

SUSITNA HYDROELECTRIC PROJECT

FINAL REPORT

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VOL. III

MOOSE FORAGE BIOMASS IN THE MIDDLE SUSITNA
RIVER BASIN, ALASKA

Earl F. Becker
Alaska Department of Fish and Game

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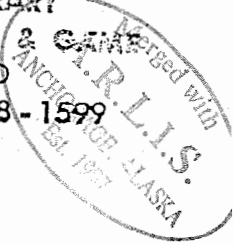
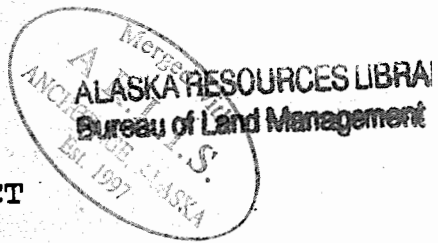
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ALASKA DEPARTMENT OF FISH AND GAME

333 RASPBERRY ROAD

ANCHORAGE, ALASKA 99518-1599

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PREFACE

Between January 1980 and June 1986, the Alaska Power Authority (APA) contracted with the Game Division of the Alaska Department of Fish and Game (ADF&G) to provide field data and recommendations to be used for assessing potential impacts and developing options for mitigating impacts of the proposed Susitna Hydroelectric Project on moose, caribou, brown bear, black bear, Dall sheep, wolf, wolverine, and belukha whales. ADF&G was only one of many participants in this program. Information on birds, small mammals, furbearers, and vegetation was collected by the University of Alaska and private consulting firms.

Formally, ADF&G's role was to collect data which could be used to describe the baseline, pre-project conditions. This information was supplemented with data from other ADF&G studies. Baseline conditions were defined to include processes which might be sufficiently sensitive to either direct or indirect project induced impacts to alter the dynamics of the wildlife populations. The responsibility of impact assessment and mitigation planning was assigned by APA to several private consulting firms. ADF&G staff worked closely with these firms, but only in an advisory capacity.

The project was cancelled before the impact assessment and mitigation planning processes were complete. In an effort to preserve the judgements and ideas of the authors at the termination of the project, the scope of this report has been expanded to include material relating to impact assessment and mitigation planning. Statements do not necessarily represent the views of the APA or its contractors. Conjectural statements sometimes are included in the hope that they may serve as hypotheses to guide future work, should the project be reactivated.

The following list of reports completely cover all of the Game Division's contributions to the project. It should not be necessary for the reader to consult the many progress reports.

Moose

Modafferri, R. D. 1987. Susitna Hydroelectric Project, Big Game Studies, Final Report Vol. I - Moose - Downstream. Alaska Dept. of Fish and Game.

Ballard, W. B. and J. S. Whitman. 1987. Susitna Hydroelectric Project, Big Game Studies, Final Report, Vol. II - Moose - Upstream. Alaska Dept. of Fish and Game.

Becker, E. F. and W. D. Steigers. 1987. Susitna Hydroelectric Project, Big Game Studies. Final Report, Vol. III - Moose forage biomass in the middle Susitna River basin, Alaska. Alaska Dept. of Fish and Game.

Becker, E. F. 1987. Susitna Hydroelectric Project. Big Game Studies. Final Report. Vol. VI - Moose Carrying Capacity Estimate. Alaska Dept. of Fish and Game.

ARLIS

Alaska Resources
Library & Information Service
Anchorage, Alaska

Caribou

Pitcher, K. W. 1987. Susitna Hydroelectric Project, Big Game Studies. Final Report. Vol. IV - Caribou. Alaska Dept. of Fish and Game. 59pp.

Black Bear and Brown Bear

Miller, S. D. 1987. Susitna Hydroelectric Project, Big Game Studies, Final Report. Vol. V - Black Bear and Brown Bear. Alaska Dept. of Fish and Game.

Wolf

Ballard, W. B., J. S. Whitman, L. D. Aumiller, and P. Hessing. 1984. Susitna Hydroelectric Project, Big Game Studies. 1983 Annual Report. Vol. V - Wolf. Alaska Dept. of Fish and Game. 44pp.

Ballard, W. B., J. S. Whitman, and C. L. Gardner. 1987. Ecology of an exploited wolf population in southcentral Alaska. Wildlife Monographs No. __ (In press).

Wolverine

Whitman, J. S. and W. B. Ballard. 1984. Susitna Hydroelectric Project, Big Game Studies. 1983 Annual Report. Vol. VII - Wolverine. Alaska Dept. of Fish and Game. 25pp.

Dall Sheep

Tankersley, N. G. 1984. Susitna Hydroelectric Project, Big Game Studies. Final Report. Vol. VIII - Dall Sheep. Alaska Dept. of Fish and Game. 91pp.

Belukha Whale

Calkins, D. 1984. Susitna Hydroelectric Project, Big Game Studies. Final Report. Vol. IX - Belukha Whale. Alaska Dept. of Fish and Game. 16pp.

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INTRODUCTION

The proposed Susitna Hydroelectric Project consists of 3 major developments on the Susitna River, approximately 180 miles north and east of Anchorage, Alaska. The first phase would be the Watana Stage I earth-fill dam and associated power and camp facilities. The Watana Dam site would be located at river mile 184 above the mouth of the Susitna River, in a broad U-shaped valley approximately 2.5 miles upriver from the Tsusena Creek confluence. The dam would create a reservoir approximately 39 miles long with a maximum width of about 3 miles (excluding tributaries), and have a surface area of 14,900 acres at the normal maximum operating level of 2,025 feet mean sea level, (MSL). The second stage would be the Devil Canyon Stage II concrete arch dam and associated facilities. The Devil Canyon Dam site would be located in the Devil Canyon gorge at river mile 152 of the Susitna River, approximately 32 miles down river from the Watana Dam site. It would form a reservoir approximately 26 miles long with a surface area of 7,800 acres at the normal operating level of 1,455 feet MSL. Stage III would consist of raising the Watana dam to create a reservoir 48 miles long and having a surface area of 38,000 acres. Maximum width of the Stage III reservoir would be approximately 5 miles.

Construction and operation of the Watana and Devil Canyon hydroelectric dams in the middle Susitna River Basin (Fig. 1) would result in both permanent and temporary losses of habitat for moose (Alces alces gigas). Approximately 72 square miles of land area would be permanently inundated, and another 24 square miles temporarily disturbed as a result of the project. Loss of the vegetation growing there to reservoir inundation, camp facilities, borrow sites, and other sources represents a loss of capacity to support moose populations. Loss of habitat carrying capacity would be the primary impact on moose of hydroelectric development in the Susitna basin.

Impacts of the Susitna Hydroelectric Project on the loss of moose habitat will be based on an assessment of the loss of carrying capacity of the affected area. Nutritional carrying capacity is defined as the number of healthy individuals that can be maintained in a designated area for a specified time period. Mathematical models of range food supply and animal food habits have been used to estimate habitat carrying capacity for roe deer (Capreolus capreolus) (Bobeck 1977), mule deer (Odocoileus hemionus hemionus) (Wallmo et al. 1977), white-tailed deer (O. virginianus) (Potvin and Huot 1983), and elk (Cervus elaphus nelsoni) (Hobbs et al. 1982, Hobbs and Swift 1985).

In Alaska, research has been underway to modify the generalized ruminant submodel developed by Swift (1983) to make it specific to moose (Regelin et al. 1985, 1986, Schwartz et al. 1984, 1986a, 1986b). The model has been

developed, tested, and verified on the Kenai Peninsula (Hubbert 1987).

In 1983 it was decided to adapt the moose carrying capacity model to assess impacts of the proposed Susitna Hydroelectric Project on moose. This model, coupled with area-specific information on moose, provided the means for the impact assessment and mitigation planning in conjunction with hydroelectric development in Alaska. This approach for impact assessment has not previously been used for moose. Development of the model represents a major advancement in assessment of the impacts of man's activities on a free-ranging population of animals.

The objective of this study was to provide an estimate of the amount of browse that is available to moose in the middle Susitna Basin. This estimate was an essential element of the moose carrying capacity model.

During the spring and summer of 1982 and 1983 preliminary browse inventory studies were conducted to make first determinations of the vegetation types and browse species most heavily utilized by moose in the areas to be affected by the project, and to determine the most cost-effective method of sampling biomass of browse species. Vegetation mapping, utilizing new aerial photography techniques, was initiated in 1984 to provide detailed maps upon which browse biomass could be stratified. The stratified vegetation map formed the sample frame, and was essential for obtaining an estimate of browse biomass.

ACKNOWLEDGMENTS

This project was a joint effort between the Alaska Department of Fish and Game and LGL Alaska Research Associates. The list of people who have contributed to the completion of the browse inventory study during 1984 and 1985 is extensive. We would like to especially thank Dr. Wayne Regelin (ADF&G) for his guidance in the initial planning stages and for his assistance in implementing the ADF&G intern program. SuzAnne Miller (ADF&G) has been of invaluable assistance in computer programming, program guidance, statistical consulting, and trouble-shooting. Randy Fairbanks (Harza-Ebasco Susitna Joint Venture), Dr. Robin Sener (LGL Alaska Research Associates), and Karl Schneider (ADF&G) have been responsible for funding and overall program guidance. We would like to thank the following people for technical assistance: ADF&G interns D. Ashby, B. Barkuloo, C. Bird, S. Brainerd, G. Chaney, J. Chumbley, R. Gonzalez, M. Hertzic, D. Hoffman, J. Keller, J. Kidd, T. LeFlamme, N. Larter, J. McCarthy, T. McKinley, I. Murto, K. Omura, C. Petersen, L. Restad, A. Swan, D. Weisel, J. Wieggers, L. Wold, and E. Wood; ADF&G employees N. Tankersley and T. Otto; and volunteers C. Burns and P. Wood. D. Anctil, P. Mieczynski, L. Aumiller, and B. Strauch of ADF&G and B. Bennett of System Integrators Inc. provided

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STUDY AREA

The 1,021-square-mile study area is located in the middle Susitna River basin, upstream of the mouth of Devil Canyon (Fig. 1). Study area boundaries were defined by Ballard et al. (1983), as the "primary zone of impact" for moose. Elevations range from about 900 feet (274 m) on the river at the mouth of Devil Canyon to 6,255 feet (1,907 m) at the top of Mt. Watana. The river elevation rises to approximately 2,500 feet (746 m) where the Denali Highway crosses the Susitna River. Topography of the study area has been strongly influenced by past glacial action and associated stream and river erosion, resulting in a broad U-shaped valley occupied by the Susitna River. The river channel slopes are very steep near Devil Canyon and become less steep and wider at the eastern end of the study area, north of the confluence of the Tyone River. Terraces above the river channel are approximately 2,000-2,500 feet (610-762 m) in elevation and make up the majority of the study area.

McKendrick et al. (1982) mapped 16 vegetation types in the middle and upper Susitna River basin at levels III or IV of the classification system developed by Viereck and Dyrness (1980). The plant communities are strongly influenced by site topography, soils, and moisture regimes. The steep, well-drained river channel slopes are dominated by forest communities such as mixed paper birch (Betula papyrifera) and white-spruce (Picea glauca) forests and open coniferous forests on both sides of the river. Benches above the river primarily contain shrub communities dominated by resin birch (B. glandulosa) on the drier sites, white-spruce forests on the well-drained slopes, and black spruce (Picea mariana) forests on the wetter sites. Willows (Salix), primarily diamondleaf willow (S. pulchra), grayleaf willow (S. glauca), Richardson willow (S. lanata), and feltleaf willow (S. alaxensis), dominate the shrub communities in the wetter sites on upland slopes and in the coniferous forests. Alpine vegetation types occur at the highest elevations.

METHODS

The primary objective of this report was to estimate the amount of browse that is available to moose during the winter. These estimates will then be used to generate carrying capacity estimates of moose in the Susitna Basin. In the initial phase of this project, it was decided to stratify willow biomass on the basis of a vegetation map. Due to 1) our inability to produce accurate stratification maps for each willow species and 2) the inherent sampling problems involved with using a stratification scheme for each species, it was decided to stratify on Salix biomass. The combining of the various willow species caused us to make assumptions about the availability of the various willow species.

Willow biomass strata were developed and analyzed using combined biomass of all willows, based on the assumption that all willow species available to wintering moose in the study area were equally preferred (and subsequently consumed), or at least not specifically avoided by the end of winter. A second assumption was that different willow species were equally available to wintering moose. In reality, not all species were equally available because each species had a distinct regional distribution and thus a different degree of accessibility.

Resin birch is an important understory component of many vegetation types in the Susitna Study area (Steigers et al. 1983). However, it was not sampled during this study because: 1) it is very time consuming to remove the small twigs of this species (Steigers and Helm 1984); and 2) it composed only 11% of the average moose diet in this region (Steigers and Becker 1986). Resin birch, for the purposes of this study, was considered to be non-limiting either in distribution or abundance. Resin birch biomass was assumed to be available to the extent that moose voluntarily limit their intake.

A vegetation map of the study area was prepared by R.A. Kreig and Associates, Inc. The study area was mapped to level IV of the Viereck et al. (1982) vegetation classification system, using 40 acres (16.19 hectares) as the minimum polygon size. The understory cover of willow, resin birch, and alder (Alnus) was classified into the following categories: 0-4%, 5-25%, 26-50%, 51-75%, and 76-100% cover (see Appendix A). The mapping was done by photo-interpretation of color infrared (CIR) photographs. Ground-truthing was done by the mappers and from information collected during the 1984 sampling season.

Vegetation sampling was conducted from July 9 through August 22, 1984 and from July 11 through August 25, 1985. During the first phase of the 1984 sampling effort, 5 1:60,000 scale CIR photos were subjectively chosen to cover the east-west gradient of the middle Susitna River basin. Using a two-stage sample design (Cochran 1977), the first stage being 1-mile line transects and the second stage

consisting of square-meter plots, these areas were sampled and the amount of current annual growth biomass (CAG) of willow and paper birch present was estimated. Whole mountain cranberry (Vaccinium vitis-idaea) plants were clipped at ground level. To maximize the number of different vegetation polygons for which browse biomass data were obtained, the transects were given a north-south orientation which corresponded to the major elevation-aspect gradient. A total of 36 transects was sampled and provided data used to stratify the study area into willow CAG strata.

After these 36 transects were sampled, the study area was divided into 3 populations: the Watana population (population B), the Devil Canyon population (population D), and the outside population (population A), to facilitate sampling during the second phase of the sampling effort. Population B was created to facilitate intensive sampling of browse within the proposed Watana impoundment. The upper elevational boundary of population B was the 2,200 foot contour; when necessary the boundaries were extended above 2,200 feet to maintain a minimum width of 0.5 mile. Population D was created to facilitate intensive browse sampling within the proposed Devil Canyon impoundment. The upper elevation boundary of population D was the 1,500 foot contour; when necessary the boundary was extended above 1,500 feet to maintain a minimum width of 0.5 mile. Population A consisted of the remaining area within the study area and below the 3,400 foot contour; the area above the 3,400 foot contour was deleted since 97% of all winter observations of moose in the study area occurred at or below this elevation (Ballard et al. 1983).

During the second phase of the 1984 season, 72 transects were sampled in the 3 populations. The number of transects sampled per population was weighted by the proportion of area, within each population, that was scheduled to be inundated by the dams, and the perceived variation in willow biomass per population; of the 72 transects, 49 were conducted in population A, 15 in population B, and 8 in population D. One-mile transects were used to sample population A, while 0.5-mile transects were used to sample the other 2 populations due to their narrow shape. In total, 108 transects were completed during the summer of 1984.

Four groups of transects were randomly selected from a 1:63,360 scale USGS topography map of the study area. Transects were then transferred to both 1:60,000 scale CIR and 1:24,000 scale true-color photographs (when available) for use by the field crews. Accurate transfer of the transects to the aerial photographs was facilitated through use of a Map-o-graph. Crews used the 1:60,000 scale CIR and the 1:24,000 scale photography, when available, for locating transect starting points. Helicopters were used to transport the crews, each consisting of 2 people, to the landing zone closest to the transect starting point. When a

crew could not be dropped off at the starting point, orienteering methods were used to reach this point.

Plots were randomly selected, without replacement, along the transect, and sampled if they fell within the population of interest. The number of plots sampled per transect varied from 20 to 30 as we attempted to maximize the average number of plots a 2-man crew could complete in a day. The number of plots sampled was changed upon the completion of a randomly selected group of transects. Twenty-two plots per transect were used after the first few weeks.

Once at the transect starting point, the crew would orient themselves to a prescribed compass heading and go the specified number of meters to the first plot. All distances were measured along a transect using a 100-meter tape. A straight-line course was maintained using a hand-held compass. If the average straight-line slope between successive plots exceeded 15 degrees, the distance traveled between successive plots was corrected, for slope, to the nearest meter. This was done to adjust ground distances to match the planar distance on the two-dimensional aerial photographs. Discrepancies between field transect locations and map locations were documented, when known, to assure accurate post-stratification.

At each plot the following information was recorded: transect number; plot number; date; crew code; distance measured from last plot; elevation (feet); aspect (degree azimuth); slope (degrees); local topography within a 100-foot radius of the plot (convex, simple slope, concave, or complex); surface drainage within a 100-foot radius of the plot (fast, intermediate, or ponded); site moisture within a 100-foot radius of the plot (very dry, dry, moist, or wet); landscape setting within a 0.5-mile radius of the plot (flat, undulating flats, hills-mountains [if hills-mountains, then whether the landscape setting was on the valley floor, lower one-third of the slope, or the ridge crest]); Viereck et al. (1982) level IV vegetation classification (see Appendix A for the classifications and codes used); percent canopy, by genus, for willow, resin birch, and alder (0=0%, 1=1-4%, 2=5-25%, 3=26-50%, 4=51-75%, 5=76-100% cover).

A 1 x 1-meter-square plot was positioned parallel to the line of travel, and at the end point of the distance measurement. The plot frame was elevated 50 cm above the ground by metal stakes and clamps, and oriented parallel to the ground surface. The current-annual-growth twigs were clipped and placed in paper bags by height categories and species for diamondleaf willow, grayleaf willow, Richardson willow, feltleaf willow, one shrub genera (other willow species), and paper birch. Height strata were to be used to adjust the amount of forage that is available during the winter at various snow depths. The 2 height strata used were 0-50 cm, and 50-250 cm. The 250-cm maximum height was not observed if the diameter-at-breast-height (dbh) of the

shrub stem was less than 2.5 cm. All current-annual-growth twigs that were within the vertical boundaries of the plot were clipped. A 20 x 50-cm subplot was positioned at ground level within the larger 1-m-square plot, parallel to the line of travel and starting at the end point of the distance measurement. All mountain cranberry leaves and twigs occurring within the vertical borders of the subplot were clipped and bagged.

All field data were recorded on Epson HX-20 notebook computers which were programmed to prompt crew members for data input at each plot. Data were transferred directly from the Epson to an IBM PC-XT computer, located at base camp, at the end of each day. Once in the IBM PC-XT the field data were run through format, error check, and sort programs to ensure high quality and organization of data. Field work ended on August 22, 1984.

Collected plant material was brought to the field laboratory each evening. Bags of samples brought into the laboratory were checked against a list of the bags that should have been present, as determined by data entered into the field computers. Bags were placed in drying ovens and dried at 60 C for at least 72 hours prior to processing. Leaves and foreign material were separated from the twigs, and the twigs were then redried and weighed to the nearest one-hundredth gram on a Mettler PC4400 electronic balance. The weights, transect number, plot number, crew code, species, and height strata were recorded on an Epson HX-20 computer. Laboratory data were transferred directly from the Epson to the IBM PC-XT computer, where they were run through format, error check, and sort programs to ensure data quality and organization. The lab data were then merged with the field data, and another error checking program reported mismatches between the field data and the weight data. When errors were discovered, all effort was made to immediately determine the source and rectify them.

After returning from the field, the transect lines were transferred from the aerial photos to vegetation map overlays that corresponded to the photos. The distance between vegetation polygon intersections with the transect line was digitized. From this information every plot in the transect could be classified into a vegetation polygon by comparing the digitized distances associated with polygon intersections with the distance of the plot from the transect starting point. Plots occurring at the border of polygon intersections (within 50 meters) were checked against vegetation calls made by the crew to prevent improper classification due to sources of error introduced in the transect transfer and digitizing process. It was felt that plot locations were accurate to within 50 meters.

The 36 phase-one stratification transects and portions of 21 phase-two 1984 transects, which fell in vegetation types not covered by the 36 phase-one stratification transects, were analyzed to provide the data base from which the stratification map was developed. For each plot, willow

biomass information, pooled over height strata and willow species, was combined with the vegetation call. Mean willow biomass per square meter, by vegetation call and population, was then calculated. A k-means cluster program was run on a CDC Cyber 700 computer, using BMDP (Dixon 1981). A centroid linkage algorithm that utilized Euclidean distances was used on the willow biomass averages to determine ranges of willow biomass in each strata. Based on this information and comparisons between average biomass and average willow cover classifications, a willow biomass stratification scheme was developed for the vegetation polygons for which data were available. Relationships between willow biomass and other recorded site factors such as elevation, slope, and aspect were also investigated to determine if strata should be further subdivided. This preliminary stratification scheme was expanded, based on the assumption that major vegetation types with similar willow cover calls should be classified into like strata, to include every vegetation polygon that occurred within the study area. Representative vegetation polygon types with insufficient data were surveyed in the early summer of 1985 and subsequently classified into strata. The finished stratification scheme is listed in Appendix B.

During the 1985 field season, sampling effort was optimized by calculating strata means, variances, and 80% confidence intervals for each population on a bi-monthly basis and allocating transects to meet the set precision goals of 80% confidence intervals with ranges equal to twice the point estimate. A two-stage ratio-to-size estimator (Cochran 1977) was used to perform these calculations. The length of the transect segment in the strata was used to weight the ratio. Transects were allocated by randomly locating their midpoint within the strata of interest using a Prime computer and Arc-Info software. Transects were generated by the computer on a USGS quadrangle base map, over-laid with the matching USGS map, and hand-transferred to aerial photographs as described for 1984. To increase the sample size, all transects in 1985 were 0.5 mile in length and had 11 plots per transect, allowing each crew to complete 2 transects per day. Three hundred thirty three one-mile transects were sampled in 1985, with 164 in population A, 126 in population B, and 43 in population D.

