Appendix 13E Expanded Terrestrial Ecosystem Mapping Legend

Methodology and Interpretations for:

Ekwan Pipeline Corridor Terrestrial Ecosystem Map

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1. BACKGROUND

The Ekwan Pipeline Inc. natural gas pipeline is a proposed utility corridor scheduled for construction in winter, 2003-2004. The project area is situated approximately 150 km east of Fort Nelson, British Columbia and occurs within the moist, warm Boreal White and Black and Spruce Biogeoclimatic Subzone, Fort Nelson variant (BWBSmw2) within the Fort Nelson Lowlands (FNL) Ecosection. The proposed pipeline is approximately 82.5km in length with the majority (78km) located in British Columbia, and a 4.5km portion in Alberta.

In order to support a range of wildlife and ecological interpretations required for environmental assessment and route location selection, AXYS Environmental Consulting Ltd. (AXYS) contracted Applied Ecosystem Management Ltd. (AEM) to develop a 1:20,000 scale terrestrial ecosystem map (TEM) for a 2km corridor centered on the proposed pipeline right-of-way. This report documents the methods, results and interpretations of the Ekwan pipeline corridor Terrestrial Ecosystem Map.

2. OBJECTIVE

The primary objective of this project was to create a 1:20,000 scale terrestrial ecosystem map for a 2km corridor centered on the proposed 80km long (160 km^2 total mapping area) Ekwan natural gas pipeline in the BWBSmw2 of the Fort Nelson Lowlands Ecosection in northeast British Columbia / northwest Alberta. In British Columbia, the project is located within TRIM mapsheets 94I.064 – 070. The small portion of the proposed pipeline corridor in Alberta is contained within NTS 84 L/12. AEM was responsible for all components of TEM map development. Wildlife and associated environmental interpretations were not completed by the terrestrial ecosystem mapping team.

3. METHODS

This project involved two major components: 1) field reconnaissance and 2) mapping. Each is describe below.

3.1. FIELD RECONNAISSANCE

On October 23rd and 24th 2002, S. Grindal (AXYS), N. Steffen (AEM) and B. Murray (LGL Ltd.) conducted helicopter overview flights along the proposed Ekwan pipeline corridor and associated road right-of-way. During the overview flight oblique colour photographs were taken by N. Steffen to assist during the aerial photograph interpretation and mapping phase of ecosystem map production. Appendix One contains images representative of the ecosystem conditions within the project area. Following the overview flight, all photographs were organized and labeled with their approximate location (km distance) along the proposed pipeline route.

On October 24th, four sites were sampled for soil, vegetation communities, fisheries and wildlife values (Appendix One contains sample soil and vegetation sample site descriptions). Helicopter access to additional sites was limited by lack of landing sites and poor weather.

3.2. MAPPING

3.2.1. MAPPING CONCEPTS AND STANDARDS

The 1:20,000 scale TEM map produced through this project used a combination of British Columbia Ministry standards and modified methods considered more appropriate for the particular goals of this project. Vegetation units (ecosystem units) and their development stages (structural stage and associated modifiers) were classified and mapped according to standard TEM codes and provincial site series (RIC 1998, DeLong et al. 1990). Terrain components of the ecosystem map were classified based on modified methods of Howes and Kenk (1997) using concepts and standards developed for use in northern environments by Francis and Steffen (2003). Two levels of terrain interpretation were completed for this project; landscape types (position) and bio-terrain units. Terrain classification codes and definitions as described by Francis and Steffen (2003) are contained in Appendix Two.

3.2.2. AERIAL PHOTOGRAPH INTERPRETATION

Black and white laser prints of 1:40,000 aerial photographs were used to interpret landscape types, bio-terrain units and ecosystem units. Aerial photographs 15BCB97032 – 215-235 and 15BCB97033 – 035-046 provided coverage for the mapping area. Available aerial photographs were of poor quality with limited contrast, making the interpretation process somewhat more difficult.

The initial step in the interpretation process was to mark the proposed pipeline right-of-way on every second photograph; this step was performed accurately using a number of small anthropogenic features as reference. A 1km buffer on either side of the centerline was then created to delineate the extent of the mapping area. Using a large format stereoscope, landscape types were first identified, followed by bio-terrain units. Landscape type was classified based on the primary ecosystem unit. Once bio-terrain units were delineated, ecosystem units (vegetation communities) were classified and nested within the bio-terrain units. Ecosystem unit structural stage descriptors were interpreted for each ecosystem unit. Given the poor quality of the available aerial photographs, oblique colour photographs taken during the helicopter overview flights were used extensively for verifying ecosystem unit and structural stage information.

3.2.3. DIGITAL DATA CAPTURE / DATABASE DEVELOPMENT

All digital data capture and database development was completed in ArcView 3.2 and ArcGIS 8.1. A 1m digital orthophoto provided by AXYS was used as the primary base map for the project. Due to the extremely limited topographic relief, it was concluded by the project team that the orthophoto provided a more accurate mapping base than TRIM. No TRIM hydrology features were used in the creation of the Ekwan TRIM map; all have been digitised manually from the orthophoto base.

The initial digital data capture step was digitising of the proposed pipeline right-of-way center line. ArcView was then used to generate a 1km buffer polygon (2km total width) around the centerline. This buffer polygon was used to define the extent of mapping. In two instances, specifically around the Hay and Kotcho Rivers, the buffer was expanded to more than 1km to facilitate the meaningful ecosystem mapping of the complex riparian / lowland areas. Maintaining the 1km buffer at these locations would have resulted in many dissected map polygons, and would have reduced the utility of potentially important interpretations. As a result, the mapped area increased by 14.6 km^2 from the original of approximately 159 km^2 to a total of approximately 173.7 km^2 for this project. All ecosystem unit digitising was performed "heads-up" in an ArcView environment; ecosystem units and polygons interpreted from the aerial photographs were digitised directly on the orthophoto basemap, ensuring accurate line transfer that properly fit the orthophoto base. All data capture as performed in UTM Zone 10 (NAD83) projection.

