Regional Ecosystems of West-Central Yukon

PART 2: METHODS, INPUT DATA ASSESSMENT AND RESULTS

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Prepared for

Environment Yukon

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FOR MORE INFORMATION: Information in this report is derived largely from published sources cited in the references. Where references are lacking, the source of information is from the authors.

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Land cover information was provided to the project by Marcus Waterreus (EOSD) and Kirk Price (Yukon Vegetation/Forest Inventory). Jeff Bond provided access to the digital surficial coverage for the project area. Val Loewen supplied existing digital plot data from the Yukon Biophysical Inventory System and Marcus Waterreus provided photos and track files from the 2010 survey conducted to update a portion of the EOSD coverage.

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1 SUMMARY

This report is a technical companion document for the west-central Yukon regional ecosystem mapping project (Grods et al. 2012). The project area, shown in Figure 1, is centered on the community of Dawson and covers 85,081 km^2. Please refer to *Regional Ecosystems of West-Central Yukon, Part 1: Ecosystem Descriptions* (Grods et al. 2012) for a full description of bioclimate zone and broad ecosystem mapping and descriptions.

This document describes the methods and data inputs to the predictive mapping exercse, and provides an assessment of data inputs and resultant mapping. It also provides considerations for users of the bioclimate and broad ecosystem mapping products, as well as recommendations for future work.

The west-central regional ecosystem mapping project built on previous work completed in the Dawson Planning Region in 2009-10. Two specific mapping projects were completed: riparian, ecodistrict and bioclimate mapping (McKenna et al. 2010), and a supplemental wetland mapping product (McKenna and Flynn 2010). The focus of the prior projects was to support regional land use planning, and provide inputs for this predictive ecosystem mapping project. In addition, the northern portions of the project area were mapped in the North Yukon (Francis et al. 2005) and Peel Watershed (Meikle and Waterreus 2008) regional ecosystem projects.

Broad ecosystem classification and mapping was completed with the guidance of the developing Yukon Ecosystem and Landscape Classification (Yukon ELC) Framework: Overview and Concepts (Flynn and Francis 2011). The classification concepts of this project also advanced some of the preliminary concepts of the developing Yukon ELC Framework. In Flynn and Francis (2011), broad ecosystem units for Yukon are identified by landscape position and vegetation conditions, inferring a relative moisture class based on topographic position. This west-central project used a revised topographic position model to take advantage of alternative approaches to classify physical landforms, avoiding the potentially subjective application of the *Landscape Type* concept as described in Flynn and Francis (2011). In this project, the term and concept of "Landform" replaced the term of *Landscape Type* (Figure 2) with landforms being identified through a consistent application of topographic position index (TPI).

1.1 Note to Users

Users of the input map layers and/or final bioclimate and broad ecosystem map products should be aware that the intended application is 1:100,000 or smaller (1:100,000 – 1:250,000 scale). Interpretations derived from the map products should not be applied at more detailed scales, even though the resultant 30m raster map allows users to view results at more detailed resolutions.

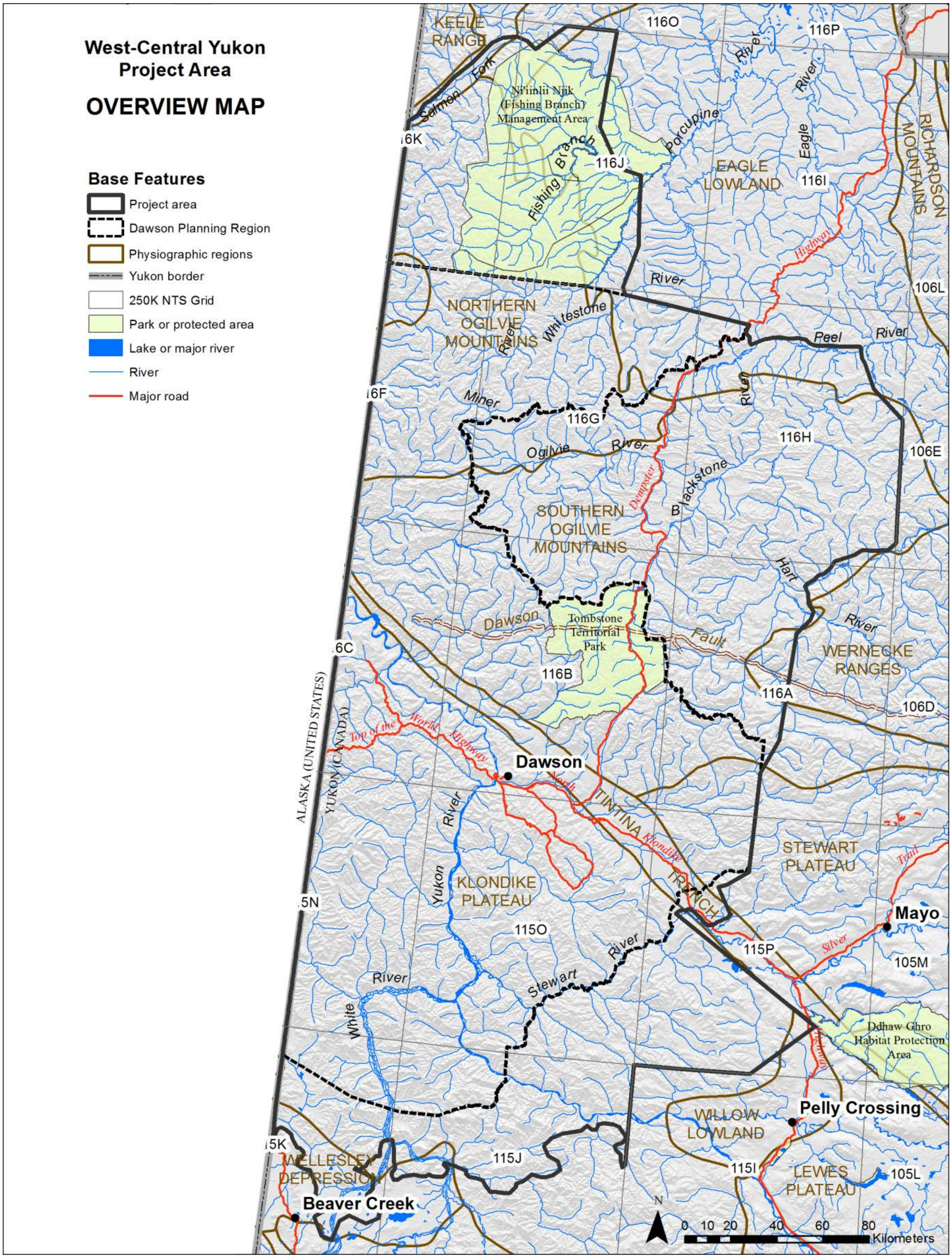

Figure 1. West-central Yukon regional ecosystem mapping project area.

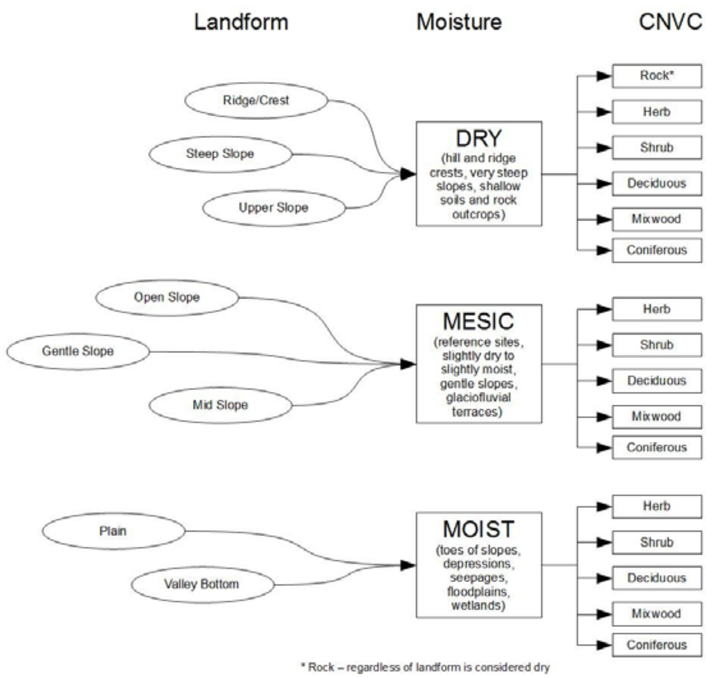

Figure 2. Proposed revision to broad ecosystem classification replacing Landscape Type with Landform.

Also of note, prior mapping conducted in support of this PEM (McKenna and Flynn 2010; McKenna et al. 2010) was only completed within the Dawson Planning Region. The west-central project area extends well north and south of the Dawson Planning Region (Figure 1), meaning that prior riparian, bioclimate, and wetland mapping was not available for these areas. The initial intent of this project was to use the models/mapping developed for the Dawson region, and expand them to the entire project area. However, those initial models were eventually modified and/or abandoned for newer models developed in this project, focused on better representing the concepts of the Yukon ELC framework (Flynn and Francis 2010), which was not available at the time of the Dawson Planning Region project. Therefore, some input layers and features included as part of final map products generated through this project (i.e. wetland and riparian broad ecosystems, and bioclimate zones) do not match the layers developed through McKenna et al. (2010) and McKenna and Flynn (2010).

Final deliverables for this project were broad-scale ecosystem mapping and input map layers; final ecosystem classification and mapping report detailing methodology and results with a synopsis of issues and project mitigation. The following is specific toward the mapping report detailing methodologies and results found in the accompanying mapping, and a synopsis of issues and mitigation employed in the project.

2 METHODS

2.1 Inputs

The following sections describe the individual input layers used as part of the predictive ecosystem mapping process, and the how each layer was derived or manipulated.

2.1.1 Project Area (Area of Interest)

The project area, or area of interest (AOI), included the entire Dawson Planning Region and extended into several surrounding ecodistricts (Figure 1). The project area is 8,508,110 ha (85,081 km^2) in size. The areas to the north of the Dawson Planning Region were previously mapped as part of the North Yukon biophysical mapping project (Francis et al. 2005), while the Ogilvie basin had received prior ecological mapping as part of the Peel Watershed predictive ecosystem mapping project (Meikle and Waterreus 2008). The southern project area extends into the Wellesley Depression, and in the southeast, also includes a portion of the Stewart Plateau.

2.1.2 CanVec

This project used CanVec 1:50,000 scale topographic mapping as the standard map base. CanVec is a 1:50,000 scale vector digital data set, providing consistent representation of base features (elevation, lakes, rivers, etc) for the territory. CanVec (NRC 2010) is the approved base feature data set for Yukon.

