highest in June and July (31% and 28%,

Table 14. Percent composition of forage ingested by bighorn sheep at Cardinal River Coals Ltd., October 1985 to September 1986 as measured by microhistological analysis.

Month	Grass	Sedge	Forb	Shrub	Tree
Oct	82	6	10	2	0
Nov	88	3	9	0	0
Dec	92	1	7	0	0
Jan	64	7	15	1	13
Feb	61	5	15	0	19
Mar	76	0	14	1	9
Apr	66	0	5	6	23
May	66	4	22	4	4
Jun	31	31	18	20	0
Jul	37	28	13	23	0
Aug	74	2	22	1	1
Sep	70	0	25	5	0
Year	67	7	15	5	6

Note:

Grass genera include: Agropyron, Agrostis, Bromus, Elymus, Festuca, Koeleria, Phleum and Poa.

Forb genera include: Artemisia, Astragalus-Oxytropis, Boraginaceae, Compositae, Descurainia, Draba, Melilotus-Medicago (likely includes Trifolium).

Shrub genera include: Juniperus, Salix, Shepherdia, Symphoricarpos and an unidentified shrub.

Tree genera include: Picea and Pinus.

Identification by: The Composition Analysis Lab, Colorado State University.

Figure 17. Members of the nursery herd grazing in the alpine area adjacent to Cardinal River Coals Ltd., July 4, 1986.

Figure 18. Rams bedded adjacent to an active haul road, Cardinal River Coals Ltd., March 10, 1986.

respectively). The sheep, during these two months, were grazing not on the study area but in the alpine region adjacent to the mine site (Figure 17); this is where pellets were collected during June and July. Use of shrub material was highest in April (29%), June (20%), and July (23%). Forb components of the diet were highest in May (22%), August (22%), and September (31%). Relatively heavy use of Pinus and Picea was made in February (19%) and April (23%).

Human Activity and Sheep Response

Bighorn sheep at CRC moved freely through the mineral surface lease despite the ongoing activity of the coal mine (Figure 18). Sheep were observed frequently walking along and crossing haul roads. Sheep commonly walked across the top of the "superpipe", a landfill constructed above HWY 40 for the passage of the large 100 and 170 ton haul trucks. Ewes were observed bedded with their lambs on the active haul road below 51-B-3 pit. On one occasion a 170 ton haul truck loaded with rock on a down hill grade was observed stopping to let sheep cross. Sheep commonly bedded and walked along the banks adjacent to the active haul roads. Only one sheep mortality has occurred at CRC to date that can be directly attributed to mining activity. This involved a ram running off a bank onto the haul road during the rutting season and being killed by a large haul truck.

On several occasions sheep were observed during mine blasting to determine their behavioural response. Older sheep commonly exhibited no appreciable outward reaction while younger sheep infrequently would startle and run a short distance before re-settling. A mixed herd of 88 sheep (24 lambs, 38 ewes, 2 female yearling, 6 male I, 13 male II, 2 male III and 3 male IV) was observed to respond as a unit to a blast from the neighbouring Gregg River Resources (GRR) mine on December 20, 1985, shortly after 1300 hrs. The sheep were calmly grazing on the west side of 50-A-2 dump on CRC when suddenly they leaped as a unit into full panic flight for no apparent reason. A few seconds later, the sound of a blast from the GRR pit (0.8 km away) was heard on the 50-A-2 dump. A subsequent consultation with Ken Holmes the CRC geologist revealed that the seam which GRR was blasting was the same as the one on which the sheep had been grazing. It seemed likely that the sheep either felt the ground shake prior to the sound arriving or reacted to the plume of dust from the blast. The sheep ran only a short distance (15 to 30 m) away from the source of the blast, then stopped and resumed their activity. On January 6, 1986, a mixed herd of 76 grazing sheep located on the large bench south of HWY 40 and west of superpipe responded to the blast from the 51-B-3 pit located on the north side of HWY 40 by temporarily bunching together.

The most extreme reaction witnessed was to a helicopter that appeared suddenly from the Gregg River below the 50-A-2 dump on October 28, 1985, at 1200 hrs. The 50-A-2 dump is 153 m higher than the Gregg River at this point. There was no warning of the approach of the helicopter, which must have been flying along the Gregg River. The sheep, which had been grazing, ran in full panic flight to the first bench located at the base of the hill south of 50-A-2 and proceeded to mill excitedly around and over each other - jumping, bumping and crashing into other sheep. This activity continued for a few minutes after the departure of the helicopter and by 1218 hrs the sheep had bedded.

In 1984, the Alberta Fish and Wildlife Division instituted a non-trophy hunt on a portion of the CRC mineral surface lease. This hunt was opened due to the concern that sheep were moving onto the mine site early in the fall and staying through the winter, thus predisposing them to a high rate of lungworm infection as has been described by Wishart et al. (1980) and Boag and Wishart (1982). An additional concern regarding overuse of the available winter range also contributed to opening the season. At that time approximately 108 ha of reclaimed grassland and 7 ha of a south-facing subalpine meadow was used intensively during the late fall and early winter months. The sheep foraged more widely over the mine site during the other seasons. The purposes of the hunt were:

1. To reduce the number of animals in the herd (about 200 sheep).

2. To use hunting as a temporary measure to move animals off the mine site (primarily 50-A-2) early in the fall, thus preserving forage for use later in the winter.

Hunting of the animals on the mine site caused the sheep not to abandon the site but to move farther north into the active area of the mine which was off limits to hunters. On October 4, 1985, a nursery group of 18 animals, which had been shot at the previous day on the 50-A-2 dump, showed up on the C-baseline where they had not been observed previously. This was the only time that members of the nursery herd were observed on the C-baseline during the fall of 1985. This type of response (movement precipitated by active hunting followed by return to preferred range in a few days) was typical throughout the hunting season. Hunt days were only on Tuesdays (primitive weapons) and Thursdays (shotgun) of each week for the duration of the season. In the fall of 1985, poor weather hindered the archery hunters and by the end of the season, shotgun hunters were the only persons taking advantage of the hunt. The sheep, therefore, would have almost a whole week to reestablish preferred grazing patterns. It is interesting to note that the sheep did not leave the mine site to occupy the neighbouring WMU438 where both trophy and non-trophy hunting were permitted. Hunter success in WMU438 is one of the highest in Alberta (pers. comm. K. Smith AFWD) indicating that hunting pressure is also high.

Other forms of human activity around the sheep at CRC were at a minimum. Once a reclaimed area is established, very little human activity occurs except for the occasional crew in the summer carrying out activities such as fertilizing, tree planting, etc. Most sheep occupied the alpine in summer thereby minimizing the chance of these interactions even less. Random human recreational activities, such as all terrain vehicle use, hiking, or cross country skiing, do not occur within the mineral surface lease boundaries.

Predation

Many instances of coyotes either rushing sheep or passing close to them were observed during the study period. One incident of a lamb escaping from a coyote onto a nearby high wall was observed; another incident involved a wounded ewe which had isolated herself from the herd and was obviously dying. Even when she was very weak and bedded most of the time, a coyote, which had been hanging around, appeared unwilling to approach the ewe as long as she was able to stand and face the coyote. It was believed that coyotes did not represent a significant predator threat to the sheep of CRC.

Wolves are present in the area surrounding the mine site, and tracks were occasionally seen on the north boundary of the mine. With the exception of a lone wolf sighted in 1986 on the 50-A-1 reclamation, no wolves were observed on the main winter ranges within the mine boundary.

Grizzly bears are commonly seen on the mine property in spring and fall seasons. No negative interactions between humans and bears have yet occurred. Bear predation of sheep would be incidental. No eagles were sighted on the mine site. Cougar sign was not sighted on the winter sheep range, although cougars exist in the area surrounding the mine site. The extent of cougar predation on the CRC sheep is not known.

This study was not designed to assess the impact of predators on the sheep herd. Nevertheless, it appears that the sheep, while on the mine site, experienced minimal predation pressure.

Other Wildlife

Mule deer were commonly sighted on the mine site, feeding in the grasslands adjacent to tree cover or moving through open areas by means of each available cluster or island of trees. The maximum count of mule deer between September 17 and December 31, 1985, was: 16 (5 does, 5 fawns, 6 bucks).

No elk were sighted on the mine site, although the habitat is suitable and there are examples of elk habituating to the activity of a mine site much like the CRC sheep. This has occurred at Westars' Elk valley mine site in British Columbia (pers. comm. Carleen Gibson) and at the Chevron Pittsburgh and Midway Coal Mining Company's Edna mine near Steamboat Springs, Colorado (Arscott 1989). Elk numbers in the Cadomin area have been depressed for several years (pers. comm. K. Smith AFWD). No moose were sighted during the surveys.

Incidental sightings of small mammals included a red fox near timberline and hoary marmots in the SE corner of the 50-A-3 pit. Red squirrels were common in the undisturbed subalpine forest. Bird sightings were summarized in the Alberta Bird Record (MacCallum 1986a, 1986b, and 1986c).

5. CRC MINE SITE AS BIGHORN SHEEP HABITAT

Wildlife populations are controlled by a combination of welfare and decimating factors and environmental processes that alter environments. Habitat requirements of wildlife have been described as welfare factors by Leopold (1933:25). Habitat can be defined as the arrangement of food, water and cover and the availability of other requirements such as mineral licks. A lack of welfare factors limits populations while the presence of decimating factors (hunting, predation, disease, parasites, accidents) depress populations (Bailey 1984:201). In this chapter, the CRC mine site is examined in terms of the habitat requirements of bighorn sheep.

Escape Terrain

Various descriptions of escape terrain appear in the literature. Tilton and Willard (1982) noted that sheep on winter range avoided areas having a slope steepness of 11-35% (6° - 19°) which were located away from cliffs and rugged terrain and preferred areas with a slope steepness greater than 80% (39°). Thorne et al. (1979:52) described escape cover ranging from sagebrush-covered slopes of approximately 100% (45°) to sheer rock cliffs as much as 270 m high. Size and steepness of escape terrain did not seem to be as important as did the proximity of escape terrain to other sites used by sheep for various activities. Van Dyke et al. (1983:6) described escape terrain as comprising of cliffs at least 8 m high and 200 m long. Stemp (1983:119) commented that on Ram Mountain, Alberta, the proximity of escape terrain to areas used by sheep appeared to be more important than the character of escape terrain. Three metre high cliffs amid steep talus slopes seemed perfectly adequate at Ram Mountain; although he did comment that selection for larger, more extensive cliffs would be expected by bighorns under moderate or heavy predation. It is generally agreed that the presence and distribution of escape terrain limits habitat use of bighorn sheep (Van Dyke et al. 1983:6; Tilton and Willard 1982).

The reclaimed landscape at CRC resembles a series of plateaus with more or less flat tops surrounded by slope angles of varying degrees. Slope angles vary from 45° (cliff-like habitat with no reclamation of pit walls), to 33° (the "natural angle of repose" achieved after dumping of rock and overburden) to 27° (slopes which have been graded and reclaimed to vegetation cover). The "plateaus" are separated by valley-like depressions which the sheep must negotiate as they travel through the mine site. Associated with some "plateaus" are south-facing slopes used for foraging, such as the slopes above HWY 40 and the centrally located subalpine meadow.

Two distinct travel routes were noted to be used by sheep when they moved north through the mineral surface lease. The first route involved the sheep descending the north slope of the 50-A-2 dump and travelling across a flat bench to the "notch" (corner of 50-B-3 dump and 50-A-2 dump), descending to

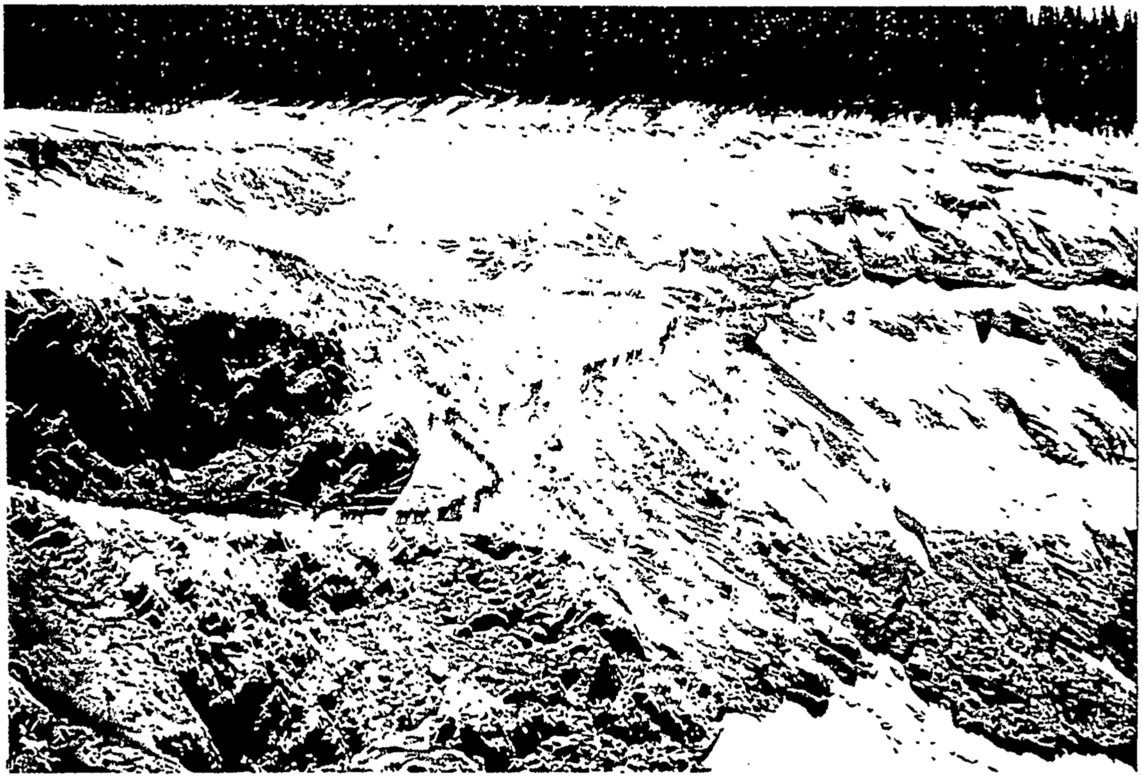


Figure 19. Bighorn sheep traversing the east wall of 50-B-3 pit.

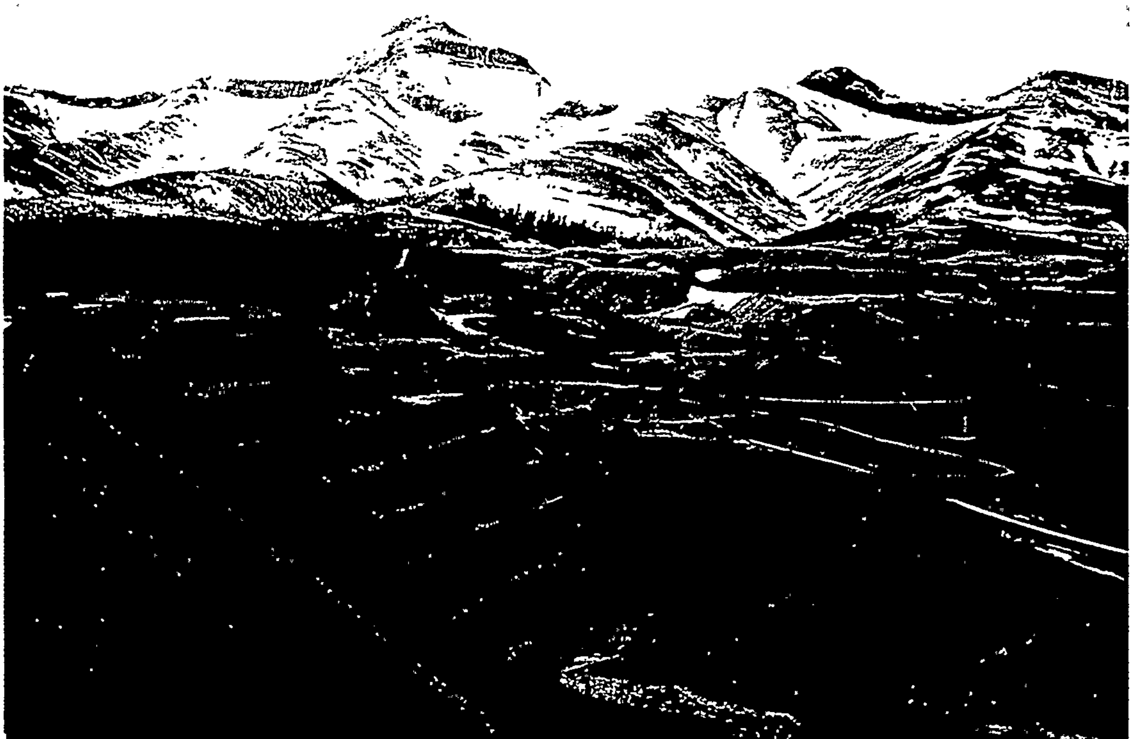


Figure 20. The east wall of 51-B-2. This wall is used for travel, escape terrain, lambing, and by injured sheep.

Cabin Creek, then ascending and crossing the 50-B-3 east pit wall (Figure 19). From there, the sheep would descend to HWY 40, then move up the south-facing slopes adjacent to the 51-B-3 east wall. The second route incorporated the use of the benches above 50-B-3 on the west side of the pit on which the sheep travelled instead of descending to Cabin Creek.

In addition to the use of steep slopes and high walls for travel corridors, high walls were used for lambing (Figure 20), for mineral sources (specifically 50-A-3 in June and the mine waste on the west and south slopes of 50-B-3 anytime), and for bedding or as escape terrain. Animals that were sick or wounded (ewe BL and ewe WO) segregated themselves from the herd and remained on grassy slopes immediately adjacent to high walls (notably the east wall of 51-B-2). Walls and steep slopes that were observed to be used for any of these purposes were described as "escape terrain" (Table 15). The locations of designated "escape terrain" were plotted on a separate computer file and this was used to calculate the distance that each sheep or group of sheep was observed from the nearest unit of escape terrain (Figure 21).

Rather than assigning distance categories for analyzing escape terrain information (Morgantini and Hudson 1981; Tilton and Willard 1982), data for distance from escape terrain were ranked and divided into quartiles. A total of 1213 groups of sheep comprising 11,933 individuals was observed between September 17, 1985, and August 10, 1986. Twenty-five percent

Table 15. Description of escape terrain used by bighorn sheep at Cardinal River Coals Ltd. mine site, 1985 to 1986.

Site	Length (m)	Height (m)	Slope (degrees)	Material	Bench # & Width (m)	Use
50-A-3 e. wall	696	81	39-42	rock	4 (7.2)	R M T E W
s. wall	590	84-105	31	rock	5-6 (4.8-9.6)	T R E
w. wall	384	66	32-35	talus	3 (16.8-96.0)	E T
n. wall	590	53	39	rock	3-4 (4.8-9.6)	E B R T
50-A-3 n. dump & n. slope	360	53	38	talus	none	B T
50-B-3 s. & w. dumps	600	121	37	talus & mine waste	3 (19.2-23.0)	T M
e. wall	346	76	39	rock	3 (4.8)	T B
n. dump	312	73	22	talus	2 (12.0)	T
51-B-2 e. wall	1046	205	45	rock	8 (4.8-24)	L E W T
s. wall	576	95	21	talus	none	T
w. wall	614	95	23	talus	none	T
north	259	38	26	rock	2 (4.8-24)	E B T
51-B-3	586	(being developed)		rock	several	future T E
C Base	768	62-108	35-36	rock/talus	0-2 (4.8)	E T
C Base (central)	1584	64-99	34-44	rock	0-4 (4.8)	T E
C Base	370	23	20	rock	2 (4.8)	T

R = rut, M = minerals, T = travel, e = escape, w = wounded, B = bedded, L = lambing NOTE: benches on the 50-A-3 west wall and the 51-B-2 east wall are partly vegetated.

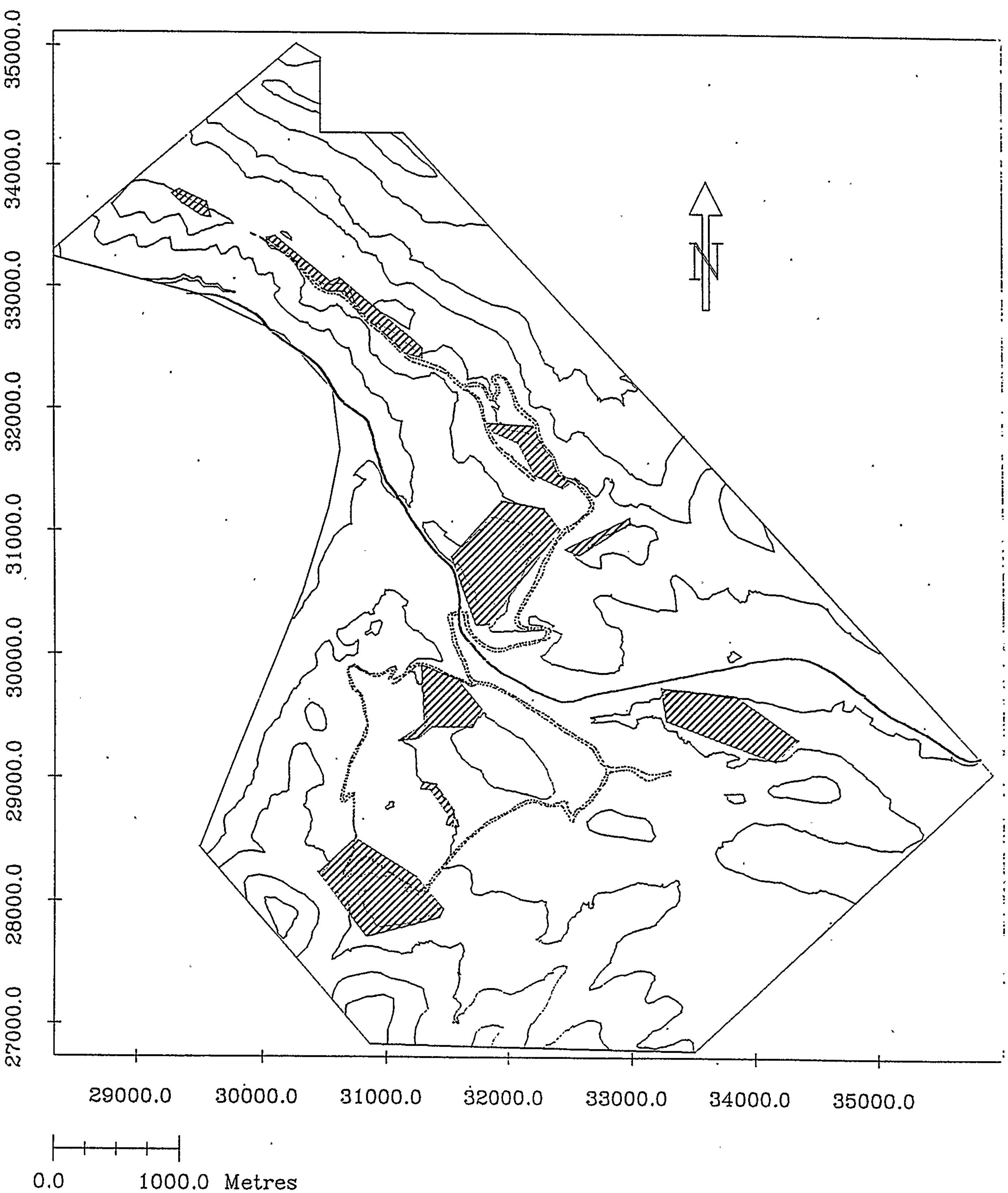


Figure 21. The location of escape terrain used by bighorn sheep at Cardinal River Coals Ltd. from September 17, 1985 to September 1, 1986.

of group observations were made between 0 and 40 m of escape terrain; 50% of group observations were made between 0 and 160 m; 75% group observations were made between 0 and 290 m; and 100% of sheep observations were made between 0 and 705 m of escape terrain (Table 16). If the distance from escape terrain calculation weights the group by the number of individuals within the group, the resulting distances are farther than if the distance to the center of the group is reported. Distances would then be reported as follows: 25% of individuals in groups within 115 m; 50% within 235 m; 75% within 360 m and 100% within 705 m. It is most common, however, to report the distance to the group of sheep, so this is what will be discussed in this study.

Sheep use of the study area during June, July, and most of August, was focused on use of the 50-A-3 pit as a mineral lick. Other activities occurred on the mine site only sporadically; distance from escape terrain for this season would reflect the concentration around the 50-A-3 pit. The months represented by lambing and summer were therefore excluded from a comparison of distance from escape terrain for groups of sheep during the pre-rut, rut, winter and spring periods. A Chi-square test was used to test the hypothesis that there was no difference in distance from escape terrain during the occupation of the pre-rut, rut, winter and spring home ranges. Results show there was no difference in distance from escape terrain between the pre-rut and rut. There was a significant difference between the pre-rut and the winter (X^2=55.11 df=3 $P<0.05$) and the pre-rut and spring (X^2=38.52 df=3

Table 16. Distance from escape terrain (m) for bighorn sheep (all classes and activities included) on the Cardinal River Coals Ltd. mine site during the pre-rut, rut, winter, spring, lambing and summer for the year 1985 to 1986.

	Measures of Location					
	Min.	Q1	Median	Q3	Max.	(n)
Pre-rut	0	60	165	290	590	195
Rut	0	35	175	320	680	339
Winter	0	95	190	285	630	213
Spring	0	115	210	300	705	276
Lambing	0	0	20	130	500	128
Summer	0	0	0	25	275	62
Year	0	40	160	290	705	1213

P<0.05). Sheep were closer to escape terrain in the pre-rut and rut than in the winter and spring.

Mineral Licks

The attraction of bighorn sheep to mineral licks has been documented by others (Geist 1971b:271; Festa-Bianchet 1987: 164) and is clearly evident at CRC. Sheep were observed licking at bare spots on the winter range (50-A-2), on haul roads, and on HWY 40 at various times throughout the year, but this activity was most pronounced in June when the ewes used water seeps located on the east wall of 50-A-3 (Figure 8 and Appendix IV Figure 38) and the exposed coal/sandstone of the southwest corner of the 50-A-3 pit as a mineral source. Part of the nursery herd at this time was located in the alpine areas of Luscar Creek. They used the 50-A-3 pit almost daily as a mineral source but returned to the alpine areas for grazing. Early in June, ewes came alone, leaving their lambs temporarily with the nursery group; later in June, ewes brought their lambs with them. As many as 56 sheep at one time have been observed using the 50-A-3 pit during this period. In June, sheep were observed in the 50-A-3 pit during 13 out of 17 days when systematic counts were made.

Soil samples were collected at 5 lick sites on the study area on July 5, 1986. Lick sites No.'s 1 - 4 were located where sheep had been observed licking during the spring of 1986 while lick site No. 5 was located where mule deer had been observed licking. Samples from lick sites No. 1 and 2 were taken from exposed coal or sandstone while the sample from lick site No. 3 was taken from the residue that remains after the coal has been "cleaned". This watery sludge is dumped into open pits and covered by 1 m of overburden. It was noticed that sheep were equally attracted to this waste material as they were to water seeps on exposed coal seams. The sample from lick site No. 4 was taken from a road bank adjacent to a haul road and the sample from No. 5 was taken from a wet depression on overburden. One sample from each site was collected from the top 5 cm of the lick surface. Samples were sent to the Provincial Soil and Feed Testing Laboratory in Edmonton for analysis of total elements.

Samples were all weakly to moderately alkaline (Table 17), a similar trend as reported by Salter (undated) during analysis of 5 natural lick sites used by feral horses in the Alberta foothills west of Sundre. Levels of P, Na, K, Ca and Mg at the CRC lick sites were much higher than levels reported by Salter.

The lower values of sodium and sulphur at CRC overlapped with the highest levels of these elements reported by Stockstad et al. (1953) for natural licks used by goat, elk, deer, and moose in western Montana. Calcium levels at CRC were similar to those reported by Stockstad et al. (1953), but magnesium and potassium levels at CRC were much higher than those reported by these authors. Upper levels of calcium at CRC overlapped with lower levels at licks reported to be used by

Table 17. pH, electrical conductivity and mineral analysis (ppm) of soil samples collected from lick sites on coal, overburden and mine waste at Cardinal River Coals Ltd. on July 7, 1986.

Site	pH	E.C. (Sm)	Total N (%)	P	K	S	Total C (%)
1	9.1	0.02	0.92	4500	11900	2800	43.4
2	9.2	0.03	0.22	1800	14600	800	12.5
3	8.8	0.21	0.70	3500	10200	3300	29.4
4	9.0	0.06	0.46	3700	12500	2200	15.8
5	10.2	0.04	0.65	3500	8100	2000	30.2

Site	Cu	Zn	Mg	Se (ppb)	Na	Ca
1	14.1	26.2	1900	795	8580	5800
2	43.8	91.3	7600	816	6940	7700
3	25.1	25.5	2300	1430	4950	4900
4	37.2	46.9	3900	1572	6470	8000
5	21.8	22.1	5400	1139	3380	6700

Site description:
1 = exposed coal on southwest corner of 50-A-3 pit
2 = edge of large puddle on haul road at hunters gate 50-A-3
3 = mine waste dumped on west slopes 50-B-3 pit
4 = road bank on haul road 50-B-3 pit
5 = edge of permanent wet depression in overburden in valley north of 50-A-2 dump

Note: Bighorn sheep were observed licking at site numbers 1 through 4. Mule deer were observed licking at site number 5.

mountain goats (Hebert and Cowan 1971). Sodium levels at CRC were much higher than levels reported by these same authors. Generally then, it appears that for the more common elements (Na, Ca, K, P, Mg) the lick sites at CRC are within the limits reported by authors for natural lick sites.

Lambing Sites

During the latter part of May, 1986, individual ewes were sighted leaving the nursery herd and moving off the mine site into the alpine zone for lambing. One of the collared ewes (Y) was located on the south slopes of Sphinx Mountain (7.5 km to the NW of CRC) and the other (W21) moved SE toward Cadomin. Both sheep returned with lambs to the vicinity of CRC to spend the summer in the alpine. The "W21" ewe was sighted near CRC on June 11, 1986, and the "Y" ewe was sighted on July 28, 1986 (Table 7).

Six ewes, however, lambed on the 51-B-2 wall (Figure 20) within 150 m of active rock dumping. The first lambs of the year were observed here on May 28, 1986. The ewes and lambs remained within the vicinity of this pit, utilizing forage adjacent to the east and north walls until June 4, 1986, when they moved west across and off the mine site. The 51-B-2 east wall is the steepest and highest pit wall utilized by the sheep on the mine site (Table 15 and Figure 20). It is noteworthy that bighorn sheep are capable of utilizing man-made walls for lambing purposes.