Digitised lines were converted to polygons using ArcGIS. The resultant polygon coverage was then converted to an ArcView shapefile where the table structure was added and ecosystem attributes entered polygon by polygon. Table 1 provides a detailed description of the attribute table structure of the resultant Ekwan TEM map. The final digital TEM map file was then converted to an ArcInfo export (.e00) file using ArcToolbox.

Table 1. Attribute table structure and definitions for Ekwan TEM map; a) ecosystem units, b) landscape types and c) bio-terrain units. Database structure modified from RIC (1998). Landscape type and bio-terrain unit definitions follow Francis and Steffen (2003) as described in Appendix Two.

a) Ecosystem Units

Field	***Definition***	***Codes***	***Notes***
ECO_SEC	Ecosection	FNL	
BGC_ZONE	Biogeoclimatic zone	BWBS	
BGC_SUBZON	Biogeoclimatic subzone	mw	
BGC_VRT	Biogeoclimatic subzone variant	2	
BGC_PHASE			Not applicable
SIMC_S1CO	Primary ecosystem unit cover (decile)	5, 6, 7, 8, 9, 10	= Percent cover / 10
SITEMC_S1	Primary ecosystem unit	AM, AH, SH, BS, TB, SG, AH, OW, PD, RZ, DP, DV	Two letter code
STRCT_S1	Primary ecosystem unit structural stage	0, 1, 2, 3, 4, 5, 6, 7	Follows RIC (1998)
STRCT_M1	Primary ecosystem unit structural stage modifier	a, b, c, d (1-3) s, t, m, i, h (4-7)	Follows RIC (1998)
STAND_A1	Primary ecosystem unit stand composition	C > 75% coniferous B > 75% broadleaf M (C<75% & B<75%)	Applicable to forested ecosystem units only
SERAL_1			Not applicable
TREE_C1			Not applicable
SHRUB_C1			Not applicable
ECOLABEL1	Primary ecosystem unit label	e.g. 7BS6iC	Concatenation of all primary ecosystem unit information (useful for cartographic purposes)
SIMC_S2CO	Secondary ecosystem unit cover (decile)	5, 6, 7, 8, 9, 10	= Percent cover / 10
SITEMC_S2	Secondary ecosystem unit	AM, AH, SH, BS, TB, SG, AH, OW, PD, RZ, DP, DV	Two letter code
STRCT_S2	Secondary ecosystem unit structural stage	0, 1, 2, 3, 4, 5, 6, 7	Follows RIC (1998)
STRCT_M2	Secondary ecosystem unit structural stage modifier	a, b, c, d (1-3) s, t, m, i, h (4-7)	Follows RIC (1998)
STAND_A2	Secondary ecosystem unit stand composition	C > 75% coniferous B > 75% broadleaf M (C<75% & B<75%)	Applicable to forested ecosystem units only
SERAL_1			Not applicable
TREE_C1			Not applicable
SHRUB_C1			Not applicable
ECOLABEL2	Secondary ecosystem unit label	e.g. 3BS6iC	Concatenation of all secondary ecosystem unit information (useful for cartographic purposes)
PRE_DEV1	Ecosystem polygon pre-anthropogenic disturbance condition		Applicable to disturbed polygons only (inferred based on surrounding polygon conditions).
COMMENTS			Relevant comments (text string)

Table 1 (cont.). Attribute table structure and definitions for Ekwan TEM map.

b) Landscape Types (based on Francis and Steffen 2003, Appendix Two)

Field	*Description*	*Codes*	*Notes*
LAND_POS	Landscape position	U-Upland L-Lowland	General landscape position (upland or lowland) classified based on primary ecosystem unit
LAND_SUBTY	Landscape sub-type	d-depressional r-riparian u-unclassified (other)	d-depressional, r-riparian, u-unclassified (other)
LAND_TYPE	Landscape type		Concatenation of LAND_POS and LAND_SUBTYP

c) Bio-Terrain Units * (based on Francis and Steffen 2003, Appendix Two)

Field	*Description*	*Codes*	*Notes*
TER_PM1	Primary bio-terrain unit parent material	K-Glacial Lacustrine H-Waterbody O-Organic F-Fluvial	
TER_DRN1	Primary bio-terrain unit soil drainage	m-moderately well i-imperfectly p-poorly v-very poorly	
TER_SLAS1	Primary bio-terrain unit slope-aspect	g-gentle	Entire mapping area has no ecologically-meaningful aspect (<25% slope)
TER_SITE1	Primary bio-terrain unit site modifier	a-anthropogenic p-permafrost	Presence of permafrost interpreted based on ecosystem unit conditions
TER_LABEL1	Primary bio-terrain unit label	e.g. 7Kigp	Concatenation of all primary bio-terrain information (cover from Simc_s1co). Useful for cartographic purposes.
TER_PM2	Secondary bio-terrain unit parent material	K-Glacial Lacustrine H-Waterbody O-Organic F-Fluvial	
TER_DRN2	Secondary bio-terrain unit soil drainage	m-moderately well i-imperfectly p-poorly v-very poorly	
TER_SLAS2	Secondary bio-terrain unit slope-aspect	g-gentle	Entire mapping area has no ecologically-meaningful aspect (<25% slope)
TER_SITE2	Secondary bio-terrain unit site modifier	a-anthropogenic p-permafrost	Presence of permafrost interpreted based on ecosystem unit conditions
TER_LABEL2	Secondary bio-terrain unit label	e.g. 7Kigv	Concatenation of all secondary bio-terrain information (cover from Simc_s2co). Useful for cartographic purposes.

