HABITAT ASSESSMENT

Delineating Ungulate Winter Range for Mountain Goats in North-central British Columbia

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ABSTRACT

This report describes the application of a mountain goat habitat model for use within the Mackenzie Forest District. The purpose of the work was to assist in the identification of ungulate winter ranges to insure the over-winter survival of mountain goats. The model was constructed as a Bayesian Belief Network and was previously applied to three study areas (Akie-Pesika, Osilinka, and Ospika) with historical relocations of radio-collared goats. The proposed goat ungulate winter range polygons within these study areas were modified to incorporate known mineral licks and trails. The model was then applied to the remaining areas of the Mackenzie Forest District. We identified a total of 96,248 ha as draft ungulate winter range within the three previous study areas, 0 ha of which occurred within an existing park. Of the 96,248 ha, 7,346 ha was composed of supplementary polygons drawn to incorporate known mineral licks and goat trails in order to add value to the UWR polygons. There was a further 541,169 ha identified as draft ungulate winter range in the remaining portions of the TSA, 113,015 ha of which was identified in parks. Due to insufficient knowledge of mineral licks and trails in this area, no supplementary polygons were delineated.

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INTRODUCTION

Under the auspices of the Forest and Range Practices Act of British Columbia (BC), the Government Actions Regulation[1] (GAR) authorizes the establishment of areas necessary for the over-winter survival of ungulates as Ungulate Winter Range (UWR). Ungulate winter ranges can be designated under a GAR provided that: 1) the designated area contains habitat necessary to meet winter habitat requirements for the specified species; 2) the habitat requires special management not otherwise provided for; and 3) an allowable impact on the timber supply is not exceeded. In the Mackenzie Timber Supply Area (TSA) of north-central British Columbia (BC), Government is pursuing the identification of UWRs to help insure the over-winter survival of mountain goats (*Oreamnos americanus*). Mountain goats are an important forest resource, are hunted regularly, and can be an important indicator of sustainable resource development (Hengeveld 2003).

Our objectives for this habitat assessment were to: 1) provide a general account of mountain goat ecology; 2) summarize existing information on the life history of mountain goats in the Mackenzie TSA; 3) describe the development of previous modeling efforts to identify mountain goat winter range; 4) augment previous model results for the Osilinka, Ospika, and Akie landscape units to include known mineral licks and associated trails; and 5) apply the model to identify important winter range habitat for goats over the remaining portions of the TSA.

This type of modeling approach has been used successfully in the past to make field reconnaissance more efficient than it would be otherwise (McNay and Sulyma 2003) and to make the selection of specific ungulate winter ranges transparent to affected land users (Schmidt and McNay 2002).

A GENERAL ACCOUNT OF MOUNTAIN GOAT ECOLOGY [2]

Habitat Use and Movement

General

Mountain goats occur primarily in high-altitude alpine and sub-alpine habitats although they sometimes descend to sea level in coastal areas. Throughout their range individuals generally remain above timberline, but they will move seasonally to lower elevations in response to winter conditions or to use mineral licks. Movements to low-elevation mineral licks often require mountain goats to traverse several kilometers through forested areas (Festa-Bianchet and Cote 2008).

In west-central BC, mountain goats use elevations that vary from 500 m to 2050 m (Demarchi et al. 2000). Schoen and Kirchoff (1982) found 90% of mountain goat annual habitat to be near treeline (~850 m) in Alaska. In coastal areas, goats will frequently

[1] http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/17_582_2004

[2] This text has been adapted from the discussion on "Mountain Goat Ecology" in *Mountain Goat Effectiveness Monitoring for North-central British Columbia* by McNay and Voller (2007)

travel to lower elevations to access forage and cover during winter (Fox et al. 1989; Taylor et al. 2004). Goats will also use forested areas to access low-elevation mineral licks from early spring to late fall (Hebert 1967).

In BC, goats tend to favor southerly aspects especially in the winter and spring (Jex 2004, Foster 1982, Turney et al. 2003, Taylor and Brunt 2003). Fox et al. (1989) found that goats in Alaska use more southerly aspects in the spring and a roughly even distribution of aspects in the summer. Mountain goats are generally found on slopes over 30^{o} (Smith1985, Turney et al. 2003, Taylor and Brunt, 2003) and use relatively steeper slopes in winter and spring (Fox et al. 1989, Taylor and Brunt, 2003). Pollard (2002) stated that the most important habitat feature in range selection was escape terrain. Broadly, escape terrain may be characterized by steep slopes between 25^{o} and 65^{o} with broken surfaces and rock outcroppings (Pollard 2002, Fox et al. 1989). Mountain goats usually remain within 400 m of escape terrain (Schoen and Kirchhoff 1982, Smith 1985, Fox 1983, Fox et al.1989, Turney et al. 2003).

Forage and Mineral Licks

Mountain goats vary their diet according to habitat. In some habitats they may feed almost exclusively on shrubs and supplement their diet with forbs, mosses and lichens. In other habitats, shrubs form only a small portion of the diet with the remaining forage being made up of grasses, rushes and sedges (Eder and Pattie 2001). Winter forage selection for mountain goats is restricted and consists primarily of browse species not covered by snow. Fox et al. (1989) suggested that up to 90% of mountain goats' winter diet consists of conifers, lichens and *Vaccinium* shrubs. During the early summer molt, salt becomes a necessity in the diet (Eder and Pattie 2001) and the pursuit of this mineral may require movements of several kilometres, often through forested areas (Festa-Bianchet 2008).

A mountain goat's diet of new-growth alpine vegetation may impair the absorption and retention of elements and reduces the digestive efficiency of the rumen (Cote and Festa-Bianchet 2003) (Parker and Ayotte 2004). Ruminants may use licks not only as sources of inorganic supplements deficient in the diet, but also to mitigate digestive disorders and elemental imbalances associated with the change from high-fiber winter forage to lush spring growth (Parker and Ayotte 2004).

Mountain goats will travel long distances on traditionally used trails, often through terrain where they are vulnerable to predation, to reach mineral licks (Cote and Festa-Bianchet 2003, Wilson 2005). Mineral licks are most often used in early spring and summer but have been observed to be used throughout the year (Hebert 1967, ASRD 2003). Parker and Ayotte (2004) found mountain goats in the Tuchodi area of north-central BC to increase attendance at a lick in early July with another peak of use occurring in early August. Wood (2005) found that some goats showed a high fidelity for a single mineral lick while others alternated between several licks.

Movement and Range

Mountain goats generally remain above the treeline throughout the year with minor movements between areas of escape terrain. Larger movements, often along traditional trails, take place between summer and winter ranges (Cote and Festa-Bianchet 2003,

Wilson 2005), to natal ranges, and to low elevation mineral licks (Festa-Bianchet 2008). Males will often travel long distances during the rut to find multiple mates.

In several studies, mountain goats have been observed to have relatively strong fidelity to their individual home ranges (Smith 1986 in Peek 2000, Fox et al. 1989, Taylor et al. 2004). Peek (2000) stated that mountain goats in Washington, especially females, demonstrated a strong site fidelity to seasonal ranges. Peek (2000) found that 84% of mountain goats returned to the same summer range; some for up to 10 years. Fox et al. (1989) found that adult males had larger home range sizes then females as well as more distinct seasonal ranges. In the Kingcome River Drainage in coastal BC, Taylor et al. (2004) reported average annual home range sizes of 295 ha and 543.8 ha for females and males, respectively.

Most recorded long movements made by mountain goats were associated with seasonal movements characterized by altitudinal changes up to 5000 ft (1524 m) and distances more than 24 km (ASRD 2003). Fox et al. (1989) found that during the rut, male goats often made movements which encompassed many female home ranges. These excursions by males frequently involved movements across forested valley bottoms (Smith and Raedeke 1982) where they were more susceptible to predation. Fox et al. (1989) reported that mean distances between summer and winter home ranges for males and females were 2.9 and 2.2 km respectively. They note that these distances were less than reported by other studies and may have been due to the high quality of the goat habitat in their study area or to movement barriers created by glaciers. Males often migrate first, followed by females when kids are strong enough (Brandborg 1955, Smith 1976).

Natal ranges are used during birthing, and for up to 2 weeks following birthing, after which solitary females and kids will group into nursery bands on the summer range (Wilson 2005) (Cote and Festa-Bianchet 2003). The natal range usually consists of rocky outcrops, cliffs and ridges at high elevations (Fox et al. 1989, Cote and Festa-Bianchet 2003).

Survival and Mortality

Similar to other ungulates, survival rates for mountain goats are generally lower and more variable in their first year of life (Cote and Festa-Bianchet 2003). Festa-Bianchet *et al.* (1994) found that goats up to 4 years had mean annual survival rates of only 29% for males and 34% for females.

In Alaska during mild winters, Smith (1986 in Peek 2000) found that goats from 2-8 years of age were moderately invulnerable to natural mortality causes. In Alberta, Festa-Bianchet *et al*. (2003) found high mean annual survival rates for adult females 4 years and older (S=0.92).

Smith (1986 in Peek 2000) found that annual mortality for yearlings was 29% and goats >9 years-old had an annual mortality rate of 32%.

Causes of Mortality

Mortality of mountain goats may be due to predation, accident, starvation, human activities, parasites, or disease. Predation is thought to be the most significant mortality source as several studies indicate it is the leading cause of death for young goats (Smith et al. 1992, Festa-Bianchet et al. 1994, Peek 2000). Cote and Festa-Bianchet (2003) assert that predation effects on the population of mountain goats may be density independent and that a single predator that specializes on mountain goats may have a large impact on a herd. Wolves (*Canis lupus*) have been found to be a major cause of death in several studies where their ranges overlap (Festa-Bianchet et al. 1994, Fox and Streveler 1986). In Alberta, grizzly bears (*Ursus arctos*) were thought to be a significant predator of mountain goats (ASRD 2003). In some studies, cougars (*Puma concolor*) were the predator most likely to impact mountain goat herds (Brandborg 1955, Rideout and Hoffmann 1975, Johnson 1983). Cote and Festa-Bianchet (2003) cited studies that indicated increased predation of goats in forest habitat due to ambush predators. Other predators of goats include black bears (*Ursus americanus*), wolverines (*Gulo gulo*; Cote and Festa-Bianchet 2003) and eagles (Smith 1976, Brandborg 1955).

Accidents such as avalanches and falls are thought to be a considerable mortality factor for mountain goats (Fox and Streveler 1986, Brandborg 1955). However, in the Alberta Goat Management Plan (ASRD 2003), the significance of accidental death was thought to be overstated because it is more easily identified compared to other mortality causes.

Starvation and malnutrition may be a significant contributor to mortality by making mountain goats vulnerable to other forms of mortality (Wigal and Coggins 1982). Wilson (2005) considered malnutrition to be related to severe winters. Adams and Bailey (1982) correlated low kid:nanny ratios to snowfall. Delay of first age of breeding, reabsorption of the fetus, and decreased maternal care may all be related to malnutrition (ASRD 2003).

Disturbance by humans may be a significant contributor to mortality by increasing stress levels. Mountain goats generally do not habituate well to human disturbance (Geist 1978) and extended periods of stress can cause organ damage, decreased viability and early death (Geist 1978). Cote (1996) in Alberta and Goldstein et al. (2005) in Alaska found helicopter activity disturbed mountain goats, especially when it occurred within 500 meters. Sopuck (1985) found that in northeast BC, mountain goats were displaced from areas within 1.5 km of a coal mine. However, in some studies, human-caused disturbance did not lead to home range abandonment (Joslin 1986, Foster and Rahs 1985). In one herd however, Joslin (1986) did find that these activities seemed to coincide with a decrease in the number of females and kids as well as reduced productivity.

Mountain goat populations are vulnerable to over-harvest (Cote and Festa-Bianchet 2003, Gonzales Voyer et al. 2003). Gonzales Voyer et al. (2003) state that populations of mountain goats are probably more effected by harvest than other ungulates because of low recruitment and the fact that both sexes are harvested. Sustainable annual harvest of natural populations is estimated to be less than 5% (Gonzales Voyez et al. 2003, Ayotte 2005).

Population

In BC, mountain goats may be found on almost all mountain ranges except for those on the coastal islands (Province of BC 2000). It is estimated that there are approximately 50,000 mountain goats in BC and 75,000 – 100,000 in all of North America (Province of BC 2000).

Mountain goat population densities vary throughout their range. Demarchi et al. (2000) reported that the population density of mountain goats in their west-central BC study area was 0.7 goats/km^2. In the north-east Kootenays, Poole (2002, 2003) reported goat densities between 0.24 goats/km2 and 0.77 goats/km^2. Goat densities in south-east Alaska averaged 1.5 goat/km^2 (Fox et al.1989).

Herd Composition

Male and female mountain goats live in different groups except during the rut (Geist 1964, Chadwick 1977). The males either live individually or in groups of 2 to 6 except in the spring when the groups can expand up to 15 individuals (Chadwick 1977). The females live in nursery groups which include kids, yearlings and 2-year-olds of both sexes as well as the adult females; the size of these groups varies with the season and the size of the population (Chadwick 1977).

Cote and Festa-Bianchet (2003) found adult female mountain goats to be the most dominant and aggressive age-sex class except during the rut. Size did not influence the hierarchy and rank was based on age; the older the female the higher the rank. Cote (2000) stated that the only way to move up in the social hierarchy of mountain goats was to survive.

Female mountain goats generally produce one kid, although both twins and triplets have been reported. Females reach reproductive age between 2 – 7 years of age. In Alberta, females on average bore young at 4 to 5 years old (Cote and Festa-Bianchet 2001a). Houston et al. (1989) reported that some studies indicated a body mass of 70 kg must be attained before females could become sexually mature. Cote and Festa-Bianchet (2001a) found that the proportion of females that produced kids increased yearly up to 9 years of age after which it decreased again. They also found that there was an increase in kid production with age-specific social rank. Although inconclusive, available data suggests that twinning is more common in introduced and expanding populations and therefore, the number of kids produced per female may be density dependent (Cote and Festa-Bianchet 2003). The average percent of kids in Alberta and Kootenay population ranges from 16 – 28% (ASRD 2003, Poole 2002).

Kid sex ratio begins at 1:1, but due to the high mortality of males this ratio soon changes (Cote and Festa-Bianchet 2003). Data on sex-age structure from Caw Ridge, Alberta indicated that on average yearling males represented 6% of the population, yearling females 8%, adult males 18% and adult females 45% of the total sample (ASRD 2003).

STUDY AREA

The Mackenzie TSA, located in north-central BC, is 6.1 million hectares in size. Williston Reservoir, the most prominent feature of the landscape, was created as a result of the WAC Bennett Dam in the 1960s (Figure 1) and runs northwest to southeast through the Rocky Mountain Trench bisecting the southern half of the TSA.

Prior to hydro-electric and forest development, the TSA was occupied primarily by Carrier (Tsay Keh Dene) and Sekani (Kwadacha) First Nations and by gold miners occupying small communities west of the Parsnip River.

A variety of parks, ecological reserves and protected areas occur in whole, or in part, within the TSA. The most notable in size are the provincial parks and associated protected areas: Omineca, Tatlatui, Kwadacha Wilderness, Chase, Finlay-Russel and Dune Za Keyih.

Williston Reservoir lies within the Rocky Mountain Trench, with the more rounded Omineca Mountains to the west and the Rocky Mountains to the east. Most of the TSA is characterized by diverse mountainous terrain, although the southernmost portion is distinguished by low rounded hills, broad valleys and numerous lakes and wetlands. The climate is continental-temperate to sub-boreal with average daily temperatures below freezing for half the year. Approximately three-quarters of the annual precipitation falls as snow.

Forests are primarily mixed stands with the predominant commercial species being Engelmann spruce (*Picea engelmannii*), white spruce (*Picea gluaca*), lodgepole pine (*Pinus contorta*) and subalpine fir (*Abies lasiocarpa*). Several deciduous species such as birch (*Betula papyrifera*) and aspen (Populus tremuloides) are also present; however, commercial utilization is on a small scale.

Five biogeoclimatic (BEC) zones (Meidinger and Pojar 1991) occur on the Mackenzie TSA[3]. These BEC zones are generally described as follows:

- Boreal Altai Fescue Alpine (BAFA) is dominated mostly by rock, ice and snow with vegetation limited to shrubs, herbs, mosses, lichens and dwarf trees
- Engelmann Spruce – Subalpine Fir (ESSF) is a forested mid-elevation zone occurring below the BAFA in the southern portion of the TSA. Spruce and fir are the dominant species although lodgepole pine occurs on drier sites.
- Spruce Willow Birch (SWB) occurs at mid-elevations below the BAFA in the northern part of the TSA. The SWB supports open forests of predominantly white spruce, subalpine fir and deciduous shrubs.
- Sub-Boreal Spruce (SBS) zone occurs at lower elevations in the southern portion of the TSA. Forests are predominantly spruce, fir and lodgepole pine.
- Boreal White and Black Spruce (BWBS) zone is found in the lower elevations primarily in the northern and western portions of the TSA. Frequent fires have resulted in extensive successional forests of lodgepole pine and trembling aspen. On gentle terrain, stands of white spruce and trembling aspen are interspersed with black spruce bogs.

[3] Text adapted from the Mackenzie SFMP; A sustainable forest management plan for the Mackenzie defined forest area. 2008. Published by Canadian Forest Products and BC Timber Sales.

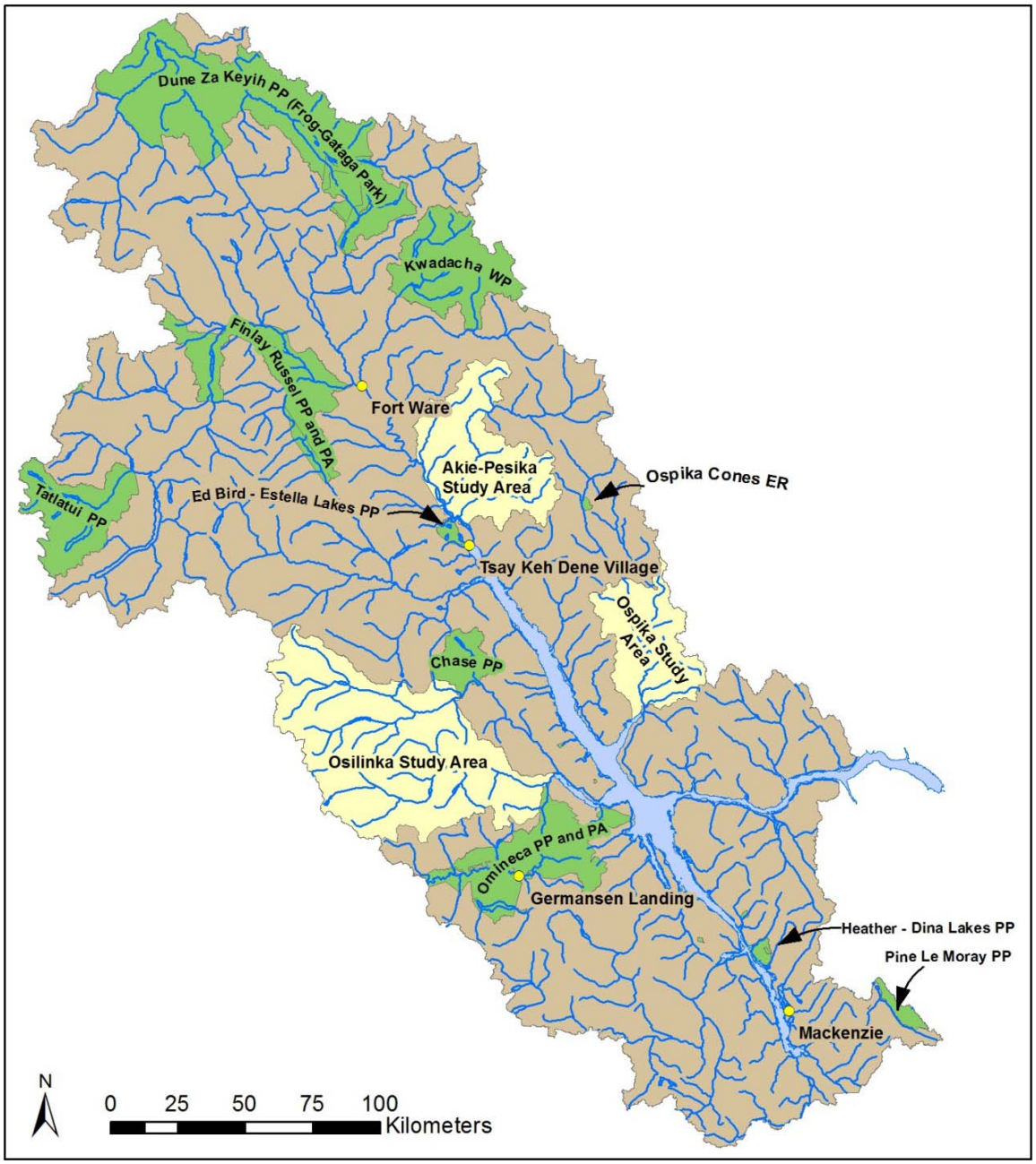

Figure 1. Mackenzie TSA Study Area. Yellow 'core areas' have existing goat information where the UWR Goat Model was tested. Draft U-7-29 UWR polygons may be found in the Akie-Ospika-Osilinka study areas. The Model was applied to the remaining brown areas to identify draft U-7-30 UWR polygons. Existing parks are identified in green.

Predators of mountain goats in the area, other than wolves (*Canis lupus*), include grizzly bears (*Ursus arctos*) and wolverines (*Gulu gulu*). Occasional, rare reports of cougar (*Felis concolor*) are consistent with the recent increase in deer (*Odocoileus* spp.) and elk (*Cervus elaphus*). Other abundant ungulates in the area include stone sheep (*Ovis dalli*

stonei) and woodland caribou (*Rangifer tarandus*). Regulated hunting of mountain goats occurs throughout the area.

Information on mountain goats in the area was observed during study of three specific landscape units: the Lower Ospika, the Osilinka and Akie landscape units. These landscape units are briefly describe below.

The Ospika study area is located in the Rocky Mountains to the east of Williston Lake. It is comprised of the SBS zone in the major valley bottoms with the ESSF dominating mid- to upper-elevations. At higher elevations, the ESSF is represented by parklands that give way to BAFA with increasing elevation. The study area is centered about the lower reaches of the Ospika River and includes the mountain ranges along both sides of the Ospika River, from Cardinal Creek south to Stevenson Creek.

The Akie study area is in the Rocky Mountains to the east of the Finlay River that flows into the north end of the Williston Reservoir. Major drainages include the Pesika River and the lower Akie River. The Akie study area is dominated by the BWBS in the valley bottoms while at mid- to upper-elevations the ESSF prevails. In the northern extents of the study area the SWB starts to replace the ESSF. The BAFA prevails above the ESSF and SWB.

The Osilinka study area encompasses the upper reaches of the Osilinka and Mesilinka rivers to the west of Williston Lake, in the Omineca Mountains. The study area is delineated by heights of land along the north, west and southern boundaries. The BWBS populates the valley bottoms and lower slopes of the major drainages with the ESSF or SWB (in the northernmost portion of the study area) replacing it at mid- to upper-elevations. At the higher elevations, parkland variants of the ESSF and SWB give way to the BAFA.

