



**ECOSYSTEM CLASSIFICATION OF THE
SUBALPINE AND ALPINE ZONES OF THE
MUSKWA-KECHIKA MANAGEMENT AREA**

Spatial Analysis & Work Plan

Seed Project 1999-2000

prepared for:

Muskwa-Kechika Advisory Board

by:

Ksenia Barton

**MADRONE CONSULTANTS LTD.
1081 Canada Avenue, Duncan, BC V9L 1V2**

March 2000



ACKNOWLEDGEMENTS

This seed project was funded by the Muskwa-Kechika Trust Fund.

The B.C. Ministry of Forests and Ministry of Environment, Lands and Parks played a critical role in providing the information on which this report is based. The following government employees took time out of their busy schedules to respond to my requests for information and advice:

- Allen Banner (Research Ecologist, Research, Ministry of Forests, Prince Rupert, B.C.)
- Tim Brierley (Quality Assurance GIS Specialist, Quality Assurance Unit, Ministry of Environment, Lands, and Parks, Victoria, B.C.)
- Carmen Cadrin (Plant Ecologist, Quality Assurance Unit, Ministry of Environment, Lands, and Parks, Victoria, B.C.)
- Adolf Ceska (Program Ecologist, Conservation Data Centre, Ministry of Environment, Lands, and Parks, Victoria, B.C.)
- Craig DeLong (Landscape Ecologist, Forest Resources, Ministry of Forests, Prince George, B.C.)
- Perry Grilz (Range Specialist, Operations, Ministry of Forests, Prince George, B.C.)
- Will Mackenzie (Research Ecologist, Wetlands & Riparian Specialist, Biogeoclimatic Ecosystem Classification, Ministry of Forests, Smithers, B.C.)
- Bob Maxwell (Pedologist/Bioterrain Specialist, Quality Assurance Unit, Ministry of Environment, Lands, and Parks, Victoria, B.C.)
- Del Meidinger (Research Ecologist, Biogeoclimatic Ecosystem Classification, Ministry of Forests, Victoria, B.C.)
- Michael Wood (Regional GIS Coordinator, GIS Section, Ministry of Environment, Lands, and Parks, Fort St. John, B.C.)
- Evelyn Hamilton (Wildlife and Range Manager, Wildlife & Range, Ministry of Forests, Victoria, B.C.)

Gill Radcliffe (Wildlife Biologist) and Jan Teversham (Ecologist) of Madrone Consultants Ltd. provided contact information and background documents on the Muskwa-Kechika Management Area.

Stephan Kesting provided helpful comments on an earlier draft of this report.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	II
LIST OF TABLES.....	IV
LIST OF FIGURES	V
EXECUTIVE SUMMARY	VI
1 INTRODUCTION.....	1
1.1 ISSUE.....	1
1.2 PROJECT OBJECTIVES	2
1.3 RELEVANCE TO REGIONAL AND PROVINCIAL PRIORITIES	2
2 DESCRIPTION OF STUDY AREA	4
2.1 LOCATION.....	4
2.2 BIOPHYSICAL ATTRIBUTES	5
2.2.1 Biogeoclimatic Zones.....	5
2.2.1.1 <i>Spruce-Willow-Birch</i>	5
2.2.1.2 <i>Alpine Tundra</i>	5
2.2.2 Ecosections	6
2.2.3 Bedrock Types.....	7
2.2.4 Special Sites and Rare Ecosystems.....	9
3 SPATIAL ANALYSIS OF VEGETATION DATA.....	10
3.1 METHODS.....	10
3.2 DISTRIBUTION OF VEGETATION SAMPLING	12
3.2.1 Biogeoclimatic Zones.....	13
3.2.2 Ecosections.....	15
3.2.3 Bedrock Types.....	17
3.2.4 Ecosystem Types	20
3.2.5 Special Sites and Rare Ecosystems.....	20
3.3 PRIORITY AREAS FOR FUTURE FIELD WORK	22
3.4 SUMMARY.....	23
4 WORK PLAN FOR 2000-2001	25
4.1 SAMPLING PLAN FOR FIELD WORK	25
4.2 FIELD WORK.....	25
4.3 ECOSYSTEM CLASSIFICATION	25
4.4 COMMUNICATING PROJECT RESULTS.....	26
4.5 SUMMARY OF WORK PLAN.....	26
REFERENCES	27
APPENDICES	29
APPENDIX 1. PROVINCIAL MAP UNITS.....	29
APPENDIX 2. STUDIES OF ALPINE AND SUBALPINE ECOSYSTEMS	34
APPENDIX 3. SOURCES OF MAP DATA	37

LIST OF TABLES

Table 1. Ecoregion classification of the study area.	6
Table 2. Bedrock types within the study area.	8
Table 3. Sources of plot data within the study area.	11
Table 4. Summary of work plan for 2000-2001	26
Table 5. Map units of the AT and SWB zones of the Prince George Forest Region.....	29
Table 6. Studies of alpine and subalpine ecosystems in and adjacent to the MKMA.	34
Table 7. Sources of map data for spatial analysis and presentation.	37

LIST OF FIGURES

Figure 1. Map of study area.	4
Figure 2. Distribution of vegetation plots within the study area.	12
Figure 3. Map of plot distribution within biogeoclimatic zones of the study area.	14
Figure 4. Distribution of biogeoclimatic zones and plots within the study area.	15
Figure 5. Map of plot distribution within ecosections of the study area.	16
Figure 6. Distribution of ecosections and plots within the study area.	17
Figure 7. Map of plot distribution over bedrock types of the study area.	18
Figure 8. Distribution of bedrock types and plots within the study area.	19
Figure 9. Map of plot distribution in relation to special sites in the study area.	21
Figure 10. Priority regions for sampling within the study area.	22

EXECUTIVE SUMMARY

The study area of this project is defined as the subalpine and alpine (Spruce-Willow-Birch and Alpine Tundra biogeoclimatic zones) regions of the Muskwa-Kechika Management Area (MKMA). The Spruce-Willow-Birch (SWB) and Alpine Tundra (AT) biogeoclimatic zones cover 74% of the MKMA. These zones have limited timber production capability, however they provide habitat for Identified Wildlife Management Strategy species (fisher, grizzly bear, and mountain goat) and several species of economic importance (including moose, caribou, Stone's sheep, mule and white-tailed deer, and black bear). The alpine and subalpine landscapes also have untapped recreation and tourism potential due their beauty and relatively pristine status.

Progressive planning, inventory, and conservation measures have used ecosystem information and interpretations as a basis for decision-making. A significant gap exists in our understanding of the SWB and AT biogeoclimatic zones, however, because the provincial Biogeoclimatic Ecosystem Classification (BEC) program has not completed site classification for those zones. As a result, projects requiring the description, inventory, or mapping of SWB and AT ecosystem units must resort to developing project-specific, non-standard units.

The goal of this project is to develop the classification and description of site-level ecosystem units for the SWB and AT zones of the MKMA. The first steps in the process, carried out in 1999-2000, were to collect available field data for the study area and undertake a spatial analysis to identify areas that require additional field surveying. This report presents the results of that spatial analysis.

The spatial analysis revealed that there are significant gaps in the sampling of the study area. Upper elevations of the AT zone have not been adequately sampled. The sampling is not representative of the physiographic diversity of the study area, and five ecosections need additional field work. New plots should be also be completed in areas underlain by igneous and metamorphic bedrock types.

A proposed work plan for 2000-2001 would complete the project tasks of collecting additional vegetation, soil, and wildlife data in the field, analyzing data from previous projects with newly collected data, and developing site-level ecosystem classifications for the study area. The results of the project would be communicated in both a technical manual and a report designed to educate local stakeholders and tourists about the ecosystems of the study area.

A completed ecosystem classification of the subalpine and alpine zones of the MKMA would provide a baseline framework for many inventory, mapping, and planning activities within the study area, including ecosystem mapping, wildlife habitat mapping, forage capability mapping, identification of rare ecosystems, and land use planning.

1 INTRODUCTION

The study area of the project is defined as the subalpine and alpine (Spruce-Willow-Birch and Alpine Tundra biogeoclimatic zones) regions that cover 74% of the Muskwa-Kechika Management Area (MKMA). These zones have limited timber production capability, however they provide habitat for Identified Wildlife Management Strategy species (fisher, grizzly bear, and mountain goat) and several species of economic importance (including moose, caribou, Stone's sheep, mule and white-tailed deer, and black bear). The alpine and subalpine landscapes also have untapped recreation/tourism potential due their beauty and relatively pristine status.

Progressive planning, inventory, and conservation measures have used ecosystem information and interpretations as a basis for decision-making. A significant gap exists in our understanding of the Spruce-Willow-Birch (SWB) and Alpine Tundra (AT) biogeoclimatic zones, however, because the provincial Biogeoclimatic Ecosystem Classification (BEC) program has not completed site classification for those zones. As a result, projects requiring the description, inventory, or mapping of SWB and AT ecosystem units must resort to developing project-specific, non-standard units.

1.1 Issue

Within each biogeoclimatic unit (zones and subzones), sites vary due to soil and physiographic properties, resulting in variation in late successional plant communities. Ecosystem units can be identified according to environmental properties such as soil moisture and nutrient regimes, as well as mature plant communities that develop on that site. The B.C. Ministry of Forests has developed site-level ecosystem classification for most biogeoclimatic units of British Columbia (Banner *et al.* 1993, MacKinnon *et al.* 1990), but there is no published classification available for the SWB and AT zones.

In the absence of classifications, non-standard ecosystem units have been developed for specific study areas within the MKMA. For example, several Terrestrial Ecosystem Mapping projects with associated wildlife capability and suitability mapping have been carried out within the study area. In the absence of published provincial classifications, mappers have developed project-specific map units for the SWB and AT (included in part in Appendix 1). This has resulted in mapping projects that are not consistent or comparable within the SWB and AT zones. While the map units have been listed in the Provincial Site Series and Map Unit List (RIC 2000), they have not been organized into any type of classification scheme, nor have they been compared to determine whether any of the map units are redundant. As a result, for the Prince George and Prince Rupert forest regions the map unit list names 20 units for the SWBmk (Moist Cool subzone of the SWB), 16 units for the SWBmks (Moist Cool Scrub subzone of the SWB), and 16 units for the AT zone.

Numerous research studies of alpine and subalpine ecosystems have been carried out in British Columbia (reviewed in Hamilton 1983). Studies carried out in and adjacent to the MKMA (listed in Appendix 2) have identified and described numerous alpine/subalpine ecosystem types. As Hamilton (1983) points out, however, it is difficult to compare studies of alpine and subalpine ecosystems as different authors have used various approaches to ecosystem sampling and classification to address different study goals.

Future research and resource inventory projects within the study area are likely to continue the *ad hoc* development of ecosystem and map units unless ecosystem classification is carried out for the SWB and AT zones of the MKMA, supported by adequate field sampling.