Table 1 (cont.). Attribute table structure and definitions for Ekwan TEM map.

c) Bio-Terrain Units (cont.) * (based on Francis and Steffen 2003, Appendix Two)

POS_PERM_R	Total amount (decile cover) of map polygon potentially containing permafrost	1p - 10% 2p -20% 3p - 30% 4p - 40% 5p - 50% 6p - 60% 7p - 70% 8p - 80% 9p - 90% 10p - 100%	Presence and amount of permafrost interpreted based on ecosystem unit conditions

* Percent cover of primary and secondary bio-terrain unit is derived from Simc_s1co and Simc_s2co, respectively.

4. RESULTS

Approximately 17,460 ha was mapped at a scale of 1:20,000. The mapping area is situated in an old glacial lakebed with very limited relief; the major mineral parent material is Glacial Lacustrine, clay rich sediments. Fluvial, Organic and Water comprise the remainder of the primary parent materials. Upland depressional ecosystems form the majority of the mapping area. Table 2 contains a listing of ecosystem units encountered within the 160km^2 Ekwan pipeline ecosystem mapping project area. Table 3 shows the distribution of primary and secondary ecosystem units encountered within the ecosystem map.

The most important upland forested ecosystem was SwAt – Stepmoss (AM) in a broadleaf stand composition, accounting for 21% of the mapping area. Poorly drained, upland depressional ecosystems cover approximately 65% of the mapping area. The most frequently encountered poorly drained, upland depressional ecosystems included Lt – Buckbean (TB), Mountain Alder – Alaska Paper Birch – beaked sedge – Horsetail (AH) and Sb – Cloudberry – Sphagnum (BS). Lowland ecosystems account for approximately 10% of the project area, with the forested Sw – Currant – Horsetail (SH) unit being the most important. Most forested lowland ecosystems are contained within the two major riparian corridors of the Kotcho and Hay Rivers. Direct human disturbance in the form of large cutlines, roads, drill pads or developed areas accounts for <1% of the mapping area.

Table 2. Ecosystem units and major structural stages encountered within Ekwan TEM mapping area.

Site Series / Ecosystem Unit*	***Code****	***Site Series / Ecosystem Unit Description***	***Structure***	***Notes***
BWBSmw2 - 01	AM	SwAt - Stepmoss	2, 3, 4, 5, 6, 7	Upland, mineral, mesic
BWBSmw2 - 05	SH	Sw – Currant - Horsetail	2, 3, 4, 5, 6, 7	Lowland, fluvial terrace, mineral
BWBSmw2 - 08	BS	Sb – Cloudberry – Sphagnum	2, 3, 4, 5, 6, 7	Upland depressional, organic, poorly drained
BWBSmw2 - 10	TB	Lt – Buckbean	2, 3, 4, 5, 6, 7	Upland depressional, organic, poorly drained
BWBSmw2 - 00	SG	Sedge – Grass fen	2	Wetland
BWBSmw2 - 00	AH	Mountain Alder – Alaska Paper Birch – beaked sedge – Horsetail	2, 3a, 3b, 5i	Added 5i, some birch stands are greater than 10m
Non-vegetated	OW	Open Shallow Water		< 2m deep water
Non-vegetated	RZ	Road		
Non-vegetated	PD	Pond		
Non-standard unit	DP	Drill Pad		
Non-standard unit	DV	Development		Buildings and structures on site

* Site Series / Ecosystem Unit descriptions from DeLong et al. (1990) - vegetated units, and RIC (1998) – non-vegetated units. Two non-standard, non-vegetated ecosystem units were created for use within this project: Drill Pad (DP), and Development (DV).

** Ecosystem Unit Codes from RIC (1998) BC Resource Inventory Committee revised codes contained in *map_codes2001.xls* (November 2001).

Table 3. Ecosystem unit distribution (primary and secondary)

Ecosystem Unit	***Primary Unit (ha)***	***Secondary Unit (ha)***	***Total (ha)***	***Total (%)***
AH	2547	322	2869	16
AM	3483	134	3617	21
BS	2079	492	2571	15
DP	14	0	14	0
DV	1	0	1	0
OW	93	137	230	1
PD	0	0	0	0
RI	205	19	224	1
RZ	0	1	1	0
SG	1022	1053	2075	12
SH	1134	8	1142	7
TB	4044	669	4712	27

Total area mapped = 17,457 ha

5. INTERPRETATIONS AND LIMITATIONS

Sw – Currant – Horsetail (SH) is the most productive forested unit within the Ekwan pipeline corridor. These forests have the capacity to reach an advanced structural stage at the earliest time-since-disturbance of all units encountered. SwAt – Stepmoss (AM) generally occurs on well-drained upland mineral sites and represent the lowest geotechnical constraints for pipeline construction and associated infrastructure development. The ecosystem mapping team did not evaluate wildlife values as part of the mapping exercise.

Permafrost is present sporadically throughout the proposed pipeline corridor with the most likely ecosystem unit containing permafrost being Lt – Buckbean (TB). TB units in a structural stage of 3b or 4iC were considered to be the most likely to contain permafrost (interpreted permafrost rate has been indicated for each polygon in the POS_PERM_R attribute field as described in Table 1). As the presence of permafrost can only be verified by sufficient field sampling, the predicted presence and abundance of permafrost determined from this mapping should be interpreted with this consideration. Some permafrost may be present in upland depressional polygons currently indicated as not containing permafrost.

The Ekwan pipeline corridor map was created to fulfill requirements of this specific project. Therefore, the Ekwan ecosystem map does not meet RIC (1998) terrestrial ecosystem mapping standards. Non-standard terrain mapping conventions (Appendix Two) and several project specific anthropogenic units have been used. Field survey intensity levels also do not meet RIC (1998) standards. However, classification and positional accuracy are expected to be very high given the available orthophoto basemaps, overview flights and limited ecological diversity of the Fort Nelson Lowlands Ecosection.

The Ekwan pipeline corridor ecosystem map was created with very limited field checks. Given this situation, the potentially most inaccurate components of the mapping are associated with ecosystem unit structural stage estimation and the predicted presence and abundance of permafrost within map polygons. Permafrost has been interpreted based on its known association with specific ecosystem units and their structural characteristics. Structural stages have been estimated largely based on overview flights and oblique photographs taken during the aerial surveys.

