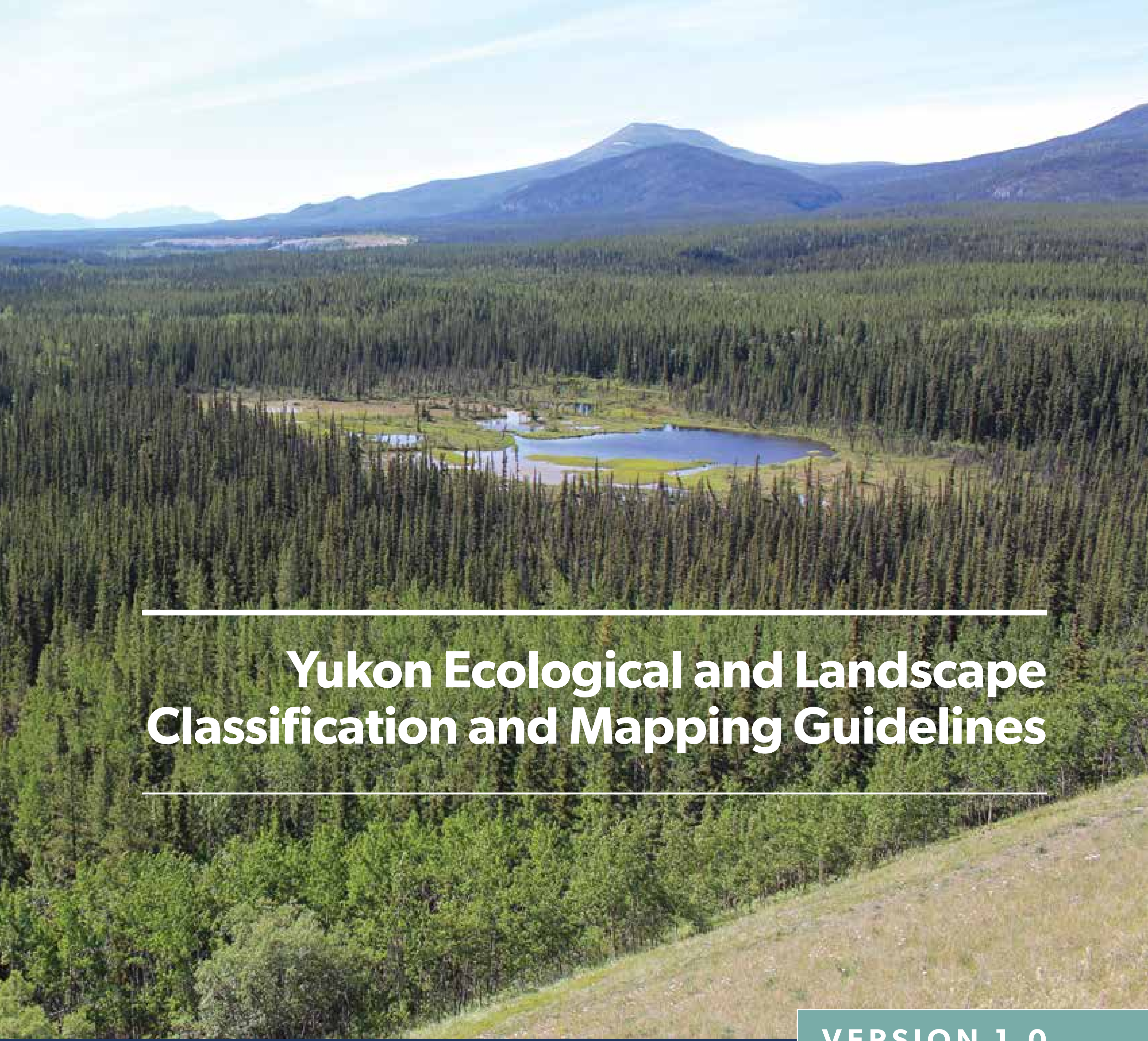

Yukon Ecological and Landscape Classification and Mapping Guidelines

VERSION 1.0

Yukon Government

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For more information on the ELC program and other publications, visit www.env.gov.yk.ca/elc.

Front cover photo: Overview of McLean Creek, a small tributary of the Yukon River, representative of the Boreal Low Southern Lakes subzone (BOLsl), Whitehorse, Yukon (photo by H. Ashthorn). © Government of Yukon

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1
INTRODUCTION

1.1 BACKGROUND

Ecological classification and mapping refers to an integrated approach to mapping and classifying units of land according to their ecological similarity (Rowe 1979). The aim of ecosystem classification and mapping is to provide information on the biological and physical characteristics of landscapes in order to facilitate a range of natural resource management tools (Rowe and Sheard 1981).

Vegetation and ecological classification and mapping have a long history of practice in Yukon. The Canadian Forest Service was the first to complete mapping work in the territory and published the formative Ecoregions of the Yukon (Oswald and Senyk 1977). In 1979 a joint federal/territorial renewable resource development agreement facilitated forest inventory, measurement and mapping programs throughout the southern half of Yukon between 1975 and 1982. Key contributors to this early work on ecological classification in Southern Lakes were Ed Oswald, John Senyk and Barry Brown, based out of the Pacific Forestry Research Centre, Canadian Forest Service, in Victoria, B.C. Shortly after this, Wiken et al. (1981) conducted ecological land surveys in northern Yukon. In the 1980s the Yukon Department of Renewable Resources initiated a resource inventory of the Southern Lakes (Davies et al. 1983) and Macmillan Pass (Davies et al. 1983) areas. Between the 1970s and 1980s the Department of Indian Affairs and Northern Development (now Indigenous and Northern Affairs Canada) completed forest inventory mapping for much of southern Yukon.

The first version of soil landscape mapping was completed by White et al. (1992). In 1996, through the Canada/Yukon Economic Development Agreement, the first field guide to forest classification in Yukon (Zoladeski et al. 1996) was published for southeast Yukon. This was a joint effort between the Government of Canada (Canadian Forest Service) and the Government of Yukon (Department of Renewable Resources). In 1995, the 1977 ecoregions map was reviewed and revised by the Yukon Ecoregions Working Group to reflect the most recent research and fieldwork in various disciplines. This map and ecozone and ecoregion descriptions were published in A National Ecological Framework for Canada (ESWG 1995). In 2004, the Yukon's terrestrial ecozones and ecoregions descriptions were updated by a Yukon working group, resulting in the widely-used publication *Ecoregions of the Yukon Territory* (Smith et al. 2004).

In 2002, a multi-agency biophysical technical working group was established by the Government of Yukon's Department of Environment to advance ecological classification and mapping concepts. Over a period of ten years, the contributions of this group led to the establishment of the Yukon Ecological and Landscape Classification (ELC) Program. In spring 2013, the Government of Yukon released a five-year strategic plan to develop and distribute ecological classification and mapping information.

1.2 PURPOSE

A standardized ecosystem classification and mapping framework is intended to help facilitate land and resource management decisions and foster coordination between Yukon resource sectors and land managers.

ELC supports multiple management activities by providing consistent, integrated base mapping from which various environmental and landscape interpretations can be derived. Basic information on the biological and physical attributes of terrain facilitates the interpretation of renewable productivity and likely responses to impacts both natural and anthropogenic (Rowe and Sheard 1981). The standards and guidelines in this document will help ensure consistency in how ecological classification and mapping are developed and used.

The Yukon Ecological and Landscape Classification Guidelines are intended for use by a variety of readers who require understanding of, and guidance on, the use and application of ecological classification and mapping products.

This publication provides guidance on the following topics:

- ELC product for specific applications;
- the map scale and level of accuracy desired for different applications; and
- methods of and considerations in conducting ELC.

The guidelines are intended to inform Yukon land and resource practitioners about the Yukon ELC Program and to provide an overview of the Yukon ELC frameworks. They also include information on important ELC classification and mapping concepts. Appendix 2 discusses the value of ELC as a tool in environmental assessment and resource planning and management in a number of case studies.

This document is the first version of Yukon specific ELC standards. Efforts to produce standardized ecological classifications and ecosystem guidebooks for various areas of the territory are ongoing. Until these Yukon products are completed, guidelines and standards from other jurisdictions will continue be used by Yukon practitioners. As the Yukon ELC Program evolves, changes to the guidelines and more detailed technical standards will be published.

1.3 HOW TO USE THESE GUIDELINES

This is how the document is organized:

- **Section 2:** A brief overview of the Yukon ELC Program;
- **Section 3:** An overview of the Yukon ELC frameworks and their ecological concepts;
- **Section 4:** Technical aspects of the Yukon Bioclimate Framework mapping guidelines, including background on mapping concepts;
- **Section 5:** Data collection and management;
- **Section 6:** Suggested steps for conducting an ELC project;
- **Section 7:** Applying the Yukon ELC frameworks to management;
- **Appendix 1:** Glossary of terms used in these guidelines and in other Yukon ELC Program documents; and
- **Appendix 2:** Seven Yukon ELC case studies that used regional and local-level classification and mapping for a range of management applications.

2 THE YUKON ELC PROGRAM

The Yukon ELC Program has a mandate to develop and deliver ecological classification and mapping on behalf of the Yukon government. The program conducts territory-wide ecological classification and mapping activities to provide expert knowledge of Yukon landscapes and accessible map products. This knowledge is the foundation for responsible resource planning and management.

A five-year strategic plan (2013–2018) outlines the governance structure, goals and major tasks for the Yukon ELC Program.

Two Yukon government departments — Environment and Energy, Mines and Resources — are working collaboratively, through a Supervisory Committee, to provide direction to the ELC program. The ELC Technical Working Group, comprised of government and non-government representatives, contributes technical expertise to the Yukon ELC Program. The working group also contributes to the development of specific products and technical methods.

The following priority areas have been identified in the Yukon ELC program's five-year strategic plan:

- **Framework:** Provide a uniform approach to Yukon ecological landscape classification and mapping to facilitate the integration and exchange of ecosystem knowledge across multiple disciplines;
- **Standards:** Ensure products are developed from a set of defined, consistent, and coordinated standards. These products provide foundational ecological information for sustainable resource planning and management; and
- **Program services:** Enhance understanding of Yukon's landscape by integrating ecological knowledge into decision making across government. This understanding will enhance our policy and decision-making for sustainable management of Yukon landscapes and ecosystems.

3
YUKON ELC FRAMEWORKS

Two ecological frameworks are used for ELC work in Yukon: the Yukon Bioclimate Ecosystem Classification (YBEC) Framework (also referred to as "Yukon Bioclimate Framework") and the National Ecological Framework (NEF) of Canada. Although these two frameworks have different ecological concepts and applications, they are intended to be used together in a complementary manner.

YBEC is generally modeled after the *Biogeoclimatic Ecosystem Classification System of British Columbia* (Pojar et al. 1987; Meidinger and Pojar 1991). It has both climate and site-level classification, but it considers climate to be the primary influence on ecosystem development and distribution. YBEC provides detailed site-level ecological mapping and interpretations. Efforts to develop detailed site-level units are ongoing.

NEF identifies and describes the biophysical properties of large land units based on ecological similarity (ESWG 1995). The NEF subdivides Canada into ecologically similar areas, based on the integration of climate, physiography, landform and vegetation. This framework is a well-developed system that supports many Yukon land and resource management activities. *Ecoregions of the Yukon Territory* (Smith et al. 2004) provides generalized regional biophysical information about the landscapes of Yukon. Although the framework supports a range of regional interpretations, it does not support detailed site-level mapping.

Each framework is discussed, as follows, in more detail.

3.1 YUKON BIOCLIMATE ECOSYSTEM CLASSIFICATION FRAMEWORK

An ecosystem results from a complex interaction of plants, animals and microorganisms with the physical environment. Ecosystems can be defined at various scales, from local to regional. The Yukon Bioclimate Ecosystem Classification (YBEC) framework groups similar segments of the landscape — i.e., ecosystems — into ecosites. Ecosite units are classified by combining components of the classification system at a local scale. A black spruce-peat moss bog is an example of a local-scale ecosystem. A regional ecosystem is broader, and encompasses many local-scale ecosystems.

For practical purposes, YBEC generally characterizes an ecosystem as a particular plant community and its associated topography, soil and climate. Although the framework does not specifically include animals, fungi and microorganisms, its classification process recognizes them as important components of ecosystems. Whether an ecosystem transitions from one to the other abruptly or gradually, depends on the environmental factors that influence the ecosystem.

Climate is the most important factor that influences the development of terrestrial ecosystems. Within areas of similar climate, ecosystems vary because of differences in topography and soil. For example, grasslands occur on steep, warm aspects; bogs and fens are found in sites with impeded drainage. The vegetation that develops on these local-scale sites reflects differences in topography and soil.

Vegetation is important when developing an ecological classification because it is readily visible and it reflects the environment, biology and history of a site. However, since vegetation changes over time — in a process called succession — it is the sum total of the vegetation at various stages of development on a site (i.e., uniform topography/soil) that characterizes an ecosite.

YBEC organizes regional- and local-scale ecosystems, as well as vegetation communities, in three classification systems that, combined together, comprise the YBEC framework (Figure 1). The ELC guidelines present the primary units of the three classification systems: bioclimate zones and subzones (subdivisions of bioclimate zones); vegetation association; and ecosites. These primary units are shown with thick grey rectangular borders in Figure 1. The YBEC system also includes the concept of ecosite phase for some ecosites.

The Bioclimate Classification is under development in Yukon and both the mapping and characterization of the units will evolve.

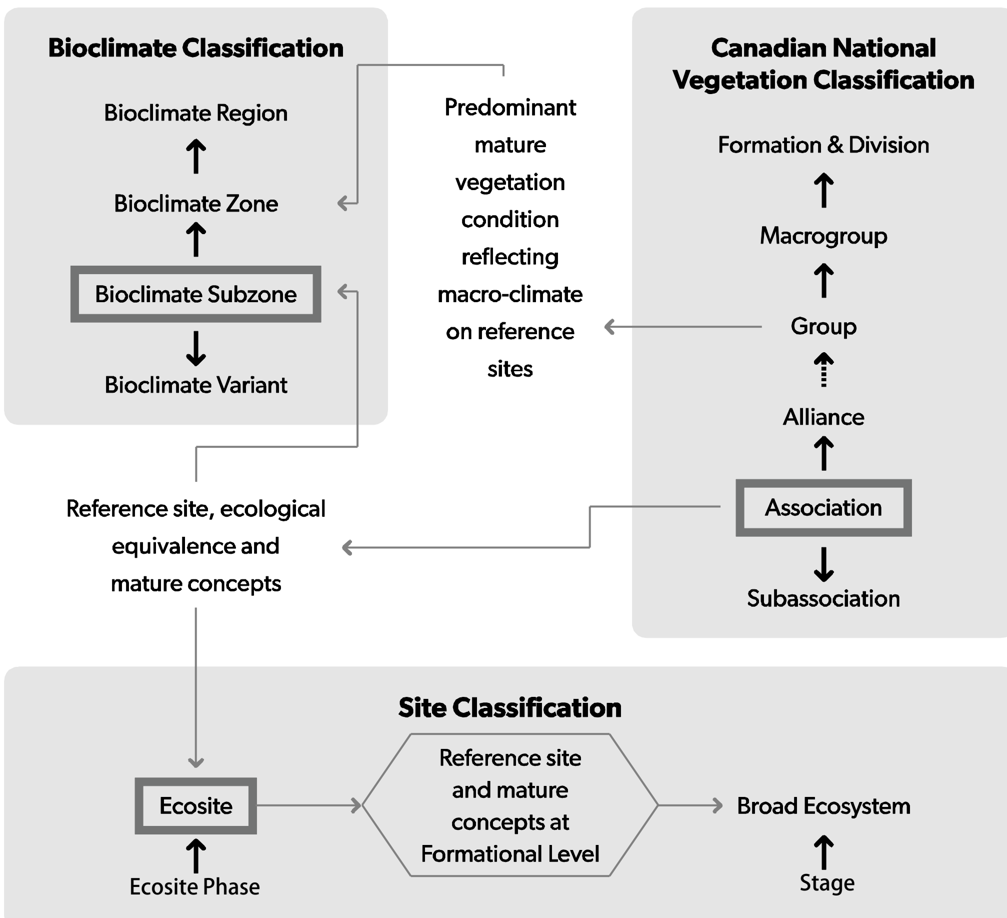


Figure 1. Structure of the Yukon Bioclimate Ecosystem Classification system

Note: Primary units (subzone, association and ecosite) for each level are shown with thick grey rectangular borders.

3.1.1 CLASSIFICATION

YBEC incorporates a hierarchical bioclimate and site classification that is based on the influence of ecological factors and scale (Figure 1). Bioclimate classification (3.1.1.1) describes regional and sub-regional climatic patterns; site classification (3.1.1.2) describes local site and vegetation conditions.

3.1.1.1 BIOCLIMATE CLASSIFICATION

The Bioclimate Classification categorizes broad areas influenced by similar regional climates into a hierarchy of bioclimate units. The broadest of these is the Bioclimate Region and the finest is the Bioclimate Subzone. In YBEC, regional climate can be expressed in terms of elevation as well as geography. For example, in the Boreal Region of southwest Yukon, the Boreal Low zone occurs at lowest elevations, at higher elevations are the Boreal High, Subalpine and Alpine zones.

This photo illustrates how three bioclimatic zones in the subarctic region of Yukon have elevational limits. In the foreground is the woodland zone; above the woodland zone (the lower yellow line) is the subalpine zone; above this (the upper yellow line) is the alpine zone (photo by Archbould.com) .

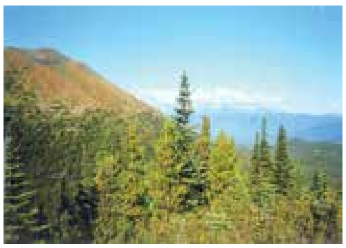
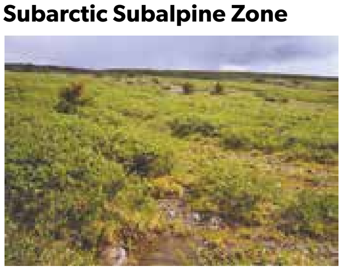
Bioclimate zone

In Yukon's broad climate regions (e.g., subarctic, boreal), **bioclimate zones** are areas with a similar climate. Each zone supports a "reference" ecological community, known as a **reference site**. The reference site reflects the regional climate with respect to soil and vegetation association development, usually on gentle slopes with medium textured soils with moderate drainage. Local site factors (soil and landscape position) are less important than climate influences. Nine bioclimate zones are currently recognized in Yukon (Table 1).

Bioclimate subzone

Bioclimate subzones are more detailed divisions of bioclimate zones. Subzones are defined by their climate and their local-level ecosystems (ecosites). This classification uses the vegetation communities or associations on circum-mesic, nutrient-medium sites — i.e., reference sites — and the kind and pattern of ecosystems on drier, wetter, poorer and richer sites to differentiate subzones. The same general ecological community will characterize both the bioclimate zone and subzone in which it occurs, but subzone reference sites may have differing productivity or vegetation characteristics. At this time, preliminary bioclimate subzones have been identified for only some areas of Yukon.