Area of Occupation of Study Area by Bighorn Sheep

The program "territory" (Faculty of Environmental Design, Computer Department) was used to calculate the area occupied by sheep on the mine site. This method is similar to the minimum area convex polygon method developed by Hayne (1949). Peripheral locations of an animal are connected so that the internal angles of the resulting polygon do not exceed 180 degrees. This method, however, can include large areas never used by the sheep and is severely affected by outliers (Macdonald et al. 1980:410). To reduce the outlier effect, a "95% convex polygon" method was used whereby the boundaries were connected to encompass only the innermost 95 percent of all observations.

The total area occupied by sheep on the study area as calculated by the "95% polygon" program for the year 1985/1986 was 12.7 sq km. The Class II, III, and IV rams occupied 7.0, 6.7 and 5.2 sq km respectively. These areas are considerably larger than those areas occupied by the nursery herd. The area of occupation of the lambs and ewes was similar (4.9 sq km) as was that of the male and female yearlings (3.9 sq km). Class I rams used 4.9 sq km of the study area.

During the pre-rut, the Class II, III and IV rams used a larger area (6.5, 6.2 and 3.4 sq km respectively) than the members of the nursery herd. Ewes occupied 3.9 sq km, lambs 3.6, female yearlings 3.4 and male yearlings 2.8 sq km. The area occupied by Class I rams (4.7 sq km) was greater than that used by ewes, lambs and yearlings, but less than that occupied by Class II, III and IV rams. Class IV rams consistently used less area than Class III rams throughout the year even in those seasons where the number of observations were similar (rut and winter).

Very large differences in area occurred when all observation locations were used in the calculations, instead of 95% of the locations, for both Class II rams (approximately 3, 4 and 5 years olds) and male yearlings in the lambing season (2.2 x area and 2.5 x area respectively). It was during this season that the male yearlings were sighted away from the ewes and in areas of the mine site where they had not been sighted previously. Usually there were larger rams nearby, and presumably it was these animals that the younger rams were following.

As some or all of the sheep use areas off the study area for late winter, spring, lambing and summer range, the above figures do not represent the complete home range occupied by the CRC herd, but rather the area used by them when they are on the mine site.

Vegetation Cover Types

Vegetation cover of CRC's mineral surface lease representing the area surveyed for sheep (21.6 sq km) was delineated into 5 types on the 1:4,800 base map: coniferous, meadow (native grass and shrubland), reclaimed grasslands, non-vegetated, open pit and water. These were defined as:

coniferous - This includes both lodgepole pine stands on well drained soils and forests of co-dominant Engelmann spruce and alpine fir on moderately well drained sites.

subalpine meadow - These are naturally occurring grasslands located mostly on steep south-facing aspects. Small amounts of aspen located on the drier hillside sites were included in this category as well as alder and willow shrub meadows found on imperfectly or poorly drained sites. Included in this category are small areas which were cleared of tree cover on the mine site but which were subsequently not disturbed during the mining process.

reclaimed grasslands - These areas have been reclaimed to commercial varieties of grasses and legumes (see page 12).

non-vegetated - These areas have been disturbed by mining and have not yet been reclaimed to a vegetative cover. They are composed of a mixture of rock, regolith and waste from the processing plant.

open pit - These are pits that may be in the process of stripping, active mining or backfilling. The benched walls used by sheep for escape terrain are included in this category as well as the pit bottom whether it was dry or water-filled.

water - Settling ponds and natural or modified lakes such as Luscar Lake fall into this category.

Cover types were digitized and a program called "area_tot" (Faculty of Environmental Design, Computer Department) was run with the base map "veg.brief.map" to calculate areas of vegetation polygons. Area calculations were planimetric and did not account for the steep terrain. The area of vegetation types that occur on slopes (all except water) are therefore underestimated.

Coniferous forest comprised the largest percentage of cover type - 9.84 sq km (46%) on the mine site followed by open pits - 3.18 sq km (15%) and similar amounts of reclaimed grasslands - 3.03 sq km (14%) and unreclaimed regolith - 3.11 sq km (14%). Lesser amounts of subalpine grass and shrub meadows - 2.28 sq km (11%) and water - 0.13 sq km (1%) comprised the rest of the area. Mining activity at CRC has changed the landscape from primarily subalpine spruce/fir forest to that of an open landscape of grass/legume grasslands interspersed with unreclaimed open pits, regolith and islands of the original coniferous cover (Figure 2a).

To calculate the number of sheep observations in each vegetation polygon, a "points_in_poly" program was run. Seventy percent of all sheep observations during the year occurred in reclaimed grasslands (Table 18). Use of these areas fell off to 8% in June and July when the sheep were grazing in the alpine off the study area. Conversely, the highest percentage of observations associated with the open pits occurred in these two seasons (36% and 67%). This reflects the use of the open pits as mineral licks during this time period. Use of the subalpine grass and shrub meadows was highest during the winter, spring and lambing seasons (February through to June) when the adult rams segregated from the nursery herd and concentrated on the south-facing slope in the center of the mine site.

Sheep use was limited to 9.07 sq km of the study area (Figure 11) of which there was about 2.06 sq km of range that was grazed by the sheep at various seasons. Eighty-two percent of this area was composed of reclaimed sites. The re-

Table 18. Percentage of sightings of bighorn sheep in various cover types at Cardinal River Coals Ltd. during the year 1985 to 1986.

Month	Conifer	Reclaim	Pits	Meadow	Regolith	n
Sep	0	72	7	3	18	645
Oct	2	76	2	10	10	1708
Nov	0.1	87	2	10	0.6	1651
Dec	1	83	4	11	1	1440
Jan	1	80	5	9	4	1709
Feb	8	45	3	36	8	1322
Mar	4	69	2	25	1	1016
Apr	2	60	9	26	3	649
May	0	76	2	17	5	1034
Jun	5	8	36	23	28	507
Jul	0	8	67	17	8	184
Aug	0	61	13	4	22	708
Year	2	70	6	15	7	12573

n = number of sheep observations

maining range was composed of subalpine grasslands or meadows that had developed after tree cover removal.

Biomass Production on Reclaimed Grasslands and Subalpine Meadows

Estimates of total above ground biomass for the reclaimed grasslands as measured during late July and early August, 1986, showed them to be highly productive (x=4,190 kg/ha, n=62, range=240-19,360 kg/ha) (Table 19). Jacques (1980:124) described similar high above ground productivity values on certain native ranges in the foothills of southwestern Alberta.

The total above ground biomass as measured on a south-facing slope comprised of native grasses and forbs was less (x=1,700 kg/ha, range=1,360-2,040 kg/ha, n=2) than that for the reclaimed grasslands.

It was noted that the clip plot size of ¼ sq m may not have been appropriate for the variety of microhabitats found on the reclaimed areas. A plot size of ½ sq m may include this variation. It is recommended that should further work involving biomass production be conducted, a test of plot sizes be carried out prior to clipping.

Crude Protein

The percent crude protein values as measured by fecal nitrogen for the CRC herd began to decrease in October, 1985, (11.60%) to reach an annual low during the winter months of November, 1985, through to March, 1986 (Figure 22). Winter

Table 19. Total above ground biomass (kg/ha), area, and elevation for the reclaimed areas and subalpine meadows used by bighorn sheep for grazing at Cardinal River Coals Ltd. Biomass was measured during late July and early August of 1986.

Location	mean (kg/ha)	range (kg/ha)	area (ha)	elevation (m)	n
50-A-1	5908	1,400-19,360	42	1812-1847	16
50-A-2	2780	240-6,280	18	1801-1824	8
50-A-3	1773	640-3,080	6	1803-1839	6
51-B dump	4276	1,200-10,880	41	1707-1737	10
51-B slope	5067	1,560-15,000	16	1661-1696	6
lower slopes beside HWY40	3630	680-8,240	26	1664-1698	8
slopes adjacent 51-B-2 pit	3040	2,280-4,400	16	1707-1743	6
C-baseline	4260	1,880-6,640	5	1699-1809	2
SUBTOTAL	4190	240-19,360	170	1661-1847	62
50-A-1 meadow		(area not sampled)	4		-
50-A-3 meadow		(area not sampled)	11		-
subalpine meadow	1700	1,360-2,040	7	1766-1775	2
north wall 51-B-2 meadow		(area not sampled)	3		-
C-baseline meadow		(area not sampled)	11		-
SUBTOTAL			36		
TOTAL			206		

Note: Vegetation polygons were digitized from the 1:4,800 base map and areas calculated by using the area_tot program.

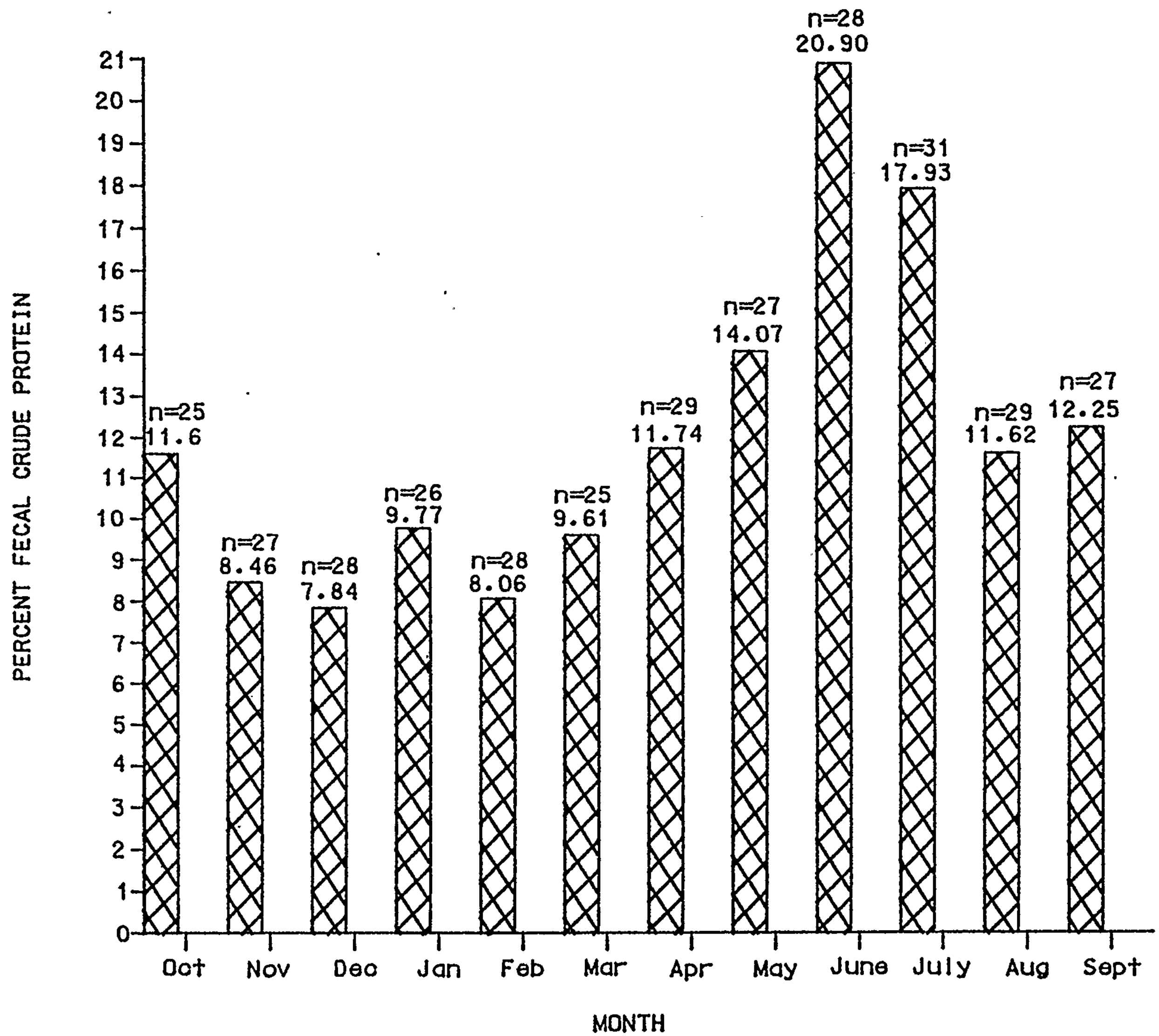


Figure 22. Percent fecal crude protein for bighorn sheep at Cardinal River Coals for the year October, 1985 to September, 1986.

values fluctuated between 7.84% and 9.77%. Crude protein values began to increase in April (11.74%) and May (14.07%) of 1986, to reach an annual high of 20.9% during the month of June. Values decreased slightly in July (17.93%) and more noticeably during August (11.62%) and September (12.25%).

The overall annual cycle of crude protein for CRC is similar to that of Ram Mountain (Jorgenson and Wishart 1986:48). Spring greenup as expressed by crude protein in April and May was later at CRC than at Ram Mountain for the years 1980, 1981, 1982 and 1983. Crude protein values for April and May, 1986, at CRC however, were similar to those at Ram Mountain for the years of 1984 and 1985. The summer peak of 20.9% at CRC was less than the summer peak at Ram Mountain during the years 1980 to 1983 but higher than those at Ram Mountain for the years 1984 and 1985. This suggests that weather patterns influencing the growing season are largely responsible for the variation in crude protein values from year to year. Percent crude protein values for CRC seem to be similar to those published for the Ram mountain herd (1980 - 1985) for the months of October, November, December, January and February.

Crude protein values as measured by fecal nitrogen seem to be similar at CRC and Ram Mountain despite the fact that the CRC sheep are grazing agronomic species in the fall, winter and early spring while the Ram Mountain sheep are using native species year round.

6. DISCUSSION

1. POPULATION NUMBERS AND TRENDS

CRC has definitely created a new habitat for bighorn sheep. Because extensive bighorn sheep inventories prior to mining do not exist for the surrounding area, it is impossible to directly address the question of whether CRC has increased bighorn numbers. Indirectly, the question can be answered in the affirmative if the number of sheep remaining on the mine site throughout the winter is taken to represent a similar number of sheep for which traditional range has been made available. Using this logic, it can be said that CRC has increased bighorn sheep numbers by the maximum count during the late winter/spring season (120 sheep in 1986).

The CRC herd (maximum count of 193 sheep during the pre-rut of 1985 and 120 during the late winter of 1986) is one of the largest in the province. Alberta Fish and Wildlife records (Gudmundson 1988; Jorgenson 1988a; Smith, K. and J. Edmonds 1989; Bruns 1990) indicate that for the 1988 and 1990 winter range surveys, the largest winter population units were: 472 (White Rabbit/Ram/Clearwater, 347 (Whitehorse Creek), 231 (Mt. Stearn), 229 (First Range/Job Creek), 161 (Scalp Creek East), 136 (Prairie Bluff/Yarrow Creek), 125 (Folding Mountain), 120 (Three Sisters/Wind Ridge), 114 (Barrier Mountain), 113 (Ram Mountain) and 111 (Ribbon Creek). CRC lies adjacent to the Whitehorse Creek survey unit and of the 347 sheep counted for the unit in the winter of 1988, 111 were located on CRC. It is possible that more sheep were present on CRC at this time, as the survey unit does not cover the complete mine site.

Home-Range Groups

Indications are that members of the nursery herd that collect on the CRC mine site in the fall are actually members of at least two home-range groups. Maximum numbers of sheep on the study area occurred in the fall (Table 5). Maximum numbers dropped slightly during the rut, then were reduced by 38% for the late winter/spring season. A reduction of this magnitude implies that one home-range group finished wintering elsewhere, presumably on traditional range. A bighorn sheep collaring program initiated by Alberta Fish and Wildlife on Cadomin Mountain in 1972 indicated that most sheep occupied the Redcap Range southeast of Cadomin. Sheep, however, were also sighted the whole length of the mountain range adjacent to CRC between Cadomin and Fiddle Pass, Jasper National Park (Lynch 1972; Smith and Lynch 1974; Kosinski 1977).

Numbers of adult rams present on the CRC mine site fluctuated very little during the late winter and spring seasons (Figure 5), indicating that the absent home-range group was composed of females and juveniles.

Summer use of the alpine adjacent to CRC by the nursery herd also indicates that at least two home-range groups are involved in the use of CRC. Several individually recognizable sheep (C, StHn and MRH) were not sighted adjacent to CRC during the summer while several others (BL, W21, MHL and Y) were consistently sighted there (Table 7). The maximum count of sheep sighted in the alpine adjacent to CRC occurred on June 25 and totalled 113 sheep (34 lamb, 51 ewe, 13 female yearling, 5 male yearling, 3 male I, 5 male II and 2 male II). This number is less than the maximum count (uncorrected for mortality) for the pre-rut, 1985, of 193 animals (47 lamb, 83 ewe, 7 female yearling, 8 male yearling, 8 male I, 28 male II, 9 male III and 3 male IV) and indicates that at least one female home-range group and the majority of adult rams summered elsewhere. Fidelity of females to a particular home-range group has been demonstrated by Geist (1971b:37), Festa-Bianchet (1986), and Goodson and Stevens (1988).

The CRC bighorn sheep herd has been shown to be composed of more than one "herd". Those animals that leave part way through the winter likely are responding to traditional movement patterns. This behaviour should be recognized and maintained so as to not encourage these animals to remain on the mine site, possibly creating a "sanctuary" problem as has been documented at Sheep River (Wishart et al. 1980). Management strategies to address future problems may include reducing the numbers of the "resident" sheep that remain on the mine site throughout the winter as has been done with elk at Westar Mining Ltd. Sparwood, British Columbia (pers. comm. Carleen Gibson 1990). Management strategies that may inadvertently decimate a home-range group should be avoided. Such strategies would include indiscriminate use of group trapping methods. Female home-range groups have been observed to remain together even when in close proximity to other groups (Festa-Bianchet 1986) and would be susceptible to disruption should group trapping or some other non-random event occur.

2. POPULATION QUALITY AND HEALTH

Most population characteristics of the CRC bighorn sheep herd are indicative of a healthy, expanding herd. Lamb:100 ewe (including female yearlings) ratios of 49:100 in the fall of 1985 are similar to other documented expanding populations (Andryk and Irby 1986; Jorgenson 1989; Woodgerd 1964). The ratio of yearlings:100 ewes of 11:100 for the fall of 1985, indicates poor lamb survival from the previous year and is less than that considered necessary (42:100 ewes) for maintaining a high quality population (Geist 1971b:291). However, the fall count of 1986 indicated that lamb survival was 68% over the summer of 1986 and that the yearling:100 ewe ratio had increased to 47:100 (MacCallum 1990). The male:female yearling sex ratio for the fall of 1985 was 53:47, roughly equivalent to the sex ratio (50:50) of bighorn lambs at birth expected for healthy populations (Geist 1981). The male:female ratio of sheep > 2.5 years old favoured ewes (35:65), but this would be expected in a population that is hunted primarily for trophy rams. Class IV rams (full curl) comprised only 1.6% of the CRC herd in the fall, an indication that this population is heavily harvested (Table 5).

Horn and body measurements of the CRC sheep indicate that they are healthy and generally large for sheep from northern Alberta. Mean horn basal circumference (13.0 cm) for adult ewes was larger than the mean found by Wishart and Brochu (1982) for northern sheep (12.9 cm) but smaller than that for southern populations (13.3) cm. Horn increment growth for the first 3 years reflected neither the pattern expected for sheep from southern Alberta nor that from northern Alberta (Wishart and Brochu 1982) but was intermediate in growth form. Skull characteristics were similar to those from northern Alberta and body weights were similar but on the upper range for weights of sheep from northern Alberta.

Lungworm

Lungworm loads in the sheep at CRC are high, but no manifestation of pneumonia has been observed to date. Infection of snails by first stage larvae has been ascribed to above normal moisture during the spring and summer (Boag and Wishart 1982) or during the previous year (Forrester and Senger 1964). The latter authors also concluded that the infection of snails is probable in the spring when the highest number of the first stage larvae were available in feces and when the humidity and rainfall were also high. Boag and Wishart (1982) found that snail species, abundance, and density were highest in habitats at Sheep River that supported some deciduous trees and shrubs (willow-fen, mature aspen, poplar-spruce, pine-poplar) than those habitats that lacked woody plants. Dry grasslands supported the fewest species and lowest densities of snails. These authors also hypothesize that bighorns are most likely to ingest large numbers of infected snails in August when the numbers of snails are highest and the sheep spend more time browsing than at other times of the year.

Aspen cover at CRC is minimal and was included in the shrub and grass meadow category, which comprises 11% of the study area. The highest percentage of sheep sightings in this cover type during the year occurred between the months February and July (Table 18). Microhistological analysis of fecal samples showed that the highest percentage of shrub and tree material ingested by sheep occurred between January and July (Table 14). A correlation of monthly LPG values and percent shrub ingestion showed no association ($r=-0.199$ $n=12$) as did a correlation of monthly LPG values and percent time spent in shrub meadows ($r=-0.055$ $n=12$). However, there was a moderate association between time spent in meadows and percent of shrub material ingested ($r=0.703$ $n=12$ $P<0.24$). Bighorns at CRC spend proportionally more time in the habitats where snail densities are likely to be highest in the late spring than at any other time of the year. It seems likely that during this time period sheep ingest over-wintered snails that had become infected the previous season. These snails are likely ingested at the edge of native grass and shrublands where aspen copses are located.

3. DISTRIBUTION PATTERNS

The most important ranges on the CRC mine site are the 50-A-1/2/3 complex at timberline and the south-facing slopes above HWY 40 which are adjacent to the escape terrain of the 51-B-2 pit (Appendix IV Figures 46 and 54). These ranges display a configuration common to winter sheep range in Alberta; snow-free slopes immediately adjacent to escape terrain. This combination of high walls and reclaimed ranges is the basic unit of habitat for bighorn sheep on the mine site. Many sheep ranges in the Rockies display a western side composed of gently sloping grassy meadows and an eastern side of sheer cliffs and rocks. Examples include the Redcap Range to the SE of Cadomin, Windy Point near Turner Valley, and the sheep ranges on the Bedson Ridge near Brule, Alberta. The ideal configuration of high walls and forage areas on the CRC reclaimed areas emulate this pattern.

The 50-A-1/2/3 range at timberline is somewhat anomalous in that the reclaimed grassland is flat and subtends a north-facing slope. This grassland, however, receives high and consistent winds throughout the six winter months as does the more exposed parts of the mine site (from October 1985 to March 1986, there were 40 days where the wind was recorded at 80 km or greater - see Table 1). In addition, the 50-A-1/2 dumps were reclaimed with coal from a burning seam left over from the Coal Branch days. The burning coal has since ignited the shale overburden which naturally contains a high percentage of volatiles. These "burning" areas move slowly underground and provide a heat source for melting snow. The sheep were observed using these hot areas for thermal control during cold winters (Figure 24). This combination of reclaimed areas (50-A-1 and 50-A-2 dumps) adjacent to the 50-A-3 pit represents the single most important range on the mine site. This area is used by the nursery herd in the pre-rut; it is the rut range and winter range for all sheep, and is the main late winter/early spring ranges for the nursery herd when it is snow-free compared with the adjacent alpine area (Figure 26). It also serves as a mineral source for the nursery herd in June when they are grazing in adjacent alpine meadows (Appendix II Figure 28).

The south-facing slopes above HWY 40 are notable in that they display the ideal configuration of exposed slopes immediately adjacent to high walls (Appendix II Figure 29). The east wall of the 51-B-2 pit was the highest and steepest wall at CRC that was used by sheep. These characteristics (Table 15) likely were influential in the choice of this site by ewes for lambing and by wounded sheep for isolation purposes.

Summer Distribution of CRC Sheep

The home range of bighorn ewes in summer is known to concentrate around the location of mineral licks (Geist 1971-b). This has been shown to be the case on the Redcap range to the south (Kosinski 1977) of the study area. This study describes a concentration of ewes and lambs using the 50-A-3

Figure 23. Bighorn rams using "burning" ground for thermal control.

Figure 24. A ewe and lamb on the 50-A-1 range in the late winter season, 1986. Note the snow in adjacent alpine area.

pit as a mineral lick during the month of June, 1986. Virtually no grazing took place on the mine at this time. Bighorns use inorganic minerals to augment forage quality and to synthesize sulphur-bearing amino acids for hair, horn and bone growth and for the production of milk. The creation of similar licks, whether deliberately or inadvertently at timberline, may affect the distribution of ewe groups in the summer. Similarly, the loss of mineral sources may force ewe groups away from the combination of abundant forage and nearby escape terrain that comprises the headwaters of the Luscar Creek and Gregg River drainages.

Bighorns are seasonally migrant animals that follow the spring flush of new growth higher into the alpine areas as the summer progresses (Shannon et al. 1975; Stelfox 1976; Goodson and Stevens 1988). Festa-Bianchet (1987), however, points out that this relationship may be tempered by other needs, such as location of mineral licks and escape terrain, or by the absence of irritants such as harassment, flies and heat. In the case of CRC it is difficult to pinpoint a factor other than the availability of new, higher protein growth that would cause the bighorns to leave the mine site during the summer (with the exception of ewes needing to find isolated places in rugged terrain to lamb in mid-May). The phenological development of the agronomic species on CRC seems to fit well into the natural cycle of bighorn grazing on cured forage on the mine site during the winter, then utilizing the new growth on the mine site in early spring, and then in nearby alpine areas in the summer. The CRC sheep have an additional advantage in that when they return to CRC in mid-to-late August, the native forage in alpine areas is well on the way to curing, while the agronomic species on the mine site are still green throughout August and well into the fall season. CRC sheep therefore have the advantage of grazing on green forage when they return to the mine site for the fall and winter. Nutrient sampling of forage would be required to establish whether there is a significant difference in reclaimed versus native forage at this time of year. Observations subsequent to this study have indicated that the sheep are primarily attracted to the first-year reclaimed grasslands when they return to the mine site in the fall.

4. BIGHORN HABITAT CREATION AT CRC

High Walls

Escape terrain at CRC was provided by high walls of un-reclaimed pits and by large "talus" slopes which had not been graded after dumping of rock overburden. Slope angle ranged from 20-45°, length ranged from 259-1584 m and height from 23-205 m (Table 13). Invariably the highest and steepest walls (east wall of 51-B-2 and east wall of 50-A-3) were used by ewes for lambing and by wounded sheep seeking to isolate themselves. These walls tended to have many benches, some of which were beginning to develop vegetative cover and were located immediately adjacent to forage areas.

The sheep used escape terrain that was either above, below or beside forage areas and seemed to move easily regardless of which way they had to travel. Evidence of similar use can be found in the wild; at Sheep River Sanctuary in southern Alberta, sheep must run up to escape terrain, while at the nearby Sheep River they run down (pers. comm. W. Wishart).

Size of escape terrain used by sheep seemed to be a function of the size of the herd and the amount of adjacent grassland that was available. The nursery herd was consistently found on the 50-A-1/2 reclaimed dump and the south-facing slopes adjacent to the 51-B-2 pit east wall. These areas were adjacent to the largest walls or combination of walls that were used by sheep - the 50-A-3 and 51-B-2 pits, respectively. The class II, III and IV rams, which never exceeded 40 in total number, were found on the central subalpine meadow (7 ha) adjacent to the 50-B-3 pit east wall and the C-baseline which had extensive high walls nearby. The C-baseline has extensive walls on the north side, but there are few benches on these walls and the forage areas are small (Table 19), and generally separated by trees or non-vegetated overburden from the walls themselves. Ewes were sighted in this area only once when pushed by hunters. When more reclamation of areas adjacent to the walls occurs, it is expected that the nursery herd would make more use of the C-baseline. The nursery herd used the subalpine meadow and the 50-B-3 east wall as a travel corridor (Figure 19) between the two main ranges; the 50-A-1/2/3 complex and the 51-B-2 pit and slopes.

It is well known that the distribution of escape terrain regulates the extent to which other habitat components are used (Van Dyke et al. 1983:6). Various authors have also suggested that if harassment is great or predation high, the sheep will select for larger or steeper cliffs (Van Dyke et al. 1983; Stemp 1983). It is probable once mining is complete and the reclaimed land reverts to the crown that the CRC sheep will experience a higher degree of predation as wolves would be expected to recolonize the main winter forage areas. In this event, it is likely that the sheep will adjust their pattern of use of the mine site and will use those areas closest to the largest and steepest high walls. Escape terrain of less than 30° and with fewer than 2 or 3 benches that is used under the current predation pressure may well be avoided in the future.

The sheep at CRC seem to forage in proximity to escape terrain within the same limits as reported in the literature. Seventy-five percent of all sheep observations occurred within 290 m of escape terrain. This has implications for the design of a bighorn habitat in that foraging beyond this distance falls off rapidly. No sheep were observed beyond 705 m of escape terrain on the mine site (Table 16).

The provision of cliffs and outcrops on reclaimed areas provide habitat diversity for species other than bighorn sheep. On CRC, hoary marmots have been observed using the large rock talus of the 50-A-3 west wall during the summers of 1989 and 1990. Ward and Anderson (1988) studied the importance of cliffs to small mammal and bird populations in high altitude short grass prairie in southcentral Wyoming. Abundance and species richness of small mammals and species richness and diversity of birds were greater on cliff sites than on control sites. They concluded that cliffs are unique habitats and, although cliffs occupied only a small percentage of the land base, they were disproportionate in importance as wildlife habitat. Rumble (1989) concluded that reclamation of surface-mined lands in southeastern Montana to include rock outcrops provided wildlife habitat diversity which benefitted certain bird and small mammal species.

Agronomic Species on Reclaimed Sites

The reclaimed sites at CRC show the potential of supporting sheep at high densities on small areas. The mean plant biomass production on the reclaimed range near timberline (elevation 1661-1847 m) was measured at 4,190 kg/ha (Table 19). This compares with 1,700 kg/ha on the central subalpine meadow at an elevation of 1766-1775 m. In comparison, Stelfox (1976) reported forage production on good sheep range in Waterton to be 619 kg/ha, on fair sites in Banff to be 474 kg/ha and on poor sites in Jasper to be 225 kg/ha (dry weight). He reported that the Waterton ranges producing 849 kg/ha appeared to be close to the maximum potential for sheep ranges in Waterton, Banff and Jasper. Clearly, the production at CRC is excessively above that of the National Park ranges. Heavy grazing pressure can negatively impact a range through species composition change, reduction of productivity, and by trampling and erosion of the soil. Most grazing pressure occurs at CRC during the fall, winter and spring months almost exclusively by sheep. Competition by elk and deer are factors that are not currently a problem at CRC. Virtually no grazing occurs during the growing season as the sheep are in the adjacent alpine region.

Andryk and Irby (1986) reported the following densities of healthy, expanding sheep herds on winter range in Montana as: Walling Reef = 1.4 (54 per 39 km^2), Choteau Mountain = 1.4 (18 per 13 km^2) and Ear Mountain = 2.8 (77 per 28 km^2). At CRC, the sheep ranged over a maximum of 906.5 ha (as calculated by grid cell method - see Figure 11). Using this figure plus the adjusted maximum fall count of 198 sheep, the density at CRC is 22 (198 per 9 km^2). The actual density of specific ranges used for grazing would be much higher than this.