1.2 Project Objectives

The goal of this project is to develop the classification and description of site-level ecosystem units for the SWB and AT zones of the MKMA. The initial step in the process is to collect available field data for the study area and undertake a spatial analysis to identify areas that require additional field surveying (1999-2000). The proposed work plan for 2000-2001 would complete the project tasks of collecting additional vegetation, soil, and wildlife data in the field, analyzing data from previous projects with newly collected data, and developing site-level ecosystem classifications for the study area. The results of the project would be communicated in both a technical report and a document suitable for general distribution. The project objectives can be summarized as follows:

1999-2000

1. Develop spatial analysis of vegetation/site sampling within the subalpine and alpine (SWB and AT) zones of the MKMA

2000-2001

2. Carry out field sampling of the vegetation within the subalpine and alpine (SWB and AT) zones of the MKMA as directed by the spatial analysis
3. Combine newly collected vegetation data with data collected for previous projects into a single database
4. Analyze data and develop ecosystem classifications for the subalpine and alpine (SWB and AT) zones of the MKMA
5. Describe and illustrate the vegetation, soil, and wildlife attributes of the new ecosystem units of the subalpine and alpine (SWB and AT) zones in a technical report
6. Produce an illustrated report designed for a broad audience entitled "The Alpine and Subalpine Ecosystems of the MKMA"

This report presents the results of the work carried out in 1999-2000 to develop a spatial analysis of vegetation/site sampling within the subalpine and alpine zones of the MKMA. This work is the basis for a work programme proposed for 2000-2001 (described in Objectives 2-6).

1.3 Relevance to Regional and Provincial Priorities

Like the existing BEC site-level classifications, the standardized classifications developed for this project would have broad applications, providing users from a wide range of disciplines with a common basis for analyzing ecosystem-related issues for alpine and subalpine areas of the MKMA. For example, the communication of project results could contribute to the understanding of the ecology and vegetation of the study area by local stakeholders and tourists.

The proposed work plan is also relevant to various regional and provincial resource inventory, conservation, habitat management, and land use planning programs. Inventorying and describing the ecosystem units of the alpine and subalpine areas of the MKMA would complement the published ecosystem unit descriptions for lowland areas.

1. Forest Renewal BC (FRBC): The Resources Inventory Program includes Terrestrial Ecosystem Mapping and Wildlife Habitat Mapping initiatives. Mapping projects in the study area have suffered from a lack of information about the distribution and typical characteristics of ecosystem units of the area. The classification of the SWB and AT zones of the MKMA would provide standardized units for ecosystem mapping.

2. B.C. Parks Legacy Project (B.C. Ministry of Environment, Lands, and Parks): One of the goals of this provincial project is to "develop closer bonds between communities and their protected areas" and "to strengthen ecological stewardship" (BCMoELP 1999). Education is one of the bridges to developing "close bonds", and community residents often develop a keen interest in and appreciation of natural areas as a result of education efforts. "The Subalpine and Alpine Ecosystems of the MKMA", one of the products of the proposed project, would convey the diversity, beauty, and recreation potential of the study area to community stakeholders.
3. Species and Ecosystems at Risk (B.C. Ministry of Environment, Lands, and Parks): The B.C. Conservation Data Centre (CDC) develops and maintains tracking lists of species and plant associations at risk in B.C. The tracking list for plants is refined by reports of species occurrences by botanists and vegetation ecologists. Little botanical surveying has been carried out in remote locations of northern B.C. Plant species occurrences collected during the proposed field work would likely generate reports of new locations of listed plant species. For example, field work for Terrestrial Ecosystem Mapping of the Dunedin study area (overlaps with the MKMA) generated reports of new locations for 12 plant species on the provincial CDC tracking list.
4. Fort Nelson and Fort St. John Land Use Management Plan (LRMP) Processes (B.C. Land Use Coordination Office): The "assembly and analysis of reliable spatial land and resource information" has been identified as a basic requirement to achieving the LRMP process goals (LUCO 1999). Classifying the SWB and AT ecosystem units of the MKMA would provide a consistent basis for mapping or inventory of subalpine and alpine land within the Fort Nelson and Fort St. John Resource Management Zones (RMZ). In addition, the field data collected for this project would constitute a survey of natural physical and biological features (soil and vegetation) of the SWB and AT zones of the MKMA, and could potentially be used in spatial analyses within the RMZs.

2 DESCRIPTION OF STUDY AREA

2.1 Location

The study area is located within the Muskwa-Kechika Management Area (MKMA) in northern British Columbia. The MKMA covers 4.4 million ha of the Northern Rocky Mountains and includes portions of the watersheds of the Fort Nelson, Prophet, Muskwa, Toad, Kechika, Graham, Sikanni Chief, and Halfway rivers. The study area includes subalpine and alpine regions of the MKMA, specifically the Spruce-Willow-Birch (SWB) and Alpine Tundra (AT) biogeoclimatic zones. The area of interest covers 74% of the MKMA (Figure 1).



Figure 1. Map of study area.

2.2 Biophysical Attributes

There are two complementary systems for stratifying and describing the landscapes of British Columbia, the Biogeoclimatic Ecosystem Classification system and the Ecoregion Classification system. The Biogeoclimatic Ecosystem Classification (BEC) is a hierarchical classification scheme (Pojar *et al.* 1987, Meidinger and Pojar 1991). Biogeoclimatic zones are broad geographic areas influenced by similar regional climates. The Ecoregion Classification provides a systematic view of broad geographic relationships (Demarchi 1996).

2.2.1 Biogeoclimatic Zones

The study area is defined by the extent of two biogeoclimatic zones within the MKMA: Spruce-Willow-Birch and Alpine Tundra. Because the climatic variation between zones significantly influences vegetation, different zones can be expected to support different ecosystem types.

2.2.1.1 Spruce-Willow-Birch

The Spruce-Willow-Birch (SWB) zone is the most northerly subalpine zone in British Columbia. The lower limit of the SWB zone ranges from 900-1000 m, while the upper limit of the zone ranges from 1500-1700 m. The climate of the SWB zone is an interior subalpine type, with long, cold winters and brief, cool, summers (Meidinger and Pojar 1991).

The SWB provides a variety of habitats for wildlife species including moose, Stone's sheep, mountain goat, mule and white-tailed deer, bison, grizzly and black bear, gray wolf, wolverine, and willow ptarmigan. The zone has high recreation potential for hiking, horseback riding, and hunting (Barner *et al.* 1993, MacKinnon *et al.* 1990).

The lower elevations of the SWB are typically wooded with white spruce and subalpine fir. Pockets of black spruce, lodgepole pine, trembling aspen also occur. Wide valleys in the SWB zone can be subject to cold air ponding and valley floors and lower slopes often support a mosaic of shrubfields, fens, and meadows. Upper elevations of the SWB typically have scrub/parkland, dominated by scrub birch and various species of willow. Warm slopes at the timberline often support groves of stunted trembling aspen or balsam poplar (Meidinger and Pojar 1991).

Humo-Ferric Podzols and Brunisols are the typical soils of the SWB, with Gray Luvisols common on fine-textured parent materials.

Six subzones have been identified within the SWB zone (RIC 1998), but they have not been described in readily available publications. One subzone of the SWB zone has been mapped on the 1:250 000 provincial biogeoclimatic map within the MKMA. The Moist Cool subzone of the SWB zone (SWBmk) has been mapped east of the Kechika River. The mapped area of SWBmk probably includes the Moist Cool Scrub subzone of the SWB zone (SWBmks), which lies between the SWBrnk and the AT on an elevational gradient. West of the Kechika River, mapped areas of the SWB zone do not indicate a subzone.

2.2.1.2 Alpine Tundra

The Alpine Tundra (AT) zone occurs on high mountaintops throughout British Columbia. The lower limit of the AT zone ranges from 1500-1700 m in the northeast. The harsh climate of the AT zone is cold, windy, snowy, and characterized by low growing season temperatures and a very short frost-free period (Meidinger and Pojar 1991).

In conjunction with the SWB zone, the AT zone provides important wildlife habitat for species including Stone's sheep, caribou, Grizzly bear, willow ptarmigan, and hoary marmot. The AT

zone has similar recreation potential to the SWB zone (Banner *et al.* 1993, MacKinnon *et al.* 1990).

The AT zone is treeless, but tree species occasionally occur at lower elevations in stunted or krummholz form. In northern B.C., lower elevations of the AT are dominated by alpine shrubfields composed of scrub birch and willow species. The most common form of vegetation in the AT zone is a dwarf scrub of prostrate woody plants. Alpine grass/sedge vegetation is also widespread. Herb meadows dominated by broad-leaved forbs are also common in the AT zone, especially at lower elevations. Moss/liverwort/lichen communities dominate high elevation fellfield habitats (Meidinger and Pojar 1991).

Soil development is usually weak or absent at the high elevations of the AT zone. Frost shattering, colluviation, soil creep, and frost churning are important soil processes in the AT zone. This zone has not been sufficiently studied to characterize subzones within it (Meidinger and Pojar 1991).

Field sampling in the Dunedin Terrestrial Ecosystem Mapping study area indicated that some lower elevation sparsely vegetated areas of mapped AT zone should probably be mapped within the SWB zone based on the elevational distribution of SWB vegetation (Barton *et al.* 1998).

2.2.2 Ecosections

The Ecoregion Classification system is used to stratify British Columbia's terrestrial and marine ecosystem complexity into discrete geographical units at five different levels: Ecodomains, Ecodivisions, Ecoprovinces, Ecoregions, and Ecosections. Ecosections, the most detailed level of classification, relate segments of the province to one another. They describe areas of similar climate, physiography, oceanography, hydrology, vegetation, and wildlife potential.

Table 1. Ecoregion classification of the study area.

Adapted from Demarchi (1996).

Ecodomain	Ecodivision	Ecoprovince	Ecoregion	Ecosection	Description
Humid Temperate	Humid Continental Highlands	Sub-boreal Interior	Central Canadian Rocky Mountains	Misinchinka Ranges	The Misinchinka Ranges Ecosection is a rugged mountain area, with deep narrow valleys. Moist Pacific air often stalls over these mountains, bringing high precipitation, both summer and winter.
				Peace Foothills	The Peace Foothills Ecosection is a blocky mountain area on the east side of the Rocky Mountains. Strong rainshadows exist.

Ecodomain	Ecodivision	Ecoprovince	Ecoregion	Ecosection	Description
Polar	Boreal	Northern Boreal Mountains	Boreal Mountains and Plateaus	Cassiar Ranges	The Cassiar Ranges Ecosection is the area with the highest and most rugged mountains in the Ecoregion. It has a broad band of mountains extending from the southeast corner of the Ecoregion to the northeast corner. The Cassiar Ranges Ecosection is the area with the highest and most rugged mountains in the Ecoregion. It has a broad band of mountains extending from the southeast corner of the Ecoregion to the northeast corner.
				Kechika Mountains	The Kechika Mountains Ecosection is an area with high mountains, but low, wide valleys in the rainshadow of the Cassiar Ranges to the west.
				Southern Boreal Plateau	The Southern Boreal Plateau Ecosection consists of several deeply incised plateaus. Extensive rolling alpine and willow/birch habitat occurs. This Ecosection is located in the south-central part of the Ecoregion.
			Liard Basin	Liard Plain	The Liard Plain Ecosection is a broad, rolling inter-mountain plain with a cold, sub-Arctic climate.
			Northern Canadian Rocky Mountains	Eastern Muskwa Ranges	The Eastern Muskwa Ranges Ecosection is the area with the highest, most rugged mountains in the Ecoprovince. It has more snowfall than the foothills to the east.
				Muskwa Foothills	The Muskwa Foothills Ecosection is an area of subdued mountains which are isolated by wide valleys. This area is in the rainshadow of the Rocky Mountains to the west; it is also more commonly under the influence of cold Arctic air in the winter.