Table 1. Overview of Yukon bioclimate zones

Bioclimate Region/Zone	Code	Description
Boreal Bioclimate Region		
Boreal Low Zone 	**BOL**	Continuously forested areas at low to middle elevations (i.e., below the BOH) of all mountain valley and plateau regions of southern and central Yukon. Winters are long and cold, with short, cool and dry summers. Forests are generally mixed wood (lodgepole pine, white spruce and aspen) with moderately developed understories. Wetlands are common.
Boreal High Zone 	**BOH**	Middle to upper elevations of forested areas in all mountain valley and plateau regions of southern and central Yukon. This zone is found above the BOL in large valleys. It is characterized by steep slopes in the southern mountainous regions and gentle rolling plateaus in the central regions. Summers are brief, cool and moist, with long cold winters. Forests are dominated by white spruce, lodgepole pine and subalpine fir. Forests tend to be more open than those of the BOL.
Boreal Subalpine Zone 	**BOS**	Shrub communities with sparse tree cover (<10%) at moderate to higher elevations on steep slopes above the BOH and BOL. This forms a transitional zone between forested BOL and BOH and the higher elevation, non-treed alpine bioclimate zone. Sparse canopy conifer forests (tree cover < 10%) and tall to medium shrub communities are characteristic vegetation. Depending on the geographic area, either subalpine fir or white spruce tree species may occur. Winters are long and cold, while summers are short, cool and moist.
Subarctic Bioclimate Region		
Subarctic Woodland Zone 	**SUW**	Coniferous or mixed wood forested areas with an open canopy in northern Yukon. Generally occur in valley bottoms and lower slopes of mountain valleys, or on plateaus and plains. Slope position, aspect and the distribution and depth of permafrost are major influences on vegetation distribution and dynamics. In steep terrain, active slope processes (rock slides, slumps, talus cones) make a major contribution to the distribution of forests.
Subarctic Subalpine Zone 	**SUS**	This zone is dominated by tall or low shrubs, with sparse or sporadic tree cover. It generally occurs at high elevations in northern mountain systems. However, its distribution in some areas of northern Yukon appears to be influenced by arctic weather systems; this situation may require a different bioclimate zone designation.

Bioclimate Region/Zone	Code	Description
Arctic Bioclimate Region		
Arctic Tundra Low Shrub Zone 	**ARLS**	This zone occurs on the Yukon North Slope, east of the Firth River. It occurs at elevations from sea level to 500 m on the coastal plain and extends southward into the lower valleys of the British and Richardson Mountains. The Arctic Low Shrub zone occurs below the Arctic Dwarf Shrub zone in the mountains; further south and east it is bounded by the Subalpine Woodland of Old Crow and the Mackenzie Delta. In the ARLS ecosystem diversity is high. Zonal vegetation is characterized by low shrubs often > 40 cm tall; however, sedge tussock tundra with low shrubs, tall shrub riparian ecosystems and peat development are also common features. This bioclimate zone is equivalent to the "E" bioclimate subzone in Circumpolar Arctic Vegetation Map (CAVM Team 2003).
Arctic Tundra Dwarf Shrub Zone 	**ARDS**	This zone occurs on the Yukon North Slope, on the coastal plain west of the Firth River (sea level to 500 m) and at mid to high elevations (approx. 500–900 m) throughout the British and Richardson Mountains, between the ARLS zone and the Arctic Alpine Tundra zone. This zone continues west, extending into the Alaska coastal plain. Zonal vegetation has high percent cover and is dominated by ground shrubs; taller shrubs do occur (typically <40cm) but are generally restricted to riparian or other protected sites. This bioclimate zone is equivalent to the "D" bioclimate subzone in Circumpolar Arctic Vegetation Map (CAVM Team 2003).
Pacific Maritime Bioclimate Region		
Pacific Maritime Glacierized Zone 	**PMG**	This zone has high elevations associated with the Saint Elias Mountains and Pacific Ocean influences. In the Yukon it is also known as the Saint Elias Icefields. Rock, ice and snow comprise the dominant ground cover. Nunataks occasionally rise above the icefields and host a sparse vegetation of herbs, cryptograms and dwarf shrubs.
Alpine Tundra Bioclimate Region (Boreal, Subarctic and Arctic)		
Alpine Tundra Zone 	**AT**	In the Boreal region, the alpine tundra zone occurs above the Boreal Subalpine (BOS) zone at high elevations (above altitudinal treeline). Moving northwards into the subarctic, the alpine tundra zone occurs at mid to high elevations, above the Subarctic Subalpine (SUS) zone. In the arctic region, arctic alpine tundra occurs on the Yukon North Slope in the British and Richardson Mountains at high elevations (> 950m), above the Tundra Dwarf Shrub (ARDS) zone, where increasingly harsh conditions reduce vegetation cover and eliminate taller woody shrubs. In all alpine tundra environments, dwarf and low shrubs, herbs and cryptogams dominate the vegetation cover. At very high elevations, bare rock, colluvium or ice/snow may be the dominant conditions. The Alpine Tundra zone that occurs in Boreal, Subarctic and Arctic regions can likely be classified and mapped as distinct alpine tundra bioclimatic zones using vegetation communities and climatic characteristics, but this work has not yet been done. The arctic alpine tundra is equivalent to the "C" bioclimate subzone in Circumpolar Arctic Vegetation Map (CAVM Team 2003).

3.1.1.2 SITE CLASSIFICATION

Ecosite

Ecosites are the detailed site-level building blocks of YBEC. They are interpreted within the context of the bioclimate zone or subzone in which they occur. Ecosites are relatively stable and enduring features. They are defined by characteristic site conditions (the soil moisture and nutrients available) and landscape positions.

Ecosites are sometimes divided into phases. **Ecosite phases** are based on soil properties within an ecosite. The different soil properties do not alter the primary ecological conditions of the ecosite, i.e., the soil moisture or nutrient conditions or other ecological drivers. Instead, they represent subsets of environmental conditions where compensating factors result in similar overall vegetation and ecological conditions. For example, a coarse-textured soil on a lower slope position can have the same moisture conditions as a medium-textured soil on a mid-slope position. When phases are designated, the selected soil conditions are thought to be important to the use of the classification.

An **edatopic grid** shows the relative moisture and nutrient conditions associated with ecosites, and illustrates how various ecosites are organized in relation to each other (Figure 3). Within a bioclimate zone or subzone, the location of ecosites in the landscape is expected to be relatively predictable. Ecosites have characteristic vegetation associations that are based on their mature or relatively stable phase. Conceptually, ecosites may be organized along a landscape profile — called a **toposequence** — where certain ecosites are associated with different areas of the landscape based on moisture, nutrients and other factors (Figure 4).

Ecosites are coded using a two-digit number that indicates, by its number "series," a certain range of soil moisture and soil nutrient conditions within the edatopic grid. Wetlands are a special case of the ecosite code. Wetlands are designated with a two-character alpha-numeric code, where the first character signifies the wetland class and the second a number. At the time of publication, site unit names and codes have only been formalized for the Boreal Low zone.

3.1.1.3 VEGETATION CLASSIFICATION

Vegetation Association

The vegetation association describes the current vegetation growing on a specific ecosite. In a landscape dominated by disturbance, such as Yukon's boreal forest (where much of the landscape may be in a young post-fire condition), describing the current vegetation characteristics of ecosites is required. However, the vegetation association that best characterizes the reference site is one that is relative stable in its composition (typically 80 to 90 years old).

The vegetation association is the basic unit of a hierarchy of vegetation units (Figure 1). It is used in YBEC to characterize the vegetation and its variation within ecosites.

An **association** is a vegetation classification unit "defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions, and physiognomy" (Faber-Langendoen et al. 2014).

A **subassociation** is a division of an association. It is generally used to characterize variation in species composition that is not considered significant enough to be an association.

Canadian National Vegetation Classification, or CNVC (http://cnvc-cnvc.ca) system protocols are used to identify, name and describe vegetation associations and subassociations.

3.1.2 NAMES AND CODES

3.1.2.1 VEGETATION UNIT NAMES AND CODES

Every vegetation association has a name and code.

Vegetation associations are named according to one or more dominant and/or indicator species. Species of different "layers" — i.e., tree, shrub, herb or moss/lichen — are separated by a forward slash (/). Species within the same layer are separated by an en dash (–). When numerous species comprise the same layer, or when sampling data or species verification were insufficient to determine the genus of the species level, species are combined into a general term or group (e.g., "lichen," "feathermoss" or "*Carex* spp.")

Vegetation subassociations are generally used to characterize variation in species composition that is not considered significant enough to be an association.

Each vegetation association is assigned an alphanumeric code. The alpha portion describes the treed or non-treed vegetation overstorey (Table 2). The numeric portion describes the soil moisture as a relative ranking (Table 3). The soil moisture value is a relative ranking between vegetation associations with similar overstorey compositions. Subassociations (if used) are coded with a single, lower-case letter added to the association code.

Treed associations are described by one or two alpha characters that represent the dominant tree species in the canopy. These alpha characters are consistent with those used by the Forest Management Branch, Department of Energy Mines and Resources, Government of Yukon.

Non-treed associations are described by four alpha characters: the first two letters of the genus and of the species of the dominant or diagnostic species in the overstorey canopy.

These are some examples of treed and non-treed vegetation association alphanumeric codes:

- Sw11 — White spruce association on a dry site;
- FSb35 — Subalpine fir-Black spruce association on a moist site;
- Caaq55 —*Carex aquatilis* association on a wet site; and
- Begl30 — *Betula glandulosa* association on a mesic site.

Table 2. Alpha characters: treed and non-treed association codes

Alpha Characters	**Treed Associations**
A	Aspen
B	Balsam poplar
W	White birch (paper, Alaska paper)
F	Subalpine fir
L	Tamarack, Larch
P	Lodgepole pine
Sw	White spruce
Sb	Black spruce
	Non-Treed Associations
Begl	*Betula glandulosa*
Hoju	*Hordeum jubatum*
Caaq	*Carex aquatilis*
Aruv	*Arctostaphylos uva-ursi*

Table 3. Numeric characters used in vegetation association codes

Numeric character	**Landscape context**	**Soil moisture condition**
	Upland Sites	
01-19		xeric to dry
20-39		mesic to moist
	Wetland Sites	
40-49	bogs	moist to wet
50-69	fens, swamps, marshes	wet
70-79	shallow open water	wet

Photo taken in the Boreal Subalpine (BOS) bioclimate zone, southwest of Dawson City, overlooking the valley below.

3.1.2.2 BIOCLIMATE UNIT

Zone names combine Bioclimate Regions (Boreal, Subarctic, Arctic), elevational position (low, high, subalpine, alpine), and/or physiognomy (woodland, low shrub, dwarf shrub). Codes are three or four letters long and use components of the descriptive terms. For example, the Boreal Low is coded BOL and Boreal High is coded BOH. The zone above the BOH is the Boreal Subalpine and is coded BOS.

Subzones are named according to the ecoregion that most overlaps the range of the subzone. They use a two-letter, lower-case code that is somewhat descriptive. For example, the BOL subzone that encompasses much of the Southern Lakes ecoregion is named Southern Lakes and the code is "sl" (see Figure 2).

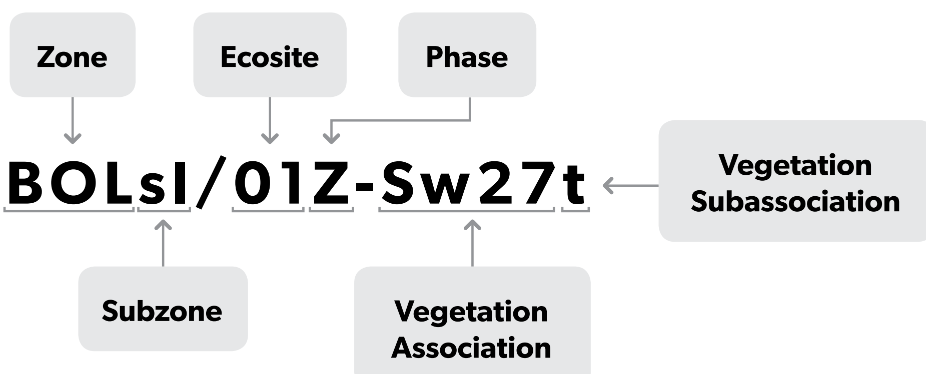


Figure 2. Ecosite coding format used for naming an ecosite within the Yukon Bioclimate Ecosystem Classification system

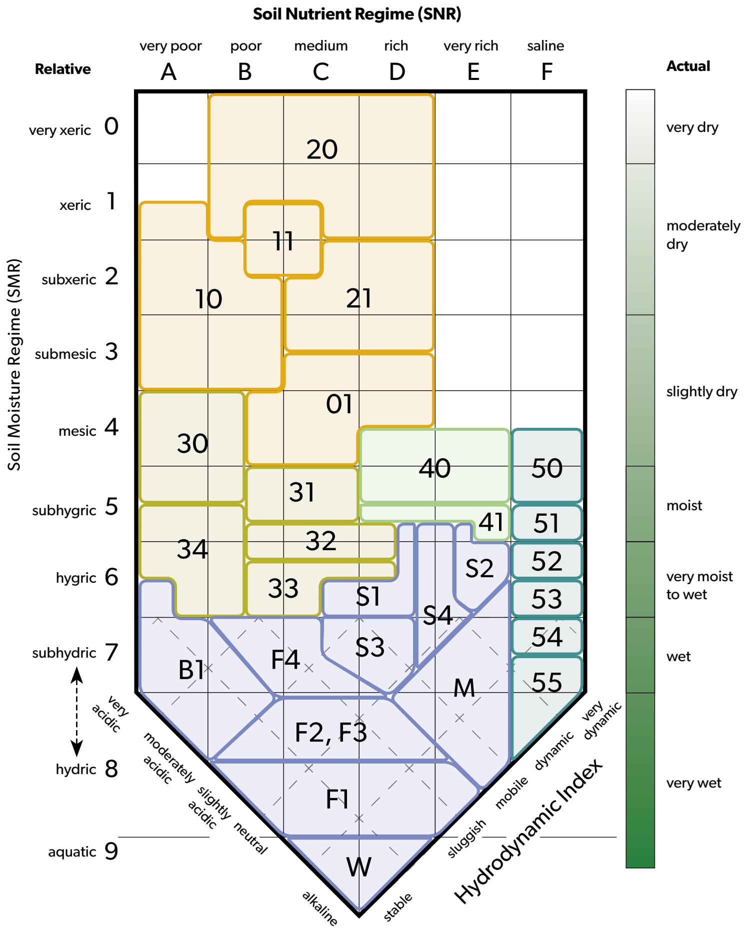


Figure 3. Example edatopic grid illustrating relative moisture and nutrient position of various ecosites in the Southern Lakes subzone of the Boreal Low bioclimate zone

Source: Environment Yukon, in press

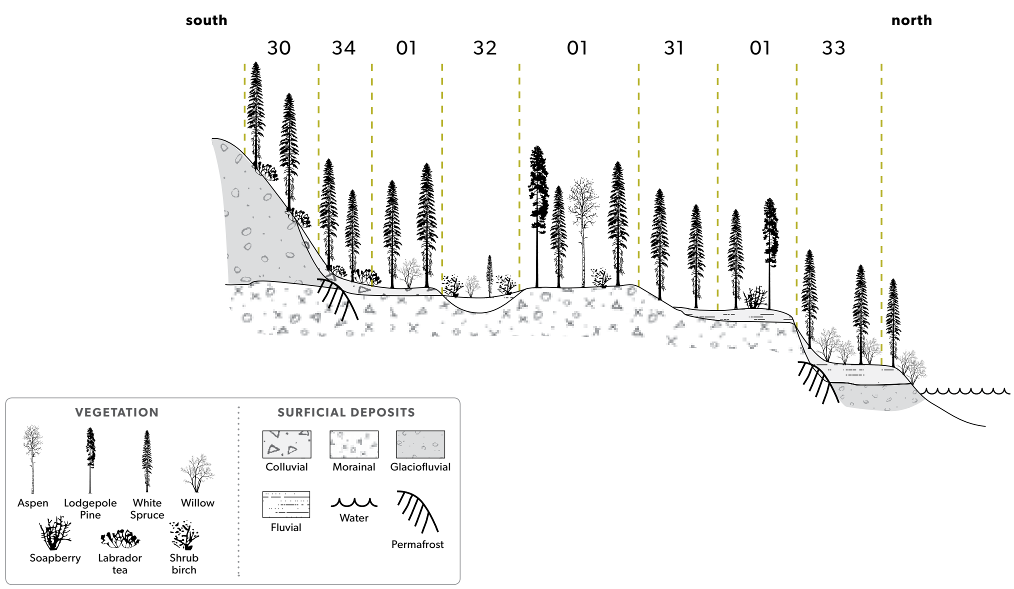


Figure 4. Example toposequence illustrating landscape positions and other factors that influence the distribution of ecosites (Environment Yukon, in press)

3.1.3 MAPPING

This section describes the three general levels of mapping used in the YBEC: bioclimate zones and subzones; broad ecosystems; and local ecosystems. (Ecological mapping guidelines are discussed in Section 4.) They are listed here, from the most general to the most detailed:

3.1.3.1 BIOCLIMATE ZONES AND SUBZONES

Bioclimate zones and subzones are relatively large areas with similar climatic conditions. They are characterized by reference sites and the kind and pattern of ecosystems on drier, wetter, poorer and richer sites to differentiate subzones. Mapping of Yukon's bioclimate zones is shown in Figure 5. Mapping of bioclimate zones and subzones shows the major ecological patterns across Yukon and is intended for regional applications (1:100,000 to 1:1,000,000 scale). This mapping is used to establish the ecological context for broad or local ecosystems. It can be combined with other map information, such as ecoregions or vegetation inventory (forest inventory), to produce the desired interpretations. As of the date of this publication, bioclimate subzone mapping had not been finalized for Yukon. A draft version of bioclimate subzones is being assessed, however, using climate data and distribution of vegetation associations on reference and non-reference sites. For more information about Yukon bioclimate zones and subzones please contact the ELC Coordinator (contact information is listed in Section 6.1).

3.1.3.2 BROAD ECOSYSTEMS

Broad ecosystems are generalized ecosites. Broad ecosystems are a map-based interpretation of the classification framework, not a formal part of the classification. This mapping level is included in YBEC to provide basic ecosystem information for large geographic areas in a rapid and cost-effective manner. Broad ecosystems can be mapped and interpreted at scales relevant to regional applications (1:50,000 to 1:250,000). These can include regional land-use planning, wildlife management and cumulative effects assessment. Broad ecosystem mapping has been completed for 50% of the Yukon, including the North Yukon, Peel Watershed and Dawson planning regions and a portion of east-central Yukon.

Broad ecosystems are usually mapped using predictive ecosystem mapping methods, including, satellite imagery or other land cover information, surficial geology and elevation model analysis. These datasets are combined in various ways, depending on the information available and the understanding of ecosystems within a project area. As with local ecosystems, Broad Ecosystem Units (BEUs) include a site and vegetation component: BEU type and BEU stage. The BEU stage in this context describes the generalized vegetation condition at a site (e.g., deciduous versus coniferous forest). BEUs are intended to be interpreted in the context of bioclimate zones or subzones.

3.1.3.3 LOCAL ECOSYSTEMS

Local ecosystem mapping is YBEC's most detailed mapping level. Local ecosystems are intended to be mapped and interpreted at a large scale (1:10,000 to 1:50,000). This mapping usually requires manual mapping methods in areas where higher levels of detail and accuracy are required, such as planning for transportation corridors, or environmental assessment related to mining, oil and gas, forest harvest planning, or municipal development activities. Local ecosystem mapping consists of **ecosite** and **ecosite phase** mapping. A number of local ecosystem mapping projects using a range of methods and terminology have been completed throughout Yukon.

Table 4 shows the spatial hierarchy of YBEC classification and associated map products.