The field methods used during 1985 were the same as those employed during the 1984 field season with the exception of: 1) mountain cranberry biomass was not clipped; 2) local topography, site moisture, and landscape were not recorded; 3) canopy cover and berry information of dwarf shrubs and forbs were recorded for a concurrent bear study; and 4) the proportion of the closest 8 willow plants within 5 m of the plot location stake that had been browsed in their recent (e.g., 5-year) history was recorded. During the 1985 field season, slope adjustments were made when the slope was greater than 10 degrees versus 15 degrees used in 1984. Eleven calibration transects were sampled to

determine if there was a difference in the production of willow CAG between 1984 and 1985. Calibration transects consisted of reconducting all 1984 transect segments located in high, medium shrub, or medium forest strata of population A. Plot spacing was offset by 1 m between years to pair the observations without overlapping previously clipped plots. Differences in willow biomass between years for each stratum were calculated, and the average difference per stratum, along with standard errors, was computed using two-stage ratio-to-size formulae. This data set formed the basis for testing whether there was a year effect in willow biomass during the 2-year course of the study. Significance level for all statistical tests was set at $\alpha = 0.05$.

RESULTS

Distribution of Browse

The completed vegetation map of the study area contains 9014 vegetation polygons, consisting of Viereck et al. (1982) level IV vegetation calls. The k-means classification identified 7 strata classifications which were used in the construction of a stratification map of willow biomass. These 7 classifications were designated as high, medium-forest, medium-shrub, low, very-low, scarce, and zero willow biomass strata. The stratification map consisted of 7, 6, and 4 strata classifications in populations A (Figure 3), B (Figure 4), and D (Figure 5), respectively. The reader is cautioned that the 3 maps mentioned above are drawn at different scales. In population B, the medium-shrub and medium-forest strata were combined to form a medium stratum, since the acreage of the medium-shrub stratum was minute. In population D, the medium-shrub and medium-forest strata classifications were lumped with the low stratum, again due to minute acreages in the medium strata.

The scarce (35.1%), very-low (24.6%), and low (22.6%) strata composed the majority of population A (Table 1). The scarce (41.6%), very-low (33.9%), and low (16.7%) strata also composed the majority of population B (Table 1). The scarce (41.2%) and very-low (49.5%) strata composed the majority of population D (Table 1).

Paired sample t-tests of differences in the biomass of willow for the high, medium-shrub, and medium-forest strata of population A between 1984 and 1985 were inconclusive (Table 2). Based on these results, it was decided to pool the willow biomass data over years, even though the power to detect a difference between years was low. Pooling of the data resulted in the biomass estimates being more heavily weighted by 1985 data than by the 1984 data.

Using a two-stage ratio-to-size estimator (Appendix C), the estimated probability of a square meter containing diamondleaf willow (Table 45), grayleaf willow (Table 46), Richardson willow (Table 47), feltleaf willow (Table 48),

unclassified willow (Table 49), and reachable paper birch (Table 50) was calculated for every stratum-population combination. These probabilities provide a crude estimate of browse species distribution. The probability of encountering a particular species in a square-meter plot was calculated for each population (Table 51). Due to small sample sizes, average plant height for each species was not calculated.

Using a two-stage ratio-to-size estimator (Appendix C), average biomass of paper birch (Table 3) along with standard errors of the mean, were calculated for the various strata-population combinations. Means and their standard errors were also calculated for paper birch biomass, by population and strata, for below and above 50 cm height categories (Tables 4 and 5 respectively). Average biomass of willow, and standard errors of the mean were calculated by population and strata for combined height, below 50 cm, and above 50 cm height categories (Tables 6, 7, and 8 respectively). The two-stage ratio-to-size estimator produces slightly biased estimates of the mean; almost all of the estimates had a bias of less than 1% (Appendix C). The largest bias was 4.4% of the mean willow biomass found below 50 cm in the very low strata of population D (Devil Canyon). A two-stage, simple random sample estimator (Appendix C) was used to estimate the average biomass of mountain cranberry, by population, and an 80% confidence interval about that average (Table 9).

Mean willow, paper birch, and mountain cranberry biomass along with their standard errors was calculated for each population using strata covariances and weighted means (Table 10, Appendix C). Mean willow biomass was significantly different and appeared to be greater in population A (outside the impoundments) than in either population B ($P=0.0036$), or population D ($P<0.0001$). Willow biomass was not significantly different between population B and population D ($P=0.1528$). Biomass of paper birch was significantly different and appeared to be greater in population B than in population A ($P=0.0020$). Biomass of paper birch in population D (Devils Canyon) was not significantly different from either population A ($P=0.0588$) or population B ($P=0.4412$). Mean mountain cranberry biomass was significantly different and appeared to be greater in population B than in population A ($P<0.0001$) but population D was not significantly different from either population A ($P=0.2502$) or population B ($P=0.1902$).

Mean willow and paper birch biomass below 50 cm in height, and their standard errors, were calculated for each population (Table 11). Mean willow biomass below 50 cm in height was significantly different and appeared to be lower for population D than for either population A ($P<0.0001$) or population B ($P=0.0088$); populations A and B were not significantly different ($P=0.7642$). Paper birch biomass below 50 cm was significantly different and appeared to be lower for population A than population B ($P=0.0244$).

Population D was not significantly different from either population A ($P=0.0950$) or population B ($P=0.0750$).

Mean willow and paper birch biomass above 50 cm in height, and their standard errors, were calculated for each population (Table 12). Mean willow biomass above 50 cm was significantly different and appeared to be greater for population A than either populations B ($P<0.0001$) or D ($P<0.0001$). Populations B and D were not significantly different ($P=0.6672$). Paper birch biomass above 50 cm was significantly different and appeared to be lower in population A than in population B ($P=0.0182$). Population D was not significantly different from either population A ($P=0.0750$) or population B ($P=0.7188$).

The precision goal of obtaining 80% confidence intervals for mean willow biomass with a range of less than twice the mean was met for all height, strata, and population combinations. This precision goal for pooled height categories of paper birch was met in all strata and population combinations except the low and scarce strata of population A, the medium strata of population B, and the zero strata of population D. This goal for paper birch below 50 cm in height was met in all strata and population combinations except the zero strata of population D, while in the above 50 cm height category this goal was met in all strata and population combinations except the low strata of population A, the medium and low strata of population B, and the zero strata of population D.

The majority of population B (98.4%), all of population D, and 63.6% of population A were in strata with a mean willow biomass of 2.00 gm/m^2 or less, in both the pooled and greater than 50 cm height categories. For willow biomass pooled over height categories the majority of the area in population A (96.1%) and population B (97.0%) was in strata with willow means of 1.00 gm/m^2 or greater versus 0% of population D. For willow biomass greater than 50 cm in height the majority of the area in population A (70.0%) was in strata with willow means of 1.00 gm/m^2 or greater versus 4.8% of population B and 0% of population D.

The amount of acreage that could be lost, by stratum, was calculated for each stage of the Susitna Dam Project (Tables 13, 14, and 15). In terms of the amount of non-water acreage lost due to construction, Stage I will result in the largest loss (17,287 acres), followed closely by Stage III (17,123 acres), Stage II would cause the least acreage (6,893 acres) to be lost.

Biomass Loss by Project Feature

The amount of willow biomass, broken down by project feature and strata, that would be lost due to the construction of Stages I through III, is recorded in Tables 16-18 respectively. The upper 80% confidence limit on the amount of willow biomass that would be lost due to the construction Stages I through III, is recorded in Tables 19-21 respectively. The amount of willow biomass above 50 cm

in height, broken down by project feature and strata, that would be lost due to the construction of the Stages I through III is given in Tables 22-24 respectively, with the upper 80% confidence limits recorded in Tables 25-27.

The amount of paper birch biomass, broken down by project feature and strata, that would be lost due to the construction of Stages I through III, is given in Tables 28-30 respectively, with upper 80% confidence limits recorded in Tables 31-33 respectively. The amount of paper birch biomass above 50 cm in height, broken down by project feature and strata, that would be lost due to Stages I through III is given in Tables 34-36 respectively, with the upper 80% confidence limits given in Tables 37-39 respectively.

The estimated amount and the 80% upper confidence estimate of the amount of mountain cranberry biomass that would be lost due to stage I is given in Table 40, in Table 41 for Stage II, and in Table 42 for Stage III.

The construction of the Stage I impoundment will result in an estimated loss of 74,430 kg of willow biomass, 6,788 kg of paper birch biomass, and 1,928,182 kg of mountain cranberry biomass (Table 43). The upper 80% confidence limit on this forage loss would be 98,396 kg of willow biomass, 11,101 kg of paper birch biomass, and 2,247,670 kg of mountain cranberry biomass (Table 43). Furthermore, it is estimated that 32,886 kg of the willow biomass and 5,000 kg of the paper birch biomass (Table 44) will be lost from the above 50 cm height category. The upper 80% confidence limits on the amount of biomass lost from the above 50 cm in height category would be 46,097 kg of willow and 8,397 kg of paper birch biomass (Table 44).

The construction of the Stage II impoundment will result in an estimated loss of 10,513 kg of willow biomass, 3,731 kg of paper birch biomass, and 538,514 kg of mountain cranberry biomass (Table 43). The upper 80% confidence limits on these estimated losses would be 15,938 kg of willow biomass, 7,431 kg of paper birch biomass, and 736,493 kg of mountain cranberry biomass (Table 43). Of the biomass lost in the construction of Stage II impoundment, approximately 7,709 kg of willow biomass and 2,968 kg of paper birch biomass (Table 44) will be lost from the above 50 cm height category. The upper 80% confidence estimates of these losses are 12,303 kg of willow biomass and 5,876 kg of paper birch biomass (Table 44).

The construction of the Stage III impoundment will result in an estimated loss of 156,160 kg of willow biomass and 16,650 kg of paper birch biomass. In the above 50 cm height category, approximately 68,723 kg of willow biomass and 11,894 kg of paper birch biomass will be lost due the construction of the Stage III impoundment.

Availability of Browse

Although an accurate estimate of the amount of willow browse present in the 3 populations was obtained, the amount

of that browse available to moose during the winter was the real parameter of interest. In order to get an indirect handle on this parameter, data on the proportion of willow plants which were browsed were collected. The response variable was dichotomous (proportion of plants browsed versus not browsed); thus, an ordinal logit model (Agresti, 1984) could be used to determine how well population and plant density explain the proportion of plants browsed. An ordinal logit model was fit to the ratio of browsed to unbrowsed willow plants within 5 m of the plot location stake. The data for population D (Devil Canyon) was not well behaved, primarily due to extremely small sample sizes at some plant densities, and as a result these data were excluded from the analysis. The observed odds of a willow plant being browsed versus not browsed, is given by population in Figure 2A. The best model ($P=0.728$) explaining differences in browsing pressure on willow plants between population A and B was:

$$\ln(m_{2jk}/m_{1jk}) = 0.28264 + s_j^P + 0.06976(d_k - \bar{d});$$

where : $s_1^P = -0.32230$ for Population A,

$s_2^P = 0.32230$ for Population B, and

$d_k = -3.5 + (k-1)*1.0$; $k=1,2,\dots,8$ (Figure 2B).

The d_k values were used to indicate the various levels of plant density (k). The results can be expressed in terms of the expected odds that a willow plant is browsed for a given plant density and given population. The expected odds of a willow plant being browsed versus not browsed increased at the same rate (1.07236) for both populations, as plant density increases by one plant. However, after the data were adjusted for plant densities, a significantly ($P<0.05$) higher proportion of browsed plants was found in population B (Watana population) than in population A (outside impoundments).

Ordinal logit models explaining browsing pressure on willows were fit for each population, with possible explanatory variables including plant density and elevation. The best model ($0.25<P<0.50$) predicting the browsing pressure on willows in population B (Watana impoundment) was:

$$\ln(m_{2jk}/m_{1jk}) = 0.699748 \text{ (Figure 3).}$$

The best model ($0.50<P<0.75$) predicting browsing pressure on willows in population A (non-impoundment) was :

$$\ln(m_{2jk}/m_{1jk}) = 0.170664 - 0.302710(e_j - \bar{e}) \text{ (Figure 4).}$$

Elevation categories were indexed by j , $j=1,2,\dots,6$, and weighted by e_j , $e_j = -2.5 + (j-1)*1.0$, where $j=1$ denoted the

elevation band from 2200-2400 feet. The expected odds that a willow plant was browsed versus unbrowsed increased at the same rate (1.3535) as elevation increased 1 category.

DISCUSSION

Willow Utilization

Information from the literature and from the data that has been collected on utilization of willows in the middle basin study area, supports our assumption that willow plants of different species are equally available, in terms of regional availability and levels of utilization. Thus, when willow biomass data are combined over species, it will not affect the carrying capacity estimates. Steigers et al. (1983: 192) found similar utilization levels of twigs among diamondleaf, grayleaf, and Richardson willows within the 5 different vegetation types sampled in which 2 or more of those species occurred together. Murie (1961) indicated that of the more than 20 species of willows in Denali Park, feltleaf, diamondleaf, and Richardson willows were particularly well liked by moose. Milke's findings agree closely with those of Murie (1969: 17), in which feltleaf, diamondleaf, and Richardson willow were all ranked high on lists of apparent preferences of moose for certain willow species at 7 interior Alaska study areas (Milke 1969: 19-21). Machida (1979) also ranked feltleaf and diamondleaf willows at the top of a preference list for moose in interior Alaska.

In contrast, Milke (1969: 19-21) ranked grayleaf willow near the bottom of his species preference list. Steigers et al. (1983: 59-61) took exception to this low ranking, for the middle Susitna basin. Furthermore, they hypothesized that relatively low densities and interspersed of grayleaf willow among other, more highly preferred, willow species in the Susitna basin had resulted in higher utilization levels, for this species, than those observed by Milke (1969). It seems probable that this type of phenomenon is also occurring with other lower-utilization species, such as alder and resin birch.

This study has documented that diamondleaf willow makes up a large proportion of the total willow biomass in the middle basin, particularly in higher-elevation "willow fields." Our observations did not suggest widely divergent levels of utilization among willow species in the absence of highly preferred feltleaf willow. The distribution of feltleaf willow is generally confined to active drainage flood plains ranging in size from riparian zones of small tributary streams to the banks of the Susitna River. Reasons that this species seems to be preferred might include its palatability, and its availability in deep snow when other willow species are buried (Mould 1977, Milke 1969, Machida 1979). In spite of their decided preference for feltleaf willow, moose do not concentrate their foraging

activities on the twigs of this species until mid-to-late winter. In the middle basin, moose appeared to browse all available willows and did not concentrate on feltleaf willow at the lowest elevations until later in the winter when moose tended to move to the lower elevations; this movement tended to coincide with increasing snow depths at the higher elevations. For example, moose had browsed very little of the concentrated feltleaf willow stand near the mouth of Watana Creek and along Devil Creek by early December 1984, but had removed nearly all of the current annual growth by early March 1985.

From the standpoint of palatability and plant height, feltleaf willow is different from all other dominant willow species in the basin. For that reason alone it might be argued that feltleaf willow should have been separated from the other species in the analysis. However, field observations suggest that where feltleaf willow has been heavily browsed (70-90%), all other willows intermixed with it (predominantly diamondleaf willow) were also heavily browsed (40-90%). Throughout the study area, it can be generalized that all willow species growing at a particular site receive comparable levels of browsing.

Feltleaf willow is also distinct, due to its taller plant height, from the other willow species that were sampled. Plant height is probably not a serious factor affecting availability until January when snow depths begin to approach levels that can severely restrict foraging movements. The taller species, such as feltleaf willow, become more important as the winter progresses and greater snow depths make shorter plants harder for moose to obtain. This phenomenon usually occurs from January to April. Even though plant height effects the local availability of forage biomass, it probably does not invalidate our conclusion that regional availability of forage is more important to foraging moose than plant height (i.e., forage availability) on a site-specific basis.

Annual Variation in CAG Biomass

Based on the information collected from the calibration transects, it was decided to pool the 1984 and 1985 data, even though the power to detect a difference between the data of these 2 years was low. This pooling resulted in the biomass estimates being more heavily weighted toward the 1985 data set, since most of the transects were sampled during that field season. Field observations during late spring, on the phenological development of willow and paper birch plants, suggested that spring came later in 1985 than 1984. If this were true, then biomass production, if different between these 2 years, would be lower in 1985. This lower production would result in conservative biomass estimates, if 1984 is assumed to be an average year with regard to phenological development. Because there is an absence of more precise data for determining which of these 2 years is most representative, and due to the fact that a

difference between these 2 years has not been quantitatively demonstrated, it is felt that the pooled data give biomass estimates that are precise enough for mitigation purposes.

Species Distribution

Population B, which contains the Watana impoundment, can be generalized as having the highest paper birch and mountain cranberry biomass concentrations of the 3 populations. This population has a fairly low relative concentration of willow biomass, though the amount of total browse biomass above 50 cm in height consists mainly of willow. Population A has the highest concentration of willow, of which the highest densities tend to be found above the tree line in either riparian habitat or on wet slopes. This population had the lowest concentrations of paper birch and mountain cranberry biomass. Population D can be characterized as a very steep canyon with very low relative amounts of willow biomass and moderate amounts of mountain cranberry and paper birch biomass. Based on the browse inventory results, which were fairly precise considering the vastness of the study area, it could be concluded that population A produces more moose browse above 50 cm in height than either of the other 2 populations, which contain the impoundments.

Distribution of Browsing Pressure

The proportion of browsed willow plants found in the Watana impoundment was significantly greater than that found outside the impoundment. Browsing pressure on willows outside of the impoundments increased with decreasing elevation at a constant rate; starting at 3400 feet the expected odds a willow plant is browsed versus not browsed increases by 35.4% as elevation decreases by 200 feet. The odds that a willow plant is browsed versus not browsed appeared to be constant, over elevation, in the Watana impoundment. Ballard and Whitman (1986) hypothesized that moose were more likely to use the Watana impoundment in severe winters than in mild ones. Their data suggest that the highest use of the Watana impoundment occurs during the winter period (February 1 through April 30) and, in general, the moose population exhibits movements toward lower elevations during this period. Their analysis of habitat use by moose shows that strata in the Watana impoundment are selected for while almost all strata in the area outside this impoundment are avoided.

The estimate of the amount of browse biomass that is available to moose in the middle Susitna basin is one of the most crucial parameters in the carrying capacity model (Hubbert 1987). To estimate the amount of browse biomass present in the study area was difficult, but to determine the proportion of that browse available to moose during the winter period is even more difficult to quantify.

The data on proportion of willow plants browsed, the results from analyzing observations of moose locations, and

the fact that the higher elevation areas, outside the impoundment, have higher willow productivity than the lower elevation areas inside the Watana impoundment is consistent with the hypotheses that a large amount of the biomass found at higher elevations is not available to moose during winter. If the hypothesis were false, then one would not expect moose to move toward lower elevations, away from the very productive "willow fields" found above tree line, especially during times of stress such as the winter period. If availability of browse were equal between the Watana impoundment and the area outside the impoundment, then it would be expected that the proportion of willow plants browsed would not be greater in the impoundment where productivity of willow biomass is lower. However, there does exist a difference in proportion of willow plants browsed between the 2 spatially distinct populations. This evidence along with decreasing browsing pressure as elevation increases in the non-impoundment areas, suggests that a discrepancy in availability of willow forage biomass exists in at least some of the higher-elevation areas outside of the Watana impoundment.

The causes of willow biomass being less available at higher elevations are not fully understood, though certain parameters are known to influence browse availability during winter. In general, as elevation increases snow depth also increases (Steigers et al. 1986). Moen and Severinghaus (1981) reported that white-tailed deer (Odocoileus virginianus) in New York have a better chance of over-winter survival by yarding and conserving energy in areas of dense conifer cover and suitable topography versus more exposed areas. The reason conifer areas at the lower elevations are being selected for more frequently by wintering moose might also be explained by the benefits of increased cover and energy conservation. Use of the lower elevations might result in a better energy balance for moose than they could obtain by over-wintering in the more exposed area of population A, even though more browse is found there. There are probably several other factors causing browse in the exposed areas of population A to be less available, and it is highly likely that there are interactions among the various factors.

Browse Utilization Rate

The extent to which a plant continues to be a source of moose browse, over time, is a function of the amount of browsing pressure that plant has received. Thus, the amount of utilization a plant can withstand over time is of interest, since the browse inventory data was primarily intended to be used in modeling moose carrying capacity over time, through use of a carrying capacity model.

The data we collected on the proportion of willow plants that were browsed does not provide insights into the browsing intensity being sustained by individual plants. Steigers et al. (1983) reported twig utilization levels

ranging from 4-30% for 3 willow species (diamondleaf, grayleaf, and feltleaf willow) collected in 10 different vegetation types occurring within the middle Susitna River basin. These estimates were biased low, because new-growth twigs from the current summer were counted as unbrowsed twigs. In heavily browsed areas, sampled for snow depth during late March 1985, ocular estimates of twigs removed from individual plants ranged from 60% to over 95% (Steigers et al. 1986). Information from these studies is the best currently available for levels of willow twig utilization by wintering moose in the study area.

Recommended levels of twig utilization in other studies have varied because of differences in species sampled, climate, and methods used to identify and count twigs. However, several "rules of thumb" have become established for hardwood browse: 1) twig utilization levels of up to 30% can increase production (Krefting et al. 1966); 2) annual removal of 50% of the twigs can occur without a reduction in total production (Aldous 1952, Krefting et al. 1966, Wolff 1976, Wolff 1978); and 3) shrubs can withstand up to 100% utilization without permanent damage, but this high level cannot be sustained for more than 3 consecutive years without decreases in vigor and production (Wolff 1978, Wolff et al. 1983).