Mineral Licks

Wild ruminant use of earth licks in North America is most evident in the spring and early summer (Jones and Hanson 1985:33). It has generally been accepted that sodium is the source of attraction to ungulate use of mineral licks (Hebert and Cowan 1971) (Stockstad et al. 1953). Sodium loss in spring is thought to be related to high levels of potassium in new forage and the succulent condition of herbage which causes the kidneys to be less efficient in resorbing sodium, resulting in a duiretic condition (Weeks and Kirkpatrick 1976).

From time to time biologists have postulated other reasons for use of mineral licks. These include the need for trace elements (Cowan and Brink 1949) and the need for calcium and magnesium (Heimer 1973). Jones and Hanson (1985) have pointed out the role of inorganic sulphur in providing the bacteria of rumen with the necessary element to form the amino acids cysteine and methionine. These authors conclude (p. 97) that sulphur salts are an important constituent of bighorn ranges in Alberta and Alaska and must contribute importantly to the sulphur nutrition of these animals. These same authors also point out that "calcium seems to be the sought after constituent in elk, mountain sheep, mountain goat and moose licks" and that magnesium and, to a lesser extent, calcium nutrition are limiting or even marginal across large areas of North America (Jones and Hanson 1985:208).

The analysis of 5 sites of lick usage at CRC cannot provide more insight as to why licks are used. It is sufficient to point out that seepages exposed on high walls after mining, and wastes produced after cleaning coal, were sought out in the critical spring and early summer months by the nursery herd and used as a source of minerals. Mining in this instance has exposed previously unavailable minerals (P, Na, K, S, Ca, Mg, Cu, Zn and Se) for use by wild ruminants.

Role of Bighorn Sheep in Maintaining Habitat

Once fertilization of reclaimed areas on CRC ceases, additional minerals would accrue to the soil through rainfall, dust, microorganisms that fix materials from the atmosphere and continual decomposition of the soil parent material. Rhizobia on legumes and other non-leguminous plants fix nitrogen. Becking (1968) indicated that about one third of 330 species in 13 genera were known to fix nitrogen in addition to the Leguminoseae. These 13 genera include: Alnus, Dryas, Elaeagnus and Shepherdia. Rock decomposition would be the most significant contributor of phosphorus to the soil while rainwater would contribute varying amounts of ammonia, nitrate, sulphate, chlorine, sodium, potassium and calcium depending on the nearness of industrial areas, oceans and the climatic conditions.

Grazing by herbivores would remove minor amounts of nutrients, but would significantly affect mineral cycles in rangelands. It is generally accepted that 80-95% of ingested nutrients are returned to the soil via excreta (Heady 1975:76). Urine is rich in nitrogen and potassium while phosphorus, calcium and magnesium is voided in the dung (Pieper 1974; Hutton et al. 1965, 1967).

The herbivore excreta to soil route provides additional pathways for nutrient cycling that are significant since they occur at different rates than nutrients cycling from soil to plants to litter to soil. Litter cover generally correlates with the productivity of the site, although an excess of litter may in fact decrease herbage growth (Heady 1975:74). Stelfox (1976:24) pointed out that the heavy mantle of dead vegetation on productive ranges appeared to "smother and kill-out some plants". He concluded that "some grazing is important in maintaining maximum forage production, especially on grasslands producing at least 454 kg (green weight) of forage". At CRC it is expected that litter would be incorporated into the soil at a very slow rate due to the desiccating nature of the winter winds and temperatures. Grazing by herbivores particularly at high levels of intensity, such as is experienced on the winter ranges at CRC, would have a significant impact on litter reduction and nutrient cycling, particularly on nitrogen as it is returned directly to the soil without the need for decomposers to further break it down. Barrow (1961) reported that where plant material is eaten by an animal and both urine and feces are returned to the soil, the proportion of nitrogen and sulphur mineralized in the soil will be greater than if plant material were returned directly to the soil. Heady (1975:81) stated that "Availability to plants of all minerals except phosphorus appears to be enhanced by passage of herbage through grazing animals. Animals increase the rate of cycling, especially of those ions, such as chlorides and nitrates, which move easily in soil solution." It seems likely that bighorn sheep at CRC will play a significant role in the maintenance of their winter ranges over the long term.

Range Extension

CRC has created an apparent range extension for the bighorn sheep using the adjacent mountain range. Mountain sheep, however, have been described as a species that appear to be incapable of dispersal (Geist 1971b). Bighorns are social animals that pass the knowledge of mineral licks, summer and winter ranges and migration routes to their offspring by manner of a living tradition. Selection for dispersal has not occurred in bighorns for these reasons. Indeed, many transplant programs involving re-introduction of bighorns to ranges that previously had been occupied have resulted in success in that the bighorns thrive but behave as relic populations, failing to colonize adjacent habitat (Goodson 1980). How then can the colonization of CRC reclaimed sites be explained in terms of bighorn behaviour? Bighorn sheep do have mechanisms to perform range extensions. Two mechanisms that may apply at CRC are described in Geist (1971b:127). The first involves the presence of open terrain between occupied habitat and unoccupied habitat. Such a configuration would present no barrier to bighorn movement. This is the case at CRC where one of the first pit developments (50-A-1,2 and 3) was located at timberline, adjacent to already occupied sheep range. The second mechanism involves spring "exploration" movements by young rams in groups. If these groups chance upon habitat not previously used it would be possible that these habitats would become incorporated into the traditional movement patterns of these rams as they become adults. Such explorations by young rams in spring have been observed at CRC. On June 6, 1986, 2 male yearlings were sighted at the northeast end of the C-baseline where no member of the nursery herd had previously been sighted. Five class II rams were also sighted in the vicinity making it likely that the young rams followed them to this location. It is likely that explorations by young rams have been instrumental in occupation of the CRC mine site by bighorn sheep.

5. BIGHORN SHEEP HABITUATION AND USE OF INDUSTRIAL SITES

The negative effects of industrial activity and mining operations on ungulates have been well documented. Kuck (1986) concluded that, without careful management, the cumulative effects of the industrial impacts of phosphate mining in Idaho would result in a reduction of big game populations of elk, moose and mule deer. Stanlake et al. (1978) documented a reduced level of elk use on lands that had been strip-mined for coal and subsequently reclaimed as compared with adjacent undisturbed habitat in southeastern British Columbia. Morgantini and Bruns (1988) described the attraction of bighorn sheep in the Alberta foothills to man-made mineral licks associated with active and abandoned gas well sites. They concluded that this attraction left them more susceptible to exploitation and risks associated with toxic chemicals, crowding and range depletion. Morgantini and

Worbets (1988) commented that there was general agreement that the disturbance associated with drilling new gas wells on bighorn sheep ranges can affect animal distribution and habitat use. Jorgenson (1988b) recorded range abandonment on Mt. Allan due to human activities on the ridge top, snow-mobiling, helicopter flights, and avalanche blasting resulting from the Nakiska ski hill development west of Calgary, Alberta.

However, many of the above authors also refer to the bighorn's ability to habituate to human activity and industrial disturbance under certain circumstances. Kuck (1986) commented that elk, moose, and mule deer appeared capable of adapting to many phosphate mining activities. Stanlake et al. (1976) believed that the effect of coal exploration and exploration roads in southeastern British Columbia on animals was minimal while Morgantini and Bruns (1988) noted the bighorn sheep using active gas well sites as a mineral lick source were apparently habituated to people and vehicular traffic in the Panther River area of Alberta. Jorgenson (1988 pers. comm.) commented that sheep were attracted to the straw bales used to pad chairlift towers at Nakiska ski hills and, as a consequence, ended up in the warmup shacks and on the ski runs. He felt this was another example of sheep being attracted by human activity and then being threatened by it.

There are also several cases of sheep utilizing terrain around active coal and limestone mines. Dall sheep use of the Usibelli Coal Mine Inc. in Alaska has been described by Elliot

(1984:139). He concluded that:

> "The proximity of the (Dall sheep) wintering area to human activity and its consequential deterring effect on predators (e.g. wolves); vertical topography for bedding sites and escape routes; and the tendency for the area to be kept snow free by wind, have all served to enhance the attractiveness of the mine site to the local sheep population".

Examples of bighorn sheep habituated to industrial sites in Alberta include the presence of sheep on Inland Cement at Cadomin and on the Canada Cement LaFarge, Steele Brothers and Burnco Limestone Operation at Exshaw.

Inland Cement is a limestone mine that has been operating in the Cadomin area since 1955. Hunting has been restricted to within 1 mile of Inland cement property as sheep have to descend to the valley bottom to travel between Cadomin mountain (NW end of Redcap range) and Leyland mountain (SE end of Nikanassin range). While travelling between these two mountains, sheep must cross mine property, often stopping to graze on slopes within the mine boundaries.

Canada Cement LaFarge has been operating in the Bow River valley since 1910. Sheep were utilizing this area previous to mining activity; indeed the type specimen for Rocky Mountain bighorn sheep collected by Duncan McGillivray in 1800 was likely from this location (pers. comm. W. Wishart). Sheep travel through the Lafarge Canada Inc. property, bed down within the mine site, and have apparently habituated to the siren used prior to drilling blasts (pers. comm. John Brown).

7. CONCLUSIONS AND RECOMMENDATIONS

Cardinal River Coals Ltd., through its reclamation efforts, has provided habitat for bighorn sheep for all seasons except summer and possibly very extreme winter storms. The basic component of bighorn habitat - quality forage in proximity to escape terrain - has been reproduced through mining and reclamation. In addition, the habitat requirements for rutting and lambing have been created as well as the opening of mineral licks that previously had been "locked away" underground. The bighorn sheep is known as a "K" selected species - a species of low reproductive potential that is adapted to stable, climax communities. Essentially very few additions to sheep range in the Rockies can be accomplished except for the occurrence of fire at timberline which serves to expand existing alpine range. The CRC sheep display the physical characteristics of a healthy, expanding herd, despite the fact they are foraging on a reclaimed landscape in the midst of an active coal mine. For these reasons the creation of bighorn sheep range at Cardinal River Coals is a significant event.

Prior to this study, guidelines for reclaiming mined lands in the subalpine zone to bighorn habitat were general in nature (Wallis and Wershler 1979) and were aimed largely at achieving a species mix that would be palatable to bighorns. A review of the use of high walls by bighorn sheep at Cardinal River Coals Ltd in 1986 led to the recommendation that maintenance of certain high walls was necessary for maintaining bighorn habitat on the reclaimed landscape (MacCallum 1986d). These recommendations were incorporated into a proposal prepared by CRC personnel to reduce reclamation costs (Acott 1986b) and was presented for review by the Development and Review Committee of the Alberta Land Conservation and Reclamation Council. As a result of the review, the maintenance of high walls and talus slopes that had been identified as being necessary components of bighorn sheep habitat was approved for the first time in Alberta for the Cardinal River Coals Ltd mine site.

The incorporation of high walls into the final reclamation plan at CRC resulted in a significant cost saving to the mine. Once the decision to reclaim to bighorn habitat is made, there must be a concerted effort to maintain that decision through to the final reclamation stage. The bighorns need for a long, unobstructed field of view runs contrary to the requirements of other ungulates that require an interspersion of open grass and shrublands with treed cover. Should a decision be made to reverse the maintenance of a high wall that was designated for sheep early on in the life of a mine, then one of the major habitat components (escape terrain) would be removed from that particular area. As the unit of habitat for sheep is the reclaimed grassland <u>and</u> the high wall, it is likely that sheep would vacate or at least drastically alter their use of an area after removal of a high wall. In this event, the area affected would have to be reclaimed as deer, elk or moose habitat, all of which require some form of treed cover. Areas removed from sheep use would then have to receive a significant tree planting program.

Mining in the foothills changes from day to day and requires a dynamic planning process. To help evaluate the value of maintaining high walls for sheep habitat, the cost savings should be calculated over the whole length of the reclamation process rather than on a per pit basis.

In addition to the recommendation to maintain high walls as a component of sheep habitat, other recommendations relative to the final reclamation plan and end land use are as follows:

1. The deliberate placement of large rocks on areas designated as bighorn grazing areas. Such rocks are used by lambs for playing "king-of-the-castle" and by older sheep as bedding sites or vantage points.

2. Low snail densities have been reported to occur on dry grasslands (Boag and Wishart 1982). Reclamation that is to be used as bighorn winter range should be well-drained and vegetated with grass legume mixtures. A minimum of shrubs and trees would reduce sites favourable for terrestrial gastropod habitat. Wetland areas should not be designed into sheep foraging areas. The ideal grassland would be well-drained with little opportunity for water to pool for long periods. Increased terrestrial snail (secondary host for Protostrongylidae larvae) activity has been associated with extended wet weather (Forrester and Senger 1964).

3. For the most part, the sheep are using CRC in a predator-free environment as wolves have infrequently been observed on the main sheep ranges even though wolves are common in the region surrounding the mine site (pers. comm. K. Smith AFWD). This implies that some adjustment in the use of grazing areas relative to the distance from escape terrain may be expected once wolves return to the study area. Stemp (1983:119) suggests that "selection for

larger, more extensive cliffs would be expected with bighorns under moderate or heavy predation". In terms of reclamation, attention must be given to providing high walls adjacent to every major sheep range (see distance from escape terrain). A concentration of high walls at one end of a mine site and foraging areas at the other does not constitute sheep range. Nursery groups are much larger than ram groups and need more extensive escape terrain. High walls that serve as escape terrain for major winter ranges should be steep (39 - 40°) and possess a minimum of 3 and preferably more benches (Table 15). Foraging areas should be available immediately adjacent to the high wall with particular emphasis on the first 290 m.

4. The competence of a high wall should be examined by a geologist or geophysical engineer prior to a recommendation that it be maintained as such. Collapse or erosion from the lip of the high wall would not be considered ecologically stable.

5. The nursery herd was considerably larger than the ram band and needed more foraging area. Winter range for approximately 140 members of the nursery herd should be 40 - 60 ha. Winter range for 40 members of the ram band should consist of either large grasslands or many smaller grasslands with a minimum size of 7 ha.

6. Mining provides a unique opportunity to expose previously buried mineral licks. On CRC, high walls which were wet or had some form of seepage were used by the sheep as mineral sources particularly in June; the sheep also used the mine waste from the plant wherever it lay exposed prior to reclamation. Summer distribution of nursery groups could be affected by the location of mineral sources. The exposure of new mineral sources is a powerful tool that should be used carefully.

7. At CRC the wall which consistently received use by ewes in the lambing season was the steepest and highest wall on the mine site used by sheep. It also had several wide benches which had been previously seeded by a helicopter, thus providing limited forage on the wall itself. As there was active dumping occurring within 100 m of the lambing ewes, it is likely that the duplication of the physical characteristics of this wall could promote use for lambing purposes.

8. The reclaimed grasslands at CRC are supporting

bighorns at very high densities. Sheep at high densities risk being infected with lungworm larvae at high rates, although migration into the alpine in the summer helps to break the cycle of lungworm infection. The CRC sheep are currently healthy and display the characteristics of an expanding herd. The bighorns at CRC use the mine site seasonally, showing the typical movement higher into the alpine in the summer as would be expected from a wild population. They congregate onto the mine site in the pre-rut and rut and a large portion of the nursery herd moves off the mine site in the late winter/early spring. This is a desirable movement in that it demonstrates that traditional wintering ranges are still being used. Continued monitoring of the sheep population will help identify any future shift in the seasonal use of the mine site by the bighorns and any change which may occur in the health of the animals. Monitoring should be an integral and ongoing part of the planning process as the mine incorporates sheep habitat requirements into the final end-use plan.

9. Management of this herd has involved a limited entry non-trophy hunt. This type of hunting pressure caused the sheep to move around the mine site, but did not force abandonment of the range. Harvesting ewes from this population has likely kept the ewe population young. Future monitoring of the herd will give insight into harvest levels and population response.

10. The bighorns at CRC have become habituated to vehicle traffic and to a certain extent to human presence. Once the landscape is reclaimed and reverts to crown land, consideration must be given to this fact and to the fact that millions of dollars have been spent on reclamation. Some management mechanism or land use designation must be found to provide public access and use of this area without causing drastic changes in wildlife distribution or without causing destruction of the landscape itself. Human use of the final landscape should be a consideration in the on-going reclamation during the operating life of the mine. Sheep are opportunists in terms of finding available habitats that are predator-free and have minimal disturbance. Management of the post-mining environment will primarily be focused on people management to promote use of the wildlife resource and at the same time to reduce harassment.

By considering the behaviour and habitat requirements of the bighorn sheep in conjunction with an operating coal mine and reclamation process, CRC has been able to tailor its reclamation to benefit the bighorn sheep. CRC introduced the wildlife study while the mining was ongoing, thus allowing time for adjustments to their final end-use plan. Despite the fact that bighorn habitat requirements are well described in the literature, it was not until the animal and its requirements were studied against the backdrop of an operating coal mine that obvious recommendations regarding the maintenance and placement of high walls were made and accepted by the government regulatory agencies.

An open pit mine can be described as a devastated landscape - trees, soil and overburden are removed to retrieve coal which may be up to 213 m underground. Overburden is returned as well as soil, but the disturbance is such that the barren landscape can be likened to the rubble left behind by the glaciers.

Careful contouring of the landscape, grading of overburden, replacement of soil, seeding with grass/legume mixtures and extensive fertilization are all designed to speed the process of plant colonization and soil development. In addition, by examining the bighorn's biological and ecological needs with respect to the specific mining operation, a unique opportunity has been discovered - the opportunity to identify elements necessary for the physical recreation of a bighorn habitat. In other words, the opportunity to "design with nature" an approach so aptly practised by I. McHarg (1969) in some of the most heavily industrialized and environmentally sensitive places in North America. This approach incorporates environmental and societal values into every aspect of development and promotes the conscious evaluation of the constraints and opportunities thus presented.

LITERATURE CITED

Acott, G. B. 1981. Cardinal River Coals Ltd. reclamation status annual report 1980. Cardinal River Coals Ltd. Hinton, AB 28pp.

------------ 1983. Reclamation strategy at Cardinal River Coals Ltd. p. 91-104 In Reclamation of lands disturbed by mining. Proc. 7th Ann. British Columbia Reclamation Symp.

------------ 1986a. Reclamation operations at Cardinal River Coals, Ltd. p. 249-256 In C. B. Powter, R. J. Fessenden and D. G. Walker (compilers). Proc. Alberta reclamation conferences 1985 and 1986 sponsored by the Alberta Chapter, Canadian Land Reclamation Association, Edmonton.

------------ 1986b. Proposal to reduce reclamation costs at Cardinal River Coals Ltd. Cardinal River Coals Ltd. 17pp.

Acott, G. B., O'Toole, M. T. and Munn, F. J. 1987. Cardinal River Coals Ltd. reclamation and mining status report 1986. Cardinal River Coals Ltd. 26pp.

Aiello, J. 1973. Open pit coal mining at Cardinal River Coals. p. 79-84 In Proc. 25th Canadian Conf. on Coal. published by Energy Development Sector, Dept. Energy, Mines and Resources, Ottawa.

Alberta Fish and Wildlife Division. undated. Rumen analysis method. Department of Forestry, Lands and Wildlife. 4pp.

Alberta Government. 1976. A coal development policy for Alberta. Department of Energy and Natural Resources. 38pp. plus Appendices.

Andryk, T. A. and L. R. Irby. 1986. Population characteristics and habitat use by mountain sheep prior to a pneumonia dieoff. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:272-291.

Arscott, R. L. 1989. letter from R. L. Arscott to B. Wishart dated November 13, 1989 regarding an elk sanctuary of Chevron's Colorado Coal Mine. 2pp.

Bailey, J. A. 1984. Principles of wildlife management. John Wiley and Sons. 373pp.

Barrow, N. J. 1961. Mineralization of nitrogen and sulphur from sheep faeces. Aust. J. Agri. Res. 12:644-650.

Becking, J. H. 1968. Nitrogen fixation by non-leguminous plants. Stikstof 12:47-74.

Bibaud, A. and Dielman, P. 1980. Region 4 sheep survey, 1980. Alberta Energy and Natural Resources, Fish and Wildlife Division. 60pp.

Blood, D. A., D. R. Flook and W. D. Wishart. 1970. Weights and growth of Rocky Mountain bighorn sheep in western Alberta. J. Wildl. Manage. 34(2):451-455.

Boag, D. A. and W. D. Wishart. 1982. Distribution and abundance of terrestrial gastropods on a winter range of bighorn sheep in southwestern Alberta. Can. J. Zool. 60:2633-2640.

Bratton, D. L. 1987. Regulatory response to changing reclamation demands. p. 5-12 In C. B. Powter (ed). Proc. of a Symp. on reclamation targets for the 1990's. Alberta Society of Professional Biologists, Alberta Chapter/CLRA, the Canadian Society of Environmental Biologists, Edmonton.

Bromley, P. T. 1977. Aspects of the behavioural ecology and sociobiology of the pronghorn (Antilocapra americana). PhD thesis, University of Calgary.

Bruns, E. H. 1990. Bighorn sheep surveys of known winter ranges within the Rocky Mountain House management district. Department of Forestry, Lands and Wildlife, Fish and Wildlife Division. 24pp.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present and future. Wildl. Monogr. #4. 174pp.

Cardinal River Coals Ltd. 1986. Cardinal River Coals Ltd., a joint venture of Luscar Ltd. and The Consolidation Coal Company of Canada Ltd. 23pp.

Caughley, G. 1965. Horn rings and tooth eruption as criteria of age in the Himalayan Thar, Hemitragus jemlahicus. New Zealand J. of Sci. 8:333-351.

Cook, A. R. 1982. Aerial bighorn sheep census of designated winter ranges within the Edson district of the East Slopes Region, February 3-26, 1982. Alberta Energy and Natural Resources, Fish and Wildlife Division. 57pp.

Cook, A. R. and Hall, W. K. 1978. Aerial sheep survey of the Edson, Red Deer and Calgary regions using the revised winter range technique. Alberta Recreation, Parks and WIldlife, Fish and Wildlife Division. 63pp.

Cormack, R. G. H. 1950. A survey of strip coal mining areas in Alberta, mountain and foothill regions. Provincial Department of Lands and Forests, Alberta Government. 77pp.

Corns, I. G. W. and R. M. Annas. 1986. Field Guide to Forest Ecosystems of West-central Alberta. Northern Forestry Centre, Canadian Forestry Service. Cat No. Fo 42-86/1986E. 251pp.

Cowan, I. McTaggart. and V. C. Brink. 1949. Natural game licks in the rocky mountain national parks of Canada. J. of Mammalogy 30(4):379-387.

DeBlase, A. F. and R. E. Martin. 1981. A manual of mammalogy with keys to the families of the world. Wm. C. Brown Company Publishers, Dubuque, Iowa. 436pp.

Elliot, C. L. 1984. Wildlife and habitat use on revegetated stripmine land in Alaska. Ph.D. thesis, Univ. of Alaska, Fairbanks. 174pp.

Festa-Bianchet, M. 1986. Seasonal dispersion of overlapping mountain sheep ewe groups. J. Wildl. Manage. 50(2):325-330.

-----------------. 1987. Individual reproductive success of bighorn sheep ewes. Ph.D. thesis, Univ. of Calgary, Calgary. 229pp.

Foreyt, W. J., and D. A. Jessup. 1982. Fatal pneumonia of bighorn sheep following association with domestic sheep. J. Wildl. Dis. 18:163-168.

Forrester, D. J. and C. M. Senger. 1964. A survey of lungworm infection in bighorn sheep of Montana. J. Wildl. Manage. 28(3):481-491.

Geist, V. 1966. Validity of horn segment counts in aging bighorn sheep. J. Wildl. Manage. 30:634-646.

--------- 1971a. A behavioural approach to the management of wild ungulates. p. 413-424. In E. Duffey and A. S. Watt (eds). The scientific management of animal and plant communities for conservation. Blackwell Scientific Publications, Oxford.

--------- 1971b. Mountain sheep, a study in behaviour and evolution. The University of Chicago Press. 383pp.

--------- 1978. Life Strategies, Human Evolution, Environmental Design. Springer Verlag, New York. 495 pp.

--------- 1981. On the reproductive strategies in ungulates and some problems of adaptation. p. 111-132. In G. G. E. Scudder and J. L. Reveal (eds). Evolution Today, Proc. of the 2nd Int. Congr. of Sys. and Evo. Biology. Hunt Institute for Botanical Documentation, Carnegie-Mellon University, Pittsburgh.

--------- 1982. On "population control" with reference to mountain sheep and goats. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:23-24.

Gilbert, J. R. 1978. Estimating population characteristics. p. 297-304 In Schmidt, J. L. and D. L. Gilbert (eds). Big game of North America. Stackpole Books.

Giles, R. H. (ed) 1971. Wildlife Management Techniques. The Wildlife Society, Washington, D.C. 633pp.

Goodson, N. 1980. Bighorn sheep in north-central Colorado, past, present and future. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:190-210.

Goodson, N. and D. R. Stevens. 1988. Home ranges, habitat use and productivity of bighorn sheep in the Never Summer Mountains, Colorado. Bienn. Symp. North. Wild Sheep and Goat Counc. 6:254-267.

Gudmundson, L. 1988. Southern region bighorn sheep survey. Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division. 28pp.

Hansen, R. M., T. M. Foppe, M. B. Gilbert, R. C. Clark and H. W. Reynolds. undated. The microhistological analyses of feces as an estimator of herbivore dietary. Composition Analysis Laboratory, Range Science Department, Colorado State University. 6pp.

Hardy Associates (1978) Ltd. 1981. Evaluation of reclamation at the Luscar open pit mine. Cardinal River Coals Ltd. 81pp.

Hayne, D. W. 1949. Calculation of size of home range. J. of Mammalogy 30:1-18.

Heady, H. F. 1975. Rangeland Management. McGraw-Hill Book Company. 460pp.

Hebert, D. and I. McTaggart Cowan. 1971. Natural salt licks as a part of the ecology of the mountain goat. Can. J. of Zool. 49:605-610.

Heimer, W. 1973. Dall sheep movements and mineral lick use. Alaska Dep. Fish and Game, Fed. Aid Wildl. Rest. Final Rep., Proj. W-17-2 through W-17-5, Job 6.1R. Juneau. 35pp.

Hoefs, M. and I. McTaggart Cowan. 1979. Ecological investigation of a population of Dall sheep (Ovis dalli dalli Nelson). Syesis 12(1). The British Columbia Provincial Museum. 81pp.

Hutton, J. B., K. E. Jury and E. B. Davies. 1965. Studies of the nutritive value of New Zealand dairy pastures. 4. The intake and utilisation of magnesium in pasture herbage of lactating dairy cattle. N. Z. J. Agric. Res. 8:479-496.

Hutton, J. B., K. E. Jury and E. B. Davies. 1967. Studies of the nutritive value of New Zealand dairy pastures. 5. The intake and utilisation of potassium, sodium, calcium, phosphorus, and nitrogen in pasture herbage by lactating dairy cattle. N. Z. J. Agric. Res. 10:367-388.

Irby, L. R., J. E. Swenson and S. T. Stewart. 1988. How much difference do different techniques make in assessing bighorn population trends? Bienn. Symp. North. Wild Sheep and Goat Council 6:191-203.

Jacques, D. 1980. LANDSAT mapping of and range condition on critical winter snow-free wildlife habitat in Southwestern Alberta. Environmental Sciences Centre Kananaskis, University of Calgary. 141pp.

Jones, R. L. and H. C. Hanson. 1985. Mineral licks, geophagy, and biogeochemistry of North American ungulates. The Iowa State University Press. 301pp.

Jorgenson, J. T. 1988a. Bighorn sheep survey of known winter ranges within the Calgary district of the Eastern slopes region. Department of Forestry, Lands and Wildlife, Fish and Wildlife Division, Calgary, Alberta. 32pp.

---------------- 1988b. Environmental impact of the 1988 winter Olympics on bighorn sheep of Mt. Allan. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 6:121-134.

---------------- 1989. Ram Mountain bighorn sheep study, 9th progress report - 1986 to 1988. Alberta Forestry, Lands and Wildlife, Fish and Wildlife Division, Calgary, Alberta. 42pp.

Jorgenson, J. T. and W. D. Wishart. 1983. Ram mountain bighorn sheep project progress report, 1983. Alberta Energy and Natural Resources, Fish and Wildlife Division, Edmonton. 28pp.

---------------------------------- 1984. Growth rates of rocky mountain bighorn sheep on Ram Mountain, Alberta. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:270-284.

---------------------------------- 1986. Ram mountain bighorn sheep project progress report - 1984 and 1985. Alberta Energy and Natural Resources, Fish and Wildlife Division, Edmonton. 72pp.

Kosinski, T. 1977. Red Cap sheep: their migrations and management (progress report). Faculty of Environmental Design, Univ. of Calgary, Calgary. 39pp.

Kuck, L. 1986. The impacts of phosphate mining on big game in Idaho: A cooperative approach to conflict resolution. Trans. 51st North American Wildlife and Natural Resource Conference. 90-97.

Lake, D. 1967. The Historical Geography of the Coal Branch. Ph.D. thesis, Univ. of Alberta, Edmonton. 170pp.

Lance, W. R. 1980. The implications of contagious ecthyma in bighorn sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:263-269.

Leopold, A. 1933. Game management. Scribner, New York. reprint by The University of Wisconsin Press. 1986. 481pp.

Lynch, G. M. 1972. Red Cap sheep; their movements and migrations (1972 progress). Alberta Fish and Wildlife Division. 18pp.

MacArthur, R. A., R. H. Johnston and V. Geist. 1979. Factors influencing heart rate in free-ranging bighorn sheep: a physiological approach to the study of wildlife harassment. Can. J. Zool. Vol. 57:2010-2021.

MacCallum, B. 1986a. Fall 1985 bird records for the Edson region. In D. Collister (ed). Alberta Bird Record 4(1):29-32.

------------- 1986b. Winter 1986 bird records for the Edson region. In D. Collister (ed). Alberta Bird Record 4(2):55-56.

------------- 1986c. Spring 1986 bird records for the Edson region. In D. Collister (ed). Alberta Bird Record 4(3):77-80.

------------- 1986d. Habitat requirements for bighorn sheep at Cardínal River Coals Ltd. preliminary assessment and recommendations. MacCallum and Associates. 5pp. plus map.

------------- 1988. Seasonal and spatial distribution of bighorn sheep at an open pit mine in the Alberta foothills. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 6:106-120.

------------- 1990. Bighorn sheep at Cardinal River Coals Ltd., Fall, 1989. progress report prepared for Cardinal River Coals Ltd., Cadomin, Alberta. 22pp.

Macdonald, D. W., F. G. Ball and N. G. Hough. 1980. The evaluation of home range size and configuration using radio tracking data. p. 405-424 In C. J. Amlaner and D. W. Macdonald (eds). A handbook on biotelemetry and radio tracking. Pergamon Press.