Ecosystem mapping, or other inventory mapping, should be tied to a consistent and known base feature map (e.g. RIC 1998, RIC 1999). For example, in British Columbia, 1:20,000 scale Terrestrial Resource Inventory Mapping (TRIM) forms the base feature mapping for all inventory projects.

The CanVec waterbody layer (lakes and double line streams) was clipped to project area and used as input during later model processes.

2.1.3 Digital Elevation Model (DEM)

A digital elevation model (DEM) is a raster representation of earth surface features (slopes and landforms). A DEM is a derivative product of the CanVec topographic data set. In Yukon, a 16m DEM is available for the entire territory, and is available from Yukon Geomatics (ftp.geomaticsyukon.ca). In this project, the 16 m DEM was used to derive three different layers that were then used as inputs to the predictive ecosystem mapping: slope (in percent); aspect (warm, cool or none); and topographic position index (TPI). Each layer is described below.

Individual 16m DEM tiles were mosaiced, and then clipped to the project area for processing.

2.1.3.1 Slope

Using ArcGIS Spatial Analyst, a slope model (slope magnitude, in percent) was created for the entire project area. This layer was utilized in subsequent steps of the PEM process.

2.1.3.2 Aspect

An aspect model (slope orientation) was also created using ArcGIS Spatial Analyst for the entire study area. Three aspect classes, based on known parameters (RIC 1999) of warm, cool and none, were developed. "None", or no aspect, was derived for slopes less than 25%. For the remainder of the landscape, where slopes were greater than 25%, these areas were then classified into either cool or warm aspects. Cool aspects occur on north and northeast-facing slopes (285° to 135° clockwise). Warm aspects occur on south and southwest-facing slopes between 136° and 284° clockwise. The aspect layer was utilized in subsequent steps of the PEM process.

2.1.3.3 Topographic Position Index – Landforms

Topographic Position Index (TPI), also known as landform classification, is a method used to describe and classify the landscape into discrete landform elements based on DEM (topographic) inputs. It utilizes a landform classification approach developed by (Weiss 2001), which can be modeled using GIS software. For this project, two software packages were used: 1) Topographic Position Index (TPI) v. 1.24, running on the Arcview 3.x platform (Jenness 2006), and 2) Land Facet Corridor Designer, a plug-in for ArcGIS 10.x (Jenness et al. 2010).

TPI is the elevation position of a raster cell within the DEM in relation to its neighbouring cells. A positive value means the cell is higher than its surroundings while a negative value means it is lower (Weiss 2001). TPI is scale dependant and varies based on the neighbourhood chosen to be evaluated (Figure 3).

Landscape position can be determined using TPI values combined with slope position. The approach used in this project classified the landscape based on Small Neighbourhood (SN) and Large Neighbourhood (LN) derived TPI relationship. This approach is similar to viewing and comparing the landscape from a meso and macro slope position context. Landscape position was standardized as suggested by Weiss (2001) to correlate the variability in scales.

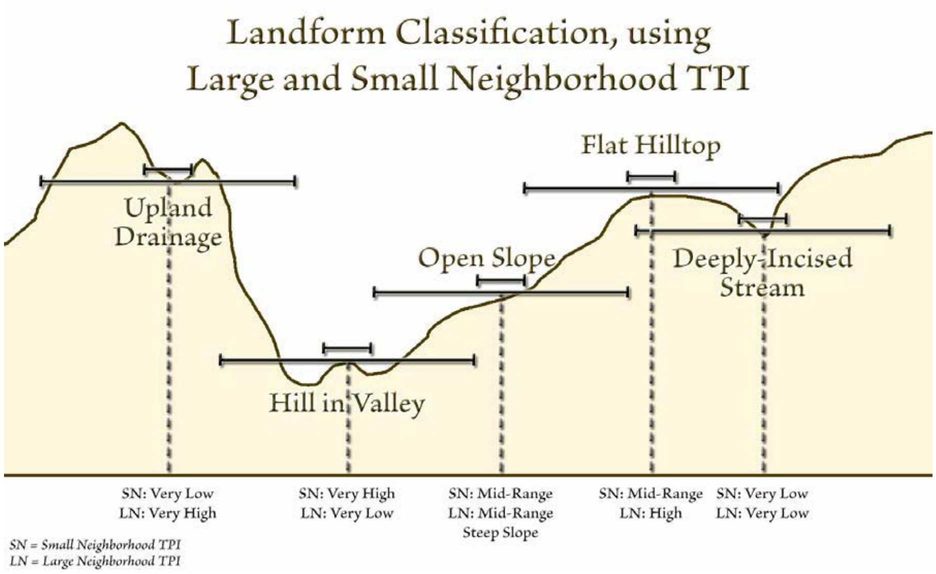

Figure 3. Small neighbourhood (SN) and large neighbourhood (LN) indexes interact to form the basis for landform delineations to form the Topographic Position Index (TPI). Source: Topographic Position Index (TPI) v. 1.2 manual (Jenness 2006). Used with permission.

TPI Parameters used for the west-central project area were:

- Small Neighbourhood (SN): 400 meters (or 25 pixel neighbourhood)
- Large Neighbourhood (LN): 1600 meters (or 100 pixel neighbourhood)

The following provides an overview of the landform classification and is discussed from the perspective of a "viewer – user" on the landscape:

1. **Plains (Class 1):** Where the SN and LN are both near zero and the viewer's position (a cell) is neither higher nor lower than neighbouring cells in both views. Overall slopes are less than 5%.
2. **Gentle Valley Bottom (Class 2):** Both views are positionally (elevationally) lower than the surrounding area. Slopes along valley floor are less than 25%.
3. **Gentle Lower Slope (Class 3):** The view is positionally flat for the SN and lower for the LN. Slopes are greater than 5%.
4. **Steep Lower Slopes (Class 4):** Both views are positionally (elevationally) lower than the surrounding area. Slopes are greater than 25%.
5. **Open Slope (Class 5):** SN and LN are relatively flat with a small incline slope greater than 5%.
6. **Mid-Slope (Class 6):** The view is positionally lower for the SN and relatively flat over the LN. Slopes vary here and often continue as valley bottoms from Gentle Valley Bottom (Class 2) higher up in elevation.
7. **Upper Slopes (Class 7):** The small view position is overall flat with a large view at or near above all else. Most often below Ridge (Class 9a).

8. **Upland Drainage (Class 8):** The view over the SN is near the bottom and the longer length view is above most all else.
9. **Ridge (Class 9):** This landform is a combination of several crest positions across the landscape. The dominant position for the viewer is above all else on the SN, but LN may have three conditions.
   a) When the LN is also above all else in position then the viewer is on a mountain top or high ridge.
   b) When LN view is overall flat the viewer is on a small hill in a large valley (ie typically associated with hills in plains)
   c) When LN is positional low as one would view on a local ridge or hill.

Figure 4 outlines the general model process to determine landforms using the TPI approach. As stated above, processing for the west-central PEM used a small neighbourhood of 25 cells (400 m) and a large neighbourhood of 100 cells (1600 m). Slope parameters (%) were applied during the process at several steps in determination of specific landforms. In Figure 4, “SN TPI” is the Small Neighbourhood TPI and is analogous to meso-slope position identified during field surveys. Similarly, “LN TPI” is Large Neighbourhood TPI and is analogous to macro-slope position.

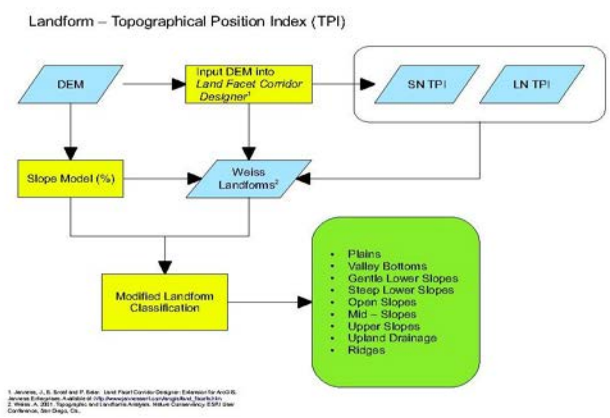

Figure 4. Landform classification model for the west-central Yukon PEM.

2.1.3.4 Moisture

Water availability, or soil moisture, is integral to the growth of different vegetation types and the organization of ecosystems. A key component to the predictive ecosystem mapping process therefore attempts to infer, or predict, relative soil moisture conditions. A simple method of modeling relative soil moisture conditions is through the use of slope curvature inputs or indexes (SCI). This approach classifies landscape position is as moisture shedding (a positive value), moisture receiving (a negative value) or neutral (a zero value—neither shedding nor receiving). Slope curvature models describe how water may converge or diverge on a point, regardless of up slope contribution. Slope curvature therefore represents a static state moisture condition as related to drainage accumulation or dispersion for a point (or in the case of a raster, a cell). This approach was also used in the Peel Watershed (Meikle and Waterreus 2008) and North Yukon (Francis et al. 2005) to represent a generalized soil moisture condition. The landforms noted in Section 2.1.3.3, above, may also be used to infer relative soil moisture conditions.

A slope curvature layer was derived from the mosaic DEM and used for later steps in the predictive ecosystem modeling process.

2.1.4 Fire History

Fire plays a critical role in vegetation renewal, and is an important disturbance agent of forest ecosystem in the Dawson region. Classified land cover imagery used in this project was collected in approximately 2000. Therefore, one decade of fire history was missing, including the extreme fire year of 2004. The Yukon fire history database (Yukon Forest Management 2010) was therefore overlaid on the imagery to update the landcover classes to 2010, and all burned areas were reclassified as shrub (EOSD class 50).

2.1.5 Human-Caused (Anthropogenic) Disturbance

Human-caused surface disturbance was requested to be part of the final broad ecosystem map. Environment Yukon provided anthropogenic disturbance map layers for the central portion of the west-central project area. It is important to recognize that this mapping was not contiguous for entire project area, and currently only represents features in vicinity of Dawson. Features represented in the mapping are:

- Developed Area (townsite, residences, industrial facilities, etc)
- Gravel Pit/Pull-out
- Placer Mining
- Quartz Mining
- Unknown Anthropogenic

These vector polygon features were combined into a single disturbance class, and then rasterized to be used as an overlay for the final ELC map.

2.1.6 Yukon Vegetation Inventory

Yukon vegetation inventory (YVI) (Yukon Forest Management 2010) is a 1:50,000 scale forest/vegetation inventory map product interpreted from 1:40,000 aerial photography. YVI provides coverage for the southern and central portion of the project area, but is not available for northern areas, primarily in the Ogilvie Mountains. In areas with YVI coverage, this was used to augment land cover mapping derived from classified imagery (EOSD). The detailed YVI cover types and proportions were re-classified into generalized EOSD land cover classes as described in Table 1, below.