LIFE HISTORY OF MOUNTAIN GOATS IN THE MACKENZIE TSA

The Mackenzie Mountain Goat Project (initially referred to as the Ospika Mountain Goat Project) was initiated in 2001 by the Peace/Williston Fish and Wildlife Compensation Program and Slocan Forest Products Ltd - Mackenzie Operations. The project components included an adaptive management trial (Corbould et al. 2010), population inventory (Caldwell 2007, Hengeveld 2004), investigations into mountain goat ecology (McNay 2006, McNay 2006a) supported by >3500 observations on 69 radio-collared goats, and habitat supply modeling (Hengeveld 2004, McNay 2007). The adaptive management trial involved a field experiment with Slocan Forest Products to determine the level of impact of forest-harvesting treatments on the use of low-elevation mineral licks and trails. The first treatment involved clear-cut logging with retention of a 150-m wide forested buffer about a trail leading to a mineral lick known to be used by goats. The clearcut and trail buffer treatment was applied in winter 2002-2003. The buffer was subsequently harvested (“clearcut treatment”) in Nov 2005 and prescribed burned in Nov 2006. Goat responses to the successive treatments were compared to the use by other goats of several nearby “control” licks where no logging occured. We summarize results of these studies conducted on the Mackenzie TSA below.

Habitat Use and Movement

General

McNay et al. (2006a) reported that both female and male goats generally used elevations ≥1500 m, with males tending to use higher elevations than females. They found the greatest variance, in the use of elevations, occurred in summer in the Akie and Ospika areas when females used lower-elevation habitats, presumably to access mineral licks. Males tended to use higher elevations than females throughout the year. The demand for nutritional elements was therefore considered to play an important role in elevational movements by goats. Corbould et al. (2010) showed use of low-elevation mineral licks (<950 m) by 94% of all radio-collared goats (males and females).

McNay et al. (2006a) found steep slopes (>30^{o}) were used by goats throughout the year although goats tended to use gentler terrain (~20^{o}) during the summer months. In this same study, they found goats tended to use southwestern aspects with males using more westerly slopes than females. Except for one study area, most goat relocations occurred on aspects ranging from 150 – 250^{0} aspect. These results are consistent those of Jex (2004), Poole (1998) and Reid et al. (2004) in other areas of BC.

Goats made extensive use of the BAFA and ESSF zones throughout the year (McNay et al. 2006a). There were seasonal trends in the use of SBS in two of the study areas which was assumed to be associated with the use of mineral licks located in valley bottoms.

Mineral Licks

In the Ospika, Corbould et al. (2010) found goats visited licks between Mid-June and early September with males tending to use licks earlier in the season than females. Goats used licks multiple times per year for an overall average of 2 visits a year per goat. Some individuals however conducted 7 – 8 visits to licks per year and one goat made 30 visits. Two of the 29 monitored goats were not observed to use a study lick. Goats with a strong fidelity to a particular lick site did not shift their use to other lick sites over the 6-year study period regardless of disturbance. Goats that typically used several licks however, increased their use of those licks that were further from industrial activity that commenced during the study.

Visits to licks generally lasted ≤4 days and goats travelled outside their normal range to access licks. Visits varied in duration among licks (6.8 hours/visit to 43.3 hours/visit). Corbould et al. (2010) also reported that use of the traditional access trails by goats was greatest during daylight hours except at one lick site where crepuscular use of the trail was more common. Mountain goats used consistent routes (i.e., trails) to access mineral licks 80% of the time (Corbould, 2010). In the first year after the treatment lick's trail was clearcut, use of the trail was reduced to 53% but returned to 80% again the following year.

Movements

Corbould et al. (2010) monitored 29 radio-collared goats in the Ospika area over a five year period. They observed goats in the Ospika to travel 3 – 22 km from their winter

range to access mineral licks. Use of trails to licks began as early as April 11 and tapered off by Nov 24. The majority of trail use occurred between June 13th and Sept 8th.

Goats in the Mackenzie area have a larger home range than reported in other studies. McNay et al. (2006b) analyzed summer and winter seasonal home range size (N=207). Mean seasonal home range size was generally not different between summer and winter but varied greatly; seasonal home range = 20.5 km^2 with a standard deviation = 41.38 km^2. Average seasonal home range in the winter for females was 11.1 km^2 and 34.8 km^2 for males. Females displayed a strong tendency to use the same summer home range as in previous years. Males were more variable in their use of range locations. Corbould et al. (2010) found mean winter ranges varied for *each group (*11 km^2 to 96 km^2). The maximum *individual* home range reported by Corbould et al. (2010) was 179 km^2.

Survival and Mortality

Survival and mortality data is limited for the Mackenzie TSA. Limited access and low sample sizes make determination of vital population parameters difficult. McNay and Voller 2006 reported that average annual survivorship was high ($\hat{S}$ = 92.3%, SE = 1.9%) for 69 collared goats. These goats varied in age from 2 to 6 years old.

Causes of Mortality

McNay and Voller 2006 observed 14 mortalities while monitoring 69 adult mountain goats from March 2002 to March 2006. Six mortalities were due to accidents, five were due to predation (three by bears), and three were of unknown causes. Statistically they were unable to detect differences among the causes of mortality, even when predation effects were pooled. The leading cause of death was accidents (avalanches) followed closely by predation.

In the trail monitoring work by Corbould et al. (2010), 8,180 of the photo-captures were of mountain goats; large predators had the next highest trail use at 650 photo-captures, followed by ungulates at 420. The number of large predators and other ungulates photo-captured on the treatment trail increased dramatically a year after nearby forest operations began in 2004 (~2 km distant or less[4]). This trend was not observed at the control licks furthest from forestry operations (~4 km distant). Large predators and other ungulates used the trails mostly during the crepuscular and night periods throughout the study in contrast to primarily daytime use by goats.

Corbould et al. (2010) found a decline in lick use by goats coincided with an increase in photo-captures of predators and other ungulates. This increase in predators and ungulates occurred two years after the first forest harvesting treatment. The corresponding decline in lick visits by mountain goats at the two southern licks (within 2 km of forestry activity) coupled with no decline in use at the two northern control licks (more than 4 km from forestry activity) suggests that goats were influenced by forest harvesting in the lower (southern) portion of the drainage (on both the east and west

[4]Estimates are based on a distance subjectively measured in Arcmap from closest cutblock to the middle of the exposed cutbank.

sides of the Ospika River). The study's forest harvesting treatment, during the course of study, appeared to provide favorable conditions for other large ungulate species and their predators.

Population Density and Composition

The average goat density over three survey areas (Ingenika, Ospika and Wolverine) of the Mackenzie TSA was estimated at 0.18 goats/km^2 (Caldwell et al. 2007). The average juvenile recruitment was estimated as 21% of the total population (Caldwell et al. 2007) over the three study areas.

Goat population density in the Ospika has been estimated between 0.23 goats/km^2 (Caldwell et al. 2007) and 0.28 goats/km^2 (Hengeveld 2003). Goat density in the Akie (to the north of Ospika study area) are estimated at 0.26 goats/km2 (Hengeveld and Schmidt, 2004).

In the study areas to the west of Williston Lake show similar density estimates;
Osilinka goat densities are slightly higher at 0.33 goats/km^2 (Hengeveld, 2004). Of the 138 goats observed, 26% were kids. Just to the north in the Ingenika, goat density was estimated at 0.17 goats/km^2 (Caldwell et al. 2007). Corbould (2001) estimated goat densities in the Russel Range to be 0.22 goats/km^2 (Corbould 2001). Further to the south, surveys in the wolverine study area estimated goat densities to be 0.17 goats/km^2 (Caldwell et al. 2007).

During a census conducted by Caldwell et al. (2007) crews observed a total of 349 goats: 21% were kids, 5% were adult males, 24% were adult females, and 49% were unidentified adults.

UWR IDENTIFICATION METHODS

Model Description[5]

Quality of winter range is considered the most limiting life requisite for mountain goats in BC. Mountain goat preference for winter range was considered to be a combination of environmental and topographic factors that determine the utility of relatively small patches of non-forested high elevation terrain types to serve as escape areas (security) that are in close proximity to sufficient supplies of available forage (Figure 2). In Table 1 below, we summarize the main model nodes and their relationships in terms of a description of the function of the node, its state values and a brief description of the weightings used. Detailed data preparation and model run steps can be found in Appendix A.

[5] Portions of this section area adapted from G Sutherland. Unpublished. *Species Models in Support of Wildlife Habitat Modeling in North-Central BC: Mountain Goat Model*. Nov 2011.

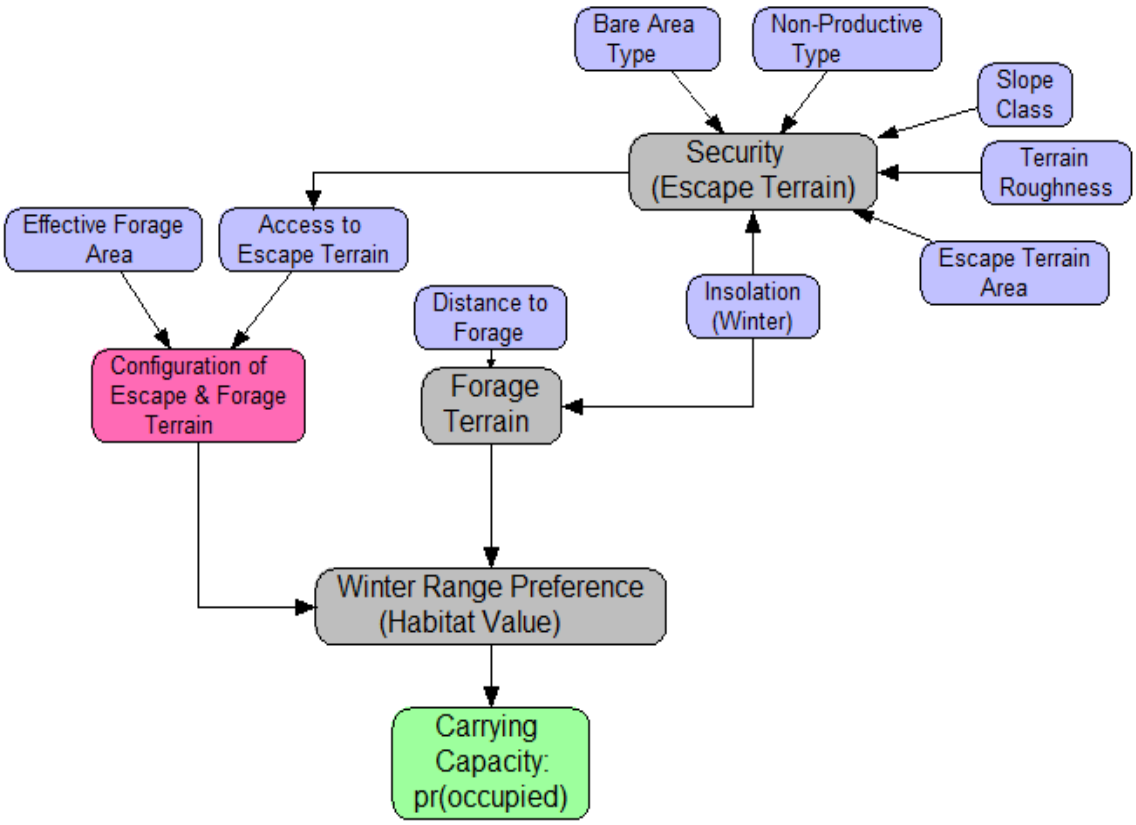

Figure 2. A general conceptual model of the probability of occurrence for mountain goats. Winter range preference is based on life requisites (grey nodes) and the ecological factors (non-managed: blue nodes) that affect this species.

We modeled winter range values for mountain goats as a Bayesian Belief Network (BBN) using Netica[6] (Figure 3). BBNs are influence diagrams that use nodes and linkages among nodes to describe, in our application, how the state or condition of various environmental inputs determines a resulting state of winter range for goats. Preliminary model form was based on a series of consultative workshops with resource specialists (Hengeveld et al. 2003) but altered by input collected over a series of workshops since that time. We applied the same model as was used in McNay et al. (2006c) to identify mountain goat winter range in Mackenzie TSA. Where it was available, updated input information was used (except in the study areas where the model was originally built and tested). In several cases, raw information was preprocessed into an input recognized by the model (e.g. solar radiation).

[6] Norsys Software Corp., Vancouver, British Columbia

Table 1. Description of general node structure and function for the mountain goat habitat model.

Function (life requisite or result)	Node Name	Description	Inputs (type)
Security (life requisite)	Security (Escape Terrain)	Specifies effectiveness of security areas, expressed as availability of winter escape terrain	• Bare Area Type (ecological) - landcover landcover feature class (i.e., glaciated/non-glaciated areas, avalanche chutes, rock) • Non-Productive Type (ecological) - classification of vegetation inventory • Slope Class (ecological) • Terrain Roughness (ecological) - index of localized relief • Escape Terrain Area (ecological) - patch sizes of local escape terrain areas • Insolation (winter) – average solar loading at site in winter
Forage availability (life requisite)	Forage Terrain	Specifies the effectiveness of forage terrain to support resident individuals during winter	• Distance to Forage –area-weighted distance (m) to forage within effective forage area • Insolation (winter) – average solar loading at site in winter
Habitat Value (summary)	Winter Range Preference (Habitat Value)	Specifies the preference index assigned to this location of winter range	• Forage Terrain – effectiveness of forage terrain • Configuration of Effective Forage Area - ha of forage (within 600 m radius) and Access to Escape Terrain – percentage of escape terrain in effective forage area

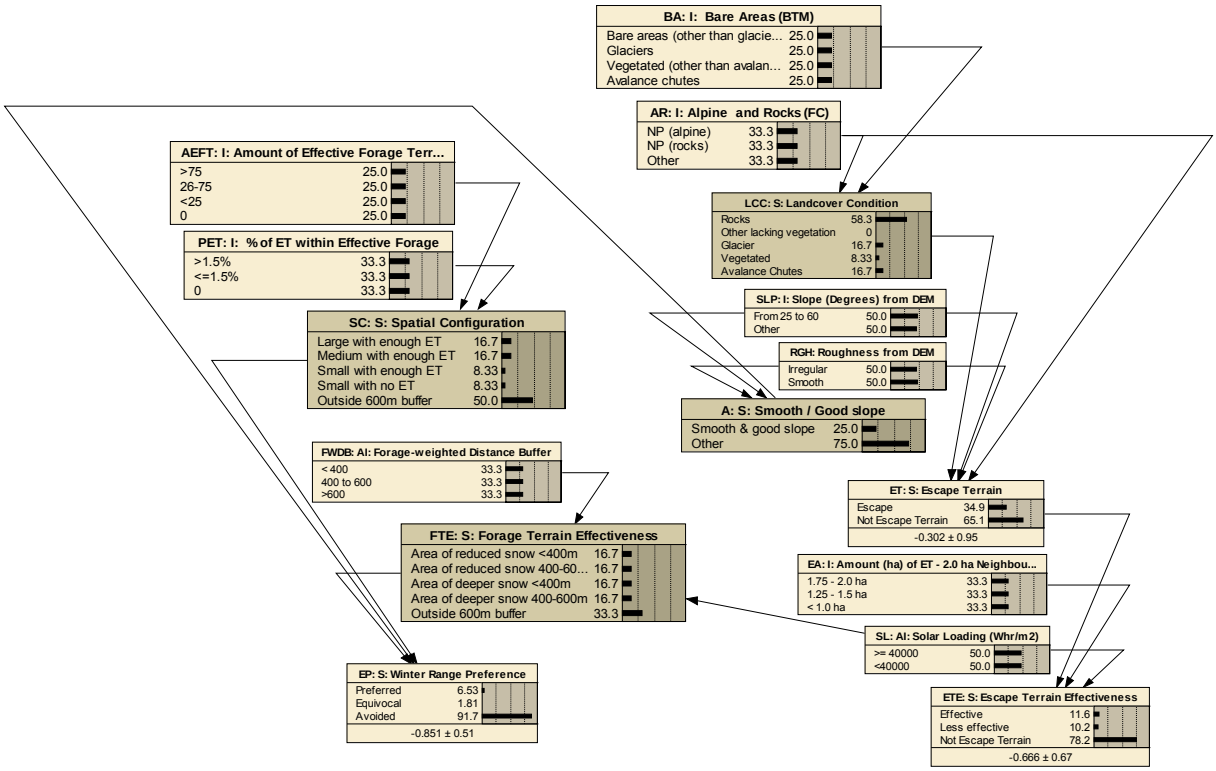

Figure 3. Bayesian Belief Network used to derive the ungulate winter range values. Figure show key environmental inputs on the likelihood of escape terrain effectiveness (ETE) and ungulate winter range preference for mountain goat habitat in north-central British Columbia.

Phase 1: Augmentation of Existing Modeling

We collected the draft UWR polygons (or core areas) generated by McNay et al. (2006c) for the three existing study areas (i.e., Ospika, Osilinka, and Akie-Pesika) and added supplementary polygons that linked licks and trails to nearby UWR polygons. The UWRs and supplementary polygons within these three study areas are referred to as UWR U-7-029.

To generate the supplementary polygons for licks and trails we used the ArcGIS Create Features tool in conjunction with several feature and polyline shapefiles (mineral licks and trails buffered by 250 m, 100 m contours, BC Freshwater Atlas Assessment Watersheds buffered by 250 m, 1/20 000 streams, and BEC). We used these layers to provide general guidance to placement of the drawn boundaries and in many instances, traced features from these layers to form boundary lines for the supplementary polygons. General protocols in drawing the supplementary polygons were to use existing features (e.g., streams) where possible as boundaries, maintain minimally a 250 m buffer about licks and trails, include ridgelines for travel within the boundaries, and to incorporate features such as BEC parkland variants, UWR pixels, and escape terrain that were peripheral to the UWR cores so as to minimize effects on forestry and to enhance the

value of the polygons to goats. Where supplementary polygons were drawn without the benefit of trail buffers, we attempted to maintain a corridor width of 400 – 500 m.

Phase 2: Model Application to Remainder of Mackenzie TSA

We applied the model across the entire Mackenzie TSA using methods that largely mirrored those used in McNay et al. (2006c) for the Akie-Pesika, Osilinka, and Ospika study areas. Resultant UWR polygons for the TSA, exclusive of those identified in Phase 1, are referenced as UWR U-7-030. As anticipated during the planning stages of this project, updates to input data sources (i.e. VRI (Vegetation Resources Inventory) and Digital Elevation Model (DEM)) necessitated that we adapt the procedures used previously to account for the changes to input data sources.

Since the 2006 work was completed, several changes to the VRI for the Mackenzie TSA affected its use in this project. First, much of the VRI attribute data in the TSA has been updated which has a direct effect on the information being fed to the model for determining goat winter range. Second, non-productive forest descriptors which are a key input to the goat model have been discontinued as an available attribute in the current VRI. To account for this, we created a form in MS Access that derives many of the non-productive descriptors previously available from the BC Land Classification System fields that are still maintained in the VRI attribute tables.

We compared the derived non-productive codes to vintage non-productive codes from legacy Forest Inventory Planning datasets for portions of the TSA and found that there was a high level of agreement between the two in areas where the Mackenzie TSA VRI had not been updated. In areas where the VRI had been updated the agreement was lower due to a marked decrease in area identified as being ‘alpine’ in the current VRI. This difference remained beyond our control to fix as it stemed from a change in VRI landscape classification methods. However, the effect of this change was mitigated somewhat by our procedures which used a combination of VRI and provincial Baseline Thematic Mapping to identify alpine areas.

As we performed the current work over a much larger extent than the Akie-Pesika, Osilinka, and Ospika study areas, a DEM with a wider extent was used. Processing of this different DEM yielded input rasters that were not identical to those used in 2006 in the areas common to both DEMs. We expect that this actually improved results as the new DEM-derived raster inputs did not exhibit raster artifacts resulting from re-projection of the data that were visible in the 2006 model inputs. Detailed methods used in completing the modeling including deviations from 2006 methods across the Mackenzie TSA are found in Appendix A.

Because we modified procedures to adjust for the differences in input data as described above, the results we generated inside the Akie-Pesika, Osilinka, and Ospika study areas were compared to winter goat relocations in these areas and to the results of the 2006 modeling. In doing so we were able to justify that the current modeling for the TSA produced similar spatial results to the 2006 modeling and that the differences did not have a detrimental effect on the ability of the model to identify areas suitable for winter use by goats. The methods and results of the comparison are presented in Appendix D.

RESULTS AND DISCUSSION

Phase 1: Draft u-7-029 UWR Polygons; Modeling UWR for Core Area; Akie/Pesika, Osilinka and Ospika

Previous modeling by McNay et al. (2006c) in the Akie-Pesika, Osilinka, and Ospika study areas yielded a total of 88,901.9 ha (Table 2) of draft UWR core area. None of this core area occurred within the boundaries of any parks, protected areas, or ecological reserves (Table 2). Using existing knowledge of mineral licks and trails, used by goats in these areas (Appendix B), we augmented the draft UWR core areas with 17 supplementary polygons that connect core areas with licks and trails (Table 3). The supplementary polygons comprised a total of 7,345.8 ha. Detailed descriptions of the rationale for each of the supplementary polygons are presented separately in Appendix C.

Table 2. Summary table of draft U-7-029 UWR polygons. Core area refers to UWR polygons generated from the model. The table summarizes polygon area (core and supplementary) for each study area.

AREA FOR U-7-29 UWR	Core Area	Core Area in Parks	Supplementary Polygons for Licks and Trails
	ha	*ha*	*ha*
Akie-Pesika	29,620.8	0	2,779.2
Osilinka	38,598.5	0	2,103.9
Ospika	20,682.6	0	2,462.7
Total	**88,901.9**	**0**	**7,345.8**

We examined area by biogeoclimatic zone for each supplementary polygon to assess potential impacts on forestry resulting from incorporating licks and trails into the UWR core areas. Representation of woodland zones (i.e., exclusive of alpine, parkland and scrub) totaled 2,130 ha, and was split equally between the ESSFmv4 and the BWBSdk1 in the Akie-Pesika study area (Table 4). In the Osilinka study area, woodland representation totaled 1,489 ha (Table 5), with the majority of this area (1,173 ha) occurring in the ESSFmv3. For the Ospika study area (Table 6), woodland representation totaled 2,435 ha with most of this area occurring in the ESSFmv4 (1,041 ha) and SBSmk2 (975 ha).

We also examined the amount of escape terrain contained within the supplementary polygons as a simple index of mortality risk to goats using these polygons. Escape terrain totaled 322 ha in the Akie-Pesika (Table 7), 664 ha in the Osilinka (Table 8), and 250 ha in the Ospika (Table 9). Individually, supplementary polygons in the Akie-Pesika had the lowest representation of escape terrain, followed by polygons in the Ospika. Representation of escape terrain for polygons in the Osilinka was high except for two polygons. In the Akie-Pesika and Ospika, forestry activities near supplementary polygons may need to consider special operating procedures to ensure functionality is maintained.

Table 3. Polygon identity, area (ha), and identified licks and trails for supplementary polygons in the Akie-Pesika, Osilinka and Ospika study areas.