McHarg, I. L. 1969. Design with nature. Published for The American Museum of Natural History by Doubleday & Company, Inc., New York. 197pp.

Morgantini, L. E. and E. Bruns. 1988. Attraction of bighorn sheep to wellsites and other man-made mineral licks along the eastern slopes of Alberta: A management concern. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 6:135-150.

Morgantini, L. E. and R. J. Hudson. 1981. Sex differential in use of the physical environment by bighorn sheep (Ovis canadensis). The Canadian Field-Naturalist 95(1):69-74.

Morgantini, L. E. and B. W. Worbets. 1988. Bighorn sheep use of a gas wellsite during servicing and testing: A case study of impact and mitigation. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 6:159-164.

Northern Wild Sheep Council. 1972. A statement of concern by the Northern Wild Sheep Council on the effects of coal mining on wild sheep populations in western Canada and northwestern United States. Trans. of the 1972 North. Wild Sheep Council. 116-117.

Onderka, D. K. and W. D. Wishart. A major bighorn sheep die-off from pneumonia in southern Alberta. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:356-363.

Pieper, R. D. 1974. Effects of herbivores on nutrient cycling and distribution. Proc. of the 2nd U.S.-Australia Range Workshop.

Root, J. D. 1976. Physical environment of an abandoned strip mine near Cadomin, Alberta. Alberta Research Council, Bulletin #34, Edmonton. 33pp.

Rumble, M. A. 1989. Wildlife associated with scoria outcrops: Implications for reclamation of surface-mined lands. Gen. Tech. Rpt. #RM-285, USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station. 7pp.

Salter, R. E. undated. Utilization of natural and artificial salt licks by feral horses. Soils 401 research project, University of Alberta. 163-206.

Samuel, W. M. and J. B. Gray. 1982. Evaluation of the Baermann technique for recovery of lungworm larvae from wild ruminants. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:25-33.

Samson, J., J. C. Holmes, J. T. Jorgenson and W. D. Wishart. 1987. Experimental infections of free-ranging Rocky Mountain bighorn sheep with lungworms (Protostrongylus spp.; nematoda:Protostrongylidae) J. of Wildl. Dis 23(3):396-403.

Schwantje, H. M. 1986. A comparative study of bighorn herds in southeastern British Columbia. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:231-252.

Shackleton, D. M. 1973. Population quality and bighorn sheep. Ph.D. thesis, Univ. of Calgary, Calgary. 228pp.

Shannon, N. H., R. J. Hudson, V. C. Brink and W. D. Kitts. 1975. Determinants of spatial distribution of rocky mountain bighorn sheep. J. Wildl. Manage. 39(2):387-401.

Smith, D. G. and G. M. Lynch. 1974. Red Cap Sheep; their movements and migrations (1973 progress). Alberta Fish and Wildlife Division. 24pp.

Smith, K. and J. Edmonds. 1989. Bighorn sheep aerial survey of designated winter ranges within the Edson district of the Eastern slopes region, Feb.1-5 and March 16-19, 24,

1988. Alberta Forestry, Lands and Wildlife, Alberta Fish and Wildlife Division, Edson, Alberta. 38pp.

Spraker, T. R. and C. P. Hibler. 1982. An overview of the clinical signs, gross and histological lesions of the pneumonia complex of bighorn sheep. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:163-172.

Spraker, T. R., C. P. Hibler, G. G. Schoonveld, and W. S. Adney. 1984. Pathologic changes and microorganisms found in bighorn sheep during a stress-related die-off. J. Wildl. Dis. 20:319-327.

Stanlake, M. G., E. A. Stanlake and D. S. Eastman. 1976. Coal exploration activities and their effect on subalpine winter ranges in southeastern British Columbia. Wildlife Management Report No. 13. Wildlife Research and Technical Services Section, Fish and Wildlife Branch, Ministry of Recreation and Conservation, Victoria, B.C. 30pp.

Stanlake, E. A., D. S. Eastman and M. G. Stanlake. 1978. Ungulate use of some recently reclaimed strip mines in southeastern British Columbia. Fish and Wildlife Report No. R-1. Wildlife Research and Technical Services Section, Fish and Wildlife Branch Ministry of Recreation and Conservation, Victoria, B.C. 88pp.

Stelfox, J. G. 1964. Bighorn management problems in the Coalbranch region (S 436 and S 438). Alberta Department of Lands and Forests, Fish and Wildlife Division. 20pp.

---------------. 1976. Range ecology of Rocky Mountain sheep in Canadian national parks. Canadian Wildlife Service report series number 39. 50pp.

Stemp, R. E. 1983. Heart rate responses of bighorn sheep to environmental factors and harassment. M.E.D.(E.S.) thesis, University of Calgary. 313pp.

Stockstad, D. S., M. S. Morris and E. C. Lory. 1953. Chemical characteristics of natural licks used by big game animals in western Montana. Proc. North Amer. Wildl. Conf. 18:247-258.

Strong, W. L. and K. R. Leggat. 1981. Ecoregions of Alberta. Alberta Energy and Natural Resources, Resource Evaluation and Planning Division. ENR Tech Rpt. #T/4 Edmonton. 64pp.

Thorne, T., G. Butler, T. Varcalli, K. Becker and S. Hayden-Wing. 1979. The status, mortality and response to management of the bighorn sheep of Whiskey mountain. Wyoming Game and Fish Department, Game and Fish Laboratory. Wildl. Tech. Rep. #7. 213pp.

Tilton, M. E. and E. E. Willard. 1982. Winter habitat selection by mountain sheep. J. Wildl. Manage. 46(2):359-366.

Uhazy, L. S., J. C. Holmes and J. G. Stelfox. 1973. Lungworms in the Rocky Mountain bighorn sheep of Western Canada. Can. J. Zool. 51:817-824.

Van Dyke, S. 1990. Final report, historical resources impact assessment, Freehold and 50-A baseline extension ASA permit #89-101. prepared for Cardinal River Coals Ltd. by Bison Historical Services Ltd. 112pp. plus appendices.

Van Dyke, W. A., A. Sands, J. Yoakum, A. Polenz and J. Blaisdell. 1983. Wildlife habitats in managed rangelands - the great basin of southeastern Oregon - bighorn sheep. Pacific northwest forest and range experiment station, Forest Service, USDA, Gen. Tech. Rpt. PNW-159 1983. 37pp.

Voigt, D. R. and R. R. Tinline. 1980. Strategies for analyzing radio tracking data. p. 387-404 In C. J. Amlaner and D. W. Macdonald (eds). A handbook on biotelemetry and radio tracking. Pergamon Press.

Wallis, C. and C. Wershler. 1979. Literature review of considerations for reclaiming lands as wildlife habitat, report prepared by Cottonwood Consultants Ltd., Hinton, Alberta. 43pp.

Ward, J. P. and S. H. Anderson. 1988. Influences of cliffs on wildlife communities in southcentral Wyoming. J. Wildl. Manage. 52(4):673-678.

Webb, R. 1980. Wildlife inventory and habitat evaluation, Luscar Freehold, Alberta. Report prepared for CRC Ltd., Hinton, Alberta. R. Webb Environmental Services Ltd., Calgary. 76pp.

Weeks, H. P. and C. M. Kirkpatrick. 1976. Adaptations of white-tailed deer to naturally occurring sodium deficiencies. J. Wildl. Manage. 40(4):610-625.

Wishart, W. D. 1969. Bighorns and "Littlehorns". Alberta Lands, Forests and Wildlife. 12(3):4-10.

--------------- 1978. Bighorn sheep. p. 161-171 In Schmidt, J. L. and D. L. Gilbert (eds). Big game of North America, ecology and management. Stackpole Books, Harrisburg, Pa.

Wishart, W. D. and D. Brochu. 1982. An evaluation of horn and skull characters as a measure of population quality in Alberta bighorns. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:127-142.

Wishart, W. D., J. Jorgenson and M. Hilton. 1980. A minor die-off of bighorns from pneumonia in southern Alberta (1978). Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:229-247.

Woodgerd, W. 1964. Population dynamics of bighorn sheep on Wildhorse Island. J. Wildl. Manage. 28:381-391.

APPENDIX I

DEFINITIONS AND METHODS

1. **"Mine site"** as defined by The Coal Conservation Act of 1983 means a location at which a facility for extracting coal by underground strip or open pit operations exist or is to be developed and includes:

1) any coal processing plant, storage facility or waste disposal facility which exists or is to be developed in connection with the mine.

2) all connected access roads.

For the purpose of this text "mine site" also includes all open pits, reclaimed sites and those locations within CRC's mineral surface lease that have not been developed for the purposes of mining and have been left as components of the original vegetative cover.

2. **"Regolith"** as defined by Buckman and Brady (1969:623) means "the unconsolidated mantle of weathered rock and soil material on the earth's surface; loose earth materials above solid rock. (Approximately equivalent to the term "soil" as used by many engineers.)"

Regolith as used by staff of Cardinal River Coals Ltd. refers to material that is normally salvaged by mining equipment during operations and is defined as "any unconsolidated material (minus topsoil) overlying bedrock and generally includes a large proportion of fine grained material (sand, silt and clay) as well as broken rock and boulders" (Hardy Associates 1978:12)

Other soil materials salvaged prior to mining are referred to as "topsoil" and are defined as "a mixture of surface soil materials (organic duff, A and B horizons) and tree slash (that is) chipped or cut into short lengths (Hardy Associates 1978:12). These soil materials meet the criteria for classification as "good" or "fair" with respect to their suitability for providing root zone material in disturbed and reclaimed land (Macyk et al. 1987:30).

Buckman, H. O. and N. C. Brady. 1970. The nature and properties of soils. Seventh Edition. The Macmillan Company. 653pp.

Hardy Associates (1978) Ltd. 1981. Evaluation of reclamation at the Luscar open pit mine. Cardinal River Coals Ltd. 81pp.

Macyk, T. M., L. K. Brocke, J. Fujikawa, J. C. Hermans and D. McCoy. 1987. Soil quality criteria relative to disturbance and reclamation. Alberta Agriculture, Soils Branch, Edmonton. 56pp.

Table 20. Behaviour patterns used in social interactions between bighorn sheep (Geist 1971:135-146).

Horn Display

lo - low stretch
p - present
t - twist

Aggressive

ho - horn threat (intention to butt)
thj - threat jump (intention to clash)
ru - rush
bu - butt (both sheep, feet on the ground)
cl - clash (both sheep, feet off the ground)

Contact Display

fk - front kick (contact display, threat)
nf - neck flight (rare vestigal behaviour)

Contact Patterns of Small Sheep on Large

hb - horning body (self or other)
rb - rubbing
nu - nuzzling

Sexual

m - mount
e - ejaculation
sn - sniffing of rear
ur - ewe urinates in response of sniffing

Other

hs - head shake
sh - shove or push with shoulder

Geist, V. 1971. Mountain sheep, a study in behaviour and evolution. The University of Chicago Press. 383pp.

Table 21. Behaviour patterns of bighorn sheep that do not elicit a behavioral response (adapted from Geist 1971:132-135).

*f - feeding includes: g - grazing
br - browsing
stcc - standing/chewing cud

wa - eating snow/drinking water

sa - licking/eating dirt or mineral lick
nu - nursing lamb

*b - bedded - includes bedded in various positions (head up/head down) and bcc - bedded/chewing cud

at - alarm posture - assume rigid posture and stares in one direction

al - alarm posture - raised head held rigidly, moves with a stiff and tense walk

st - standing

*w - walking

r - running

pa - panic flight

oc - orientation to conspecific (includes vocalization)

hv - horning vegetation

ru - rubbing body on post or stump for comfort

*the most common postures

Geist, V. 1971. Mountain sheep, a study in behaviour and evolution. The University of Chicago Press. 383pp.

Table 22. Name codes given to sheep with identifiable characteristics present on the Cardinal River Coals Ltd. mine site, 1985 to 1986.

Code	Name	Classification
BL	broken leg	ewe

- ewe with injured left leg. She would carefully place weight on it if walking, but did not use it when running. Apparently she had been present on the mine site for a few years before this study began.

BLL	broken leg lamb	lamb

- lamb accompanying BL ewe, spring 1986.

C	collared	ewe

- old ewe with a orange canvas collar put on by G. Lynch, Alberta Fish and Wildlife Division on August 6, 1977 at the tunnel in Red Cap Mountain operated by Inland Cement. At that time she weighed 72.6 kg and was described as a "large old ewe". The number on the collar was 39.

CLA	c lamb	lamb

- a very small lamb half the size of the other lambs, that accompanied the "C" ewe summer and fall, 1986.

MHL	missing horn light	ewe

- a large ewe in prime condition with a light tan coat colour and an indistinct colour difference between the body and rump patch. This ewe had a white face and a missing right horn. She was originally named "BH" (broken horn).

MHM	missing horn medium	ewe

- a young ewe with a missing right horn and a light brown coat colour and brownish face with white encircling the nose. She has a distinct white rump patch. This ewe died giving birth, May 1986. The remains of both the ewe and lamb were found on the 51-B-2 east wall. No signs of predation.

MHD	missing horn dark	ewe

- a ewe with a missing right horn and a dark brown coat colour. There was a definite distinction between the dark body colour and white rump patch. This was an old ewe often seen in association with the "C" ewe.

MLH	missing left horn	ewe

- a ewe with a missing left horn

StHn	stubby horn	ewe

- a young ewe with a right horn broken off leaving a short straight stub. The left horn is beginning to curl over the ear and point down as is the case with many ewes in this herd.

TSTH tall stubby horn ewe
- a ewe with a piece broken off the right horn similar to "STH" except that the stub was longer.

MRH missing round horn ewe
- a ewe missing her right horn. The left horn curves over her ear.

MRHL missing round horn-left ewe
- a ewe missing a left horn. The right horn curves over the ear.

NBH new broken right horn ewe

RH round horn ewe
- an old ewe with a dark drown coat colour. Her horns do not stand straight but curve over her ears and point downward. She has a white face with no colour differentiation.

YRH young round horn ewe
- a young ewe with horns curving over the ear and pointing down.

BRH broken right horn ewe
- brh became "MH4" on July 14, 1986

WO wounded ewe ewe
- ewe injured by hunters fall 1986. May have come onto the mine site after being injured. Her left shoulder was injured causing her to limp and she was exhaling blood from her nose. She isolated herself on the 50-A-3 wall. Coyotes would not approach her even when she was very weak, as long as she could stand up. An attempt to dispatch her was foiled by bad weather.

W21 W21 ewe
- a ewe with a white ear tag in the right ear with the number 21 in black letters on the tag. The tag has yellowed with time. Tagged by K. Smith, Alberta Fish and Wildlife, spring 1986.

Y Y ewe
- a young ewe tagged with a yellow ear tag in the right ear by K. Smith, Alberta Fish and Wildlife, spring, 1986.

GH grey horn m Y
- a light brown coloured sheep with a light face, light rump and small, grey horns.

NSH new split horn m (2½) I

K | kinky horn | m (3½) I

WF | white face | m (5½) II
- a ram with a very light coat colour and a white face with no colour differentiation. Coat is still light in the fall when other rams are dark.

SR | small rings | m (5½) II

SRH | split right horn | m (6½) III
- a ram with a long piece broken off the outside of his right horn.

DR | double ring | m (6½) III
- the 5th ring on both horns is actually 2 rings.

NH | notch horn | m (7½) III
- this ram has a large nick between the 5th and 6th ring on the right horn. His horns are also heavily broomed

CR | circle ram | m (8½) IV
- has perfect horns, but not large horns completing a circle to the eye. The 2nd and 4th rings are indistinct. This ram is an even brown colour with a distinct rump and white nose. He has no facial scars and dark brown "eyebrows".

SPH | splinter horn | m (8½) IV

NB | narrow band | m IV

SN | scar nose | m (9½) IV
- this ram has a distinct white nose and a large rectangle-shaped scar with no hair on his face.

BAH | bash horn | m (10½) IV

Table 23. Programs used to process bighorn sheep observation and distribution data at Cardinal River Coals Ltd.

Program	Use
area_tot	Calculates area of individual vegetation polygons
area_all	Calculates overall area of each vegetation type
dbi	Enter field observation data using a 25 field header file
dba	Retrieves observation data in desired combination of species, age class, time period and activity
dist_to_esc	Calculates the distance that sheep were located from escape terrain on first observation
make_header	Creates index to access location data within the allobs.table file
make_feat	Retrieves coordinates using the index created by make_header to correspond to the observation data searched by dba
pts_in_poly	Calculates the number of sheep for a specified time period located in a specified vegetation type
terr	Calculates the area occupied by bighorn sheep within the grid boundaries
n%poly	Calculates any percentage of the area occupied by bighorn sheep within the grid boundaries
nmap	Combines the base map and coordinates retrieved using make_feat to produce a map

The following are programs used to scale and format the data, to build base maps and to convert to metric equivalents:

adj*	neworig_ref_pt	scale*
build_active.csh	orig_other_end_ref_pt	scale.c
build_escape_map.csh*	orig_ref_pt	scale.in*
build_grps.csh	print*	scale.in.c
build_haul.csh*	print.err	sep
build_hwy40.csh*	print.log	westorig_ref_pt
build_metric.csh	rm_mu_ref_pt	
build_route.csh	rm_ref_pts.ed	
build_veg_brief.csh*	rotate	
fix_daily.csh	rotate.180	
fix_daily.log2	rotate.1st_pt	
new.adj.c	rotate_val	

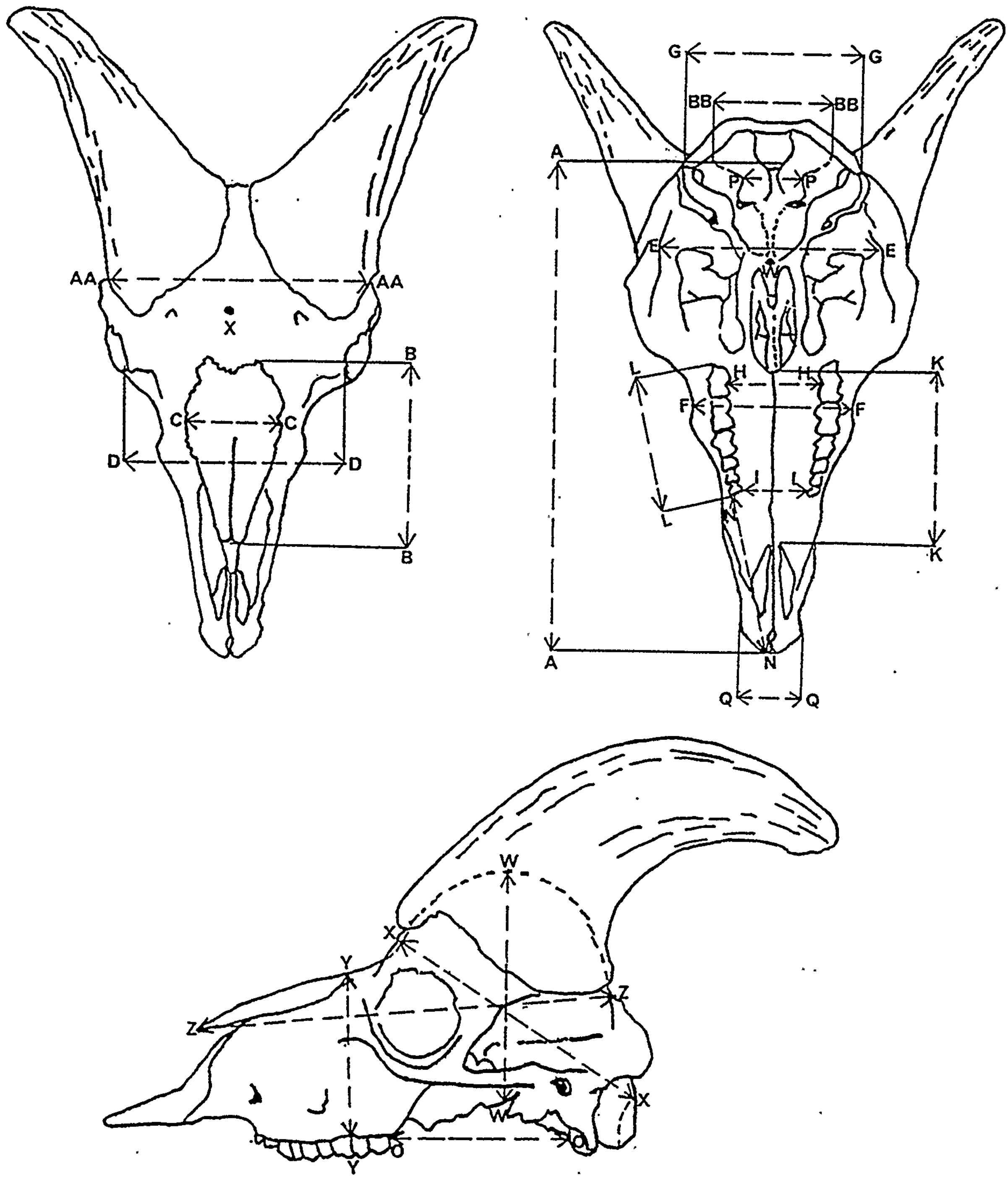


Figure 25. Reference points for bighorn skull measurements as described in Table 12 (after Shackleton 1973).

Rumen Analysis Method

(Alberta Fish and Wildlife Division, O.S. Longman Bldg.)

1. Thaw out rumen and depending on time, they can be washed and either stored in jars with 10% buffered formalin or done fresh. If stored in formalin the leaves and stems will discolour after a period of time.

2. Wash the rumen through three 3 sieves, the largest #4 (4.75 mm) on top, #7 (2.80 mm) in the middle and #10 (2.00 mm) on the bottom. Wash the whole sample through the sieves, putting the material from each sieve into three separate piles.

3. Fill a 250 ml beaker (not too tightly) with the material from sieve #4. If the beaker is not full use the material from sieve #7. If still not full use the material from sieve #10. If a full beaker cannot be obtained record the volume of sample on the sample tag along with date of kill, type of animal, sex and location, for the final report.

4. Take the 250 ml beaker of sample material and put into a pan. Add enough water to float the sample. Spread out some paper towels and using tweezers sort out the sample into its different components. Each different type of species should be put into a different pile.

5. Leaves are separated by colour, leaf margin, shape (thick, thin, leathery, prominent veins, etc.). Also with the use of smaller sieve material, the leaves become less easy to identify except as to colour. Twigs and stems are separated as to colour, bud type and scars (use in identification), also if lucky they will be attached to a leaf, so you can match both leaves and twigs. Seeds and berries are separated into their different shapes and colour. Grasses were generalized because to identify each blade and stem would take too much time. Sedges were also lumped into the grasses because stems were identifiable but leaf blades were not. If sedges occurred they were noted only.

6. There are different methods of evaluating percent use by rumen analysis. One method is dry weight. The samples are sorted into different species and left for 24 to 48 hours to dry. Samples with lots of grass will take longer to dry. Each species is then weighed on a gram balance, and all the information (weight, sex, animal type, date and location and lab number) and sample are then put in a bag or envelope for future reference.

Plant Species Cited in Text

Agropyron riparium Scribn. & Smith	Streambank Wheatgrass
Alnus crispa (Ait.) Pursh	Green Alder
Astragalus cicer L.	Cicer Milk Vetch
Betula pumila L.	Dwarf Birch
Bromus inermis Leyss.	Awnless Brome
Dactylis glomerata L.	Orchard Grass
Eleaegnus commutata Bernh. ex Rydb.	Wolf Willow
Festuca ovina var. duriuscula (L.) Koch	Hard Fescue
Festuca rubra L.	Creeping Red Fescue
Medicago spp. L.	Alfalfa
Melilotus spp. Mill.	Sweet Clover
Onobrychis viciifolia Scop.	Sainfoin
Picea engelmannii Parry ex Engelm.	Engelmann Spruce
Pinus contorta Loudon	Lodgepole Pine
Poa compressa L.	Canada Bluegrass
Poa pratensis L.	Kentucky Bluegrass
Populus balsamifera L.	Balsam Poplar
Populus tremuloides Michx.	Trembling Aspen
Rosa woodsii Lindl.	Common Wild Rose
Salix spp. L.	Willow
Sambucus melanocarpa (Gray) McMinn	Elderberry
Shepherdia canadensis (L.) Nutt.	Canadian Buffalo-berry
Trifolium hybridum L.	Alsike Clover

APPENDIX II

SITE PHOTOGRAPHS

Figure 26. The 50-A-1/2/3 range complex, April 27, 1986.

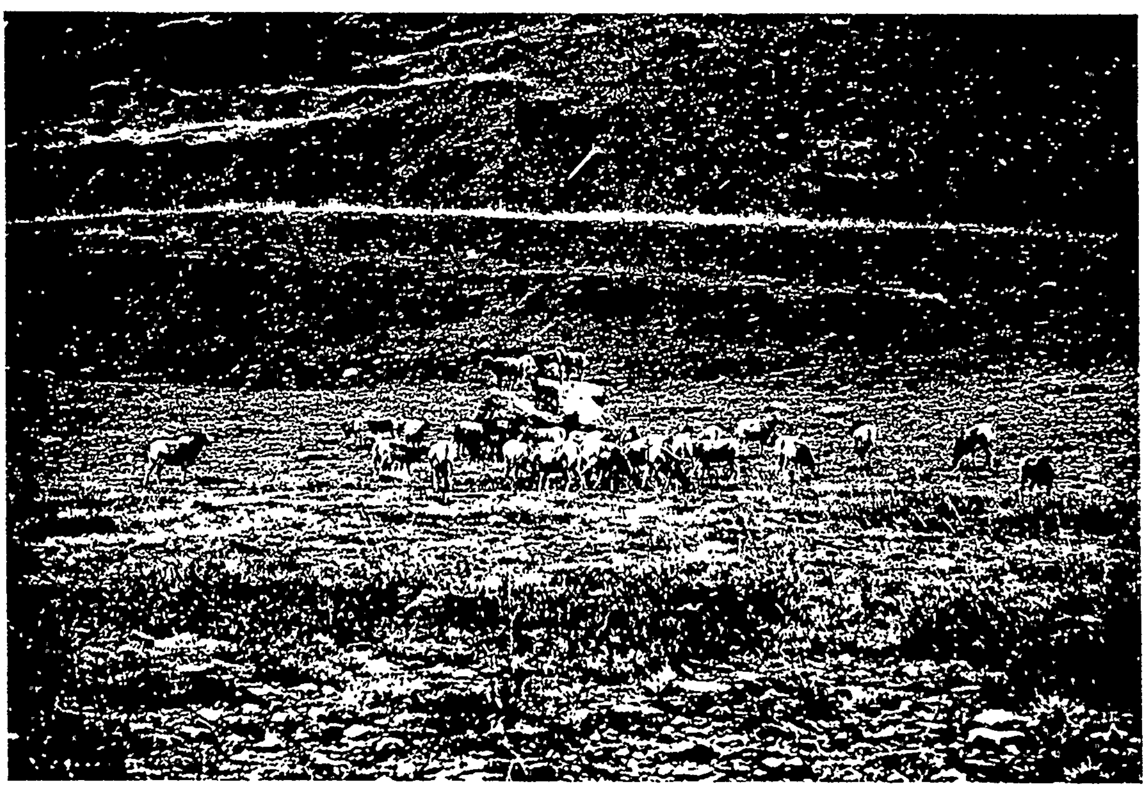


Figure 27. Lambs playing "king-of-the-castle" in the pre-rut, 1985 on 50-A-1.

Figure 28. Seeps on the east wall of the 50-A-3 pit, June 28, 1986 used by the nursery herd as a mineral source.

Figure 29. The south-facing slopes above HWY 40 showing part of the adjacent 51-B-2 east wall.

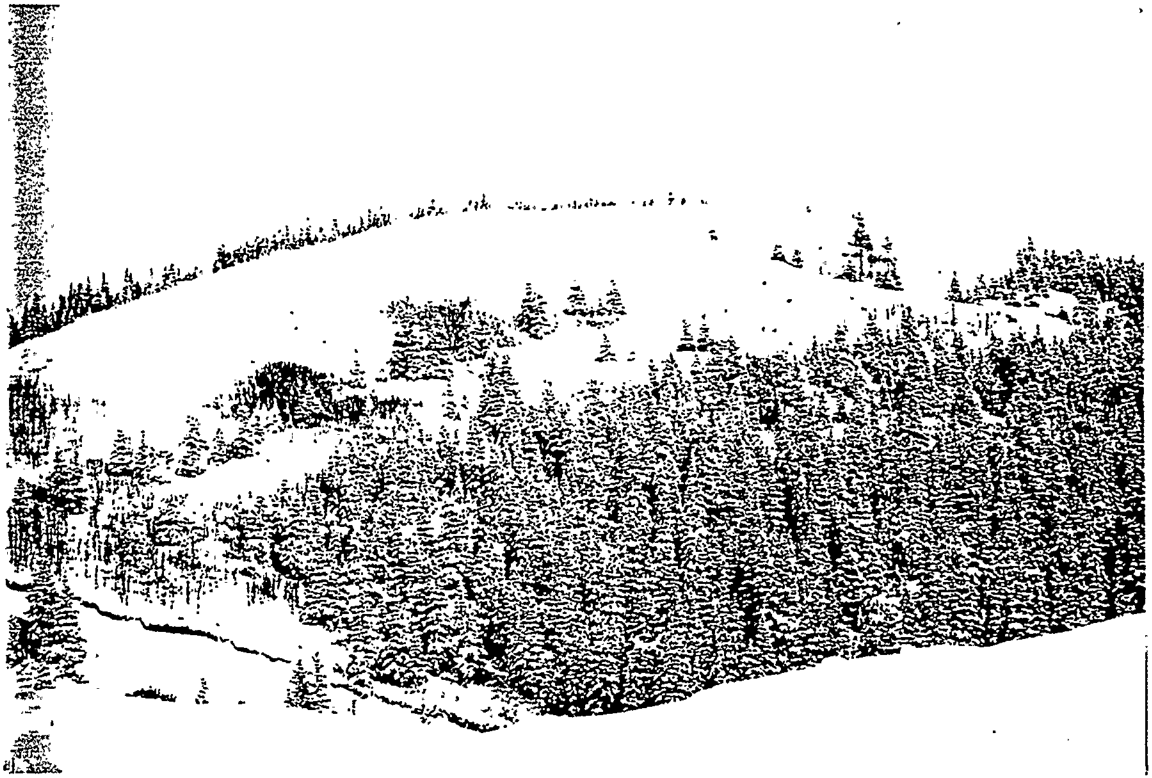


Figure 30. The subalpine meadow located centrally on the mine site used by rams in the winter and spring seasons in 1986.

Figure 31. The configuration of the subalpine meadow and escape terrain provided by the east wall of the 50-B-3 pit.