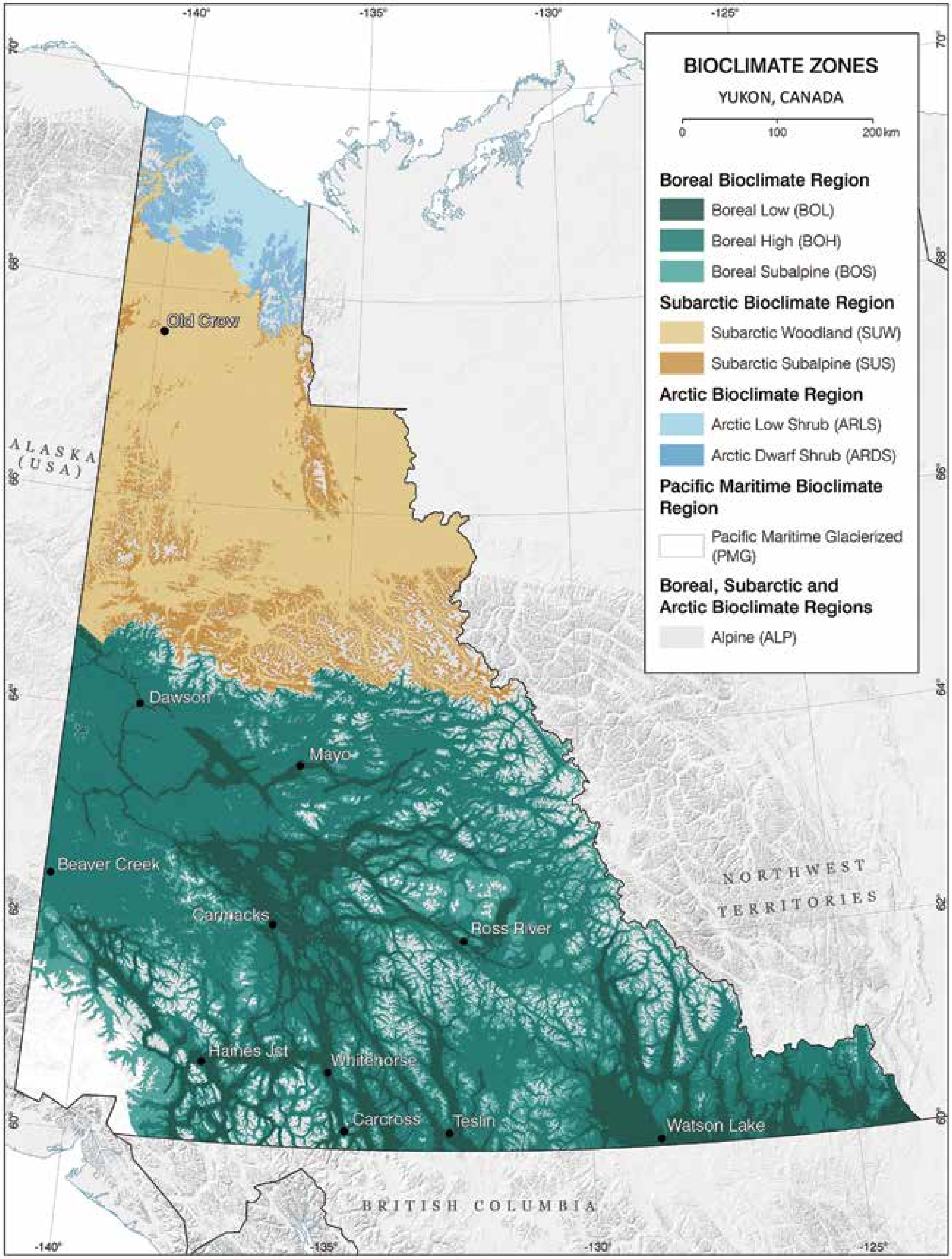


Figure 5. Yukon bioclimate zones (Version 1.0)

Table 4. Spatial hierarchy of Yukon bioclimate framework classification and mapping

YBEC classification level	YBEC mapping level and scale		Example
BIOCLIMATE	**Bioclimate**	Zone	Boreal Low
	(1:100,000 to 1:1,000,000)	Subzone	Southern Lakes
SITE	**Broad Ecosystems**	Type	Dry Terrace and Plain
	(1:50,000 to 1:250,000)	Stage	Coniferous
	Local Ecosystems	Ecosite	Lodgepole Pine-Spruce-Grass-Lichen
	(1:10,000 to 1:50,000)	Association	Lodgepole Pine-Lichen/young-seral

Regional ↑ SCALE ↓ Local

3.1.4 STATUS OF YBEC

Development of a vegetation association classification for Yukon was initiated in 2004 by Environment Yukon, in partnership with the Canadian Forest Service (Natural Resources Canada). The ELC Program is coordinating the development of vegetation associations for treed, shrub, grassland and wetland communities across Yukon. This initiative has produced a vegetation association classification for the arctic region of Yukon and preliminary vegetation associations for treed associations across Yukon.

These vegetation associations can be organized within an edatopic grid (Figure 3) and used to describe ecosites along generalized toposequences for various bioclimate zones and subzones.

A field guide to ecosite identification for the Boreal Low zone of Yukon with one subzone chapter completed for Southern Lakes is due to be released in fall 2016.

For more information about the status of ecosite, vegetation association classification and/or how vegetation associations are incorporated in YBEC please contact the ELC Coordinator. Contact information is provided in Section 6.1.

3.2 NATIONAL ECOLOGICAL FRAMEWORK OF CANADA

3.2.1 OVERVIEW

The National Ecological Framework (NEF) classifies and maps ecological areas to identify land units with similar biophysical properties at different scales (ESWG 1995). The system is hierarchical: more detailed units are divisions of broader units. The NEF has a strong focus on physiography and landscape patterns, but also considers climate and vegetation.

At the continental scale, ecological units are subdivisions of major climatic zones and broad physiographic regions (e.g., Boreal Cordillera and Taiga Cordillera) Within these broad **ecozones**, smaller geographic areas — **ecoregions** — are identified, with an increasing emphasis on similar landforms, climate and vegetation patterns. The NEF views each area as a discrete system resulting from the interactions of geology, landform, soil, vegetation, climate, wildlife and human activities (Smith et al. 2004).

Three levels of the NEF are used in Yukon. From the most general to the most detailed they are ecozones, ecoregions and ecodistricts:

3.2.1.1 ECOZONES

Ecozones are large and very generalized ecological units; they are characterized by interactive and modifying abiotic and biotic factors. Five ecozones are recognized in Yukon; the Boreal and Taiga cordilleras are the largest units.

3.2.1.2 ECOREGIONS

Ecoregions are smaller areas within an ecozone. They are characterized by distinctive physiography and ecological responses to climate, as expressed by the development of vegetation, soil, water and fauna. Ecoregions provide an important reporting framework for many Yukon management initiatives and processes.

3.2.1.3 ECODISTRICTS

Ecodistricts are components of an ecoregion. They are characterized by distinctive relief, geology, landforms, soils and vegetation. Ecodistricts are the most detailed level of the NEF used in Yukon, and have been used as reporting units and inputs to mapping initiatives.

Each ecodistrict contains smaller areas called Soil landscape units. Soil landscape units of the Soil Landscapes of Canada (SLC) database are large-scale and detailed physiographic units. The SLC database, developed and maintained by Agriculture and Agri-food Canada, is the foundation on which ecodistricts, ecoregions and ecozones are developed. Updated soil landscape unit mapping was completed in 2012 for all of Yukon at a map scale of 1:250,000 — release of this is pending.

3.2.2 STATUS OF THE NEF

Ecoregions of the Yukon Territory (Smith et al. 2004) should be referenced as the primary source of ecoregion descriptions. A map depicting Yukon's NEF units at the ecozone and ecoregion level is shown in Figure 6. A revision to the boundaries of Yukon ecoregions is underway at the time of writing. This revision will reflect current understanding of glacial history and boreal vegetation characteristics, and will incorporate advances in digital base data and relief mapping. Revised ecoregion boundaries are being correlated with adjacent jurisdictions (Alaska, Northwest Territories and British Columbia). See Case Study 1, describing the ecoregion updates, in Appendix 2.

Wetland complex showing areas of permafrost degradation (basins) and growth (treed areas).

Figure 6. Yukon ecoregions

Source: National Ecological Framework for Canada (ESWG 1995)

4
ECOLOGICAL MAPPING GUIDELINES

Ecosystem mapping divides a landscape into map units that represent single or multiple ecosystems. Broad and local ecosystem units are identified by integrating a range of ecological factors, including climate, physiography, geology, surficial material and surface expression, as well as vegetation type and successional stage. For many land and resource managers, Ecological and Landscape Classification (ELC) maps and their derived interpretations are the most frequently used ELC products. Guidelines for conducting broad and local ecosystem mapping, and an introduction to ELC mapping concepts, are provided below.

The Yukon ELC Program will be responsible for completing bioclimate zone and subzone mapping, and for producing and distributing Ecoregions of Yukon updates using the NEF. Mapping guidelines for these products have therefore not been included in this document. For more information on NEF mapping methods, please refer to the documentation provided in Ecological Stratification Working Group (ESWG 1995).

4.1 MAPPING METHODS

4.1.1 TYPES OF ECOSYSTEM MAPS

In general, ecosystem mapping is conducted using one of three methods:

- Manual process — visually interpreting aerial photographs or satellite images to identify and delineate ecosystems and their attributes;
- GIS modeling, or predictive approaches — using knowledge of ecosystem patterns and relationships to predict the locations of ecosystems on the landscape; and
- Hybrid approach — using manual methods to supplement, or increase the accuracy of, certain features within a map modelled with GIS.

Each method is described in detail below.

4.1.1.1 MANUAL ECOSYSTEM MAPPING

In this method, mappers examine and interpret aerial photographs, satellite imagery or similar information. They then manually delineate ecosystem units (e.g., draw polygons on aerial photographs or digitize polygons in GIS). Before the development of advanced GIS and the availability of digital spatial data (such as elevation models, land cover and soil mapping) most ecosystem mapping used this process. Detailed, manually derived ecosystem mapping products can be more costly to produce than modeled ELC products. They are used for specific applications where a higher level of detail, accuracy and/or map resolution is needed, or to create map products that are difficult to model, such as wetlands.

Producing manual ecosystem maps may use base feature mapping at a matching scale (e.g., water bodies, rivers, topography, etc.). In most areas of Yukon a 1:50,000 base feature map is the most detailed scale available. Maps with scales greater than 1:50,000 may exist for specific areas such as Yukon communities and major transportation corridors. If an adequate base feature map is not available for the project area, base features may be captured from imagery at an appropriate scale.

Manually produced ecosystem maps might be needed for environmental impact assessment; development of transportation and industrial infrastructure; planning for transportation, municipal and forestry site-level initiatives; and mapping of sensitive features. The City of Whitehorse baseline studies for the Southern Lakes (Case Study 5) and baseline studies for Selwyn (Case

Study 7) are examples of manually created, local-scale ecosystem mapping.

4.1.1.2 MODELLED ECOSYSTEM MAPPING

This method uses knowledge-based computer models and GIS-based approaches to develop ecosystem maps. It is also called predictive ecosystem mapping (PEM). This type of modeling makes it possible to map ecosystems across large geographic areas in a rapid and cost-effective manner. Ecosystem modeling creates single, consistent coverage at one point in time and at a uniform map scale; this is often not possible through manual mapping methods.

Modeling approaches are typically used to provide basic ecological information. They are well-suited to support regional planning, wildlife and habitat management, regional cumulative effects assessment and management, and similar applications. For many of these management activities, detailed mapping may not be needed and would be costly to develop. The Ross River area (Grods et al. 2012a) and Dawson Planning Region (Grods et al. 2012b) provide examples of Yukon PEM methods and applications. Case Study 3, describing the use of predictive broad ecosystem mapping in the Peel Watershed (Meikle and Waterreus 2008), is provided in Appendix 2.

Ecosystem modeling requires an assessment of the spatial and thematic source data used. Assessing the relative accuracy of spatial data inputs determines where classification errors are likely to occur. It also helps establish confidence in the resulting map products and guides the mapping process and modeling effort.

Although modeling ecosystems can be cost-effective and efficient, it is important to recognize its limitation. The ability to produce modeled ecosystem maps — and the quality of the output — relies heavily on both the availability and quality of the digital GIS information, and on an adequate knowledge of ecosystems within an area. Detailed, manually-created ELC products to support site-specific management activities are still relevant.

4.1.1.3 HYBRID ECOSYSTEM MAPPING

This method combines manual interpretation methods with modeling to create a single integrated product. A common approach is to conduct ecosystem modeling across a large geographic area, and then use manual interpretation to better delineate and classify ecosystems of limited spatial extent, such as wetlands, grasslands or alpine areas. Hybrid products can deliver general, consistent ecosystem information for large geographic areas, while also providing additional detail about ecosystems of management interest or concern.

Understanding the objectives and intended uses of an ecosystem mapping exercise is important to the success of hybrid mapping projects. A hybrid approach was used to map ecosystems along the proposed Alaska Highway Pipeline corridor (see Case Study 6, Appendix 2).

4.1.2 MAPPING SCALE AND INTENDED USE

Map scale refers to the ratio between the size of the feature on a map and the size of a feature in the real world. For example, a map scale of 1:50,000 means one unit on the map relates to 50,000 units in the real world. Large-scale mapping is generally considered to be a map scale of 1:50,000 or larger (e.g., 1:10,000 scale). Maps created at scales of 1:100,000 or smalller (e.g., 1:250,000) are considered to be small-scale maps.

As the map scale becomes larger (e.g., 1:10,000 scale), map features can more closely approximate those features in the real world; they can be represented with higher resolution and greater levels of detail.

Different applications require different scales and types of ecosystem mapping. Mapping objectives are therefore important considerations when beginning a mapping project. Selecting the appropriate map scale and product for the intended application will ensure that the mapping meets the needs of the end user. Different map products also have different costs. To illustrate this further, Figure 7 shows the relationship between map scale, cost and intended management applications, and the most appropriate Yukon ELC Framework map product to use. More generalized mapping may be appropriate for applications such as regional land-use planning; more detailed local ecosystem mapping is needed for applications such as planning for infrastructure corridors or identifying locally important habitat values for a species of interest. Local ecosystem maps generally cost more per unit area to complete than smaller scale (less detailed) mapping.

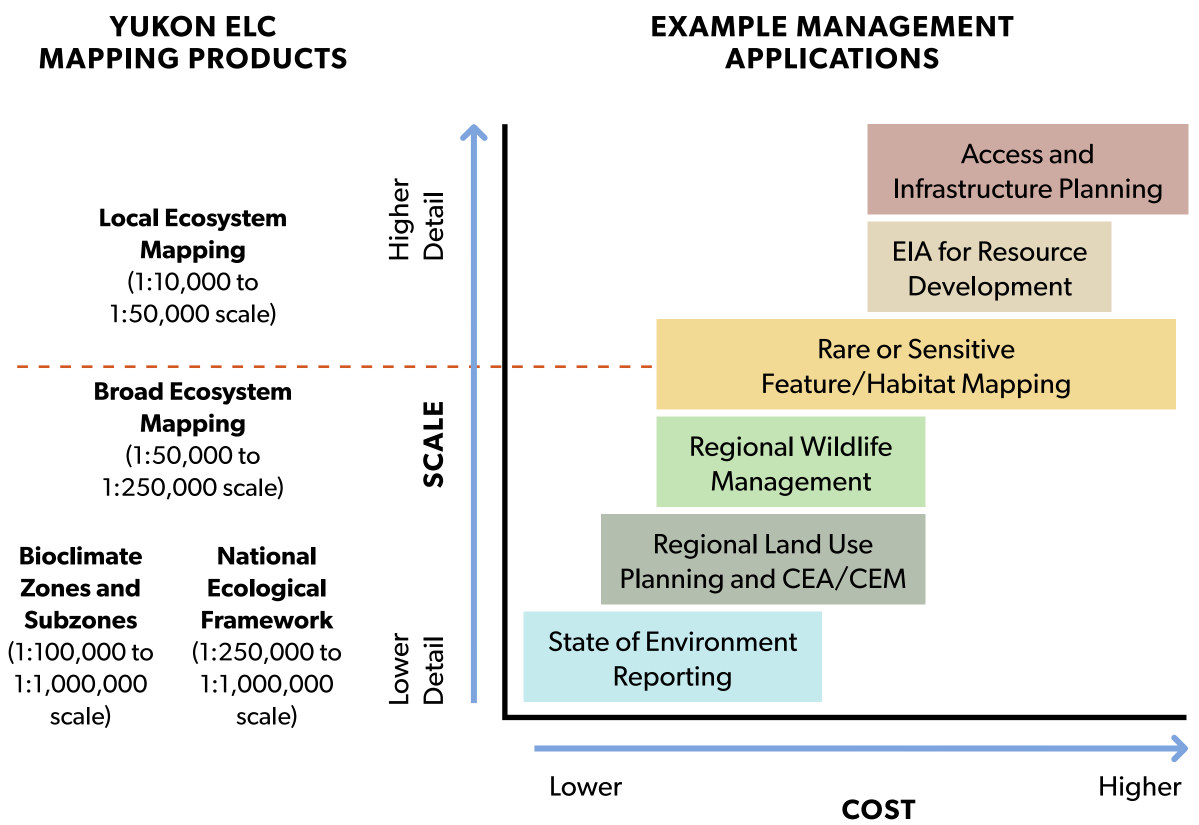


Figure 7. Generalized relationship between map scale and cost, showing example management applications and relevant Yukon ELC mapping products

CEA: Canadian Environmental Assessment   CEM: Cumulative Effects Modelling
Adapted from Meikle, John, in Jones et al. 2008

4.1.3 REPRESENTING MAP FEATURES: POLYGONS VERSUS GRIDS

The spatial representation of map units is an important consideration in mapping. The spatial properties (shape and area) of ecosystem map units can be represented through either raster (grids) or vector (polygons) geometry. Raster-based ecosystem mapping divides the mapping area into a grid of equally sized cells, and assigns an ecosystem class to each cell or group of cells. This approach is used in satellite image classification: each pixel receives a distinct value. Vector approaches represent ecosystem map units as polygons. Each polygon represents a single ecosystem or multiple ecosystems. Examples of raster and vector mapping are shown in Figure 8.

Both raster and vector mapping have benefits and drawbacks. Raster approaches are typically used for creating predictive maps, while vector approaches are commonly used to create manual ecosystem maps. Vector mapping more accurately represents the true size and geometry of map features, including linear components such as rivers and roads. In comparison, raster mapping uses pixel geometry. It is more computationally efficient when used in a GIS and it allows for efficient data updates and map revisions when new information or improved data layers become available.

4.1.4 MAP UNIT SIZE

Very small real-world features cannot be represented as discrete polygons or pixels on ecosystem maps. Vector mapping requires a minimum polygon size, which is a function of the scale of available base feature map and the desired scale of the ecosystem map. For most applications, a minimum map polygon size of 0.5 cm^2 (e.g., 0.7 cm × 0.7 cm) is recommended. At different map scales, this minimum map polygon size corresponds to various land areas:

- 0.5 hectares (ha) at a scale of 1:10,000;
- 2.0 ha at 1:20,000;
- 12.5 ha at 1:50,000;
- 50.0 ha at 1:100,000; and
- 306 ha at 1:250,000.

In raster mapping, the grid cell size determines the minimum size of an ecosystem map unit. Determining a suitable grid cell size should be based on the resolution of the most generalized input source data layer. For most broad ecosystem mapping projects completed in Yukon, a 25 m or 30 m cell size is used. These cell sizes correspond to land areas of 0.0625 and 0.090 ha, respectively. A 30 m cell size matches the resolution of the Yukon 30 m digital elevation model, which is an important GIS data input for broad ecosystem mapping.