LU	Polygon ID	Ha	Included Licks[1]	Included Trails[2]
Akie/Pesika	u-7-029_23	612.8	Predicted Akie River A Predicted Akie River B	
Akie/Pesika	u-7-029_26	666.8	Canfor1	Akie River Trail
Akie/Pesika	u-7-029_78	169.6	Predicted Pesika Creek	
Akie/Pesika	u-7-029_51	1330.0	Blanchard Creek Truncate Creek 1 – 4	Truncate Creek Trail
Akie Total		**2779.2**		
Osilinka	u-7-029_109	178.6	Croydon Creek	
Osilinka	u-7-029_140	17.6	Mesilinka Tributary	
Osilinka	u-7-029_158	102.1	Abraham Creek	
Osilinka	u-7-029_185	469.6	Klakring Creek Tributary	
Osilinka	u-7-029_224	144.7	Osilinka	
Osilinka	u-7-029_273	539.5	Thane Creek A – F	Thane Creek Trail
Osilinka	u-7-029_280	17.1	Flegel Creek	
Osilinka	u-7-029_118	634.6	Polaris Creek Lay Creek	
Osilinka Total		**2103.8**		
Ospika	u-7-029_357	871.4	Ospika Complex 40 a – f	Ospika Complex 40 Trail
Ospika	u-7-029_374	386.6	Ospika Complex 30 a – j	Ospika Complex 30 Trail
Ospika	u-7-029_381	560.0	Ospika Complex 28 a – r	Ospika Complex 28 Trail
Ospika	u-7-029_378	168.5	Aley Creek	
Ospika	u-7-029_384	476.3	Ospika Complex 17 a – g	Ospika Complex 17 Trail
Ospika Total		**2462.8**		
Grand Total		**7345.8**		

[1] See Appendix B for description of licks.
[2] See Appendix B for description of trails.

Table 4. Biogeoclimatic (BEC) zones located within the supplementary polygons in the Akie-Pesika study area.

Polygon ID	BAFAun (alpine)		ESSFmvp		ESSFmv4		BWBSdk1	
	ha	*%*	*ha*	*%*	*ha*	*%*	*ha*	*%*
u-7-029_23	0.0	0.0	17.8	2.9	308.9	50.4	286.0	46.7
u-7-029_26	0.0	0.0	18.2	2.7	202.0	30.3	446.6	67.0
u-7-029_78	0.0	0.0	0.0	0.0	52.0	30.7	117.6	69.3
u-7-029_51	107.2	8.1	505.2	38.0	507.4	38.2	210.1	15.8

Table 5. Biogeoclimatic (BEC) zones located within the supplementary polygons in the Osilinka study area.

Polygon ID	BAFAun (alpine)		ESSFmvp		ESSFmv3		BWBSdk1		SWBmk		SWBmks	
	ha	*%*	*ha*	*%*	*ha*	*%*	*ha*	*%*	*ha*	*%*	*ha*	*%*
u-7-029_109	157.988	88.5	0	0.0	0	0.0	0	0.0	0	0	20.609	11.5
u-7-029_140	0	0.0	17.397	98.8	0.205	1.2	0	0.0	0	0	0	0.0
u-7-029_158	102.132	100.0	0	0.0	0	0.0	0	0.0	0	0	0	0.0
u-7-029_185	0.122	0.0	26.205	5.6	443.311	94.4	0	0.0	0	0	0	0.0
u-7-029_224	114.652	79.2	26.186	18.1	3.89	2.7	0	0.0	0	0	0	0.0
u-7-029_273	50.209	9.3	119.92	22.2	369.376	68.5	0	0.0	0	0	0	0.0
u-7-029_280	0	0.0	0.189	1.1	16.95	98.9	0	0.0	0	0	0	0.0
u-7-029_118	0	0.0	0	0.0	339.707	53.5	91.891	14.5	201.995	31.8	0.981	0.2

Table 6. Biogeoclimatic (BEC) zones located within the supplementary polygons in the Ospika study area.

Polygon	ESSFmvp		ESSFmv 4		ESSFwc 3		ESSFwcp		ESSFwk 2		SBSmk 2		SBSwk2	
ID	*ha*	*%*	*ha*	*%*	*ha*	*%*	*ha*	*%*	*ha*	*%*	*ha*	*%*	*ha*	*%*
u-7-029_357	11.8	1.4	635.3	72.9	0.0	0.0	0.0	0.0	0.0	0.0	224.3	25.7	0.0	0.0
u-7-029_374	0.0	0.0	165.4	42.8	0.0	0.0	0.0	0.0	0.0	0.0	221.2	57.2	0.0	0.0
u-7-029_381	4.7	0.8	140.7	25.1	0.0	0.0	0.0	0.0	0.0	0.0	414.6	74.0	0.0	0.0
u-7-029_378	10.8	6.4	99.6	59.1	0.0	0.0	0.0	0.0	0.0	0.0	58.0	34.5	0.0	0.0
u-7-029_384	0.0	0.0	0.0	0.0	75.7	15.9	36.4	7.6	118.9	25.0	57.2	12.0	188.1	39.5

Table 7. Hectares of escape terrain within the supplementary polygons in the Akie-Pesika study area.

Polygon ID	Escape Terrain	
	ha	*%*
u-7-029_23	55.7	9.1
u-7-029_26	11.7	1.8
u-7-029_78	2.3	1.3
u-7-029_51	252.7	19.0

Table 8. Escape terrain located within the supplementary polygons in the Osilinka study area.

Polygon ID	Escape Terrain	
	ha	*%*
u-7-029_109	178.597	100.0
u-7-029_140	16.474	93.6
u-7-029_158	102.132	100.0
u-7-029_185	51.777	11.0
u-7-029_224	134.332	92.8
u-7-029_273	143.216	26.5
u-7-029_280	9.751	56.9
u-7-029_118	27.702	4.4

Table 9. Escape terrain located within the supplementary polygons in the Ospika study area.

Polygon ID	Escape Terrain	
	(ha)	*%*
u-7-029_357	107.6	12.3
u-7-029_374	21.8	5.6
u-7-029_381	57.8	10.3
u-7-029_378	30.1	17.9
u-7-029_384	32.3	6.8

Phase 2: Draft u-7-030 UWR Polygons; Modeling of UWR for Mackenzie TSA (excluding Akie/Pesika, Osilinka and Ospika)

In applying the model to the remainder of the Mackenzie Forest District, we identified 541,169 ha of draft UWRs. Of this area, 113,015 ha occur within parks, protected areas, or ecological reserves (Table 10). This modeling incorporated the changes to input data and methods discussed in the Methods section. As such we felt the need to address questions as to how this model application compares to the existing modeling in the Akie-Pesika, Osilinka, and Ospika study areas. The results of a comparison between the existing and new modeling are discussed later in this document (Phase 2b).

Table 10. Summary table of draft U-7-030 UWR polygons, including areas in parks.

AREA FOR U-7-30 UWR	Core Area *ha*	Core Area in Parks *ha*
Mackenzie TSA (excluding core areas)	541169.2	113015.3

The u-7-030 draft UWR polygons are heavily concentrated in the more rugged and mountainous areas of the district, particularly north and east of the Williston Reservoir (Figure 4).

Phase 2b: Verification of draft UWRs using collared goats

A total of 580 relocations, that met eligible criteria, were extracted from relocations of radio-collared and incidentally observed goats. Eligible winter locations were considered to be those which occurred between December 1 and March 31 and were neither records of goat mortalities or captures. Only 28.4% of goat winter relocations were found in habitats other than alpine tundra and subalpine parkland.

We used these winter goat relocations to compare the results of the existing modeling in the Akie-Pesika, Osilinka, and Ospika study areas to the new modeling carried out for the entire Mackenzie TSA. In order to verify that the new model application was comparable to previous work we performed several quantitative and qualitative tests within the boundaries of the previously modeled areas. First, a direct comparison of the areas identified as draft UWRs in each of the three study areas was performed to gauge both the difference in area and the amount of overlap that existed between the existing and new modeling. The results of this test are presented in Table 11.

Table 11. Summary table of draft U-7-029 UWR polygons. The table compares model results from 2006 to the present model results (without additions for licks and trails) which utilized updated VRI and DEM inputs.

AREA OF UWR	**Area in Akie-Pesika** *(ha)*	**Area in Osilinka** *(ha)*	**Area in Ospika** *(ha)*
Modelling in 2006 (Rpt. 194)	29620.8	38598.5	20682.6
Modeling in 2011 (this report)	33940.7	43289.2	29033.7
Percent of UWRs common to both	77.8	65.7	79.8

Next, we compared the ability of the existing and new UWRs (without lick and trail extensions) to contain winter goat relocations. This revealed that the new UWRs performed comparably, though somewhat less well than the existing model results. Because the draft UWR polygons represent a generalized view of core high density winter range preference for goats, it is not surprising to note that there is much goat winter range that exists outside of the draft UWR polygons. For this reason, we chose to perform an additional test which summarized how many of the relocations were found within 100m of areas identified as preferred winter range. In this test we found much higher agreement between model results and goat relocations. Again, the results for the existing modeling and new modeling were comparable although the new modeling captured fewer relocations. The results of these tests are presented in Table 12.

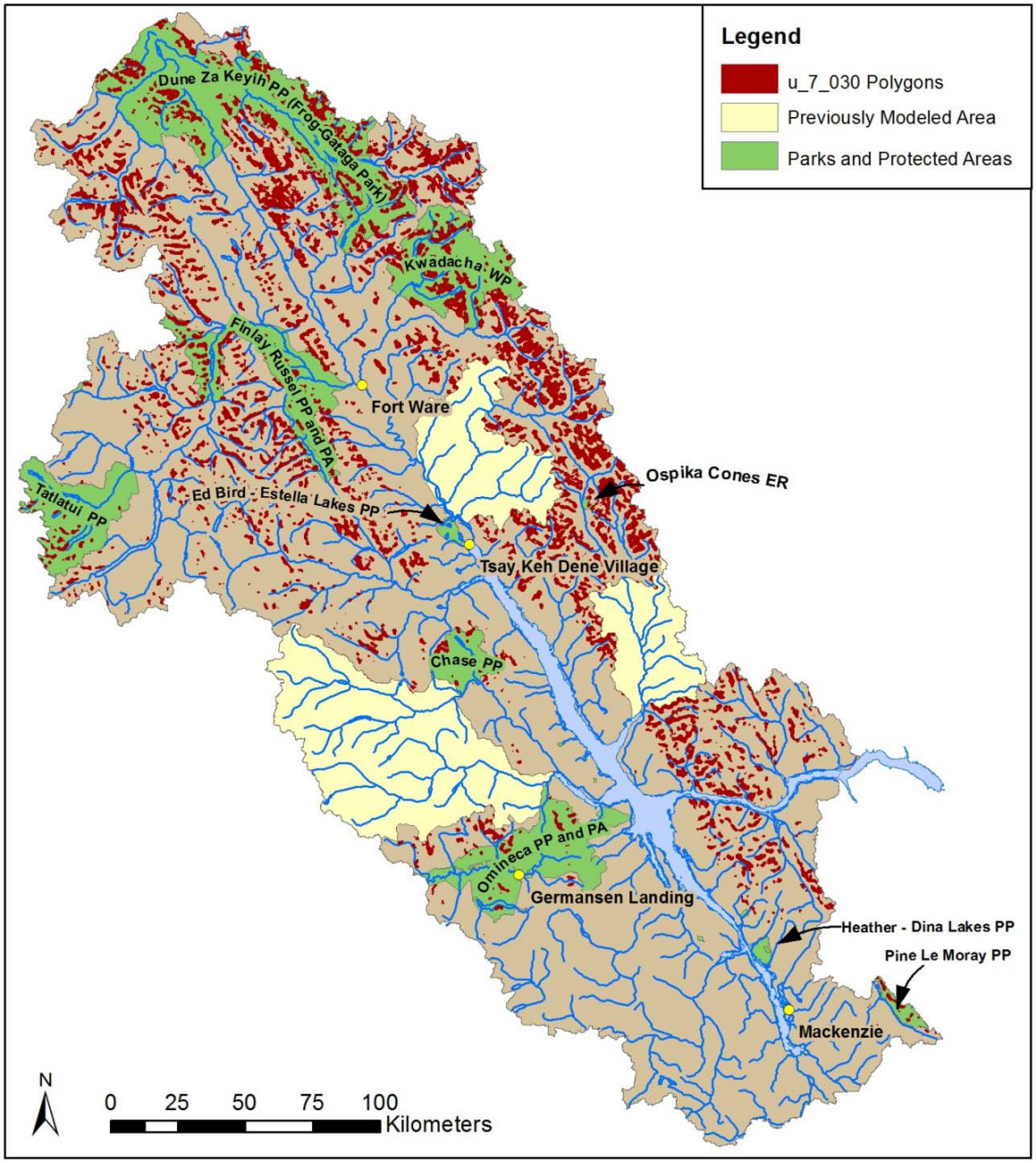

Figure 4. Distribution of draft UWR polygons in newly-modeled portions of the Mackenzie TSA.

Qualitatively, we visually assessed the agreement of the existing and new modeling at the boundary between the existing modeling for u-7-029 and u-7-030. We examined the boundary for disjointed polygons and polygons that abruptly ended on either side of the boundary as these would be signals for spatial disagreement between the two applications of the winter goat model. The results of this examination were favourable in that only minor interruptions in the spatial continuity between u-7-029 and u-7-030 were

Table 12. U-7-029 % relocations in UWRs and % of winter relocations of radio-collared goats situated within 100m of modeled winter range (% locations).

RELOCATIONS	Number of goats (winter relocations)	Akie-Pesika	Osilinka	Ospika	Total
		%	%	%	%
Existing Model UWRs (Rpt. 194 (2006)	47 (580)	34.1	51.6	58.5	53.9
New Model UWRs (Rpt. 385, 2011)	47 (580)	34.1	26.5	54.6	42.2
Existing Model within 100m of modeled winter range(Rpt. 194, 2006)	47 (580)	70.4	95.5	95.2	93.4
New Model within 100m of modeled winter range(Rpt. 385, 2011)	47 (580)	63.6	78.4	85.0	80.9

observed. Visual representations of this comparison and the quantitative comparisons previously discussed can be found in Appendix C.

Based on the results of these tests, we conclude that the new inventory data and DEM and did not unduly affect the model as applied for u-7-030. We feel it performs sufficiently well to be used in conjunction with the existing modeling across all study areas.

Phase 3: Synthesis of knowledge regarding mountain goats in the Mackenzie TSA

Please refer to this section earlier in the text.

MANAGEMENT IMPLICATIONS

Our work has incorporated the latest ecological knowledge of mountain goats to further refine understanding and mapping of UWR in north-central BC. Raw results (i.e., raster pixels) of the model application within the Mackenzie Forest District area resulted in the prediction of 133,613.5 ha of winter range for goats in the Akie-Pesika, Osilinka, and Ospika study areas (u-7-029) and 653,363.25 ha of winter range in the remainder of the Mackenzie Forest District (u-7-030).

Our approach to generalizing winter range into draft polygons resulted in 96,247.7 ha (n = 407 polygons) including additions for licks and trails in u-7-029 and 541,169.2 ha (n = 2451 polygons) in u-7-030. Nevertheless, when independently tested against known locations of mountain goats the model performed well.

Value added to the UWRs by including supplementary polygons for licks and trails is difficult to address for those polygons lacking reconnaissance-level information to confirm use by goats. For those polygons incorporating well-used trails and ample amounts of escape terrain, it is likely that the polygons, in conjunction with appropriate

management protocols, would provide security to mountain goats as they access low elevation licks within forested landscapes. The general intent of the supplementary polygons was to establish a natural corridor about licks and trails and to maintain the functionality of this corridor by:

1) keeping trails free of slash and obstructions,
2) maintaining natural forest features that goats are accustomed to, and
3) providing visual screening from human disturbances.

Mature forest buffers about trails may also be increasingly important as adjacent cutblocks regenerate with dense second growth (Corbould et al. 2010). Visibility and movements within mature forest buffers are expected to be less restricted. This may have implications on the prescribed width of the forest buffers so as not to create light conditions that promote shrub and second growth within the buffers. The major impact of forest harvesting, however, within the vicinity of licks and trails appears to be due to altered predator-prey dynamics resulting from creation of early seral habitats that favor ungulates. The effect of altered predator-prey dynamics resulting from forest harvesting appears to be spatially much larger than the extent of the clearcuts themselves.

Some general management protocols can be suggested for forestry activities proximal to, or within supplementary polygons:

- winter harvesting only
- short duration planting windows
- road management
- road buffers to obscure views of the licks
- minimum distances between harvesting and licks or trails
- restrictions on the percent of early seral stages within or proximal to supplementary polygons
- no forestry roads crossing lick trails
- goat hunting regulations

Although minimizing the creation of early seral habitats about licks and trails appears to be an important consideration, specific recommendations are difficult to determine. We recommend that additional resources be directed to establishing specific general wildlife measures for areas peripheral to licks and trails.

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APPENDICES

Appendix A. Methods and model development of ungulate winter range values for mountain goats.

1.0 Introduction

The Goat Model User Manual version 1 (50m cell size) purposefully focuses on the development of the grids, shapefiles and tables required for running the goat model. Procedures for creating associated grids, shapefiles and tables have not been incorporated; please refer to the AutoCHASE User Manual v.3 for instructions for developing these files. The exception is a few grids, specifically developed for making the ETE grid, where instructions have been provided.

The purpose for writing this manual was to bring all instructional documents for the goat model into one. To create a consistent process for running the goat model with the expectation of reducing or eliminating processing errors.

2.0 Information requirements

The goat model, *MG_WinterEscapeTerrain_OspOsiAkifinal_111125.dne*, currently requires that the model be run twice:

- First run will generate the *ete* grid, this will allow for the *aeft*, *fwdb* and *pet* grids to be created afterwards
- second to generate the winter range preference results

2.1 Escape Terrain Effectiveness (ete)

Spatial Data Requirements:

- *buf_msk (your buffered study area)*
- *fc_id (VRI polygon ids to link to polylayer rank 1 table)*
- provincial coverage of Baseline Thematic Mapping (BTM) polygons and attributes
- 25m DEM
- *tem* (TEM and PEM polygon IDs [zero where no TEM or PEM])
- *solar* (solar loading raster)

Tabular Data Requirements:

- polylayer rank 1 (Forest Inventory Planning Database)
- Layer (optionally simplified version of polylayer rank 1)
- TEMPEM (TEM and PEM polygon attributes)
- Pem_small (optionally simplified version of TEMPEM)
- Btm (linking table containing IDs to translate btm grid values to PLU_LABELS)

The *ete* grid describes winter escape terrain effectiveness generated by the winter escape terrain model that is contained in the Mountain Goat Habitat Supply Model (MGHSM).

1) Create *aeft*, *fwdb*, and *pet* input grids. These grids do not have any actual bearing on the ETE node of the winter escape terrain model. Their presence is however required to allow the Winter Escape Terrain BBN to execute.
    - **COPY** *buf_msk* three times and save the copies as *aeft*, *fwdb*, and *pet* respectively.

2) Create the *ar* (alpine and rocks) grid.
   - **JOIN** a table of Non-Productive codes from the Forest Inventory Planning database to the *fc_id* grid in ArcMap.
   - **RECLASSIFY** the grid based on the joined non-productive code field such that cells are reassigned the following values:

NP Values	Reclassified Values
All but 2 and 3	0
2	2
3	3

   - **RESAMPLE** the resulting grid to 50m cells using the 'Bilinear Interpolation' option of the Resample option in the Spatial Analyst menu and save the resulting grid as *ar_temp1*.
   - Load a layer of BTM information for your study area into ArcMap and add a field called btm_ar (short integer) to the attribute table.
   - Populate the btm_ar field such that:

PLU_LABEL	Reclassified Values
ALP, AVA	2
BARE	3
All other values	0

   - **CONVERT** the clipped shapefile to a 50m grid using the BTM_ar field of the attribute table to provide cell values and save the resulting grid as *ar_temp2*.
   - Augment the VRI-derived ar values with the BTM-derived values with a Con statement in the raster calculator:

```
Con("ar_temp1" == 0,"ar_temp2", "ar_temp1")
```

   - **SAVE** the resulting grid as *ar.*

3) Create the *btm* grid.
   - Load the provincial coverage of BTM polygons into ArcMap and if necessary, **ADD** a field called 'BTM_id' and populate it with a unique numeric identifier using the following **FIELD CALCULATOR** expression:

```
[FID]+1
```

   - **CLIP** the coverage to the extent of *buf_msk*.
   - **EXPORT** the table of the resulting shapefile as a dBASE table called *btm.dbf*. **IMPORT** this table into working Access database that will be used to produce case files for processing this model.
   - **CONVERT** the clipped shapefile to a 50m grid using the BTM_id field of the attribute table to provide cell values.
   - **SAVE** the resulting grid as *btm*.

4) Create the *elev_code* grid.

- Load a 25m DEM with the extent of *buf_msk* into ArcMap.
- **RECLASSIFY** the DEM such that cells bear the following values:

Elevation (m)	Reclassified Values
>=1300	0
<1300m	1

- **RESAMPLE** the resulting grid to have 50m cells using the 'Bilinear Interpolation' method in the Resample option of the Spatial Analyst menu.

5) **SAVE** the resulting grid as *elev_code.*

6) Create the *slope_code* grid.

- Load a 25m DEM with the extent of *buf_msk* into ArcMap and select **SURFACE ANALYSIS → SLOPE** (degrees) from the Spatial Analyst menu.
- **RECLASSIFY** the resulting grid such that cells bear the following values:

Slope (º)	Reclassified Values
25º - 60º	0
Other	1

- **RESAMPLE** the resulting grid to have 50m cells using the 'Bilinear Interpolation' method in the Resample option of the Spatial Analyst menu.
- **SAVE** the resulting grid as *slope_code.*

7) Create the *rough_code* grid to describe terrain roughness.
   - Load a 25m DEM with the extent of *buf_msk* into ArcMap and select **SURFACE ANALYSIS → SLOPE** from the Spatial Analyst menu.
   - **RESAMPLE** the dataset back to 50m using the 'Bilinear Interpolation' method of the Resample option in the Spatial Analyst menu.
   - Perform a Neighbourhood Statistics operation on the resulting grid to quantify surface roughness (**SPATIAL ANALYST → NEIGHBOURHOOD STATISTICS** [Range, rectangle, 3-cell by 3-cell radius]). This creates a temporary grid; call it *temp1*.
   - Make *temp1* active and **RECLASSIFY** it into the roughness categories used by the escape terrain model (Analysis → Reclassify). Perform the reclassification such that the following classes emerge:

Roughness Values (temp1)	Reclassified Values
>10 (rough)	0
≤10 (smooth)	1

   - **CONVERT** all NoData values to zero.
   - **SAVE** the resulting grid as *rough_code*.

8) Load a shapefile of VRI covering your buffered study area and add a field called L_FC_ID (Long Integer) to the attribute table. Populate the L_FC_ID field with the following field calculator expression:

```
[FID]+1
```

CONVERT the shapefile to a 50m raster and save it as *fc_id*. Export the attribute table to your working access database as the Layer table and make the L_FC_ID field the primary key.

9) Create a dummy *tem* grid if there is no TEM or PEM data available. Make a copy of the *buf_msk* grid and reclassify the grid value to 0 (zero). Export a table called *tem.dbf*. If there is TEM and PEM information merge it into a single shapefile and assign unique polygon IDs into a field called 'ECP_ID' (Long Integer). Any areas not covered by TEM or PEM should be assigned an ID of 0. **CONVERT** this shapefile to a 50m raster called *tem* based on the values in the ECP_ID field. Export the attribute table as *tem.dbf* and import it into your working Access database.

