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Local-scale biophysical mapping for integrated resource management, Watson Lake area (NTS 105A/2), Yukon

P.S. Lipovsky and K. McKenna

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[1]Yukon Geological Survey
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Any revisions or additional information known to the user would be welcomed and appreciated.
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Cover photo. Northward view of fluted till terrain and fen wetlands, 13 km northeast of the town of Watson Lake.

EXECUTIVE SUMMARY

Biophysical or ecosystem mapping is built on the principle that vegetation composition and distribution responds in predictable ways to specific abiotic terrain conditions. Terrain (surficial geology) mapping and subsequent stratification into ecosystem units forms the basis for local-scale biophysical mapping. Biophysical mapping is therefore an integrated system of mapping which describes both terrain conditions (surficial material type, slope, landscape position, drainage and permafrost conditions) and ecological factors (vegetation community and structure, and soil moisture and nutrient regimes).

The Watson Lake area was selected for a pilot biophysical mapping project because of imminent resource activities in southeast Yukon. Local-scale (1:50 000) biophysical mapping was carried out in the 105A/2 NTS map area during 2004 in cooperation with Yukon Environment, Yukon Geological Survey and Cryogeographic Consulting. Analysis of hard copy 1:40 000-scale aerial photographs was conducted to outline preliminary terrain (surficial geology) and ecosystem units. Four weeks of summer field work was then conducted to ground truth the preliminary aerial photograph interpretation and develop a more detailed ecological classification system for southeast Yukon. Following the field season, the corrected mapping was digitized using stereo-georeferenced high-resolution scanned aerial photographs in Microstation Diap Viewer. Subsequent geographic information system (GIS) manipulation was performed in ArcGIS 9.0. Part of the purpose of the project was to develop a methodology for performing biophysical mapping using these technological tools.

In most Canadian jurisdictions biophysical mapping has provided a common language for multi-agency integrated resource management. In Yukon, the lack of a standardized framework for ecological land classification and mapping is a major barrier to many territorial initiatives including road, rail, and pipeline corridor planning and permitting processes; forest management planning; oil and gas disposition processes; cumulative effects management; land use planning; and wildlife habitat management. Developing a local-scale standardized ecological classification system for southeast Yukon was therefore also a major goal of this project.

This report describes the background of this work, and methodology used to carry out local-scale biophysical mapping in the Watson Lake area. In addition, it provides documentation and guidelines for interpreting the terrain and biophysical maps accompanying the report. Practical applications of biophysical mapping are also demonstrated. The report, maps and accompanying digital GIS data are presented to support future stewardship, integrated resource management, land use planning and sustainable development in the Watson Lake area, and also to build guidelines for future local-scale biophysical mapping projects undertaken by industry proponents.

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The project would not have been possible without the terrain mapping standards and applications established by Howes and Kenk (1997) and the Government of British Columbia (Ministry of Sustainable Resource Management). Likewise, the project could not have been undertaken without significant efforts and ecosystem classification groundwork laid by the Government of British Columbia Ministry of Environment, Lands and Parks and Ministry of Forests; John Grods of Makonis Consulting Ltd. (Kelowna, BC); Shawn Francis of former Applied Ecosystem Management Ltd. (Whitehorse); and members of the Yukon Biophysical Mapping Working Group.

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POCKET AT BACK OF REPORT INCLUDES:

- surficial geology map (Open File 2005-07)
- biophysical map (Open File 2005-08)
- CD-ROM containing digital (pdf) versions of this report and the accompanying surficial geology and biophysical maps; GIS files and metadata, digital photos, and field database

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1.0) INTRODUCTION

Biophysical or ecosystem mapping is an integrated system of mapping describing both terrain conditions (surficial material type, slope, landscape position, drainage and permafrost conditions) and ecological factors (vegetation community and structure, and soil moisture and nutrient regimes). Terrain (surficial geology) mapping and subsequent stratification into ecosystem units forms the basis for local-scale biophysical mapping. Vegetation responds in predictable ways to specific abiotic terrain conditions. Knowledge of terrain can therefore allow a general interpretation of associated vegetation, and likewise, knowledge of particular vegetation communities allows an interpretation of associated terrain conditions.

A comprehensive biophysical or ecosystem mapping framework includes both regional-scale (1:250 000) and local-scale (1:50 000) components. Regional mapping is intended to be utilized by land managers for broad land use planning. Local-scale mapping, on the other hand, is envisioned to be project specific and largely completed by project proponents. By building on previous work, the Yukon Biophysical Mapping Working Group has been working to develop both regional- and local-scale guidelines to establish an Ecosystem Land Classification (ELC) framework for the Yukon. Surficial geology and terrain information is currently the biggest knowledge gap for the larger initiatives aimed at achieving this.

In most Canadian jurisdictions biophysical mapping has provided a common language for multi-agency integrated resource management. In Yukon, the lack of a standardized framework for ecological land classification and mapping is a major barrier to many territorial initiatives including road, rail, and pipeline corridor planning and permitting processes; forest management planning; oil and gas disposition processes; cumulative effects management; land use planning; and wildlife habitat management.

For this project, southeast Yukon served as an ideal location for a pilot study. Resource decisions are imminent in this region as it is being considered for interim wood supply and anticipated oil and gas dispositions, and it also contains a number of infrastructure corridors. The Kaska Forest Resources Stewardship Council (http://www.kfrsc.ca/) requested biophysical pilot projects be directed to areas under consideration for these resource related projects. Until completion of this project, surficial geology of the Watson Lake area had only been mapped at 1:250 000-scale, and the production of a 1:50 000-scale terrain map would be a natural derivative of the biophysical mapping process. Upon completion, the final biophysical map would also serve as an essential tool for making informed decisions regarding resource management in the area and would facilitate stewardship and sustainable development of the Territory's energy, mineral, and land resources in the Watson Lake area.

***Figure 1**. Map of Yukon showing overall location of the Watson Lake study area. Small box outlines the extent of the NTS 105A/2 map area. Major towns are represented by black squares (D – Dawson, WH – Whitehorse, WL – Watson Lake).*

1.1) Objectives

The specific objectives of this project were:

- To develop a local-scale standardized ecological classification system legend that will be useful for planning and regulatory assessment processes in southeast Yukon.

- To compile a report summarizing surficial geology and glacial history of the area, and guidelines and methods used for digital terrain and biophysical mapping.

- To produce a 1:50 000-scale terrain (surficial geology) map and biophysical map (incorporating surficial geology and ecological classifications) for the 105A/2 NTS map area, including a digital compilation of all field data, derivative GIS spatial data and digital photos on an accompanying CD.

1.2) Partnerships

Integrating the knowledge and needs of a variety of land managers was an important component of this project. Involving the Kaska Stewardship Council, Yukon Environment's Fish & Wildlife Branch, Yukon Forest Management and the Yukon Land Use Planning Council in the project has ensured maximum benefit to key user groups. The Yukon Oil & Gas Business Development & Pipeline branch has also been supportive of working towards establishing biophysical mapping procedures. Collaboration with Makonis (Ecological) Consulting Ltd. was also integral to the project's success. Extensive previous research by these and other organizations in the field of ecological land classification formed the foundation for the methodology of this study. This project also involved cooperation with other government departments including Yukon Environment's Parks Branch and Yukon Energy Mines and Resources Forest Planning and Development branch. In addition, education outreach was performed in early September 2004, to demonstrate local scientific research to both elementary and secondary students in Watson Lake.

2.0) PREVIOUS WORK

2.1) Geological mapping

Although general surficial geology and bedrock geology have been mapped at a regional (1:250 000) scale for the entire map area, no extensive local-scale studies have been carried out for the Watson Lake area, aside from scattered project specific exploration work (documented in Yukon MINFILE, Deklerk and Traynor, 2005). Gabrielse (1967) mapped bedrock geology and some ice flow features for the Watson Lake area (NTS 105A). Regional surficial geology mapping, which included the Watson Lake area, was carried out by Klassen and Morison (1978, 1981) between 1977 and 1981. The Tertiary-Quaternary stratigraphy of the entire Yukon portion of the Liard Plain was then described by Klassen (1987) as a result of his previous regional mapping. Denny (1952) summarized general surficial geology along the Alaska Highway. As part of a Yukon-wide glacial limits mapping project, Duk-Rodkin (2001) mapped glacial meltwater channels for the region, including the 105A map sheet. A GEOPROCESS map was produced by Mougeot and Walton (1996) which summarized general geological conditions and identified potential terrain hazards at a regional scale. Huscroft et al. (2004) documented selected landslides within the Alaska Highway corridor in the area.

2.2) Ecosystem mapping

Ecosystem mapping has been evolving in the Yukon since the Ecoregions of the Yukon (Oswald and Senyk, 1977) was first published[1]. Various regional and local ecosystem mapping projects have been completed in different parts of the Yukon since then. Between 1970 and 1973, the Department of Indian Affairs and Northern Development commissioned the Arctic Land Use Research Program during which extensive field studies were carried out to develop an environmental classification for the Watson Lake

[1] A new Ecoregions of the Yukon volume (Smith et al., 2004) is now available with an accompanying map.

area. As part of this program, physical environmental and pedologic (Lavkulich, 1972; Lavkulich et al., 1973), hydrologic (Verschuren et al.,1972; Vershuren and Bristol,1974) and ecologic (Murray et al.,1973) studies involved collecting baseline data in a number of watersheds (including stream flow, basic surficial geology, soil properties, ground frost occurrence, vegetation communities, effects of wildfire and forest regeneration) to evaluate suitability for wildlife habitat, recreational land use, road bank stability, engineering, and other land use activities in the area. In addition, the Yukon Forest Management Branch has prepared forest cover inventory maps of the area at 1:50 000-scale.

More recently in 1999, an ecological site classification system was developed for southeast Yukon (Zoladeski et al., 1996). A first approximation for a Yukon-wide ecosystem land classification and mapping framework was produced by Applied Ecosystem Management Ltd. in 2003 [1]. A new field guide to southeast Yukon ecosystem classification is presently in the draft stage [2]. An ongoing project in Western Canada is the development of Canadian National Vegetation Classification (CNVC)/ Canadian Forest Ecological Stratification (CFES) Western Boreal Forest and Woodland Vegetation Associations. These associations have assisted the development of Grods'ecosystem site classification[2] for southeast Yukon. A new project, the development of a Yukon Vegetation Classification based on all available Yukon site data has recently been initiated. This Yukon Vegetation Classification will hopefully provide an improved basis for future ecosystem classifications in other parts of the Territory.

The Yukon Biophysical Mapping Working Group is now pursuing an initiative to establish a standardized ecosystem land classification (ELC) framework for the entire Yukon by building on all of these existing ELC efforts. The results of the local biophysical mapping in Watson Lake will be critical to the final development of these standards as detailed field data collected for the project is tested against the existing classification system(s), and adjustments are made to better fit the field data.

3.0) SETTING

The study area lies primarily within the Liard Lowland physiographic region (Mathews, 1986), in a broad southeast-trending plain (the Tintina Trench) occupied by the Liard River at about 700 m above sea level. The uplands in the eastern part of the map sheet extend up to 1200 m above sea level and form the western edge of the Mackenzie Mountains.

The map area lies in the Liard Basin ecoregion and the Boreal Cordillera ecozone, entirely below treeline and is dominated by boreal coniferous forest (Smith et al., 2004) with mixed younger stands. Forest fire disturbance is extensive. The region experiences a sub-arctic continental climate with moderate precipitation. Climate normals for Watson Lake are listed in Table 1.

Table 1. *Environment Canada climate normals for Watson Lake.*

(60º 7' N, 128º 49' W, elevation 687 m) for the period 1971-2000

	January	July	Annual
Daily mean temperature (ºC)	-24.2	15.1	-2.9
Extreme maximum temperature (ºC)	8.9	33.3	34.2
Extreme minimum temperature (ºC)	-58.9	0.6	-58.9
Mean precipitation (mm)	26.1	59.9	404.4
Mean snow depth (cm)	48	-	-

[1] A Yukon ecosystem classification and mapping framework, first approximation, draft version 1.3. Unpublished report prepared by Applied Ecosystem Management Ltd., Whitehorse, Yukon, 2003.

[2] The other southeast Yukon ecosystem classification field guide (7/8 approximation) 2nd Draft. Currently in preparation by J. Grods of Makonis Consulting Ltd, Kelowna, BC, 2005.

Soils in the region are relatively well developed due to the moderate amount of precipitation during the growing season. Orthic and Eluviated Eutric Brunisols are the most common soils, generally found in sandy loam till, colluvium and sandy glaciofluvial parent materials. Nutrient-rich silty to fine sandy Cumulic Regosols and Rego Gleysols are found in floodplain environments. Mesisol and Fibrisol organic soils, sometimes frozen and therefore classed as Cryosols, are commonly found in organic parent materials throughout the map area (Smith et al., 2004).

3.1) Glacial history

The Watson Lake map area has been glaciated at least six times since the Quaternary period (the last 2 million years; Jackson et. al, 1991). Aside from scattered section localities, evidence of the older glacial episodes are completely masked by deposits from the latest glaciation, which is known as the McConnell Glaciation. During this late Wisconsinan McConnell Glaciation, the Liard Lobe of the Cordilleran ice sheet flowed in an easterly direction out of the Cassiar Mountains and in a southeasterly direction out of the Pelly and Selwyn mountains, following the Tintina Trench / Liard Lowland.

At Tom Creek, just northwest of the map area, twig fragments in a silt unit underlying the McConnell till were found to be as young as 23 900 ± 1140 BP by radiocarbon dating (Klassen, 1987), implying that the onset of glaciation in the Watson Lake area occurred some time after that. The timing of deglaciation likely occurred after 10 700 years ago, according to radiocarbon dating on Marcella Lake cores in southwestern Yukon (Anderson et al., 2002). At the height of the McConnell Glaciation, ice in the Liard Lowland would have overtopped the highest uplands suggesting a minimum ice thickness of at least 500 m.

Northeast of the Liard River floodplain, a thick, gently undulating and rolling till plain is extensively streamlined with drumlins, flutings and grooves that provide clear indications of southeasterly to easterly ice flow directions (Figure 2). Till blankets and veneers are found on the slopes further to the northeast, while the higher ridge tops have been scoured to bedrock.

Figure 2*. Typical landscape north of Watson Lake, showing rolling fluted till plain, with beaver dammed wetlands in valley bottoms.*

At some point prior to glacial retreat, damming of meltwater by the ice sheet produced extensive glacial lakes in the Liard valley floor. Fine-grained glaciolacustrine deposits underlying glaciofluvial outwash are exposed along the banks of the Liard River immediately south of the town of Watson Lake and just upstream of the mouth of Watson Creek (Figure 3).

As the ice sheet down-wasted and retreated to the northwest, vast amounts of meltwater deposited outwash plains of sand and gravel up to 30 m thick along the valley floor currently occupied by the Liard River. Extensive ice stagnation during deglaciation left behind blocks of ice that became buried by the outwash. The buried ice blocks have subsequently melted out leaving steep sided depressions and the distinctive pitted, hummocky terrain around Upper Liard (Figure 4), Lucky Lake and the town of Watson Lake. The meltwater also carved deep meltwater channels through bedrock in various locations north and northeast of town.

Figure 3*. Thick beds of laminated glaciolacustrine sediments are exposed along the Liard River, capped by several metres of sand, just upstream of the mouth of Watson Creek.*

Figure 4*. Hummocky glaciofluvial terrain (sgFGh-H), south of Upper Liard. Liard River in background.*

3.2) Permafrost

Permafrost is defined as soil that remains at or below 0º C for two or more years. The active layer is the layer above the permafrost which thaws and refreezes seasonally. The Watson Lake map area is in the 'sporadic discontinuous' permafrost zone. Permafrost is limited to north-facing slopes covered by thick organic mats, heavily shaded areas and at the margins of wetlands where drainage is restricted.

Permafrost transects by Murray et al. (1973) revealed active layer depths of 1-2 feet (0.3-0.6 m) beneath organic materials, but beneath drier upland sites, active layers can be up to 2 m thick (Hoggan Engineering and Testing, unpublished data, 1991)[1]. Permafrost is generally found on north-facing slopes with thick organic mats, around the margins of wetlands, and beneath heavily shaded areas. Fine-grained materials (containing silts and clays) and organic materials contain visible segregated ice. Along the Alaska Highway, Rampton et al. (1983) found permafrost in <5% of boreholes drilled east of Rancheria.

Murray et al. (1973) describe how "the presence of sphagnum moss and or stunted, sparse to moderately dense black spruce growth has been found to be nearly always associated with permafrost, provided that well-drained conditions exist." These conditions are common on the margins of wetlands, where there is enough water to support sphagnum and insulate the permafrost, but not so much water that the permafrost thaws. The effect of tree height and density on near-surface wind velocities, snow accumulation and shading was also found to be an important factor.

[1] Hoggan Engineering and Testing, 1991. Soils investigation, Campbell Highway km 0-54, December 1991.

Flat terrain subject to permafrost processes (such as the area adjacent to McDonald Creek, where it crosses the Robert Campbell Highway, and along the margins of many wetlands) is subject to thermokarst activity when disturbed in any way.

3.3) Vegetation

Most of the Liard Basin lies below treeline and the vegetation is dominantly boreal forest. The low elevation, moderate precipitation and relatively long, warm summers result in productive vegetative growth. Coniferous forests dominate the landscape.

The best growth, with tree heights of 30 m or more, occurs along the nutrient-rich loamy floodplains of the Liard River. White spruce is the dominant tree species found on river terraces, where it is underlain by feathermoss and a rich shrub layer including willow, alder, rose, high-bush cranberry and ground shrubs (Zoladeski and Cowell, 1996). Younger stands are commonly mixed with balsam poplar. On very dry and gravelly fluvial sites, a lichen-kinnikinnick ground cover is found under lodgepole pine or white spruce. Some alpine fir is found in mixed stands at higher elevations and on cooler sites. On low wooded hills and broad treed uplands, white and black spruce are found with a moss or moss and shrub understory. Lodgepole pine-black spruce forests are common where soils are drier and nutrient-poor, as on many morainal and glaciofluvial soils. Younger stands and disturbed sites are commonly covered by mixed forests of spruce, pine, and trembling aspen. Paper birch and black spruce are typically found on north aspects, and white spruce and balsam poplar are common on fluvial sites. Shrubby-herbaceous fens surrounded by permafrost-induced moss-sphagnum (peat) plateau bogs are typical wetlands in the ecoregion (Smith et al., 2004).

4.0) METHODOLOGY

The general methodology for the project consisted of three phases: pre-field preparation, field investigations, and post-field compilation.

4.1) Pre-field preparation

Over several weeks, preliminary terrain units were delineated directly onto 1998 and 1999 1:40 000 scale hard copy aerial photographs for the entire map area, using a manual stereoscope. Table 2 below lists the air photos used. Originally this stage was planned to have been carried out digitally using MicroStation DiapViewer softcopy software, but delays in licensing and hardware setup prevented digital interpretation until after the field season. The terrain classification system for British Columbia (Howes and Kenk, 1997) is a comprehensive and well established terrain mapping system that was used, with minor modifications, for formulating a terrain legend (see Terrain Mapping Standards, Section 5.1).

Table 2. *Aerial photographs used for preliminary terrain and ecosystem interpretation.*

Flight Line	Photo Numbers	Scale	Date
A28343	167-175, 255-258	1: 40 000	28/06/1998
A28344	66-74, 85-93, 209-217	1: 40 000	27/06/1998
A28425	147-153	1: 40 000	02/08/1999

The terrain interpretation was completed in cooperation with an ecologist. In doing so, the quality of the terrain interpretation was enhanced by fully considering vegetation indicators of various soil conditions. For example, slight changes in the vegetation cover can be due to topographical aspect, fire, forest harvesting, surface texture variability, presence of near surface permafrost and/or bedrock. Where applicable, these factors were incorporated into the terrain interpretation. Understanding how vegetation indicators reflected different terrain conditions and/or site history was critical for a comprehensive biophysical interpretation.

Terrain polygons were used to outline initial biophysical polygons, but often these were further subdivided to delineate different vegetation cover that resulted from variations in aspect, elevation, fires or forest harvesting history. Some biophysical subdivisions were also made to distinguish small ecologically important areas such as wetlands that were too small to be included on the terrain map.

Biophysical polygons were assigned preliminary ecosystem unit designations as defined by Grods (unpublished report, 2004) [1]. Ecosystem unit classification is based on analysis of detailed terrain, soil, and vegetation site data, including site position, aspect, slope, parent material, ecological moisture, hydrologic conditions, nutrient regime and site history, all of which combine to determine the vegetation community found at a site. The preliminary ecosystem unit classification system was not ideal for this particular study area, and therefore required significant modification both during and after the field season (see section 4.3.2).

A database and handheld computer interface were also designed for handling field site data collection. The database was based on existing Yukon Geological Survey digital surficial geology site characterization standards. This was then augmented with detailed soil characterization forms taken from Yukon soil field forms and the BC field manual for describing terrestrial ecosystems (BC Ministry of Environment, 1998) and also incorporated Yukon Environment's standard site characterization form (see Appendix 3).