Table 1. Yukon Vegetation Inventory (YVI) rule set to convert YVI codes into land cover in areas of data gaps.

EOSD Land Cover Class	YVI Cover Classes and Attributes				
	Class	CL_MOD	% Composition	Species	FOR_TYPE
No Data					
Rock/Rubble (32)	RR	Ro, Ru,			
Exposed land (33)	RS, E				
Byroids (40)	C				
Shrub (51)	S	LS			
Shrub (52)	S	TS, Tso, TSc			
Wetland Shrub (82)	S	TSc			W
Herb (100)	H				
Coniferous (213)			>75%	SW, SB, F, L, P	
Deciduous (221)			>75%	A, B, W	
Mixedwood (233)			Neither met above		

2.1.7 Land Cover

Satellite image derived land cover, or Earth Observation for Sustainable Development of Forests—EOSD (www.geobase.ca), provided the primary earth cover data source for the west-central project area. Land cover was available, as 1:250K NTS tiles, for the entire project area. Individual image scenes were provided by Environment Yukon, and mosaiced. Although providing complete coverage, the land cover contained cloud, shadow and "no data" gaps. As well, previous experience with the EOSD from other projects revealed classification issues with deciduous and shrub classes; the classification of these types was known to be inconsistent and often mixed. The imagery used to create the EOSD classification was circa 2000, and as described in Section 2.1.4 above, recent burn history was missing from the land cover. Several steps were therefore undertaken to update or improve the classification accuracy of the land cover:

1. YVI was used to fill in the cloud, shadow and "no data" gaps for the southern portion of the project area where YVI was available. Gaps were polygonized from raster and intersected with YVI polygons. The resultant YVI data areas were then re-classified to EOSD classes using criteria described in Table 1. The YVI attributes "soil moisture" and "total basal area" were not used. Data was then converted back to raster and incorporated into the land cover.
2. Cloud, shadow and "no data" gaps in the northern portion of the project area that overlapped with the North Yukon (Francis et al. 2005) and Peel Watershed (Meikle and Waterreus 2008) PEM projects where filled with data previously hand mapped from those projects (the same EOSD imagery was used as inputs). This layer was then incorporated back into the land cover used for this project. Through these procedures, only several gaps remained throughout the entire west-central project area.
3. In the southern portion of the project area where the YVI was available, YVI attributes were selected for deciduous and mixedwood components based on the criteria described in Table 1, above. These selected areas then were used to update the land cover shrub classification. Where shrub (EOSD 51, 52) occurred in the land cover and was identified as containing deciduous trees as identified by YVI, these areas were re-classified to either deciduous or mixedwood depending on the appropriate YVI class.
4. Burn history polygons within the project area, as identified by the Yukon Fire History database, were used to re-classify treed EOSD classes to shrub classes where burns occurred post 1999.
5. Through field observation, it was known that extensive areas of exposed land (EOSD 33) occurring throughout the land cover at lower elevations (BOL and BOH bioclimate zones) were often very recent burns (1-2 years prior to 1999 image acquisition). These areas have generally re-established with sparse shrub and herb, as part of an early successional post-fire vegetation community. The low elevation exposed soil areas were therefore selected with the burn history coverage and converted to shrub.
6. Through interpretation of many oblique landscape photos, it was determined that large areas of the exposed land class (EOSD 33) occurring at high elevations (ALP bioclimate zone) was exposed bedrock or colluvium. Therefore, EOSD class 33 (exposed land) in the ALP bioclimate zone was reclassified to EOSD class 32 (rock).
7. The CanVec waterbodies, described in Section 2.1.2, were rasterized and incorporated into the land cover as water features (EOSD 20).

These updates and adjustments to the EOSD circa 2000 land cover were needed to approximate current conditions not present at that time and to improve on it's possible short-comings. This is further discussed in Section 4.2.3 (land cover quality assessment) of this report.

2.2 Map Compilation

The final broad ecosystem map compilation process is similar in concept to that outlined in the Peel Watershed PEM (Meikle and Waterrreus 2008). However, in this project the water features, wetlands, and floodplains (riparian) formed the first pass mask utilized to filter subsequent classification routines. This approach was used in order to avoid artificial classification differences due to bioclimate zones and/or ecodistrict boundaries, a situation noted by Meikle and Waterreus (2008).

Aligning the PEM map compilation process to the proposed broad ecosystem classification (Figure 2), was completed in a step-wise process as illustrated in Figure 5, below. The initial process created a primary mask from the three fundamental layers already in place, waterbodies, wetlands and floodplains (riparian). The appropriate broad ecosystem unit was derived using raster math or conditional statements from derived inputs of bioclimate, moisture, landform and the formation level of the Canadian National Vegetation Classification (CNVC), which are formed from aggregated EOSD classes (e.g. EOSD 51, 52 = shrub). As the process progresses the subsequent derived layer is added into the mask. The final step involves reclassify the resultant raster, built from the multiple input layers, into the final broad ecosystem unit codes.

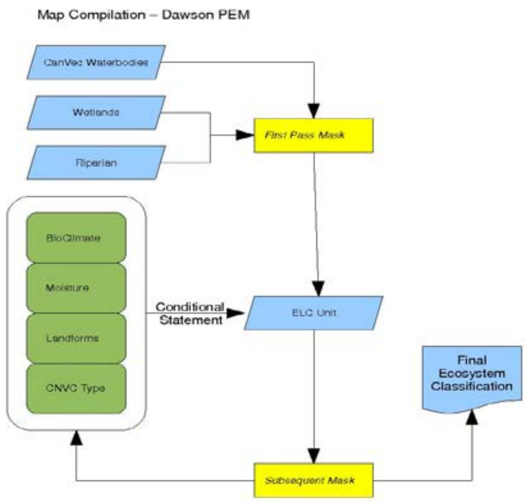

Figure 5. Broad ecosystem unit classification model for west-central Yukon PEM.

2.2.1 Broad Ecosystem Units

An overview of the broad ecosystem units (BEUs) identified in the west-central Yukon project area is provided in Table 2. Please refer to the accompanying report, *Regional Ecosystems of West-Central Yukon, Part One: Ecosystem Descriptions* (Grods et al. 2012), for full reporting and description of the resultant BEUs.

2.2.2 Bioclimate Zones

Through this project, a consistent bioclimate zone map was completed for the entire west-central project area. This was completed by incorporating and revising elements and concepts of previous mapping. The recent bioclimate mapping of McKenna et al. (2010) was only developed for the Dawson Planning Region, while versions of earlier bioclimate mapping were developed through the North Yukon (Francis et al. 2005) and Peel Watershed (Meikle and Waterreus 2008) PEM projects. Our approach was to initially utilize bioclimate zone elevation parameters from these projects, and then revise as required to conform to Yukon ELC Framework concepts. Patterns of land cover observed from available imagery were used to evaluate and refine the distribution of bioclimate zones. The only portion of the project area without any prior bioclimate mapping was the area south and south-east of the Dawson Planning Region. In this area the elevation rules developed for Dawson Planning Region were extended.

Bioclimate zone elevation rules were applied across the landscape by using topographic contours as the zone delineations. Where required, elevation breaks were selected and then edged matched for continuity. This was particularly important at the Boreal – Taiga Cordillera boundary.

2.2.2.1 Bioclimate Zone Elevation Ranges

The bioclimate elevation parameters used for the Boreal Cordillera (southern) portion of the project area are reported in Table 3, while elevation parameters for the Taiga Cordillera (northern portion) are listed in Table 4. Generally the bioclimate elevation breaks in the south were viewed as an adequate first approximation and required no further work until supported through field verification. However, bioclimate mapping in the northern portion was more problematic.

As was identified in McKenna et al. (2010), bioclimate delineation in the northern portion of the project area was challenging due to “patchy distributions and inconsistent elevational sequences”. In this project we modified and re-aligned the Dawson Planning Region mapping to better conform with the Yukon ELC Framework concepts (Flynn and Francis 2011) and previous North Yukon and Peel Watershed bioclimate delineations. McKenna et al. (2010) shifted the boreal bioclimate zones much further north than previously interpreted, thus creating edge matching issues between the previous projects. Our approach was to move the boreal – taiga zones back to previously reported concepts, based on the Boreal and Taiga Cordillera ecozone boundary described by Smith et al. (2004). This boundary is generally defined by the height of land between the Yukon and Mackenzie watersheds. This approach eliminated a significant encroachment of the Boreal High (BOH) bioclimate zone northward, and was more consistent with the Peel and North Yukon projects. Elevation breaks were then developed and mapped for the Taiga Wooded (TAW) – Taiga Shrub (TAS) – Alpine (ALP) bioclimate zones (Table 4).

Table 2. Overview of west-central Yukon broad ecosystem units.

Group	Type		Phase
DRY	UPLAND Ecosystems (100)	Rock (700)	Not applicable
		Ridge (110)	Ridge – Herb-Bryoid (111) Ridge – Shrub (112) Ridge – Deciduous (113) Ridge – Mixedwood (114) Ridge – Coniferous (115)
		Steep South-Facing Slope (120)	Steep South-Facing Slope – Herb-Bryoid (121) Steep South-Facing Slope – Shrub (122) Steep South-Facing Slope – Deciduous (123) Steep South-Facing Slope – Mixedwood (124) Steep South-Facing Slope – Coniferous (125)
		Upper Slope (130)	Upper Slope – Herb-Bryoid (131) Upper Slope – Shrub (132) Upper Slope – Deciduous (133) Upper Slope – Mixed-wood (134) Upper Slope – Coniferous (135)
MOIST		Gentle Slope and Plain (140)	Gentle Slope – Herb-Bryoid (141) Gentle Slope – Shrub (142) Gentle Slope – Deciduous (143) Gentle Slope – Mixedwood (144) Gentle Slope – Coniferous (145)
		Steep North-Facing Slope (150)	Steep North-Facing Slope – Herb-Bryoid (151) Steep North-Facing Slope – Shrub (152) Steep North-Facing Slope – Deciduous (153) Steep North-Facing Slope – Mixedwood (154) Steep North-Facing Slope – Coniferous (155)
WET		Drainage and Depression (160)	Drainage and Depression – Herb-Bryoid (161) Drainage and Depression – Shrub (162) Drainage and Depression – Deciduous (163) Drainage and Depression – Mixedwood (164) Drainage and Depression – Coniferous (165)
	WETLAND Ecosystems (300)	Wetland (310)	Wetland – Herb-Bryoid (311) Wetland – Shrub (312) Wetland – Treed (315)
		Floodplain (370/380/390)	High Flood Frequency (370): • Floodplain – Gravel Bar-Herb-Bryoid (371) • Floodplain – Shrub (372) Moderate Flood Frequency (380): • Floodplain – Deciduous (383) • Floodplain – Mixedwood (384) Low Flood Frequency (390): • Floodplain – Coniferous (395)
	WATER and ICE (400)		Water (401) Ice (Glacier) (403)
OTHER	**DISTURBANCE (500)**		Natural Disturbances (501) Anthropogenic Disturbances (502) Minesite Disturbances (503)

Table 3. Elevation rules for bioclimate zone boundary delineation in the southern (Boreal Cordillera) portion of the project area.