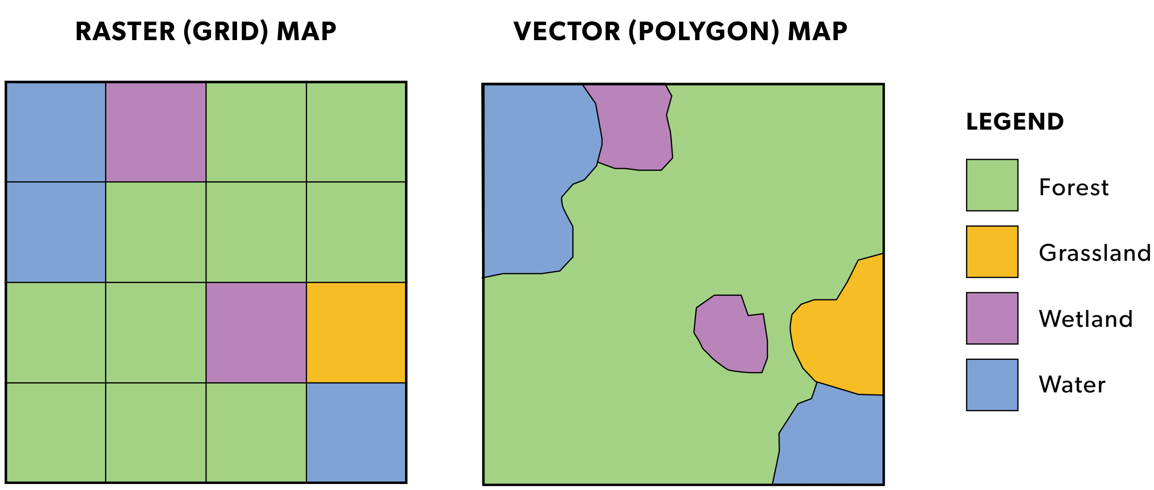


Figure 8. Examples of raster (grid) and vector (polygon) map feature geometry that can be used to represent ecosystem map units

4.1.5 FIELD SAMPLING

Before beginning a mapping exercise, mappers use field surveys to familiarize themselves with the project area and its ecosystem characteristics. Field sampling is also needed to develop and refine the classification of ecosystem units and to confirm ecosystem boundaries.

Survey intensity refers to the level of field sampling effort completed during a mapping project. It is a measure of sampling density and is often characterized as the percentage of polygons that received field inspection. Sampling density can also be expressed as hectares per sample — which may be desired for sampling a raster mapping product or for setting contract goals, as actual number of polygons will not be known until after the mapping. Depending on the mapping scale and intended use, different levels of survey intensity are needed to adequately sample a project area. Table 5 presents survey intensity levels (SIL) along with other factors that can assist with determining the appropriate SIL for a project. These include recommended percentage of polygon inspections, hectares per inspection, possible mapping methods, and likely study area size, mapping scale and desired interpretations. These recommended survey intensity levels are the same as those in Resource Inventory Committee (RIC 1998) but the table content has been modified somewhat to reflect Yukon requirements.

A qualitative evaluation of map accuracy data with survey intensity level in British Columbia shows a positive correlation. However, other factors also impact on map accuracy, including experience of mappers in the area of mapping, quality of imagery, number of ecosystem types (mapping entities) to be mapped, and distinctiveness of the ecosystem types on imagery.

Various sample types could be used in mapping. Full plots, for example, those that use the Environment Yukon forms: Project, Plot, Vegetation, and Soil, are the most complete data that can be collected to evaluate an ecosystem. However, these plots are not normally collected during a mapping project due to the time required to collect the data. These detailed plots are very useful for developing an ecosystem or vegetation classification and are valuable additions to a mapping project, where a classification framework is needed. Two inspection types are recommended for use in map sampling:

1. Ground inspections: These are generally the most detailed type of map assessment check. These are usually plots of a standard size (400m2) where basic site, soil and vegetation data is collected. These inspections differ from "full" plots in that only key data fields are considered, and the species list (including cover) is abbreviated, e.g., setting a lower limit of about 1% cover for recording.
2. Visual checks: These are very quick recordings of the location and ecosystem or map unit identification, and any other information that the project requires (e.g., structural stage, stand composition). A visual check may or may not be 'on-site', i.e., it could be an observation from a helicopter or a viewpoint or with high-quality drone photography, etc.

In polygon mapping, if it is possible to observe most of the polygon, it is also very helpful to include an estimate of proportion of the polygon covered by the inspection, or if there are other types in the polygon.

In raster mapping, belt transects generally provide the best quality data for assessing mapping algorithms. If transects are used for sampling, each segment of about 50 m is approximately equivalent to a ground inspection, as long as equivalent data is collected along the transect.

See Section 6 of RIC (1998) for detailed information on field sampling methods and concepts.

Table 5. Recommended survey intensity levels for different scales of polygon-based ecosystem mapping

Survey intensity level	Percent of polygon inspections[1] (ha per inspection)	Ratio of ground insp: visual checks[2]	Applicable scales[3] (k=1000)	Area covered by 0.5 cm^2 (ha)	Range of study area[4] (ha)	Mapping method	Interpretation examples[4]
1	76–100% (0.9–5)	15 : 85	1:5K to 1:10K	0.25 – 0.5	20–500	Manual	Access and infrastructure planning; detailed environmental assessment of small area; silviculture planning for proposed cutblock, etc.
2	51–75% (5–30)	20 : 80	1:10K to 1:20K	0.5 – 2	100 – 10,000	Manual	Access and infrastructure planning; detailed environmental assessment of small area; silviculture planning for small area, etc.
3	26–50% (10–350)	25 : 75	1:10K to 1:50K	0.5 – 12.5	5,000 – 50,000	Manual	Detailed environmental assessment, habitat enhancement, environmental mitigation, or silviculture planning of moderate area, etc.
4	15–25% (60 – 600)	25 : 75	1:20K to 1:50K	2 – 12.5	10,000–500,000	Manual, predictive, hybrid	Wildlife, land-use planning, forestry planning, environmental assessment or mitigation for moderate to large area, etc.
5	5–14% (100–1,800)	25 : 75	1:20K to 1:50K	2 – 12.5	10,000 – 1,000,000	Manual, predictive, hybrid	Wildlife, land-use planning, forestry planning, environmental assessment or mitigation for moderate to large area, etc.
R	0–4% (300–9,000)	25 : 75	1:20K to 1:50K+	12.5 – 306	50,000–1,000,000+	Manual, predictive, hybrid	All regional applications (wildlife, regional land-use planning, cumulative effects, etc.)

Adapted from RIC 1998: 48–49; R = reconnaissance

1. Polygon inspection percentages are approximations, as the actual number of polygons is unknown until after the mapping; for contract purposes, suggest using hectares per inspection values appropriate to the scale of mapping and anticipated number of polygons.

2. Ground inspections and Visual checks are explained in the text. Full plots are not included in map survey inspections at this time. Where an existing classification does not exist, ground plots need to include enough detail to allow for classification; in these cases full plots are helpful in supplementing the ground data for greater understanding of mapping entities. Suggest contacting ELC Coordinator to discuss whether to include full plots for a project.

3. Scale, as noted here, refers to a printed map scale and gives a relative idea of the resolution of polygons on the map. In reality, with digital imagery and prevalence of GIS software, many maps are not produced in hard copy and mapping can be created and viewed at various scales.

4. Study area sizes and Interpretation examples are provided to give an idea of the kind of project that might fit the survey intensity level.

4.1.6 MAP ACCURACY

Map accuracy describes how closely the map represents the real world. It has two aspects:

- Thematic (classification) accuracy: Are the map units correctly classified when compared to the real world? For example, is a dry-terrace coniferous forest in the real world classified in the same way on the map?
- Spatial (feature) accuracy: Are the map units represented correctly? Do they have the correct area; are they in the correct location; and do they have the same shape (geometry) as real-world features?

Ecosystem mapping often has standards for an acceptable level of classification accuracy. To illustrate: if 100 map polygons are randomly checked through fieldwork and 50 polygons are found to be classified accurately, then the map could be assumed to have a classification accuracy of 50%. In most ecosystem mapping, achieving a polygon classification accuracy of 65% is considered adequate.

Performing an accuracy assessment is different than using field survey information to calibrate or train mappers during the mapping process. A true accuracy assessment should be completed by a third-party assessor, but this may become prohibitively expensive.

Mappers should determine the best methods to validate ecosystem mapping products. Assessing the accuracy of raster maps developed through GIS modeling can be challenging. It requires consideration of both the input data sources and the resultant mapping, and whether the assessment should be directed towards individual cells or groups of cells.

At this time, Environment Yukon has not developed rigorous methods for assessing raster GIS mapping or spatial accuracy. All mapping practitioners should strive to report their product accuracy using whatever best-practice methods are available to them. See Meidinger (2003) for additional guidance and methods on how to conduct accuracy assessments on various ecosystem map products.

4.2 MAPPING ECOSYSTEM UNITS

Guidelines for mapping broad and local ecosystem units are provided below. The bioterrain mapping concept is the initial step in delineating broad and local ecosystem units.

4.2.1 BIOTERRAIN MAPPING

Broad and local ecosystem mapping is based on the concept of bioterrain mapping. Bioterrain mapping identifies terrain, slope, landform, surficial material and soil conditions that affect the distribution of ecosystems by influencing moisture, nutrients, temperature and exposure to the sun. Bioterrain units are the relatively stable, enduring features on which vegetation and ecosystems develop. When identifying bioterrain units, mappers should not focus on identifying vegetation conditions; the goal is to identify relatively uniform site conditions that influence vegetation development. Vegetation conditions are then combined with the bioterrain unit to form the integrated ecosystem unit. Within a bioclimate zone or subzone, the pattern of ecosystems that develop on bioterrain units is relatively predictable.

An example of general bioterrain map units is provided in Table 6. Although there is no formal bioterrain classification, mappers are encouraged to produce a working legend, similar to that in Table 6, to show how terrain, slope, landform and soil conditions relate to ecosystem units. When delineating bioterrain units as part of local ecosystem mapping, practitioners are encouraged to refer to the definitions and descriptions of terrain features as described in *Terrain Classification System for British Columbia* (Howes and Kenk 1997), while considering Yukon-specific terrain processes (such as permafrost).

Table 6. Example working legend for bioterrain map units

Landscape position	Surficial material	Soil depth or texture
Level	Fluvial (floodplain)	Fine-textured
		Coarse-textured (rapidly drained)
	Glaciofluvial Terrace	Coarse-textured (rapidly drained)
		Medium-textured
	Morainal Till	Coarse-textured
		Medium-textured
	Eolian	Coarse-textured (rapidly drained)
	Lacustrine	Fine-textured (rapidly drained)
	Organic	Poorly drained
Moderate slope	Morainal till	Medium-textured
	Glaciofluvial	Coarse-textured (rapidly drained)
		Medium-textured
	Colluvial	Deep
		Shallow
Steep warm slope	Colluvial	Deep
		Shallow
	Morainal till	Deep
		Shallow
Steep cool slope	Colluvial	Deep
		Shallow
	Morainal till	Deep
		Shallow

Source: Adapted from Table 6.1 of RIC 1998

4.2.2 BROAD ECOSYSTEM UNITS

Broad ecosystem units (BEUs) are derived from combinations of landforms, special features and surficial materials, as well as vegetation and land cover. Landforms and special features/surficial materials are generalized bioterrain conditions. These conditions are used to infer general site conditions that represent the relative moisture and nutrient regime of BEUs.

To date, at least four broad ecosystem mapping projects using similar methods have been completed in Yukon. Mapping areas include the North Yukon Planning Region (Francis et al. 2005), the Peel Watershed Planning Region (Meikle and Waterreus 2008), the Ross River region of east-central Yukon (Grods et al. 2012a) and the Dawson Planning Region (Grods et al. 2012b). The Ross River and Dawson projects provide the most relevant examples of BEUs and methods that are listed here.

BEUs include a type and stage, and are organized by relative moisture groups:

> BEU type is a generalized bioterrain unit (Figure 9) that describes the landform or landscape position that represents the stable site on which vegetation develops. BEU types are grouped into one of three soil moisture classes: dry, moist or wet. BEU types in different bioclimate zones or subzones have different vegetation potential. A standard suite of BEU types and codes has been developed and is recommended for use throughout Yukon (Table 7).
>
> Permafrost has a strong influence on the relative moisture, site productivity and vegetation potential of BEU types. In areas of extensive permafrost, such as northern Yukon, the BEU type "gentle slope and plain" is wet and poorly drained. In southern Yukon, a region with only localized permafrost distribution, this BEU type is typically mesic.
>
> BEU stage describes the general vegetation or land cover condition of a BEU type. Six potential stages can occur on most BEU types: 1) herb-bryoid; 2) shrub; 3) deciduous; 4) mixed wood; 5) coniferous; and 6) rock/exposed. The classification level used to map vegetation stages is based on the formation level of the Canadian National Vegetation Classification (see http://cnvc-cnvc.ca). Physiognomy predominates at the formation level.

Broad ecosystems, similarly to ecosites, can be thought of as part of an edatopic grid of moisture and nutrients (Figure 10). In the broad ecosystem context, broadly defined BEU types (terrain) are associated with richer/poorer or wetter/drier conditions (Table 7). When BEU types and stages are combined, they form broad ecosystem units. Although a standard suite of broad ecosystems exist in concept for all of Yukon, it is also necessary to understand the bioclimate context in which a BEU occurs. When broad ecosystems are located within a known bioclimate zone or subzone, they can be described with more certainty and within a narrower range of vegetation and ecological conditions. For example, steep, low-elevation, south-facing slopes in northern Yukon may be forested, but are predominantly grasslands in southern Yukon.

Table 7. Recommended descriptions for broad ecosystem types for non-permafrost landscapes

Moisture group	Broad ecosystem unit type	Numeric code, broad ecosystem unit type *	Description
Dry	Ridge	110	Slope crests with convex surface form (moisture shedding sites).
	Steep South Slope	120	Slopes >25% with warm aspects (slopes facing south and southwest with orientation between 136° and 284°, as measured in a clockwise direction).
	Upper Slope	130	Slopes of varying steepness located below Ridges (110) but above Steep South Slope (120), Steep North Slope (150) or Gentle Slope and Plain (140).
	Dry Terrace and Plain	230	Generally level, raised river terraces and undulating outwash plains composed of coarse-textured glaciofluvial or eolian materials. These landforms are a special case of Gentle Slope and Plain (140), and are defined by their surficial materials.
Moist	Gentle Slope and Plain	140	Level or gently sloping (<15%) areas composed of non-glaciofluvial or non-eolian surficial materials. These BEU types are typically well-drained to moderately drained morainal till, and usually represent reference sites for bioclimate zones or subzones. In valley bottoms and gently rolling terrain, this BEU type may comprise large areas of the landscape. In some situations, particularly in permafrost landscapes, it may be appropriate to create two slope classes from this BEU type: Level (<5% slope) and Gentle Slope (6–15%). In that case, Level sites should be identified as (140) and Gentle Slopes as (220). Mappers are encouraged to investigate slope and vegetation patterns within their project area and use appropriate slope values.
	Steep North Slope	150	Slopes >25% with cool aspects (slopes facing north and northeast with orientation between 310° and 85°, as measured in a clockwise direction).
Wet	Drainage and Depression	160	Catchments and drainages in uplands with concave slope form (moisture receiving sites). These catchment areas may occur below Ridges (110) or Upper Slopes (130), or may occur as depressions within more level areas.
	Wetland	310	Bogs, fens, marshes and swamps with various vegetation development.
	Floodplains	370/380/390	Flat (<5% slope) areas along rivers influenced by fluvial processes (flooding, erosion and deposition). These areas contain riparian ecosystems. Floodplains may be subdivided into areas of Low, Moderate and High flood frequency.
	Open water and Ice	400	Open water bodies and large rivers defined by base feature mapping. Ice may be glaciers or perennial snow patches.

Note: Broad ecosystem types are generalized bioterrain types.
*See Figure 10

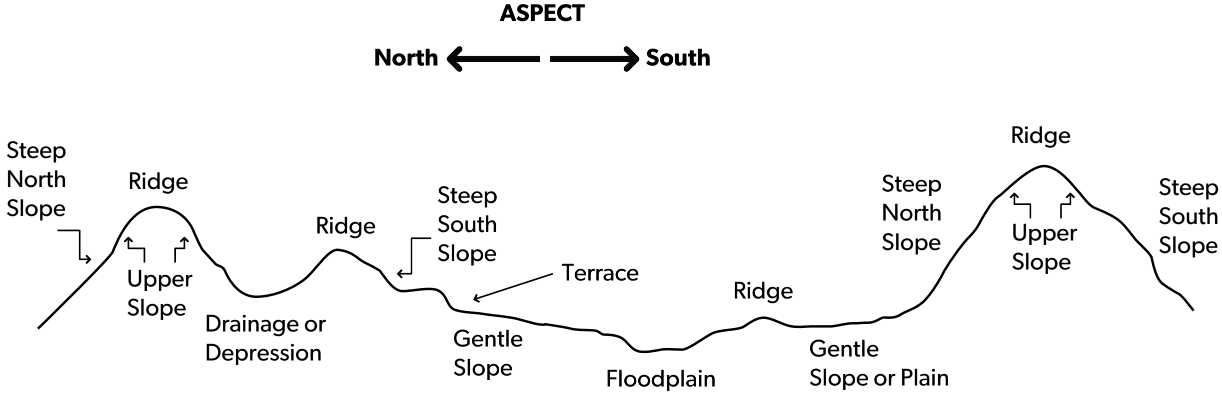


Figure 9. Example toposequence of generalized bioterrain used for broad ecosystem mapping

Source: *Regional Ecosystems of East-Central Yukon* (Grods et al. 2012a)

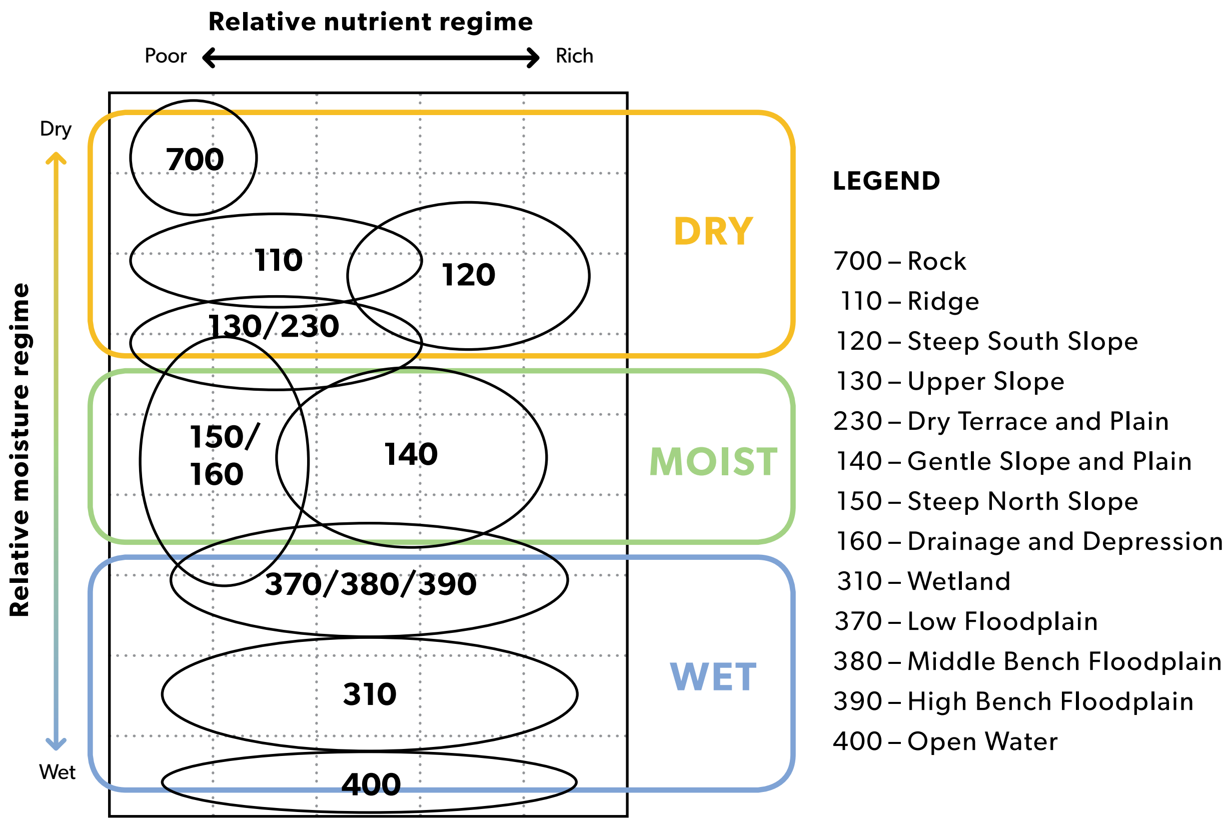


Figure 10. Example edatopic grid illustrating relative moisture and nutrient position of various broad ecosystem types in east-central Yukon

Source: *Regional Ecosystems of East-Central Yukon* (Grods et al. 2012a)

4.2.2.1 MAPPING

Broad ecosystems are usually mapped using a modeled GIS approach such as Predictive Ecosystem Mapping (PEM) that represents features as raster map units. However, broad ecosystems can also be depicted using polygons. The specific methods used to map broad ecosystems will depend on the availability, resolution and quality of data (vegetation and land cover, elevation model, surface material/special feature mapping, etc.), ecological characteristics of the project area, and knowledge the PEM practitioner has of the area being mapped. In broad ecosystem mapping, the goal of a mapping exercise is to identify generalized bioterrain units as BEU types listed in Table 7 and then to integrate land cover or vegetation mapping (BEU stage) to create the ecosystem unit.