Willows appear to be capable of withstanding relatively high utilization levels while still maintaining productivity, particularly on riparian flood plains where nutrient concentrations are also high. Riparian feltleaf willows in the Susitna Study area regularly experience winter utilization levels exceeding 90% of their current annual growth while reproducing new twigs up to 1.3 m long the following summer. In the case of feltleaf willow, high cropping rates and the resultant stem breakage hinders the plants from rapidly growing out of reach of moose.

Local utilization of shrubs in the Susitna study area varies by distribution and density of wintering moose, timing of utilization, and both the quantity and availability of forage biomass over a specified time period. However, to precisely estimate a recommended utilization rate for forage shrubs across the entire study area, one would need to place the greatest emphasis on those local areas receiving the burden of the mid-to-late winter (January-April) browsing, when moose populations are concentrated on a limited range. Average annual utilization rates, for this period, of 60% of the current-annual-growth twigs, is recommended for all forage species except feltleaf willow, for which 70% is recommended. For all species, 100% of the twigs could be removed for 3 consecutive winters without detrimental loss of habitat value.

Based on the above discussion, it seems evident that flooding the Watana impoundment would have a greater impact on moose winter browse than suggested by average biomass per unit area alone. It is very difficult to estimate the amount of moose browse, above 50 cm in height, that is not

available to moose during the winter. The amount not available in population A probably increases with winter severity, since the majority of this population is above the tree line and thus exposed to the full brunt of winter storms. The Devil Canyon impoundment is sheltered from winter storms but has a very low production of both willow and paper birch browse per unit area, not all of which is available due to the extreme steepness of some sections of the canyon. This, plus the small size of the Devil Canyon impoundment compared with the size of the Watana impoundment, suggests that the construction of the Watana impoundment would have a much greater impact on moose winter habitat than the construction of just a Devil Canyon dam.

SUMMARY

The primary impact on moose of the proposed Susitna Hydroelectric Project would be the loss of moose habitat. Therefore, it was decided that an assessment of the loss of moose carrying capacity, based on a moose carrying capacity model, would be a meaningful way to measure the impacts of the proposed project on moose. Nutritional carrying capacity is defined as the number of healthy individuals that can be maintained in a designated area for a specified period of time. One of the major inputs to the carrying capacity model is the amount of browse that is available to moose during the winter. The estimation of this parameter was the primary objective of this study.

A stratified two-stage sampling design was used to estimate the amount of willow, paper birch, and mountain cranberry browse that is contained in the primary impact zone, which was delineated on the basis of movements of radio-collared moose. The study area was broken up into 3 sub-study areas, the Devil Canyon Population (population D), the Watana Impoundment Population (population B), and the remaining area (population A). Resin birch was assumed to be a non-limiting browse item, due to its ubiquitous distribution. The impact of snow depth on browse availability was crudely adjusted for by calculating the amount of browse biomass above 50 cm in height.

Willow browse greater than 50 cm in height was higher (1.72 gm/m^2) outside the impoundments (population A) than inside either the Watana (0.47 gm/m^2) or the Devil Canyon (0.35 gm/m^2) Impoundments. Paper birch biomass above 50 cm in height was lower (0.007 gm/m^2) outside of the impoundments than in either the Watana (0.063 gm/m^2) or Devil Canyon (0.051 gm/m^2) Impoundments. Mountain cranberry browse appeared to be greater in the Watana Impoundment (28.01 gm/m^2) than in either the Devil Canyon Impoundment (19.74 gm/m^2) or the areas outside of the impoundments (13.31 gm/m^2). Based on upper 80% confidence limits, the construction of either Stage I or III (Watana Impoundments) will result in a loss of about 4 times more willow biomass

(over 50 cm in height) than the construction of the Stage II impoundment (Devil Canyon). Based on upper 80% confidence limits, the construction of either Stage I or III will result in a loss of about 1.4 times more willow biomass (over 50 cm in height) than the construction of the Stage II impoundment. Based on the above figures, it would appear that the construction of the Watana Dam, either Stage I or both Stages I and III, will have a far larger impact than the construction of the Devil Canyon Dam. In general, willow biomass over 50 cm in height was about 2.5 times greater than paper birch biomass over 50 cm in height in Stage II, and 5 times greater in Stages I or III.

The majority of the browse was found outside of the impoundment areas. This outside area also had higher willow productivity than any of the proposed impoundments. However, a logit regression model on the proportion of willow plants that were browsed, showed heavier browsing pressure occurring in the Watana impoundment than in areas outside of the impoundments, and browsing pressure decreasing with increasing elevation in the non-impoundment areas. This difference would indicate that not all of the willow browse found outside of the proposed impoundments is available to moose in the winter. Increasing snow depths with increasing elevation is one mechanism that would explain the different levels of browsing pressure. The extent to which browse outside of the proposed impoundments is not available to moose is not fully known at this time, nor is it likely to ever be fully known.

Table 1. Percent area, broken down by population, of willow biomass strata.

Population	Strata	Area (ha)	Proportion of population (%)
A (Non- Impoundment)	High	14,425.7	6.27
	Medium-Forest	4,488.2	1.95
	Medium-Shrub	12,649.0	5.50
	Low	52,086.3	22.64
	Very-Low	56,669.3	24.63
	Scarce	80,706.4	35.07
	<u>Zero</u>	<u>9,073.7</u>	<u>3.94</u>
	TOTAL	230,098.6	100.00
B (Watana Impoundment)	High	129.0	0.65
	Medium	820.0	4.16
	Low	3,287.1	16.68
	Very-Low	6,682.1	33.91
	Scarce	8,190.2	41.56
	<u>Zero</u>	<u>598.0</u>	<u>3.03</u>
D (Devil Canyon Impoundment)	TOTAL	19,706.4	99.99
	Low	255.9	3.20
	Very-Low	3,952.3	49.49
	Scarce	3,293.6	41.24
	<u>Zero</u>	<u>484.1</u>	<u>6.06</u>
	TOTAL	7,985.9	99.99

Table 2. Differences in willow biomass between 1984 and 1985 for the high, medium-forest, and medium-shrub strata of population A.

Strata	$\bar{X}_{1984} - \bar{X}_{1985}$ (gm/m ²)	S.E.	P value	Power of test (2-tailed test) alpha=.05 (.10)
High	-1.38	5.37	P>0.25	0.038 (0.075)
Medium-Forest	1.73	4.17	P>0.25	0.025 (0.06)
Medium-Shrub	1.67	3.62	P>0.25	0.045 (0.08)
All Mediums	1.72	3.43	P>0.25	0.05 (0.10)

Table 3. Mean paper birch biomass and standard error, pooled over height categories, by population and strata.

Population	Strata	Mean (gm/m ²)	SE (gm/m ²)	df
A (Non- Impoundment)	High	0.000	0.000	70
	Medium-Forest	0.000	0.000	28
	Medium-Shrub	0.000	0.000 [#]	52
	Low	0.030	0.030 [#]	72
	Very-Low	0.000	0.000 [#]	73
	Scarce	0.004	0.004 [#]	93
	Zero	0.000	0.000	27
B (Watana Impoundment)	High	0.000	0.000 [#]	20
	Medium	0.013	0.011 [#]	41
	Low	0.030	0.023	56
	Very-Low	0.108	0.053	59
	Scarce	0.106	0.051	68
	Zero	0.129	0.058	15
D (Devil Canyon Impoundment)	Low	0.002	0.000 [*]	10
	Very-Low	0.000	0.000	13
	Scarce	0.114	0.049 [#]	34
	Zero	0.270	0.196 [#]	17
* denotes zero value due to rounding				
# denotes 80% C.I. with a range > 2 \bar{X}				

Table 4. Mean paper birch biomass and standard error, below 50 cm in height, by population and strata.

Population	Strata	Mean (gm/m ²)	SE (gm/m ²)	df
A (Non- Impoundment)	High	0.000	0.000	70
	Medium-Forest	0.000	0.000	28
	Medium-Shrub	0.000	0.000	52
	Low	0.000	0.000	72
	Very-Low	0.000	0.000	73
	Scarce	0.000*	0.000*	93
	Zero	0.000	0.000	27
B (Watana Impoundment)	High	0.000	0.000	20
	Medium	0.003	0.003	41
	Low	0.007	0.006	56
	Very-Low	0.046	0.032	59
	Scarce	0.021	0.011	68
	Zero	0.034	0.017	15
D (Devil Canyon Impoundment)	Low	0.000	0.000	10
	Very-Low	0.000	0.000	13
	Scarce	0.003	0.002	34
	Zero	0.056	0.053 [#]	17

* denotes zero value due to rounding

denotes 80% C.I. with a range $> 2\bar{X}$

Table 5. Mean paper birch biomass and standard error, above 50 cm in height, by population and strata.

Population	Strata	Mean (gm/m ²)	SE (gm/m ²)	df
A (Non- Impoundment)	High	0.000	0.000	70
	Medium-Forest	0.000	0.000	28
	Medium-Shrub	0.000	0.000	52
	Low	0.025	0.024 [#]	72
	Very-Low	0.000	0.000	73
	Scarce	0.003	0.002	93
	Zero	0.000	0.000	27
B (Watana Impoundment)	High	0.000	0.000	20
	Medium	0.010	0.010 [#]	41
	Low	0.023	0.017 [#]	56
	Very-Low	0.062	0.028	59
	Scarce	0.085	0.044	68
	Zero	0.095	0.047	15
D (Devil Canyon Impoundment)	Low	0.002	0.000 [*]	10
	Very-Low	0.000	0.000	13
	Scarce	0.091	0.049	34
	Zero	0.214	0.196 [#]	17
* denotes zero value due to rounding				
# denotes 80% C.I. with a range > 2 \bar{X}				

Table 6. Mean willow biomass and standard error, pooled over height categories, by population and strata.

Population	Strata	Mean (gm/m ²)	SE (gm/m ²)	df
A (Non- Impoundment)	High	6.20	0.89	70
	Medium-Forest	5.09	1.43	28
	Medium-Shrub	3.27	0.54	52
	Low	3.09	0.70	72
	Very-Low	1.99	0.33	73
	Scarce	1.14	0.20	93
	Zero	0.70	0.40	27
B (Watana Impoundment)	High	6.86	2.44	20
	Medium	1.74	0.58	41
	Low	1.16	0.25	56
	Very-Low	1.05	0.29	59
	Scarce	1.01	0.22	68
D (Devil Canyon Impoundment)	Zero	0.20	0.11	15
	Low	0.17	0.08	10
	Very-Low	0.77	0.46	13
	Scarce	0.20	0.11	34
	Zero	0.05	0.04	17
* denotes zero value due to rounding				
# denotes 80% C.I. with a range > $2\bar{X}$				

Table 7. Mean willow biomass and standard error below 50 cm in height, by population and strata.

Population	Strata	Mean (gm/m ²)	SE (gm/m ²)	df
A (Non- Impoundment)	High	1.04	0.17	70
	Medium-Forest	1.68	0.62	28
	Medium-Shrub	0.84	0.16	52
	Low	0.73	0.10	72
	Very-Low	0.50	0.16	73
	Scarce	0.34	0.06	93
	Zero	0.12	0.06	27
B (Watana Impoundment)	High	2.18	0.87	20
	Medium	0.49	0.11	41
	Low	0.62	0.13	56
	Very-Low	0.59	0.16	59
	Scarce	0.67	0.17	68
D (Devil Canyon Impoundment)	Zero	0.09	0.04	15
	Low	0.15	0.07	10
	Very-Low	0.19	0.10	13
	Scarce	0.05	0.03	34
	Zero	0.03	0.02	17

* denotes zero value due to rounding

denotes 80% C.I. with a range $> 2\bar{X}$

Table 8. Mean willow biomass and standard error, above 50 cm in height, by population and strata.

Population	Strata	Mean (gm/m ²)	SE (gm/m ²)	df
A (Non- Impoundment)	High	5.07	0.83	70
	Medium-Forest	3.41	1.10	28
	Medium-Shrub	2.43	0.47	52
	Low	2.36	0.68	72
	Very-Low	1.49	0.28	73
	Scarce	0.80	0.16	93
	Zero	0.58	0.36	27
B (Watana Impoundment)	High	4.69	1.90	20
	Medium	1.25	0.54	41
	Low	0.54	0.17	56
	Very-Low	0.46	0.15	59
	Scarce	0.34	0.10	68
D (Devil Canyon Impoundment)	Zero	0.11	0.09	15
	Low	0.01	0.01	10
	Very-Low	0.58	0.40	13
	Scarce	0.15	0.10	34
	Zero	0.01	0.01	17
* denotes zero value due to rounding				
# denotes 80% C.I. with a range > $2\bar{X}$				

Table 9. Mean mountain cranberry biomass and 80% confidence interval by population.

Population	Mean (gm/m ²)	80% Confidence Interval (gm/m ²)
A (Non- Impoundment)	13.31	(11.05, 15.55)
B (Watana Impoundment)	28.01	(23.35, 32.65)
D (Devil Canyon Impoundment)	19.74	(12.21, 27.19)

Table 10. Average biomass and standard errors of willow, paper birch, and mountain cranberry in populations A, B, and D.

Forage-Group	Population	Mean (gm/m ²)	Std. Error (gm/m ²)
Willow	A	2.28	0.16
	B	1.09	0.37
	D	0.47	0.22
Paper Birch	A	0.007	0.006
	B	0.092	0.028
	D	0.062	0.028
Cranberry	A	13.31	1.73
	B	28.01	3.46
	D	19.74	5.29

Table 11. Average biomass and standard errors of willow and paper birch below 50 cm in height for populations A, B, and D.

Forage-Group	Population	Mean (gm/m ²)	Std. Error (gm/m ²)
Willow	A	0.56	0.09
	B	0.62	0.18
	D	0.12	0.06
Paper Birch	A	0.000	0.000
	B	0.027	0.012
	D	0.005	0.003

Table 12. Average biomass and standard errors of willow and paper birch above 50 cm in height for populations A, B, and D.

Forage-Group	Population	Mean (gm/m ²)	Std. Error (gm/m ²)
Willow	A	1.72	0.22
	B	0.47	0.20
	D	0.35	0.19
Paper Birch	A	0.007	0.006
	B	0.063	0.023
	D	0.051	0.024

Table 13. Acres of forage biomass stratum to be permanently or temporarily lost by facility, for Stage I. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	183	169	1490	3268	8190	2001	15301
Access Road ^{1A}	96	76 ^B	104	88	136	28	528
Camps ²	0	0	26	88	174	0	288
Borrow Pits ³	0	0	77	275	641	25	1018
Other ⁴	1	7	0	50	94	0	152
Total	280	251	1697	3769	9235	2054	17287

A - Located primarily within Population A.

B - Indicates medium shrub acreages.

1 - Includes only the Denali Highway-Watana access road. Assumed an average clearing width of 100 feet for this 43.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.

2 - Includes the Watana construction camp and villages. Approximately 200 acres will be rehabilitated following the completion of Stage III.

3 - Includes proportionally 1/3 of the area of quarry site A, 2/3 of the area of borrow pit D, and 2/3 of the area of borrow pit E that is above the Devil Canyon impoundment. All quarry and borrow pit areas will be rehabilitated.

4 - Includes the airport (44 acres), Watana construction roads (80 acres), and the transmission line switchyards at Watana (12 acres) and for Gold Creek (16 acres). Approximately 30 acres used in building construction roads will be rehabilitated.

5 - Figure 6 shows the location of the various features.

Table 14. Acres of forage biomass stratum to be permanently or temporarily lost by facility, for Stage II. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	0	49 ^A	48	323	3502	1684	5606
Access Road ^{1B}	75	6 ^C	106	157	100	23	467
Camps ²	0	0	23	0	141	36	200
Borrow Pits ³	0	97 ^A	1	252	95	0	445
Other ⁴	0	0	14	8	90	63	175
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Total	75	152	192	740	3928	1806	6893

A - Treated as low strata of population D.

B - Located primarily within population A.

C - Indicates medium shrub acreages.

1 - Includes only the Watana-Devil Canyon access road. Assumed an average clearing width of 100 feet for this 38.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.

2 - Includes the Devil Canyon construction camp and villages, which will be rehabilitated following the completion of Stage III.

3 - Includes quarry site K. All quarry and borrow pit areas will be rehabilitated.

4 - Includes the railroad (73 acres), railhead facility (40 acres), Devil Canyon construction roads (50 acres), and the Devil Canyon transmission line switchyards (12 acres). Approximately 22 acres cleared for the railroad and 19 acres cleared for construction roads will be rehabilitated after construction.

5 - Figure 6 shows the location of the various features.

Table 15. Acres of forage biomass stratum to be permanently or temporarily lost by facility, for Stage III. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment ¹	86	543	2893	6531	849	5474	16376
Borrow Pits ²	0	0	40	164	531	12	747
	--	---	----	-----	-----	-----	-----
Total	86	543	2933	6695	1380	5486	17123

1 - Includes only the area inundated by Stage III.

2 - Includes proportionally 2/3 of the area of borrow pit A, 1/3 of the area of borrow pit D, and 1/3 of the area of borrow pit E that is above the Devil Canyon impoundment.

3 - Figure 6 shows the location of the various features.

All borrow pit areas will be rehabilitated.

Table 16. Kg of willow biomass, pooled over height categories, to be permanently or temporarily lost by facility and stratum, for Stage I. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	5081	1190	6995	13887	33476	1620	62248
Access Rd ^{1A}	2409	1006 ^B	1301	709	627	79	6130
Camps ²	0	0	122	374	711	0	1207
Borrow Pits ³	0	0	362	1169	2620	20	4170
Other ⁴	28	49	0	213	384	0	674
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Total	7517	2245	8779	16351	37819	1919	74430

A - Located primarily within Population A.

B - Indicates medium shrub acreages.

- 1 - Includes only the Denali Highway-Watana access road. Assumed an average clearing width of 100 feet for this 43.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.
- 2 - Includes the Watana construction camp and villages. Approximately 200 acres will be rehabilitated following the completion of Stage III.
- 3 - Includes proportionally 1/3 of the area of quarry site A, 2/3 of the area of borrow pit D, and 2/3 of the area of borrow pit E that is above the Devil Canyon impoundment. All quarry and borrow pit areas will be rehabilitated.
- 4 - Includes the airport (44 acres), Watana construction roads (80 acres), and the transmission line switchyards at Watana (12 acres) and for Gold Creek (16 acres). Approximately 30 acres used in building construction roads will be rehabilitated.

Table 17. Kg of willow biomass, pooled over height categories, to be permanently or temporarily lost by stratum and facility, for Stage II. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	0	34 ^A	33	1007	2835	341	4249
Access Rd ^{1B}	1882	79 ^C	1326	1264	461	65	5078
Camps ²	0	0	16	0	114	7	137
Borrow Pits ³	0	67 ^A	1	785	77	0	930
Other ⁴	0	0	10	25	73	13	120
Total	1882	180	1385	3081	3560	426	10513

A - Treated as low strata of population D.

B - Located primarily within population A.

C - Indicates medium shrub acreages.

1 - Includes only the Watana-Devil Canyon access road. Assumed an average clearing width of 100 feet for this 38.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.

2 - Includes the Devil Canyon construction camp and villages, which will be rehabilitated following the completion of Stage III.

3 - Includes quarry site K. All quarry and borrow pit areas will be rehabilitated.

4 - Includes the railroad (73 acres), railhead facility (40 acres), Devil Canyon construction roads (50 acres), and the Devil Canyon transmission line switchyards (12 acres). Approximately 22 acres cleared for the railroad and 19 acres cleared for construction roads will be rehabilitated after construction.

Table 18. Kg of willow biomass, pooled over height categories, to be permanently or temporarily lost by facility and stratum, for Stage III. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment ¹	2388	3824	13581	27753	3470	4431	55446
Borrow Pits ²	0	0	188	697	2170	10	3065
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Total	2388	3824	13769	28449	5641	4440	58511

1 - Includes only the area inundated by Stage III.

2 - Includes proportionally 2/3 of the area of borrow pit A, 1/3 of the area of borrow pit D, and 1/3 of the area of borrow pit E that is above the Devil Canyon impoundment.

All borrow pit areas will be rehabilitated.

Table 19. Upper 80% confidence limit of kg of willow biomass, pooled over height categories, to be permanently or temporarily lost by facility and stratum, for Stage I.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	7473	1703	8924	18913	43088	2834	82935
Access Rd ^{1A}	2856	1221 ^B	1679	858	771	139	7524
Camps ²	0	0	156	509	915	0	1580
Borrow Pits ³	0	0	461	1592	3372	35	5461
Other ⁴	41	71	0	289	495	0	895
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Total	10369	2995	11221	22161	48641	3009	98396

A - Located primarily within Population A.

B - Indicates medium shrub acreages.

- 1 - Includes only the Denali Highway-Watana access road. Assumed an average clearing width of 100 feet for this 43.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.
- 2 - Includes the Watana construction camp and villages. Approximately 200 acres will be rehabilitated following the completion of Stage III.
- 3 - Includes proportionally 1/3 of the area of quarry site A, 2/3 of the area of borrow pit D, and 2/3 of the area of borrow pit E that is above the Devil Canyon impoundment. All quarry and borrow pit areas will be rehabilitated.
- 4 - Includes the airport (44 acres), Watana construction roads (80 acres), and the transmission line switchyards at Watana (12 acres) and for Gold Creek (16 acres). Approximately 30 acres used in building construction roads will be rehabilitated.

Table 20. Upper 80% confidence limit of kg of willow biomass, pooled over height categories, to be permanently or temporarily lost by facility and stratum, for Stage II. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	0	56 ^A	54	1817	4960	682	7569
Access Rd ^{1B}	2231	96 ^C	1712	1531	567	115	6251
Camps ²	0	0	26	0	200	15	240
Borrow Pits ³	0	110 ^A	1	1418	135	0	1663
Other ⁴	0	0	16	45	128	26	214
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Total	2231	262	1809	4811	5989	836	15938

A - Treated as low strata of population D.

B - Located primarily within population A.