2.2.3 Bedrock Types

Alpine and subalpine landscapes tend to have less soil development and shallower soils than lowland areas. As a result, bedrock characteristics therefore tend to more important effects on alpine ecosystems than on lowland ecosystems. Bedrock influences ecosystems by its effects on landscape shape and soil nutrient quality, depth, and texture. The main characteristics of bedrock types that influence ecosystem distribution are erodability, chemistry, and structure. Table 2 describes the types of bedrock that occur within the MKMA.

Table 2. Bedrock types within the study area.
 Definitions are adapted from Bates and Jackson (1984).

Type	Subtype	Properties	Definition
Igneous	rhyolite	extrusive, acidic	A group of extrusive igneous rocks, typically porphyritic and commonly exhibiting flow texture, with phenocrysts of quartz and alkaline feldspar in a glassy to cryptocrystalline groundmass.
	basalt	extrusive, basic	A dark-coloured igneous rock, commonly extrusive, composed primarily of calcic plagioclase and pyroxene.
	gabbro	extrusive, basic	A group of dark-coloured, basic intrusive igneous rocks composed principally of labradorite or bytownite and augite, with or without olivine and orthopyroxene.
	granodiorite	intrusive, acidic	A group of coarse-grained plutonic rocks intermediate in composition between quartz diorite and quartz monzonite, containing quartz, oligoclase or andesine, and potassium feldspar, with biotite, hornblende, or, more rarely, pyroxene, as the mafic components
	granite	intrusive, acidic	A plutonic rock in which quartz makes up 10 to 50 percent of the felsic components and the alkali feldspar/total feldspar ratio is 65 to 90 percent
	diorite	intrusive, intermediate	A group of plutonic rocks intermediate in composition between acidic and basic, characteristically composed of hornblende, oligoclase or andesine, pyroxene, and sometimes a little quartz
Metamorphic	marble	calcareous	A metamorphic rock consisting predominately of fine- to coarse-grained recrystallized calcite and/or dolomite.
	greenschist	non-calcareous	A schistose metamorphic rock whose green colour is due to the presence of chlorite, epidote, or actinolite.
	greenstone	non-calcareous	A field term for any compact dark-green altered or metamorphosed basic igneous rock that owes its color to chlorite, actinolite, or epidote
	mylonite	non-calcareous	A compact, chertlike rock with a streaky or banded structure, produced by the extreme granulation and shearing of rocks that have been pulverized and rolled during overthrusting or intense dynamic metamorphism.
Sedimentary	calcareenite	calcareous	A limestone, more than half of which consists of cemented sand-size grains of calcium carbonate.
	limestone	calcareous	A sedimentary rock consisting chiefly of the mineral calcite (calcium carbonate, CaCO ₃), with or without magnesium carbonate.
	micrite	calcareous	A descriptive term for the semiopaque crystalline matrix of limestones, consisting of chemically precipitated carbonate mud with crystals less than 4 microns in diameter, and interpreted as lithified ooze.
	arenite	non-calcareous	A general name for consolidated sedimentary rocks composed of sand-sized fragments irrespective of composition (generally known as "sandstone").
	chert	non-calcareous	A hard, dense microcrystalline or cryptocrystalline sedimentary rock, consisting chiefly of interlocking crystals of quartz less than about 30 microns in diameter; it may contain amorphous silica (opal).

Type	Subtype	Properties	Definition
Sedimentary	clastic	non-calcareous	Pertaining to a rock or sediment composed principally of fragments derived from pre-existing rocks or minerals and transported some distance from their places of origin.
	conglomerate	non-calcareous	A coarse-grained clastic sedimentary rock, composed of rounded to subangular fragments larger than 2mm in diameter (granules, pebbles, cobbles, boulders) set in a fine-grained matrix of sand or silt, and commonly cemented by calcium carbonate, iron oxide, silica, or hardened clay.
	dolomite	non-calcareous	A sedimentary rock, of which more than 50% by weight consists of the mineral dolomite; specifically a rock containing more than 90% mineral dolomite and less than 10% calcite.
	mudstone	non-calcareous	An indurated mud having the texture and composition of shale, but lacking its fissility; a blocky fine-grained sedimentary rock in which the proportions of clay and silt are approximately equal.
	turbidite	non-calcareous	A sediment deposited from a turbidity current. It is characterized by graded bedding, moderate sorting, and well-developed primary structures, esp. lamination

2.2.4 Special Sites and Rare Ecosystems

Rare or unusual ecosystems are typically found at "special" sites with atypical characteristics. Within the study area, calcareous fens and sand dunes are the sites that are most likely to support rare or atypical ecosystems (Adolf Ceska, personal communication). Topographic mapping doesn't show any sand dunes within the study area. There are, however, large sand bars and eskers within the study area that are worthy of investigation. There are also numerous fens that are underlain by calcareous bedrock.

The study area occurs within the Cassiar, Fort Nelson, and Fort St. John Forest Districts. The British Columbia Conservation Data Centre is tracking two rare plant associations for the SWB and AT zones within those Forest Districts (BCCDC 1999a, b, c). The plant associations are "Luzula piperi" (AT) and "Poa rupicola" (AT/SWB), they occur in the Cassiar Forest District, and they are considered provincially imperiled (BCCDC 1999a). These plant associations should be treated as occurrences, however, not as valid plant associations (Adolf Ceska 2000). There are likely other rare plant associations within the study area, and the Conservation Data Centre Plant Association Tracking Lists should be considered incomplete, especially in alpine areas (BCCDC 1999a, b, c).

3 SPATIAL ANALYSIS OF VEGETATION DATA

The ultimate goal of this project is to develop the classification and description of site-level ecosystem units for the SWB and AT zones of the MKMA. In order to produce a representative classification for the biogeoclimatic units within the study area, the plot data used for analysis must be representative of the diversity within the study area. The primary statistical method used for classification, ordination, also requires a large dataset of plots.

In order to determine whether existing plots adequately sample the study area, the plot data was collected and analyzed in GIS (Geographic Information Systems). GIS is an organized collection of computer hardware, software, and geographic data designed for capturing, storing, updating, manipulating, analyzing, and displaying all forms of geographically referenced information (ESRI 2000).

Spatial analysis is the study of the locations and shapes of geographic features and the relationships between them (ESRI 2000). It was used to determine whether existing vegetation sampling is representative of the diversity of the study area. This section outlines the methods and results of the spatial analysis of vegetation plot data from previous projects within the study area.

3.1 Methods

The first task was to identify sources of plot data within the study area. For the purposes of classification, the plots have to have a complete vegetation list with associated % cover, and at least enough site information to infer the relative soil moisture regime and soil nutrient regime (Craig DeLong, personal communication). Many vegetation plots types would fulfill these criteria, including the Completed Ground Inspection or Ecosystem Field Forms, the standard plot types for describing ecosystems in B.C. (BCMoeLP and BCMoF 1998).

Some potential sources of plot data were identified:

- Terrestrial Ecosystem Mapping projects
- Biophysical Mapping projects
- B.C. Ministry of Forests classification plots
- B.C. Ministry of Forests range monitoring plots

Numerous provincial government employees and several resource inventory specialists were contacted to attempt to identify additional sources of reliable plot data within the study area, but none were found.

Once projects within the study area were identified that had associated plot data, requests for data (spatial locations and plot data) were made. Several factors made collecting the plot data difficult:

- the task of responding to requests for data is typically assigned to extremely busy government employees, resulting in delays in receiving requested data
- the spatial locations of plots, whether digital or hard copy, are typically archived separately from the actual plot data
- plot data is sometimes stored digitally without associated site data or project metadata
- some older projects could not be located by the government departments that initiated them
- most older maps have not been digitized into GIS systems

Table 3 details the sources of plot data within the study area. Plot data was collected for most of the identified sources of data within the study area. There are ongoing efforts to

locate plot data from the Liard Hotsprings Provincial Park Biophysical Habitat Mapping project and the Fort Nelson East Slope Wildlife and Forest Capability Mapping project.

Table 3. Sources of plot data within the study area.

Project Name	Plots Sampled By	Sampling Year	Data Form	Spatial Locations	Number of Plots
North East Burn TEM	Dave Clark, Bob Maxwell	1991	VPro	digital	85
Smith Fishing TEM	Norecol, Dames and Moore and ECO-concepts Ecological Services	1997	Venus	digital	65
Dunedin TEM	Madrone Consultants	1997	Venus	digital	101
Besa Prophet TEM	R.A. Sims and Associates	1998	Venus	digital	132
North East Burn Evaluation – Bison Habitat Monitoring	Dave Clark, Bob Maxwell, Bill Harper, Andy Stewart, and Jamie Duncan	1992	hard copy	hard copy	11
Range Reference Area Exclosures (Fort St. John and Fort Nelson Forest Districts)	Perry Grilz and other contractors	1998-99	Access	hard copy	7
Liard Hotsprings Provincial Park Biophysical Habitat Mapping	JMJ Holdings	1994	VPro	?	?
Fort Nelson East Slope Wildlife and Forest Capability Mapping	Chris Clement	1992	VPro	?	?

Data were collected for 401 plots from 6 projects within the study area (SWB and AT zones of the MKMA). Some plot locations were marked on hard copy maps only. For the purpose of carrying out the spatial analysis, the approximate locations of those plots were digitized in ArcView GIS (ESRI 1998) on a 1:250 000 scale topographic base map.

Maps of plot locations, biogeoclimatic units, ecosections, bedrock geology, and topographic mapping were imported, displayed, combined, and modified in ArcView GIS. Appendix 3 lists the sources of map data used for the spatial analysis.

The spatial analysis was carried out by constructing a spatial overlay of plot locations, topographic base mapping, and various maps in ArcView GIS. Spatial overlay is the process of superimposing layers (themes) of geographic data that occupy the same space in order to study the relationships between them (ESRI 2000). The question of whether existing vegetation sampling is representative of the study area was answered by carrying out a series of queries of the superimposed map themes in ArcView GIS.

Results of the spatial analysis are displayed in map and graph form. All maps were produced in ArcView GIS and are projected in the B.C. Ministry of Environment standard projection, Albers Equal Area Conic. Graphs were created in Microsoft Excel 97 (Microsoft Corp. 1997).