Landform, slope and aspect conditions are characterized through topographic analysis of digital elevation models. Surficial material and base feature mapping are used to delineate special soil conditions (e.g., glaciofluvial or eolian materials and floodplains), water bodies and rivers. Land cover and vegetation data will change over time. Currently, land-cover data may include classified satellite imagery such as that from the Earth Observation for Sustainable Development of Forests (EOSD), Yukon Vegetation Inventory (forest inventory), Yukon Fire History mapping, and manually interpreted land-cover information. Higher resolution multi-spectral and NIR satellite imagery is becoming more readily available and affordable and may provide much-improved vegetation and land cover data for mapping purposes. The derived BEUs are then interpreted within the context of bioclimate zones or subzones.

4.2.3 LOCAL ECOSYSTEM UNITS

Local ecosystem units are comprised of one or more ecosites that can be mapped together as a unit. The ability to accurately delineate local ecosystems units depends on map scale, ground-truth data, the skill of the interpreter and knowledge of the relationships between bioterrain units and vegetation associations in a specific region.

Local ecosystem units include an **ecosite** which may include an **ecosite phase** (or more than one, if that is the case). In a bioclimate subzone, ecosites are organized by landscape position. Along the toposequence, characteristic ecosites occur in predictable locations, based on slope, aspect, parent material, and soil moisture and nutrients. The **reference site** generally occurs in a relatively level, moderately drained position. Permafrost conditions may affect the location of reference sites. Identifying ecosites in the mapped unit depends on an understanding of the bioclimate zone and subzone as well as knowledge about ecosystem patterns in a specific region.

To date, several local ecosystem mapping projects, using different classification and mapping methods, have been completed. Examples include the City of Whitehorse ecosystem mapping (Case Study 5), Southern Lakes wetlands mapping (Case Study 2) and the Selwyn project environmental baseline studies (Case Study 7; case studies are found in Appendix 2).

Local ecosystems are mapped at scales of 1:10,000 to 1:50,000. In Yukon, local ecosystem maps are usually produced through the manual interpretation of imagery (aerial photographs or fine-scale satellite imagery) and delineating polygons, either by hard-copy mapping or digital mapping. Using polygon (vector) mapping methods, the delineation of map units at a finer scale (e.g., 1:10,000) generally results in polygons having more uniform composition.

When only one ecosytem unit (or map unit) occurs in the polygon, this is called a **simple polygon**. At smaller map scales (e.g., 1:250,000), site conditions become less uniform and map polygons may contain more than one ecosytem unit. These are referred to as **complex polygons** (e.g., a map polygon composed of 60% ecosystem unit x and 40% ecosystem unit y).

Although polygon-based mapping methods are most common, local ecosystems may also be represented by raster cells using GIS modeled approaches. If raster approaches are used, a single pixel may represent either a single ecosystem unit (similar to a simple polygon), or a multiple ecosytem units (similar to complex polygons).

Some Yukon projects have also developed hybrid map products (see Case Study 6: Predictive Ecosystem Mapping, Proposed Alaska Highway Pipeline Project, in Appendix 2). If hybrid methods are used, the practitioner should assess the accuracy of available input data for the study area. Most available land-cover mapping, such as EOSD or Yukon Vegetation Inventory (forest inventory), is inadequate when used alone to predict vegetation associations. This information should be combined with analysis of other factors, such as soil, surficial materials and topography or, if available, higher resolution imagery. The largest scale of base feature mapping in Yukon, outside of municipal areas and major corridors, is 1:50,000. With available digital imagery, however, mapping scale will be dependent on the resolution or ground sample distance of the imagery.

An ecological map should provide a suitable base to support interpretations for various land management activities. When undertaking an ecological mapping project, mappers should follow the Yukon bioclimate ecosystem classification system (Section 3) to characterize ecological units. When delineating and attributing ecological units, it is recommended that mappers use the mapping methods outlined in this section and in *Standard for terrestrial ecosystem mapping in British Columbia* (RIC 1998) as guidelines. In ecosystem mapping, classification of terrain (surficial geology) follows Howes and Kenk (1997), with modifications adopted by the Yukon Geological Survey, EMR (YGS 2011). Soil drainage classification follows the Canada Soil Survey Committee (CSSC 1978).

RIC (1998) describes standards for ecosystem mapping at scales of 1:5,000 to 1:50,000 used in British Columbia to map Biogeoclimatic Ecosystem Classification units for zones, subzones and sites. In Yukon, mappers should use the Yukon Bioclimatic Ecosystem Classification units for zones, subzones and ecosites (Section 3.1.2.2). These standards describe mapping methods using manual methods, starting with bioterrain mapping and guiding ecological principles and including vegetation, topography, and terrain (surficial geology). Section 3.1.2.2 also outlines the standards established for ecosystem unit characterization, symbols, sampling, mapping procedures, interpretations and legends. Terrain features and soil drainage are used as delineation criteria and to describe characteristics of ecosystems. Mappers should consider each ecosystem mapping project according to what should or can be delineated and characterized.

Environment Yukon follows the species name authority maintained by the Yukon Conservation Data Centre (CDC) and the surficial geology/terrain attributes established by the Yukon Geological Survey. Standardized Bioclimate Ecosystem Classification codes for ecosites and vegetation associations are described in Section 3.1.2 (Figure 2).

Before starting a new mapping project, practitioners are encouraged to contact the ELC Coordinator regarding standards, mapping units and naming conventions for a particular mapping project (see Section 6 for contact information).

5
DATA COLLECTION AND MANAGEMENT

This section presents guidelines for data collection and management in the production of ELC maps and in collecting biophysical inventory for classification and map assessment. British Columbia Resource Inventory Standards (RIC; see RIC 1998) are referred to wherever they apply. Yukon's ELC program standards are provided when RIC standards do not apply.

5.1 FIELD DATA COLLECTION

Environment Yukon is developing a *Field Manual for Describing Yukon Ecosystems* and accompanying field forms. The manual follows the field data collection standards of British Columbia's *Describing Terrestrial Ecosystems in the Field, 2nd Edition* (BC Ministry of Forests and Range and Ministry of Environment 2010). The Yukon manual will describe ecosystems, with specific consideration of ecological conditions in the territory.

At this time, Environment Yukon produces field forms only for site, soil and vegetation, as well as a general form for project metadata. Tree measurement data are collected and recorded in the comments section of the site field form. The Yukon ELC Program adopted the *Terrain Classification System for British Columbia* (Howes and Kenk 1997) as a legend standard and database structure for surficial geology mapping in Yukon, following protocols adopted by the Yukon Geological Survey (YGS), EMR (YGS 2011). YGS modified the Howes and Kenk (1997) standards to accommodate additional landforms, processes and permafrost features common in Yukon.

5.2 FIELD DATA STORAGE AND RETRIEVAL

All data collected using Environment Yukon field forms can be entered and stored in the department's Yukon Biophysical Inventory System (YBIS).

YBIS is a web-based Oracle application for vegetation plot data, soil classification and description, and terrain classification. Other types of data, mainly relating to habitat assessment projects, are also stored in the system. A system administrator manages the system and has access to all data.

In addition to entering new data into YBIS, considerable effort has been made to also add data collected over the past 30 years. YBIS currently has information related to 115 projects.

ELC practitioners with an account in YBIS are able to access all data that are considered ready for use and not confidential. ELC practitioners who wish to learn more about YBIS and/or receive an account should contact the ELC Coordinator (see Section 6).

Each project that is entered into YBIS must have a Project Data Manager. This person is responsible for the quality of data entered for the project, and for deciding when the data in the project are ready for general use. Before that time, a project's data are accessible only to account holders assigned to the project. Completed projects can also be flagged as confidential if there is good reason to do so. The data in confidential projects are available only to specific account holders.

The Yukon ELC Program invites all holders of biophysical data in the private and public sectors to contribute field ecological data to YBIS. Practitioners may request YBIS data in order to verify map products or develop ecological interpretations. Over time, the goal is to enable ELC practitioners to use YBIS to enter their own field data.

ELC practitioners who choose to use YBIS will need to follow the field manual and use the YBIS forms outlined in Section 5.1.

5.3 SPATIAL DATA STANDARDS

The Yukon ELC Program has not yet established standards for capturing the spatial data needed in ecosystem mapping that would apply to all projects. For guidelines on the capture and storage of ecological data and associated metadata for local ecosystem manual and predictive mapping projects, the ELC Program recommends following *Standards for Predictive Ecosystem Mapping (PEM): Digital Data Capture* (RIC 2000a); and *Standards for Terrestrial Ecosystem Mapping (TEM): Digital Data Capture* (RIC 2000b).

Over the last ten years, most of the ecological mapping projects that were commissioned or completed by the Government of Yukon were related to regional planning processes. These maps, which covered extensive areas, were raster based and employed predictive ecosystem methods (Section 4.1.1.2). In the private sector, however, several local-level ecosystem maps have been completed for specific projects (for example, Case Study 2: Wetland Mapping, Southern Lakes, in Appendix 2).

Geospatial digital data is often used as a source of ecological information. It can describe and map landscapes and be used in mapping broad and local ecosystems. The Yukon ELC Program recommends using the geospatial digital data sources listed in Table 8 for ecological mapping projects.

For clarity on what digital products would appropriate for a particular project, please contact the ELC Coordinator (see Section 6).

An Anicia Checkerspot butterfly *(Euphydryas anicia)* sitting on the stem of a Sticky goldenrod *(Solidago simplex)*

Table 8. Recommended digital data for broad and local ecosystem mapping

Name	Descriptions	Source	Local (<1:30k)	Local (1:30k to 1:50k)	Broad (1:50k to 1:250k)
NTDB 1:50,000	National Topographic Data Base; a nationwide, vector-based dataset depicting physical and cultural features. Derived from hard-copy National Topographic System (NTS) maps.	Contact Geomatics Yukon	3	2	1
Imagery (high to low)	Imagery of varying spectral and spatial resolution may be available through Yukon government (e.g., GeoEye, WorldView, Ikonos, LiDAR).	Contact Geomatics Yukon	1	1	2
Yukon 30 m Digital Elevation Model (DEM)*	Yukon-wide DEM derived from NTDB contours, spot elevations, and elevation-tagged water bodies.	Download 30 m DEM from the Yukon government site. ftp.geomaticsyukon.ca/DEMs/mosaics/yt_30m_dem.tif For methods see www.env.gov.yk.ca/publications-maps/geomatics/data/30m_dem.php	3	2	1
CanVec 1:50,000	CanVec is the NTDB orthocorrected using Landsat 7 imagery.	Contact Geomatics Yukon	3	2	1
CDED	Canadian Digital Elevation Dataset; a 16-metre, nationwide Digital Elevation Model derived from CanVec contours and spot elevations.	Download 16m DEM from the Yukon government site. ftp.geomaticsyukon.ca/DEMs/CDED_50k/	3	2	1
EOSD land cover map 25 m pixel	The Earth Observation for Sustainable Development of Forests (EOSD) land cover map is based on Landsat 7 Enhanced Thematic Mapper (ETM+) data and represents conditions circa 1999–2001.	SAFORAH www.saforah.org/ or contact the ELC Coordinator	2	3	3
Yukon Vegetation Inventory 1:50,000	Yukon forest inventory includes a number of ecological modifiers and non-forest vegetation attributes.	FTP site Geomatics Yukon www.geomaticsyukon.ca/data/datasets	3	1	1
Ecoregions of Yukon 1:1,000,000	Yukon Ecozones, Ecoregions and Ecodistricts (described in Smith et al. 2004).	FTP site Geomatics Yukon www.geomaticsyukon.ca/data/datasets	3	3	1

Mapping scales: 1 = data source recommended for use; 2 = data source used with caution; 3 = data source should not be used

*Note: The 30 m DEM should be used with NTDB base data, and CDED with Canvec and/or instrument sensed data (satellite imagery, GPS). Most Yukon 50k vector data in current use are derived from/against NTDB. The 30 m DEM is considered a better product than the CDED across valley bottoms and in hilly regions where the source contours are of higher intervals. The most efficient way to examine this difference is to generate shaded relief images and look for telltale artifacting particular to each resolution: "benches" and "waves"in the CDED, and features that are just a little too smooth and soft looking in the 30 m.

6
CONDUCTING AN ELC MAPPING PROJECT

ELC mapping provides a common base map for developing a range of environmental interpretations. The methods used in ELC mapping will vary depending on the geographic area, available information and intended applications. Adequate pre-planning and clearly defined project objectives are important in all projects. Figure 11 lists the steps an ELC practitioner would typically take to complete an ELC mapping project.

Mapping guidelines and digital data capture guidelines are described in section 4.2.3 (mapping local ecosystem units) and section 5.3 (spatial data standards).

Before initiating an ELC mapping project (or even if it has already started) practitioners are encouraged to contact the ELC Coordinator to share information to support fieldwork and map production for the project.

6.1 CONTACTS AND ADDITIONAL INFORMATION

Contacts	Activities
Nadele Flynn, **Ecological and Landscape Classification (ELC) Coordinator** Fish and Wildlife Branch, Environment Yukon EMAIL: Nadele.Flynn@gov.yk.ca WORK: 867-667-3081 FAX: 867-393-6213	• ELC Five-Year Strategic Plan • ELC Technical Working Group • Bioclimate ecosytem classification • Ecoregions of Yukon • Ecosystem mapping (bioclimate/broad/local) • Vegetation/Ecological Classification • Collection/maintenance of ecological/biophysical plot data

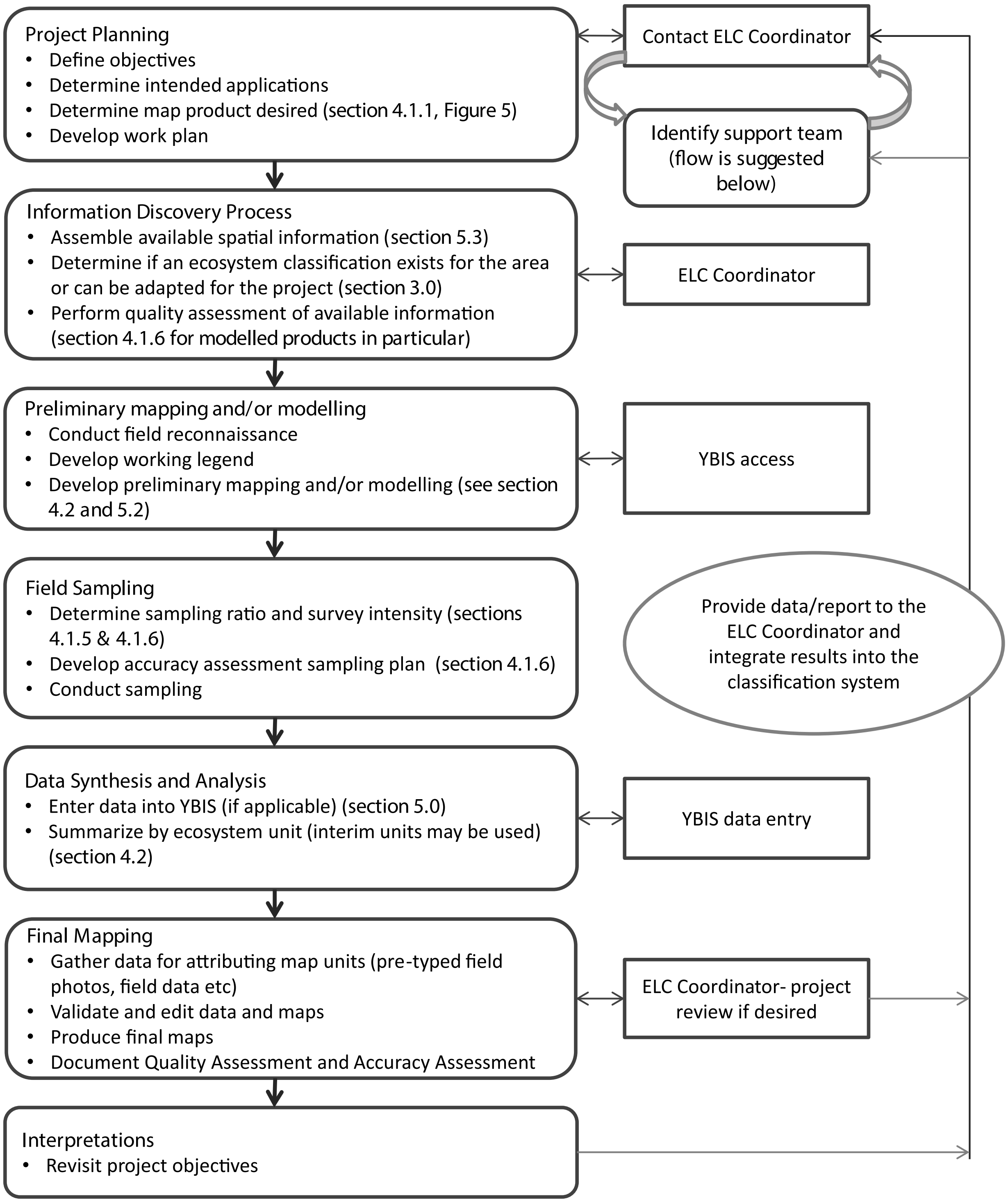


Figure 11. Recommended steps for conducting an ecosystem mapping project in Yukon

Adapted from Figure 6.1 in *Standard for Terrestrial Ecosystem Mapping in British Columbia* (RIC 1998: 38)

7 MANAGEMENT APPLICATIONS

7.1 YUKON BIOCLIMATE FRAMEWORK

The broad ecosystem and local ecosystem mapping levels are well suited to identify and describe ecosystems at the scales required by resource management and planning activities. Bioclimate zones and subzones establish the appropriate ecological context for interpreting broad and local ecosystem mapping. Examples of management applications of the various mapping levels within the Yukon Bioclimate Ecological Classification (YBEC) are listed in Table 9. Appendix 2 provides case studies that illustrate how various mapping products have been used to support different Yukon land and resource management initiatives. Many YBEC mapping products can be used for multiple applications.