Figure 32. The 51-B dump located south of HWY 40 used by the nursery herd in the pre-rut, 1985.

Figure 33. A topsoil stockpile on the C-baseline used by rams in the pre-rut, 1985.

APPENDIX III

BIGHORN SHEEP CENSUS AT CARDINAL RIVER COALS LTD.
FOR THE YEAR 1985-1986.

Table 24. Bighorn sheep census, Cardinal River Coals Ltd. September, 1985.

AGE CLASS	19	23	24	25	28	30
LAMB	25	31	31	21	34	20
EWE	42	67	57	36	74	42
F YEAR	4	3	4	0	4	3
M YEAR	5	4	3	1	0	4
M I	3	4	6	7	8	3
M II	2	5	10	11	28	18
M III	4	2	3	4	7	3
M IV	0	0	1	1	0	0
TOTAL	85	116	115	81	155	93

NOTE: 3 ewes were taken by hunters on the first day of hunting season on September 10, 1985.

Table 25. Bighorn Sheep Census, Cardinal River Coals Ltd. October, 1985.

Age Class	4	8	9	10	11	15	16	18	21	23	25	28	29	30
Lamb	34	45	30	18	29	35	41	37	29	14	32	39	22	39
Ewe	74	83	79	44	77	74	80	76	52	44	63	76	23	76
F Y	5	5	7	1	4	5	5	4	3	2	7	3	4	5
M Y	3	3	4	3	6	5	5	6	6	6	6	7	1	5
I	2	6	4	4	2	3	5	4	3	2	3	4	1	3
II	22	24	16	23	23	17	20	18	26	22	12	21	11	14
III	6	8	5	4	5	6	4	9	5	9	4	4	2	6
IV	1	1	3	1	2	1	2	1	0	1	0	0	0	0
TOT.	147	175	148	98	148	146	162	155	124	100	127	154	64	148
	F	G	G	P	P	P	G	G	I	G	G	G	I	G

NOTE: Hunters removed 10 ewes during October: 1 ewe (Oct. 3), 3 ewes (Oct. 10), 3 ewes (Oct. 17), 2 ewes (Oct. 24), 1 ewe (Oct. 31). In addition, 1 dead male II was found October 19, and 1 male IV was killed in Farmer's basin on October 23, 1985.

Table 26. Bighorn sheep census, Cardinal River Coals Ltd. November, 1985

Age Class	Date														
	1	5	6	7	12	13	14	15	19	20	21	23	28	29	30
Lamb	39	30	3	47	41	46	30	35	39	36	26	41	34	37	35
Ewe	57	42	6	61	64	74	54	63	59	60	48	72	46	56	54
F Year	2	2	0	6	5	4	4	5	5	3	3	5	6	8	6
M Year	6	4	0	7	7	7	8	5	6	5	6	5	3	5	5
M I	3	1	0	2	6	8	4	3	8	7	6	8	8	8	10
M II	18	11	2	19	11	12	7	10	17	18	16	20	13	17	12
M III	1	3	2	7	8	5	3	5	6	5	9	8	8	9	6
M IV	0	0	0	1	0	0	0	1	3	4	5	7	3	2	4
SUM	126	93	13	150	142	156	110	127	143	138	119	166	121	142	132
	F	I	I	P	P	F	F	P	F	F	P	G	I	F	P

NOTE: 1 wounded ewe disappeared on November 6, 1985 and was presumed dead.

Table 27. Bighorn sheep census, Cardinal River Coals Ltd. December, 1985

Age Class	Date																	
	3	4	4	5	5	9	11	12	12	14	18	19	20	23	28	29	29	30
Lamb	28	4	28	37	30	36	12	16	29	30	27	25	26	36	41	34	32	36
Ewe	56	16	32	59	47	41	17	42	50	43	42	45	42	57	74	55	55	36
F Y	2	0	2	4	1	1	2	1	2	2	2	2	2	2	4	3	5	1
M Y	2	0	2	3	1	2	0	1	1	2	0	0	0	2	4	4	5	4
I	9	4	4	6	12	7	2	5	5	7	9	7	6	7	10	7	7	6
II	21	6	6	20	10	17	4	7	12	13	11	9	14	20	21	21	12	8
III	4	3	5	3	3	6	2	2	4	4	2	4	2	4	4	3	7	4
IV	5	4	3	6	6	3	1	2	4	4	3	3	3	5	6	5	4	0
SUM	127	37	82	138	110	113	40	76	107	105	96	95	95	133	164	132	127	95
	F	I	I	G	F	G	P	P	F	G	G	F	G	F	G	F	F	G

Table 28. Bighorn sheep census, Cardinal River Coals Ltd. January 1986

Age Class	Date																	
	6	8	9	9	10	14	15	17	18	21	22	23	28	29	29	30	31	31
L	28	33	36	38	28	36	37	42	42	38	38	27	35	37	34	35	34	38
E	43	45	48	57	44	60	60	56	64	50	59	45	63	64	64	65	59	70
F	3	3	2	6	1	4	5	2	3	5	2	2	2	2	3	2	1	3
M	3	5	4	4	2	5	5	5	4	3	3	4	5	3	5	5	4	5
I	7	5	8	7	5	7	7	9	6	8	9	4	8	8	9	11	6	8
II	15	18	21	23	21	19	23	19	25	21	18	13	21	24	24	20	19	25
III	5	4	3	6	2	6	2	5	8	2	3	1	4	2	3	5	6	6
IV	6	4	4	5	4	2	6	4	3	5	5	3	3	5	3	5	4	4
	110	117	126	146	107	139	145	142	155	132	137	99	141	145	148	148	133	159
	I	F	F	G	I	G	G	P	P	G	G	I	G	G	G	F	I	P

Table 29. Bighorn sheep census, Cardinal River Coals Ltd. February 1986

Age Class	Date																	
	3	4	4	5	5	6	10	11	12	13	13	17	17	18	25	26	27	28
Lamb	21	31	31	41	37	38	33	39	31	39	33	7	10	0	4	12	8	8
Ewe	30	56	48	45	57	63	56	61	40	61	55	23	25	1	13	32	35	34
F Y	2	1	2	1	2	3	1	2	3	3	2	0	0	0	0	0	0	0
M Y	2	2	1	0	4	4	3	4	2	4	3	0	1	0	0	2	1	1
I	7	8	6	1	5	7	5	8	7	9	7	6	6	1	2	5	4	5
II	14	15	18	18	21	25	9	19	13	18	21	20	19	13	10	20	23	20
III	5	5	4	4	2	7	2	8	4	7	6	5	4	2	2	2	3	6
IV	2	1	3	2	2	3	1	1	1	2	2	2	2	2	0	1	3	2
SUM	83	119	113	112	130	150	110	142	101	143	129	63	67	19	31	74	77	76
	G	F	F	P	G	G	P	G	P	G	P	F	F	F	F	G	G	G

Table 30. Bighorn sheep census, Cardinal River Coals Ltd. March 1986

Age Class	Date 3	4	4	5	5	6	10	10	18	19	21	21	25	26	26	27	
Lamb	4	15	13	15	13	13	12	12	17	18	16	17	12	17	17	17	16
Ewe	13	26	37	48	42	43	41	41	35	35	26	38	28	33	38	38	38
F Y	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0
M Y	1	2	1	1	2	3	2	2	3	3	3	3	3	2	3	3	4
I	4	6	8	6	7	6	6	6	3	4	5	6	3	5	6	6	6
II	15	18	21	22	21	20	21	18	18	18	16	18	4	10	19	19	20
III	5	4	6	5	5	9	2	8	7	5	2	5	4	1	6	5	6
IV	3	1	2	4	5	4	1	3	2	2	1	3	3	1	3	2	2
SUM	45	73	89	101	95	99	86	91	85	85	69	90	57	69	92	90	92
	G	G	G	G	G	G	G	G	G	G	P	G	P	P	G	G	G

NOTE: Fish and Wildlife removed 7 ewes on March 14, 1986.

Table 31. Bighorn sheep census, Cardinal River Coals Ltd. April 1986

Age Class	Date 1	1	2	2	8	9	10	15	16	A 21	A 22	A 23	24	28	30
Lamb	16	16	16	16	12	16	16	16	14	14	8	11	16	16	17
Ewe	37	36	36	36	38	31	36	34	37	44	40	39	37	38	22
F Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M Y	2	3	3	3	3	3	2	3	3	2	4	0	4	3	4
M I	6	5	5	7	6	2	5	7	7	5	6	5	5	8	5
M II	8	5	18	19	14	1	24	14	20	17	15	14	17	18	10
M III	2	2	6	5	8	0	3	5	4	7	0	11	4	5	3
M IV	0	0	2	3	1	0	1	3	2	0	0	0	2	2	0
SUM	71	67	86	89	82	53	87	82	87	89	73	80	85	90	61
	P	F	F	G	F	I	G	G	P	P	P	P	I	G	P

NOTE: 1 ewe was removed by Fish and Widlife on April 9, 1986.
A = assistant counting

Table 32. Bighorn sheep census, Cardinal River Coals Ltd. May, 1986

Age Class	Date																	
	2	2	A 5	A 6	A 7	A 8	9	13	14	15	A 19	A 20	A 21	A 22	28	29	30	30
Lamb	19	17	15	16	17	16	13	15	15	16	13	14	4	13	4	0	5	5
Ewe	37	31	34	36	36	31	36	25	32	23	30	25	22	27	13	6	11	15
F Y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	4	4
M Y	4	3	6	4	2	3	4	3	2	1	1	1	2	3	6	0	8	8
I	5	6	5	5	7	4	2	5	3	3	2	6	4	6	1	1	2	2
II	16	13	14	14	14	8	14	19	8	11	20	11	7	15	12	17	13	11
III	6	6	5	7	9	2	7	5	4	3	8	10	4	6	9	7	3	6
IV	0	2	0	1	2	0	3	2	2	2	4	2	2	2	2	1	2	1
SUM	87	78	79	83	87	64	79	74	66	59	78	69	45	72	53	32	48	52
	G	G	P	F	F	F	G	F	F	G	G	F	I	G	F	G	G	G

NOTE: First lambs of the year sighted on May 28. All age classes adjusted from this date.
Fish and Widlife removed 1 ewe and 2 female lambs on May 6 and 1 male lamb on May 20, 1986.
One ewe and one new lamb were found dead on May 28, 1986.

Table 33. Bighorn sheep census, Cardinal River Coals Ltd. June, 1986

Age Class	1	2	3	4	6	9	10	11	12	A 15	A 16	A 17	A 18	24	25	26	27
Lamb	0	5	5	6	6	10	4	0	11	0	0	0	7	0	0	2	0
Ewe	8	8	19	20	14	32	10	0	24	1	3	4	15	6	0	13	37
F Y	6	2	8	10	5	3	2	0	8	0	5	4	3	3	0	2	11
M Y	5	4	3	7	5	5	0	0	6	0	3	4	4	5	0	1	5
M I	2	0	1	2	2	0	0	0	2	0	3	4	3	1	0	2	1
M II	7	7	0	0	10	5	0	0	1	0	3	10	17	1	0	2	2
M III	0	2	0	0	0	0	0	0	0	0	1	2	9	0	0	2	1
M IV	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0
SUM	28	28	36	45	42	55	16	0	52	1	19	28	60	16	0	24	57
	F	G	G	G	F	F	G	G	F	G	G	G	G	F	G	F	F

NOTE: A = assistant counting

Table 34. Bighorn sheep census, Cardinal River Coals Ltd. July, 1986

Age Class	2	3	4	7	9	10	A 14	A 15	A 16	A 17	21	22	24	A 28	A 29
Lamb	1	1	0	24	0	2	1	1	0	0	2	0	0	0	6
Ewe	6	1	1	35	0	2	8	6	0	0	7	0	0	0	9
F Y	0	0	0	6	0	1	2	0	0	0	3	0	0	0	0
M Y	7	0	0	1	0	0	6	0	0	0	2	0	0	0	4
M I	1	0	0	1	0	0	0	0	0	1	1	0	0	0	3
M II	4	0	0	9	2	1	2	1	0	1	4	0	0	1	1
M III	0	1	0	0	0	0	0	1	0	0	1	0	0	2	1
M IV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	19	3	1	76	2	6	19	9	0	2	20	0	0	3	24
	G	G	G	F	F	G	G	G	G	G	G	G	G	G	G

Table 35. Bighorn sheep census, Cardinal River Coals Ltd. August, 1986

Age Class	6	8	|	11	13	14	19	20	22	26	S1
Lamb	4	15	|	32	15	16	18	22	37	44	40
Ewe	7	29	|	51	14	18	41	47	67	63	52
F Y	2	3	|	4	1	1	6	7	9	15	11
M Y	5	3	|	7	3	4	4	12	17	14	10
M I	0	0	|	0	1	1	4	5	4	3	6
M II	0	0	|	3	8	8	1	0	0	0	8
M III	0	0	|	3	5	3	0	1	0	0	1
M IV	0	0	|	0	1	0	0	0	0	0	0
SUM	18	50	|	100	48	51	74	94	134	139	128
	G	F		G	F	G	P	P	F	F	G

NOTE: A = Assistant counting
| = Beginning of 1986 pre-rut
1 ewe was killed on HWY 40 at superpipe on August 19, 1986.

APPENDIX IV

INTENSITY OF USE BY BIGHORN SHEEP OF CARDINAL RIVER COALS LTD. FOR THE YEAR 1985-1986.

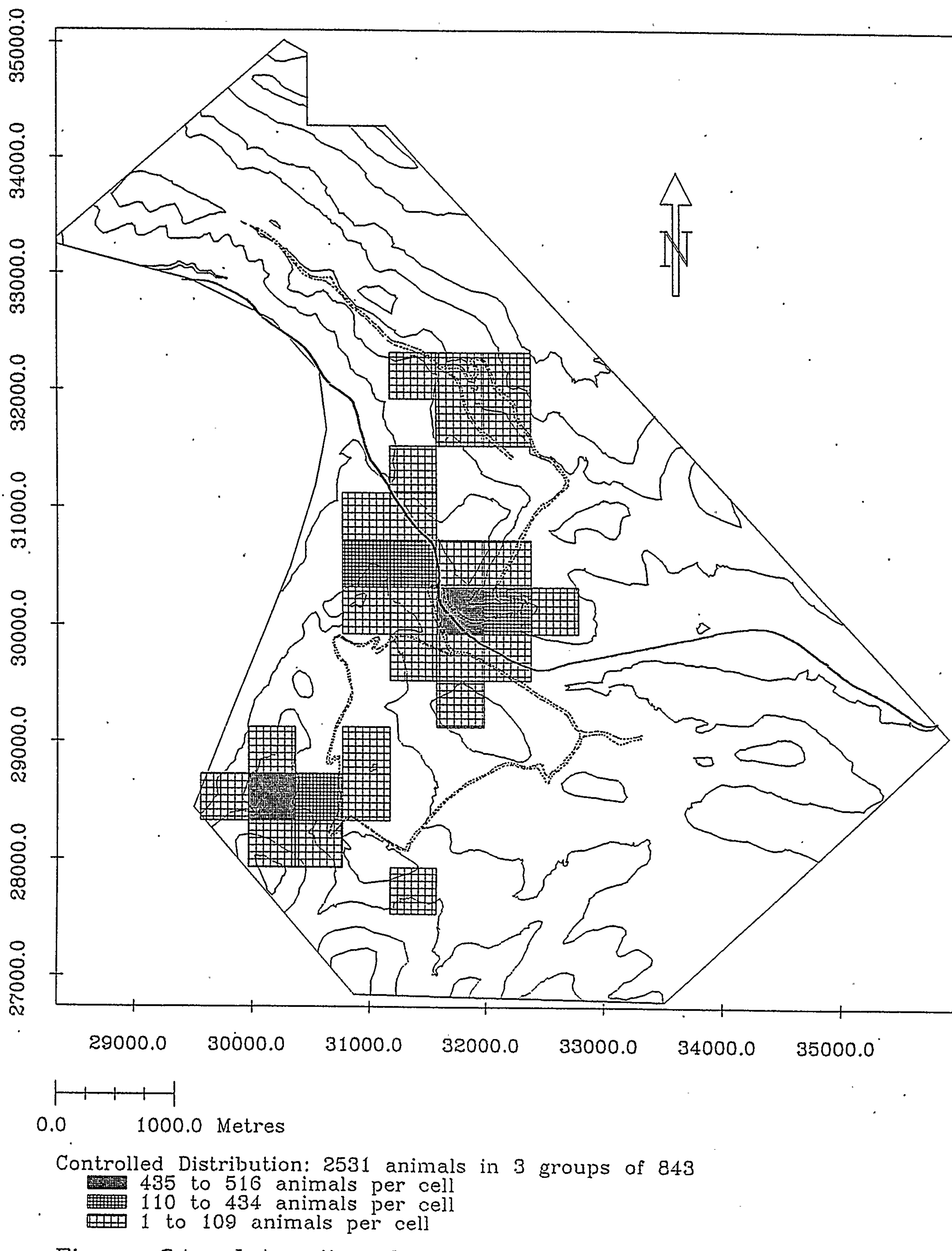


Figure 34. Intensity of use by lambs, ewes, yearlings and class I rams at Cardinal River Coals Ltd. for the prerut, September 17 - November 14, 1985.

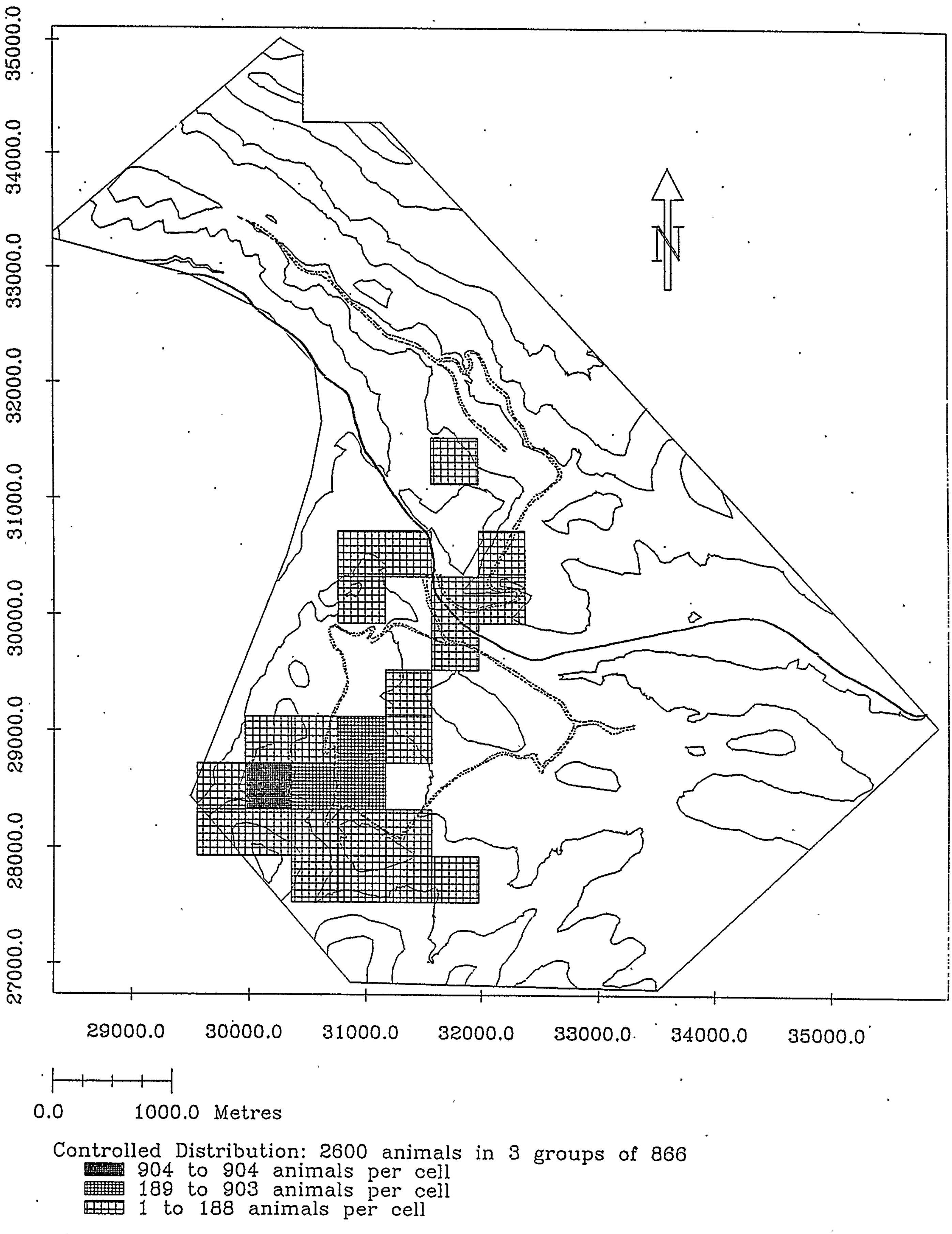
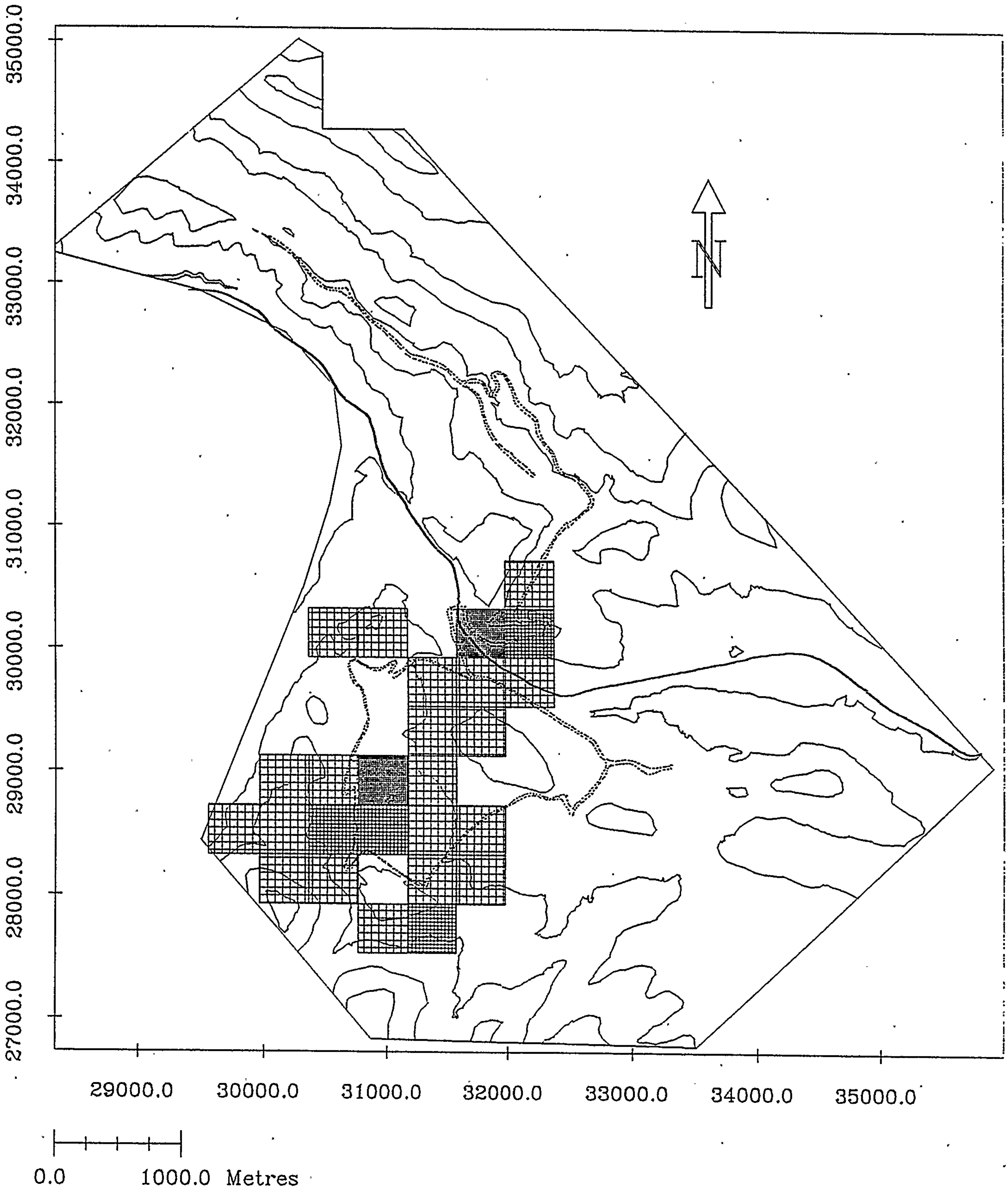


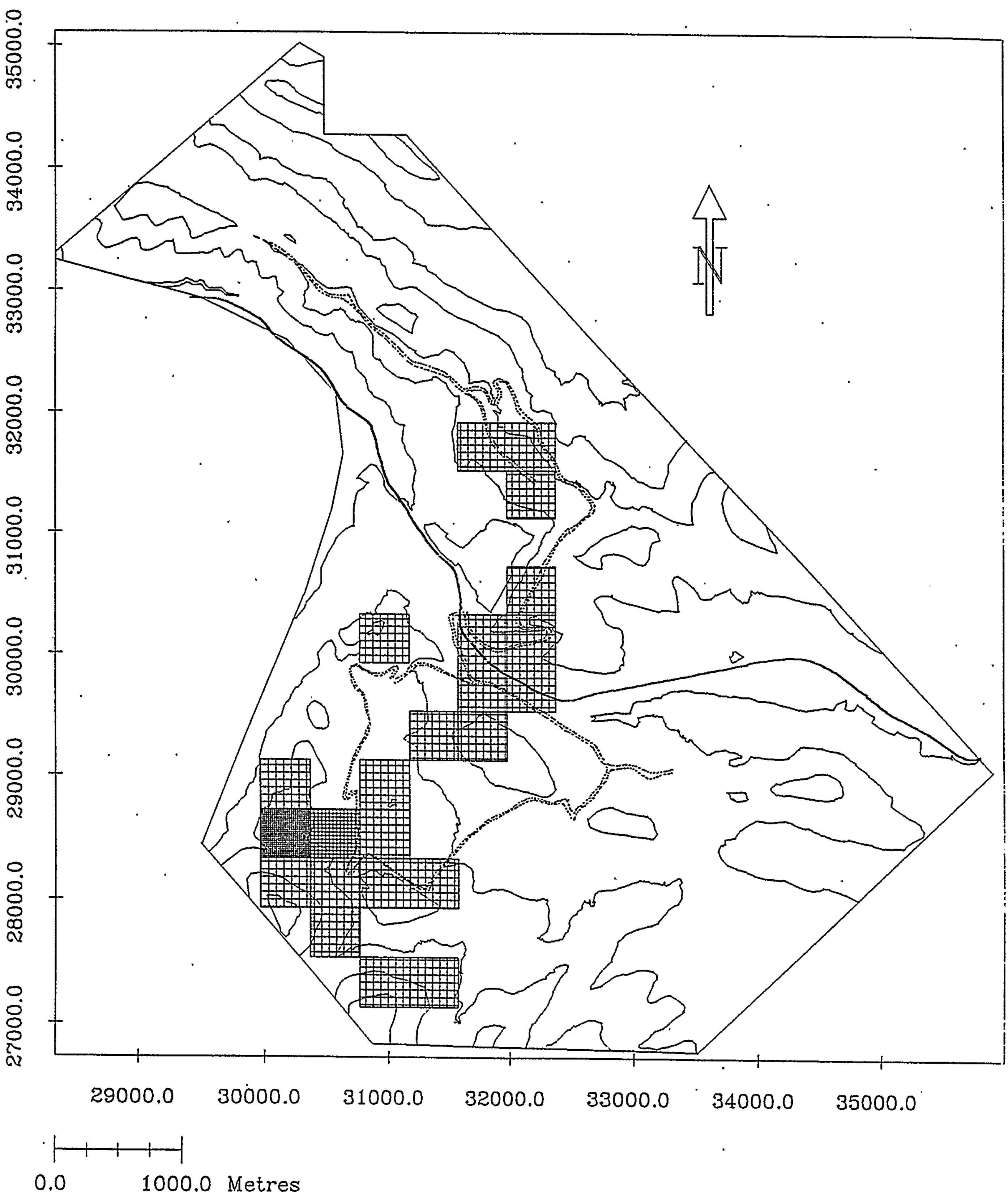
Figure 35. Intensity of use by lambs, ewes, yearlings and class I rams at Cardinal River Coals Ltd. for the rut, November 15, 1985 - January 18, 1986.



Controlled Distribution: 1479 animals in 3 groups of 493

- 199 to 321 animals per cell
- 88 to 198 animals per cell
- 1 to 87 animals per cell

Figure 36. Intensity of use by lambs, ewes, yearlings and class I rams at Cardinal River Coals Ltd. for the winter, January 19 - February 14, 1986.



Controlled Distribution: 2026 animals in 3 groups of 675
882 to 882 animals per cell
489 to 881 animals per cell
1 to 488 animals per cell

Figure 37. Intensity of use by lambs, ewes, yearlings and class I rams at Cardinal River Coals Ltd. for the spring, February 15 – May 27, 1986.