[1] The other southeast Yukon ecosystem classification field guide (1st draft). Prepared by J. Grods of Makonis Consulting Ltd, Kelowna, BC, 2004.

4.2) Field investigations

Representative units were field checked by teams of two or three people (one surficial geologist and/or soil scientist and one botanist and/or ecologist) over a period of five weeks between July 5 and September 17, 2004. Due to excellent back road access, most of the field checking was truck and foot supported, although one day of canoe supported work, three days of ATV-supported traverses and three days of spot helicopter checking were also carried out.

Field checks consisted of either visual checks (112 sites) or detailed investigations (111 sites) of one or both of terrain or vegetation, depending on location. A visual site check consisted of, at a minimum, a GPS location and elevation, and descriptive notes confirming or rejecting the presence of particular terrain, topographic, edaphic or vegetation features that were interpreted from air photos.

A detailed site investigation consisted of the following components, and required about 1.5 hours on average to complete:

- A GPS was used to provide Universal Transverse Mercator (UTM) Zone 9 location coordinates accurate to within 10 m, and elevations accurate to within approximately 20 m.

- Physical site characterization (aspect, slope, microtopography, topographic concavity or convexity, slope position, soil drainage, ecological moisture and nutrient regime) using Yukon Environment standard site description forms (see Appendix 3). Notes were made of any significant localized climatic factors (cold air drainage, wind exposure, frost pockets, insulation) or disturbances (such as fire, windfall, logging, urban/industrial development, mining, slides, floods, evidence of wildlife use, ecosystem pathogens (such as pine beetle), etc.)

- Description of soil horizons from a pit (Figure 5) dug as deep as possible into the parent material (50 to 90 cm) using a standard long handled shovel. Soil description included Munsell colour, hand texture, coarse fragments, Helige-Truogg pH, soil structure, and soil classification following soil description guidelines in British Columbia field manual for describing terrestrial ecosystems (1998) and the Canadian System of Soil Classification standards as outlined by the Soil Classification Working Group (1998). An auger was extremely useful for sampling depths down to 150 cm, especially in wetlands and in other non-frozen, fine-textured and organic soils.

Figure 5*. Typical soil pit (90 cm deep) for site soil and terrain classification. Pit is dug in hummocky glaciofluvial terrain (sgFGh-H). Site 04WL098.*

- Identification and description of surficial materials, following the Yukon Geological Survey standard description procedures (texture, colour, sedimentary structures, coarse fragments, clast abundance and roundness). This step was combined with the soil description component as it is nearly the same process as describing the C horizon or parent material of the soil.

- Characterization of vegetation community (Figure 6) within a 10 m radius circular plot (selected to be as uniform in structure and composition as possible and representative of the entire mapped polygon), including percent cover of all species, bare soil, and coarse woody debris, using standard Yukon Environment vegetation plot forms. A laser range finder was used to determine tree heights and an increment borer was used to determine the age of selected trees.

Figure 6*. Typical ground cover and surface expression of kettle in hummocky glaciofluvial terrain (sgFGh-H), southwest of the town of Watson Lake (site 04WL098).*

- Field data was compared to the ecosystem type characterizations provided in the field guide (Grods, unpublished report, 2004)[1] to determine the ecosystem unit. The ecosystem unit which best described the site was selected according to where it plotted on an edatopic grid. This is a triangular approach, where terrain and soils, topography, and vegetation occupy the corners of a triangle and support the decision of where to place a site ecologically in the classification system. If a suitable plant association did not exist, a new one was assigned.

- Digital photographs documenting soil horizons, vegetation and physical site characteristics.

- Collection of surficial material (till, gravel, rock or buried preserved wood) and vegetation samples as required to confirm identification or use for future reference, radiocarbon dating and/or particle size or other laboratory analyses. See Appendix 2 for laboratory results.

4.3) Post-field compilation

Based on the field observations, corrections were made to the preliminary terrain and biophysical mapping as appropriate, digitization of the linework was completed, classification of ecosystem units was further refined, and final terrain and biophysical maps were produced.

4.3.1) Digitizing

A large part of the post-field work consisted of establishing and carrying out new protocols for heads-up (on-screen) digitizing of mapping linework from hard copy aerial photographs using Microstation DiapViewer software. High resolution digitally scanned (at 8 µm from negatives) soft copy air photos were stereographically viewed, interpreted, and digitized directly on the screen. This eliminated the less accurate and often more time-consuming intermediate step of transferring linework from hard copy air photos to hard copy topographic maps and subsequent manual tablet digitization.

One of the most important outcomes of this project is that the digital mapping procedures followed will form the basis for future digital surficial geology mapping and GIS standards, templates and protocols for all surficial geology mapping projects at the Yukon Geological Survey. In particular, the GIS data model (database) established for the surficial geology component of this project will form the basis for an upcoming Territory-wide digital surficial geology compilation project at the Yukon Geological Survey.

[1] The other southeast Yukon ecosystem classification field guide (1st draft). Prepared by J. Grods of Makonis Consulting Ltd, Kelowna, BC, 2004.

In some areas where linework followed lake and river boundaries or major slope breaks, there was a significant discrepancy between the digitized linework (based on the aerotriangulated scanned aerial photographs) and the underlying digital topographic data (NTDB) upon which the linework is displayed on the final map. According to the aerotriangulation contractor who corrected the scanned air photographs (Neale, 2004), these errors are both random, and in some cases cumulative, and it is impossible to pin-point the source of the errors. The aerotriangulation process involves choosing control points from the NTDB (National Topographic Database) data sets, and distorting the aerial photograph to fit these points. Much of the error arises out of the inherent shortcomings of using topographic data based on survey work done between 1980-1990, and in some cases as far back as the 1950's. Compounding this is the fact that the surface file used to provide the digital stereoscopic view was also derived from relatively coarse 90-m DEMs based on the same out-of-date NTDB data. It was therefore decided not to adjust the mapping linework to fit the NTDB topography, because new updated topographic data (GEOBASE) is expected to be released in the next year. A subset of sample GEOBASE data was used to confirm that the mapping linework matches the GEOBASE data much more closely.

High-resolution scanned air photographs and aerotriangulation (georeferencing) were supplied by Yukon Energy Mines and Resources Forest Planning and Development Branch. Microstation setup, hardware support and final conversion of spatial data from MicroStation into ArcGIS format using Feature Manipulation Engine (FME) software was supplied by Yukon Energy Mines and Resources Information Systems.

4.3.2) Ecosystem classification refinements

Once field work was completed, the preliminary ecosystem classification (from Grods, unpublished report, 2005)[1] was revised to incorporate all field sites visited in the NTS 105A/2 study area during the summer of 2004. Some existing ecosystem units were modified while other new ones were added to the original classification system. The dominant distinguishing or controlling environmental variables used in the Yukon ecosystem classification in boreal ecosystems is the parent material followed by the ecological moisture and nutrient regime[1].

The ecosystem classification consists of floristically similar plant associations occupying sites with similar environmental characteristics of parent material, soil moisture, and nutrient regimes (see Biophysical Mapping Standards Section 5.2 and Appendix 1). The classification is based on analysis of detailed terrain, soil, and vegetation site data, including site position, aspect, slope, parent material, ecological moisture, hydrologic conditions, nutrient regime and site history, all of which combine to determine the vegetation community found at a site. The detailed site data was analysed using VPRO, a database capable of generating numerous tables for easy visualization, analysis and modification of the classification system.

The ecosystem classification field guide[1] is comprised of two-page fact sheets for each ecosystem unit. The fact sheets highlight bioclimate zone, parent material, ecological moisture, nutrient status and vegetation association to facilitate identification in the field. Determination of the ecosystem unit at a site is done by comparison of the field attributes with the characteristics in the guide.

Ecosystem units were correlated with the Western Canada Boreal Forest and Woodland classification (WCBFW; Western Boreal Forest and Woodland Committee, 2004). This is a floristic vegetation classification based on field data compiled throughout western Canada. The classification is restricted to forest and woodland associations, including wetlands and other non-forested types. The correlation was reasonably good, but numerous WCBFW associations, as expected, were not found within the study area. Furthermore, some WCBFW associations correlated with more than one ecosystem unit because they occur on several different parent materials, or under wider ranges of moisture conditions. In some cases, the different ecosystem units correspond better to WBFWC sub-associations. In others, an association or sub-association was split into two or more ecosystem units where it occurred on two or more parent materials or under a wide range of soil conditions.

[1] The other southeast Yukon ecosystem classification field guide (7/8 approximation) 2nd Draft. Currently in preparation by J. Grods of Makonis Consulting Ltd, Kelowna, BC, 2005.

Comparison between the wetland types found in southeast Yukon and the Wetland Classification of BC (Mackenzie and Moran 2004) indicated that while many wetland types are similar, they do not exactly correspond in both regions.

4.3.3) Biophysical mapping

The final modified ecosystem classification was used as the basis for 1:50 000-scale biophysical mapping. A number was assigned to each ecosystem unit within the classification, using the correlated WCBFW unit number, where applicable. Where the ecosystem unit was not correlated with a WCBFW unit, a new number was allocated. Each biophysical polygon on the map was designated a single ecosystem unit number where an ecosystem unit was uniform, or a complex of two or more numbers where the topography and distribution of parent materials formed patterns too small or intermixed to map separately.

4.4) Recommended methodology for future mapping projects

Future local-scale biophysical mapping projects that are adjacent to the Watson Lake NTS 105A/2 map area (in the same ecoregion) should follow the same steps listed above in their approach. This would involve preliminary air-photo interpretation of terrain and ecosystem units (on softcopy scanned air photos if available) followed by extensive field checking and final map corrections, compilation and documentation.

Where local-scale biophysical mapping is carried out in entirely different ecoregions, significant work will need to be carried out to compile a new ecosystem classification system by analysing detailed field vegetation plots. As local-scale biophysical maps occur in other parts of the Yukon, this process will become less time consuming, as more ecosystem units will already have been defined.

In the future, it is anticipated that ecosystem units may be based on the Yukon Vegetation Classification. This project has recently been initiated as an offshoot of the Western Boreal Forest and Woodland Classification. The Yukon Vegetation Classification will include all vegetation communities from boreal forests to alpine and arctic tundra. However, it will be focused mainly on plant physiognomy and floristics. The ecosystem classification will incorporate environmental characteristics associated with each vegetation association or sub-association.

Suggested steps for future biophysical mapping in southeast Yukon using Grods (2005) field guide[1]:

The ecosystem units defined for the NTS 105A/2 study area can easily be used for adjacent and nearby map sheets within the Liard Plain Ecoregion. In addition, the ecosystem classification field guide[1] outlines ecosystem units which can be applied to the entire southeast Yukon.

Grods[1] summarizes how to use this guide in the field and a similar process can be followed for preliminary air-photo interpretation. Parent material, topography, ecological moisture and dominant vegetation association can often be determined from aerial photographs. Comparison of these data with the detailed ecosystem unit descriptions in the field guide enables the air-photo interpreter to assign the preliminary ecosystem units before going into the field.

The following steps are suggested for future biophysical mapping projects in southeast Yukon:

1) Identify the bioclimate zone(s) by reviewing background information and bioclimate mapping (if available) for the region. A summary of distinguishing characteristics for each bioclimate zone is provided in the field guide.

2) Identify the range of ecosystem units described in the field guide that are likely found in the study area. This forms the working biophysical legend.

[1] The other southeast Yukon ecosystem classification field guide (7/8 approximation) 2nd Draft. Currently in preparation by J. Grods of Makonis Consulting Ltd, Kelowna, BC, 2005.

3) Delineate the terrain polygons using preliminary air-photo interpretation and subdivide them into biophysical polygons based on changes in vegetation cover (if it is not uniform throughout the terrain polygon).

4) Assign the ecosystem unit based on the terrain classification, moisture conditions and vegetation association interpreted from the air photos.

5) Field investigations should be made to check and supplement air-photo interpretation of terrain characteristics (terrain unit, texture, surficial material, surface expression, geomorphic processes, or bedrock type), edaphic (soil) conditions (ecological moisture or nutrient regime) and vegetation characteristics (vegetation association, percent cover of major species and overall ecosystem unit designation). New ecosystem units may be identified in this process, and others may not be found within the study area at all, and can therefore be eliminated from the working legend.

   Where appropriate, field investigations can be in the form of simple visual checks or more detailed analyses. Detailed field investigations (following the methodology outlined in section 4.2) should be carried out to document new ecosystem units and/or the range of conditions characterizing an existing ecosystem unit. New units will be added to a Yukon-wide database. Visual checks should be made where required to confirm or reject initial air-photo interpretation of terrain, topographic, edaphic or vegetation features.

6) Location of all site investigations should be recorded in Nad 83 UTM or latitude/longitude coordinates and plotted on a base map at the same scale as the mapping.

7) All field data should be entered into a digital Micosoft Access database so it can be easily incorporated into a future Yukon-wide database for biophysical data. This future database needs to be further developed and stored in an accessible, maintained location. It should include a field data-entry tool similar to Venus, which is used in British Columbia.

5.0) GUIDE TO INTERPRETING SURFICIAL GEOLOGY AND BIOPHYSICAL MAPS

Two 1:50 000-scale maps accompany this report ("Surficial Geology of Watson Lake area (NTS 105A/2), Yukon" and "Biophysical Map of Watson Lake area (NTS 105A/2), Yukon") along with a CD containing the digital GIS data for the ecosystem and terrain polygons as well as the supporting field database. The biophysical map is based on the terrain (surficial geology) map, such that the terrain polygons are subdivided into discrete ecosystem units. It is difficult to display all the information potentially of interest to the user because of the extensive amount of information that a biophysical map includes. The GIS data (provided on the accompanying CD), allows the user to visualize and query information of interest to fit their unique needs.

5.1) Terrain mapping standards

The well-established Terrain Classification System for British Columbia (Howes and Kenk, 1997), which has not been previously used in the Yukon, was adopted for the terrain mapping component of this project. Since this system is planned to be adopted for all future surficial geology mapping done at the Yukon Geological Survey, part of the purpose of this project was to test and become accustomed to its methodology. The descriptions of the various surficial materials and terrain classification components listed in this section are based on the BC classification system definitions and are supplemented with project specific comments pertaining to local terrain conditions.

This section of the report is intended to aid in the interpretation of labels used on the accompanying 1:50 000-scale terrain map. For a complete description of the classification system used, please refer to the Terrain Classification for British Columbia manual (Howes and Kenk, 1997; available online at http://srmwww.gov.bc.ca/risc/pubs/teecolo/terclass/).

On the terrain map, polygons are labeled with a composite group of letters, which are arranged so that each letter position represents a particular characteristic of the terrain, including some or all of the following: texture and type of surficial material, surface expression, geomorphologic processes, and qualifiers. There may be one single or multiple surficial material units included in one label.

In the hypothetical sample label below, the characteristic that each letter represents is identified. For more details on each characteristic, refer to the appropriate sections below.

This sample label indicates that the polygon is dominantly covered by muddy (m) sandy (s) pebbly (p) active (A) floodplain (F^{A}p) with lesser amounts of flat lying (p) and terraced (t) silty clay (zc) glaciolacustrine (L^{G}) deposits, all of which is modified by thermokarst (e) permafrost (X) processes, gullying (V) and beaver damming (Q), and is underlain by gently dipping (j) phyllite (ph) bedrock (R).

5.1.1) Qualifiers

Qualifier symbols are used to indicate a glacial mode of surficial material formation, or the activity status of a surficial material or geomorphological processes. Qualifier symbols are denoted by an upper case superscript that follows the surficial material symbol or the geomorphological process symbol. Up to two qualifiers may be used together.

Table 3. *Surficial material and geomorphological process qualifiers.*

LABEL	NAME	DESCRIPTION
G	Glacial	Used where there is direct evidence that glacier ice has controlled deposition
A	Active	Used where there is evidence that a surficial material is undergoing formation at the present time, or where a geomorphological process is occurring at present, unless activity is already inferred in the definition of surficial material or process.
I	Inactive	Used where there is no evidence that a surficial material is undergoing formation at the present time, or where a geomorphological process is occurring at present, unless inactivity is already inferred in the definition of surficial material or process.

5.1.2) Delimiters

Where multiple surficial materials are impossible to separate at map scale, up to three surficial materials can be listed, along with their textures and surface expressions, in order of decreasing importance. Each surficial material is separated by one of the following three delimiters:

Table 4. *Delimiters used to separate multiple terrain components found in a single map polygon.*

.	components on either side of the symbol are of approximately equal proportion
/	the component in front of the symbol is more extensive than the one that follows
//	the component in front of the symbol is considerably more extensive than the one that follows
\	partial cover (moderately extensive, but discontinuous)

5.1.3) Surficial materials: genesis, properties and distribution

Surficial materials are non-lithified, unconsolidated sediments. They are produced by weathering, sediment deposition, biological accumulation, and by human and volcanic activity at the earth's surface. In general, surficial materials are of relatively young geological age and they constitute the parent material of most (pedological) soils.

On a map, surficial materials form the core of the terrain polygon label. They are symbolized with a single upper case letter (indicated in brackets in the descriptions below), with texture written to the left, and surface expression to the right. If actual activity is different than the assumed activity (indicated in brackets below), a qualifier (A - active or I - inactive) must be used as a superscript following the surficial material label. Note that a single polygon will be coloured for the dominant surficial material, but other materials may still exist in that unit.

<u>Anthropogenic (A)</u>

Anthropogenic materials have been so modified by human activities that their original physical properties (e.g., structure, cohesion, compaction) have been drastically altered. These materials commonly have a wide range of textures. They are typically formed by the removal of material from an original site followed by redeposition elsewhere, and are applied to such features as landfills and tailings.

<u>Colluvium (C)</u>

Colluvium can be derived from any of the other surficial materials, which have reached their present positions as a result of direct, gravity-induced mass movement involving no agent of transportation such as water or ice, although the moving material may have contained water and/or ice. It generally consists of massive to moderately well-stratified, non-sorted to poorly-sorted sediments. The texture usually reflects the source materials and can include any range of particle sizes from clay to boulders and blocks. Colluvium includes landslide debris, talus slopes and weathered mantles of till or bedrock. The activity state of colluvial materials is assumed to be active, unless stated as inactive with a qualifier.

Within the map area, colluvium is most common on moderate to steep slopes in association with till blankets or steep bedrock cliffs. It also applies to the scattered landslide deposits throughout the area.

<u>Eolian (E)</u>

Eolian materials have been transported and deposited by wind action. They generally consists of medium to fine sand and coarse silt that is well-sorted, non-compacted, and contains internal structures such as cross-bedding or ripple laminae, or they may be massive. Eolian materials are assumed to be inactive, unless stated as active with a qualifier.

A thin veneer of silty loess (zEvw) between 5 and 30 cm thick is widespread throughout the map area over till (Figure 7) and glaciofluvial deposits, especially in hollows and depressions. Inactive sand dune fields (sEr) are found immediately north and south of the Liard River, just east of Porter Lakes.

***Figure 7**. Typical soil pit (55 cm deep) in till, with 15 cm of oxidized loess at top (site 04WL175).*

Fluvial (F)

Fluvial (alluvial) materials have been transported and deposited by streams and rivers. Deposits generally consist of rounded gravel and interstitial sand in the main channel, with sand and/or silt (and rarely, clay) in flood or overbank deposits. Fluvial sediments are usually moderately to well-sorted and display stratification. Floodplain, delta, fluvial terrace and fan deposits are all mapped as fluvial features. Fluvial materials are assumed to be inactive, unless stated as active with a qualifier (such as present-day channels and areas subject to regular flooding).

Throughout the map area, unchannelized downslope seepage is common on moderate till slopes, resulting in thin fluvial veneers. The Liard River takes on an irregularly sinuous to meandering morphology, and has formed the main valley floor which is up to 3 km wide. The Liard River floodplain deposits range from cobble gravel in the main channel to silty sand in abandoned channels and overbank areas. Marshes and swamps are also common throughout the floodplain. Oxbow lakes are found north of Albert Creek.

Water Survey of Canada hydrometric records since 1960 show that extreme daily flows on the Liard River at Upper Liard have ranged between a maximum of 3060 m^3/s (June 2, 1972) and a minimum of 32 m^3/s (Nov 11, 1995). For the same period, peak flows average around 1500 m^3/s in early June, but ranged between 800 and 3000 m^3/s. Ice conditions are recorded at the gauging station between mid-September to early October until mid-March to early April.

Most bank erosion takes place during and immediately after ice breakup when spring floods occur (Verschuren et al., 1972). Vershuren & Bristol (1974) measured erosion rates and calculated erosion indices based on river geometry for a 5-km reach of the Liard River just upstream of Upper Liard. At one site they measured bank erosion rates of greater than 30 m/year over a two-year period.