Bioclimate Zone Boundaries	Elevation Breaks (meters)
BOL - BOH	<450
BOH - SUB	450 - 1100
SUB - ALP	1100 - 1500
ALP	>1500

Table 4. Elevation rules for bioclimate zone boundary delineation in the northern (Taiga Cordillera) portion of the project area.

Bioclimate Zone Boundaries	Elevation Breaks (meters)
TAW	<880
TAS	880 - 1200
ALP	>1200

2.2.2.2 Minimum Polygon Size

McKenna et al. (2010) reported that bioclimate polygons less than 250 ha were merged (dissolved) into their surrounding bioclimate zone. The 250 ha minimum polygon size was selected to best represent "regional climate concepts". In this project, we observed that if these rules were applied to all areas, particularly the northern ALP units, much of the ALP would be dissolved into the TAS or SUB, resulting in a bioclimate map with limited detail. Therefore, in this project the minimum bioclimate zone polygon sizes applied were 10 ha for ALP in the north (Taiga Cordillera), and 50ha for all else.

2.2.3 Wetlands

An important goal of this project was to create a single consistent layer of wetland mapping for the entire west-central project area. Similar to bioclimate zones, several sources of wetland mapping existed for the west-central project area. McKenna et al. (2010) and McKenna and Flynn (2010) delineated wetlands within the Dawson Planning Region, while wetlands were also identified in the North Yukon (Francis et al. 2005) and Peel Watershed (Meikle and Waterreus 2008) projects. However wetland mapping was not available for the area south of the Dawson Planning Region.

Given the various modeling methods and inputs used for the previous projects, it was felt that a single, consistent approach applied to the entire project area would yield better results. None of the previous mapping was manually interpreted. For this reason, the wetland mapping completed for the Dawson Planning Region (McKenna and Flynn 2010) was not directly used. However, model parameters developed during those previous exercises informed wetland mapping completed here.

The wetland model for the Dawson Planning Region (McKenna and Flynn 2010) was based on a slope and slope curvature modelling approach that identified five wetland types. This approach formed the basis for completing wetland modeling across the west-central project area. The slope curvature layer (described in Section 2.1.3.4, above) was modeled for moisture receiving areas (negative SCI values), and intersected with slopes of less than 4%, as identified by the DEM-derived slope layer. A range of values and conditions was examined during development of this model. Inputs were compared to wetland mapping in the Yukon Vegetation Inventory (YVI) and manually interpreted using available imagery (i.e. Geoeye and Google Earth) to determine optimal slope and slope curvature parameters.

In addition to this topographic approach, the land cover (EOSD) also classified wetlands based primarily on CanVec wetland mapping (EOSD 81, 82 and 83). Both the topographic parameters and EOSD inputs were used in later steps of wetland broad ecosystem identification.

2.2.4 Floodplains (Active Riparian)

Similar to bioclimate zones, a number of different map data sources had to be reconciled into a single floodplain layer. Floodplains, or active riparian areas—areas influenced by fluvial process of flooding, deposition and erosion—were previously modeled by McKenna et al. (2010) for the Dawson Planning Region, but were not developed for the southern and northern portions of the west-central project area. McKenna et al. (2010) focused on large river systems and identified floodplains from available surficial material mapping. In this project, several steps were used to identify floodplain environments where broad ecosystem units influenced by fluvial processes may occur.

Floodplains are considered a special case of wetlands, areas where soils are influenced by water. However floodplains only occur adjacent to flowing water features, while wetlands may occur in flat areas or depressions independent of water features.

2.2.4.1 Large River Systems

Floodplains associated with large river systems in the southern portion of project were initially delineated using Canvec waterfeatures and waterbodies, Yukon Vegetation Inventory (YVI), contours and imagery. In the northern portion of the project area, floodplains identified in the North Yukon (Francis et al. 2005) and Peel Watershed (Meikle and Waterreus 2008) PEM maps were selected. Both northern projects completed a separate surficial mapping process, aided by topographic features, to define the large system floodplains. These different layers were then merged into a single large river floodplain layer for the west-central project area.

This merged large river floodplain layer was then clipped with the TPI landform layer. Constraining the larger floodplains to the “plain” landform confined the extent of previous floodplain mapping to flat landforms, preventing manually delineated floodplain environments from ‘creeping up’ the sides of slopes. This step is further discussed in Section 4.2.6, assessment of data sources. These processes resulted in a single large river floodplain coverage for the project area.

2.2.4.2 Small River Systems

In addition to large river floodplains, floodplains associated with smaller river features also occur on lower gradient environments across much of the landscape. To assist in delineating these features a separate process was undertaken for the small river systems. Gentle Valley Bottoms and Mid-slope landforms were identified as the landform features where most small river systems occur. In these landforms, slopes less than 6% that intersected a CanVec water feature were selected as potential small system floodplains.

The large and small river system floodplain layers were then combined to create a single floodplain mask for the west-central project area.

2.2.5 Modeling of Broad Ecosystem Units

Figure 5 provides an overview of the final broad ecosystem unit modeling process. Each step described below was completed in a step-wise manner and evaluated prior to conducting additional steps. In the following sections, modified land cover refers to the updated and revised land cover input described in Section 2.1.7.

2.2.5.1 No Data Areas

The first sub-routine in the BEU modeling process was to assign values to the remaining “no data” area in the modified land cover. The EOSD values remaining for cloud (31), shadow (12) and no data (0) were aggregated into one “No data” BEU classification (BEU 0).

2.2.5.2 Water and Snow/Ice (BEU Type 400)

CanVec waterbodies were labelled as BEU 401, and already formed part of the modified land cover. BEU 401 took precedence as the ‘base water layer’. Where additional water features were represented by the EOSD water class (EOSD 20), these were labelled separately as BEU 404. All EOSD snow/ice (EOSD 31) was reclassified to BEU 403.

2.2.5.3 Wetland Ecosystems (BEU Type 300)

The wetland modeling process utilized the wetland mask generated in Section 2.2.3, above. Potential wetlands occurring outside of floodplains and EOSD derived wetlands were identified and classified as one of three BEU values—311 (wetland herb), 312 (wetland shrub), and 315 (wetland treed). The wetland classes from the modified land cover mapping (EOSD 81, 82 and 83) were then reclassified to BEU values, as shown in Table 5.

Table 5. Correlation between EOSD wetland land cover classes and wetland BEU phases.

Land cover class	BEU
81 (wetland - treed)	315
82 (wetland - shrub)	312
83 (wetland – herb)	311

2.2.5.4 Floodplain Ecosystems (BEU Type 300)

The floodplain mask described in Section 2.2.4, above, was used to identify floodplain broad ecosystems. The floodplain mask was intersected with the modified land cover layer to produce different vegetation types occurring within the floodplain (see Table 2 for overview of floodplain units). Five floodplain BEUs were identified (BEU 371, 372, 383, 384, and 395). Low bench floodplains are dominated by early successional herb-gravel bar (BEU 371) and shrub (BEU 372) units. Middle bench floodplains are predominantly deciduous and mixed-wood (BEUs 384 and 385, respectively). High bench floodplains are predominantly characterized by coniferous forest (BEU 395).

Where wetland units (BEU 311, 312 and 315) occurred within the floodplain, these values were maintained.

2.2.5.5 Upland Ecosystems (BEU Type 100 and 700)

Uplands (areas outside of floodplains and wetlands) form the majority of the west-central project area. Upland BEUs were identified based primarily on an overlay between the TPI landforms and modified land cover inputs. This overlay results in a series of land cover phases (herb, shrub, deciduous, mixedwood and coniferous) occurring on different landforms, providing the integration of the BEU type and phase (see Table 2). Ridge (BEU Type 110), Upper Slope (BEU Type 130), Gentle Slope and Plain (BEU Type 140) and Drainage and Depression (BEU Type 160) ecosystems were identified in this manner.

The slope and aspect layers described in Section 2.1.3, above, were used to identify two upland units that occur as special conditions of Gentle Slope and Plain (BEU Type 140). Steep South-facing Slopes (BEU Type 120) and Steep North-facing Slopes (BEU Type 150) were created by selecting slope magnitudes > 35% occurring on BEU Type 140 that were south and southwest-facing, and north and north-east facing, respectively. These slope and aspect parameters were chosen based on visual interpretation and strong spatial correspondence of the distribution of grasslands to steep south-facing slopes, and sparse, wet conifer forests to steep north-facing slopes.

The modified land cover class of rock (EOSD 32) was reclassified to BEU Type 700, and no additional processing was completed.

2.2.5.6 Disturbances (BEU Type 500)

The final process in the creation of the broad ecosystem map was to overlay the anthropogenic disturbance mask over the prior delineated units. Two human-caused disturbance types were identified: General human development (BEU 502), and mine sites (BEU 503). Due to a lack of input data, natural terrain disturbances (slope failures, landslides, etc.; BEU 501) were not able to be represented.

3 RESULTS

3.1 Bioclimate Zones

The resultant bioclimate layer produced for the project area is seamless and consistent (Figure 6). As with the bioclimate mapping recently completed for the Dawson Planning Region (McKenna et al. 2010), the bioclimate layer produced through this project does not edge match well to the North Yukon (Francis et al. 2005) or Peel Watershed (Meikle and Waterreus 2008) PEM projects. The bioclimate zone concepts used for this project are considered to be more consistent with the evolving concepts of the Yukon ELC Framework (Flynn and Francis 2010), but future revisions should be expected. Table 6 provides an overview of the distribution of bioclimate zones across the west-central project area.

Table 6. Bioclimate zone distribution within west-central Yukon project area.