Table 9. Examples of potential management applications of the Yukon Bioclimate Framework mapping levels

YBEC mapping level and scale	Management applications
Bioclimate (1:100,000 to 1:1,000,000)	• Forest management • Conservation area planning and representation • Climate change studies • Regional land-use planning • State of Environment reporting
Broad Ecosystems (1:50,000 to 1:250,000)	• Wildlife and habitat management • Assessment and management of cumulative effects • Regional land-use planning • Conservation area planning and mapping • Mineral exploration and development planning • Oil and gas exploration and development planning • Land capability (e.g., agriculture) • Cultural use
Local Ecosystems (1:10,000 to 1:50,000)	• Transportation and infrastructure planning (transportation corridors and other industrial infrastructure) • Municipal and local area planning (urban and rural residential) • Site- or project-level environmental impact assessment (e.g., fish and wildlife values, environmental sensitivity) • Mapping of rare and sensitive ecosystems • Mapping habitat for species of interest • Watershed planning and effects modeling • Mineral development planning (mine sites) • Oil and gas exploration and development • Land reclamation (e.g., mining, gravel pits) • Forest management

7.2 NATIONAL ECOLOGICAL FRAMEWORK

The ecoregions, ecodistricts and soil landscape units mapped in the National Ecological Framework (NEF) are used extensively to characterize broad regions according to their physical, vegetation and climate characteristics. These units were originally mapped at a scale of 1:1,000,000. Their use for land-management applications was enhanced in March 2014, when the map scale was updated to 1:250,000. New mapping criteria were also introduced at that time to ensure that ecological units, such as valley systems, were kept intact.

Ecoregions and ecodistricts form logical management or planning units, as they identify ecologically distinctive areas of Yukon. Although ecoregions and ecodistricts do not provide the detailed site-level mapping required by some resource sectors, they can be used to complement a bioclimate ecosystem mapping and classification approach. Ecodistricts and soil landscape units are useful inputs for modeled ecosytem maps. Management applications of the NEF mapping levels are listed in Table 10.

Table 10. Examples of potential management applications for Yukon ecoregions, ecodistricts and soil landscape units

National ecological framework mapping level	Scale	Management applications
Ecoregions	1:1,000,000	• Conservation area planning and representation • Regional land-use planning • State of Environment reporting
Ecodistricts	1:250,000	• Regional land-use planning (planning units) • Conservation area planning and representation • Inputs to predictive ecosystem mapping • Cultural use
Soil Landscape Units	1:50,000	• Inputs to predictive ecosystem mapping • Inputs to ecodistrict and ecoregion mapping • Cultural use

8
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APPENDIX I
GLOSSARY

Reference used in developing the glossary: Ecosystem Classification Group (2010).

abiotic – An ecological term that refers to the component of ecological systems in non-living things (chemical, parent material, water regime, etc).

alpine – The ecological zone that occurs above an elevational tree line, characterized by a distinct climate and vegetation.

arctic – The ecological zone north of the latitudinal tree line, characterized by a distinct climate and vegetation.

association – a plant community type at the lowest level of the CNVC hierarchy, with consistency of species dominance and overall floristic composition, as well as having a clearly interpretable ecological context in terms of site-scale climate, soil and/or hydrology conditions, moisture/nutrient factors and disturbance regimes, as expressed by diagnostic indicator species, e.g., *Picea glauca/Hylocomium splendens* (White spruce/Step moss) association.

bioclimate – All the climatic conditions (climate factors) of a region that have a fundamental influence on the survival, growth and reproduction of living organisms.

bioclimate region – A level in the YBEC system that is the collective grouping of bioclimate zones that represent large and very generalized ecological units.

bioclimate zone – A level in the YBEC system that represents areas with the same regional climate. See ecoclimatic region, ecoregion, and ecological region.

bioclimate subzone – A level in the YBEC system below the bioclimate zone that represents areas with the same subregional or meso climate.

Biogeoclimatic Ecosystem Classification (BEC) – A hierarchical ecosystem classification system applied in British Columbia that describes the variation in climate, vegetation, and site conditions throughout the province.

Biophysical Land Classification – An approach that combines the physical and biological components of the environment. This hierarchical system originally included four levels, within which the physical components of classification were sometimes more heavily weighted than the biological components. The term *biophysical* was subsequently replaced by *ecological*.

boreal –

1. Pertaining to the north.
2. A climatic and ecological zone that occurs south of the subarctic, but north of the temperate hardwood forests of eastern North America, the parkland of the Great Plains region, and the montane forests of the Canadian cordillera.

circum-mesic – Used to describe the moisture condition of a site as being close to (or near) that of a mesic moisture class such that available soil moisture reflects climatic inputs.

classification – The systematic grouping and organization of objects, usually in a hierarchical manner.

climate – The accumulated long-term effects of weather that involves a variety of heat and moisture exchange processes between the earth and the atmosphere.

climatic climax – Stable, self-perpetuating vegetation developed through succession in response to long-term climatic conditions (as opposed to edaphic climax).

edaphic climax – Stable, self-perpetuating vegetation developed through succession on sites that do not reflect climatic inputs - relatively extreme nutrient or moisture conditions. See also climax.

climatic index – Number indicating a combination of climatic factors, most often temperature and precipitation, in order to describe vegetation distribution.

climax – Stable, self-perpetuating vegetation that represents the final stage of succession.

CNVC – Canadian National Vegetation Classification.

complex polygon – An ecological mapping term that refers to the condition where more than one ecosystem occurs in the map polygon.

continuous permafrost – Permafrost that occurs everywhere beneath the exposed land surface throughout a geographic region, with the exception of widely scattered sites, such as newly deposited unconsolidated sediments, where the climate has just begun to impose its influence on the thermal regime of the ground, causing the development of continuous permafrost.

continuous permafrost zone – The major subdivision of a permafrost region in which permafrost occurs everywhere beneath the exposed land surface, with the exception of widely scattered sites.

deciduous forest – A plant community made up of 75% or more of deciduous trees. Also known as broadleaf forest.

ecoclimatic region – A level that represents areas whose same regional climate is the major environmental factor influencing vegetation development. See bioclimate zone ecoregion, and ecological region.

ecodistrict – A subdivision of an ecoregion, at a scale of 1:500,000 to 1:125,000, based on distinct assemblages of relief, geology, landform, soils, vegetation, water, and fauna. A system unit in Canadian ecological land classification. It is based on distinct physiographic and/or geological patterns. Originally referred to as a land district. See ecological district.

ecological district – Area of land characterized by a distinctive pattern of relief, geology, geomorphology, and regional vegetation. See ecodistrict.

ecological factor – Element of a site that can possibly influence living organisms (e.g., water available for plants). This term is also frequently used to refer to ecological descriptors.

ecological region – A region characterized by a distinctive regional climate as expressed by vegetation.

ecological unit – General term used to refer to a mapping or classification unit of any rank that is based on ecological criteria.

ecology – Science that studies the living conditions of living beings and all types of interactions that take place between living beings, and between living beings and their environment.

ecoprovince – A subdivision of an ecozone that is characterized by major assemblages of landforms, faunal realms, and vegetation, hydrological, soil and climatic zones. A system unit in Canadian ecological land classification.

ecoregion – An area, at a scale of 1:3,000,000 to 1:1,000,000, characterized by a distinctive regional climate as expressed by vegetation. A system unit in Canadian ecological land classification. Originally referred to as a land region. See ecological region and biogeoclimatic zone.

ecosite – an area with a unique recurring combination of vegetation, soil, landforms and other environmental components.

ecosite phase – Ecosite phases are subsets of ecosites (YBEC framework) based on soil properties within an ecosite. These properties represent subsets of environmental conditions where compensating factors result in similar overall vegetation and ecological conditions. When phases are designated, the selected soil conditions are deemed to be important to the use of the classification.

ecosystem –

1. A complex interacting system that includes all plants, animals and their environment within a particular area.

2. The sum total of vegetation, animals and physical environment in whatever size segment of the world is chosen for study.
3. A volume of earth space that is set apart from other volumes of earth space in order to study the processes and products of production, particularly transactions between a community of organisms and its non-living environment.

ecozone – An area of the earth's surface representing large and very generalized ecological units that are characterized by interacting biotic and abiotic factors; the most general level of the National Ecological Framework for Canada.

edaphic – Related to the soil.

edaphic climax – See climax.

edaphic grid – A two-dimensional graphic that illustrates the relationship between soil moisture and soil fertility.

edatopic grid – See edaphic grid.

elevational zone – Altitudinal zonation of vegetation.

environment – The sum of all living and non-living factors that surround and potentially influence an organism.

forest – A relatively large assemblage of tree-dominated stands.

habitat – The place where a plant or animal lives. The sum of environmental circumstances in the place inhabited by an organism, population or community.

hydric – A moisture class along a relative soil moisture regime gradient where water is removed so slowly that the water table is at or above the soil surface all year; gleyed mineral or organic soils.

hygric – A moisture class along a relative soil moisture regime gradient where water is removed slowly enough to keep soil wet for most of the growing season; permanent seepage and mottling; gleyed colours common.

inventory – The systematic survey, sampling, classification and mapping of an entity, including natural resources.

landform – The various shapes of the land surface resulting from a variety of actions, such as deposition, sedimentation, erosion and earth crust movements.

landscape – A heterogeneous land area composed of a cluster of interacting ecosystems that repeat throughout it in similar form. Landscapes can vary in size, down to a few kilometres in diameter.

medium texture – Intermediate descriptor between fine-textured and coarse-textured (soils). It includes very fine sandy loam, loam, silt loam and silt.

mesic – Sites that are neither humid (hydric) nor very dry (xeric). Average moisture conditions for a given climate.

mixed wood – Forest stands composed of conifers and angiosperms, each representing between 25% and 75% of the cover; e.g., Trembling aspen and White spruce mixed wood forests.

moisture regime – Refers to the moisture available for plant growth, estimated in relative or absolute terms.

mountain – Land with large differences in relief; usually refers to areas with more than 600 m of relief.

nutrient – Usually refers to one of a specific set of primary elements found in soil, such as nitrogen, phosphorus, potassium, calcium, magnesium and sulphur, that are required by plants for healthy growth.

nutrient regime – The relative level of nutrients availability for plant growth.

parent material – The unconsolidated and more or less chemically unweathered material from which soil develops.

permafrost – Ground (soil or rock and included ice and organic materials) that remains at or below 0° C for at least two consecutive years.

phase – (as in ecosite phase) A subdivision of an ecosite based on soil properties.

physiognomy – The structure or outward appearance of vegetation or of a plant community as expressed by the dominant growth forms. The CNVC recognizes seven physiognomy types:

forest: a vegetation community characterized by tree species > 5 m tall, the crowns of which generally form a continuous canopy with typically > 30% cover; a large area of tree-dominated stands.

woodland: a vegetation community characterized by tree species > 5 m tall (by CNVC convention), the crowns of which form a sparse, discontinuous canopy as a result of ecological limitations such as climate, shallow soils, wetlands, etc; by CNVC convention, woodland canopies are typically between 10% and 30% cover.

shrubland: a vegetation community characterized by shrub species > 10 cm tall.

grassland: a vegetation community characterized primarily by grass species, typically occurring on arid sites.

forb meadow: a vegetation community characterized by forb species, often occurring on moist sites.

dwarf shrubland: a vegetation community characterized by shrub species that have a prostrate growth form and are <10 cm tall.

cryptogamic vegetation: vegetation characterized by species such as bryophytes and lichens.

plain – A relatively large, level, featureless topographic surface.

plateau – An elevated area with steep-sided slopes and a relatively level surface platy, consisting of soil aggregates that are developed predominately along the horizontal axes, laminated; flaky.

plot – A vegetation sampling unit; a fixed amount of area for the purpose of estimating plant cover, biomass or density. Plots vary in size, depending on the purpose of the study and the individual researcher.

potential – The possible biological productivity or carbon production capability of a site resource (or an area), usually expressed in terms of values to an appropriate management regime. It may be generally established or estimated from site components that represent a permanent character (e.g., soil quality).

productivity – A measure of the physical yield of a particular crop. It should be related to a specified management. For example, merchantable wood volume productivity is generally expressed in m^3/ha/yr. It may be further subdivided into types (gross, net, primary) or allocations (leaves, wood, above-ground, below-ground).

reconnaissance – A level of field analysis that involves relatively quick sampling for the purpose of obtaining general information about an area. In some cases, sampling quality may be high, but the intensity of sampling is very low relative to the size of the total area being studied.

reference site – A site that best reflects the regional climate and is least influenced by local topography and/or soil properties. These sites tend to have intermediate soil moisture and nutrient regimes, mid-slope positions on gentle to moderate slopes, and moderately deep to deep soils and free drainage (except in areas where permafrost is a characteristic of the regional climate). These sites are used in the identification and characterization of a regional ecological system.

relief – The difference between extreme elevations within a given area (local relief).

simple polygon – An ecological mapping term that refers to the condition where only one ecosystem occurs in a map polygon.

site – The place or the category of places, considered from an environmental perspective that determines the type and quality of plants that can grow there.

slope – The steepness of an inclined surface, measured in degrees or percentages from the horizontal.

subarctic – A zone immediately south of the Arctic and characterized by stunted, open-growing spruce vegetation.

subassociation – A division of the association (YBEC framework) generally used to characterize variation in species composition that is not considered significant enough to be an association.

succession – The progression within a community whereby one plant species is replaced by another until a stable assemblage for a particular environment is attained. Primary succession occurs on newly created surfaces; secondary succession involves the development or replacement of one stable successional species by another on a site with a developed soil. Secondary succession occurs on a site after a disturbance (fire, cutting, etc.).

successional stage – Stage in a vegetation =sequence in a given site. Also known as the seral stage.

taiga – A coniferous boreal forest. This term is often used to refer to the vegetation zone of transition between boreal forest and tundra.

toposequence – Related soils that differ from each other primarily because of topography and its influence on soil-forming processes. The relationship between soil and vegetation types is primarily a response to differences in relief.

tree line – The uppermost elevation or northern limit of tree growth, usually on upland sites.

tundra – Treeless terrain, with a continuous cover of vegetation, found at both high latitudes and high altitudes. Tundra vegetation includes lichens, mosses, sedges, grasses, forbs and low shrubs (including heaths), and dwarf willows and birches. In high altitudes, tundra occurs immediately above the forest zone. The term *tundra* is used to refer to both the region and the vegetation growing in the region. It should not be used as an adjective to describe lakes, polygons or other physiographic features. Areas of discontinuous vegetation in the polar semi-desert of the High Arctic are better termed *barrens*.

upland – A general term for an area that is higher in elevation than the surrounding area, but not a plateau.

vegetation – The general cover of plants growing on the landscape.

vegetation association – A vegetation classification unit of the CNVC ; it is defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions and physiognomy.

vegetation potential – (also vegetation climax) The species or plant community that will form the stable-mature vegetation on a site. The existing species or plant association may be different from the vegetation climax due to site disturbance or successional stage.

vegetation type – An abstract vegetation classification unit not associated with any formal system of classification.

xeric – A moisture class along a relative soil moisture regime gradient where water is removed very rapidly in relation to supply; soil is moist for brief periods following precipitation.

APPENDIX 2
CASE STUDIES

APPENDIX 2 – CASE STUDIES

CASE STUDY 1: ECOREGIONS OF YUKON

Nadele Flynn (material extracted from McKenna, K, J. Meikle and N. Flynn. 2014.)

BACKGROUND

In 1991 a group of Yukon specialists initiated a review of the 1977 Ecoregions of Yukon. Based on field experience and improved mapping, the group contributed a new version of Yukon Ecoregions to the National Ecological Framework in 1995 (ESWG 1995). This 1995 version was reported on in 2004 (Smith et al. 2004) and was correlated to the mapping carried out by British Columbia (Demarchi 1996) and by Alaska (Gallant et al. 1995). Figure 1.1 shows the 1995 National Ecological Framework (NEF) map, with ecozones and ecoregions.

PROJECT OVERVIEW

In 2011, the Yukon Ecological and Landscape Classification Program formed an ecoregion working group. The goal was to revise the 1995 mapping to match newly developed ecological regions in the Northwest Territories, and to accommodate minor revisions made in British Columbia and significant revisions in Alaska. The Yukon ecoregion revisions also incorporated newly available input information such as surficial and land cover/vegetation mapping, Digital Elevation Models and date from advances in GIS technology. Because of people's familiarity with the 1995 NEF, and its use in management and planning, these ecoregion revisions attempted to retain the 1995 divisions unless there were compelling reasons to change them. The revised Ecoregions of Yukon are shown in Figure 1.2.

METHODS

Mapping the ecoregions of Yukon is largely a top-down process and the divisional hierarchy is nested. The lowest level of the hierarchy is the Soil Landscapes of Canada unit (Soil Landscape Component, or SLC). Ecozones, ecoregions and

Figure 1.1 Ecoregions of Yukon (ESWG 1995)

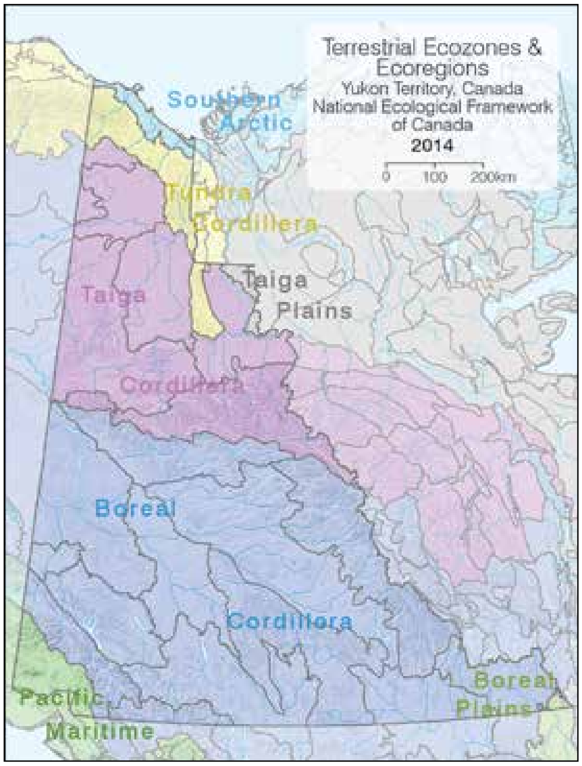


Figure 1.2 Revised Ecoregions of Yukon (ELC-TWG 2014)

ecodistricts are subdivisions at the continental scale of climatic zones; attention to physiography increases as map scale increases. SLCs are organized according to a uniform set of national soil and landscape criteria that are based on permanent natural attributes. There are many reasonable ways to distinguish Yukon ecoregions. Ecoregions are delineated principally on abiotic features, such as bedrock geology, glacial history and physiography, and so are relatively stable (i.e. enduring) over time.

While considering changes to the 1995 NEF, the project team continued to recognize major physiographic and climatic distinctions. At the ecozone level the team included a stronger regional climate element and related the ecozone level to the bioclimate framework.

HOW THE PRODUCT WAS USED

The Ecoregions of Yukon concept is used for broad-scale management applications. Its structure helps define ecologically relevant management units at various scales. The process frequently incorporates the work done in 1995 (ESWG 1995) and in 2004 (Smith et al. 2004) in order to place landscapes in their ecological context. *The Ecoregions of the Yukon Territory* (Smith et al. 2004) can also be used as a framework for conservation network planning, ecological reporting, wildlife management and ecological mapping.

IMPORTANT OBSERVATIONS

- No changes are proposed to the concepts of Taiga and Boreal ecozones. The Working Group did propose an adjustment to use the height of land (watershed break) to differentiate between Taiga and Boreal. The watershed break aligns well with climatic differences on the leeward and windward side of mountain chains. It is also reflected in the demarcation of the boreal high and taiga wooded bioclimate zones.
- The Working Group proposed new ecoregions in order to accommodate revisions along the Alaska and Northwest Territories boundaries. Most of the area of these new ecoregions is located in the adjacent jurisdiction.
- Smaller revisions resulting in minor changes to boundaries based on the higher resolution Soil Landscapes of Canada mapping and regional ecosystem mapping completed for regional land-use planning, which generally do not change ecoregion concepts.
- Ecodistricts were entirely redistributed to be more consistent with Soil Landscape Units and their attributes. They also better reflect the ecological processes (i.e., active fluvial systems, large extents of cold-air drainage, landforms and soil assemblages) relevant to the ecodistrict.
- The SLC map and attributes were revised using a 1:250,000 NTDB base. An earlier version of the SLC map (SLC version 2.2) had last been updated in December 1996 and used a 1:1,000,000 NTDB base.