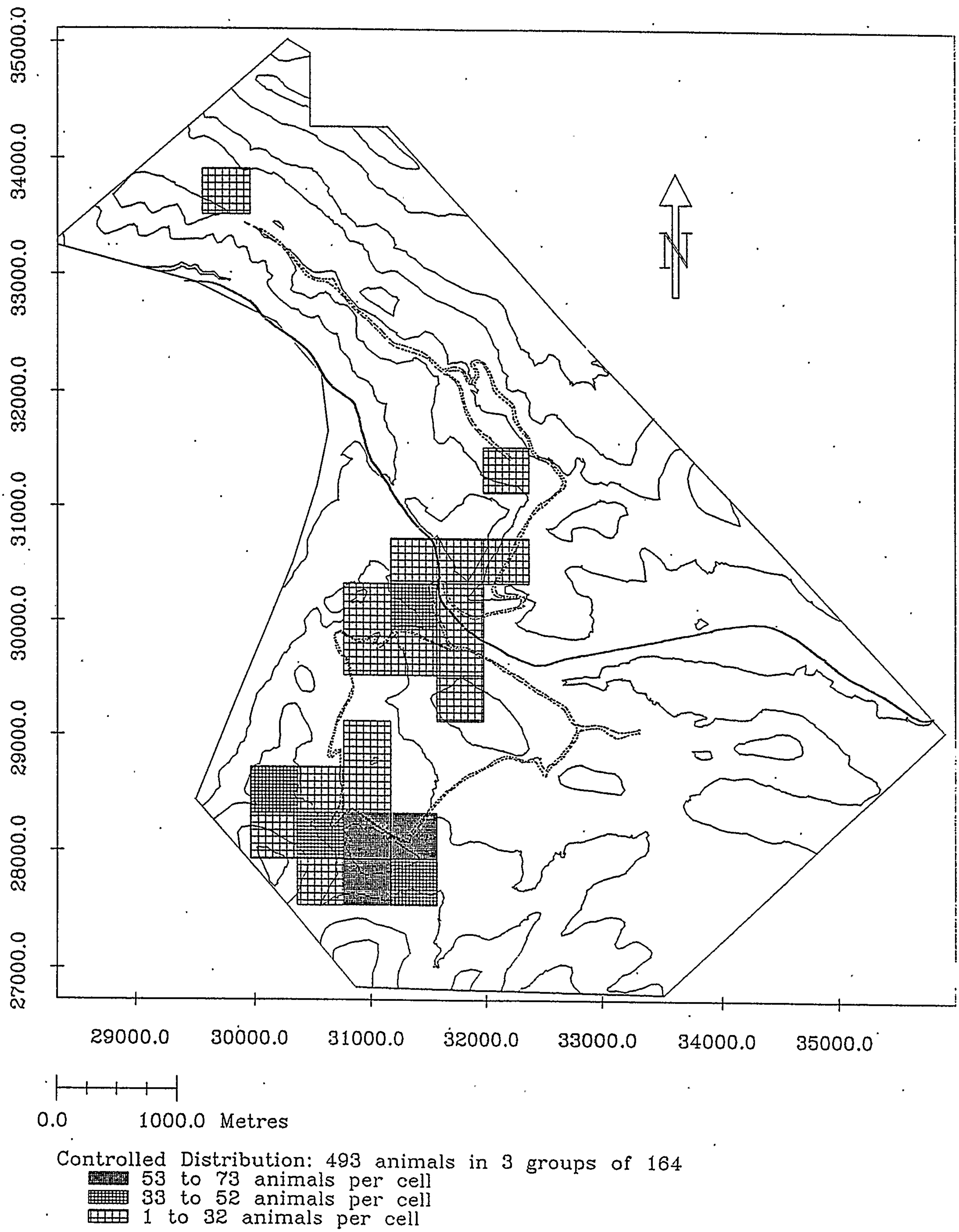


Figure 38. Intensity of use by lambs, ewes, yearlings and class I rams at Cardinal River Coals Ltd. for the lambing, May 28 - June 30, 1986.

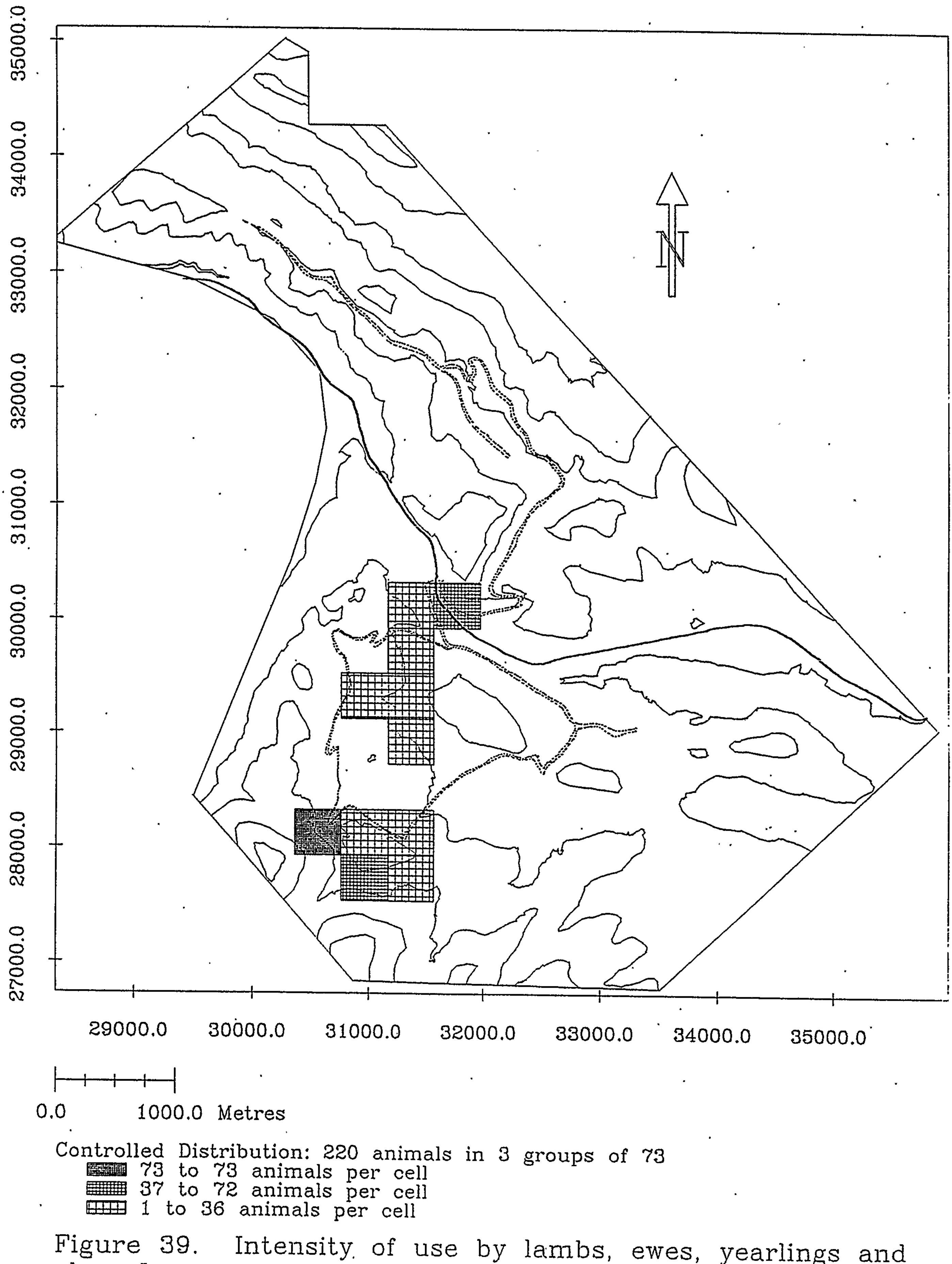
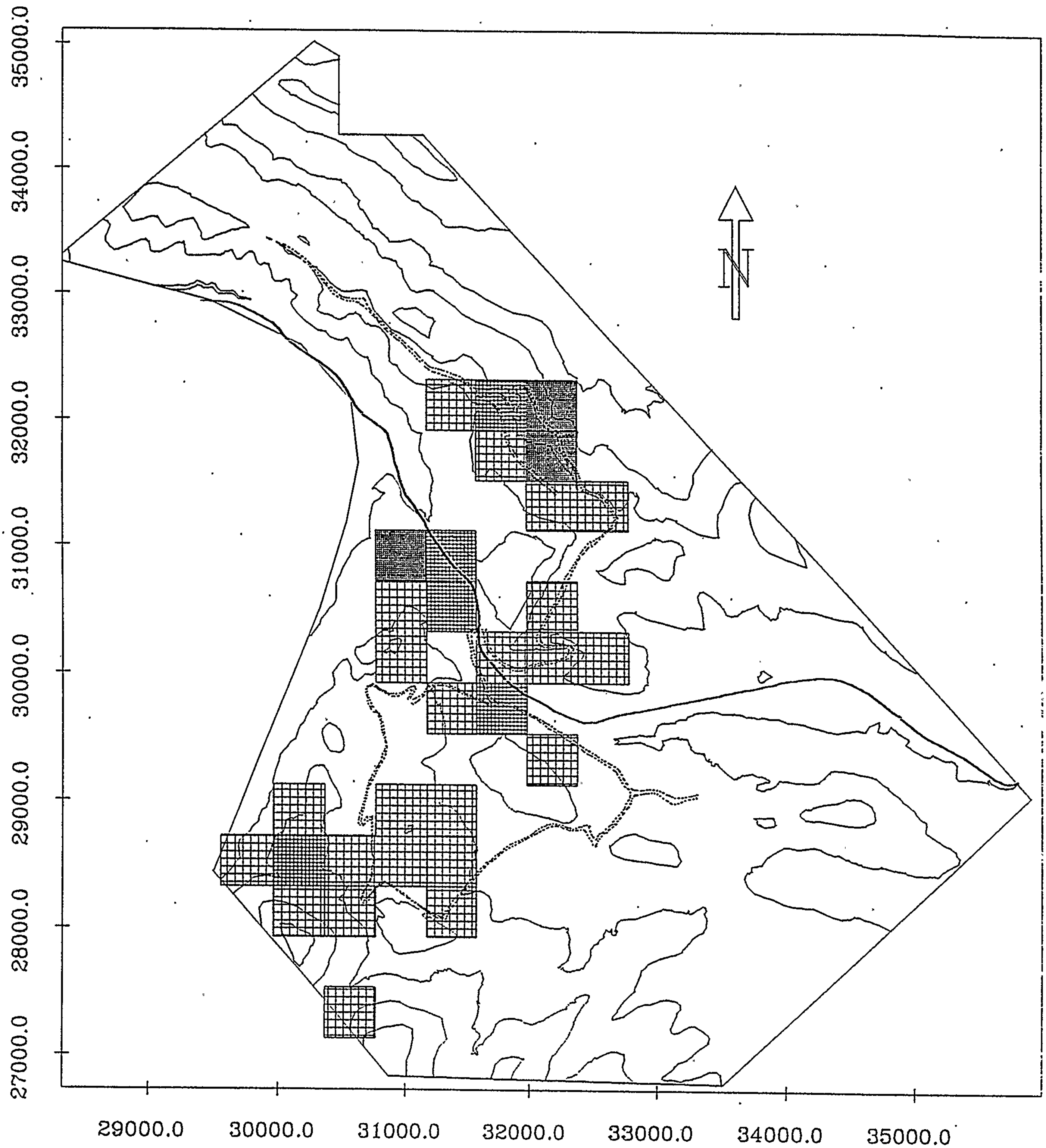


Figure 39. Intensity of use by lambs, ewes, yearlings and class I rams at Cardinal River Coals Ltd. for the summer, July 1 - August 10, 1986.



0.0 1000.0 Metres

Controlled Distribution: 506 animals in 3 groups of 168
- 42 to 81 animals per cell
- 28 to 41 animals per cell
- 1 to 27 animals per cell

Figure 40. Intensity of use by class II, III, and IV rams at Cardinal River Coals Ltd. for the prerut, September 17 – November 14, 1985.

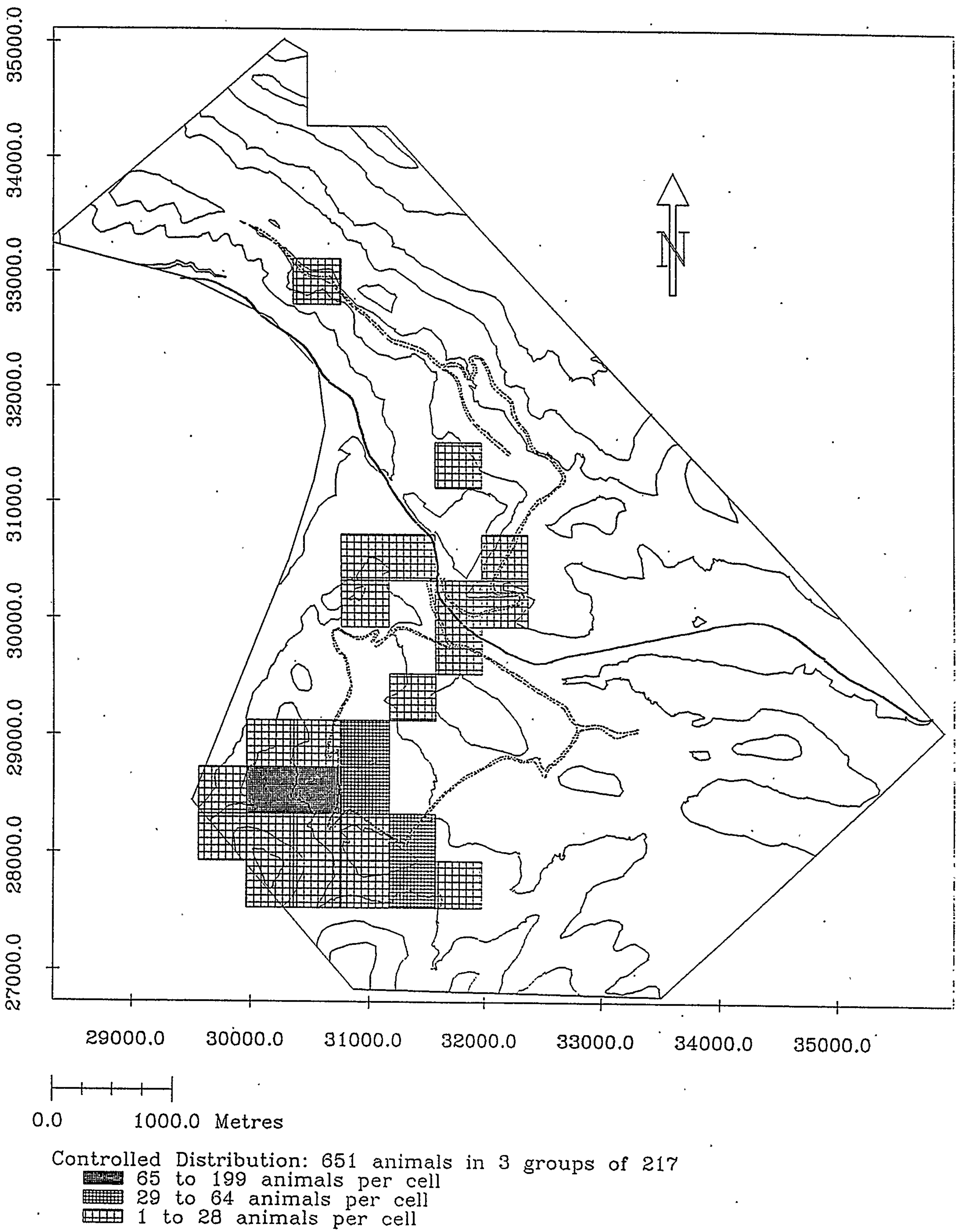
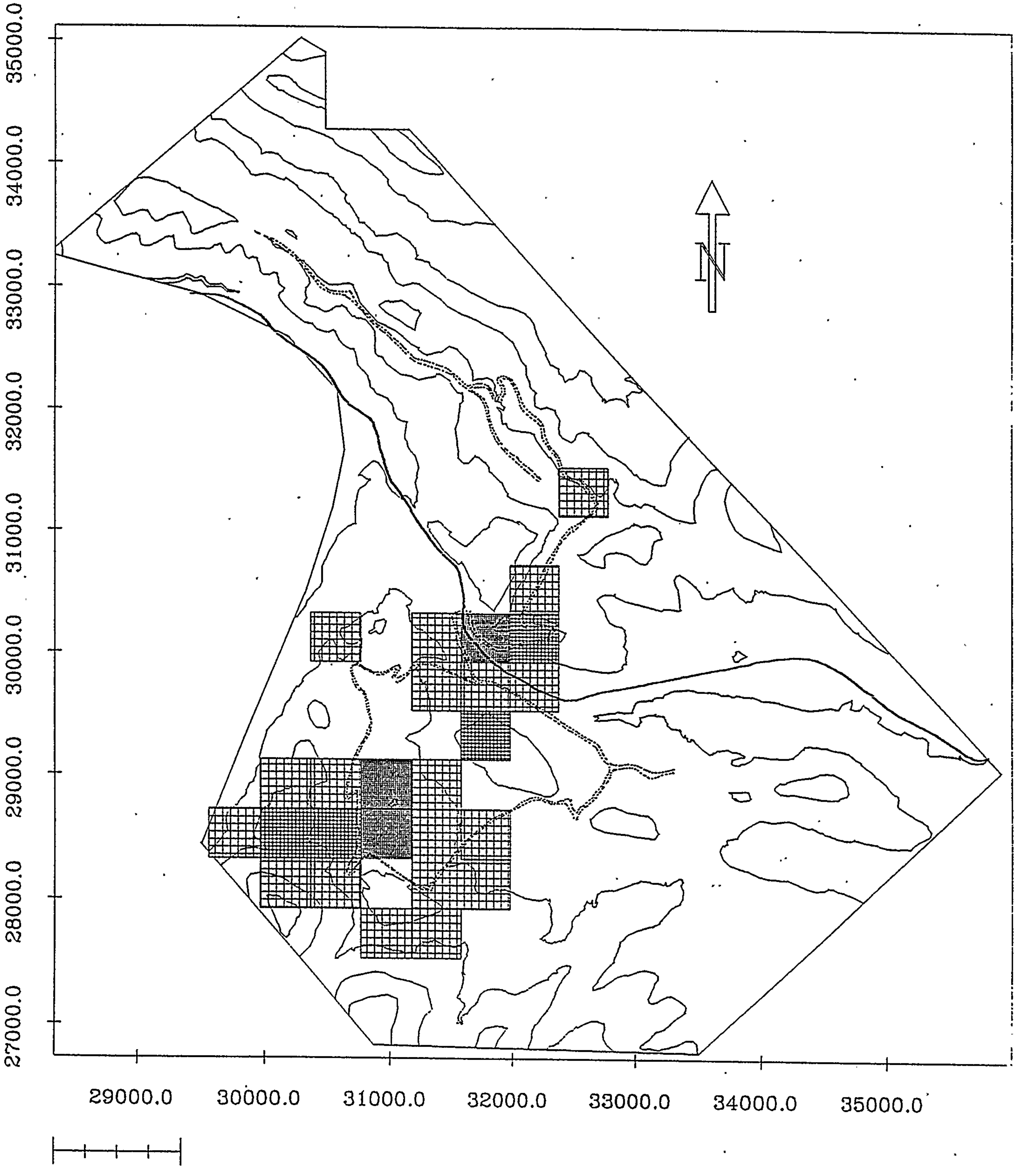


Figure 41. Intensity of use by class II, III, and IV rams at Cardinal River Coals Ltd. for the rut, November 15, 1985 – January 18, 1986.



Controlled Distribution: 364 animals in 3 groups of 121
39 to 48 animals per cell
25 to 38 animals per cell
1 to 24 animals per cell

Figure 42. Intensity of use by class II, III, and IV rams at Cardinal River Coals Ltd. for the winter, January 19 – February 14, 1986.

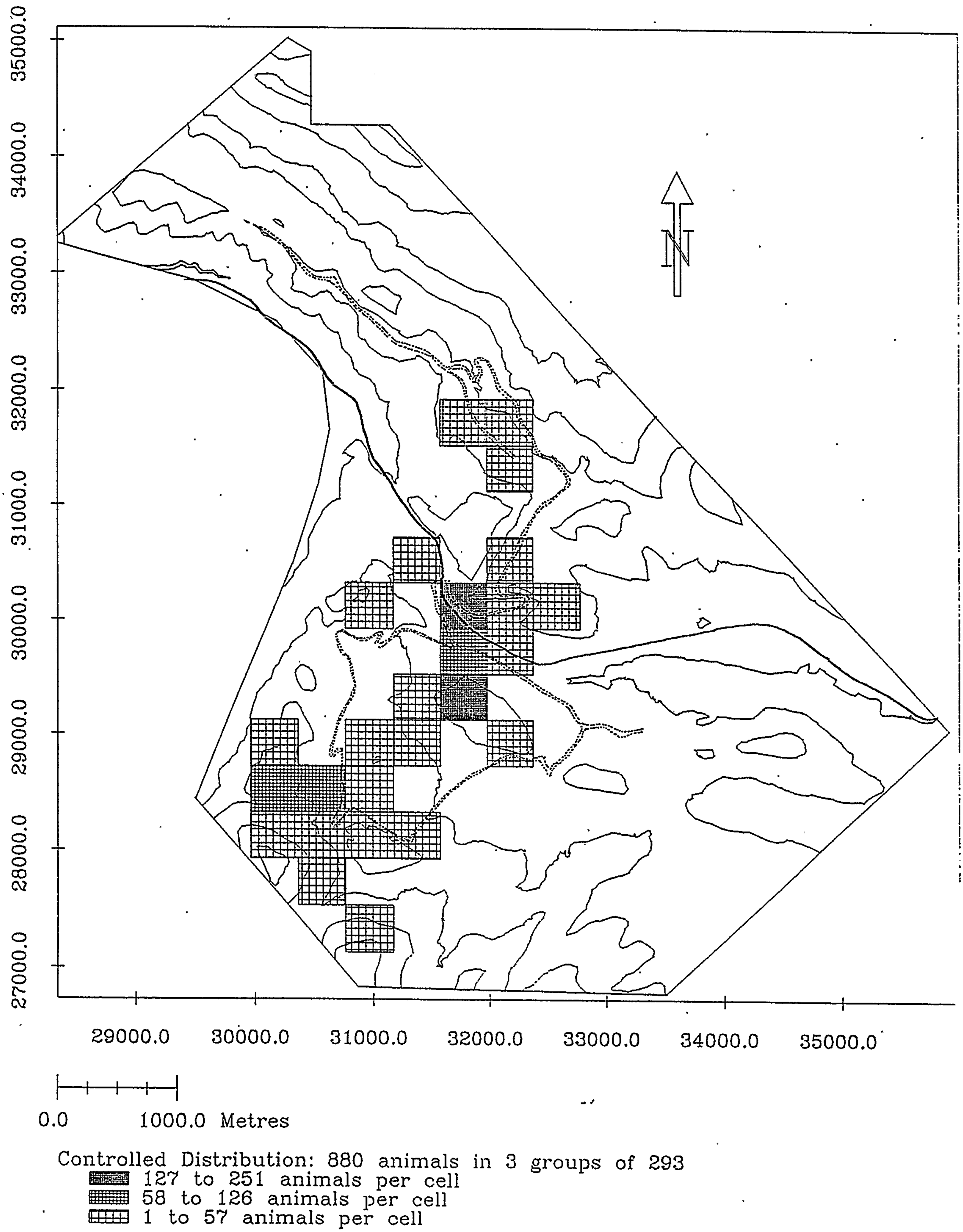


Figure 43. Intensity of use by class II, III, and IV rams at Cardinal River Coals Ltd. for the spring, February 15 – May 27, 1986.

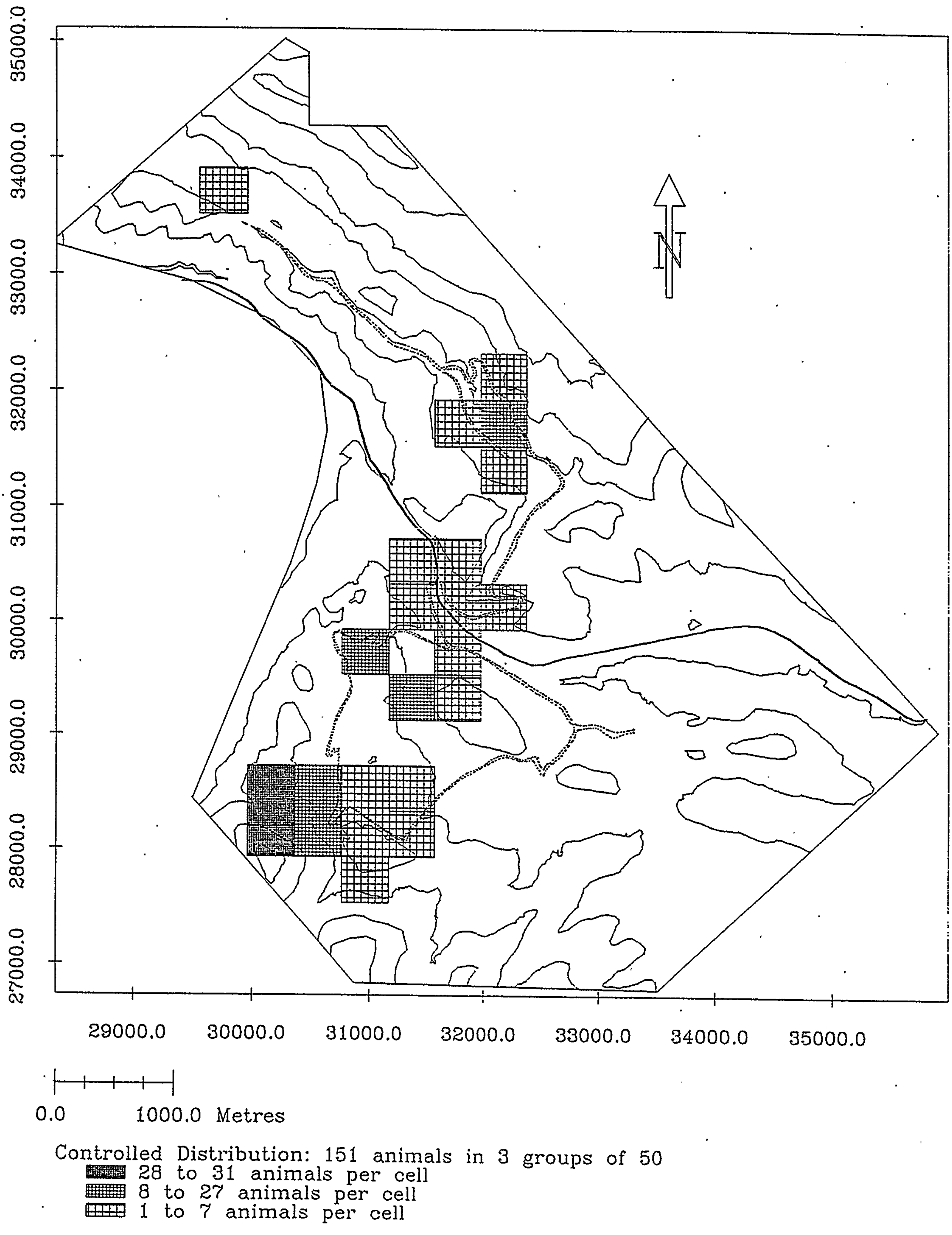


Figure 44. Intensity of use by class II, III, and IV rams at Cardinal River Coals Ltd. for the lambing, May 28 – June 30, 1986.

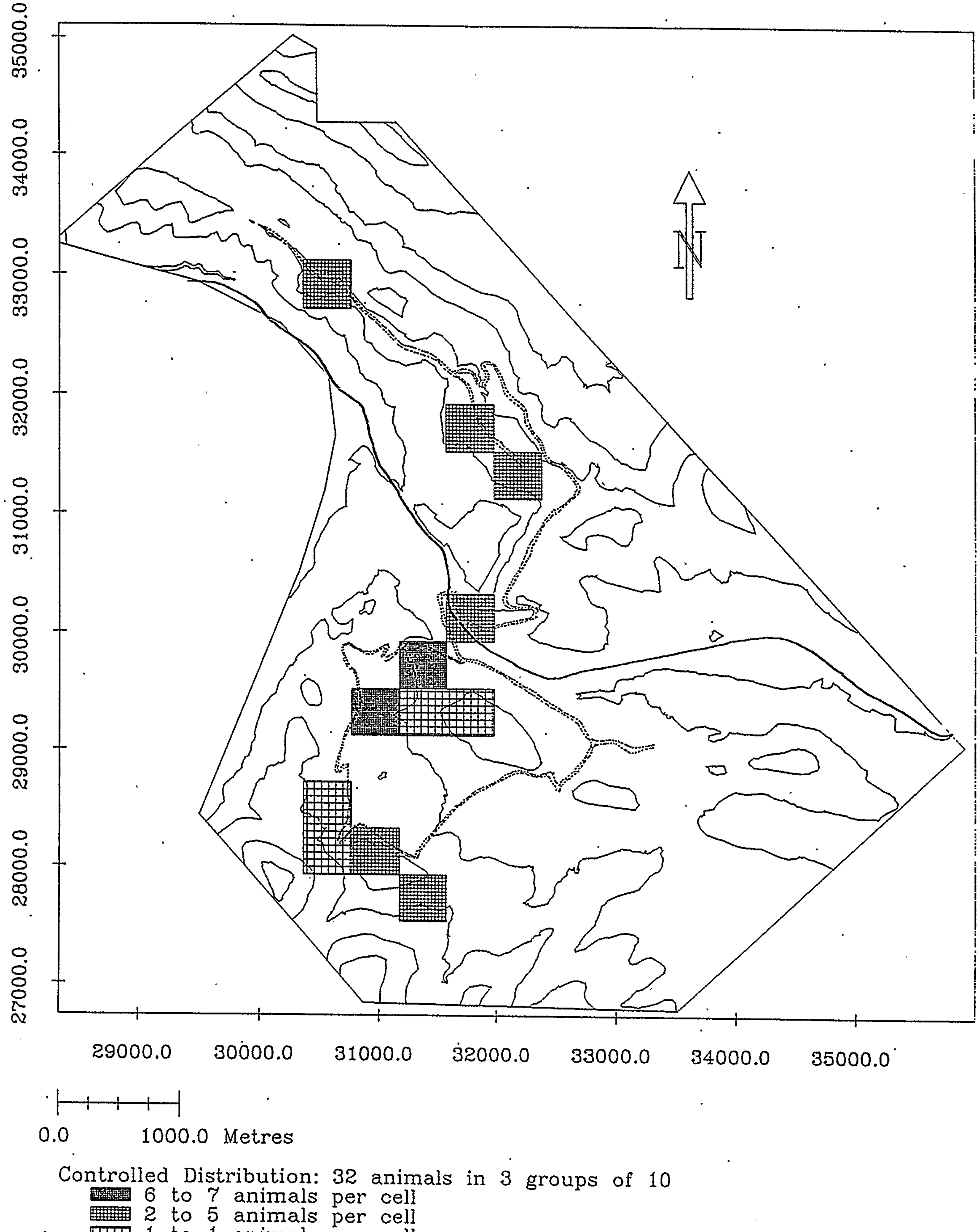


Figure 45. Intensity of use by class II, III, and IV rams at Cardinal River Coals Ltd. for the summer, July 1 – August 10, 1986.

APPENDIX V

BIGHORN SHEEP DISTRIBUTION ON THE PRINCIPLE WINTER RANGES AT CARDINAL RIVER COALS LTD.