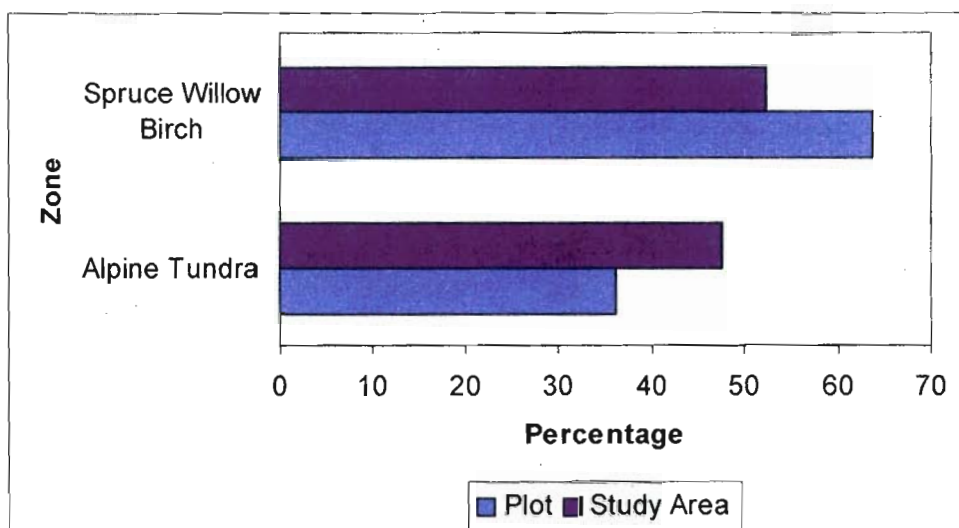


Figure 4. Distribution of biogeoclimatic zones and plots within the study area.

The plot percentage is calculated as the proportion of plots that occur within each biogeoclimatic zone. The study area percentage is calculated as the proportion of the study area (in ha) that is covered by each biogeoclimatic zone.

3.2.2 Ecosystems

The second question addressed by the spatial analysis was whether the study area has been sampled adequately in terms of physiography. Ecosystems relate segments of the province to one another. They describe areas of similar physiography, climate, oceanography, hydrology, vegetation, and wildlife potential. The ecosystems of the study area are described in section 2.2.2. The climatic, physiographic, and hydrological variation between ecosystems has the potential to significantly influence the types and distribution of ecosystems.

Figure 5 is a map of plot distribution with respect to ecosystems, and Figure 6 shows the result of the spatial analysis in graph form. The figures indicate that plot sampling is not well distributed among the ecosystems within the study area. The Muskwa Foothills have been disproportionately sampled, while the Eastern Muskwa Ranges and the Kechika Mountains have been sampled to a lesser extent. Five ecosystems cover a relatively small part of the study area, but they have not been sampled at all. The five ecosystems are therefore priority areas for future sampling within the study area: Cassiar Ranges, Peace Foothills, Misinchinka Ranges, Liard Plain, and the Southern Boreal Plateau.

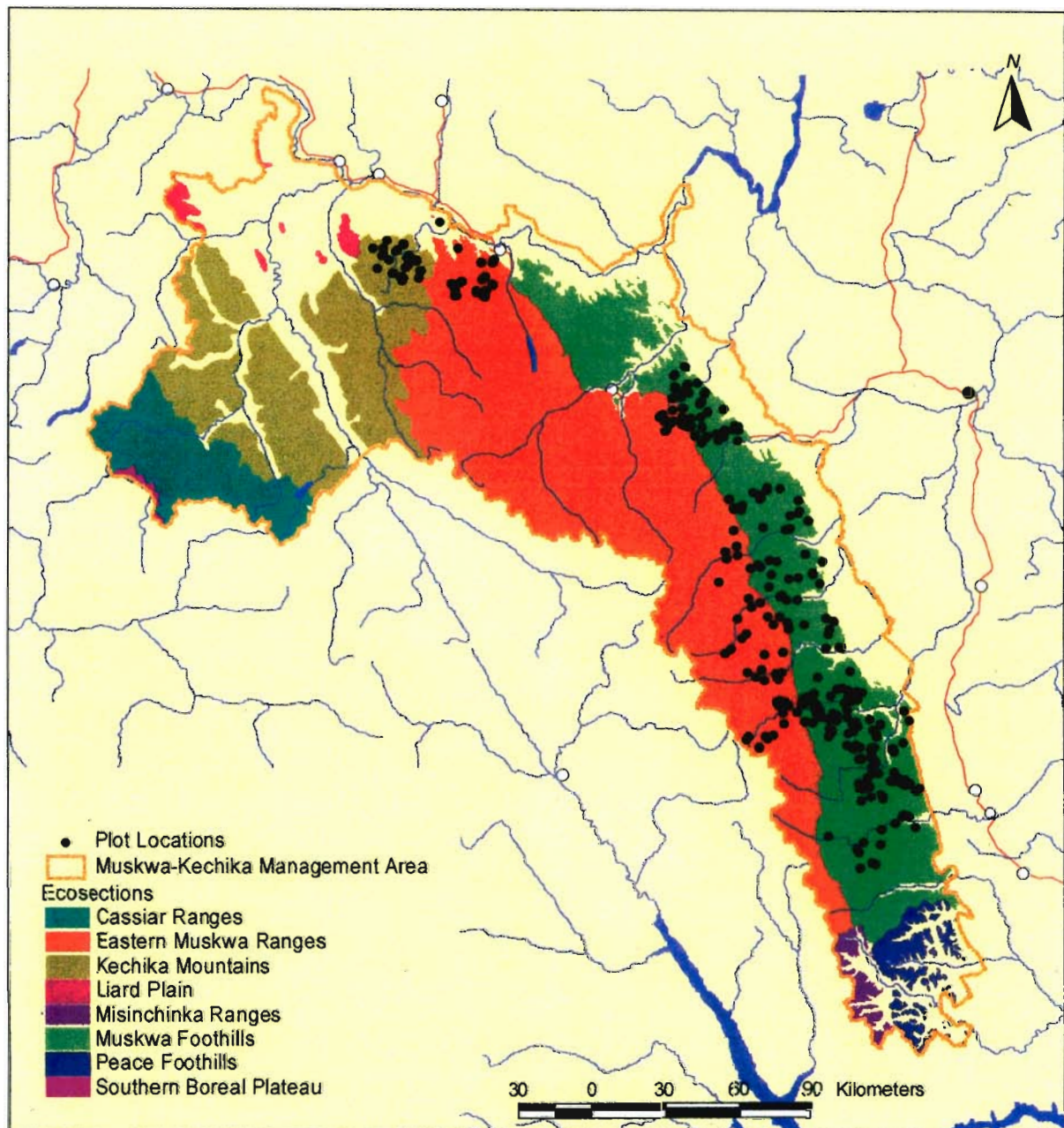


Figure 5. Map of plot distribution within ecosections of the study area.

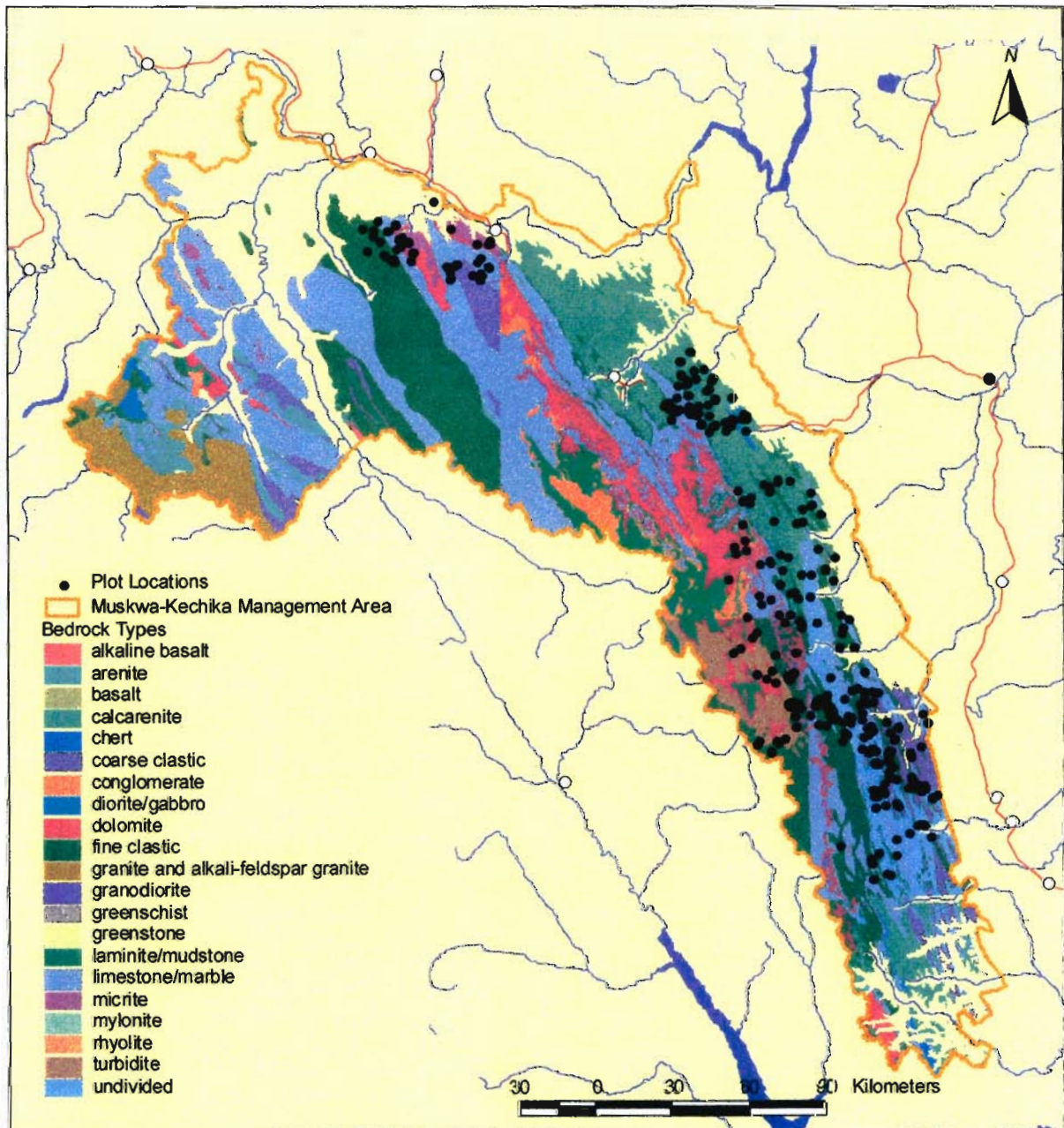


Figure 7. Map of plot distribution over bedrock types of the study area.