10) Create the *size* grid. This grid depicts the location of winter escape terrain capable cells and the number of escape terrain cells which are among the eight cells immediately adjacent to them.

- Load the *ar*, *tem*, *rough_code*, and *slope_code* grids into ArcMap and **COMBINE** them in the raster calculator using the 'Combine' command. Save the resulting grid as *rescap*.
- Load *tem.dbf* into ArcView and perform the following join with the *rescap* attribute table. **JOIN** *pem_small.dbf* and *rescap* based on the ECP_ID and tem fields respectively. Make the join permanent.

- **ADD** a field to *rescap*'s attribute table (name: rocky, type: text, width: 8) and populate it by selecting all records where the *ar* value is 2 or 3 or the site series is one of RO, RU, TA, or CL. CALCULATE the 'rocky' field for all selected records to assign it the value 'rocky'. Assign all other records the value of 'other'.
- **OPEN** the *rescap* attribute table and **ADD** the following fields.

Field Name	Data Type	Size
wEsc_cap	Number	Width = 4
esc_cap	string	Width = 30

- With the *rescap* attribute table open, select the cells which have winter escape terrain capability by selecting those records which have a slope between 25º and 60º, a rough_code value of '0', and a rocky value of 'rocky'.
- Populate the wEsc_cap field by **CALCULATING** its value to '0' for all of the selected records.
- **SWITCH** the selection on the table to select the remainder of the records and finish populating the wEsc_cap field by **CALCULATING** these records to a value of '1'.

- Populate the esc_cap field in the same manner as the wEsc_cap field. Re-select the records with winter escape terrain capability and **CALCULATE** a value of '0 = escape capability' for them. **SWITCH** the selection one more time and assign a value of '1 = no escape capability'.
- Using the Spatial Analyst 'Reclassify' function, **RECLASSIFY** the *rescap* grid based on the wEsc_cap field into two classes where cells with a value of zero will be reclassed to a value of 1 and cells with a value of 1 will be reclassed to a value of 2. **SAVE** the resulting grid as *win_esc_cap.*
- Select all cells in *win_esc_cap* with a value of 1 and **EXPORT** them to a new grid. For the purposes of this document this grid will be referred to as *temp5*.
- **RECLASSIFY** *temp5* such that all cell values are now 10000 rather than 1. Call this grid *temp6*.
- Perform a Neighbourhood Analysis on *temp5* to determine the number of winter escape terrain cells adjacent to each individual winter escape terrain cell. In the **NEIGHBOURHOOD STATISTICS** dialog box select the following options: statistic = sum; neighbourhood = rectangle; width = 3; height = 3; units = cells. This will produce a temporary grid, call it *temp7*. The listed values are based on a grid with 50m cells. Height and width would change when cell size is varied.
- Perform a **RASTER CALCULATION** from the Spatial Analyst menu in which the *temp6* grid is added to *temp7*. Call the output of this calculation *temp8*.
- In *temp8*, the cell values do not directly reflect the number of escape terrain cells which are directly adjacent to each individual escape terrain cell. Also, we do not wish to count the center cell of the neighbourhood in this total. To correct for this, **RECLASSIFY** the values as shown below.

***temp8* Value**	**New Value**
10001	0
10002	1
10003	2
10004	3
10005	4
10006	5
10007	6
10008	7
10009	8

- **CONVERT** the NoData values in the resulting grid to '0'
- **SAVE** this grid as *size*.

11) Create the *solar* (solar loading grid) according to the procedures below:
As used in the 2006 goat winter range mapping of the Fort St. James Forest district[7], the *solar* grid depicts global solar loading values for your buffered study area over the course of the winter season (December 1 to March 31; Julian days 335 – 90).

[7] R.S. McNay, R.M. McKinley, and L. Giguere. 2006. Identification of mountain goat winter range in the Fort St. James Forest District. Wildlife Infometrics Inc. Report No. 194. Wildlife Infometrics Inc., Mackenzie, British Columbia, Canada.

i. Open the '**AREA SOLAR RADIATION**' tool in the Spatial Analyst toolbox in ArcMap. Load a 25m DEM into as the Input Raster that is large enough to encompass the *buf_msk* raster. If the raster has a large enough north-south extent ensure improved results by separating it into 30 km latitudinal bands (20km bands with 5km of overlap on northern and southern boundaries

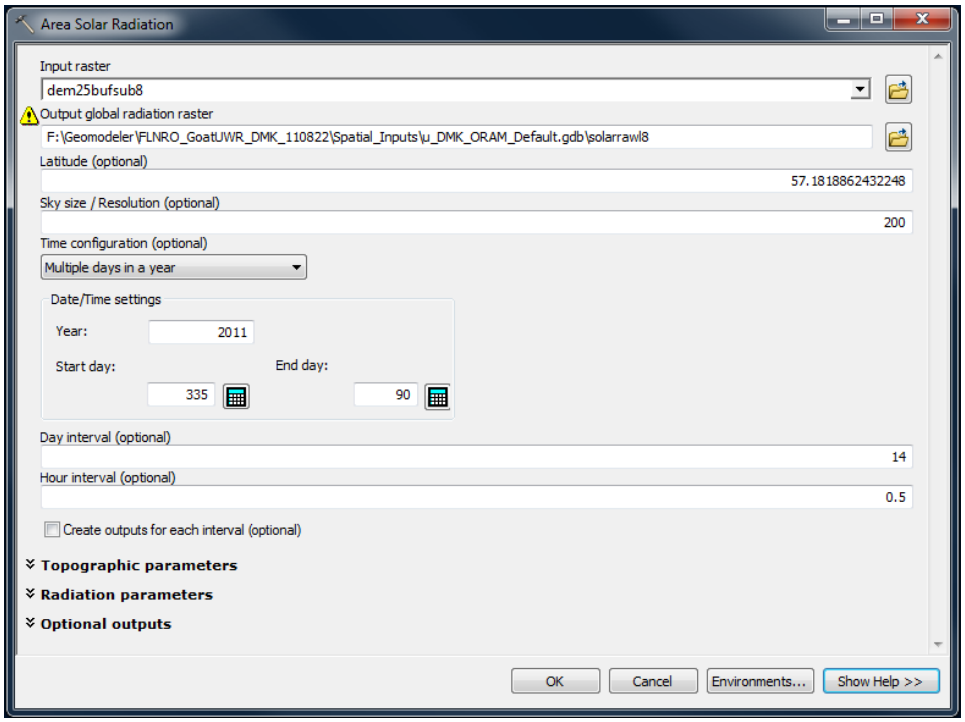
ii. Enter a name for the output global radiation raster.

iii. Set the 'Time configuration' for 'Multiple days in a year' and give the dates as December 1, 2010 – March 31, 2011 to avoid leap years. This equates to Julian days 335 to 90.

iv. Leave all other inputs at their default values.

v. Solar loading is calculated separately for each band to improve accuracy of the latitude values used in the calculation. A correctly filled out example of the 'Area Solar Radiation' dialog is shown below for reference.

vi.



vii. **REPEAT** steps 1 through 6 for each band that has at least a portion of its extent residing within your buffered study area.

viii. **MOSAIC** all of the individual band solar loading grids into a seamless mosaic using the 'MOSAIC TO NEW RASTER' tool in the **Data Management Tools → Raster → Raster Dataset** toolbox. Add all of your solar bands in order from north to south and fill in the dialog as follows:

- Output location: your default geodatabase
- Raster Dataset Name: solarmos25
- Spatial reference: select one appropriate to your project
- Pixel Type: 32-bit unsigned
- Number of Bands: 1
- Mosaic Operator: Mean

- Mosaic Colormap Mode: Default

ix. **RECLASSIFY** this grid into the following two classes and set the raster analysis cell size and mask to match *buf_msk* in the tool environments. **SAVE** the resulting grid as *solar*:

Old Cell Values	New Cell Values
0 → 39,999	1
40,000→ maximum	0

12) Load the *aeft*, *ar*, *btm*, elev_code, fc_id, *fwdb*, *pet*, *rough_code*, *size*, *slope_code*, and *solar* grids into ArcMap and combine them using the '**COMBINE**' command in the raster calculator. **SAVE** the resulting grid as *res_a*.

13) **EXPORT** the attribute table of the *res_a* grid as a dBASE table called *res_a.dbf*.

14) **IMPORT** *res_a.dbf* into the working Access database and change the name of the 'Value' field to 'ID' and make the field the Primary Key. If there is no TEM table, then add a field called ECP_TAG (text), this will allow for a link to the dummy TEM table created earlier in Section 2.1 6).

15) **IMPORT** the dummy TEM table if there is no TEM or PEM data available, rename it TEMPEM. **ADD** 3 fields to the table:
    - ECP_TAG (text, 50) and make it the Primary Key. Populate the field with N/A.
    - SITEMC_S1 (text, 50), do not populate.
    - ECP_ID (long integer), do not populate.

16) **OPEN** the 'DMK Goat Netica Manager 111125' form and fill in the blanks as follows: Layer Table = Layer; Result Table = res_a; TEMPEM Table = TEMPEM; Export Path = location where the case file to be created by Netica Manager will be saved; Import Path = location where Netica BBN outputs will be found after running the winter escape terrain BBN on the case file.

17) **PRESS** the 'Winter Escape Model' button on the 'Export To:' side of the form to generate a case file.

18) **OPEN** the Winter Escape Terrain BBN in Netica and process the case file saved by Netica Manager.

19) Return to the Netica Manager form and IMPORT the results generated by Netica by **PRESSING** the 'Winter Escape Model' button on the 'Import From:' side of the form.

20) **CREATE** a new table in Access containing the res_a table's ID field and the Netica output from the ETE node of the winter escape terrain model (WE_ETE).

21) **EXPORT** this table as a dBASE file called *ete.dbf.*

22) **IMPORT** the *ete.dbf* table into ArcView 3.2 and **JOIN** it to the *res_a* grid's attribute table permanently.

23) **RECLASSIFY** the *res_a* grid such that all cells with a WE_ETE value >0.666 are assigned a value of '1' and the remaining cells get a value of '0'.

24) **SAVE** the resulting grid as *ete*.

2.2 FWDB

Spatial Data Requirements:

- *buf_msk*
- *ete* (Section 2.1)
- *res_a (with joined ete results)*

The fwdb grid (Forage Weighted Distance Buffer) describes the distance of forage to escape terrain.

1) Using the res A grid with the ETE results permanently joined:
   - use the raster calculator to select from the AR field those records with a value of '3'. Call it *fwdb_temp1*.
   - Take the calculation output and use Single Output Map Algebra to fill all nulls with zero using the following Con statement:
     i) Con(IsNull([AR]), 0,[AR])
     ii) **SAVE** the grid as *ar_rock*
   - Use the raster calculator to select from the BTM field those records with a value of '5' OR '10'. Representing 'Bare' and 'Ice' respectively. Call it *fwdb_temp2*.
   - Take the calculation output and use Single Output Map Algebra to fill all nulls with zero using the following Con statement:
     i) Con(IsNull([BTM]), 0,[BTM])
     ii) **SAVE** the grid as *btm_rock*
   - Use the raster calculator to combine the *ar_rock* and *btm_rock* grids, naming the resulting grid as *fwdb_temp5.*
     i) Add a field called ISNONVEG to *fwdb_temp5* (numeric short integer, 4)
     ii) Select AR_ROCK <> 0 OR BTM_ROCK <> 0 and calculate ISNONVEG = 5
     iii) Switch the selection and calculate ISNONVEG = 1
     iv) Create a grid VEGNONVEG based on the ISNONVEG field

2) Create the *ete.shp*:
   - Take the ete grid and convert it to a polygon shapefile using the Raster to Polygon tool, call it ete_tmp.shp. Allow the tool to simplify polygons.
   - Start an editing session and select all records from the GRIDCODE field with a value of 0 (zero), delete these features and stop editing.
   - Using the remaining features, dissolve on the GRIDCODE field and call it ete.shp

3) Create the *fwdb* grid
   - Add the ete.shp, vegnonveg grid, and the buf_msk grid to ArcMap

- Use the cost distance tool to create a temporary *fwdb* grid, call it *fwdb_tmp4,*
    - Input feature source = *ete.shp*
    - Input cost raster = *vegnonveg* grid
- Reclassify the *fwdb_tmp* where 1 = <400m, 2 = 400 – 600m, 3 = >600m
- Save the grid as *fwdb*

2.3 AEFT

Spatial Data Requirements:

- *buf_msk*
- *ete.shp*
- *res_a (with joined ete results)*

The *aeft* grid (Amount of Effective Forage Terrain)

1) Create the ETE polygons:
    - Using the *ete.shp* made during the *fwdb* grid development, run the Multipart to Singlepart tool. Call it *ete_tmp.shp*
    - Add to this shapefile a field called ETE_ID (double, 16) and calculate using FID+1
    - Add to this shapefile a field called ETE_AREA (double, 16) and calculate the hectares
    - Delete all fields except ETE_ID and ETE_AREA

2) Create FORAGE polygons:
    - Using the raster calculator, select from the *fwdb* values 1 and 2 representing area <= 600m
    - Convert the calculation to polygon and call the file *forage_tmp.shp*
    - Select all records from the GRIDCODE field with a value of 1 (one), make this a layer
    - Dissolve on the GRIDCODE field.
    - Run the Multipart to Singlepart tool (call this *forage.shp*)
    - Add a field called F_ID (double,16) and calculate using FID+1
    - Add a field called F_AREA (double,16) and calculate the hectares
    - Delete all fields except F_ID and F_AREA

3) Identify the ETE polygons that occur within the FORAGE polygons:
    - In ArcMap use the Spatial Join tool to identify the ETE polygons that occur within FORAGE polygons:
        - Target = *ete_tmp.shp*
        - Join = *forage.shp*
        - Join Operation = join one to one
        - Check ‘Keep All Target Features’
        - Match options = Is Within
        - In ‘Environments’ change the XY Tolerance to 5 (m) to help deal with mismatched polygon boundaries near edges.
    - Export the attribute table from *ete.shp* which has the spatial join with the forage polygons, call it *aeft_e.dbf*
    - Import the *aeft_e.dbf* into Access. Make sure that the database already contains the necessary ‘AEFT DATA PROCESSING’ form and the 10 queries it references:

- 1 SUM OF ETE AREA
- 2 UPDATE_AEFT_SUM_ETE
- 3 UPDATE_F_AREA_L_ETE
- 4 CALC_F_15PER
- 5 UPDATE ETE_ID15PER IS NULL
- 6 UPDATE_ETE_IS15PER
- 7 UPDATE AEFT1
- 8 UPDATE AEFT2
- 9 UPDATE AEFT3
- 10 MAKE AEFT_I

- Add the following fields to *aeft_e:*
  - SUMETE (double)
  - F_AREA_L_ETE (double)
  - F_15PER (double)
  - IS_15PER (long integer)
  - AEFT (integer)
- Open the AEFT Data Processing form and click the buttons in the following order to run the 10 queries:
  - SUM_ETE_AREA
  - AEFT_SUM_ETE
    1. **NOTE:** Prior to running the AEFT_SUM_ETE query establish a join between the aeft_e and AEFT_area_sum tables using the F_ID field. Set the join property to:
       a. "Include all records from 'aeft_e' and only those records from 'AEFT_area_sum' where the joined fields are equal".
  - F_AREA_L_ETE
  - F 1.5%
  - ETE 1.5% NULL
  - ETE 1.5%
  - AEFT_CAT1
  - AEFT_CAT2
  - AEFT_CAT3
  - MAKEEXP_TABLE
- Export the *aeft_i.dbf*

4) Create the *aeft* grid:
   - Join the *aeft_i.dbf* to the *forage.shp* attribute table based on their common F_ID fields.
   - Convert *forage.shp* to a raster with the cell size and extent of *buf_msk* to create a grid called *aeft_tmp4* using the values in the joined AEFT field.
   - Using Single Output Map Algebra, run the following statement, be sure to set your analysis cell size and mask to match the *buf_msk* raster:
     - CON(IsNull([AEFT_TMP4]),0,[AEFT_TMP4]) to fill all nulls with zero, call the grid *aeft.* In this grid the cell values represent the following states in the goat BBN:
       - 1 = 1 (>75 ha of effective forage terrain)
       - 2 = 2 (25 ha to 75 ha of effective forage terrain)
       - 3 = 3 (<25 ha effective forage terrain)

- 0 = 0 (is null)

2.4 PET

Spatial Data Requirements:

- *buf_msk*
- *forage.shp*
- *aeft_i.dbf*

The *pet* grid (Percent of Escape Terrain Effectiveness), represents the percentage of escape terrain effectiveness within an AEFT area.

1) Using the *forage.shp* with the *aeft_i.dbf* fields joined onto it, create a grid called *pet_tmp* using the IS15PER field, call it *pet_tmp*
2) Using Single Output Map Algebra, run the following statement, be sure to set your analysis cell size and mask to match the *buf_msk* raster:
   - CON(IsNull([PET_TMP]),0,[PET_TMP]) to fill all nulls with zero, call the grid *pet*. In this grid the cell values represent the following states in the goat BBN:
     - 1 = 1 (>1.5% of ET within the AEFT polygon)
     - 2 = 2 (<= 1.5% of ET within the AEFT polygon)
     - 0 = 0 (Is Null)

Perform Second Model Iteration

Now that all of the required data inputs have been created the second iteration of the goat winter model may be performed to generate escape preference values.

1. Load the *aeft*, *ar*, *btm*, elev_code, fc_id, *fwdb*, *pet*, *rough_code*, *size*, *slope_code*, and *solar* grids into ArcMap and combine them using the '**COMBINE**' command in the raster calculator. **SAVE** the resulting grid as *res_b*
2. **EXPORT** the attribute table of the *res_b* grid as a dBASE table called *res_b.dbf*.
3. **IMPORT** *res_b.dbf* into the working Access database and change the name of the 'Value' field to 'ID' and make the field the Primary Key. If there is no TEM table, then add a field called ECP_TAG (text), this will allow for a link to the dummy TEM table created earlier in Section 2.1 6).
4. **IMPORT** the dummy TEM table if there is no TEM or PEM data available, rename it TEMPEM. **ADD** 3 fields to the table:
   i. ECP_TAG (text, 50) and make it the Primary Key. Populate the field with N/A.
   ii. SITEMC_S1 (text, 50), do not populate.
   iii. ECP_ID (long integer), do not populate.
5. **OPEN** the 'DMK Goat Netica Manager 111125' form and fill in the blanks as follows: Layer Table = Layer; Result Table = res_b; TEMPEM Table = TEMPEM; Export Path = location where the case file to be created by Netica Manager will be saved; Import Path = location where Netica BBN outputs will be found after running the winter escape terrain BBN on the case file.
6. **PRESS** the 'Winter Escape Model' button on the 'Export To:' side of the form to generate a case file.

7. **OPEN** the Winter Escape Terrain BBN in Netica and process the case file saved by Netica Manager.
8. Return to the Netica Manager form and IMPORT the results generated by Netica by **PRESSING** the 'Winter Escape Model' button on the 'Import From:' side of the form.
9. **CREATE** a new table in Access containing the res_b table's ID field and the Netica output from the EP node of the winter escape terrain model (WE_EP).
10. **EXPORT** this table as a dBASE file called *ep.dbf.*
11. **IMPORT** the *ep.dbf* table into ArcMap and **JOIN** it to the *res_b* grid's attribute table permanently.

Preparing Draft Ungulate Winter Range Polygons

After running the *MG_WinterEscapeTerrain_OspOsiAkifinal.dne* model and joining the results back on to your resultant grid; you may create draft ungulate winter range polygons as follows:

1) Add the *DMK_Goat_Tools_111117.tbx* to Arcmap and run the tool '*5_111208 create EP grid*' model to create a grid of escape preference for goats. In short, this model will select all records in the WE_EP field of the resultant attribute table that have a value >= to 0.9 (escape preference) and reclassifies it to values of 0 (no escape preference) and 1 (escape preference). The result is saved to a raster called *ep*.
2) Perform a neighbourhood analysis on the *ep* raster to being defining polygons around areas of higher density of escape terrain. Open the **FOCAL STATISTICS** tool and enter the following parameters:

    - Input Raster: *ep*
    - Output raster: *ep_blob* (place in default geodatabase)
    - Neighbourhood: Circle
    - Radius: 750m
    - Units: Map
    - Statistics Type: SUM

3) **RECLASSIFY** *ep_blob* such that all cells with a value >= 275 are assigned a value of 1 and the remaining cells get a value of 0. Set your analysis cell size and mask to match the *buf_msk* raster. **SAVE** this raster *uwr275*
4) Depending on the project requirements you may at this point need to convert *uwr275* to a polygon shapefile (*pot_uwr_poly_275*), split by areas inside/outside parks and add standard attribution.

Appendix B: Background information on licks and trails that were incorporated into supplementary polygons

Table 13. Background information for identified mineral licks.

LICK IDENTIFICATION	EASTING - ALBERS	NORTHING - ALBERS	SOURCE	STUDY_AREA	SUPPLEMENTARY POLGYON ID
Predicted Akie River A	1065959	1373160	Predicted - HSM 2005	Akie	u-7-029_23
Predicted Akie River B	1064976	1373203	Predicted - HSM 2005	Akie	u-7-029_23
Canfor1	1060933	1365007	People - Canfor	Akie	u-7-029_26
Predicted Pesika Creek	1060398	1335145	Predicted - HSM 2005	Akie	u-7-029_78
Blanchard Creek	1048859	1352815	Telemetry	Akie	u-7-029_51
Truncate Creek 1	1043285	1232845	Incidental - Lick Survey 2005	Akie	u-7-029_51
Truncate Creek 2	1051726	1349009	Telemetry	Akie	u-7-029_51
Truncate Creek 3	1051488	1349460	Telemetry - ORAM 2004	Akie	u-7-029_51
Truncate Creek 4	1051473	1349671	Telemetry	Akie	u-7-029_51
Akie 1	1047014	1354774	Telemetry - ORAM 2004	Akie	Not included - isolated lick.
Akie 2	1066020	1331391	Telemetry	Akie	Not included - within a goat UWR in the Akie buffer.
Croydon Creek	995988	1278618	Unknown	Osilinka	u-7-029_109
Mesilinka Tributary	1003974	1263405	Random Sample - 2005	Osilinka	u-7-029_140
Abraham Creek	1004047	1259307	Unknown	Osilinka	u-7-029_158
Klakring Creek Tributary	1010377	1252551	People - D. Smith	Osilinka	u-7-029_185
Osilinka	1024146	1242523	Unknown	Osilinka	u-7-029_224
Thane Creek A	1043289	1232940	Peace Williston	Osilinka	u-7-029_273
Thane Creek B	1043245	1232871	Telemetry	Osilinka	u-7-029_273
Thane Creek C	1043549	1232839	Telemetry	Osilinka	u-7-029_273
Thane Creek D	1034733	1232055	Unknown	Osilinka	u-7-029_273
Thane Creek E	1038548	1231963	Unknown	Osilinka	u-7-029_273
Thane Creek F	1043285	1232845	Unknown	Osilinka	u-7-029_273
Flegel Creek	1066855	1228505	Survey	Osilinka	u-7-029_280
Polaris Creek	1015796	1273553	People - Unknown	Osilinka	u-7-029_118
Lay Creek	1016546	1273130	Unknown	Osilinka	u-7-029_118
Predicted Osilinka	1050337	1268448	Predicted - HSM 2005	Osilinka	Not included - no obvious goat UWR to link to.