REFERENCES

Demarchi, D.A. 1996. *An Introduction to the Ecoregions of British Columbia.* Wildlife Branch, B.C. Ministry of Environment, Lands and Parks.

McKenna, K, J. Meikle and N. Flynn. 2014. Ecoregions of Yukon: Revisions to the Yukon portion of the National Ecological Framework. Technical Working Group Subcommittee. Prepared for the Ecosystem and Landscsape Classification program. 30 pp.

Gallant, A.L., E.F. Binnian, J.W. Omernik and M.B. Shasby. 1995. Ecoregions of Alaska. Report prepared jointly by Colorado State University, U.S. Environmental Protection Agency and U.S. Geological Survey. Draft map and report.

CASE STUDY 2: WETLAND MAPPING, SOUTHERN LAKES

By: Anne-Marie Roberts, A. Roberts Ecological Consulting

BACKGROUND

The Southern Lakes Enhanced Storage Project proposed by Yukon Energy Corporation (YEC) would increase the winter full-supply water level of Marsh Lake by 0.3 m and potentially lower the low-supply level by 0.1 m. The project would use the existing Lewes River control structure to manage water storage, holding back water in the summer and fall and releasing water throughout the winter. Baseline studies within the Southern Lakes area were conducted to assess the potential effects from a proposed change in Marsh Lake water storage. As part of the baseline studies, four representative and important wetland ecosystems were mapped. This mapping is being used — together with bathymetric data and hydrological models — to evaluate impacts on wetlands.

PROJECT OVERVIEW

In 2010–11, 1:10,000-scale wetland ecosystem mapping was completed for four wetland complexes within the Southern Lakes area: Lewes Marsh, Nares Lake wetland, Tagish/6 Mile wetlands, and Monkey Beach wetlands, located midway along Marsh Lake (Figure 2.1).

Figure 2.1 Location of study area

Mapping was conducted using principles of Yukon Bioclimate Ecosystem Classification and the B.C. terrestrial ecosystem mapping (TEM) process. Some additional information was collected for wetland sites. A. Roberts Ecological Consulting and Ardea Biological Consulting completed mapping for AECOM and YEC, both in Whitehorse.

METHODS

The method used to map wetlands followed the *Standard for Terrestrial Ecosystem Mapping in British Columbia* (RIC 1998) and the *Standards for Terrestrial Ecosystem Mapping Digital Data Capture in British Columbia* (RIC 2000b), using principles outlined in *The Yukon Ecosystem and Landscape (ELC) Framework: Overview and Concepts - Interim Draft* (Flynn and Francis 2011). It also used elements of wetland description and classification derived from the *Wetlands of British Columbia: A Guide to Identification* (Mackenzie and Moran 2004). The work was organized into eight phases:

- review of existing wetland and ecosystem mapping information;
- pre-typing and field planning;
- identification of ecosystem field plots;
- collection of detailed elevation and bathymetry data;
- processing of field data and development of final ecosite unit;
- development of wetland and associated ecosite edatopic grid and generalized toposequences;
- interpretation of final orthophoto and polygon delineation, labelling and mapping; and
- quality control and assurance process.

Each ecosite map unit was summarized in a detailed expanded legend that includes a representative photo and list of characteristic vegetation by layer, as well as site information.

HOW THE PRODUCT WAS USED

The map (Figure 2.2) provides a baseline that can be used in monitoring and assessing the effects of proposed water management changes over time. The wetland ecosystem maps, together with the bathymetric and Digital Elevation Model (DEM) contours and hydrological models, are being used in the assessment of the potential ecological impacts of modifying the water regime. Wetlands by their nature are dynamic ecosystems that fluctuate with annual and inter-annual variation. The transition zones between wetland types can be either gradual or relatively sharp. The assessment phase of this project will use this static ecosystem map in the assessment of a dynamic system. It will also use various sources of information, such as modeled water depth (based on continuous average of water level measured at Marsh Lake together with bathymetric and DEM contours). It will also estimate the duration and timing at depth, based on water depth and hydrological models developed for the project. This information will indicate the range of potential changes to wetland communities and vegetation, and will aid in the assessment of potential impacts to fish and wildlife.

IMPORTANT OBSERVATIONS

- This scale of wetland ecosystem mapping was possible only because of the availability of recent 1-m digital orthophotos and the 5-m DEM.
- Bioclimate concepts were incorporated mainly using wetland units from biogeoclimate concepts in British Columbia. However, the most current Yukon ELC information was also incorporated and considered.
- Some of the vegetation units were analogous to those described in *Wetlands of British Columbia* (Mackenzie and Moran 2004); others were unique to this study or described only partially by other classifications.
- Several challenges arose in describing and classifying wetlands that are not described in Mackenzie and Moran 2004:
  - having sufficient data and plots to confidently delineate, describe and classify types not previously described;
  - understanding the expected conditions for types not previously described, especially given the project's spatial limits; and
  - the higher costs of developing a classification compared to using an existing classification and modifying it for site types

Figure 2.2 Ecosite map produced for the Southern Lake wetland mapping project

specific to the project. The greater cost is mainly due to the need for more plot data to describe new site types and more time to interpret data and describe new types.

- The influence of permafrost on vegetation units that are largely defined by moisture are not fully understood or defined in the Southern Lakes and are not captured in the B.C. guidebook. In mapping the Southern Lakes wetlands, the project team encountered a few locations that would be described as marshes, based on the definition of marshes and fens, but appeared to function more as fens due to permafrost at less than 1 m depth.
- A 1:10,000-scale map is very useful to understand and model potential impacts to habitats at a relatively fine scale. Creating this type of map without a previous classification system in place (i.e., the B.C. wetland guidebook or the British Columbia biogeoclimatic site series) required more time and money. This was a result of the need to develop a project-specific classification and ecosite descriptions (Figure 2.3) that would be useful in the interpretation of potential effects.

REFERENCES

Flynn, N. and S.R. Francis. 2011. Yukon Ecosystem and Landscape Classification (ELC) Framework: Overview and Concepts. Whitehorse: Government of Yukon. 46 pp.

MacKenzie, W.H. and J.R. Moran. 2004. *Wetlands of British Columbia: a guide to identification.* Land Management Handbook No. 52. Research Branch, B.C. Ministry of Forests, Victoria, B.C. www.for.gov.bc.ca/hfd/pubs/docs/lmh/lmh52.htm.

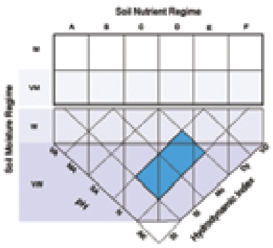
Bioclimatic Zone	Site Class	Class Code	Cover Types	Ecosite Code	Ecosite Unit Name
BOL	Marsh	Wm	Graminoid	BW	Beaked sedge - Water sedge

Mineral wetland dominated by emergent graminoid macrophytes and less than 25% aquatic vegetation. Saturated to permanently flooded hydrolic conditions. The most common and widespread Marsh ecosite unit. This site is commonly found on gleyed mineral soils.

Species diversity is low and plant cover is strongly dominated by beaked sedge (*Carex utriculata*) and/or water sedge (*C. aquatilis*) with scattered forbs, aquatics, and mosses. On sites that experience surface drying, species diversity increases and sites become more meadow like.

Floristically, this site can be very similar to the Sedge Fen (SF) and the two sites are primarily differentiated by the BW growing on mineral soils and the SF growing on organic soils.

The BW site is similar to the site description of the Beaked sedge - Water sedge (Wm01) site described in Mackenzie and Moran (2004).



SITE INFORMATION	
Elevation (masl):	660-663
Slope (%):	0-2
Aspect (°):	140, no aspect
Slope Position:	DP, LV, TO, LW
Structural Stage:	2b
Surficial Material:	L, F
Hydrodynamic Index:	Si-Mo
pH:	N
ASMR:	VW 6-8
SNR:	C, (D-E)

Assumed Modifiers:	j
Mapped Modifiers:	y
Number of Plots:	42
Plot Numbers:	006, 044, 060, 074, 076, 079, 082, 086, 227, 229, 230, 231,407, 800, 804A, 804B, 807, 809, 810, 812, 818, 814, 1000, 1005, 1007,1006, 1017, 1019, 1029, 1046, 1051, 1056, 1058, 1059, 1078, 1083, 1084, 1091, 1098, 1110, 1111, 1115
List of Mapped Units:	BW2b, BWy2b

Occurrence:

The most common ecosystem.
Mapped in 202 out of 652 polygons.
407 ha out of 3533 ha

Tree Layer (0)	Shrub Layer (0)	Herb Layer (55-79-90)	Moss Layer (0-46-90)
		Carex utriculata, C. aquatilis, Hippurus vulgaris, Comarum palustre, Cerastium arvense	*Drepanocladus, Calliegeron, Amblystegium riparium*

Figure 2.3 Ecosite description for a marsh wetland unit

CASE STUDY 3: HABITAT SUITABILITY MAPPING, PEEL WATERSHED

By: Sam Skinner, former Land-use planner for the Peel Watershed Planning Commission; and Donald Reid, Wildlife Conservation Society Canada

BACKGROUND

The Peel Watershed Planning Commission was established in 2004 to develop a regional land-use plan for the portion of the Peel Watershed within Yukon (Figure 3.1). One of the commission's mandates was to consider traditional and local knowledge. The commission's initial consultations resulted in the *Issues and Interests Report* in 2005. This report, including its "Concluding Comments," gave planning staff and local conservation experts at the Government of Yukon and Wildlife Conservation Society Canada guidance to develop the *Conservation Priorities Assessment: Criteria and Indicators Report*. This report recommended that habitats of a number of species be mapped across the Peel Watershed in order to inform conservation priorities. Habitat maps for most of these species were either absent or incomplete, and many needed to be modeled; ideally they would use local and scientific knowledge.

Figure 3.1 Location of the Peel Watershed planning region

PROJECT OVERVIEW

Over two years, planning staff and local conservation experts at the Government of Yukon and Wildlife Conservation Society Canada collaboratively developed habitat suitability and species diversity maps based on the 25-m Ecological Land Classification (ELC) product for the Peel Watershed (Meikle and Waterreus 2008; Figure 3.2). The goal was to provide comprehensive mapping across the planning region of the distribution of species-specific habitats of varying quality. This would allow sub-regional concentrations of high-value habitats across many species to be identified, which would assist in establishing land-use zoning.

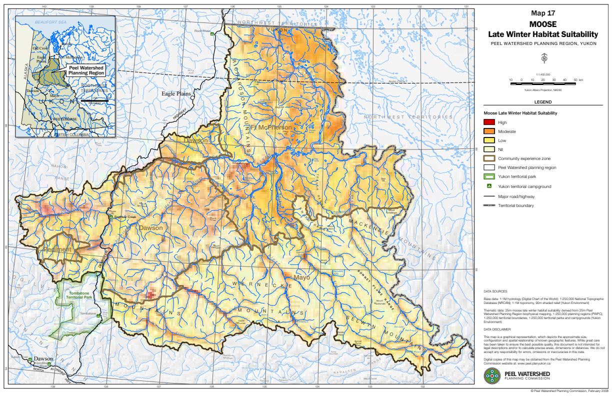


Figure 3.2 Habitat suitability map for moose in the Peel Watershed planning region

METHODS

At community workshops in Mayo, Dawson City and Fort McPherson, and in interviews in Whitehorse with people familiar with the Peel Watershed and its wildlife, a PowerPoint presentation showed on-the-ground images typical of each of the 31 ecosystem classes. Each ecosytem class was considered to be a separate habitat. People were asked to collectively rank the habitat suitability of each class for various species or herds (the Porcupine Boreal and Bonnet Plume caribou herds, moose, Dall's sheep, Grizzly bear, marten, waterbirds and breeding birds) for critical seasons. Commission members and biologists chose the range of species as indicators of the interests and values brought forward in the Criteria and Indicators process (e.g., subsistence resources; rare species; scale-dependent species). Biologists who were confident in their understanding of a certain species in the region were also asked to rank the ecosystem classes according to its habitat importance for each species. At the workshops, each ecosystem class was ranked on a four-point scale (Nil – High value), based on local knowledge and scientific expertise.

HOW THE PRODUCT WAS USED

The resulting maps and methods were published with maps of other conservation values in the commission's 2008 *Conservation Priorities Assessment Report*. The commission then used a number of ranking tools (e.g., a GIS overlap analysis, Marxan and Zonation) to merge the large number of maps in these reports. The aim was to locate areas of especially high conservation priority or potential land-use conflicts. Although the ranking analysis informed some of the commission's decisions, the *Conservation Priorities Assessment Report and Resource Assessment Report*, both published in 2008, became their primary reference while they developed their draft and recommended land-use plan.

IMPORTANT OBSERVATIONS

- The ability to inform land-use planning (e.g., zoning, management guidelines) with wildlife data depends on comprehensively mapping the distributions of diverse wildlife species or the distribution of habitats that are likely currently occupied by a species or may be so occupied in the future.
- The Government of Yukon's Wildlife Key Area (WKA) database provides polygonal mapped data that shows areas of particularly high occurrence (actual distribution) for specific species. This mapping is rarely complete for a species over an entire planning region, so it is has limited usefulness. However, the WKA can be useful in sub-regional planning, and in checking the quality of habitat mapping.
- The habitat suitability approach depends on a region-wide map of habitats (in this project habitat was derived from ecosystem classes) and a process to apply rankings of quality to those habitats, species by species. This process depends heavily on the scale and particular parameters used to model the habitat classes. These constraints can result in a mismatch between the mapped model and the actual distribution of a species.
- The habitat suitability mapping would not have been possible without the ELC mapping or a similar land-classification system that provides a region-wide mapping of habitats. A habitat map is a prerequisite for an interpretive map of habitat quality.
- Habitat suitability mapping can use land-cover data such as that provided by Earth Observation for Sustainable Development (EOSD), together with other data, as was done with the Peel ELC. There are limitations, however:
    - In mountainous areas, the EOSD shows a significant amount of the "Shadow" class. This, together with some "Cloud" pixels, leaves more work for the habitat modeler (or results in poorer models).
    - In mountainous regions, EOSD classes can differ considerably in habitat attributes, depending on their elevation, so a bioclimate or elevation zonation mask is required.
    - Since the ELC has 50% more ecologically relevant classes than the EOSD, more fine-grained suitability determinations are possible.
    - It is not clear if the EOSD's approach to "splitting" broad vegetation classes (e.g., dense, open or sparse) is more informative than the Peel ELC's approach (e.g., high, low-mid, riparian, or wetland and wet, moist, or dry). A comparison of the habitat suitability between the "High Elevation Coniferous Forest" class and the "Low-Mid Elevation Dry Coniferous Forest" class

showed few major differences (except for Dall's sheep).
  - Potentially splitting the classes (keeping all possible combinations) would be more informative (e.g., Low-Mid elevation wet open coniferous forest), although this would result in a very large number of habitat types. The EOSD dense/open/sparse split were combined into one class type because of accuracy, usefulness and other problems.
- Alternatively, a model that combines EOSD data, topographic position data and Digital Elevation Model (DEM) and moisture data might allow a modeler/facilitator more flexibility in choosing what information is most relevant when providing information to stakeholders. In that case, preliminary EOSD rankings could be adjusted by rankings for other factors. This may or may not be compatible with Environment Yukon's mapping guidelines for habitat suitability.
- Habitat suitability mapping may be possible using forest cover mapping together with other data, such as fire history mapping and DEM data. There are limitations, however:
  - Forest cover mapping does not cover the whole territory. It focuses on harvestable forest stands and is often dated. However, this approach may be useful for regions with complete and recent coverage.
  - Forest cover attributes may be more informative than EOSD-derived habitat classes for some species (e.g., those limited by forest tree species, age class or canopy conditions), and less informative for other species (e.g., alpine species; early seral specialists).
- The predictive ecosystem map of the Peel Watershed was similar to that used in the North Yukon Planning Region's ELC, which facilitated comparisons.
- An important assumption when merging maps (e.g., overlap analysis, Marxan and Zonation) was that all contributing spatial data are comprehensive; i.e., there are no gaps in knowledge throughout the region. This assumption must be weighed against data quality. In some cases, data that is comprehensive but somewhat speculative may be more informative than detailed but very localized data.
- The ELC and the products that derive from it extended beyond the Peel Region's boundary by a set distance. This was useful because it allowed some subsequent analyses to go right to the boundary, or even a short distance beyond it.
- In general, the 25-m pixel size was adequate for the required interpretations:
  - 25-m data yielded attractive maps that were not obviously pixelated.
  - using 25-m data in the Zonation software was too time-consuming. Input data for that analysis was therefore generalized. This software will not likely be used in upcoming planning processes.
- There were some concerns over seemingly spurious pixels or "dirty" transitions between classifications, so commission staff attempted to reconcile these boundaries using a filtering approach. The cleaned versions were not used because the resulting regional patterns were no different than the originals.
- There were seemingly spurious pixels that represented flowing water environments next to still water environments. This problem was significant for only one habitat suitability map: waterbirds. For this product, the ELC was first cleaned to remove the spurious pixels.

The model/script for this cleaning process is available upon request.

- The ELC alone was adequate for expert-driven habitat suitability modeling for some species. Although not perfect, the models were easy to explain and yielded results that roughly matched the experts' understanding of regional patterns. However, habitat suitability for other species, such as Dall's sheep, depended more on context. Habitat suitability models for these species had to incorporate several other data layers (e.g., projected snow depths) in addition to the ecosystem classes.

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CASE STUDY 4: WINTER RANGE OF THE LITTLE RANCHERIA CARIBOU HERD, SOUTHEAST YUKON

By: Shawn Francis, S. Francis Consulting Inc.

BACKGROUND

In the mid-1990s, the level of forest harvesting activity in southeast Yukon increased dramatically. Within a few years, over 700,000 m^3 of timber was harvested around the community of Watson Lake, in an area that previously had experienced limited harvesting activity (Figure 4.1). A forest products mill was constructed and plans were being developed for additional volumes. Much of the harvesting activity and planning was within the winter range of the Little Rancheria woodland caribou herd. Concerns over existing and potential habitat impacts within the herd's range prompted an evaluation of the quality and use of caribou winter habitat, resulting in recommendations regarding habitat management.

PROJECT OVERVIEW

Four different land-cover and ecological map products were examined for their potential to adequately represent winter range caribou habitat values. Environment Yukon was the lead agency. Habitat mapping and caribou use is described by Florkiewicz et al. (2003). Resulting habitat management recommendations are described by Adamczewski et al. (2003).

Figure 4.1 Location of study area within Yukon

METHODS

Four different habitat and ecosystem mapping approaches were compared:

- 1:50,0000-scale forest inventory mapping (ESWG 1995);
- 1:250,000-scale Broad Ecosystem Inventory mapping (AEM 1998);
- 1:100,000-scale surficial geology mapping (Reid 1975; Rostad et al. 1977); and
- 1:50,000-scale derived ecosystem map.

The derived ecosystem map was created specifically for the winter range assessment. It grouped forest ecosystems of the Southeast Yukon forest ecosystem classification (Zoladeski et al. 1996) according to similar landforms and surficial materials (McKenna 1996). Spatial map units were then developed using GIS methods to intersect the 1:50,000-scale forest inventory polygons with surficial geology mapping. Ecosystems were classified based on ecological rule sets, using a predictive mapping approach.