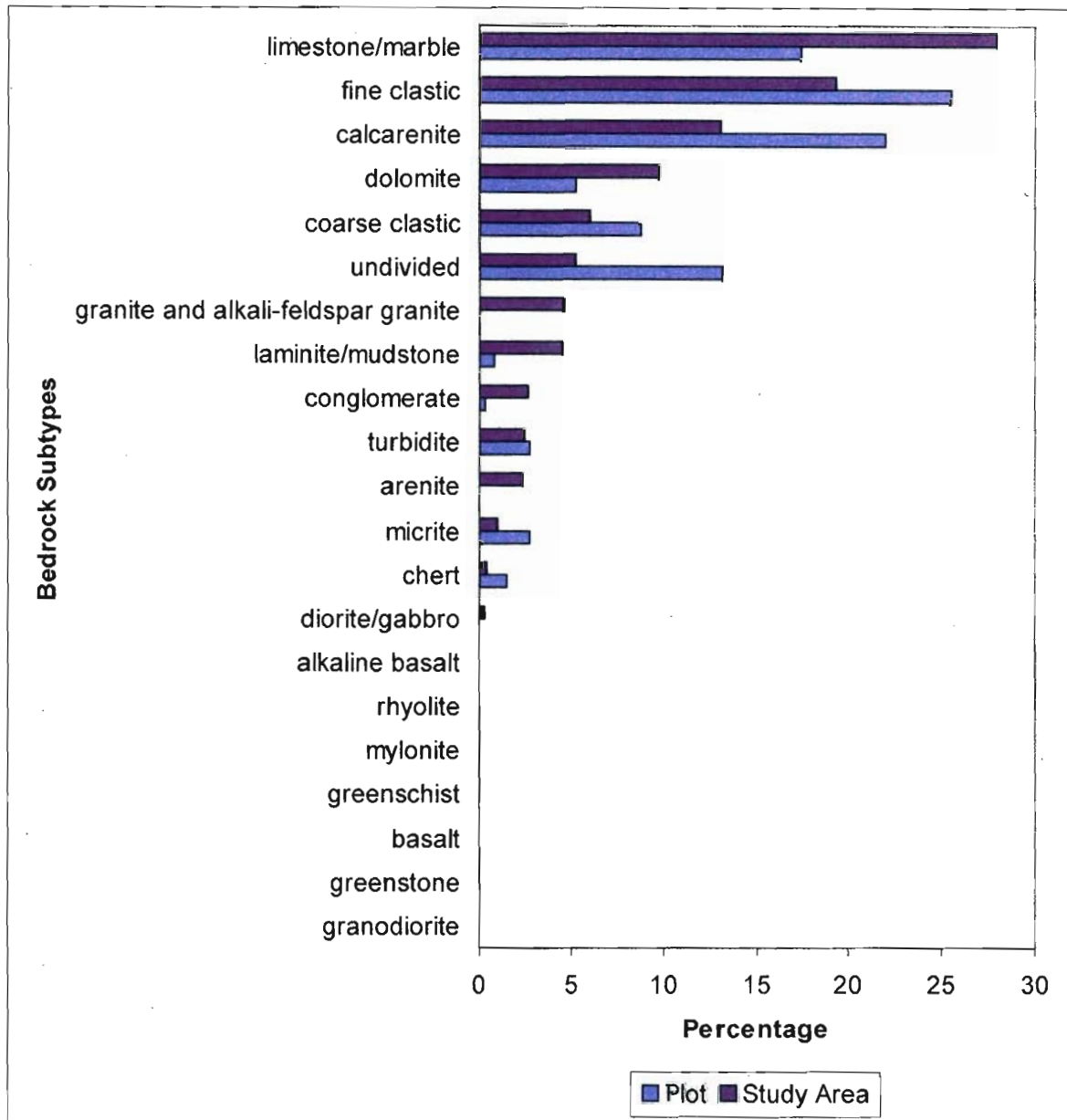


Figure 8. Distribution of bedrock types and plots within the study area.

The plot percentage is calculated as the proportion of plots that occur within each bedrock type. The study area percentage is calculated as the proportion of the study area (in ha) that is covered by each bedrock type.

3.2.4 Ecosystem Types

Existing plot data was examined to determine whether there was a bias in sampling with respect to ecosystem type. Ecosystem types include woodlands, fens, grasslands, subalpine meadows, krummholz, etc. The sources of plot data are listed in Table 3. Most of the plots (96%) were completed for ecosystem/biophysical/wildlife capability mapping projects. Sampling plans for ecosystem mapping projects are generally designed to maximize the diversity of ecosystem types sampled. Given the competence of the field workers involved in collecting the field data for those projects, it is reasonable to assume that sampling is relatively unbiased with respect to ecosystem types. Informal examination of the plot data supports that assumption.

3.2.5 Special Sites and Rare Ecosystems

Rare or unusual ecosystems are typically found at "special" sites with atypical characteristics. Topographic mapping of the study area indicates that there are large sand bars and eskers within the study area that are worthy of investigation. There are also numerous fens that are underlain by calcareous bedrock. Figure 9 is a map showing the distribution of special sites and plots within the study area. The map indicates that there has been limited sampling of eskers, sand dunes, and calcareous fens within the study area. Future mapping should carry out additional sampling at these sites where convenient.

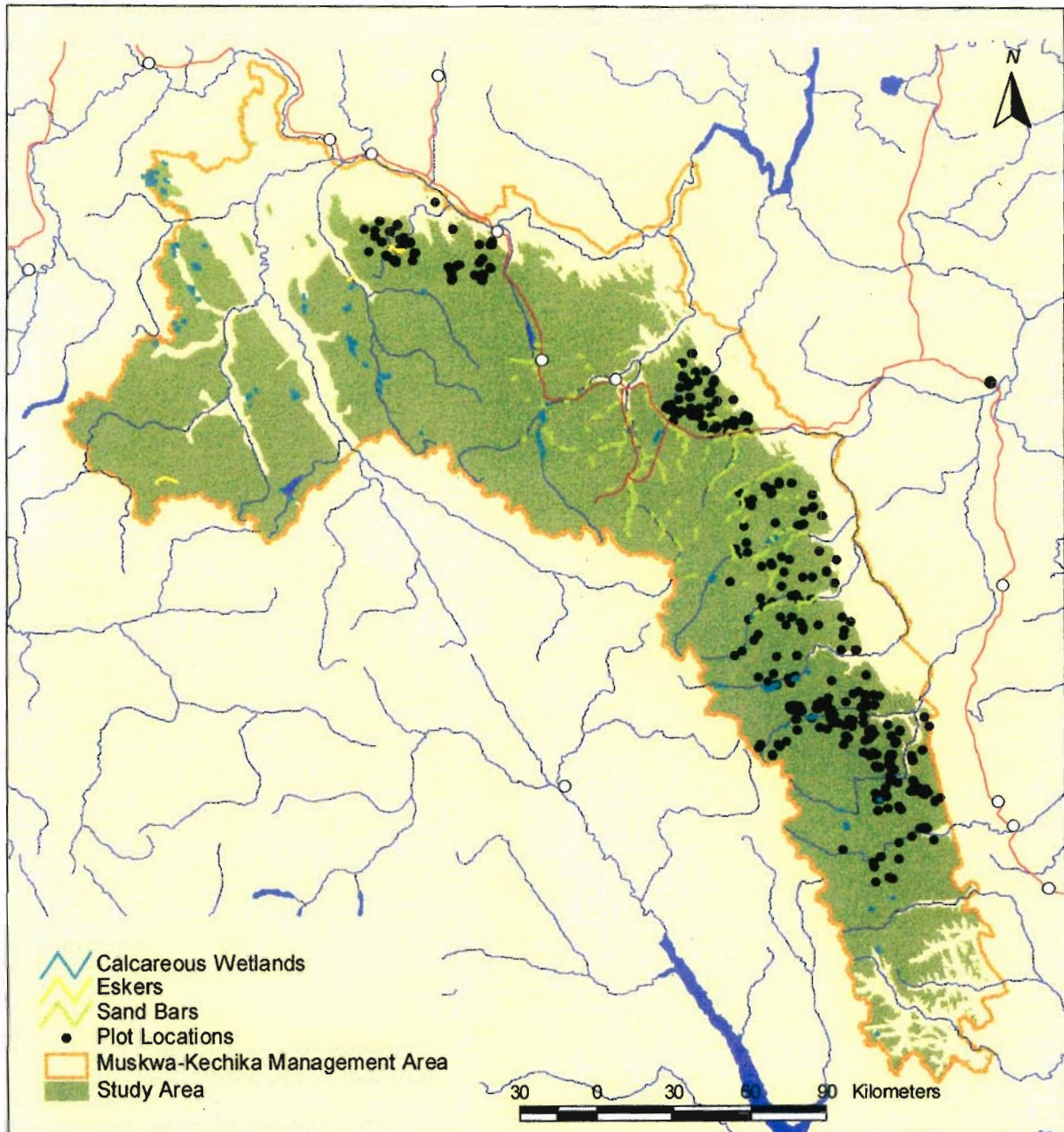


Figure 9. Map of plot distribution in relation to special sites in the study area.

3.3 Priority Areas for Future Field Work

Spatial analysis of the distribution of existing plots within the study area indicates that there are regions within the study area that have not been adequately sampled (Section 3.2). Figure 10 is a map of the priority areas for future field work. Upper elevations of the mapped area of the AT zone requires additional field sampling. Five undersampled ecosections and several undersampled bedrock types have also been identified as priority areas for future vegetation sampling within the study area. Finally, special sites have been identified within the study area that merit further investigation.