Glaciofluvial (F^G)

Glaciofluvial materials exhibit clear evidence of having been deposited by glacial meltwater streams either directly in front of, or in contact with, glacier ice. Materials typically range from non-sorted and non-bedded gravel made up of a wide range of particle sizes, to moderately to well sorted, stratified sand and gravel (Figures 8 and 9); flow tills may occur in some deposits. Hummocky or irregular terrain may be present and is indicative of collapse of the material due to melting of supporting ice. Kettles may occur on the surface of these deposits as a result of buried or partially buried ice melting out. Pitted outwash plains, kames and eskers are all formed of glaciofluvial deposits. The activity state of glaciofluvial materials is inactive throughout the map area.

Thick outwash plains of sand and gravel are found southwest of the Liard River, with extensive areas of kettled hummocky terrain around Upper Liard (Figure 4), Lucky Lake and the town of Watson Lake. Thick beds within these deposits contain large amounts of buried wood (Figures 10-13), reworked from an upstream source. Four samples of the buried coniferous wood were radiocarbon dated (Appendix 2) and returned ages of between >44 200 (Lab No. 197224) and >46 750 BP (Lab No. 197222). Glaciofluvial outwash plains are also prevalent along most of the low-lying valley floors north and northeast of town.

***Figure 8**. Classic climbing ripples in Liard River cutbank into glaciofluvial sands, 10 km downstream of Upper Liard (site 04WL197).*

Figure 9*. Exposed face of active gravel pit on Robert Campbell Highway (site 04WL067), showing glaciofluvial gravel and sand in which buried fragments of wood were radiocarbon dated at > 46 000 BP.*

Figure 10 *(below left). A 41-m-high Liard River glaciofluvial cutbank, 10 km downstream from Upper Liard (site 04WL197), with silt and fine sand beds containing buried wood (dark material falling out of section at right), overlain by gravel.*

Figure 11 *(below right). Glaciofluvial cutbank with buried wood layers exposed to right of shovel (site 04WL197).*

Figure 12 *(above left). Highly oxidized Liard River glaciofluvial cutbank, 10 km downstream from Upper Liard (site 04WL197), contains thick beds of sand with large amounts of buried wood, dating >44 000 years old.*

Figure 13 *(above right). Buried coniferous wood from Liard River cutbank, 10 km downstream of Upper Liard (site 04WL197), radiocarbon dated older than 44 000 years.*

Prominent eskers (Figure 14) are found in the northeastern and mideastern part of the map area, extending from 1 to 3 km generally in a west to east direction on the surface of till plains and blankets. Eskers are sinuous ridges formed by deposition in subglacial or englacial meltwater channels. The eskers are on the order of 10 m high, 25 m wide at the base, 2 m wide at the top and have up to 25º sideslopes. They are composed of poorly sorted loose sand and gravel with beds of well sorted fine to medium sand.

***Figure 14**. View to west of esker ridge in till plain southwest of Lingfish Lake (site 04WL168).*

<u>Lacustrine (L)</u>

Lacustrine sediments have settled in bodies of standing fresh water either from suspension or from underwater gravity flows, such as turbidity currents. Lacustrine sediments can also accumulate along lake margins through the action of waves.

Sediments commonly consist of stratified fine sand, silt and/or clay deposited on the lake bed from suspension, or moderately to well sorted, stratified sand and coarser materials that are beach and other littoral sediments transported and deposited by wave action. Lacustrine materials are assumed to be inactive, unless stated as active with a qualifier (such as in areas beneath and on the margins of present day lakes).

Where the Robert Campbell Highway crosses McDonald Creek (04WL202), there is an extensive area of post-glacial lacustrine sediment containing abundant marl (shell fragments) and shallow permafrost. Many other lakes in the map sheet, such as Wye Lake near town, contain marl (Figures 15 and 16), leading to very alkaline local soil conditions.

***Figure 15** (above). White specks are shell fragments in marl (site 04WL199), which forms along the margins of shallow lakes.*

***Figure 16** (right). Looking west toward the town of Watson Lake; the lighter coloured areas along the margins of Wye Lake are composed of marl.*

Glaciolacustrine (L^G)

Glaciolacustrine materials are deposited in or along the margins of glacial (ice-dammed) lakes, including sediments that were released by the melting of floating ice.

The sediments typically consist of well sorted stratified or laminated fine sand, silt and/or clay (Figure 3); commonly containing ice-rafted stones and lenses of till and/or glaciofluvial material. Slump structures and contorted bedding (Figure 17) and/or their topographic expression, such as hummocky or irregular terrain, may be present and are indicative of collapse of the material due to melting of supporting ice. Kettle holes may also occur on the surface of these deposits due to the melting of buried or partially buried ice leading to local collapse. Glaciolacustrine materials can also include moderately sorted to well sorted, stratified sand and coarser beach sediments transported and deposited by wave action along the margins of glacial lakes. Throughout the map area, glaciolacustrine materials are inactive.

Figure 17*. Fine sands and silts showing load deformation near base, just above glaciofluvial gravels in gravel pit (site 04WL128).*

Stiff laminated glaciolacustrine silts and clays up to 10 m thick are exposed in landslides along the banks of the Liard River south of Watson Lake town (03AH090) and near the mouth of Watson Creek (04WL159) (Figure 18). In these exposures, the sediments underlie thick till and glaciofluvial deposits.

Figure 18. *(A - left) Cutbank exposure of colluviated till overlying lacustrine clays (darker unit at base) created by active stream undercutting (site 04WL159) at the mouth of Watson Creek.*

(B - right) Stiff glaciolacustrine clays at base of stream exposure.

Morainal Material / Till (M)

Till is material deposited directly by glacier ice without modification by any other agent of transportation. Till can be transported and deposited beneath (basal till), beside, on, within and in front of a glacier. The physical characteristics of till deposits are highly variable and depend upon both the source of material incorporated by the glacier and the mode of deposition. In general, till consists of well compacted to non-compacted material that is non-stratified and contains a heterogeneous mixture of particle sizes, usually supported by a matrix of sand, silt and clay (Figure 19). Throughout the entire map area, till is inactive.

***Figure 19**. Typical structure of sandy basal till in Watson Lake area (site 04WL125).*

In the Watson Lake map area, till is primarily of the basal variety. This till is highly compacted, dense, matrix-supported with between 35-65% matrix supporting primarily granule and pebble clasts of varying lithologies. Basal till is streamlined into fluted landforms or drumlin fields in flat-lying plains (Figure 2 and 19), blankets most slopes and becomes colluviated on steeper slopes. Along ridge tops, till is present as a thin veneer, with bedrock at or close to the surface. Basal till is generally quite poorly drained due to its density and because it contains fine textures. Textures are commonly gravelly sandy loam. Sandy ablation till (materials melted out from inside or on top of glacial ice) lacking significant fine-textured silt or clay is also common. In many places, till has been reworked or dissected by meltwater activity and is found in close association with sandy glaciofluvial deposits. Erratics, or rocks transported and deposited by glacial ice, can be found in selected areas (Figure 20).

***Figure 20**. Erratic near Windid Lake (site 04WL148).*

Organic (O)

Organic sediments are composed largely of organic materials resulting from the accumulation of vegetative matter; they contain at least 30% organic matter by weight (17% or more organic carbon). Organic materials are commonly saturated with water and consist mainly of peat or the accumulated remains of mosses, sedges, or other hydrophytic vegetation in wetland settings. Throughout the entire map area the organic deposits are assumed to be active.

Organic deposits are widespread in low-lying wetland areas throughout the map area (Figures 2 and 21), infilling shallow depressions in till plains, ox-bow lakes and back-swamp areas of the Liard floodplain, and along most small creeks. Most organic deposits deeper than 40 cm are classified as bogs and fens according to the Canadian System of Wetland Classification. Bogs with restricted drainage, fibric peat (containing permafrost), and fens (with or without permafrost, and with slightly more water movement and soils slightly higher in nutrients) are common.

***Figure 21**. Typical wetland in fluted till plain, in the northwest part of the map area. Note gradational decrease in tree height as height of drumlin decreases in centre of wetland. Drumlin shape indicates that ice flow direction was from right to left.*

Bedrock (R)

Areas with bedrock outcrops, which may or may not be covered by a thin mantle (< 10 cm) of unconsolidated mineral or organic material, are mapped as bedrock.

Bedrock outcrop is scarce in the map area, but regional mapping was done by Gabrielse in 1967 and digitally compiled by Gordey and Makepeace (2003). The most extensive lithology identified was a north-trending ridge of southerly dipping Devonian-Mississippian Earn Group clastic sedimentary rocks, in the upland area north-northeast of the town of Watson Lake. The clastic rocks include chert-pebble conglomerate, carbonaceous black slate, impure siltstone and sandstone, quartzite and greywacke. The next ridge to the west was mapped as Upper Carboniferous and Permian chert, argillite, chert breccia and pebble conglomerate, and phyllite with minor amounts of limestone and greenstone. Liard canyon area (Figure 22) is formed of Cambrian and Ordivician dark grey phyllite, chert, siltstone, limestone and conglomerate.

***Figure 22**. Liard Canyon, looking south.*

Columnar-jointed, vesicular olivine basalts up to 60 m thick (Klassen, 1987) outcrop in various places in the southwest of the map area. They have been noted near the municipal landfill, in Alaska Highway roadcuts between Upper Liard and Watson Lake town, along the northeast side of the Liard River upstream of Upper Liard (Figure 23), in the floodplain of the Liard River, and in the very southwest corner of the map area in incised meltwater channels (Figure 24). In many cases, the basalts have slumped and formed extensive blockfields at their toes (Figure 24). Klassen (1987) reports potassium-argon ages for the basalt of 604 ± 39 ka (along the Alaska Highway) and 765 ± 49 ka (along the Liard River just north of Upper Liard). Volcanism is reported to have been centred in the Cassiar Mountains to the southwest of the Liard Plain.

Lower Tertiary clastic rocks, including coal, are found in the very northwest corner of the map sheet (Gordey and Makepeace, 2003). Coal of lignite A and B rank was exposed in trenches directly south of the town of Watson Lake, along the Liard River (Deklerk and Traynor, 2005). Similar coal prospects have also been drilled in the southwest corner of the map area along Albert Creek and south of Upper Liard, where seams up to 17 m thick were encountered, hosted by upwardly fining and thinning, highly deformed claystone, siltstone and minor sandstone of a meandering stream point bar facies (Deklerk and Traynor, 2005). Fragments of this lignite are commonly found in the glaciofluvial outwash deposits of the Liard Plain, and are also abundant in the Liard River floodplain (Figure 25).

Figure 23. *Columnar basalts on east side of Liard River, 3 km upstream of Upper Liard.*

Figure 24. *Basalt boulders at base of large bedrock slump, 5 km southwest of Upper Liard.*

Figure 25. *Boulders containing seams of lignite coal are common in the Liard River floodplain.*

5.1.4) Texture

Texture refers to the size, shape (roundness) and sorting of particles in clastic sediments, and the proportion and degree of decomposition of plant fibre in organic sediments. Texture is indicated by up to three lower case letters that are listed before the surficial material designator in order of increasing importance. The use of two or three textural terms together indicates that either the various textures are intermixed or they are interstratified. Generalized textures are assigned based on representative field checking, but users should realize that textures can vary both laterally and vertically within a polygon.

***Table 5**. Texture classes and codes used in terrain mapping.*

LABEL	NAME	SIZE (mm)	DESCRIPTION
a	blocks	>256	angular
b	boulders	>256	rounded
c	clay	<0.002	
d	mixed fragments	>2	rounded and angular
e	fibric	fibric	poorly decomposed organic material
g	gravel	>2	mixture of two or more size ranges of rounded particles
h	humic		organic material at an advanced stage of decomposition
k	cobbles	64 - 256	rounded
m	mud	<0.0625	mixture of silt and clay
p	pebbles	2-64	rounded
r	rubble	2-256	angular
s	sand	0.0625 - 2	
u	mesic		organic material with decomposition between fibric and humic
x	angular	>2	mixture of angular blocks and rubble
y	fragments		sediment consisting dominantly of shells and/or shell
z	shells	0.002 - 0.0625	fragments
	silt		

5.1.5) Bedrock Subclasses

When describing bedrock (R), bedrock subclass precedes the surficial material descriptor (R), instead of using a textural term as above. Bedrock subclasses used on the terrain map include:

LABEL	NAME
bs	basalt
ph	phyllite
ss	sandstone

***Figure 26**. Highly oxidized pocket of soil found at the top of a 26-m-high glaciofluvial cutbank on the Liard River, 10 km downstream of Upper Liard. Intensely red soil is likely the result of deeply weathered basalt boulder.*

5.1.6) Surface expression

Surface expression refers to the form (assemblage of slopes) and pattern of forms expressed by a surficial material at the land surface. This three-dimensional shape of the material is equivalent to "landform" used in a non-genetic sense (e.g., ridges, plain). Surface expression symbols also describe the manner in which unconsolidated surficial materials relate to the underlying substrate (e.g., veneer). Surface expression is indicated by up to three lower case letters (Table 6), placed immediately following the surficial material designator, listed in order of decreasing extent.

***Table 6**. Surface expression classes and codes used in terrain mapping.*

---

a - Moderate slope: unidirectional (planar) surface; 16-26° (27-50%) slope; longitudinal profile smooth and straight, or slightly concave/convex; relief of local surface irregularities generally <1 m.

b - Blanket: a layer of unconsolidated material thick enough (>1 m) to mask minor irregularities of the surface of the underlying material, but still conforms to the general underlying topography; outcrops of the underlying unit are rare.

c - Cone: a cone or sector of a cone, mostly steeper than 15° (26%); longitudinal profile is smooth and straight, or slightly concave/convex; typically applied to talus cones.

d - Depression: circular or irregular area of lower elevation (hollow) than the surrounding terrain, >2 m deep, delimited by an abrupt break in slope steeper than the surrounding terrain; commonly applied to kettle holes and pitted outwash plains in glaciofluvial materials.

f - Fan: sector of a cone with a slope gradient less than 15° (26%) from apex to toe; longtitudinal profile is smooth and straight, or slightly concave/convex.

h - Hummock: steep-sided hillock(s) and hollow(s) with multidirectional slopes dominantly between 15-35° (26-70%) if composed of unconsolidated materials, whereas bedrock slopes may be steeper; local relief >1 m, in plan, an assemblage of non-linear, generally chaotic forms that are rounded or irregular in cross-profile; commonly applied to knob-and-kettle glaciofluvial terrain (Figure 4).

j - Gentle slope: unidirectional (planar) surface; 4-15° (7-26%) slope; longitudinal profile smooth and straight, or slightly concave/convex; relief of local surface irregularities generally <1 m.

k - Moderately steep slope: unidirectional (planar) surface; 27-35° (50-70%) slope; longitudinal profile smooth and straight, or slightly concave/convex; relief of local surface irregularities generally <1 m.

m - Rolling: elongate hillock(s); slopes dominantly between 3-15° (5-26%); local relief >1 m; in plan, an assemblage of parallel or sub-parallel linear forms with subdued relief; commonly applied to bedrock ridges and fluted or streamlined till plains (Figure 2).

p - Plain: a level or very gently sloping, unidirectional (planar) surface with slopes 0-3° (0-5%); relief of local surface irregularities generally <1 m; applied to (glacio)fluvial floodplains, organic deposits, lacustrine deposits and till plains.

r - Ridge: elongate hillock(s) with slopes dominantly 15-35° (26-70%) if composed of unconsolidated materials; bedrock slopes may be steeper; local relief is >1 m; in plan, an assemblage of parallel or sub-parallel linear forms; commonly applied to drumlinized till plains, eskers (Figure 14), morainal ridges, crevasse fillings and ridged bedrock.

Table 6 continued on next page…

Table 6 continued…

s - Steep slope: unidirectional (planar) surface; >35° (70%) slope; longitudinal profile smooth and straight, or slightly concave/convex; relief of local surface irregularities generally <1 m; bedrock slopes may be more irregular; commonly applied to terrace scarps, gully side walls and bedrock cliffs.

t - Terrace: a single or assemblage of step-like forms where each step-like form consists of a scarp face and a horizontal or gently inclined surface above it; applied to fluvial and lacustrine terraces and stepped bedrock topography.

u - Undulating: gently sloping hillock(s) and hollow(s) with multidirectional slopes up to 15° (26%); local relief >1 m; in plan, an assemblage of non-linear, generally chaotic forms that are rounded or irregular in cross-profile; commonly applied to till plains, sand dunes and kame topography.

v - Veneer: a layer of unconsolidated materials too thin (10 cm – 1 m thick) to mask the minor irregularities of the surface of the underlying material; commonly applied to colluvial and till veneers on steep upland slopes.

w - Mantle of variable thickness: a layer or discontinuous layer of surficial material of variable thickness (0-3 m) that fills or partly fills depressions in an irregular substrate.

x - Thin veneer: a very thin layer of unconsolidated material, 2-20 cm thick. Commonly applied to eolian/loess veneers (Figure 7).

5.1.7) Geomorphological processes

Geomorphological processes are natural mechanisms of weathering, erosion and deposition that result in the modification of the surficial materials and landforms at the earth's surface. Unless a qualifier (A (active) or I (inactive)) is used, all processes are assumed to be active, except for deglacial processes. Process is indicated by up to three upper case letters (Table 7), listed in order of decreasing importance, placed after the surface expression symbol, and separated from the surface expression by a dash (-).

Subclasses can be used to provide more specific information about a general geomorphological process, and are represented by lower case letter(s) placed after the related process designator. Up to three subclasses can be attached to each process. Process subclasses used on this map are defined with the related process in Table 7.

Figure 27*. Looking east at gullying (arrow highlights sub-parallel grooves crossing road in background) on moderately steep till slopes, 6 km east of the town of Watson Lake. Caution should be exercised in these areas when planning road and cutblock layouts in order to minimize sediment erosion. Beaver damming in valley bottom has produced numerous ponds which may trap some sediment.*

***Table 7**. Geomorphological process classes and codes used in terrain mapping.*

EROSIONAL PROCESSES
V - Gully erosion: running water, mass movement and/or snow avalanching, resulting in the formation of parallel and sub-parallel long, narrow ravines (Figure 27).

FLUVIAL PROCESSES
I - Irregularly sinuous channel: a clearly defined main channel displaying irregular turns and bends without repetition of similar features; back-channels may be common, and minor side-channels, and a few bars and islands may be present, but regular and irregular meanders are absent.

J - Anastomosing channel: a channel zone where channels diverge and converge around many islands. The islands are vegetated and have surfaces that are relatively far above mean maximum discharge levels. Some channels are dry at moderate or low flows.

M - Meandering channel: a clearly defined channel characterized by a regular and repeated pattern of bends with relatively uniform amplitude and wave length.

Q - Beaver damming: interruption of regular fluvial transport by beaver dams leading to widespread and repeated ponding.

MASS MOVEMENT PROCESSES
F - Slow mass movements: slow downslope movement of masses of cohesive or non-cohesive surficial material and/or bedrock by creeping, flowing or sliding.
Subclass (k) tension cracks: fissures commonly near the crest of a slope.

R - Rapid mass movements: rapid downslope movement by falling, rolling, sliding or flowing of dry, moist or saturated debris derived from surficial material and/or bedrock.
Subclasses: (") initiation zone: headscarps of debris slides or earthflows and source areas for rockfall and debris flows; (d) debris flow: rapid flow of saturated debris; (m, u) slump: sliding of internally cohesive masses of bedrock (m) or surficial material (u) along a slip plane that is concave upward or planar; (r) rockslide.

PERIGLACIAL PROCESSES
C - Cryoturbation: movement of surficial materials by heaving and/or churning due to frost action (repeated freezing and thawing).

X - Permafrost processes: processes controlled by the presence of permafrost, and permafrost aggradation or degradation. Subclass (e) - thermokarst: depressions created by melting of ice-rich permafrost due to heat transfer from water bodies.

DEGLACIAL PROCESSES
E - Channeled by meltwater: erosion and channel formation by meltwater alongside, beneath, or in front of a glacier.

H - Kettled: depressions in surficial materials resulting from the melting of buried glacier ice (Figure 4).

HYDROLOGIC PROCESSES
U - Inundation: terrain seasonally under standing water, which results from high watertable.

L - Surface seepage: abundant surface seepage, or evidence of substantial seasonal seepage, is provided by physical or vegetation indicators.

5.1.8) Map reliability

In British Columbia, standards have been laid out specifying intensity levels for field checking terrain maps, as a measure of the reliability of mapping (British Columbia Ministry of Forests, 1999). Five terrain survey intensity levels (TSIL) range from A (most checks) to E (least checks). These are based on scale of mapping, average size of polygons mapped, number of polygons field checked, method of field checking, and rate of progress of field checking (Table 8).

The ranges used in the criteria defining the intensity levels reflect the potential range of mapper experience, the complexity of the terrain, and possible access constraints (dense bush, severe topography, limited helicopter and road access).