6. DELIVERABLES

Two primary deliverables were created through this project: 1) seamless digital ecosystem map for proposed Ekwan pipeline corridor, 2) metadata document.

Digital file:	ekwan_jan10.e00 / ekwan_jan10
Data format:	ArcInfo export / ArcInfo coverage
Projection:	UTM Zone 10, NAD 83
Metadata file:	AEM_AXYS_Ekwan_final_report_Feb11-2003.pdf

7. REFERENCES

DeLong, C., MacKinnon, A. and Jang, L. 1990. *A Field Guide for Identification and Interpretation of Ecosystems of the Northeast Portion of the Prince George Forest Region*. B.C. Ministry of Forests.

Francis, S.R., and Steffen, N. 2002. *Rationale, Concepts and Proposed Methods for the Yukon Ecosystem Classification and Mapping Framework – First Approximation*. *Draft ver. 1.3.* Document prepared by Applied Ecosystem Management Ltd. and Yukon Ecosystem Classification and Mapping Working Group for DIAND Environment Directorate and DIAND Lands Branch. January, 2003.

Howes, D.E. and Kenk, E. 1997. *Terrain Classification System for British Columbia*. Ver. 2. Resources Inventory Branch, Ministry of Environment, Victoria.

Resources Inventory Committee. 1998. *Standards for Terrestrial Ecosystem Mapping in British Columbia*. Terrestrial Ecosystems Task Force, Ecosystem Working Group, Province of British Columbia, Publication #315.

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Appendix One:

Ekwan Pipeline Corridor Terrestrial Ecosystem Map
Landscape Photos and Sample Sites

1. Photos

Photo 1. Hay River showing lowland riparian ecosystems (SH, RI) along proposed Ekwan pipeline corridor (~ km 60).

Photo 2. Townsoitoi Creek showing lowland riparian ecosystems (SG, RI) along proposed Ekwan pipeline corridor (~ km 52-53).

Photo 3. Upland forested ecosystems (AM) in the background; upland depressional ecosystems (AH, BS, SG, OW) in the foreground along proposed Ekwan pipeline corridor (~ km 14-15 looking west). AM is zonal site series (typical) for BWBSmw2.

Photo 4. Upland depressional ecosystems (TB, SG) along proposed Ekwan pipeline corridor (~ km 67). Permafrost is generally associated with the TB unit.

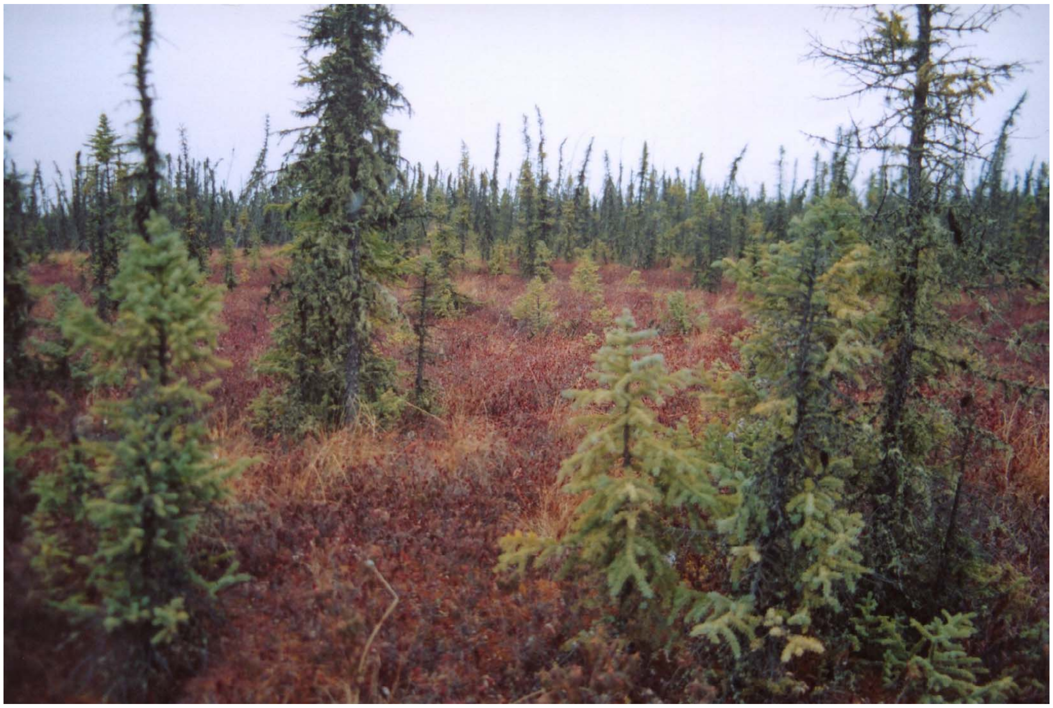

Photo 5. Upland depressional ecosystem (BS) in structural stage 3b along proposed Ekwan pipeline corridor (~ km 79-80). This organic site does not contain permafrost.

Photo 6. Upland depressional ecosystem (TB) in structural stage 4iC along proposed Ekwan pipeline corridor. Site organic contains permafrost – note hummocky surface.

2. Sample Sites

Vegetation community and associated soil / terrain conditions described from field sample sites:

Location	*Descriptions*
Site #1 *UTM NAD83, Zone10* *635238* *6505225* *Site Series / Ecosystem Unit:** ***BWBS mw2 /08 (BS)*** Sb – Cloudberry – Sphagnum	***Vegetation information*** ***Tree core species:*** Sb, Sw, Lt ***Tree core age counted:*** Sb – origin ~1916; Sw – origin ~ 1880; Lt – origin ~ 1870 ***Vegetation community:*** Mixed forest of white and black spruce with interspersed tamarack. Ground cover consisted of thick feathermoss and Labrador tea. Soil information ***Landform:*** Glacial Lacustrine ***Soil drainage:*** Poorly ***Soil texture***: Silty Clay to Silty Clay Loam ***Soil matrix:*** Mottled ***Organic Horizons (forest floor)***: approximately 35 cm thick ***Permafrost:*** absent ***Hand Auger Core depth***: ~120cm ***Coarse Fragments:*** Absent ***Seepage:*** Present at about 35cm General information During the overview flight, this type was seen at varying locations along both pipeline corridors. Some areas consisted of more stunted trees (smaller heights) than the sampled site.