Bioclimate Zone	Total Area (hectares)	% of Project Area
ALP	464,864	5
BOH	3,369,748	40
BOL	322,309	4
SUB	570,721	7
TAS	1,398,794	16
TAW	2,381,662	28

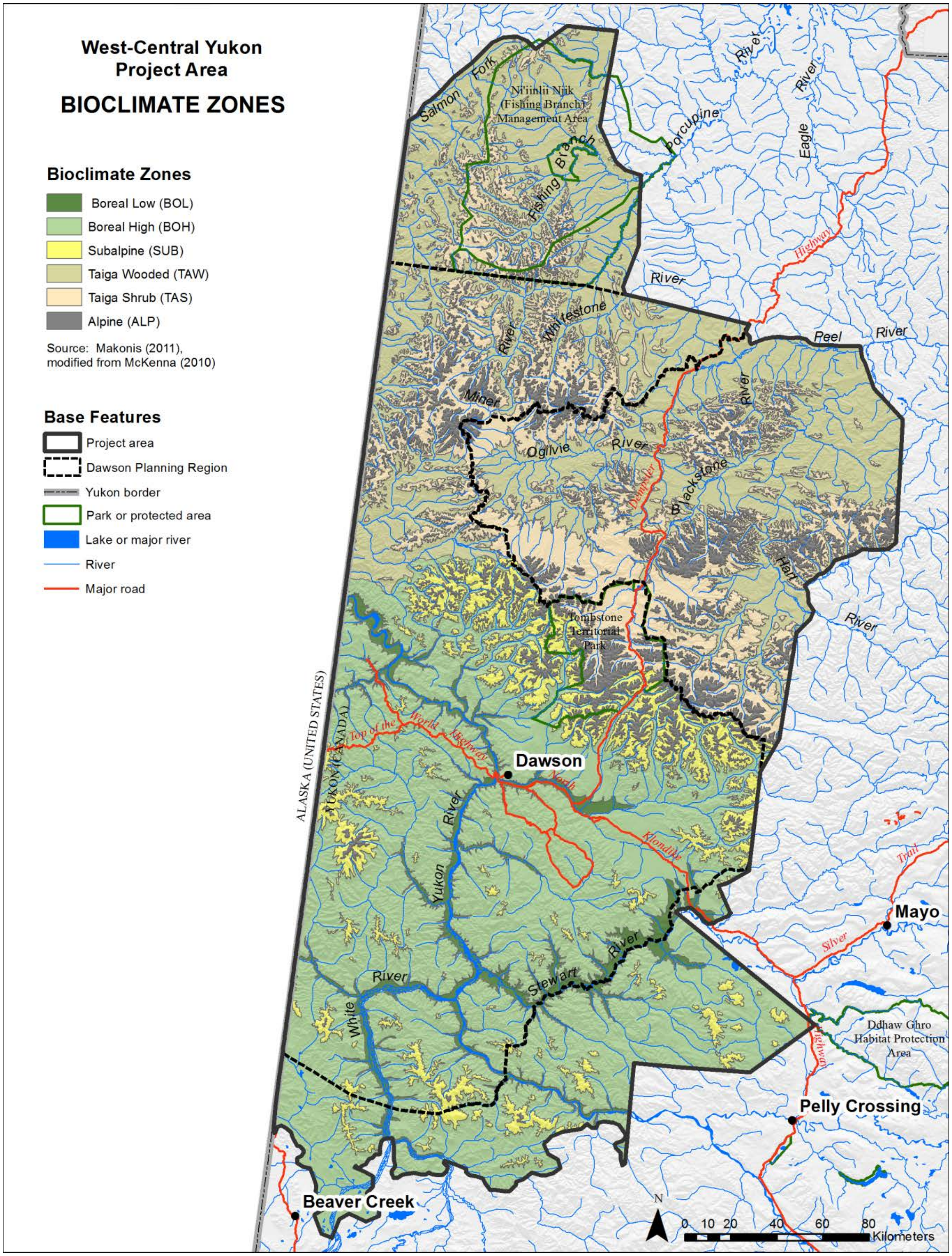

Figure 6. Distribution of bioclimate zones in west-central Yukon project area. Dashed line is the Dawson Planning Region.

3.2 Broad Ecosystems

As shown in Table 2, above, a total of 44 broad ecosystem units (BEUs) were mapped in the west-central Yukon project area. The 44 BEUs are phases of a smaller number of BEU Types and Groups. Figure 7 illustrates the location of BEU Types across the project area, organized by moisture group. Full descriptions of the 44 BEUs and their classification concepts are provided in the companion report, *Regional Ecosystems of West-Central Yukon, Part One: Ecosystem Descriptions* (Grods et al. 2012). Table 7 shows the distribution of BEU Moisture Groups by bioclimate zone.

At this time, individual BEUs have not been identified uniquely within individual bioclimate zones. If organized by bioclimate zone, the number of potential BEUs would increase from the current 44 to 257 possible units, as each unit can potentially exist in all bioclimate zones (but not all units would be present). Users of the broad ecosystem map are encouraged to combine the current 44 units with other data products, including bioclimate mapping, for further analysis and interpretations. As data improves through future field work, it may be possible to identify unique BEUs within individual bioclimate units, creating a product similar to Table 2, for each bioclimate zone. Alternatively, this more detailed approach could be attempted only at the local ecosystems level of the Yukon ELC Framework.

Table 7. Area (ha) of BEU moisture groups occurring within each bioclimate zone of west-central Yukon project area.

MOISTURE GROUP	ALP	SUB	TAS	TAW	BOH	BOL
DRY	347,564	287,947	535,133	327,712	891,014	18,154
MOIST	74,143	265,012	780,816	1,687,105	2,270,250	156,137
WET	253	2,445	52,956	314,814	177,703	88,075
WATER	12,706	4,562	4,393	22,574	16,654	54,033
ANTHRO	0	205	167	511	10,702	5,641
no data	30,198	10,551	25,328	28,946	3,424	270
Total Area	464,864	570,721	1,398,794	2,381,662	3,369,748	322,309

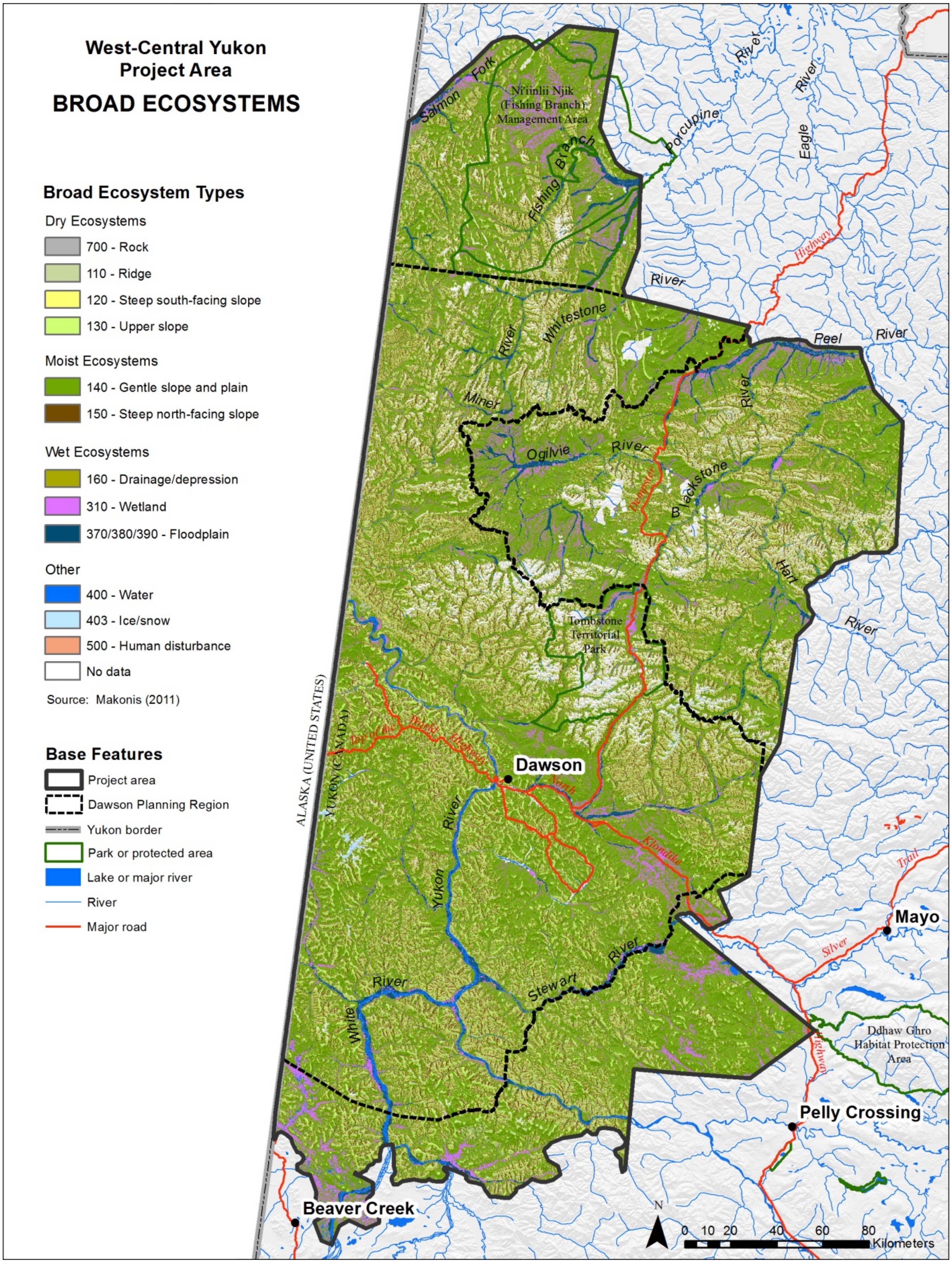

Figure 7. Distribution of broad ecosystem units in west-central Yukon project area, shown by type (landform).

A secondary goal of this PEM project was to further develop the broad ecosystem classification concepts of the Yukon ELC Framework. A central concept in the Yukon ELC Framework is *reference site*—a site that is characteristic, or representative, of the regional climate and bioclimate zone. The data developed through this project provides an initial quantitative approach to identifying potential reference sites for bioclimate zones in the west-central project area.

Table 8 shows potential BEU reference sites (BEU Phase) for each bioclimate zone. These BEUs represent the dominant (i.e. largest area) BEU Phase in each bioclimate zone, as summed from the broad ecosystem mapping. With the exception of the ALP bioclimate zone, these units occur on the gentle slope and plain landform (slopes <25%), and generally represent the "average", or moist, relative soil moisture condition. In the ALP bioclimate zone, two dry ecosystems—rock (BEU 700) and ridge – herb-bryoid (BEU 111)—characterize the highest elevation areas.

Table 8. Potential broad ecosystem unit (BEU) reference sites for west-central Yukon project area.