During ground checks, emphasis should be placed on walking across polygons, checking their boundaries, and investigating and describing all terrain attributes relevant to the entire polygon. Collecting detailed site data for one point in a polygon is rarely sufficient for characterizing an entire polygon. Vehicle traverses of existing road networks and low-level helicopter inspections can be used to supplement, but not replace, information obtained from foot traverses.

***Table 8**. Terrain survey intensity levels (TSIL) for terrain mapping.*

(from British Columbia Ministry of Forests, 1999)

Terrain Survey Intensity Level	Preferred map scale	Estimated range of average polygon sizes (ha)	% of polygons ground-checked	Method of field-checking	Rate of field progress per crew day (ha)
A	1:5000 to 1:10 000	2-5 5-10	75-100	Ground checks by foot traverses	20-100
B	1:10 000 to 1:20 000	5-10 10-15	50-75	Ground checks by foot traverses	100-600
C	1:20 000 to 1:50 000	15-20 50-200	20-50	Ground checks by foot traverses, supported by vehicle and/or flying	500-1200
D	1:20 000 to 1:50 000	20-30 100-400	1-20	Vehicle and flying with selected ground observations	1500-5000
E	1:20 000 to 1:100 000	20-40 200-600	0	No field work, only photo interpretation	n/a

The level of survey intensity chosen for a specific project depends on the purpose of mapping. Level A is usually reserved only for very site specific detailed mapping. Standard 1:50 000-scale terrain mapping is usually done at TSIL C. In watersheds or portions of watersheds with very complicated or very hazardous soil and terrain conditions TSIL B may be more appropriate. Levels D or E may be specified for large contiguous inoperable or alpine areas.

Map reliability for this project is rated at terrain survey intensity level C.

5.2) Biophysical mapping standards

5.2.1) Ecosystem classification system

Table 9 outlines the classification system used to define the ecosystem units, or types, on the accompanying biophysical map. The 69 types are classified by various combinations of parent material, soil moisture regime, ecological nutrient regime, plant community, and disturbance history. This classification system follows biophysical mapping work which has been under development by the Yukon Ecosystem Working Group over the last few years, and is still a work in progress. A more detailed guide to the classification system will be produced in the near future.

5.2.2) Interpreting the ecosystem type map labels

There may be up to four ecosystem types or components defined for a single polygon. Where multiple types are defined, the most dominant (by percent cover) is listed first, followed by the next dominant listed beneath it. The proportion of each type, in deciles, is indicated by the superscript number.

The hypothetical map label below summarizes the ecosystem designations for a single map polygon, which in this case consists of three components:

M4C-WSw-L^{6}
G3B-SbP^{3}
O7C-SxCx:Wf^{1}

M4C-WSw-L^{6} : **60%** till parent material, mesic soil moisture regime, mesotrophic nutrient regime, logged, Alaska birch / white spruce vegetation association.

G3B-SbP^{3}: **30%** glaciofluvial parent material, submesic soil moisture regime, submesotrophic nutrient regime, black spruce / lodgepole pine vegetation association.

O7C-WiCx:Wf^{1} : **10%** organic parent material, subhydric soil moisture regime, mesotrophic nutrient regime, willow / sedge / fen wetland vegetation association.

Within each ecosystem component:

- Parent material is indicated by the first letter.
- Moisture regime is indicated by the next number.
- Nutrient regime is indicated by the next letter.
- Vegetation association is indicated by the group of letters following the dash.
- Wetland class (if applicable) follows the vegetation association, and is preceded by a colon.
- Disturbance modification (logging, agriculture or other development) is indicated by the capital letter following the second dash.
- Percent cover decile is indicated by the superscript digit (between 1 and 10) shown at the end of the component (multiply by 10 to get percent cover).

***Table 9**. Ecosystem type descriptions.*

(See Appendix 1 for more detailed site and vegetation descriptions for each type.)

PARENT MATERIAL	ECOSYSTEM TYPE (MAP LABEL)	ECOSYSTEM NAME (DOMINANT VEGETATION)	MOISTURE REGIME	NUTRIENT REGIME
COLLUVIUM	C2C-AuFb	Colluvial: arctostaphylos - forb	subxeric	mesotrophic (medium)
	C3B-P	Colluvial: pine	submesic	submesotrophic (poor)
	C3C-BA	Colluvial: balsam poplar - aspen	submesic	mesotrophic (medium)
	C3C-SwSb	Colluvial: white spruce - black spruce	submesic	mesotrophic (medium)
	C4B-SbP	Colluvial: black spruce - pine	mesic	submesotrophic (poor)
	C4C-FSw	Colluvial: fir - white spruce	mesic	mesotrophic (medium)
	C4C-Sh-L	Colluvial: shrub regen (logged)	mesic	mesotrophic (medium)
	C4C-WSw	Colluvial: Alaska birch - white spruce	mesic	mesotrophic (medium)
EOLIAN	E3B-PSbLi	Eolian: pine - black spruce - lichen	submesic	submesotrophic (poor)
	E4B-SbP	Eolian: black spruce - pine	mesic	submesotrophic (poor)
FLUVIAL	F5D-A	Fluvial: aspen	subhygric	permesotrophic (rich)
	F5D-Al	Fluvial: alder	subhygric	permesotrophic (rich)
	F5D-B	Fluvial: balsam poplar	subhygric	permesotrophic (rich)
	F5D-FSw	Fluvial: fir - white spruce	subhygric	permesotrophic (rich)
	F5D-Gr-C	Fluvial: grass (cultivated)	subhygric	permesotrophic (rich)
	F5D-NV	Fluvial: non-vegetated	subhygric	permesotrophic (rich)
	F5D-NV-D	Fluvial: non-vegetated (developed)	subhygric	permesotrophic (rich)
	F5D-SbSw	Fluvial: black spruce - white spruce	subhygric	permesotrophic (rich)
	F5D-Sh-L	Fluvial: shrub regen (logged)	subhygric	permesotrophic (rich)
	F5D-SwB	Fluvial: white spruce - balsam poplar	subhygric	permesotrophic (rich)
	F5D-SwFm	Fluvial: white spruce - feathermoss	subhygric	permesotrophic (rich)
	F6C-Wi:Ws	Fluvial: willow - swamp wetland	hygric	mesotrophic (medium)
	F6D-SwL	Fluvial: white spruce - larch	hygric	permesotrophic (rich)
	F6E-Cc	Fluvial: bluejoint grass	hygric	eutrophic (very rich)
	F8D-CaCu:Wm	Fluvial: water sedge - beaked sedge - marsh wetland	hydric	permesotrophic (rich)
	F8D-Eq:Wm	Fluvial: Equisetum - marsh wetland	hydric	permesotrophic (rich)

PARENT MATERIAL	ECOSYSTEM TYPE (MAP LABEL)	ECOSYSTEM NAME (DOMINANT VEGETATION)	MOISTURE REGIME	NUTRIENT REGIME
GLACIOFLUVIAL	G3B-ASw	Glaciofluvial: aspen - white spruce	submesic	submesotrophic (poor)
	G3B-NV-D	Glaciofluvial: non-vegetated (developed)	submesic	submesotrophic (poor)
	G3B-P	Glaciofluvial: pine	submesic	submesotrophic (poor)
	G3B-PASw	Glaciofluvial: pine - aspen - white spruce	submesic	submesotrophic (poor)
	G3B-PSbLi	Glaciofluvial: pine - black spruce - lichen	submesic	submesotrophic (poor)
	G3B-SbFm	Glaciofluvial: black spruce - feathermoss	submesic	submesotrophic (poor)
	G3B-SbP	Glaciofluvial: black spruce - pine	submesic	submesotrophic (poor)
	G4C-Sh-L	Glaciofluvial: Shrub Regen (logged)	mesic	mesotrophic (medium)
	G4C-SwSb	Glaciofluvial: white spruce - black spruce	mesic	mesotrophic (medium)
	G5B-SbFm	Glaciofluvial: black spruce - feathermoss	subhygric	submesotrophic (poor)
LACUSTRINE	L4C-NV-D	Lacustrine: non-vegetated (developed)	mesic	mesotrophic (medium)
	L5D-Gr-C	Lacustrine: grass (cultivated)	subhygric	permesotrophic (rich)
	L5E-SwSb	Lacustrine: white spruce - black spruce	subhygric	eutrophic (very rich)
	L6C-Sb	Lacustrine: black spruce	hygric	mesotrophic (medium)
	L6C-Wi:Ws	Lacustrine: willow - swamp wetland	hygric	mesotrophic (medium)
	L6E-Cc	Lacustrine: bluejoint grass	hygric	eutrophic (very rich)
	L8D-CaCu:Wm	Lacustrine: water sedge - beaked sedge - marsh wetland	hydric	permesotrophic (rich)
MORAINAL	M2B-PASw	Morainal: pine - aspen - white spruce	subxeric	submesotrophic (poor)
	M2B-PLi	Morainal: pine - lichen	subxeric	submesotrophic (poor)
	M3B-NV-D	Morainal: non-vegetated (developed)	submesic	submesotrophic (poor)
	M3B-P	Morainal: pine	submesic	submesotrophic (poor)
	M3B-PSbLi	Morainal: pine - black spruce - lichen	submesic	submesotrophic (poor)
	M4B-PFm	Morainal: pine - feathermoss	mesic	submesotrophic (poor)
	M4B-SbP	Morainal: black spruce - pine	mesic	submesotrophic (poor)
	M4C-ASw	Morainal: aspen - white spruce	mesic	mesotrophic (medium)
	M4C-FSw	Morainal: fir - white spruce	mesic	mesotrophic (medium)
	M4C-Sh-L	Morainal: shrub regen (logged)	mesic	mesotrophic (medium)
	M4C-SwSb	Morainal: white spruce - black spruce	mesic	mesotrophic (medium)

PARENT MATERIAL	ECOSYSTEM TYPE (MAP LABEL)	ECOSYSTEM NAME (DOMINANT VEGETATION)	MOISTURE REGIME	NUTRIENT REGIME
MORAINAL	M4C-SwSbP	Morainal: white spruce - black spruce - pine	mesic	mesotrophic (medium)
	M4C-SwSbPA	Morainal: white spruce - black spruce - pine - aspen	mesic	mesotrophic (medium)
	M4C-WSw	Morainal: Alaska Birch - white spruce	mesic	mesotrophic (medium)
	M5B-SbFm	Morainal: black spruce - feathermoss	subhygric	submesotrophic (poor)
	M6D-SwL	Morainal: white spruce - larch	hygric	permesotrophic (rich)
ORGANIC	O6C-SbFm:Ws	Organic: black spruce - feathermoss - swamp wetland	hygric	mesotrophic (medium)
	O6D-Gr-C	Organic: grass (cultivated)	hygric	permesotrophic (rich)
	O7B-BtCx:Wb	Organic: shrub birch - sedge - bog wetland	subhydric	submesotrophic (poor)
	O7B-Cl:Wf	Organic: shore sedge - fen wetland	subhydric	submesotrophic (poor)
	O7B-SbSp:Wb	Organic: black spruce - Sphagnum - bog wetland	subhydric	submesotrophic (poor)
	O7C-WiCx:Wf	Organic: willow - sedge - fen wetland	subhydric	mesotrophic (medium)
	O7D-LSb:Wf	Organic: larch - black spruce - fen wetland	subhydric	permesotrophic (rich)
	O8D-CaCu:Wf	Organic: water sedge - beaked sedge - fen wetland	hydric	permesotrophic (rich)
ROCK	Rb	Rock: basalt	N/A	N/A
WATER	W9-:Ww	Shallow open water	shallow open water	N/A

5.2.3) Regional bioclimate zones

Bioclimate classification zones characterize broad vegetation zones with similar regional climate influences and extents of distinct plant associations. The main climatic influences noted are temperature and precipitation over the course of the year, which determines factors such as growing season and moisture availability. The delineation of bioclimate zones for the Yukon results in a landscape stratification at an intermediate regional level (Level 4 in the Yukon ECM Framework) that recognizes observable vegetation patterns specifically associated with predominant elevation and latitudinal gradients (i.e., local climates and slope/aspect) (Grods, unpublished report, 2005 [1]; Francis and Steffen, 2003).

The bioclimate zones found in the entire Liard Basin region include:

BOL Boreal Low
BOH Boreal High
SUB Subalpine
AT Alpine

Normally, the ecosystem units of a region are first broadly subdivided by bioclimate zone. The letters representing the bioclimate zone are not included in the ecological mapping labels for this biophysical map because the Watson Lake NTS 105A/2 map sheet, which lies primarily below 1000 m in elevation, is entirely within the Boreal Low Watson bioclimate zone (BOLwat) (Grods, unpublished report, 2005) [1].

5.2.4) Parent material

The parent material codes (Table 10) for the biophysical map are the same as those used in terrain mapping except that the F is dropped from the glaciofluvial (FG) code to minimize the number of letters required for map labels.

***Table 10**. Parent material classes.*

C	colluvial
F	fluvial
G	glaciofluvial
L	lacustrine
M	till
O	organic
R	rock
W	water

[1] The other southeast Yukon ecosystem classification field guide (7/8 approximation) 2nd Draft. Currently in preparation by J. Grods of Makonis Consulting Ltd, Kelowna, BC, 2005.

5.2.5) Soil moisture regime

Moisture regime (Table 11) is classified between 0 and 9, based on an assessment of environmental factors, soil properties, and indicator plants. The definitions for classes 0 through 8 are based on the BC Field Manual for Describing Terrestrial Ecosystems (1998). Class 9 was added for this project.

***Table 11**. Soil moisture regime classes.*

0 - Very xeric: water removed extremely rapidly in relation to supply; soil is moist for a negligible time after precipitation. Precipitation is the primary water source.

1 - Xeric: water removed very rapidly in relation to supply; soil is moist for brief periods following precipitation. Precipitation is the primary water source.

2 - Subxeric: water removed rapidly in relation to supply; soil is moist for short periods following precipitation. Precipitation is the primary water source.

3 - Submesic: water removed readily in relation to supply; water available for moderately short periods following precipitation. Precipitation is the primary water source.

4 - Mesic: water removed somewhat slowly in relation to supply; soil may remain moist for a significant, but sometimes short period of the year. Available soil moisture reflects climatic inputs. Precipitation in moderate- to fine-textured soils and limited seepage in coarse-textured soils is the primary water source.

5 - Subhygric: water removed slowly enough to keep soil wet for a significant part of growing season; some temporary seepage and possibly mottling below 20 cm. Precipitation and seepage are the primary water sources.

6 - Hygric: water removed slowly enough to keep soil wet for most of growing season; permanent seepage and mottling; gleyed colours common. Seepage is primary water source.

7 - Subhydric: water removed slowly enough to keep water table at or near surface for most of year; gleyed mineral or organic soils; permanent seepage <30 cm below surface. Seepage or permanent water table is primary water source.

8 - Hydric: water removed so slowly that water table is at or above soil surface all year; gleyed mineral or organic soils. Permanent water table is primary water source.

9 - Shallow open water: water is at the surface all year. This moisture regime consists of shallow water wetlands of the Canadian Classification System characterized by emergent or aquatic vegetation. This is applied to small wetlands not included in the NTDB hydrographic base.

5.2.6) Nutrient regime

Nutrient regime (Table 12) is classified between A and F, based on an assessment of soil properties, indicator plants and site characteristics. Table 12 is from the British Columbia field manual for describing terrestrial ecosystems (1998).

***Table 12**. Nutrient regime classes and relationships between nutrient regime and site properties.*

	Oligotrophic	Submesotrophic	Mesotrophic	Permesotrophic	Eutrophic	Hypereutrophic
	A Very Poor	B Poor	C Medium	D Rich	E Very Rich	F Saline
Available Nutrients	very low	low	average	plentiful	abundant	excess salt accum.
Humus Form		Mor				
				Moder		
					Mull	
A horizon		Ae horizon present				
			A horizon absent			
				Ah horizon present		
Organic Matter Content		low (light coloured)				
			medium (inter. in colour)			
				high (dark coloured)		
C:N Ratio		high				
			moderate			
					low	
Soil Depth	extremely shallow					
				very shallow to deep		
Soil Texture		coarse textured				
				medium to fine textured		
% Coarse Fragments	high					
				moderate to low		
Parent Material Mineralogy	base-low					
			base-medium			
					base-high	
Soil pH	extremely – mod. acid					
			moderately acid – neutral			
				slightly acid – mildly alk.		
Water pH (Wetlands)	<4 - 5	4.5 - 5.5	5.5 - 6.5	6.5 - 7.4	7.4+	
Seepage			temporary	⟶	permanent	

5.2.7) Wetland classes

Wetlands are classified according to the Canadian System of Wetland Classification. Wetland codes used (Table 13) are from Wetlands of British Columbia (MacKenzie and Moran, 2004).

***Table 13**. Wetland classes.*

Wb	bog
Wf	fen
Ws	swamp
Wm	marsh
Ww	shallow open water

5.2.8) Vegetation association

One or more vegetation associations are listed in the label for each ecosystem unit in Table 14. An association simply characterizes the dominant plant species composition in a community, but does not exclude other species from being present.

***Table 14**. Codes used to describe ecosystem units.*

VEGETATION TYPE CODES		
CODE	*SCIENTIFIC NAME*	*COMMON NAME*
A	*Populus tremuloides*	trembling aspen
Al	*Alnus sp.*	alder species
Au	*Arctostaphylos uvaursi*	bearberry
B	*Populus balsamifera*	balsam poplar
Bt	*Betula species*	birch species
Ca	*Carex aquatilis*	water sedge
Cc	*Calamagrostis canadensis*	bluejoint grass
Cl	*Carex limosa*	shore sedge
Cu	*Carex utriculata*	beaked sedge
Cx	*Carex sp.*	Carex species
Eq	*Equisetum sp.*	horsetail species
F	*Abies lasiocarpa*	subalpine fir
Fb		forb species
Fm		feathermoss
Gr		graminoid species
L	*Larix laricina*	larch
Li		lichen species
P	*Pinus contorta*	lodgepole pine
Ra	*Rosa acicularis*	prickly rose
Sb	*Picea mariana*	black spruce
Sh		shrub species
Sp	*Sphagnum sp.*	sphagnum species
Sw	*Picea glauca*	white spruce
Wi	*Salix sp.*	willow species
W	*Betula neoalaskana*	Alaska birch

NON VEGETATION CODES		
NV	non-vegetated	
RB	rock (basalt)	

5.2.9) Disturbance modifiers

The presence of ecosystem disturbance such as recent forest fire, urban development, cultivation or logging is indicated by the disturbance modifiers listed below (Table 15).

***Table 15**. Disturbance modifiers.*

B	recently burned (forest fire)
D	developed
C	cultivated
L	logged

6.0) APPLICATIONS OF THE TERRAIN MAP

Aside from supporting ecological classification, a surficial geology or terrain map is integral to regional land-use planning by allowing the preliminary identification of potential road, railway and pipeline corridors, and town, industrial or development sites through an assessment of textural properties and terrain hazards[1]. Terrain maps can also be used to classify terrain stability and associated potential for landslide debris entering streams, potential for soil erosion, and risk of sediment delivery into streams.

6.1) Granular resources

A terrain map provides an indication of potential sources of granular resources for construction and road aggregate and bulk fill. It can therefore guide detailed field investigations for granular resources (Table 16) or preliminary planning of road layouts. In general, fluvial, glaciofluvial and colluvial deposits are most suitable for aggregate potential, although in the Watson Lake area, the sandy nature of much of the local till may make it suitable for bulk fill.

***Table 16**. Granular resource potential of various terrain units (based on Ryder and Howes, 1986).*

Map Unit	Landform	Granular Resource Potential
 Ft Ff F^Gr F^Gp F^Gh F^Gt	Inactive fluvial: river terrace fan or delta Glaciofluvial: esker outwash plain kame kame terrace	Good gravel and sand aggregate sources, but sorting and clast lithologies can be variable.
 F^Ap F^Af F^At	Active fluvial: floodplain fan, delta low terrace	Possibly suitable aggregate materials, but subject to flooding and disruption of riparian or wetland environments. Character can be highly variable, ranging from well-sorted gravel to fine-grained silty or organic-rich back-swamp deposits.
Colluvium Cf, Ca, Cc	Colluvium: talus slopes and fans	Possible subgrade material
Mb, Mv, Mp, Mm	Till: ablation and basal	Good low permeability bulk fill material

[1]*This section is based on information gathered from the following website: "Terrain information; A user's guide to terrain maps in British Columbia" by Ryder, J.M. and Howes, D.E. for British Columbia Ministry of Sustainable Resource Management, Terrain Resource Inventory (http://srmwww.gov.bc.ca/terrain/inventory/guide/index.html).*

6.2) Land use

The suitability of various surficial materials to certain land uses are rated in Table 17. This table is intended as a general guide only, which can be used to plan detailed field investigations for specific land uses.