Site #2 *UTM NAD83,* *Zone10* *669496* *6502835* *Site Series /* *Ecosystem Unit:** ***BWBS mw2 /08 (BS)*** Sb – Cloudberry – Sphagnum	***<u>Vegetation information</u>*** ***Tree core species:*** None taken ***Tree core age counted:*** - ***Vegetation community:*** Stunted forest of black spruce. Ground cover consisted of thick sphagnum moss. Soil information ***Landform:*** Organic ***Soil drainage:*** Poorly ***Soil texture***: Fibric ***Soil matrix:*** ***Organic Horizons (forest floor)***: ~120 cm ***Permafrost:*** absent ***Hand Auger Core depth:*** ~120cm ***Coarse Fragments:*** Absent ***Seepage:*** Absent General information During the overview flight, this type was seen at varying locations along both pipeline corridors.
Site #3 *UTM NAD83,* *Zone10* *646182* *64966488* *Site Series /* *Ecosystem Unit:** ***BWBS mw2 /05 (SH)*** Sw – Currant – Horsetail	***<u>Vegetation information</u>*** ***Tree core species:*** Sw, Ep ***Tree core age counted:*** Sw – origin ~ 1947; Ep – origin ~ 1933 ***Vegetation community:*** Mixed forest of white and black spruce with interspersed tamarack. Ground cover consisted of thick feathermoss and Labrador tea. Soil information ***Landform:*** Fluvial Terrace ***Soil drainage:*** Moderately well to imperfectly ***Soil texture***: silty clay loam to clay loam ***Soil matrix:*** Granular Soil Structure ***Organic Horizons (forest floor)***: approximately 8-10cm ***Permafrost:*** Absent ***Hand Auger Core depth***: ~30cm ***Coarse Fragments:*** Absent ***Seepage:*** Absent General information This vegetation community was found mainly along major drainages such as Hay River and Kotcho River. Sample site at Hay River. There was an abundance of mycelium found in the forest floor.

Site #4 *UTM NAD83, Zone10* *636981* *6496414* *Site Series / Ecosystem Unit:** ***BWBS mw2 /08 (BS)*** Sb – Cloudberry – Sphagnum	***<u>Vegetation information</u>*** ***Tree core species:*** Sb, Sw, Lt ***Tree core age counted:*** Sw – origin ~ 1951; Sb – origin ~ 1920 ***Vegetation community:*** Mixed forest of white and black spruce with interspersed tamarack. Ground cover consisted of thick feathermoss and Labrador tea. Soil information ***Landform:*** Organic ***Soil drainage:*** Poorly ***Soil texture***: Fibric ***Soil matrix:*** ***Organic Horizons (forest floor)***: approximately 35 cm thick ***Permafrost:*** present (~55cm) from surface ***Hand Auger Core depth***: ~55cm ***Coarse Fragments:*** Absent ***Seepage:*** Absent General information During the overview flight, this type was seen at varying locations along both pipeline corridors. Some areas may have more percentage of Tamarack (larch) than others.

* Site Series / Ecosystem Unit descriptions based on DeLong et al. 1990.

Appendix Two:

Bio-Terrain Classification and Mapping Standards for Ekwan Pipeline Corridor Terrestrial Ecosystem Map[1]

[1] Bio-terrain mapping standards (proposed) contained in:

Francis, S.R., and Steffen, N. 2002. *Rationale, Concepts and Proposed Methods for the Yukon Ecosystem Classification and Mapping Framework – First Approximation*. *Draft ver. 1.3.* Document prepared by Applied Ecosystem Management Ltd. and Yukon Ecosystem Classification and Mapping Working Group for DIAND Environment Directorate and DIAND Lands Branch. January, 2003.

Bio-terrain mapping standards closely follow Howes and Kenk (1997).

1. TERRAIN CLASSIFICATION

Terrain and soil conditions, in addition to the atmospheric and hydrologic inputs and processes, form the abiotic component of ecosystems. The terrain classification component of the proposed Yukon Ecosystem Classification and Mapping Framework (YECMF) attempts to describe and delineate the relatively static, ecologically meaningful abiotic components of the landscape. Due to the general physiographic similarities between Yukon and British Columbia, some terms and concepts from well established British Columbia terrain mapping methods and nomenclature (Howes and Kenk 1997) are proposed for use within the YECMF. Concepts used in Terrestrial Ecosystem Mapping (RIC 1998) are especially relevant. However, mapping concepts and standards are also relevant to subdued boreal forest landscapes.

The goal of terrain mapping within the YECMF is not to create a detailed terrain map as would be required through an independent terrain mapping exercise, but to identify terrain characteristics that are ecologically-meaningful in the sense of influencing ecosystem processes, distribution and pattern. The term "**Bio-Terrain**" mapping is therefore more appropriate within the YECMF. In Local Ecosystem mapping, the production of a detailed terrain map would provide the same results to the YECMF but at higher cost due to increased mapping intensity and survey levels. Terrain mapping produced through the YECMF could be used as a basis to develop more detailed terrain mapping and interpretations, if required, generally through the use of additional modifiers. For Regional Ecosystem mapping, detailed terrain mapping is not appropriate due to issues associated with mapping scale.

Within the YECMF, two levels of terrain classification are proposed: 1) general terrain conditions, termed "**Landscape Types**", and 2) detailed terrain conditions, termed "**Bio-Terrain Units**". Landscape Types form the generalised terrain classification component and are used to represent terrain conditions within Regional Ecosystem Mapping. Both Landscape Types and Bio-Terrain Units are classified and mapped for Local Ecosystems. Bio-Terrain Units are sub-units of Landscape Types and are nested within Landscape Types.