C - Indicates medium shrub acreages.

- 1 - Includes only the Watana-Devil Canyon access road. Assumed an average clearing width of 100 feet for this 38.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.
- 2 - Includes the Devil Canyon construction camp and villages, which will be rehabilitated following the completion of Stage III.
- 3 - Includes quarry site K. All quarry and borrow pit areas will be rehabilitated.
- 4 - Includes the railroad (73 acres), railhead facility (40 acres), Devil Canyon construction roads (50 acres), and the Devil Canyon transmission line switchyards (12 acres). Approximately 22 acres cleared for the railroad and 19 acres cleared for construction roads will be rehabilitated after construction.

Table 21. Upper 80% confidence limit of kg of willow biomass, pooled over height categories, to be permanently or temporarily lost by facility and stratum, for Stage III. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment ¹	3512	5472	17328	37796	4467	7754	76328
Borrow Pits ²	0	0	240	949	2794	17	3999
	--	---	----	----	----	----	-----
Total	3512	5472	17567	38745	7260	7771	80327

1 - Includes only the area inundated by Stage III.

2 - Includes proportionally 2/3 of the area of borrow pit A, 1/3 of the area of borrow pit D, and 1/3 of the area of borrow pit E that is above the Devil Canyon impoundment.

All borrow pit areas will be rehabilitated.

Table 22. Kg of willow biomass over 50 cm in height, to be permanently or temporarily lost by facility and stratum, for Stage I. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	3473	855	3256	6084	11269	891	25828
Access Rd ^{1A}	1970	747 ^B	993	531	440	66	4747
Camps ²	0	0	57	164	239	0	460
Borrow Pits ³	0	0	168	512	882	11	1573
Other ⁴	19	35	0	93	129	0	277
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Total	5462	1638	4475	7383	12960	968	32886

A - Located primarily within Population A.

B - Indicates medium shrub acreages.

- 1 - Includes only the Denali Highway-Watana access road. Assumed an average clearing width of 100 feet for this 43.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.
- 2 - Includes the Watana construction camp and villages. Approximately 200 acres will be rehabilitated following the completion of Stage III.
- 3 - Includes proportionally 1/3 of the area of quarry site A, 2/3 of the area of borrow pit D, and 2/3 of the area of borrow pit E that is above the Devil Canyon impoundment. All quarry and borrow pit areas will be rehabilitated.
- 4 - Includes the airport (44 acres), Watana construction roads (80 acres), and the transmission line switchyards at Watana (12 acres) and for Gold Creek (16 acres). Approximately 30 acres used in building construction roads will be rehabilitated.

Table 23. Kg of willow biomass over 50 cm in height, to be permanently or temporarily lost by facility and stratum, for Stage II. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	0	2 ^A	2	758	2126	68	2956
Access Rd ^{1B}	1539	59 ^C	1012	947	324	54	3935
Camps ²	0	0	1	0	86	2	88
Borrow Pits ³	0	4 ^A	0	592	58	0	653
Other ⁴	0	0	1	19	55	3	77
	----	---	----	----	----	----	----
Total	1539	65	1016	2315	2648	126	7709

A - Treated as low strata of population D.

B - Located primarily within population A.

C - Indicates medium shrub acreages.

1 - Includes only the Watana-Devil Canyon access road. Assumed an average clearing width of 100 feet for this 38.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.

2 - Includes the Devil Canyon construction camp and villages, which will be rehabilitated following the completion of Stage III.

3 - Includes quarry site K. All quarry and borrow pit areas will be rehabilitated.

4 - Includes the railroad (73 acres), railhead facility (40 acres), Devil Canyon construction roads (50 acres), and the Devil Canyon transmission line switchyards (12 acres). Approximately 22 acres cleared for the railroad and 19 acres cleared for construction roads will be rehabilitated after construction.

Table 24. Kg of willow biomass over 50 cm in height, to be permanently or temporarily lost by facility and stratum, for Stage III. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment ¹	1632	2747	6322	12158	1168	2437	26465
Borrow Pits ²	0	0	87	305	731	5	1129
	--	---	----	----	----	----	-----
Total	1632	2747	6410	12464	1899	2442	27593

1 - Includes only the area inundated by Stage III.

2 - Includes proportionally 2/3 of the area of borrow pit A, 1/3 of the area of borrow pit D, and 1/3 of the area of borrow pit E that is above the Devil Canyon impoundment.

All borrow pit areas will be rehabilitated.

Table 25. Upper 80% confidence limit of the kg of willow biomass over 50 cm in height, to be permanently or temporarily lost by facility and stratum, for Stage I. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	5340	1334	4583	8597	15247	1782	36881
Access Rd ^{1A}	2386	935 ^B	1360	659	556	119	6014
Camps ²	0	0	80	232	324	0	635
Borrow Pits ³	0	0	237	723	1193	22	2176
Other ⁴	29	55	0	132	175	0	391
Total	7754	2324	6259	10342	17495	1923	46097

A - Located primarily within Population A.

B - Indicates medium shrub acreages.

- 1 - Includes only the Denali Highway-Watana access road. Assumed an average clearing width of 100 feet for this 43.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.
- 2 - Includes the Watana construction camp and villages. Approximately 200 acres will be rehabilitated following the completion of Stage III.
- 3 - Includes proportionally 1/3 of the area of quarry site A, 2/3 of the area of borrow pit D, and 2/3 of the area of borrow pit E that is above the Devil Canyon impoundment. All quarry and borrow pit areas will be rehabilitated.
- 4 - Includes the airport (44 acres), Watana construction roads (80 acres), and the transmission line switchyards at Watana (12 acres) and for Gold Creek (16 acres). Approximately 30 acres used in building construction roads will be rehabilitated.

Table 26. Upper 80% confidence limit on the kg of willow biomass over 50 cm in height, to be permanently or temporarily lost by facility and stratum, for Stage II. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	0	4 ^A	4	1464	4110	136	5718
Access Rd ^{1B}	1864	74 ^C	1386	1176	409	98	5005
Camps ²	0	0	2	0	166	3	170
Borrow Pits ³	0	8 ^A	0	1142	112	0	1262
Other ⁴	0	0	1	36	106	5	148
Total	1864	86	1393	3818	4901	242	12303

A - Treated as low strata of population D.

B - Located primarily within population A.

C - Indicates medium shrub acreages.

1 - Includes only the Watana-Devil Canyon access road. Assumed an average clearing width of 100 feet for this 38.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.

2 - Includes the Devil Canyon construction camp and villages, which will be rehabilitated following the completion of Stage III.

3 - Includes quarry site K. All quarry and borrow pit areas will be rehabilitated.

4 - Includes the railroad (73 acres), railhead facility (40 acres), Devil Canyon construction roads (50 acres), and the Devil Canyon transmission line switchyards (12 acres). Approximately 22 acres cleared for the railroad and 19 acres cleared for construction roads will be rehabilitated after construction.

Table 27. Upper 80% confidence limit on the kg of willow biomass over 50 cm in height, to be permanently or temporarily lost by stratum and facility, for Stage III. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment ¹	2509	4285	8898	17180	1581	4874	39327
Borrow Pits ²	0	0	123	431	989	11	1554
	--	---	----	----	----	----	-----
Total	2509	4285	9021	17612	2569	4884	40881

1 - Includes only the area inundated by Stage III.

2 - Includes proportionally 2/3 of the area of borrow pit A, 1/3 of the area of borrow pit D, and 1/3 of the area of borrow pit E that is above the Devil Canyon impoundment.

All borrow pit areas will be rehabilitated.

Table 28. Kg of paper birch biomass pooled over height categories, to be permanently or temporarily lost by facility and stratum for Stage I. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	0	9	181	1428	3513	1045	6176
Access Rd ^{1A}	0	0 ^B	13	0	2	0	15
Camps ²	0	0	3	39	75	0	116
Borrow Pits ³	0	0	9	120	275	13	418
Other ⁴	0	0	0	22	40	0	63
Total	---	---	----	-----	-----	-----	-----
	0	9	206	1609	3906	1058	6788

A - Located primarily within Population A.

B - Indicates medium shrub acreages.

- 1 - Includes only the Denali Highway-Watana access road. Assumed an average clearing width of 100 feet for this 43.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.
- 2 - Includes the Watana construction camp and villages. Approximately 200 acres will be rehabilitated following the completion of Stage III.
- 3 - Includes proportionally 1/3 of the area of quarry site A, 2/3 of the area of borrow pit D, and 2/3 of the area of borrow pit E that is above the Devil Canyon impoundment. All quarry and borrow pit areas will be rehabilitated.
- 4 - Includes the airport (44 acres), Watana construction roads (80 acres), and the transmission line switchyards at Watana (12 acres) and for Gold Creek (16 acres). Approximately 30 acres used in building construction roads will be rehabilitated.

Table 29. Kg of paper birch biomass pooled over height categories, to be permanently or temporarily lost by facility and stratum, for Stage II. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	0	0 ^A	0	0	1616	1840	3457
Access Rd ^{1B}	0	0 ^C	13	0	2	0	15
Camps ²	0	0	0	0	65	39	105
Borrow Pits ³	0	1 ^A	0	0	44	0	45
Other ⁴	0	0	0	0	42	69	110
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Total	0	1	14	0	1768	1948	3731

A - Treated as low strata of population D.

B - Located primarily within population A.

C - Indicates medium shrub acreages.

- 1 - Includes only the Watana-Devil Canyon access road. Assumed an average clearing width of 100 feet for this 38.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.
- 2 - Includes the Devil Canyon construction camp and villages, which will be rehabilitated following the completion of Stage III.
- 3 - Includes quarry site K. All quarry and borrow pit areas will be rehabilitated.
- 4 - Includes the railroad (73 acres), railhead facility (40 acres), Devil Canyon construction roads (50 acres), and the Devil Canyon transmission line switchyards (12 acres). Approximately 22 acres cleared for the railroad and 19 acres cleared for construction roads will be rehabilitated after construction.

Table 30. Kg of paper birch biomass pooled over height categories, to be permanently or temporarily lost by facility and stratum, for Stage III. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment ¹	0	29	351	2855	364	2858	6456
Borrow Pits ²	0	0	5	72	228	6	311
	--	---	----	-----	-----	-----	-----
Total	0	29	356	2926	592	2864	6767

1 - Includes only the area inundated by Stage III.

2 - Includes proportionally 2/3 of the area of borrow pit A, 1/3 of the area of borrow pit D, and 1/3 of the area of borrow pit E that is above the Devil Canyon impoundment.

All borrow pit areas will be rehabilitated.

Table 31. Upper 80% confidence limit on kg of paper birch biomass pooled over height categories, to be permanently or temporarily lost by facility and stratum for Stage I. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	0	19	356	2341	5701	1676	10092
Access Rd ^{1A}	0	0 ^B	29	0	5	0	34
Camps ²	0	0	6	63	121	0	190
Borrow Pits ³	0	0	18	197	446	21	683
Other ⁴	0	1	0	36	65	0	102
	---	---	---	---	---	---	---
Total	0	19	409	2637	6339	1697	11101

A - Located primarily within Population A.

B - Indicates medium shrub acreages.

- 1 - Includes only the Denali Highway-Watana access road. Assumed an average clearing width of 100 feet for this 43.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.
- 2 - Includes the Watana construction camp and villages. Approximately 200 acres will be rehabilitated following the completion of Stage III.
- 3 - Includes proportionally 1/3 of the area of quarry site A, 2/3 of the area of borrow pit D, and 2/3 of the area of borrow pit E that is above the Devil Canyon impoundment. All quarry and borrow pit areas will be rehabilitated.
- 4 - Includes the airport (44 acres), Watana construction roads (80 acres), and the transmission line switchyards at Watana (12 acres) and for Gold Creek (16 acres). Approximately 30 acres used in building construction roads will be rehabilitated.

Table 32. Upper 80% confidence limit on kg of paper birch biomass pooled over height categories, to be permanently or temporarily lost by facility and stratum, for Stage II. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	0	0 ^A	0	0	2792	4103	6896
Access Rd ^{1B}	0	0 ^C	30	0	4	0	33
Camps ²	0	0	0	0	112	88	200
Borrow Pits ³	0	1 ^A	0	0	76	0	77
Other ⁴	0	0	0	0	72	154	225
	--	---	---	---	----	----	----
Total	0	1	30	0	3056	4344	7431

A - Treated as low strata of population D.

B - Located primarily within population A.

C - Indicates medium shrub acreages.

1 - Includes only the Watana-Devil Canyon access road. Assumed an average clearing width of 100 feet for this 38.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.

2 - Includes the Devil Canyon construction camp and villages, which will be rehabilitated following the completion of Stage III.

3 - Includes quarry site K. All quarry and borrow pit areas will be rehabilitated.

4 - Includes the railroad (73 acres), railhead facility (40 acres), Devil Canyon construction roads (50 acres), and the Devil Canyon transmission line switchyards (12 acres). Approximately 22 acres cleared for the railroad and 19 acres cleared for construction roads will be rehabilitated after construction.

Table 33. Upper 80% confidence limit on kg of paper birch biomass pooled over height categories, to be permanently or temporarily lost by facility and stratum, for Stage III. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment ¹	0	59	691	4678	591	4586	10605
Borrow Pits ²	0	0	10	118	370	10	507
	--	---	----	-----	-----	-----	-----
Total	0	59	700	4796	961	4596	11112

1 - Includes only the area inundated by Stage III.

2 - Includes proportionally 2/3 of the area of borrow pit A, 1/3 of the area of borrow pit D, and 1/3 of the area of borrow pit E that is above the Devil Canyon impoundment.

All borrow pit areas will be rehabilitated.

Table 34. Kg of paper birch biomass over 50 cm in height, to be permanently or temporarily lost by facility and stratum for Stage I. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	0	7	139	820	2817	769	4552
Access Rd ^{1A}	0	0 ^B	11	0	2	0	12
Camps ²	0	0	2	22	60	0	84
Borrow Pits ³	0	0	7	69	221	10	306
Other ⁴	0	0	0	13	32	0	45
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Total	0	7	159	924	3132	779	5000

A - Located primarily within Population A.

B - Indicates medium shrub acreages.

- 1 - Includes only the Denali Highway-Watana access road. Assumed an average clearing width of 100 feet for this 43.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.
- 2 - Includes the Watana construction camp and villages. Approximately 200 acres will be rehabilitated following the completion of Stage III.
- 3 - Includes proportionally 1/3 of the area of quarry site A, 2/3 of the area of borrow pit D, and 2/3 of the area of borrow pit E that is above the Devil Canyon impoundment. All quarry and borrow pit areas will be rehabilitated.
- 4 - Includes the airport (44 acres), Watana construction roads (80 acres), and the transmission line switchyards at Watana (12 acres) and for Gold Creek (16 acres). Approximately 30 acres used in building construction roads will be rehabilitated.

Table 35. Kg of paper birch biomass over 50 cm in height, to be permanently or temporarily lost by facility and stratum, for Stage II. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	0	0 ^A	0	0	1290	1458	2749
Access Rd ^{1B}	0	0 ^C	11	0	1	0	12
Camps ²	0	0	0	0	52	31	83
Borrow Pits ³	0	1 ^A	0	0	35	0	36
Other ⁴	0	0	0	0	33	55	88
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Total	0	1	11	0	1411	1544	2968

A - Treated as low strata of population D.

B - Located primarily within population A.

C - Indicates medium shrub acreages.

1 - Includes only the Watana-Devil Canyon access road. Assumed an average clearing width of 100 feet for this 38.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.

2 - Includes the Devil Canyon construction camp and villages, which will be rehabilitated following the completion of Stage III.

3 - Includes quarry site K. All quarry and borrow pit areas will be rehabilitated.

4 - Includes the railroad (73 acres), railhead facility (40 acres), Devil Canyon construction roads (50 acres), and the Devil Canyon transmission line switchyards (12 acres). Approximately 22 acres cleared for the railroad and 19 acres cleared for construction roads will be rehabilitated after construction.

Table 36. Kg of paper birch biomass over 50 cm in height, to be permanently or temporarily lost by facility and stratum, for Stage III. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment ¹	0	22	269	1639	292	2105	4327
Borrow Pits ²	0	0	4	41	183	5	232
	---	---	---	---	---	---	---
Total	0	22	273	1680	475	2109	4559

1 - Includes only the area inundated by Stage III.

2 - Includes proportionally 2/3 of the area of borrow pit A, 1/3 of the area of borrow pit D, and 1/3 of the area of borrow pit E that is above the Devil Canyon impoundment.

All borrow pit areas will be rehabilitated.

Table 37. Upper 80% confidence limit of kg of paper birch biomass over 50 cm in height, to be permanently or temporarily lost by facility and stratum for Stage I. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	0	16	308	1296	4740	1280	7639
Access Rd ^{1A}	0	0 ^B	27	0	3	0	31
Camps ²	0	0	5	35	101	0	141
Borrow Pits ³	0	0	16	109	371	16	512
Other ⁴	0	1	0	20	54	0	75
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Total	0	16	356	1460	5269	1296	8397

A - Located primarily within Population A.

B - Indicates medium shrub acreages.

- 1 - Includes only the Denali Highway-Watana access road. Assumed an average clearing width of 100 feet for this 43.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.
- 2 - Includes the Watana construction camp and villages. Approximately 200 acres will be rehabilitated following the completion of Stage III.
- 3 - Includes proportionally 1/3 of the area of quarry site A, 2/3 of the area of borrow pit D, and 2/3 of the area of borrow pit E that is above the Devil Canyon impoundment. All quarry and borrow pit areas will be rehabilitated.
- 4 - Includes the airport (44 acres), Watana construction roads (80 acres), and the transmission line switchyards at Watana (12 acres) and for Gold Creek (16 acres). Approximately 30 acres used in building construction roads will be rehabilitated.

Table 38. Upper 80% confidence limit of kg of paper birch biomass over 50 cm in height, to be permanently or temporarily lost by facility and stratum, for Stage II. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment	0	0 ^A	0	0	2211	3237	5449
Access Rd ^{1B}	0	0 ^C	28	0	2	0	30
Camps ²	0	0	0	0	89	69	158
Borrow Pits ³	0	1 ^A	0	0	60	0	61
Other ⁴	0	0	0	0	57	121	178
Total	0	1	29	0	2419	3428	5876

A - Treated as low strata of population D.

B - Located primarily within population A.

C - Indicates medium shrub acreages.

- 1 - Includes only the Watana-Devil Canyon access road. Assumed an average clearing width of 100 feet for this 38.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.
- 2 - Includes the Devil Canyon construction camp and villages, which will be rehabilitated following the completion of Stage III.
- 3 - Includes quarry site K. All quarry and borrow pit areas will be rehabilitated.
- 4 - Includes the railroad (73 acres), railhead facility (40 acres), Devil Canyon construction roads (50 acres), and the Devil Canyon transmission line switchyards (12 acres). Approximately 22 acres cleared for the railroad and 19 acres cleared for construction roads will be rehabilitated after construction.

Table 39. Upper 80% confidence limit on kg of paper birch biomass over 50 cm in height, to be permanently or temporarily lost by facility and stratum, for Stage III. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	High	Medium	Low	Very Low	Scarce	Zero	Total
Impoundment ¹	0	51	597	2590	491	3500	7229
Borrow Pits ²	0	0	8	65	307	8	388
	--	---	----	-----	-----	-----	-----
Total	0	51	605	2655	799	3508	7618

1 - Includes only the area inundated by Stage III.

2 - Includes proportionally 2/3 of the area of borrow pit A, 1/3 of the area of borrow pit D, and 1/3 of the area of borrow pit E that is above the Devil Canyon impoundment.

All borrow pit areas will be rehabilitated.

Table 40. Kg of mountain cranberry to be permanently or temporarily lost by facility for Stage I. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	Mean Mt. Cranberry	Upper 80% C.L. Mt. Cranberry
Impoundment	1,734,467	2,021,791
Access Rd ^{1A}	28,441	32,228
Camps ²	32,647	38,055
Borrow Pits ³	115,397	134,513
Other ⁴	17,230	20,084
	-----	-----
Total	1,928,182	2,247,670

A - Located primarily within Population A.

- 1 - Includes only the Denali Highway-Watana access road. Assumed an average clearing width of 100 feet for this 43.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.
- 2 - Includes the Watana construction camp and villages. Approximately 200 acres will be rehabilitated following the completion of Stage III.
- 3 - Includes proportionally 1/3 of the area of quarry site A, 2/3 of the area of borrow pit D, and 2/3 of the area of borrow pit E that is above the Devil Canyon impoundment. All quarry and borrow pit areas will be rehabilitated.
- 4 - Includes the airport (44 acres), Watana construction roads (80 acres), and the transmission line switchyards at Watana (12 acres) and for Gold Creek (16 acres). Approximately 30 acres used in building construction roads will be rehabilitated.

Table 41. Kg of mountain cranberry to be permanently or temporarily lost by facility for Stage II. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	Mean Mt. Cranberry	Upper 80% C.L. Mt. Cranberry
Impoundment	447,851	616,873
Access Rd ^{1A}	25,155	29,389
Camps ²	15,978	22,008
Borrow Pits ³	35,550	48,967
Other ⁴	13,980	19,257
	-----	-----
Total	538,514	736,493

A - Located primarily within Population A.

- 1 - Includes only the Denali Highway-Watana access road. Assumed an average clearing width of 100 feet for this 43.6-mile road. Approximately 40 feet of this width will be revegetated after the access road is constructed.
- 2 - Includes the Watana construction camp and villages. Approximately 200 acres will be rehabilitated following the completion of Stage III.
- 3 - Includes proportionally 1/3 of the area of quarry site A, 2/3 of the area of borrow pit D, and 2/3 of the area of borrow pit E that is above the Devil Canyon impoundment. All quarry and borrow pit areas will be rehabilitated.
- 4 - Includes the airport (44 acres), Watana construction roads (80 acres), and the transmission line switchyards at Watana (12 acres) and for Gold Creek (16 acres). Approximately 30 acres used in building construction roads will be rehabilitated.