Table 17. *Land use suitability ratings of various surficial materials (based on Ryder and Howes, 1986).*

Material	**Map Unit**	**Constraints**	**Potential Hazards**	**Light Found-ations**	**Heavy Found-ations**	**Exca-vations**	**Liquid Waste Disposal**	**Solid Waste Disposal**	**Highways Railroads Airfields**	**Unpaved Roads**	**Above Ground Water storage**
Colluvial	C	slope drainage topography	landslides	2	3	2	3	3	3	2	3
Eolian	E			1	3	1	2	3	1	1	3
Fluvial – active	F^A	drainage	floods, shifting channels	3	3	1	3	3	1	1	2
Fluvial – inactive	F^I			1	1	1	2	3	1	1	3
Glaciofluvial	F^G	topography		1	1	1	2	3	1	1	3
Glaciolacustrine	L^G	drainage	erosion, slumping	1	3	1	2	1	2	1	2
Lacustrine	L	topography	erosion, slumping	1	3	1	2	1	2	1	2
Organic	O	drainage		3	3	3					
Till – basal	M	drainage		1	1	2	2	1	1	1	1
Till - ablation	M	topography		1	1	1	2	3	1	1	3
Bedrock	R			1	1	3	3	3	3	3	3

1 = Desirable: terrain is generally capable of supporting the indicated land use.

2 = Possible problems: terrain may be suitable for the indicated land use, but potential problems exist.

3 = Undesirable: terrain is generally unsuitable for the indicated land use, although substantial modification of existing conditions (e.g., drainage, landfill) may overcome natural constraints.

6.3) Terrain hazards

Terrain hazards are naturally occurring processes and conditions that present a risk to life and property. Hazards portrayed on terrain maps result from gravity-induced downslope movement of materials, and processes water, wind or permafrost subsidence. They range from catastrophic and dramatic effects, such as avalanches, rockslides, and thermokarst to barely perceptible but persistent processes such as slow earthflows. Geomorphological hazards resulting from earthquake and volcanic activity are not identified.

The process of terrain mapping identifies geomorphological processes that are actively occurring or have occurred in the recent past. Certain surficial materials, textures and surface expressions are also associated with various terrain hazards. These are summarized in Table 18. By identifying areas subject to these processes or conditions, a hazards map can be generated.

A hazards map generated from a terrain map will, however, have certain limitations. Because terrain mapping only indicates geomorphological processes that may be active under present-day conditions, it provides no information about the intensity, frequency, or time of occurrence of any process, nor does it permit areas to be rated with regard to relative hazard potential. The identification of two or more processes within a unit does not indicate that the area is potentially more hazardous than a unit modified by only one process. The potential hazards implied on the map may not affect the whole unit; the map merely indicates that a certain geomorphological hazard may exist within a designated area. A hazards map derived from a terrain map is no more accurate than the original terrain map. Since the terrain map is prepared primarily from air photo interpretation supplemented by limited field checking, both terrain and hazards maps should be used only to indicate the general condition of the land surface over large areas. Detailed ground investigations will be necessary for assessment of small areas and specific sites.

Table 18. *Potential terrain hazard concerns with various geomorphological processes, surficial materials, textures and surface expressions (based on Ryder and Howes, 1986).*

Geomorphological Process	Potential Hazard
A	Snow avalanches
B	Braided channels – channel shifting and great variations in water level
D	Deflation - soil erosion by wind, or blowing dust
E^A	Active glacial meltwater - river with shifting channels and eroding banks
F	Slow mass movment - slow downslope movement and/or potential landslide
I	Irregularly sinuous channel - river with eroding banks
J	Anastamosing channel - river with shifting banks
K	Karst processes - surface collapse over underground cavities in bedrock
P	Piping - surface collapse over cavities in surficial material
R	Rapid mass movement - rockfall on bedrock terrain or debris (mud) flows on surficial material
V	Gully erosion - floods or debris flows may emerge from lower end of gullies, and gully sidewalls may be unstable
X	Permafrost processes – areas subject to thermokarst subsidence and thermal erosion by water

Surficial Material	Potential Hazard
C (Colluvium)	Potential landslides (rockfalls, debris flows, slumps) or surface erosion
E^A (Active Eolian)	Potential wind erosion and blowing dust
F^A (Active Fluvial)	Active fluvial environment, subject to flooding and bank erosion or collapse; debris flows in smaller steep drainages.
L, L^G (Lacustrine and Glaciolacustrine)	Slopes and steep scarps are potentially subject to gullying, landslides (mudflows) and surface and subsurface erosion (piping) if large amounts of water are introduced on site. Commonly contains permafrost that is subject to thermokarst activity.
O (Organic)	Highly susceptible to disturbance, and thermokarst thaw where underlain by permafrost.
M (Till)	Potential gullying, debris flows and slumps on moderate to steep slopes, especially where underlain by permafrost.

Texture	Potential Hazard
a (blocks), r (rubble), x (angular fragments)	Potential rockfall sites
c (clay)	Highly plastic and slippery when wet
z (silt)	Potential to contain ground ice (permafrost)
m (mud)	Plastic and slippery when wet and potential to contain ground ice (permafrost)
s (sand)	Potential liquefaction if saturated and seismically shaken

Surface Expression	Potential Hazard
c (cone)	Subject to mass movement processes (rockfall, etc.)
f (fan)	Subject to mass movement and fluvial processes, including debris flows and avulsions.
a, k, s (moderate, moderately steep and steep slopes)	Potential for surface erosion, gullying, and/or mass movement
P (plain)	subject to active fluvial processes (where part of F^Ap unit)

6.4) Terrain stability mapping

Another important derivative of terrain mapping is terrain stability mapping, where GIS can be used to divide the landscape into classes of susceptibility to landsliding particularly with respect to disturbance by timber harvesting and road construction. Terrain stability mapping standards have been rigorously established in British Columbia in association with the Forest Practices Code, for managing forest harvesting and road construction[2].

Slope gradient, surficial materials, material texture, material thickness, slope morphology, moisture conditions and ongoing geomorphic processes all play a critical role in terrain stability. Specific stability criteria must be customized for particular projects because these factors as well as climate, geology and soils vary considerably in different physiographic regions. Sample hypothetical criteria for terrain stability classes are given in Table 19. The following aspects can also be assessed from a terrain map in association with terrain stability mapping.

6.4.1) Potential for landslide debris to enter streams

When performing terrain stability mapping, the potential for landslide debris to enter a stream should be assessed for terrain stability classes IV and V. This is an interpretation of the likelihood of bedload sized material and organic debris to colluvially enter a stream. An example classification system and associated criteria are given in Table 20, based on hillslope gradient and slope morphology downslope from the polygon, evidence of landslide runout, presence or absence of a runout zone, length of the runout zone, and the presence of gullies that give direct access to the stream channel. This interpretation is usually only performed for detailed site-specific assessments, such as along short segments of road.

6.4.2) Soil erosion potential

Soil erosion potential ratings can be developed from the terrain map based on slope gradients, surficial material, texture and soil drainage. These interpretations may be required in some terrain stability mapping assessments, particularly ones for community watersheds. Most fine sediment production from soil erosion is from surfaces exposed by roads and trails. An example of a soil erosion potential rating system is shown in Table 21.

6.4.3) Risk of sediment delivery to streams

The risk of sediment delivery to streams indicates the likelihood that sediment derived from erosion sources in a specific terrain polygon will be transported or delivered to a stream. This interpretation is made for polygons that have a high or very high surface erosion potential. An example of a criteria used to assess this risk is shown in Table 22.

[2]*This section is based on the British Columbia Ministry of Forests' "Mapping and Assessing Terrain Stability Guidebook" Second Edition, August 1999, which is available online at http://www.for.gov.bc.ca/TASB/LEGSREGS/FPC/FPCGUIDE/terrain/index.htm*

Table 19. *Example terrain stability assessment criteria.*

(from British Columbia Ministry of Forests, 1999)

Terrain stability class	**Sample Criteria**	**Interpretation**
I	floodplains and level to undulating coastal plain areas most terrain with slopes <20%. Exceptions are noted in higher classes	No significant stability problems exist.
II	most gently sloping (20-40%), poorly to well drained lower slope landforms. Exceptions are noted in higher classes. moderately sloping (40-60%), well-to rapidly drained surficial deposits	There is a very low likelihood of landslides following timber harvesting or road construction. Minor slumping is expected along road cuts, especially for 1 or 2 years following construction.
III	moderately sloping (40-60%), imperfectly to poorly drained surficial deposits that are not glaciomarine or glaciolacustrine level to gently sloping (0-40%), imperfectly to poorly drained deep glaciomarine clays and glaciolacustrine deposits moderately sloping, deeply gullied surficial deposits that are not glaciomarine or glaciolacustrine	Minor stability problems can develop. Timber harvesting should not significantly reduce terrain stability. There is a low likelihood of landslide initiation following timber harvesting. Minor slumping is expected along road cuts, especially for 1 or 2 years following construction. There is a low likelihood of landslide initiation following road construction.
IV	steeply sloping (>60%), well drained, deeply gullied surficial deposits steeply sloping, poorly drained surficial deposits moderately sloping, deeply gullied or imperfectly to poorly drained glaciolacustrine or glaciomarine deposits	Expected to contain areas with a moderate likelihood of landslide initiation following timber harvesting or road construction.
V	any areas where natural landslide scars are visible on air-photographs or in the field very steeply sloping (>70%), imperfectly to poorly drained, deeply gullied surficial deposits	Expected to contain areas with a high likelihood of landslide initiation following timber harvesting or road construction.

***Table 20**. Example criteria for assessing potential for landslide debris to enter streams.*

(from British Columbia Ministry of Forests, 1999)

Class	Interpretation	Example criteria
1	Low likelihood that a landslide originating in the polygon will enter a stream.	The hillslope below the polygon is uniform and the toe of the slope is >100 m from the stream edge. Gully channels within and below the polygon terminate on fans that do not impinge on the stream channel. There is no air-photo or field evidence of landslides entering the stream.
2	Moderate likelihood that a landslide originating in the polygon will enter a stream.	The hillslope below the polygon is uniform and the toe of the slope is 50-100 m from the stream edge. Gully channels within and below the polygon terminate on fans that impinge on, or are partially truncated by, the stream channel. There is air-photo or field evidence of limited landslide debris entering the stream.
3	High likelihood that a landslide originating in the polygon will enter a stream.	The hillslope below the polygon is uniform and the toe of the slope is <50 m from the stream edge. Gully channels within and below the polygon terminate at the stream channel (there is no fan present). There is clear air-photo or field evidence of landslides entering the stream.

Table 21. *Example criteria for assessing soil erosion potential.*
(from British Columbia Ministry of Forests, 1999)

Class	Rating	Example criteria	Management implications
VL	Very low	Blocky colluvial deposits Terrain dominated by competent bedrock	No, or only very minor, surface erosion.
L	Low	Morainal veneers; most rubbly colluvial deposits with high coarse fragment content	Expect minor erosion of fines in ditch lines and disturbed soils.
M	Moderate	Morainal blankets (depends on texture and coarse fragment content) Glaciofluvial gravels Soft, friable bedrock	Expect moderate erosion when water is channeled down road surfaces or ditches.
H	High	Some morainal blankets steeper than 60%, or steeper than 30% if gullied or poorly drained (depends on texture and coarse fragment content) Fine-textured lacustrine silts & clays, glaciolacustrine, glaciomarine, glaciofluvial or eolian silts, slopes less than 15% Glaciofluvial or fluvial sands with low bulk density, slopes less than 30% Colluvial deposits derived from the above materials with the same slope or moisture criteria Colluvium derived from soft, friable rock (e.g., soft phyllite, some pyroclastic rocks), steeper than 60% or steeper than 30% if gullied	Significant erosion problems can be created when water is channeled onto or over exposed soil on these sites.
VH	Very high	Fine textured lacustrine (silts & clays), glaciolacustrine, glaciomarine, glaciofluvial or aeolian silts, slopes steeper than 15%, or gullied or poorly drained. Glaciofluvial or fluvial sands with low bulk density, steeper than 30% or gullied or poorly drained Peat, organic soils or tufa on sloping ground Colluvial deposits derived from the above materials with the same slope or moisture criteria	Severe surface and gully erosion problems can be created when water is channeled onto or over these sites.

__Table 22__. Example criteria for assessing risk of sediment delivery to streams.

(from British Columbia Ministry of Forests, 1999[2])

Risk of sediment delivery to streams	**Proximity of stream channel to polygon delivery to streams**		
	No stream channel in or adjacent to polygon	*Minor stream channel in or adjacent to polygon*	*Major stream channel in or adjacent to polygon*
Very Low	Gentle to Steep slope		
Low		Gentle slope	
Moderate		Moderate slope	Gentle slope
High		Steep slope	Moderate slope
Very High			Steep slope
	- Slope steepness downslope from polygon to stream channel -		

6.5) Mineral exploration

Terrain maps are useful in the field of mineral exploration, particularly where bedrock exposure is minimal due to extensive overburden coverage, such as in the Watson Lake area. To assist in the discovery of mineral deposits, soil geochemistry is employed as a tracking method for blind deposits. The genesis of the surficial material from which the soil was derived becomes an important aspect in the interpretation of results. Generally it is preferable to sample sediment that is more closely linked to its bedrock source. This means till and colluviated till or colluviated bedrock would be better sample material because they are first order derivatives of bedrock. Fluvial or lacustrine sediment is commonly further removed from its bedrock origin. A terrain map which shows the location of till and the direction of its transport can therefore become an extremely valuable tool in the mineral exploration process.

7.0 APPLICATIONS OF THE BIOPHYSICAL MAP

7.1) Land use planning

This biophysical map will be extremely useful for supporting all sustainable land-use planning near the community of Watson Lake. It can be used for coordinated planning of infrastructure and municipal development, forest management, wildlife habitat suitability and ecosystem conservation. As an example, Williston et al. (2004) recently related the occurrence of glaciofluvial landforms (specifically eskers and pitted outwash plains) to biodiversity, wildlife use, and the presence of rare and uncommon species. The map can also assist planning for rural or recreational subdivisions by evaluating the distribution of suitable terrain and vegetation communities, and can be used for land use permitting and spot land applications.

7.2) Forestry

The biophysical map can support forest-management planning at the landscape, operational and site planning levels by describing both terrain and ecological characteristics. Specifically, the biophysical map will greatly assist with further defining the forest land base beyond the level of forest cover maps, evaluating timber resources, planning seral targets, cutblock layouts, road access, operational logging methods, silvicultural prescriptions, wildlife corridors and wetland buffers and assessing potential forest regeneration based on nutrient availability and soil moisture regimes.

For example, the distribution of till on slopes could be queried from the biophysical map to identify areas susceptible to gully erosion when cleared, and areas where fish-bearing creeks might be subject to increasing sediment loads. The map is also useful for assisting interim wood supply planning in the Watson Lake area, and for evaluating existing and potential clear-cutting impacts on marten habitat (the most economically important species to trappers in the area) (Kiemele et al., unpublished report, 2003)[1].

7.3) Wildlife management

In combination with wildlife habitat models developed for individual species, the biophysical map enables wildlife managers to produce wildlife suitability or capability maps. The habitat models might incorporate the forage, denning and travel requirements of a species during different seasons, or for different sexes. As an example, reconnaissance-level rating criteria and standards for developing habitat models for British Columbia wildlife species are available in British Columbia Wildlife Habitat Ratings Standards (Ministry of Environment, Lands and Parks Resources Inventory Branch, 1999). Extensive field work may be required to develop detailed habitat models for a particular study area.

Some examples of specific applications of a biophysical map to wildlife management include:

- The distribution of minimum-sized areas with significant lichen in the understory vegetation could be mapped as potential caribou winter range.

- Ecosystem units could be correlated with species and numbers of migrating birds captured in nets at the Albert Creek Banding station. The results could be extrapolated to estimate migratory bird use of the surrounding wetlands along the Liard River (J. Meikle, pers. comm., 2005).

- The distribution of ecosystem units associated with sandy surficial materials suitable for denning could be analysed.

- Based on the population of wildlife (marten, voles, etc.) in one location, expected populations could be estimated for other occurrences of the same ecosystem unit.

[1] Kiemele, K., Adamczewski, J. and Gill, M., 2003. Interim Wood Supply for Southeast Yukon, Proposed amendments and additions, Draft November 30. Interim Wood Supply Committee reporting to Kaska Forest Resources, whitehorse, Yukon.

- In conjunction with species location data or tracking information, seasonal and diurnal habitat use patterns could be correlated with specific vegetation or terrain types.

- Habitat suitability models could be produced for various wildlife species (bear, moose, caribou, marten) based on ecosystem units. Wildlife sightings and telemetry data could then be overlain to test the models and confirm their validity. Yukon Fish and Wildlife Branch in Watson Lake is currently undertaking this type of exercise to model marten habitat using this data set.

- Yukon Fish and Wildlife Branch in Watson Lake has also used the biophysical data to select ecological monitoring grid locations based on forest type.

- In southeast Alaska and coastal British Columbia, biophysical GIS maps have been used to create habitat models for wide-ranging species such as grizzly bears to assist with ecoregional planning and designing conservation strategies (http://www.grizzlybear.org/Coastal_Forests).

8.0) SUMMARY

Plant communities reflect the underlying surficial materials they are growing on due to the effect of terrain characteristics and surficial geology on ecological nutrient and moisture regimes. Terrain mapping therefore provides an effective basis for accurately delineating ecosystem units to produce a detailed biophysical map.

This project has been instrumental in the establishment of the latest terrain mapping and local-scale ecological mapping standards for the Yukon, and these should be used to guide similar projects in the future. It is not cost-effective to carry out at a regional scale for broad areas because biophysical mapping is a labour intensive process. Instead, it should be performed on a project by project basis by proponents following the standards and procedures described in this report. In particular, the well established and well defined standards already developed in British Columbia should be used for detailed guidance for all terrain mapping and terrain stability mapping in the territory.

It is not as appropriate to adopt a set of fixed guidelines for biophysical mapping and ecosystem land classification for the Yukon from another jurisdiction with different ecological landscapes and classification goals. The biophysical mapping methods utilized in this project have built on an ecological mapping knowledge base that has accumulated over the last 30 years throughout the Yukon, British Columbia, Alberta and Ontario. It is hoped that this project has at least advanced the Territory closer toward achieving the ultimate goal of establishing its own biophysical mapping system.

Terrain and biophysical maps are invaluable for sustainable land use planning and integrated resource management, particularly for planning linear developments, forest harvesting, watershed management, wildlife management and habitat suitability modelling. In addition, by analysing the textural and structural properties of surficial materials using a GIS, preliminary assessments can be easily made to evaluate granular resources, potential for terrain hazards, terrain stability, soil erosion potential, and risk of landslide debris and sediment entering streams.

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APPENDIX 1: ECOSYSTEM TYPE DESCRIPTIONS

Note: Vegetation species are listed in order of mean percent cover, by strata.