Bioclimate Zone	BEU Group	Relative SMR	Potential Reference Site (BEU Phase)	Area (ha)	Area (%)
ALP	100	DRY	Ridge – Herb Bryoid (111);	106,232	23%
	700	DRY	Rock (700)	151,271	33%
SUB	100	MOIST	Gentle Slope and Plain – Shrub (142)	101,389	18%
BOH	100	MOIST	Gentle Slope and Plain – Conifer (145)	491,137	15%
BOL	100	MOIST	Gentle Slope and Plain – Conifer (145)	54,917	17%
TAW	100	MOIST	Gentle Slope and Plain – Conifer (145)	339,078	14%
TAS	100	MOIST	Gentle Slope and Plain – Shrub (142)	261,463	19%

4 ASSESSMENT OF DATA INPUTS AND RESULTANT MAPPING

Predictive ecosystem mapping combines existing spatial information such as land cover mapping, surficial material mapping and topographic base feature mapping in a GIS environment, with knowledge of ecosystems, to model, or predict, which ecosystems are likely to occur at a specific location (how these data inputs were combined is discussed in Section 2.2). As such, PEM is highly dependent on the availability and quality of the input information. Understanding the utility and potential limitations of important data sources therefore becomes important. The following sections provide an assessment of the data inputs used to generate the bioclimate and predictive broad ecosystem mapping, and an accuracy assessment of the resultant broad ecosystem map.

In addition to the technical assessment, the project team applied three broad criteria to evaluate the effectiveness of the approaches and map and report products developed through this project:

1. Were bioclimate zone and broad ecosystem unit classification concepts consistent with the goals and concepts of the developing Yukon ELC Framework (Flynn and Francis 2010)? At each step, products and methods were evaluated to ensure this objective was met
2. Were bioclimate zone and broad ecosystem map products seamless and as high of quality as data inputs would allow?
3. Does the bioclimate zone and broad ecosystem unit mapping and reporting (i.e. Part 1: Ecosystem Descriptions) provide a template for future ELC work in Yukon, and assist in advancing the Yukon ELC Framework and standards?

4.1 Review Base

Assessment of the west-central project area data inputs and resultant mapping was facilitated by field plots and imagery. Each is described below.

4.1.1 Field Survey Plots

In the summer of 2011, 63 field survey plots were collected along primary road access (Dempster Highway and North Klondike Highway) in the west-central project area. The survey plots were selected without supporting mapping. The primary site selection criterion was that each sample site had to be located in a cover type that could be captured as a relatively uniform cover class by EOSD (25x25 m cell)—a minimum size threshold of 1.0 ha for each cover type was therefore used. At each sample location the following information were collected:

- Location (GPS with a positional accuracy set at PDOP of 6)
- Representative photo
- EOSD (land cover) classification
- BEU classification
- Surficial Material
- Landform
- General site notes

4.1.2 Imagery

As the mapping component of this project was largely completed as a desk-top mapping exercise, it relied extensively on landscape photography and satellite imagery for mapping checks. It was also used to develop classification concepts and parameters. For example, during the wetland modeling process, several iterations were visually checked with available Geoeye imagery. Similarly, Google Earth and other available Landsat image mosaics were used to examine bioclimate zone boundaries and general vegetation patterns to assist in model parameter development.

4.2 Assessment of Data Inputs

As described in Section 2.1, multiple data sources were used as inputs to the bioclimate and predictive broad ecosystem mapping. However, not all information used in this project could be formally evaluated. The mapping and documentation of the North Yukon (Francis et al. 2005) and Peel Watershed (Meikle and Waterreus 2008) PEM projects, and the recently completed ecodistrict, bioclimate and special feature mapping for the Dawson Planning Region (McKenna et al. 2010) provided important foundational mapping and concepts for this project. Rigorous assessment of these projects were not completed as part of this exercise, but team members and associates were very familiar with them, and provided insights into potential limitations, uses and lessons learned.

A technical assessment of the primary data inputs is provided below.

4.2.1 Digital Elevation Model (DEM)

Three different DEM products—a 16 m (developed from 30 m DEM), 30 m and a 90 m gridded DEM—provide continuous coverage for the west-central project area. As the DEM forms the basis for much of the PEM modeling approach, the 16 m DEM was selected as the most appropriate product. The finer resolution DEM has a greater chance of distinguishing subtle landscape features (ridges, depressions, benches, etc) that form important elements of the landform/TPI classification. The 16 m DEM provides contiguous coverage for most of Yukon, and is recognized as one of the highest quality and most consistent digital data sets in Yukon. The only minor drawback to using the higher resolution product is increased data storage and processing time.

A rapid method to conduct a qualitative assessment of DEM accuracy is to produce surface flow models, and then to compare the resultant to topographic stream networks and/or available imagery. This approach was used for evaluate the accuracy of the 16 m DEM. An overlay of the DEM-derived surface flow model and the CanVec watercourse features for a portion of the Klondike Plateau is shown in Figure 8. This overlay illustrates that in higher relief areas, the DEM-derived flow model is well aligned with the CanVec watercourse features. In areas of lower relief—plains and wide valley bottoms—there is less alignment to the actual CanVec stream network, watercourse features are represented as channels that appear to cut across the landscape erratically, resulting from minor problems with the elevation surface.

This comparison suggests that any detailed modelling based on the DEM in areas of lower relief will likely be inaccurate and should be interpreted cautiously.

Conclusion:

- The 16 m DEM is generally a high quality, seamless product providing very good representation of surface features in areas of moderate to high relief (i.e. ridges and moderate to steep slopes). However, in areas of lower relief the DEM may produce inaccurate results if used for detailed wetland-floodplain modeling. Other data inputs should be used in these areas to improve the overall reliability of predictive ecosystem models for wetlands and floodplains, including surficial material mapping, Yukon Vegetation Inventory (YVI) and CanVec.

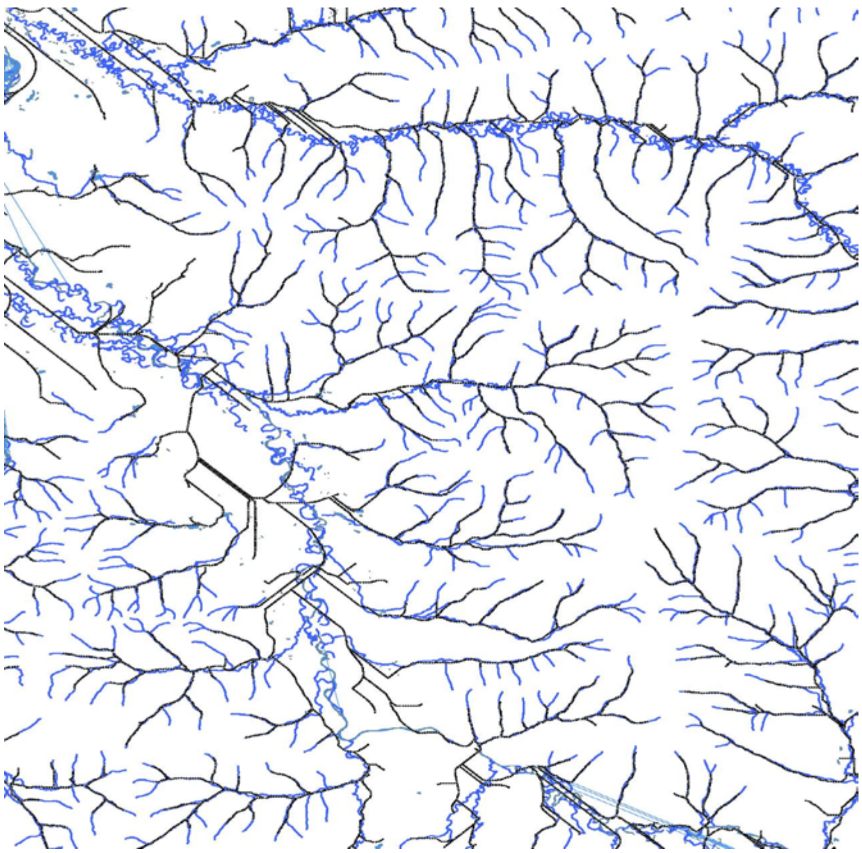

Figure 8. A portion of the Klondike Plateau showing two stream networks: 1) a stream network derived from the 16 m DEM (black lines), and 2) CanVec stream network (blue lines). This figure illustrates that in areas of higher relief (ridges and moderate to steep slopes), the 16 m DEM-derived stream network is well aligned with CanVec streams, but in areas of lower relief (plains and wide valleys bottoms) there is limited correspondence due to small errors in the elevation surface.

4.2.2 CanVec

As of 2009, CanVec became the standard 1:50,000 scale topographic base feature mapping for Canada, replacing the National Topographic Database (NTDB). Yukon is also in the process of adopting CanVec as the standard map base, as NTDB will no longer be supported nationally (NRC 2010b). CanVec is an updated version of NTDB, with various updates and improvements from several sources (NRC 2010a).

While much of the current Yukon Government digital spatial data has been created using the NTDB base (e.g. YVI, surficial geology mapping), CanVec was selected as the base feature mapping for this project. Developing new Yukon ELC products on the CanVec base will ensure longevity and will promote a faster migration of Yukon products to the CanVec base. While it is recognized that the two products are different, specific changes could not be identified during a comparison of the NTDB and CanVec for the west-central project area—they are very similar. Spatial position shifts for some features range between 100 m to 200 m

No major concerns were identified with the CanVec base feature mapping used in this project; mapsheets were edge-matched well and the majority of streams appeared to have appropriate connectivity and well placed within topographic contours. In some other project areas (e.g. Southern Lakes), some examples of missing streams, streams flowing in the wrong direction, or streams terminating suddenly with no connections have been noted. It should also be noted that the early NTDB base mapping was photo interpreted, and in some cases provides a better delineation of wetlands and other special features versus CanVec.

<u>Conclusion</u>:

- The 1:50,000 scale CanVec map base should be selected as the 'go forward' map base for Yukon ELC products. As other Yukon data sources are updated and moved to the new CanVec map base, the Yukon ELC program will be able to directly those data sets. In the interim, as PEM maps are created from data inputs created on different base feature mapping, some alignment problems will persist. However, as noted above, for regional applications the CanVec and NTDB base maps are quite similar, and can be used together without significant issues. Other issues, such as land cover classification accuracy, will have a far greater influence on the accuracy of resultant regional predictive ecosystem maps.

4.2.3 Land Cover

Land cover refers to a satellite image-derived land (or earth) cover classification that depicts land cover classes as raster cells. Land cover in the Yukon is available in many different versions, but in this project refers to a product of Earth Observation for Sustainable Development of Forests (EOSD) lineage created from Landsat imagery. EOSD was created for the forested regions of Canada by the Canadian Forest Service in conjunction with several partners, including Environment Yukon (Canadian Forest Service 2005).

The first iteration of EOSD was completed in 1999 and is known as circa 1999 EOSD. This was a draft product prior to the official national release of EOSD. Circa 2000 EOSD was the second version, and is considered the official EOSD version that has been distributed by Natural Resources Canada (www.geobase.ca). Both the circa 1999 and circa 2000 products were developed using the NTDB base feature mapping. A third iteration of EOSD was completed in approximately 2004-2005, and has become known as the circa 2005 EOSD product. The circa 2005 product has been updated with newer cloud free imagery, and is built on the new CanVec base features. Many map tiles in Yukon were included as part of the circa 2005 release. Nationally, EOSD remains as a stand-alone product (the circa 2005 release is available from http://tree.pfc.forestry.ca/nts_prov.html), but has since been merged with other land cover data from northern Canada and the prairie region, creating what has become known as the Land Cover of Canada (www.geobase.ca).