Table 42. Kg of mountain cranberry to be permanently or temporarily lost by facility for Stage III. Unless otherwise denoted with a footnote, all potential for forage biomass production is considered permanently lost.

Project Feature	Mean Mt. Cranberry	Upper 80% C.L. Mt. Cranberry
Impoundment	1,856,326	2,163,835
Borrow Pits ¹	84,677	98,705
	-----	-----
Total	1,941,003	2,262,540

1 - Includes proportionally 1/3 of the area of quarry site A, 2/3 of the area of borrow pit D, and 2/3 of the area of borrow pit E that is above the Devil Canyon impoundment. All quarry and borrow pit areas will be rehabilitated.

Table 43. The mean and upper 80% confidence limit on the amount of biomass lost, by stage and species.

Project Stage	Forage-Group	Biomass (Kg)	80% Upper Limit (Kg)
I	Willow	74,430	98,396
	Paper Birch	6,788	11,101
	Mt. Cranberry	1,928,182	2,247,670
II	Willow	10,513	15,938
	Paper Birch	3,731	7,431
	Mt. Cranberry	538,514	736,493
III	Willow	58,511	80,327
	Paper Birch	6,767	11,112
	Mt. Cranberry	1,941,003	2,262,540

Table 44. The mean and upper 80% confidence limit on the amount of biomass (above 50 cm in height) lost, by stage and species.

Project Stage	Forage-Group	Biomass (Kg)	80% Upper Limit (Kg)
I	Willow	32,886	46,097
	Paper Birch	5,000	8,397
II	Willow	7,709	12,303
	Paper Birch	2,968	5,876
III	Willow	27,593	40,881
	Paper Birch	4,559	7,618

Table 45. The estimated probability, and standard error, of a plot containing diamondleaf willow, by population and strata.

Population	Strata	Proportion	SE
A	High	0.490	0.032
A	Medium Forest	0.464	0.070
A	Medium Shrub	0.401	0.044
A	Low	0.343	0.034
A	Very Low	0.275	0.031
A	Scarce	0.202	0.023
A	Zero	0.085	0.023
B	High	0.336	0.066
B	Medium	0.229	0.043
B	Low	0.244	0.033
B	Very Low	0.147	0.027
B	Scarce	0.188	0.035
B	Zero	0.095	0.062
D	Low	0.157	0.066
D	Very Low	0.219	0.076
D	Scarce	0.045	0.014
D	Zero	0.009	0.010

Table 46. The estimated probability, and standard error, of a plot containing grayleaf willow, by population and strata.

Population	Strata	Proportion	SE
A	High	0.020	0.009
A	Medium Forest	0.000	0.000
A	Medium Shrub	0.016	0.008
A	Low	0.010	0.007
A	Very Low	0.008	0.004
A	Scarce	0.006	0.004
A	Zero	0.000	0.000
B	High	0.022	0.023
B	Medium	0.050	0.018
B	Low	0.039	0.017
B	Very Low	0.057	0.017
B	Scarce	0.009	0.005
B	Zero	0.010	0.009
D	Low	0.000	0.000
D	Very Low	0.016	0.015
D	Scarce	0.000	0.000
D	Zero	0.000	0.000

Table 47. The estimated probability, and standard error, of a plot containing Richardson willow, by population and strata.

Population	Strata	Proportion	SE
A	High	0.061	0.016
A	Medium Forest	0.100	0.032
A	Medium Shrub	0.048	0.020
A	Low	0.051	0.015
A	Very Low	0.048	0.016
A	Scarce	0.019	0.008
A	Zero	0.009	0.009
B	High	0.063	0.051
B	Medium	0.062	0.024
B	Low	0.049	0.019
B	Very Low	0.045	0.015
B	Scarce	0.028	0.010
B	Zero	0.010	0.009
D	Low	0.000	0.000
D	Very Low	0.014	0.014
D	Scarce	0.006	0.006
D	Zero	0.000	0.000

Table 48. The estimated probability, and standard error, of a plot containing felleaf willow, by population and strata.

Population	Strata	Proportion	SE
A	High	0.015	0.006
A	Medium Forest	0.007	0.007
A	Medium Shrub	0.003	0.003
A	Low	0.008	0.004
A	Very Low	0.000	0.000
A	Scarce	0.002	0.002
A	Zero	0.006	0.005
B	High	0.134	0.071
B	Medium	0.026	0.011
B	Low	0.016	0.009
B	Very Low	0.013	0.006
B	Scarce	0.022	0.009
B	Zero	0.011	0.011
D	Low	0.000	0.000
D	Very Low	0.000	0.000
D	Scarce	0.000	0.000
D	Zero	0.000	0.000

Table 49. The estimated probability, and standard error, of a plot containing unknown willows, by population and strata.

Population	Strata	Proportion	SE
A	High	0.072	0.017
A	Medium Forest	0.115	0.034
A	Medium Shrub	0.053	0.016
A	Low	0.073	0.024
A	Very Low	0.049	0.013
A	Scarce	0.023	0.008
A	Zero	0.031	0.017
B	High	0.247	0.098
B	Medium	0.072	0.028
B	Low	0.109	0.021
B	Very Low	0.070	0.024
B	Scarce	0.083	0.022
B	Zero	0.051	0.029
D	Low	0.012	0.012
D	Very Low	0.028	0.018
D	Scarce	0.006	0.006
D	Zero	0.018	0.019

Table 50. The estimated probability, and standard error, of a plot containing reachable paper birch, by population and strata.

Population	Strata	Proportion	SE
A	High	0.000	0.000
A	Medium Forest	0.000	0.000
A	Medium Shrub	0.000	0.000
A	Low	0.004	0.004
A	Very Low	0.000	0.000
A	Scarce	0.007	0.004
A	Zero	0.000	0.000
B	High	0.000	0.000
B	Medium	0.010	0.008
B	Low	0.004	0.003
B	Very Low	0.032	0.010
B	Scarce	0.044	0.016
B	Zero	0.137	0.049
D	Low	0.010	0.010
D	Very Low	0.000	0.000
D	Scarce	0.057	0.019
D	Zero	0.085	0.044

Table 51. The estimated probability, and standard error, of a plot containing reachable paper birch, diamondleaf, grayleaf, Richardson, feltleaf, and unknown willows, by population.

Population	Species	Proportion	SE
A	Diamondleaf	0.281	0.0137
B	willow	0.183	0.0188
D		0.133	0.0396
A	Grayleaf	0.008	0.0033
B	willow	0.032	0.0070
D		0.008	0.0075
A	Richardson	0.039	0.0067
B	willow	0.038	0.0083
D		0.009	0.0070
A	Feltleaf	0.004	0.0012
B	willow	0.019	0.0048
D		0.000	0.0000
A	Unknown	0.048	0.0073
B	willow	0.083	0.0131
D		0.018	0.0093
A	Reachable	0.003	0.0017
B	Paper	0.034	0.0080
D	Birch	0.029	0.0082

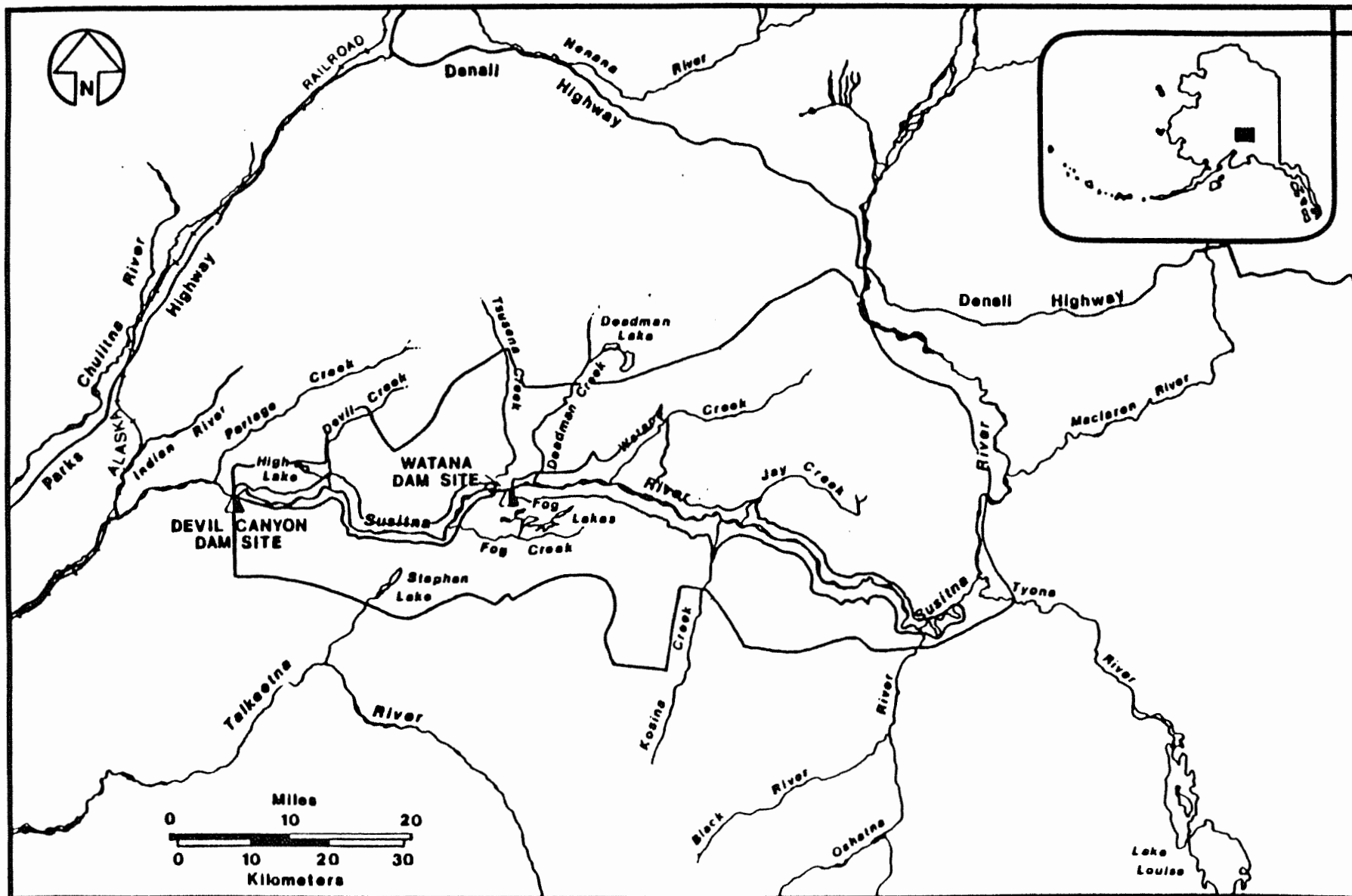


Figure 1. Watana, Devil Canyon, and surrounding area sample population boundaries for the browse inventory study.

Figure 2A.

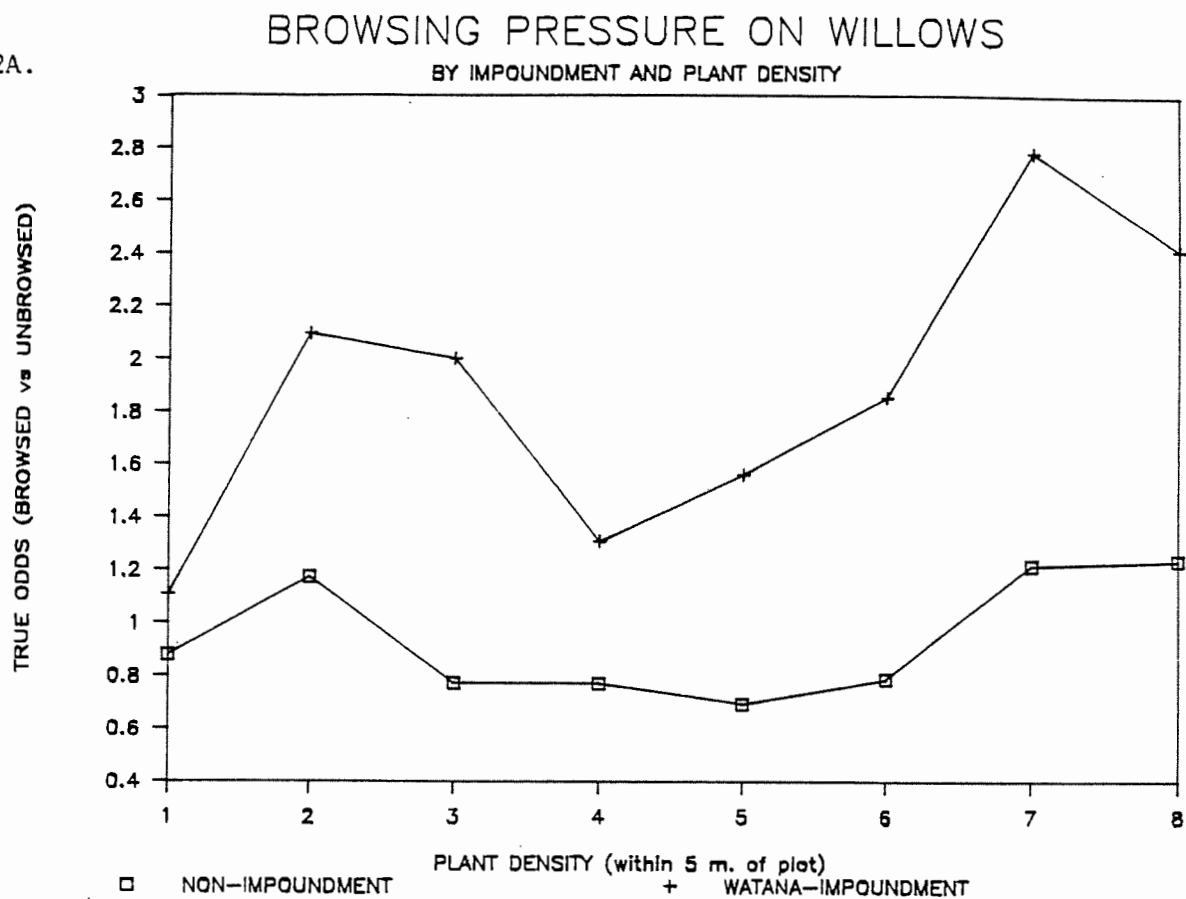
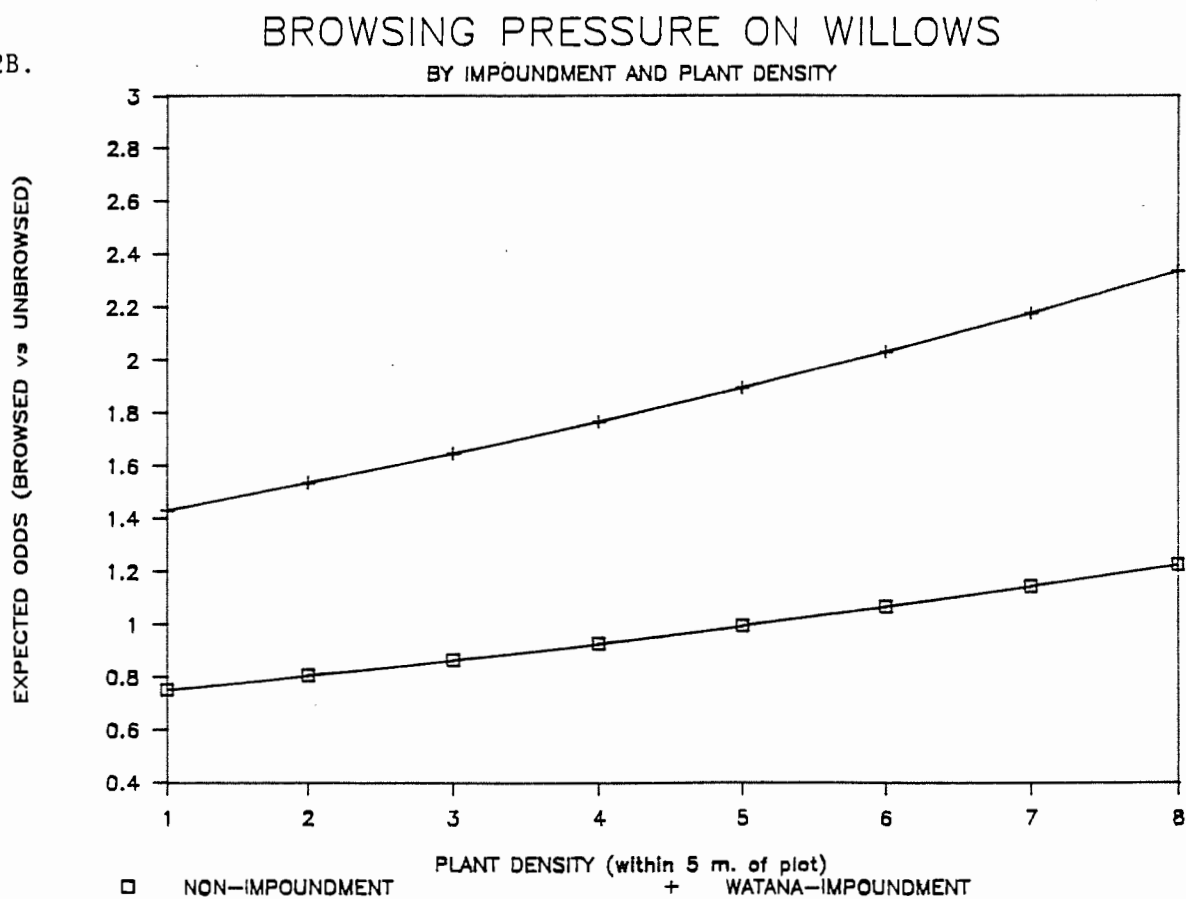


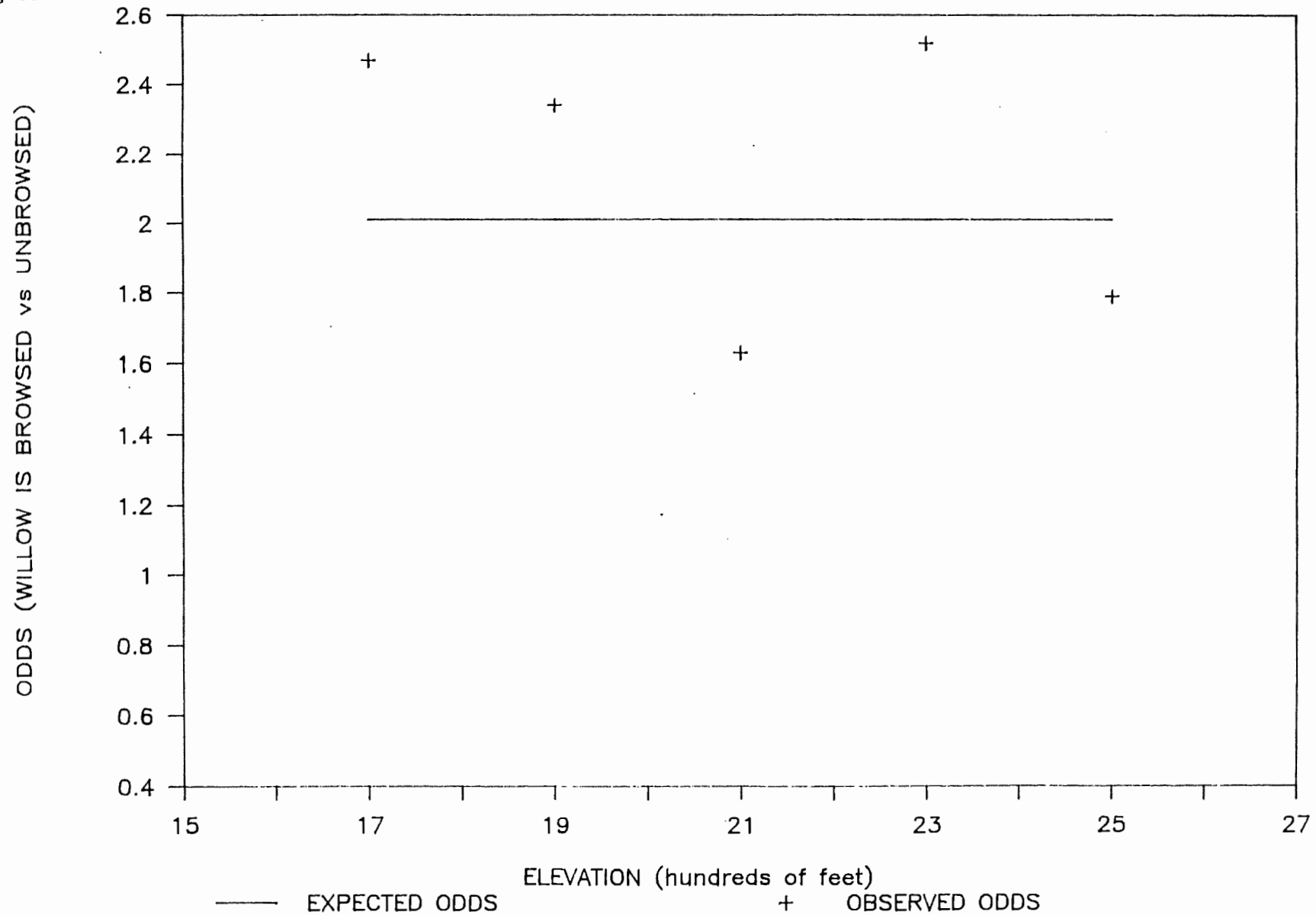
Figure 2B.



BROWSING PRESSURE ON WILLOWS

IN THE WATANA-IMPOUNDMENT BY ELEVATION

Figure 3.



BROWSING PRESSURE ON WILLOWS

IN THE NON-IMPOUNDMENT BY ELEVATION

Figure 4.