COLLUVIAL TYPES

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
C2C-AuFb	Colluvium: Arctostaphylos - Forb	9.1	
Site	This ecosystem represents steep south facing slopes. Parent materials and textures are variable.		
Vegetation	Rose, buffalo berry, juniper; kinnickinick, forbs, sage, grass. *Rosa acicularis, Shepherdia canadensis, Juniperus communis, Arctostaphylos uva-ursi, Artemisia frigidus, Calamagrostis purpurescens, Poa sp.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
C3B-P	Colluvium: Pine	437.3	
Site	Early to mid seral stands found on various slopes and aspects. Similar species and description to M3C-P.		
Vegetation	Dense lodgepole pine; sparse ground cover: lowbush cranberry, kinnickinnick, twinflower, freckled lichen, Cladonia lichen. Dense *P. contorta*; sparse ground cover: *V. vitis idaea, A. uva-ursi, L. borealis, Peltigera apthosa, Cladonia sp.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
C3C-BA	Colluvium: Balsam Poplar - Aspen	402	092
Site	Sparsely vegetated unstable colluvial slopes as found along the Liard River.		
Vegetation	Trembling aspen, balsam poplar; forbs form a very sparse ground cover. *P. tremuloides, P balsamifera*, forbs.		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
C3C-SwSb	Colluvium: White Spruce-Black Spruce	422.1	160
Site	This ecosystem is found on moderate west slopes. Soils are sandy and range from well drained to imperfectly drained. They are likely Regosols or Brunisols.		
Vegetation	White spruce, black spruce; sparse rose; northern comandra, one sided wintergreen, lowbush cranberry, twinflower; stepmoss, redstemmed moss, knight's plume. *P. glauca, P. mariana; sparse R. acicularis, G. lividum, O. secunda, V. vitis idaea, L. borealis; H. splendens, P. schreberei, P. crista castrensis.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
C4B-SbP	Colluvium: Black Spruce - Pine	438.5	130
Site	This ecosystem is similar to the much more widely sampled M4C-SbP. It occurs on moderately to rapidly drained slopes of various orientations. Soils are likely Eutric and Dystric Brunisols, or Regosols.		
Vegetation	Black spruce, lodgepole pine; alder, labrador tea, willow; bunchberry, northern comandra, grass; red bearberry, kinnickinnick, lowbush cranberry, crowberry; feathermoss. *P. mariana, P. contorta; A. crispa, L. groenlandicum, Salix scouleriana; C. canadensis, G. lividum, L. innovatus; A. rubra, A. uva ursi, V. vitis idaea, E. nigrum, P. schreberei, H. splendens.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
C4C-FSw	Colluvium: Fir - White Spruce	425.3	
Site	These mixed coniferous ecosystems are found on mid slopes over 800 metres in elevation. Site and soils are similar to M4C-FSw.		
Vegetation	Subalpine fir, lodgepole pine, white spruce, Alaska birch; shrubs may include alder, labrador tea, willow; bunchberry, one sided wintergreen; step moss, knight's plume, red stemmed moss. *A. lasiocarpa, P. contorta, P. glauca, B. neoalaskana*; shrubs may include *A. crispa, L. groenlandicum, S. scouleriana; C. canadensis, O. secunda; H. spendens, P. crista-castrensis, P. schreberei, P. apthosa*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
C4C-Sh-L	Colluvium: Shrub Regen	36.4	
Site	These sites have been clearcut.		
Vegetation	Regeneration may be variable and patchy: Aspen, balsam poplar, Alaska birch, white spruce; mixed shrubs, forbs, lichen, mosses. *P. tremuloides, P. balsamifera, Betula neoalaskana, P. glauca.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
C4C-WSw	Colluvium: Alaska Birch - White Spruce	1.2	111, 139
Site	This ecosystem is commonly found in mid to lower slope positions. Soils are usually well drained Orthic Eutric and Dystric Brunisols.		
Vegetation	Alaska birch, white spruce, lodgepole pine, black spruce, aspen; willow, alder, labrador tea, rose, arctic raspberry, highbush cranberry; bunchberry, stoloniferous mitrewort, tall bluebell; lowbush cranberry, twinflower. *B. neoalaskana, P. glauca, P. contorta, P. mariana, P. tremuloides; Salix scouleriana, S. sp., A. crispa, L. groenlandicum, R. acicularis, Rubus idaeus, V. edule; C. canadensis, Lycopodium annotinum, Mitella nuda, Mertensia paniculata; Vaccinium vitis idaea, Linea borealis; H. splendens, P. schreberei, P. apthosa.*		

EOLIAN TYPES

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
E3B-PSbLi	Eolian: Pine - Black Spruce - Lichen	436.1	179
Site	This ecosystem is associated with rapid to well drained, sandy eolian soils, likely Brunisols.		
Vegetation	Black spruce, lodgepole pine; Labrador tea, rose, northern comandra, grass; kinnickinnick, lowbush cranberry; stepmoss, usually >20% lichen. *P. mariana, P. contorta; L. groenlandicum; R. acicularis; G. lividum, L. innovatus; A. uva ursi, V. vitis idaea; H. splendens, C. mitis, P. apthosa, C. uncialis, C. stellaris.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
E4B-SbP	Eolian: Black Spruce - Pine	438.4	
Site	This ecosystem is associated with well to poorly drained, sandy eolian soils. Soils are likely Brunisols or Gleysols.		
Vegetation	Black spruce, lodgepole pine; Labrador tea, alder, willow; northern comandra, horsetail; lowbush cranberry; stepmoss, freckled lichen. *P. mariana, P. contorta; L. groenlandicum, A. crispa, S. scouleriana; G. lividum, Equisetum scirpoides; V. vitis idaea; H. splendens, C. mitis, P. apthosa.*		

FLUVIAL TYPES

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F5D-A	Fluvial: Aspen	415	015, 083
Site	These moderately well to imperfectly drained sites are found on floodplains. Soils are likely Brunisols or Regosols.		
Vegetation	Aspen, white spruce, willow, buffalo berry, rose, high bush cranberry, horsetail, twinflower, lowbush cranberry, moss *P. trembuloides, P. glauca; Salix scouleriana, Shepherdia canadensis, S. myrtillifolia, R. acicularis, V. edule; Equisetum arvense, E. scirpoides; L. borealis, V. vitis idaea;* mosses may include *H. splendens, Ceratodon purpurea.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F5D-Al	Fluvial: Alder	21	088
Site	This is a swamp ecosystem occuring on the banks of larger rivers subject to periodic flooding.		
Vegetation	Mountain alder, willow, red osier dogwood, rose; bunchberry, horsetail. *Alnus incana, Salix arbuscoloides, S. alaskensis, Salix sp., C. stolonifera, R. acicularis; C. canadensis, Equisetum arvense.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F5D-B	Fluvial: Balsam Poplar	401.1	052, 188
Site	This ecosystem occurs on level to gently sloping plains and terraces. Soils are variable in texture and generally classified as Orthic or Gleyed Regosols.		
Vegetation	Sparse to dense cover of balsam poplar commonly with some white spruce; rose, red osier dogwood, highbush cranberry; sparse groundcover including horsetail, pussytoes, strawberry, northern bedstraw, black-tipped groundsel; kinnickinnick, twinflower. Sparse to dense cover of *P. balsamifera*, commonly with some *P. glauca; R. acicularis, C. stolonifera, V. edule*; sparse groundcover including *Equisetum sp., Antenaria pulcherrima, Fragaria virginiana, Galium boreale, Senecio lugens; A. uva ursi, L. borealis.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F5D-FSw	Fluvial: Fir - White Spruce	425.1	027, 028, 135
Site	These are rich ecosystems often located along small drainages where the channel has frequently shifted across the slope or valley. Soils are variable in texture and range from Humic Regosols to Gleyed Melanic Brunisols to Terric Mesic Organic Cryosols.		
Vegetation	Subalpine fir, lodgepole pine, white spruce, black spruce; alder, highbush cranberry, rose, wild red currant, horsetail, lycopodium, bunchberry, arctic sweet coltsfoot, stoloniferous mitrewort, tall bluebell, one sided wintergreen, twinflower. *Abies lasiocarpa, P. glauca, P. mariana; Alnus crispa,Viburnum edule, R. acicularis, A. incana, Ribes trieste; Equisetum sp. Lycopodiella sp., Cornus canadensis, Mitella nuda, Mertensia paniculata, Petasites frigidus, Orthilia secunda, Linnea borealis; Hylocomnium splendens, Pleurozium schreberei, P. crista-castrensis.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F5D-Gr-C	Fluvial: Cultivated	37.1	
Site	Cultivated fluvial soils.		
Vegetation	Planted graminoid vegetation.		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F5D-NV	Fluvial: Non-vegetated	40	
Site	Mainly non-vegetated gravel/sand bars.		
Vegetation	Non-vegetated.		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F5D-NV-D	Fluvial: Non-vegetated	38.1	
Site	Anthropogenic. These areas have been stripped of vegetation for borrow pits, parking, staging areas, future development, etc.		
Vegetation	Non-vegetated.		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F5D-SbSw	Fluvial: Black Spruce - White Spruce	429.1	
Site	This ecosystem typically occurs on a valley floor or toe slope position. Soil texture varies from sand to loam. Soils are likely well to poorly drained Regosols or Gleysols.		
Vegetation	Black spruce, white spruce, larch; Labrador tea, rose, alder, willow, highbush cranberry; horsetail, bunchberry, grass, northern comandra; feathermosses. *P. mariana, P. glauca, L. laricina; L. groenlandicum, Rosa acicularis, Alnus crispa, Salix bebbiana, S. glauca, S. arbusculoides, Salix sp., V. edule; Equisetum arvense, Cornus canadensis, Leymus innovatus, Geocaulon lividum; Hylocomnium splendens, Pleurozium schreberei, P. crista-castrensis.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F5D-Sh-L	Fluvial: Shrub regen	36.1	
Site	These sites have been clearcut. Skid roads, log piles and wood chip piles are common.		
Vegetation	Shrub strata regeneration may be variable and patchy. Aspen, balsam poplar, Alaska birch, numerous shrubs, forbs, lichens and mosses. *P. tremuloides, P. balsamifera, Betula neoalaskana.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F5D-SwB	Fluvial: White Spruce - Balsam Poplar	403	094, 189
Site	This early to late seral ecosystem is found along creeks and major rivers and is subject to periodic flooding. The clay loam to sandy soils are generally well to imperfectly drained Cumulic Regosols, other Regosols or Brunisols.		
Vegetation	White spruce, balsam poplar, highbush cranberry, rose, alder, willow, Buffalo berry, raspberry; horsetail, grass; bunchberry, northern comantra, stoloniferous mitrewort, tall bluebell, twinflower, lowbush cranberry; feathermosses. *P. glauca, P. balsamifera; V. edule, Rosa acicularis, Cornus stolonifera, Alder sp., Salix sp., Shepherdia canadensis, Rubus pubescens; E. arvense, Leymus innovatus; C. canadensis, G. lividum, Mitella nuda, Mertensia paniculata ; L. borealis, V. vitis idaea; (cont.) Hylocomnium splendens, P. crista-castrensis, Pleurozium schreberei, P. crista-castrensis.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F5D-SwFm	Fluvial: White Spruce - Feathermoss	418	049
Site	This is a classic white spruce-feathermoss ecosystem generally found on level fluvial sites. Silt loam to sandy soils are typically well to imperfectly drained Orthic or Gleyed Regosols or Brunisols.		
Vegetation	White spruce, balsam poplar; rose, highbush cranberry, alder, willow, raspberry; horsetail, grass; bunchberry, wild sarsparilla, arnica, northern comandra; twinflower, lowbush cranberry; feathermosses. *P. glauca, P. balsamifera; Rosa acicularis, V. edule, A. incana, Salix sp., Shepherdia canadensis, Rubus pubescens; E. arvense, Leymus innovatus; C. canadensis, Aralia nudicaulis, Arnica latifolia, G. lividum; L. borealis, V. vitis idaea; Hylocomnium splendens, P. crista-castrensis, Pleurozium schreberei, P. crista-castrensis.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F6C-Wi:Ws	Fluvial: Ws willow	22.1	018
Site	This willow shrub dominated swamp ecosystem is typically found along creeks. Soils are sandy and loamy, likely imperfect to very poorly drained Regosols and Gleysols.		
Vegetation	Willow, shrub birch , sweet gale; horsetail; sedge, grass, mosses. *Salix planifolia, S. sp, S. alaskensis, Betula glandulosa, Myrica gale; E. fluviatile, E. arvense; C. aquatilis, C. canadensis, C. lapponica, Hierochloe hirte, Potentilla sp.;* mosses may include *Sphagnum sp., Pleurozium schreberei, Tomenhypnum nitens.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F6D-SwL	Fluvial: White Spruce - Larch	434.2	
Site	This ecosystem is found on level or gently sloping areas along creeks. Soils are poor to very poorly drained, and high in nutrients. Shallow organic layers accumulate on the surface. Soils are likely Gleysols.		
Vegetation	Larch, white spruce, black spruce, Labrador tea, willow, lowbush cranberry, twinflower, red bearberry, horsetail, step moss, red stemmed moss, knight's plume. *Larix laricina, P. glauca, P. mariana, Ledum groenlandicum, Salix sp., V. vitis idaea, L. borealis, A. rubra, Equisetum sp., H. splendens, Pleurozium shreberei, Ptillium crista-castrensis.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F6E-Cc	Fluvial: Bluejoint Grass	24.1	087
Site	This is a graminoid ecosystem occuring in the floodplain zone, usually in abandoned or inactive channels.		
Vegetation	Bluejoint grass; other species may or may not be present. Willow, currant, raspberry, highbush cranberry; water sedge, beaked sedge, sedge, spike rush manna grass, horsetail, moss. *Calamagrostis canadensis*; other species may or may not be present. Shrubs: *Salix sp., Ribes sp., Rubus idaeus, V. edule; graminoids: C. utriculata, C. aquatilis, C. saskatilis, Eleocharis palustris, Glyceria sp., Hieraceum sp., Equisetum sp.,* mosses: *Drepanocladus aduncus.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F8D-CaCu:Wm	Fluvial: Water Sedge - Beaked Sedge - Marsh Wetland	25.1	051A
Site	Herb dominated marsh. This ecosystem may be a zone within a larger marsh adjacent to the wetter equisetum zone.		
Vegetation	Water sedge, beaked sedge, horsetail, cinquefoil, various mosses. *Carex aquatilis, C. utriculata,* sometimes *Equisetum fluviatile;* mosses may include *Aulacomnium sp., Sphagnum sp., Rhizomnium pseudopunctatum.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
F8D-Eq:Wm	Fluvial: Equisetum – Marsh Wetland	27	016, 051B, 086
Site	Equisetum dominated marsh subject to high water fluctuation in back channels or along banks of the Liard River.		
Vegetation	Horsetails, sedges, forbs *Equisetum palustre, E. fluviatile, E. scirpoides, C utriculata,* may also contain *Carex sp. and various forbs.*		

GLACIOFLUVIAL TYPES

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
G3B-ASw	Glaciofluvial: Aspen - White Spruce	416	084, 105, 106
Site	This ecosystem is typically found on southern or westerly gentle to moderate slopes. The well to rapidly drained soils are likely Dystric or Eutric Brunisols.		
Vegetation	Aspen, white spruce, alaska birch; alder, rose, highbush cranberry, buffalo berry, red osier dogwood, raspberry; bunchberry, fireweed, pyrola; stepmoss, twinflower, kinnickinnick, lowbush cranberry. *P. tremuloides, P.glauca, Betula neoalaskana, A. crispa, R. acicularis, V. edule, S. canadensis, S. scouleriana, C. stolonifera, Rubus pubescens; C. canadensis, Epilobium angustifolium, Pyrola asarifolia; L. borealis, A. uva ursi, V. vitis idaea; Hylocomn*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
G3B-NV-D	Glaciofluvial: Non-vegetated	38.3	
Site	Anthropogenic. These areas have been stripped of vegetation for borrow pits, parking, staging areas, and future development.		
Vegetation	Non-vegetated.		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
G3B-P	Glaciofluvial: Pine	437.1	136, 207
Site	This is a seral ecosystem commonly occuring after fire.		
Vegetation	Dense lodgepole pine, some black spruce; Labrador tea; sparse ground cover: crowberry, lowbush cranberry; moss, lichen. *Dense P. contorta* with some *P. mariana; L. groenlandicum;* sparse ground cover: *Empetrum nigrum, V. vitis idaea; Pleurozium schreberei, H. splendens: Cladina mitis, Cladonia sp.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
G3B-PASw	Glaciofluvial: Pine - Aspen - White Spruce	417	024, 038, 047, 054, 116
Site	This mid to late seral mixed forest ecosystem is found on level to moderately steep, commonly west or east facing slopes. The rapidly drained generally sandy soils are generally classified as Eutric Brunisols.		
Vegetation	Lodgepole pine, aspen, white spruce, black spruce; Labrador tea, alder; northern comandra, bunchberry, fireweed; lowbush cranberry, kinnickinnick, twinflower; feathermosses. *P. contorta, P. tremuloides, P. glauca, P. mariana; L. groenlandicum A. crispa; Geocaulon lividum, Cornus canadensis, Epilobium angustifolium; V. vitis idaea, Arctostaphylos uva ursi, L. borealis; H. splendens, P. crista-castrensis, P. schreberei.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
G3B-PSbLi	Glaciofluvial: Pine - Black Spruce - Lichen	436.2	001, 020, 022, 056, 069, 096, 098, 145, 147, 150, 206
Site	This ecosystem is found on generally level plains. The well to rapidly drained sandy soils are often classified as Orthic or Eluviated Eutric Brunisols.		
Vegetation	Lodgepole pine, black spruce, white spruce; Labrador tea; northern comandra, lodgepole pine; kinnickinnick, lowbush cranberry, twinflower; lichen cover usually > 25%; redstemmed moss, stepmoss. *P. contorta, P. mariana, P. glauca; L. groenlandicum; Geocaulon lividum, Lupinus arcticus; Artostaphylos uva ursi, V. vitis idaea, L. borealis;* lichen cover usually > 25% *C. mitis, C. stellata, C. rangiferina, Cladonia sp.; P. schreberei, H. splendens*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
G3B-SbFm	Glaciofluvial: Black Spruce - Feathermoss	429.2	
Site	This climax ecosystem is typical of moderate to steeper slopes. Soils are well drained Brunisols.		
Vegetation	Black spruce; alder, Labrador tea; bunchberry; lowbush cranberry, twinflower; stepmoss, redstemmed moss; lichen. *P. mariana; A. crispa, L. groenlandicum; Cornus canadensis; Vaccinium vitis idaea, L. borealis; Hylocomnium splendens; P. schreberei; Peltigera apthosa, N. arcticum, C. rangiferina, C. mitis, Cladonia sp.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
G3B-SbP	Glaciofluvial: Black Spruce - Pine	438.1	040, 080, 081, 128, 156, 193
Site	This widespread ecosystem occurs on level to gentle slopes of upland areas. The well drained sandy and loamy soils are generally classified as Eluviated or Orthic Eutric and Dystric Brunisols.		
Vegetation	Black spruce, lodgepole pine, (white spruce); alder, Labrador tea, rose; northern comandra; lowbush cranberry, twinflower, crowberry; feathermosses. *P. mariana, P. contorta, (P. glauca); A. crispa, L. groenlandicum, R. acicularis; Geocaulon lividum; V. vitis idaea, L. borealis, E. nigrum; P. schreberei, H. splendens, Ptillium crista-castrensis.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
G4C-Sh-L	Glaciofluvial: Shrub Regen	36.3	
Site	These sites have been clearcut		
Vegetation	Shrub strata regeneration may be variable and patchy. Aspen, balsam poplar, Alaska birch, numerous shrubs, forbs, lichens and mosses. *P. tremuloides, P. balsamifera, Betula neoalaskana.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
G4C-SwSb	Glaciofluvial: White Spruce - Black Spruce	422.2	093
Site	This ecosystem is commonly found on level sites to steep slopes, commonly facing south and west. Moderately well drained soils are generally classified as Dystric Brunisols or Humo Ferric Podzols.		
Vegetation	White spruce, black spruce, lodgepole pine; Labrador tea, alder, highbush cranberry; northern comandra; twinflower, lowbush cranberry; feathermosses, freckled lichen. *P. glauca, P. mariana, P. contorta; L. groenlandicum, A. crispa, V. edule; G. lividum; L. borealis, V. vitis idaea; Hylocomnium splendens, P. schreberei, P. crista-castrensis; Peltigera apthosa.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
G5B-SbFm	Glaciofluvial: Black Spruce - Feathermoss	429.3	123
Site	This ecosystem is found on level sites and on cool northerly slopes. Soils are usually moderately well to imperfectly drained and are likely classified as Gleyed or Orthic Brunisols.		
Vegetation	Black spruce; Labrador tea, shrub birch, alder; bunchberry, horsetail; lowbush cranberry; stepmoss, redstemmed moss, knight's plume; lichen. *P. mariana; L. groenlandicum, Betula glandulosa, A. crispa; Cornus canadensis, Equisetum scirpoides; Vaccinium vitis idaea; P. schreberei, Hylocomnium splendens, P. crista-castrensis; P. apthosa, Cladonia sp., C. uncialis, C. gracilis.*		

LACUSTRINE TYPES

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
L4C-NV-D	Lacustrine: Non-vegetated	38.5	
Site	Anthropogenic. These areas have been stripped of vegetation for borrow pits, parking, staging areas, and future development.		
Vegetation	Non-vegetated		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
L5D-Gr-C	Lacustrine: Cultivated	37.5	
Site	Cultivated lacustrine soils.		
Vegetation	Planted graminoid vegetation.		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
L5E-SwSb	Lacustrine: White Spruce - Black Spruce	422.7	202
Site	This ecosystem occurs locally on the Watson Lake map where former lakes have drained. Silty, calcareous soils may be frozen and subject to thermokarst. Soils may be classified as Turbic Cryosols.		
Vegetation	Black spruce, white spruce; low cover of shrubs: Salix sp. alder, shrub birch; lowbush cranberry; feathermosses, freckled lichen. *P. mariana, P. glauca, L. laricina;* low cover of shrubs: *Salix sp., Alnus crispa, B. glandulosa; V. vitis idaea; H. splendens, P. schreberei, P. crista-castrensis; Peltigera apthosa, Nephroma arctica.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
L6C-Sb	Lacustrine: Black Spruce	431	
Site	This ecosystem is found on level sites. Loam or silty fine sand soils are generally poor to very poorly drained and are likely classified as Gleysols, Gleyed Brunisols or Regosols.		
Vegetation	Black spruce, some white spruce, larch; Labrador tea, shrub birch, horsetail, bunchberry, sedge, mosses, frecked, lichen. *P. mariana, some P. glauca and Larix laricina; L. groenlandicum, B. glandulosa; Equisetum arvense, E. scirpoides; Cornus canadensis; Carex aquatilis; H. splendens, P. schreberei, Aulacomnium palustre, P. crista-castrensis; P. apthosa*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
L6C-Wi:Ws	Lacustrine: Willow – Swamp Wetland	22.2	122
Site	This shrub ecosystem is associated with drained basins. Fine textured soils are imperfect to poorly drained and are likely classified as Gleyed Regosols.		
Vegetation	Willow, shrub birch, Labrador tea, leatherleaf, red osier dogwood; sedge, grass, moss. *Salix sp., Betula glandulosa, Ledum groenlandicum, Chamaedaphne calyculata, Cornus stolonifera; Carex aquatilis, Calamagrostis canadensis; bryophytes.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
L6E-Cc	Lacustrine: Bluejoint Grass	24.2	121B
Site	This ecosystem is restricted to a former lake basins. Fine textured soils are imperfect to poorly drained and are typically Gleyed Regosols.		
Vegetation	bluejoint grass; other species may include willow, red osier digwood; other grasses, sedges, buckbean; mosses. *Calamagrostis canadensis;* other species may include: Shrubs: *Salix sp., C. stolonifera;* graminoids: *Calamagrostis stricta, Glyceria sp., C. utriculata, C. aquatilis; Menyanthes trifoliata;* mosses: *Aulacomnium palustre, Drepanocladus sp., Calliergon sp.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
L8D-CaCu:Wm	Lacustrine: Wm Water Sedge - Beaked Sedge	25.2	121
Site	This ecosystem may be found on the margins of lakes or ponds or in former lake basins. Poor to very poorly drained fine textured soils are likely Gleysols.		
Vegetation	Sedges, grasses, horsetail, aquatic plants, moss. *Carex utriculata, C. aquatilis, Glyceria sp.; Sparganium sp., Equisetum fluviatile, Potamogeton sp., Eleocharis sp., Ranunculus sp.; Calliergon sp.*		