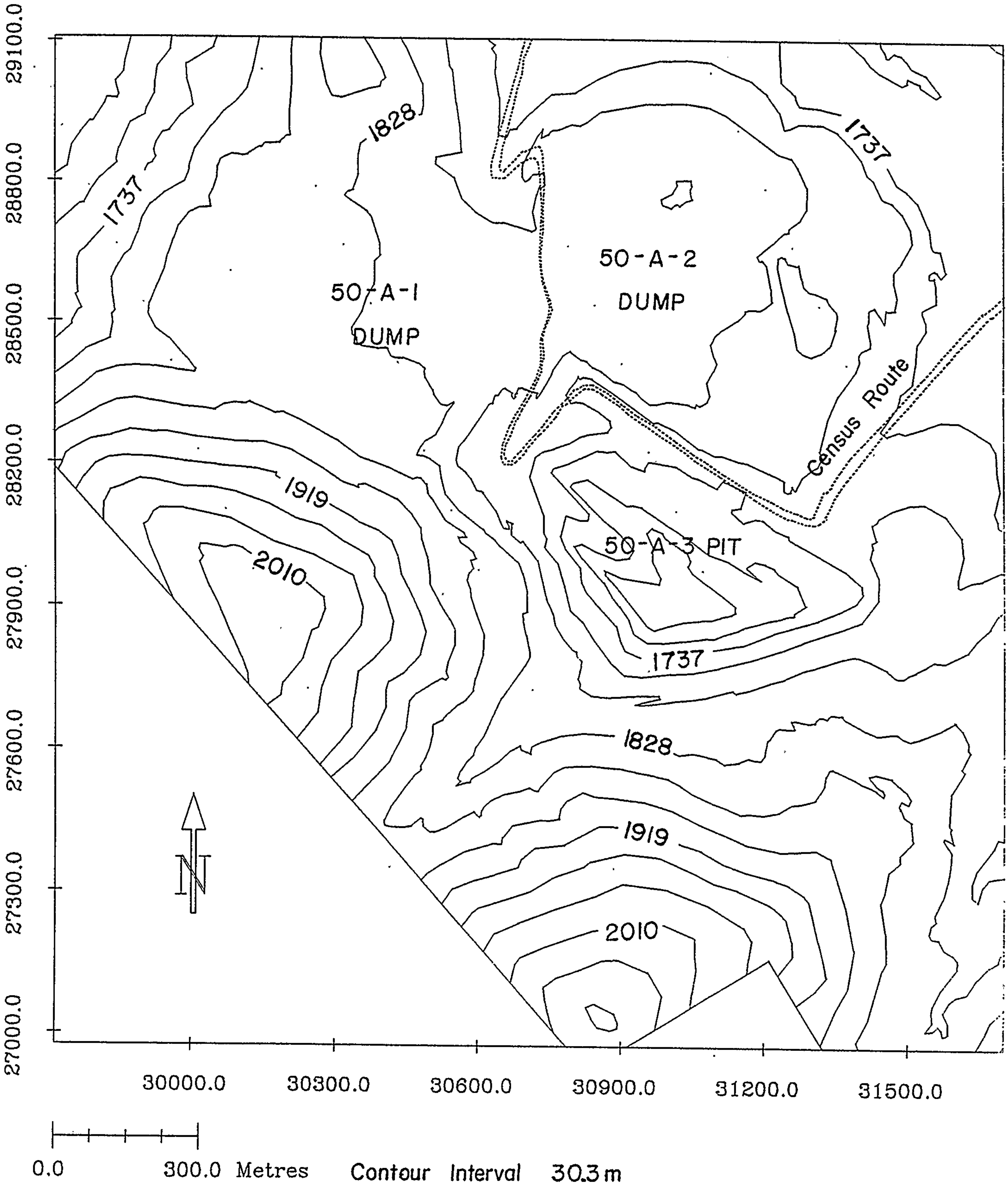


Figure 46. Base map of the 50-A-2 range with elevations and locations of the 50-A-1 and 50-A-2 dumps and the 50-A-3 pit.

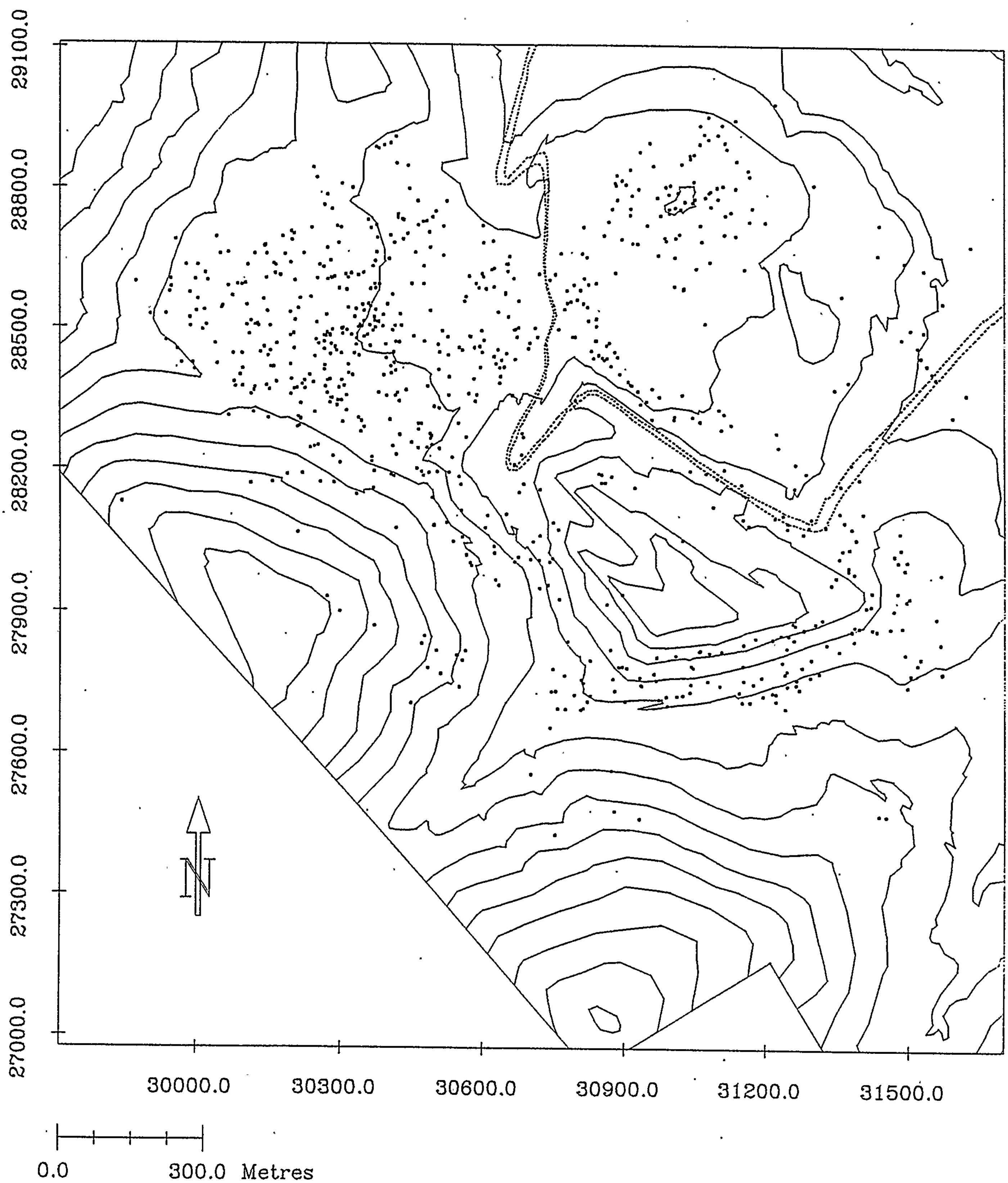


Figure 47. Bighorn sheep observation locations on the 50-A-2 range at Cardinal River Coals Ltd. for the year, September 17, 1985 - August 10, 1986.

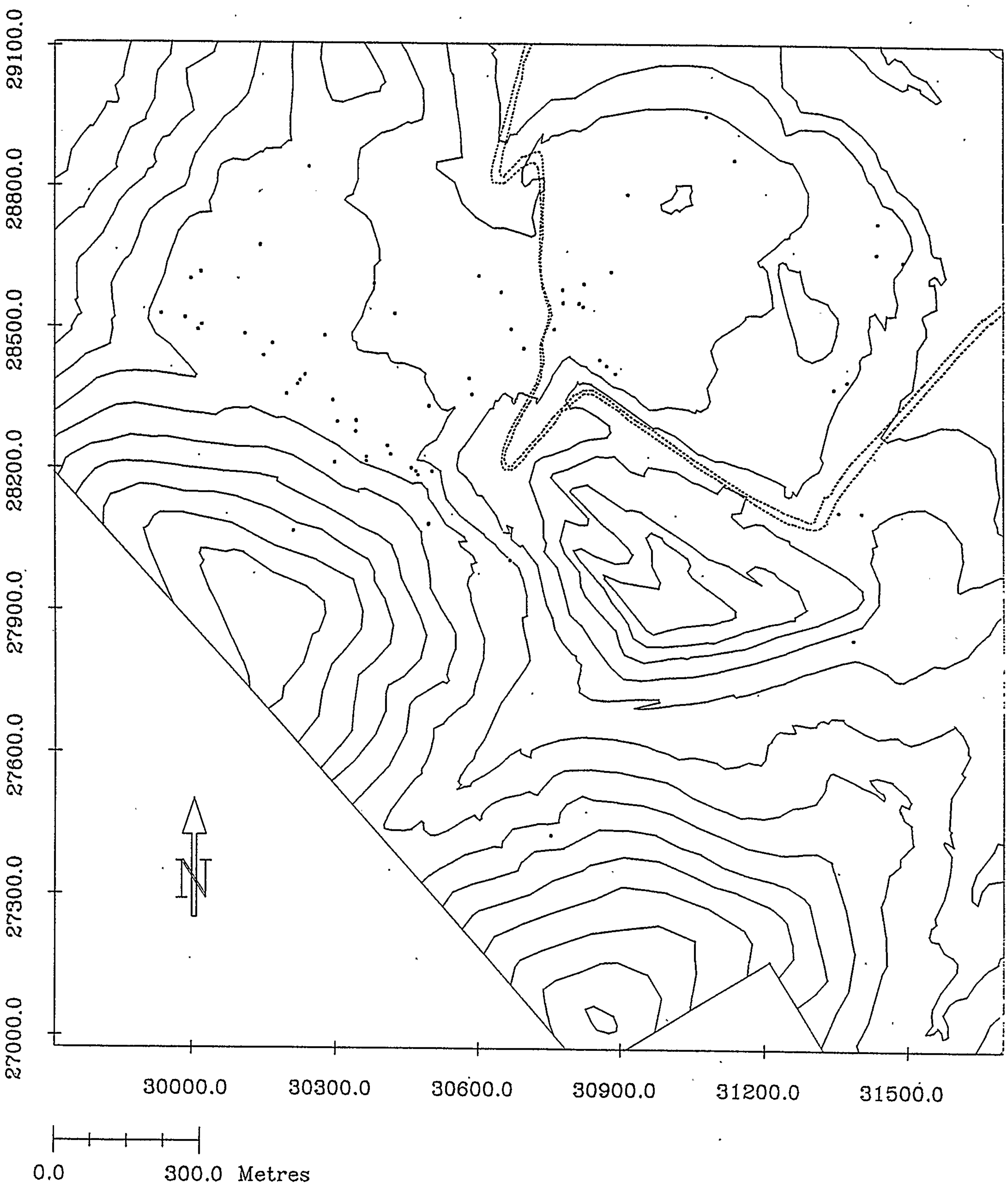


Figure 48. Bighorn sheep observation locations on the 50-A-2 range at Cardinal River Coals Ltd. for the prerut, September 17, 1985 - November 14, 1985.

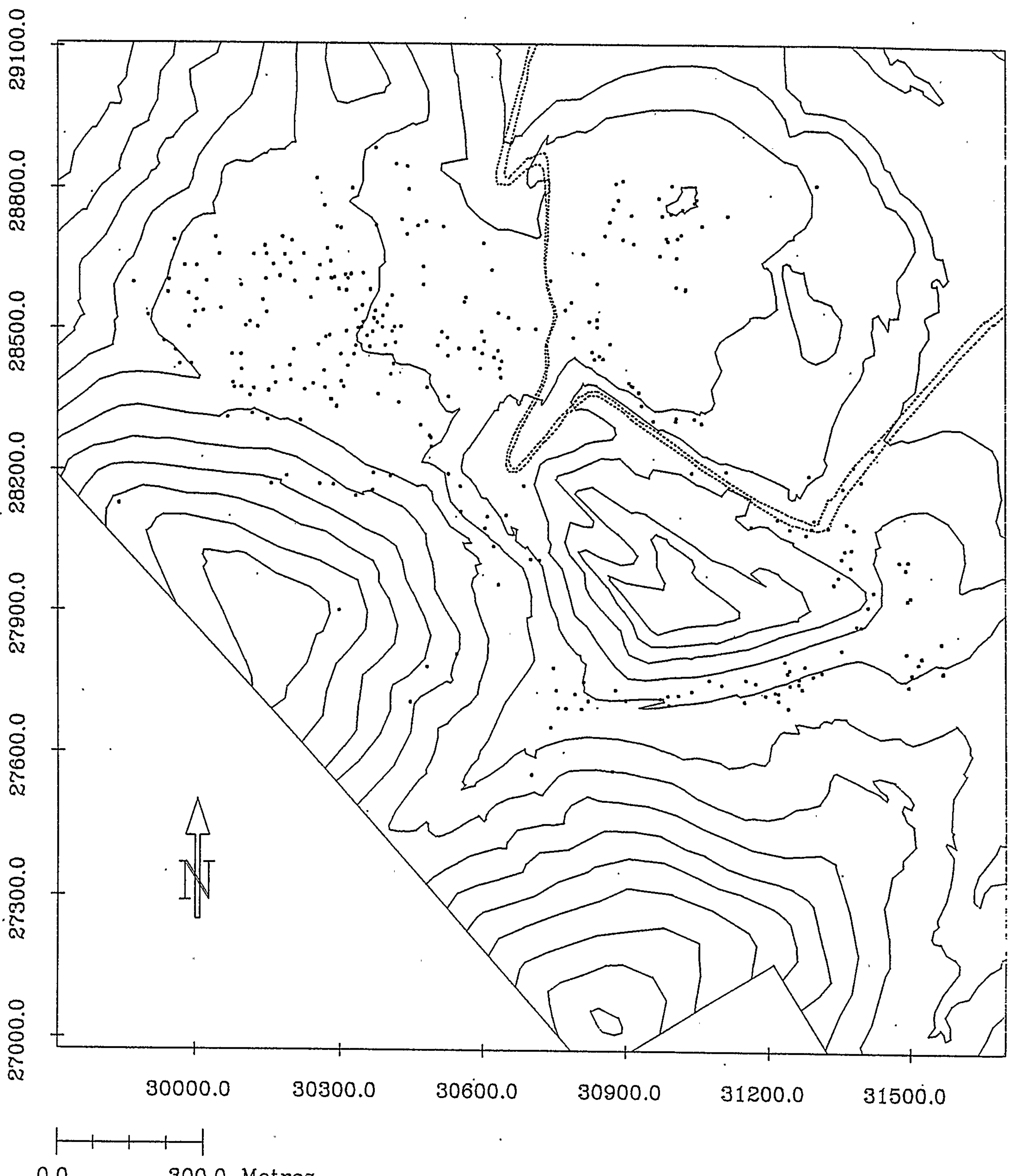


Figure 49. Bighorn sheep observation locations on the 50-A-2 range at Cardinal River Coals Ltd. for the rut, November 15, 1985 - January 18, 1986.

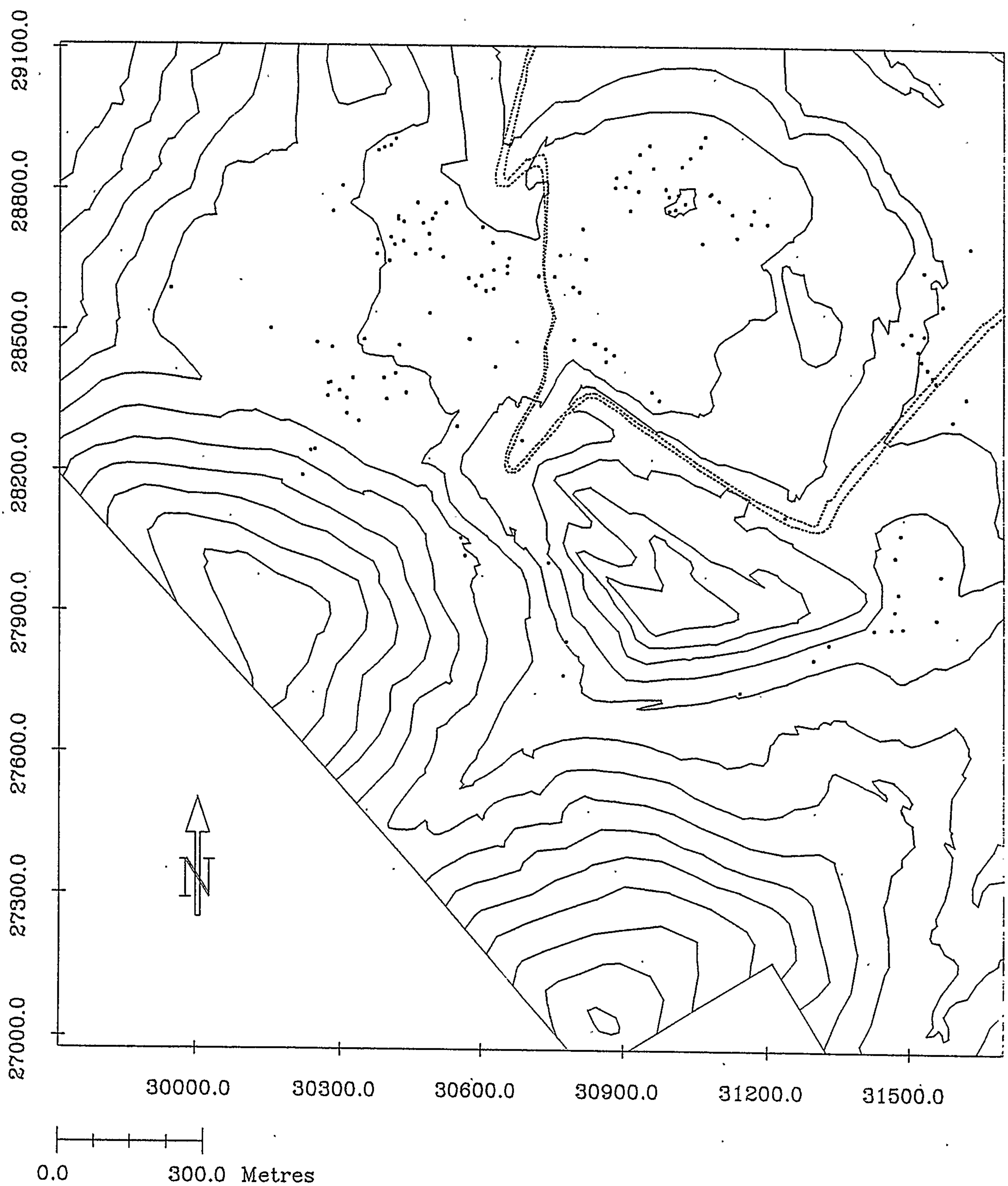


Figure 50. Bighorn sheep observation locations on the 50-A-2 range at Cardinal River Coals Ltd. for the winter, January 19, 1986 - February 14, 1986.

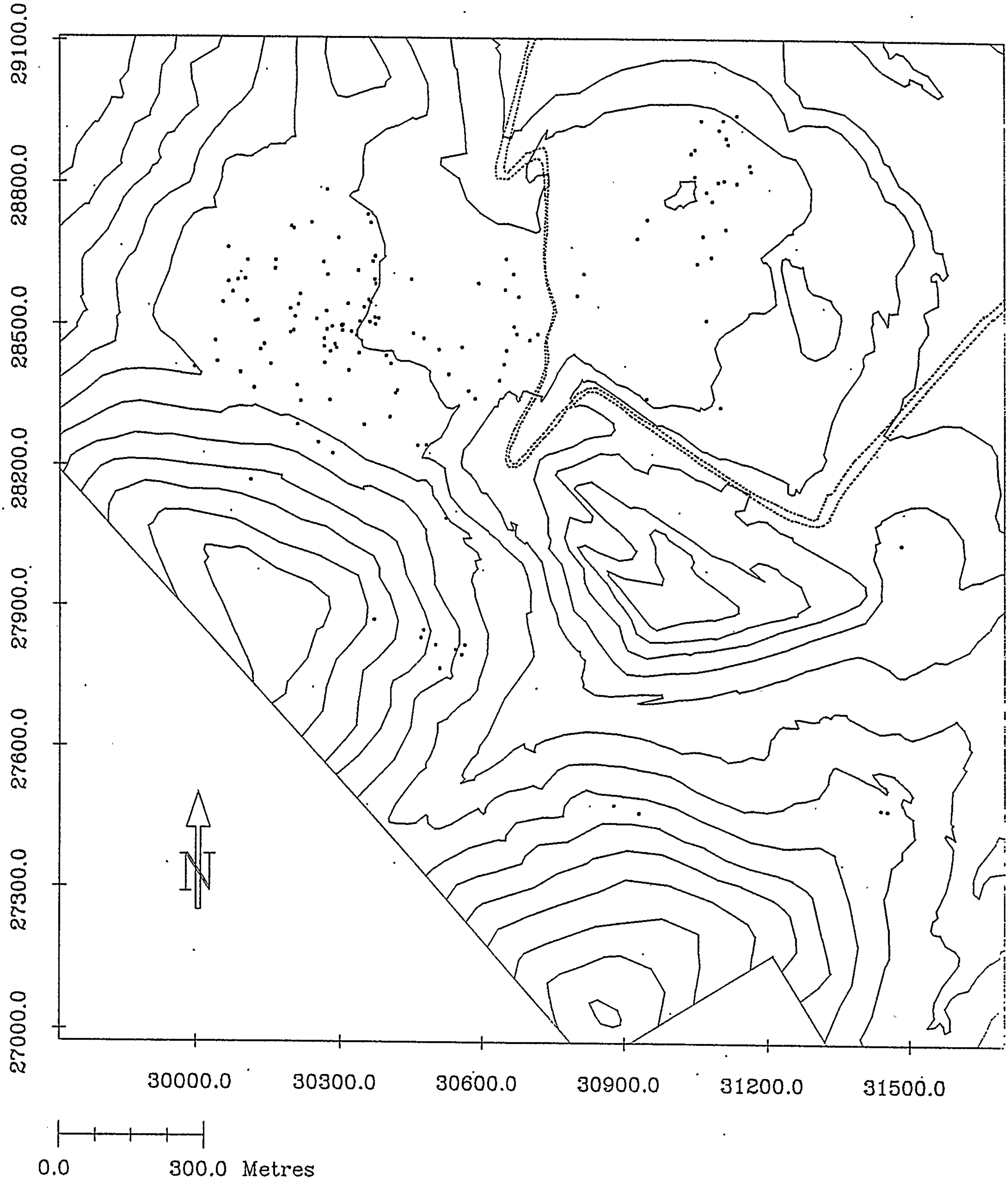


Figure 51. Bighorn sheep observation locations on the 50-A-2 range at Cardinal River Coals Ltd. for the spring, February 15, 1986 - May 27, 1986.

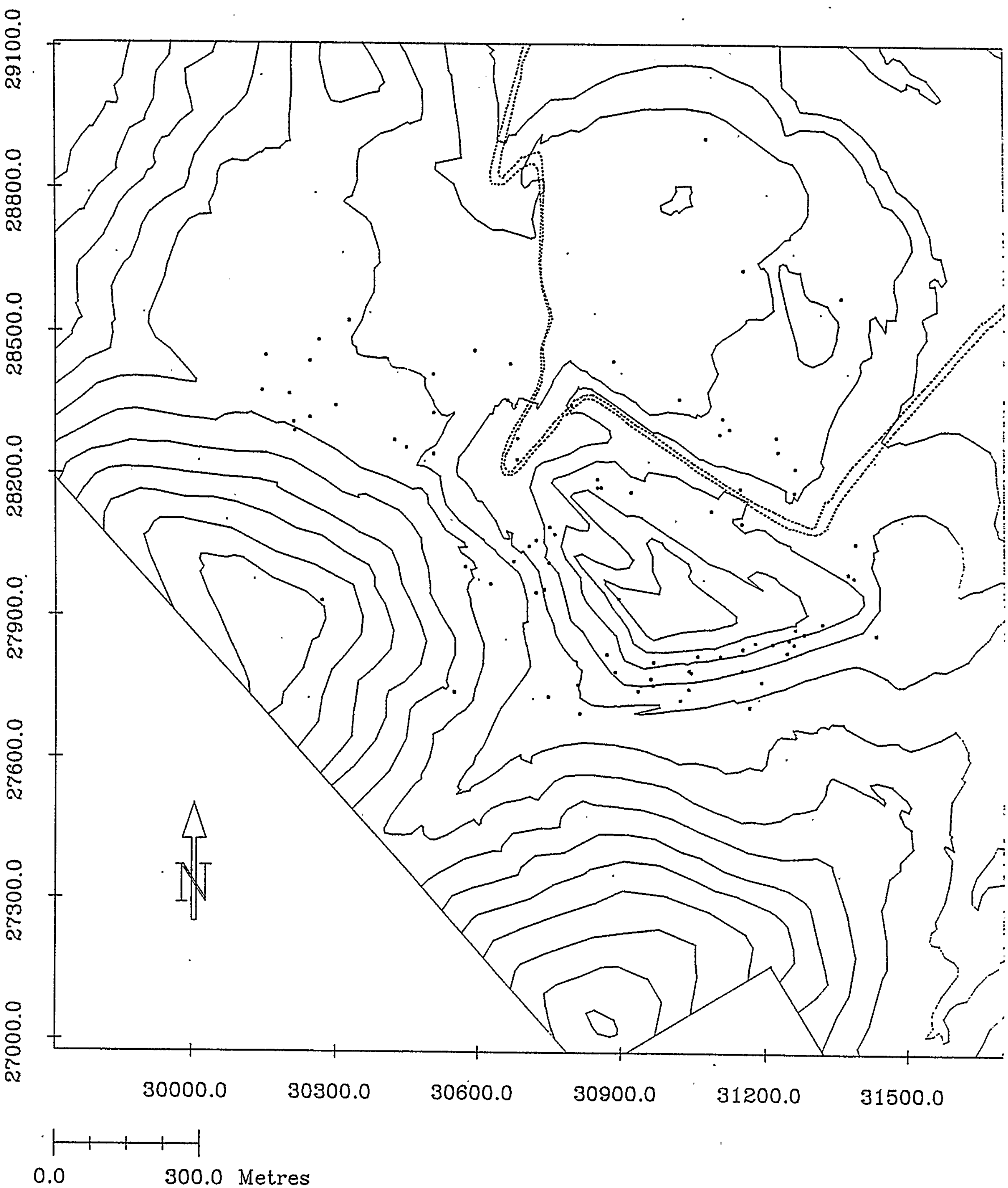


Figure 52. Bighorn sheep observation locations on the 50-A-2 range at Cardinal River Coals Ltd. for the lambing, May 28, 1986 - June 30, 1986.

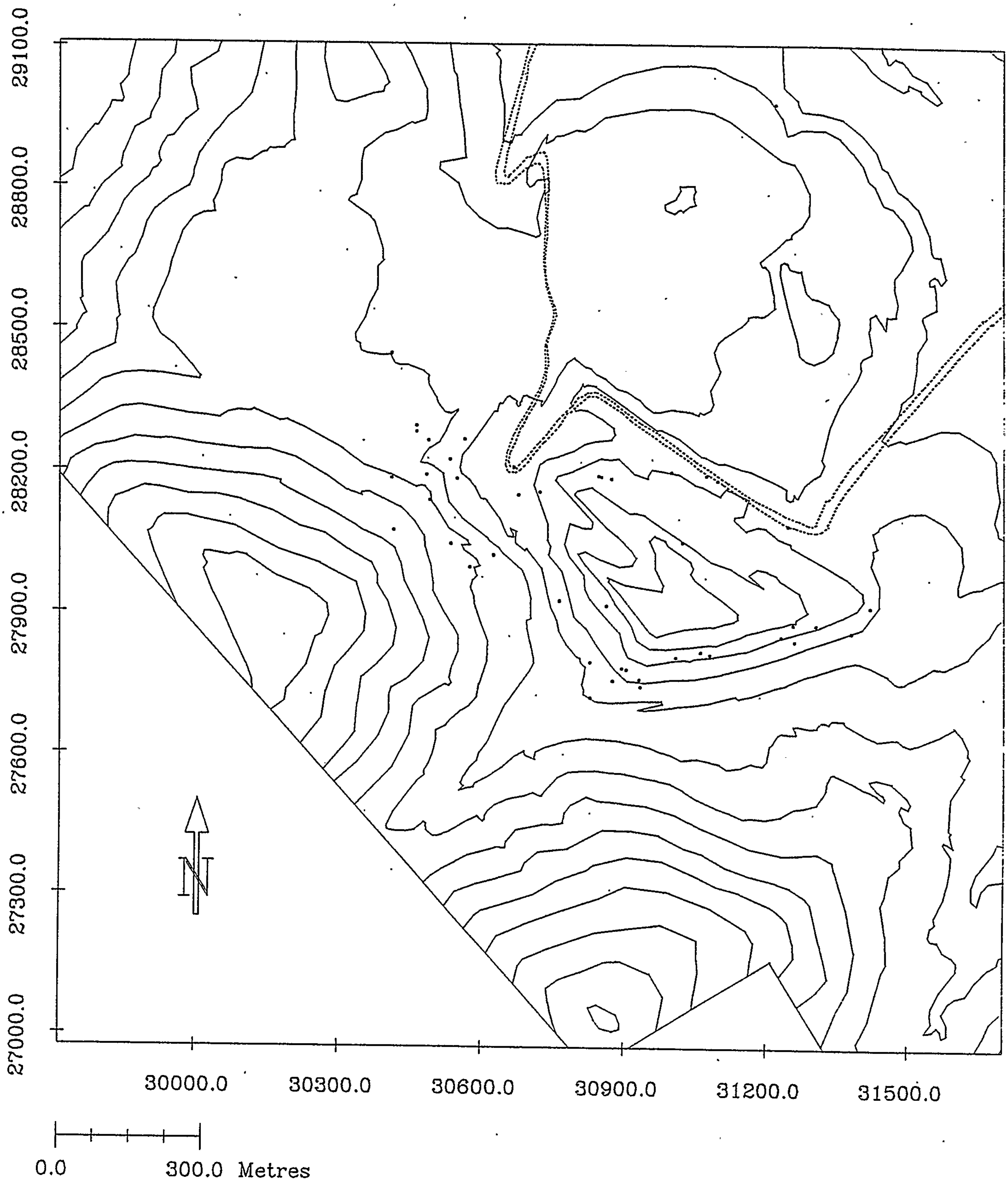


Figure 53. Bighorn sheep observation locations on the 50-A-2 range at Cardinal River Coals Ltd. for the summer, July 1, 1986 - August 10, 1986.