1.1. General Terrain Classification – Landscape Types

Within the YECMF, **Landscape Position** incorporates the concepts of broad-scale topographic position and site processes. Landscape Position provides information on the major physical processes influencing the development and dynamics of ecosystems; it also provides an ecologically-meaningful method to rapidly stratify forested landscapes with subdued topography (eg. Liard Basin or Eagle Plains). Two general Landscape Positions are recognised: upland and lowland. General Landscape Position, when combined with appropriate modifiers, produce **Landscape Types**. Two major Landscape Types, **Upland** and **Lowland**, with currently recognised sub-types are described fully in Table A2-1. General definitions for Upland and Lowland Landscape Types are listed below:

Upland: Sites not influenced by the groundwater regime/flooding regime of adjacent lowland areas. Parent materials generally consist of morainal, glaciofluvial, eolian, lacustrine or colluvial materials. Upland landscapes form the majority of the Yukon landscape. Poorly drained, topographically depressed areas that occur within the matrix of upland landscapes are termed **Upland Depressional (Ud)**.

Lowland: Significant riparian corridors of fluvial or glaciofluvial origin within the matrix of upland landforms, and lake basins. In the case of riparian corridors, this Landscape Type is characterised by active fluvial processes (flooding / deposition / erosion / transport). Lake basins are also considered to be Lowland Landscape Types. Lowland environments generally comprise a small proportion of the Yukon landscape but are ecologically significant features in terms of biodiversity and material/nutrient/energy transport. They may also have different disturbance regimes compared to Upland Landscape Types. Areas that experience active flooding and deposition are termed **Lowland Riparian (Lr)**. Inactive sites (no or very infrequent flooding and deposition) include terraces or benches (**Lowland Terrace - Lt**) and wet oxbows or back channels (**Lowland Depressional - Ld**). Lakes basins are also considered to be Lowland Depressional (Ld) features.

Within the YECMF, Landscape Type is recommended to replace the term "Landscape Position". Landscape Types, when combined with Bio-Climate Zones, provide the primary ecological framework in which to classify and describe ecological conditions for the purposes of terrain, vegetation and ecosystem classification and mapping at the detailed mapping levels. Landscape Types are proposed to be used as the terrain component of the classification and mapping for YECMF Regional Ecosystems (1:250,000 scale).

Table A2-1. Proposed Landscape Types for use within the YECMF (proposed codes are included in brackets following the general Landscape Type and Sub-Type).

Landscape Type	***Sub-Type***	***Description***
Upland (U)	Any upland landform that is not or has not been influenced by the fluvial processes of flooding, transport and deposition. Parent materials generally consist of morainal, glaciofluvial, eolian, lacustrine or colluvial sediments. Exposed bedrock may also be important in some areas.	
	Depressional (d)	Poorly drained, depressional topographic features occurring in a predominantly upland environment. This landscape type generally occurs in defined basins such as kettles or old glacial melt-water channels. Upland Depressional types are usually moist or under the influence of a fluctuating water table. They are influenced by local groundwater flow and may be saturated periodically. However, unlike Lowland Riparian areas, Upland Depressional sites are not affected by active flooding and sediment deposition. These areas may contain mineral parent materials that have resulted from a number of different depositional and erosional processes but are usually comprised of organic parent materials. <u>Lakes and major wetlands and wetland complexes are considered Upland Depressional landscape features.</u>
	Terraced (t)	Major glacial fluvial terraces or outwash plains with coarse textured parent material. These areas may be flat or associated with complex ice stagnant terrain and eskers.
	Unclassified (u)	Any Upland Landscape Type not classified as one of the above listed types. In most situations, the majority of a mapping area will be composed of unclassified Landscape Types and will be composed of glacial (morainal) till.

Table A2-1 (continued). Proposed Landscape Types for use within the YECMF (proposed codes are included in brackets following the general Landscape Type and Sub-Type).

Landscape Type	***Sub-Type***	***Description***
Lowland (L)	Any major lowland landform that is or has been influenced by the active fluvial processes of erosion, transport and deposition. Lowlands are delineated using the heights of land containing the entire feature (tops of the highest banks) and then stratified into fluvial and non-fluvial components.	
	Braided (b)	Areas governed by aggrading river processes, with high rates of erosion and deposition. Landscape Types in braided river environments are very dynamic due to constant flooding, deposition, erosion and channel diversion. Large areas of exposed gravels and sediments are common.
	Depressional (d)	Poorly drained, depressional topographic features occurring within the lowland environment. These usually consist of backwater channels, shallow oxbow lakes and related wetland features.
	Riparian (r)	Lowland areas adjacent to rivers (including the river channel) that experience active flooding and depositional processes.
	Terraced (t)	Elevated terraces or benches within the Lowland environment that are rarely if ever affected by fluvial processes. Many terraces were formed by glacial fluvial processes and are characterised by coarse textured soils with rapid drainage.
	Unclassified (u)	Any Lowland Landscape Type not classified as one of the above listed types. In most situations, unclassified Lowland landscape components will be composed of steep colluvial slopes forming containing fluvial features.

1.2. Detailed Terrain Classification – Bio-terrain Units (Local Ecosystems)

Bio-terrain mapping is unique to Local Ecosystem mapping; this Level is not used to describe Regional Ecosystems. Bio-terrain units are nested within the various Landscape Types to provide a more detailed ecological description of the physical site characteristics. The term "**Bio-terrain**" mapping has been adopted from the British Columbia Terrestrial Ecosystem Mapping standards (RIC 1998) to describe a modified mapping approach to detailed terrain mapping described by Howes and Kenk (1997). Within the YECMF, the goal of Bio-terrain mapping is to describe important landform and surficial material conditions that influence the ecological characteristics, productivity and processes of an area. A minimum of four Bio-terrain attributes are proposed to be described for Local Ecosystems: 1) primary parent (surficial) material, 2) soil drainage, 3) slope and aspect conditions, 4) special soil conditions. Each is described below.