HOW THE PRODUCT WAS USED

Based on a spatial analysis of caribou GPS and radio telemetry locations in relation to ecosystem units, winter habitat suitability ranks were developed for each ecosystem, and a habitat suitability map was produced (Figure 4.2). Caribou preferred habitats with the highest cover of lichens. The habitat suitability mapping, along with an associated risk assessment, was then used to develop caribou habitat management recommendations to guide future forest management (Adamczewski et al. 2003).

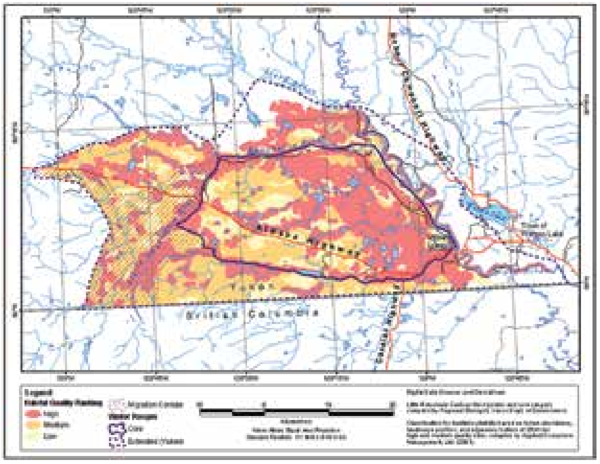

Figure 4.2 Little Rancheria Herd winter range habitat suitability map, based on derived ecosystem units (red = high habitat suitability)

IMPORTANT OBSERVATIONS

- The 1:50,000-scale forest inventory was not able to capture important ecological differences between forest communities. This resulted in important differences in caribou habitat values.
- The 1:250,000-scale broad ecosystem inventory mapping represented the landscape well, but was too generalized for the scale of planning required by this project.
- The derived ecosystem mapping — which was based on surficial geology/terrain features, forest cover polygons, and interpreted forest communities — was able to differentiate among important ecological communities and their corresponding caribou winter habitat values. The resulting map was also found to be an appropriate scale for forest management planning. Incorporating data on terrain and surficial geology into the ecosystem classification was felt to be the key improvement over forest inventory mapping.
- The process used to develop the derived ecosystem mapping highlighted the importance of having an ecosystem classification that could be represented spatially (i.e., that is mappable).

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CASE STUDY 5: LOCAL ECOSYSTEM MAPPING, CITY OF WHITEHORSE

By: Shawn Francis, S. Francis Consulting Inc.

BACKGROUND

In 1998, the City of Whitehorse was updating its Official Community Plan and developing new subdivisions. The City of Whitehorse commissioned studies to identify important fish and wildlife habitats through focus groups and input from knowledgeable citizens (AEM 1998) The mapping that resulted from this work was general, however, making it challenging to apply it to subdivision planning. In response to this concern, ecosystem mapping — with its associated ranking of wildlife values and environmental sensitivity — was suggested as a useful alternative to the mapping of generalized wildlife areas.

PROJECT OVERVIEW

Over a period of three years, 1:20,000 scale ecosystem mapping was completed for most of the City of Whitehorse (Figure 5.1). Using expert-based habitat suitability methods, each ecosystem unit was ranked according to its fish and wildlife values and environmental sensitivity. Mapping and environmental interpretations were completed by Applied Ecosystem Management Ltd. (AEM).

METHODS

Detailed methods are described in AEM (2000a). Mapping concepts generally followed those of the Resource Inventory Committee (RIC 1998). Bio-terrain units, based on those of Mougeot et al. (1998), were used as the primary ecological map unit. Vegetated ecosystems were developed based on a review of previous vegetation and ecological mapping in the Whitehorse area, including Boyd et al. (1982), Davies et al. (1983), Oswald and Brown (1986) and AEM 1999. Vegetation structural stages were modified from RIC (1998).

Detailed, 1-m resolution digital orthophotos were available for the entire project area, as were base feature and digital terrain models. This provided a high degree of mapping resolution. Terrain and ecosystem units were manually interpreted and digitized on screen in MapInfo GIS. Field sampling was used to guide the mapping concepts and to check for quality assurance. A wildlife habitat and environmental sensitivity ranking (Figure 5.2) was applied to each ecosystem unit based on establish criteria (AEM 2000b).

Figure 5.1 Location of study area within Yukon

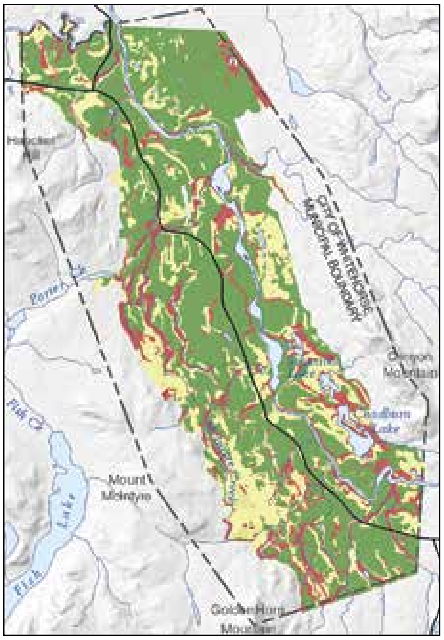

Figure 5.2 City of Whitehorse ecosystem map, themed for environmental sensitivity (green = low; red = high)

HOW THE PRODUCT WAS USED

The City of Whitehorse Planning Department used the ecosystem mapping to determine new zoning designations for updates to the Official Community Plan. They directly incorporated ecologically sensitive areas and important wildlife habitats into the design of new subdivisions.

IMPORTANT OBSERVATIONS

- The ecosystem mapping would not have been possible without the detailed City of Whitehorse digital orthophoto and associated base feature mapping.
- Since the vegetation units were not standardized, it was therefore difficult to correlate them with other vegetation and ecosystem classifications. However, a review suggests that many units could be correlated with CNVC associations.
- Bioclimate concepts were not incorporated in the project. All mapping was completed in the Yukon River valley and surrounding lower forested slopes.

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CASE STUDY 6: PREDICTIVE ECOSYSTEM MAPPING, PROPOSED ALASKA PIPELINE PROJECT

By: Terry Conville, Stantec Consulting

BACKGROUND

The Alaska Pipeline Project (APP) completed ecosystem mapping between 2010 and 2012 to meet the regulatory requirements of a proposed pipeline from Alaska to Alberta. The mapping provided up-to-date baseline information that would support an Environmental Impact Assessment of the proposed project (Figure 6.1).

PROJECT OVERVIEW

ELC mapping for portions of the proposed project within Yukon and British Columbia was created using a modified Predictive Ecosystem Mapping (PEM) approach. This included mapping ecological site units within the existing ecoregion framework of Yukon (Smith et al. 2004). The mapping team completed Predictive Ecosystem Mapping at 1:20,000 scale using the most recent data and information available that was suitable for the project objectives and requirements. In Yukon, the mapping was completed within a corridor 1,500 metres wide along the proposed 750-km route.

Figure 6.1 Location of study area within Yukon

METHODS

Mapping adhered to fundamental ecological principles. The modified PEM approach is the digital organization and manipulation of ecological building blocks in knowledge-based modeling. This is different than traditional mapping methods based only on air photograph interpretation. The mapping team reviewed and used available data sets from the Government of Yukon, including planimetric and hydrological data and a Digital Elevation Model (DEM) created from the National Topographic Data Base. Data also included land classification mapping from the Earth Observation for Sustainable Development of Forests and information from the Yukon Forest Inventory, as well as ecoregion linework and terrain mapping from other sources and projects. Focused air-photo interpretation was carried out for specific ecological features of the Yukon landscape that were difficult to model. The data was organized by ecoregion and combined in a raster GIS environment. Selected attributes were chosen and developed from the base data according to their spatial and thematic quality, and then combined using fuzzy logic algorithms.

Field data was collected in 2010 and 2011 by a Terrestrial Ecosystem Mapping team that consisted of specialists in soils/terrain, vegetation and wildlife. This work was used to classify the ecosystems and characterize environmental relationships across the landscape. It also informed the development of the ecosystem knowledge base within the study area. Standardized data collection protocols were developed and followed for all fieldwork activities. More than 300 field sample sites were established, and more than half of these were detailed ground plots.

HOW THE PRODUCT WAS USED

The ELC mapping product was used as an ecological base map to help determine the representation and distribution of ecosystems across the project area. It also had other uses:

- identification of rare and endangered communities and species;
- identification and location of old forest;
- identification of wetland types;
- assessment of soil and terrain; and
- assessment of wildlife habitat capability and suitability.

Secondary applications also include biodiversity assessment, determination of cumulative environmental effects, climate change strategies and analysis, reclamation planning, and mitigation and monitoring.

IMPORTANT OBSERVATIONS

- This project required developing a project-specific (site-level) ecosystem classification across various ecoregions within the southern Yukon.
- Consistent coverage of vegetation at a moderate resolution was not available at the time of this project.
- Development of a moderate-resolution DEM proved to be beneficial for local-scale mapping.
- Focused materials and exceptions mapping was key.
- Updated disturbance (fire and human) mapping is required.

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CASE STUDY 7: BASELINE STUDIES, SELWYN PROJECT
TERRESTRIAL ECOSYSTEM MAPPING AND WILDLIFE HABITAT SUITABILITY MAPPING

By: Tania Tripp and Jackie Churchill,
Madrone Environmental Services Ltd.

BACKGROUND

Madrone Environmental Services Ltd. (Madrone) was contracted by Selwyn Chihong Mining Ltd. (SCML) to complete environmental baseline studies, including terrestrial ecosystem mapping (TEM) and interpretations of wildlife habitat suitability, for a proposed zinc-lead mine site (Selwyn Project) and its associated infrastructure. These studies were prepared to support project proposal submissions to the Yukon Environmental and Socio-economic Assessment Board, and the Mackenzie Valley Environmental Impact Review Board, and any associated permitting requirements.

The Selwyn Project is located in the Howard's Pass area of the Selwyn Mountains. Situated in the western portion of the Nahanni Map area (NTS 105I), it straddles the Yukon/Northwest Territories (NWT) border (Figure 7.1).

PROJECT OVERVIEW

From 2007 until 2012, baseline environmental assessments for vegetation and wildlife habitat suitability were completed for approximately 226,000 hectares (ha) in Yukon and an additional 15,000 ha in the NWT. The study area delineated around the proposed mine site to map ecosystems (vegetation communities) covered an area of 56,839 ha (the Don Creek watershed). Reports produced for each of the areas mapped included a description of the physical environment, the methodologies for field data collection and mapping, and the distribution and composition of vegetation communities. The report and associated maps were used to identify and quantify ecosystems and vegetation that may be affected by future development activities.

Figure 7.1 Project location in the Howard's Pass area of the Selwyn Mountains

The ecosystem mapping was also used to model wildlife habitat suitability throughout the Selwyn Project area for many species, including Woodland caribou, Grizzly bear, moose, wolverine, American beaver and Trumpeter swan.

METHODS

Ecosystem Classification System

From the initiation to the completion of the vegetation baseline studies for the Selwyn Project, no standard for ecosystem mapping was available in Yukon. Therefore, in 2007 the authors developed one for the mine site study area that worked within the standardized Terrestrial Ecosystem Mapping (TEM) framework. The framework was developed and established for British Columbia (Pojar et al. 1987; RIC 1996; RIC 1998). TEM uses a hierarchical ecosystem classification system. Lines are delineated around differences in bioterrain and ecological features, creating a series of polygons. Bioterrain mapping identifies terrain features and landforms such as aspect and slope. Ecological mapping identifies plant communities, site modifiers, structural stage and disturbances (RIC 1998). The rationale for using this system was to produce a hierarchical, robust, intuitive classification that reflected the bioterrain features of the landscape with sufficient detail. This helps categorize specific vegetation associations that could be used to model wildlife habitat.

As part of the ecosystem mapping process, a systematic, hierarchical approach to classify the landscape into broad ecological zones was applied to the study areas. This was based on background research, air photos and field observation. These broad ecological zones reflect regional climate, soils, vegetation, topography and time (Pojar et al. 1987), and are analogous to the biogeoclimatic (BGC) zones that are used throughout British Columbia. The pattern of undisturbed climax vegetation communities reflect the abiotic features and climatic influences in a consistent and repeatable pattern within a zone and are not driven solely by elevational limits (Meidinger and Pojar 1991).

Vegetation classification and associated coding for map labels were adapted from relevant Yukon studies (including Zoladeski et al. 1996, Lipovsky and McKenna 2005, and Jones et al. 2007). These provided data in a format that would fulfill project objectives. The classification studies were compared to forested BGC units for adjacent regions in British Columbia (DeLong 2004). Additional guides describing plant indicator values, along with local reports, were also reviewed. This included the ecosystem network report prepared for the La Biche river watershed (Loewen et al. 1999), and the Wolverine Project Environmental Assessment Report prepared for Yukon Zinc Corporation (AXYS Environmental Consulting Ltd. and Yukon Zinc Corporation 2005).

Wetland units were classified according to the Wetland and Riparian Ecosystem Classification system, which is based on the Biogeoclimatic Ecosystem Classification system (Mackenzie and Moran 2004). Background materials on geological history, biophysical mapping and ecological classification, land management, rare species, protected areas, soils, and other relevant topics were also researched.

Based on the information available, vegetation community labels were created to describe the dominant vegetation type, based on drainage and nutrient regimes. Labels were then assigned to polygons for vegetated and non-vegetated units. These generally followed the biophysical approach by assigning plant communities to discrete, homogeneous ecosystems within broad ecological zones. Ecosystem profiles that integrated bioterrain and ecosystem data were adapted from the draft legend prior to final polygon labeling to provide a working tool.

Preliminary Mapping

Hard copies of black-and-white aerial photographs taken in 2004 were used to map ecosystems in the mine site portion of the project area. Stereoscopes were used to view the photos and map directly on them. The remaining project area was mapped using orthophotos dating from 1992 to 2004 and using ArcGIS9.3, 3D PurVIEW software, which allowed for mapping directly on-screen at a scale of 1:15,000.

The photos were pre-typed for bioterrain (surficial geology material, thickness, expression, processes, modifiers and drainage) following RIC (1996) standards and Howes and Kenk (1997). Photos were then pre-typed for terrestrial ecosystem mapping. This consisted of stratifying the area into clearly visible ecological zones (analogous to delineating biogeoclimate zones). Zones were subdivided into bioterrain polygons, where multiple discrete ecosystem polygons were visible. The existing bioterrain polygons were adjusted to align with the ecosystem polygons, where applicable (RIC 1998).

Field Verification

Customized data collection forms were developed for soils and bioterrain and vegetation, with interpretive keys for field crews. For consistency, a blank edatopic grid, or site characterization tool (see Figure 3, Section 3.1.2.2) was included in the field cards. This allowed the vegetation mapper to rapidly assess the site's relative soil moisture and nutrients. At each field site, a representative plot within the polygon was chosen for assessment. Plots with comprehensive data collection are termed ground inspections; less detailed field verification is referred to as a visual inspection. The same field form was used for both levels of field inspection. Guided by RIC (1998), the assessments generally characterized a plot that was 20 m by 20 m, but dimensions were modified for linear or irregular ecosystems. At the plots subject to more detailed ground inspection, full soil pits were dug and evaluated and species presence and cover were recorded for all vegetation within each layer. Bioterrain features and processes were noted.

Information collected at all plots included Universal Transverse Mercator coordinates, elevation, aspect, slope, drainage, soil moisture and nutrient regimes, canopy closure, stand structural stage, and photos. If the polygon was a mosaic of more than one type, other ecosystems comprising the polygon were noted. Features relevant to wildlife habitat suitability for a predetermined list of species and life history stages were also recorded. The field crew discussed their data to ensure that relative assessments of drainage and other parameters were consistent.

Final Mapping

All polygons were assigned a final ecosystem label and polygon boundaries (linework) were modified based on the field assessment. Where applicable, ecosystem site modifiers were mapped following RIC (1998) to depict aspect, slope, material thickness and other features. Ecosystem structure was also classified according to RIC (1998) structural stages to reflect stand development and provide important wildlife habitat information. However, the structural stages developed by RIC (1998) reflect the range of ecosystems throughout British Columbia, and only a subset of these occurs in the Selwyn Project area.

A total of 2,970 verification plots were completed for the Selwyn Project area during TEM field sessions in 2007, 2010 and 2011. This included the proposed mine site and areas for additional infrastructure. The plot data provided valuable insights into the ecosystem classification system used. It also increased the accuracy of the ecosystem and wildlife map products. The high sampling intensity and detailed mapping resulted in a polygon size and accuracy level that can support interpretations that correspond to RIC standards for Level 4 survey intensity (i.e., 15–25% polygon verification). Data was collected to a standard that was modified to suit this particular project; more intense sampling was carried out around proposed development areas.

IMPORTANT OBSERVATIONS

- Ecosystem mapping is useful to obtain baseline conditions of large landscape areas.
- Vegetation/ecosystem mapping has numerous future applications, including wildlife habitat mapping, identifying and quantifying areas affected by development activities, planning for restoration and compensation activities, and protecting rare and special (unique) features within the landscape.
- The scale of ecosystem mapping over large landscape areas can limit the ability to delineate and identify small-scale features.
- Environmental studies can be conducted at varying levels of intensity to meet a range of project objectives and scopes. Broad, overview inventory projects — which typically include a large area and show regional trends with less detail — are termed regional study areas (RSAs). Site-specific projects — which require more detail and focus on a smaller area — are termed local study areas. There is a distinct lack of standards regarding which scale (size of area) is appropriate for the RSA for this type of project. Although it is logical to use watershed boundaries, distinct, natural landform boundaries are not always present or obvious for the vast expanses of flat topography throughout a significant portion of Yukon.
- The vegetation RSA for the Selwyn Project included the mining company's claim blocks within Don Creek watershed and surrounding watershed sub-basins in Yukon and NWT. This area is 56,839 ha. The RSA was subdivided into local study areas, zones of influence and development footprint areas for assessments of potential impacts on wildlife and vegetation.
- Field verification is critical to ensure a reasonable level of mapping accuracy.
- Ecosystem mapping requires air photo/ orthophoto coverage and mapping of associated base features. Mapping limitations can occur based on the quality (resolution), year, season, and time of day when the image was taken.
- Mapping of non-forested units from air photo interpretation is subject to greater uncertainty than more clearly visible units. Experience in the project area and the draft legend and profiles were used to support these interpretations, which integrated the bioterrain information in order to extrapolate the ecosystem type most likely to occur on the site.
- Digital mapping (ArcGIS/PurVIEW) is more efficient and cost effective than traditional hard-copy mapping. The other key advantage to on-screen mapping with high resolution photos is the ability to zoom in to areas that are less obvious in order to assign a more accurate label to a polygon feature.
- The vegetation classification system was standardized across all the areas mapped for all portions of the Selwyn Project. Due to the lack of a standardized ecosystem classification system for Yukon, however, these results would be difficult to compare to other ecosystem mapping conducted throughout Yukon.

CONCLUSION

The TEM product for this project was designed to be a tool that can be used to monitor changes in abundance and distribution of plant species and vegetation within and around the future project footprint. This data can also be used to support project design and management decisions, and to model focal species wildlife habitat. The final product provides baseline information that can be used in support of future recommendations and mitigation associated with the Selwyn Project.

When the project began, ecosystem classification in Yukon was in the early developmental stages due to the limited distribution of ecosystem projects, and very little data had been collected in the Selwyn Mountains. To develop an appropriate ecosystem classification for the Selwyn Project, Madrone adapted and modified existing classifications to suit the local conditions. For future environmental baseline studies, a standardized ecosystem classification system for Yukon would make it easier to compare results between projects. It would also improve data collection and coverage for the region, increase efficiencies and decrease costs.

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