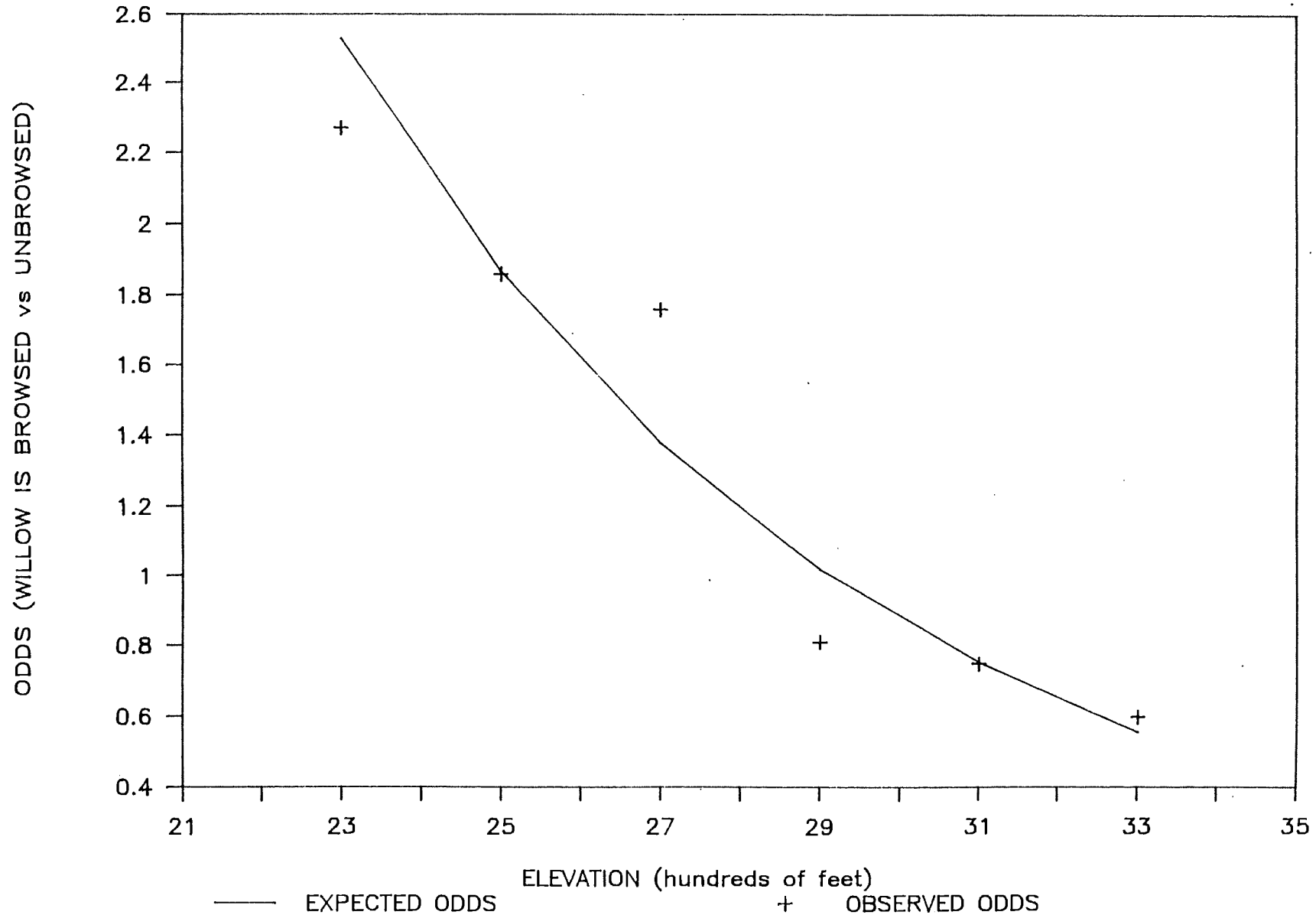
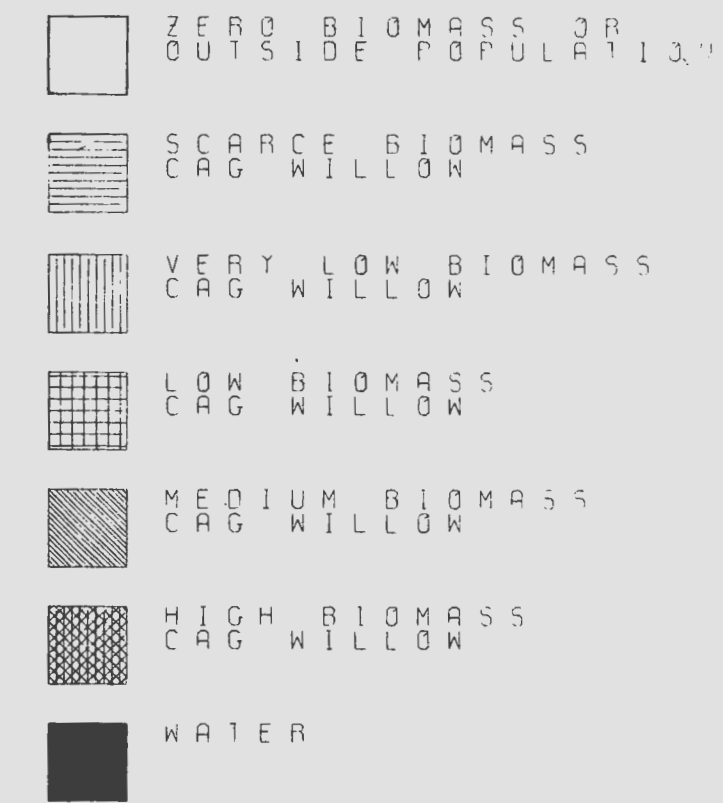




FIGURE 5.
STRATIFICATION MAP OF THE NON-
IMPOUNDMENT POPULATION (A)



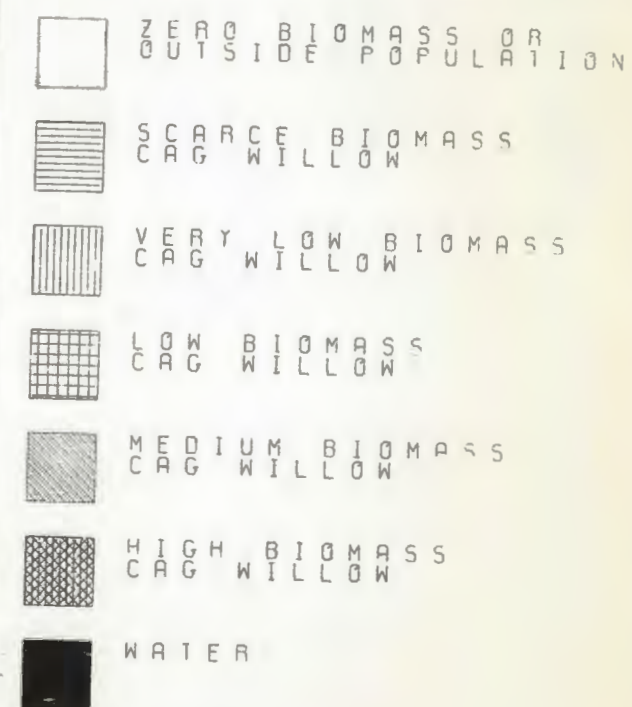
SCALE = 1:241000

NORTH





FIGURE 6.
STRATIFICATION MAP OF THE WHARF
IMPOUNDMENT POPULATION IRI



SCALE = 1:136370



FIGURE 7 STRATIFICATION MAP OF THE
VIL CANYON IMPOUNDMENT POPULATION (D)

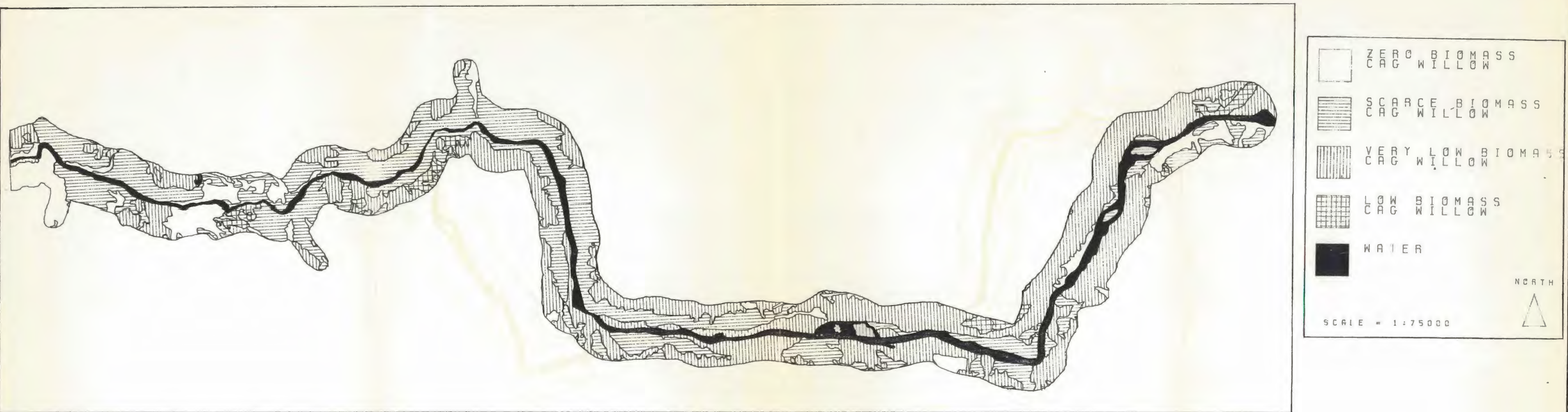
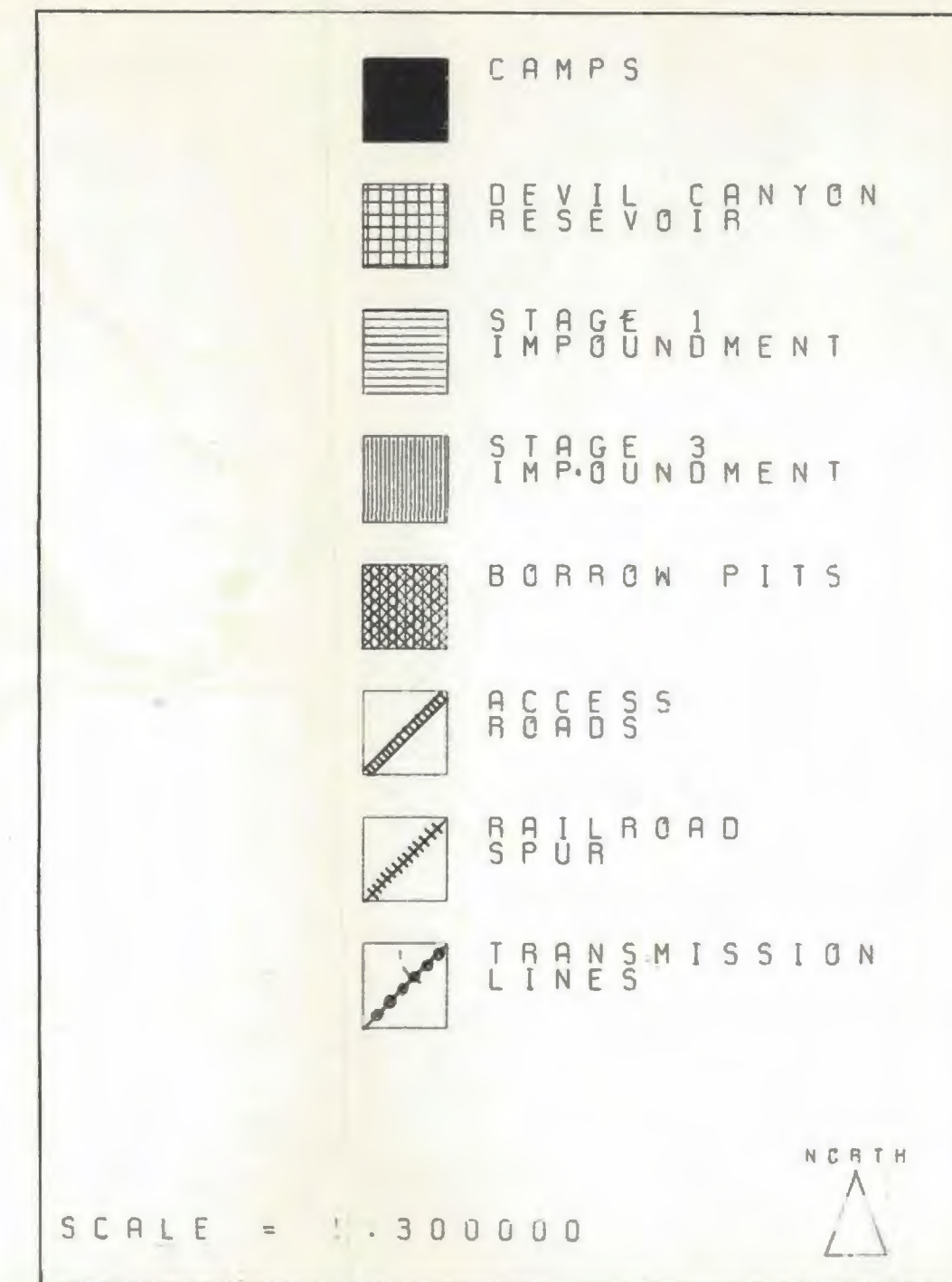
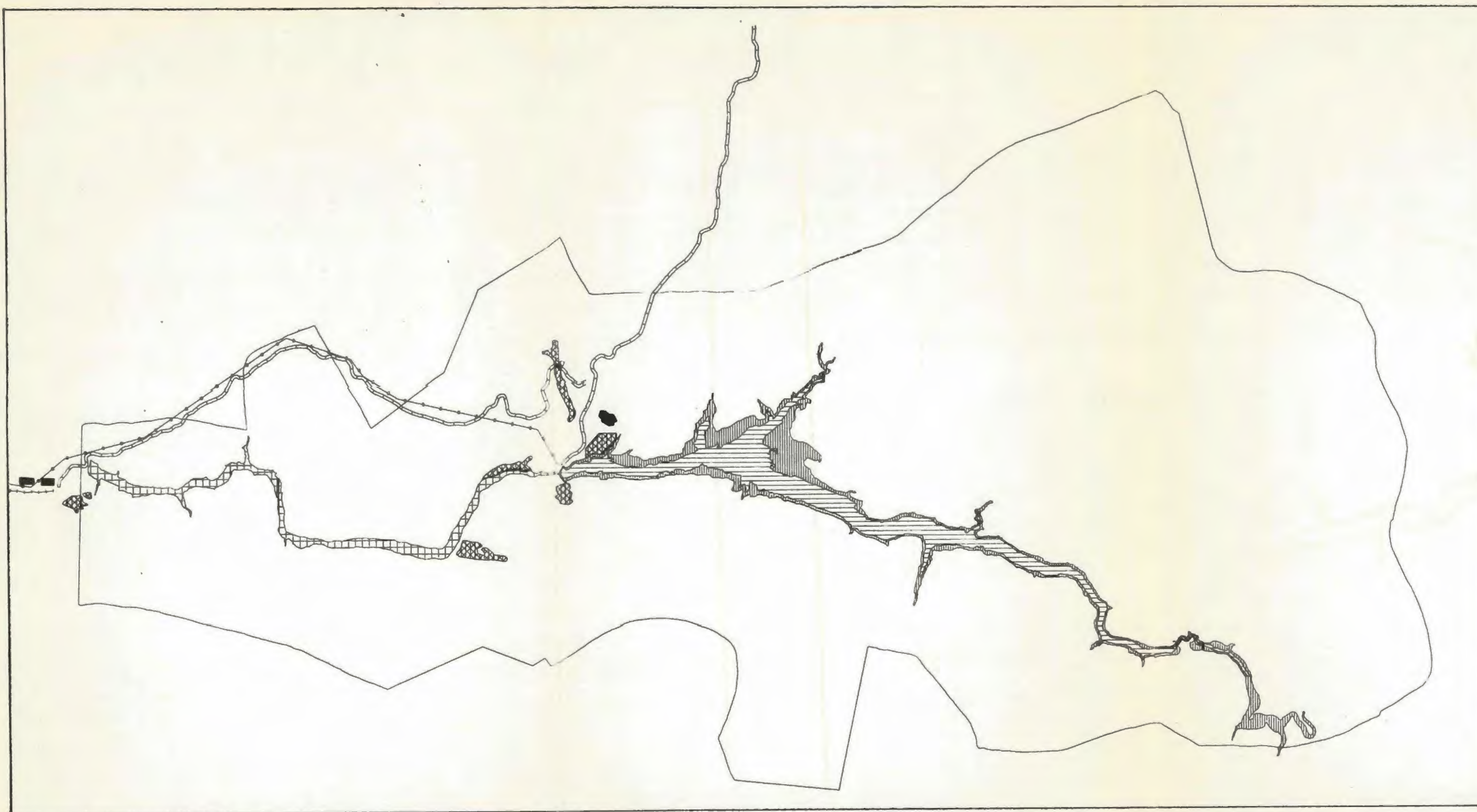


FIGURE 8. MAP OF PROJECT FEATURES



LITERATURE CITED

- Agresti, A. 1984. Analysis of ordinal categorical data. John Wiley and Sons. New York. 287 pp.
- Aldous, S.D. 1952. Deer browse clipping in the Lake States Region. J. Wildl. Manage. 16:401-409.
- Ballard, W.B., J.S. Whitman, N.G. Tankersley, L.D. Aumiller, and P. Hessing. 1983. Moose - Upstream. Vol. III Susitna Hydroelectric Project big game studies, Phase II Prog. Rep. by Alaska Dept. Fish and Game to Alaska Power Authority. 141 pp.
- Ballard, W. B., and J.S. Whitman. 1987. Susitna Hydroelectric Project, Final Report Vol. I - Moose - Downstream. Alaska Dept. of Fish and Game.
- Bobeck, B. 1977. Summer food as a factor limiting roe deer population size. Nature 268:47-49.
- Cochran, W.G. 1977. Sampling techniques, 3rd edition. John Wiley and Sons. New York. 428 pp.
- Dixon, W.J. 1981. BMDP statistical software. Chief editor. University of California Press, Berkeley. 725 pp.
- Hobbs, N.T., D.L. Baker, E.J. Ellis, D.M. Swift, and R.A. Green. 1982. Energy and nitrogen-based estimates of elk winter range carrying capacity. J. Wildl. Manage. 46:12-21.
- Hobbs, N.T., and D.M. Swift. 1985. Estimates of habitat carrying capacity incorporating explicit nutritional constraints. J. Wildl. Manage. 49:814-822.
- Hubbert, M. 1987. The effects of dietary quality and quantity on energy partitioning in moose. Ph.D. Thesis. Univ. of Alaska, Fairbanks. 158 pp.
- Krefting, L.W., M.H. Stenlund, and R.K. Seemel. 1966. Effects of simulated and natural deer browsing on mountain maple. J. Wildl. Manage. 30:481-488.
- Machida, S. 1979. Differential use of willow species by moose in Alaska. M.S. Thesis. Univ. of Alaska, Fairbanks. 97 pp.

- McKendrick, J., W. Collins, D. Helm, J. McMullen, and J. Koranda. 1982. Plant ecology studies phase I final report. Environmental Studies. Susitna Hydroelectric Project. Prepared for the Alaska Power Authority. 124 pp.
- Milke, G.C. 1969. Some moose-willow relationships in the interior of Alaska. M.S. Thesis. Univ. of Alaska, Fairbanks. 79 pp.
- Moen, A.N, and C.W. Severinghaus. 1981. The annual weight cycle and survival of white-tailed deer in New York. N.Y. Fish and Game J. 28:162-177.
- Mould, E.D. 1977. Movement patterns of moose in the Colville River area of Alaska. M.S. Thesis, Univ. of Alaska, Fairbanks. 82 pp.
- Murie, A. 1961. A naturalist in Alaska. The Devin-Adair Co. New York. 320 pp.
- Potvin, F., and J. Huot. 1983. Estimating carrying capacity of white-tailed deer wintering area in Quebec. J. Wildl. Manage. 47:463-475.
- Regelin, W.L., C.C. Schwartz, and A.W. Franzmann. 1985. Seasonal energy metabolism of adult moose. J. Wildl. Manage. 49:388-393.
- Regelin, W.L., C.C. Schwartz, and A.W. Franzmann. 1986. Effects of forest succession on nutritional dynamics of moose forage. Viltrevy. In press.
- Schwartz, C.C., W.L. Regelin, and A.W. Franzmann. 1984. Seasonal dynamics of food intake in moose. Alces 20:223-244.
- Schwartz, C.C., W.L. Regelin, and A.W. Franzmann. 1986a. Annual weight cycle of moose. Viltrevy. In press.
- Schwartz, C.C., W.L. Regelin, and A.W. Franzmann. 1986b. Food passage rates in moose. J. Wildl. Manage. In press.
- Steigers, W.D., Jr., W.B. Ballard, E.F. Becker. 1986. March 1985 snow depth survey in the middle Susitna River basin, Alaska. LGL ALaska Research Assoc., Inc. for Alaska Power Authority Susitna Hydroelectric Project. 73 pp.