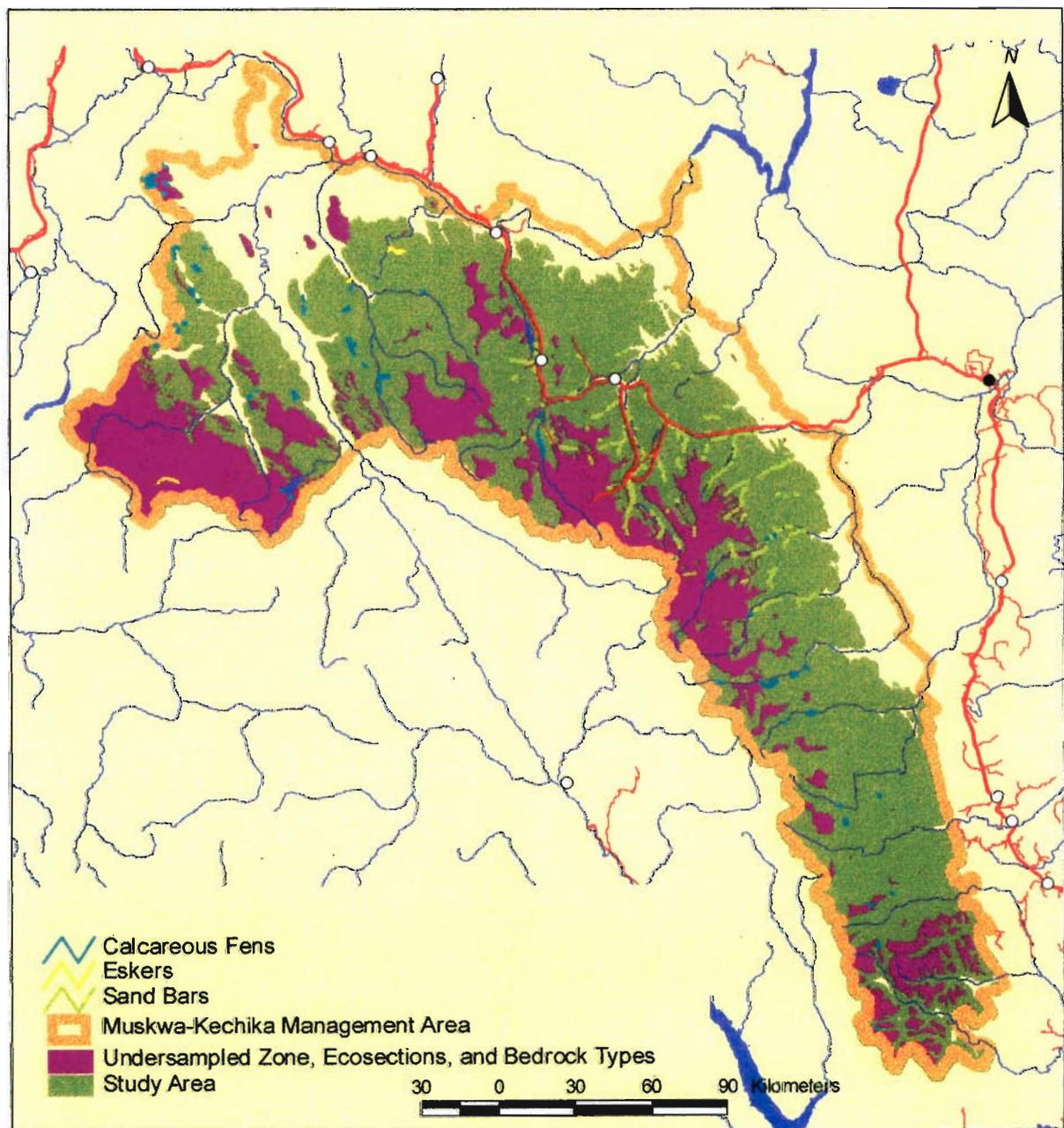


Figure 10. Priority regions for sampling within the study area.

3.4 Summary

The goal of this project is to develop the classification and description of ecosystems of the SWB and AT zones of the MKMA. In order to produce a representative classification for the biogeoclimatic units of the study area, the plot data used for analysis must be representative of the area's diversity. Spatial analysis was used to determine whether the distribution of existing plots is adequate for classification purposes.

The initial step in the spatial analysis was to identify potential sources of plot data within the SWB and AT zones of the MKMA, including Terrestrial Ecosystem Mapping projects, Biophysical Mapping projects, B.C. Ministry of Forests classification plots, and B.C. Ministry of Forests range monitoring plots. Obtaining plot data was complicated by problems with government archive and information delivery systems. Data were collected for 401 plots from 6 projects within the study area.

Maps of plot locations, biogeoclimatic units, ecosections, bedrock geology, and topographic mapping were imported, displayed, combined, and modified in ArcView GIS. To carry out the spatial analysis, a spatial overlay of map themes was constructed, then analyzed using spatial queries.

Existing vegetation plots are not distributed evenly throughout the study area. Some portions of the study area are well sampled, including watersheds of the Vents, Dunedin, Tuchodi, Muskwa, Prophet, Besa, and Sikanni Chief Rivers. Other areas have barely been sampled, including the watersheds of the Turnagain, Rabbit, Toad, Halfway, and Graham Rivers.

The distribution of plots within the study area initially appears to be fairly representative with respect to biogeoclimatic zone, with a slight bias towards sampling the SWB zone. Further examination of the plot distribution reveals, however, that most of the plots within the mapped area of AT are located at lower elevations of the zone, and may actually be located in the upper reaches of the SWB zone. The higher elevations of the mapped AT zone are therefore priority areas for future vegetation sampling.

The distribution of plots within the study area is not very representative with respect to ecosections. There is a strong bias toward sampling of the Muskwa Foothills, while the Eastern Muskwa Ranges and the Kechika Mountains have been sampled to a lesser extent. Five ecosections cover a relatively small part of the study area, but they have not been sampled at all. The five ecosections are therefore priority areas for future sampling within the study area: Cassiar Ranges, Peace Foothills, Misinchinka Ranges, Liard Plain, and the Southern Boreal Plateau.

Most of the study area is underlain by sedimentary bedrock types, with small pockets of igneous and metamorphic bedrock types located west of Kechika River. Spatial analysis indicates that plot sampling is somewhat representative for sedimentary bedrock types, but igneous and metamorphic bedrock types were not sampled at all. Laminite/mudstone and conglomerate bedrock types are significantly undersampled. Ten bedrock types cover a relatively small part of the study area, but they have not been sampled at all: granite and alkali-feldspar granite, arenite, diorite/gabbro, alkaline basalt, rhyolite, mylonite, greenschist, basalt, greenstone, and granodiorite. The areas underlain by bedrock types that were undersampled or not sampled at all are therefore priority areas for future sampling within the study area.

Existing plot data was examined to determine whether there was a bias in sampling with respect to ecosystem type. Most of the collected plots were completed for ecosystem/biophysical/wildlife capability mapping projects. Sampling plans for ecosystem

mapping projects are generally designed to maximize the diversity of ecosystem types sampled. It is therefore assumed that sampling is relatively unbiased with respect to ecosystem types. Informal examination of the plot data supports that assumption.

Topographic mapping of the study area indicates that there are large sand bars and eskers within the study area that are worthy of investigation. There are also numerous fens that are underlain by calcareous bedrock. Spatial analysis indicates that there has been limited sampling of eskers, sand dunes, and calcareous fens within the study area. Future mapping should carry out additional sampling at these sites where convenient.

4 WORK PLAN FOR 2000-2001

This section outlines a work plan for 2000-2001 based on the spatial analysis presented in the previous section. The plan would complete the project objectives of collecting additional vegetation, soil, and wildlife data in the field, analyzing data from previous projects with newly collected data, and developing an ecosystem classification for the study area. This plan is contingent on funding of a proposal that is currently under review by the Muskwa-Kechika Advisory Board.

4.1 Sampling Plan for Field Work

The first step of the project would be to prepare a detailed sampling plan for field work, using maps and aerial photographs, if possible. The sampling plan would be designed to sample priority areas identified in the spatial analysis (Section 3.3, Figure 10). The priority areas include upper elevations of the AT zone and proportionately undersampled ecosections and bedrock types. The map also shows calcareous fens, sand bars, and eskers that are worthy of further sampling because they may support rare or unusual ecosystems.

Due to the remoteness of the majority of the study area, it would be important to determine the most cost-effective and efficient methods of access to priority areas for sampling. Transportation methods could include truck, helicopter, float plane, or boat. Figure 10 shows that there is little road access to the priority areas for sampling within the study area. Helicopter access, though expensive, would likely be necessary for some of the field work. Costs could be minimized, however, by restricting helicopter trips to moves between temporary base camps every few days.

4.2 Field Work

Field work would be carried out by a four person crew, working in teams of two. The two person teams would have combined expertise in plant identification, wildlife habitat interpretation, and soil description. Ecosystem sampling methodology would be based on the "Field Manual for Describing Terrestrial Ecosystems" (BCMoELP and BCMoF 1998). Plots would be recorded on the standardized Ecosystem Field Form (FS882), including site, vegetation, and soil descriptions, with additional notes about the wildlife habitat characteristics of the sampled ecosystems. Plant vouchers would be collected for later confirmation of identification. Some of the field work would be based from remote camps established with helicopter support.

Following field work, plot data would be entered in VENUS, the provincial plot database program (BCMoELP and BCMoF 1999). Plant identifications would be confirmed with assistance from botanical experts.

4.3 Ecosystem Classification

The first step in the data analysis would be to establish a single plot database for the study area, including the new plots and plots from previous projects. The next step would be to analyze the plot data for each BGC unit of the study area to develop the ecosystem classification.

While there are many methods for vegetation classification, there are two methods that are most pertinent to this project. The first method is based on the approach to forest classification developed by V.J. Krajina and his students at the University of British Columbia and later adopted by the B.C. Ministry of Forests as the Biogeoclimatic Ecosystem Classification system (Meidinger and Pojar 1991). The approach is based on the Braun-Blanquet method (Braun-Blanquet 1928), with some major modifications, including (1)

collecting both vegetation and environmental data, (2) using relative floristic differentiation in framing vegetation units, and (3) placing the classification into a climatic and edaphic framework. The second method is National Vegetation Classification System, developed by the Nature Conservancy in the U.S. (Grossman *et al.* 1998). The latter framework has been adopted by the B.C. Conservation Data Center for rare plant associations. The two approaches are related and differ primarily in their nomenclature and hierarchical system.

The preliminary ecosystem classification would be circulated to the Regional Ecologists of the Prince George and Prince Rupert Forest Regions for review. Suggested revisions would be carried out and the classification would be circulated for final approval.

4.4 Communicating Project Results

The ecosystem classification for the SWB and AT zones of the MKMA would be presented in a technical manual designed for resource inventory specialists. The manual would include technical descriptions of the ecosystems, along with descriptions of the associated wildlife habitat characteristics. Resource inventory workers could use this manual to identify ecosystems.

A second report, "The Subalpine and Alpine Ecosystems of the MKMA", would be designed for a broader audience, including local stakeholders and tourists. This report would be designed to educate readers about the ecosystems of the study area, to convey the study area's diversity, beauty, wildlife values, and recreation potential, and to promote ecosystem-based planning within the MKMA. The report could be presented as a brochure and/or an Internet-ready document.

4.5 Summary of Work Plan

Table 4 summarizes the steps planned to complete the project in 2000-2001, along with associated deliverables and timetable.

Table 4. Summary of work plan for 2000-2001

Task	Outcome/Deliverable	Timing
1. Produce sampling plan	Sampling plan for field work	May-Jun 2000
2. Plan field work logistics	Travel, accommodation, and meal plans	May-Jun 2000
3. Field work	Completed FS882 Ecosystem Field Forms; plant vouchers collected to confirm plant identifications	Jul 2000
4. Plant ID	Ecosystem Field Forms updated with correct plant names; B.C. Conservation Data Centre notified of rare plants; plant vouchers deposited to herbarium	Oct-Nov 2000
5. Data entry	Full plot database submitted to provincial plot archive in VENUS format	Dec 2000
6. Digitize plots	Digital map of plot locations	Oct 2000
7. Analyze data	Database containing all plot data for the study area; preliminary ecosystem classification	Jan 2000
8. Finalize ecosystem classification	Final ecosystem classification	Jan 2000
9. Produce technical report	Technical report that outlines new classification and describes ecosystems (designed for resource inventory workers)	Feb 2000
10. Produce educational report	Educational report that describes the subalpine and alpine ecosystems of the MKMA (designed for laypersons)	Feb 2000