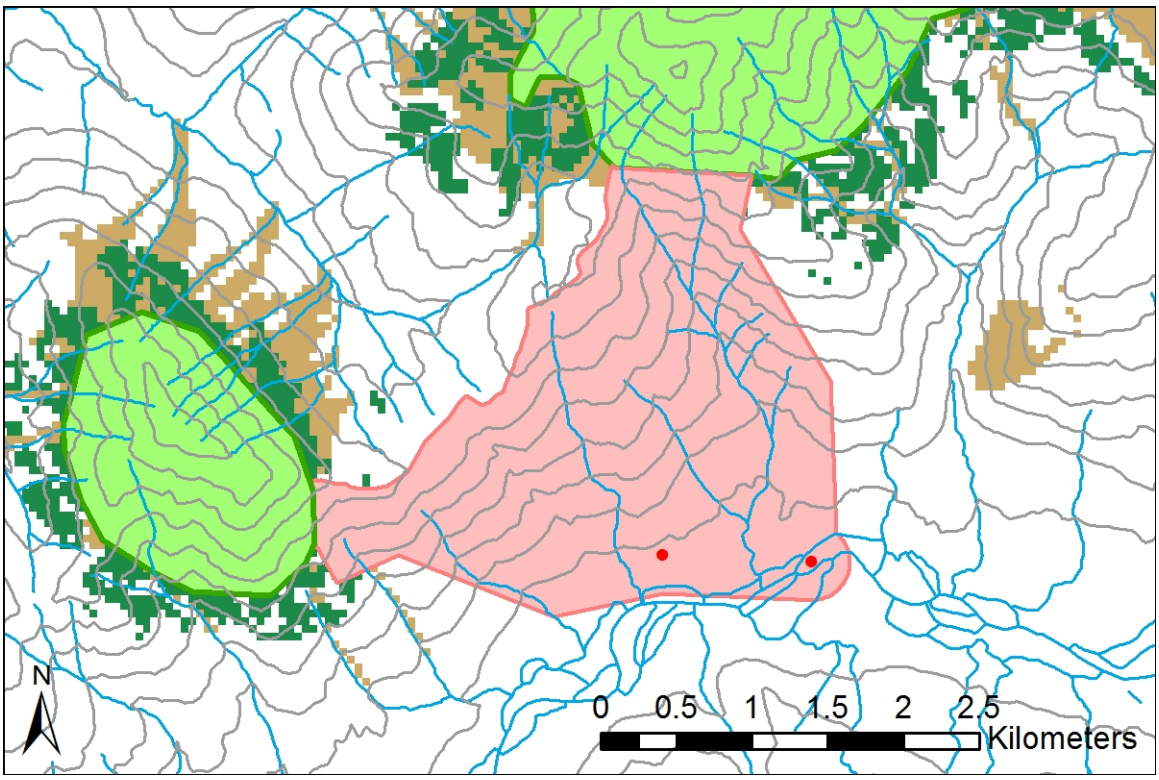
LICK IDENTIFICATION	EASTING - ALBERS	NORTHING - ALBERS	SOURCE	STUDY_AREA	SUPPLEMENTARY POLGYON ID
Mesilinka River	1059755	1269292	Telemetry - RATA 1999	Osilinka	Not included - probable caribou lick.
Ospika Complex 40 a	1127989	1291082	Peace Williston - orthophoto	Ospika	u-7-029_357
Ospika Complex 40 b	1128154	1290666	Peace Williston	Ospika	u-7-029_357
Ospika Complex 40 c	1128072	1290204	Telemetry	Ospika	u-7-029_357
Ospika Complex 40 d	1128040	1291292	Telemetry	Ospika	u-7-029_357
Ospika Complex 40 e	1127235	1288735	Telemetry	Ospika	u-7-029_357
Ospika Complex 40 f	1128300	1289457	Unknown	Ospika	u-7-029_357
Ospika Complex 30 a	1127540	1283709	Peace Williston - orthophoto	Ospika	u-7-029_374
Ospika Complex 30 b	1127859	1283870	Peace Williston - orthophoto	Ospika	u-7-029_374
Ospika Complex 30 c	1128171	1284710	Peace Williston - orthophoto	Ospika	u-7-029_374
Ospika Complex 30 d	1127906	1284296	Peace Williston - orthophoto	Ospika	u-7-029_374
Ospika Complex 30 e	1127912	1284177	Peace Williston	Ospika	u-7-029_374
Ospika Complex 30 f	1129281	1283512	Telemetry	Ospika	u-7-029_374
Ospika Complex 30 g	1130214	1283706	Telemetry	Ospika	u-7-029_374
Ospika Complex 30 h	1128432	1284139	Telemetry	Ospika	u-7-029_374
Ospika Complex 30 i	1129844	1284514	Telemetry	Ospika	u-7-029_374
Ospika Complex 30 j	1130175	1284795	Telemetry	Ospika	u-7-029_374
Ospika Complex 28 a	1129874	1278449	Peace Williston - orthophoto	Ospika	u-7-029_381
Ospika Complex 28 b	1130857	1279903	Peace Williston - orthophoto	Ospika	u-7-029_381
Ospika Complex 28 c	1131338	1280116	Peace Williston - orthophoto	Ospika	u-7-029_381
Ospika Complex 28 d	1127895	1279538	Peace Williston - orthophoto	Ospika	u-7-029_381
Ospika Complex 28 e	1128223	1279692	Peace Williston - orthophoto	Ospika	u-7-029_381
Ospika Complex 28 f	1128312	1279895	Peace Williston - orthophoto	Ospika	u-7-029_381
Ospika Complex 28 g	1128757	1279989	Peace Williston - orthophoto	Ospika	u-7-029_381
Ospika Complex 28 h	1128471	1280279	Peace Williston - orthophoto	Ospika	u-7-029_381
Ospika Complex 28 i	1130283	1279076	Peace Williston	Ospika	u-7-029_381
Ospika Complex 28 j	1129410	1280492	Peace Williston	Ospika	u-7-029_381
Ospika Complex 28 k	1130124	1279746	Peace Williston	Ospika	u-7-029_381
Ospika Complex 28 l	1130210	1279160	Peace Williston	Ospika	u-7-029_381

LICK IDENTIFICATION	EASTING - ALBERS	NORTHING - ALBERS	SOURCE	STUDY_AREA	SUPPLEMENTARY POLGYON ID
Ospika Complex 28 m	1128754	1279849	Telemetry	Ospika	u-7-029_381
Ospika Complex 28 n	1128836	1280059	Telemetry	Ospika	u-7-029_381
Ospika Complex 28 o	1128762	1280263	Telemetry	Ospika	u-7-029_381
Ospika Complex 28 p	1128634	1280403	Telemetry	Ospika	u-7-029_381
Ospika Complex 28 q	1128733	1280425	Telemetry	Ospika	u-7-029_381
Ospika Complex 28 r	1128872	1280599	Telemetry	Ospika	u-7-029_381
Aley Creek	1134333	1281910	Peace Williston - orthophoto	Ospika	u-7-029_378
Ospika Complex 17 a	1125656	1277135	Unknown	Ospika	u-7-029_384
Ospika Complex 17 b	1125674	1277105	Unknown	Ospika	u-7-029_384
Ospika Complex 17 c	1126159	1275658	Unknown	Ospika	u-7-029_384
Ospika Complex 17 d	1126916	1275301	Peace Williston	Ospika	u-7-029_384
Ospika Complex 17 e	1125983	1276062	Peace Williston	Ospika	u-7-029_384
Ospika Complex 17 f	1125950	1276470	Peace Williston	Ospika	u-7-029_384
Ospika Complex 17 g	1125691	1277074	Peace Williston	Ospika	u-7-029_384
Ospika 2	1127895	1262503	Peace Williston	Ospika	Not Included - outside of study area.
Ospika 29	1127726	1282117	Peace Williston - orthophoto	Ospika	Not included - isolated lick uncertain status/access route by goats.

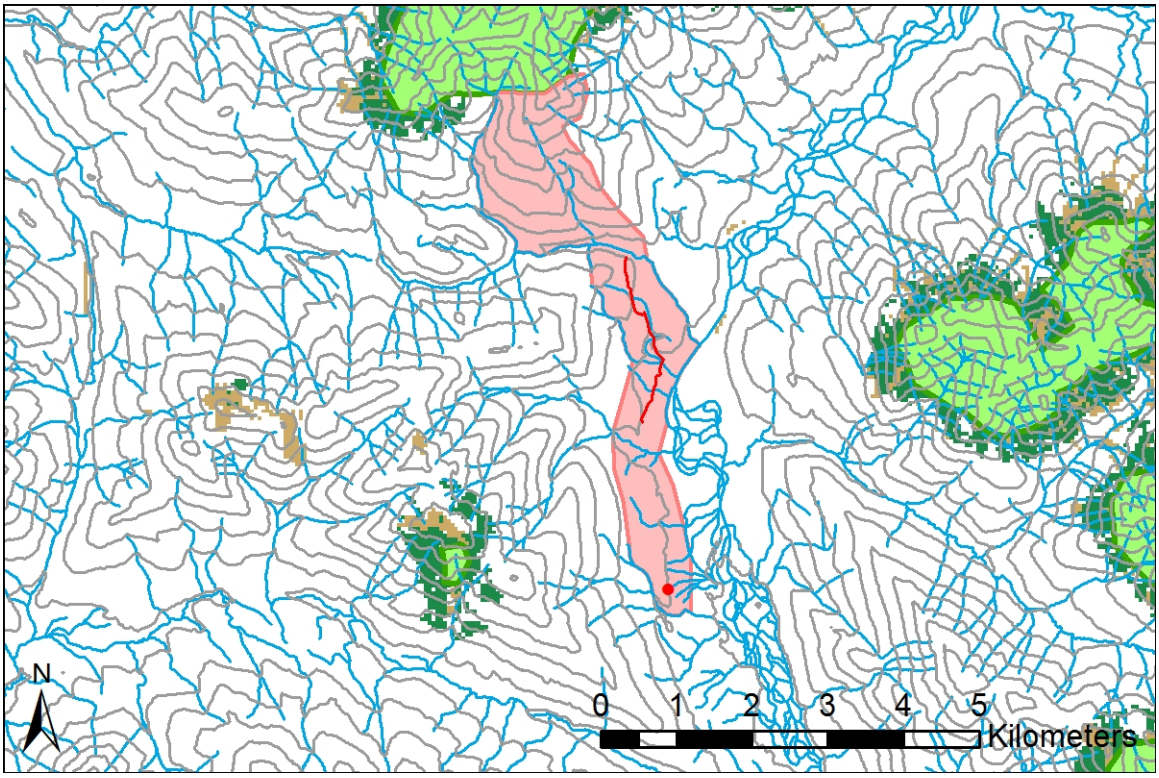
Table 14. Background information for identified trails.

TRAIL NAME	TRAIL LENGTH (all legs)	STUDY AREA	SUPPLEMENTARY POLGYON ID
Akie River Trail	2475m	Akie	u-7-029_26
Truncate Creek Trail	4062m	Akie	u-7-029_51
Thane Creek Trail	9041m	Osilinka	u-7-029_273
Ospika Complex 40 Trail	1000m	Ospika	u-7-029_357
Ospika Complex 30 Trail	2813m	Ospika	u-7-029_374
Ospika Complex 28 Trail	5336m	Ospika	u-7-029_381
Ospika Complex 17 Trail	1455m	Ospika	u-7-029_384

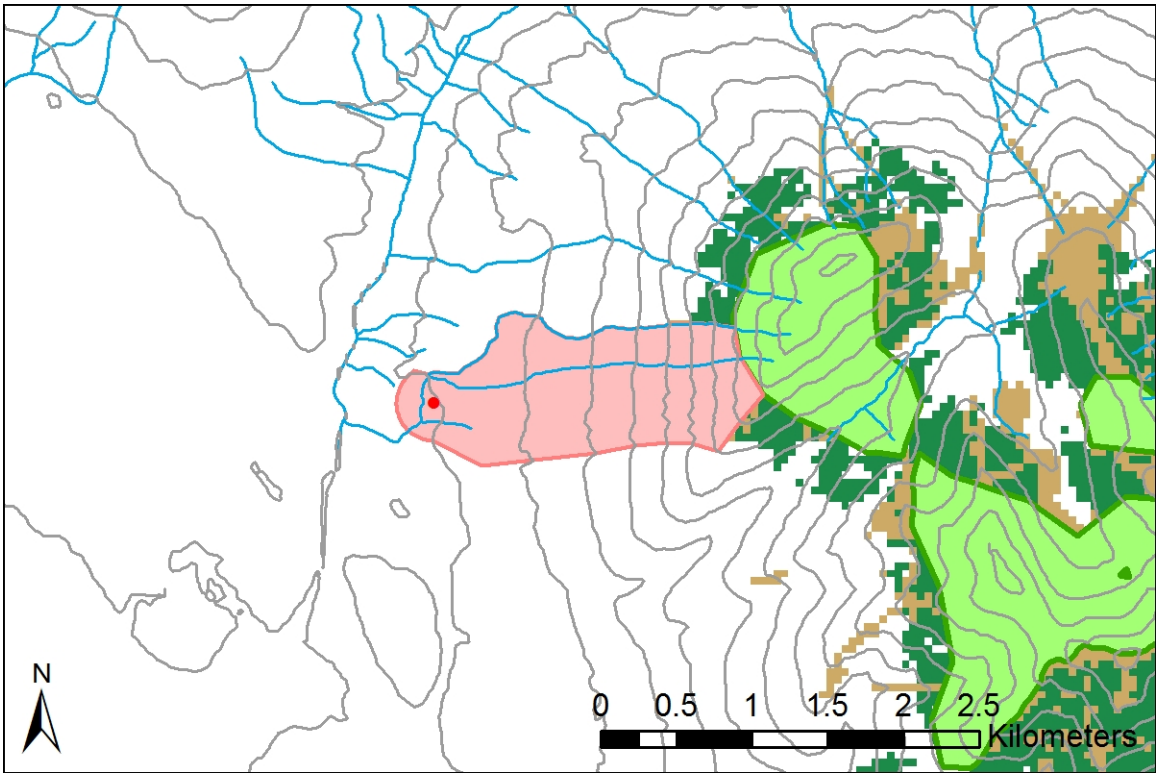
Appendix C. Descriptions and images of the supplementary polygons to incorporate licks and trails into draft UWRs



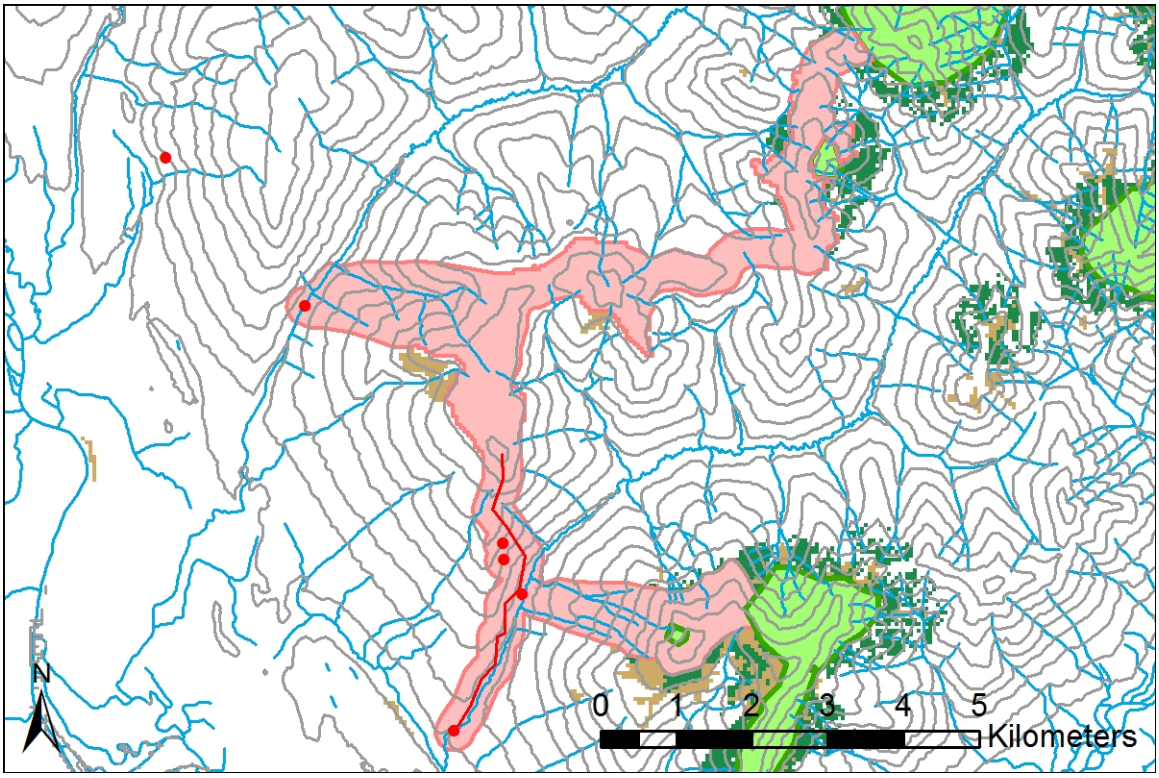
U-7-029_23 – This supplementary polygon joins two mineral licks (Akie River A and B) to modeled UWR units 20 and 24. In drawing the polygon boundary we ensured that the licks, buffered by 250 m, were fully within the polygon, and emphasized inclusion of preferred winter range and escape terrain that was peripheral to the modeled UWR units. The northwest boundary of the polygon follows the height of land between the two modeled UWR units as determined by a watershed boundary. The southern polygon boundary attempts to follow the boundary of the Akie River floodplain before continuing upslope to join UWR unit 24. The eastern boundary of the polygon approximates a ridgeline up to UWR unit 20.



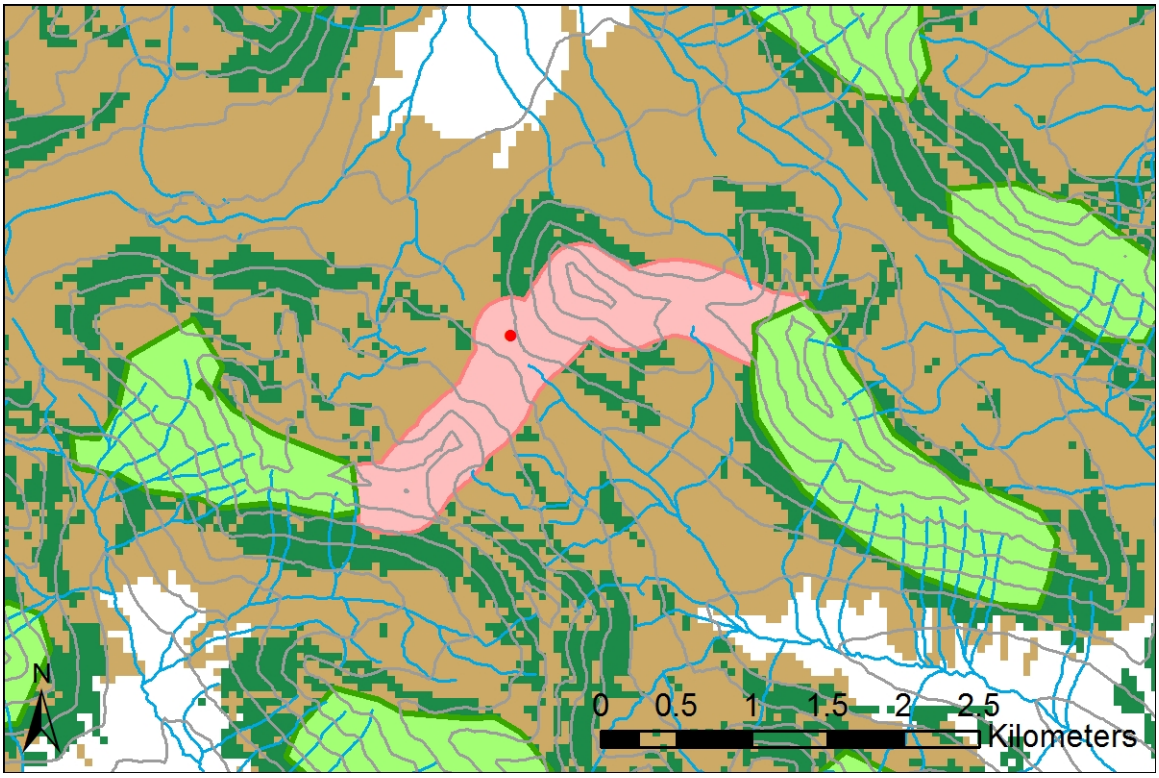
U-7-029_26 – This supplementary polygon joins the Canfor1 mineral lick and the Akie River Trail to the modeled UWR unit 25. At upper elevations the western boundary of the polygon follows a series of unnamed streams. At lower elevations where the polygon parallels the Akie River floodplain there are fewer options for incorporating identifiable features and the eastern boundary is drawn freehand but ties in to a stream junction and then ties into a stream that forms the southern tip of the polygon. The eastern boundary approximates the edge of the Akie River floodplain then ties in to a stream junction from which it ties into a stream that follows the edge of the floodplain. The eastern boundary rises out of the floodplain along a tributary and then departs from the tributary to follow a ridgeline up to the UWR unit. Use of streams in the boundary of this supplementary polygon resulted in slight impingements (≈20 – 40 m) to the 250 m buffer about licks and trails; however the polygon maintains a minimum of width of ≈450 m.



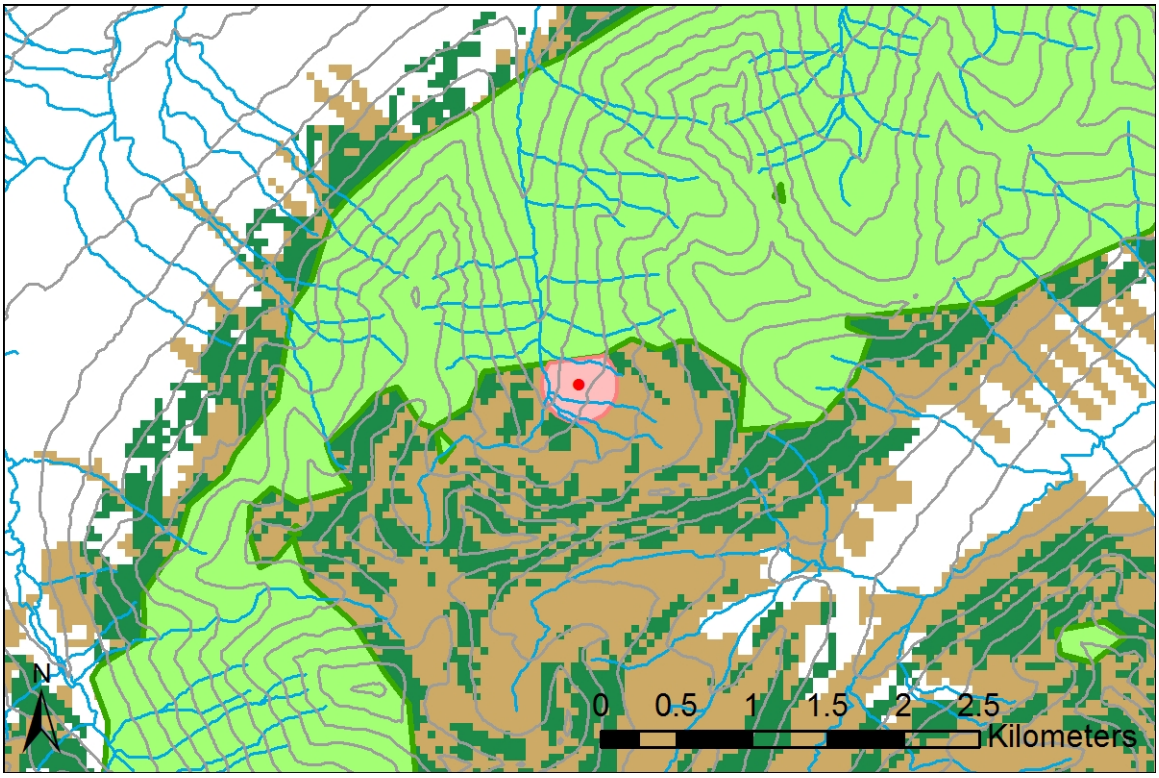
U-7-029_78 – This supplementary polygon links the Pesika Creek lick to modeled UWR unit 76. The northern boundary of the polygon follows a stream from the boundary of the UWR unit down to the 250 m buffer about the lick, follows the western edge of the buffer and then branches out to follow an apparent (i.e., not on the streams layer) small drainage as determined by contours for the southern boundary. The use of a stream to form the northern boundary of the polygon results in a small impingement (≈50 m) on the buffer about the lick.