The land cover map utilized in this project was the circa 2000 EOSD, provided by Environment Yukon as a 25m raster mosaic. This is the 'first generation' EOSD product tied to NTDB base feature mapping. The land cover mosaic used in this project is the same land cover mosaic utilized for the North Yukon (Francis et al. 2005) and Peel Watershed (Meikle and Waterreus 2008) regional PEM projects. The project team was familiar with the EOSD product and its classification strengths and weaknesses were generally known.

The main classification issues identified for the land cover mapping are 1) mis-classification of shrub versus deciduous (or deciduous versus shrub), 2) mis-classified tree density and 3) incorrectly assigned coniferous classes (or confusion with shadow at higher elevations). However, given that the BEU phase classification is only working at the CNVC formation level (herb-bryoid, shrub, deciduous, mixedwood and coniferous) some classification issues become less problematic (e.g. land cover classes sparse conifer (211), open conifer (212) and dense conifer (213) become aggregated into a single coniferous class).

Prior to completing the land cover modifications described in Section 2.1.7, an accuracy assessment was completed on the original land cover map. The 63 survey plots were used to conduct the assessment based on the direct methods described by (Meidinger 2003). The survey plot locations were intersected with the land cover map and a simple 'correct' or 'incorrect' tally was reported (Table 9). The same tally was reported for the modified land cover following its development (Table 9).

Table 9. Accuracy assessment of land cover and modified land cover for the west-central Yukon PEM based on aggregated EOSD land cover classes.

EOSD Class	Land cover		Modified Land cover	
	Correct	Incorrect	Correct	Incorrect
Conifer	13	4	13	4
Bryoid - herb (40)	2	0	2	0
Deciduous	0	14	11	3
Herb (100)	4	0	4	0
Mixedwood	1	6	2	5
Shrub	4	2	4	2
Exposed soil (33)	1	0	1	0
Wetland – conifer (83)	0	4	0	4
Wetland – shrub (82)	0	8	0	8
Percent Accuracy	40%		59%	

Another potential source of classification error is caused by differences between individual satellite image scenes, likely due to time of image acquisition or how individual scenes were processed. Figure 9, land cover from the Ogilvie River basin, shows a large band of shrub (light yellow) surrounded by predominantly herb (bright green). However, upon closer inspection, the differences are not restricted to specific classes but occur across all classes. These classification differences are clearly associated with the boundaries of satellite image tiles. Survey plots were not collected in the area shown but the classification differences would have a major effect on the resultant broad ecosystem classification across the scene.

During the land cover assessment (Table 9), it was also noted that a defined break exists between land cover in the northern portion of the region (Peel Watershed) versus the southern portion (Tombstone and south). Of the 17 survey plots sampled in the north, 60% scored correct. In contrast, of the 46 survey plots samples in the south, only 31% scored correct, suggesting variations among the scenes classified (the southern portion is also more forested with mixes of shrub, deciduous, mixedwood and coniferous).

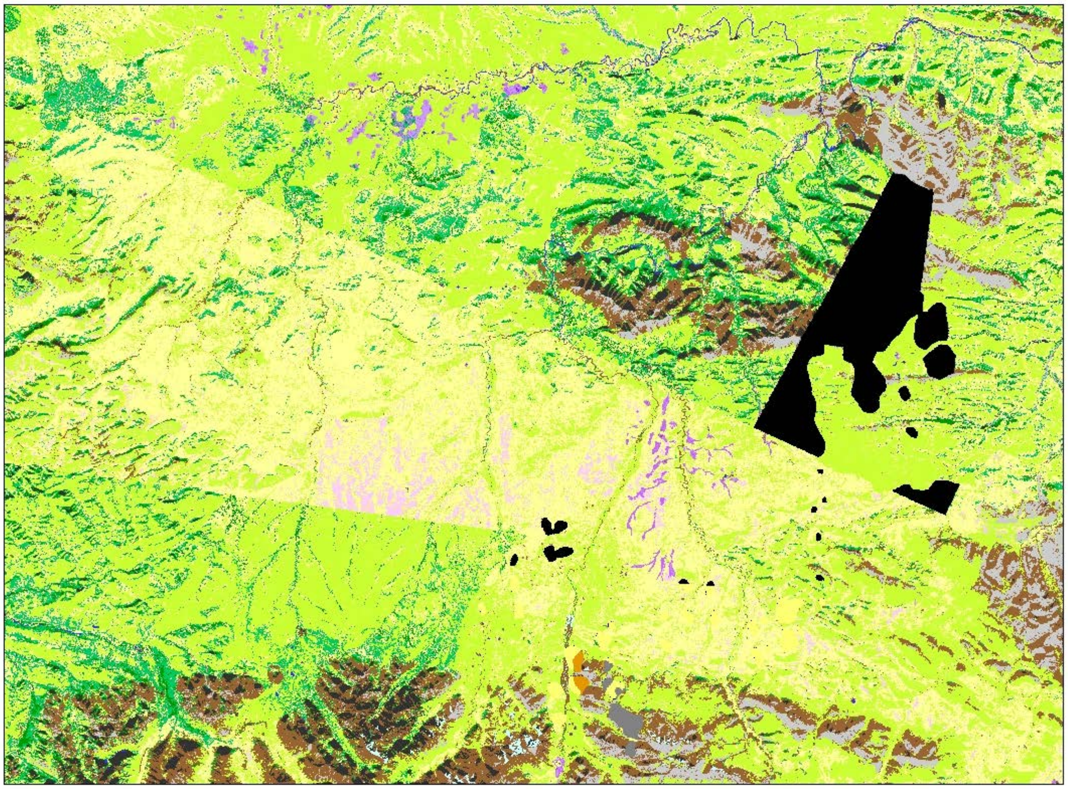

Figure 9. Land cover in the Ogilvie River basin, north of the Tombstone Mountains. Differences in land cover classification between satellite image scenes are clearly visible (black areas are no data).

Conclusion

- While several classification issues are noted for the land cover input, it is currently the only relatively consistent representation of earth cover for large areas of Yukon. Due to the aggregated nature of the broad ecosystem phase classification, some classification errors are not significant. However, the mis-classification of shrub versus deciduous (or deciduous versus shrub) affects very large areas. Important differences between some satellite image scenes are also apparent. As demonstrated by the modified land cover assessment scores, other spatial data can be integrated with the land cover map to improve its accuracy. Based on a preliminary assessment, the use of land cover as a 'stand alone' input to regional PEM may be more applicable in northern Yukon. An important factor that impedes improvement of the land cover mapping is the relative lack of documentation for the various versions—a similar situation as has been noted with the many iterations of ecoregions, ecodistricts, and soil landscapes produced at various times in Yukon.

4.2.4 Yukon Vegetation Inventory (YVI)

Given its photo interpreted inputs, forest cover mapping can be an accurate product and provide important and detailed information for the purposes of PEM modeling and ecological classification. The Yukon Vegetation Inventory (YVI) is the current version of Yukon forest cover mapping. While some desirable non-forested units are inconsistent or missing, over the years the YVI has greatly expanded the attributes captured beyond forest polygons. Classification and attribute limitations of YVI between years and projects have been previously reported and are not re-examined here. The focus of this discussion is on the high accuracy portions of the YVI as noted by the survey plot assessment (Table 10), that can be leveraged in PEM processes.

Based on the survey plots collected in summer 2011, the YVI scored 67% accurate for low – middle elevation cover types.

The YVI scored very well for conifer and deciduous classes, with mixed results for other classes. Wetland-shrub was distinguished well and was captured as shrub and wetland in both the "class" and "Type_For" YVI attribute fields, but did not distinguish wetland-treed (conifer) well, defaulting "forested". Upland shrub conditions were not distinguished well.

A key learning is that YVI was found to be much better at distinguishing between deciduous and shrub than the land cover map. The YVI was therefore used to update shrub classes in the land cover map with YVI-derived deciduous and mixedwood (Section 2.1.7).

Table 10. Accuracy assessment of YVI for the southern portion of the west-central Yukon project area, based on aggregated EOSD land cover classes. This evaluation does not reflect the overall accuracy of YVI as the entire polygon was not considered; this only reflects how well the sample point corresponds to the intersected YVI.

EOSD Class	**YVI**	
	Correct	**Incorrect**
Conifer	10	4
Deciduous	12	1
Mixedwood	4	3
Shrub	0	4
Wetland – conifer (83)	2	2
Wetland – shrub (82)	5	2
Percent Accuracy	67%	

Conclusion

- Where available, the YVI is a more accurate input to the PEM modeling than the land cover mapping. However, incomplete map coverage, inconsistency in the application of map attributes, and issues associated with base mapping and spatial shifts make the current version of YVI best suited as a supportive role to land cover in the west-central regional PEM. If future versions of YVI are produced with a stronger focus on non-forested units, YVI may ultimately replace land cover mapping as a primary input to regional ecosystem mapping in some areas of Yukon.

4.2.5 Wetlands

Wetland mapping completed by McKenna and Flynn (2010) and McKenna et al. (2010) was available for the Dawson Planning Region portion of the project area. As described in Section 2.2.3, the original intent of the project was to extrapolate this Dawson Planning Region wetland mapping to the entire project area. However, due to differences in concepts and data inputs, it was found more efficient, and consistent, to create a new wetland layer.

Prior to this decision, the wetland mapping of McKenna and Flynn (2010) was reviewed and assessed against the 63 survey sample plots. Only the wetland mask was assessed, not individual wetland types (i.e., was a wetland area noted in the survey sample plots located within the wetland mask). Of the 12 wetland survey sample plots, 9 of the 12 (75%) were correctly identified as wetlands. The west-central wetland model yielded only slightly better results in correctly identifying wetlands. Of the 12 wetland survey sample plots, 10 of the 12 (83%) were correctly identified as wetlands.

The extent to which the wetland masks extend beyond gentle valley bottoms and level areas was observed to be the major difference between the two wetland products. Both the McKenna and Flynn (2010) and west-central project area wetland masks extend into adjacent upland conditions. However, due to the use of a constrained slope model, the west-central wetlands encroach into uplands to a lesser degree.

As part of the broad ecosystem assessment, only the west-central project area wetland phases were assessed for accuracy (McKenna and Flynn 2010 wetland types were not assessed). Discrepancies in the land cover classification reduced the accuracy of broad ecosystem wetland phases (herb, shrub or treed) to 4 out of 12 (33%) correct. Confusion between the wetland-shrub and wetland-conifer signatures was the primary issue. Results are further described in Section 4.3, below.