REFERENCES

- Banner, A., W. MacKenzie, S. Haeussler, S. Thomson, J. Pojar, and R. Trowbridge. 1993. A Field Guide to Site Identification for the Prince Rupert Forest Region. Land Management Handbook Number 26, B.C. Ministry of Forests, Victoria, B.C.
- Barton, K., L. Veach, G. Radcliffe, and P. Williams. 1998. Terrestrial Ecosystem Mapping and Wildlife Interpretations for the Dunedin Study Area. Prepared for Slocan Forest Products Ltd. by Madrone Consultants Ltd., Duncan, B.C.
- Bates, R.L. and J.A. Jackson (eds.). 1984. Dictionary of Geological Terms (Third Edition). Prepared under the direction of the American Geological Institution, Doubleday, New York.
- Braun-Blanquet, J. 1928. Pflanzensoziologie. Grundzuge der vegetationskunde. Springer-Verlag, Berlin, Germany.
- British Columbia Conservation Data Centre (BCCDC). 1999a. Rare Plant Association Tracking List: Cassiar portion of Bulkley Cassiar Forest District. B. C. Ministry of Environment, Lands, and Parks, Victoria, B.C.
- British Columbia Conservation Data Centre (BCCDC). 1999b. Rare Plant Association Tracking List: Fort Nelson Forest District. B. C. Ministry of Environment, Lands, and Parks, Victoria, B.C.
- British Columbia Conservation Data Centre (BCCDC). 1999c. Rare Plant Association Tracking List: Fort St. John Forest District. B. C. Ministry of Environment, Lands, and Parks, Victoria, B.C.
- British Columbia Ministry of Environment, Lands, and Parks (BCMoELP). 1999. McGregor Announces Next Steps to Protect B.C.'s Parks and Protected Areas. Press release Jan. 15, 1999.
- British Columbia Ministry of Environment, Lands, and Parks and British Columbia Ministry of Forests (BCMoELP and BCMoF). 1998. Field Manual for Describing Terrestrial Ecosystems. Land Management Handbook Number 25, Crown Publications, Victoria, B.C.
- British Columbia Ministry of Environment, Lands, and Parks and British Columbia Ministry of Forests (BCMoELP and BCMoF). 1999. VENUS: Vegetation and Environment NexUS, data-entry, reporting, and analysis tool (software package). Victoria, B.C.
- Ceska, A. 2000. Personal Communication. Program Ecologist, Conservation Data Centre, Ministry of Environment, Lands, and Parks, Victoria, B.C.
- DeLong, C. 2000. Personal Communication. Landscape Ecologist, Forest Resources, Ministry of Forests, Prince George, B.C.
- Demarchi, D.A. 1996. An Introduction to the Ecoregions of British Columbia. Wildlife Branch, Ministry of Environment, Lands, and Parks, Victoria, B.C.
- Environmental Systems Research Institute, Inc. (ESRI). 1998. ArcView GIS Version 3.1. Software Package.
- Environmental Systems Research Institute, Inc. (ESRI). 2000. Glossary. World Wide Web Online Document, ESRI Virtual Campus (<http://campus.esri.com/>).
- Grossman, D.H., D. Faber-Langendoen, A.S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K.D. Patterson, M. Pyne, M. Reid, and

- L. Sneddon. 1998. International classification of ecological communities: terrestrial vegetation of the United States. Volume 1. The National Vegetation Classification System: development, status, and applications. The Nature Conservancy, Arlington, VA, USA.
- Hamilton, E. 1983. A problem analysis of the classification of alpine tundra and subalpine parkland subzones within the British Columbia Ministry of Forests Ecosystem Classification Program (Draft Report). Research Branch, B.C. Ministry of Forests, Victoria, B.C.
- Land Use Coordination Office (LUCO). 1999. Guide to Spatial Land and Resource Information in Land and Resource Management Planning. Online edition (<http://www.luco.gov.bc.ca/lrmp/spatial/aboutguide.htm>).
- MacKinnon, A., C. DeLong, and D. Meidinger. 1990. A Field Guide for Identification and Interpretation of Ecosystems of the Northwest Portion of the Prince George Forest Region. Land Management Handbook Number 21, B.C. Ministry of Forests, Victoria, B.C.
- Meidinger, D. and J. Pojar (eds.). 1991. Ecosystems of British Columbia. Special Report Series 6, B.C. Ministry of Forests, Victoria, B.C.
- Microsoft Corp. 1997. Microsoft Excel 97. Software Package.
- Pojar, J., K. Klinka, and D.V. Meidinger. 1987. Biogeoclimatic ecosystem classification in British Columbia. For. Ecol. Manage. 22: pp. 119-154.
- Resources Inventory Committee (RIC). 1998. Field Manual for Describing Terrestrial Ecosystems. Land Management Handbook Number 25, Ecosystems Working Group, Terrestrial Ecosystems Task Force, Resources Inventory Committee, B.C. Ministry of Environment, Lands, and Parks, B.C. Ministry of Forests, Victoria, B.C.
- Resources Inventory Committee (RIC). 2000. Provincial Site Series Mapping Codes and Typical Environmental Conditions. Ecosystems Working Group, Terrestrial Ecosystems Task Force, Resources Inventory Committee, Victoria, B.C. (ftp://ftp.env.gov.bc.ca/dist/wis/tem/map_code.xls).

APPENDICES

Appendix 1. Provincial Map Units

Table 5 summarizes the map units that are potentially applicable to the study area. The table is adapted from the Provincial Site Series & Map Code List (RIC 2000).

Table 5. Map units of the AT and SWB zones of the Prince George Forest Region.

Zone	Subzone/ Variant	Site Series Symbol	Site Series Name	Typical Situation	Typical Soil Moisture Regime	Forest Region	Project(s)
AT		AD	Mountain arnica - Subalpine daisy meadow	Meadow	mesic	P. George; Cariboo	McGregor Model Forest; West Fraser
		AH	Heath Meadows	Heath Meadows		P. Rupert	
		AK	Alpine Krummholz	Alpine Krummholz (no erect tree growth form - pure krummholz)		P. Rupert	
		AM	Herbaceous Meadows	Herbaceous Meadows	mesic	P. Rupert	
		AW	Entire-leaved white mountain-avens - Netted Willow	Wind swept slopes; gentle thin or coarse well drained soils; vegetation dominated by low willows, dwarf blueberry, Dryas spp., or other dwarf shrubs.		P. George; Cariboo	Penfold; Smith/Vents
		DL	Dry Lichen Fellfields	Dry Lichen Fellfields		P. Rupert	
		GM	Grassland meadows	Grassland meadows (dry to moist)		P. Rupert	
		HB	Hellebore - Sedge - Bluejoint seepage meadow			P. George	McGregor Model Forest
		HL	Heather - Lichen meadow	Dry heath meadow. In areas where snow lies longer and soils are well drained (mesic and drier). Vegetation a mix of heathers and dry site graminoids and low forbs.	xeric - mesic	P. George; Cariboo	McGregor Model Forest; Penfold

ECOSYSTEM CLASSIFICATION OF THE SUBALPINE AND ALPINE ZONES OF THE MUSKWA-KECHIKA MANAGEMENT AREA

Spatial Analysis & Work Plan

Appendices

Zone	Subzone/ Variant	Site Series Symbol	Site Series Name	Typical Situation	Typical Soil Moisture Regime	Forest Region	Project(s)
AT		HW	Netted willow - Four-angled mountain heather			P. George	Smith/Vents
		LC	Bracted lousewort - Palmate coltsfoot			P. George	McGregor Model Forest
		MH	Mountain heather meadows	shallow rocky soils on ridgetops and down gentle to moderate slopes of all aspects	subxeric - mesic		
		MK	Montane krummholz	well drained, gentle to steep rocky slopes with thin soil development; aspect variable	xeric - submesic		
		ML	Alpine Meadow			P. George	Dunedin
		SS	Leatherleaf saxifrage - Sedge wetland			P. George	McGregor Model Forest
SWB	mk	WM	Wet seepage meadows	Wet seepage meadows (late snow melt areas)		P. Rupert	
		AO	Great northern aster - Timber catgrass			P. George	Smith/Vents
		BB	Bog birch - Buckbean			P. George	Smith/Vents
		HS	Mountain hairgrass - Sedge	marsh; deep coarse-textured soils on active fluvial materials	hygric - subhydryc	P. George	Smith/Vents
		JB	Tall Jacob's ladder - Bluejoint	gentle slopes; deep, medium-textured soils; wet meadow unit	hygric		
		PA	Cow - Parsnip - Arrow - leaved groundsel wet meadow			P. George	Smith/Vents
		PL		significant slope, warm aspect, shallow soils over bedrock*	xeric - subxeric	P. George; P. Rupert	Smith/Vents; Dunedin
		SB		gentle slope; deep, medium-textured soils *	mesic	P. George; P. Rupert	Smith/Vents; Dunedin
		SC		significant slope, cool aspect; deep medium-textured soils *	subhygric	P. George; P. Rupert	Smith/Vents; Dunedin

ECOSYSTEM CLASSIFICATION OF THE SUBALPINE AND ALPINE ZONES OF THE MUSKWA-KECHIKA MANAGEMENT AREA
Spatial Analysis & Work Plan

Appendices

Zone	Subzone/ Variant	Site Series Symbol	Site Series Name	Typical Situation	Typical Soil Moisture Regime	Forest Region	Project(s)
SWB	mk	SF	Sedge fen	fen; deep organic wetland	hygric - subhydryc	P. George	Smith/Vents
		SH		gentle slope, deep, coarse-textured soils *	hygric - subhydryc	P. George; P. Rupert	Smith/Vents; Dunedin
		SK		significant slope, warm aspects; deep, medium-textured soils *	xeric - subxeric	P. George; P. Rupert	Smith/Vents; Dunedin
		SL		significant slope, cool aspect; deep medium-textured soils *	submesic- subhydryc	P. George; P. Rupert	Smith/Vents; Dunedin
		SP	Sw - Polargrass	gentle slopes; deep, medium-textured soils; stunted bog community	hygric - subhydryc	P. George	Dunedin
		SS		gentle slope; deep medium-textured soils *	subhydryc	P. George; P. Rupert	Smith/Vents; Dunedin
		SW		gentle slope, deep medium-textured soils*	submesic - mesic	P. George; P. Rupert	Smith/Vents; Dunedin
		WB	Willow - Bluejoint	level sites; deep, coarse-textured soils	subhydryc	P. George	Smith/Vents
		WF	Willow - Sedge wetland	level sites; deep, coarse-textured soils	subhydryc - hygric	P. George	Smith/Vents
		WH	Willow - Common horsetail	gentle slopes; deep, coarse-textured soils	hygric - subhydryc	P. George	Smith/Vents
		WS	Willow - Bog birch - Sedge	organic wetland *	subhydryc	P. George; P. Rupert	Smith/Vents; Dunedin
		WY	Willow - Yellow mountain-avens	vegetated gravel bar		P. George	Dunedin
		AS	Entire-leaved white mountain avens - Sedges	crest slope positions; shallow soil over bedrock, coarse-textured; dry sites, sparsely vegetated in wind swept positions	xeric - subxeric	P. George	Smith/Vents
	mks	AW	Entire-leaved mountain-avens - Netted willow	gentle slopes; shallow soils, medium- textured	subxeric - submesic	P. George	Dunedin