1.2.1. Primary Parent (Surficial) Material

Primary parent (surficial) material provides a description of the dominant material comprising soils, the growth medium for terrestrial vegetation. Primary surficial material, when combined with knowledge of local terrain conditions, can also provide important information about anticipated landform, slope/aspect and soil drainage conditions, plus potential management considerations. Table A2-2 lists the proposed parent material types and codes for use within the YECMF.

1.2.2. Soil Drainage

Soil drainage is defined as "the time required to remove excess water from a soil" (Soil Classification Working Group 1998). Soil drainage is an ecologically-meaningful description of soil moisture as it provides direct information about both soil texture and the potential for summer moisture deficit. Table A2-3 describes Soil Drainage Classes proposed for use within the YECMF. Some consideration may be given towards reducing the current seven drainage classes to five, particularly at the extremes of the drainage class scale (eg. combine very rapidly and rapidly drained).

1.2.3. Slope and Aspect Conditions

In moisture and energy limited environments, slope and aspect is a major determinant of vegetation pattern, composition and growth. A description of slope conditions can also provide important management-related interpretations. In traditional terrain mapping (e.g. Howes and Kenk 1997), a large number of slope classes and slope process modifiers are used to stratify landscapes into detailed slope types, primarily for the purpose of terrain evaluation (terrain hazards, stability, processes, etc.). However, ecologically, a smaller number of slope conditions influence the energy and water balance of a site. When combined with aspect, a single ecologically meaningful "Slope-Aspect" descriptor can be developed. Similar concepts are used in the British Columbia Terrestrial Ecosystem Mapping system (RIC 1998); Slope-Aspect classes proposed for use within the YECMF are modified from RIC (1998). Table A2-4 describes the slope and aspect classes proposed to describe Bio-terrain Units for Local Ecosystems within the YECMF.

Table A2-2. Parent material types and codes proposed for Bio-terrain Unit (Level 6) description of YECMF Local Ecosystems.

Parent Material [1]	***Parent Material Code***	***Description*** [1]
Anthropogenic	A	Anthropogenic materials are any human-disturbed or transported materials such as gravel pits, roads, landfills, etc. Cultivated areas are not considered Anthropogenic parent materials.
Colluvium	C	Colluvium is gravity eroded material existing along or at the base of slopes. Colluvium may consist of unsorted sediments, broken rock or any combination of material. Due to the length of time North Yukon has remained unglaciated, colluvium is the dominant parent material.
Weathered Bedrock	D	Weathered Bedrock is degraded (broken) bedrock. Soil development on these sites occurs in-situ within the weathered rock materials.
Eolian	E	Eolian landforms are wind transported and deposited parent materials generally consisting of medium-to-coarse textured sediments. The most common eolian landforms are sand dunes.
Fluvial	F	Fluvial landforms are water transported and deposited parent materials. Fluvial materials are found on active floodplains and may be composed of variable materials (silts, sand, gravels, cobbles, etc).
Glacial Fluvial	G	Glacial Fluvial landforms are composed of coarse textured, rapidly drained materials. Glacial Fluvial landforms were formed by flowing post-glacial meltwater, which sorted and deposited large amounts of material; most fine materials have been removed. Surface expression is variable.
Waterbodies	H	Water bodies include any surface water feature that can be mapped at the scale of interpretation (lakes and rivers).
Ice	I	Ice includes any surface exposed, multi-annual ice body that is relatively persistent from year-to-year. Ice parent materials are generally considered to be glaciers.
Glacial Lacustrine	K	Glacial Lacustrine landforms are composed of sediments that were deposited in post-glacial standing water environments, generally post-glacial lakes. Glacial lacustrine sediments are typically fine-sandy and/or silty in texture.
Lacustrine	L	Lacustrine landforms are composed of lake sediments deposited following the post-glacial period (differentiated from Glacial Lacustrine). Some lakes may drain rapidly exposing lake bottom sediments. Other situations would include slow processes of eutrophication converting an aquatic environment to a terrestrial landform.
Glacial (Morainal) Till	M	Glacial (Morainal) Till landforms are composed of unsorted sediment, gravel and rocks that were transported and deposited by glaciers. Sediment texture, stoniness and drainage are highly variable. Till is the dominant parent material for most Upland Landscape Types in South and Central Yukon.

Table A2-2 (continued). Parent material types and codes proposed for Bio-terrain Unit (Level 6) description of YECMF Local Ecosystems.

Parent Material [1]	***Parent Material Code***	***Description*** [1]
Organic	O	Organic landforms are composed of poorly decomposed organic materials greater than 40 cm in thickness. Organic landforms generally occur in low-lying, poorly drained depressional sites. Organic materials originate primarily from slowly decomposing plant material.
Bedrock	R	Bedrock landforms may occur throughout the landscape and are defined anywhere bedrock is exposed at the surface. Shallow, weakly developed soils are commonly associated with Bedrock.
Glacial Marine	S	Glacial Marine landforms typically occur where glaciers enter the ocean. Unsorted glacial materials are deposited as a result melting glacial ice. Glacial Marine parent materials are rare in Yukon.
Undifferentiated	U	Undifferentiated landforms are identified where multiple landforms / parent materials occur together, resulting in a complex landform / parent material that is difficult to classify.
Volcanic	V	Volcanic landforms are typically lava flows and/or pumas that were deposited during volcanic eruptions.
Marine	W	Marine parent materials are typically found near oceans, where the isostatic rebound of land following de-glaciation has exposed marine-deposited sediments. Marine sediments are generally extremely clay rich. Marine parent materials are rare in Yukon.

[1] Parent Material type and definitions modified from Howes and Kenk (1997) and Soil Classification Working Group (1998).