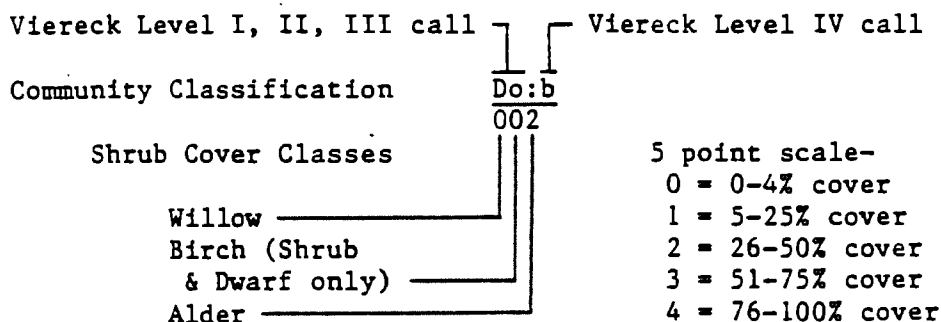
- Steigers, W.D., Jr., and E.F. Becker. 1986. Moose food habits and nutritional quality of forage in the middle Susitna River basin, Alaska. LGL Alaska Research Assoc., Inc. for Alaska Power Authority Susitna Hydroelectric Project.
- Steigers, W.D., Jr., and D. Helm. 1984. Terrestrial program 1983 browse pilot study. University of Alaska, Fairbanks for Alaska Power Authority Susitna Hydroelectric Project. 341 pp.
- Steigers, W.D., Jr., D. Helm, J.G. MacCracken, J.D. McKendrick and P.V. Mayer. 1983. 1982 plant ecology studies. Univ. of Alaska, Agric. and For. Exp. Sta. for Alaska Power Authority Susitna Hydroelectric Project. 288 pp.
- Swift, D.M. 1983. A simulation model of energy and nitrogen balance for free-ranging moose. J. Wildl. Manage. 47:620-645.
- Viereck, L.A., and C.T. Dyrness, 1980. A preliminary classification for vegetation in Alaska. Pacific Northwest For. and Range Exp. Sta., Gen. Tech. Rep. PNW-106. 38 pp.
- Viereck, L.A., C.T. Dyrness, and R.A. Batten. 1982. 1982 revision of preliminary classification for vegetation of Alaska. Anchorage Workshop on Classification of Alaskan Vegetation. USDA Pac. N.W. Res. Sta., Institute of N. For., Fairbanks, Alaska. 72 pp.
- Wallmo, O.C., L.C. Carpenter, W.L. Regelin, R.B. Gill, and D.L. Baker. 1977. Evaluation of deer habitat on a nutritional basis. J. Range Manage. 30:122-127.
- Wolff, J.O. 1976. Utilization of hardwood browse by moose on the Tanna flood plain of Interior Alaska. U.S. For. Serv. Pac. N.W. For. and Range Exp. Sta. Res. Note PNW-267. 7 pp.
- Wolff, J.O. 1978. Burning and browsing effects on willow growth in Interior Alaska. J. Wildl. Manage. 42:135-140.
- Wolfe, M.L., W.H. Babcock, and R.M. Welch. 1983. Effects of simulated moose browsing on Drummond's Willow. Alces 19:14-35.

APPENDIX A

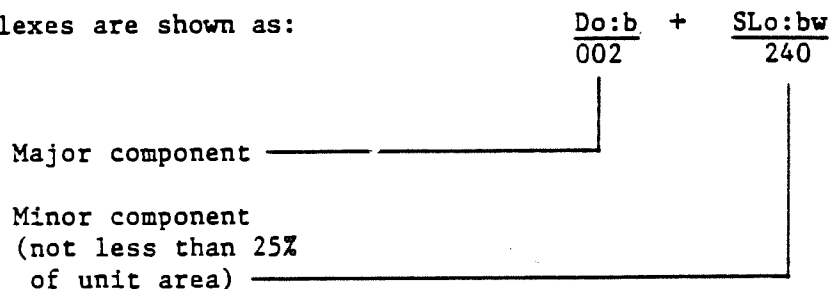
Susitna Hydroelectric Project Vegetation Mapping
 Source: R.A. Kreig & Associates, Inc.
 Mapping Legend (Revision 2)
 June 15, 1984

Mapping legend is based primarily on the 1982 Revision of Preliminary Classification for Vegetation of Alaska (Viereck et al. 1982). Modifications to the classification made as a result of the Alaska Vegetation Classification Workshop (Anchorage - February 21, 1984) are also incorporated. Level 4 categories recognized in this study area, but not listed in Viereck et al. (1982), are indicated by an asterisk (*).

The following symbology design is used on the maps:



Complexes are shown as:



APPENDIX A

<u>Alaska Vegetation Classification Unit Name (Viereck et al. 1982)</u>				<u>Susitna Vegetation</u> <u>Mapping Unit Symbol</u>
1. Forest	A. Conifer	1. Closed (60-100%)	K) White Spruce	Cc:w
			L) Black Spruce	Cc:m
			M) Black & White Spruce	Cc:mw
		2. Open (25-60%)	F) White Spruce	Co:w
			G) Black Spruce	Co:m
			H) Black & White Spruce	Co:mw
		3. Woodland (10-25%)	C) White Spruce	Cw:w
			D) Black Spruce	Cw:m
			E) Black & White Spruce	Cw:mw
	B. Broadleaf	1. Closed (60-100%)	B) Black Cottonwood	Dc:o
			C) Balsam Poplar	Dc:p
			D) Paper Birch	Dc:b
			E) Aspen	Dc:a
			F) Birch - Aspen	Dc:ba
		2. Open (25-60%)	A) Paper Birch	Do:b
			B) Aspen	Do:a
			C) Balsam Poplar	Do:p
		3. Woodland (10-25%)	A) Paper Birch	Dw:b
			B) Poplar	Dw:p
			C) Paper Birch - Poplar	Dw:bp
	C. Mixed	1. Closed (60-100%)	A) Spruce - Birch	Mc:sb
			B) Spruce - Birch - Poplar	Mc:sbp
			C) Spruce - Birch - Aspen	Mc:sba
			D) Aspen - Spruce	Mc:as
			E) Poplar - Spruce	Mc:ps
		2. Open (25-60%)	A) Spruce - Birch	Mo:sb
			B) Aspen - Spruce	Mo:as
			C) Spruce - Birch - Poplar	Mo:sbp
			D) Spruce - Poplar	Mo:sp
		3. Woodland (10-25%)	A) Spruce - Birch	Mw:sb
			B) Spruce - Poplar	Mw:sp
			C) Spruce - Birch - Poplar	Mw:sbp
2. Scrub	A. Dwarf Tree	Conifer		
		1. Closed (60-100%)		FCc
		2. Open (25-60%)		FCo
		3. Woodland (10-25%)		FCw

APPENDIX A

Broadleaf

- | | |
|-------------------------|-----|
| 1. Closed
(60-100%) | FDc |
| 2. Open
(25-60%) | FDo |
| 3. Woodland
(10-25%) | FDw |

Mixed

- | | |
|-------------------------|-----|
| 1. Closed
(60-100%) | FMc |
| 2. Open
(25-60%) | FMo |
| 3. Woodland
(10-25%) | FMw |

B. Tall Shrub

- | | | |
|------------------------|---|--|
| 1. Closed
(75-100%) | A) Willow
B) Alder
C) Shrub Birch
D) Alder - Willow
E) Shrub Birch - Willow
*) Alder - Shrub Birch -
Willow | STc:w
STc:l
STc:b
STc:lw
STc:bw
STc:lbw |
| 2. Open
(25-75%) | A) Willow
B) Alder
C) Shrub Birch
D) Alder - Willow
E) Shrub Birch - Willow
*) Alder - Shrub Birch | STo:w
STo:l
STo:b
STo:lw
STo:bw
STo:lb |

C. Low Shrub

- | | | |
|------------------------|---|--|
| 1. Closed
(75-100%) | A) Dwarf Birch
B) Low Willow
C) Dwarf Birch - Low Willow
D) Ericaceous Shrub Tundra | SLc:b
SLc:w
SLc:bw
SLc:e |
| 2. Open
(25-75%) | A) Dwarf Birch
B) Low Willow
C) Dwarf Birch - Willow
D) Low Alder
J) Ericaceous Shrub -
Sphagnum Bog
S) Willow Grass Tundra
T) Birch & Ericaceous Shrub
*) Ericaceous Shrub | SLo:b
SLo:w
SLo:bw
SLo:l
SLo:eu
SLo:wg
SLo:be
SLo:e |

APPENDIX A

3. Herbaceous	D. Dwarf Shrub	1. Closed (75-100%)		SMc
			A) Mat & Cushion - Sedge	SMc:s
			B) Mat & Cushion - Grass	SMc:g
			D) Cassiope	SMc:j
			G) Low Ericaceous Shrub	SMc:e
		2. Open (25-75%)		SMo
			E) Low Willow	SMo:w
			*) Ericaceous Shrub	SMo:e
	A. Graminoid	1. Dry		HGd
		2. Mesic		HGm
		3. Wet		HGw
			A) Wet Sedge Meadow	HGw:s
			C) Wet Sedge - Herb	HGw:sh
			M) Sedge - Moss Bog	HGw:sm
	B. Forb	1. Dry		HFd
		2. Mesic		HFd:h
		3. Wet	C) Alpine Herbs	HFm
	C. Bryoid	1. Mosses		HFw
		2. Lichens		HBm
	D. Aquatic	1. Fresh water		HB1
				HAF
4. Sparse Vegetation	A. Forest			Pf
	B. Scrub			Ps
	C. Herbaceous			Ph
5. Barren	A. Bedrock			O
				Ob

APPENDIX B WILLOW STRATIFICATION SCHEME

MAJOR VEGETATION	COMPLEX	ELEVATION	WILLOW-STRATA
** STRATA HIGH			
CO:MW3--	+3--		HIGH
CO:MW301	SLO:W300		HIGH
CO:MW4--	+4--		HIGH
MO:SB212	SLC:BW320	GE2000	HIGH
MO:SB212	SLC:BW320	L2000	HIGH
MO:SB310		GE2000	HIGH
SLC:B3--			HIGH
SLC:BW2--	+4--		HIGH
SLC:BW3--			HIGH
SLC:BW3--	SLO:BEG010		HIGH
SLC:BW4--			HIGH
SLC:LW3--			HIGH
SLC:W3--			HIGH
SLC:W3--	+0--		HIGH
SLC:W3--	+1--		HIGH
SLC:W3--	+2--		HIGH
SLC:W3--	+3--		HIGH
SLC:W3--	SMO		HIGH
SLC:W4	+1--		HIGH
SLC:W4--			HIGH
SLC:W4--	+4--		HIGH
SLO:B320	CW:W210		HIGH
SLO:BW310			HIGH
SLO:BW320			HIGH
SLO:W3--			HIGH
SLO:W3--	+1--		HIGH
SLO:W3--	HGW		HIGH
SLO:W3--	SLO:L003		HIGH
SLO:W3--	STO:L003		HIGH
SLO:W4--			HIGH
SLO:WG3--			HIGH
SLO:WG3--	1--		HIGH
SLO:WG3--	HGW		HIGH
SLO:WG300	CO:MW210		HIGH
SLO:WG310			HIGH
STC:W3--			HIGH
STC:W311			HIGH
STC:W4--			HIGH
STO:L4--			HIGH
STO:W3--			HIGH

APPENDIX B
WILLOW STRATIFICATION SCHEME

MAJOR VEGETATION	COMPLEX	ELEVATION	WILLOW-STRATA
** STRATA MEDIUM-FOREST			
CO:M3--	SLO:WG310		MEDIUM-FOREST
CO:M300	SLO:WG3--		MEDIUM-FOREST
CO:MW2--	+3--		MEDIUM-FOREST
CO:MW2--	+4--		MEDIUM-FOREST
CO:MW2--	SLO:BW3--		MEDIUM-FOREST
CO:MW2--	SLO:W3--		MEDIUM-FOREST
CO:MW3--			MEDIUM-FOREST
CO:MW300	HGW		MEDIUM-FOREST
CW:MW2--	+3--		MEDIUM-FOREST
CW:MW3--			MEDIUM-FOREST
CW:MW320			MEDIUM-FOREST
CW:W201	SLC:BW320		MEDIUM-FOREST
CW:W3--			MEDIUM-FOREST
CW:W310			MEDIUM-FOREST
FCO3--			MEDIUM-FOREST
FCO3--	HGW		MEDIUM-FOREST
FCW210	SLO:BW320		MEDIUM-FOREST
FCW211	SLO:BW320		MEDIUM-FOREST
FCW3--			MEDIUM-FOREST
MO:SB2--		L2000	MEDIUM-FOREST
MO:SB2--		GE2000	MEDIUM-FOREST
MO:SP3--		GE2000	MEDIUM-FOREST

APPENDIX B
WILLOW STRATIFICATION SCHEME

MAJOR VEGETATION	COMPLEX	ELEVATION	WILLOW-STRATA
** STRATA MEDIUM-SHRUB			
SLC:B2--			MEDIUM-SHRUB
SLC:BW2--			MEDIUM-SHRUB
SLC:W2--			MEDIUM-SHRUB
SLC:W2--	HGW		MEDIUM-SHRUB
SLC:WG2--			MEDIUM-SHRUB
SLC:WG3--			MEDIUM-SHRUB
SLO:BW2--	+3--		MEDIUM-SHRUB
SLO:BWG3--			MEDIUM-SHRUB
SLO:WG3--	SMO		MEDIUM-SHRUB
STC:LW3--	1--		MEDIUM-SHRUB
STC:LW3--			MEDIUM-SHRUB
STC:W2--			MEDIUM-SHRUB
STO:BW2--			MEDIUM-SHRUB
STO:L3--			MEDIUM-SHRUB
STO:L3--	SLC:B140		MEDIUM-SHRUB
STO:LW3--			MEDIUM-SHRUB
STO:W2--			MEDIUM-SHRUB

APPENDIX B
WILLOW STRATIFICATION SCHEME

MAJOR VEGETATION	COMPLEX	ELEVATION	WILLOW-STRATA
** STRATA LOW			
CC:MW3--			LOW
CC:MW3--	CW:MW220		LOW
CC:MW3--	HGW		LOW
CC:W3--			LOW
CO:M3--			LOW
CO:MW120	SLC:W310		LOW
CO:MW120	SLC:W410		LOW
CO:MW120	SLC:WG301		LOW
CO:MW2--			LOW
CO:MW2--	FCO110		LOW
CO:MW2--	HGW		LOW
CO:MW2--	SLC:B1--		LOW
CO:MW2--	SLC:BE1--		LOW
CO:MW2--	SLO:B1--		LOW
CO:MW2--	SLO:BW2--		LOW
CO:W1--	+3--		LOW
CO:W3--			LOW
CO:W3--	HGW		LOW
CW:MW2--			LOW
CW:MW211	SLO:WG210		LOW
CW:W2--			LOW
CW:W210	SLO:B130		LOW
FCC1--	SLO:W3--		LOW
FCC2--			LOW
FCC2--	SLO:BW2--		LOW
FCO2--			LOW
FCO210	HGW		LOW
FCO210	SLO:BW220		LOW
FCW2--			LOW
FCW210			LOW
FMW:211	SLC:B230		LOW
HGM			LOW
HGW			LOW
HGW	SLO:BW110		LOW
HGW	SLO:W200		LOW
MC:SB2--		GE2000	LOW
MC:SP2--		GE2000	LOW
MO:SP2--		GE2000	LOW
SLC:B0--	+3--		LOW
SLC:B0--	+4--		LOW
SLC:B040	SLC:W311		LOW
SLC:B1--	SLC:W3--		LOW
SLC:B1--	SLC:W4--		LOW
SLC:B1--	SLO:W2--		LOW
SLC:B1--	SLO:W3--		LOW
SLC:B1--	STC:W4--		LOW
SLC:BE2--			LOW
SLC:BEG2--			LOW
SLC:W100			LOW
SLO:B2--			LOW

APPENDIX B
WILLOW STRATIFICATION SCHEME

MAJOR VEGETATION	COMPLEX	ELEVATION	WILLOW-STRATA
SLO:BE230			LOW
SLO:BEG1--	+3--		LOW
SLO:BEG1--	+4--		LOW
SLO:BEG2--			LOW
SLO:BG2--			LOW
SLO:BW2--			LOW
SLO:BW2--	HGM		LOW
SLO:BW210	SLO:BE020		LOW
SLO:BW220	SLO:B130		LOW
SLO:BW220	SLO:BE120		LOW
SLO:BW220	STO:L103		LOW
SLO:BWG2--			LOW
SLO:W2--	+3--		LOW
SLO:W2--	+4--		LOW
SLO:W2--	HGW		LOW
SLO:WG2--			LOW
SLO:WG2--	HGW		LOW
SLO:WG2--	SLO:BE020		LOW
SLO:WG2--	SLO:BW120		LOW
STC:LW2--			LOW
STO:L2--	PH		LOW
STO:L2--			LOW
STO:L2--	SLO:BW130		LOW
STO:LW2--			LOW

APPENDIX B
WILLOW STRATIFICATION SCHEME

MAJOR VEGETATION	COMPLEX	ELEVATION	WILLOW-STRATA
** STRATA VERY-LOW			
CC:M3--			VERY-LOW
CC:MW1--			VERY-LOW
CC:MW1--	+1--		VERY-LOW
CC:MW110-	FC0110		VERY-LOW
CC:MW120	FC0110		VERY-LOW
CC:MW2--			VERY-LOW
CO:M1--	SLC:W3--		VERY-LOW
CO:M1--	SLO:WG3--		VERY-LOW
CO:M220	SLO:WG300		VERY-LOW
CO:MW0--	CW:W310		VERY-LOW
CO:MW110	SLC:W400		VERY-LOW
CO:MW112			VERY-LOW
CO:MW112	SLC:W300		VERY-LOW
CO:MW120			VERY-LOW
CO:MW121			VERY-LOW
CO:MW121	STO:L113		VERY-LOW
CO:MW122			VERY-LOW
CO:MW130	SLC:W3--		VERY-LOW
CO:W1--			VERY-LOW
CO:W101			VERY-LOW
CO:W102			VERY-LOW
CO:W110			VERY-LOW
CO:W111			VERY-LOW
CO:W112	SLO:B120		VERY-LOW
CO:W120			VERY-LOW
CO:W121			VERY-LOW
CO:W122			VERY-LOW
CO:W130			VERY-LOW
CO:W2--			VERY-LOW
CW:MW1--			VERY-LOW
CW:MW1--	SLO:B120		VERY-LOW
CW:W103-			VERY-LOW
CW:W104			VERY-LOW
CW:W110			VERY-LOW
CW:W111			VERY-LOW
CW:W112			VERY-LOW
CW:W113			VERY-LOW
CW:W121			VERY-LOW
CW:W122			VERY-LOW
CW:W123			VERY-LOW
CW:W130			VERY-LOW
CW:W130	CO:MW220		VERY-LOW
CW:W131			VERY-LOW
CW:W132			VERY-LOW
CW:W140			VERY-LOW
FCC1--			VERY-LOW
FCC1--	+1--		VERY-LOW
MC:SB1--		GE2000	VERY-LOW
MC:SB1--	+1--	GE2000	VERY-LOW
MC:SB102	CO:W202	GE2000	VERY-LOW

APPENDIX B
WILLOW STRATIFICATION SCHEME

MAJOR VEGETATION	COMPLEX	ELEVATION	WILLOW-STRATA
MC:SBA2--			VERY-LOW
MC:SBP101		GE2000	VERY-LOW
MC:SP1--		GE2000	VERY-LOW
MO:SB0--		GE2000	VERY-LOW
MO:SB1--		GE2000	VERY-LOW
MO:SB310		L2000	VERY-LOW
MO:SBP1--		GE2000	VERY-LOW
MO:SP1--		GE2000	VERY-LOW
MW:SB2--		GE2000	VERY-LOW
MW:SBA212		GE2000	VERY-LOW
MW:SP2--		GE2000	VERY-LOW
SLC:B1--			VERY-LOW
SLC:BW1--			VERY-LOW
SLC:EG2--			VERY-LOW
SLC:L1--			VERY-LOW
SLO:B0--	+2--		VERY-LOW
SLO:B0--	+3--		VERY-LOW
SLO:B1--	+3--		VERY-LOW
SLO:BE0--	+3--		VERY-LOW
SLO:BE1--	+3--		VERY-LOW
SLO:BEG1--			VERY-LOW
SLO:BEG120	SLO:B030		VERY-LOW
SLO:LW1--			VERY-LOW
SLO:W1--			VERY-LOW
SLO:W1--	HGW		VERY-LOW
SLO:W1--	SMO		VERY-LOW
SLO:W100			VERY-LOW
SLO:W100	PH		VERY-LOW
SLO:W2--			VERY-LOW
SLO:W2--	+1--		VERY-LOW
SLO:W2--	SMO		VERY-LOW
SLO:WG1--			VERY-LOW
SLO:WG100			VERY-LOW
SMC:E	+3--		VERY-LOW
SMO	+3--		VERY-LOW
SMO	+4--		VERY-LOW
SMO	SLC:W410		VERY-LOW
SMO	SLO:W310		VERY-LOW
STC:L1--	+2--		VERY-LOW
STC:L2--	SLC:BW221		VERY-LOW
STC:L2--	SLO:BW220		VERY-LOW
STC:L221	SMO		VERY-LOW
STC:LW202	SLC:B040		VERY-LOW
STC:LW202	SMC		VERY-LOW
STO:L1--	+2--		VERY-LOW
STO:L1--	SLO:BW220		VERY-LOW
STO:LW1--	+2--		VERY-LOW
STO:W100	SMO		VERY-LOW

APPENDIX B
WILLOW STRATIFICATION SCHEME

MAJOR VEGETATION	COMPLEX	ELEVATION	WILLOW-STRATA
** STRATA SCARCE			
CC:M1--			SCARCE
CC:M1--	HGM		SCARCE
CC:M1--	HGW		SCARCE
CC:M2--			SCARCE
CC:W1--			SCARCE
CC:W1--	+0--		SCARCE
CC:W2--			SCARCE
CC:W2--	SLO:B1		SCARCE
CC:W200			SCARCE
CC:W212			SCARCE
CO:M1--			SCARCE
CO:M1--	+1--		SCARCE
CO:M110	HGM		SCARCE
CO:M2--			SCARCE
CO:M211			SCARCE
CO:M220			SCARCE
CO:MW0--			SCARCE
CO:MW0--	+0--		SCARCE
CO:MW100			SCARCE
CO:MW102			SCARCE
CO:MW103			SCARCE
CO:MW110			SCARCE
CO:MW110	FCO010		SCARCE
CO:MW110	FCW100		SCARCE
CO:MW111			SCARCE
CO:MW113			SCARCE
CO:MW123			SCARCE
CO:MW130			SCARCE
CO:MW131			SCARCE
CO:MW140			SCARCE
CO:W0--			SCARCE
CO:W020			SCARCE
CO:W022			SCARCE
CO:W030			SCARCE
CW:M1--			SCARCE
CW:M210	SLO:BE120		SCARCE
CW:MW0--			SCARCE
CW:W0--			SCARCE
CW:W120			SCARCE
DC:B1--			SCARCE
DC:BA1--			SCARCE
DC:BP2--			SCARCE
DC:P1--			SCARCE
DC:P2--			SCARCE
DO:B1--			SCARCE
DO:P1--			SCARCE
DO:P2--			SCARCE
DW:B1--			SCARCE
DW:P1--			SCARCE
FCO1--			SCARCE