ECOSYSTEM CLASSIFICATION OF THE SUBALPINE AND ALPINE ZONES OF THE MUSKWA-KECHIKA MANAGEMENT AREA

Spatial Analysis & Work Plan

Appendices

Zone	Subzone/ Variant	Site Series Symbol	Site Series Name	Typical Situation	Typical Soil Moisture Regime	Forest Region	Project(s)
SWB	mks	BH	Bog birch - Four-angled mountain heather	gentle slopes; shallow soils over bedrock, coarse-textured; moist swale areas	mesic - subhygric	P. George	Smith/Vents
		BL	Bog birch - Common coral lichen	gentle slope; deep coarse-textured soils; shrub community on knolls	submesic	P. George	Smith/Vents
		FB	Subalpine fir - Five-leaved bramble	significant slope, cool aspect; deep, coarse-textured soils; krummholz site	submesic	P. George	Smith/Vents
		FG	Subalpine fir - Globeflower	significant slope, warm aspect; deep, coarse-textured soils; forested site	subxeric - submesic	P. George	Smith/Vents
		FV	Subalpine fir - Sitka valerian	significant slope, cool aspect; deep, coarse-textured soils forested site	mesic - subhygric	P. George	Smith/Vents
		FW	Subalpine fir - Grey-leaved willow	significant slope, warm aspect; shallow soils over bedrock, coarse-textured soils; krummholz site	submesic	P. George	Smith/Vents
		MA	Entire-leaved white mountain-avens - Arctic lupine	significant slope, warm aspect; shallow soils over bedrock, coarse-textured soils; herb dominated community	subxeric - submesic	P. George	Smith/Vents; Dunedin
		MB	Entire-leaved white mountain avens - Bog birch	significant slope, cool aspect; shallow soils over bedrock, coarse textured soils; herb dominated community	submesic - mesic	P. George	Smith/Vents
		PA	Cow-parsnip - Arrow-leaved groundsel, wet meadow	moist herb meadow; gentle slope; deep, coarse-textured soils	hygric	P. George	Smith/Vents
		SA	Scrub birch - Altai fescue	gentle slopes; deep, medium textured soils	mesic - subhygric	P. George	Dunedin
		SC	White spruce - Crowberry	significant slopes, cool aspects; shallow soils, medium-textured	subhygric	P. George	Dunedin
		VH	Sitka valerian - Indian hellebore	significant slope, cool aspect; shallow soils over bedrock, coarse-textured; avalanche chute	mesic	P. George	Smith/Vents

Zone	Subzone/ Variant	Site Series Symbol	Site Series Name	Typical Situation	Typical Soil Moisture Regime	Forest Region	Project(s)
SWB	mks	WM	Willow - Mountain sagewort	significant slope; cool aspect; deep, medium-textured soils; shrub dominated community	submesic	P. George	Smith/Vents
		WV	Willow - Sitka valerian	gentle slopes; deep, medium-textured soils, moist shrub units	mesic - subhygric	P. George	Smith/Vents

* Noncorrelated Unit, talk with Regional Ecologist

Appendix 2. Studies of alpine and subalpine ecosystems

Numerous studies of alpine and subalpine ecosystems have been carried out in and adjacent to the MKMA (Table 6). These studies vary in their objectives, methodology, and availability.

Table 6. Studies of alpine and subalpine ecosystems in and adjacent to the MKMA.

References primarily drawn from a literature review of alpine and subalpine parkland ecosystems of British Columbia (Hamilton 1983).

Province	Region	Study Area	Reference
British Columbia	Cassiar Mountains		Pojar, J., R. Trowbridge and T. Lewis. 1983. Biogeoclimatic zones of the Cassiar Timber Supply Area, northwestern British Columbia. <i>In</i> : Northern fire ecology project Cassiar Timber Supply Area. B.C. Min. For., Smithers, B.C. (unpub. report).
		Horseranch Range	Clement, C. and M. Fenger. 1981. Forest zonation, vegetation landscapes and general terrain description for the Horseranch Range. B.C. Min. Env. Victoria, B.C. Map.
		Level Mountain	Clement, C. and M. Fenger. 1981. Forest zonation, vegetation landscapes and general terrain description for the Level Mountain Range. B.C. Min. Env., Victoria, B.C. Map.
	Liard Plateau		Polster, D.F. 1975. Vegetation of talus slope on the Liard Plateau. B.Sc. thesis, University of Victoria, Victoria, B.C.
			Raup, H.M. 1934. Phytogeographic studies in the Peace and Upper Liard River Regions, Canada. <i>Contrib. Arnold Arbor.</i> 6:1-230.
	Stikine Plateau	Spatsizi Plateau	Bergerud, A.T. and H.E. Butler. 1978. Life history studies of caribou in Spatsizi Wilderness Park 1977-78. B.C. Min. of Recreation and Conservation. Parks Branch Report. Victoria, B.C.
			Osmond-Jones, E.J., M. Sather, W.G. Hazelwood and B. Ford. 1977. Wildlife and fisheries inventory of Spatsizi Wilderness and Tatlatui Provincial Parks. Parks Branch, Victoria, B.C.
			Pojar, J. 1977. Vegetation and some plant-animal relationships of Ecological Reserve #68, Gladys Lake. Ecological Reserves Unit, Department of Environment, Victoria, B.C. (unpublished report)
			Welsh, S.L. and J.K. Rigby. 1971. Botanical and physiographic reconnaissance of northern British Columbia. <i>Brigham Young Univ. Sci. Bull. Biol. Ser.</i> 14:1-49.
			Szczawinski, A.F. 1959. Vegetation reconnaissance survey of Spatsizi Plateau (Cold Fish Lake area) of British Columbia. (Unpub. manuscript in B.C. Prov. Mus. files).
	Yukon Plateau		Buttrick, S.C. 1978. The alpine vegetation ecology and remote sensing of Teresa Island, British Columbia. Ph.D. thesis, University of British Columbia, Vancouver, B.C.

Province	Region	Study Area	Reference
British Columbia	Yukon Plateau		Buttrick, S.C. 1977. The alpine flora of Teresa Island, Atlin Lake, B.C. with notes on its distribution. <i>Can. J. Bot.</i> 55:1399-1409.
			Anderson, J.H. 1970. A geobotanical study in the Atlin region in northwestern British Columbia and south-central Yukon Territory. Ph.D. thesis, Mich. State Univ., East Lansing, Mich.
	Rocky Mountain Foothills	Nevis Mountain	Lord, T.M. and A.J. Luckhurst. 1974. Alpine soils and plant communities of a Stone sheep habitat in northeastern British Columbia. <i>Northwest Sci.</i> 48:38-51.
			Luckhurst, A.J. 1973. Stone sheep and their habitat in the northern Rocky Mountain foothills of British Columbia. M.Sc. thesis, Univ. British Columbia, Vancouver, B.C.
			Brink, V.C., A. Luckhurst and D. Morrison. 1972. Productivity estimates from alpine tundra in British Columbia. <i>Can. J. Plant Sci.</i> 52:321-323.
B.C., Yukon and Alaska	St. Elias Mountains		Murray, D.F. 1971. Notes on the alpine flora of the St. Elias Mountains. <i>Arctic</i> 24:301-304.
			Grier, C.C. and T.M. Ballard. 1981. Biomass, nutrient distribution, and net production in alpine communities on the Kluane Mountains, Yukon Territory, Canada. <i>Can. J. Bot.</i> 59:2635-2699.
			Oosenbrug, S.M. and J.B. Theberge. 1980. Altitudinal movements and summer habitat preferences of woodland caribou in the Kluane Ranges, Yukon Territory. <i>Arctic</i> 33:59-72.
			Douglas, G.W. and D.H. Vitt. 1976. Moss-lichen flora of St. Elias - Kluane Ranges, Southwestern Yukon. <i>The Bryologist</i> 79:437-456.
			Hoefs, M., I. McTaggart-Cowan and V.J. Krajina 1975. Phytosociological analysis and synthesis of Sheep Mountain, southwest Yukon Territory, Canada. <i>Sysis</i> 8 (suplement 1):125-228.
Yukon			Bird, C.D. 1972. Botanical studies in the Yukon and Northwest Territories. <i>Geol. Survey Can. Open File</i> 225.
			Geist, V., R.T. Ogilvie, D.E. Reid, D.H. Gubbe and I.D. Hubbard. 1979. Report on Wolf Lake (Yukon Territory), panel 10, c.t. site 18. Univ. Calgary, Calgary, Alta.
			Kojima, S. 1973. Phytocoenoses in the North Klondike River Valley and adjacent areas, Yukon Territory. Pages 33-44. In V.J. Krajina (editor). <i>Progr. Rep., Nat. Res. Council. No. A-92.</i> Univ. British Columbia, Vancouver, B.C.
			Orlaci, L. and W. Stanek. 1979. Vegetation survey of the Alaska Highway, Yukon Territory: types and gradients. <i>Vegetatio</i> 41:1-56.
			Oswald, E.T. and J.P. Senyk. 1977. Ecoregions of Yukon Territory. Report BC-X-164. Can. Dep. Environ., Can. For. Serv. Pac. For. Res. Center, Victoria, B.C. 115 pp.

Province	Region	Study Area	Reference
Yukon	Southeast Yukon		Zoladeski, C.A. and D.W. Cowell. 1996. Ecosystem classification for the southeast Yukon (Field Guide, First Approximation). Yukon Renewable Resources, Whitehorse, Yukon.

Appendix 3. Sources of Map Data

Table 7 summarizes the sources of map data used for the spatial analysis. All digital mapping was obtained in ARC/INFO export format in Albers Equal Area Conic projection.

Table 7. Sources of map data for spatial analysis and presentation.

Map Type	Original Scale	Source	Access
MKMA Boundary (digital)	?	B.C. Land Use Coordination Office	World Wide Web: http://www.gis.luco.gov.bc.ca/sup/muskwa.html
Base Mapping (digital)	1:250 000	GIS Section, B.C. Ministry of Environment, Lands, and Parks	supplied by the Ministry with permission
Compiled Geology (digital)	1:250 000	B.C. Ministry of Energy and Mines	World Wide Web: http://www.em.gov.bc.ca/Download/arcview1/arcview1.htm
Ecoregion Mapping (digital)	1:250 000	Quality Assurance Unit, B.C. Ministry of Environment, Lands, and Parks	supplied by the Ministry
Biogeoclimatic Ecosystem Classification with Coastline (Version 3; digital)	1:250 000	B.C. Ministry Of Forests Research Branch	File Transfer Protocol: ftp://ftp.env.gov.bc.ca/dist/arcwhse/wildlife/ges_bc.zip
Terrestrial Ecosystem Mapping Plot Locations (digital)	1:50 000	Quality Assurance Unit, B.C. Ministry of Environment, Lands, and Parks	supplied by the Ministry
NE Bison Habitat Plot Positions	1:20 000	approximate plot positions documented in ESRI ArcView based on plots marked on aerial photographs	borrowed from Quality Assurance Unit, B.C. Ministry of Environment, Lands, and Parks
Range Exclosure	1:250 000	approximate plot positions documented in ESRI ArcView based on plots marked on topographic maps	supplied by Operations, Ministry of Forests, Prince George
Permanent Plots	1:250 000	approximate plot positions documented in ESRI ArcView based on plots marked on topographic maps	supplied by Forest Resources, Ministry of Forests, Prince George