MORAINAL TYPES

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
M2B-PASw	Morainal: Pine - Aspen - White Spruce	440	161, 170
Site	This is a mixed forest ecosystem which occurs on warmer aspects at low to high elevation. It commonly occurs on slopes where openings in the forest allow establishment of deciduous trees. It may be also be associated with some disturbance such as fire or logging. Soils are Orthic Dystric and Eutric Brunisols. Textures are sandy loam to silty clay.		
Vegetation	Lodgepole pine, aspen, spruce, labrador tea, alder, buffalo berry, rose, bunchberry, northern comandra, strawberry, kinnickinnick, twinflower, lowbush cranberry; moss, Cladonia sp. *P. contorta, P. tremuloides, P. glauca, L. groenlandicum, A. crispa, S. canadensis, R. acicularis; Cornus canadensis, G. lividum, Fragaria virginiana, Leymus innovatus; A. uva ursi, L. borealis, V. vitis idaea; H. splendens, P. schreberei, Polytrichum sp., Cladonia sp., Peltigera sp.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
M2B-PLi	Morainal: Pine - Lichen	436.3	104
Site	Found on rapid to moderately well drained plains and gentle slopes, lodgepole pine/lichen ecosystems are usually late seral to mature forests.		
Vegetation	Lodgepole pine, some shrubs: alder, buffalo berry, rose may be present; kinnickinnick, lowbush cranberry; redstemmed moss, stepmoss; lichens. *P. contorta,* some shrubs: *Alnus crispa, Shepherdia canadensis, R. acicularis; A. uva-ursi, V. vitis idaea; mosses: P. schreberei, H. splendens; Cladonia mitis, Peltigera apthosa, Cladonia sp. , C. gracilis.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
M3B-NV-D	Morainal: Non-vegetated	38.2	
Site	Anthropogenic. These areas have been stripped of vegetation for borrow pits, parking, staging areas, future development.		
Vegetation	Non-vegetated.		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
M3B-P	Morainal: Pine	437.2	
Site	This is a young seral stage of post fire dense lodgepole pine usually less than 90 years old. Well to rapidly drained soils may be Eutric or Dystric Brunisols.		
Vegetation	Lodgepole pine, some aspen; sparse ground cover: feather mosses, ground shrubs, Cladonia sp. and Peltigera apthosa. *P. contorta, P. tremuloides;* sparse ground cover: *H. splendens; L. borealis, V. vitis idaea, A. uvaursi, Cladonia sp., P. apthosa.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
M3B-PSbLi	Morainal: Pine-Black Spruce - Lichen	436.4	048, 175, 177, 198
Site	This ecosystem is found on well to rapidly drained level to moderate slopes. Soils are Brunisols and Luvisols; late seral to mature forests.		
Vegetation	Black spruce, lodgepole pine, labrador tea, shrub birch; lowbush cranberry, kinnickinnick, crowberry, bunchberry; feathermosses, groundcover is usually >30% lichen. *P. mariana, P. contorta, L. groenlandicum, B. nana; V. vitis idaea, A. uva-ursi, Empetrum nigrum, C. canadensis; P. schreberei, H. splendens; Cladina stellata, C. mitis, C. rangiferina, Cladonia sp., Peltigera apthosa, P. canina.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
M4B-PFm	Morainal: Pine - Feathermoss	438.3	103
Site	This ecosystem occupies moderate to rapidly drained level to moderate slopes with variable aspects; Orthic and Eluviated Eutric and Dystric Brunisol and Humo-Ferric Podzol soils.		
Vegetation	Lodgepole pine; alder, Labrador tea, shrub birch, tall blueberry; lowbush cranberry, bunchberry, northern comandra; step moss, red stemmed moss, knight's plume. *P. contorta; A. crispa, L. groenlandicum, B. glandulosa; V. membranaceum, V. vitis idaea, C. canadensis, G. lividum; H. splendens, P. schreberei, P. crista-castrensis.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
M4B-SbP	Morainal: Black Spruce - Pine	438.2	037, 072, 073, 082, 119, 124, 130, 141, 144, 149, 152, 154, 157, 169, 183
Site	This ecosystem is common and widely distributed, occupying moderate to rapidly drained level to moderate slopes with variable aspects. Orthic and Eluviated Eutric and Dystric Brunisol and Humo-Ferric Podzol soils.		
Vegetation	Black spruce, lodgepole pine, alder, Labrador tea, shrub birch, tall blueberry, lowbush cranberry, bunchberry, northern comandra; step moss, red stemmed moss, knight's plume. *P. mariana, P. contorta, A. crispa, L. groenlandicum, B. glandulosa; V. membranaceum, V. vitis idaea, C. canadensis, G. lividum, H. splendens, P. schreberei, P. crista-castrensis.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
M4C-ASw	Morainal: Aspen - White Spruce	410	007, 110
Site	This ecosystem is typical of level to moderate slopes with warmer aspects. There may be some history of disturbance such as selective logging. Most soils are Eutric or Melanic Brunisols.		
Vegetation	Mixed forest dominated by aspen, white spruce, some lodgepole pine; alder, willow, rose, highbush cranberry and groundshrubs – twinflower, kinnickinnick, lowbush cranberry and northern comandra. Mixed forest canopy dominated by *P. tremuloides, P. glauca, P. contorta; A. crispa, Salix sp., V. edule,* and groundshrubs: *L. borealis, Arctostaphyllos uva ursi, V. vitis-idaea.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
M4C-FSw	Morainal: Fir - White Spruce	425.2	025, 030, 178
Site	These mixed coniferous ecosystems are found on mid slopes over 800 metres in elevation.		
Vegetation	Subalpine fir, lodgepole pine, white spruce, Alaska birch; shrubs may include alder, labrador tea, willow; bunchberry, one sided wintergreen; step moss, knight's plume, red stemmed moss. *A. lasiocarpa, P. contorta, P. glauca, B. neoalaskana;* shrubs may include *A. crispa, L. groenlandicum, S. scouleriana; C. canadensis, O. secunda; H. spendens, P. crista-castrensis, P. schreberei, P. apthosa*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
M4C-Sh-L	Morainal: Shrub Regen	36.2	117
Site	These sites have been clearcut. Skid roads, log piles and wood chip piles are common.		
Vegetation	Regeneration may be variable and patchy; aspen, balsam poplar, birch, shrubs, forbs, lichens, mosses. *P. tremuloides, P balsamifera, Betula neoalaskana*, shrubs, forbs, lichens and mosses.		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
M4C-SwSb	Morainal: White Spruce - Black Spruce	422.4	
Site	Mesic sites on level to moderate slopes with various aspects characterise this ecosystem. Soil textures are mixed. Soils are classified as Brunisols.		
Vegetation	White spruce, with black spruce and or lodgepole pine; with shrub understory of alder, labrador tea, buffalo berry, rose; feather mosses, freckled lichen. *Picea glauca, P. mariana, Pinus contorta*, shrubs: *Ledum groenlandicum, Alnus crispa, Shepherdia canadensis, Rosa acicularis, Hylocomnium splendens, Pleurozium schreberei, Ptillium crista-castrensis, Peltigera apthosa.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
M4C-SwSbP	Morainal: White Spruce - Black Spruce - Pine	422.6	100, 101, 157, 212
Site	These moderate to well drained ecosystems are found on mid slopes. Soils may be Orthic or Eluviated Dystric or Eutric Brunisols and Grey Luvisols.		
Vegetation	White spruce, black spruce, lodgepole pine, alder, Labrador tea, lowbush cranberry, twinflower, bunchberry, one-sided wintergreen. *P. glauca, P. mariana, P. contorta, Alnus crispa, L. groenlandicum;* ground shrubs: *V. vitis-idaea, L. borealis, C. canadensis, Orthilia secunda; H. splendens, P. schreberei, P. crista-castrensis*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
M4C-SwSbPA	Morainal: White Spruce - Black Spruce - Pine - Aspen	422.5	109, 127
Site	These ecosystems are found on upper and mid slope to 30% slopes and level and crest positions. These are generally well drained sites with Eluviated Dystric or Eutric Brunisols.		
Vegetation	White spruce, back spruce, lodgepole pine, aspen; alder, Labrador tea, lowbush cranberry, bunchberry may be present; mosses. *P. glauca, P. mariana, P. contorta, P. tremuloides, A. crispa, L. groenlandicum, V. vitis-idaea, C.canadensis, H. splendens, P. schreberei, P. crista-castrensis.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
M4C-WSw	Morainal: Alaska Birch - White Spruce	1.1	012, 114, 134, 139, 214, (168)
Site	These mixed forest ecosystems are found in occasional patches on cool, east and west slopes, and on slope crests including eskers.		
Vegetation	Alaska birch, aspen, lodgepole pine, black spruce, white spruce; alder, highbush cranberry; northern comandra, twinflower, lowbush cranberry; red stemmed moss, stepmoss, knight's plume. *Betula neoalaskana, P. tremuloides, P. contorta, P. mariana, P. glauca, A. crispa, V. edule; G. lividum, L. borealis, V. vitis idaea; P. schreberei, H. splendens, P. crista-castrensis.*		

Type	Type Name	Type No.	Site No. (04WL XXX)
M5B-SbFm	Morainal: Black Spruce - Feathermoss	429.5	200, 213
Site	This type is common but does not cover extensive areas. Imperfect to poorly drained sites in lower or toe slope positions; may be associated with permafrost.		
Vegetation	Black spruce, labrador tea, willow, horsetail; lowbush cranberry; red stemmed moss, step moss, freckled lichen. *P. mariana; L. groenlandicum, Salix sp.; V. vitis idaea; Pleurozium schreberei, H. splendens; Peltigera apthosa.*		

Type	Type Name	Type No.	Site No. (04WL XXX)
M6D-SwL	Morainal: White Spruce - Larch	429.6	
Site	This ecosystem generally occupies gently sloping lower slope or toe slope positions. Imperfectly drained to poorly drained soils, influenced by subsurface seepage, are generally classified as Gleyed Regosols or Humic Gleysols.		
Vegetation	larch, white spruce, black spruce, Labrador tea, willow; lowbush cranberry, twinflower, red bearberry, horsetail; step moss, red stemmed moss, knight's plume. *Larix laricina, P. glauca, P. mariana, L. groenlandicum, Salix sp.; V. vitis idaea, L. borealis, A. rubra, Equisetum sp.; H. splendens, Pleurozium shreberei, Ptillium crista-castrensis.*		

ORGANIC TYPES

Type	Type Name	Type No.	Site No. (04WL XXX)
O6C-SbFm:Ws	Organic: Black Spruce - Feathermoss - Swamp Wetland	429.8	046, 064, 162, 164, 205
Site	This ecosystem occupies lower slope or toe slope positions. Imperfect to poorly drained soils, influenced by subsurface seepage, are generally Terric Mesisols, though some are Mesic Organic Cryosols with permafrost on cooler sites.		
Vegetation	Black spruce, Labrador tea, willow, lowbush cranberry, step moss, red stemmed moss, green reindeer lichen. Moderate to low cover of *P. mariana, L. groenlandicum, Salix sp., V. vitis idaea, H. splendens, P. shreberei, C. mitis.*		

Type	Type Name	Type No.	Site No. (04WL XXX)
O6D-Gr-C	Organic: Cultivated	37.6	
Site	Cultivated organic soils.		
Vegetation	Planted graminoid vegetation.		

Type	Type Name	Type No.	Site No. (04WL XXX)
O7B-BtCx:Wb	Organic: Shrub Birch - Sedge - Bog Wetland	31	167, 209
Site	Poor to very poorly drained bog ecosystem with shallow to moderately deep peat; generally non-frozen.		
Vegetation	Shrub birch, Labrador tea; water sedge or shore sedge, Sphagnum moss. *Betula glandulosa, L. groenlandicum; C. aquatilis, C. utriculata, Sphagnum angustifolium.*		

Type	Type Name	Type No.	Site No. (04WL XXX)
O7B-Cl:Wf	Organic: Shore Sedge - Fen Wetland	33	062
Site	This nutrient-poor fen ecosystem often occurs in a larger wetland complex associated with bogs.		
Vegetation	Willow, sedge, Scheuchzeria, buckbean, mosses. *Salix pedicellaris; Carex limosa; Scheuchzeria palustris; Menyanthes trifoliata;* bryophytes.		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
O7B-SbSp:Wb	Organic: Black Spruce - Sphagnum - Bog Wetland	430	045, 061, 108, 204
Site	This bog ecosystem occurs as islands in, or surrounding, larger wetland complexes. It is generally imperfect to very poorly drained. Soils are typically Fibric Organic Cryosol or Terric Mesic Organic Cryosols, commonly frozen close to the surface.		
Vegetation	Black spruce, labrador tea, shrub birch, horsetail, lowbush cranberry, cloudberry, Sphagnum, red stemmed moss, golden fuzzy fen moss, reindeer lichen. *P. mariana, L. groenlandicum, B. glandulosa, E. sylvaticum, V. vitis idaea, R. chamaemorus, Shagnum sp., Pleurozium shreberei, Tomenhypnum nitens, C. stellata, C. mitis, C. rangiferina.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
O7C-WiCx:Wf	Organic: Willow - Sedge - Fen Wetland	34	210
Site	This is a poorly drained fen wetland ecosystem. Soils are likely Typic Fibrisols or Mesisols.		
Vegetation	Willow, sedge, Scheuchzeria, Sphagnum, mosses. *Salix planifolia, Salix, sp., C. aquatilis, C. utriculata, Scheuchzeria palustris;* mosses may include: *Sphagnum sp., Drepanocladus sp., Aulacomnium palustre.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
O7D-LSb:Wf	Organic: Larch - Black Spruce - Fen Wetland	434.1	
Site	This ecosystem is found throughout the study area in drainage channels and in larger wetlands. It is associated with poor to very poorly drained soils and Terric or Typic Mesisols and Fibrisols.		
Vegetation	Sparse cover of Larch and black spruce; labrador tea, shrub birch, water sedge; mosses may include: golden fuzzy fen moss, glow moss, Sphagnum. *L. laricina, and P. mariana; L. groenlandicum, B. glandulosa, C. aquatilis, T. nitens, Aulacomnium palustre, Sphagnum sp.*		

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
O8D-CaCu:Wf	Organic: Water Sedge - Beaked Sedge - Fen Wetland	25.3	043, 151, 211
Site	Common fen wetland ecosystem which is usually subject to annual flooding.		
Vegetation	Usually low species diversity. Water sedge, beaked sedge, locally Equisetum fluviatile, aquatic emergents; mosses. *Carex aquatilis, C. utriculata, sometimes equisetum fluviatile;* mosses may include *Drepanocladus sp., Sphagnum sp., Scorpidium revolvens.*		

ROCK TYPES

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
Rb	Rock: Basalt	39	
Site	Basalt bedrock outcrops (commonly columnar), or talus blocks.		
Vegetation	Non-vegetated.		

WATER TYPES

Type	*Type Name*	*Type No.*	*Site No. (04WL XXX)*
W9-:Ww	Shallow Open Water	41	
Site	Lakes and ponds, such as beaver ponds, too small to be outlined on the 1:50 000-scale topographic base map.		
Vegetation	Non-vegetated.		

APPENDIX 2: LABORATORY ANALYSES

A) Particle Size Analyses

The following particle size analysis results were received from Pacific Soils Analysis, Richmond, BC, November 1, 2004.

Results are reported in % by weight. Particle size was determined by the pipette method. Sedimentation times were determined using the Tanner and Jackson Nomograph I (McKeague, 1978). Sand content was determined by wet sieving.

Overall percent sand, silt and clay, corresponding textures in Table 24 and the ternary texture diagram (Figure A1) were each calculated from the results in Table 23.

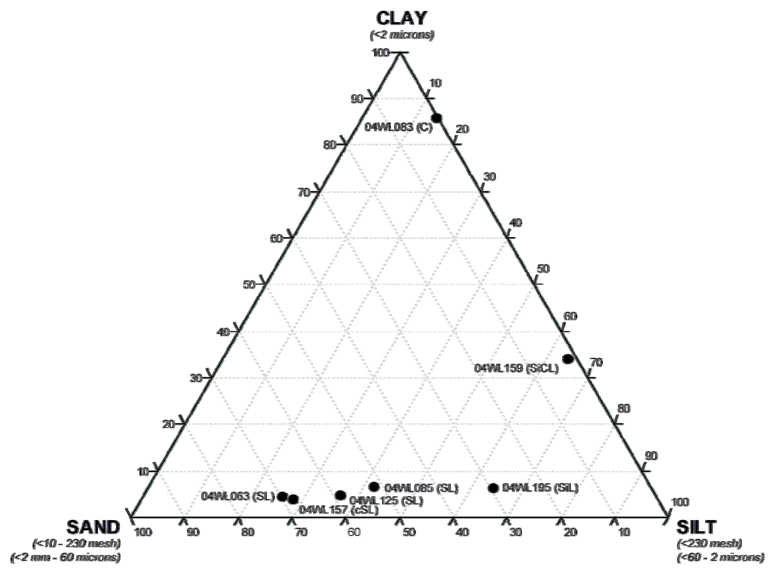


***Figure 28**. Ternary texture diagram of percent sand, silt and clay for analysed samples.*

***Table 23**. Bulk sample particle size analysis results.*

US Standard Sieve Mesh	% <3 inches	% <5	% <10	% <18	% <35	% <60	% <120	% <230	% <270	% <2 microns
Wentworth size	pebbles	granules	v. coarse sand	coarse sand	med. sand	fine sand	v. fine sand	coarse silt	med. – fine silt	clay
04WL063	14	9.1	3.1	8.5	16.7	16.2	9.1	3.8	16.6	2.9
04WL083	0	0	0.1	0.1	0.1	0.1	0.1	0.1	14.4	85
04WL085	46.8	11.7	3.7	5	6.1	3.8	2.9	1.6	15.9	2.5
04WL125	40.8	8.5	2.7	5.1	9.2	8.3	4.6	2	16.8	2
04WL157	35.5	12.3	6.5	9.2	9	6.5	4.4	1.6	13.3	1.7
04WL159	0	0	0	0	0.1	0.4	1.5	0.5	64.3	33.2
04WL195	1	7.3	1.9	4.7	6.1	7.2	7.5	4.8	54.5	5

***Table 24**. Sample materials, matrix texture and sample locations for particle size analysis samples.*

Site No.	Sample Material	Texture	% Sand	% Silt	% Clay	UTM Easting Zone 9-NAD 83	UTM Northing Zone 9-NAD 83
04WL063	till	sandy loam (SL)	69.7	26.5	3.8	503 982	6 671 132
04WL083	fluvial overbank clay	clay (C)	0.5	14.5	85.0	513 566	6 654 650
04WL085	till	sandy loam (SL)	51.8	42.2	6.0	513 013	6 654 979
04WL125	till	sandy loam (SL)	59.0	37.1	3.9	506 863	6 659 064
04WL157	till	sandy loam (SL)	68.2	28.5	3.3	501 616	6 652 151
04WL159	glaciolacustrine silt/clay	silty clay loam (SiCL)	2.0	64.8	33.2	503 833	6 665 446
04WL195	weathered basalt / red soil	silt loam (SiL)	29.9	64.7	5.5	509 503	6 653 348

B) Radiocarbon dates and buried wood identification

The following radiocarbon results were received from Beta Analytic, Inc., Florida, USA, November 22, 2004. Wood identification was performed by R.J. Mott, RJM Services, Ottawa, ON, November 24, 2004.