APPENDIX B
WILLOW STRATIFICATION SCHEME

MAJOR VEGETATION	COMPLEX	ELEVATION	WILLOW-STRATA
FC01--	+0--		SCARCE
FC0110	STO:L103		SCARCE
FCW0--			SCARCE
FCW0--	HGW		SCARCE
FCW1--			SCARCE
HGD			SCARCE
MC:SB0--		GE2000	SCARCE
MC:SB1--		L2000	SCARCE
MC:SB1--	+1--	L2000	SCARCE
MC:SB102	CO:W202	L2000	SCARCE
MC:SB2--		L2000	SCARCE
MC:SBA0--			SCARCE
MC:SBA1--			SCARCE
MC:SBP101		L2000	SCARCE
MC:SP0--		GE2000	SCARCE
MC:SP1--		L2000	SCARCE
MC:SP2--		L2000	SCARCE
MO:SB0--		L2000	SCARCE
MO:SB1--		L2000	SCARCE
MO:SBP0--		L2000	SCARCE
MO:SBP0--		GE2000	SCARCE
MO:SBP1--		L2000	SCARCE
MO:SP0--		GE2000	SCARCE
MO:SP1--		L2000	SCARCE
MO:SP2--		L2000	SCARCE
MO:SP3--		L2000	SCARCE
MW:SB0--		GE2000	SCARCE
MW:SB1--		GE2000	SCARCE
MW:SB2--		L2000	SCARCE
MW:SBA212		L2000	SCARCE
MW:SP1--		GE2000	SCARCE
MW:SP2--		L2000	SCARCE
O	W		SCARCE
PF			SCARCE
SLC-B	+2		SCARCE
SLC:B	+1		SCARCE
SLC:B0--	SLC:BW2--		SCARCE
SLC:B0--	SLO:BW2--		SCARCE
SLC:B0--	SLO:W2--		SCARCE
SLC:B0--	SLO:WG2--		SCARCE
SLC:B040	SLO:W200		SCARCE
SLC:BE0--			SCARCE
SLC:BE0--	SLO:W2--		SCARCE
SLC:BE030	SLO:W200		SCARCE
SLC:BE1--			SCARCE
SLC:BEG0--			SCARCE
SLC:BEG1--			SCARCE
SLC:E1--			SCARCE
SLC:EG1--			SCARCE
SLO:B0--			SCARCE
SLO:B1--			SCARCE

APPENDIX B
WILLOW STRATIFICATION SCHEME

MAJOR VEGETATION	COMPLEX	ELEVATION	WILLOW-STRATA
SLO:B1--	+0--		SCARCE
SLO:B1--	+1--		SCARCE
SLO:B1--	SMO		SCARCE
SLO:BE0--			SCARCE
SLO:BE0--	+0--		SCARCE
SLO:BE0--	+1--		SCARCE
SLO:BE0--	+2--		SCARCE
SLO:BE1--			SCARCE
SLO:BE1--	+0--		SCARCE
SLO:BE1--	+1--		SCARCE
SLO:BE1--	+2--		SCARCE
SLO:BE1--	SMO		SCARCE
SLO:BEG0--			SCARCE
SLO:BG0--			SCARCE
SLO:BW1--			SCARCE
SLO:BW1--	+0--		SCARCE
SLO:BW1--	+1--		SCARCE
SLO:BW1--	SMO		SCARCE
SLO:BWG1--			SCARCE
SLO:E0--			SCARCE
SLO:E010			SCARCE
SLO:E1--			SCARCE
SLO:E110			SCARCE
SLO:EG010			SCARCE
SLO:EG1--			SCARCE
SLO:EG1--	SMC		SCARCE
SLO:EG110			SCARCE
SLO:L1--			SCARCE
SMC			SCARCE
SMC	+1--		SCARCE
SMC	+2--		SCARCE
SMC	PH		SCARCE
SMC:E	+1--		SCARCE
SMO	+1--		SCARCE
SMO	+2--		SCARCE
SMO	SLO:BW110		SCARCE
SMO	SLO:BW210		SCARCE
SMO	SLO:B130		SCARCE
SMO	SLC:BW210		SCARCE
SMO	SLO:BW220		SCARCE
SMO	SLO:BWG110		SCARCE
SMO	SLO:E110		SCARCE
SMO	SLO:W100		SCARCE
SMO	SLO:W200		SCARCE
SMO	SLO:W211		SCARCE
SMO	SLO:WG100		SCARCE
SMO	STO:L111		SCARCE
SMO	SLO:W210		SCARCE
SMO	STO:W101		SCARCE
SMO:E	SMO:W		SCARCE
SMO:E	SLO:W200		SCARCE

APPENDIX B
WILLOW STRATIFICATION SCHEME

MAJOR VEGETATION	COMPLEX	ELEVATION	WILLOW-STRATA
SMO:E111			SCARCE
SMO:W	SMO:E		SCARCE
STC:L0--	SLO:BW110		SCARCE
STC:L0--	O		SCARCE
STC:L0--			SCARCE
STC:L1--	+0--		SCARCE
STC:L1--	+1--		SCARCE
STC:L1--			SCARCE
STC:L2--	SLO:B020		SCARCE
STC:L2--			SCARCE
STC:L2--	O		SCARCE
STC:LW1--			SCARCE
STC:LW103	SLO:BEG020		SCARCE
STO:B121			SCARCE
STO:B130			SCARCE
STO:L0--	1--		SCARCE
STO:L0--			SCARCE
STO:L003			SCARCE
STO:L012			SCARCE
STO:L1--			SCARCE
STO:L1--	SMO		SCARCE
STO:L1--	SMO		SCARCE
STO:L1--	+0--		SCARCE
STO:LW1--			SCARCE

APPENDIX B
WILLOW STRATIFICATION SCHEME

MAJOR VEGETATION	COMPLEX	ELEVATION	WILLOW-STRATA
** STRATA ZERO			
CC:M0--			ZERO
CC:M1--	MO:SBO--		ZERO
CC:M1--	MC:SPO--		ZERO
CC:M1--	MC:SP1--		ZERO
CC:M1--	MO:SB1--		ZERO
CC:MW0--			ZERO
CC:MW1--	MO:SBO--		ZERO
CC:MW1--	MO:SB1--		ZERO
CC:W0--			ZERO
CO:M001			ZERO
CO:M010			ZERO
DC:A0--			ZERO
DC:B0--			ZERO
DC:BA0--			ZERO
DO:B0--			ZERO
DW:B0--			ZERO
DW:BP0--			ZERO
FCO0--			ZERO
MC:SBO--		L2000	ZERO
MC:SPO--		L2000	ZERO
MO:SBA0--			ZERO
MO:SPO--		L2000	ZERO
MW:SBO--		L2000	ZERO
MW:SB1--		L2000	ZERO
MW:SP1--		L2000	ZERO
O			ZERO
O	PH		ZERO
O	SMO		ZERO
O	STO:L002		ZERO
PH			ZERO
PH	O		ZERO
PH	SMO		ZERO
SLC:B0--			ZERO
SLC:E0--			ZERO
SMC:E			ZERO
SMO			ZERO
SMO	HBL		ZERO
SMO	PH		ZERO
SMO	O		ZERO
SMO	SMC		ZERO

APPENDIX B - WILLOW STRATIFICATION SCHEME

Explanation of the coding key :

- 1) When the 'complex' column is blank and the major vegetation call includes dashes '--', this indicates that any combination of alder and dwarf birch forage calls that could occur with the level IV Viereck call is covered under this strata code unless this major vegetation call is listed under another strata code with a specific alder and dwarf birch forage call. When this occurs all calls that are not covered specifically are covered by the major vegetation call that uses dashes.
- 2) When the 'complex' column is not blank, then the conditions of both the major vegetation call and the complex call have to be met in order for the strata code to be valid.
- 3) Some of the listings in the complex column do not contain complete complex codes but rather a number preceded by a '+' sign, for example '+3', this number represents any vegetation polygon occurring in the complex which has a '3' in the willow forage component.
- 4) The strata code is only valid for polygons or the portions of polygons at or above the 2000 foot contour which meet the conditions of the major vegetation and complex call when 'GE2000' appears in the elevation column.
- 5) The strata code is only valid for polygons or portions of polygons below the 2000 foot contour which meet the conditions of the major vegetation and complex call when 'L2000' appears in the elevation column.

APPENDIX C

STATISTICAL RESULTS USED TO ESTIMATE MOOSE FORAGE BIOMASS

I) Two stage ratio to size estimators

A) Biomass per m² per population-strata category

$$\hat{\mu}_{jkl} = \frac{\sum_{i=1}^n M_{ijk} \bar{Y}_{ijkl}}{\sum_{i=1}^n M_{ijk}} \quad (1)$$

where i - indexes transects

j - indexes strata

k - indexes the population (A,B,D)

l - indexes species (willow, paper birch, mt. cranb.)

M - denotes transect length

\bar{Y}_{ijkl} - denotes mean biomass per m² for the i th transect, j th strata, k th population, and l th species

$\hat{\mu}_{jkl}$ - denotes mean biomass per m² for the j th strata, k th population, and l th species

$$V(\hat{\mu}_{jkl}) = \frac{\sum_{i=1}^n M_{ijk}^2 (\bar{Y}_{ijkl} - \hat{\mu}_{jkl})^2}{n(n-1)\bar{M}^2} + \underbrace{\left\{ \left(\frac{1}{Nn\bar{M}^2} \right) \sum_{i=1}^n M_{ijk}^2 [(M_{ijk} - m_{ijk})/M_{ijk}] S_{ijkl}^2 / m_{ijk} \right\}}_{2 \text{ nd TERM}} \quad (2)$$

Since the transects were sampled with replacement,

$N = \infty \rightarrow 2 \text{ nd TERM} = 0.$

$$\text{Where } S_{ijk}^2 = \frac{\sum_{g=1}^{m_{ijk}} (Y_{gijkl} - \bar{Y}_{ijkl})^2}{(m_{ijk} - 1)} \quad (3)$$

m_{ijk} = number of plots in the i th transect, j th strata and k th population

g - indexes the plots in the i th transect, j th strata, and k th population

So :

$$V(\hat{\mu}_{jkl}) = \frac{\sum_{i=1}^n M_{ijk}^2 (\bar{Y}_{ijkl} - \hat{\mu}_{jkl})^2}{n(n-1)\bar{M}^2} \quad (4)$$

APPENDIX CB) Biomass per m² per population

$$\hat{\mu}_{kl} = \frac{\sum_{j=1}^h A_{jk} \hat{\mu}_{jkl}}{\sum_{j=1}^h A_{jk}} \quad (5)$$

where A - denotes area of the j th strata in the k th pop.

$$V(\hat{\mu}_{kl}) = \left(\frac{1}{\sum_{j=1}^h A_{jk}} \right)^2 \left\{ \sum_{j=1}^h A_{jk}^2 V(\hat{\mu}_{jkl}) + 2 \sum_{j=1}^h \sum_{j'=1, j' \neq j}^h A_{jk} A_{j'k} \text{Cov}(\hat{\mu}_{jkl}, \hat{\mu}_{j'kl}) \right\} \quad (6)$$

$$\text{where } \text{Cov}(\hat{\mu}_{jkl}, \hat{\mu}_{j'kl}) = \quad (7)$$

$$\left(\frac{1}{\sum_{i=1}^n M_{ijkl}} \right) \left(\frac{1}{\sum_{i=1}^n M_{ij'kl}} \right) \sum_{i=1}^{n^*} M_{ijkl} M_{ij'kl} (\bar{Y}_{ijkl} \bar{Y}_{ij'kl} - \hat{\mu}_{jkl} \hat{\mu}_{j'kl})$$

n* - denotes the number of transects with plots in both the jth and j' th strata, for a given population (k)

C) Bias of biomass per m² per population strata category

$$E(\hat{\mu}_{jkl}) = E \left\{ \frac{\sum_{i=1}^n M_{ijk} \bar{Y}_{ijkl}}{\sum_{i=1}^n M_{ijk}} \right\} = E(\bar{Y}_{ljk} / \bar{M}_{jk}) \quad (8)$$

(9)

$$\approx (\mu_{Yljk} / \mu_{Mjk}) - (1/\mu_{Mjk}^2 n^2) \text{Cov}(\bar{Y}_{ljk}, \bar{M}_{jk}) + (\mu_{Yljk}^2 \sigma_{Mjk}^2 / n \mu_{Mjk}^3)$$

Based on a 2 nd order Taylor Series Approximation.

$$\begin{aligned} \text{Note } \mu_{jkl} &= (T_{Yljk} / T_{Mjk}) = (N \mu_{Yljk} / N \mu_{Mjk}) \\ &= (\mu_{Yljk} / \mu_{Mjk}). \end{aligned} \quad (10)$$

$$\therefore \text{Bias} = \mu_{jkl} - E(\hat{\mu}_{jkl}) \quad (11)$$

$$\approx - (1/\mu_{Mjk}^2 n^2) \text{Cov}(\bar{Y}_{ljk}, \bar{M}_{jk}) + (\mu_{Yljk}^2 \sigma_{Mjk}^2 / n \mu_{Mjk}^3)$$

APPENDIX C

$$\text{So } b = (-1/\bar{M}_{jk}^2 n^2) \text{Cov}(\bar{Y}_{1jkl}, \bar{M}_{jk}) + (\bar{Y}_{1jkl} \hat{\sigma}_{Mjk}^2/n \bar{M}_{jk}^3). \quad (12)$$

Where b - denotes the estimated bias of $\hat{\mu}_{jkl}$.

$$\bar{Y}_{1jkl} = \sum_{i=1}^n \bar{Y}_{ijkl} M_{ijk}/n \quad (13)$$

$$\bar{M}_{jk} = \sum_{i=1}^n M_{ijk}/n \quad (14)$$

$$\text{Cov}(\bar{Y}_{1jkl}, \bar{M}_{jk}) = \sum_{i=1}^n \bar{Y}_{ijkl} M_{ijk} - n \bar{Y}_{1jkl} \bar{M}_{jk} \quad (15)$$

$$\hat{\sigma}_{Mjk}^2 = \sum_{i=1}^n (M_{ijk} - \bar{M}_{jk})^2 / (n-1) \quad (16)$$

D) Probability of species occurrence per m^2 per population-strata category.

$$\hat{\rho}_{jkl} = \sum_{i=1}^n M_{ijk} \hat{\rho}_{ijkl} / \sum_{i=1}^n M_{ijk} \quad (17)$$

where i - indexes transects

j - indexes strata

k - indexes the population (A,B,D)

l - indexes species (willow, paper birch, mt. cranb.)

M - denotes transect length

$\hat{\rho}_{ijkl}$ - denotes the proportion of plots in the i th transect, j th strata, k th population, that contain plants of the l th species

$\hat{\rho}_{jkl}$ - denotes the estimated probability of a plot in the j th strata, and k th population, containing a plant of the l th species

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$$V(\hat{\rho}_{jkl}) = \sum_{i=1}^n M_{ijk}^2 (\hat{\rho}_{ijkl} - \hat{\rho}_{jkl})^2 / n(n-1)\bar{M}^2 \quad (18)$$

$$+ \left\{ (1/n\bar{M}^2) \sum_{i=1}^n M_{ijk}^2 [(M_{ijk} - m_{ijk})/M_{ijk}] \hat{\rho}_{ijkl} (1 - \hat{\rho}_{ijkl}) / (m_{ijk} - 1) \right\}$$

$$\left(\underbrace{\hspace{15em}}_{2 \text{ nd TERM}} \right)$$

Since the transects were sampled with replacement,
 $N = \infty \rightarrow 2 \text{ nd TERM} = 0.$

where m_{ijk} = number of plots in the i th transect,
 j th strata and k th population

So :

$$V(\hat{\rho}_{jkl}) = \sum_{i=1}^n M_{ijk}^2 (\hat{\rho}_{ijkl} - \hat{\rho}_{jkl})^2 / n(n-1)\bar{M}^2 \quad (19)$$

E) Probability of species occurrence per m^2 per
 population category.

$$\hat{\rho}_{kl} = \sum_{j=1}^h A_{jk} \hat{\rho}_{jkl} / \sum_{j=1}^h A_{jk} \quad (20)$$

where A - denotes area of the j th strata in the k th pop.

$$V(\hat{\rho}_{kl}) = \left(\frac{1}{\sum_{j=1}^h A_{jk}} \right)^2 \left\{ \sum_{j=1}^h A_{jk}^2 V(\hat{\rho}_{jkl}) + 2 \sum_{j=1}^h \sum_{j'=1}^h A_{jk} A_{j'k} \text{Cov}(\hat{\rho}_{jkl}, \hat{\rho}_{j'kl}) \right\} \quad (21)$$

$j < j'$

$$\text{where } \text{Cov}(\hat{\rho}_{jkl}, \hat{\rho}_{j'kl}) = \quad (22)$$

$$\left(\frac{1}{\sum_{i=1}^n M_{ijkl}} \right) \left(\frac{1}{\sum_{i=1}^n M_{ij'kl}} \right) \sum_{i=1}^{n^*} M_{ijkl} M_{ij'kl} (\hat{\rho}_{ijkl} \hat{\rho}_{ij'kl} - \hat{\rho}_{jkl} \hat{\rho}_{j'kl})$$

n^* - denotes the number of transects with plots in both the
 j th and j' th strata, for a given population (k)

APPENDIX C

F) Bias of probability of species occurrence per m^2 per population category

$$E(\hat{\rho}_{jkl}) = E\left\{ \sum_{i=1}^n M_{ijk} \hat{\rho}_{ijkl} / \sum_{i=1}^n M_{ijk} \right\} = E(\bar{W}_{jkl} / \bar{M}_{jk}) \quad (23)$$

(24)

$$\approx (\mu_{Wjkl} / \mu_{Mjk}) - (1/\mu_{Mjk}^2) \text{Cov}(\bar{W}_{jkl}, \bar{M}_{jk}) + (\mu_{Wjkl} \sigma_{Mjk}^2 / n \mu_{Mjk}^3)$$

Based on a 2 nd order Taylor Series Approximation.

$$\begin{aligned} \text{Note } \rho_{jkl} &= \left(\sum_{i=1}^N M_{ijk} \rho_{ijkl} / \sum_{i=1}^N M_{ijk} \right) = \left(\left(\sum_{i=1}^N M_{ijk} \rho_{ijkl} / N \right) / \left(\sum_{i=1}^N M_{ijk} / N \right) \right) \\ &= (\mu_{Wjkl} / \mu_{Mjk}) \end{aligned} \quad (25)$$

$$\therefore \text{Bias} = \rho_{jkl} - E(\hat{\rho}_{jkl}) \quad (26)$$

$$\approx -(1/\mu_{Mjk}^2) \text{Cov}(\bar{W}_{jkl}, \bar{M}_{jk}) + (\mu_{Wjkl} \sigma_{Mjk}^2 / n \mu_{Mjk}^3)$$

(27)

$$\text{So } b = (-1/\bar{M}_{jk}^2 n^2) \text{Cov}(\bar{W}_{jkl}, \bar{M}_{jk}) + (\bar{W}_{jkl} \hat{\sigma}_{Mjk}^2 / n \bar{M}_{jk}^3).$$

Where b - denotes the estimated bias of $\hat{\rho}_{jkl}$.

$$\bar{W}_{jkl} = \sum_{i=1}^n M_{ijk} \hat{\rho}_{ijkl} / n \quad (28)$$

$$\bar{M}_{jk} = \sum_{i=1}^n M_{ijk} / n \quad (29)$$

$$\text{Cov}(\bar{W}_{jkl}, \bar{M}_{jk}) = \sum_{i=1}^n \bar{W}_{ijkl} M_{ijk} - n \bar{W}_{jkl} \bar{M}_{jk} \quad (30)$$

$$\hat{\sigma}_{Mjk}^2 = \sum_{i=1}^n (M_{ijk} - \bar{M}_{jk})^2 / (n-1) \quad (31)$$

APPENDIX C

II) Ordinal logit model for proportion of willow plants browsed.

A) Full Models :

1) Regular model

$$\ln(m_{2jk}/m_{1jk}) = \alpha + r_j + r_k + r_{jk} \quad (32)$$

2) Linear Model

$$\ln(m_{2jk}/m_{1jk}) = \alpha + r_j + \beta(w_k - \bar{w}) + \lambda_j(w_k - \bar{w}) \quad (33)$$

3) Quadratic Model

$$\ln(m_{2jk}/m_{1jk}) = \alpha + r_j + \beta(w_k - \bar{w})^2 + \lambda_j(w_k - \bar{w})^2 \quad (34)$$

B) Model with Best Fit

- Reduced Linear Model with no interactions

$$\ln(m_{2jk}/m_{1jk}) = \alpha + r_j + \beta(w_k - \bar{w}) \quad (35)$$

where j - indexes population (A, or B)

k - indexes plant density (1,2,...,8)

m_{1jk} - denotes the number of plots in the j th population and at the k th plant density level that were not browsed

m_{2jk} - denotes the number of plots in the j th population and at the k th plant density level that were browsed

α - denotes the mean of the 2X8 logits

r_j - denotes the deviation of the cell count from the mean due to the j th population

r_k - denotes the deviation of the cell count from the mean due to the k th level of plant density

β - denotes the linear change in the logit due to plant density

w_k - denotes the value of the k th level of plant density (1,2,...,8)

\bar{w} - denotes the mean level of plant density (4.5)

λ_j - denotes the additional change in the logit due to the interaction of the j th population with the k th plant density