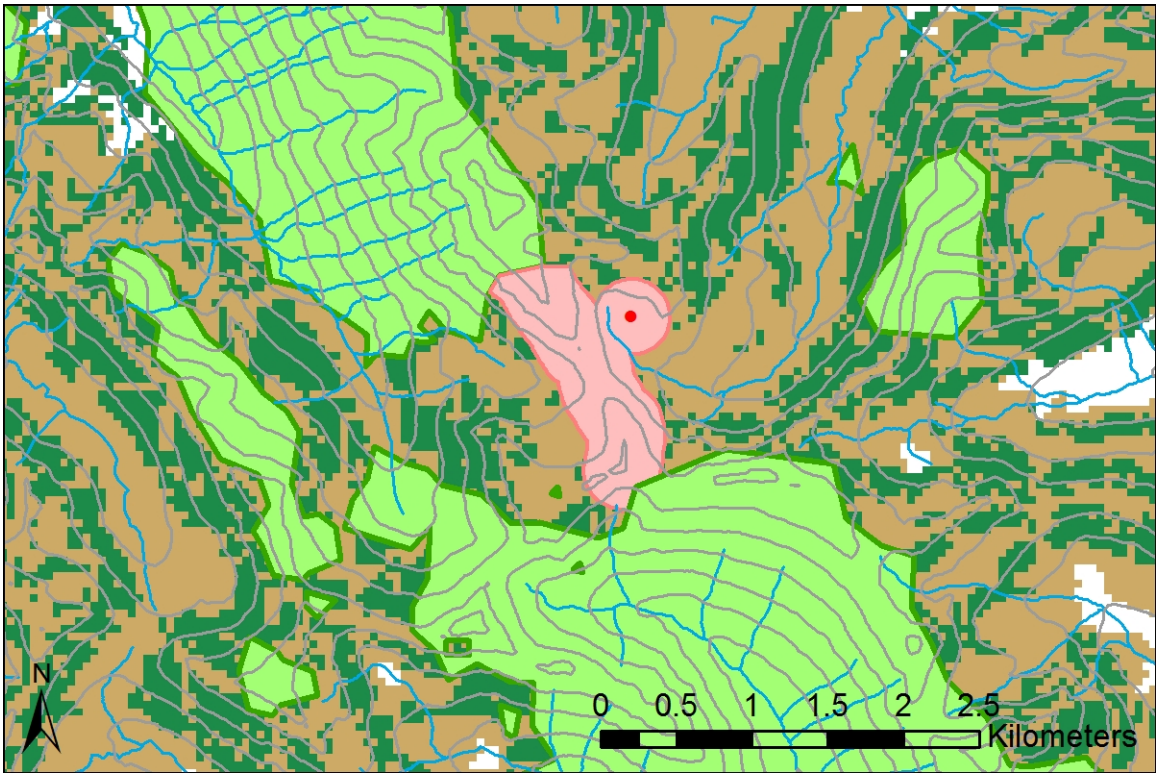
U-7-029_51 – This supplementary polygon links Truncate Creek licks 1 – 4, Blanchard Creek lick, and the Truncate Creek trail to modeled UWR units 40 and 61. The primary consideration in drawing the southern portion of the polygon was to follow the 250 m buffer about the licks and trails. Above the Truncate Creek trail, the boundary exploits the boundary of the ESSFmvp, a small (15 ha) UWR (unit 42) and a 250 m buffer about a watershed boundary to form a ridgeline access route to UWR unit 40. The Blanchard Creek lick is incorporated by polygon boundaries that approximate ridgelines for the north and south boundaries with the western boundary formed by the 1000 m contour and the buffer boundary about the lick. This portion of the polygon is designed to be wide enough to fully incorporate a complete ridgeline within it. To link to UWR unit 61, the polygon boundaries approximate ridgelines before tying in to the 1600 m contour for the northern boundary and the 1800 m contour for the southern boundary.



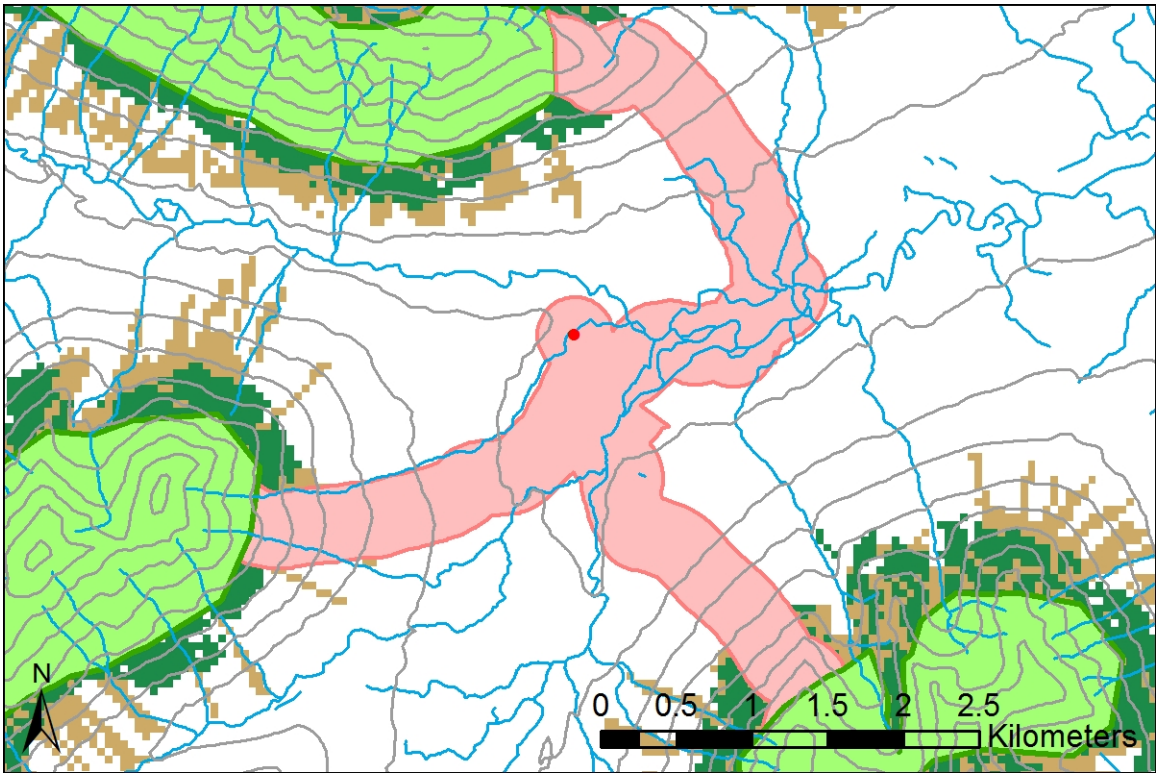
U-7-029_109 – This supplementary polygon links the Croydon Creek lick to modeled UWR units 111 and 112. The boundaries for this addition are formed by a 250 m buffer about a watershed boundary and expanded where the buffer boundary about the lick extends beyond the watershed buffer.



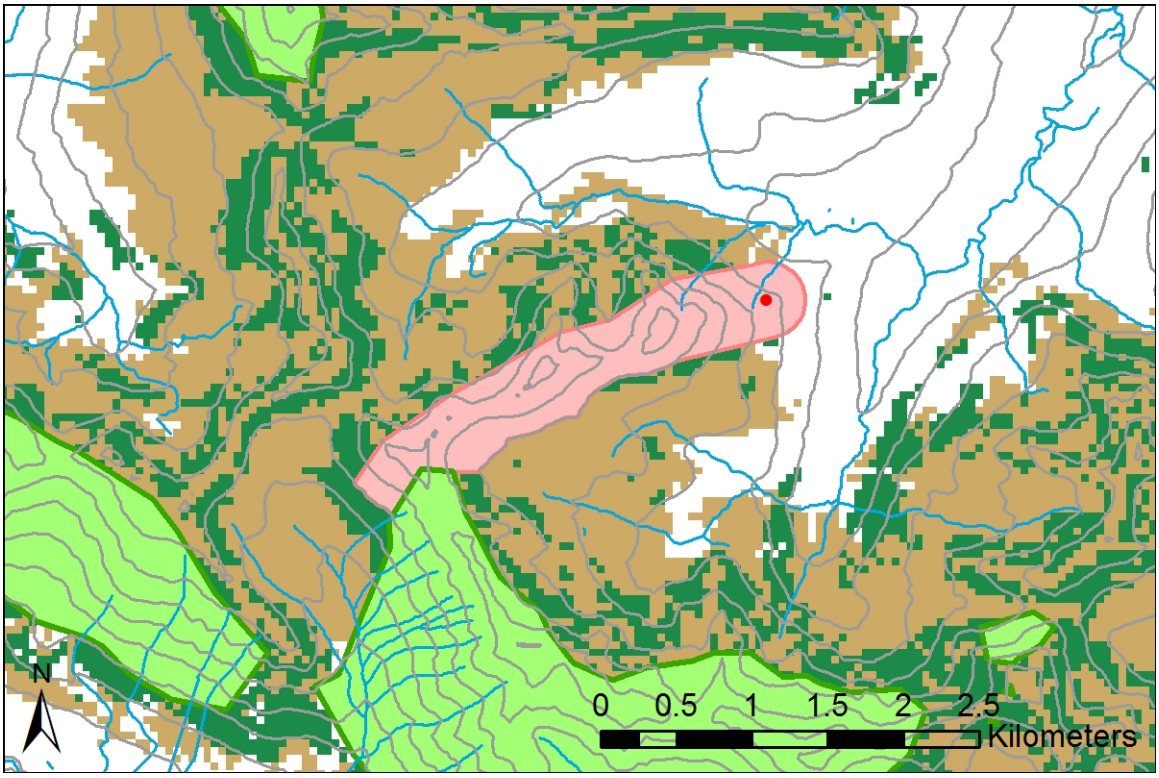
U-7-029_140 – This small supplementary polygon links the Mesilinka Tributary lick to the modeled UWR unit 138. The lick is <200 m from the boundary to the UWR unit and the boundary for this polygon simply traces that portion of the lick's 250 m buffer that is outside the UWR unit.



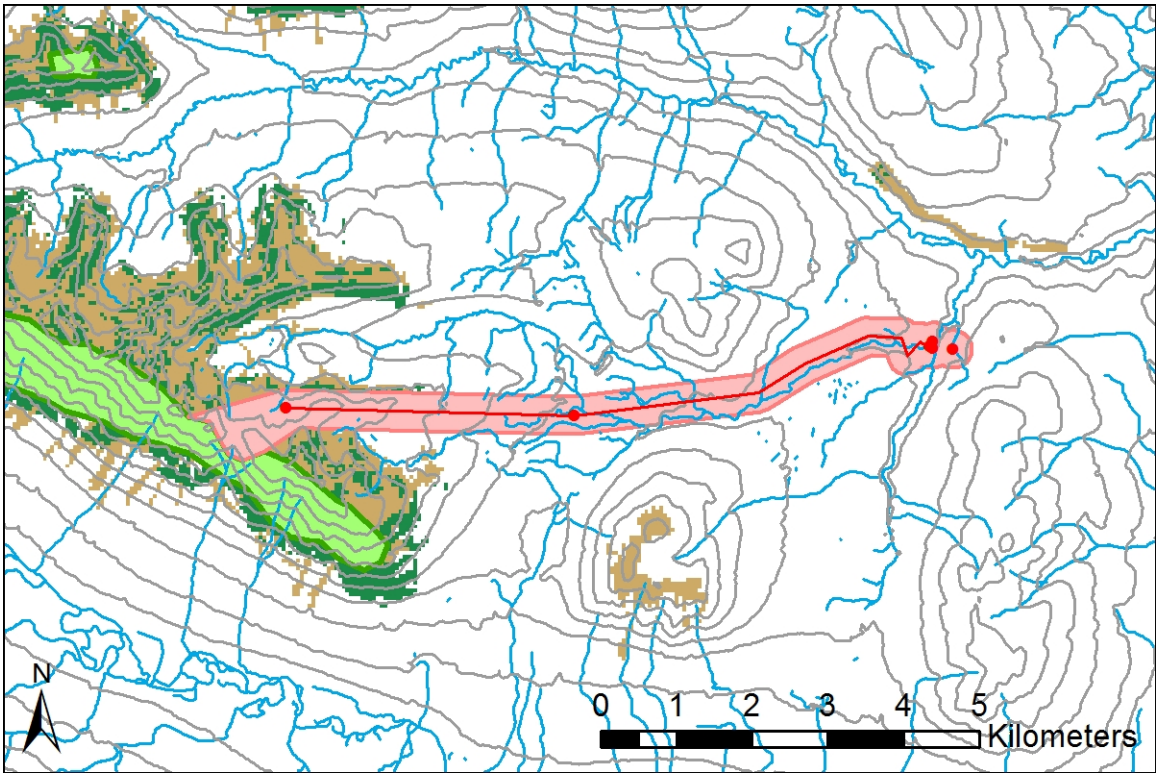
U-7-029_158 – This supplementary polygon links the Abraham Creek lick to modeled UWR units 138 and 171. The boundaries for this polygon are formed by a 250 m buffer about a watershed boundary and expanded where the buffer boundary about the lick extends beyond the watershed buffer.



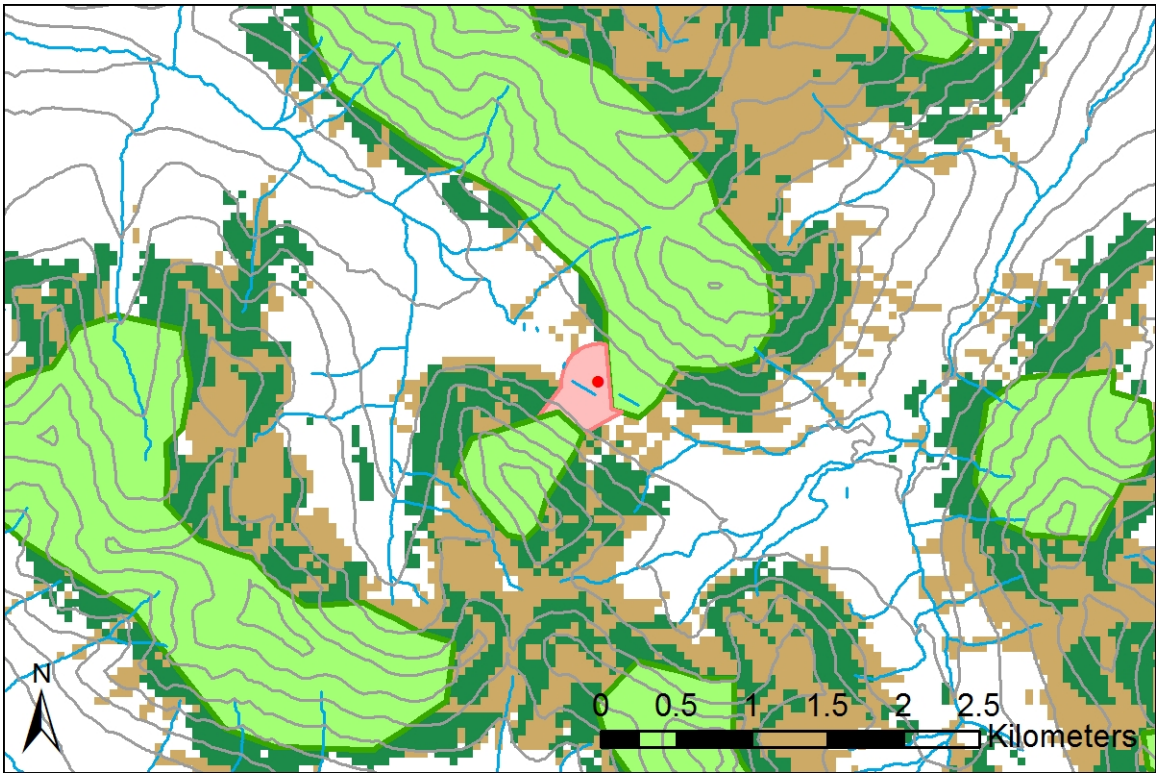
U-7-029_185 – This supplementary polygon connects the Klakring Creek Tributary lick to modeled UWR units 171, 188 and 194. The boundaries for this polygon are formed by a 250 m buffer about a watershed boundary and expanded where the buffer boundary about the lick extends beyond the watershed buffer.



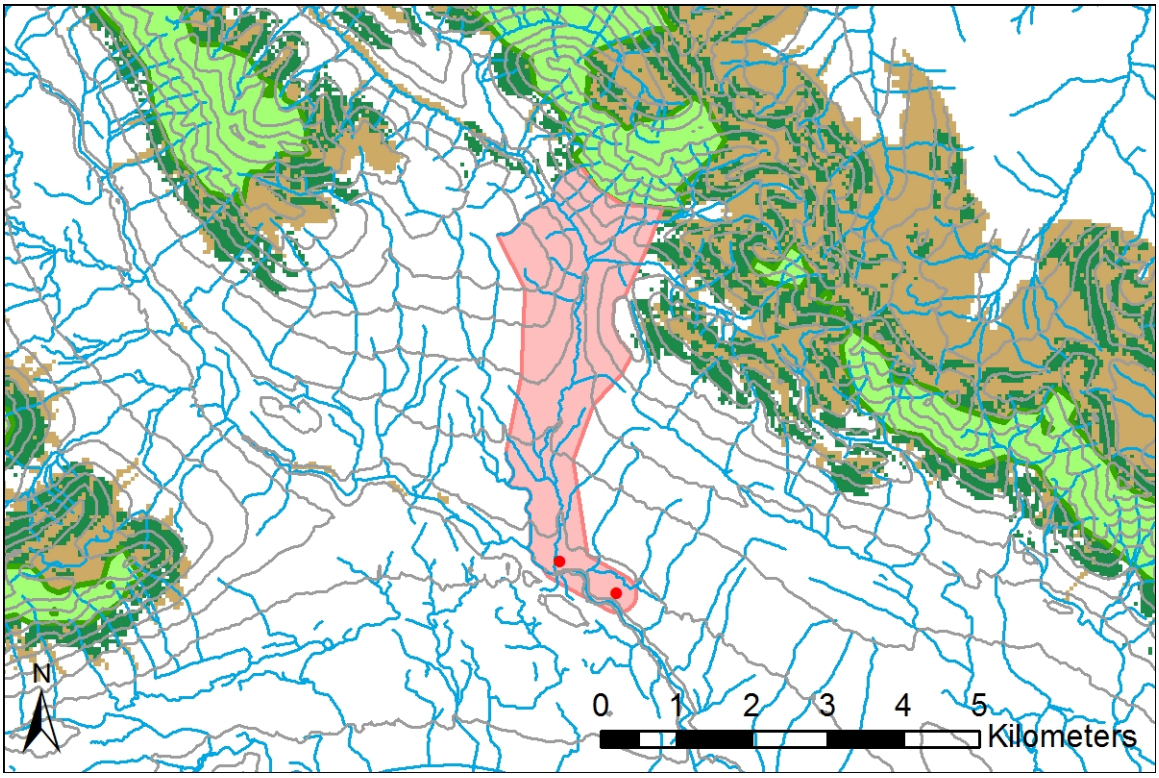
U-7-029_224 – This supplementary polygon joins the Osilinka lick to a modeled UWR unit 256. The eastern boundary of the polygon is formed by the 250 m buffer about the lick. The southern boundary extends from the lick buffer with a ≈600 m freehand drawn segment to the 1900 m contour and follows the contour until connecting to the UWR unit with a short (≈175 m) freehand drawn segment. The northern boundary of the addition is drawn freehand with the intent of maintaining a polygon width of 400 – 500 m and incorporating an alpine ridgeline.



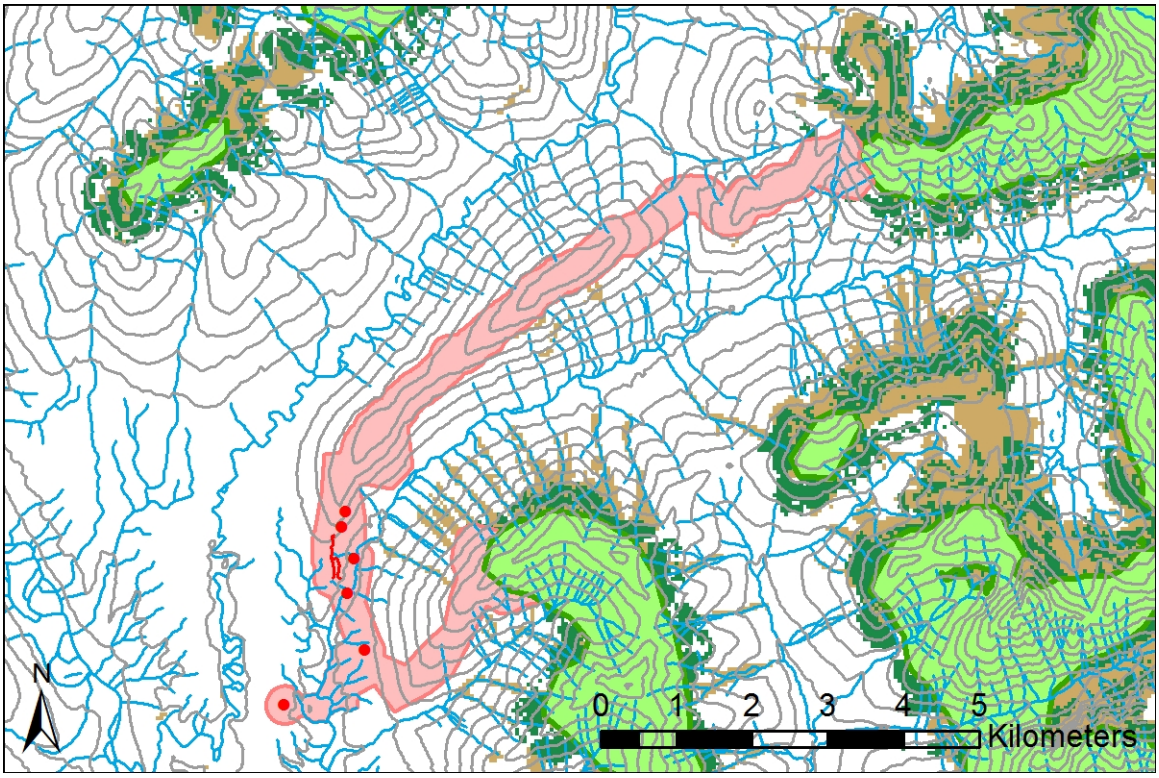
U-7-029_273 – This supplementary polygon connects the Thane Creek A – F licks and the Thane Creek trail to modeled UWR unit 256. The boundaries of the polygon are almost exclusively determined by the amalgamation of the 250 m lick and trail buffers with the exception of the last ≈700 m that connects to the UWR unit. The boundaries to connect the last 700 m to the UWR unit are drawn freehand and are approximately centered about the height of land as determined by the headwaters of creeks and a watershed boundary.