***Table 25**. Radiocarbon dates, sample context, wood identifications, and locations of buried wood samples.*

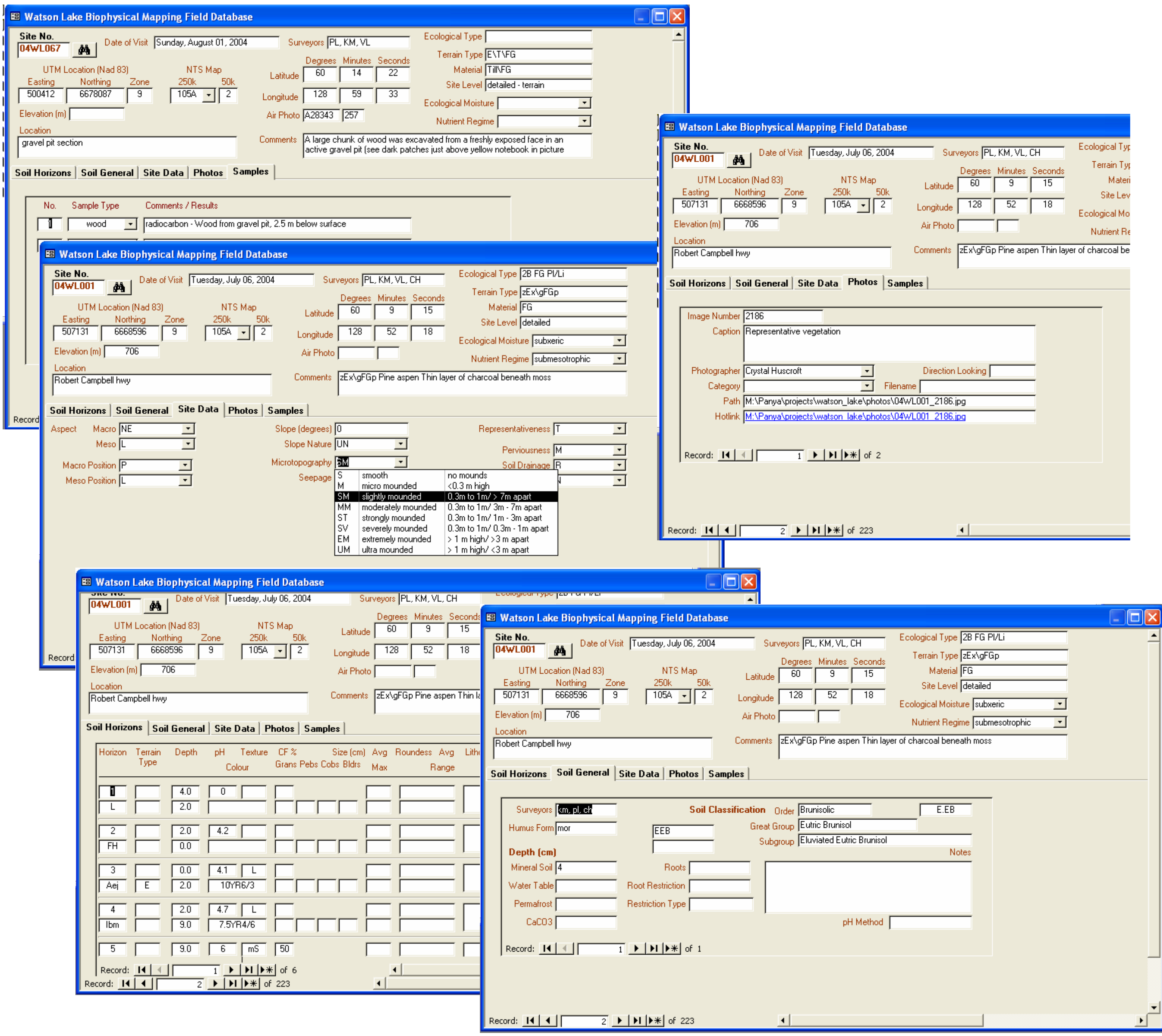
Site No.	Lab No.	Context	Measured Age	$^{13}C/^{12}C$ ratio	Conventional Age	Wood Identification	UTM Easting Zone 9-NAD 83	UTM Easting Zone 9-NAD 83
03AH090	197222	Wood buried in glaciofluvial sands 26 m above Liard River level; exposed by debris flow down bank.	> 46 750 BP	-24.7 o/oo	> 46 750 BP	Very poorly preserved wood. Identified as conifer. No precise identification possible.	518 865	6 654 550
04WL067	197223	Wood buried in gravely sand exposed in active gravel pit, 2.5 m below surface.	> 46 460 BP	-21.0 o/oo	> 46 530 BP	Highly lignified, compressed and distorted wood. No identification possible because of poor condition of wood.	500 412	6 678 087
04WL191	197224	Wood buried in glaciofluvial sands 9.4 m above river level in Liard River cutbank.	> 44 190 BP	-24.3 o/oo	> 44 200 BP	Not identified	507 570	6 656 882
04WL196		Wood buried in glaciofluvial sands 13 m above river level in 35 m Liard River cutbank.	Not radiocarbon dated			Very poorly preserved wood. Identified as probably Picea spp. (spruce).	509 811	6 653 298
04WL197	197225	Wood buried in glaciofluvial sands 20 m above river level in 41 m Liard River cutbank.	> 44 910 BP	-23.7 o/oo	> 44 930 BP	Poorly preserved wood. Friable, compressed and distorted. Coniferous wood, but no further identification can be made.	510 099	6 653 407

Conventional radiocarbon dating was used with wood acid/alkali/acid pre-treatment.
2-sigma calibration could not be performed because the result was outside the calibration range.

APPENDIX 3: FIELD DATABASE

Figure 29 depicts the Microsoft Access field database interface designed for this project. After location data is entered for a site, one toggles between five tabs (Soil Horizons, Soil General, Site Data, Photos and Samples) to enter the appropriate data. Much of the data was entered into handheld palms directly in the field, and then downloaded into this database.

Figure 29*. Interface of field database designed for this project.*



APPENDIX 4: SPECIES LIST

STRATUM	GENUS	SPECIES	COMMON NAME
TALL TREES (> 5 m)	*Abies*	*lasiocarpa*	Subalpine Fir
	Betula	*neoalaskana*	Alaska Birch
	Betula	*papyrifera*	Paper Birch
	Larix	*laricina*	Larch
	Picea	*glauca*	White Spruce
	Picea	*mariana*	Black Spruce
	Pinus	*contorta*	Lodgepole Pine
	Populus	*balsamifera*	Balsam Poplar
	Populus	*tremuloides*	Trembling Aspen
	Salix	*scouleriana*	Scouler's Willow
LOW TREES (< 5 m)	*Abies*	*lasiocarpa*	Subalpine Fir
	Betula	*neoalaskana*	Alaska Birch
	Betula	*papyrifera*	Paper Birch
	Larix	*laricina*	Larch
	Picea	*glauca*	White Spruce
	Picea	*mariana*	Black Spruce
	Pinus	*contorta*	Lodgepole Pine
	Populus	*balsamifera*	Balsam Poplar
	Populus	*tremuloides*	Trembling Aspen
SNAGS	*Betula*	*papyrifera*	Paper Birch
	Picea	*glauca*	White Spruce
	Pinus	*contorta*	Lodgepole Pine
	Populus	*tremuloides*	Trembling Aspen
TALL SHRUBS (> 2 m)	*Alnus*	*crispa*	Green Alder
	Alnus	*incana*	Grey Alder
	Betula	*glandulosa*	Shrub Birch
	Cornus	*stolonifera*	Red Osier Dogwood
	Salix	*alaxensis*	Willow
	Salix	*arbusculoides*	Willow
	Salix	*barclayi*	Willow
	Salix	*bebbiana*	Long Beaked Willow
	Salix	*glauca*	Blue-Green Willow
	Salix	*planifolia*	Willow
	Salix	*scouleriana*	Scouler's Willow
	Sorbus	*scopulina*	Mountain Ash
MEDIUM SHRUBS (0.5 - 2.0 m)	*Abies*	*lasiocarpa*	Subalpine Fir
	Alnus	*crispa*	Green Alder
	Alnus	*incana*	Grey Alder
	Amelanchier	*alnifolia*	Saskatoon/Serviceberry
	Betula	*glandulosa*	Shrub Birch
	Betula	*occidentalis*	Birch
	Cornus	*stolonifera*	Red Osier Dogwood
	Juniperus	*communis*	Ground Juniper

MEDIUM SHRUBS (0.5 - 2.0 m)	*Larix*	*laricina*	Larch
	Ledum	*groenlandicum*	Labrador Tea
	Picea	*glauca*	White Spruce
	Picea	*mariana*	Black Spruce
	Pinus	*contorta*	Lodgepole Pine
	Populus	*balsamifera*	Balsam Poplar
	Populus	*tremuloides*	Trembling Aspen
	Potentilla	*fruticosa*	Shrubby Cinquefoil
	Ribes	*hudsonianum*	Black Currant
	Ribes	*lacustre*	Bristly Black Currant
	Ribes	*triste*	Wild Red Currant
	Rosa	*acicularis*	Prickly Rose
	Salix	*alaxensis*	Willow
	Salix	*arbusculoides*	Willow
	Salix	*barclayi*	Willow
	Salix	*bebbiana*	Long Beaked Willow
	Salix	*exigua*	Sandbar Willow
	Salix	*glauca*	Blue-Green Willow
	Salix	*pedicellaris*	
	Salix	*planifolia*	Willow
	Salix	*scouleriana*	Scouler's Willow
	Shepherdia	*canadensis*	Soapberry/Buffalo Berry
	Sorbus	*scopulina*	Mountain Ash
	Spiraea	*beauverdiana*	Beauverd's Spiraea
	Viburnum	*edule*	Highbush Cranberry
LOW SHRUBS (0.1 - 0.5 m)	*Abies*	*lasiocarpa*	Subalpine Fir
	Alnus	*crispa*	Green Alder
	Andromeda	*polifolia*	Bog Rosemary
	Betula	*glandulosa*	Shrub Birch
	Betula	*neoalaskana*	Alaska Birch
	Chamaedaphne	*calyculata*	Leatherleaf/Cassandra
	Cornus	*stolonifera*	Red Osier Dogwood
	Juniperus	*communis*	Ground Juniper
	Larix	*laricina*	Larch
	Ledum	*groenlandicum*	Labrador Tea
	Picea	*glauca*	White Spruce
	Picea	*mariana*	Black Spruce
	Pinus	*contorta*	Lodgepole Pine
	Populus	*balsamifera*	Balsam Poplar
	Populus	*tremuloides*	Trembling Aspen
	Potentilla	*fruticosa*	Shrubby Cinquefoil
	Ribes	*hudsonianum*	Black Currant
	Ribes	*lacustre*	Bristly Black Currant
	Ribes	*triste*	Wild Red Currant
	Rosa	*acicularis*	Prickly Rose
	Rubus	*pubescens*	Raspberry
	Salix	*athabascensis*	Willow
	Salix	*exigua*	Sandbar Willow
	Salix	*myrtillifolia*	Willow

LOW SHRUBS (0.1 - 0.5 m) cont'd…	*Salix*	*scouleriana*	Scouler's Willow
	Shepherdia	*canadensis*	Soapberry/Buffalo Berry
	Vaccinium	*caespitosum*	Dwarf Blueberry
	Vaccinium	*membranaceum*	Tall Blueberry
	Vaccinium	*uliginosum*	Alpine Blueberry
	Viburnum	*edule*	Highbush Cranberry
GROUND SHRUBS (<0.1 m)	*Andromeda*	*polifolia*	Bog Rosemary
	Arctostaphylos	*rubra*	Red Bearberry
	Arctostaphylos	*uva-ursi*	Bearberry
	Empetrum	*nigrum*	Crowberry
	Linnaea	*borealis*	Twin Flower
	Oxycoccus	*microcarpus*	Bog Cranberry
	Rubus	*pubescens*	Raspberry
	Salix	*myrtillifolia*	Willow
	Vaccinium	*caespitosum*	Dwarf Blueberry
	Vaccinium	*vitis-idaea*	Lowbush Cranberry
FORBS	*Achillea*	*millefolium*	Common Yarrow
	Aconitum	*delphinifolium*	Northern Monkshood
	Actaea	*rubra*	Red Baneberry
	Agoseris	*glauca*	Mountain dandelion
	Anemone	*multifida*	Cut Leaf Anemone
	Anemone	*parviflora*	Northern Anemone
	Anemone	*richardsonii*	Yellow Anemone
	Arnica	*latifolia*	
	Aster	*sibiricus*	Siberian Aster
	Botrychium	*lunaria*	Moonwort
	Cardamine	*pensylvanica*	Bitter Cress
	Chrysosplenium	*tetrandrum*	Golden Saxifrage
	Cicuta	*virosa*	Water Hemlock
	Corallorrhiza	*trifida*	Northern Coral Root
	Cornus	*canadensis*	Bunchberry
	Crepis	*tectorum*	Hawk's Beard
	Delphinium	*glaucum*	Tall Delphinium
	Dryas	*drummondii*	Yellow Dryas
	Epilobium	*angustifolium*	Fireweed
	Equisetum	*arvense*	Common Horsetail
	Equisetum	*fluviatile*	Water Horsetail
	Equisetum	*palustre*	Marsh Horsetail
	Equisetum	*pratense*	Meadow Horsetail
	Equisetum	*scirpoides*	Dwarf Scouring Rush
	Equisetum	*species*	
	Equisetum	*sylvaticum*	Wood Horsetail
	Fragaria	*virginiana*	Wild Strawberry
	Galium	*boreale*	Northern Bedstraw
	Galium	*trifidum*	Bedstraw
	Galium	*triflorum*	Bedstraw
	Geocaulon	*lividum*	Northern Comandra

FORBS continued…	*Geum*	*macrophyllum*	Large Leaved Avens
	Goodyera	*repens*	Northern Rattlesnake Plantain
	Hedysarum	*boreale*	Liquorice-root
	Lupinus	*arcticus*	Arctic Lupine
	Lycopodium	*annotinum*	Bristly Club Moss
	Lycopodium	*clavatum*	Running Club Moss
	Lycopodium	*complanatum*	Ground Cedar
	Maianthemum	*trifolium*	False Solomon's Seal
	Mentha	*arvensis*	Wild Mint
	Menyanthes	*trifoliata*	Buckbean
	Mertensia	*paniculata*	Bluebells
	Mitella	*nuda*	Stoloniferous Mitrewort
	Moneses	*uniflora*	One Flowered Pyrola
	Orthilia	*secunda*	One-sided Wintergreen
	Oxytropis	*species*	Locoweed
	Parnassia	*palustris*	Bog Star
	Pedicularis	*labradorica*	Labrador Lousewort
	Pedicularis	*macrodonta*	Lousewort
	Pentstemon	*procerus*	Tall Pentstemon
	Petasites	*frigidus*	Arctic Sweet Coltsfoot
	Petasites	*palmatus*	Sweet Coltsfoot
	Pinguicula	*vulgaris*	Butterwort
	Platanthera	*obtusata*	Northern Bog Orchid/One Leaved Rein Orchid
	Polygonum	*amphibium*	Water Smartweed
	Polygonum	*viviparum*	Alpine Bistort
	Potentilla	*palustris*	Swamp Cinquefoil
	Pyrola	*asarifolia*	Large Wintergreen
	Pyrola	*chlorantha*	Greenish Flowered Wintergreen
	Pyrola	*species*	
	Ranunculus	*aquatilis*	White Water Buttercup
	Ranunculus	*flammula*	Buttercup
	Ranunculus	*macounii*	Buttercup
	Rorippa	*palustris*	Bog Yellowcress
	Rubus	*acaulis*	Dwarf Raspberry
	Rubus	*arcticus*	Raspberry
	Rubus	*chamaemorus*	Cloudberry/Baked Apple
	Senecio	*species*	Groundsel
	Solidago	*decumbens*	Dune Goldenrod
	Solidago	*simplex*	Goldenrod
	Spiranthes	*romanzoffiana*	Hooded Ladies' Tresses
	Thalictrum	*sparsiflorum*	Few Flowered Meadowrue
	Tofieldia	*glutinosa*	Western False Asphodel
	Veronica	*wormskjoldii*	Alpine Speedwell
	Viola	*epipsila*	Marsh Violet
	Viola	*renifolia*	Violet
	Zygadenus	*elegans*	Mountain Death Camas
GRAMINOIDS	*Agrostis*	*scabra*	Bentgrass
	Arctagrostis	*latifolia*	Polar Grass
	Calamagrostis	*canadensis*	Bluejoint

GRAMINOIDS continued…	*Calamagrostis*	*purpurascens*	Purple Reedgrass
	Calamagrostis	*species*	
	Calamagrostis	*stricta*	Slimstem Reedgrass
	Carex	*aquatilis*	Sedge
	Carex	*brunnescens*	Sedge
	Carex	*canescens*	Sedge
	Carex	*concinna*	Sedge
	Carex	*crawfordii*	Sedge
	Carex	*dioica*	Sedge
	Carex	*disperma*	Sedge
	Carex	*limosa*	Sedge
	Carex	*magellanica*	Sedge
	Carex	*phaeocephala*	Sedge
	Carex	*saxatilis*	Sedge
	Carex	*species*	
	Carex	*tenuiflora*	Sedge
	Carex	*utriculata*	Sedge
	Carex	*vaginata*	Sedge
	Danthonia	*intermedia*	Timber Oat Grass
	Deschampsia	*caespitosa*	Tufted Hairgrass
	Eleocharis	*acicularis*	Spike Rush
	Eleocharis	*palustris*	Spike Rush
	Eleocharis	*uniglumis*	Spike Rush
	Elymus	*calderi*	Wild Rye
	Elymus	*species*	
	Elymus	*trachycaulus*	Wild Rye
	Eriophorum	*viridi-carinatum*	Cotton Grass
	Festuca	*altaica*	Fescue
	Festuca	*saximontana*	Fescue
	Glyceria	*striata*	Fowl Manna Grass
	Gramineae	*species*	Grass
	Hierochloe	*odorata*	Holy Grass
	Juncus	*filiformis*	Bog Rush
	Oryzopsis	*pungens*	Mountain Rice
	Poa	*glauca*	Bluegrass
	Scheuchzeria	*palustris*	
	Trichophorum	*alpinum*	Bulrush
	Triglochin	*maritimum*	Seashore Arrow Grass
	Triglochin	*palustre*	Arrow Grass
BRYOPHYTES	*Aulacomnium*	*palustre*	
	Aulacomnium	*species*	
	Aulacomnium	*turgidum*	
	Brachythecium	*species*	
	Bryophytes	*crustose*	
	Calliergon	*species*	
	Campylium	*stellatum*	
	Dicranum	*acutiflorum*	
	Dicranum	*species*	
	Dicranum	*spadiceum*	

BRYOPHYTES continued…	*Dicranum*	*undulatum*	
	Drepanocladus	*species*	
	Helodium	*blandowii*	
	Hylocomium	*splendens*	
	Pleurozium	*schreberi*	
	Polytrichastrum	*alpinum*	
	Polytrichum	*commune*	Var. diminutum
	Polytrichum	*juniperinum*	
	Polytrichum	*piliferum*	
	Polytrichum	*strictum*	
	Ptilidium	*pulcherrimum*	
	Ptilium	*crista-castrensis*	
	Rhizomnium	*species*	
	Sanionia =Drepanocladus	*uncinata*	
	Sphagnum	*angustifolium*	
	Sphagnum	*capillifolium*	
	Sphagnum	*fuscum*	
	Sphagnum	*magellanicum*	
	Sphagnum	*Species*	
	Sphagnum	*warnstorfii*	
	Thuidium	*abietinum*	
	Thuidium	*recognitum*	
	Tomenthypnum	*nitens*	
LICHENS	*Cetraria*	*cucullata*	
	Cetraria	*ericetorum*	
	Cetraria	*islandica*	
	Cetraria	*nivalis*	
	Cladina	*mitis*	
	Cladina	*rangiferina*	
	Cladina	*stellaris*	
	Cladonia	*crispata*	
	Cladonia	*ecmocyna*	
	Cladonia	*gracilis*	
	Cladonia	*phyllophora*	
	Cladonia	*pyxidata*	
	Cladonia	*species*	
	Cladonia	*sulphurina*	
	Cladonia	*uncialis*	
	Icmadophila	*ericetorum*	
	Lichen	*crustose*	
	Nephroma	*arcticum*	
	Peltigera	*aphthosa*	
	Peltigera	*malacea*	
	Stereocaulon	*paschale*	
	Stereocaulon	*tomentosum*	
AQUATICS	*Hippuris*	*vulgaris*	Mare's Tail
	Potamogeton	*filiformis*	Pondweed
	Potamogeton	*gramineus*	Pondweed
	Sparganium	*angustifolium*	Bur Reed