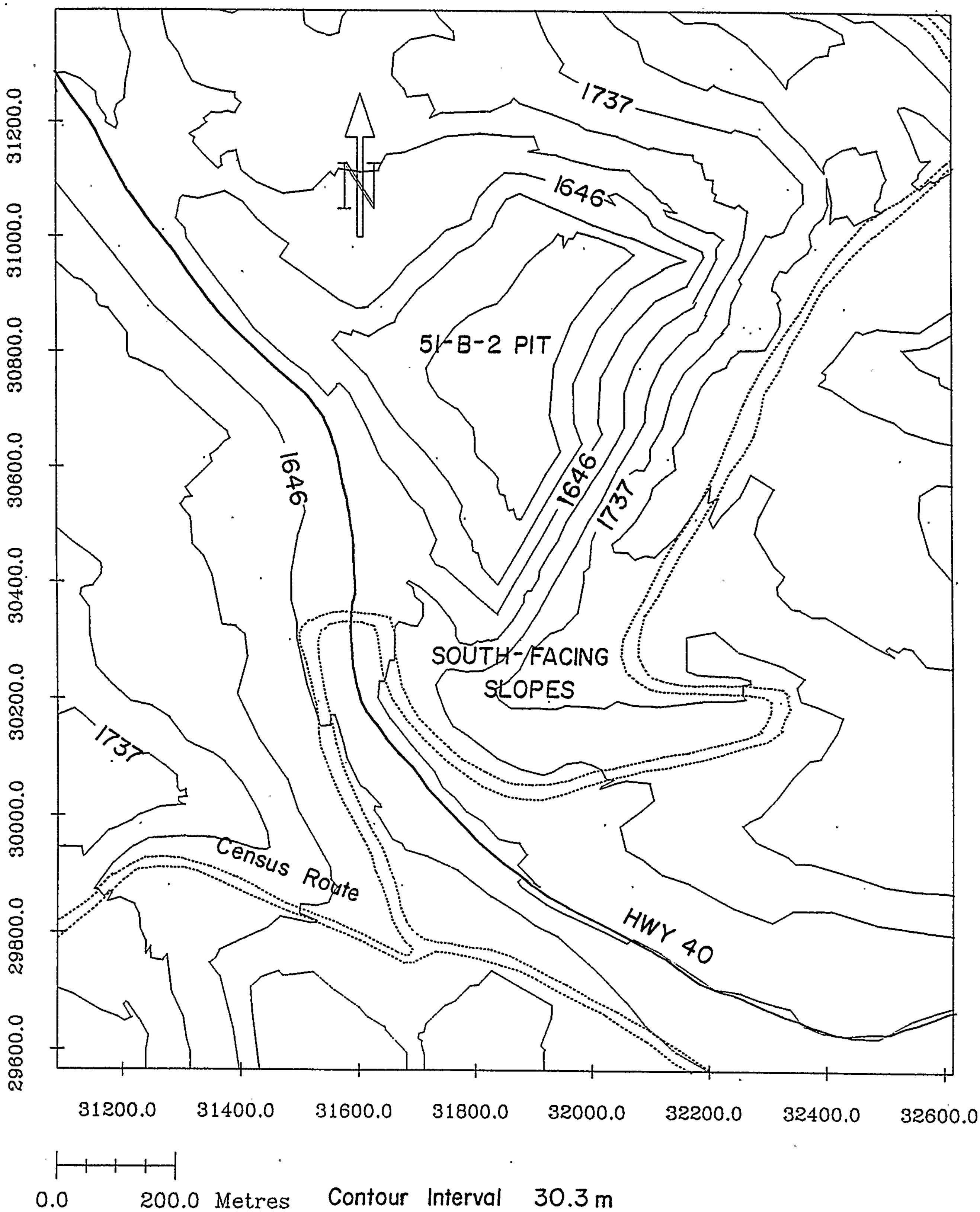


Figure 54. Base map of the 51-B-2 range with elevations and locations of the 51-B-2 pit and the adjacent south-facing slopes.

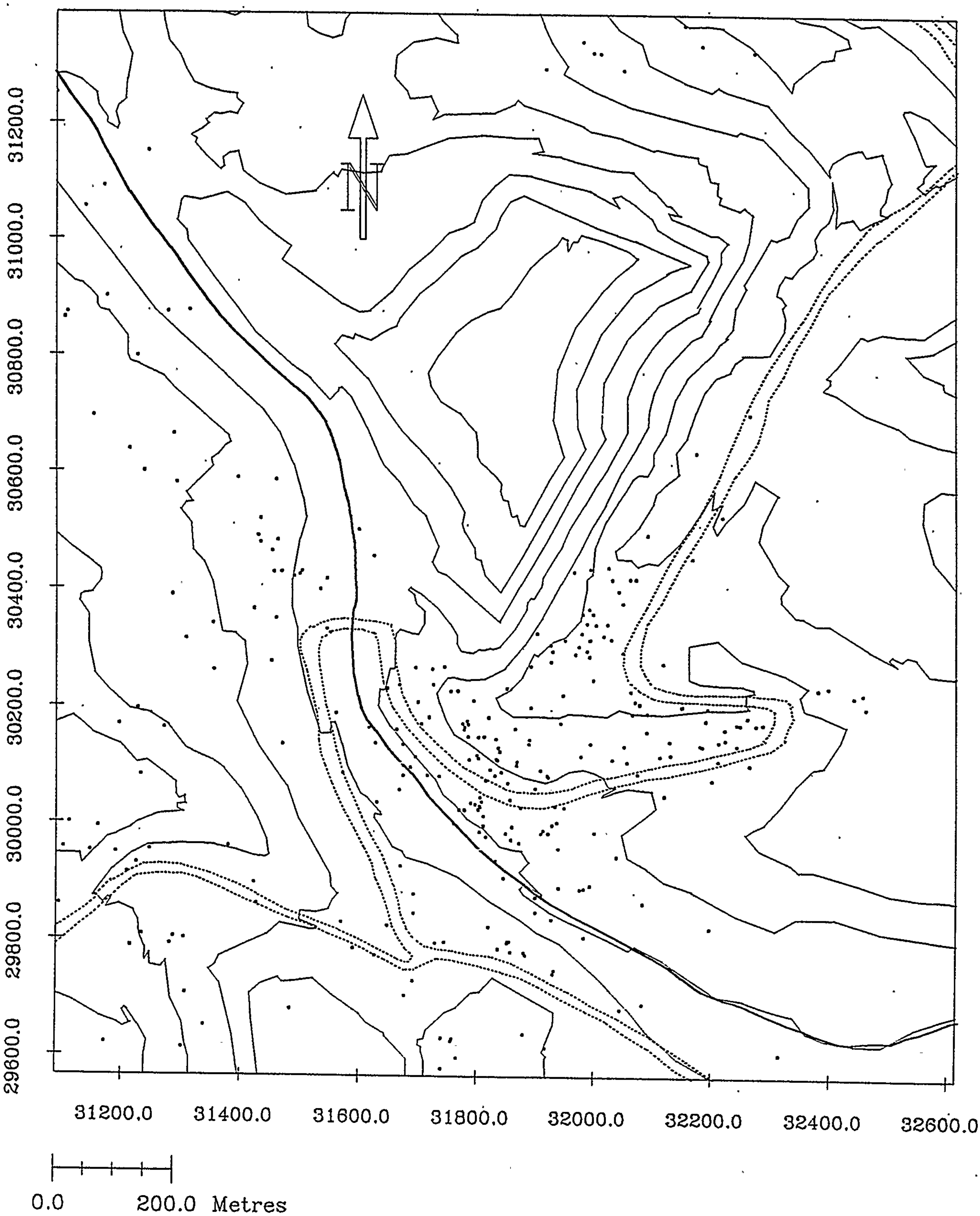


Figure 55. Bighorn sheep observation locations on the 51-B-2 range at Cardinal River Coals Ltd. for the year, September 17, 1985 - August 10, 1986.

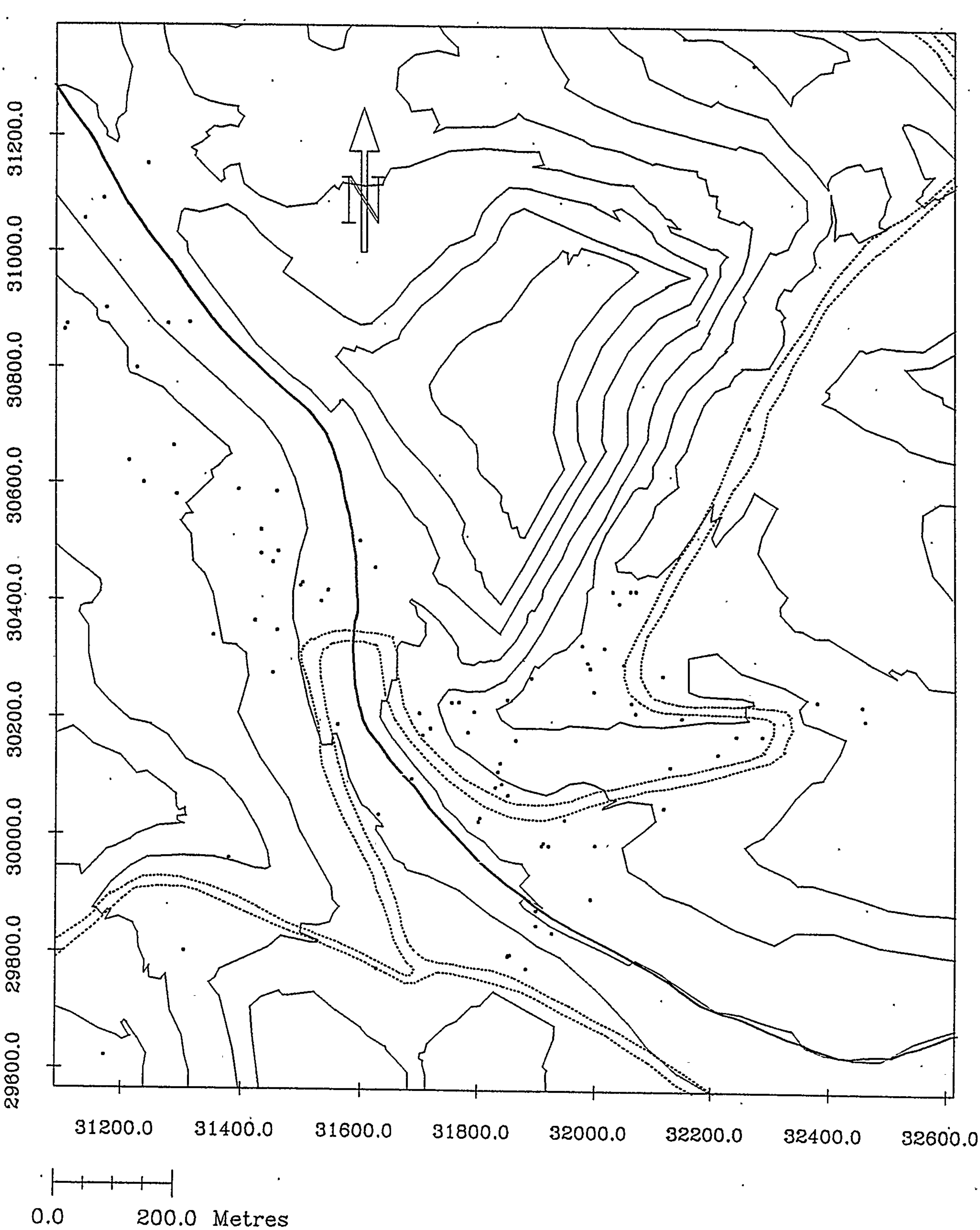


Figure 56. Bighorn sheep observation locations on the 51-B-2 range at Cardinal River Coals Ltd. for the prerut, September 17, 1985 - November 14, 1985.

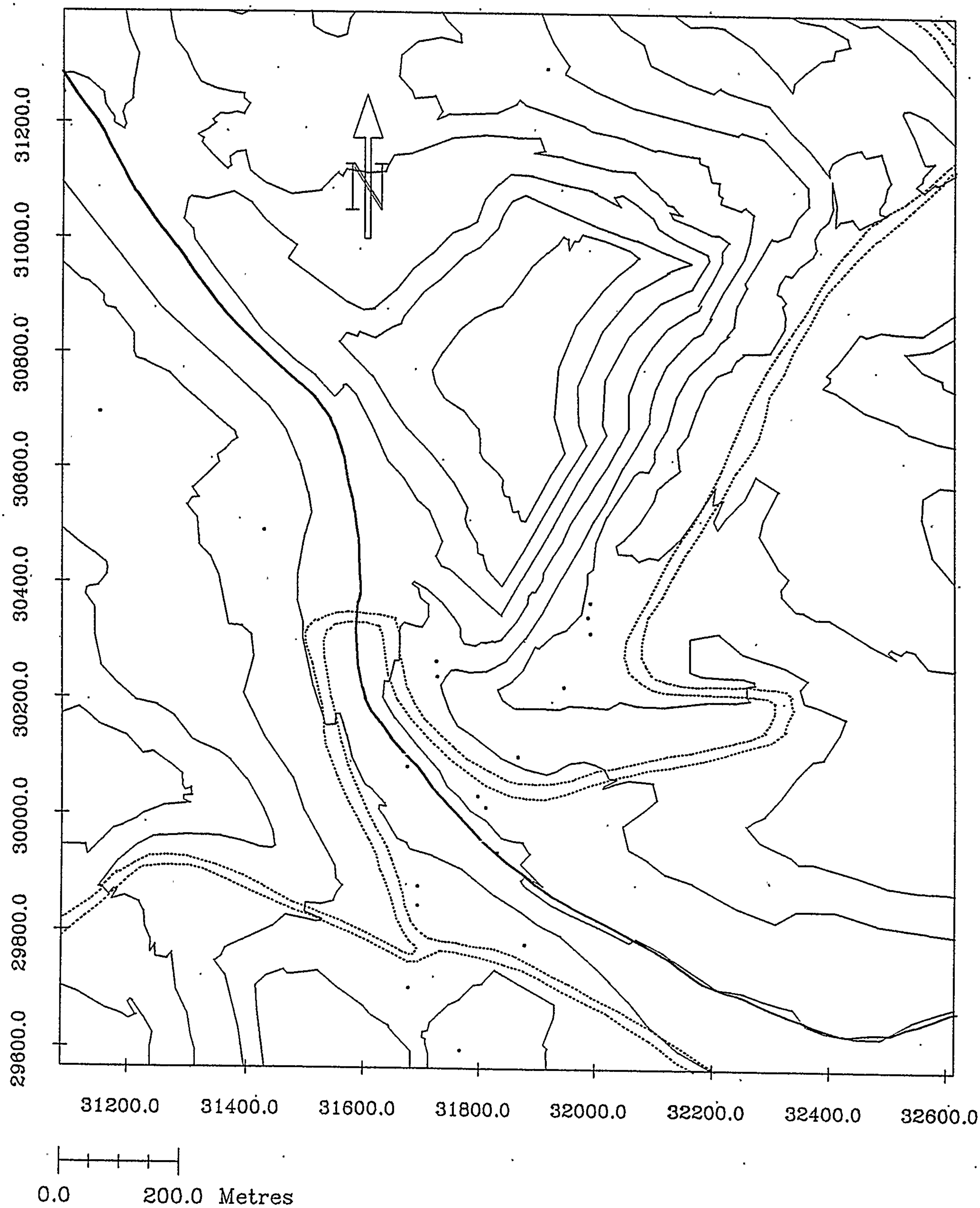


Figure 57. Bighorn sheep observation locations on the 51-B-2 range at Cardinal River Coals Ltd. for the rut, November 15, 1985 - January 18, 1986.

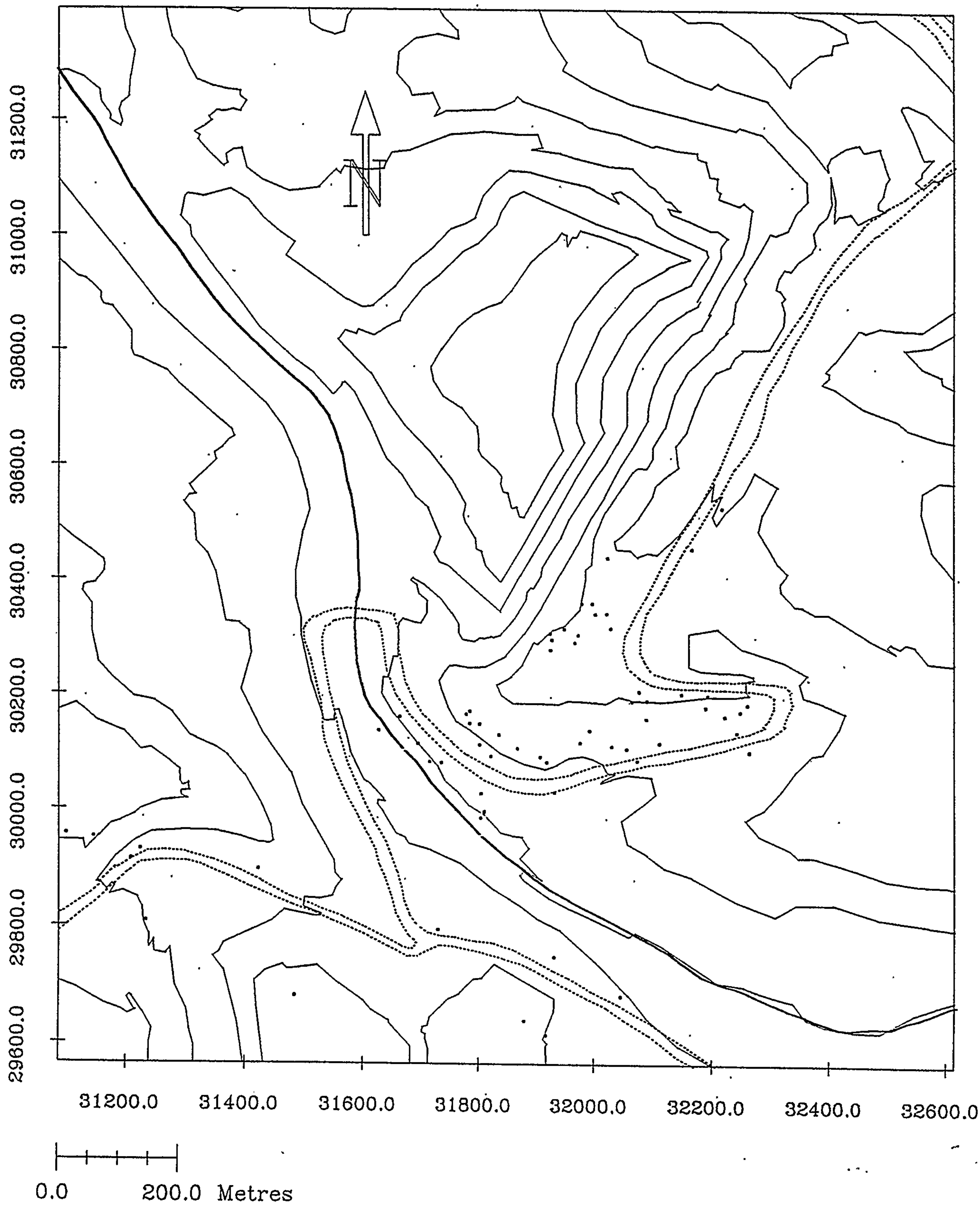


Figure 58. Bighorn sheep observation locations on the 51-B-2 range at Cardinal River Coals Ltd. for the winter, January 19, 1986 - February 14, 1986.

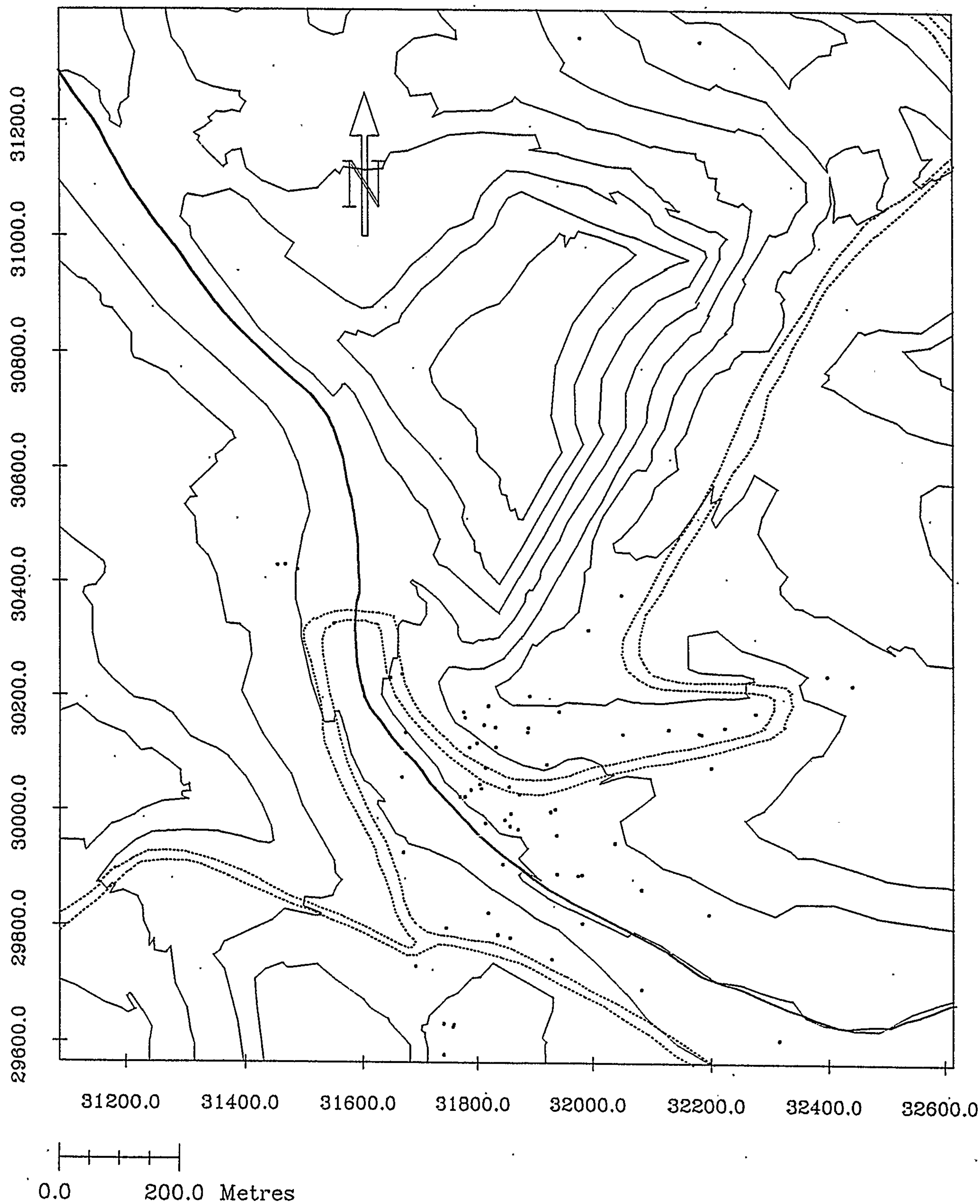


Figure 59. Bighorn sheep observation locations on the 51-B-2 range at Cardinal River Coals Ltd. for the spring, February 15, 1986 - May 27, 1986.

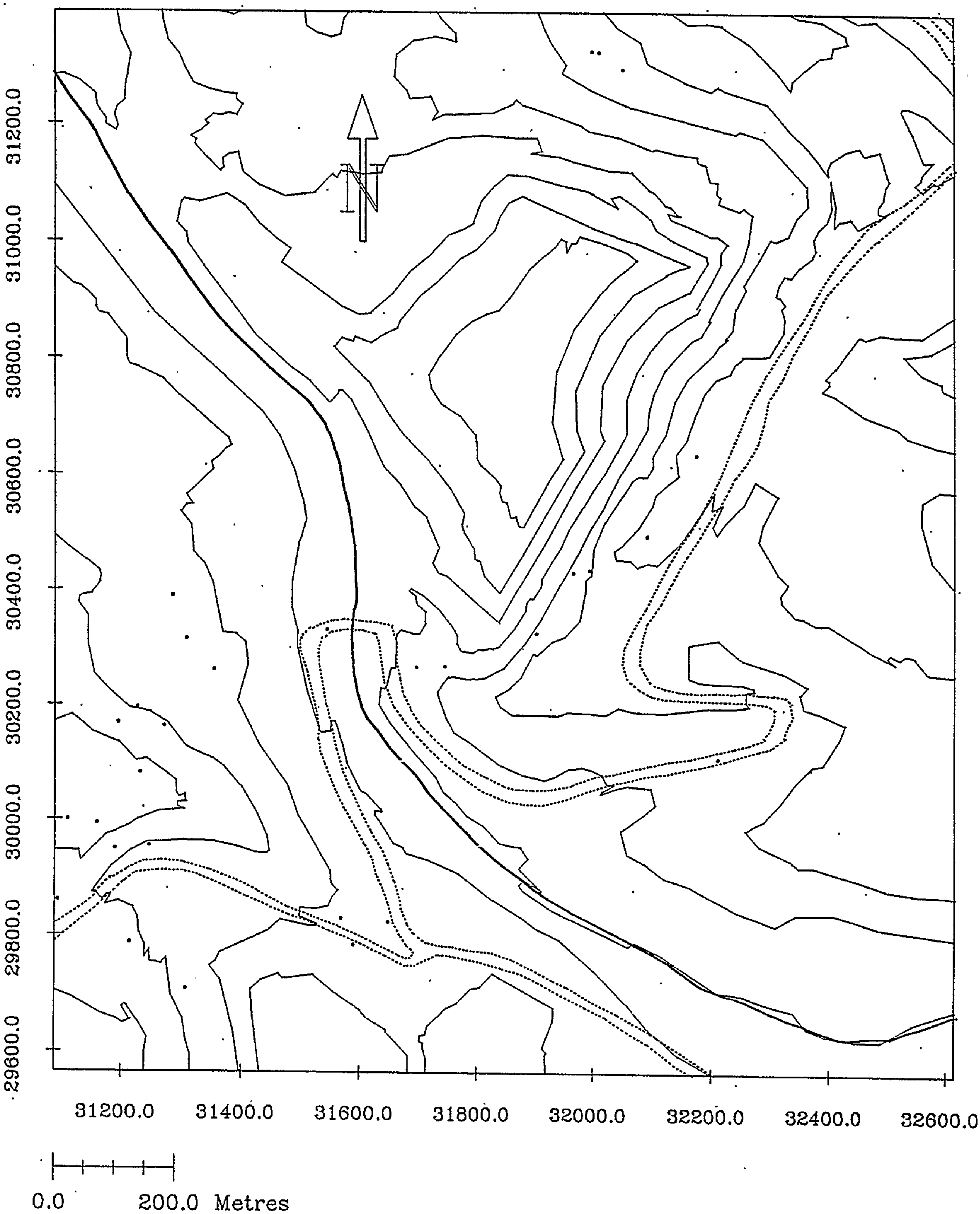


Figure 60. Bighorn sheep observation locations on the 51-B-2 range at Cardinal River Coals Ltd. for the lambing, May 28, 1986 - June 30, 1986.

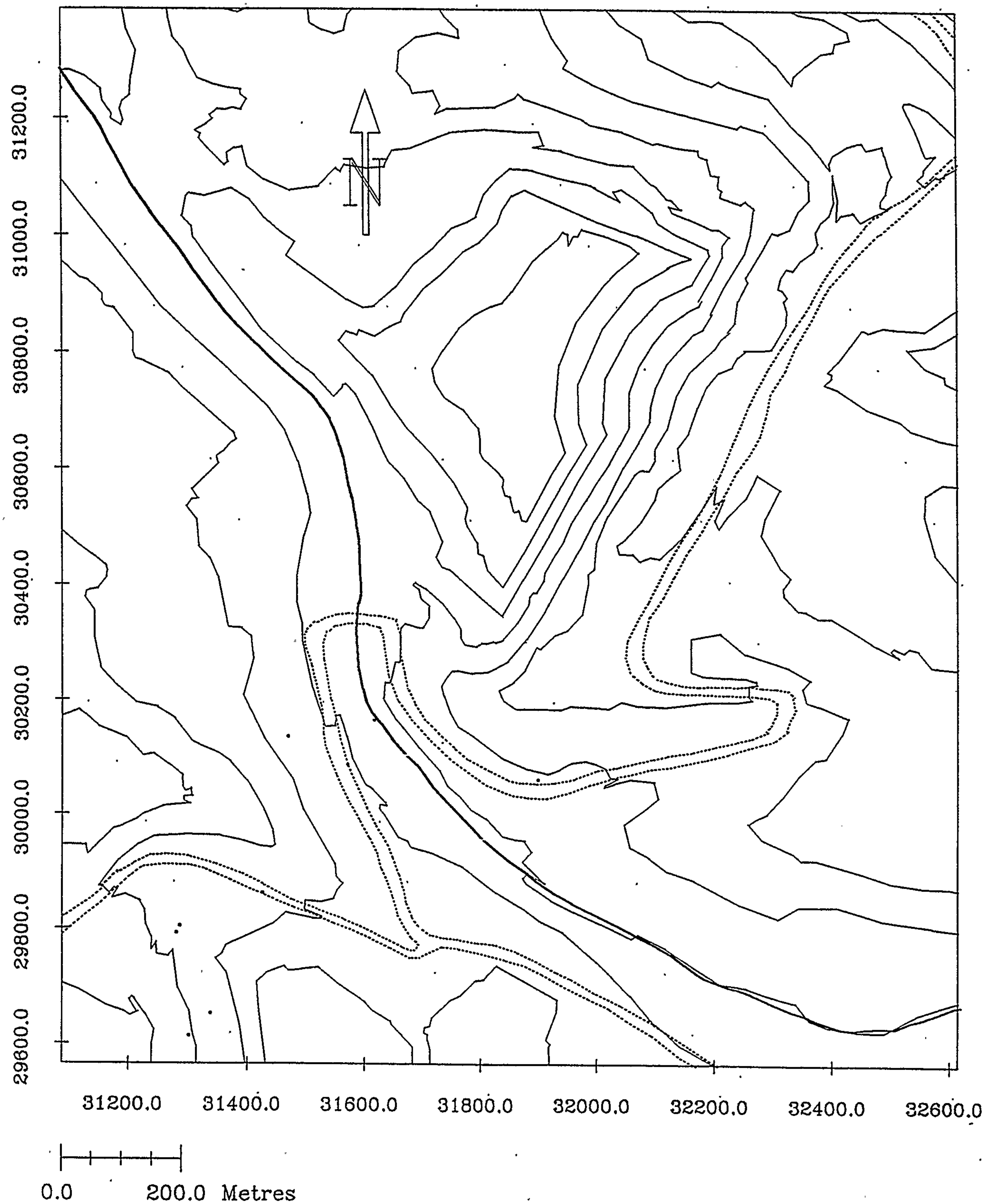


Figure 61. Bighorn sheep observation locations on the 51-B-2 range at Cardinal River Coals Ltd. for the summer, July 1, 1986 - August 10, 1986.