Table A2-3. Proposed soil drainage classes used to describe Bio-terrain Units (Level 6) of YECMF Local Ecosystems.

Drainage Class [1]	***Drainage Class Code*** [1]	***Description*** [1]
Very Rapidly Drained	x	Water is removed from the soil very rapidly in relation to supply. Excess water flows downward very rapidly if underlying material is pervious. There may be very rapid subsurface flow during heavy rainfall provided there is a steep gradient. Soils have very low available water storage capacity (usually < 2.5 cm) within the control section and are usually coarse textured, or shallow, or both. Water source is precipitation.
Rapidly Drained	r	Water is removed from the soil rapidly in relation to supply. Excess water flows downward if underlying material is pervious. Subsurface flow may occur on steep gradients during heavy rainfall. Soils have low available water storage capacity (2.5-4 cm) within the control section and are usually coarse textured, or shallow, or both. Water source is precipitation.
Well Drained	w	Water is removed from the soil readily but not rapidly. Excess water flows downward readily into underlying pervious material or laterally as subsurface flow. Soils have intermediate available water storage capacity (4-5 cm) within the control section, and are generally intermediate in texture and depth. Water source is precipitation. On slopes, subsurface flow may occur for short duration but additions are equaled by losses.
Moderately Well Drained	m	Water is removed from the soil somewhat slowly in relation to supply. Excess water is removed somewhat slowly due to slow perviousness, shallow water table and lack of gradient or some combination of these. Soils have intermediate to high water storage capacity (54 cm) within the control section and are usually medium to fine-textured. Precipitation is the dominant water source in medium to fine textured soils; precipitation and significant additions by subsurface flow are necessary in coarse textured soils.
Imperfectly Drained	i	Water is removed from the soil sufficiently slowly in relation to supply to keep soil wet for a significant part of the growing season. Excess water moves slowly downward if precipitation is the major supply. If subsurface water or groundwater, or both, is the main source, the flow rate may vary but the soil remains wet for a significant part of the growing season. Precipitation is the main source if available water storage capacity is high; contribution by subsurface flow or groundwater flow, or both, increases as available water storage capacity decreases. Soils have a wide range in available water supply, texture, and depth, and are gleyed phases of well drained subgroups.
Poorly Drained	p	Water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time the soil is not frozen. Excess water is evident in the soil for a large part of the growing season. Subsurface flow or groundwater flow, or both, in addition to precipitation are the main water sources; there may also be a perched water table with precipitation exceeding evapotranspiration. Soils have a wide range in available water storage capacity, texture, and depth, and are gleyed subgroups, Gleysols, and Organic soils.
Very Poorly Drained	v	Water is removed from the soil so slowly that the water table remains at or on the surface for the greater part of the time the soil is not frozen. Excess water is present in the soil for the greater part of the time. Groundwater flow and subsurface flow are the major water sources. Precipitation is less important except where there is a perched water table with precipitation exceeding evapotranspiration. Soils have a wide range in available water storage capacity, texture, and depth, and are either Gleysolic or Organic.

[1] Soil drainage class, codes and definitions from Canadian Soil Classification System, 3rd Edition (Soil Classification Working Group 1998)

Table A2-4. Proposed slope and aspect classes used to describe Bio-terrain Units (Level 6) of YECMF Local Ecosystems.

Slope_Aspect Class	***Slope_Aspect Code***	***Description*** [1]	
Gentle	g	no ecologically-meaningful aspect	< 25% slope
Warm	w	$135^o – 285^o$ aspect (southerly and westerly-facing aspects on moderate-steep slopes)	25 – 100% slope
Very Steep, Warm	z	$135^o – 285^o$ aspect (southerly and westerly-facing aspects on very steep slopes)	> 100% slope
Cool	c	$285^o – 135^o$ aspect (northerly and easterly-facing aspects on moderate-steep slopes)	25 – 100% slope
Very Steep, Cool	k	$285^o – 135^o$ aspect (northerly and easterly-facing aspects on very steep slopes)	> 100% slope
Variable	v	Complex topography with moderate-very steep slopes of no dominant aspect. Topography is often hummocky with steeply contrasting warm and cool aspects.	≥ 25% slope

[1] Slope and aspect class codes and definitions modified from Howes and Kenk (1997) and RIC (1998)

1.2.4. Special Soil and Site Conditions

Special soil conditions are described when a particular soil condition, such as permafrost, plays a major role in influencing vegetation development and dynamics. Special soil conditions may also have important management implications and can be used to guide management decisions, such as the presence or absence of permafrost for the purposes of construction or forest harvesting. Currently, a limited number of special soil conditions are being considered for use within the YECMF, with the understanding that additional conditions will be developed as required (Table A2-5).

Table A2-5. Special soil and site conditions proposed to describe Bio-terrain Units (Level 6) of YECMF Local Ecosystems.

Special Condition [1]	***Code***	***Description***
Anthropo-genic	a	Soils that have been severely modified by anthropogenic activities. Dense urban developments, gravel pits, graded surfaces, road cuts, mine sites and tailings are examples of anthropogenic features. Clearings and forest harvest blocks that have not experienced major soil disturbances would not be considered anthropogenic soils.
Shallow Soil (Lithic)	l	Shallow soils often associated with bedrock (B) or weathered bedrock (W) parent materials. Vegetation growth and pattern is strongly influenced by shallow soil condition and bedrock outcrops.
Permafrost	p	Permafrost occurs within 1 m of surface and has important influence on vegetation pattern, soil drainage and site ecological processes. The presence of permafrost can be difficult to confirm; in the absence of field sampling, presence is often inferred. If presence is inferred, this should be noted in a comments database field.
Saline / Calcareous	s	Soils that contain a high concentration of salts or calcium may be moisture limited and can be dominated by halophytic (salt tolerant) or rare plant species (eg. orchids associated with marl fens). Vegetation growth and species composition on these sites is strongly influenced by the presence of salts or large amounts of calcium.

[1] Additional special soil condition definitions will be developed as required.

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