4.2.6 Floodplains

Floodplain mapping can be accomplished through either modeling or manual delineation. Typically, manual delineation is used for large river systems, while modeling is used for smaller features (see Section 2.2.4). McKenna et al. (2010) chose to represent floodplain environments by selecting fluvial materials from surficial geology mapping. A review of the floodplains mapped using this approach illustrated that while the surficial material mapping accurately identified areas of active fluvial conditions, it tended to greatly over-represent their spatial extent.

Figure 10 shows a topographic cross section of Bonanza Creek near Dawson, illustrating the extent of fluvial materials as identified by 1:100,000 scale surficial geology mapping (red line, labelled 'Silvatech'). The generalized nature of the surficial geology fluvial unit results in active floodplains occurring well above the active channel, and covering side slopes. This situation could be improved by constraining the fluvial materials to level areas (<3% slopes as derived from DEM).

In comparison, the same floodplain environment delineated by the west-central project is shown as a green line, labelled 'Makonis' (alss shown on Figure 10). The initial floodplain masks developed for the west-central project area were mainly comprised of fluvial material mapping, but active floodplains were constrained to relatively level areas (<3% slope) within the fluvial unit.

Only three survey plots were collected from floodplain areas. Of these three plots, 3 out of 3 (100%) occurred within the modeled floodplain mask. Results for the predicted broad ecosystem phase (herb-bryoid, shrub, deciduous, mixedwood, coniferous) also scored 100% accuracy.

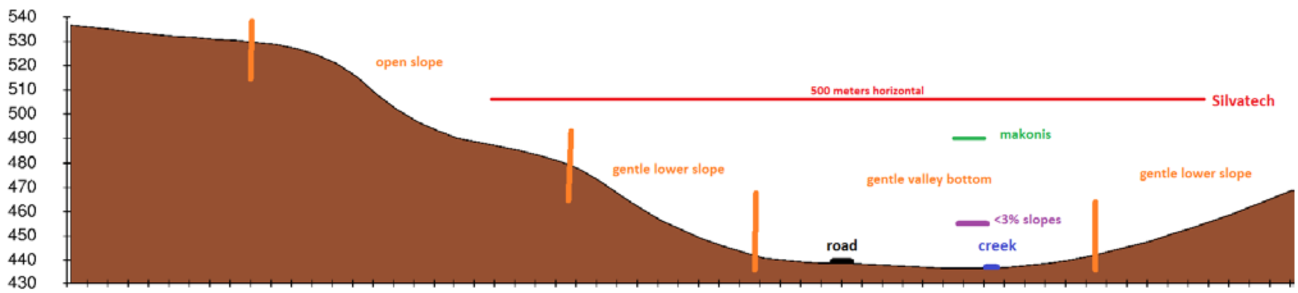

Figure 10. Cross section of Bonanza Creek south of Dawson. Surficial mapping of fluvial conditions, shown in red, runs well up slope, beyond the active fluvial channel.

4.3 Assessment of Predictive Broad Ecosystem Mapping

Based on the 63 survey sample plots, the overall accuracy of the final predictive broad ecosystem map (to BEU phase) was determined to be 57% (36 of 63 plots correct). Inconsistencies associated with the land cover data input layer are the most significant source of error (see Table 9).

Wetlands (shrub and treed), mixedwood forest and anthropogenic disturbances were the areas of greatest concern, accounting for almost half of the combined mapping errors. As discussed in Section 4.2.4 above, accuracy of the wetland mask was found to be 83% (10 of 12 survey sample plots correct), yet wetland phase classification only scored 33% (4 of 12 survey sample plots correct). The major contributing factor was misclassification between conifer and shrub wetlands (conifer dominated wetlands, typically bogs, were incorrectly classified as shrub dominated wetlands) (Figure 11). Of the 7 survey sample plots located in mixedwood forest, 6 were misclassified as deciduous (Figure 12). Most errors associated with anthropogenic disturbance mapping resulted from over-representation of feature extents, due to the conversion from vector to raster.

The remaining mapping errors are spread evenly among the remaining units, illustrating the small issues and inconsistencies inherent throughout all of the PEM input data layers.

Figure 11. Sample photo of conifer wetland where land cover classified as shrub wetland.

Figure 12. Sample photo of mixedwood condition where land cover classified as deciduous.

5 RECOMMENDATIONS

5.1 Considerations for Use

The following points should be considered while using and interpreting the bioclimate and broad ecosystem map products developed for this project:

- The bioclimate and broad ecosystem mapping completed through this project is not intended for use at scales larger (more detailed) than 1:100,000. These products do not replace the requirement for detailed ecosystem mapping at local scales for transportation corridor development, mine site assessment, urban development, etc.
- Bioclimate and predictive broad ecosystem mapping was completed as a desktop exercise. At this time, ecosystem descriptions included in the companion report, *Part 1: Ecosystem Descriptions*, are based primarily on team member experience in the project area and the interpretation of a large number of representative oblique landscape photographs.
- The organization of broad ecosystem units within an edaptopic grid, along a gradient of relative soil moisture, is based on sound ecological principles but at this time, is somewhat conceptual. Within a mapped BEU, fine scale variability may occur that is not able to be captured at the broad scale of this mapping.
- While only classified generally (wetland-herb, shrub and treed), wetlands appear to be reasonable well delineated (approximately 80% of the estimated total wetlands in region are captured). However, wetland phase classification accuracy is currently low (estimated less than 50%) due to classification errors associated with input land cover mapping.
- Broad ecosystem mapping in areas of low relief (plains and valley bottoms) may be inaccurate due to mis-representation of surface relief by the DEM. These low relief areas, while all classified as moist or wet, may include a range of conditions.
- At this time, accuracy of the BEU mixedwood phase is not well understood, but appears to be greatly underrepresented in the final broad ecosystem map. At this time, for the purposes of interpretation and display, it may be more accurate to combine the mixedwood phase with the deciduous phase (3), and treat as deciduous-dominated.

5.2 Future Work

With a view to advancing the Yukon ELC Framework, and improving the products developed through this project, the following sections identify potential areas for future work or research regarding broad and local ecosystems, bioclimate zones, and data inputs.

5.2.1 Broad Ecosystems

- Future field sessions should be conducted to improve the BEU delineations and better develop the broad ecosystem classification for inclusion in a second version of the *Part 1: Ecosystem Descriptions* guidebook.

- Interpreting the BEUs in the context of bioclimate zones is important to understanding their ecological function and distribution. As part of future focused field work, a matrix table of BEUs occurring in each bioclimate zone should be developed and proven out. The current map products can be used as an initial guide to focus field efforts.

- Formally developing the more detailed level of the Yukon ELC Framework, local ecosystems, in an accessible portion of the west-central project area, is strongly recommended. This exercise would ensure that all concepts within the ELC classification hierarchy adequately link, and can be appropriately scaled up or down. To date, there are few (or no) areas in Yukon where bioclimate, broad ecosystem, and local ecosystem classification and mapping have occurred using current Yukon ELC Framework concepts in the same geographic area.

5.2.2 Bioclimate Zones

- At this time, current bioclimate concepts should be further developed prior to making additional changes to the bioclimate zone mapping in the west-central project area.

- A recommended approach to advancing bioclimate zone concepts for Yukon, as part of the Yukon ELC Framework, is to complete a mapping process for the entire territory. The identification of bioclimate subzones would be secondary to the formalization and completion of bioclimate zone concepts. If a territory-wide initiative is completed. Some subzones and changes in zone boundaries will naturally evolve in the course of completing the bioclimate mapping. This and prior work in the Dawson area, in addition to the Ross River PEM and previous North Yukon and Peel Watershed projects, provide a solid basis to advancing bioclimate mapping across the territory.

5.2.3 Data Inputs

- Predictive ecosystem mapping relies heavily on digital elevation models (DEM) to represent landform, slope and aspect conditions. These conditions inform relative soil moisture, a primary determinant of ecosystem pattern. While the current 16 m DEMs provide good representation of surface features in areas of moderate to high relieve, low relief areas continue to be problematic (see Figure 8). Given the current resolution of the input data to create the DEMs, it may not be possible to improve the surface representation of low relief areas without adding a higher density of elevation points in these areas.

- CanVec 1:50,000 scale base feature mapping should be selected as the common base map for all future bioclimate and broad ecosystem map products developed through the Yukon ELC

Framework. CanVec hydrology features should be integrated into the ELC products, and remain unaltered during the mapping process.

- If future PEM mapping in Yukon is envisioned, consideration should be given to expanding the Yukon Vegetation Inventory (YVI) territory-wide. Being a photo-interpreted product, it was found to be of higher accuracy than available satellite image derived land cover products. If expanded YVI mapping is completed in areas with low forestry potential, it should place a higher focus on mapping non-forested areas, and wetlands. If such an approach were taken, the YVI could become the primary source of wetland mapping in Yukon. If YVI mapping is expanded, it is strongly recommended that the new CanVec base features mapping be adopted as the new base map.

- While the EOSD/land cover product provides relatively comprehensive map coverage across all of Yukon, in some areas and for some land cover types classification accuracy may be less than 50%. If EOSD/land cover is to be used as the primary landcover input for future exercise, it should be refocused to the level four classification (herb, shrub, deciduous, etc.) and improved. In addition, independent QA should be performed as an evaluation process to guide the classification.

- Surficial geology mapping can form an important input to PEMs. In Yukon, a large amount of the historical surficial geology mapping has been digitized and is available. However, due to different scales and mapping styles, using the surficial geology mapping in a consistent manner across large areas continued to be problematic. While potential a significant undertaking, a logical next step in the evolution of surficial geology would be a 1:50,000 – 1:100,000 scale Yukon-wide product built on the 1:50,000 scale CanVec base feature mapping.

- While it is recognized that the National Ecological Framework terrestrial ecozone, ecoregions and ecodistricts (Smith et al. 2004) is not a formal part of the Yukon ELC Framework, maintaining these layers for Yukon is recommended. The boreal and taiga bioclimate zones are currently based on the Boreal and Taiga Cordillera ecozone boundaries, and were found very useful in this project. Ecoregions and ecodistricts, while based on somewhat different classification criteria, continue to be useful land units for management and interpretation. Further, the ecoregion and ecodistrict mapping should be maintained as "official" layers until approved by appropriate bodies—continuous modifications to these layers through individual mapping projects becomes problematic. As an example, since 2004, multiple sets of ecoregion and ecodistrict linework has been developed for the west-central project area, including Francis et al. (2005), Meikle and Waterreus (2008), and McKenna et al. (2010). All of these products are different, in either scale or concept, from the published ESWG (1996) version as reported by Smith et al. (2004).

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