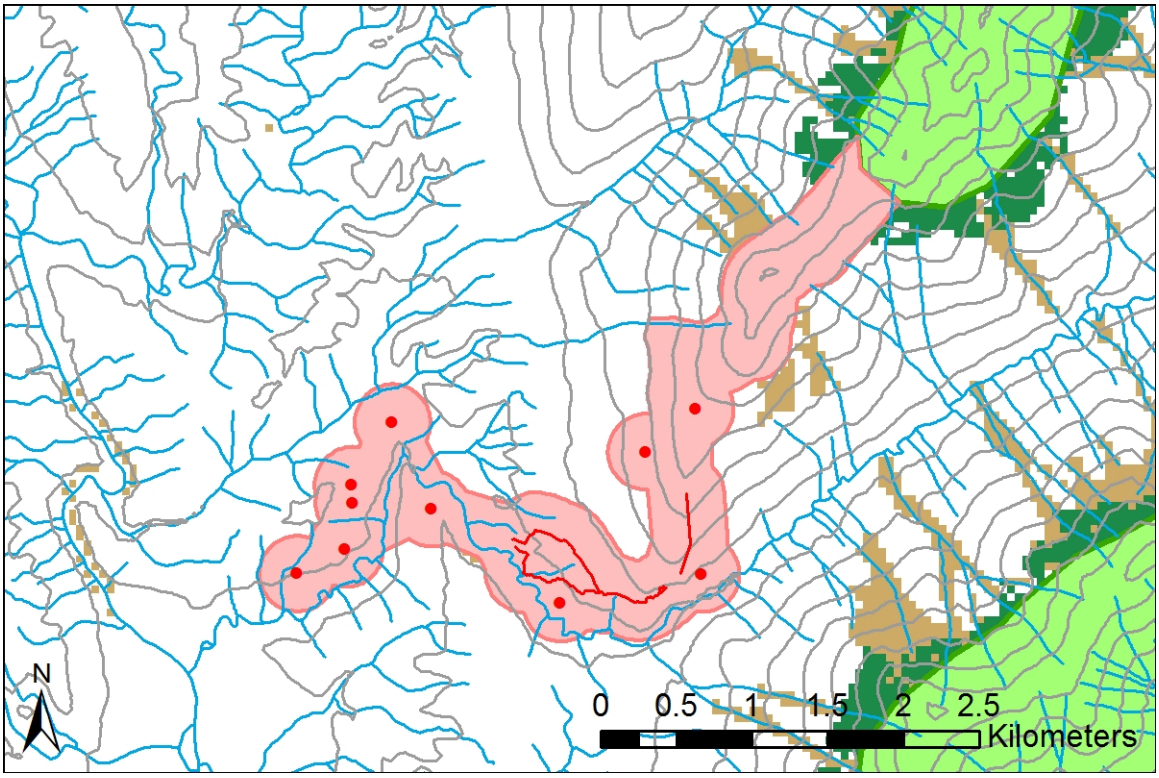
U-7-029_280 – This small supplementary polygon links the Flegel Creek lick to modeled UWR units 277 and 284. The lick is only ≈60 m from the boundary of UWR unit 277 and ≈330 m from the boundary of UWR unit 284. The boundary for this addition is formed from the 250 m buffer about the lick with two short freehand drawn boundary extensions to connect with the second UWR.



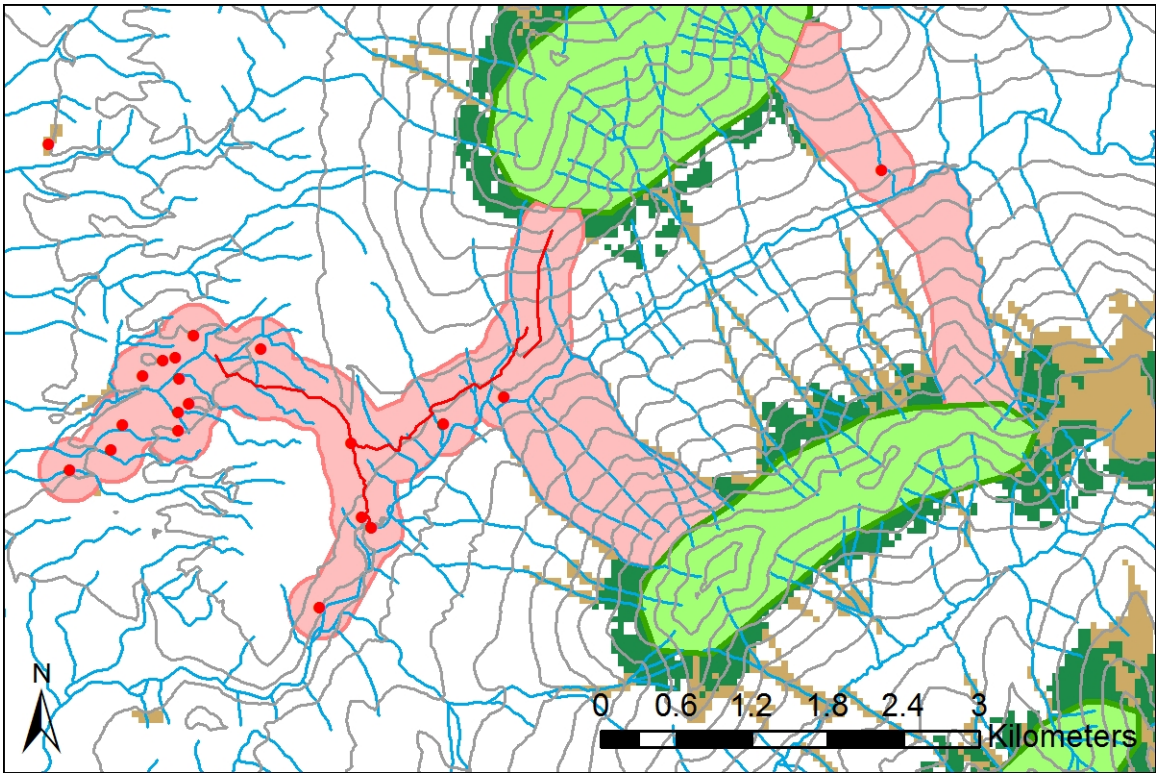
U-7-029_118 – This supplementary polygon links the Lay Creek and Polaris Creek licks to modeled UWR unit 107. The western boundary departs from the UWR unit along a tributary to Polaris Creek, briefly follows Polaris Creek upstream to tie in to another tributary that flows in from the southwest and then departs from the headwaters of this tributary. The next portion of the boundary is drawn freehand with the intention of remaining to the west of the ridgeline above Polaris Creek until it joins an unnamed tributary to Lay Creek. The boundary then follows Lay Creek briefly to the point where it intersects with the 250 m buffer about Polaris Creek lick. The southern tip of this polygon is formed by a combination of the buffers about both licks and freehand drawn boundaries with the intent to maintain a polygon width of 500 m. The eastern boundary of the polygon is drawn freehand as there is little by way of features to exploit without making the polygon excessively large. The objective in drawing the eastern boundary is to ensure sufficient space (>200 m) along the eastern side of Polaris Creek for use by goats.



U-7-029_357 – This supplementary polygon joins the Ospika Complex 40 licks (a – f) and the Ospika Complex 40 Trail to the modeled UWR units 351 and 367. Boundaries for the southwest arm of the polygon are formed by the 250 m buffer about lick 'e' with the north and south boundaries of the arm following unnamed creeks. The southeast arm that rises to UWR unit 367 encompasses a ridgeline with the intent of describing a corridor ≈400 – 500 m in width. As the southeast arm approaches UWR unit 367 the boundaries trace the escape terrain and the potential winter range habitat peripheral to the UWR. Boundaries for the north arm are guided by the merged 250 m buffers about the licks and trail and then are formed by a 250 m buffer about a watershed boundary that extends almost to UWR unit 351. One exception was made to using the buffered watershed boundary in order to wholly encompass an area of escape terrain that extends from the top of the trail. As the north arm approaches UWR unit 351, the boundaries approximate escape terrain peripheral to the UWR unit boundary.

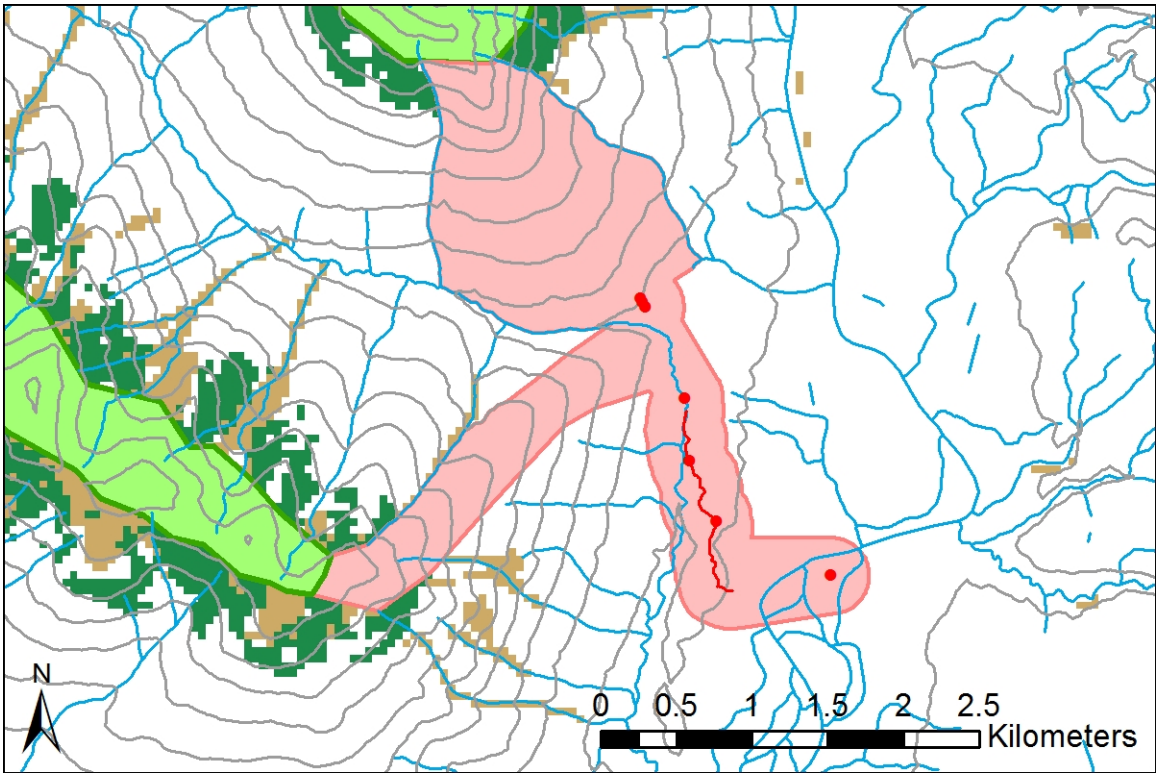


U-7-029_374 – This supplementary polygon links the Ospika Complex 30 licks (a – j) and Ospika Complex 30 Trail to modeled UWR unit 367. The boundaries of the western portion of this polygon are formed primarily from the merged 250 m buffers about licks and trails and then follow the 250 m buffer about a watershed boundary to the UWR.



U-7-029_381 – This supplementary polygon joins the Ospika Complex 28 licks (a – r) and Ospika Complex 28 Trail to the modeled UWR units 376 and 382. The boundaries for this polygon trace the 250 m buffer about trails and licks with the exception of the arm that rises to UWR unit 382. Boundaries for this latter arm follow unnamed creeks that flow from the UWR unit and encompass two ridgelines and extensions of escape terrain.

U-7-029_378 – This supplementary polygon links the Aley Creek lick to the modeled UWR units 376 and 382. The southeast boundary of the polygon is formed by an unnamed tributary to Aley creek that flows from UWR unit 382 and then follows Aley Creek to join the 250 m buffer about the lick. The boundary briefly traces the lick buffer and then runs upslope to tie into the upper reaches of a creek and then traces potential goat winter range peripheral to the UWR unit 376. The northwest boundary of the polygon follows an unnamed creek that flows from UWR unit 376 and then departs from the stream to tie in to the lick buffer. After briefly tracing the buffer boundary the boundary runs upslope to UWR unit 382. We note that the entire western boundary of this polygon could be formed by tracing two tributaries to Aley Creek however our objective was to keep the addition small but functional and chose to primarily encase a ridgeline that extends from UWR unit 382 to the valley bottom.



U-7-029_384 – This supplementary polygon joins the Ospika Complex 17 licks (a – g) and the Ospika Complex 17 Trail to modeled UWR units 377 and 387. The southern arm of this polygon is formed primarily by the merged 250 m buffers about the licks and trail. The southwest arm of the polygon that extends to UWR unit 387 encases a ridgeline within a ≈400 – 500 m corridor. The northern boundary of this arm ties in to a stream at approximately mid-slope. The northern section of the polygon that connects to UWR unit 377 is bounded by streams. We note that a watershed boundary bisects this northern section of the polygon but chose not to simply use a 250 m buffer about the watershed boundary due to the ill-defined nature of this ridge.

Appendix D. 2006-2011 comparison of goat modeling in the Akie, Osilinka and Ospika study areas

Background for Testing Procedure

It was necessary to test both the 2006 results and the current modeling using the same methods. The specifications for these methods are given below.

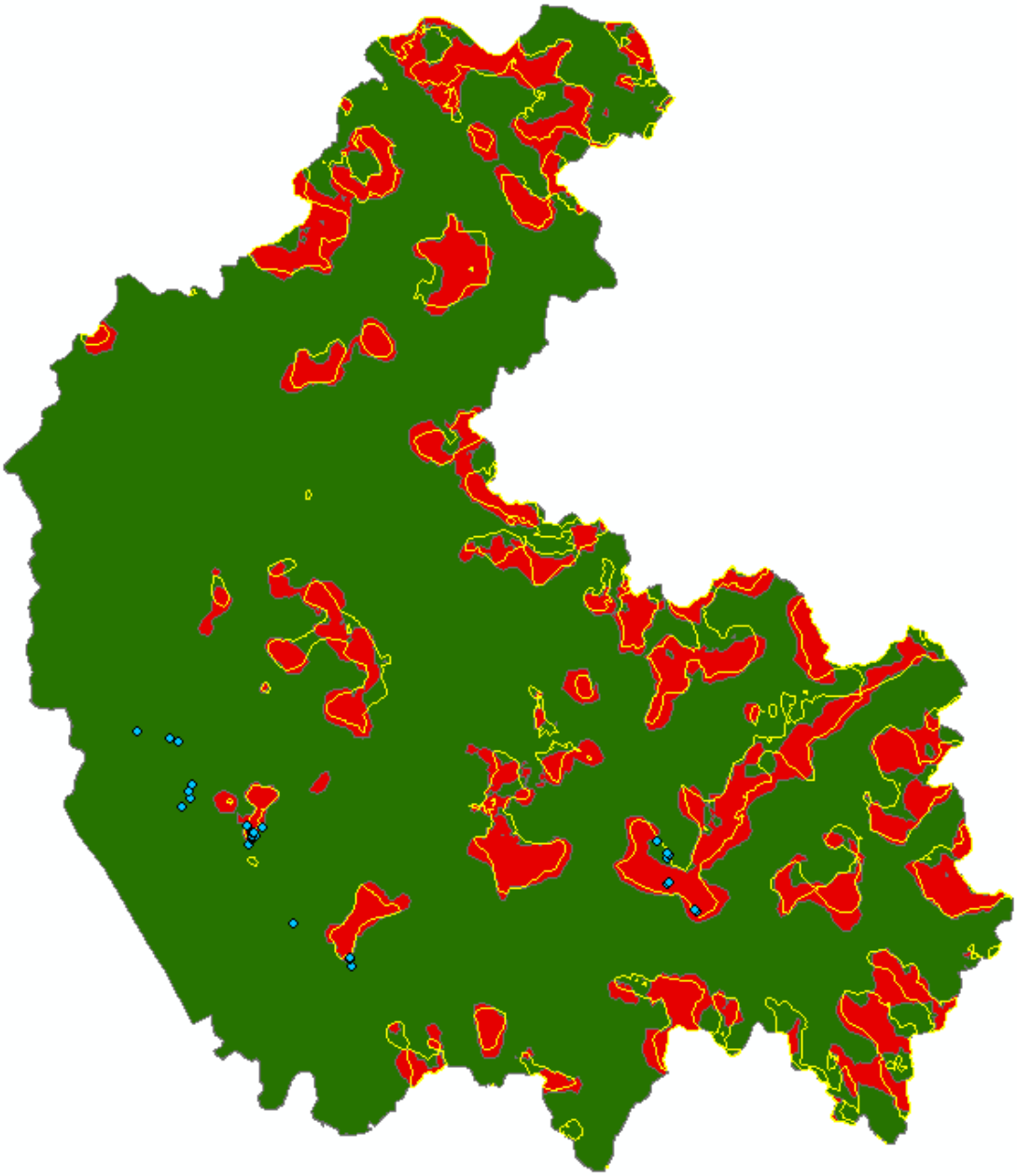
- Prepare goat relocations based on locations found in 2006 modeling directories
    - Take only winter locations (Dec. 1 – Mar. 31)
    - Remove captures and mortalities
    - Clip to Akie-Pesika, Osilinka, and Ospika unbuffered study areas
- Clip 2006 UWRs to unbuffered study areas
- Clip 2011 UWRs to unbuffered study areas
- Perform comparisons on blobbed draft UWRs, not model results generated with a cutpoint of 0.33 rather than 0.9, as that method from report 194might mislead readers of the report.
- Determine how many locations are close to UWRs since the UWRs represent areas of the highest density of escape preference but areas of escape preference extend well beyond these core areas without attaining the same density.

Results

Results for each of the three study areas are presented below. In the images you will see these features:

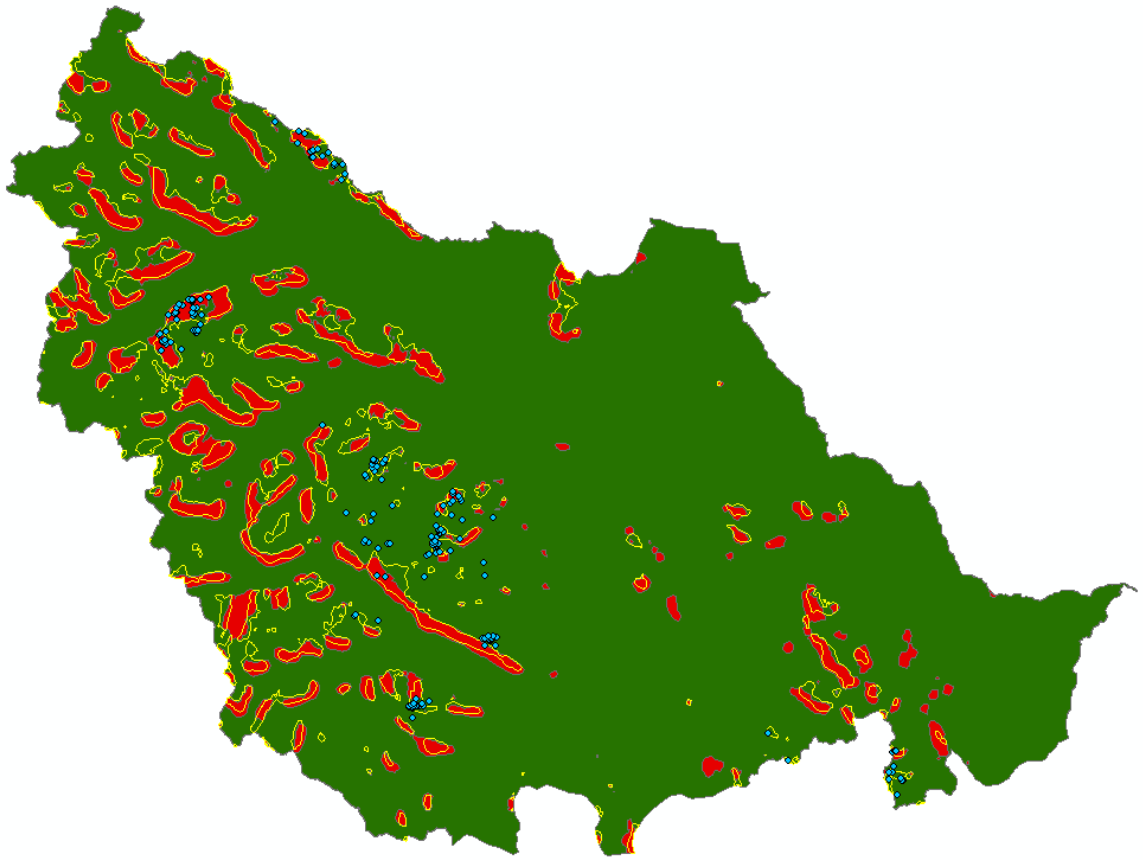
- Green polygon = unbuffered study area
- Red polygons = 2011 UWR polygons
- Yellow outlines = 2006 UWR polygons
- Blue points = winter goat relocations

Akie:



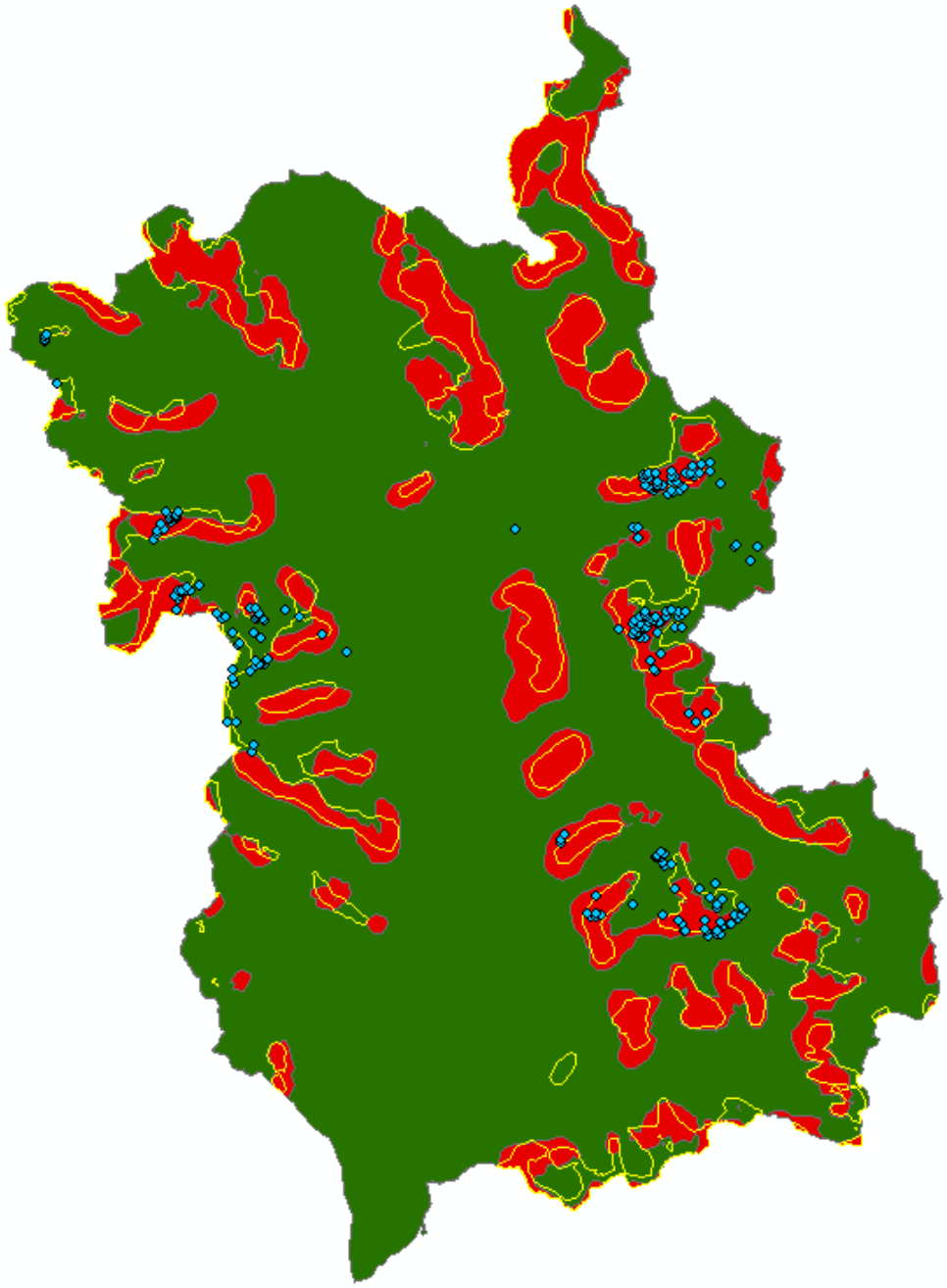
Statistic	2006	2011
UWR Area (ha)	29620.8	33940.7 (+14.6%)
Area common to both 2006 and 2011 UWRs	22850.1 (77.8%)	
Total # of relocations	44	
# of relocations in UWR	15 (34.1%)	15 (34.1%)
# of relocations within 250m of UWR	-	28 (63.6%)
# of relocations within 500m of UWR	-	30 (68.2%)

Osilinka:



Statistic	2006	2011
UWR Area (ha)	38598.5	43289.2 (+12.2%)
Area common to both 2006 and 2011 UWRs	25363.3 (65.7%)	
Total # of relocations	223	
# of relocations in UWR	115 (51.6%)	59 (26.5%)
# of relocations within 250m of UWR	-	81 (36.3%)
# of relocations within 500m of UWR	-	109 (48.9%)

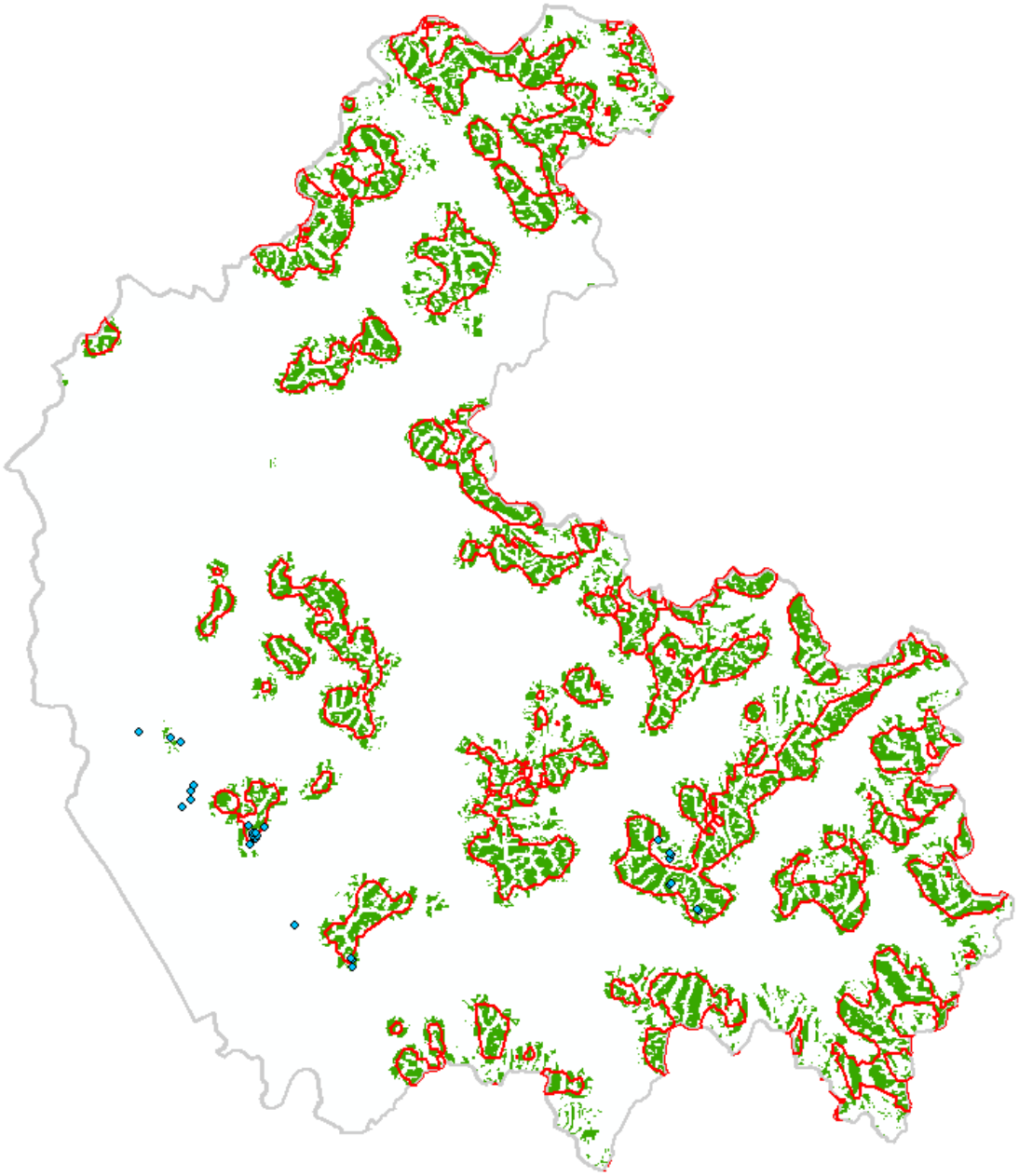
Ospika:



Statistic	2006	2011
UWR Area (ha)	20682.6	29033.7 (+40.4%)
Area common to both 2006 and 2011 UWRs	16511.7 (79.8%)	
Total # of relocations	313	
# of relocations in UWR	183 (58.5%)	171 (54.6%)
# of relocations within 250m of UWR	-	220 (70.3%)
# of relocations within 500m of UWR	-	258 (82.4%)

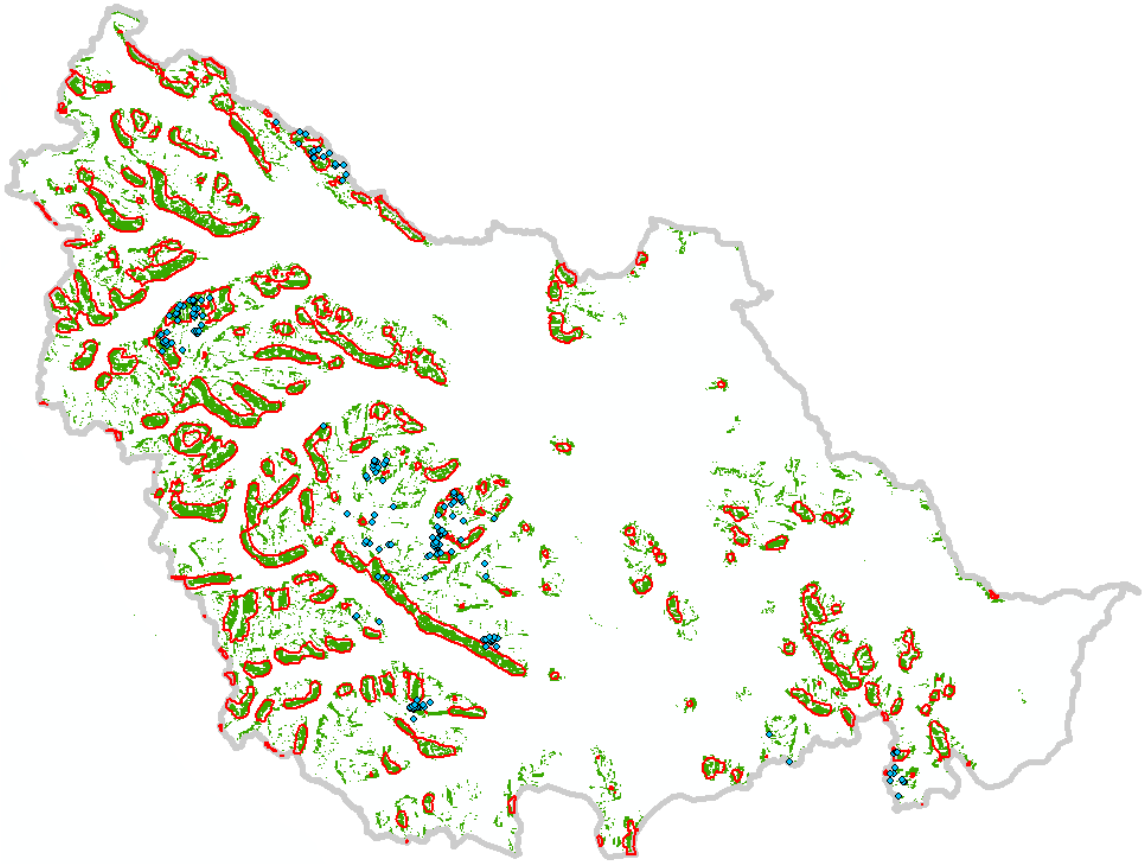
Test of present modeling (raw model outputs, rather than draft UWR polygons)
To confirm the quality of the present modeling and justify the search for locations within 250m and 500m of newly mapped draft UWRs(as seen in the tables above), we tested how many of the locations fell in or within 100m of areas defined as having escape preference by the BBN (EP node >=0.9). For reference, these are the same cells whose neighbourhood is calculated to find core areas that become draft UWR polygons. In the images below the red outlines are 2011 modeled UWRs and the green areas are the EP >=0.9 cells used to create the UWRs. The greater extent of suitable modeled terrain beyond the draft UWRs is evident.

Akie:



Result: **28/44** or **63.6%** of relocations are inside or within 100m of 2011 model results.

Osilinka:



Result: **175/223** or **78.4%** of relocations are inside or within 100m of 2011 model results.

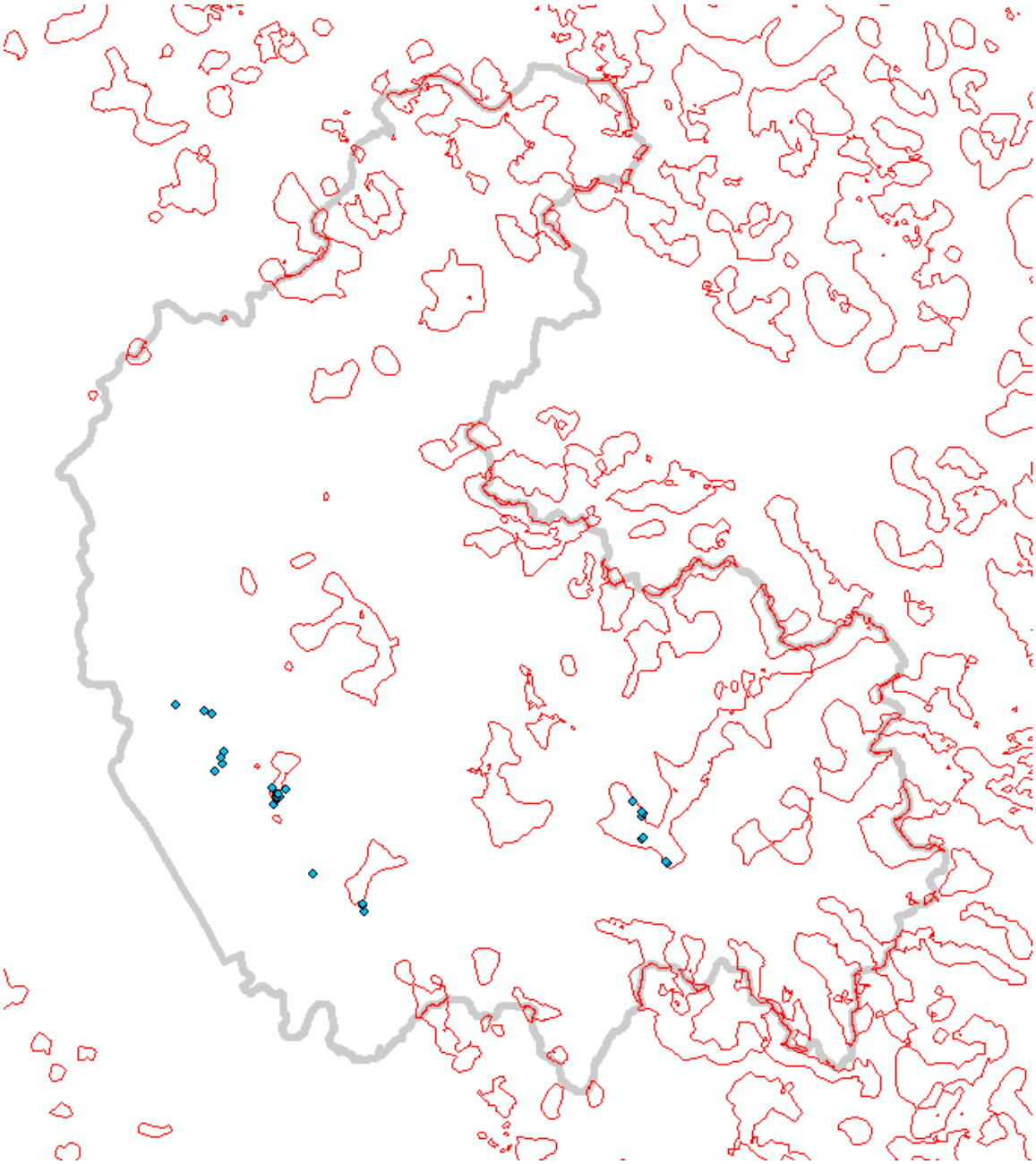
Ospika:

Result: **266/313** or **85.0%** of relocations are inside or within 100m of 2011 model results.

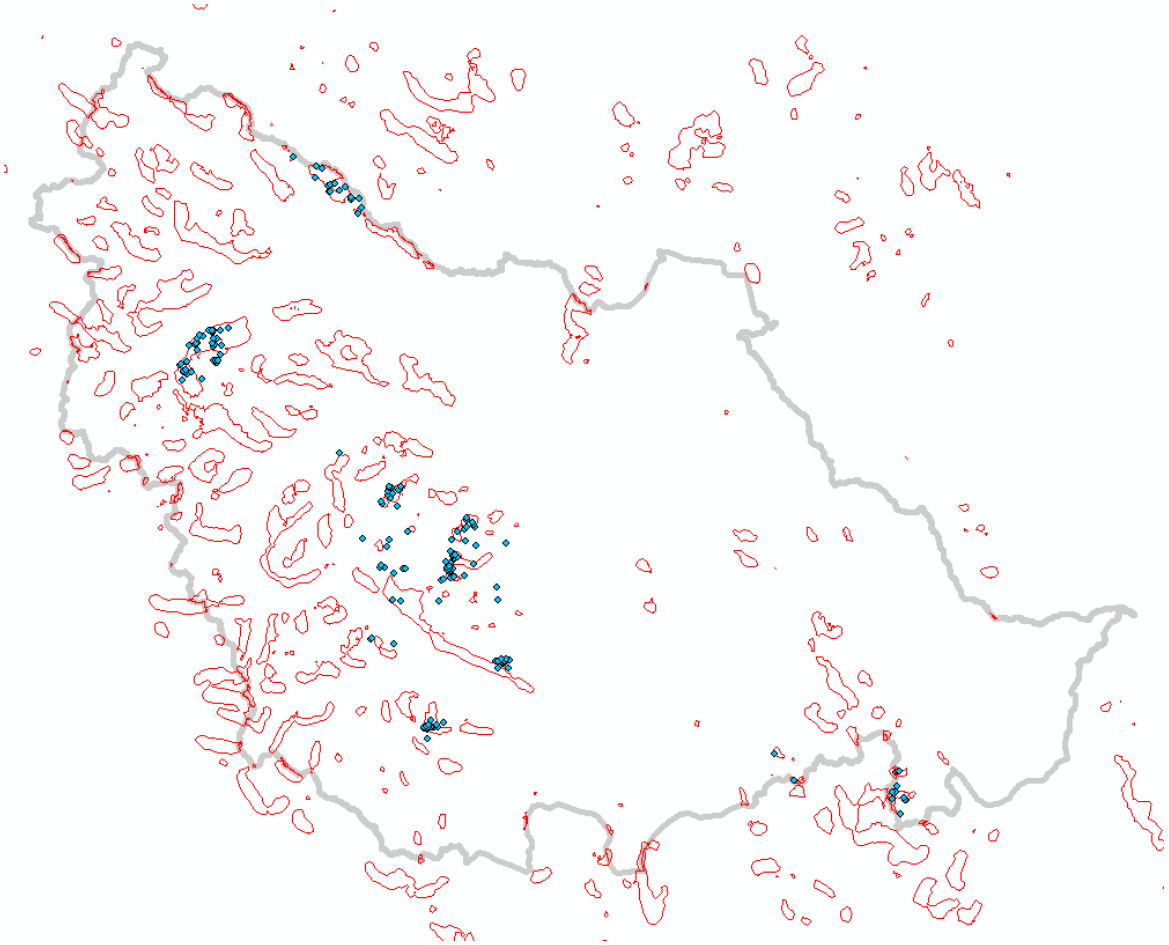
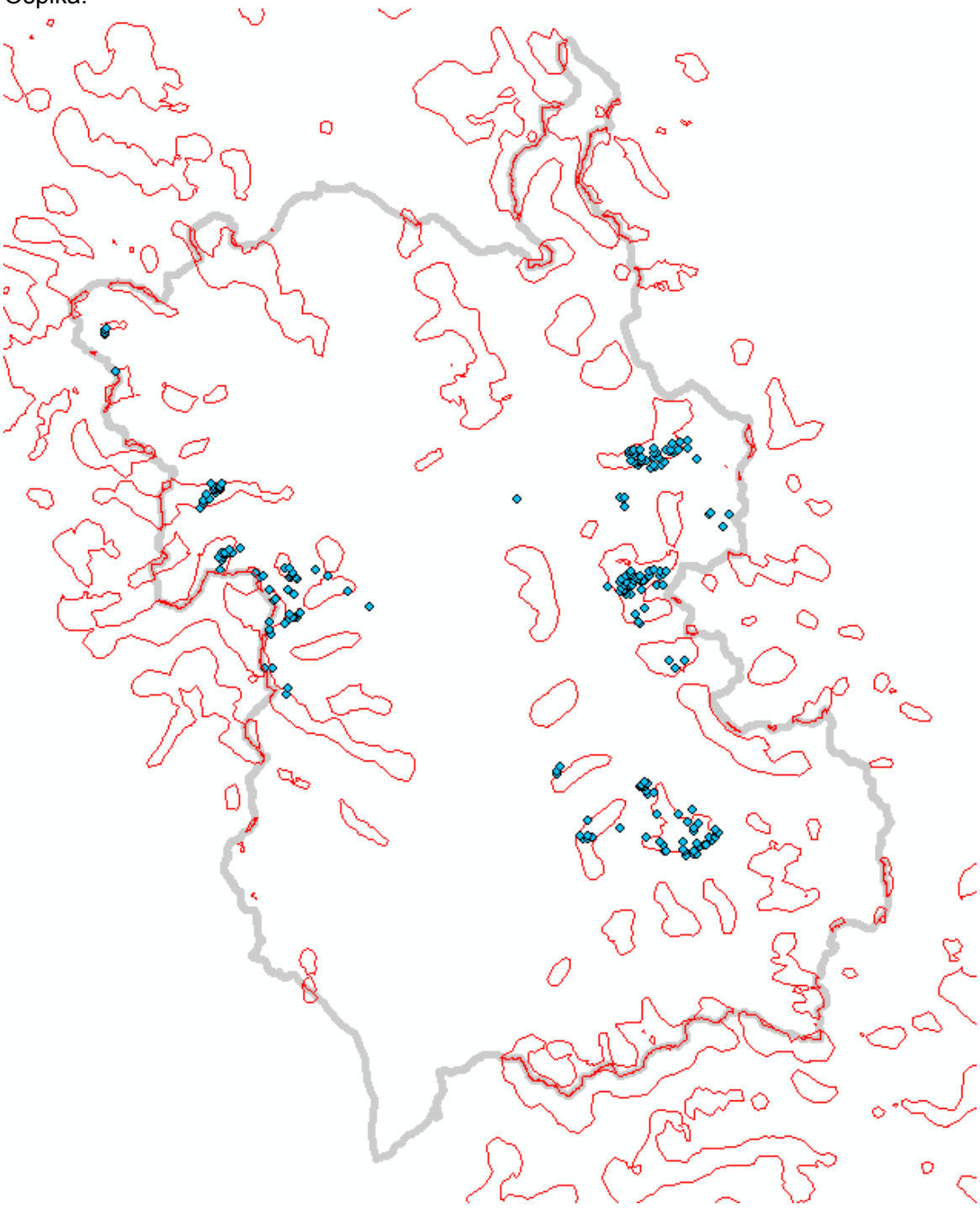
Comparison to modeling in remainder of TSA

This project required the delivery of 2006 model results augmented with additions for licks and trails plus the current modeling for the remainder of the forest district. This made it necessary to stamp out the three unbuffered 2006 study areas from the 2011 draft UWR polygons and have the 'holes' filled with the augmented 2006 results. For this reason we need to confirm that the 2011 modeling 'meshes' with the 2006 modeling at the boundaries of these three areas. The figures below demonstrate that this has been achieved. The interior of the study areas are filled with 2006 draft UWRs while the remainder is composed of the new draft UWRs.

Akie:



Osilinka:



Ospika: