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EMS Solutions Ltd.

Soil and Terrain Report
Joslyn North Mine Project

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Table of Contents

TABLE OF CONTENTS I
LIST OF TABLES II
LIST OF FIGURES IV
LIST OF APPENDICES IV
1.0 INTRODUCTION 1
2.0 THE STUDY AREAS 2
2.1 Project Location 2
2.2 Regional Study Area 2
2.3 Sub-regional Study Area 2
2.4 Local Study Area 3
3.0 ENVIRONMENTAL SETTING 3
3.1 Geology 3
3.1.1 Bedrock Geology 3
3.1.2 Surficial Geology 4
3.2 Ecological Stratification 4
3.2.1 Ecozone, Ecoregion, and Ecodistrict Levels 4
3.2.2 Land System Level 6
3.3 Vegetation 10
3.4 Traditional Land Use 11
4.0 BASELINE INFORMATION 11
4.1 Soil Investigation Methods 12
4.1.1 Field Investigation Methods 12
4.1.2 Laboratory Methods 14
4.1.3 Data Analysis and Mapping Methods 14
4.2 Taxonomic Entities – Soil Series and Variants 16
4.2.1 Classifying Soils to the Subgroup Level 16
4.2.2 Classifying Soil Parent Materials 16
4.2.3 Classifying Soils to the Series Level 20
4.3 Spatial Entities – Soil Map Units 23
4.3.1 The Soil Map Unit Symbol – Soil Landscape Models 23
4.3.2 Mineral Soil Map Units 23
4.3.3 Organic Soil Map Units 24
4.3.4 Landscape Models 24
4.3.5 Soil Map Units (Soil Landscape Models) of Joslyn SSA 24
4.4 Soils of the Regional Study Area (RSA) 28
4.4.1 Generalized Soil Map Compilation 28
4.4.2 RSA Soil Map Units 29
4.5 Map Unit Areas 29
5.0 BASELINE LAND CAPABILITY 35
5.1 Thickness of Soil Layers 35
5.2 Land Capability Classification for Forest Ecosystems 36
5.2.1 Procedure for Assessing Land Capability 36
5.2.2 Land Capability Assessment Results 38
5.3 Reclamation Suitability 40
5.3.1 Soil Suitability Ratings for Surface Soils 42

5.3.2 Soil Suitability Ratings for Overburden 44
5.4 Soils and Acid Deposition 47
5.4.1 Soil Sensitivity to Acid Deposition 47
5.4.2 Potential of Soils to Reduce Acidic Inputs 49
5.5 Acid Mine Drainage 50
5.6 Natural Erosion Risk Assessment 51
6.0 SOIL CONSERVATION AND RECLAMATION 53
6.1 Soil Reclamation Goal 53
6.2 Available Soil Resources 54
6.2.1 Mineral Soil Resources 54
6.2.2 Organic Soil Resources 58
6.2.3 Volume and Properties of Soil Available for Salvage 59
6.3 Landscape Construction 60
6.4 Soil Salvage and Replacement Plan 62
6.5 Soil Erosion 67
7.0 ENVIRONMENTAL EFFECTS ASSESSMENT 68
7.1 Project Scope 68
7.2 Evaluation Process 68
7.3 Effects Assessment Terminology 69
7.4 Valued Environmental Components & Environmental Effects 71
7.4.1 Soil Resource Potential Effects and Mitigation 71
7.4.2 Land Capability Potential Effects and Mitigation 72
7.4.3 Spoil Weathering Effects 76
7.5 Mitigation and Monitoring 76
7.5.1 Mitigation 76
7.5.2 Monitoring 76
7.6 Environmental Effects Summary 77
8.0 REFERENCES 81

List of Tables

Table 3.1 Bedrock Groups and Formations of the RSA (accompanies Figure 3.1; Hamilton et al. 1999). 3
Table 3.2 Ecoregions and Ecodistricts of the Joslyn RSA (accompanies Figure 3.2). 6
Table 3.3 Brief Descriptions of the Land Systems covering the SSA (Figure 3.3). 7
Table 4.1 Overburden Sample Locations Representing Pit 1. 14
Table 4.2 Brief Descriptions of the Major Parent Materials of the Joslyn SSA. 18
Table 4.3 List of Soil Series, Variants and Taxonomic Complexes used in the Joslyn SSA. 21
Table 4.4 Descriptive Summary of Soil Map Units (SLMs) of the Joslyn SSA. 25
Table 4.5 Soil Map Units of the RSA (adapted from Turchenek and Lindsay 1982a) 30
Table 4.6 Soil Map Unit Counts and Area Calculations for the RSA (soils). 32
Table 4.7 Soil Map Unit (SLM) Counts and Area Calculations for the Joslyn SSA. 33
Table 4.8 Soil Map Unit (SLM) Count and Area Calculations for the Joslyn North Mine Development Footprint. 34
Table 5.1 Soil Layer (Organic, Topsoil, Upper Subsoil) Thicknesses by Soil Model (SM portion of SLM). 36
Table 5.2 Baseline Land Capability Ratings for Forest Ecosystems by SLM. 39

Table 5.3 Criteria for Evaluating the Suitability of Surface Material (topsoil) for Revegetation in the Northern Forest Region. 41
Table 5.4. Criteria for Evaluating the Suitability of Subsurface Material (upper subsoil) for Revegetation in the Northern Forest. 41
Table 5.5 Reclamation Suitability Ratings for Baseline Soil Units (SM) of the Joslyn SSA. 42
Table 5.6 Reclamation Suitability Ratings* of Pit 1 Overburden. 44
Table 5.7 Other Characteristics of Non-sodic Overburden from Pit 1. 45
Table 5.8 Baseline Trace Element Content (mg/kg) of Pit 1 Overburden. 46
Table 5.9 Acid Sensitivity Ratings for Soil Map Units of the RSA. 48
Table 5.10 Sensitivity to/potential to Reduce Acidifying Inputs by Soil Model (SM) in the Joslyn SSA. 49
Table 5.11 Acid-Base Accounting Results for Pit 1 Overburden. 51
Table 5.12 Potential for Soil Erosion of Baseline Soils. 52
Table 6.1 Topsoil Suitability Parameters 55
Table 6.2 Upper Subsoil Suitability Parameters 56
Table 6.3 Lower Subsoil Suitability Parameters. 56
Table 6.4 Predicted Suitability of Surface (0 to 30 cm) Mineral Soil. 58
Table 6.5 Predicted Characteristics of Salvaged Peat:Mineral Mix. 59
Table 6.6 Physical and Chemical Parameters of Salvaged Soil. 59
Table 6.7 Project Available Soil Salvage Volumes. 60
Table 6.8 Physical and Chemical Parameters of Constructed Landscape Subsoil. 61
Table 6.9 Reconstructed Terrains 61
Table 6.10 Soil Handling and Material Balance 64
Table 6.11 Reclaimed Soil Distribution and Capability. 66
Table 6.12 Potential Soil Erosion by Water on Reclaimed Soils. 67
Table 7.1 Valued Environmental Components (VEC's). 71
Table 7.2 Comparison of Baseline & Reclaimed Terrain 73
Table 7.3 Comparison of Land Capability for Forests. 73
Table 7.5 Project Effects of Potential Acid Inputs on Soil. 75
Table 7.6 Cumulative Effects of Potential Acid Inputs on Soil 75
Table 7.1 Significance of Impacts on Soil Resources. 79

List of Figures

Figure 2.1. Regional study area (RSA) surrounding DCEL's Joslyn Lease
Figure 2.2. DCEL's Joslyn Lease showing the sub-regional (SSA) and local (LSA) study areas.
Figure 2.3. Local study area (LSA) showing proposed Joslyn North Mine development footprint.
Figure 3.1. Generalized bedrock geology of the RSA.
Figure 3.2. Ecoregions and ecodistricts of the RSA.
Figure 3.3. Land systems of the SSA.
Figure 4.1 Inspection site locations overlaid on the soil map of the SSA
Figure 4.2 Soil map of the SSA.
Figure 4.3 Soil map of the LSA.
Figure 4.4 Generalized soil map of the RSA.
Figure 5.1 Soil material depths displayed for the area surrounding the Joslyn North Mine footprint.
Figure 5.2 Soil capability ratings for forest ecosystems of the SSA.
Figure 5.3 Soil capability ratings for forest ecosystems of the LSA.
Figure 5.4a Upper lift (TS) reclamation suitability ratings for the LSA
Figure 5.4b Lower lift (SS) reclamation suitability ratings for the LSA
Figure 5.5 Soil sensitivity to acid deposition of the RSA
Figure 5.6 Soil sensitivity to acid deposition of the SSA.
Figure 5.7 Soil sensitivity to acid deposition of the LSA.
Figure 6.1 Slopes of Reclaimed Landscapes
Figure 6.2 Mine Closure Drainage Scheme.
Figure 6.3 Three Dimensional Characterization of Reclaimed Mine.
Figure 6.4 Capability Classes of Reclaimed Soil Landscapes.

List of Appendices

Appendix A: Soil Series and Variant Description
Appendix B: Soil Unit (SM) and Map Unit (SLM) Descriptions
Appendix C: Borehole Logs and Analytical Results

1.0 Introduction

Millennium EMS Solutions Ltd. (MEMS) was commissioned to conduct a soil survey and impact assessment for the Deer Creek Energy Limited (DCEL), Joslyn North Mine Project. The land area included within this study encompasses most of DCEL's Oil Sands Leases 7280060T24, 7404110452, and 7405070799, here after referred to as Joslyn Lease. This report expands on previous soil surveys compiled for Joslyn SAGD Project, Phase II (MEMS 2003) and Phase IIIA (MEMS 2005). This document contains the information required as per Section 5.7.2 in the Final Terms of Reference (AENV 2005) which states:

Describe the bedrock and surficial geology, soils and terrain in the Study Areas. Where appropriate, use maps of suitable scale, cross-sections and figures to illustrate these features. Explain the significance of any changes for the regional landscape, biodiversity, productivity, ecological integrity, aesthetics and the future use of the regional landscape area. Discuss the following:

- *a) the selection criteria used to determine the Study Areas, including information sources and assessment methods;*
- *b) the overburden geology and mineralogy;*
- *c) the distribution of soil types in the proposed project areas using appropriate soil survey procedures as outlined in the Soil Survey Handbook, Vol. 1 (Agriculture Canada, 1987);*
- *d) the soil survey maps should show approximate soil inspection and sampling locations corresponding to appropriate survey intensities in the footprint areas. The soil survey report should include necessary landscape and soil characteristics for land capability rating;*
- *e) the sensitivity and buffering capacity of the local and regional soil types to potential acid deposition from the proposed development and the predicted deposition patterns;*
- *f) the predicted acidifying impact to local and regional soils resulting from the Project with reference to local studies, current guidelines and management objectives for acidifying emissions consistent with the CEMA acid deposition management framework;*
- *g) the implications of environmental effects on ecosystem sustainability and regional management, including:*
  - *i) any constraints or limitations to achieving vegetation restoration including wetlands based on anticipated soil conditions and topography;*
  - *ii) an assessment of soil types for reclamation suitability and the approximate volume of suitable soil materials for reclamation;*
  - *iii) the potential for soil erosion and measures to minimize the effects of any such erosion; and*
  - *iv) any other issues that will affect the soil capability of the Study Areas or the reclaimed landscape and the mitigation measures proposed;*
- *h) an estimate of the effects of surface disturbance on geological features and soils, including:*
  - *i) the type and extent of changes to the pre-disturbance topography;*
  - *ii) the overburden characteristics in relation to the needs of post-mining reclamation programs; and*
  - *iii) an assessment and maps of the pre- and post-disturbance land capability and resiliency of the Project Area and a description of the changes to land capability classes resulting from the Project.*

Field data used to identify and map the soils was collected in May and August, 2003; mid June to early October, 2004; and late July to early August, 2005. Landscapes were described in terms of landform, surficial material types, and slope. Data collected on soil features included texture of horizons, stoniness, topsoil thickness, drainage conditions, and profile morphology. Soils were examined to depths of up to

220 cm at 2,463 locations within the Joslyn Lease. The soil taxa (soil series and variants) and resultant soil-landscape mapping units, used to map the distribution of soils, are described in this report.

This report outlines the methods used for collection and classification of soil data and development of mapping units. It also covers interpretation of soil data to determine soil reclamation suitability based on *Land Capability Classification for Forest Ecosystems in the Oil Sands* (Leskiw 1998), *Soil Quality Criteria Relative to Disturbance and Reclamation* (Soil Quality Criteria Working Group 1987), and *Soil sensitivity to acid deposition* (Holowaychuk and Fessenden 1987). The baseline soil information was then used to determine the potential impacts the project may have on soil resources of the survey area.

2.0 The Study Areas

2.1 Project Location

Deer Creek Energy Limited's (DCEL) Joslyn Lease (Oil Sands Leases 24, 452, and 799) lies on the west side of the Athabasca River approximately 70 km north of Fort McMurray in the Boreal Mixedwood Ecoregion of the Northern Alberta Plains. The Joslyn Lease is located in TWP 94-96 RGE 11-13 W4M. The Joslyn North Mine Project is the focus of three nested study areas, each intended to portray different levels of information required in the environmental impact assessment. The Joslyn Lease is outlined on Figures 2.1 and 2.2.

2.2 Regional Study Area

The regional study area (RSA), an area of approximately 1.1 million ha (Figure 2.1), was selected to assess regional effects, namely of acid deposition, which may affect soils beyond the boundaries of the proposed development. The boundary of the soils-RSA was established to contain the "Application Case" isopleth created by the critical potential acid input load (≥0.25 keq H+/ha/yr) for sensitive soils using criteria developed by CASA (1999). Critical load isopleths were defined by the results of air quality modelling for the Joslyn North Mine Project (AMEC 2005). The area selected for the RSA encompasses Townships 88-100 and Ranges 6-14, west of the 4th Meridian. Generalized soil, eco-stratification, and geological information were compiled and displayed at the regional level (Sections 3.0 and 4.0).

2.3 Sub-regional Study Area

The sub-regional study area (SSA) consists of the total area of detailed soil mapping conducted for DCEL. It covers 21,572 ha, or 96%, of the Joslyn Lease plus an additional 268 ha of buffer area outside the Lease. Total area of the SSA is 21,842 ha.

Figure 2.1 outlines the Lease area in relation to the soil RSA, for the Joslyn North Mine Project. The focus of the local study area is situated in the north-eastern portion of the SSA, as shown in Figure 2.2. Three buffer areas are described as part of the local study area (Section 2.4), and are shown in more detail in Figure 2.3.

Although different survey intensity levels were used throughout the SSA, the population of soil types found in this area formed the basis of the soil classification and mapping procedures. In other words, soil

mapping units developed to depict soil landscapes of the area were based on the population of soils and on soil-vegetation-terrain patterns in the SSA. In this report, the majority of discussion on environmental setting, soil patterns, and soil-based interpretations focuses on the SSA.

2.4 Local Study Area

A local study area (LSA) was defined to assess project-specific effects on soils and terrain. The LSA covers an area of approximately 8,352 ha, and encompasses the main pit, soil and overburden storage areas, plant and other infrastructure areas, tailings pond, and stream storage and channel diversions as shown in Figure 2.3. The footprint of the proposed Joslyn North Mine development covers 5,400 ha, which is 60% of the LSA. The detailed soil map of the LSA includes additional areas that extend outside the Joslyn Lease boundary in three different areas (Figure 2.3).

3.0 Environmental Setting

3.1 Geology

3.1.1 Bedrock Geology

Bedrock geology of the RSA, shown in Figure 3.1, was extracted from the 1:1M scale geological map of Alberta (Hamilton et al. 1999). Table 3.1 provides brief descriptions of the bedrock groups and formations, listed from youngest to oldest, which underlie the unconsolidated surficial materials of the region.

Table 3.1 Bedrock Groups and Formations of the RSA (accompanies Figure 3.1; Hamilton et al. 1999).

CRETACEOUS		
Upper Cretaceous		
	Ks	**Smoky Group**: shale & silty shale with ironstone; marine
Upper & Lower Cretaceous		
	Ksh	**Shaftesbury Formation**: shale & silty shale with ironstone; marine
Lower Cretaceous		
	Kpl	**Pelican Formation**: sandstone; marine
	Kj	**Joli Fou Formation**: shale; marine
	Kg	**Grand Rapids Formation**: sandstone, siltstone, & silty shale with thin coal beds; shoreline complex
	Kc	**Clearwater Formation**: silty shale, siltstone, and sandstone; marine
	Km	**McMurray Formation**: sandstone and siltstone with silty shale interbeds; oil impregnated; nonmarine to deltaic
DEVONIAN		
Upper Devonian		
	Dw	**Waterways Formation**: shale and limestone; marine
Middle Devonian		
	Ds	**Slave Point Formation**: limestone & dolomitic limestone with minor shale & gypsum; marine
	DM	**Middle Devonian** (undivided): various sandstone, shale, dolomite, and dolomitic limestone formations with minor gypsum and anhydrite; marine to evaporitic

Within the SSA, unconsolidated materials are underlain by the Lower Cretaceous Clearwater Formation (Hamilton et al. 1999). This formation is described as "dark grey, fossiliferous, silty shale; laminated siltstone and fine grained cherty sandstone; glauconitic sandstone (Wabiskaw Member) near base" and is of marine origin. The fine grained makeup of this local bedrock is likely reflected to a significant degree in the composition of the overlying clayey till, lacustro-till, and glaciolacustrine surficial sediments.

The McMurray Formation underlies the Clearwater Formation, and replaces it as the uppermost bedrock type on the east side of the SSA (Hamilton et al. 1999). The McMurray Formation is dominated by coarser grained rock (sandstone and siltstone), and is commonly oil impregnated (i.e. bitumen). Its influence on the surficial materials of the SSA is considered minor.

Waterways Formation bedrock underlies the McMurray Formation, and forms the uppermost bedrock in the southeast corner of the OSL, where it is likely exposed in the MacKay River valley. This bedrock type is described as "grey and greenish grey shale and argillaceous limestone interbedded with grey and greyish brown, fine grained to coarse clastic limestone", and is of marine origin.

3.1.2 Surficial Geology

Surficial deposits of the region were first mapped at a very broad scale in the in the 1960's and 70's (Bayrock 1971). Outwash sands were recognized as dominating the eastern portion of the SSA area, mixed and bedded glaciolacustrine sediments overlying glacial till in the western part. The glaciolacustrine sediments were described as including sand and till-like layers.

More detailed information about the surficial deposits of the area was provided by Thompson (1979), Thompson et al. (1978), and Turchenek and Lindsay (1982a). They described different types of glacial till and glaciolacustrine sediments, including how the glaciolacustrine sediments are similar to "lacustro-till" deposits recognized in other parts of northern Alberta.

Additional information on the surficial materials (soil parent materials) and landforms was obtained during the field survey. The information is assembled in the descriptions of "Land Systems", which describe generalized soil patterns of the SSA (Section 3.2.2).

3.2 Ecological Stratification

Hierarchical subdivision of the earth's surface into areas of similar biological and physical characteristics is the basis for ecological stratification, or ecological land classification (CAESA-SIWG 1997). Principles of ecological land classification were followed during the soil inventory for the Joslyn Project. Ecological land classification is a process of delineating and classifying ecologically distinctive areas of the earth's surface (Wiken 1986). Ecological units recognize distinctive combinations of geologic, landform, soil, vegetative, climatic, wildlife, water, and human parameters. The relative importance and detail of each parameter varies regionally and with scale (i.e. larger scale, greater detail).

3.2.1 Ecozone, Ecoregion, and Ecodistrict Levels

Ecological land classification in Canada is a hierarchical system. Using the national ecological framework (ESWG 1995), the three highest levels of generalization are **Ecozone** (scale 1:7.5M),

Ecoregion (scales ranging from 1:5M to 1:2M), and **Ecodistrict** (scales ranging from 1:3M to 1:1M). The level of detail about ecological composition and linkages increases from Ecozone to Ecodistrict.

Ecozone

The Joslyn soils-RSA lies within the **Boreal Plains Ecozone** (ESWG 1995). The climate of the Boreal Plains Ecozone, typified by cold winters and moderately warm summers, is strongly influenced by continental conditions (ESGW 1995). Broadleaf (aspen), coniferous (white and black spruce), and mixed forests dominate the vegetation. This nearly level to gently rolling plain is dominated by glacial moraine and lacustrine deposits. Its soils are largely Luvisolic, although wetlands including those with Organic soils are extensive in some parts.

Ecoregions

The RSA spans portions of two ecoregions, as shown in Figure 3.2, based on the ecological stratification of Alberta (CAESA-SIWG 1998). Table 3.2 provides brief descriptions of the two ecoregions and eight ecodistricts that comprise the RSA.

The Joslyn SSA lies within the **Slave-Athabasca Lowland** Ecoregion (CAESA-SIWG 1998). In the national ecological framework (ESWG 1995), this large area (Slave-Athabasca Lowland) consists of two sub-regions – the Slave River Lowland (136), which is mainly an undulating sandy plain, and the Wabasca Lowland (142), a gently sloping plain that features thick glacial till and glaciolacustrine deposits. The national system also identifies several sub-regions of the Mid-Boreal Uplands Ecoregion.

Ecodistricts

Eight ecodistricts cover the area selected as the Joslyn soils-RSA. These are shown in Figure 3.2 and described briefly in Table 3.2. General characteristics of the ecodistricts were complied from descriptions and data tables provided by CAESA-SIWG (1998), ESWG (1995), Selby and Santry (1996), and Turchenek and Lindsay (1982a).

The Joslyn SSA spans small portions of just two of these ecodistricts. The majority of the SSA occurs in the **Mackay Plain** Ecodistrict (CAESA-SIWG 1998), labelled Ecodistrict 608 in the national system (ESWG 1995). The eastern end of the SSA occurs in the **Embarras Plain** Ecodistrict (CAESA-SIWG 1998), labelled Ecodistrict 579 in the national framework (ESWG 1995).

Table 3.2 Ecoregions and Ecodistricts of the Joslyn RSA (accompanies Figure 3.2).		
Ecoregion	**Ecodistricts**	
Name (Codes*)	**Name (Codes†)**	**General Characteristics**
Mid-Boreal Uplands (08 / 141, 147) Sub-humid, mid-boreal ecoclimate	Birch Upland (08.4b / 605)	Mean elevation ~700 m ASL (250-900 m); hummocky moraine; moderately fine textured glacial till; mainly Gray Luvisols with significant wetland (Organic and Organic Cryosol) soils
	Hart Lake Plain (08.1e / 632)	Mean elevation ~400 m ASL (250-600 m); undulating, level, and rolling terrain; glaciofluvial, glaciolacustrine, and morainal deposits; wetland (Organic and Gleysolic) soils and Dystric Brunisols
	Muskeg Upland (08.1c / 634)	Mean elevation ~530 m (400-700 m); undulating to hummocky moraine; medium textured glacial till; Gray Luvisol and Organic soils
	Steepbank Plain (08.1b / 635)	Mean elevation ~470 m (250-600 m); undulating to level terrain; peat overlying glaciolacustrine and till deposits; Gray Luvisol and wetland (mainly Organic) soils
Slave-Athabasca Lowland (10 / 136, 142) Sub-humid, mid-boreal ecoclimate	Birch Fans (10.2e / 580)	Mean elevation ~250 m (200-350 m); undulating to level terrain; medium textured fluvial overlying sandy and glacial till deposits; wetland (mainly Gleysolic soils) with significant Gray Luvisols
	Embarras Plain (10.2f / 579)	Mean elevation ~ 270 m (200-350 m); undulating terrain; very coarse textured (S) glaciofluvial (outwash) material with eolian sands in some areas; mainly Dystric Brunisols with significant wetland soils
	Mackay Plain (10.1a / 608)	Mean elevation ~ 500 m (250-700 m); level to undulating terrain; moderately fine textured till and fine textured glaciolacustrine deposits; Organic (wetland) and Gray Luvisolic soils
	Wabasca Plain (10.1b / 609)	Mean elevation ~ 550 m (250-750 m); level to undulating terrain; sandy eolian and medium to fine textured glaciolacustrine deposits; wetland (Organic & Gleysolic soils) and Brunisolic soils

*Ecoregion codes: 2-digit (08) from provincial system (CAESA-SIWG 1998), 3-digit (141) from national system (ESWG 1995).
†Ecodistrict codes: alpha-numeric (08.1c) from provincial system (CAESA-SIWG 1998); 3-digit (634) from national system (ESWG 1995).

3.2.2 Land System Level

Ecozone, ecoregion, and ecodistrict levels of the eco-stratification system define broad regions of the earth at relatively small scales (1:1M and smaller). **Land System** was developed as a larger scale (about 1:250K) level to bridge the gap between the ecodistrict level and soil-landscape mapping in Alberta (CAESA-SIWG 1998). As a result, land system mapping is one of the featured products available in the Agricultural Region of Alberta Soil Information Database (AGRASID; ASIC 2001). Land System is equivalent to the Ecosection level defined in earlier national eco-stratification systems (Wiken 1986).

A Land System is defined as a subdivision of an Ecodistrict that recognizes differences in general patterns of land surface form, surficial materials, soils, and proportions of lakes and wetlands (CAESA-SIWG 1998). Land system maps delivered as part of AGRASID have demonstrated to be beneficial in municipal level planning and program delivery. Land systems provide an overview and general understanding of biological and physical features of an area, and help to organize more detailed data.

AGRASID does not provide land system data for most areas in the Boreal Plains because they are located outside the "white zone" (agricultural area) of the province. However, it is a common practice during the course of modern detailed soil surveys to modify boundaries and attributes of existing land systems, or to create new land systems where they have not yet been identified. Such is the case in the Joslyn SSA.

Four land systems have been identified as part of this study for the Joslyn SSA (Figure 3.3). The four land systems connect fairly closely with the original "ecodistricts" mapped (1:500K) for the first major soil survey of the area (Turchenek and Lindsay 1982a). Physiographic information (Pettapiece 1986) also played a role in identifying the areas. New names were applied to the land systems in this report in order to avoid confusion with names used at the ecodistrict level in the provincial ecological classification (Section 3.2.1). Descriptions of the four land systems of the SSA are provided in Table 3.3 and the text that follows.

Table 3.3 Brief Descriptions of the Land Systems covering the SSA (Figure 3.3).

Land System	Landform & Parent Materials	General Soil Patterns	General Vegetation Patterns
Within Ecodistrict 579 (Embarras) and the Slave River Lowland Ecoregion:			
Athabasca-Ells Valley	Escarpments and floodplains of the Ells, MacKay, and Athabasca rivers	Regosolic soils on floodplain; Luvisolic & Brunisolic soils on slopes; only 14% wetland soils	Balsam poplar on floodplain; aspen & white spruce on slopes
Joslyn Plain	Undulating glaciofluvial sands with significant wetlands; stratified coarse + finer materials in some areas	Uplands (52%): mainly Dystric Brunisols, some Gray Luvisols. Wetlands (46%): Mainly shallow (<1m) Organic soils and peaty Gleysols	Uplands: Jack pine forest (a1, b1) with some aspen (d1). Wetlands: Various types of fen with some bog
Within Ecodistrict 608 (Mackay) and the Wabasca Lowland Ecoregion:			
Lower Dover Plain	Low-relief, level to undulating terrain; clayey lacustro-till and glaciolacustrine deposits of variable color, including grayish pink layers	Uplands (50%): Orthic, Gleyed, & Solonetzic Gray Luvisols Wetlands (49%): Mainly shallow (<1m) Organic soils and peaty Gleysols	Uplands: Aspen forest (d1) and slightly moister variations. Wetlands: Variable.
Upper Dover Plain	Undulating (high-relief) to hummocky moraine; clay textured (some CL), brownish to grayish glacial till	Uplands (85%): Orthic & Solonetzic Gray Luvisols Wetlands (14%): deep Organic soils in closed basins; various Organic and Gleysolic soils along water courses	Uplands: Aspen forest (d1). Wetlands: Bogs in enclosed basins; fens along water courses

"Athabasca-Ells Valley" Land System

The **Athabasca-Ells Valley** Land System represents the broad, stream-cut, valley landscapes that dissect the survey area. It covers 2,391 ha or 10.9% of the SSA. This land system was expanded from previous reports to encompass all of the Ells, Athabasca, and MacKay river valleys mapped within the SSA. Wider parts of some tributaries like the lower portion of Joslyn Creek valley are also included. These valley landscapes are made up of two major components, each mappable at the intended scale used in this soil survey.

- Valley floor – level to terraced floodplain that includes the present-day stream channel plus oxbows and other channel remnants; and
- Valley walls – steeply sloping, erosional escarpments that confine the floodplains and often form the boundaries of the land system. Erosional features, most of which appear to be inactive at the present time, include rotational slumps and shallow gullies (inactive).

Parent materials of the Athabasca-Ells Valley Land System are mainly shallow to thick, medium (SiL-L) to moderately fine (SiCL-CL-SCL) textured, water-laid deposits often overlying clayey (C), glaciolacustrine and lacustro-till materials. Bedrock may underlie the water-laid materials near the eastern edge of the survey area.

Upland (i.e. dryland) areas are dominated by weakly developed Gray Luvisols, Dystric Brunisols, and Regosolic soils. They occur on (84%) the Athabasca-Ells Valley Land System mapped within the SSA. Weak development in these soils – B horizons are either weakly developed or absent – reflects the young age of these landscapes compared to those of surrounding land systems. In fact, Regosolic soils dominate the valley landscape along the Ells River below its confluence with Joslyn Creek.

Wetland areas account for 14% of the Athabasca-Ells Valley Land System, and most often occur in oxbows and deep channels that are part of the valley floor floodplain. A variety of Gleysolic and Organic soils occur on these wetlands. Mineral parent materials for the wetland soils are mainly medium to fine textured, relatively recent, water-laid sediments. The organic materials (peat) that often blanket the wetlands come from fen (including marsh) and bog vegetation. Peat depths range from almost nil along water courses where deposition of mineral material still occurs frequently to over 100 cm in a few basin-like locations. In general, peat deposits are relatively thin in this land system.

The Athabasca-Ells Valley Land System includes a unique combination of soil landscapes along the upper edge of the Athabasca River Valley, mainly in sections 26 and 35, 95-11-W4. Here, bedrock controls the hummocky to ridged landform surfaces. Soil materials range widely in thickness and texture, but are predominantly shallow and medium to coarse textured. Stones and boulders are a common feature, both throughout the soil materials and on the ground surface. It is hypothesized that an early stage of the post-glacial Athabasca River eroded outwash and other glacial materials as it began to down-cut its present-day valley. Remnants (i.e. lag deposits) of the glacial and immediate post-glacial materials are all that remain amongst the bedrock ridges and hummocks exposed by the erosion.

“Joslyn Plain” Land System

The **Joslyn Plain** Land System was previously called the “Embarras Plain” (MEMS 2005), and equates to the “Outwash Plain” identified for the CNRL Horizon Project (Golder Associates 2002) to the north of the Joslyn Lease. It covers 3,543 ha or 16.2% of the SSA. The Joslyn Plain is characterized by undulating terrain comprised of medium to very coarse textured, water-laid (mainly glaciofluvial) deposits. Textural variability may be negligible in some areas; in others the parent materials occur as interbedded (stratified) deposits. And in some parts of the Joslyn Plain, the medium to coarse sediments overlie clayey (glaciolacustrine or lacustro-till) deposits. While outwash sands are a familiar and defining feature of this land system, wetlands are also common.

Landform surface form is primarily undulating, with extensive areas of both high-relief (U1h, mainly slope class 3) and low-relief (U1l, slope class 2) types. Wetlands tend to be level overall but often have internal relief associated with raised knolls of mineral soils, or with stream channel landforms.

Upland areas are dominated by Eluviated Dystric Brunisols and Orthic Gray Luvisols developed in the water-laid deposits. They occur on 52% of the Joslyn Plain area within the SSA. Mildred (MIL) series, an Eluviated Dystric Brunisol developed on glaciofluvial sands, is one of the defining soils for this land system. Other Eluviated Dystric Brunisols found in the area are mostly variants of Orthic Gray Luvisols common to the area. The main Orthic Gray Luvisols are Fort (FRT; medium textured, water-laid veneer

overlying sands), Peavine (PEA; medium textured deposits), and Winefred-xc (WNFxc; coarse textured overlying clayey materials). Dover (DOV) and Livock (LVK) soils, typically found in land systems to the west, also occur on the Joslyn Plain. Expanded descriptions of the main soil series and variants are provided in later sections of this report.

Wetland areas account for 46% of the Joslyn Plain area within the SSA. A variety of Gleysolic and Organic soils occur on these wetlands. Mineral parent materials for the wetland soils are mainly coarse and medium textured, water-laid deposits. A Gleysolic soil complex found almost exclusively on the Joslyn Plain is based on the Bitumount (BMT) series, a peaty Orthic Gleysol developed on glaciofluvial sands. The organic materials (peat) that often blanket the wetlands come from fen (including marsh) and bog vegetation. Peat depths range from almost nil along water courses where deposition of mineral material still occurs frequently to over 100 cm in a few basin-like locations. In general, the Joslyn Plain has relatively thin peat deposits, similar to those of the Lower Dover Plain.

"Lower Dover Plain" Land System

The **Lower Dover Plain** Land System is a transitional area with subtly complex variations in landform, soil, and vegetation patterns. It is similar to the "Glaciolacustrine/Glaciofluvial Plain" identified for the CNRL Horizon Project (Golder Associates 2002) to the north of the Joslyn Lease. It covers 8,779 ha or 40.2% of the SSA. Although its surficial materials are dominated by clayey (C-HC-SiC) lacustro-till and glaciolacustrine sediments, the Lower Dover Plain does exhibit some elements of the sandier soils to the east (Joslyn Plain) and the morainal plain to the west (Upper Dover Plain). Where present, the sandy or other stratified, water-laid deposits tend to occur as a veneer overlying the clayey material.

Landform surface form is primarily level to low-relief undulating (mainly slope class 2 with some 3), with the exception of several stream course "valleys' that dissect the area. Changes between upland (dryland) and wetland areas are subtle and often defined by broad transitional areas with gleyed soils and moist vegetation types.

Upland areas are dominated by Orthic, Gleyed, and Solonetzic Gray Luvisols developed in the clayey or layered deposits. They occur on 50% of the Lower Dover Plain area contained within the SSA. Orthic Gray Luvisols are mainly Dover (DOV; clayey parent material) and Livock (LVK; medium textured, water-laid veneer overlying clayey material) series. The main Gleyed Gray Luvisols are Kilome (KME; clayey) series and Livock-gleyed (LVKgl; veneer over clayey) variant. The main Solonetzic Gray Luvisol is Steen (SEN; clayey material) series. Expanded descriptions of the main soil series and variants are provided in later sections of this report.

Wetland areas account for 49% of the Lower Dover Plain area contained within the SSA. A variety of Gleysolic and Organic soils occur on these wetlands. Mineral parent materials for the wetland soils are mainly clayey, water-laid and lacustro-till deposits, or medium textured, relatively recent, water-laid sediments overlying the clayey materials. The organic materials (peat) that often blanket the wetlands come from fen (including marsh) and bog vegetation. Peat depths range from almost nil along water courses where deposition of mineral material still occurs frequently to over 200 cm in a few basin-like locations. In general, the Lower Dover Plain has thinner peat deposits than occur in the Upper Dover Plain.

"Upper Dover Plain" Land System

The **Upper Dover Plain** Land System is dominated by undulating to hummocky glacial moraine comprised of clayey to loamy glacial till, or till-like material. It is similar to the "Moraine Plain" identified for the CNRL Horizon Project (Golder Associates 2002) to the north of the Joslyn Lease. Upper Dover Plain covers 7,130 ha or 32.6% of the SSA. High-relief undulating slopes (mainly class 3) characterize the eastern side and hummocky terrain (slope classes 4 to 5) the western side of this land system.

Upland areas are dominated by Orthic and Solonetzic Gray Luvisols developed on the predominantly clayey (some loamy) glacial till. They occur on 85% of the Upper Dover Plain area contained within the SSA. Orthic Gray Luvisols are mainly Dover (DOV; clayey till) and Horse River (HRR; loamy till) series. Since both soils occur in intimate association, they are represented in soil map units by Dover series, which tends to be dominant throughout the area. The main Solonetzic Gray Luvisol is Steen (SEN; clayey till) series. Gleyed Gray Luvisols, represented by the Kilome (KME) series, occur in small drainages and slopes that are transitional to wetlands. Expanded descriptions of the main soil series and variants are provided in later sections of this report.

Wetland areas account for 14% of the Upper Dover Plain area, a much lower proportion than on the Lower Dover and Joslyn plains. A variety of Gleysolic and Organic soils occur on these wetlands. Mineral parent materials for the wetland soils are mainly clayey, water-laid, lacustro-till, and till deposits, or medium textured, relatively recent, water-laid sediments overlying the clayey materials. The organic materials (peat) that often blanket the wetlands come from fen (including marsh) and bog vegetation. Peat depths range from almost nil along water courses where deposition of mineral material still occurs frequently to well over 200 cm in confined wetland basins that are a common feature of the moraine. In general, the Upper Dover Plain has thicker peat deposits than occur in other land systems.

3.3 Vegetation

The vegetation that covers the Joslyn SSA is mainly aspen and aspen-spruce mixedwood forest, which is reasonably typical of the Boreal Mixedwood ecological area (Beckingham and Archibald 1996). Wetlands, various types of bogs and fens, are also common. More detailed vegetation information, including an ecosite phase map and wetland classification, is provided as part of the environmental impact assessment (EIA) for the Joslyn North Mine Project (Komex 2005b).

Most upland areas are dominated by aspen (*Populus tremuloides*) forest with the most common ecosite phase being low-bush cranberry – aspen (d1). This type is especially extensive on the Upper Dover Plain. More mature aspen stands include higher proportions of white spruce (*Picea glauca*). Some transitional areas, especially on the Lower Dover and Joslyn plains, have truly mixed stands that include aspen, white spruce, jack pine (*Pinus banksiana*), and possibly balsam poplar (*Populous balsamifera*), white birch (*Betula papyrifera*), or black spruce (*Picea mariana*). While sandy or medium textured veneer soils may be found with this mixedwood forest in some localities, imperfectly drained, gleyed soils with subsurface seepage are often associated.

Upland areas dominated by soils developed on glaciofluvial sands are dominated by jack pine (*Pinus banksiana*) forest with the most common ecosite phases being lichen jack pine (a1) and blueberry jack pine – aspen (b1). These types are especially extensive on the Joslyn Plain.

Four types of general vegetation assemblages – bog, poor fen, rich fen, and marsh – occur on wetlands. All four are characterized by a variety of poorly to very poorly drained Gleysolic and Organic soils. The bog ecosite (i) is characterized very poor to poor nutrient levels. Stagnant water and impeded drainage foster the accumulation of organic matter (peat), primarily from peat moss (*Sphagnum* spp.) as succession slowly progresses. If treed, stunted black spruce (*Picea mariana*) is common. Labrador tea (*Ledum groenlandicum*) and bog cranberry (*Vaccinium vitis-idaea*) are common shrubs.

The poor fen ecosite (j) is intermediate in nutrient levels between bog and rich fen. Plant species are similar to those found in bogs but include tamarack (*Larix laricina*) in the tree layer, if present, and dwarf birch (*Betula pumila*, *Betula glandulosa*) in the shrub layer.

The rich fen ecosite (k) is associated with flowing water and alkaline, nutrient-rich, soil conditions. Tamarack (*Larix laricina*) dominates the tree canopy if present. Two other types of rich fen are also common. Shrubby rich fen is dominated by shrubs (willow, dwarf birch, and river alder). Graminoid rich fen is dominated by sedges and reed grasses.

The marsh ecosite (l) is characterized by the presence of sedges and rushes. Water level is above the rooting zone for some portion of the growing season. It occurs mostly along shorelines of water bodies, including confined water courses where ponding is common. Deposition of fresh mineral material (fluvial or fluviolacustrine sediments) may occur in such environments.

3.4 Traditional Land Use

A Traditional Ecological Knowledge and Land Use report was completed as part of the Joslyn North Mine project application (FMA 2005a). It has been found that landscapes with sandy soils and jackpine vegetation are culturally significant. The Joslyn North Mine soil salvage and replacement plan takes this into consideration and the reclaimed soil profiles will be able to sustain a variety of end land uses including these sandy jackpine areas.

4.0 Baseline Information

This section focuses the most of its information on the baseline soil survey of the Joslyn sub-regional study area (SSA), which contains the local study area (LSA), and includes:

- methods of soil investigation, consisting of field, laboratory, and data analysis and mapping;
- brief descriptions of important soil series and variants – taxonomic entities that define the types of soils found in the area; and
- brief descriptions of soil map units – spatial entities that define the distribution of soils.

Information on soils of the regional study area (RSA) is inserted where applicable, including Section 4.4 on the methods employed to create the generalized RSA soil map.

4.1 Soil Investigation Methods

4.1.1 Field Investigation Methods

Survey Design – Intensity Levels

The field segment of the soil survey for the entire SSA was conducted in May and August, 2003, mid June to early October, 2004, and late July to early August, 2005. After the initial work in 2003, the SSA was pre-typed into generalized soil-vegetation patterns on an orthophoto image, and an initial survey plan was developed to target different areas for different survey intensity levels (SIL) based on published guidelines (Leskiw 1998, MSWG 1981). The survey plan considered four main areas:

- North-central portion of DCEL's Joslyn OSL, north of the Ells River, amply covering the SAGD Phase I, II, and IIIA footprint areas – SIL 1 (at least 1 inspection per 5 ha);
- Footprint area of the North Mine LSA (NE portion of SSA), north and west of the Ells River – SIL 1 (target set at 1 inspection per 5 ha);
- Remainder of the Joslyn OSL located north and west of the Ells River – SIL 2 (target set at 1 inspection per 15 ha); and,
- Remainder of the survey area south and east of the Ells River – SIL 3 (1 inspection per 30 ha).

In general, planned survey intensity levels were achieved by the end of the field season in October, 2004. An additional 218 inspection sites were added in July and August, 2005, covering proposed area changes to the SAGD Phase IIIA and North Mine footprints. To-date, a total of 2,463 soil inspection sites have been logged in the SSA (Figure 4.1), with the highest concentrations (SIL 1) located north and east of the Ells River in the LSA, and in the area containing the SAGD developments. Of the 1,493 inspection sites in the LSA, 1,085 are located within the proposed North Mine footprint area. SIL 2 was achieved in the remainder of the area north of the Ells River; SIL 3 in the mapped area located between the Ells and MacKay rivers.

Soil inspection sites were selected to adequately represent the soil-vegetation patterns pre-typed on an orthophoto image. In general, these patterns were mapped to identify general differences in landforms, surficial materials, topography, and vegetation (Beckingham and Archibald 1996). Access was also a significant factor in determining location of site inspections. Access was by vehicle on the few roads traversing the survey area, by ATV on passable trails and cut-lines, by helicopter to remote areas with landing access, and on foot in areas with limited vehicular access.

Site and Soil Characteristics

Each soil inspection, or exposure as defined by MSWG (1981), involved digging a shallow hole with a shovel into the upper part of the B horizon if present, often to about 30-40 cm depth. A hand auger was used to examine soil materials to approximately 100 cm depth in mineral soils, up to 220 cm depth in organic soils. Numerous site and soil characteristics were observed and recorded on field forms, following accepted guidelines and classification systems (Beckingham and Archibald 1996, ECSS 1983, Leskiw 1998, SCWG 1998).

Site characteristics recorded at each inspection included date of observation, observers, surficial geologic material, slope, aspect, slope position, landform surface form, soil type, soil drainage, edatope, humus form, surface stoniness, dominant water supply, depth to apparent water table, tree canopy cover with the main tree species, main shrubs, main herbs/forbs, moss cover with main moss species, main land use,

estimated stand quality, and whether there were any signs of erosion and compaction. UTM location coordinates were captured by hand-held GPS units and later transferred to the soil site database.

Soil characteristics recorded at each inspection site included horizon types (per the Canadian soil classification system, SCWG 1998), horizon depths, soil texture by manual (field) tests, structure, consistence, and the presence of coarse and fine roots. In addition, color (Munsell soil color charts), pH (field test using Hellige-Truog reaction indicator), and mottles were described and recorded for some horizons.

Soil characteristics were later used to calculate thicknesses of the surface organic layer (LFH or wetland peat), topsoil (Ae, Ah, Ahe, AB, and related horizons), and upper subsoil (B and BA horizons); parent material groupings (Section 4.2); and soil classification to the subgroup and series levels (Section 4.2). Land system identification code and name (Section 3.2.2), ecosite phase, and soil map unit were determined from the soil mapping or other project maps and logged in the database.

Soil Sampling

Samples of one or more soil horizons or layers were collected at 124 of the soil inspection sites located throughout the Joslyn SSA. These ranged from "grab" samples collected to determine or check specific characteristics to detailed pedon samples intended to represent the most common soils in the area.

A pedon sampling program was undertaken in 2004 on most of the major soil series/variants encountered in the area. Detailed pedon descriptions and bulk samples of most horizons or layers were obtained from 15 sites. At these sites, large soil pits at least 0.5 m wide and 1 m long were dug using shovels to depths that exposed the parent material, allowing it to be described and sampled. At upland sites, pits were excavated by shovel to at least 70 cm from the mineral surface, with deeper horizons being sampled to at least 100 cm, sometimes with the aid of an auger. In the wettest sites, soil sampling pits were often quite shallow and an auger was used to carefully extract saturated material from horizons below the water table. Approximately 1 kg of soil from each horizon (excluding very thin, discontinuous horizons) was collected in a labelled "zippered" plastic bag, and then sealed for transport to laboratory facilities.

The detailed pedons and the sites surrounding them were described using as the primary guideline *The Canadian Soil Information System: Manual for describing soils in the field* (ECSS 1983). Some features were described using other soil (Leskiw 1998, SCWG 1998) and site (Beckingham and Archibald 1996) references. Morphological data collected at the detailed sites included a more comprehensive description of color, soil structure, mottles, coarse fragments, and roots compared to the routine inspection sites. In addition, soil pores, clay films, and horizon boundaries were described. Data were recorded on field sheets designed for the pedon sampling portion of the project.

Overburden Sampling

Overburden is considered in this report to include all geologic material below the soil profile and above the material to be mined. The overburden excavated from above the mined material is termed **spoil**.

A total of 6 bedrock core samples from 5 test holes were collected and analysed for soil quality parameters (pH, detailed salinity, lime content), trace elements and acid base accounting. Overburden sample locations from the Pit 1 area are shown in Figure 4.1 and described in Table 4.1. Each sample

represents either the Clearwater formation or recent surficial deposits of fluvial, lacustrine and till material. A mixture of these overburden materials will form the spoil and when used within 1.0 m of the surface, will form the subsoil or rootzone of mine soils.

Table 4.1 Overburden Sample Locations Representing Pit 1.

Site ID	Location	Depth (m)	Material
06-03	06-03-96-11 W4	2.0-7.6	Clearwater formation.
12-05	12-05-96-11 W4	2.0-7.0	Fluvial sand / lacustrine clay / clayey till.
		7.0-9.8	Clearwater formation. (McMurray fm @ 10.7m).
07-30	7-30-95-11 W4	2.0-7.0	Lacustrine clay / clayey till. (Clearwater fm @ 6.1 to 7.6+ m).
14-20	14-20-95-11 W4	2.0-6.1	Lacustrine clay / clayey till. (McMurray fm @ 6.9m – no Clearwater).
01-33	01-33-95-11 W4	2.0-6.1	Lacustrine clay / clayey till. (McMurray fm @ 6.1m – no Clearwater).

4.1.2 Laboratory Methods

Surface soil samples were stored in coolers and delivered to Enviro-Test Laboratories, generally on a bi-weekly basis. Maximum storage time for any set of samples was generally about one week. Laboratory methods used by Enviro-Test Laboratories are based on a series of reference methods. Analytical procedures included the determination of:

- Soil reaction (pH) – pH in $CaCl_2$, using a 1:2 ratio of 0.01 M $CaCl_2$ solution (Carter 1993).
- Total Carbon (TC) – by combustion using a Carlo Erba NC 2100 soil analyzer, with evolved CO_2 separated chromatographically and detected by thermal conductivity (Nelson and Sommers 1996).
- Inorganic Carbon (IC) – determined by digestion in 6N HCl, capture of evolved CO_2 in a NaOH trap, and titration as carbonic acid (Tiessen et al. 1983).
- Organic (OC) – calculated as the difference between total (TC) and inorganic (IC) carbon.
- Total Nitrogen (N) – determined using a Kjeldahl method for conversion of organic N to ammonia N by digestion in H_2SO_4 with K_2SO_4 and $CuSO_4$, and measurement of ammonia N by distillation into boric acid and titration with standard acid (Bremner and Mulvaney 1982).
- Calcium carbonate in soil – calculated from inorganic carbon (IC) values.
- Cation exchange capacity – determined using a buffered (pH 7), NH4OAc distillation process (McKeague 1978).
- Soluble salts and electrical conductivity – determined on saturation extracts (McKeague 1978). Results included with this method were pH in water, saturation percentage, and sodium adsorption ratio (SAR).
- Particle size analysis (sand, silt, and clay content) – determined by the hydrometer method (Kalra and Maynard 1991).
- Trace metals – determined by digestion in nitric acid and hydrogen peroxide with measurement of metals in the digest by inductively coupled plasma – mass spectrometry (Edgell 1988).

4.1.3 Data Analysis and Mapping Methods

Site inspection data, including detailed pedon sampling sites, were entered into a MS Access database system designed for this Project. The design of the database accommodated the complex entry of site and layer data (one-to-many data relationship) on a single form, and facilitated editing and updating. With completion of the 2005 field work, 2,463 site inspection records joined to 11,650 horizon/layer records were logged into the SSA database.

After site data was edited and classified, the database was used to filter and query the soil data to establish trends and patterns. The database worked well for importing and exporting data with the geographic information system used to create the soil map. Additional information is provided on classifying the soil data (Section 4.2) and on mapping soil patterns (Section 4.3).

A variety of mapping tools were used collectively to develop the soil map for the Joslyn SSA. These tools included:

- the site inspection (point) database;
- ecosite phase vegetation map for the Joslyn OSL (Komex 2005b);
- hillshade image derived from a detailed (1 m pixel) digital elevation model (DEM);
- orthophoto image derived from 1:30,000, black & white, aerial photographs taken in 2003;
- laser prints of stereoscopic, 1:30,000, black & white, aerial photographs taken in 2003;
- geographic information system (ArcMap GIS); and
- the experienced mapper's knowledge of the soil patterns in the survey and similar areas.

The geographic information system (GIS) facilitated the layering and visual integration of the main data sources. The final version of the ecosite phase vegetation map (Komex 2005b) became the starting layer for the soil map. Patterns related to soils were developed through database querying and filtering techniques. For example, a preliminary "land system" map (Section 3.2.2) was created. The soil data were then filtered to establish trends (i.e. soil series counts) for each ecosite phase within each land system. The correlation of soils with land systems and vegetation types was particularly helpful in developing soil map unit concepts. Soil map units were then applied to the ecosite phase polygons.

Other layers of information visible in the GIS helped to refine the soil map and its map unit concepts. The hillshade image revealed landform and topographic patterns. A "land systems" map was created which defined stream course (e.g. river and creek valleys) landscapes. It provided visual clues for applying soil map units to wetlands, based on their shape and "depth" compared to surrounding terrain. The orthophoto image showed drainage patterns that affected vegetation cover, especially for landscapes with intricate combinations of upland and wetland areas. Although not a part of the GIS, the laser print aerial photographs were used to stereoscopically check landscape patterns in problem areas. Finally, point (soil inspection site) data, visible on a GIS layer, was consulted in the assigning of soil map units to polygons.

Additional areas of LSA , which extend beyond the Joslyn OSL boundary (Section 2.4), were mapped by extrapolating information from inside the OSL boundary. The extrapolated mapping was supported by interpretation of 1:30,000 air photo images, the hillshade DEM image, and in some areas, ecosite phase or Alberta vegetation inventory data.

As the mapping progressed in its typical iterative manner, soil map unit concepts evolved and the soil map was refined. The target map scale – 1:10,000 – helped to define minimum sized polygons. Update of data in the database and GIS continued throughout the process. As a final step, soil map units with only a few polygons and low areal extent were amalgamated with similar, more extensive map units. Additional information on the system used to define soil map units is provided in Section 4.3.

4.2 Taxonomic Entities – Soil Series and Variants

It is important to differentiate between taxonomic units and mapping units, and to understand how the two entities are used to "build" a soil survey product (ECSS 1987, MSWG 1981). Taxonomic units are developed through rigorous classification of soil individuals (exposures) found during survey activities. Classifying soils to the series level determines their population in an area and helps reveal soil distribution patterns (i.e. soil taxa that occur together in different types of terrain). Soil taxa at the series level can be considered analogous to plant species in vegetation classification. Different soil series/variants occupy different "niches" in the landscape and can occupy spaces as small as one meter across.

Classification of all available soil data in an area provides the framework for building map units with which to depict the distribution of those soils. Soil map units may be considered analogous to plant communities, e.g. ecosite phases.

Soil classification to the series level involves three major steps:

- Taxonomy to the soil subgroup level based on morphological features (e.g. types of A and B horizons, degree of gleying based on morphological evidence, etc.);
- Classification, or grouping, of soil parent materials according to mode of deposition plus textural and chemical characteristics; and
- Merging the two classifications to define soil series level taxa.

4.2.1 Classifying Soils to the Subgroup Level

Soils of inspection sites were classified to the subgroup level based on an assessment of their morphological features using the guidelines of the *Canadian System of Soil Classification* (SCWG 1998).

An exception to these guidelines, utilized in the CNRL Horizon Project north of Joslyn Lease (Golder Associates 2002), was applied to organic soils. Depth of organic material, especially peat, is a critical data set for the client, so it was expedient to choose one minimum thickness to define the Organic Order soils rather than two as stipulated in the taxonomic system (SCWG 1998). Guidelines regarding depths of peat were adopted as follows:

- Less than 15 cm of peat – non-peaty mineral soil.
- 15-40 cm – peaty-phase, Gleysolic soil.
- 40 cm or more – Organic soil (fits Humisol and Mesisol but not Fibrisol great groups).

The process of assigning soil subgroups to soil inspection sites included a review of the soil data, both field and database, for accuracy and consistency. At this stage, horizon sequences and depths, drainage classes, depth of peat, and other recorded characteristics affecting the selection of a subgroup for each profile were scanned. Analytical results for sampled horizons were also consulted, especially Ca:Na ratios and SAR values for the assessment of Solonetzic and solonetzic-like horizons. With large number of soil inspection sites (2,643), this review and edit process was cursory.

4.2.2 Classifying Soil Parent Materials

Soil series classification has always relied on differentiating parent materials based on a variety of physical and chemical characteristics. Prior to the 1990's in Alberta, these were applied on a rather ad hoc basis. In the early '90s, steps were taken to correct this problem with an evaluation of soil series

throughout the province (ASSWG 1993). Further refinements to the grouping of parent materials for soil classification purposes were implemented for mapping the soils of the agricultural area of the province (CAESA-SIWG 1998), resulting in AGRASID (ASIC 2001).

The latest edition of the Alberta Soil Names File (AG30SNF) is an integral part of AGRASID, and lists all established soil series in the province. A foundation of this soil series list is the modernized classification of soil parent materials – a grouping that places greater emphasis on textural characteristics, less on color and mode of deposition. Appendix A provides additional information on soil parent material classification, and includes a list (Table A-1) of all parent material textural groupings used in Alberta.

The process of assigning parent material groupings to soil inspection sites provided another opportunity for review of the soil data, in particular, horizon texture and thickness and parent material type. A site by site review within "land systems" was conducted in order to evaluate layering (i.e. layered parent materials), thickness of layers, depth of organic materials, coarse fragment content, and presence of bedrock. A set of general guidelines were followed in order to perform the assessment:

- Horizon sequence and textural data were scanned to determine if a significant parent material discontinuity (e.g. an overlay) occurred above the bottom horizon(s).
- If textural discontinuities were noted (i.e., for applying a group "L" code), thickness of the upper material became a factor in the assessment. Traditionally, 30 cm (1 foot) has been used in Alberta as the minimum thickness for recognition of overlays in mineral soils. Layers thinner than 30 cm were ignored in the assessment unless a series of layers with similar textures (e.g. LS, S, and SL), and a cumulative thickness of at least 30 cm, occurred close together in the profile.
- Many soils in the SSA exhibited some degree of stratification, a few to extreme levels with contiguous layers ranging from sand to clay. If an "L" code was applicable, the parent material variability was generalized to two major layers.
- In situations with extreme variability amongst several thin layers, an "L" code may not have been the most appropriate. In such cases, an "average" textural grouping (e.g. M2 or M3) was applied, estimating texture of the material as if the layers were mixed.
- Textural variation resulting from soil development, e.g. finer textured illuvial (Bt) and coarser textured eluvial (Ae) horizons, were downgraded in the assessment process.

Chemical characteristics of parent materials, namely calcareousness and salinity, are also important to soil development, hence to their taxonomy. Classes of calcareousness (6) and salinity (4) were defined by ECSS (1983). Most parent materials of the Joslyn SSA are non- or weakly calcareous and non-saline. Explicit information about these characteristics can be found with the soil series descriptions.

Table 4.2 lists and briefly describes the most common parent materials of the SSA. Descriptions were compiled from Bayrock (1971), Thompson et al. (1978), Thompson (1979), Turchenek and Lindsay (1982a, 1982b), and the Joslyn SSA site inspection data.

Table 4.2 Brief Descriptions of the Major Parent Materials of the Joslyn SSA.

Parent Material Group / Type	Physical Features	Chemical Features	Comments
Tills, including lacustro-till:			
M4 Horse River Till	Moderately fine textured (CL-L); 5-20% coarse fragments; usually dark grayish brown	Weakly to moderately calcareous; non-saline (weakly saline in places)	• Occurs with fine textured "Dover" till on Upper Dover Plain • Low carbonate content – carbonates usually encountered within 1 m of mineral surface • Weakly saline where Solonetzic Gray Luvisols are common
F3/F4 "Dover Till" (lacustro-till)	Fine textured (C); low coarse fragment content (<15% usually); grayish brown and "pink" (5YR4-5/3-4) layers	1. Dover – Weakly calcareous; non-saline 2. Joslyn / Steen – Weakly to moderately calc.; weakly saline	• "Mixed glaciolacustrine" material of Turchenek & Lindsay (1982a) • Occurs with and often overlying Horse River Till – Turchenek & Lindsay (1982a) noted that shallow "till-like" glaciolacustrine material (<1m / till) was more extensive than deep glaciolacustrine materials • Grayish pink bands a common feature (also noted by previous authors)
L19 Stony drift over bedrock	Stony to cobbly, medium textured (L, CL, SCL) till-like drift over sandstone or bituminous (oilsand) bedrock	Non-calcareous; non-saline	• Shallow, usually stony or cobbly, often stratified, till-like drift found mostly along the upper escarpment of the Athabasca River valley • Layers of coarse textured (SL, LS) materials may occur with this drift; carbonates were found in a few profiles • Bedrock usually occurs at depths of a few cm to over 1 m
Coarse textured glaciofluvial and fluvial materials:			
C2 Outwash sands	Very coarse textured (LS, S); may contain minor amounts of gravel or stones	Non-calcareous; non-saline	• Sands are relatively well sorted with very little, if any, silt and clay; minor stratification (e.g. in sand sizes) evident in many profiles • Surfaces reworked in many areas by eolian activity
C3 MC textured sediments	Moderately coarse textured (SL); may contain minor amounts of gravel or stones	Non-calcareous; non-saline	• Thin SiS, VFSL, or very coarse textured layers may occur • Carbonates found at depth (<1 m) in a few profiles
L9 CT sediments / lacustro-till	Coarse textured C2 and C3 deposits / M4 or F4 tills	Weakly calcareous in till; non-saline	• Variable carbonate content – often found at depths below 1 m
L18 MT / CT sediments	Medium textured / coarse textured deposits; few, if any, coarse fragments	Non-calcareous; non-saline	• Carbonates occur in some layers in a few profiles

Table 4.2 Brief Descriptions of the Major Parent Materials of the Joslyn SSA.			
Parent Material Group / Type	**Physical Features**	**Chemical Features**	**Comments**
L20 CT / MT sediments	Coarse textured / medium textured deposits; few, if any, coarse fragments	Non-calcareous; non-saline	• Carbonates occur in some layers in a few profiles, usually at depths of about 1 m or more
Medium textured glaciolacustrine, glaciofluvial, and fluvial materials:			
M2 ME textured sediments	Medium textured (L, SiL); few if any coarse fragments	Mainly non-calcareous; non-saline	• Includes "recent" fluvial deposits on river and creek floodplains • Was not identified in AOSERP area (Turchenek & Lindsay 1982a)
M3 MF textured sediments	Moderately fine textured (CL, SiCL, SCL); few if any coarse fragments	Weakly calcareous; non-saline	• Variable carbonate content – may occur well below 1 m in some profiles
L10 MT sediments / lacustro-till	Medium textured M2 & M3 layer / F3 (F4) materials	Weakly calcareous in lacustro-till; non-saline	• Variable carbonate content – may occur at depths below 1 m
Peat (organic) materials:			
L12 Peat / MT materials	Undifferentiated peat 40-120 cm thick / dominantly MT (L, SiL, CL, SiCL, SCL) materials	Mineral substrata: non- to weakly calcareous; non-saline	• Mineral substrata include tills (HLY and MRN series), which are most frequently calcareous at depth, often > 1m • Water-laid substrata may be stratified, often lack carbonates
L13 Peat / FT materials	Undifferentiated peat 40-120 cm thick / dominantly FT (C, SiC, HC) materials	Mineral substratum: non- to weakly calcareous; non-saline	• Mineral substrata includes some fine textured tills • Water-laid substrata may be stratified • Carbonates present in some layers, and often found at substantial depth
L12z (Lz) Frozen peat	Frozen, undifferentiated peat; depth not determined	Non-calcareous & non-saline peat; mineral substrata not determined	• Commonly occurs in pockets with non-frozen peats • Surface layers predominantly fibric material • Substrata underlying peat rarely seen due to frozen layers above
P1, P2 Deep peat	Bog (P1) and fen (P2) peat at least 120 cm thick	Non-calcareous & non-saline peat	• Most peat deposits layered and from different sources as the wetland evolved – not critical to differentiate the peat types in this study

4.2.3 Classifying Soils to the Series Level

Appendix A includes additional information on classifying soils to the series level, and provides descriptions of 17 of the major soil series/variants encountered in the Joslyn SSA.

Soil Series

Soil subgroup classification and parent material groupings were integrated in order to assign soil series or variants to soil inspection sites. A list of available **soil series** names derived from the Alberta Soil Names File (ASIC 2001) became the starting point for this process.

The Joslyn OSL occurs within Soil Correlation Area (SCA) 20, defined as the Mid Boreal Mixedwood Ecoregion of the Northern Alberta Plains (ASSWG 1993). The latest edition of the Alberta Soil Names File listed over 70 established soil series and variants that could be used in the region. This list was reduced to about 25 soil names that were applicable to the ecodistricts and parent materials of the SSA.

Six additional new names, added for the CNRL Horizon Project to the north (Golder Associates 2002), were also used initially in the SSA. Following correlation exercises with the Provincial Correlator in early 2005 however, it was decided to discard three of these new names and reserve a fourth for future use. It was felt that the taxonomic concepts represented by these four names could be adequately covered (in mapping and interpretations) by variants of established series. Consequently, only two new names – Daphne (DAN) and Ings (ING) – were added to the provincial soil names file.

Soil Variants

Considering the complexity of parent materials encountered in the Joslyn SSA, the soil series choices available from the Alberta Soil Names File were rather limited. Most were defined from the low intensity inventories of the early '80s (Turchenek and Lindsay 1982a). A tool commonly used to identify soil series equivalents without naming them is variants. **Soil variants** are used to define soil entities that are sufficiently different from established soil series to warrant recognition, but do not justify a new soil name due to limited geographic extent.

The use of variants substantially extends the soil series list for an area. Variants are particularly useful through the pilot and working stages of classification and mapping. Table A-2 in Appendix A lists all variants and their codes used in Alberta, with a few additions. The codes are most often applied as lower case letters after the soil series symbol (e.g. LVKgl).

The main soil series and variants used as the building blocks for map units that represent the soil patterns of the SSA are described briefly in Table 4.3, and more extensively in Appendix A. Soil information was obtained from 2,463 site inspections within the SSA. Other profile and analytical data was drawn from the Alberta Soil Name and Layer Files (ASIC 2001), the Alberta Oil Sands Environmental Research Program Study Area (Turchenek and Lindsay 1982b), and the CNRL Horizon Project to the north (Golder Associates 2002).

Table 4.3 List of Soil Series, Variants and Taxonomic Complexes used in the Joslyn SSA.

Code	Name	Subgroup†	Parent Material‡	Comments
ALG-pt*	Algar Lake – peaty*	Various peaty Luvic Gleysols	F1 or F3 – water-laid or lacustro-till	Complex based on ALG (peaty Orthic Luvic Gleysol); 15-40 cm of surface peat
ALG-np*	Algar Lake – non-peaty*	Various non-peaty Luvic Gleysols	F1 or F3 – water-laid or lacustro-till	Complex based on ALG (peaty Orthic Luvic Gleysol) but with < 15 cm of peat
BMT-pt*	Bitumount – peaty	Various peaty Gleysols	C2 – outwash sands	Complex based on BMT series (peaty Orthic Gleysol); 15-40 cm of surface peat
BMT-np*	Bitumount – non-peaty	Various non-peaty Gleysols	C2 – outwash sands	Complex based on BMT series (peaty Orthic Gleysol) but with < 15 cm of peat
BMTxc*	Bitumount-clayey subsoil	Various Gleysols	L9 – sands overlying lacustro-till	Sands 30-99 cm thick; peaty and non-peaty variants
CHT-pt*	Chateh – peaty*	Various peaty Gleysols	F1 or F3 – water-laid or lacustro-till	Complex based on CHT series (peaty Orthic Gleysol); 15-40 cm of surface peat
CHT-np*	Chateh – non-peaty*	Various non-peaty Gleysols	F1 or F3 – water-laid or lacustro-till	Complex based on CHT series (peaty Orthic Gleysol) but with < 15 cm of peat
DAN	Daphne	Eluviated Dystric Brunisol	L19 – stony drift over bedrock	Paralithic (some lithic) soils
DOV	Dover	Orthic Gray Luvisol	F3 or F4 – clayey lacustro-till or till	
FRT	Fort	Orthic Gray Luvisol	L18 – medium over coarse water-laid	Eluviated Dystric Brunisol (FRTzb) variant common
FRTxl	Fort-paralithic	Orthic Gray Luvisol	Shallow L18 materials overlying bedrock	Paralithic variant of FRT
HRR	Horse River	Orthic Gray Luvisol	M4 – medium textured till	Occurs with DOV on west side of SSA
KME	Kilome	Gleyed Gray Luvisol	F3 or F4 – clayey lacustro-till or till	Similar to DOV but with weak gleying (mottling)
LVKxc	Livock-clayey subsoil	Orthic Gray Luvisol	L10 – water-laid over lacustro-till or till	Water-laid veneer (30-99 cm) is medium textured
LVKgl	Livock-gleyed	Gleyed Gray Luvisol	L10 – water-laid over lacustro-till or till	Gleyed variant of LVK
MIL	Mildred	Eluviated Dystric Brunisol	C2 – outwash sands	

Table 4.3 List of Soil Series, Variants and Taxonomic Complexes used in the Joslyn SSA.				
Code	**Name**	**Subgroup†**	**Parent Material‡**	**Comments**
MILfi	Mildred-fine	Eluviated Dystric Brunisol	C3 – water-laid	Similar to MIL but dominated by SL textures
MILxc	Mildred-clayey subsoil	Eluviated Dystric Brunisol	L9 – sands overlying lacustro-till	Sands 30-99 cm thick over C textured lower parent material
MLD1*x**	McLelland – shallow peat*	Terric and related Mesisols/Fibrisols	L12 or L13 – shallow fen peat over mineral	40-100 cm peat; MLD1m – medium; MLD1c – clayey; MLD1s – sandy
MLD*	McLelland	Mesisols & Fibrisols	P2 – mainly fen peat	>100 cm peat
MMW-pt*	Mamawi – peaty*	Various peaty Gleysols	M3, L3, or L10 – mainly water-laid	Complex based on MMW series (Rego Gleysol) but with 15-40 cm of surface peat
MMW-np*	Mamawi – non-peaty*	Various non-peaty Gleysols	M3, L3, or L10 – mainly water-laid	Complex based on MMW series (Rego Gleysol); <15 cm of surface peat
MMY	McMurray	Cumulic Regosol	M2 – fluvial deposits	
MMYzhgl	McMurray – humic, gleyed	Gleyed Cumulic Humic Regosol	M2 – fluvial deposits	Variant of MMY series (Cumulic Regosol)
MMYgl	McMurray – gleyed	Gleyed Cumulic Regosol	M2 – fluvial deposits	Similar to MMYzhgl but less humus in topsoil
MMYxl	McMurray – paralithic	Cumulic Regosol	Shallow M2 deposits overlying bedrock	Paralithic variant of MMY
MUS1*x**	Muskeg – shallow peat*	Terric and related Mesisols/Fibrisols	L12 or L13 – shallow bog peat over mineral	40-100 cm peat; MUS1m – medium; MUS1c – clayey; MUS1s – sandy
MUS*	Muskeg	Mesisols & Fibrisols	P1 – mainly bog peat	>100 cm peat
PEA	Peavine	Orthic Gray Luvisol	M2 or M3 – water-laid	Eluviated Dystric Brunisol (PEAzb) variant common
PEAxl	Peavine-paralithic	Orthic Gray Luvisol	Shallow M2 or M3 deposits over bedrock	Paralithic variant of PEA
SEN	Steen	Solonetzic Gray Luvisol	F3 or F4 – clayey lacustro-till or till	Similar to DOV but with a Solonetzic-like Btnj horizon
WNFxc	Winefred-clayey subsoil	Orthic Gray Luvisol	L9 – sands overlying lacustro-till	Sands 30-99 cm thick over C textured lacustro-till;
WNFxl	Winefred-paralithic	Orthic Gray Luvisol	Shallow L9 materials overlying bedrock	Paralithic variant of WNF

*A taxonomic complex (i.e. conceptual grouping) of related soils – useful for describing the soils and making interpretations.
†Soil classification to the subgroup level based on the Canadian System of Soil Classification (SCWG 1998).
‡Refer to other sections of this report for parent material descriptions (Table 4.2) and textural groupings (Table A-1).

In some cases, it was expedient to use taxonomic complexes (groupings of related series and variants) to identify complex soil patterns and assess soil characteristics for interpretive ratings. Use of this convention was restricted to wetland soils. The best example involved the medium textured grouping of Gleysolic soils (Mamawi, MMW) where 10 different series and variants were identified in the field data. The most important parameter for interpretive ratings and reclamation planning was depth of peat; consequently the MMW series plus variants were dealt with as non-peaty and peaty complexes (Table 4.3).

4.3 Spatial Entities – Soil Map Units

With the completion of the parent material and soil classification phases, all soil inspection sites were categorized in terms of soil series/variants. This provided a gauge of the soil population in the project area. The next step was to determine which soil entities tended to occur together in the landscape, and to build map units with which to depict these distribution patterns.

4.3.1 The Soil Map Unit Symbol – Soil Landscape Models

Soil map unit symbols are based on the AGRASID model (ASIC 2001), also referred to as the **Soil Landscape Model** (**SLM**). They have a numerator that describes the soil patterns and a denominator that describes the landscape. The numerator (soil model) is created by using one or two soil series/variant symbols (e.g. LVK, DOKM) plus a numbering system (e.g. LVK4, DOKM2) that identifies recognizable patterns of soils. The named soils identify the dominant or co-dominant soil series or variants of the map unit; the one- or two-digit model number identifies significant soils that are part of the pattern. The denominator of the SLM symbol is the landscape model (LM), which describes the landform surface and topography.

A more in-depth explanation of the SLM, including a diagram showing its parts, is provided in Appendix B. As in the CNRL Horizon Project to the north (Golder Associates 2002), mineral and organic soil map units had different soil model numbering systems.

4.3.2 Mineral Soil Map Units

Mineral soil patterns were depicted with soil model symbols that use one or two soil series/variants codes for naming plus a soil model number as described above and in Appendix B. Soil model numbers identify recognizable patterns involving the dominant (60% or more) or co-dominant (30-60%) and significant (10-30%) soils. Soil model numbers used in the SSA, with area-specific definitions, are:

1 Relatively "pure" unit dominated by the named soil(s). Inclusions do occur but tend not to be extensive or important.

2 Soil model features significant wetland soils (Gleysolic and/or Organic) that occur in low-lying areas too small to map on their own. Dominant/co-dominant soils occupy drier "uplands".

4 Soil model features significant disturbed and/or eroded soils relating to natural disturbances such as occur along steep stream course and valley walls.

5 Soil model features significant finer textured soils compared to dominant/co-dominant soils.

6 Soil model features significant coarser textured soils compared to dominant/co-dominant soils.

9 Soil model features significant coarser textured soils (as in #6), and significant wetland soils (Gleysolic and/or Organic) that occur in low-lying areas too small to map on their own (as in #2).

10 Soil model features significant Solonetzic or Solonetzic-like (e.g. Solonetzic Gray Luvisol) soils where the dominant/co-dominant soils are not Solonetzic, and significant wetland soils (Gleysolic and/or Organic) that occur in low-lying areas too small to map on their own (as in #2).

11 Soil model features significant disturbed and/or eroded soils relating to natural disturbances such as occur along steep stream course and valley walls (as in #4), and significant coarser textured soils compared to the dominant/co-dominant soils (as in #6).

12 Soil model features significant Organic soils where the dominant/co-dominant soils are Gleysolic.

4.3.3 Organic Soil Map Units

Organic soil map units were identified somewhat differently than those dominated by mineral soils. To simplify the complexity of peat-dominated areas, the naming soil series were restricted to McLelland (MLD) or Muskeg (MUS). MLD was used with fen ecosite types, MUS with bog and poor fen vegetation. The numerical portion of the map unit symbol indicates depth of peat as follows.

1 Peat depth 40-100 cm

2 Peat depth 100-200 cm

3 Peat depth >200 cm

One of three lower case symbols indicates the dominant texture of the mineral substratum underlying the peat in Organic soils:

c Mineral substratum below peat is predominantly clayey.
m Mineral substratum below peat is predominantly medium textured.
s Mineral substratum below peat is predominantly sandy.

Map units dominated by Organic soils but containing significant Gleysolic soils were identified with a "-G" postscript in the symbol (e.g. MLD1m-G).

4.3.4 Landscape Models

The landscape model (LM) forms the denominator of the SLM symbol. The LM symbol combines surface form, slope class, and surface form modifier attributes that are used to describe the topographical features of landscapes. LMs are not coupled to genetic (parent) materials, and do not include all of the traditional surface form classes.

A more in-depth explanation of landscape models, including a table (Table B-1) listing those used for the Joslyn SSA soil map, is provided in Appendix B.

4.3.5 Soil Map Units (Soil Landscape Models) of Joslyn SSA

Thirty-three taxonomic entities (soil series, variants, and taxonomic complexes, Table 4.3) were organized into 57 soil map units (SLMs) representing common soil patterns found in the SSA. Two non-soil map units were also identified, bringing the total number of map units to 59.

Table 4.4 lists the 59 map units that cover the Joslyn SSA and provides a brief summary of selected features. Detailed descriptions are provided in Appendix B.

Soil patterns were mapped to a planned scale of 1:10,000. At this scale, the recommended minimum-sized polygon for differentiating highly contrasting soil patterns is 0.5 ha (0.5 cm^2 on the map; MSWG 1981). Averaged sized polygons at this scale should be about 10 ha (approximately 20 times the minimum size). The average size of soil map polygons covering the Joslyn SSA is 10.2 ha.

Soil maps for the SSA and LSA have been included as Figure 4.2 and 4.3. A full size copy (scale 1:10,000) is available upon request.

Table 4.4 Descriptive Summary of Soil Map Units (SLMs) of the Joslyn SSA.

SLM Symbol	Major Soil Series/Variants (Refer to Section 4.2.3)	Parent Material & Terrain (Refer to Section 4.2.2)
BMT5 L1	Co-dom: Wetland – Gleysolic (BMT & related variants) Signif: Finer textured soils (e.g. BMTxc)	Coarse (C2) and layered (L9; coarse over fine to medium) mainly water-laid sediments L1 – level plain; slope classes 1-2
CHMM1 FP3 CHMM1 U1l	Co-dom: Wetland – Gleysolic (CHT, MMW & related variants)	Fine (F1, F3), medium (M3) and layered (L3, L10) water-laid and glacial sediments FP3 – confined floodplain; slope classes 1-2 U1l – low-relief undulating; mainly class 2
DAPE6 HR2hr	Co-dom: Eluviated Dystric Brunisol (DAN) Co-dom: Orthic Gray Luvisol (PEA, PEAxl) Signif: Coarser textured soils (FRTxl, WNFxl)	Stony-cobbly, medium textured drift (L19), medium textured (M2, M3), and layered (L18, L20) water-laid materials over bedrock HR2hr – high-relief hummocky and ridged overlying bedrock at shallow depths; mainly class 5, some 6
DOKM2 U1h	Co-dom: Orthic Gray Luvisol (DOV) Co-dom: Gleyed Gray Luvisol (KME) Signif: Wetland – Gleysolic (e.g. CHT, ALG) & shallow Organic soils (e.g. MLD1m)	Clayey lacustro-till or till (F3, F4) U1h – high-relief undulating; mainly class 3, some 4
DOLV6 U1h	Co-dom: Upland soils – Orthic Gray Luvisols (DOV, LVKxc) Signif: Coarser textured soils (e.g. WNFxc, MILxc, FRT†)	Clayey (F3) lacustro-till and layered (L10 – medium over fine, L9 – coarse over fine, L18 – medium over coarse) deposits U1h – high-relief undulating; mainly class 3
DOLV9 H1l DOLV9 U1h DOLV9 U1l	Co-dom: Upland soils – Orthic Gray Luvisols (DOV, LVKxc) Signif: Imperfectly drained soils (KME, LVKgl) Signif: Coarser textured soils (e.g. WNFxc, MILxc, FRT†, PEA)	Clayey (F3) lacustro-till, layered (L10 – medium over fine, L9 – coarse over fine, L18 – medium over coarse), and medium (M2) textured deposits H1l – low-relief hummocky; class 4, some 5 U1h – high-relief undulating; mainly class 3 U1l – low-relief undulating; mainly class 2
DOSE1 H1l	Co-dom: Orthic Gray Luvisol (DOV) Co-dom: Solonetzic Gray Luvisol (SEN)	Clayey lacustro-till and till (F3, F4) H1l – low-relief hummocky; class 4, some 5
DOSE2 H1l	Co-dom: Upland Orthic (DOV) and Solonetzic (SEN) Gray Luvisols Signif: Wetland – Gleysolic (e.g. CHT, ALG) & shallow Organic soils (e.g. MLD1m)	Clayey lacustro-till or till (F3, F4) H1l – low-relief hummocky; class 4, some 5
DOV10 U1h DOV10 U1l	Dom: Orthic Gray Luvisol (DOV) Signif: Gleyed Gray Luvisol (KME, LVKgl) Signif: Solonetzic Gray Luvisol (SEN)	Clayey lacustro-till (F3) U1h – high-relief undulating; class 3-4 U1l – low-relief undulating; mainly class 2
FRDA6 R2lr	Co-dom: Orthic Gray Luvisol (FRT†, FRTxl) Co-dom: Eluviated Dystric Brunisol (DAN) Signif: Coarse textured soils (e.g. WNFxl, MILfi)	Layered (L18, L20), stony to cobbly, medium textured drift (L19), and other water-laid deposits (C3) commonly overlying bedrock R2lr – low-relief ridged overlying bedrock at shallow depths; classes 3 to 4
FRLV2 U1h FRLV2 U1l	Co-dom: Orthic Gray Luvisols (FRT†, LVKxc) Signif: Wetland – Gleysolic (e.g. MMW) & shallow Organic soils (e.g. MLD1m)	Layered (L18 – medium over coarse; L10 – medium over fine) deposits U1h – high-relief undulating; mainly class 3 U1l – low-relief undulating; mainly class 2

Table 4.4 Descriptive Summary of Soil Map Units (SLMs) of the Joslyn SSA.

SLM Symbol	Major Soil Series/Variants (Refer to Section 4.2.3)	Parent Material & Terrain (Refer to Section 4.2.2)
KMLVl U1h KMLVl U1l	Co-dom: Upland Gleyed Gray Luvisols (KME, LVKgl) Signif: Orthic Gray Luvisols (DOV, LVKxc)	Clayey lacustro-till (F3) and layered (L10 – medium over fine) deposits U1h – high-relief undulating, with shallow channels in some locations; mainly class 3 U1l – low-relief undulating; mainly class 2
KMLV2 U1h KMLV2 U1l	Co-dom: Upland Gleyed Gray Luvisols (KME, LVKgl) Signif: Wetland – Gleysolic (ALG, CHT, MMW) & shallow Organic soils (e.g. MLD1m) Signif: Orthic Gray Luvisols (DOV, LVKxc)	Clayey lacustro-till (F3) and layered (L10 – medium over fine) deposits U1h – high-relief undulating; mainly class 3 U1l – low-relief undulating; mainly class 2
LVK4 I5	Dom: Orthic Gray Luvisol (LVKxc) Signif: Naturally disturbed (eroded) soils (Brunisols and Regosols)	Layered (L10 – medium over fine) deposits I5 – inclined to steep valley walls with failure slumps in some areas, dissections in others; slope classes 5-7
LVK11 I4 LVK11 I5	Dom: Orthic Gray Luvisol (LVKxc) Signif: Naturally disturbed (eroded) soils (Regosols and Brunisols) Signif: Coarser textured variants (e.g. WNFxc, MILfi) Signif: Paralithic/lithic variants of above soils (LVK11/I4 only)	Layered (L10 – medium over fine, L9 – coarse over fine to medium) deposits I4 – inclined to steep valley walls with >10% exposed bedrock; some failure slumps and dissections; slope classes mainly 6-8 I5 – inclined to steep valley walls with failure slumps in some areas, dissections in others; slope classes 5-7
MIFR5 U1h MIFR5 U1l	Co-dom: Eluviated Dystric Brunisol (MIL) Co-dom: Orthic Gray Luvisol (FRT†) Signif: Finer textured (including layered) soils (PEA†, MILfi, WNFxc, MILxc)	Coarse (C2, C3), layered (L18 – medium over coarse, L9 – coarse over fine to medium), and medium (M2, M3) water-laid deposits U1h – high-relief undulating; mainly class 3 U1l – low-relief undulating; mainly class 2
MIL1 U1h	Dom: Eluviated Dystric Brunisol (MIL)	Very coarse (C2) glaciofluvial material U1h – high-relief undulating with some ridges (dunes) and hummocks; mainly class 3, some 4
MIL5 U1h	Dom: Eluviated Dystric Brunisol (MIL) Signif: Finer textured & layered soils (FRT†, MILfi, WNFxc, MILxc)	Coarse (C2, C3) and layered (L18 – medium over coarse, L9 – coarse over fine to medium) deposits U1h – high-relief undulating with some ridges (dunes) and hummocks; mainly class 3, some 4
MLD1c-G O3	Dom: Wetland – Organic (MLD1c complex) Signif: Wetland – Gleysolic (ALG, CHT, MMW & related variants)	Shallow (40-100 cm) fen peat over clayey materials (L13) O3 – confined floodplain with channels; slope classes 1-2 O5 – "level" organic landform with undulating to hummocky surface; slope classes 2-4
MLD1m-G O3 MLD1m-G O5	Dom: Wetland – Organic (MLD1m complex) Signif: Wetland – Gleysolic (MMW complex)	Shallow (40-100 cm) fen peat over medium textured materials (L12) O3 – confined floodplain with channels; slope classes 1-2 O5 – "level" organic landform with undulating to hummocky surface; slope classes 2-4
MLD1s-G O5	Dom: Wetland – Organic (MLD1s complex) Signif: Wetland – Gleysolic (BMT complex)	Shallow (40-100 cm) fen peat over coarse textured materials (L11) O5 – "level" organic landform with undulating to hummocky surface; slope classes 2-4

Table 4.4 Descriptive Summary of Soil Map Units (SLMs) of the Joslyn SSA.

SLM Symbol	Major Soil Series/Variants (Refer to Section 4.2.3)	Parent Material & Terrain (Refer to Section 4.2.2)
MLD2c O1	Dom: Wetland – Organic (MLD series and variants)	Moderately deep (100-200 cm) fen peat over clayey textured materials (mainly P2) O1 – "level" wetland; slope classes 1-3
MLD2m O1	Dom: Wetland – Organic (MLD series and variants)	Moderately deep (100-200 cm) fen peat over medium textured materials (mainly P2) O1 – "level" wetland; slope classes 1-3
MLD2s O1	Dom: Wetland – Organic (MLD series and variants)	Moderately deep (100-200 cm) fen peat over coarse textured materials (mainly P2) O1 – "level" wetland; slope classes 1-3
MLD3 O2	Dom: Wetland – Organic (MLD series and variants)	Deep (>200 cm) fen peat over various mineral materials (P2) O2 – basin (bowl) wetland; slope classes 1-3
MMW2 FP3	Co-dom: Wetland – Gleysolic (MMW complex) Co-dom: Water bodies	Medium (M3) and layered (L10 – medium over fine) deposits FP3 – confined floodplain; slope classes 1-2
MMW21 U1h MMW21 U1l	Co-dom: Wetland – Gleysolic (MMW complex) Signif: Wetland – Organic (MLD1m complex) Signif: Wetland – fine (ALG, CHT) & coarse (BMTxc) textured Gleysols	Medium (M2, M3), layered (L9, L10), and fine (F1, F3) deposits with areas of shallow (40-100 cm) peat U1h – high-relief undulating; mainly class 3 U1l – low-relief undulating; mainly class 2
MMY2 SC1 MMY2 SC2	Co-dom: Regosolic soils (MMY) Co-dom: gleyed Regosolic soils (MMYzhgl & MMYgl variants) Signif: Wetland – Gleysolic (CHT & MMW variants)	Medium textured (M2, M3) and layered (L10, L20) fluvial sediments SC1 – valley-bottom floodplain with channels; slope classes 3-5 SC2 – Terraced valley bottom with risers and channels; slope classes 2-3, some 4-5
MMY6 SC2r	Dom: Regosolic soils (MMY) Signif: Coarser textured (MIL variants) Signif: Paralithic/lithic variants (MMYxl, MILxl)	Medium (M2, M3) and coarse textured (C2, C3) fluvial sediments; shallow over bedrock SC2r – Terraced valley bottom with risers and channels; slope classes 2-3, minor 4-5
MUS1c-G O5	Dom: Wetland – Organic (MUS1c complex) Signif: Wetland – Gleysolic (ALG, CHT, MMW & related variants)	Shallow (40-100 cm) bog peat over fine textured materials (L13) O5 – "level" organic landform with undulating to hummocky surface; slope classes 2-4
MUS1m-G O5	Dom: Wetland – Organic (MUS1m complex) Signif: Wetland – Gleysolic (ALG, CHT, MMW & related variants)	Shallow (40-100 cm) bog peat over medium textured materials (L12) O5 – "level" organic landform with undulating to hummocky surface; slope classes 2-4
MUS1s-G O5	Dom: Wetland – Organic (MUS1s complex) Signif: Wetland – Gleysolic (BMT complex)	Shallow (40-100 cm) bog peat over coarse textured materials (L11) O5 – "level" organic landform with undulating to hummocky surface; slope classes 2-4
MUS2c O1	Dom: Wetland – Organic (MUS series and variants)	Moderately deep (100-200 cm) bog peat over fine textured materials (mainly P1) O1 – "level" wetland; slope classes 1-3
MUS2m O1	Dom: Wetland – Organic (MUS series and variants)	Moderately deep (100-200 cm) bog peat over medium textured materials (mainly P1) O1 – "level" wetland; slope classes 1-3
MUS3 O2	Dom: Wetland – Organic (MUS series and variants)	Deep (>200 cm) fen peat over various mineral materials (P1) O2 – basin (bowl) wetland; slope classes 1-3

Table 4.4 Descriptive Summary of Soil Map Units (SLMs) of the Joslyn SSA.		
SLM Symbol	**Major Soil Series/Variants (Refer to Section 4.2.3)**	**Parent Material & Terrain (Refer to Section 4.2.2)**
PEA9 U1h PEA9 U1l	Dom: Orthic Gray Luvisol (PEA†) Signif: Coarser textured soils (FRT†, WNFxc, MILxc) Signif: Wetland – Gleysolic (MMW complex)	Medium textured (M2, M3) and layered (L18 – medium over coarse; L9 – coarse over fine to medium) deposits U1h – high-relief undulating; class 3, some 4 U1l – low-relief undulating; mainly class 2
PELV1 L3 PELV1 U1h	Co-dom: Orthic Gray Luvisols (PEA, LVKxc)	Medium textured (M2, M3) and layered (L10 – medium over fine) deposits L3 – level and terraced; slope classes 2-3 U1h – high-relief undulating, often with shallow channels; mainly class 3, some 4
PELV11 SC2	Co-dom: Orthic Gray Luvisols (PEA, LVKxc) Signif: Coarser textured (MIL & related variants) Signif: Regosolic soils (e.g. MMY and variants)	Medium (M2, M3), layered (L10, L9), and coarse (C2, C3) deposits SC2 – Terraced valley bottom with risers and channels; slope classes 2-3, minor 4-5
PEWN1 HR2mr	Co-dom: Orthic Gray Luvisols (PEA†, WNFxc, MILxc) Co-dom: Paralithic/lithic variants (e.g. PEAxl, WNFxl)	Medium (M2, M3) and layered (L9 – coarse over fine to medium) deposits; some bedrock HR2mr – moderate-relief hummocky and ridged overlying bedrock at shallow depths; mainly class 4, some 5
PEWN1 U1h PEWN1 U1l	Co-dom: Orthic Gray Luvisols (PEA†, WNFxc, MILxc)	Medium (M2, M3) and layered (L9 – coarse over fine to medium) deposits; stony in places U1h – high-relief undulating with some ridges and hummocks; mainly class 3, some 4 U1l – low-relief undulating(with some terraces); mainly class 2
Water	Dom: Water bodies (mainly ponds, lakes & sloughs)	Water bodies; also floating organic material in NWF ecosite phase areas
ZDL	Disturbed and reconstructed land	Undifferentiated disturbed/reconstructed soils

†Named soils classed as Orthic Gray Luvisols; similar Eluviated Dystric Brunisols also usually occur

4.4 Soils of the Regional Study Area (RSA)

A regional study area (RSA), described in Section 2.0 and outlined in Figure 2.1, was selected to assess potential cumulative effects linked to atmospheric deposition of acidifying substances on soils. Generalized soil survey information was compiled for the RSA from existing sources. The compilation procedure and soil map results are presented in the following sections.

4.4.1 Generalized Soil Map Compilation

A geographic information system (GIS) facilitated the layering and visual integration of the main data sources in a fashion similar to that used for mapping the Joslyn SSA. Starting layer for the generalized RSA soil map was the 1:500,000 scale map of "soil parent materials in the AOSERP Study Area" (Turchenek and Lindsay 1982a). After the parent materials map was scanned and digitized, the resulting map layer was overlaid on scanned images of AOSERP soil maps (Turchenek and Lindsay 1982a), from which dominant and subordinate soil units were selected to identify initial RSA polygons. Some of the largest initial polygons were split into smaller polygons, based on interpreted soil patterns, during this process.

Soil units used on the AOSERP maps had been labelled with soil names used throughout NE Alberta at that time (Turchenek and Lindsay 1982a). The RSA mapping process included updating old names (e.g. Kenzie, Eaglesham, and Heart) with new names (e.g. Muskeg, McLelland, and Marguerite) from ABSNF lists for Soil Correlation Areas 19 and 20 (ASIC 2001). Through the iterative review and soil assessment processes, the RSA soil map and map unit concepts were refined.

4.4.2 RSA Soil Map Units

Because of the relatively small scale and level of information that can be portrayed, the soils of the Joslyn RSA are depicted by map units based on established soil series names. They do not represent soil series, but can be represented by dominant or co-dominant soil series. For example, polygons mapped as ALG are best represented by Algar Lake series but contain many other types of soils as well, including related soils of both upland (dryland) and wetland landscapes.

To further the example, AOSERP soil units amalgamated into the simplified RSA soil map units had already been generalized. ALG1 soil unit defined by Turchenek and Lindsay (1982a) is comprised of peaty Gleysols (dominant), Gleyed Gray Luvisols (significant soils), and Orthic Gray Luvisols (inclusions). In this system, peaty Gleysols of the Algar soil group likely include Algar and Chateh series and a number of related variants.

Despite this acknowledged variability, the "root" soil series – Algar Lake (ALG) in the examples – provide the link to various soil characteristics needed to assess landscapes for sensitivity to acid deposition and other interpretative classifications. In other words, the dominant (or co-dominant) soils that "name" the soil map units must also be considered as proxies for the variety of related soils that can also occur in the same landscapes.

To further confound the issue, many polygons on the AOSERP maps (Turchenek and Lindsay 1982a) are identified by dominant and subordinate (or subdominant) soil units. For example, MUS1-ALG1 identifies areas with both Organic (bog Mesisols) and peaty Gleysol soils. Mixtures of mineral with organic soil groups were particularly common. These combinations were defined by Turchenek and Lindsay (1982a) as the first soil unit being predominant (>50% of the polygon) and the second being subdominant (<50% of the polygon). This mapping convention was also used in amalgamating AOSERP soil units for the generalized soil map of the Joslyn RSA. Where two names identify an area (e.g. MUS ALG), proportions were arbitrarily set at 60% first soil and 40% second soil.

The RSA soil map units, many of which are unique because of the compilation process, are listed and briefly described in Table 4.4. The RSA soil map (Figure 4.4) is presented at a scale of 1:600,000.

4.5 Map Unit Areas

Map unit areas and polygon counts were calculated using ArcMap GIS software; averages were computed using MS Excel. Results for the RSA (Table 4.5), SSA (Table 4.6), and the proposed Joslyn North Mine development footprint (Table 4.7) are presented in this section.

Map unit (SLM) areas, polygon counts, and related information for the Joslyn SSA are presented in Table 4.6. Total area of the SSA is 21,842 ha, and is covered by 2,139 soil map polygons. Average size of polygon on the SSA map is 10.2 ha.

The map unit with the largest area, proportion of the SSA, and largest average polygon size is DOSE1/H1l. MLD2c/O1 has the smallest area, proportion, and average polygon size within the SSA. MUS1m-G/O5 has the largest number of polygons in the SSA, with an average polygon size of 10.4 ha.

Table 4.5 Soil Map Units of the RSA (adapted from Turchenek and Lindsay 1982a).

Map Unit			Generalized Characteristics	
Code	**Name**	**SCA**	**Classification**	**Parent Materials**
BKN	Buckton	19	Gray Luvisols & Regosols	Loamy to clayey colluvial material
DOV	Dover	20	Orthic Gray Luvisol	Clayey glaciolacustrine and till
DOV ALG	Dover-Algar	20	Orthic Gray Luvisol; Peaty Gleysols	Clayey glaciolacustrine and till
DOV MIL	Dover-Mildred	20	Orthic Gray Luvisol; Eluviated Dystric Brunisol	Clayey glaciolacustrine and till; sandy glaciofluvial (outwash)
DOV RUT	Dover-Ruth Lake	20	Orthic Gray Luvisol; Eutric & Dystric Brunisols	Clayey glaciolacustrine and till; sandy & gravelly glaciofluvial
DOV SEN	Dover-Steen	20	Orthic Gray Luvisol; Solonetzic Gray Luvisol	Clayey glaciolacustrine and till
DOV STP	Dover-Steepbank	20	Orthic Gray Luvisol; peaty Gleysols	Clayey glaciolacustrine and till; loamy to clayey, acid to neutral till
FIR	Firebag	20/19	Eluviated Dystric Brunisol	Gravelly-stony glaciofluvial sands
FIR MUS	Firebag-Muskeg	20	Eluviated Dystric Brunisol; Organic soils (bog)	Gravelly-stony glaciofluvial sands; fibric & mesic peats (bog)
HRR	Horse River	20	Orthic Gray Luvisol	Loamy to clayey till
HRR LVK	Horse River-Livock	20	Orthic Gray Luvisol	Loamy to clayey till; glaciolacustrine/fluvial over till
KNS	Kinosis	20	Orthic Gray Luvisol	Loamy, acid to neutral till
KNS LVK	Kinosis-Livock	20	Orthic Gray Luvisol	Loamy, acid to neutral till; glaciolacustrine/fluvial over till
KNS MIL	Kinosis-Mildred	20	Orthic Gray Luvisol; Eluviated Dystric Brunisol	Loamy, acid to neutral till; sandy glaciofluvial (outwash)
KNS MUS	Kinosis-Muskeg	20	Orthic Gray Luvisol; Organic soils (bog)	Loamy, acid to neutral till; fibric & mesic peats (bog)
KNS STP	Kinosis-Steepbank	20	Orthic Gray Luvisol; peaty Gleysols	Loamy to clayey, acid to neutral till
LGD MKW	Legend-Mikkwa	19	Orthic Gray Luvisol; Organic Cryosols	Loamy to clayey till; fibric & mesic peats (bog)
LVK	Livock	20	Orthic Gray Luvisol	Glaciolacustrine/fluvial over till
LVK MAR	Livock-Marguerite	20	Orthic Gray Luvisol; Eluviated Dystric Brunisol	Glaciolacustrine/fluvial over till; sandy eolian material
LVK MLD	Livock-McLelland	20	Orthic Gray Luvisol; Organic soils (fen)	Glaciolacustrine/fluvial over till; mesic & fibric peats (fen)
MAR	Marguerite	20	Eluviated Dystric Brunisol	Sandy eolian material
MIL	Mildred	20	Eluviated Dystric Brunisol	Sandy glaciofluvial (outwash)

Table 4.5 Soil Map Units of the RSA (adapted from Turchenek and Lindsay 1982a).

Map Unit			Generalized Characteristics	
Code	**Name**	**SCA**	**Classification**	**Parent Materials**
MIL BMT	Mildred-Bitumount	20	Eluviated Dystric Brunisol; peaty Gleysols	Sandy glaciofluvial (outwash)
MIL MAR	Mildred-Marguerite	20	Eluviated Dystric Brunisol	Sandy glaciofluvial (outwash); sandy eolian material
MIL STP	Mildred-Steepbank	20	Eluviated Dystric Brunisol; peaty Gleysols	Sandy glaciofluvial (outwash); loamy to clayey, acid to neutral till
MKW FIR	Mikkwa-Firebag	19	Organic Cryosols; Eluviated Dystric Brunisol	Fibric & mesic peats (bog); gravelly-stony glaciofluvial sands
MKW LGD	Mikkwa-Legend	19	Organic Cryosols; Orthic Gray Luvisol	Fibric & mesic peats (bog); loamy to clayey till
MLD	McLelland	20	Organic soils (fen)	Mesic & fibric peats (fen)
MMY	McMurray	20	Regosolic soils	Sandy to clayey fluvial (channel)
MUS	Muskeg	20	Organic soils (bog)	Fibric & mesic peats (bog)
MUS ALG	Muskeg-Algar	20	Organic soils (bog); peaty Gleysols	Fibric & mesic peats (bog); clayey glaciolacustrine and till
MUS KNS	Muskeg-Kinosis	20	Organic soils (bog); Orthic Gray Luvisol	Fibric & mesic peats (bog); loamy, acid to neutral till
MUS MAR	Muskeg-Marguerite	20	Organic soils (bog); Eluviated Dystric Brunisol	Fibric & mesic peats (bog); sandy eolian material
MUS MIL	Muskeg-Mildred	20	Organic soils (bog); Eluviated Dystric Brunisol	Fibric & mesic peats (bog); sandy glaciofluvial (outwash)
MUS MLD	Muskeg-McLelland	20	Organic soils (bog); Organic soils (fen)	Fibric & mesic peats (bog); mesic & fibric peats (fen)
MUS SEN	Muskeg-Steen	20	Organic soils (bog); Solonetzic Gray Luvisol	Fibric & mesic peats (bog); clayey glaciolacustrine and till
MUS STP	Muskeg-Steepbank	20	Organic soils (bog); peaty Gleysols	Fibric & mesic peats (bog); loamy to clayey, acid to neutral till
NAM	Namur	20	Regosolic soils	Sandy to clayey fluvial (fan/apron)
RUT	Ruth Lake	20	Eutric/Dystric Brunisols	Sandy & gravelly glaciofluvial
RUT MIL	Ruth Lake-Mildred	20	Eutric/Dystric Brunisols	Sandy & gravelly glaciofluvial; sandy glaciofluvial (outwash)
RUT MMY	Ruth Lake-McMurray	20	Eutric/Dystric Brunisols; Regosolic soils	Sandy & gravelly glaciofluvial; sandy to clayey fluvial (channel)
SEN	Steen	20	Solonetzic Gray Luvisol	Clayey glaciolacustrine and till
SRT	Surmount	19/20	Orthic Gray Luvisol	Loamy to clayey, acid till
STP MUS	Steepbank-Muskeg	20	Peaty Gleysols; Organic soils (bog)	Loamy to clayey, acid to neutral till; fibric & mesic peats (bog)
W	Water (lakes & river)	19/20	N/A	N/A
ZRB	"Rough Broken"	20	Undifferentiated	Undifferentiated

Table 4.6 Soil Map Unit Counts and Area Calculations for the RSA (soils).				
RSA MU	**Area (ha)**	**% of RSA**	**Polygon Count**	**Average Size (ha)**
BKN	20,075	1.8	5	4,015
DOV	18,018	1.6	4	4,504
DOV ALG	12,653	1.1	1	12,653
DOV MIL	3,201	0.3	1	3,201
DOV RUT	3,104	0.3	1	3,104
DOV SEN	66,908	6.0	2	33,454
DOV STP	9,727	0.9	1	9,727
FIR	38,704	3.5	4	9,676
FIR MUS	5,063	0.5	1	5,063
HRR	4,696	0.4	2	2,348
HRR LVK	15,991	1.4	1	15,991
KNS	10,071	0.9	5	2,014
KNS LVK	9,253	0.8	1	9,253
KNS MIL	4,567	0.4	1	4,567
KNS MUS	9,033	0.8	2	4,517
KNS STP	8,597	0.8	1	8,597
LGD MKW	52,337	4.7	2	26,168
LVK	1,991	0.2	3	664
LVK MAR	4,148	0.4	2	2,074
LVK MLD	2,928	0.3	1	2,928
MAR	16,272	1.5	2	8,136
MIL	18,542	1.7	4	4,635
MIL BMT	10,053	0.9	2	5,027
MIL MAR	83,603	7.5	3	27,868
MIL STP	6,286	0.6	6	1,048
MKW FIR	10,224	0.9	2	5,112
MKW LGD	15,309	1.4	3	5,103
MLD	11,793	1.1	3	3,931
MMY	25,566	2.3	8	3,196
MUS	54,745	4.9	17	3,220
MUS ALG	14,659	1.3	2	7,330
MUS KNS	20,286	1.8	4	5,071
MUS MAR	82,978	7.5	3	27,659
MUS MIL	2,241	0.2	1	2,241
MUS MLD	56,552	5.1	8	7,069
MUS SEN	32,955	3.0	1	32,955
MUS STP	141,097	12.7	11	12,827
NAM	29,533	2.7	1	29,533
RUT	14,920	1.3	8	1,865
RUT MIL	10,391	0.9	1	10,391
RUT MMY	2,613	0.2	1	2,613
SEN	73,902	6.7	6	12,317
SRT	14,475	1.3	1	14,475
STP MUS	1,085	0.1	1	1,085
W	14,554	1.3	9	1,617
ZRB	45,224	4.1	19	2,380
TOTALS	1,110,924	100.0	168	6,613

Table 4.7 Soil Map Unit (SLM) Counts and Area Calculations for the Joslyn SSA.

SLM	Area (ha)	% of SSA	Polygon Count	Average Size (ha)
BMT5/L1	83	0.4	15	5.5
CHMM1/FP3	635	2.9	91	7.0
CHMM1/U1l	314	1.4	66	4.8
DAPE6/HR2hr	112	0.5	11	10.2
DOKM2/U1h	189	0.9	26	7.3
DOLV6/U1h	84	0.4	10	8.4
DOLV6/U1l	143	0.7	17	8.4
DOLV9/H1l	61	0.3	6	10.2
DOLV9/U1h	591	2.7	39	15.1
DOLV9/U1l	778	3.6	87	8.9
DOSE1/H1l	2608	11.9	51	51.1
DOSE2/H1l	349	1.6	15	23.2
DOV10/U1h	1378	6.3	53	26.0
DOV10/U1l	225	1.0	15	15.0
FRDA6/R2lr	60	0.3	15	4.0
FRLV2/U1h	66	0.3	14	4.7
FRLV2/U1l	67	0.3	14	4.8
KMLV1/U1h	583	2.7	31	18.8
KMLV1/U1l	586	2.7	59	9.9
KMLV2/U1h	315	1.4	51	6.2
KMLV2/U1l	483	2.2	96	5.0
LVK11/I4	133	0.6	6	22.1
LVK11/I5	528	2.4	16	33.0
LVK4/I5	185	0.8	20	9.2
MIFR5/U1h	288	1.3	40	7.2
MIFR5/U1l	77	0.4	18	4.3
MIL1/U1h	317	1.4	24	13.2
MIL5/U1h	330	1.5	29	11.4
MLD1c-G/O3	98	0.4	9	10.9
MLD1c-G/O5	82	0.4	14	5.9
MLD1m-G/O3	517	2.4	89	5.8
MLD1m-G/O5	341	1.6	56	6.1
MLD1s-G/O5	26	0.1	6	4.3
MLD2c/O1	11	0.0	4	2.7
MLD2m/O1	378	1.7	49	7.7
MLD2s/O1	34	0.2	3	11.4
MLD3/O2	30	0.1	10	3.0
MMW2/FP3	231	1.1	49	4.7
MMW21/U1h	28	0.1	6	4.7
MMW21/U1l	85	0.4	15	5.7
MMY2/SC1	516	2.4	51	10.1
MMY2/SC2	216	1.0	69	3.1
MMY6/SC2r	51	0.2	10	5.1
MUS1c-G/O5	1971	9.0	59	33.4
MUS1m-G/O5	1385	6.3	133	10.4
MUS1s-G/O5	132	0.6	15	8.8
MUS2c/O1	629	2.9	57	11.0
MUS2m/O1	926	4.2	93	10.0
MUS3/O2	465	2.1	105	4.4

Table 4.7	**Soil Map Unit (SLM) Counts and Area Calculations for the Joslyn SSA.**			
SLM	**Area (ha)**	**% of SSA**	**Polygon Count**	**Average Size (ha)**
PEA9/U1h	52	0.2	6	8.6
PEA9/U1l	52	0.2	18	2.9
PELV1/L3	127	0.6	28	4.5
PELV1/U1h	192	0.9	11	17.4
PELV11/SC2	633	2.9	103	6.1
PEWN1/HR2mr	123	0.6	21	5.8
PEWN1/U1h	172	0.8	28	6.1
PEWN1/U1l	201	0.9	24	8.4
Water	251	1.2	42	6.0
ZDL	322	1.5	21	15.3
TOTALS	**21,842**	**100**	**2,139**	**10.2**

Table 4.7 lists areas and counts of SLM map units that cover the proposed North Mine development footprint. The map unit with the largest area, proportion of the footprint, and largest number of polygons is MUS1m-G/O5. As in the SSA, DOSE1/H1l has the largest average polygon size.

While efforts were made to meet accepted mapping conventions for minimum-sized polygons and unique map units (Section 4.3) in the SSA, such was not the case for the LSA and Joslyn North Mine footprint areas. Instead, LSA and footprint boundaries were overlaid on the SSA soil map, and information was "clipped" to these smaller study areas using GIS techniques. Consequently, there are several SLMs represented by only 1 or 2 polygons. MLD3/O2 is one of those map units, and accounts for the smallest area of the footprint (about 1 ha). MLD3/O2 and "Water" map units account for the smallest proportion (0.03%) of the proposed footprint area. Areas mapped as "Water" also have the smallest average size.

Table 4.8	**Soil Map Unit (SLM) Count and Area Calculations for the Joslyn North Mine Development Footprint.**			
SLM	**Area (ha)**	**% of Footprint**	**Polygon Count**	**Avg Size (ha)**
BMT5/L1	78	1.5	15	5.2
CHMM1/FP3	41	0.8	13	3.1
CHMM1/U1l	176	3.5	32	5.5
DOKM2/U1h	27	0.5	5	5.5
DOLV6/U1h	14	0.3	4	3.6
DOLV9/H1l	10	0.2	1	10.0
DOLV9/U1h	235	4.6	15	15.7
DOLV9/U1l	104	2.0	23	4.5
DOSE1/H1l	128	2.5	4	31.9
DOV10/U1h	194	3.8	22	8.8
DOV10/U1l	59	1.2	11	5.4
FRLV2/U1h	62	1.2	14	4.4
FRLV2/U1l	60	1.2	13	4.6
KMLV1/U1h	200	3.9	15	13.3
KMLV1/U1l	183	3.6	16	11.5
KMLV2/U1h	96	1.9	16	6.0
KMLV2/U1l	125	2.5	24	5.2
LVK11/I5	71	1.4	4	17.6

Table 4.8 Soil Map Unit (SLM) Count and Area Calculations for the Joslyn North Mine Development Footprint.				
SLM	**Area (ha)**	**% of Footprint**	**Polygon Count**	**Avg Size (ha)**
LVK4/I5	37	0.7	8	4.6
MIFR5/U1h	267	5.2	39	6.8
MIFR5/U1l	46	0.9	13	3.6
MIL1/U1h	316	6.2	24	13.2
MIL5/U1h	321	6.3	27	11.9
MLD1c-G/O3	10	0.2	4	2.5
MLD1c-G/O5	37	0.7	5	7.4
MLD1m-G/O3	54	1.1	17	3.2
MLD1m-G/O5	163	3.2	32	5.1
MLD1s-G/O5	15	0.3	5	2.9
MLD2c/O1	4	0.1	3	1.4
MLD2m/O1	142	2.8	24	5.9
MLD2s/O1	34	0.7	3	11.4
MLD3/O2	1	0.0	1	1.3
MMW2/FP3	45	0.9	12	3.8
MMW21/U1h	24	0.5	6	4.0
MMW21/U1l	55	1.1	8	6.9
MMY2/SC1	69	1.4	9	7.6
MMY6/SC2r	31	0.6	1	31.0
MUS1c-G/O5	298	5.8	22	13.5
MUS1m-G/O5	673	13.2	64	10.5
MUS1s-G/O5	125	2.5	14	8.9
MUS2c/O1	93	1.8	13	7.1
MUS2m/O1	142	2.8	16	8.9
MUS3/O2	51	1.0	5	10.1
PELV1/U1h	30	0.6	3	10.0
PELV11/SC2	48	0.9	11	4.4
PEWN1/U1h	8	0.2	4	2.0
PEWN1/U1l	2	0.0	1	2.4
Water	2	0.0	2	0.9
ZDL	91	1.8	9	10.1
TOTALS	**5097**	**100**	**652**	**7.9**

5.0 Baseline Land Capability

5.1 Thickness of Soil Layers

Average depths of forest litter, peat on wetland soils, and topsoil are an important part of interpretive assessments for soils. Organic material, topsoil, and subsoil layers were defined as follows during the data capture and logging process:

- Organic, Forest Litter – L, F, and H horizons, commonly combined as LF or LFH and occurring on the mineral soil surface.
- Organic, Peat – Peaty organic horizons (Of, Om, and Oh) occurring at the soil surface were summed to determine depth of peat.
- Topsoil – Ae, Ah, Ahe, AB, AC, A+C, O+C, C+O, and gleyed and weakly gleyed versions of these horizons were usually considered to be part of the topsoil. BA horizons might also be

considered as belonging to the topsoil if they occurred at the mineral surface and there were no other topsoil horizons.

- Upper Subsoil – all types of B horizons (Bm, Bt, Bg, Bnt), plus gleyed (g) and juvenile (j) versions of them were considered to be part of the upper subsoil for depth calculations. BA horizons were also included if they were transitional to an underlying B horizon. In most rating systems, the upper subsoil extends from the bottom of the topsoil to 50 cm depth.
- Lower Subsoil – generally considered to be BC and C horizons of all types. In most interpretive rating systems, the lower subsoil extends from 50 to 100 cm below the mineral surface.

The complete Joslyn SSA data set was analyzed to determine average thicknesses of soil layers. Thickness data for organic layers, topsoil, and upper subsoil were grouped by soil model (SM, Section 4.3.1) and averaged. Minor, highly contrasting sites and unknowns (early season frozen sites) were excluded from the calculations.

Results for soil models are listed in Table 5.1 and displayed in map form for the area around the proposed Joslyn North Mine footprint (Figure 5.1). Several soil models had substantial variability in their data sets. It was therefore practical to round the reported results, especially for calculating lift and salvage volumes. Results for litter layers were not rounded. Results for peat and mineral layers were rounded:

- to the nearest 5 cm if averages were in the 10-25 cm range, or
- to the nearest 10 cm for most averages above 25 cm thickness.

The same process was used to calculate average thicknesses of soil layers for individual soil series, variants, or complexes (peaty vs. non-peaty Gleysols) where the results were needed for performing interpretive assessments.

5.2 Land Capability Classification for Forest Ecosystems

5.2.1 Procedure for Assessing Land Capability

Soil series and variants were used as the building blocks for rating soil landscapes according to the Land Capability Classification for Forest Ecosystems in the Oil Sands (Leskiw 1998). Typically, analytical data for soils is appropriately available only at the series level. For any use or management of land however, it is far easier to deal at the map unit (i.e. landscape) level than at the individual soil series level. Consequently, procedures to "scale-up" taxonomic data to landscapes are needed.

Table 5.1 Soil Layer (Organic, Topsoil, Upper Subsoil) Thicknesses by Soil Model (SM portion of SLM).

Soil Model (SM)	Thickness (cm)*		
	Litter/Peat	Topsoil	Upper Subsoil
BMT5	25	15	50
CHMM1	15	15	25
DAPE6	7	20	35†
DOKM2	7	15	25
DOLV6	5	20	30
DOLV9	7	20	30
DOSE1	7	15	30
DOSE2	7	10	25

Table 5.1 Soil Layer (Organic, Topsoil, Upper Subsoil) Thicknesses by Soil Model (SM portion of SLM).

Soil Model (SM)	Thickness (cm)*		
	Litter/Peat	Topsoil	Upper Subsoil
DOV10	7	15	25
FRDA6	7	20	40†
FRLV2	11	25	60
KMLV1	8	20	25
KMLV2	11	15	30
LVK4	9	15	35
LVK11	9	10	20†
MIFR5	6	25	70
MIL1	6	25	70
MIL5	8	25	75
MLD1c-G	50	5	10
MLD1m-G	60	5	20
MLD1s-G	60	10	30
MLD2c	130	n/a	n/a
MLD2m	130	n/a	n/a
MLD2s	130	n/a	n/a
MLD3	250	n/a	n/a
MMW2	15	10	10
MMW21	20	20	30
MMY2	8	15	15
MMY6	4	5	0†
MUS1c-G	60	5	10
MUS1m-G	50	5	25
MUS1s-G	60	5	40
MUS2c	140	n/a	n/a
MUS2m	140	n/a	n/a
MUS3	250	n/a	n/a
PEA9	8	20	40
PELV1	6	20	25
PELV11	6	15	40
PEWN1	6	20	50
PEWN1 (lithic)	8	30	20†
Water	n/a	n/a	n/a
ZDL	n/a	n/a	n/a

*Rounded to the nearest 5 or 10 cm for all but litter (LF, LFH) layers
†Bedrock common in indicated soil units, and may limit soil profile depth

Use of weighted averages is a suitable approach and has been recently used for determining land capability. Even in landscapes with drastically different and obvious soil patterns (e.g. dry upland with small discrete wetlands), the wetlands can be ignored (80:20 approach, Leskiw 1998), or factored into the overall map unit rating using a weighted average approach, as done for this application. The latter procedure was felt to be more realistic of how the land would be used and managed.

The procedure for determining map unit land capability (for forestry) first involved calculating an index for each soil series/variant. First, individual soil series and variants were rated by applying capability classification guidelines to soil data collected for this survey. Thickness data for organic and topsoil layers of soil series, variants, and complexes (Section 5.1) were an important part of the determinations. Morphological and analytical data for sampled pedons played a key role in determining basic index points; inspection site and grab sample data collected for the Joslyn Project were also consulted. If local analytical data were limited for some soils, the Alberta Soil Layers File (AG30SLF), available via AGRASID (ASIC 2001), was consulted. It contains profile data for all recognized soil series and variants in the province. Other nearby studies, especially CNRL's Horizon Project (Golder Associates 2002), were also consulted for soil data.

The second step involved multiplying the soil series/variant index by the proportion of that entity within each map unit. Using KMLV1/U1l as an example, it was estimated from soil inspection data and general knowledge of this landscape that the main soil types were KME 40%, LVKgl 40%, and drier terrain (comprised of mainly DOV and LVK) 20%. KME and LVKgl are imperfectly drained Gleyed Gray Luvisols. Their associated edaphic moisture regime (6) multiplied the "interim soil index" by 1.25 yielding the highest final soil index (>80) in the SSA. The drier soils have similar indexes (DOV 65, LVK 69) and were lumped together using the average (mid point) index of 67 (same result as listing them individually at 10% each). In this procedure, proportions of the soil entities within each SLM must add up to 100%.

The sum of the products of soil index times proportion within each map unit yields the weighted average soil index for the map unit (SLM), and was labelled "amalgamated soil index" in Table 5.2. As mentioned earlier, this index number takes into account all of the major entities within a map unit, even those that are widely disparate. Amalgamated soil index was compared to landscape index, with the lowest number defining the "final SLM index" and "final SLM rating". Landscape index can only be calculated for map units since soil series/variants tend to occur in specific "niches" within a landscape pattern.

5.2.2 Land Capability Assessment Results

The amalgamated soil, landscape, and final indices along with the final ratings classes (with sub-classes) for all map units of SSA are listed in Table 5.2. The final SLM ratings for the SSA and LSA are included as Figures 5.2 and 5.3.

In the Joslyn SSA, landscapes with the highest suitability (KMLV1/U1h and KMLV1/U1l) were rated as Class 1. The dominant soils in these landscapes were considered to have optimum water availability because of lateral seepage or seasonally high water tables that produce a subhygric moisture regime. Least suitable landscapes were rated as Class 5, usually as a result of excessively wet moisture regime (R) plus thick peaty surfaces (O) or a combination of limiting soil properties (S). All other landscapes were rated between these two.

Table 5.2 Baseline Land Capability Ratings for Forest Ecosystems by SLM.

Soil Landscape Model (SLM)	Amalgamated Soil Index	Landscape Index	Final SLM Index	Final SLM Rating
BMT5/L1	31	100	31	**4R**
CHMM1/FP3	36	90	36	**4R**
CHMM1/U1l	36	100	36	**4R**
DAPE6/HR2hr	36	43	36	**4MD**
DOKM2/U1h	65	100	65	**2R**
DOLV6/U1h	64	100	64	**2R**
DOLV6/U1l	64	100	64	**2R**
DOLV9/H1l	68	90	68	**2R**
DOLV9/U1h	68	100	68	**2R**
DOLV9/U1l	68	100	68	**2R**
DOSE1/H1l	62	90	62	**2R**
DOSE2/H1l	52	90	52	**3SR**
DOV10/U1h	69	100	69	**2R**
DOV10/U1l	69	100	69	**2R**
FRDA6/R2lr	39	71	39	**4MD**
FRLV2/U1h	58	100	58	**3R**
FRLV2/U1l	58	100	58	**3R**
KMLV1/U1h	84	100	84	**1**
KMLV1/U1l	84	100	84	**1**
KMLV2/U1h	69	100	69	**2R**
KMLV2/U1l	69	100	69	**2R**
LVK4/I5	68	60	60	**3T**
LVK11/I4	55	39	39	**4TP**
LVK11/I5	63	60	60	**3T**
MIFR5/U1h	49	100	49	**3MR**
MIFR5/U1l	49	100	49	**3MR**
MIL1/U1h	26	100	26	**4MK**
MIL5/U1h	37	100	37	**4MK**
MLD1c-G/O3	18	90	18	**5OR**
MLD1c-G/O5	18	90	18	**5OR**
MLD1m-G/O3	18	90	18	**5OR**
MLD1m-G/O5	18	90	18	**5OR**
MLD1s-G/O5	16	90	16	**5OR**
MLD2c/O1	10	100	10	**5OR**
MLD2m/O1	10	100	10	**5OR**
MLD3/O2	10	90	10	**5OR**
MMW2/FP3	19	100	19	**5R**
MMW21/U1h	30	100	30	**4R**
MMW21/U1l	30	100	30	**4R**
MMY2/SC1	64	81	64	**2V**
MMY2/SC2	64	94	64	**2V**
MMY6/SC2r	57	66	57	**3SR**
MUS1c-G/O5	13	90	13	**5SR**
MUS1m-G/O5	16	90	16	**5SR**
MUS1s-G/O5	16	90	16	**5SR**
MUS2c/O1	5	100	5	**5SR**
MUS2m/O1	5	100	5	**5SR**
MUS2s/O1	5	100	5	**5SR**

Table 5.2 Baseline Land Capability Ratings for Forest Ecosystems by SLM.				
Soil Landscape Model (SLM)	**Amalgamated Soil Index**	**Landscape Index**	**Final SLM Index**	**Final SLM Rating**
MUS3/O2	5	90	5	**5SR**
PEA9/U1h	59	100	59	**3R**
PEA9/U1l	59	100	59	**3R**
PELV1/L3	69	98	69	**2R**
PELV1/U1h	69	100	69	**2R**
PELV11/SC2	57	94	57	**3SR**
PEWN1/HR2mr	42	67	42	**3SR**
PEWN1/U1h	56	100	56	**3SR**
PEWN1/U1l	56	100	56	**3SR**
Water	Not rated	Not rated	n/a	**Not rated**
ZDL	Not rated	Not rated	n/a	**Not rated**

5.3 Reclamation Suitability

Reclamation suitability was assessed for the topsoil (TS), upper subsoil (US) and overburden (spoil) of the Joslyn LSA. The material is rated based on criteria set by the Alberta Soils Advisory Committee (1987). Ratings are divided into three categories of suitability and one category indicating that the material is unsuitable as a rooting medium. The four categories are described as follows:

1. Good (G) No or slight limitations that affect use as a plant growth medium.

2. Fair (F) Moderate limitations that affect use but can be overcome by proper planning and good management.

3. Poor (P) Severe limitations that make use questionable. This does not mean the material cannot be used, but rather careful planning and very good management is required.

4. Unsuitable (U) Chemical or physical properties are so severe reclamation would not be economically feasible or in some cases impossible. (i.e. special reclamation strategies must be implemented and land use may be severely restricted.)

The chemical characteristics of each soil suitability category are outlined in Table 5.3 and 5.4. The guidelines provide very little information on how to assess even thin organic (litter) layers, let alone thick peat deposits. A single paragraph (page 29, SQCWG 1987) indicates that organic soils be salvaged and used as a soil conditioner. For Organic and peaty Gleysolic soils, peat layers were rated as O (for Organic).

Table 5.3 Criteria for Evaluating the Suitability of Surface Material (topsoil) for Revegetation in the Northern Forest Region.

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)[1]	5.0-6.5	4.0-5.0 & 6.5-7.5	3.5-4.0 & 7.5-9.0	<3.5 and >9.0
Salinity (E.C.)[2] (dS/m)	<2	2-4	4-8	>8
Sodicity (SAR)[2]	<4	4-8	8-12	>12[3]
Saturation (%)[2]	30-60	20-30, 60-80	15-20, 80-120	<15 and >120
Stonines/Rockiness[4] (% Area)	<30/<20	30-50/20-40	50-80/40-70	>80/>70
Texture	SL, FSL, VFSL, L, SiL	CL, SCL, SiCL	S, LS, SiC, C, HC	
Moist Consistence	Very friable, Friable	Loose, Firm	Very firm	Extremely firm
$CaCO_3$ Equivalent (%)	<2	2-20	20-70	>70

1 pH values presented are most appropriate for trees, primarily conifers. Where reclamation objective is for other end land uses, such as erosion control, and where other plant species may be more important refer to the topsoil table of the Plains region.
2 Limits may vary depending on plant species to be used.
3 Materials characterized by a SAR of 12 to 20 may be rated as poor if texture is sandy loam or coarser and saturation % is less than 100.
4 <25 cm diameter stones/rocks intercepting surface.

Table 5.4. Criteria for Evaluating the Suitability of Subsurface Material (upper subsoil) for Revegetation in the Northern Forest.

Rating/Property	Good (G)	Fair (F)	Poor (P)	Unsuitable (U)
Reaction (pH)[1]	5.0-7.0[2]	4.0-5.0 & 7.0-8.0[2]	3.5-4.0 & 8.0-9.0	<3.5 and >9.0
Salinity (E.C.)[3] (dS/m)	<3	3-5	5-8	>8
Sodicity (SAR)	<4	4-8	8-12	>12[4]
Saturation (%)	30-60	20-30, 60-80	15-20, 80-100	<15 and >100
Coarse Fragments (% / Vol)	<30[5] / <15[6]	30-50[5] / 15-30[6]	50-70[5] / 30-50[6]	>70[5] / >50[6]
Texture	FS, SL, VFSL, L, SiL	CL, SiC, SiCL	S, LS, SiC, C, HC	Bedrock
Moist Consistence	Very friable, Friable, Firm	Loose, Very firm	Extremely firm	Hard rock
$CaCO_3$ Equivalent (%)	<5	5-20	20-70	>70

1 pH values presented are most appropriate for trees, primarily conifers. Where reclamation objective is for other end land uses, such as erosion control, and where other plant species may be more important refer to the topsoil table of the Plains region.
2 Higher value takes into consideration that in the lower lift the pH values of the soils are generally higher. Normally the pH rating should not be different than subsoil fro other regions.
3 Limit may vary depending on plant species to be used.
4 Materials characterized by a SAR of 12 to 20 may be rated as Poor if texture is sandy loam or coarser and saturation % is less than 100.
5 Matrix texture (modal) finer than sandy loam.
6 Matrix texture (modal) sandy loam and coarser.

5.3.1 Soil Suitability Ratings for Surface Soils

Since landscape (i.e. topography or terrain) was not a factor in this assessment, reclamation suitability ratings were actually assigned to the soil model (SM) portion of the SLM. Table 5.5 summarizes reclamation suitability ratings for SMs of the Joslyn SSA. Reclamation suitability ratings for the topsoil and upper subsoil are is shown on Figure 5.4a and Figure 5.4b. The guidelines do not provide much information on how to assess even thin organic (litter) layers, let alone thick peat deposits therefore Organic and peaty Gleysolic soils, peat layers were rated as O (for Organic).

Table 5.5 Reclamation Suitability Ratings for Baseline Soil Units (SM) of the Joslyn SSA.

Soil Model (SM)	Topsoil (TS)		Upper Subsoil (US)		Area (ha)	Comments
	Rating	Limitations	Rating	Limitations		
BMT5	O*	Peat-mineral mix	P	Very coarse texture	83	Wetness limits process
CHMM1	O*	Peat-mineral mix	F	Moderately fine to fine textures (SiCL-SiC-C)	949	Wetness limits lift process
DAPE6	P	Stones, boulders, bedrock	P	Stones, boulders, bedrock	112	Bedrock outcrops & boulders common
DOKM2	F	Low saturation % of topsoil horizons	P	Fine textured (C) upper subsoil horizons	189	LFH addition may improve TS rating
DOLV6	G-F	Low saturation % of some topsoil horizons	F-P	Highly variable fine to coarse textures	227	LFH addition may improve TS rating
DOLV9	G-F	Low saturation % of some topsoil horizons	P	Highly variable fine to coarse textures	1430	LFH addition may improve TS rating
DOSE1	F	Low saturation % of topsoil horizons	P	Fine textured (C) upper subsoil horizons	2608	LFH addition may improve TS rating
DOSE2	F	Low saturation % of topsoil horizons	P	Fine textured (C) upper subsoil horizons	349	LFH addition may improve TS rating
DOV10	F	Low saturation % of topsoil horizons	P	Fine textured (C) upper subsoil horizons	1603	LFH addition may improve TS rating
FRDA6	P	Stones, bedrock, very coarse texture	P	Stones, bedrock, very coarse texture	60	Boulders, some bedrock outcrops
FRLV2	G†	†Significant wetlands	F	Variable moderately fine to coarse textures	133	
KMLV1	G-F	Low saturation % of some topsoil horizons	F-P	Fine to moderately fine textures	1169	
KMLV2	G-F†	Low saturation % of some topsoil horizons	F-P	Fine to moderately fine textures	798	
LVK4	G-F	Low saturation % of some topsoil horizons	F	Moderately fine (CL) texture	185	Steep slopes may hinder salvage process

Table 5.5	**Reclamation Suitability Ratings for Baseline Soil Units (SM) of the Joslyn SSA.**					
Soil Model (SM)	**Topsoil (TS)**		**Upper Subsoil (US)**		**Area (ha)**	**Comments**
	Rating	**Limitations**	**Rating**	**Limitations**		
LVK11	G-F	Low saturation % of some topsoil horizons	F	Moderately fine, some coarse, textures	660	Steep slopes may hinder salvage process
MIFR5	F‡	Mixture of very coarse and medium textures	F-P	Highly variable coarse to moderately fine textures	365	
MIL1	P	Very coarse texture	P	Very coarse texture	317	
MIL5	P	Very coarse texture	P	Very coarse texture	330	
MLD1c-G	O	Mainly fen peat + some mineral soil	P	Fine texture	180	Wetness limits lift process
MLD1m-G	O	Mainly fen peat + some mineral soil	F	Medium to moderately fine textures	859	Wetness limits lift process
MLD1s-G	O	Mainly fen peat + some mineral soil	P	Coarse texture	26	Wetness limits lift process
MLD2c	O	Mainly fen peat	n/a	No SS	11	Wetness limits lift process
MLD2m	O	Mainly fen peat	n/a	No SS	378	Wetness limits lift process
MLD2s	O	Mainly fen peat	n/a	No SS	34	Wetness limits lift process
MLD3	O	Mainly fen peat	n/a	No SS	30	Wetness limits lift process
MMW2	O$	Peat-mineral mix	F$	Moderately fine textures	231	~40% water bodies
MMW21	O*	Peat-mineral mix	F	Variable moderately fine to coarse textures	114	Wetness limits lift process
MMY2	G†		G		733	Valley bottomland
MMY6	G†		G-F		51	Valley bottomland, some bedrock
MUS1c-G	O	Mainly bog peat + some mineral soil	P	Fine texture	1971	Wetness limits lift process
MUS1m-G	O	Mainly bog peat + some mineral soil	F	Medium to moderately fine textures	1385	Wetness limits lift process
MUS1s-G	O	Mainly bog peat + some mineral soil	P	Coarse texture	132	Wetness limits lift process
MUS2c	O	Mainly bog peat	n/a	No SS	629	Wetness limits lift process
MUS2m	O	Mainly bog peat	n/a	No SS	926	Wetness limits lift process
MUS3	O	Mainly bog peat	n/a	No SS	465	Wetness limits lift process
PEA9	G†		G-F		104	

Table 5.5 Reclamation Suitability Ratings for Baseline Soil Units (SM) of the Joslyn SSA.						
Soil Model (SM)	**Topsoil (TS)**		**Upper Subsoil (US)**		**Area (ha)**	
	Rating	**Limitations**	**Rating**	**Limitations**		**Comments**
PELV1	G		G-F		319	
PELV11	G†		F-P	Variable moderately fine to coarse textures	633	
PEWN1 (lithic)	F‡	Mixture of medium & very coarse textures	F‡	Variable moderately fine to coarse textures	495	Shallow (lithic) soils common
PEWN1	F‡	Mixture of medium & very coarse textures	F‡	Variable moderately fine to coarse textures		
Water	n/a		n/a		251	Not rated
ZDL	n/a		n/a		322	Not rated

*TS material will be dominantly organic (peat) but contain significant (up to 40%) mineral material.
†Rated G or G-F overall but has significant (~20-30%) highly contrasting soils (wetland or sandy) rated P, F, F-P, or O.
‡Selected intermediate rating (F) where co-dominant soil components were rated P vs. G or G-F.
$Overall rating of O (TS) or F (SS) may be misleading considering high proportion of water in MMW2 landscape.

In many upland soils, the TS rating was down-graded from G to F primarily by relatively low saturation percentage values (20-30). These low numbers likely reflect low organic carbon content, and to a lesser extent, coarser textures (L-SiL-SL-CL) than in the subsoil horizons. It is possible that the incorporation of litter (LFH) would raise the saturation percentage to optimum levels, but there are no guidelines or data to support this theory.

5.3.2 Soil Suitability Ratings for Overburden

5.3.2.1 Overburden Quality

The results of laboratory analysis of key quality parameters and the quality rating for each overburden sample are shown in Table 5.6. Original analytical results are provided in Appendix C.

Table 5.6 Reclamation Suitability Ratings* of Pit 1 Overburden.													
Site ID	**Depth**	**Texture**		**SAT**		**pH (upper/lower)**			**ECe**		**SAR**		**Most Limiting**
	(m)		Rating	(%)	Rating	(paste)	Trees	Grass	(dS/m)	Rating	-	Rating	Rating**
+06-03	2.0-7.6	Clay loam	F	66	F	8.4	P	F	1.5	G	**22**	U	U (3)
12-05	2.0-7.0	Loam	G	47	G	7.8	P/F	F	1.9	G	4.2	F	F (1,3)
+12-05	7.0-9.8	Clay	P	91	P	9.0	P	P	1.1	G	**21**	U	U (3)
+07-30	2.0-7.0	Clay loam	F	75	F	9.0	P	P	1.1	G	**24**	U	U (3)
14-20	2.0-6.1	Loam	G	44	G	8.0	P/F	F	0.5	G	1.6	G	F (1)
01-33	2.0-6.1	Loam	G	43	G	7.3	F	G	0.5	G	0.8	G	F (1)

+Clearwater formation is present.
Note: Northern Forest Region ratings for surface and subsurface material (After ASAC, 1987 – Tables 8&9)

*Rating
G - Good
F - Fair
P - Poor
U - Unsuitable

**Limitations
1 - pH
2 - EC
3 - SAR
4 - CaC03

Clearwater Formation

Three overburden samples were taken from the Clearwater formation (Table 4.1) which is described as dark grey, fossiliferous, silty shale; laminated siltstone and fine grained cherty sandstone; glauconitic sandstone (Wabiskaw member) near base; of marine origin (Hamilton et al. 1999). When excavated, this material is known to have poor load bearing properties indicating that the excavated material is likely to be soft (weathered) with few coarse fragments.

Overburden of the Clearwater formation will produce spoil rated as unsuitable quality for revegetation that is limited by sodicity. The sodium adsorption ratio (SAR) ranges between 21 and 22 (Table 5.6) and describes the proportion of sodium to calcium plus magnesium in the fine (< 2 mm) fraction. A good balance is required for the formation of a suitable soil structure which allows unrestricted plant root growth and water use. If spoil from the Clearwater overburden is used as rooting material, the excessive sodium will displace the calcium and magnesium on the clay particles causing dispersion and the formation of poor structure and tilth resulting in limited root growth and water use. Spoil from the Clearwater formation is not recommended for use as soil material within 1.0 m of the surface.

Stone content, coarse fragments and consistence are not measured by laboratory methods. These characteristics will vary according to the degree of material handling. Mining will use the truck and shovel technique to load and haul overburden material. The actions of excavation, dumping and re-contouring will cause significant disturbance and mixing. The resulting spoil is expected to be largely fine grained, reflecting the grain size of siltstones and shales with minimal coarse fragments.

Quaternary Deposits

Quaternary deposits are surface deposits of fluvial, glaciolacustrine and till origin and have been divided into two categories of suitability based on proximity to the Clearwater formation which influences sodicity. Three overburden samples of surface deposits with no underlying Clearwater formation are rated as being able to produce spoil with a fair suitability rating as reclamation material (Table 5.6). The SAR of this material ranges between 0.8 and 4.2 (good to fair quality) and the spoil is expected to be non-sodic. Soil reaction (pH) ranges between 7.3 and 8.0 (fair quality) and is the most limiting parameter for suitability. Other non-limiting parameters include loam texture (based on ground samples), % saturation ranging between 43 and 47 and electrical conductivity (0.5 to 1.9 dS/m). The soil inventory encountered few stones in surficial deposits and on that basis, few stones are expected in the quaternary overburden and resulting spoil. Non-sodic overburden from pit 1 has other characteristics important to soil capability as summarized in Table 5.7 and is recommended for use as soil material within 1.0 m of the surface.

Table 5.7 Other Characteristics of Non-sodic Overburden from Pit 1.

Site ID	Depth	Cation Exchange Capacity	Organic Carbon*	Water Holding Capacity
	(m)	(meq/100)g	(%)	(%)
12-05	2.0-7.0	6.9	2.5	23
14-20	2.0-6.1	6.6	2.7	14
01-33	2.0-6.1	6.8	2.2	13

* Method by loss on ignition.

One overburden sample representing surface deposits that overlie the Clearwater formation (Site ID 07-03 Table 5.6) has an SAR of 24 and spoil from this material is unsuitable for reclamation. These surface deposits may have a high SAR by originating from (or partially from) the Clearwater formation or through sodium movement with the groundwater or a combination of both. Spoil composed of surface deposits above the Clearwater formation is not recommended for use as soil material within 1.0 m of the surface.

The Clearwater formation isopach included in the Joslyn North Mine project application (DCEL 2006) is used to predict the location of overburden that is suitable or not suitable for use as rootzone material.

5.3.2.2 Trace Elements

Analysis of 15 trace elements was conducted to identify baseline levels in the Pit 1 overburden samples. Levels were compared to the existing Canadian Environmental Quality Guidelines (CCME 1999) for Parkland land use. Results of trace element analysis (Appendix C) of the overburden samples indicate that mean values of the common metals are less than the Parkland land use criteria (Table 5.8). The maximum concentration values found for barium and selenium marginally exceed the protection guidelines for parkland soils indicating that some high concentrations of elements occur naturally. Each of the maximum concentration values slightly above the CCME criteria is represented by one different sample and all other sample results are substantially less than the CCME criteria. The results of trace element analysis indicate that concentrations within the overburden (and the resulting mixed spoil) are sufficiently low to provide continued protection of plants and animals.

Table 5.8 Baseline Trace Element Content (mg/kg) of Pit 1 Overburden.

Element	Site ID (Pit 1 Overburden)						Results Summary			CCME Criteria
	06-03	12-05		07-30	14-20	01-33	Mean	Min.	Max.	(1999)
	(2.0-7.6m)	(2.0-7.0m)	(7.0-9.8m)	(2.0-7.0m)	(2.0-6.1m)	(2.0-6.1m)				Parkland land use
As	8.6	4.7	8.5	4.6	2.4	2.4	5.2	2.4	8.6	12
Ba	64	86	**502**	214	95	74	173	64	**502**	500
Be	<1	<1	<1	<1	<1	<1	<1	<1	<1	4
Cd	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	10
Co	9	6	10	7	5	5	7	5	10	50
Cr	13.9	10.2	11.1	10.9	10.5	9.4	11	9.4	13.9	64
Cu	23	11	27	17	9	9	16	9	27	63
Hg	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	6.6
Mo	<1	<1	<1	<1	<1	<1	<1	<1	<1	10
Ni	24	15	23	16	13	12	17	12	24	50
Pb	10	6	13	8	6	<5	9	6	13	140
Se	<0.2	0.4	**1.1**	0.5	0.3	0.3	0.5	0.3	**1.1**	1
Tl	<1	<1	<1	<1	<1	<1	<1	<1	<1	1
V	19	15	13	12	15	12	14	12	19	130
Zn	70	40	80	40	30	30	28	30	80	200

Laboratory Methods: Preparation by EPA 3050, Analytical by EPA 6020
Canadian Council of Ministers of the Environment (CCME). 1999, updated 2001, updated 2002, updated 2004.
Note: **Bold** values exceed CCME criteria.

5.4 Soils and Acid Deposition

Two systems were used to rate the baseline soils of the Joslyn SSA and RSA in terms of their ability to offset acidic inputs that might accrue through atmospheric deposition. They are "soil sensitivity to acid deposition" and the "potential of soils to reduce acidic inputs". Both systems were developed to map acid sensitivities of Alberta soils (Holowaychuk and Fessenden 1987).

5.4.1 Soil Sensitivity to Acid Deposition

Methodology

Soil sensitivity to acid deposition is the most commonly used system to rate the ability of soils to offset acidic inputs. As in previous assessments, soil series and variants were used as the building blocks for rating soil landscapes. For acid sensitivity however, mineral soils are rated differently than soils with relatively thick organic layers at their surface. Mineral soils were rated using the system developed by Holowaychuk and Fessenden (1987). Rating of Organic and peaty Gleysol soils followed the system developed by Turchenek et al. (1998).

For determining soil sensitivity to acid deposition of mineral soils, only the top 20 cm of the soil profile (i.e. the topsoil) was considered. Forest litter (LF and LFH horizons) widespread on upland soils was ignored. Important soil parameters used for rating upland mineral soils were cation exchange capacity (CEC) and pH (as measured in soil-water mixes). For this report, data from a wide variety of sources was used. The data sources sampled pedon, inspection site, and grab sample data collected for the Joslyn Project; the Alberta Soil Layers File (AG30SLF), available via AGRASID (ASIC 2001); CNRL's Horizon Project report (Golder Associates 2002); and the AOSERP soil profile data (Turchenek and Lindsay 1982b).

Non-peaty Gleysolic soils were rated using the mineral soil system (Holowaychuk and Fessenden 1987). Analytical data on CEC and pH proved useful to determine their ratings. Peaty Gleysols, which averaged about 25 cm of peat on the soil surface, and Organic soils were rated using the system for Organic soils (Turchenek et al. 1998). Based on pH data and information on associated vegetation types, peatland systems were classed as either eutrophic, mesotrophic, or oligotrophic, as follows:

- Peaty Gleysols (peaty ALG, BMT, CHT, and MMW complexes) – mesotrophic or eutrophic.
- MLD (McLelland) soil variants/complexes (fens) – mesotrophic.
- MUS (Muskeg) soil variants/complexes (bogs and poor fens) – oligotrophic.

The final step for acid sensitivity assessment was to amalgamate individual soil series/variants ratings into mapping unit sensitivity ratings. This was accomplished by visually weighting individual soil type ratings according to their proportions of each mapping unit. Generally, map unit ratings were assigned according to the predominant series or variant; soil entities less than 20% of a mapping unit were often disregarded. In the cases of co-dominant soil types with different ratings classes, a "compound", or "hyphenated", rating was assigned. For SSA soils, hyphenated ratings always involved adjacent classes (e.g. low-medium and high-medium).

The procedure of assigning hyphenated ratings was particularly true as applied to generalized soil information compiled for the RSA. The general rule for using the ratings in follow-up evaluations is 60% for the first class and 40% for the second class, e.g. medium-low is interpreted as 60% medium and 40%

low. This arbitrary division was based on the AOSERP soil unit descriptions (Turchenek and Lindsay 1982a).

Results

Acid sensitivity ratings for the generalized soil map units of the RSA are presented in Table 5.9 and displayed in Figure 5.5.

For the Joslyn SSA, acid sensitivity ratings are listed for soil models (SMs) in Table 5.10. Since landscape (i.e. topography) was not a factor in this assessment, acid sensitivity ratings were actually assigned to the soil model (SM) portion of the SLM. Overall sensitivity ratings to acidic inputs are also shown on Figures 5.6 and 5.7.

Table 5.9 Acid Sensitivity Ratings for Soil Map Units of the RSA.

RSA MU	Amalgamated Overall Acid Sensitivity Rating	RSA MU	Amalgamated Overall Acid Sensitivity Rating
BKN	Medium	MIL MAR	High
DOV	Medium	MIL STP	High-Low
DOV ALG	Medium-Low	MKW FIR	Medium-High
DOV MIL	Medium-High	MKW LGD	Medium
DOV RUT	Medium-High	MLD	Low
DOV SEN	Medium	MMY	Medium
DOV STP	Medium-Low	MUS	Medium
FIR	High	MUS ALG	Medium-Low
FIR MUS	High-Medium	MUS KNS	Medium
HRR	Medium	MUS MAR	Medium-High
HRR LVK	Medium	MUS MIL	Medium-High
KNS	Medium	MUS MLD	Medium-Low
KNS LVK	Medium	MUS SEN	Medium
KNS MIL	Medium-High	MUS STP	Medium-Low
KNS MUS	Medium	NAM	Medium
KNS STP	Medium-Low	RUT	High
LGD MKW	Medium	RUT MIL	High
LVK	Medium	RUT MMY	High-Medium
LVK MAR	Medium-High	SEN	Medium
LVK MLD	Medium-Low	SRT	Medium
MAR	High	STP MUS	Low-Medium
MIL	High	W	n/a
MIL BMT	High-Low	ZRB	Medium

General trends were evident in the acid sensitivity ratings for both the RSA and SSA soils.

- Wetland soils dominated by fen vegetation were rated as having low sensitivity.
- Wetland soils dominated by bog and poor fen vegetation were rated medium.
- Upland mineral soils with medium to fine textured subsoil (e.g. DOV, LVK, PEA, SEN, etc.) were rated medium.
- Upland very coarse textured soils (e.g. FIR, MAR, MIL, RUT, WNF, etc.) were rated high.

5.4.2 Potential of Soils to Reduce Acidic Inputs

Rating the potential to reduce acidity refers to the relative capability of soil, and particularly subsoil materials, to reduce the acidity of acid deposition before its possible entry into an aquatic ecosystem as leachate or effluent (Holowaychuk and Fessenden 1987).

The same procedures were used as for other interpretive assessments previously described. They involved determining the potential to reduce acidic inputs (low, medium, or high rating) for each soil series, variant, or taxonomic complex. Individual ratings were then amalgamated into map unit ratings, determined by weighting the individual soil type ratings according to their proportions of the map unit.

Ratings of the potential to reduce acidic inputs are listed in Table 5.10 for soil models (SMs) of the Joslyn SSA. Landscape (i.e. topography) was not a factor in the assessment, thus the ratings were assigned to the soil model (SM) only.

Table 5.10 Sensitivity to/potential to Reduce Acidifying Inputs by Soil Model (SM) in the Joslyn SSA.

Soil Unit (SM)	Amalgamated Overall Acid Sensitivity Rating	Amalgamated Potential to Reduce Acidic Inputs
BMT5	Low-Medium	High
CHMM1	Low	High
DAPE6	Medium	Medium
DOKM2	Medium*	High
DOLV6	Medium	High
DOLV9	Medium	High
DOSE1	Medium	High
DOSE2	Medium	High
DOV10	Medium	High
FRDA6	Medium*	Medium
FRLV2	Medium*	Medium**
KMLV1	Medium	High
KMLV2	Medium*	High
LVK4	Medium	High
LVK11	Medium	High
MIFR5	Medium-High	Low
MIL1	High	Low
MIL5	High	Low
MLD1c-G	Low	Medium†
MLD1m-G	Low	Medium†
MLD1s-G	Low	Medium†
MLD2c	Low	Medium
MLD2m	Low	Medium
MLD2s	Low	Medium
MLD3	Low	Medium
MMW2	Low	High
MMW21	Low	High
MMY2	Medium*	High
MMY6	Medium	High
MUS1c-G	Medium*	Low†
MUS1m-G	Medium*	Low†

Table 5.10	**Sensitivity to/potential to Reduce Acidifying Inputs by Soil Model (SM) in the Joslyn SSA.**	
Soil Unit (SM)	**Amalgamated Overall Acid Sensitivity Rating**	**Amalgamated Potential to Reduce Acidic Inputs**
MUS1s-G	Medium	Low†
MUS2c	Medium	Low
MUS2m	Medium	Low
MUS3	Medium	Low
PEA9	Medium*	High
PELV1	Medium	High
PELV11	Medium	Low†
PEWN1 (lithic)	Medium-High	High-Medium
PEWN1	Medium-High	High
Water	n/a	n/a
ZDL	Not rated	Not rated

*Dominantly high or medium but with significant (20-30%) highly contrasting areas rated as low.
**Soil (map) unit rated medium if its co-dominant soil components were rated high and low.
†Dominantly medium or low but with significant (20-30%) highly contrasting areas rated as high.

Ratings of SSA soil series, variants, and taxonomic complexes were based on soil depth, exchangeable base content of soils, parent material type, and soil drainage as outlined by Holowaychuk and Fessenden (1987). The majority of upland soils exceed 100 cm in depth and have calcareous parent materials (BCk and Ck horizons) that occur in the lower subsoil (usually 60 cm or deeper). These all rated high.

Exceptions amongst upland soils were DAN (Daphne), FRT (Fort), and MIL (Mildred) series and variants. FRT and MIL soils, with lower subsoil dominated by outwash sands, are mainly non-calcareous, acidic, and have very low exchangeable cation content. DAN soils, developed on stony to gravelly material overlying clastic, sedimentary bedrock at shallow depths, also tended to be non-calcareous and acidic.

Poorly drained Gleysolic soils were rated high, per the guidelines set out by Holowaychuk and Fessenden (1987). Mesotrophic peatlands (MLD soil complexes) were rated medium, and oligotrophic peatlands (MUS soil complexes) were rated low in terms of potential to reduce acidity.

5.5 Acid Mine Drainage

Acid drainage from overburden and spoil can be a problem for reclamation. Sulphide minerals in overburden, exposed to oxygen and water, will oxidize and cause sulphuric acid to form. Unless the acid is neutralized (usually by carbonate minerals), trace elements from the spoil or exposed overburden may dissolve resulting in high concentrations in the drainage water and thus, acid rock drainage. Naturally occurring carbonate minerals and carbonate ions in solution may partially or completely neutralize acidity within the overburden and spoil material.

In Canada, mines are a major source of acid drainage because of sulphide minerals in geologic formations. Tremblay and Hogan (2000) estimate that mines in the province of Ontario have the most acid-generating wastes, with Quebec, British Columbia and Manitoba having much less acid generating wastes (4 to 5 times less). No acid generating wastes were reported for Alberta but because of the potential environmental consequences of acid rock drainage, the overburden has been tested for its acid producing and neutralizing potential.

The Mine Environment Neutral Drainage (MEND) and MEND 2000 programs use acid-base accounting to assess risk of acid rock drainage (Tremblay and Hogan – editors, 2000). Acid base accounting is a two-part analytical procedure for determining the Acid Potential (AP) and the Neutralizing Potential (NP) of mine waste so that an "account" can be made to assess the net potential for acid generation. This concept can be expressed as net neutralizing potential (NNP) or the neutralizing potential ratio (NPR):

NNP = NP – AP and

NPR = NP/AP.

An overburden sample is classified as a potential source of acidic drainage if the net neutralizing potential is negative. A neutralizing potential ratio of greater than 1 is considered non-acid producing and a larger number corresponds to lower potential. The neutralizing potential ratio allows comparison of a wide range of neutralizing and acid potentials and is the preferred expression. The acid-base accounting results for the Pit 1 overburden samples are summarized in Table 5.11.

Table 5.11 Acid-Base Accounting Results for Pit 1 Overburden.

Sample ID	Sample Depth (m)	NP*	AP*	NNP (NP-AP)	NPR NP/AP
06-03	2.0-7.6	61	20.9	40	2.9
12-05	2.0-7.0	61	18.8	42	3.2
	7.0-9.8	42	25.3	17	1.7
7-30	2.0-7.0	31	17.2	14	1.8
14-20	2.0-6.1	64	21.6	42	3.0
01-33	2.0-6.1	63	12.2	51	5.2

*Units are tonnes of $CaCO_3$ per 1000 tonnes of overburden.

All six overburden samples have positive net neutralizing potential and a neutralizing potential ratio greater than 1 indicating that acid drainage is not expected to occur. This is consistent with the groundwater alkalinity (pH) in the study area which generally ranges from 7.5 to 8.5. Surface waters collected from the study area were also slightly alkaline (pH of 7.5 to 8.5) indicating that surface waters are somewhat buffered against acidification (Hatfield 2005).

5.6 Natural Erosion Risk Assessment

Soil erosion hazard is the expected rate and amount of soil loss, by water and/or wind, which may be expected in an area following unmitigated removal of the protective vegetation cover. The rate of erosion depends on several factors: the amount, intensity, and seasonal distribution of rainfall or snowmelt; the steepness and length of slopes; the absence or presence of channels of concentration; the type of vegetation cover; and the nature of the soil. Infiltration capacity and structure stability are two important soil characteristics influencing erosion by water. Particle size, durability of surface cloddiness, rock fragments, organic matter and lime content are important soil characteristics influencing erosion by wind.

The risk of soil erosion by water is assessed using the modified Universal Soil Loss Equation (Tajek et al, 1985) and the baseline soil mapping of the local study area. The soil landscape units encountered have been rated for erosion hazard by water and are summarized in Table 5.12. These erosion ratings are for non-frozen soils following vegetation clearing – a condition expected to have a short duration prior to soil salvage and excavation of overburden. Organic and peaty Gleysolic soils are not rated for erosion.

The risk of soil erosion by wind is generally low within the study area (Table 5.12) according to Pedocan Land Evaluation Ltd. (1993). Vegetation removal on sandy soils prior to mining will expose a soil surface highly susceptible to erosion by wind for a short duration prior to excavation of overburden (no soil salvage). Following reclamation, the risk of soil erosion by wind is expected to be low on most landscapes. Higher risk areas are likely to occur at the top of exposed slopes and control measures can be focused at such locations as required. The risk of erosion by wind decreases as vegetation becomes established.

Table 5.12 Potential for Soil Erosion of Baseline Soils.

Soil Landscape Model	Water				Wind	Area (ha)
	Erodability (K value*)	Topography Class	Sl Factor (LS value)	Erosion Class	Erosion Class*	
BMT5/L1	-	3	-	Not Rated	Not Rated	78
CHMM1/FP3	0.040	3	0.4	Slight	Low	41
CHMM1/U1l	0.059	3	0.4	Moderate	Low	176
DOKM2/U1h	0.059	3	0.4	Moderate	Low	27
DOLV6/U1h	0.059	3	0.4	Moderate	Low	14
DOLV9/H1l	0.059	4	0.8	High	Low	10
DOLV9/U1h	0.059	3	0.4	Moderate	Low	235
DOLV9/U1l	0.059	3	0.4	Moderate	Low	104
DOSE1/H1l	0.059	4	0.4	Moderate	Low	128
DOV10/U1h	0.059	3	0.4	Moderate	Low	194
DOV10/U1l	0.059	3	0.4	Moderate	Low	59
FRLV2/U1h	0.059	3	0.4	Moderate	Low	62
FRLV2/U1l	0.059	3	0.4	Moderate	Low	60
KMLV1/U1h	0.059	3	0.4	Moderate	Low	200
KMLV1/U1l	0.059	3	0.4	Moderate	Low	183
KMLV2/U1h	0.059	3	0.4	Moderate	Low	96
KMLV2/U1l	0.059	3	0.4	Moderate	Low	125
LVK11/I5	0.059	6	0.6	Moderate	Low	71
LVK4/I5	0.059	6	0.6	Moderate	Low	37
MIFR5/U1h	0.040	3	0.4	Slight	High	267
MIFR5/U1l	0.040	3	0.4	Slight	High	46
MIL1/U1h	0.040	3	0.4	Slight	High	316
MIL5/U1h	0.040	3	0.4	Slight	High	321
MLD1c-G/O3	-	0	-	Not Rated	Not Rated	10
MLD1c-G/O5	-	0	-	Not Rated	Not Rated	37
MLD1m-G/O3	-	0	-	Not Rated	Not Rated	54
MLD1m-G/O5	-	0	-	Not Rated	Not Rated	163
MLD1s-G/O5	-	0	-	Not Rated	Not Rated	15
MLD2c/O1	-	0	-	Not Rated	Not Rated	4
MLD2m/O1	-	0	-	Not Rated	Not Rated	142
MLD2s/O1	-	0	-	Not Rated	Not Rated	34
MLD3/O2	-	0	-	Not Rated	Not Rated	1
MMW2/FP3	-	3	-	Not Rated	Not Rated	45
MMW21/U1h	-	3	-	Not Rated	Not Rated	24
MMW21/U1l	-	3	-	Not Rated	Not Rated	55
MMY2/SC1	0.040	6	0.6	Moderate	Low	69
MMY6/SC2r	0.040	6	0.6	Moderate	Low	31
MUS1c-G/O5	-	0	-	Not Rated	Not Rated	298
MUS1m-G/O5	-	0	-	Not Rated	Not Rated	673

Table 5.12 Potential for Soil Erosion of Baseline Soils.						
Soil Landscape Model	**Water**				**Wind**	**Area (ha)**
	Erodability (K value*)	**Topography Class**	**Sl Factor (LS value)**	**Erosion Class**	**Erosion Class***	
MUS1s-G/O5	-	0	-	Not Rated	Not Rated	125
MUS2c/O1	-	0	-	Not Rated	Not Rated	93
MUS2m/O1	-	0	-	Not Rated	Not Rated	142
MUS3/O2	-	0	-	Not Rated	Not Rated	51
PELV1/U1h	0.040	3	0.4	Slight	Moderate	30
PELV11/SC2	0.040	6	0.6	Moderate	Moderate	48
PEWN1/U1h	0.040	3	0.4	Slight	Moderate	8
PEWN1/U1l	0.040	3	0.4	Slight	Moderate	2
Water	Water	-	-	Not Rated	Not Rated	2
ZDL	ZDL	-	-	Not Rated	Not Rated	91
Total						5,098

Assumptions:
Precipitation factor for Fort Chipewyan was used.
Slope length = 30-50m; inclined slopes = 200m.
Soil cover factor = 0.6 (bare soil after clearing).
* Based on Pedocan Land Evaluation Ltd. (1993).

6.0 SOIL CONSERVATION AND RECLAMATION

6.1 Soil Reclamation Goal

The objective of conservation and reclamation, in support of the Environmental Protection Enhancement Act (Province of Alberta, 2000), is to return specified land to an equivalent land capability (Province of Alberta, 2005). Land capability is defined as, "the ability of the land to support a given land use, based on an evaluation of the physical, chemical and biological characteristics of the land, including topography, drainage, hydrology, soils and vegetation". Land, for the purposes of this soil and terrain EIA report, is defined as terrestrial landscapes. Other sections of the EIA report will address semi-aquatic and aquatic landscapes. Equivalent land capability then, means that "the ability of the land to support various land uses after conservation and reclamation is similar to the ability that existed prior to an activity being conducted on the land, but that the individual land uses will not necessarily be identical" (Province of Alberta 2005).

- Conservation and reclamation guidelines (AEP, 1997) provide further clarification of reclamation requirements:
- The land capability must be sustainable under normal land management practices.
- The capability must be based on pre-disturbance soil, landscape, and vegetation conditions as the targets for comparison.
- A change in land use is permitted on a reclaimed site, with prior approval of all stakeholders, and this change must meet the goal of equivalent land capability.
- The value of soil, its sensitivity to disturbance, and the difficulty of reclaiming degraded soil is recognized.
- The re-establishment of vegetation that is compatible with adjacent land is needed.

The Oil Sands Mining End Land Use Committee Report and Recommendations (AEP 1998a) identify priorities for earliest reclamation to be natural and conservation areas (wildlife use) and commercial

forests. The goal for reclamation of terrestrial land at the Joslyn North Mine is that it will support a forest ecosystem (equivalent to a pre-disturbance capability) and thereby support an end land use of both wildlife habitat and commercial forests. Other land uses will be supported in the project area, including lakes.

The framework for evaluating the capability of pre-disturbance and reclaimed landscapes to support a forest ecosystem is the Land Capability Classification for Forest Ecosystems in the Oil Sands (Leskiw 1998). This system provides a mechanism to determine landscape and soil capability ratings of both baseline conditions (prior to disturbance) and the reclaimed soil landscapes for the purposes of obtaining reclamation certification. The classification system is also suited to predicting the capability ratings of planned soil landscapes based on the physical and chemical characteristics of available soil building resources, thereby allowing decisions for planning soil salvage and soil building to return equivalent land capability (AEP 1998b). Guidelines for Reclamation to Forest Vegetation in the Athabasca Oil Sands Region (Oil Sands Vegetation Reclamation Committee, 1998) and (AEP 1999) also include establishment of target ecosites as a measure of equivalent land capability. Vegetation of the ecosites is supported by type of landscape, drainage and soils that are re-established. Monitoring of ecosystem development, biodiversity, forest productivity and wildlife habitat suitability will demonstrate the achievement of equivalent land capability.

6.2 Available Soil Resources

Baseline soils are the result of soil formation processes over many years and are a valuable resource that should be salvaged for reclamation use and not wasted. The baseline soil inventory identifies opportunities for salvage of materials from both mineral and organic soils. Mineral soils usually have topsoil, upper subsoil and lower subsoil horizons with different characteristics and often with differing suitability as reclamation material. Organic soils are composed of peat material (>40 cm) derived from decomposing mosses and forest litter and have properties that are both useful and challenging for soil reclamation. Soil salvage recommendations are developed according to the baseline soils of the development area.

The Joslyn North Mine project encompasses approximately 5400 ha of which includes areas for the Joslyn Creek diversion, reclamation material stockpiles and water intake line (Figure 2.3). The focus of this assessment is on areas of disturbance required for sequential development of the mine. The mine development sequence shows that soil must be salvaged from 4727 ha of the development. An additional 370 ha will have minimal disturbance of the soil profile (i.e. depressurization wells) and is included in the closure planning (total area 5097 ha). The remainder of the area (303 ha) is required for associated facilities such as the Joslyn Creek diversion, reclamation material stockpiles and water intake pipeline. This 303 ha will not be discussed in detail in the Conservation and Reclamation plan and DCEL will ensure that proper operational procedures are in place to allow for reclamation to equivalent capability.

6.2.1 Mineral Soil Resources

Most mineral soils have developed topsoil, upper subsoil and lower subsoil horizons with different characteristics and often with differing suitability as reclamation material. General characteristics of each horizon group and their suitability for reclamation and revegetation were provided in Section 5.3.

Topsoil of existing mineral soils (Ae, Ahe, Ah and AB horizons) is usually 15 to 20 cm thick with a suitability rating for revegetation of Good to Fair. The surface leaf litter (LFH horizon) is usually 5 to 15

cm thick and overlies the topsoil layer. Incorporation of the litter layer with topsoil will contribute little to volume. However, adding surface organic matter, including peaty surfaces <40 cm thick, will benefit the topsoil resource by enhancing functions such as water holding capacity, nutrient capacity and structure stability. Table 6.1 lists the chemical properties of the topsoil and the suitability for reclamation. Chemical properties of soil reaction (pH), salinity and sodicity are generally suitable except for the acidic pH of coarse textured materials. Saturation % is sometimes low (<30%) which causes soil structure to be unstable but the limitation is easily overcome through horizon mixing and incorporation of organic matter. Sandy loam and loam textured topsoil often corresponds with a friable consistence and is favourable for revegetation. Loamy sand and sand textured topsoil and a corresponding loose consistence is poorly suited for revegetation and as reclamation material and therefore will not be salvaged. The quality ratings for thin peat mixed with mineral topsoil is subjective only and is intended to reflect the higher water-holding capacity of organic:fine textured material over the organic:coarse textured material.

Table 6.1 Topsoil Suitability Parameters

Soil Model (SM)	Peat / Litter (m)	Thickness (m)	pH	E.C. dS/m	SAR	Sat%	Texture*	Consistence	Topsoil Suitability (ASAC 1987)
BMT5	0.25	0.15	5.5-6.0	<2	<4	30-60	O:S	Friable	Fair
CHMM1	0.15	0.15	5.5-6.5	<2	<4	30-60	O:CL-C	Friable	Good
DOKM2	0.07	0.15	~5.0	<2	<4	20-30	SL-L	V. friable-Fr	Fair
DOLV6	0.05	0.20	~5.0	<2	<4	20-30	SL-L	V. friable-Fr	Good-F
DOLV9	0.07	0.20	~5.0	<2	<4	20-30	SL-L	V. friable-Fr	Good-F
DOSE1	0.07	0.15	~5.0	<2	<4	20-30	SL-L	V. friable-Fr	Fair
DOV10	0.07	0.15	~5.0	<2	<4	20-30	SL-L	V. friable-Fr	Fair
FRLV2	0.11	0.25	~5.0	<2	<4	25-40	FSL-L	V. friable-Fr	Good
KMLV1	0.08	0.20	~5.0	<2	<4	20-30	FSL-L	V. friable-Fr	Good-F
KMLV2	0.11	0.15	~5.0	<2	<4	20-30	FSL-L	V. friable-Fr	Good-F
LVK4	0.09	0.15	~5.0	<2	<4	20-30	FSL-L	V. friable-Fr	Good-F
LVK11	0.09	0.10	~5.0	<2	<4	20-30	FSL-L	V. friable-Fr	Good-F
MIFR5	0.06	0.25	~5.0	<2	<4	25-40	LS-L	Loose-V.Fr	Poor-F
MIL1	0.06	0.25	4.6-5.0	<2	<4	20-30	LS-S	Loose	Poor
MIL5	0.08	0.25	4.6-5.0	<2	<4	20-30	LS-S	Loose	Poor
MMW2	0.15	0.10	5.5-6.5	<2	<4	30-60	O:CL	Sticky	Good
MMY2	0.08	0.15	5.0-6.0	<2	<4	~30	L-SL	V. friable-Fr	Good
MMY6	0.04	0.05	~6.0	<2	<4	~30	L-SL	V. friable-Fr	Good
PELV1	0.06	0.20	~5.0	<2	<4	25-40	FSL-L	V. friable-Fr	Good
PELV11	0.06	0.15	~5.0	<2	<4	25-40	FSL-L	V. friable-Fr	Good
PEWN1	0.06	0.20	~5.0	<2	<4	25-40	L-S	V. friable-L	Fair

* S=sand; LS=loamy sand; SL=sandy loam; FSL=fine sandy loam; L=loam; CL=clay loam; O=organic.

Upper subsoil (BA, Bm, Bt, Btgj, Bg horizons) occurs below the topsoil layer and is usually 25 to 30 cm thick (sometimes thicker) with a suitability rating for revegetation of Fair to Poor (Table 6.2). Chemical properties of soil reaction (pH), salinity and sodicity are generally suitable for revegetation. Limitations to suitability are generally related to texture with the best suitability provided by loam to sandy loam textures. Clay loam and silty clay loam textured material is rated as Fair suitability while clay and sand textured material is rated as Poor suitability. Suitability rating based on texture (in combination with consistence) reflects the balance of water and nutrient holding capacity and pore spaces for air exchange required for plant growth. For example, coarse textures have high pore space and are droughty while clay textures can hold more water and nutrients but have small pore spaces and allow less air exchange. The structure of upper subsoil contributes to air exchange in soil.

Table 6.2 Upper Subsoil Suitability Parameters									
Soil Model	**Area**	**Thickness**	**pH**	**E.C.**	**SAR**	**Sat%**	**Texture**	**Consistence**	**Suitability**
(SM)	**(ha)**	**(m)**		**dS/m**					**(ASAC 1987)**
BMT5	77.8	0.50	5.5-6.0	<3	<4	30-60	S	Loose	Poor
CHMM1	215.1	0.25	6.5-7.0	<3	<4	30-60	SiCL-C	Sticky	Fair-P
DOKM2	27.4	0.25	5.0-6.5	<3	<4	30-60	C	Firm-friable	Poor
DOLV6	14.4	0.30	5.0-6.5	<3	<4	30-60	CL-C	Firm-friable	Fair-P
DOLV9	347.9	0.30	5.0-6.5	<3	<4	30-60	C	Firm-friable	Poor
DOSE1	127.5	0.30	5.0-7.0	<3	<4	30-60	C	Firm-friable	Poor
DOV10	242.3	0.25	5.0-7.0	<3	<4	30-60	C	Firm-friable	Poor
FRLV2	122.6	0.60	5.0-6.0	<3	<4	30-60	CL	Firm-friable	Fair
KMLV1	378.3	0.25	5.0-6.0	<3	<4	30-60	CL-C	Firm-friable	Fair-P
KMLV2	220	0.30	5.6-6.0	<3	<4	30-60	CL-C	Firm-friable	Fair-P
LVK4	21	0.35	5.6-6.0	<3	<4	30-60	CL	Firm-friable	Fair
LVK11	70.5	0.20	5.6-6.0	<3	<4	30-60	CL	Firm-friable	Fair
MIFR5	313	0.70	5.0-6.0	<3	<4	30-60	S-CL	Loose	Fair-P
MIL1	316.2	0.70	5.0-6.0	<3	<4	30-60	S	Loose	Poor
MIL5	321	0.75	5.0-6.0	<3	<4	30-60	S	Loose	Poor
MMW2	45.3	0.10	6.5-7.0	<3	<4	30-60	SiCL-CL	Sticky	Fair
MMY2	48.4	0.15	5.0-6.0	<3	<4	30-60	L-SL	V. friable-Fr	Good
MMY6	31	0	5.5-6.5	<3	<4	30-60	L-SL	V. friable-Fr	Good
PELV1	30	0.25	5.6-6.0	<3	<4	30-60	L-CL	Firm-friable	Fair-G
PELV11	32.9	0.40	5.6-6.0	<3	<4	30-60	CL-S	Fr-loose	Fair-P
PEWN1	10.6	0.50	5.6-7.0	<3	<4	30-60	CL-S	Fr-loose	Fair-P

** S=sand; SL=sandy loam; L=loam; SiCL=silty clay loam; CL=clay loam; C=clay.

Lower subsoil (BC, Ck, Ckgj and Ckg horizons) is considered to be the soil parent material, located below the upper subsoil layer at approximately 40 to 50 cm below the surface, and usually has a suitability rating for revegetation of Fair to Poor (Table 6.3). The suitability rating is influenced by texture in a manner similar to upper subsoil (discussed above) plus the lack of lower subsoil structure results in poor air exchange. Lower subsoil reaction is often higher (pH 7.0 to 8.0) than the upper subsoil. Soil reaction represents chemical conditions that influence nutrient availability. Trees (primarily conifers) prefer slightly acidic conditions (pH 5.0 to 6.5) while grasses and forbes prefer soil conditions closer to neutral (pH 6.5 to 7.5). When used as reclamation material, the slight limitation of reaction is slowly overcome as rainfall (slightly acidic) reacts with the soil.

Table 6.3 Lower Subsoil Suitability Parameters.								
Soil Model	**Depth***	**pH**	**E.C.**	**SAR**	**Sat%**	**Texture****	**Consistence**	**Suitability**
(SM)	**(m)**		**(dS/m)**					**(ASAC 1987)**
BMT5	0.65	5.0-7.0	<3	<4	30-60	S	Loose	Poor
CHMM1	0.40	7.0-8.0	<3	<4	30-60	SiCL-SiC	Sticky	Fair-P
DOKM2	0.40	7.0-8.0	<3	<4	30-60	C	Firm-friable	Poor
DOLV6	0.50	7.0-8.0	<3	<4	30-60	CL-C	Firm-friable	Fair-P
DOLV9	0.50	7.0-8.0	<3	<4	30-60	C	Firm-friable	Poor
DOSE1	0.45	7.0-8.0	<3	<4	30-60	C	Firm-friable	Poor
DOV10	0.40	7.0-8.0	<3	<4	30-60	C	Firm-friable	Poor
FRLV2	0.85	5.0-7.0	<3	<4	30-60	SCL	Firm-friable	Fair
KMLV1	0.45	5.0-6.0	<3	<4	30-60	C-CL	Firm-friable	Fair-P
KMLV2	0.45	5.6-6.0	<3	<4	30-60	C-CL	Firm-friable	Fair-P

Table 6.3 Lower Subsoil Suitability Parameters.

Soil Model (SM)	Depth* (m)	pH	E.C. (dS/m)	SAR	Sat%	Texture**	Consistence	Suitability (ASAC 1987)
LVK4	0.50	7.0-8.0	<3	<4	30-60	CL	Firm-friable	Fair
LVK11	0.30	7.0-8.0	<3	<4	30-60	CL	Firm-friable	Fair
MIFR5	0.95	5.0-6.0	<3	<4	30-60	S-CL	Loose	Poor-F
MIL1	0.95	5.0-6.0	<3	<4	30-60	S	Loose	Poor
MIL5	1.00	5.0-6.0	<3	<4	30-60	S	Loose	Poor
MMW2	0.20	7.0-8.0	<3	<4	30-60	SiL-SiCL	Sticky	Fair
MMY2	0.30	5.0-6.0	<3	<4	30-60	L-SL	V friable-Fr	Good
MMY6	0.30	5.0-6.0	<3	<4	30-60	L-SL	V friable-Fr	Good
PELV1	0.45	7.0-8.0	<3	<4	30-60	L-CL	Friable-firm	Good-F
PELV11	0.55	7.0-8.0	<3	<4	30-60	CL-S	Firm-Loose	Fair-P
PEWN1	0.70	7.0-8.0	<3	<4	30-60	CL-S	Firm-loose	Fair-P

* Approximate depth (m) of lower subsoil below mineral surface.
** S=sand; SL=sandy loam; L=loam; SiL=silt loam; SiCL=silty clay loam; CL=clay loam; SCL=sandy clay loam; C=clay; SiC=silty clay.

While topsoil is better suited for revegetation than the underlying subsoil, salvaging the variably thin (15 to 20 cm) A horizons is challenging under ideal working conditions and during frozen soil conditions, mixing topsoil and upper subsoil is inevitable. A solution is to salvage a thickness of surface soil that is readily accomplished with large equipment and still results in material that is suited for reclamation use. A salvage lift of 30 cm is considered practicable with large dozers and where topsoil thickness average is 15 cm, results in a 1:1 mixture of topsoil and upper subsoil. A mixture of topsoil and upper subsoil will result in a material with characteristics reflecting the relative proportions of the pre-mixed horizons. The predicted characteristics of salvaged soil (30 cm) are shown in Table 6.4. Mixing A and B horizons will result in a material with more uniform characteristics (less extremes) and a suitability rating that is mostly Fair.

Salvage of mineral soil will include the surface litter (LFH horizon) and surface peat material (<40 cm thick) associated with poorly drained soils. Litter and peat material is an important source of organic matter and contributes greatly to soil functions such as nutrient retention, water-holding capacity and structure stability.

Coarse textured mineral soil is poorly suited for revegetation. Limitations of loamy sand and sand textured material include low nutrient supply capacity, weak or no structure, low water-holding capacity and a high susceptibility to erosion by wind. No soil salvage is recommended from areas having predominately coarse textured soils (MIFR5, MIL1 and MIL5 soil models).

Table 6.4 Predicted Suitability of Surface (0 to 30 cm) Mineral Soil.

Soil Model	Litter / Peat	Topsoil	Upper Subsoil	Salvage PT+TS:US	pH	E.C.	SAR	Sat %	Text*	Consist	Suitability
(SM)	(m)	(m)	(m)	(cm)		dS/m					(ASAC 1987)
BMT5	0.25	0.15	0.50	25+15:15	5.5-6.0	<2	<4	-	O:S	Friable	Fair
CHMM1	0.15	0.15	0.25	15+15:15	5.0-6.5	<2	<4	-	O:CL	Friable	Fair
DOKM2	0.07	0.15	0.25	15:15	5.0-6.5	<2	<4	30-60	CL	Friable	Fair
DOLV6	0.05	0.20	0.30	20:10	5.0-6.5	<2	<4	30-60	CL	Friable	Fair
DOLV9	0.07	0.20	0.30	20:10	5.0-6.5	<2	<4	30-60	CL	Friable	Fair
DOSE1	0.07	0.15	0.30	15:15	5.0-6.5	<2	<4	30-60	CL	Friable	Fair
DOV10	0.07	0.15	0.25	15:15	5.0-6.5	<2	<4	30-60	CL	Friable	Fair
FRLV2	0.11	0.25	0.60	25:05	5.0-6.0	<2	<4	30-60	L	Friable	Good
KMLV1	0.08	0.20	0.25	20:10	5.0-6.0	<2	<4	30-60	CL	Friable	Fair
KMLV2	0.11	0.15	0.30	15:15	5.0-6.0	<2	<4	30-60	CL	Friable	Fair
LVK4	0.09	0.15	0.35	15:15	5.0-6.0	<2	<4	30-60	CL	Friable	Fair
LVK11	0.09	0.10	0.20	10:20	5.0-6.0	<2	<4	30-60	CL	Friable	Fair
MIFR5	0.06	0.25	0.70	25:05	4.6-5.6	<2	<4	30-60	LS	Loose	Poor
MIL1	0.06	0.25	0.70	25:05	4.6-5.6	<2	<4	30-60	S	Loose	Poor
MIL5	0.08	0.25	0.75	25:05	4.6-5.6	<2	<4	30-60	S	Loose	Poor
MMW2	0.15	0.10	0.10	15+10:20	5.5-7.0	<2	<4	30-60	CL	Friable	Fair
MMY2	0.08	0.15	0.15	15:15	5.0-6.0	<2	<4	30-60	L-SL	Friable	Good
MMY6	0.04	0.05	0.95	5:25	5.5-6.5	<2	<4	30-60	L-SL	Friable	Good
PELV1	0.06	0.20	0.25	20:10	5.6-6.0	<2	<4	30-60	L-CL	Friable	Fair-G
PELV11	0.06	0.15	0.40	15:15	5.6-6.0	<2	<4	30-60	FSL-CL	Friable	Fair-G
PEWN1	0.06	0.20	0.50	20:10	5.6-6.0	<2	<4	30-60	L-CL	Friable	Fair-G

* S=sand; LS=loamy sand; SL=sandy loam; FSL=fine sandy loam; L=loam; CL=clay loam; O=organic.

6.2.2 Organic Soil Resources

Organic soil is composed of accumulated peat material (>40 cm thick) derived from decomposing mosses and forest litter. The various properties are both useful and challenging for soil reclamation. Surface peat (Of horizons) is composed of poorly decomposed, fibric material while layers below the surface have moderately decomposed, mesic peat (Om horizons) and well decomposed, humic peat (Oh horizons). Organic soil often has a high water table and may require dewatering prior to salvage. Peat has a high water holding capacity and a high nutrient holding capacity which makes it a valuable soil resource. Peat also has a low bulk density and dries quickly when spread on the surface, is susceptible to erosion by wind, is susceptible to fire and can prevent heat transfer causing the underlying soil to be cold. Mixing peat and mineral material together will improve the physical and chemical properties.

Salvage of surface peat with the underlying mineral material can be accomplished with powered shovels (mine equipment) to create a peat:mineral mix for soil reclamation use. Where peat thickness is relatively shallow, mixing peat with underlying mineral material will be accomplished by salvaging both layers in one scoop. Where peat thickness is deep, mixing will be accomplished by salvaging a bucket of peat followed by a bucket of mineral material. Additional mixing will occur when the material is dumped from trucks, re-handled from storage piles and during final surface spreading.

A quality rating of Good is given to peat mixed with sandy loam or finer mineral material (organic:fine texture) while peat mixed with loamy sand or coarser mineral material (organic:coarse texture) is given a Fair quality rating. The quality ratings for peat:mineral mixes is not related to the suitability ratings given to mineral soil and is intended to reflect the higher water-holding capacity of organic:fine textured material over the organic:coarse textured material. Predicted characteristics of salvaged peat:mineral mix is demonstrated in Table 6.5.

Table 6.5 Predicted Characteristics of Salvaged Peat:Mineral Mix.

Soil Model (SM)	Peat Thickness (m)	pH	E.C. dS/m	SAR	Sat%	Texture*	Salvaged Peat:Mineral (cm)	Salvaged Peat:Mineral Texture*	Quality Rating**
BMT5	0.25	5.0-7.0	<3	<4	30-60	S	25:30	O:coarse	Fair
MLD1c-G	0.50	6.5-7.5	<3	<4	30-60	C	50:50	O:fine	Good
MLD1m-G	0.60	6.5-7.5	<3	<4	30-60	L-CL	60:60	O:fine	Good
MLD1s-G	0.60	6.5-7.5	<3	<4	30-60	S	60:60	O:coarse	Fair
MLD2c***	1.30	6.5-7.5	<3	<4	30-60	C	130:130	O:fine	Good
MLD2m***	1.30	6.5-7.5	<3	<4	30-60	L-CL	130:130	O:fine	Good
MLD2s***	1.30	6.5-7.5	<3	<4	30-60	S	130:130	O:coarse	Fair
MLD3***	2.50	6.5-7.5	<3	<4	30-60	L-CL	250:250	O:fine	Good
MMW21	0.20	6.5-7.0	<3	<4	30-60	SiCL-CL	20:30	O:fine	Good
MUS1c-G	0.60	5.0-7.0	<3	<4	30-60	C	60:60	O:fine	Good
MUS1m-G	0.50	5.0-7.0	<3	<4	30-60	CL	50:50	O:fine	Good
MUS1s-G	0.60	5.0-7.0	<3	<4	30-60	S	60:60	O:coarse	Fair
MUS2c***	1.40	5.0-7.0	<3	<4	30-60	C	140:140	O:fine	Good
MUS2m***	1.40	5.0-7.0	<3	<4	30-60	CL	140:140	O:fine	Good
MUS3***	2.50	5.0-7.0	<3	<4	30-60	CL	250:250	O:fine	Good

* S=sand; L=loam; CL=clay loam; SiCL=silty clay loam; C=clay; O=organic; fine = sandy loam or finer; coarse = loamy sand or coarser.
** Rating reflects difference in water-holding capacity and is not related to rating of mineral soil.
*** Mineral parameters are based on subsoil from shallow organic soils.

6.2.3 Volume and Properties of Soil Available for Salvage

Soil will be salvaged ahead of mine development and, when operationally feasible, direct replaced. Salvaging 30 cm of surface mineral soil but excluding the poor quality sands (Table 6.4) will produce salvaged material with the chemical parameters listed in Table 6.6. Salvaging the various thicknesses of surface peat with a range of thickness of underlying mineral material (from 1:1 to 2:1) will produce a peat:mineral mix suitable for revegetation with the chemical characteristics summarized in Table 6.6.

Table 6.6 Physical and Chemical Parameters of Salvaged Soil.

Salvage Type	Quality Rating	pH*	E.C.* dS/m	SAR*	Sat %*	Consistence	Texture
Peat:Mineral (Pt:M)	Good**	5.0-7.5	<3	<4	30-60	Friable	Organic:Sandy loam and finer
	Fair**	5.0-7.5	<3	<4	30-60	Friable	Organic:Loamy Sand and coarser
Mineral Soil (MS)	Good	5.0-6.5	<2	<4	30-60	Friable	Loam
	Fair	5.0-6.5	<2	<4	30-60	Friable	Clay Loam

* Parameter of mineral component only.
** Peat:Mineral rating reflects difference in water-holding capacity and is not related to rating of mineral soil.

Volumes of mineral soil and peat:mineral mix available for salvage in each year or time period was based on the sequential mine plans (DCEL 2005) and is summarized in Table 6.7. These volumes of available soil are compared to the soil volumes needed for reclamation in Section 7.5 and used for soil salvage planning.

Table 6.7 Project Available Soil Salvage Volumes.

Year	Salvage Area	Mineral Soil		Peat:Mineral Mix		Total
		Good	Fair	Peat:Fine	Peat:Coarse	
	ha	(m^3)	(m^3)	(m^3)	(m^3)	(m^3)
2009	855	0	1,649,100	5,518,500	0	7,167,600
2010	413	96,000	597,100	2,237,100	4,500	2,934,700
2011	111	0	90,500	1,013,800	84,500	1,188,800
2012	521	0	702,100	4,534,000	0	5,236,100
2013	187	3,400	291,500	1,340,800	124,100	1,759,800
2014	164	49,400	333,100	611,600	593,000	1,587,100
2015	272	126,500	742,200	544,100	182,000	1,594,800
2016	236	67,200	504,600	462,300	1,400	1,035,500
2017	197	58,700	184,900	1,351,900	6,900	1,602,400
2018	118	18,600	6,800	32,600	39,000	97,000
2019	243	23,400	75,500	987,400	177,800	1,264,100
2020 to 2024	530	122,100	193,100	825,000	251,200	1,391,400
2025 to 2029	420	36,000	62,100	1,365,200	923,800	2,387,100
2030 to 2034	404	44,400	37,400	2,858,200	519,600	3,459,600
2035 to 2036	56	4,500	0	261,200	58,900	324,600
Total	4,727	650,200	5,470,000	23,943,700	2,966,700	33,030,600

Note: m^3 = in situ volume-

6.3 Landscape Construction

Many new landscapes will be constructed with overburden material from Pit 1 and processing by-products from the plant site. These materials will be hauled with trucks and end-dumped to create new slopes. The landscapes are designed to be geotechnically stable which controls the rate of surface erosion to maintain integrity of the terrain plus adjacent terrestrial and aquatic environments. The new landscapes must also support the re-establishment of ecosites. Placement of sodic spoil (identified in Section 5.3) and processing waste will be managed to ensure that the final landscape surface (minimum of 80 to 100 cm) is composed of suitable, non-sodic material (Table 6.8).

Other constructed landscapes requiring a soil cover will include tailing sands and original parent material. Closure of ponds will occur by capping with tailing sands: 3 m thick over Pond 1, and 2 m thick over the freeze / thaw pond on top of main external disposal area (EDA C). An expected characteristic of the tailing sands is outlined in Table 6.8. Areas of tailing sands will have nearly level final slopes with shallow swales to direct surface runoff into wetlands. These wetlands are designed to control erosion and sediment transport, and to maintain acceptable water quality and flow rates to local water courses. The plant site will be constructed on original materials following soil salvage. After decommissioning, remediation (as required) and site preparation for soil replacement, the material on the former plant site is

expected to have characteristics and properties that resemble the original parent material of Dover, Kilome and Livock soil series.

Table 6.8 Physical and Chemical Parameters of Constructed Landscape Subsoil.

Landscape Material	pH	E.C. (dS/m)	SAR	Sat%	Texture*	Consistence	L Subsoil Suitability (ASAC 1987)
Non-sodic spoil (NSS)	7.3-8.0 (7.5)	<3	<4	30-60	L	Friable	Fair
Parent material (PM)	5.0-8.0 (7.8)	<3	<4	30-60	CL-C	Firm	Fair-Poor
Tailings Sand (TS)**	6.0-7.9 (7.0)	<3	<4	30-60	S	Loose	Poor

* S=sand; L=loam; CL=clay loam; C=clay.
** Leskiw, L.A., C. Qualizza and S. Tuttle. 2000.

Two pit lakes will be created upon final mine closure. Each lake will have a wetland/littoral zone along the perimeter where depth of water is expected to be <3 m. The littoral zone will receive a thin (15 cm) soil cover to improve the rooting medium for wetland and aquatic vegetation and no soil cover is planned for the lake bottoms.

Various slope categories, as listed in Table 6.9, are part of the final landscape design (Figure 6.1). Berms surrounding Pond 1 will have long, gentle slopes (<20% grade) and an elevation of 20 to 30 m above the original ground surface. External disposal area C will have similar berm steepness (<20%) with a 50 to 60 m elevation gain resulting in longer slopes. Shape of the slopes is designed to maximize capability for forestry and to blend into the surrounding landscape as much as possible. The slopes will include slight dips and swales and will not be benched. When Pit 1 is reclaimed, some slopes will be steeper than 20% and these short slopes will have an elevation gain from 20 to 50 and 75 m. Inclusions of short, steep slopes contribute to landscape diversity and will allow for larger areas of the reclaimed landscape to be nearly level. The final (designed) terrain is illustrated on the mine closure drainage scheme (Figure 6.2) and on a three dimensional characterization of the entire DCEL lease (Figure 6.3).

Table 6.9 Reconstructed Terrains

Reclaimed Mine Component	Slopes (%)	Area (ha)
Plant Site and Pond 1		
Pond 1 + EDA	0	235
Pond 1 Wetland	0	9
Pond 1 + EDA	0-5	25
Tailings Pond Berm	5-20	309
Plant, maintenance & laydown	0	154
Plant Site Wetland	0	16
Plant Site	0-5	19
Berm by plant site wetland	5-20	12
Minimal Disturbance*	0-5	276
External Disposal and Joslyn Fill		
Freeze thaw pond	0	355
Wetland	0	15
Area around wetland	0-5	16

Table 6.9 Reconstructed Terrains		
Reclaimed Mine Component	**Slopes (%)**	**Area (ha)**
Waste Disposal Berm	0-5	35
Joslyn Creek Fill	0-5	86
Waste Disposal Berm	5-20	882
Minimal Disturbance*	0-5	9
Pit 1		
Pit 1 + EDA	0	1081
Pit 1 wetland	0	19
Pit 1 + EDA	0-5	98
Pit 1	5-20	88
Pit 1 & EDA	20-26	527
Pit 1	26-30	15
Pit 1	30-35	40
Pit 1	40-45	20
Pit 1	45-50	4
Minimal Disturbance*	0-5	178
West lake	-	408
East lake	-	166
Total		5097

* minimal disturbance terrain will be equivalent to baseline terrain

Miscellaneous disturbances outside of the mine development footprint include reclamation material storage (RMS) piles, the Joslyn Creek diversion with associated features, and a water intake line. No soil salvage is recommended for the RMS piles (180 ha) as storage material will be placed and removed in a manner resulting in minimal soil preparation requirements for revegetation. The Joslyn diversion (107 ha) will include a dam and lake with diversion channels and an overflow spillway. A water intake pipeline is also planned and will cover about 16 ha. Specific soil conservation and reclamation planning for the diversion infrastructure and pipeline will be done at the operational level in a manner that maintains land capability.

6.4 Soil Salvage and Replacement Plan

New soils will be created by salvaging mineral soil and a peat:mineral mix ahead of mine development for direct placement over constructed landscapes. The annual salvage volume needed for reclamation will be determined by the area of completed landscapes and a 30 cm thick soil cover. No cover soil will be placed on the lake bottoms, although a 15 cm cover will be placed over the littoral zones. The plan is to salvage (and directly place) one half of the suitable mineral soil available for salvage each year; and to salvage a mixture of peat:mineral material to cover the remaining landscapes.

In most years, there will be more soil available for salvage than is needed (Table 6.10) and the likelihood for direct placement of salvaged material is high. In some years however, the need for cover soil will be greater than the volume available for salvage. This is especially the case as mining is completed through to final closure. Salvage and storage of peat:mineral material is recommended in years when available material is much greater than reclamation needs. Research has found that higher temperatures near the surface of storage piles allow microbial activity to decompose some peat (Kong et al., 1980). Below 50 cm of the surface however, temperatures remain below 10^{o}C and no decomposition occurs. Beneficial

effects of peat decomposition include: reduced fibre content, pore volume and air capacity, which leads to increased water storage capacity and available nutrient content. The recommended volume of material placed in storage should be the volume required for future reclamation (30 cm thick per hectare) plus 40% to account for peat decomposition or additional requirements.

As shown in Table 6.10 there is approximately 33.0 Mm^3 of suitable reclamation material available over the mine footprint but only 12.7 Mm^3 is required to reclaim this area to equivalent capability. An additional 2.3 Mm^3 or material will be salvaged when peat:mineral material is stockpiled to account for decomposition and potential additional requirements.

Table 6.10 Soil Handling and Material Balance

Year	Soil Available for Salvage				Reclamation Requirements		Soil Handling			
	Area (ha)	Upland (Mm^3)	Peat/ Mineral (Mm^3)	Total (Mm^3)	Area (ha)	Volume (Mm^3)	Upland Direct Placed (Mm^3)	Peat/ Mineral Direct Placed (Mm^3)	Peat/ Mineral to Stockpile** (Mm^3)	Peat/ Mineral from Stockpile (Mm^3)
2009	855	1.65	5.52	7.17		0	0.00	0	4.00	
2010	413	0.69	2.24	2.93	57	0.17	0.17	0	1.50	
2011	111	0.09	1.10	1.19	194	0.58	0.05	0.54		
2012	521	0.70	4.53	5.24	90	0.27	0.27	0		
2013	187	0.29	1.46	1.76	20	0.06	0.06	0		
2014	164	0.38	1.20	1.59	300	0.90	0.19	0.71		
2015	272	0.87	0.73	1.59	141	0.42	0.42	0	0.72	
2016	236	0.57	0.46	1.04	67	0.20	0.20	0	1.00	
2017	197	0.24	1.36	1.60	28	0.08	0.08	0	1.00	
2018	118	0.03	0.07	0.10	321	0.96	0.01	0.07		0.88
2019	243	0.10	1.17	1.26	82	0.25	0.05	0.20		
2020 to 2024	530	0.32	1.08	1.39	327	0.98	0.16	0.82		
2025 to 2029	420	0.10	2.29	2.39	409	1.23	0.05	1.18		
2030 to 2034	404	0.10	3.38	3.46	426	1.28	0.04	1.24		
2035 to 2036	56	0.05	0.32	0.32	335	1.01	0	0.32		0.68
2036 to Closure	0	0	0	0	1930*	4.31	0	0		4.31
TOTAL	**4727**	**6.18**	**26.91**	**33.03**	**4727**	**12.70**	**1.75**	**5.08**	**8.22**	**5.87**

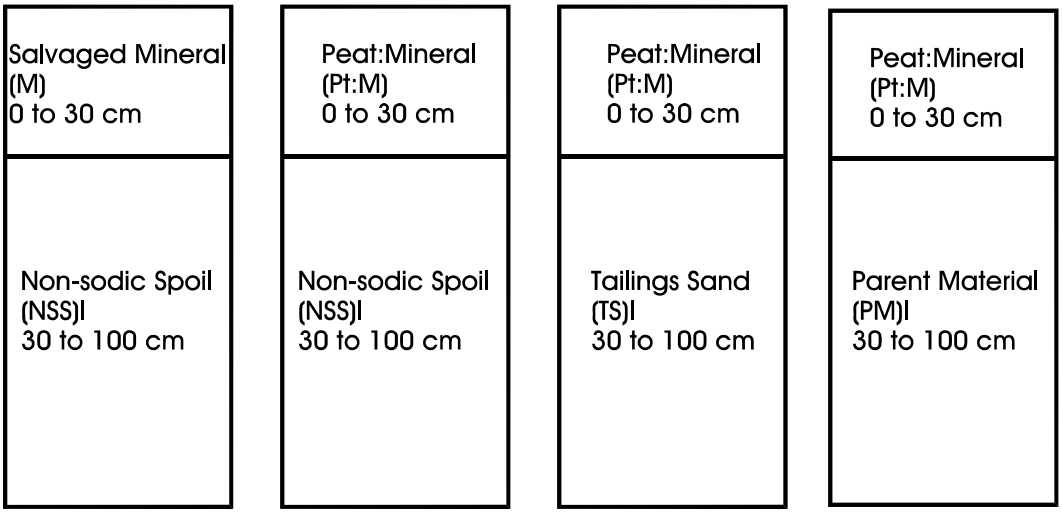
Summary

Coversoil Material Required (Mm^3)		12.7	
Material Direct Placed (Mm^3)		6.83	
Upland Direct Placed (Mm^3)	1.75		
Peat Direct Placed (Mm^3)	5.08		
Material Required from Stockpile (Mm^3)		5.87	+ 40%
Material Required to Stockpile (Mm^3) **		8.22	
Excess Stockpiled Material (Mm^3)		2.35	

* Area includes lakes and littoral zones (no soil replacement on lakes and 15 cm on littoral zones)

** Peat:Mineral material (1:1 by volume) stockpiled includes additional 40% volume to account for peat decomposition and potential additional requirements

Reclamation will occur through placement of a soil cover on new landscapes to provide new soils for vegetation growth. Two types of soil cover (0 to 30 cm) over three rootzone or subsoil materials (30 to 100 cm) will result in the diversity of soil profiles illustrated below. The location of these profiles will be distributed across the reclaimed landscape as indicated in Table 6.11.



Topographical patterns represented by a range of slope steepness, aspect and drainage conditions contribute to various moisture regimes and provide additional diversity to soil. The landscape with slopes between 1 and 20% is expected to be moderately well to well drained, and to provide normal soil moisture for forest vegetation growth. On topography with > 20% slopes, upper slope positions shed rainfall and will be drier than mid slope positions while lower slope positions receive extra soil moisture for vegetation growth through run-on. In addition, exposure to sun causes south facing slopes to be drier than north facing slopes. Level topography is expected to be imperfectly drained (except on sands) and the excess of soil moisture will contribute to greater forest productivity. Concave landscapes (depressions) are expected to be poorly drained and best suited to support wetland species.

The reclamation plan is intended to provide for ecological diversity. Development of various landscape shapes, aspect and rootzone materials set the patterns for soil moisture regimes to support a range of habitat types. Direct placement of mineral soil will contribute to further ecological diversity. The seed bank included within the replaced mineral soil will allow establishment of native vegetation and provide early cover and erosion control without aggressive competition. The reclaimed landscape is expected to be a patchwork of planned ecosites rather than large, homogeneous areas. Based on the predicted occurrences of new landscapes, spoil material and replaced soil cover, the expected land capability for forest ecosystems has been summarized in Table 6.11 and is illustrated in Figure 6.4. Monitoring of soil conditions and vegetation growth will demonstrate how well the planned ecosites become established.

Table 6.11 Reclaimed Soil Distribution and Capability.

Landscape Components	Slope (%)	Aspect Note 1	Slope Position Note 2	Reclaimed Soil Profile Note 3	Final Capability (Leskiw 1998)	Area (ha)
Plant Site and Pond 1						
EDA D	0	-	-	SM / NSS	1	16
EDA D	0-5; 5-20	-	-	SM / NSS	3D	41
Tailings Pond Berm	5-20	-	-	SM / NSS	3D	54
Tailings Pond Berm	5-20	-	-	Pt:M / NSS	2D	195
Pond 1	0	-	-	Pt:M / TS	2M	219
Pond 1 Wetland	0	-	-	Pt:M / TS	5R	9
Pond 1	0-5	-	-	Pt:M / TS	2M	17
Pond 1	5-20	-	-	Pt:M / NSS	2D	27
Plant, maint & laydown	0	-	-	Pt:M / PM	2VR	154
Plant site wetland	0	-	-	Pt:M / PM	5R	16
Plant site	0-5	-	-	Pt:M / PM	3V	19
Berm by plant site wet	5-20	-	-	Pt:M / PM	3V	12
Minimal Disturbance	0-5	-	-	Baseline	1	1
Minimal Disturbance	0-5	-	-	Baseline	2R, 2V	138
Minimal Disturbance	0-5	-	-	Baseline	4R	29
Minimal Disturbance	0-5	-	-	Baseline	5R, 5OR, 5SR	108
External Disposal Area C and Joslyn Fill						
Freeze thaw pond	0	-	-	Pt:M / TS	2M	355
Wetland	0	-	-	Pt:M / TS	5R	15
Area around wetland	0-5	-	-	Pt:M / TS	2M	16
Waste disposal berm	0-5	-	-	Pt:M / NSS	2D	35
Joslyn Creek fill	0-5	-	-	SM / NSS	3D	86
Waste Disposal Berm	5-20	-	-	SM / NSS	3D	302
Waste Disposal Berm	5-20	-	-	Pt:M / NSS	2D	580
Minimal Disturbance	0-5	-	-	Baseline	1	2
Minimal Disturbance	0-5	-	-	Baseline	2R	3
Minimal Disturbance	0-5	-	-	Baseline	5OR, 5SR	4
Pit 1						
Pit 1 + EDA's	0	-	-	Pt:M / NSS	1	994
Pit 1 + EDA's	0	-	-	SM / NSS	2DR	87
Pit 1 wetland	0	-	-	Pt:M / NSS	5R	19
Pit 1 + EDA's	0-5	-	-	Pt:M / NSS	2D	98
Pit 1	5-20	-	-	Pt:M / NSS	2D	88
Pit 1 & EDA's	20-26	N + S	U + M	Pt:M / NSS	2TDX, 2DT, 2D	353
Pit 1 & EDA's	20-26	N + S	L	Pt:M / NSS	2DR	174
Pit 1	26-30	N + S	U + M	Pt:M / NSS	2TXD, 2TD, 2D	10
Pit 1	26-30	N + S	L	Pt:M / NSS	2DR	5
Pit 1	30-35	N + S	U + M	Pt:M / NSS	3TX & 2TD	26
Pit 1	30-35	N + S	L	Pt:M / NSS	2TD & 2DR	13
Pit 1	40-45	N + S	U + M	Pt:M / NSS	3T & 2TD	14
Pit 1	40-45	N + S	L	Pt:M / NSS	2TDR	7
Pit 1	45-50	North	U + M	Pt:M / NSS	3T	3
Pit 1	45-50	North	L	Pt:M / NSS	2TDR & 3T	1

Table 6.11 Reclaimed Soil Distribution and Capability.						
Landscape Components	**Slope**	**Aspect**	**Slope Position**	**Reclaimed Soil Profile**	**Final Capability**	**Area**
	(%)	**Note 1**	**Note 2**	**Note 3**	**(Leskiw 1998)**	**(ha)**
West lake and littoral	-	-	-	-	-	408
East lake and littoral	-	-	-	-	-	166
Minimal Disturbance	0-5	-	-	Baseline	2R, 2V	26
Minimal Disturbance	0-5	-	-	Baseline	3MR, 3R	10
Minimal Disturbance	0-5	-	-	Baseline	4MK, 4R	48
Minimal Disturbance	0-5	-	-	Baseline	5OR, 5R, 5SR	94
					Total	5097

Note 1: N = North; S = South.
Note 2: U = Upper; M = Mid; L = Lower.
Note 3: M = salvaged mineral soil; Pt:M = peat:mineral mix; NSS = non-sodic spoil; TS = tailing sand; PM = parent material.

6.5 Soil Erosion

The soil erosion hazard of water immediately following reclamation has been assessed (Table 6.12). For evaluation purposes, the erodability (K value) of peat:mineral material is assumed to be equal to that of replaced mineral soil and is expected to represent an over-estimation. The risk of soil erosion by water on long slopes (0-20%) and short steep slopes (>20%) during non-frozen conditions is significant immediately following reclamation when no protection is provided by vegetation growth. As vegetation becomes established, the risk of soil erosion by water will diminish leaving a redistribution of soil materials that also occurs on natural landscapes.

Table 6.12 Potential Soil Erosion by Water on Reclaimed Soils.				
Reclaimed Mine Component	**Erodability**	**Slope**	**Slope Factor**	**Soil Erosion**
	(K Value*)	**(%)**	**(LS Value)**	**(Class)**
Plant Site and Pond 1				
Pond 1 + EDA	0.059	0	0.2	Slight
Pond 1 Wetland	-	0	-	Not Rated
Pond 1 + EDA	0.059	0-5	0.8	Moderate
Tailings Pond Berm	0.059	5-20	8.0	Severe
External Disposal and Joslyn Fill				
Freeze thaw pond	0.059	0	0.2	Slight
Wetland	-	0	-	Not Rated
Area around wetland	0.059	0-5	0.8	Moderate
Waste Disposal Berm	0.059	5-20	8.0	Severe
Pit 1				
Pit 1 + EDA	0.059	0		Slight
Pit 1 wetland	-	0	-	Not Rated
Pit 1 + EDA	0.059	0-5	0.8	Moderate
Pit 1	0.059	5-20	4.0	Severe
Pit 1 & EDA	0.059	20-26	9.0	Severe
Pit 1	0.059	26-30	13.0	Severe
Pit 1	0.059	30-35	18.0	Severe
Pit 1	0.059	40-45	20.0	Severe
Pit 1	0.059	45-50	20.0	Severe

Table 6.12 Potential Soil Erosion by Water on Reclaimed Soils.				
Reclaimed Mine Component	**Erodability**	**Slope**	**Slope Factor**	**Soil Erosion**
	(K Value*)	**(%)**	**(LS Value)**	**(Class)**
West lake	-	-	-	Not Rated
East lake	-	-	-	Not Rated

Assumptions:
Precipitation factor for Fort Chipewyan was used
Slope length = 200 m for most long slopes; 100 m for short steep slopes.
Soil cover factor = 0.6 (bare soil at start of first year after reclamation).
* Soil K values are from Pedocan Land Evaluation Ltd., 1993.

7.0 ENVIRONMENTAL EFFECTS ASSESSMENT

7.1 Project Scope

The following evaluation identifies potential environmental effects of the Joslyn North Mine project on the soil and terrain resources with opportunities for mitigation and residual effects. The activities that are likely to affect the soils and terrain resources are:

1. Surface mining and related activities;
2. Reclamation and revegetation; and
3. Potential acid inputs.

Surface mining will completely disrupt the natural terrain and the natural soil landscapes of the mine development footprint (local study area) and will be mitigated by reclamation. Reclamation is the creation of new terrain and new soil profiles followed by revegetation. Industrial processing releases emissions with potential acid inputs to the soil resource within the sub-regional and regional area.

7.2 Evaluation Process

The activities to identify valued environmental components (VECs) and to evaluate environmental effects of mining are summarized in the following order of occurrence:

1. Map the baseline soil resources of the Joslyn Lease sub-regional study area (SSA), with emphasis on the local study area (LSA) covered by the proposed North Mine development, and compile a soil map of the regional study area (RSA).
2. Test and evaluate the overburden from the Pit 1 area of the mine.
3. Review mining, operating and closure plans.
4. Identify valued environmental components (VECs).
5. Develop an initial assessment of environmental effects (negative or positive) to the soil and terrain.
6. Develop the soil salvage and reclamation plan to mitigate adverse effects where possible.
7. Evaluate the significance of any residual and cumulative adverse effects to the soil and terrain.

The decision pathway used to evaluate the significance of environmental effects is illustrated by the following list of questions that directed this evaluation:

1. Will the activity likely result in a known environmental effect?
2. Will the effect on the environment be adverse or positive?
3. If adverse, will the effect be mitigable or reversible to any extent?
4. Is there a residual effect after mitigation?
5. Are the effects (if mitigation is not possible) or the residual effects (if mitigation is possible) significant?
6. What are the cumulative effects?

7.3 Effects Assessment Terminology

Terms used for evaluating significance of environmental effects are described below.

1) Type of effect is described as:

- **project** - effects which occur in the short term.
- **residual** - effects which occur for a long or extended period, after reclamation and mitigation.
- **cumulative** - effects which occur for a long or extended period after reclamation and mitigation, and do not diminish with time.

2) Geographic extent is described as:

- **local** - effects on soil and terrain are limited to the disturbance site.
- **regional** - effects are extended to the regional area due to cumulative effects or due to loss of a regionally unique feature.

3) Duration of effects is identified as:

- **short term** - effects occurring within the development phase.
- **long term** - effects occurring after completion of mining and reclamation (i.e. mine abandonment).
- **extended term** - effects occurring after completion of mining and reclamation but diminishing with time.
- **residual** - effects persisting after completion of mining and reclamation for a long period of time.

4) Frequency of effect is described as:

- **continuous** - effects occurring continually over assessment period.
- **isolated** - effects confined to a specified period.
- **periodic** - effects occurring intermittently and sporadically over assessment period.

5) Potential for reversibility or recovery is described as:

- **reversible** - effects with are reversible and diminish upon cessation of activities.
- **reversible in long-term** - effects which remain after cessation of activities but diminish with time.
- **irreversible** - effects which are not reversible and do not diminish upon cessation of activities and do not diminish with time.

6) Magnitude or severity of effect is described as:

- **nil** - no change from background conditions anticipated after mitigation.
- **low** - disturbance predicted to be somewhat above typical background conditions, but well within established or accepted protective standards and normal socio-economic fluctuations, or to cause no detectable change in ecological, social or economic parameters.
- **moderate** - disturbance predicted to be considerably above background conditions, but within scientific and socio-economic effects thresholds, or to cause detectable change in ecological, social or economic parameters within range of natural variability.
- **high** - disturbance predicted to exceed established criteria or scientific and socio-economic effects thresholds associated with potential adverse effects, or to cause a detectable change in ecological, social or economic parameters beyond the range of natural variability.

Note: No catastrophic or human health risk issues are applicable to effects on soils and terrain resources. We have not evaluated slope stability or other geotechnical issues - those issues are dealt with elsewhere in the Joslyn North Mine report.

7) Probability of occurrence is described as:

- **low** - unlikely
- **medium** - possible or probable
- **high** - certain

8) Significance of potential environmental effect is described as:

- **insignificant** - effects of short duration that will be mitigated by reclamation; or residual effects that are of low (and moderate) magnitude that extend beyond reclamation, but are reversible with time.
- **significant** - residual effects that are not reversible with time, and cause detectable changes in ecological parameters beyond the range of natural variability.

9) Project contribution is described as:

- **neutral** - No net benefit or loss to the resource, communities, region or province.
- **positive** - Net benefit to the resource, communities, region or province.
- **negative** - Net loss to the resource, sites, access roads, communities, region or province.

10) Confidence rating is described as:

- **low** - based on incomplete understanding of cause-effect relationships and incomplete data pertinent to study area.

- **moderate** - based on a good understanding of cause-effect relationships using data from elsewhere or incomplete understanding of cause-effect relationships using data pertinent to study area.
- **high** - based on good understanding of cause-effect relationships and data pertinent to study.

7.4 Valued Environmental Components & Environmental Effects

The VECs related to soil and terrain that could be affected by the Joslyn North mine project are listed in Table 7.1. Identification of these VECs are derived from the soil and terrain inventory, through input from government requirements, and from project team members.

Table 7.1 Valued Environmental Components (VECs).

#	Description
1	The soil resources; includes topsoil and peat material.
2	Land capability for preferred, future land uses and soil landscape diversity.
3	Overburden (spoil) characteristics function to support water quality and normal trace element concentrations.

7.4.1 Soil Resource Potential Effects and Mitigation

The soil resource is a valued environmental component, especially the topsoil and peat material, and it should be conserved in a manner that maintains resource quality. Soil salvage and reclamation will mitigate the disruption. Potential effects include loss or degradation of the resource and management of effect is discussed below.

7.4.1.1 Effect by Disruption

In the short term (mining phase) there is complete disruption of the baseline soil profiles and landscapes in the mine footprint. This adverse effect is mitigated by sequential development and progressive reclamation. DCEL will undertake progressive reclamation through construction of new landscapes and placement of a cover soil to create new soil profiles. Progressive mine development will minimize the duration of some soil disruption. Areas not required for mine development will be left alone and not disturbed.

The residual effect of soil disruption is that newly constructed soils will have different horizons or layers than the baseline soils and some different properties. The effect is reversible in the long term through normal soil forming processes but is not significant because the reconstructed soil will function similarly to the pre-disturbance soils. This effect will persist for many years and is cumulative.

7.4.1.2 Effect by Loss of Soil

The soil salvage and reclamation plan (Section 7.5 of this report), designed to ensure equivalent capability of replaced soil, will result in the loss of some soil resources. Salvage and reclamation planning revealed that the volume of suitable material available for salvage exceeds the volume of material needed for reclamation (by direct placement) in most years. The salvage plan provides for storage of peat:mineral material in years when available salvage volumes greatly exceed replacement volumes (Table 6.10).

When stockpiling is required, extra soil salvage (40% volume) will ensure that sufficient soil is available for final reclamation as the loss of soil is irreversible. Salvage of the better quality soil, identified by detailed soil mapping, will ensure that best quality material is used and that poor quality material is avoided. Salvaging better quality soil material and storage to ensure adequate volume is available for reclamation results in a neutral and insignificant effect, with no residual or cumulative effects.

7.4.1.3 Effect by Mixing Soils

Mineral soil required for reclamation will be salvaged to a depth of 30 cm for direct placement only (no storage). Salvaging one lift of surface soil will cause incorporation of some upper subsoil material (B horizon) into the topsoil (A horizon), thereby altering some physical and chemical properties according to the proportion of A and B horizons. The magnitude of mixing effect is considered low because the property changes will still result in a suitable reclamation material. Salvage of poor quality, coarse textured soil (identified from detailed soil mapping) will be avoided, allowing the better quality material to be used. The effect of mixing is also residual because the effect will persistent after reclamation and will diminish with time as the soil functions and is subject to continued soil forming processes.

Organic soil salvage and incorporation of the underlying mineral material will produce a peat:mineral mix better suited for reclamation than peat material alone. Valuable peat properties include a high water holding capacity and a high nutrient holding capacity. A low bulk density however, causes peat to have many limitations for reclamation use. When mixed together, the physical and chemical properties are improved (positive effect & moderate magnitude), resulting in a material suited for reclamation allowing the desired land capability to be achieved (Leskiw 1998). The effect of mixing will persist after reclamation (residual) and will diminish slightly with time as the fibric portion of peat decomposes.

7.4.2 Land Capability Potential Effects and Mitigation

Land capability and future productivity is an important VEC. The goal of reclamation (a legislative requirement) is to return equivalent land capability. The main land use will be for forestry although other land uses will also be supported. Reclamation involves the construction of new landscapes with materials suitable for root growth (minimum 80 to 100 cm below the surface) followed by surface placement of salvaged material (30 cm thick) as a cover soil. Constructing new landscapes and soil profiles will replace capability so that it will be sustainable through normal land management practices. The effect of creating new landscapes and soils will be changes to capabilities compared to pre-disturbance conditions.

7.4.2.1 Effect by Landscape Changes

In the short term (mining phase) mining will disrupt natural landscapes. New landscapes will be created as mining progresses with the final landscape surface composed of non-sodic material suitable for root growth. The new landscapes will have a greater diversity of slope classes than the pre-disturbance landscapes (Table 7.2). Additional landscape diversity is provided by various rootzone materials, elevation and aspect and drainage conditions. No landscape disturbance will occur on areas not required for mine development.

The addition of two lakes to the landscape is a positive, residual effect not reversible with time and is significant. The effect is also cumulative because lakes are created at other mines in the region. The residual effect of constructing a diversity of new landscapes (including lakes) to support land capability is the change at specific locations and is considered neutral and insignificant.

Table 7.2 Comparison of Baseline & Reclaimed Terrain						
Slopes (%)	**Baseline Terrain**		**Reclaimed Terrain**		**Change**	
	(ha)	**(%)**	**(ha)**	**%**	**(ha)**	**%**
0	2	0	1884	37	1882	37
0-5	4645	91	742	15	-3903	-77
5-20	370	7	1291	25	921	18
20-30	38	1	542	11	504	10
30-35	10	0	40	1	30	1
35-40	7	0	0	0	-7	0
40-45	5	0	20	0	15	0
45-50	17	0	4	0	-13	0
Water	3	0	574	11	571	11
Total	5097	100	5097	100	0	0

7.4.2.2 Effect by Change to Land Capability

In the short term (mining phase) disruption of soil and landscapes causes loss of land capability. Land capability is reclaimed through construction of new landscapes and soil profiles. The landscape is designed to provide a range of slopes and subsequent moisture regimes to support planned habitats suitable for forestry and wildlife use. The placement of cover soil will improve the soil function of storing and providing moisture and nutrients for plant growth. The residual effect of reclamation is soil landscapes that function with a higher capability than pre-mining conditions (Table 7.3). Approximately 3,600 ha of the reclaimed soil landscapes are predicted to have a land capability of Class 1 and 2 compared to pre-disturbance conditions of approximately 1,500 ha.

Table 7.3 Comparison of Land Capability for Forests.						
	Predevelopment Area		**Post Reclamation Area**		**Difference**	
Capability	**(ha)**	**(%)**	**(ha)**	**(%)**	**(ha)**	**(%)**
Class 1	383	8	1013	20	630	12
Class 2	1170	23	2620	51	1450	28
Class 3	553	11	557	11	4	0
Class 4	1011	20	77	2	-934	-18
Class 5	1887	37	256	5	-1631	-32
Water	2	0	574	11	572	11
Disturbed	91	2	0	0	-91	-2
Total	5097	100	5097	100	0	0

7.4.2.3 Effect by Erosion of Reclaimed Soil

After reclamation, portions of the soil landscapes will be subject to the modifying influence of erosion. Mitigation includes shaping the landscape to provide dips and swales to reduce slope steepness and slope length thereby reducing surface flow rates and distance. Some erosion of cover soil material is expected to occur on steep slopes and long slopes. The natural process of erosion, sediment transport and re-deposition within the reclaimed landscape may modify the thickness and texture of surface layers. The loss and deposition of soil adds to diversity and develops more natural soil landscapes. As vegetation

cover becomes established and provides effective protection, the frequency and magnitude of erosion will decrease.

7.4.2.4 Effect by Acid Inputs

Soils have a natural ability to buffer against pH changes from acid inputs through the function of cation exchange capacity (CEC). Coarse textured soils are the most sensitive to acidification because the CEC and amount of nutrients and cations available for exchange is normally low. Soils with a high CEC are better able to resist the loss of base cations from the exchange complex – the first step in the mechanism of acidification. Prolonged exposure to acidifying inputs leads to saturation of the buffering capacity, a lowered pH from base cation loss and eventual mobilization of aluminum (CASA 1999). The processes of soil acidification are gradual. The effects can include deficiencies of soil nutrients (calcium, magnesium, molybdenum and phosphorus) and toxicity of elements such as aluminum, manganese and hydrogen (Brady and Weil, 2002). Organic soil can also resist changes from acid inputs (similar to minerals soil) according to the pH and nutrient concentrations.

Potential acid inputs (PAI) to the region have been modeled according to the Acid Deposition Management Framework (CASA 1999 and CEMA 2004) representing baseline, project and cumulative scenarios. Potential acid inputs are expressed in units of keq of H^+ /hectare/year. The regional soils rated as having High, Medium or Low sensitivity to acid deposition (Section 5.5) represent critical loading limits of 0.25, 0.5 and 1.0 keq of H^+ /hectare/year. The critical load is defined as "the highest load of acid deposition that will not cause chemical changes leading to long-term harmful effects on the most sensitive ecological systems". Environmental damage will not necessarily result when a critical load limit is exceeded because the buffering capacity provides a measure of protection. It is expected that damage will occur however, if critical load limits are continually exceeded over many years.

Comparison of the baseline PAI scenario and regional soils (Figure 5.5) reveals the potential extent of acid input effects on soil prior to project development, and forms the basis for evaluating the project and cumulative effects. PAI mitigation and modeling results are described in AMEC 2005.

Potential project effects of acid inputs to soil is illustrated in Figure 5.5 and summarized in Table 7.5. Baseline results indicate that soils representing 195,635 ha have received acid inputs exceeding critical load limits prior to project development. The project results indicate that the critical load limit will be exceeded on an additional 14,484 ha (7%).

The magnitude of potential impacts to individual soils has not been quantified. It is understood that the effect varies according to the soil sensitivity and concentration of inputs. For example, soils with a moderate sensitivity rating have no effects at inputs less than 0.5 keq/ha/yr because buffering prevents change. An adverse effect is expected to occur where inputs exceed 0.5 keq/ha/yr, and the effect is expected to be greater where inputs exceed 1.0 keq/ha/yr. The magnitude is greater on highly sensitive soils and less on soils with a low sensitivity. The majority of affected soils have a moderate sensitivity therefore the overall magnitude is estimated to be moderate. The effect is residual and partly reversible in the long-term as inputs diminish (Brady and Weil, 2002).

Table 7.5 Project Effects of Potential Acid Inputs on Soil.							
Soil Sensitivity	Baseline PAI			Project PAI			
	>0.25-0.5*	>0.5-1.0*	>1.0*	>0.25-0.5*	>0.5-1.0*	>1.0*	Change
	Ha	Ha	Ha	Ha	Ha	Ha	ha (%)
HIGH	**51,058**	**37,539**	**15,692**	**52,980**	**39,857**	**15,972**	**4,520 (4)**
MOD	220,160	**76,963**	**9,677**	229,866	**82,818**	**13,552**	**9,730 (11)**
LOW	36,009	26,878	**4,706**	35,240	28,172	**4,940**	**234 (5)**
WATER	5,651	4,280	1,256	5,590	4,519	1,315	-
Total	313,176	145,660	31,331	324,036	155,366	35,779	**14,484 (7)**

* PAI concentrations expressed in keq of H^+/hectare/year.
Note: **bold value**s = soil areas where critical load limit is exceeded.

Potential cumulative effects of acid inputs to soil is illustrated in Figure 5.5 and summarized in Table 7.6. The cumulative PAI represent all regional inputs expected to occur from known current and future projects. Results indicate that acid inputs could cause the critical load limit to be exceeded on 143,271 ha (73%) of land above baseline condition. The majority of these soils are rated as moderate and high sensitivity therefore the magnitude is estimated as moderate to high.

Table 7.6 Cumulative Effects of Potential Acid Inputs on Soil.							
Soil Sensitivity	Baseline			Cumulative PAI			
	>0.25-0.5*	>0.5-1.0*	>1.0*	>0.25-0.5*	>0.5-1.0*	>1.0*	Change
	Ha	Ha	Ha	Ha	Ha	Ha	ha (%)
HIGH	**51,058**	**37,539**	**15,692**	**118,829**	**53,674**	**19,652**	**87,866 (84)**
MOD	220,160	**76,963**	**9,677**	380,350	**116,725**	**21,939**	**52,024 (60)**
LOW	36,009	26,878	**4,706**	58,331	38,642	**8,087**	**3,381 (72)**
WATER	5,651	4,280	1,256	7,798	3,776	2,306	-
Total	313,176	145,660	31,331	565,308	212,807	51,984	**143,271 (73)**

* PAI concentrations expressed in keq of H^+/hectare/year.
Note: **bold value**s = soil areas where critical load limit is exceeded.

7.4.2.5 Effect by Climate Change

Climate change predictions to the year 2050 for Fort McMurray are reported in Section D.1 of the Joslyn North Mine project application (DCEL 2005a). The expected changes include increases in annual mean temperature, annual precipitation, growing degree days above 5°C, and annual moisture index. A higher moisture index means that a longer growing period divided by the annual precipitation results in increased moisture limitations.

No effect to soil is expected from increased moisture limitations as the resource will continue to function and have the same capability to store and supply moisture for plant growth. Greater moisture deficits could slow vegetation growth on both reclaimed and non-disturbed land (no soil effect) and lengthen the time for ecosites to become established (a vegetation effect).

A change to air quality resulting from climate change is predicted to be low. Small changes to PAI patterns would redistribute acid inputs causing some soils to receive higher inputs and some soils to receive lower inputs. With no change to emission output, the overall impact is neutral and insignificant.

7.4.3 Spoil Weathering Effects

Weathering of sulphide minerals in mine spoil produces acids which can lead to acid mine drainage. Weathering of mine spoil also produces carbonates which neutralize acids. Testing of the Joslyn North mine overburden was done to determine the acid-generating and acid-neutralizing potential of weathering spoil.

Testing results show that the acid generating potential of the overburden is low relative to the acid neutralizing potential and all of the samples have a neutralizing potential ratio of >1 (Table 5.11). Overburden sample results indicate that acid rock drainage is not expected to occur. The alkalinity of surface and groundwater samples representing baseline conditions is expected to be maintained. With no acid mine drainage, the concentration of trace elements in the overburden (Table 5.8) will result in acceptable concentrations in the spoil.

7.5 Mitigation and Monitoring

7.5.1 Mitigation

The effect of surface mining is the complete disruption of the natural terrain and the natural soil landscape. The key mitigation strategy is the utilization of appropriate conservation and reclamation techniques to create new terrain and new soil landscapes for the intended end land use. Such procedures will include:

- Salvaging surface soil prior to sequential mine development.
- When operationally feasible, direct placing mineral soil on reclaimed landscapes.
- Replacing coversoil with minimal levelling resulting in soil with low bulk density and excellent porosity. These rough surfaces will catch and hold snow, reduce the risk of erosion and provide a greater diversity of microsites.
- Revegetating soil stockpiles and reclaimed areas as soon as possible.
- Establishing nurse crops on areas with moderate potential for soil erosion.
- Alternate erosion control measures, in addition to nurse crops, will be used in areas of high potential for soil erosion.

7.5.2 Monitoring

The following is a summary of follow-up monitoring that could be done to ensure the long term sustainability of the soils resource:

- Ensure experienced personnel supervise all soil salvage activities to ensure maximum quality of soil and sufficient volumes are salvaged.
- Monitor soil replacement activities to ensure an appropriate depth of coversoil is placed on recontoured landscapes.
- Monitor soil replacement activities to ensure potential for compaction is minimized.
- Monitor soil stockpiles to ensure adequate vegetation exists to minimize erosion of soil resource from wind or water and reduce weed establishment.

- Monitor reclaimed areas to ensure erosion is kept to a minimum.
- Undertake routine sampling and analysis of recontoured areas, prior to coversoil replacement, to ensure replaced soils will provide suitable growing medium.
- Undertake ongoing assessment and management of reclaimed areas until reclamation certification is achieved.
- Utilize information gained by CEMA and other regional monitoring initiatives that have established monitoring sites to periodically sample soils and vegetation in areas of high sensitivity to acid deposition. Respond to any adverse findings and incorporate appropriate mitigation strategies.

7.6 Environmental Effects Summary

A summary of potential environmental effects, planned mitigation, residual effects, cumulative effects and significance is presented in Table 7.1.

The effects on the soil resource are summarized as:

1. Newly created landscapes and soils have different properties than pre-mine landscapes and soil profiles. The effect is partly reversible in the long term through natural soil forming processes. Replaced soils will function to support plant growth so the effect is considered low in magnitude and insignificant.
2. There is an unavoidable loss of some soil resources. The effect is mitigated by salvaging sufficient suitable materials to build new landscapes and a new cover soil to meet end land use objectives.
3. Mixing of soil layers during salvage, storage and replacement occurs for both mineral soil and organic soil. Salvage of the better quality mineral soils produces a suitable material for reclamation use. Mixing mineral material with salvaged peat improves the peat resource by creating a suitable material for reclamation use without the extreme limitations of peat. The effects on mineral material are neutral and residual; positive on peat material and also residual.
4. Erosion control measures that focus on steep slopes and long slopes is expected to limit excessive erosion. Redistribution of sediments within the reclaimed landscape is a natural process and will diminish as vegetation cover becomes established. Residual effects reversible in the long-term and neutral.
5. Loss of original terrain will occur at a local level. Mitigation is achieved by building a diversity of landscapes to support planned ecosites. The residual effect is that landscapes have changed at specific locations and since they will function to achieve end land use goals, the effect is neutral and insignificant. The addition of two lakes to the landscape is a long term, irreversible change that adds to landscape diversity. The change is cumulative to existing lakes in the region and allowable as other lakes are being added at other mines. The overall effect is considered positive.
6. Land capability after reclamation is expected to be significantly improved over pre-disturbance conditions. Even with the conversion of some terrestrial land to lakes, the amount of soil landscapes with Capability Class 1 and 2 is projected to increase from about 1,500 ha to approximately 3,600 ha. There will be considerable diversity within Class 1 and 2 soil landscapes in terms of slope, aspect and soil profiles. The amount of land with low capability (Class 4 and 5) is predicted to be much reduced compared to baseline conditions.

7. The potential project contribution to soil acidification, based on continually exceeding the critical loading limit over many years, is approximately 14,500 ha (7%) above baseline conditions. The residual effect is partly reversible in the long-term. Similarly, the potential cumulative contribution of all known current and future projects is an increase of approximately 143,000 ha (73%) above baseline conditions. The magnitude varies according to soil sensitivity and overall is considered moderate for the project case and moderate to high for the cumulative case.

   While the cumulative effects of oil sands regional development for soil acidification is predicted to be significant, the confidence rating in this determination is low. The key component of this prediction is generated from the predicted air emission estimates from each project. Individually, these are extremely conservative, and when they are all combined likely over estimate the air emissions. Future air monitoring will determine the accuracy of these predictions. DCEL is a member of WBEA and will participate in these programs. The other factor of uncertainty comes from the predictions of effects of acidification on the different soils types. While the theory is well known, the actual effects in this region are not. DCEL is a member of the CEMA which has an initiative to monitor the emissions and deposition, through the NOx/SOx working group to validate the assumptions. If the monitoring information concludes that environmental effects are occurring, industry in the region will need to adjust their operating practices accordingly.

8. Climate change is expected to cause moisture deficits during the growing season and to redistribute acidifying emissions in the landscape. Soil moisture limitations will affect vegetation growth on both non-disturbed and reclaimed areas and not the soil resource. A redistribution of acid emissions will cause some soils to receive greater inputs and other soils to receive fewer inputs compared to current weather pattern predictions. The net effect to soil acidification is expected to be neutral and insignificant.

9. No acid mine drainage is expected to occur. Testing results show that weathering of carbonate minerals is sufficient to neutralize the acid potential in the spoil.

10. No increase of trace element concentrations in soil and near-surface materials is expected to occur. Testing results show overburden to have acceptable background concentrations of metals and other elements.

Table 7.1 Significance of Impacts on Soil Resources.

VEC	Nature of Potential Impact or Effect	Mitigation/ Protection Plan	Criteria for Determining Significance							Confidence Rating[7]	Project Contribution[8]	Significance[9]
			Type of Effect	Extent[1]	Duration[2]	Frequency[3]	Recovery[4]	Magnitude[5]	Probability[6]			
SOIL RESOURCES												
Disruption of natural soil landscapes	Soil salvage and reclamation of soil landscapes		Project	Local 5,098 ha	Short	Continuous	Reversible (long term)	High	High	High	Negative	Insignificant
			Residual	Local 5,098 ha	Residual	Continuous	Reversible (long term)	Low	High	High	Neutral	Insignificant
			Cumulative	Local 5,098 ha	Residual	Continuous	Reversible (long term)	Low	High	High	Neutral	Insignificant
Loss of non-salvaged soil	Salvage best quality soil to meet reclamation requirements		Project	Local	Short	Isolated	Irreversible	Low	High	High	Neutral	Insignificant
			Residual	No residual effects noted								Insignificant
			Cumulative	No cumulative effects noted								Insignificant
Change in soil quality by mixing during salvage	Salvage best quality soil material		Project	Local 5,098 ha	Short	Periodic	Reversible (long term)	Low to Moderate	High	High	Neutral to Positive	Insignificant
			Residual	local 5,098 ha	Residual	Continuous	Reversible (long term)	Low	High	High	Neutral	Insignificant
			Cumulative	No cumulative effects noted								Insignificant
LAND CAPABILITY												
Landscape changes	Build a diversity of landscapes		Project	local 5,098 ha	Short	Continuous	Reversible (long term)	Moderate	High	High	Neutral	Insignificant
			Residual	local 5,098 ha	Extended	Continuous	Reversible (long term)	Low	High	High	Positive	Significant
			Cumulative	local 5,098 ha	Extended	Continuous	Reversible (long term)	Low	High	High	Neutral	Insignificant
Land capability changes	Reclaim to meet land use goals		Project	Local 5,098 ha	Short	Continuous	Reversible	Moderate	High	High	Negative	Insignificant
			Residual	Local 5,098 ha	Extended	Continuous	Reversible	Moderate	High	High	Neutral	Insignificant
			Cumulative	Local 5,098 ha	Extended	Continuous	Reversible	Moderate	High	High	Neutral	Insignificant
Erosion of reclaimed soil	Design and construct for erosion control		Project	local 5,098 ha	Short	Isolated	Reversible (long term)	Low	High	High	Neutral	Insignificant
			Residual	local 5,098 ha	Residual	Isolated	Reversible (long term)	Low	High	High	Neutral	Insignificant
			Cumulative	No cumulative effects noted								Insignificant

Table 7.1 Significance of Impacts on Soil Resources.

VEC	Nature of Potential Impact or Effect	Mitigation/ Protection Plan	Criteria for Determining Significance							Confidence Rating[7]	Project Contribution[8]	Significance[9]
			Type of Effect	Extent[1]	Duration[2]	Frequency[3]	Recovery[4]	Magnitude[5]	Probability[6]			
LAND CAPABILITY (Concluded)												
Soil acidification	Reduce source emissions		Project	Regional 14,484 ha	Short	Continuous	Reversible (long term)	Moderate	High	Low	Negative	Significant
			Residual	Regional 14,484 ha	Extended	Continuous	Reversible (long term)	Moderate	High	Low	Negative	Significant
			Cumulative	Regional 143,271 ha	Extended	Continuous	Reversible (long term)	Moderate to High	High	Low	Negative	Significant
Climate change increases moisture deficits	No adverse affects – no mitigation required		Project	No project effects noted								Insignificant
Climate change causes redistribution of acid inputs	None required		Project	Regional 14,484 ha	Short	Continuous	Reversible (long term)	Low	High	High	Neutral	Insignificant
			Residual	Regional 14,484 ha	Extended	Continuous	Reversible (long term)	Low	High	High	Neutral	Insignificant
			Cumulative	Regional 143,271 ha	Extended	Continuous	Reversible (long term)	Low	High	High	Neutral	Insignificant
OVERBURDEN CHARACTERISTICS												
Acid mine drainage	No adverse affects – no mitigation required		Project	No project effects noted								Insignificant
Increased concentration of trace elements	Not adverse affects – no mitigation required		Project	No project effects noted								Insignificant

[1] Extent – Local, Regional, Provincial, National, Global
[2] Duration – Short, Long, Extended, Residual
[3] Frequency – Continuous, Isolated, Periodic, Occasional, Accidental, Seasonal
[4] Recovery – Reversible in short term, Reversible in long term, Irreversible – rare
[5] Magnitude – Nil, Low, Moderate, High
[6] Probability – Low, Medium, High
[7] Confidence Rating – Low, Moderate, High
[8] Project Contribution – Neutral, Positive, Negative
[9] Significance – Insignificant, Significant

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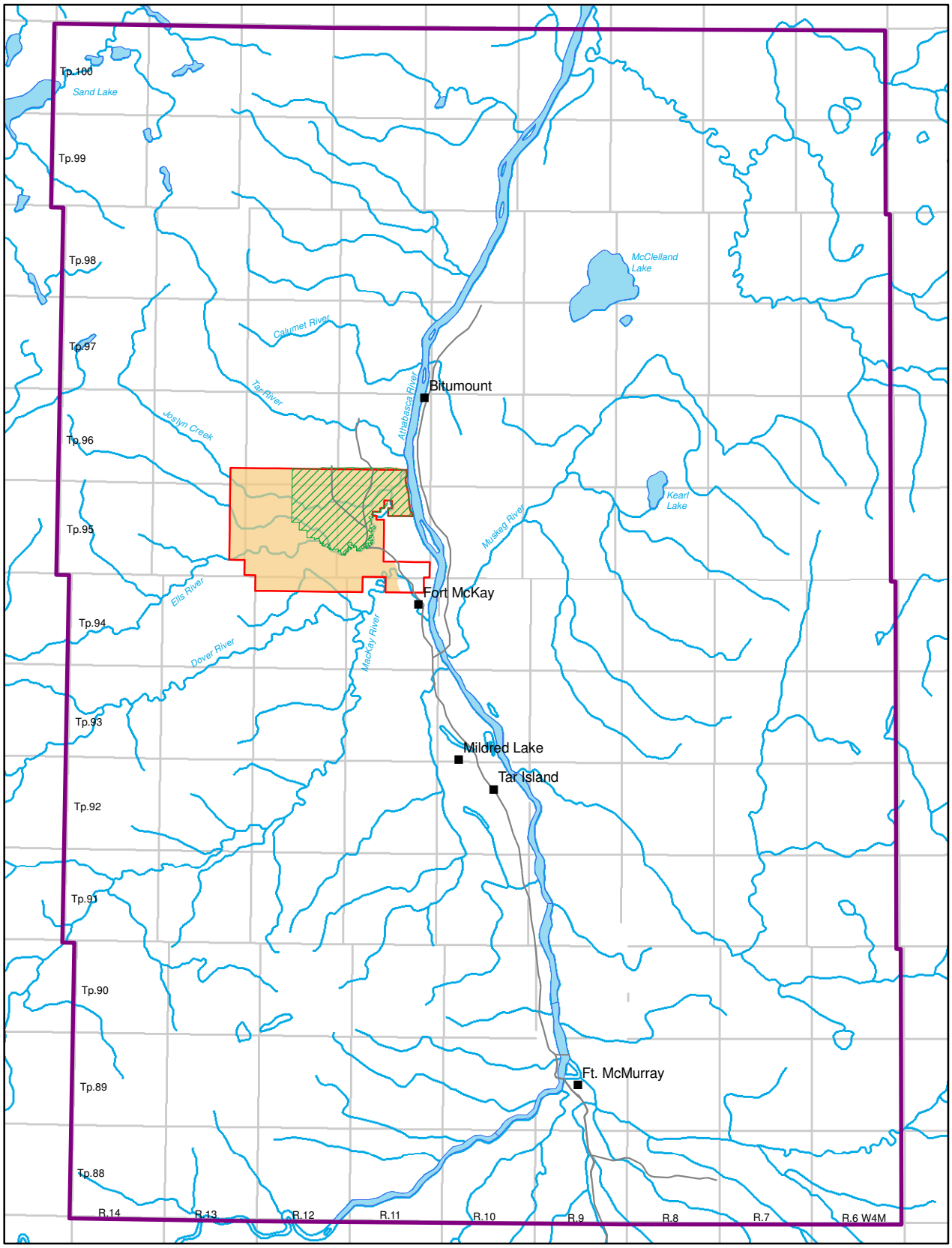
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Regional Study Area (RSA) | Sub-Regional Study Area (SSA) | Local Study Area (LSA) | DCEL Lease Bounday

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PROJECT
Joslyn North Mine Project

TITLE
Figure 2.1 Study Areas

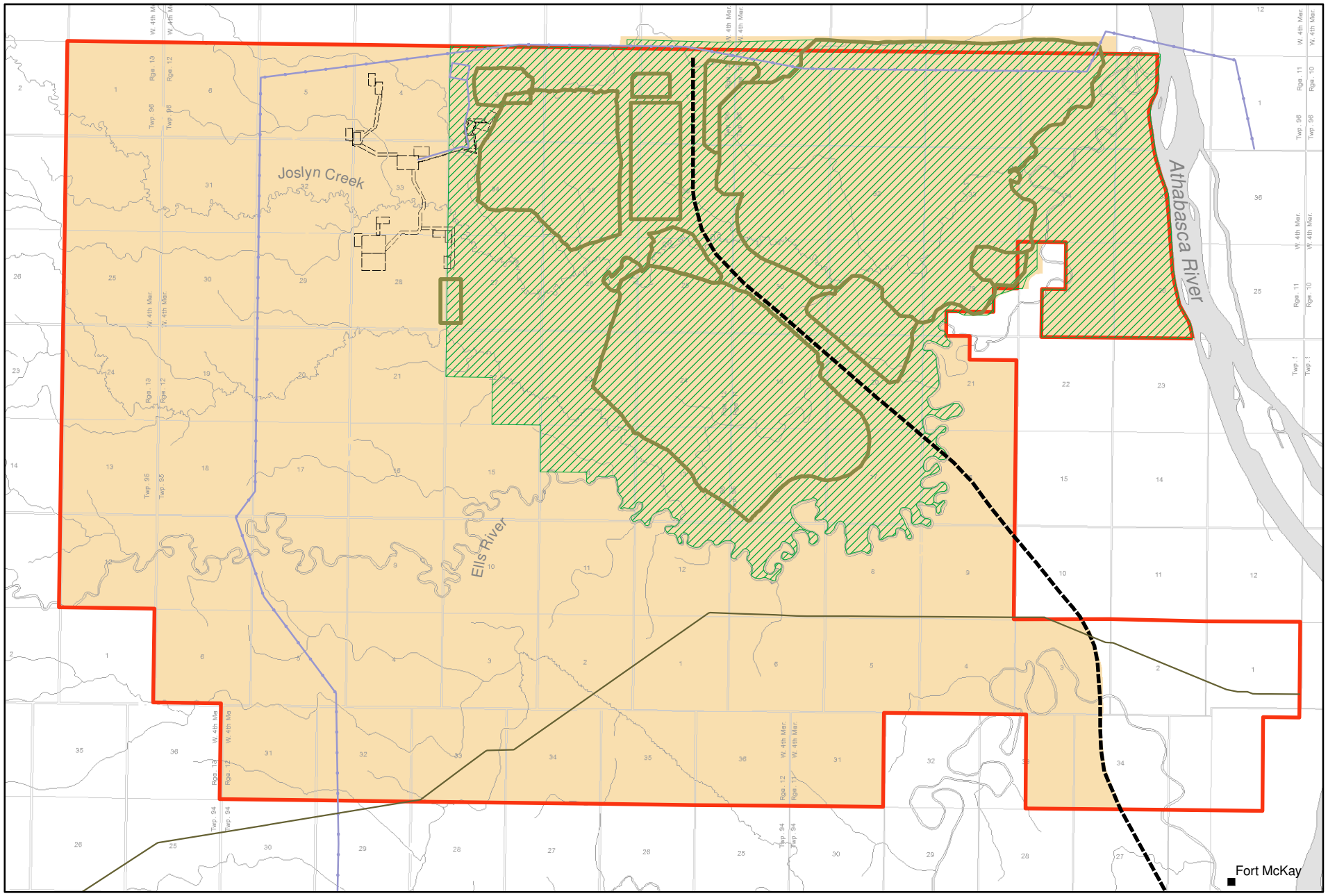
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SCALE 1:600,000
0 3.75 7.5 15
Kilometres

PROJECTION: UTM Zone 12 NAD83

DRAWING NAME: Fig 2.1 Study Areas

FIGURE **2.1**



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TITLE

Figure 2.2 Sub-Regional Study Area

LEGEND

- Local Study Area (LSA)
- Sub-Regional Study Area (SSA)
- SAGD
- DCEL Lease Boundary
- Mine Footprint
- CNRL Road
- ATCO Power ROW
- ATCO Gas ROW

	BY	DATE
DRAWN	P.S.	25Oct05
CHECKED	B.W.	21Dec05

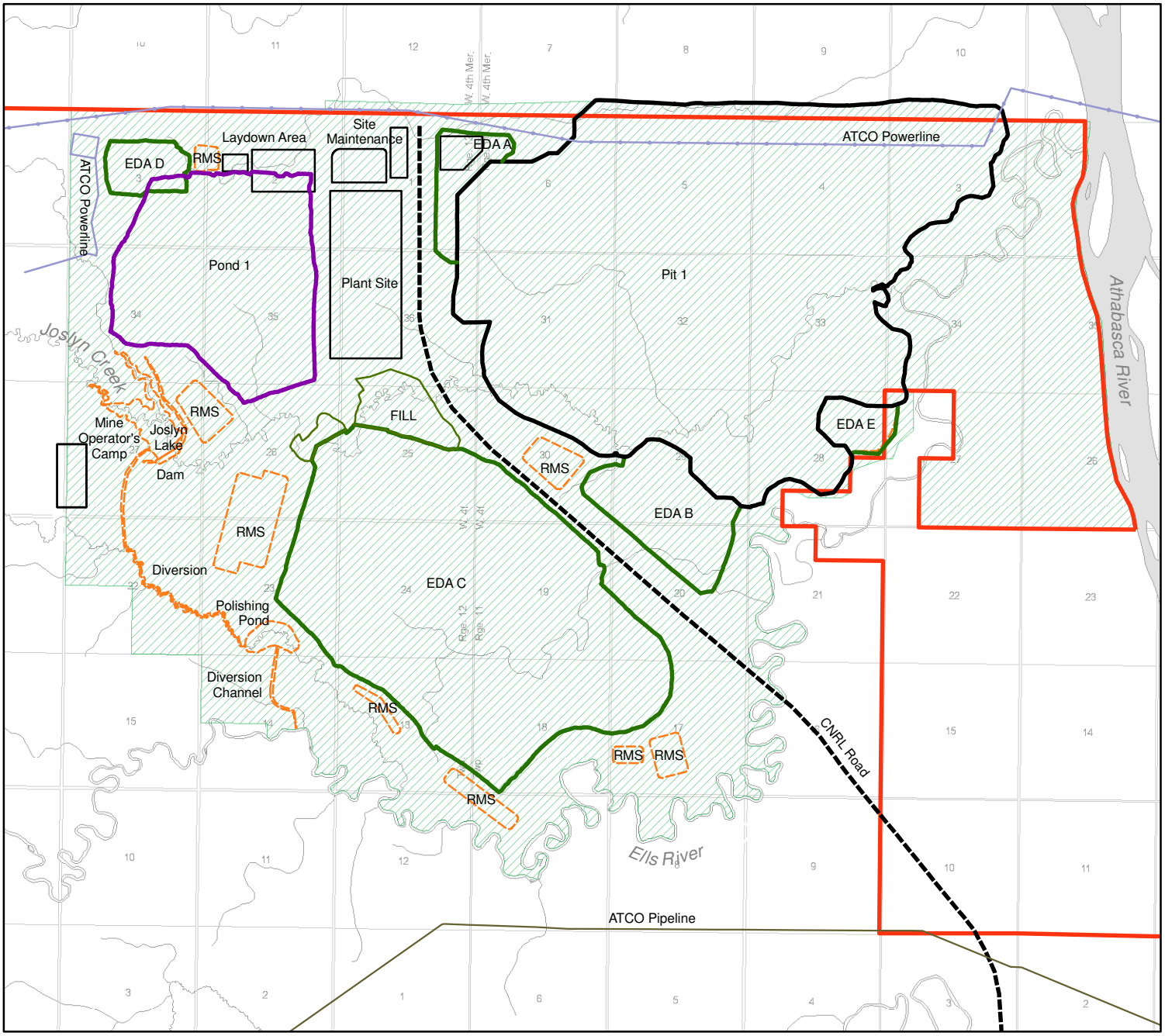
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DRAWING NAME: Fig 2.2 SSA

SCALE: 1:90,000

0 1 2 Kilometres

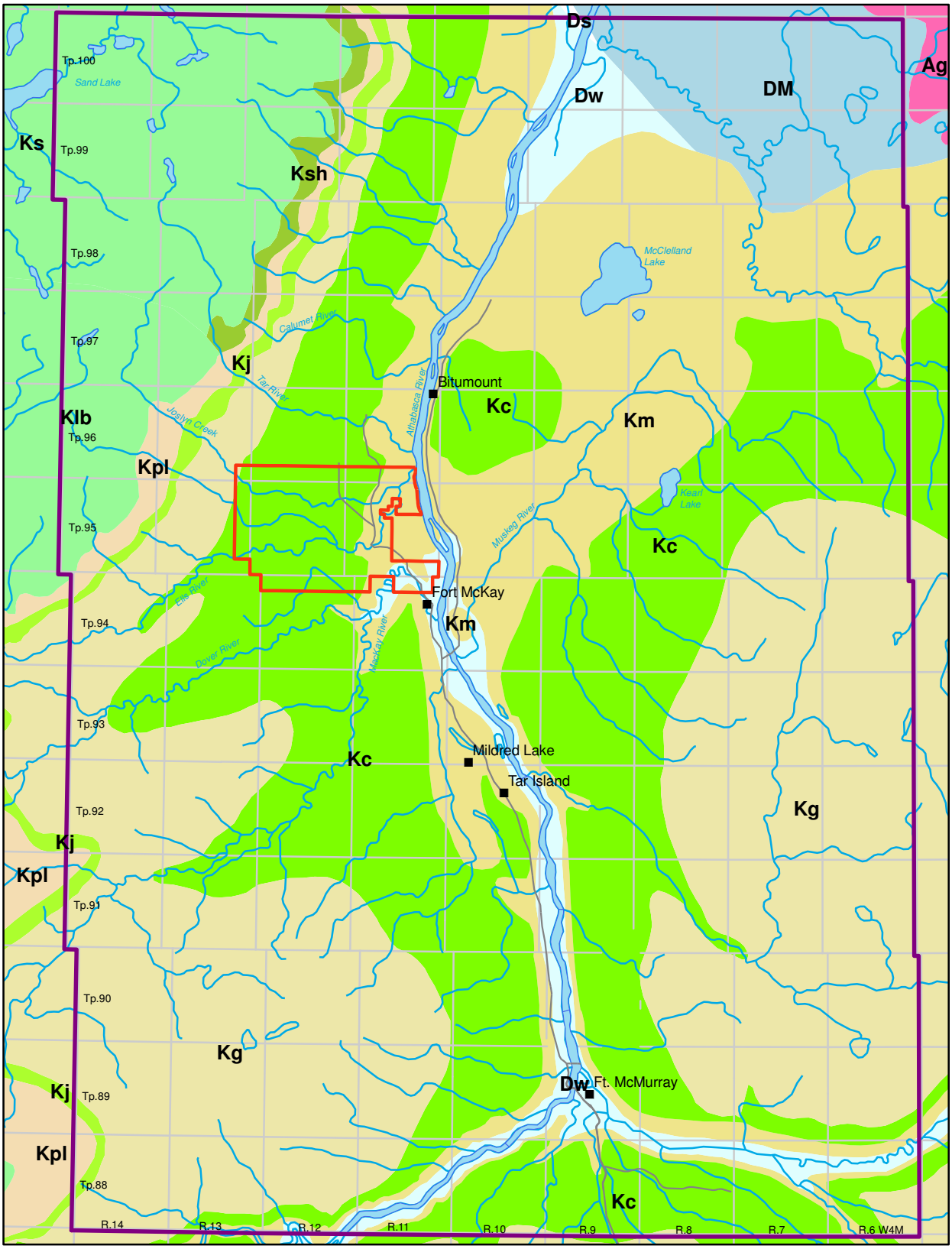
FIGURE: **2.2**



Legend

- DCEL Lease Boundary
- Local Study Area (LSA)

DEER CREEK Energy Limited	PROJECT: Joslyn North Mine Project		PROJECTION: UTM Zone 12 NAD83
Millennium EMS Solutions Ltd.	TITLE: Figure 2.3. Local Study Area	DRAWN: PS 25Oct05; CHECKED: BW 21Dec05	DRAWING NAME: Fig 2.3 LSA
		SCALE: 1:70,000 (0 0.5 1 2 Kilometres)	FIGURE: 2.3



DCEL Lease Bounday
Regional Study Area (RSA)

Klb Labiche Formation
Ksh Shaftesbury Formation
Ks Smoky Group
Kpl Pelican Formation
Kj Joli Fou Formation
Kg Grand Rapids Formation
Kc Clearwater Formation
Km McMurray Formation
Dw Waterways Formation
DM Middle Devonian
Ag Arch Lake Granitoids

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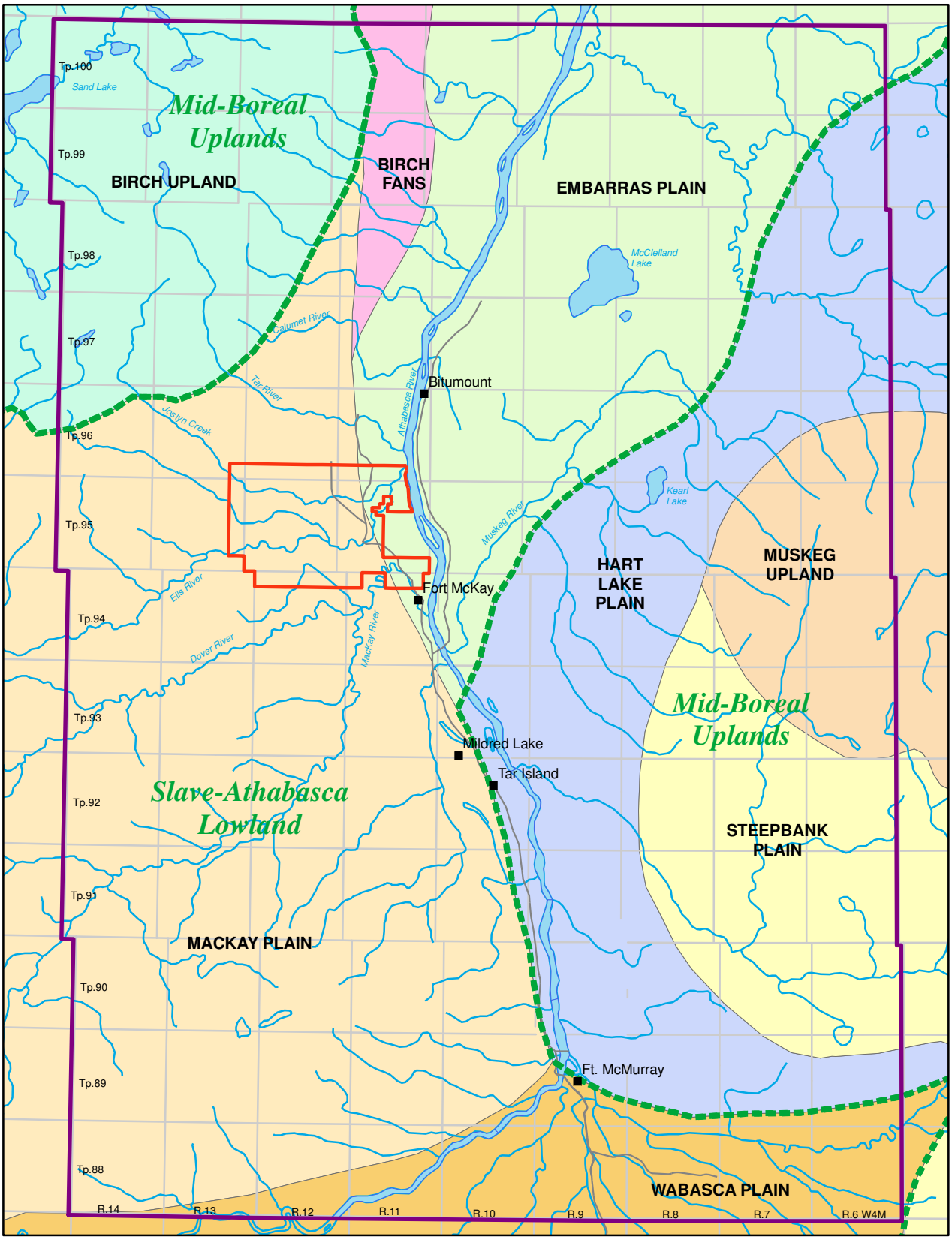
PROJECT
Joslyn North Mine Project

TITLE
Figure 3.1. Bedrock Geology of the Regional Study Area

	BY	DATE
DRAWN	PS	25Oct05
CHECKED	BW	21Dec05

SCALE 1:600,000
0 3.75 7.5 15
Kilometres

PROJECTION: UTM Zone 12 NAD83
DRAWING NAME: Fig 3.1 Bedrock Geology
FIGURE **3.1**

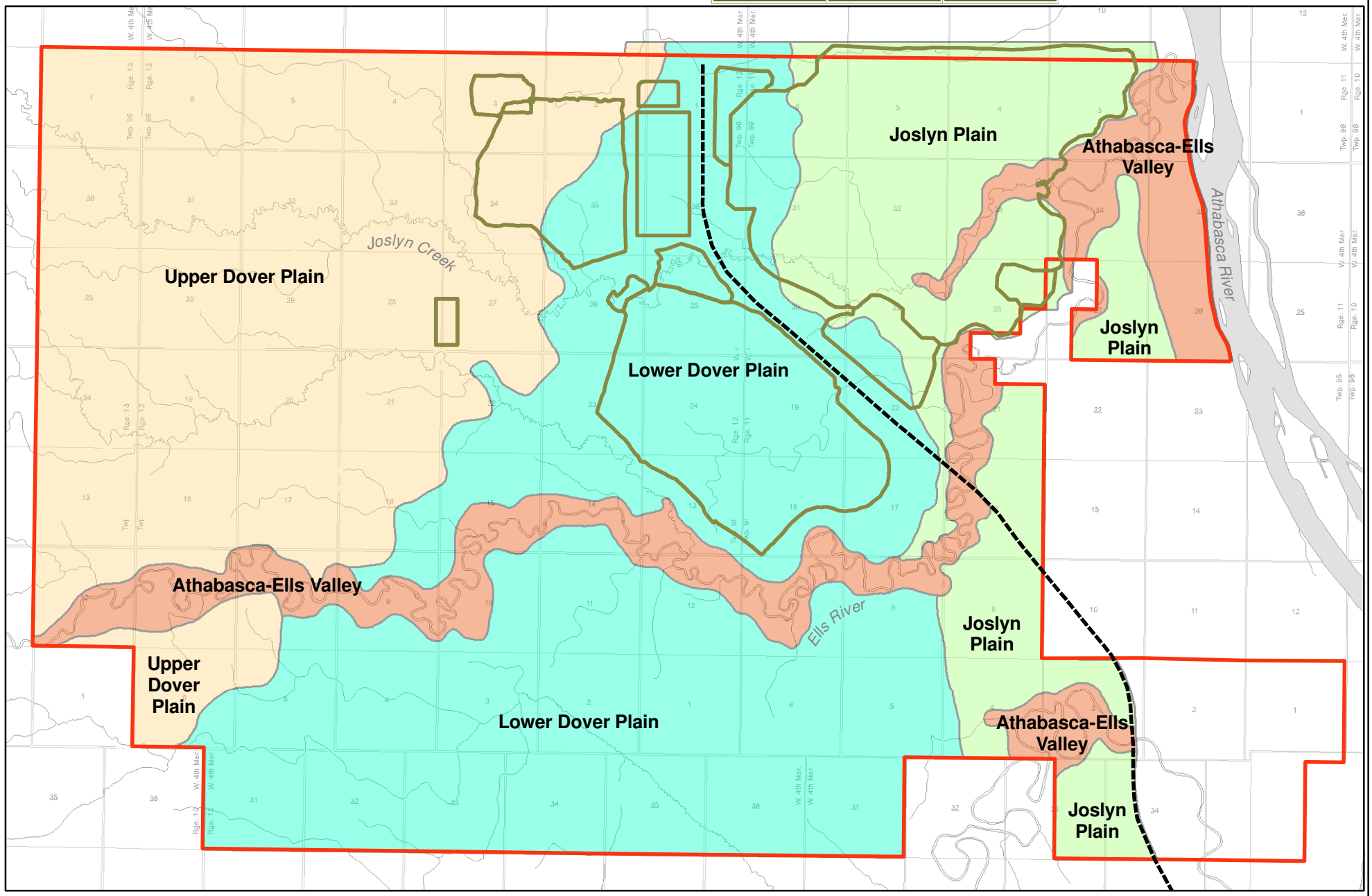


Ecoregion | Regional Study Area (RSA) | DCEL Lease Bounday

DEER CREEK Energy Limited	PROJECT: Joslyn North Mine Project		
Millennium EMS Solutions Ltd.	TITLE: Figure 3.2. Ecoregions and Ecodistricts in the Regional Study Area		

	BY	DATE
DRAWN	PS	25Oct05
CHECKED	BW	21Dec05

PROJECTION: UTM Zone 12 NAD83
DRAWING NAME: Fig 5 Ecodistricts
SCALE: 1:600,000 (0 3.75 7.5 15 Kilometres)
FIGURE: 3.2



Soil survey informaiton compiled by Beauterre Soilscapes Consulting Inc. 2005

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PROJECT

Joslyn North Mine Project

TITLE

Figure 3.3. Land Systems

LEGEND

- Joslyn Plain
- Lower Dover Plain
- Upper Dover Plain
- Athabasca-Ells Valley
- DCEL Lease Boundary
- Mine Footprint
- CNRL Road

	BY	DATE
DRAWN	P.S.	25Oct05
CHECKED	B.W.	21Dec05

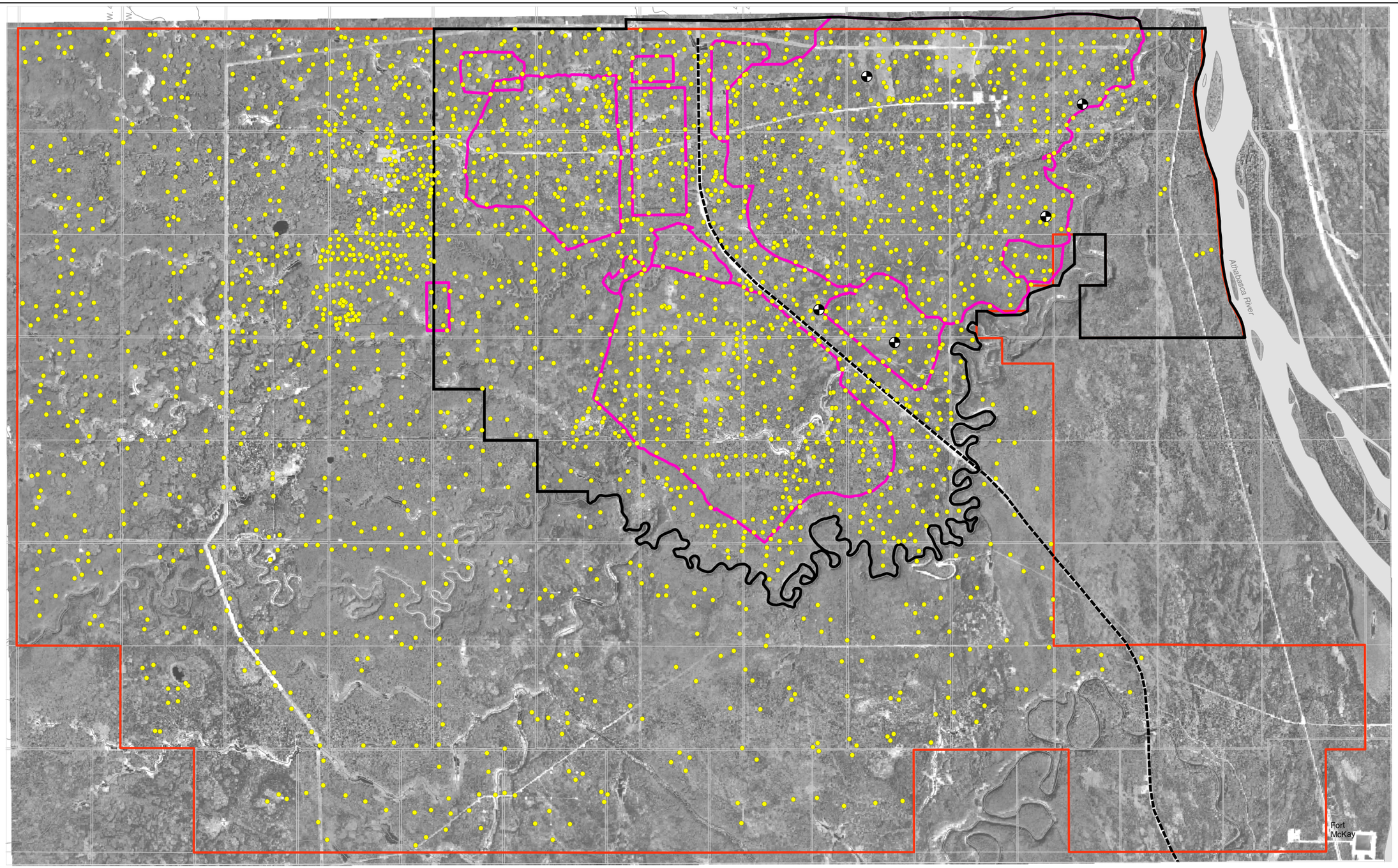
SCALE 1:85,000

0 1 2 Kilometres

PROJECTION UTM Zone 12 NAD 83

DRAWING NAME Fig 3 Land Systems

FIGURE **3.3**



Soil survey information compiled by Beauterre Soilscapes Consulting Inc., 2005

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PROJECT

Joslyn North Mine Project

TITLE

Figure 4.1. Soil Inspection Sites.

LEGEND

- Soil inspection site
- Overburden sample site
- Local Study Area
- DCEL Lease Boundary
- Mine Footprint
- CNRL Road

	DRAWN	DATE
DRAWN	PS	07Nov05
CHECKED	BW	19Jan06

SCALE 1:60,000

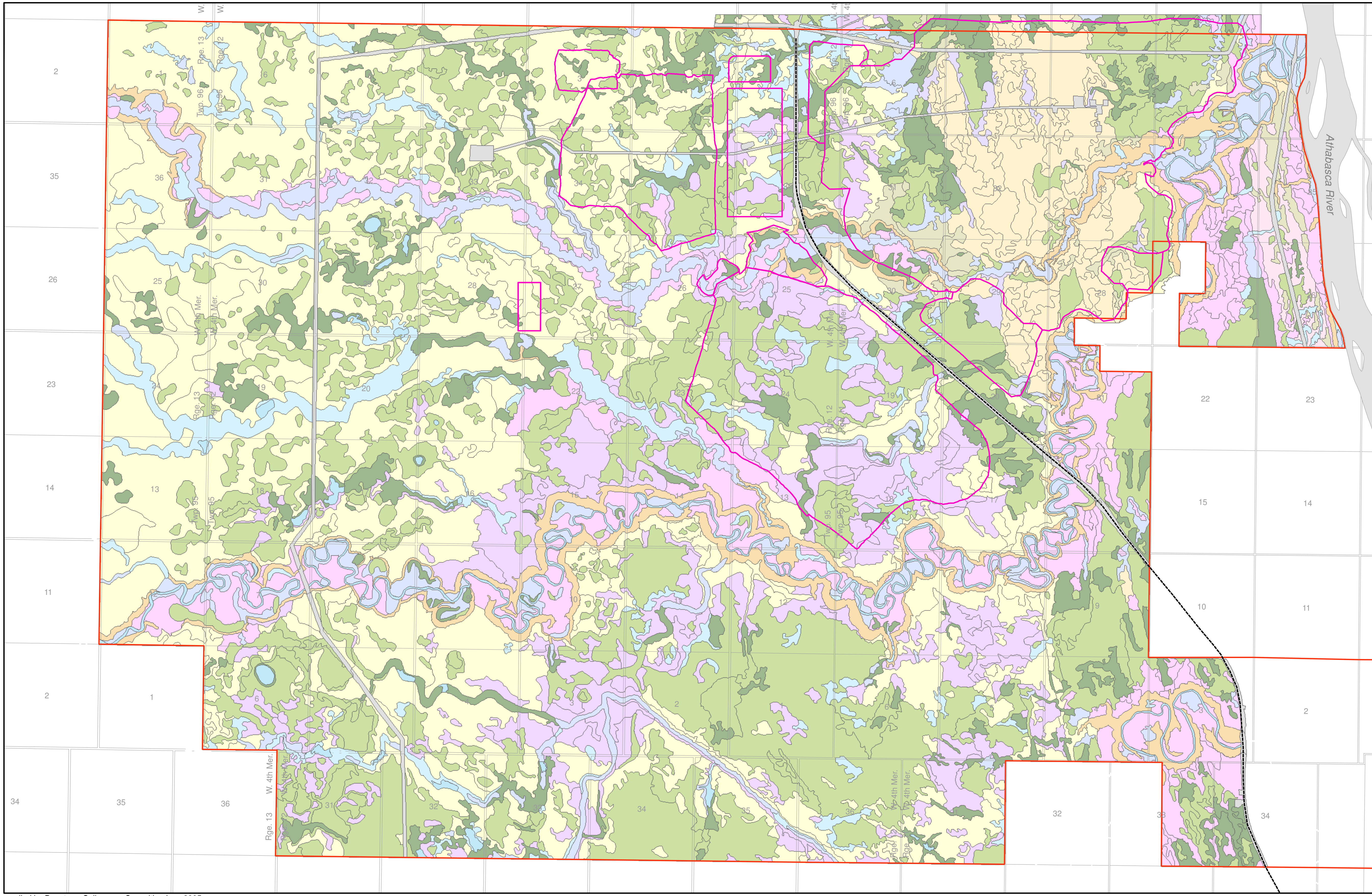
0 0.5 1 2

Kilometres

PROJECTION: UTM Zone 12 NAD 83

DRAWING NAME: Fig 4.1 Inspection Sites

FIGURE: **4.1**



Soil survey information compiled by Beauterre Soilscapes Consulting Inc., 2005

PROJECT

Joslyn North Mine Project

TITLE

Figure 4.2 Soils Map of the Sub-regional Study Area

LEGEND

Major Soil Series

Bitumount	Livock	Water
Chateh	Mildred	Disturbed Land
Daphne	McLelland	Lease Boundary
Dover	Mamawi	Mine Footprint
Fort	Muskeg	CNRL Road
Kilome	Peavine	

	DRAWN	DATE
DRAWN	PS	07Nov05
CHECKED	BW	30Dec05

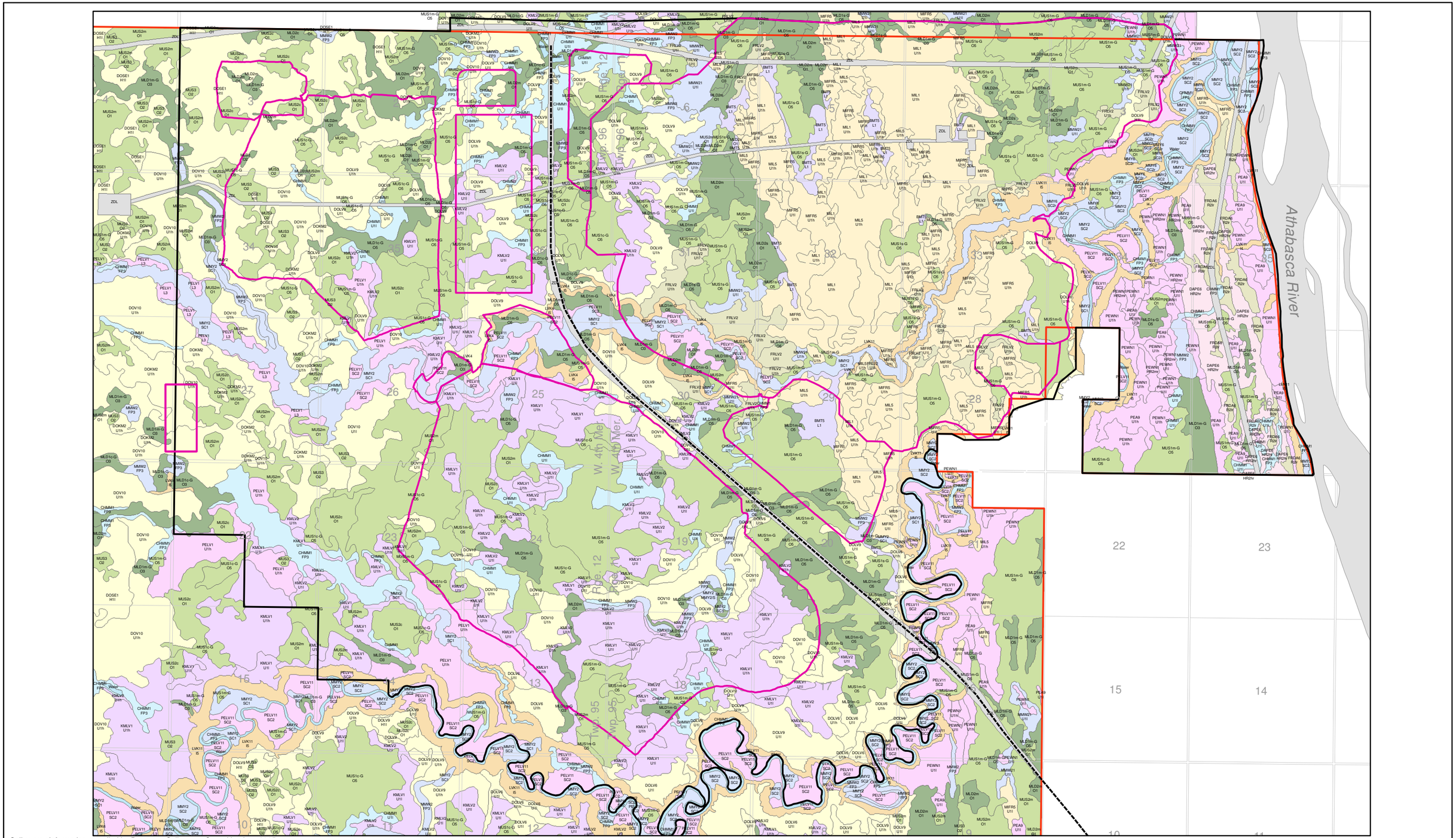
SCALE 1:60,000

0 1 2 Kilometres

PROJECTION UTM Zone 12 NAD 83

DRAWING NAME Fig 4.2 Soils of the SSA

FIGURE 4.2



Soil survey information compiled by Beauterre Soilscapes Consulting Inc., 2005

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Millennium EMS Solutions Ltd.

PROJECT

Joslyn North Mine Project

TITLE

Figure 4.3 Soils Map of the Local Study Area

LEGEND

Major Soil Series

- Bitumount
- Chateh
- Daphne
- Dover
- Fort
- Kilome
- Livock
- Mildred
- McLelland
- Mamawi
- Muskeg
- Peavine
- Water
- Disturbed Land
- Local Study Area
- Lease Boundary
- Mine Footprint
- CNRL Road

	DRAWN	DATE
DRAWN	PS	07Nov05
CHECKED	BW	21Dec05

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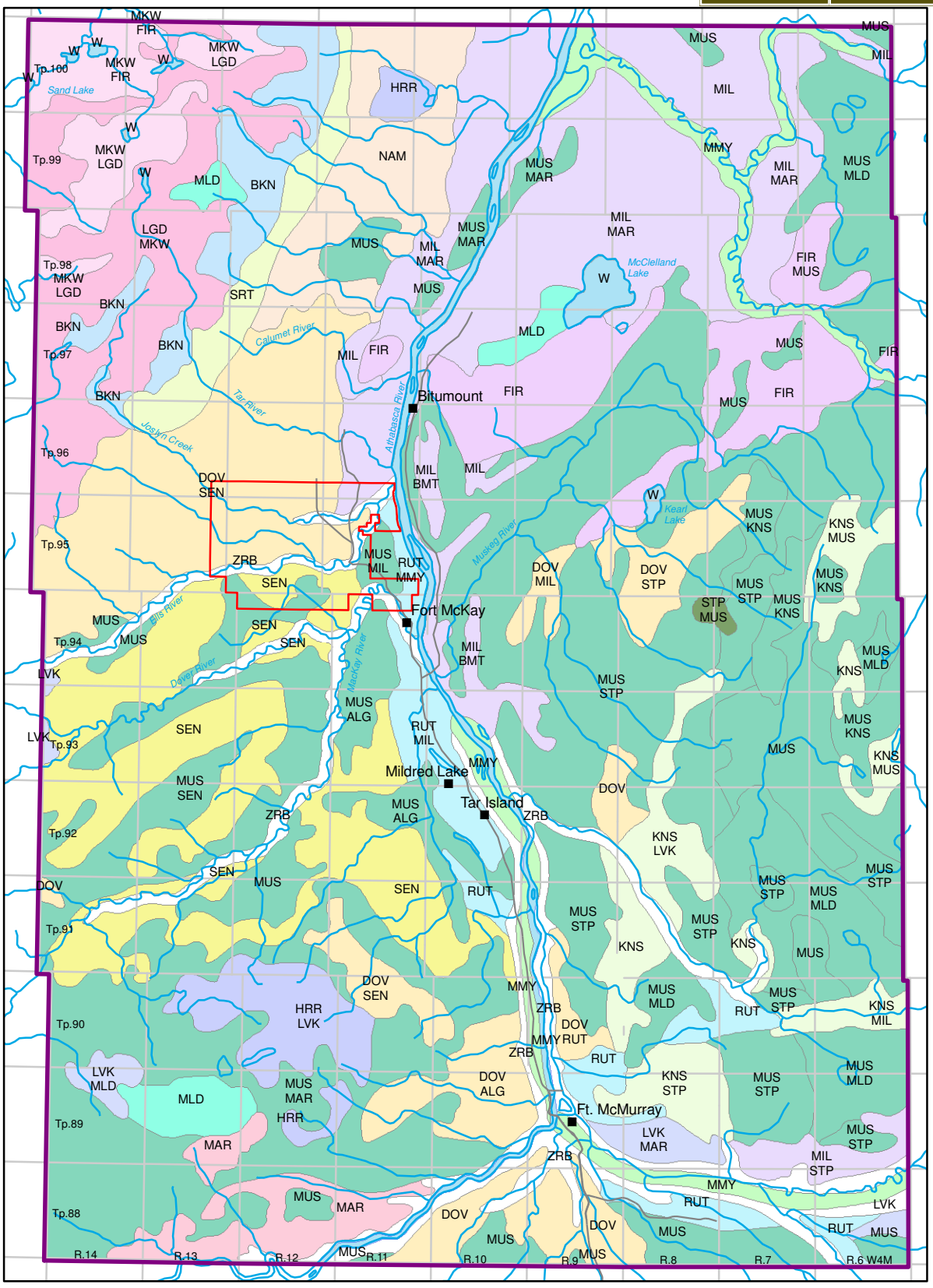
0 0.5 1

Kilometres

PROJECTION: UTM Zone 12 NAD 83

DRAWING NAME: Fig 4.3 Soils of the LSA

FIGURE: **4.3**



DCEL Lease Bounday | Regional Study Area (RSA)

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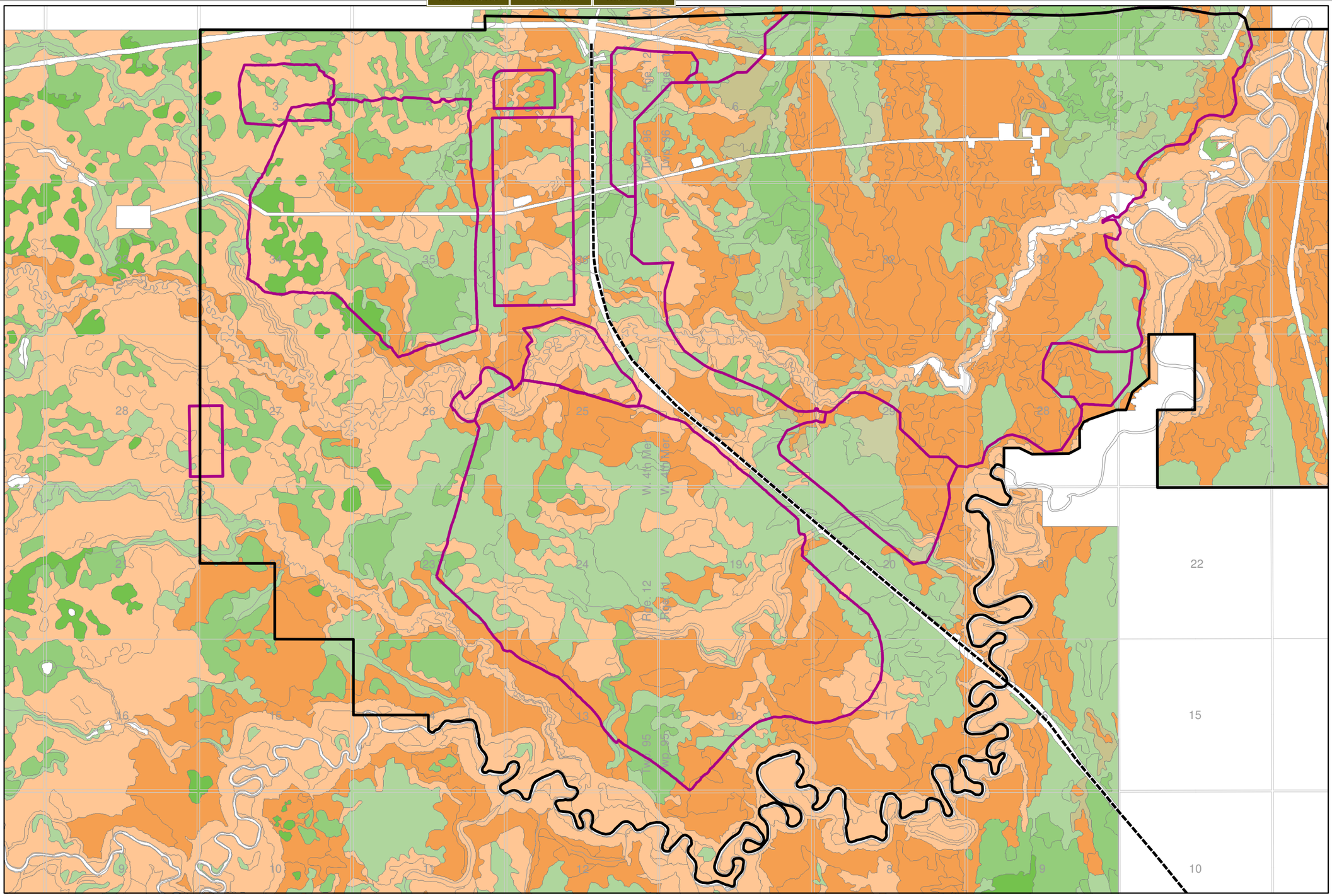
PROJECT
Joslyn North Mine Project

TITLE
Figure 4.4. Generalized Soil Map of the Regional Study Area

	BY	DATE
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CHECKED	BW	21Dec05

SCALE 1:600,000
0 3.75 7.5 15
Kilometres

PROJECTION: UTM Zone 12 NAD83
DRAWING NAME: Fig 4.4 RSA Soils
FIGURE: **4.4**



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PROJECT

Joslyn North Mine Project

TITLE

Figure 5.1 Soil Material Thickness of the Local Study Area

LEGEND

Litter/Peat Thickness (cm)	Topsoil Thickness (cm)
> 200	16 - 25
101 - 200	6 - 15
41 - 100	0 - 5
16 - 40	Mine Footprint
0 - 15	CNRL Road
Local Study Area	

	DRAWN	DATE
DRAWN	PS	07Nov05
CHECKED	BW	21Dec05

SCALE 1:40,000

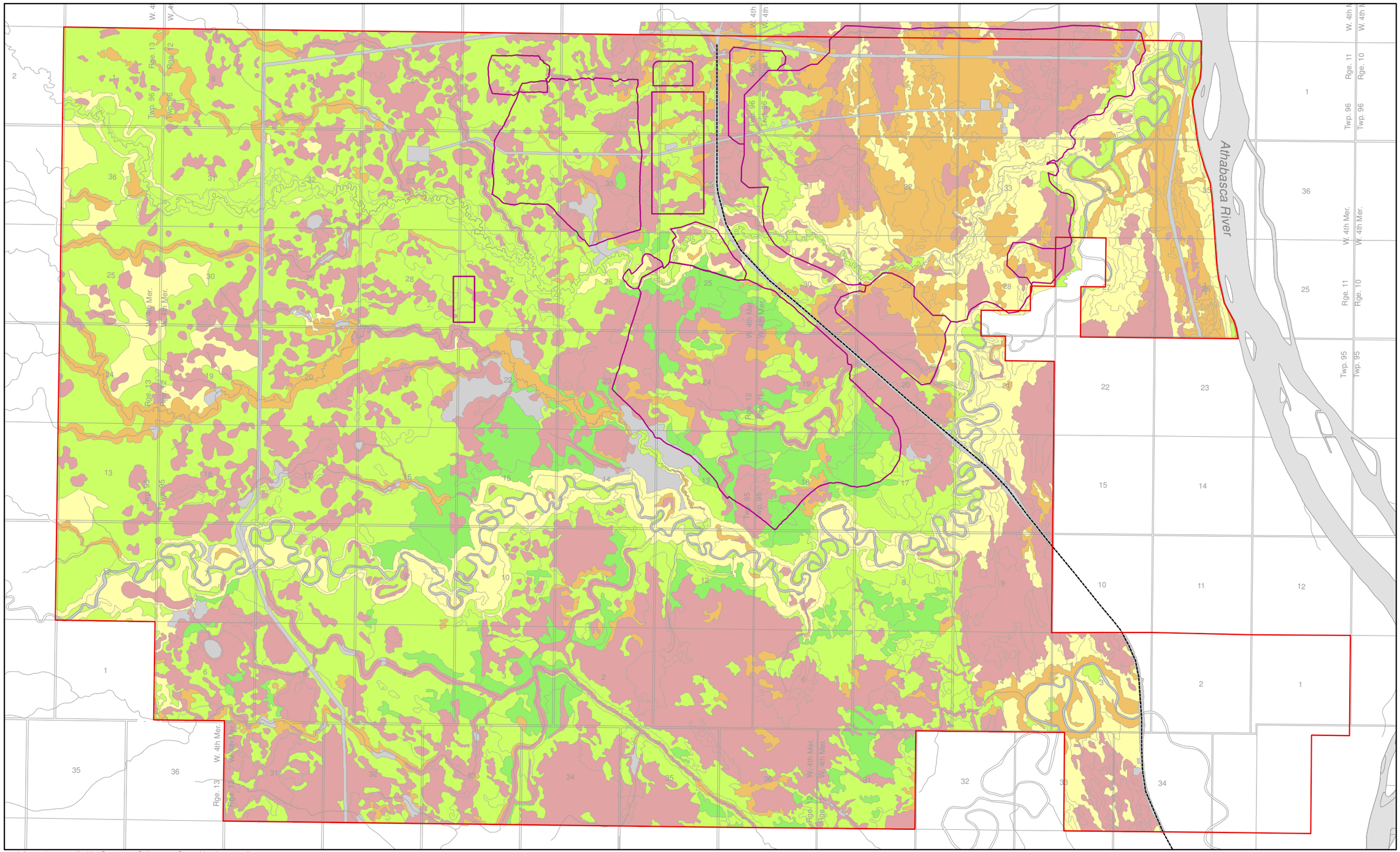
0 0.5 1

Kilometres

PROJECTION: UTM Zone 12 NAD 83

DRAWING NAME: Fig 5.1 Material Thickness

FIGURE: **5.1**



Soil survey information compiled by Beauterre Soilscapes Consulting Inc., 2005

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PROJECT

Joslyn North Mine Project

TITLE

Figure 5.2. Land Capability Classes for Forest Ecosystems - Subregional Study Area

LEGEND

Capability Class
- 1
- 2
- 3
- 4
- 5
- N/A

- Mine Footprint
- CNRL Road
- DCEL Lease Boundary

	DRAWN	DATE
DRAWN	PS	07Nov05
CHECKED	BW	21Dec05

SCALE 1:60,000

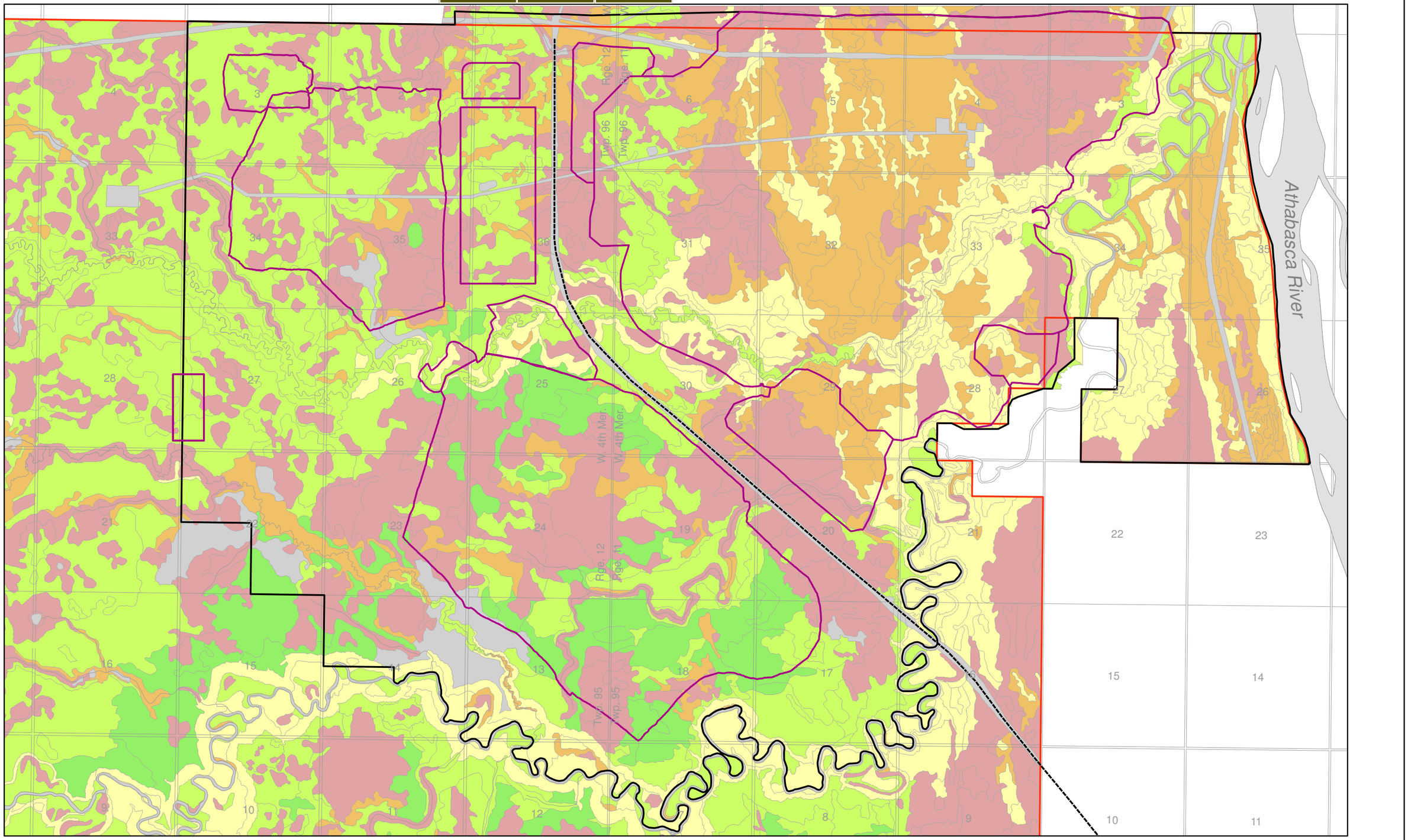
0 0.5 1 2

Kilometres

PROJECTION: UTM Zone 12 NAD 83

DRAWING NAME: Fig 5.2 Capability

FIGURE: **5.2**



DEER CREEK Energy Limited

Millennium EMS Solutions Ltd.

PROJECT

Joslyn North Mine Project

TITLE

Figure 5.3. Land Capability Classes for Forest Ecosystems - Local Study Area

LEGEND

Capability Class
- 1
- 2
- 3
- 4
- 5
- N/A

- Local Study Area
- Lease Boundary
- Mine Footprint
- CNRL Road

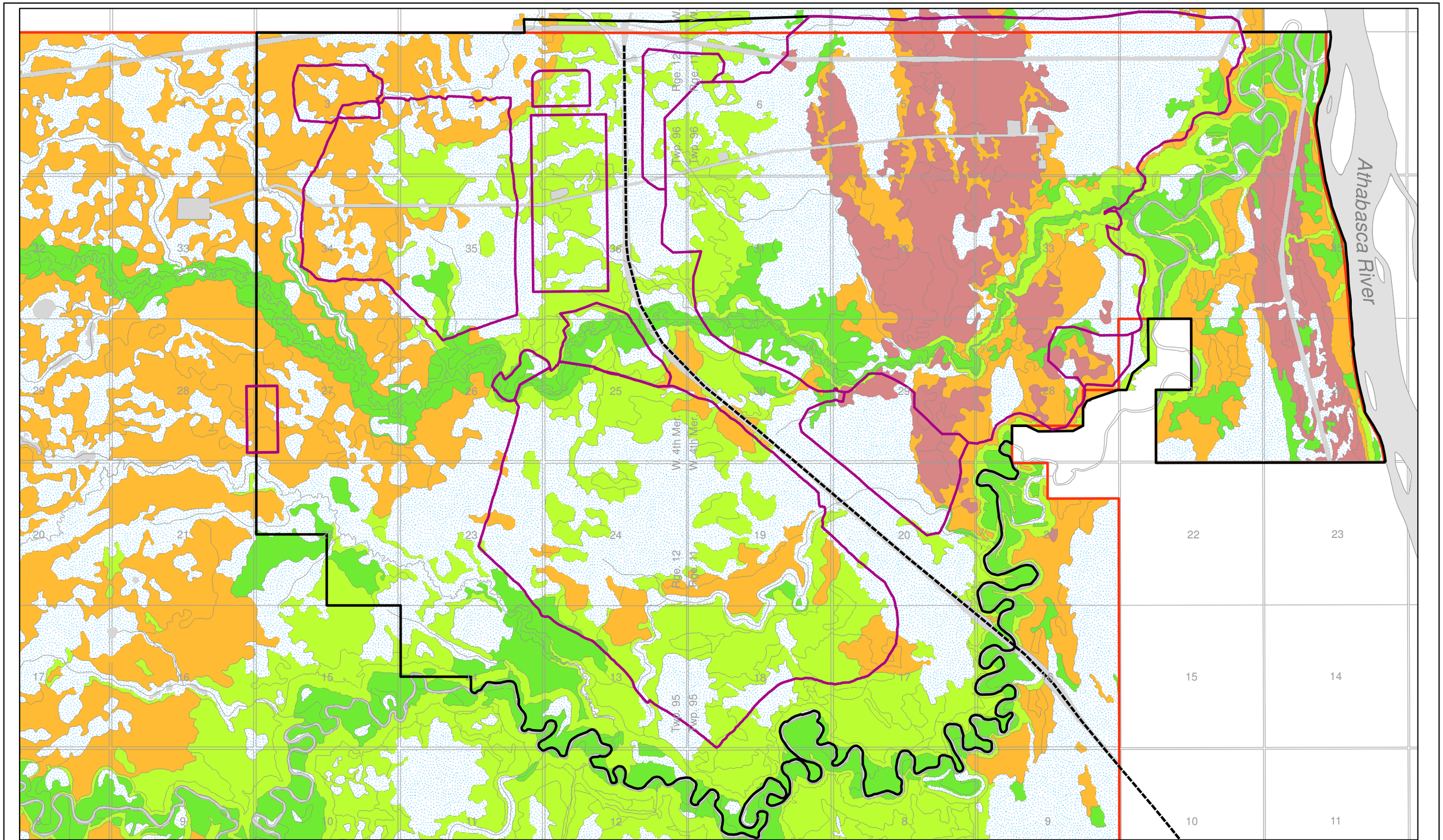
	DRAWN	DATE
DRAWN	PS	07Nov05
CHECKED	BW	21Dec05

SCALE 1:40,000
0 0.3 0.6 1.2
Kilometres

PROJECTION: UTM Zone 12 NAD 83

DRAWING NAME: Fig 5.3 Capability

FIGURE: **5.3**



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PROJECT

Joslyn North Mine Project

TITLE

Figure 5.4a. Reclamation Suitability of the Local Study Area - Topsoil

LEGEND

Topsoil Rating
- Good
- Good-Fair
- Fair
- Poor

- Organic (no topsoil)
- Disturbed Land
- Local Study Area
- Lease Boundary
- Mine Footprint
- CNRL Road

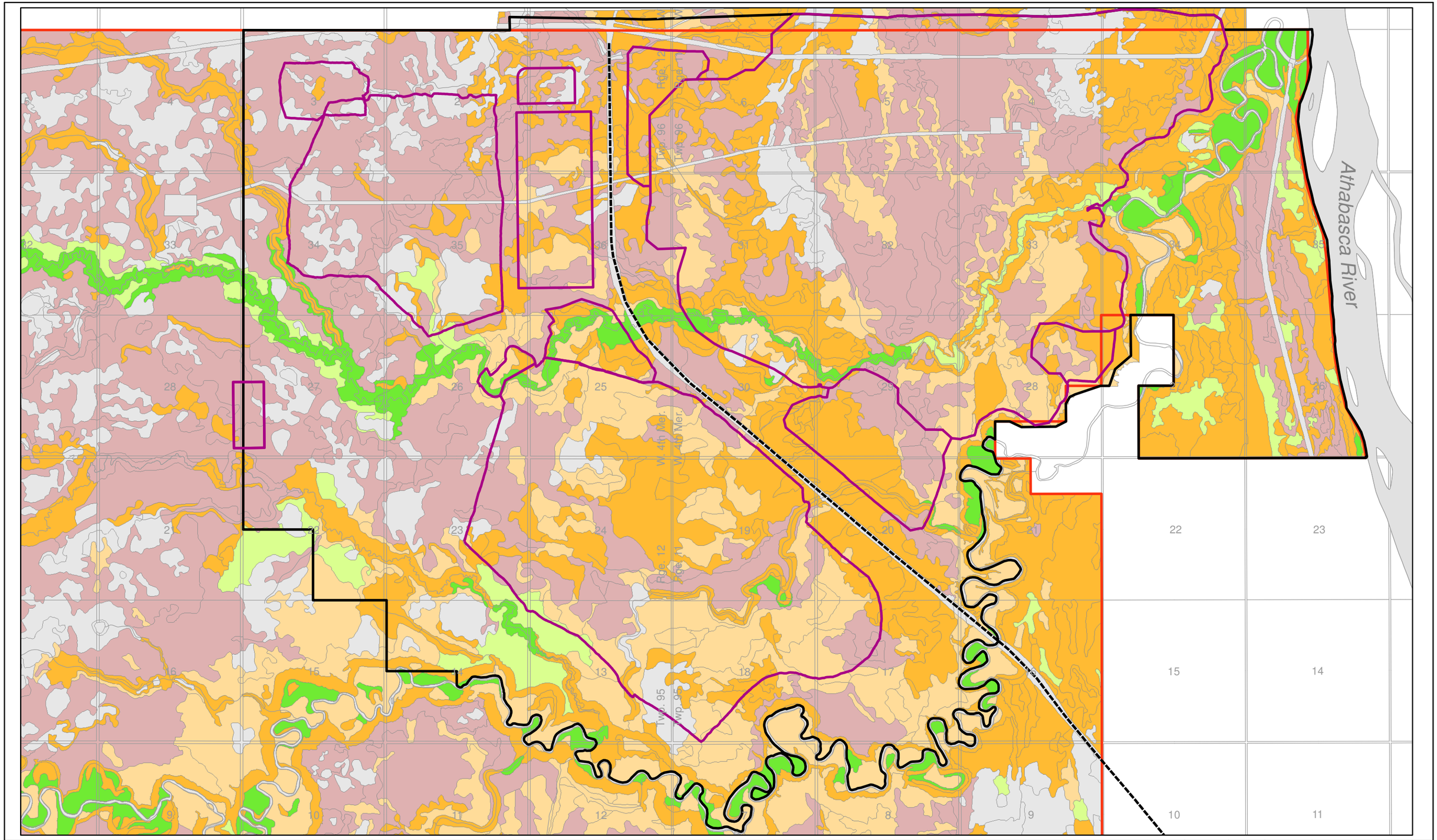
	DRAWN	DATE
DRAWN	PS	07Nov05
CHECKED	BW	21Dec05

SCALE 1:40,000
0 0.25 0.5 1
Kilometres

PROJECTION: UTM Zone 12 NAD 83

DRAWING NAME: Fig 5.4a Rec Suit Topsoil

FIGURE: **5.4a**



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PROJECT

Joslyn North Mine Project

TITLE

Figure 5.4b. Reclamation Suitability of the Local Study Area - Upper Subsoil

LEGEND

Upper Subsoil Rating
- Good
- Good-Fair
- Fair
- Fair-Poor
- Poor
- N/A

- Local Study Area
- Lease Boundary
- Mine Footprint
- CNRL Road

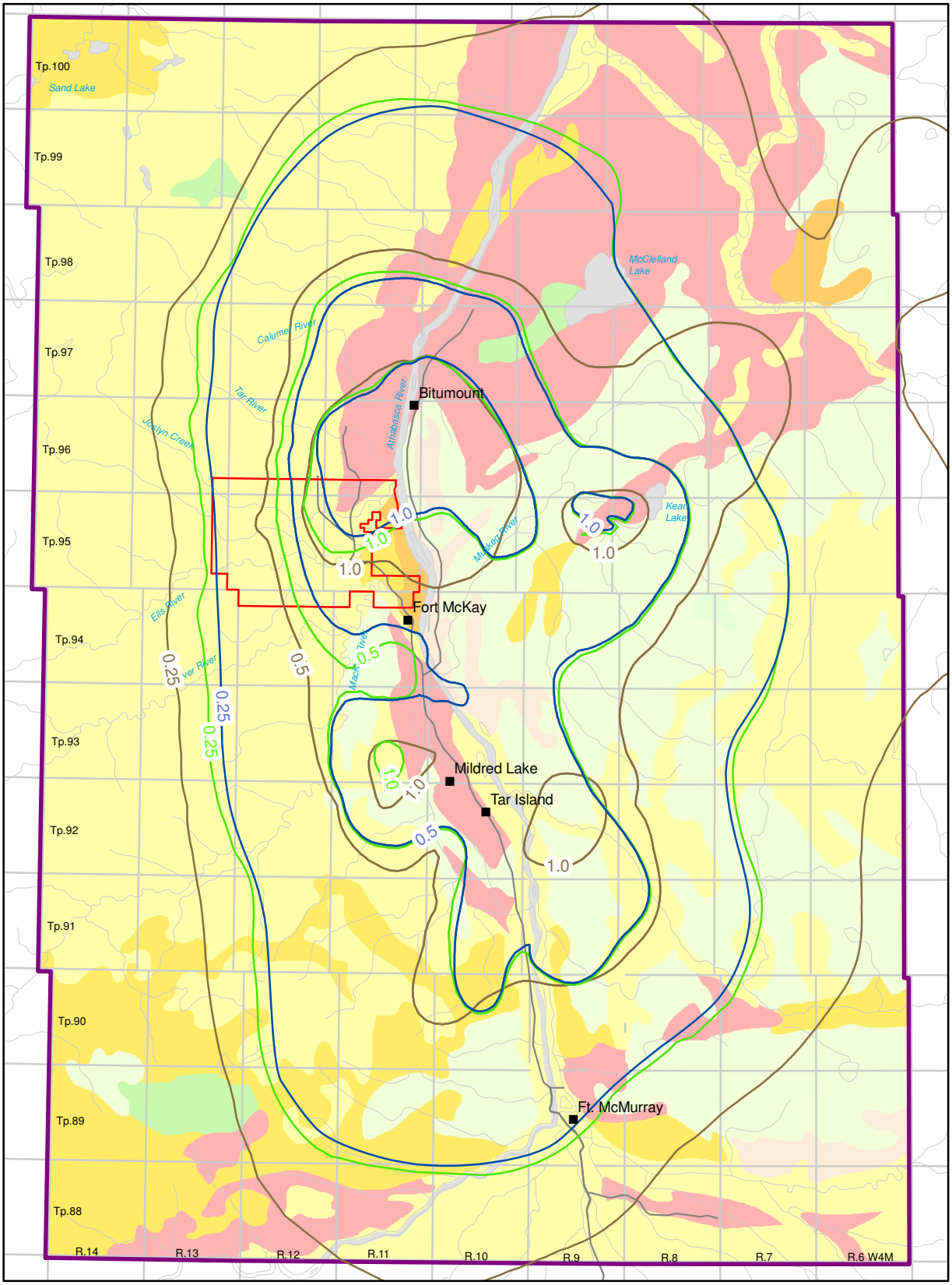
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SCALE 1:40,000
0 0.25 0.5 1
Kilometres

PROJECTION: UTM Zone 12 NAD 83

DRAWING NAME: Fig 5.4b Rec Suit - subsoil

FIGURE: **5.4b**



High | High (Low*) | Medium | Low (Medium*) | PAI Baseline | DCEL Lease Bounday
High (Medium*) | Medium (High*) | Medium (Low*) | Low | PAI Application | Regional Study Area (RSA)
* Rating for secondary soil | N/A | PAI CEA

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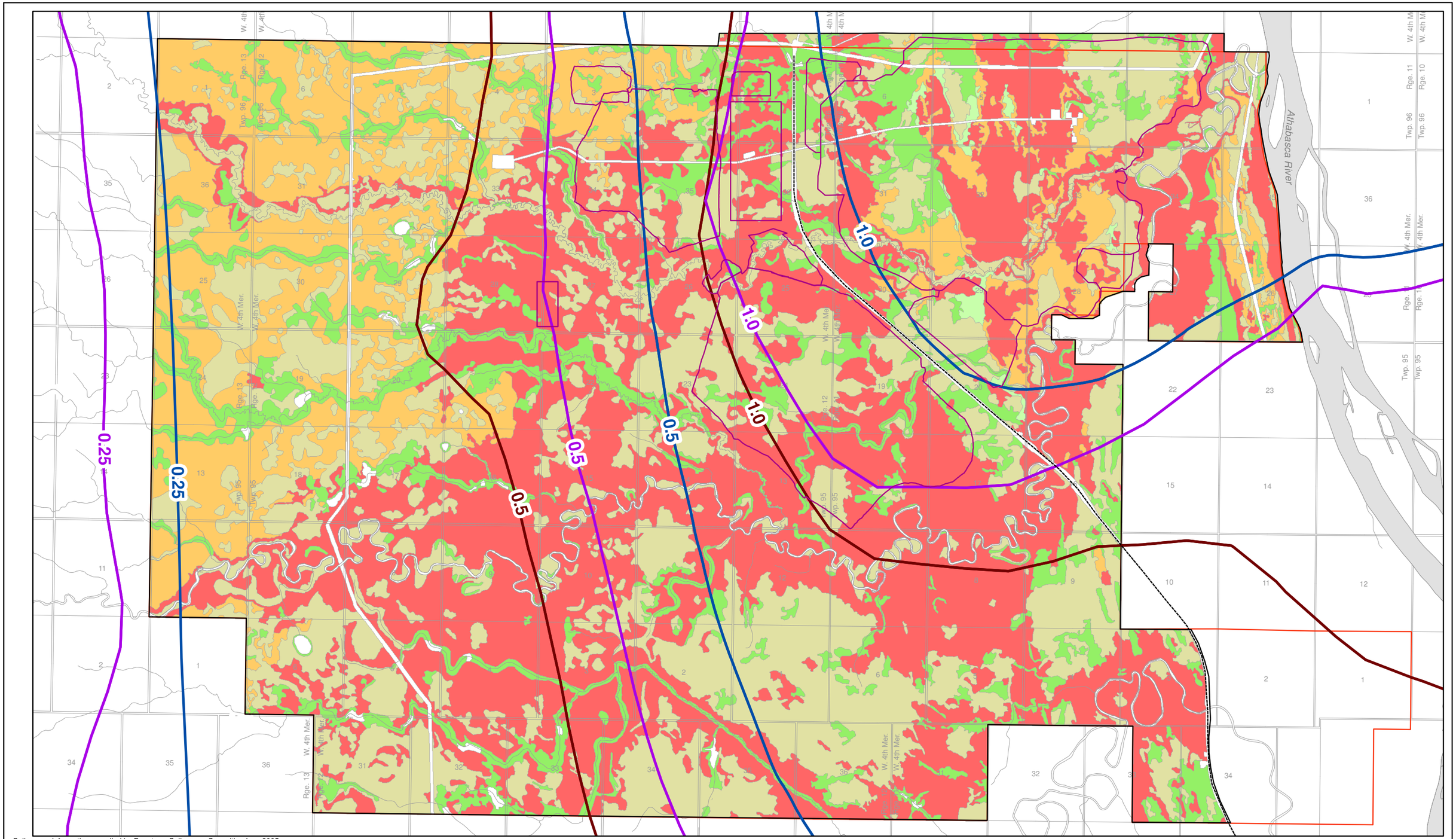
PROJECT
Joslyn North Mine Project

TITLE
Figure 5.5. Acid Sensitivity of soils in the Regional Study Area

	BY	DATE
DRAWN	PS	07Nov05
CHECKED	BW	19Jan06

SCALE 1:600,000
0 3.75 7.5 15
Kilometres

PROJECTION: UTM Zone 12 NAD83
DRAWING NAME: Fig 13 RSA Acid Rating
FIGURE: **5.5**



Soil survey information compiled by Beauterre Soilscapes Consulting Inc., 2005

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PROJECT

Joslyn North Mine Project

TITLE

Figure 5.6. Soil Sensitivity to Acid Deposition - Subregional Study Area

LEGEND

Acid Sensitivity
- High
- High-medium
- Medium
- Low-medium
- Low

- PAI Baseline
- PAI Application
- PAI CEA
- Sub-regional Study Area
- Mine Footprint
- CNRL Road
- Lease Boundary

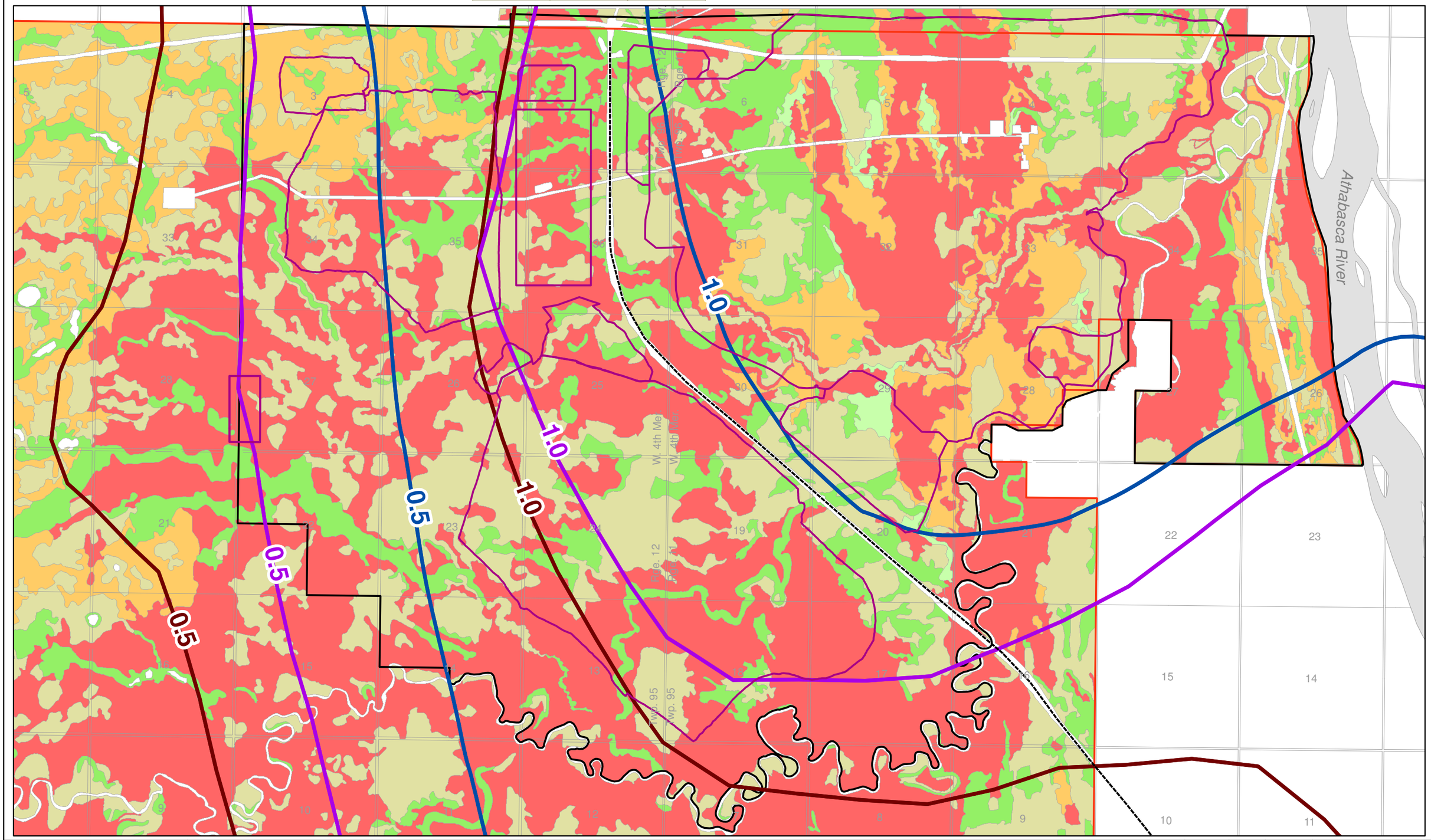
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SCALE 1:60,000
0 0.5 1 2
Kilometres

PROJECTION: UTM Zone 12 NAD 83

DRAWING NAME: Fig 5.6 Soil Sense to Acid

FIGURE: **5.6**



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PROJECT

Joslyn North Mine Project

TITLE

Figure 5.7. Soil Sensitivity to Acid Deposition - Local Study Area

LEGEND

Acid Sensitivity
- High
- High-medium
- Medium
- Low-medium
- Low

- PAI Baseline
- PAI Application
- PAI CEA

- Local Study Area
- Mine Footprint
- CNRL Road
- Lease Boundary

	DRAWN	DATE
DRAWN	PS	07Nov05
CHECKED	BW	30Dec05

SCALE 1:40,000

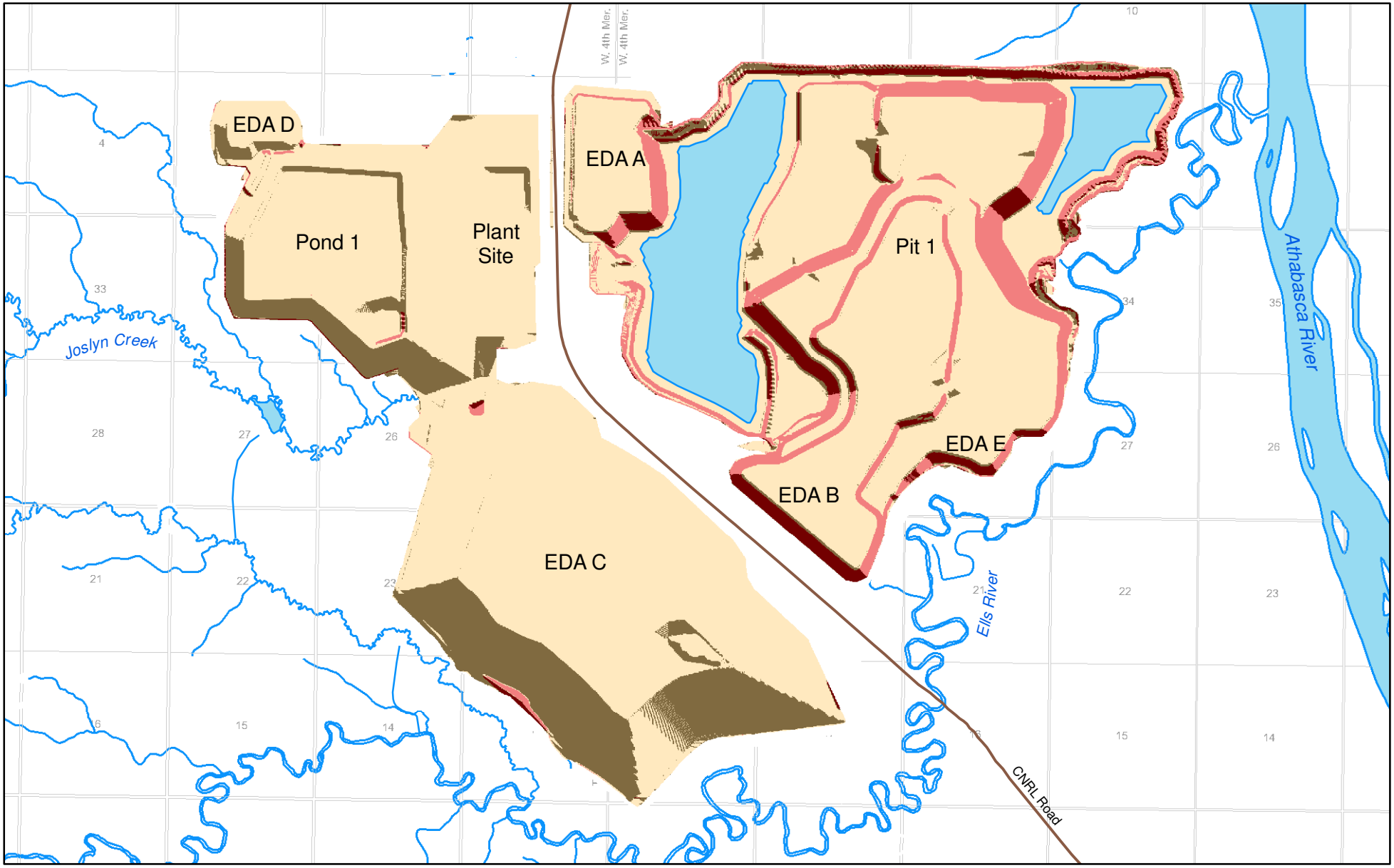
0 0.25 0.5 1

Kilometres

PROJECTION: UTM Zone 12 NAD 83

DRAWING NAME: Fig 5.7 soil sense to acid - lsa

FIGURE: **5.7**



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PROJECT

Joslyn North Mine Project

TITLE

Figure 6.1 Slopes of Reclaimed Landscapes

LEGEND

Slope (Percent)
- 0 - 20
- > 20

Aspect
- South (135 - 270°)

	BY	DATE
DRAWN	PS	25Oct05
CHECKED	KY	28Dec05

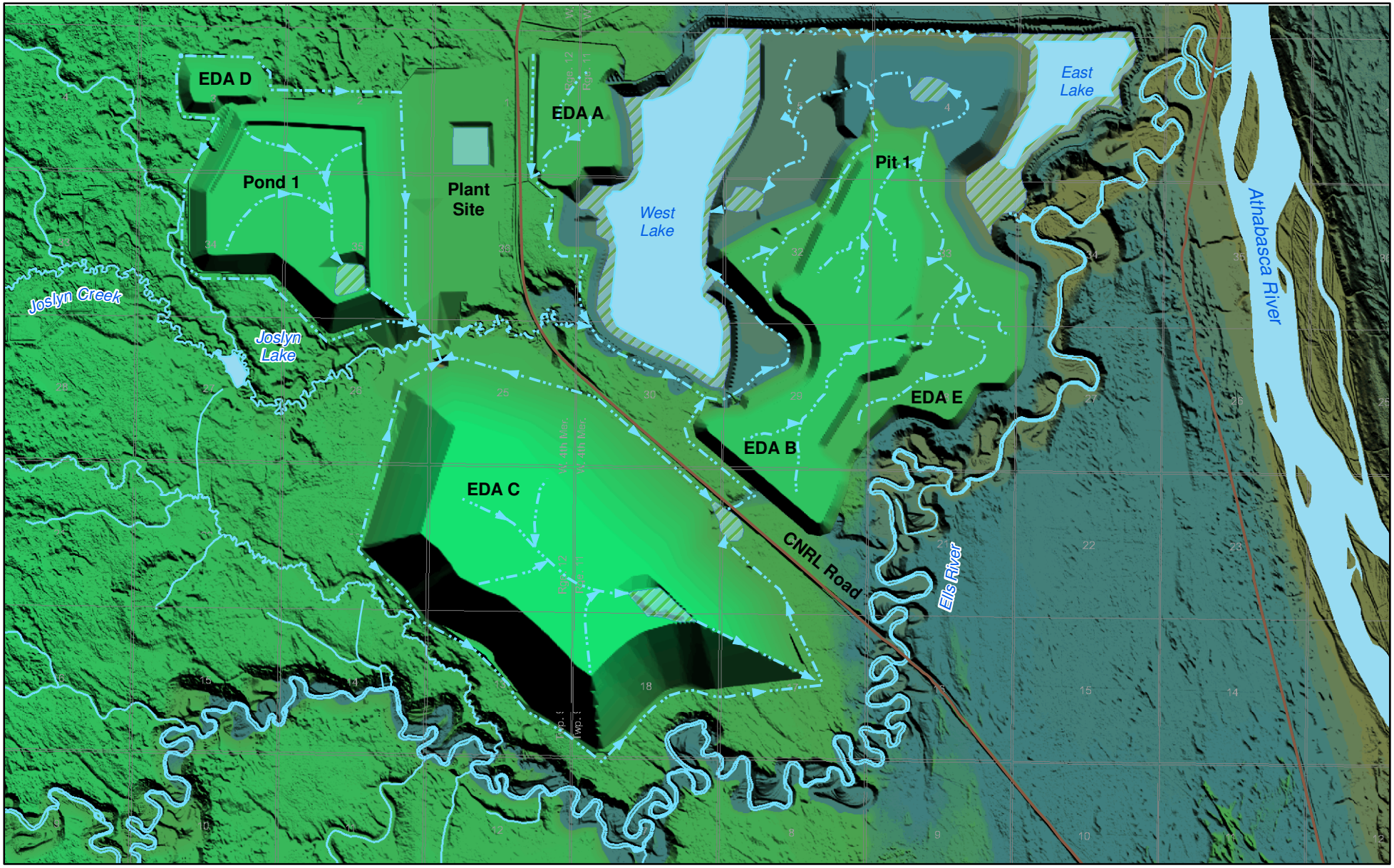
SCALE 1:60,000

0 0.25 0.5 1 Kilometres

PROJECTION UTM Zone 12 NAD 83

DRAWING NAME Fig 6.1 Slopes of Reclaimed Land

FIGURE **6.1**



DEER CREEK Energy Limited

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PROJECT

Joslyn North Mine Project

TITLE

Figure 6.2 Mine Closure Drainage Scheme

LEGEND

- River / Creek
- Drainage
- Water
- Wetland / Littoral Zone
- Road

	BY	DATE
DRAWN	PS	25Oct05
CHECKED	KY	30Dec05

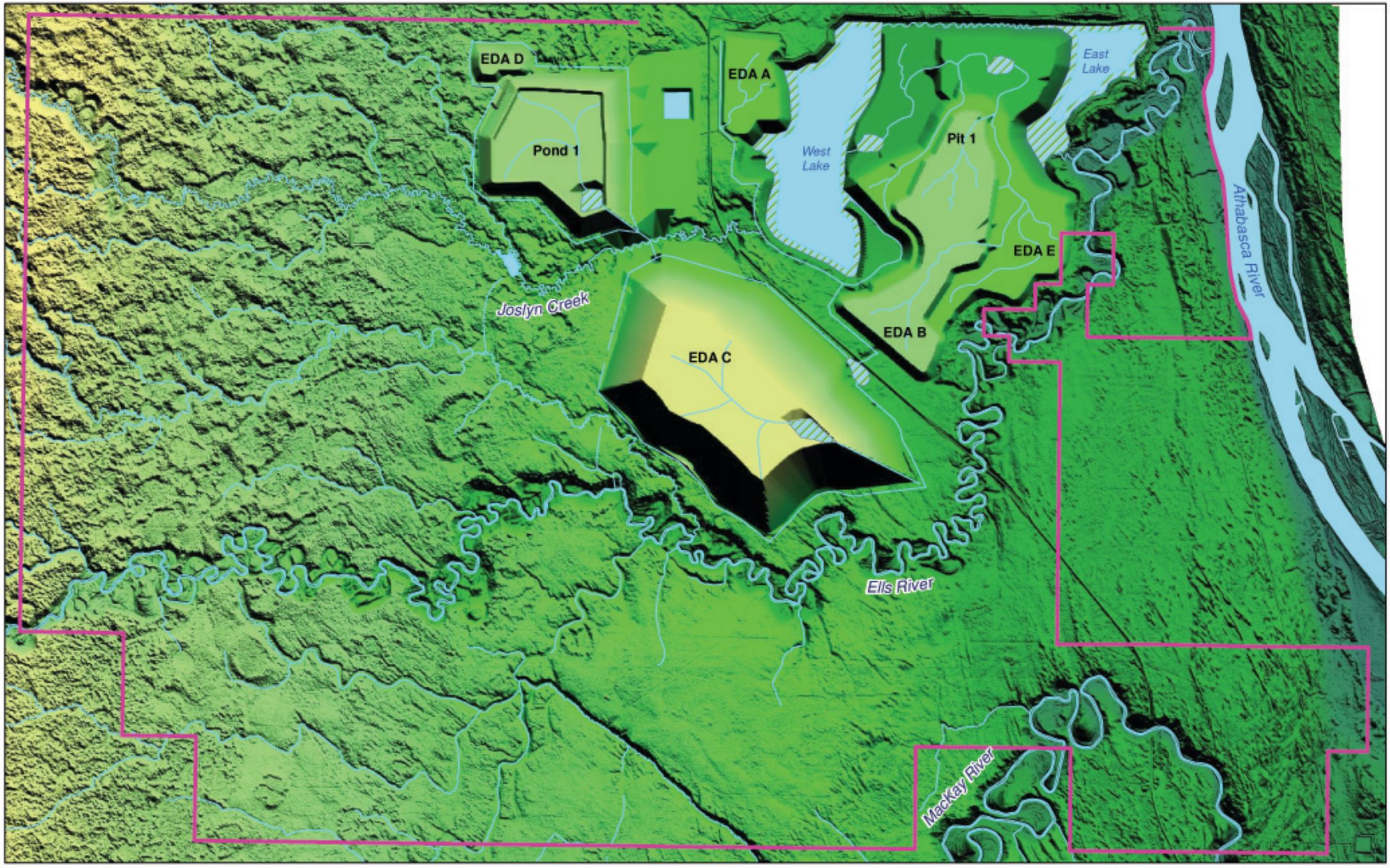
SCALE 1:60,000

0 0.25 0.5 1 Kilometres

PROJECTION UTM Zone 12 NAD 83

DRAWING NAME Fig 6.2 Mine Closure Drainage

FIGURE **6.2**



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PROJECT

Joslyn North Mine Project

TITLE

Figure 6.3 Three Dimensional Characterization of Reclaimed Mine

LEGEND

490
350
300
250
Elevation (mASL)

Lease Boundary
Rivers/Creek
Lake
Wetland/Litoral Zone

	DRAWN	DATE
DRAWN	PS	11Nov05
CHECKED	KY	19Jan06

SCALE 1:60,000

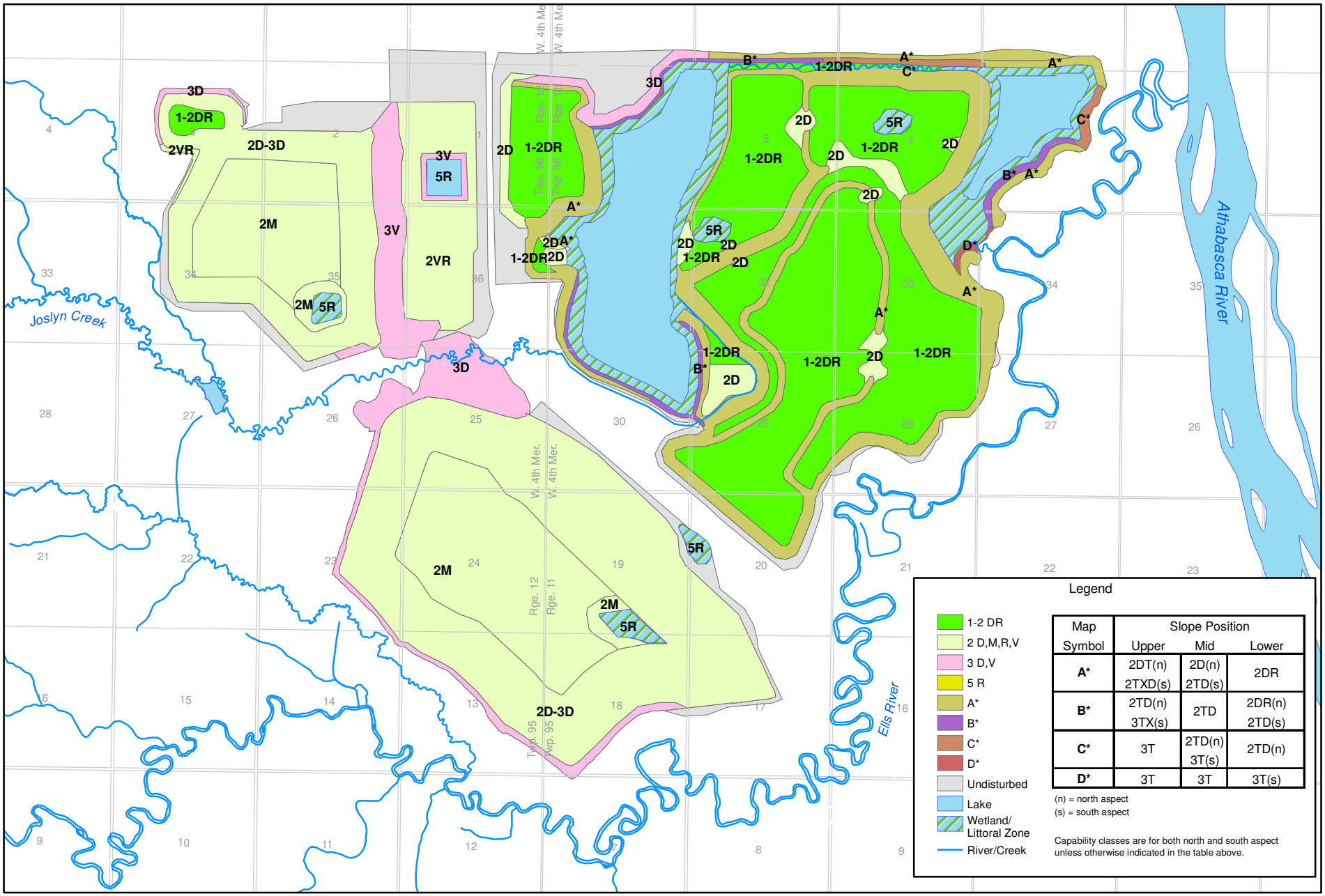
0 0.5 1 2

Kilometres

PROJECTION
UTM Zone 12 NAD 83

DRAWING NAME
Fig 6.3 Three Dimensional of Reclaimed Mine

FIGURE
6.3



DEER CREEK Energy Limited

PROJECT

Joslyn North Mine Project

Millennium EMS Solutions Ltd.

TITLE

Figure 6.4 Capability Classes of Reclaimed Soil Landscapes

	BY	DATE
DRAWN	PS	25Oct05
CHECKED	KY	28Dec05

PROJECTION: UTM Zone 12 NAD 83

DRAWING NAME: Fig 6.4 Reclaimed Capability

SCALE: 1:50,000

0 0.25 0.5 1 Kilometres

FIGURE: **6.4**

APPENDICES

Table of Contents

Table of Contents i
List of Tables i
Appendix A: Soil Series and Variants 4
Introduction 4
Soil Correlation Area (SCA) 4
Parent Material Classification 4
Soil Variants 6
Soil Series and Variant Descriptions 7
Appendix B: Descriptions of Soil Map Units 40
Introduction – Soil Landscape Model 41
Soil Models 41
Soil Models for Mineral Soils 41
Soil Models for Organic Soils 42
Landscape Models 42
Soil Model (SM) and Soil Landscape Model (SLM) Descriptions 43

List of Tables

Table A-1. Parent material textural groupings (adapted from AGRASID, ASIC 2001). 5
Table A-2. Soil variant codes (adapted from CAESA Soil Inventory Working Group 1997). 6
Table A-3. Brief description of an inspection pedon (BW051) representing ALGnp variant. 8
Table A-4. Description of a pedon (BW101P) representing BMT series. 9
Table A-5. Selected chemical and physical properties of the BMT pedon (BW101P). 9
Table A-6. Description of a pedon (BW092P) representing CHT series. 10
Table A-7. Selected chemical and physical properties of the CHT pedon (BW092P). 11
Table A-8. Brief description of an inspection pedon (GW004) representing DAN series. 12
Table A-9. Description of a pedon (BW106P) representing DOV series. 13
Table A-10. Selected chemical and physical properties of the DOV pedon (BW106P). 14
Table A-11. Brief description of an inspection pedon (GW089) representing FRT series. 15
Table A-12. Description of a pedon (BW094P) representing KME series. 16
Table A-13. Selected chemical and physical properties of the KME pedon (BW094P). 17
Table A-14. Description of a pedon (BW110P) representing LVKxc variant. 18
Table A-15. Selected chemical and physical properties of the LVK pedon (BW110P). 19
Table A-16. Brief description of an inspection pedon (BW028) representing LVKgl variant. 20
Table A-17. Description of a pedon (BW102P) representing MIL series. 21
Table A-18. Selected chemical and physical properties of the MIL pedon (BW102P). 21
Table A-19. Description of a pedon (BW096P) representing MLDzz variant/series. 23
Table A-20. Selected chemical and physical properties of the MLDzz pedon (BW096P). 23
Table A-21. Description of a pedon (BW103P) representing MLD1m variant. 24
Table A-22. Selected chemical and physical properties of the MLD1m pedon (BW103P). 24
Table A-23. Description of a pedon (BW107P) representing MMWpt variant. 26
Table A-24. Selected chemical and physical properties of the MMWpt pedon (BW107P). 27
Table A-25. Description of a pedon (BW097P) representing MMYzhgl variant. 28

Table A-26. Selected chemical and physical properties of the MMYzhgl pedon (BW097P). 29
Table A-27. Description of a pedon (BW095P) representing MUSzz variant. 31
Table A-28. Selected chemical and physical properties of the MUSzz pedon (BW095P). 31
Table A-29. Description of a pedon (BW105P) representing MUS1m variant. 32
Table A-30. Selected chemical and physical properties of the MUS1m pedon (BW105P). 32
Table A-31. Brief description of an inspection pedon (JH733) representing PEA series. 34
Table A-32. Description of a pedon (BW091P) representing SEN series. 35
Table A-33. Selected chemical and physical properties of the SEN pedon (BW091P). 36
Table A-34. Brief description of an inspection pedon (JH135) representing WNFxc variant. 37
Table A-35. Selected chemical and physical properties of the WNF pedon (JH135). 38
Table B-1. Landscape models used in soil map units of the SSA (adapted from AGRASID, ASIC 2001). 43
Table B-2. Surface form modifiers identified for use in AGRASID (ASIC 2001). 43

APPENDIX A

SOIL SERIES AND VARIANT DESCRIPTIONS

Appendix A: Soil Series and Variants

Introduction

Prior to 1990 in Alberta, the differentiation of soil series and the mapping units based on them was rather imprecise. Some arbitrarily broad levels of biophysical or ecological zonation had long been a foundation for classifying soils, but were applied on a rather ad hoc basis. Identification of parent material types for soil series classification was also applied informally and irregularly across the province. In the early '90s, steps were taken to correct these problems with an evaluation of soil series throughout the province (ASSWG 1993). Further developments and refinements to both soil series taxonomy and soil mapping in Alberta continued through the 1990s (CAESA-SIWG 1998), culminating in publication of AGRASID (ASIC 2001).

Appendix A provides more in-depth discussion of the tools used for classifying soils to the series level in Alberta – soil correlation areas, a revised parent material classification (grouping) system, and the use of soil variants. Descriptions of the major soil series and variants found in the Joslyn Lease are also included.

Soil Correlation Area (SCA)

Some level of biophysical or ecological zonation has long been a foundation for classifying soil series in Alberta. But beyond use of the broad soil zones, application of ecological regions was ad hoc prior to 1990. This situation was changed with the implementation of the Soil Correlation Area "model" in the early '90s (ASSWG 1993).

Soil correlation areas (SCAs) were developed to identify areas of similar soil climate and landscape ecology (ASSWG 1993). Twenty-three SCAs were established to cover the province, each defined according to a combination of soil zone, ecoregion, and agro-climatic parameters. SCAs, initially presented in map form, introduced geographic limits for the distribution of soil names. SCA is now a key characteristic of each soil series or variant listed in the Alberta Soil Names File (ASIC 2001).

The Joslyn Lease occurs within SCA 20, defined as the Mid Boreal Mixedwood Ecoregion of the Northern Alberta Plains (ASSWG 1993). The latest edition of the Alberta Soil Names File (AG30SNF), distributed as part of AGRASID (ASIC 2001), listed over 70 established soil series and variants that can be used in the region. This list was reduced to about 25 soil names that were applicable to the ecodistricts and parent materials of the Joslyn Lease area. After correlation with the provincial correlator in 2005, two additional new names, added for the CNRL Horizon Project to the north (Golder Associates 2002), were also available for use in the Joslyn Lease. The new series are Daphne (DAN) and Ings (ING).

Parent Material Classification

Refinements to the grouping of parent materials for classifying soil series were implemented for the soil survey work that became AGRASID (ASIC 2001). The Alberta Soil Names File is an integral part of AGRASID and lists all established soil series in the province. A foundation of this soil series list is the modernized classification of soil parent materials – a grouping that places greater emphasis on textural characteristics, less on mode of deposition and colour.

The entire list of parent material groupings developed for AGRASID is presented in Table A-1 (adapted from CAESA-SIWG 1998). Each parent material group (or type) is identified by the codes in the middle column. A "look-up" column was added for this report to help the reader quickly pick out the different types of parent materials. Figure A-1 illustrates the textural groups (FT, MT, CT) and sub-groups (VF, FI, MF, ME, MC, VC) referred in the descriptions of the parent material groupings. Not all of the parent material groupings listed in Table A-1 were used in the Joslyn SSA.

Table A-1. Parent material textural groupings (adapted from AGRASID, ASIC 2001).

Look-up	Code	Description
Coarse textured materials:		
Undifferentiated	**C0**	Undifferentiated coarse textured (S, LS, SL) material
Gravels	**C1**	Gravels or gravelly (cobbly/stony) coarse textured material
Very coarse	**C2**	Very coarse (S, LS) sediments deposited by wind or water
Mod. coarse	**C3**	Moderately coarse (SL, FSL) sediments deposited by wind or water
Tills	**C4**	Very coarse textured till (*Till name*)
	C5	Moderately coarse textured tills (*Till name*)
Bedrock	**C6**	Coarse textured (S, LS, SL) softrock
	C7	Coarse grained bedrock
Medium textured materials:		
Undifferentiated	**M0**	Undifferentiated medium textured (VFSL, L, SiL, SiCL, CL, SCL) materials
Gravelly	**M1**	Gravelly, medium textured, water-laid sediments (also cobbly and stony variations)
Medium	**M2**	Medium textured (L, SiL, VFSL) sediments deposited by wind and water
Moderately fine	**M3**	Moderately fine textured (CL, SCL, SiCL) sediments deposited by water
Till	**M4**	Medium textured (L to CL) till (*Till name*)
Bedrock	**M5**	Medium textured (L to CL) softrock
Gravelly till	**M6**	Gravelly, cobbly or stony, medium textured till
Fine textured materials:		
Undifferentiated	**F0**	Undifferentiated fine textured (C, SiC, HC) materials
Fine	**F1**	Fine textured (C, SiC) water-laid sediments
Very fine	**F2**	Very fine textured (HC) water-laid sediments
Till-like	**F3**	Fine textured (C) water-laid sediments with till-like features
Till	**F4**	Fine textured (C) till (*Till name*)
Bedrock	**F5**	Fine textured (C, SiC) softrock
Layered materials (parent material change occurs between 30 and 100 cm):		
Gravelly CO to ME / till	**L1**	Gravel or gravelly (or cobbly/stony) coarse over medium or fine textured till
	L2	Coarse textured (S, LS, SL) over medium or fine textured till
	L3	Medium textured (VFSL, L, sic, CL) over medium or fine textured till
CO to ME / gravel	**L4**	Coarse textured over gravel or gravelly coarse (includes cobbly and stony variations)
	L5	Medium textured over gravel or gravelly coarse (includes cobbly and stony variations)
Various dep. / softrock	**L6**	Till (Till name) over softrock
	L7	Coarse (not till) over softrock
	L8	Medium (not till) over softrock
CO to ME / Fine	**L9**	Coarse (not till) textured over fine or very fine (not till)
	L10	Medium (not till) textured over fine or very fine (not till)
Peat / various materials	**L11**	Peat (any) over coarse textured
	L12	Peat (any) over medium textured
	L13	Peat (any) over fine textured
Fine / till	**L14**	Fine textured (not till) over medium to moderately fine textured till
	L15	Very fine textured (not till) over medium to moderately fine textured till
Fine / rock	**L16**	Fine to very fine textured (not till) over softrock
Gr ME / till	**L17**	Gravelly (or cobbly/stony) medium textured material over medium or fine textured till
ME / CO	**L18**	Medium textured material over coarse textured material
Gr ME / rock	**L19**	Gravelly medium textured material over softrock
CO / ME	**L20**	Coarse textured over medium or moderately fine (not till)
Gr CO / ME	**L21**	Gravelly coarse textured over medium or moderately fine (not till)
FI / ME	**L22**	Fine (not till) over medium (not till)
Peat Materials:		
Undifferentiated	**P0**	Undifferentiated peat
Bog	**P1**	Bog (Sphagnum) peat
Fen	**P2**	Fen peat
Forest	**P3**	Forest peat

Soil Variants

Considering the complexity of parent materials encountered in the Joslyn SSA, soil series choices available from the Alberta Soil Names File were rather limited. Most were defined from low intensity inventories of the early '80s (Turchenek and Lindsay 1982a). A tool commonly used to identify soil series equivalents without naming them is variants. **Soil variants** are used to define soil entities that are sufficiently different from established soil series to warrant recognition, but do not justify a new soil name due to limited geographic extent.

Table A-2 lists the variant codes, with their definitions, used in Alberta (CAESA-SIWG 1998). Four variants (NP, XM, YM, and ZO) were added for this study. The codes are most often applied as lower case letters after the soil series symbol (e.g. LVKgl).

The use of variants substantially extends the soil series list for an area. Variants are particularly useful through the pilot and working stages of classification and mapping. Officially, up to two variant codes (e.g. MMYzhgl) are allowed in published soil name lists and map legends (ASIC 2001). However, more than two variants can be used in working lists in order to outline the entire soil population and identify where new series names might be needed.

Table A-2. Soil variant codes (adapted from CAESA Soil Inventory Working Group 1997).

Code	Description	Code	Description
AA	Not modal SCA	*XM*	Medium material at 30-99 cm
AC	Acid	XP	Paralithic at 30-99 cm
CA	Calcareous	XS	Sand at 30-99 cm
CB	Cobbly	XT	Till at 30-99 cm
CO	Coarse	XU	Undifferentiated material at 30-99 cm
CR	Carbonated	XZ	Permafrost at 30-99 cm
CY	Cryic	YC	Clay at 100-200 cm
DA	Dark Ap (cultivated)	YG	Gravel at 100-200 cm
DL	Disturbed	YL	Lithic at 100-200 cm
ER	Eroded	*YM*	Medium material at 100-200 cm
FI	Fine	YP	Paralithic at 100-200 cm
GL	Gleyed	YS	Sand at 100-200 cm
GM	Grumic	YT	Till at 100-200 cm
GR	Gravelly (entire profile)	YZ	Permafrost at 100-200 cm
OB	Overblown	ZB	Brunisolic
OW	Overwashed	ZE	Eluviated
NP	Non-Peaty	ZF	Fibric
PT	Peaty	ZG	Gleyed Rego
SA	Saline	ZH	Humic
SC	Saline subsoil	ZL	Luvisolic
ST	Stony	ZM	Mesic
TA	Thin A	*ZO*	Orthic
TK	Thick A / *Material thicker than modal*	ZR	Rego
XC	Clay at 30-99 cm	ZS	Solodic
XG	Gravel at 30-99 cm	ZT	Solonetzic
XL	Lithic at 30-99 cm	ZZ	Atypical subgroup

Soil Series and Variant Descriptions

Sixteen groupings of the 33 major soil series and variants recognized in Joslyn SSA are described below. They are organized in alphabetical order, based on the symbol (code) of the "root" soil name.

ALG – Algar Lake Series and Variants

ALG series represents a complex of closely related soil types found on confined floodplains of several streams in the survey area, and in small wetlands scattered throughout upland areas. The related types include non-peaty Orthic Luvic Gleysols (ALGnp), peaty Orthic Luvic Gleysols (ALG), and a few non-peaty to peaty Humic Luvic Gleysols (ALGzh). ALG soils are often associated with the more common CHT complex of Gleysolic soils, and with various Organic soils in some peatland landscapes. ALG series is described below; ALGnp variant in Table A-3.

Soil Classification (Subgroup):	Orthic Luvic Gleysol, peaty phase
Parent Material; Grouping:	Fine textured, mainly water-laid or glacial materials; F1 or F3
Drainage:	Imperfect or poor
Soil Moisture Regime:	Subhygric (6) to subhydric (8)
Texture:	Peat (15-40 cm in peaty soils) / clayey (C-SiC) material
Profile Coarse Fragments:	Usually none
Surface Organic Material:	Fen or bog peat; averaged 29 cm in thickness in ALG series
Topsoil Thickness:	Averaged 10 cm in SSA; absent in some cases
Soil Capability Rating (Forestry):	Index points – 38 peaty, 34 non-peaty; Class 4R for both
Soil Sensitivity to Acid Deposition:	Peaty – Low; Non-peaty – Low

Common Algar Lake variants found in the SSA:

Algar Lake-non-peaty (ALGnp) – similar to ALG but non-peaty because it has less than 15 cm of organic materials (peat) on the surface (average 7 cm based on site inspections in the SSA).

Comments on ALG series and variants:

- The non-peaty variant (ALGnp) was by far the most commonly occurring member of the complex, followed by ALG series. Humic Luvic Gleysol variants (ALGzh) were found infrequently.

Parent material of ALG and related soils consists of subtly layered fluviolacustrine (post-glacial) and related water-laid or glacial (lacustro-till) deposits. Textures tend to be mostly clayey (clay to silty clay); thin coarser layers (silty clay loam, clay loam, or sandy clay) may occur in some pedons.

- Fen or bog peat up to 40 cm thick often mantles the mineral surface. Peat averaged 29 cm thickness in ALG series, 7 cm thickness in the non-peaty ALGnp variant.
- Topsoil thickness was highly variable in the ALG soil complex, averaging 10 cm but ranging from 0 to 24 cm. Horizons included in "topsoil" thickness calculations were mainly Aeg, Aegj, Ae, and ABg. Upper subsoil (i.e. Btg horizon including BAg where present) averaged 22 cm thickness.
- A detailed pedon description and samples for analytical characterization were not obtained for ALG soils. Instead, a brief description of an ALGnp profile from an inspection site is provided (Table A-3). Analytical data for ALG series is available in the Alberta Soil Layers File (AG30SLF, ASIC 2001).

Table A-3. Brief description of an inspection pedon (BW051) representing ALGnp variant.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
Om	10-0	Mesic peat	--	--	--
Aeg	0-8	Fine sandy loam	--	Weak platy	--
ABg	8-17	Fine sandy loam	--	Weak platy	--
Btg	17-40	Clay	5YR4/3m	Subangular blocky	--
BCg	40-75	Clay	5YR4/3m	Massive	--
Ckg	75-90	Clay	5YR4/3m	Massive	--

BMT – Bitumount Series and Variants

BMT series represents a complex of closely related soil types found on some wetlands scattered throughout the Joslyn Plain and Lower Dover Plain land systems. The related types include peaty and non-peaty Orthic Gleysols (BMT and BMTnp) and similar soils developed on coarse overlying fine textured materials (BMTxc). BMT soils are often associated with various Organic soils in some peatland landscapes. BMT series is described below and in Table A-4 and

Soil Classification (Subgroup):	Orthic Gleysol, peaty phase
Parent Material; Grouping:	Very coarse textured, glaciofluvial material (outwash sands); C2
Drainage:	Poor or imperfect
Soil Moisture Regime:	Hygric (7) to subhydric (8)
Texture:	Peat (15-40 cm in peaty soils) / very coarse (S-LS) material
Profile Coarse Fragments:	Usually none
Surface Organic Material:	Fen or bog peat; averaged 27 cm thickness in peaty members of complex
Topsoil Thickness:	Highly variable & poorly defined in Gleysols; about 10-15 cm in complex
Soil Capability Rating (Forestry):	Index points – 33 peaty, 32 non-peaty; Class 4R for both
Soil Sensitivity to Acid Deposition:	Peaty – Low; Non-peaty – Medium

Common Bitumount variants found in the SSA:

Bitumount-non-peaty (BMTnp) – similar to BMT but non-peaty because it has less than 15 cm of organic materials (peat) on the surface (average 8 cm based on site inspections in the SSA).

Bitumount-clayey subsoil (BMTxc) – similar to BMT but developed on shallow sand deposits overlying clayey glaciolacustrine or lacustro-till material within 100 cm of the mineral surface. The sands range from 30 to 99 cm in thickness. Both peaty (BMTxc, index points 30) and non-peaty (BMTxcnp, index points 29) versions were found in the SSA.

Comments on BMT series and variants:

- BMT series and BMTnp variant accounted for most of the soil types in the BMT complex. Other less commonly occurring variants included peaty and non-peaty Rego Gleysols (BMTzr & BMTzrnp), one with sands overlying moderately fine textured (CL-SCL) subsoil (BMTxm), and various mostly peaty Luvic Gleysols (BMTzl).
- Parent material of BMT and related soils consists of glaciofluvial (outwash) sands. Textures tend to be very coarse (sand to loamy sand); thin finer layers (sandy loam, fine sandy loam, and finer) occur in some pedons.
- Fen or bog peat up to 40 cm thick often mantles the mineral surface. Peat averages about 27 cm thickness in the peaty members of the complex such as BMT and BMTxc, 8 cm thickness in the non-peaty members BMTnp and BMTxcnp.

- Topsoil thickness was highly variable in the BMT soil complex, averaging 12 cm but ranging from 0 to 55 cm. Horizons included in "topsoil" thickness calculations were Ae/Aeg, Aheg, and AB/ABg. In many profiles, the topsoil (A or AB horizon) was absent. Upper subsoil (i.e. B horizons) averaged 50 cm thickness overall, which included 0 cm logged for Rego Gleysols.
- A sampled BMT pedon is described in Table A-4, with selected chemical and physical data in

Table A-4. Description of a pedon (BW101P) representing BMT series.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
Om	18-0	Mesic peat	10YR2/1m	--	--
Aegj	0-20	Sand	10YR6/3m	Single grain	Loose
ABgj	20-35	Loamy sand	10YR5/3m	Single grain	Loose
Bg	35-70	Sand	10YR4.5/4m	Single grain	Loose; non-sticky, non-plastic
BCg	70-100	Sand	2.5Y5/3m	Single grain	Loose; non-sticky, non-plastic

Table A-5. Selected chemical and physical properties of the BMT pedon (BW101P).

Horizon	Depth (cm)	pH	EC	OC	$CaCO_3$ Equiv.	TN	PSA (%)			Texture Class	CEC	BS %	SAR
							Sand	Silt	Clay				
Om	18-0	5.0	--	38.8	--	2.18	--	--	--	--	104.0	53	--
Aegj	0-20	5.0	--	0.4	--	0.04	97	1	2	S	9.7	9	--
ABgj	20-35	5.1	--	0.1	--	<0.02	94	1	5	S	1.1	91	--
Bg	35-70	5.3	--	<0.1	--	<0.02	96	1	3	S	0.4	525	--
BCg	70-100	5.7	--	--	--	--	97	1	2	S	--	--	--

pH – measured in $CaCl_2$ solution EC – electrical conductivity (dS/m) OC – total organic carbon (%)
CaCO3 Equiv. – calcium carbonate equivalent (%) TN – total nitrogen (%), Kjeldahl method
PSA – particle size analysis (% sand, silt, and clay separates) by the hydrometer method, with texture class
CEC – cation exchange capacity (meq/100g) BS % – base saturation percentage SAR – sodium adsorption ratio

Comments on the BMT pedon:

- Colors are specific Munsell soil color chart notations indicating hue (e.g. 10YR), value (e.g. 2/), chroma (e.g. /2), and whether taken for moist (m) or dry (d) soil.
- Om horizon includes a thin (1-2 cm) layer of Oh material at its base, and a very thin (<1 cm) layer of Of material at its top.
- Strong mottling (prominent mottles) were observed in the Bg horizon, distinct mottles in the Aegj and BCg horizons, and faint mottles in the ABgj horizon. The BCg horizon was very wet; the apparent water table was encountered at 70 cm.
- Roots were observed in all but the BCg horizon – plentiful, very fine to fine in the upper profile; few, very fine to fine in the Bg horizon.
- Humus-enriched blotches and streaks were observed in the Bg horizon, and are likely associated with roots.

CHT – Chateh Series and Variants

CHT series represents a complex of closely related soil types found on confined floodplains of several streams in the survey area, and in small wetlands scattered throughout upland areas. The related types include peaty and non-peaty Orthic Gleysols (CHT and CHTnp), peaty and non-peaty Rego Gleysols

(CHTzr and CHTzrnp), and a few non-peaty Orthic Humic Gleysols (CHTzhnp). CHT series is described below and in Table A-6 and

Soil Classification (Subgroup):	Orthic Gleysol, peaty phase
Parent Material; Grouping:	Fine textured, mainly water-laid or glacial materials; F1 or F3
Drainage:	Imperfect or poor
Soil Moisture Regime:	Subhygric (6) to subhydric (8)
Texture:	Peat (15-40 cm in peaty soils) / clayey (C-SiC) material
Profile Coarse Fragments:	Usually none
Surface Organic Material:	Fen or bog peat; averaged 25 cm in thickness in CHT series
Topsoil Thickness:	Virtually non-existent in CHT series; common in some variants
Soil Capability Rating (Forestry):	Index points – 36 peaty, 38 non-peaty; Class 4R for both
Soil Sensitivity to Acid Deposition:	Peaty – Low; Non-peaty – Low

Common Chateh variants found in the SSA:

Chateh-non-peaty (CHTnp) – similar to CHT but non-peaty because it has less than 15 cm of organic materials (peat) on the surface (average 8 cm based on site inspections in the SSA).

Chateh-rego (CHTzr) – Rego Gleysol variants differ from the Orthic Gleysol versions (CHT & CHTnp) because they lack developed B (i.e. Bg horizons). Both peaty (CHTzr) and non-peaty (CHTzrnp) versions were found in the SSA.

Comments on CHT series and variants:

- Based on inspection site counts, Orthic Gleysols (CHT series & CHTnp variant) accounted for 58% of the soil types in the CHT complex. Rego Gleysols (CHTzr & CHTzrnp variants) accounted for nearly 35%. The remaining 7% were classified as non-peaty Orthic Humic Gleysols (CHTzhnp variant).
- Parent material of CHT and related soils consists of subtly layered fluviolacustrine (post-glacial) and related water-laid or glacial (lacustro-till) deposits. Textures tend to be mostly clayey (clay to silty clay); thin coarser layers (silty clay loam to clay loam) may occur in some pedons.
- Fen or bog peat up to 40 cm thick often mantles the mineral surface. Peat averages about 26 cm thickness in the peaty members of the complex such as CHT and CHTzr, 5 cm thickness in the non-peaty members CHTnp and CHTzrnp.
- Topsoil thickness was highly variable in the CHT soil complex, averaging 8 cm but ranging from 0 to 65 cm. Horizons included in "topsoil" thickness calculations were Ah/Ahg, ABg, ACg, and even BAg if there was no underlying B horizon. Upper subsoil (i.e. B horizon) was absent in Rego Gleysols, averaged 20 to 26 cm in Orthic and Orthic Humic Gleysol groupings.
- A sampled CHT pedon is described in Table A-6; selected chemical and physical data for this pedon are listed in

Table A-6. Description of a pedon (BW092P) representing CHT series.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
Om	25-10	Mesic peat	2.5YR2/4m	--	--
O+C	10-0	--	10YR2/2m	Massive	--
Bg1	0-14	Silty clay to silty clay loam	5Y3/2m	Moderate, fine, subangular blocky	Sticky, slightly plastic
O+Cb	14-25	--	10YR2/1m	Massive	--

Table A-6. Description of a pedon (BW092P) representing CHT series.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
Bg2	25-65	Silty clay to silty clay loam	2.5Y3/2m	Weak, fine, subangular blocky	Sticky, slightly plastic
BCg	65-100	Clay to silty clay	2.5Y4/4m	Massive	Slightly sticky, non-plastic

Table A-7. Selected chemical and physical properties of the CHT pedon (BW092P).

Horizon	Depth (cm)	pH	EC	OC	$CaCO_3$ Equiv.	TN	PSA (%)			Texture Class	CEC	BS %	SAR
							Sand	Silt	Clay				
Om	25-10	5.8	--	14.6	--	0.94	--	--	--	--	74.0	83	--
O+C	10-0	5.6	--	5.3	--	0.41	--	--	--	--	38.0	93	--
Bg1	0-14	5.4	--	2.0	--	0.16	11	44	45	SiC	30.0	98	--
O+Cb	14-25	5.6	--	3.1	--	0.29	--	--	--	--	38.0	92	--
Bg2	25-65	6.4	--	2.0	--	0.16	13	44	43	SiC	31.5	106	--
BCg	65-100	7.3	0.4	--	--	--	--	--	--	--	11.4	122	1.4

pH – measured in $CaCl_2$ solution EC – electrical conductivity (dS/m) OC – total organic carbon (%)
CaCO3 Equiv. – calcium carbonate equivalent (%) TN – total nitrogen (%), Kjeldahl method
PSA – particle size analysis (% sand, silt, and clay separates) by the hydrometer method, with texture class
CEC – cation exchange capacity (meq/100g) BS % – base saturation percentage SAR – sodium adsorption ratio

Comments on the CHT pedon:

- Colors are specific Munsell soil color chart notations indicating hue (e.g. 10YR), value (e.g. 2/), chroma (e.g. /2), and whether taken for moist (m) or dry (d) soil.
- The Om horizon in the sampled pedon contained many small fragments of wood.
- O+C horizons like the two in the sampled pedon are bands of mesic and fibric organic materials infused with thin layers of trapped sediment. They represent former transitional surfaces where there were periods of peat accumulation interrupted by flooding and deposition of mineral sediments.
- Strong mottling (prominent mottles) were observed in all mineral horizons. The BCg horizon was very wet; the apparent water table was encountered at 90 cm.
- Roots were observed in all but the BCg horizon – abundant, very fine to fine in the upper profile; few, very fine in the Bg2 horizon.
- Very fine to fine pores were observed in the Bg horizons only.
- The BCg horizon contained bands of sandy loam material that were incorporated (by auger) with the clayey materials during sampling. There appeared to be some stratification in the lower profile.

DAN – Daphne Series

DAN series represents a unique set of soils developed on stony (or cobbly or gravelly) drift overlying sandstone bedrock in the Athabasca-Ells Valley Land System. It is classed as Eluviated Dystric Brunisol developed on layered (L19) materials, and occurs mostly on the upper wall of the Athabasca River valley.

Soil Classification (Subgroup): Eluviated Dystric Brunisol
Parent Material; Grouping: Stony, medium textured drift overlying soft bedrock; L19
Drainage: Well to moderately well drained
Soil Moisture Regime: Mesic (5)

Texture:	SL topsoil / L-CL-SCL upper subsoil / L-SL lower subsoil or weathered rock
Profile Coarse Fragments:	Typically 20-50% by volume in stratified drift (above the soft rock)
Surface Organic Material:	Mainly forest litter (LFH); averaged 8 cm thickness in area
Topsoil Thickness:	Averaged 12 cm in area – A horizon (mainly Ae and Ahe)
Soil Capability Rating (Forestry):	16 index points; Class 5MD
Soil Sensitivity to Acid Deposition:	Medium

Comments on DAN soils:

- Based on inspection site counts within the SSA, DAN series accounted for a very small percentage of the total because its distribution is limited to the Athabasca River valley. Variants of DAN were rare, with Daphne-gleyed (DANgl) being found occasionally on lower slopes in the bedrock-controlled landscape.
- DAN soils occur with other soil types in hummocky to ridged landforms controlled by bedrock. Stones and boulders are a common feature, both throughout the soil materials and on the ground surface. Parent materials of the DAN soils consist of stony (to cobbly or gravelly), medium to coarse textured drift overlying bedrock. The drift is thought to be lag material left behind after an early stage of the post-glacial Athabasca River eroded outwash and other glacial materials as it down-cut its present-day valley.
- The upper material, or drift, varies in thickness and texture. Depth to bedrock averaged just under 50 cm. Textures range mainly from L-SL, with some finer (CL-SiCL-SCL) layers, and usually include high coarse fragment (stones, cobbles, and gravel) content (i.e. 20-50% by volume).
- The underlying bedrock (lower parent material) is mainly partially weathered sandstone and siltstone of the McMurray Formation (Hamilton et al. 1999). It is usually oil impregnated (i.e. bitumen), and varies in hardness from friable (as in the pedon described below) to nearly impenetrable by shovel or hand-auger. Fracturing and coarse fragment characteristics also vary with degree of hardness.
- A detailed pedon description and samples for analytical characterization were not obtained for DAN series. Instead, a brief description from an inspection site is provided (Table A-8).

Table A-8. Brief description of an inspection pedon (GW004) representing DAN series.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
LF	15-0	Litter	--	--	--
Ahe	0-3	Fine sandy loam, stony	10YR2/1m	Granular	Friable
Bm	3-26	Sandy loam, stony	10YR3/6m	Granular	Friable
BC	26-30	Silty clay loam, stony	10YR4/4m	Granular	Friable
IIBC	30-100	Soft rock, SL, bituminous	10YR2/1m	--	Friable

DOV – Dover Series

DOV series is one of the most common soils of the area. It is classified as Orthic Gray Luvisol and is developed on clayey glacial deposits. DOV usually occurs in association with Steen (SEN), Kilome (KME), or Livock (LVK) soils on the drier upland portions of the SSA. DOV series is described below and in Table A-9 and

Soil Classification (Subgroup):	Orthic Gray Luvisol
Parent Material; Grouping:	Clayey, calcareous lacustro-till (or till); F3 (or F4)
Drainage:	Moderately well to well
Soil Moisture Regime:	Mesic (5)

Texture:	L-SL-SiL topsoil / C subsoil
Profile Coarse Fragments:	Typically 1-5% by volume, occasionally higher in some layers
Surface Organic Material:	Mainly forest litter (LFH); averaged 6 cm thickness in area
Topsoil Thickness:	Averaged 16 cm in area – A horizon (mainly Ae) plus AB transition
Soil Capability Rating (Forestry):	65 index points; Class 2R
Soil Sensitivity to Acid Deposition:	Medium

Comments on DOV series:

- DOV series is the most common soil type in the SSA, accounting for about 15% of all inspection sites. Rarely occurring DOV variants include Dark Gray Luvisol (DOVzh), Dystric Brunisols or Brunisolic Gray Luvisol (DOVzb), and Orthic Regosol (DOVzr).
- Parent materials of DOV soils are clayey lacustro-till (F3) and till (F4). The two materials are similar, with the lacustro-till being somewhat more stratified and containing "grayish pink" till-like layers.
- Topsoil thickness does not include the organic layer (LF or LFH) above it; leaf litter is present at all sites.
- Color transition from topsoil to upper subsoil is moderate. Transitional horizons – an AB or BA (as in the sampled profile) – are common in DOV soils. They have structural peds with brownish inped colors like the Bt below and exped colors similar to the Ae above it. Carbonates are usually found below 60 to 70 cm.
- Soil structure below the B horizon is often weak and tends to be interpreted as massive when seen in hand-auger samples. High clay content in BC and C horizons contributes to relatively tough consistence (firm) in these horizons.

A sampled DOV pedon is described in Table A-9; selected chemical and physical data for this pedon are listed in

Table A-9. Description of a pedon (BW106P) representing DOV series.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
LF	5-0	Litter	10YR2/1m	--	
Ae1	0-6	Fine sandy loam	10YR5.5/2m	Weak, medium to coarse, platy	Very friable
Ae2	6-15	Fine sandy loam	10YR5/3m	Weak to moderate, medium to coarse, platy	Very friable
BA	15-25	Clay	7.5YR4/4m & 10YR6/3m	Weak, medium, columnar breaking to strong, medium to coarse, subangular blocky	Firm
Bt1	25-35	Clay	7.5YR4/4m	Strong, very fine to fine, subangular blocky	Firm
Bt2	35-55	Clay	7.5YR3/3m	Strong, very fine, subangular blocky	Friable
Ck1	55-65	Clay loam to sandy clay loam	10YR5/3d	Weak, fine to medium, subangular blocky	Slightly hard
Ck2	65-100	Clay to silty clay	7.5YR4/4d	Weak, fine, platy breaking to weak, fine, subangular blocky	Slightly hard

Table A-10. Selected chemical and physical properties of the DOV pedon (BW106P)

Horizon	Depth (cm)	pH	EC	OC	$CaCO_3$ Equiv.	TN	PSA (%)			Texture Class	CEC	BS %	SAR
							Sand	Silt	Clay				
LF	5-0	5.9	--	35.8	--	1.45	--	--	--	--	59.1	119	--
Ae1	0-6	4.2	0.6	0.5	--	0.04	46	46	8	L	2.8	79	0.4
Ae2	6-15	4.5	0.3	0.3	--	0.02	43	44	13	L	2.9	66	0.2
BA	15-25	4.5	0.1	0.4	--	0.05	32	33	35	CL	12.8	77	0.2
Bt1	25-35	5.0	0.1	0.3	--	0.04	29	27	44	C	18.6	98	0.4
Bt2	35-55	6.0	0.2	0.3	--	0.04	22	26	52	C	18.5	111	0.4
Ck1	55-65	7.7	0.4	--	8.0	--	35	35	30	CL	--	--	0.5
Ck2	65-100	7.9	0.3	--	8.1	--	25	30	45	C	--	--	0.9

pH – measured in $CaCl_2$ solution EC – electrical conductivity (dS/m) OC – total organic carbon (%)
CaCO3 Equiv. – calcium carbonate equivalent (%) TN – total nitrogen (%), Kjeldahl method
PSA – particle size analysis (% sand, silt, and clay separates) by the hydrometer method, with texture class
CEC – cation exchange capacity (meq/100g) BS % – base saturation percentage SAR – sodium adsorption ratio

Comments on the DOV pedon:

- Colors are specific Munsell soil color chart notations indicating hue (e.g. 10YR), value (e.g. 2/), chroma (e.g. /1), and whether taken for moist (m) or dry (d) soil.
- Roots were observed throughout the entire profile – abundant, fine to coarse in the upper profile; few, fine to medium in the Ck horizons.
- Very fine to micro sized pores were observed throughout the profile.
- Clay skins were observed in both Bt horizons – continuous, thin clay skins in the Bt1; continuous, moderately thick clay skins in the Bt2.
- Dark brown to reddish brown colors, as recorded for the Bt and Ck2 horizons, represent the so-called "grayish pink" layers commonly found in the clayey till/lacustro-till materials of the area.

FRT – Fort Series and Variants

FRT series represents a group of closely related, upland, soil types developed on medium or moderately fine textured overlying coarse textured, water-laid sediments (L18), mainly in the Joslyn Plain and Athabasca-Ells Valley land systems. The related types include Orthic Gray Luvisol (FRT series) and Eluviated Dystric Brunisol (FRTzb variant). The two types are similar, differing only in degree of B horizon development with FRT having a clay-enriched Bt horizon and FRTzb a more weakly developed Btj or Bm horizon. FRT series is described below and in Table A-11.

Soil Classification (Subgroup):	Orthic Gray Luvisol
Parent Material; Grouping:	Medium to moderately fine textured overlying coarse textured, water-laid materials; L18
Drainage:	Well to rapid
Soil Moisture Regime:	Mesic (5) to submesic (4)
Texture:	SiL-FSL-L topsoil / CL-SCL upper subsoil / LS-S-SL lower subsoil
Profile Coarse Fragments:	Typically <2% by volume, occasionally higher in some layers
Surface Organic Material:	Mainly forest litter (LFH); averaged 6 cm thickness in area
Topsoil Thickness:	Averaged 26 cm in area – A horizon (mainly Ae) plus AB transition
Soil Capability Rating (Forestry):	73 index points; Class 2R
Soil Sensitivity to Acid Deposition:	Medium

Common Fort variants found in the SSA:

Fort-brunisolic (FRTzb) – similar to FRT but classified as Eluviated Dystric Brunisol rather than Orthic Gray Luvisol. The main difference is in the degree of pedogenic clay enrichment in the B

horizon. FRT has a reasonably well developed Bt (clay-enriched) horizon; FRTzb has Btj or Bm horizons in which morphological evidence of illuviation is weakly expressed (i.e. poorly developed clay films or lamellae). For assessing soil capability, acid sensitivity, and reclamation suitability, the differences between FRT and FRTzb were considered negligible.

Fort-paralithic/lithic (FRTxl) – similar to FRT series or FRTzb variant but with variable soft (paralithic) to hard (lithic) bedrock occurring within 100 cm of the mineral soil surface. FRTxl soils occur mainly on the eastern edge of the SSA, frequently in association with DAN and other lithic soils. The bedrock, which is partially weathered, bituminous sandstone and siltstone of the McMurray Formation (Hamilton et al. 1999), usually occurs in the lower subsoil (between 50 and 100 cm) of FRTxl soils.

Comments on FRT series and variants:

- FRT series and FRTzb variant were by far the most common soils of the FRT group, which together accounted for roughly 2% of all inspection sites. A Gleyed Gray Luvisol variant (FRTgl) was also encountered on occasion.
- Layered soils such as FRT require 30 to 99 cm of parent material I overlying parent material II. In this case, parent material I is medium to moderately fine textured, water-laid (glaciofluvial or glaciolacustrine) material; parent material II is coarse textured glaciofluvial sediments. Parent material grouping for this combination is L18. Contact between the two parent materials averaged just over 50 cm in the SSA. The upper material is like that which characterizes the Peavine (PEA) series; the lower material is the same as occurs in Mildred (MIL) soils.
- Topsoil thickness does not include the organic layer (LF or LFH) above it; leaf litter is present at all sites.
- A detailed pedon description and samples for analytical characterization were not obtained for the FRT series. Instead, a brief description of an FRT profile from an inspection site is provided (Table A-11). Analytical data for FRT series is available in the Alberta Soil Layers File (AG30SLF, ASIC 2001).

Table A-11. Brief description of an inspection pedon (GW089) representing FRT series.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
LF	8-0	Litter	--	--	--
Aej	0-6	Silt loam	--	Granular	Friable
AB	6-22	Silty clay loam	--	Granular	Friable
Bt	22-45	Sandy clay	--	Subangular blocky	Firm
IIBm1	45-70	Sand	--	Single grain	Loose
IIBm2	70-125	Sand	--	Single grain	Loose

KME – Kilome Series

KME series is an imperfectly drained Luvisolic soil commonly found in association with Dover (DOV) and Livock-gleyed (LVKgl) variant on "upland" areas in the SSA. KME series is described below and in Table A-12 and Table A-13.

Soil Classification (Subgroup):	Gleyed Gray Luvisol
Parent Material; Grouping:	Clayey, calcareous lacustro-till (or till); F3 (or F4)
Drainage:	Imperfect
Soil Moisture Regime:	Subhygric (6)
Texture:	L-SL-SiL topsoil / C subsoil
Profile Coarse Fragments:	Typically 1-5% by volume, occasionally higher in some layers

Surface Organic Material:	Mainly forest litter (LFH); averaged 7 cm thickness in area
Topsoil Thickness:	Averaged 18 cm in area – A horizon (mainly Ae) plus AB transition
Soil Capability Rating (Forestry):	86 index points; Class 1
Soil Sensitivity to Acid Deposition:	Medium

Comments on KME series:

- KME series is one of the more common soil types in the SSA, accounting for 10% of all inspection sites.
- Parent materials of KME soils are clayey lacustro-till (F3) and till (F4). The two materials are similar, with the lacustro-till being somewhat more stratified and containing "grayish pink" till-like layers.
- Upper and mid solum horizons are often affected by seepage waters perched on somewhat impervious underlying fine textured materials, a fairly common occurrence in KME and LVKgl soils.
- Topsoil thickness does not include the organic layer (LF or LFH) above it; leaf litter is present at all sites.
- Color transition from topsoil to upper subsoil is moderate. Transitional horizons – an AB or BA (as in the sampled profile) – are common in KME soils. They have structural peds with brownish inped colors like the Bt below and exped colors similar to the Ae above.
- 2003 field data was reassessed in light of 2004 findings. Transitional AB horizons found in most of these soils are now considered part of topsoil; carbonates were often found at depths below 70 or 80 cm. KME soils were reclassified from Kinosis-GL (glKNS) based on the characteristics of the parent material (clayey and calcareous).
- Soil structure below the B horizon is often weak and tends to be interpreted as massive when seen in hand-auger samples. High clay content in BC and C horizons contributes to relatively tough consistence (firm) in these horizons.
- A sampled KME pedon is described in Table A-12, selected chemical and physical data in Table A-13.

Table A-12. Description of a pedon (BW094P) representing KME series.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
LF	6-0	Litter	10YR2/2m	--	--
Ae	0-13	Fine sandy loam	10YR6/2m	Weak to moderate, coarse, platy	Very friable
Aeg	13-20	Sandy loam	10YR6/2m	Weak, coarse, platy	Very friable
BAgj	20-37	Silty clay	10YR5/3d & 10YR6/2d	Strong, fine to medium, subangular blocky	Friable
Btgj	37-50	Clay	5YR4/4d	Weak, medium, prismatic breaking to strong, medium to coarse, blocky	Slightly hard
Bt	50-65	Clay	10YR3/2d	Moderate, medium, prismatic breaking to strong, medium to coarse, blocky	Slightly hard
BC	65-100	Clay	5YR4/3d	Moderate, medium, prismatic breaking to strong, medium to coarse, blocky	Hard

Table A-13. Selected chemical and physical properties of the KME pedon (BW094P).

Horizon	Depth (cm)	pH	EC	OC	$CaCO_3$ Equiv.	TN	PSA (%)			Texture Class	CEC	BS %	SAR
							Sand	Silt	Clay				
LF	6-0	4.3	--	40.4	--	0.93	--	--	--	--	15.4	260	--
Ae	0-13	4.4	0.3	0.4	--	0.03	45	45	10	L	3.0	57	0.2
Aeg	13-20	4.9	0.2	0.1	--	<0.02	59	32	9	SL	2.7	81	0.1
BAgj	20-37	4.9	0.1	0.4	--	0.03	27	31	42	C	15.2	89	0.2
Btgj	37-50	4.9	0.1	0.3	--	0.03	15	25	60	C	20.7	90	0.4
Bt	50-65	4.8	0.1	0.4	--	0.03	24	27	49	C	21.1	89	0.5
BC	65-100	5.2	0.2	--	--	--	8	22	70	HC	--	--	0.6

pH – measured in $CaCl_2$ solution EC – electrical conductivity (dS/m) OC – total organic carbon (%)
CaCO3 Equiv. – calcium carbonate equivalent (%) TN – total nitrogen (%), Kjeldahl method
PSA – particle size analysis (% sand, silt, and clay separates) by the hydrometer method, with texture class
CEC – cation exchange capacity (meq/100g) BS % – base saturation percentage SAR – sodium adsorption ratio

Comments on the KME pedon:

- Colors are specific Munsell soil color chart notations indicating hue (e.g. 10YR), value (e.g. 2/), chroma (e.g. /1), and whether taken for moist (m) or dry (d) soil.
- Roots were observed in all but the BC horizon – plentiful, fine to coarse in the upper profile; few, fine in the Bt horizon.
- Very fine to micro sized pores were observed throughout the profile.
- Clay skins were observed in several horizons – many thin in BAgj, continuous thin in Btgj, continuous thin in Bt, many moderately thick in BC.
- Reddish brown color, as recorded for the BC horizon, represents the so-called "grayish pink" layers commonly found in the clayey till/lacustro-till materials of the area.
- As in most KME soils, upper and mid solum horizons of the pedon were affected by seepage waters perched on the underlying fine textured materials. Prominent mottles were recorded for the Aeg, distinct mottles in the BAgj, and faint mottles in the Btgj.
- This profile has a distinctive glaciofluvial or fluvial veneer 20 cm thick (Ae and Aeg horizons). The Livock-gleyed (LVKgl) soil variant is closely related in that it has 30-99 cm of glaciofluvial or other medium textured veneer overlying the finer textured till/lacustro-till.

LVKxc – Livock-clayey subsoil Variant

LVKxc variant represents Orthic Gray Luvisols that have developed in layered materials, namely medium textured, water-laid sediments overlying lacustro-till (or fine textured till). It is commonly found in association with Dover (DOV), Fort (FRT), and Peavine (PEA) soils on upland areas in the SSA. A closely related variant, classified as Gleyed Gray Luvisol (LVKgl), is also a common soil of the SSA, often in association with Kilome (KME) soils under subhygric conditions. LVKxc variant is described below and in Table A-14 and Table A-15; LVKgl is briefly described in Table A-16.

Soil Classification (Subgroup):	Orthic Gray Luvisol
Parent Material; Grouping:	Medium textured, water-laid material overlying calcareous, fine to moderately-fine textured, lacustro-till or till; L10
Drainage:	Well to moderately well
Soil Moisture Regime:	Mesic (5)
Texture:	L-SL-SiL topsoil / L-CL-SCL upper subsoil / C lower subsoil
Profile Coarse Fragments:	Typically 1-5% by volume in parent material II (till-like)
Surface Organic Material:	Mainly forest litter (LFH); averaged 6 cm thickness in area
Topsoil Thickness:	Averaged 20 cm in area – A horizon (mainly Ae) plus AB transition
Soil Capability Rating (Forestry):	69 index points; Class 2R

Soil Sensitivity to Acid Deposition: Medium

Other common Livock variants found in the SSA:

Livock-gleyed (LVKgl) – similar to LVKxc in terms of parent material and related features, but is imperfectly drained and classified as Gleyed Gray Luvisol. LVKgl is one of the more common soil types of the SSA, and is similar to and often found in association with Kilome (KME) in subhygric (6) "upland" areas. Because of this optimum moisture regime, LVKgl was assessed 91 index points (Class 1) for soil capability for forestry. For other assessments, LVKgl was rated the same as LVKxc.

Comments on LVKxc and LVKgl variants:

- LVKgl and LVKxc variants are amongst the most common soil types in the SSA, together accounting for nearly 10% of all inspection sites. LVKgl tends to be more common than LVKxc. Less commonly occurring LVK variants include Orthic Regosol (LVKzr) and Eluviated Dystric Brunisol or Brunisolic Gray Luvisol (LVKzb).
- LVKxc variant is closely related to the LVK series – an Orthic Gray Luvisol developed on L3 parent material (medium textured, water-laid material overlying medium to moderately fine textured till). LVK series soils are not common in the survey area.
- Layered soils such as LVKxc and LVKgl require 30 to 99 cm of parent material I overlying parent material II. In these soils, parent material I is medium to moderately fine textured, water-laid (glaciofluvial or glaciolacustrine) material; parent material II is fine textured lacustro-till or till. Parent material grouping for this combination is L10. The upper material is like that which characterizes the Peavine (PEA) series; the lower material is the same as occurs in Dover (DOV) and Kilome (KME) soils.
- Topsoil thickness does not include the organic layer (LF or LFH) above it; leaf litter is present at all sites.
- 2003 field data was reassessed in light of 2004 findings. Transitional AB horizons found in most of these soils are now considered part of topsoil; carbonates were often found at depths below 60 to 80 cm.
- Color transition from topsoil to upper subsoil is good to moderate. Transitional horizons – an AB, ABgj BA, or BAgj – are common in LVKxc and LVKgl soils. They have structural peds with brownish inped colors like the Bt below and exped colors similar to the Ae above.
- Soil structure below the B horizon is often weak and tends to be interpreted as massive when seen in hand-auger samples. High clay content in IIBC and IIC horizons contributes to relatively tough consistence (firm) in these horizons.
- Mottling tends to be moderate (distinct to faint mottles) in the upper profiles of LVKgl soils.
- A sampled LVKxc pedon is described in Table A-14, selected chemical and physical data in Table A-15.
- A detailed pedon description and samples for analytical characterization were not obtained for LVKgl. Instead, a brief description from an inspection site is provided (Table A-16).

Table A-14. Description of a pedon (BW110P) representing LVKxc variant.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
LF	4-0	Litter	10YR2/1m	--	--
Ae	0-6	Sandy loam	10YR6/2m	Moderate, fine to medium, platy	Very friable
Aeu	6-20	Loam to sandy clay loam	10YR5/3m & 7.5YR5/4m	Weak, fine, platy	Very friable

Table A-14. Description of a pedon (BW110P) representing LVKxc variant.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
AB1	20-28	Sandy clay	10YR6/3m & 7.5YR5/4m	Moderate to strong, fine to medium, subangular blocky	Firm
AB2	28-38	Loamy sand	10YR6/3m & 7.5YR5/3m	Single grain	Loose
Bt	38-50	Clay loam	7.5YR4/6m	Weak, medium, prismatic breaking to strong, fine to medium, subangular blocky	Friable
IIBt	50-65	Clay	7.5YR4/4m	Moderate to strong, very fine, subangular blocky	Friable
IICk1	65-90	Clay to heavy clay	7.5YR5/2m	Weak to moderate, fine to medium, subangular blocky	Very firm
IICk2	90-105	Clay	10YR3/4m	Weak, fine to medium, subangular blocky	Firm

Comments on the LVKxc pedon:

- Colors are specific Munsell soil color chart notations indicating hue (e.g. 10YR), value (e.g. 2/), chroma (e.g. /1), and whether taken for moist (m) or dry (d) soil.
- The Aeu, and to a lesser extend AB horizons, consist of mixed materials (evidenced by color streaks and swirls), likely the remnant effects of disruption by tree-throw. Such physical disturbances were found in many of the soils of the area.
- Roots were observed throughout the entire profile – abundant, fine to coarse in the upper profile; very few, very fine in the Ck horizons.
- Very fine to micro sized pores were observed throughout the profile.
- Clay skins were observed in both B horizons – many thin in Bt, continuous thin in IIBt.
- Brown to reddish brown colors, as recorded for the IIBt and IICk1 horizon, represents the so-called "grayish pink" layers commonly found in the clayey till/lacustro-till materials of the area. Material like that in IICk1 was encountered below 105 cm.
- This profile has a distinctive glaciofluvial veneer approximately 50 cm thick that is somewhat coarser textured than typical of LVK and LVKxc soils. The Bt horizon is actually a transitional layer between the glaciofluvial overlay and the underlying glacial till/lacustro-till.

Table A-15. Selected chemical and physical properties of the LVK pedon (BW110P).

Horizon	Depth (cm)	pH	EC	OC	$CaCO_3$ Equiv.	TN	PSA (%)			Texture Class	CEC	BS %	SAR
							Sand	Silt	Clay				
LF	4-0	6.2	--	21.2	--	0.76	--	--	--	--	32.7	109	--
Ae	0-6	6.0	0.5	0.8	--	0.04	--	--	--	--	4.3	177	0.3
Aeu	6-20	4.4	0.1	0.2	--	<0.02	66	25	9	SL	3.2	50	0.2
AB1	20-28	4.7	0.2	0.3	--	0.03	54	24	22	SCL	9.1	69	0.3
AB2	28-38	4.9	0.2	0.1	--	<0.02	81	10	9	LS	3.8	79	0.9
Bt	38-50	5.5	0.1	0.2	--	<0.02	59	18	23	SCL	11.0	100	0.9
IIBt	50-65	6.3	0.3	0.4	--	0.03	30	21	49	C	17.3	112	1.3
IICk1	65-90	7.8	0.3	--	7.2	--	27	22	51	C	--	--	2.3
IICk2	90-105	7.9	0.4	--	12.8	--	42	26	32	CL	--	--	3.2

pH – measured in $CaCl_2$ solution EC – electrical conductivity (dS/m) OC – total organic carbon (%)
CaCO3 Equiv. – calcium carbonate equivalent (%) TN – total nitrogen (%), Kjeldahl method
PSA – particle size analysis (% sand, silt, and clay separates) by the hydrometer method, with texture class
CEC – cation exchange capacity (meq/100g) BS % – base saturation percentage SAR – sodium adsorption ratio

Table A-16. Brief description of an inspection pedon (BW028) representing LVKgl variant.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
LFH	6-0	Litter	--	--	--
Aegj	0-12	Loam	Pale brown	Weak subangular blocky	Very friable
ABgj	12-20	Loam	--	Weak subangular blocky	Very friable
Btgj	20-40	Clay loam	Dark yellowish brown	Weak subangular blocky	Friable
IIBtgj	40-70	Clay	--	Weak subangular blocky	Firm
IICk1	70-85	Clay	Reddish brown	--	Firm
IICk2	85-95	Clay to clay loam	Dark grayish brown	--	Friable

MIL – Mildred Series and Variants

MIL series represents a complex of closely related Dystric Brunisols that have developed on very coarse textured, glaciofluvial (outwash sand) deposits. Major related soil types include Eluviated Dystric Brunisol (MIL series), a variant in which outwash sands are shallow and overlie clayey material (MILxc), and a coarse textured (sandy loam) variant (MILfi). MIL soils are a defining feature of the Joslyn Plain Land System, the area in which they are prevalent. MIL series is described below, and in Table A-17 and Table A-18.

Soil Classification (Subgroup):	Eluviated Dystric Brunisol
Parent Material; Grouping:	Very coarse textured, glaciofluvial sediments (outwash sands); C2
Drainage:	Rapid
Soil Moisture Regime:	Subxeric (3) to submesic (4)
Texture:	S topsoil / S upper subsoil / S lower subsoil (LS textures also occur)
Profile Coarse Fragments:	Typically 1-10% by volume throughout (generally small gravel)
Surface Organic Material:	Mainly forest litter (LFH); averaged 7 cm thickness in area
Topsoil Thickness:	Averaged 22 cm in area – A horizon (mainly Ae) plus AB transition
Soil Capability Rating (Forestry):	26 index points; Class 4MK
Soil Sensitivity to Acid Deposition:	High

Common Mildred variants found in the SSA:

Mildred-clayey subsoil (MILxc) – similar to MIL except that MILxc is developed on L9 layered parent material – shallow (30-99 cm thick) outwash sands overlying clayey lacustro-till (or till). Average contact depth between upper and lower parent materials is 60-65 cm. A similar variant (MILxm), developed on L20 layered deposits where the underlying material is medium to moderately fine textured, was found on occasion.

Mildred-fine (MILfi) – similar to MIL series but developed in slightly finer materials. Parent material of MILfi variant was labelled as coarse textured (mainly sandy loam), glaciofluvial material, and grouping C3. In reality, most soils tagged as MILfi variant had stratified profiles with alternating coarse (SL-SiS), very coarse (S-LS), and medium-fine (SiL-L-SCL-SC-C) layers. Such stratification is common in geomorphic environments associated with deposition by running water.

Comments on MIL series and variants:

- MIL series is by far the most common member of its group, and accounted for about 5% of all inspection sites in the SSA. MILxc and MILfi were far less common in terms of inspection site numbers. Infrequently occurring MIL variants included Orthic Dystric Brunisol (MILzo), Gleyed

Eluviated Dystric Brunisol (MILgl), Orthic Gray Luvisol (MILzl), paralithic/lithic variant (MILxl), and one developed on L20 parent material (MILxm).

- Topsoil thickness does not include the organic layer (LF or LFH) above it; leaf litter is present at all sites.
- Color transition from topsoil to upper subsoil is good to moderate. Transitional horizons – an AB (as in the pedon) or BA – are common in MIL soils.
- The parent material of MIL soil is typified by sandy glaciofluvial material (S-LS outwash), group C2. This material is non-calcareous and acidic. Carbonates were not found in any profile. Black, weathered, sandstone fragments impregnated with bitumen are common in MIL soils.
- A sampled MIL pedon is described in Table A-17, selected chemical and physical data in Table A-20.

Table A-17. Description of a pedon (BW102P) representing MIL series.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
LF	6-0	Litter	10YR2/1m	--	--
Ae	0-10	Sand	10YR5/3m	Single grain	Loose
AB	10-18	Sand	7.5YR5/4m	Single grain	Loose
Bm1	18-40	Sand	5YR4/8m	Single grain	Loose
Bm2	40-70	Sand	7.5YR4/6m	Single grain	Loose
Bm3	70-90	Sand	10YR4/6m	Single grain	Loose
BC	90-110	Sand	10YR5/6m	Single grain	Loose

Table A-18. Selected chemical and physical properties of the MIL pedon (BW102P).

Horizon	Depth (cm)	pH	EC	OC	$CaCO_3$ Equiv.	TN	PSA (%)			Texture Class	CEC	BS %	SAR
							Sand	Silt	Clay				
LF	6-0	3.5	--	43.7	--	1.01	--	--	--	--	60.3	42	--
Ae	0-10	4.7	--	0.5	--	<0.02	96	1	3	S	0.5	180	--
AB	10-18	4.2	--	0.2	--	<0.02	96	1	3	S	0.9	133	--
Bm1	18-40	4.5	--	<0.1	--	<0.02	96	1	3	S	0.6	233	--
Bm2	40-70	5.0	--	<0.1	--	<0.02	98	0	2	S	0.4	225	--
Bm3	70-90	5.2	--	--	--	--	96	1	3	S	--	--	--
BC	90-110	5.3	--	--	--	--	95	1	4	S	--	--	--

pH – measured in $CaCl_2$ solution EC – electrical conductivity (dS/m) OC – total organic carbon (%)
CaCO3 Equiv. – calcium carbonate equivalent (%) TN – total nitrogen (%), Kjeldahl method
PSA – particle size analysis (% sand, silt, and clay separates) by the hydrometer method, with texture class
CEC – cation exchange capacity (meq/100g) BS % – base saturation percentage SAR – sodium adsorption ratio

Comments on the MIL pedon:

- Colors are specific Munsell soil color chart notations indicating hue (e.g. 10YR), value (e.g. 2/), chroma (e.g. /1), and whether taken for moist (m) or dry (d) soil.
- Roots were observed throughout the entire profile – abundant, fine to medium in the upper profile; very few, coarse in the bottom 2 horizons.
- Field pH was estimated at 5.5 in the upper Bm2 horizon.
- The BC horizon contained 20-25% by volume of black, weathered (soft), sandstone fragments impregnated with bitumen. Similar fragments were also observed higher in the profile, but at much lower proportions.

MLD – McLelland Series and Variants

MLD series represents a complex of related Organic soils found on fen-dominated wetlands in the survey area. Depth of peat, ranging from 40 to well over 200 cm, is the most important variable that defines entities in this complex. To facilitate the mapping system used in the area (Golder Associates 2002), peat depth was categorized as shallow (40-100 cm), moderately deep (100-200 cm), and deep (>200 cm). Soil subgroup also varied – Typic Mesisol, Fibric Mesisol, Terric Mesisol, Typic Fibrisol, Mesic Fibrisol, Terric Fibrisol, and a few others occur in the area, often in proximity to one another. A third factor defines, in broad textural groupings (coarse, medium, or fine), the type of mineral substrate beneath the shallower (<200 cm) peat deposits. Two pedons are described below – a Fibric Mesisol (MLDzz variant, Table A-19 and Table A-20) representing deeper peat soils, and a Terric Mesisol (MLD1m variant, Table A-21 and Table A-22) representing shallow peat soils.

Significant MLD series/variants found in the SSA:

McLelland series (MLD) – classified as Typic Mesisol in the Alberta Soil Names File (AG30SNF, ASIC 2001). Parent material is dominantly fen peat (P2) at least 100 cm thick for practical (mapping) purposes. [Technically for taxonomic purposes, peat depth should be 120 cm.] Several closely related soils differing mainly in subgroup classification (e.g. Fibric Mesisol, Typic Fibrisol, and Mesic Fibrisol) were found in the SSA. An example of these deeper fen peat soils, a Fibric Mesisol variant (MLDzz), is described below and in Table A-19 and Table A-20.

Shallow peat over clayey material variant (MLD1c) – classified as Terric Mesisol, Terric Fibric Mesisol, Terric Fibrisol, or Terric Mesic Fibrisol. Parent material is dominantly fen peat 40-100 cm thick (for practical mapping purposes) overlying clayey (C-SiC-HC) mineral materials.

Shallow peat over medium material variant (MLD1m) – classified as Terric Mesisol, Terric Fibric Mesisol, Terric Fibrisol, or Terric Mesic Fibrisol. Parent material is dominantly fen peat 40-100 cm thick (for practical mapping purposes) overlying medium to moderately fine textured (L-SCL-SiL-CL-SiCL) materials. An example of these shallow fen peat soils, a Terric Mesisol variant (MLD1m), is described below and in Table A-21 and Table A-22.

Shallow peat over sandy material variant (MLD1s) – classified as Terric Mesisol, Terric Fibric Mesisol, Terric Fibrisol, or Terric Mesic Fibrisol. Parent material is dominantly fen peat 40-100 cm thick (for practical mapping purposes) overlying coarse textured (S-LS-SL) materials.

MLDzz Variant (representing deeper fen peat)

Soil Classification (Subgroup):	Fibric Mesisol
Parent Material; Grouping:	Fen peat; P2
Drainage:	Poor to very poor
Soil Moisture Regime:	Subhydric (8) to hydric (9)
Texture:	Peat
Profile Coarse Fragments:	None (may be wood fragments in some peat horizons)
Surface Organic Material:	Mainly fen peat (Of and Om horizons) over 120 cm thick
Topsoil Thickness:	N/A
Soil Capability Rating (Forestry):	10 index points; Class 5OR
Soil Sensitivity to Acid Deposition:	Low

Table A-19. Description of a pedon (BW096P) representing MLDzz variant/series.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
Of1	0-40	Fibric peat	10YR4/3m	--	--
Om1	40-70	Mesic peat	10YR3/3m	--	--
Of2	70-100	Fibric peat	5YR3/3m	--	--
Om2	100-170	Mesic peat	10YR2/2m	--	--
W	170-220	Water	--	--	--

Table A-20. Selected chemical and physical properties of the MLDzz pedon (BW096P).

Horizon	Depth (cm)	pH	EC	OC	$CaCO_3$ Equiv.	TN	PSA (%)			Texture Class	CEC	BS %	SAR
							Sand	Silt	Clay				
Of1	0-40	4.6	--	21.1	--	0.72	--	--	--	--	53.1	117	--
Om1	40-70	3.2	--	44.6	--	0.93	--	--	--	--	130	29	--
Of2	70-100	3.1	--	46.3	--	0.81	--	--	--	--	138	25	--
Om2	100-170	3.6	--	48.2	--	1.63	--	--	--	--	239	23	--

pH – measured in $CaCl_2$ solution EC – electrical conductivity (dS/m) OC – total organic carbon (%)
CaCO3 Equiv. – calcium carbonate equivalent (%) TN – total nitrogen (%), Kjeldahl method
PSA – particle size analysis (% sand, silt, and clay separates) by the hydrometer method, with texture class
CEC – cation exchange capacity (meq/100g) BS % – base saturation percentage SAR – sodium adsorption ratio

Comments on MLDzz variant (sampled pedon) and MLD series:

- The MLDzz pedon represents numerous closely related, deep, organic soil types found on fen-dominated wetlands in the survey area. Variability amongst these closely related soils centers on soil subgroup. Common soil subgroups are Typic Mesisol (McLelland series, ASIC 2001), Fibric Mesisol (sampled pedon), Typic Fibrisol, and Mesic Fibrisol. All reflect that fact peat types tend to be layered in these soils.
- The sampled MLDzz pedon also represents two soil complexes used in mapping soils of the SSA. The two complexes were created to conveniently indicate depth of surface organic materials. MLD2 has peat depths of 100-200 cm; MLD3 has peat depths greater than 200 cm.
- MLD2 is further defined by adding a "c", "m", or "s". The "m" (MLD2m soil unit as in the sampled pedon) indicates a mineral substrate with predominantly medium texture (loam, silt loam, silty clay loam, clay loam, etc.). Related soil complexes have clayey (MLD2c) and sandy (MLD2s) mineral substrates beneath the peat. The sampled pedon was unusual in that the peat material was "floating" on water (below the control section). The pedon was located in a substantially widened portion of a stream channel, an area that likely once contained a large water body due to downstream damming, and that has become in-filled with organic materials.
- Current vegetation is fen, and fen peat dominates the surface organic materials of these soils. Other types of peat (bog peat, organic material high in wood fragments) may occur deeper in the soil profile.
- Color transition from topsoil (surface organic layers) to subsoil (deeper organic layers) is poor.
- Colors are specific Munsell soil color chart notations indicating hue (e.g. 10YR), value (e.g. 2/), chroma (e.g. /1), and whether taken for moist (m) or dry (d) soil.
- Most fen peats tend to be neutral although in some situations acidic pHs may be encountered (Turchenek and Lindsay 1982b). However, in the sampled MLD pedon, pH values are exceptionally low, especially for the deeper horizons. This may be a reflection of the water-logged environment in which the soil was found.

- The Of1 horizon of the sampled pedon was essentially a raw, sedge-sphagnum, root mat with minimal decomposition.

MLD1m Variant (representing shallow fen peat)

Soil Classification (Subgroup):	Terric Mesisol
Parent Material; Grouping:	Fen peat overlying medium textured materials; L12
Drainage:	Poor to very poor
Soil Moisture Regime:	Subhydric (8) to hydric (9)
Texture:	Peat (40-100 cm) / clayey (C-SiC) material
Profile Coarse Fragments:	Occasional wood fragments in peat / 1-5% in mineral layers
Surface Organic Material:	Mainly fen peat (Of and Om horizons) between 40 and 120 cm thick
Topsoil Thickness:	N/A
Soil Capability Rating (Forestry):	10 index points; Class 5OR
Soil Sensitivity to Acid Deposition:	Low

Table A-21. Description of a pedon (BW103P) representing MLD1m variant.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
Om	0-60	Mesic peat	10YR2/1m	--	--
Oh	60-75	Humic peat	10YR2/1m	--	--
BCg	75-100	Sandy clay loam	5Y4/2m	Massive	Slightly sticky, slightly plastic

Table A-22. Selected chemical and physical properties of the MLD1m pedon (BW103P).

Horizon	Depth (cm)	pH	EC	OC	$CaCO_3$ Equiv.	TN	PSA (%)			Texture Class	CEC	BS %	SAR
							Sand	Silt	Clay				
Om	0-60	6.9	--	40.6	--	1.89	--	--	--	--	162	117	--
Oh	60-75	6.3	--	40.3	--	1.95	--	--	--	--	167	114	--
BCg	75-100	6.9	0.3	--	--	--	46	35	19	L	--	--	0.6

pH – measured in $CaCl_2$ solution EC – electrical conductivity (dS/m) OC – total organic carbon (%)
CaCO3 Equiv. – calcium carbonate equivalent (%) TN – total nitrogen (%), Kjeldahl method
PSA – particle size analysis (% sand, silt, and clay separates) by the hydrometer method, with texture class
CEC – cation exchange capacity (meq/100g) BS % – base saturation percentage SAR – sodium adsorption ratio

Comments on the MLD1m pedon and related series/variants:

- MLD1m pedon represents numerous, closely related, shallow, organic soil types (MLD1m soil complex) found on unconfined, fen-dominated wetlands in the survey area. With peat thickness (40-100 cm) and mineral parent materials (medium textured) fixed, variability centers on soil subgroup. Common soil subgroups in the complex are Terric Mesisol (sampled pedon), Terric Fibric Mesisol, Terric Fibrisol (HLY series), and Terric Mesic Fibrisol.
- MLD1m complex includes Hartley (HLY) series, listed as a Terric Fibrisol in the Alberta Soil Names File (AG30SNF, ASIC 2001).
- Related soil complexes have clayey (MLD1c) and sandy (MLD1s) mineral substrates beneath the peat.
- Current vegetation is fen, and fen peat dominates the surface organic materials of these soils.
- To facilitate mapping and conveniently indicate depth of surface organic materials, peat depth in the MLD1*x* soil complex was restricted to 40-100 cm. Technically, similar soils with peat depths of 100-120 cm also fit the "Terric" subgroups (SCWG 1998).

- For rating purposes, the surface (0-20 cm) organic material was considered to be "topsoil". However, material depth calculations include the peat with "surface organic materials" rather than topsoil.
- Color and texture transition from topsoil (surface organic layers) to upper subsoil (deeper organic layers) is usually poor; transition from upper subsoil (organic material) to lower subsoil (mineral material) is good. In the sampled pedon, the transition from Oh to BCg horizon included thin (1 to 2 cm), discontinuous Ahg and ABg horizons. The ABg showed hints of eluviation and inclusion of humic material in places.
- Colors are specific Munsell soil color chart notations indicating hue (e.g. 10YR), value (e.g. 2/), chroma (e.g. /1), and whether taken for moist (m) or dry (d) soil.
- The Om horizon in the sampled pedon included a thin Of root mat layer at the ground surface.
- The BCg horizon was somewhat stratified and included thin, discontinuous, sandy layers.
- Roots were observed throughout the entire profile – abundant, fine to coarse in the Om; few, fine in the BCg horizon.
- The sampled pedon was very wet (apparent water table at 20 cm); samples of deeper horizons were collected using a hand auger.
- Mineral materials tend to be dull coloured (dark gray to gray, sometimes olive gray), and may also have faint to distinct mottles. Dull soil colors in conjunction with high water tables and subhydric or hydric vegetation indicate extensive periods of water logging during the year. Mottling indicates that there are drier periods with some aeration of the soil material. Prominent mottles were observed in the sampled pedon.

MMW – Mamawi Series and Variants

MMW series represents a large complex of related Gleysolic soil types found on confined floodplains of several streams, and occasionally on other types of wetlands in the survey area. The related types occurring on deep, medium textured (M3) deposits include non-peaty Rego Gleysol (MMW series), peaty Rego Gleysols (MMWpt, sampled pedon), peaty and non-peaty Orthic Gleysols (MMWzopt and MMWzo), and peaty Orthic Luvic Gleysols (MMWzlpt). Similar subgroup and peaty vs. non-peaty groupings occur on shallow medium textured deposits overlying clayey materials (L3, L10). MMW series is described below; a pedon representing MMWpt variant is presented in Table A-23 and Table A-24.

Soil Classification (Subgroup):	Rego Gleysol (non-peaty)
Parent Material; Grouping:	Moderately-fine textured, mainly water-laid deposits; M3
Drainage:	Poor or very poor
Soil Moisture Regime:	Hygric (7) to subhydric (8)
Texture:	Loamy (SiCL-CL-SCL) water-laid materials
Profile Coarse Fragments:	Usually none
Surface Organic Material:	Mainly fen peat; 5 cm average for non-peaty soils, 26 cm in peaty versions
Topsoil Thickness:	Highly variable; averaged 15 cm in non-peaty soils, 9 cm in peaty versions
Soil Capability Rating (Forestry):	Index points –36 non-peaty, 33 peaty; Class 4R for both
Soil Sensitivity to Acid Deposition:	Low

Common Mamawi variants found in the SSA:

MMW series represents numerous closely related soil types (MMW soil complex). MMW soil complex consists of about 10 common series/variant entities, including MMW series and MMWpt variant (sampled pedon). This variability recognizes three main factors:

- Subgroup – Rego Gleysols, Orthic Gleysols, and Orthic Luvic Gleysols occur frequently in these wetlands. Rego Humic and Orthic Humic Gleysols may also occur occasionally.
- Peaty vs. non-peaty – Any of the soil subgroups in this complex can have peaty (15-40 cm) or non-peaty (less than 15 cm) surface layers.
- Parent materials – Two dominant types (groups) of parent materials occur. MMW series and the sampled pedon (MMWpt) occur on M3 (moderately fine textured) water-laid materials. Layered materials (L10) with medium textured sediments overlying clayey, water-laid or glacial (lacustro-till) materials are also common.

Mamawi-peaty (MMWpt) – similar to MMW but has a peaty surface horizon ranging from 15-40 cm in thickness. Peat thickness averaged 26 cm in all peaty versions of MMW soils.

Mamawi-orthic (MMWzo) – Orthic Gleysol variant of MMW; characterized by the occurrence of a developed B (i.e. Bg horizon). Both non-peaty (MMWzo) and peaty versions (MMWzopt) occur in the SSA.

Mamawi-luvic (MMWzl) – Orthic Luvic Gleysol variant of MMW – defined by having an illuvial Btg horizon. Both non-peaty (MMWzl) and peaty versions (MMWzlpt) were found in the SSA. MMWzlpt is similar to Algar Lake (ALG) series, which is developed on finer textured (clayey) glacial materials.

Mamawi-clayey subsoil (MMWxc) – similar to MMW except that MMWxc is developed on L10 layered parent material – shallow (30-99 cm thick) medium to moderately fine water-laid material overlying clayey, water-laid or glacial (lacustro-till) materials. Rego Gleysols (MMWxc), Orthic Gleysols (MMWzoxc), and Orthic Luvic Gleysols (MMWzlxc), in both non-peaty and peaty phases, were found the SSA.

Comments on MMW series and variants:

- Fen or occasionally bog peat up to 40 cm thick often mantles the mineral surface. Peat averages 25 cm (range 24-28) thickness in the peaty members of the complex, 5 cm thickness in the non-peaty members.
- Topsoil thickness was highly variable in the MMW soil complex, averaging 9 cm (peaty) & 16 cm (non-peaty), but ranging from 0 to 100 cm. Horizons included in topsoil thickness calculations were Ah/Ahg, ABg, ACg, and even BAg if there was no underlying B horizon. Upper subsoil (i.e. B horizon), absent in Rego Gleysols, averaged 25 to 35 cm in Orthic, Orthic Humic, and Orthic Luvic Gleysol groupings.
- A sampled MMWpt pedon is described in Table A-23, with chemical and physical data in Table A-24.

Table A-23. Description of a pedon (BW107P) representing MMWpt variant.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
Om	20-11	Mesic peat	10YR2/2m	--	--
Oh	11-0	Humic peat	10YR3/2m	--	--
ACg	0-10	Silty clay loam	10YR3/1m	Massive	Slightly sticky, plastic
Cg1	10-60	Silty clay loam	5YR4/2m	Massive	Slightly sticky, plastic
Cg2	60-90	Silt loam to silty clay loam	5Y5/2m	Massive	Slightly sticky, slightly plastic
Cg3	90-100	Sandy clay loam	5Y4/3m	Massive	Slightly sticky, slightly plastic

Table A-24. Selected chemical and physical properties of the MMWpt pedon (BW107P).

Horizon	Depth (cm)	pH	EC	OC	$CaCO_3$ Equiv.	TN	PSA (%)			Texture Class	CEC	BS %	SAR
							Sand	Silt	Clay				
Om	20-11	5.8	--	20.4	--	1.40	--	--	--	--	47.9	104	--
Oh	11-0	5.9	--	11.0	--	0.71	--	--	--	--	38.7	108	--
ACg	0-10	6.5	--	10.8	--	0.21	22	37	41	C	24.7	111	--
Cg1	10-60	6.6	0.3	0.4	--	0.05	15	49	36	SiCL	20.3	100	1.9
Cg2	60-90	7.6	0.3	--	--	--	23	45	32	CL	--	--	2.0

pH – measured in $CaCl_2$ solution EC – electrical conductivity (dS/m) OC – total organic carbon (%)
CaCO3 Equiv. – calcium carbonate equivalent (%) TN – total nitrogen (%), Kjeldahl method
PSA – particle size analysis (% sand, silt, and clay separates) by the hydrometer method, with texture class
CEC – cation exchange capacity (meq/100g) BS % – base saturation percentage SAR – sodium adsorption ratio

Comments on the MMWpt pedon:

- Colors are specific Munsell soil color chart notations indicating hue (e.g. 10YR), value (e.g. 2/), chroma (e.g. /2), and whether taken for moist (m) or dry (d) soil.
- The Om and Oh horizons in the sampled pedon contained a few wood fragments.
- The Oh horizon contained some trapped sediment, likely deposited during one or more flooding events that took place during the time that this peat layer was developing.
- Distinct to prominent mottles were observed in Cg1 and Cg2 horizons. The lower profile was very wet; the apparent water table was encountered at 40 cm.
- Roots were observed in all but the Cg2 and Cg3 horizons – abundant, fine to medium in the upper profile; few, very fine to fine in the Cg1 horizon.
- Pores were not observed in this pedon.

MMY – McMurray Series and Variants

MMY series represents a group of closely related Regosolic soil types found on confined, relatively dry, channelled floodplains of stream valleys like Joslyn Creek and Ells River. Most of the variability is defined by different Regosolic subgroups that express presence or absence of gley features (mottling) and humus accumulation. Parent materials also vary to some degree. The major related types of MMY soils are Cumulic Regosol (MMY series), Gleyed Cumulic Regosol (MMYgl variant), Gleyed Cumulic Humic Regosol (MMYzhgl variant), and a paralithic/lithic variant (MMYxl). MMY series is described below; a sampled pedon representing the MMYzhgl variant is presented in Table A-25 and Table A-26.

Soil Classification (Subgroup):	Cumulic Regosol
Parent Material; Grouping:	Medium to moderately fine textured, fluvial material; M2, M3
Drainage:	Moderately well drained
Soil Moisture Regime:	Mainly mesic (5), some subhygric (6)
Texture:	L-SiL topsoil / L-SiL-CL-SiCL subsoil; occasional sandy layers
Profile Coarse Fragments:	Typically <1% by volume
Surface Organic Material:	Mainly forest litter (LFH); averaged 5-6 cm thickness for all MMY soils
Topsoil Thickness:	Averaged 1 cm (Ah & Ahe horizons); averaged 29 cm in Humic Regosols
Soil Capability Rating (Forestry):	78 index points; Class 2R
Soil Sensitivity to Acid Deposition:	Medium

Common McMurray variants found in the SSA:

McMurray-gleyed (MMYgl) – similar to MMY in terms of parent material and related features, but is imperfectly drained and classified as Gleyed Cumulic Regosol. Associated with subhygric (6) moisture regime.

McMurray-humic, gleyed (MMYzhgl) – similar parent material and drainage as MMYgl, but has a humus-rich topsoil horizon(s) and is classified as Gleyed Cumulic Humic Regosol. MMYzhgl is imperfect drained and associated with subhygric (6) moisture regime. A sampled MMYzhgl pedon is described below.

McMurray-paralithic/lithic (MMYxl) – similar to MMY series but with variable soft (paralithic) to hard (lithic) bedrock occurring within 100 cm of the mineral soil surface. The bedrock, which is partially weathered, bituminous sandstone and siltstone of the McMurray Formation (Hamilton et al. 1999), usually occurs in the lower subsoil (between 50 and 100 cm). MMYxl soils occur mainly on the eastern edge of the SSA.

Comments on MMY series and variants:

- MMY, MMYzhgl, and MMYgl are the most common examples of several closely related soil types found on the drier floodplains of streams like Joslyn Creek and Ells River. A variety of other Regosolic soils, both imperfectly drained (e.g. Gleyed Humic Regosol) and moderately well drained (e.g. Cumulic Humic Regosol), also occur in this landscape.
- The parent material consists of layered fluvial (post-glacial) or glaciofluvial deposits intermixed with bands of organic material mixed with mineral that mark the position of former surfaces. Textures are commonly medium (M2 – loam and silt loam) to moderately fine (M3 – clay loam, silty clay loam, sandy clay loam), but may include a few coarse layers (sandy loam, loamy sand, or sand). Related variants with layered (L10, L18) parent materials also occur in this environment.
- Topsoil thickness does not include the organic layer (LF or LFH) above it; leaf litter occurs at most sites.
- Transition from topsoil to upper subsoil is poor – soil horizons are layered and intermixed due to repetitive deposition throughout their post-glacial history. Consequently, horizons similar to those at the mineral surface may repeat at depth.
- A subhygric moisture regime, good range in textures, amenable structure and consistence, and relatively high organic matter content in upper horizons means that the gleyed MMY variants (MMYzhgl & MMYgl) rate fairly high for forest production (Leskiw 1998), with the only limitation being acidic soil reaction (pH). However, the high rating fails to account for a landscape that involves a channelled fluvial floodplain with irregular and variable slopes, frequent flooding, and periodic deposition of mineral material.
- A sampled MMYzhgl pedon is described in Table A-25, with chemical and physical data in Table A-26.

Table A-25. Description of a pedon (BW097P) representing MMYzhgl variant.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
LF	5-0	Litter	5YR3/2m	--	--
Ah	0-18	Silt loam	10YR3/2m	Very weak, fine to medium, platy and weak, fine, subangular blocky	Very friable
LFHb	18-20	--	10YR2/1m	--	--
ABgj	20-25	Silt loam	10YR3/3m	Very weak, fine to medium, platy	Very friable
BC	25-28	Sandy loam	10YR4/3m	Single grain	Very friable
BCgj1	28-40	Silt loam	10YR3/2m	Very weak, fine to medium, platy	Very friable
BCgj2	40-50	Silty clay loam	2.5Y3/2m	Moderate, fine to medium, platy	Very friable
BCgj3	50-70	Loam	10YR3/3m	Very weak, medium, platy	Very friable

Table A-25. Description of a pedon (BW097P) representing MMYzhgl variant.					
Horizon	**Depth (cm)**	**Field Texture**	**Color**	**Structure**	**Consistence**
BCgj4	70-80	Fine sandy loam	10YR3/3m	Weak, medium, platy	Very friable
BCg	80-100	Silt loam	5Y3/1m	Weak, fine, subangular blocky	Very friable

Table A-26. Selected chemical and physical properties of the MMYzhgl pedon (BW097P).

Horizon	Depth (cm)	pH	EC	OC	$CaCO_3$ Equiv.	TN	PSA (%)			Texture Class	CEC	BS %	SAR
							Sand	Silt	Clay				
LF	5-0	5.7	--	26.5	--	1.50	--	--	--	--	66.7	90	--
Ah	0-18	4.2	--	3.0	--	0.22	22	51	27	SiL	19.0	61	--
ABgj	20-25	4.1	--	2.5	--	0.15	22	57	21	SiL	18.2	67	--
BCgj1	28-40	3.6	--	3.4	--	0.21	21	54	25	SiL	21.1	46	--
BCgj2	40-50	3.4	--	2.2	--	0.14	21	59	20	SiL	23.9	35	--
BCgj3	50-70	3.6	--	1.7	--	0.10	52	30	18	L-SL	21.2	33	--
BCgj4	70-80	3.7	1.3	--	--	--	58	26	16	SL	--	--	0.5
BCg	80-100	3.8	1.2	--	--	--	24	55	21	SiL	--	--	0.6

pH – measured in $CaCl_2$ solution EC – electrical conductivity (dS/m) OC – total organic carbon (%)
CaCO3 Equiv. – calcium carbonate equivalent (%) TN – total nitrogen (%), Kjeldahl method
PSA – particle size analysis (% sand, silt, and clay separates) by the hydrometer method, with texture class
CEC – cation exchange capacity (meq/100g) BS % – base saturation percentage SAR – sodium adsorption ratio

Comments on the MMYzhgl pedon:

- Colors are specific Munsell soil color chart notations indicating hue (e.g. 10YR), value (e.g. 2/), chroma (e.g. /1), and whether taken for moist (m) or dry (d) soil.
- The Ah horizon in the sampled pedon contained small chunks of burnt wood along its lower boundary.
- Soil structure throughout this profile is weak (poorly developed); materials tend to be very friable or soft. The platy structure prevalent in most horizons is non-pedogenic, being related primarily to layering of sediments during deposition. The BCg horizon in the sampled pedon was nearly wet, and close to the apparent water table associated with the nearby creek. Wet consistence was sticky, non-plastic.
- Mottling tends to be weak to moderate (faint to distinct mottles) in the mid to lower sola of these soils. In the sampled pedon, faint mottles were observed in the ABgj, BCgj1, and BCjg4 horizons; distinct mottles in the BCgj3 horizon; and prominent mottles in the BCgj2 and BCg horizons. Reddish mottles in the BCgj2 horizon were all associated with roots and root channels.
- Roots were observed throughout the entire profile – abundant, fine to medium or coarse in the upper profile; very few, very fine in the BCg horizon.
- Very fine pores were observed throughout the profile.
- Soil reaction (pH) in the sampled pedon was unusually low, especially for the deeper horizons, and lower than reported for other MMY pedons sampled in the oils sands region (Turchenek et al. 1982b; AG30SLF, ASIC 2001). The higher reported values were used for soil capability and acid sensitivity assessments.

MUS – Muskeg Series and Variants

MUS series represents a complex of related Organic soils found on wetlands dominated by bog and poor fen vegetation in the survey area. Depth of peat, ranging from 40 to well over 200 cm, is the most

important variable that defines entities in this complex. To facilitate the mapping system used in the area (Golder Associates 2002), peat depth was categorized as shallow (40-100 cm), moderately deep (100-200 cm), and deep (>200 cm). Soil subgroups also varied – Typic Mesisol, Fibric Mesisol, Terric Mesisol, Typic Fibrisol, Mesic Fibrisol, Terric Fibrisol, and a few others occur in the area, often in proximity to one another. A third factor defines, in broad textural groupings (coarse, medium, or fine), the type of mineral substrate beneath the shallower (<200 cm) peats. Two pedons are described below – a Fibric Mesisol (MUSzz variant, Table A-27 and Table A-28) representing deeper peat soils, and a Terric Mesisol (MUS1m variant, Table A-29 and Table A-30) representing shallow peat soils.

Significant MUS series/variants found in the SSA:

- **Muskeg series (MUS)** – classified as Typic Mesisol in the Alberta Soil Names File (AG30SNF, ASIC 2001). Parent material is dominantly bog peat (P1) at least 100 cm thick for practical (mapping) purposes. [Technically for taxonomic purposes, peat depth should be 120 cm.] Several closely related soils differing mainly in subgroup classification (e.g. Fibric Mesisol, Typic Fibrisol, and Mesic Fibrisol) were found in the SSA. An example of these deeper bog peat soils, a Fibric Mesisol variant (MUSzz), is described below and in Table A-27 and Table A-28.

Shallow peat over clayey material variant (MUS1c) – classified as Terric Mesisol, Terric Fibric Mesisol, Terric Fibrisol, or Terric Mesic Fibrisol. Parent material is dominantly bog peat 40-100 cm thick (for practical mapping purposes) overlying clayey (C-SiC-HC) mineral materials

Shallow peat over medium material variant (MUS1m) – classified as Terric Mesisol, Terric Fibric Mesisol, Terric Fibrisol, or Terric Mesic Fibrisol. Parent material is dominantly bog peat 40-100 cm thick (for practical mapping purposes) overlying medium to moderately fine textured (L-SCL-SiL-CL-SiCL) materials. An example of these shallow bog peat soils, a Terric Mesisol variant (MUS1m), is described below and in Table A-29 and Table A-30.

Shallow peat over sandy material variant (MUS1s) – classified as Terric Mesisol, Terric Fibric Mesisol, Terric Fibrisol, or Terric Mesic Fibrisol. Parent material is dominantly bog peat 40-100 cm thick (for practical mapping purposes) overlying coarse textured (S-LS-SL) materials.

MUSzz Variant (representing deeper bog peat)

Soil Classification (Subgroup):	Fibric Mesisol
Parent Material; Grouping:	Bog peat; P1
Drainage:	Poor to very poor
Soil Moisture Regime:	Subhydric (8)
Texture:	Peat
Profile Coarse Fragments:	None (may be wood fragments in some peat horizons)
Surface Organic Material:	Bog and other peats (Of and Om horizons) over 120 cm thick
Topsoil Thickness:	N/A
Soil Capability Rating (Forestry):	5 index points; Class 5OV
Soil Sensitivity to Acid Deposition:	Medium

Comments on the MUSzz variant (sampled pedon) and MUS series:

- MUSzz pedon represents numerous closely related, deep, organic soil types found on bog-dominated wetlands in the SSA. Variability amongst these closely related soils centers on soil subgroup. Common soil subgroups are Typic Mesisol (Muskeg series, ASIC 2001), Fibric Mesisol (sampled pedon), Typic Fibrisol, and Mesic Fibrisol. All reflect that fact peat types tend to be layered in these associated soils.
- The sampled MUSzz variant also represents two soil complexes used in mapping soils of the SAGD-RSA. The two complexes were created to conveniently indicate depth of surface organic materials. MUS2 has peat depths of 100-200 cm; MUS3 has peat depths greater than 200 cm.

Table A-27. Description of a pedon (BW095P) representing MUSzz variant.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
Of1	0-15	Fibric peat	7.5YR3/2m	--	--
Of2	15-30	Fibric peat	7.5YR3/2m	--	--
Of3	30-90	Fibric peat	7.5YR4/4m	--	--
Om	90-160	Mesic peat	10YR2/1m	--	--
Oh	160-175	Humic peat	10YR2/1m	--	--
Cg	175-200	Clay	5Y4/1m	Massive	Slightly sticky, slightly plastic

Table A-28. Selected chemical and physical properties of the MUSzz pedon (BW095P).

Horizon	Depth (cm)	pH	EC	OC	$CaCO_3$ Equiv.	TN	PSA (%)			Texture Class	CEC	BS %	SAR
							Sand	Silt	Clay				
Of1	0-15	3.2	--	36.5	--	0.73	--	--	--	--	67.6	28	--
Of2	15-30	3.0	--	43.9	--	0.80	--	--	--	--	99.4	29	--
Of3	30-90	3.3	--	46.9	--	0.82	--	--	--	--	123	33	--
Om	90-160	4.6	--	47.4	--	1.17	--	--	--	--	152	67	--
Oh	160-175	4.8	--	32.3	--	1.72	--	--	--	--	--	--	--
Cg	175-200	6.7	0.3	--	--	--	28	30	42	C	--	--	0.9

pH – measured in $CaCl_2$ solution EC – electrical conductivity (dS/m) OC – total organic carbon (%)
CaCO3 Equiv. – calcium carbonate equivalent (%) TN – total nitrogen (%), Kjeldahl method
PSA – particle size analysis (% sand, silt, and clay separates) by the hydrometer method, with texture class
CEC – cation exchange capacity (meq/100g) BS % – base saturation percentage SAR – sodium adsorption ratio

- MUS2 is further defined by adding a "c", "m", or "s". The "c" (MUS2c soil unit as in the sampled pedon) indicates a mineral substrate with predominantly clayey texture (clay, silty clay, heavy clay). Related soil complexes have medium textured (MUS2m) and sandy (MUS2s) mineral substrates beneath the peat.
- Current vegetation is bog or poor fen; bog peat dominates the surface organic layers of these soils. Other types of peat (fen peat, organic material high in wood fragments) may occur deeper in the soil profile.
- Color transition from topsoil (surface organic layers) to subsoil (deeper organic layers) is poor.
- Colors are indicated as specific Munsell soil color chart notations indicating hue (e.g. 10YR), value (e.g. 2/), chroma (e.g. /1), and whether taken for moist (m) or dry (d) soil.
- Peat derived from sphagnum and related bog vegetation tends to be acidic. Low pH (4.0 or lower) in near-surface peat layers is typical (as in the sampled pedon), and hinders growth of most trees. Higher pH values in deeper peats may indicate a different vegetative source (e.g. fen vegetation) or the influence of underlying mineral materials.
- The Of1 horizon of the sampled pedon was essentially a raw root mat reflecting the current vegetative cover. It included a small amount of sedge roots. The Of2 horizon contained a high proportion of poorly decomposed sedge and rush fibres. The Of 3 horizon included many thin bands of Om (mesic) material.

MUS1m Variant (representing shallow bog peat)

Soil Classification (Subgroup): Terric Mesisol
Parent Material; Grouping: Bog peat overlying fine textured materials; L12
Drainage: Poor to very poor
Soil Moisture Regime: Subhydric (8)
Texture: Peat (usually 40-100 cm) / medium textured (L-CL-SCL-SiCL) material

Profile Coarse Fragments: None (may be wood fragments in some peat horizons)
Surface Organic Material: Mainly bog peat (Of and Om horizons) between 40 and 120 cm thick
Topsoil Thickness: N/A
Soil Capability Rating (Forestry): 7 index points; Class 5SR
Soil Sensitivity to Acid Deposition: Medium

Table A-29. Description of a pedon (BW105P) representing MUS1m variant.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
Of	0-10	Fibric peat	10YR2/2m	--	--
Om	10-70	Mesic peat	10YR2/1m	--	--
ABg	70-80	Sandy clay loam	10YR3/1m	Massive	Non-sticky, slightly plastic
BCg	80-110	Sandy clay loam	10YR5/4m	Massive	Non-sticky, slightly plastic

Table A-30. Selected chemical and physical properties of the MUS1m pedon (BW105P).

Horizon	Depth (cm)	pH	EC	OC	$CaCO_3$ Equiv.	TN	PSA (%)			Texture Class	CEC	BS %	SAR
							Sand	Silt	Clay				
Of	0-10	6.3	--	43.0	--	1.12	--	--	--	--	86.3	118	--
Om	10-70	6.1	--	43.6	--	1.13	--	--	--	--	117	109	--
ABg	70-80	6.0	--	2.1	--	0.13	60	25	15	SL	15.8	111	--
BCg	80-110	6.5	0.4	--	--	--	53	29	18	SL	--	--	0.9

pH – measured in $CaCl_2$ solution EC – electrical conductivity (dS/m) OC – total organic carbon (%)
CaCO3 Equiv. – calcium carbonate equivalent (%) TN – total nitrogen (%), Kjeldahl method
PSA – particle size analysis (% sand, silt, and clay separates) by the hydrometer method, with texture class
CEC – cation exchange capacity (meq/100g) BS % – base saturation percentage SAR – sodium adsorption ratio

Comments on the MUS1m pedon and related series/variants:

- MUS1m pedon represents numerous, closely related, shallow, organic soil types (MUS1m soil complex) found on bog-dominated wetlands in the survey area. With peat thickness (40-100 cm) and mineral parent materials (medium textured) fixed, variability centers on soil subgroup. Common soil subgroups in the complex are Terric Mesisol (example pedon and MRN series), Terric Fibric Mesisol, Terric Fibrisol, and Terric Mesic Fibrisol.
- MUS1m complex includes Mariana (MRN) series, listed as a Terric Mesisol in the Alberta Soil Names File (AG30SNF, ASIC 2001).
- Related soil complexes have clay (MUS1c) and sandy (MUS1s) mineral substrates beneath the peat.
- Current vegetation is bog or poor fen; bog peat dominates the surface organic layers of these soils. Other types of peat (especially fen peat) may occur deeper in the soil profile.
- Peat derived from sphagnum and related bog vegetation tends to be acidic. Low pH values (4.5 or lower) in near-surface peat layers are typical, and hinder grow of most trees. pH values of the sampled pedon are unusually high, and may reflect the proximity of this site to a major roadway and construction disturbance.
- To facilitate mapping and conveniently indicate depth of surface organic materials, peat depth in the MUS1*x* soil complex was restricted to 40-100 cm. Technically, similar soils with peat depths of 100-120 cm also fit the "Terric" subgroups (SCWG 1998).
- Color and texture transition from topsoil (surface organic layers) to upper subsoil (deeper organic layers) is usually poor; transition from upper subsoil (organic material) to lower subsoil (mineral material) is good.

- Mineral materials tend to be dull coloured (dark gray to gray, sometimes olive gray), and may also have faint to distinct mottles. Dull soil colors in conjunction with high water tables and subhydric or hydric vegetation indicate extensive periods of water logging during the year. Mottling indicates that there are drier periods with some aeration of the soil material.
- For rating purposes, the surface (0-20 cm) organic material was considered to be "topsoil". However, material depth calculations include the peat with "surface organic materials" rather than topsoil.
- Colors are specific Munsell soil color chart notations indicating hue (e.g. 10YR), value (e.g. 2/), chroma (e.g. /1), and whether taken for moist (m) or dry (d) soil.
- Roots were observed in the Of, Om, and ABg horizons.
- The sampled pedon was very wet (apparent water table at 10 cm); samples of deeper horizons were collected using a shovel and hand auger with loss of some finer material by washing. Consequently, lab results for textures of the ABg and BCg horizons were coarser than expected.

PEA – Peavine Series

PEA series represents a group of closely related, upland, soil types developed on medium or moderately fine textured water-laid sediments (M2, M3). Two main related types include Orthic Gray Luvisol (PEA series) and Eluviated Dystric Brunisol (PEAzb variant). These two types are similar, differing only in degree of B horizon development with PEA having a clay-enriched Bt horizon and PEAzb a more weakly developed Btj or Bm horizon. PEA series is described below and in Table A-31. Other commonly occurring variants included Gleyed Gray Luvisol (PEAgl), Dark Gray Luvisol (PEAzh), a paralithic/lithic variant (PEAxl), and Gray Luvisols developed on slightly coarser textured (C3) materials (PEAco).

Soil Classification (Subgroup):	Orthic Gray Luvisol
Parent Material; Grouping:	Medium to moderately fine textured, water-laid material; M2, M3
Drainage:	Moderately well to well
Soil Moisture Regime:	Mesic (5)
Texture:	L-SL-SiL topsoil / CL-SiCL-SiL-L-SCL subsoil
Profile Coarse Fragments:	Typically <2% by volume, occasionally higher in some layers
Surface Organic Material:	Mainly forest litter (LFH); averaged 6 cm thickness in area
Topsoil Thickness:	Averaged 22 cm in area – A horizon (mainly Ae) plus AB transition
Soil Capability Rating (Forestry):	68 index points; 2R
Soil Sensitivity to Acid Deposition:	Medium

Significant PEA variants found in the SSA:

Peavine-brunisolic (PEAzb) – similar to PEA but classified as Eluviated Dystric Brunisol rather than Orthic Gray Luvisol. The main difference is in the degree of pedogenic clay enrichment in the B horizon. PEA has a reasonably well developed Bt (clay-enriched) horizon; PEAzb has Btj or Bm horizons in which morphological evidence of illuviation is weakly expressed (i.e. poorly developed clay films or lamellae). For assessing soil capability, acid sensitivity, and reclamation suitability, the differences between PEA and PEAzb were considered negligible.

Peavine-gleyed (PEAgl) – similar to PEA in terms of parent material and related features, but is imperfectly drained and classified as Gleyed Gray Luvisol. Although relatively common based on site inspection numbers, PEAgl soils tended to be scattered throughout numerous upland landscapes dominated by other soils, were often found in lower-lying localities.

Peavine-paralithic/lithic (PEAxl) – similar to PEA series or PEAzb variant but with variable soft (paralithic) to hard (lithic) bedrock occurring within 100 cm of the mineral soil surface. The bedrock, which is partially weathered, bituminous sandstone and siltstone of the McMurray Formation (Hamilton et al. 1999), usually occurs in the lower subsoil (between 50 and 100 cm).

PEAxl soils occur mainly on the eastern edge of the SSA, frequently in association with DAN and other lithic soils.

Comments on PEA series and variants:

- PEA soils (PEA, PEAzb, PEAgl, PEAzh, PEAco, and PEAxl) together accounted for just over 3% of all inspection sites. Although relatively common based on site inspection numbers, PEAgl soils tended to be scattered throughout several upland landscapes dominated by other soils. The less common PEAco and PEAzh variants were also scattered throughout other landscapes.
- PEA soils are developed on moderately fine textured, water-laid materials (i.e. glaciofluvial, glaciolacustrine, or fluvial sediments). FRT (Fort) soils are closely related in that they have similar profiles developed on shallow (30-99 cm), medium to moderately fine textured overlying coarse textured, water-laid materials. The upper parent material of LVK (Livock) soils is also similar to that of PEA soils.
- Topsoil thickness does not include the organic layer (LF or LFH) above it; leaf litter is present at all sites.
- Topsoil horizons in PEA soils may show weak eluviation, mixing of materials due to physical disturbances like tree-throw, or minor humus accumulation (Ah or Ahe). All such horizon peculiarities reflect the fluvial system (stream channel/valley environments) heritage that affected their development.
- Color transition from topsoil to upper subsoil is moderate. Transitional horizons (an AB or BA) are common in PEA soils, and are usually considered as part of the topsoil. They have structural peds with brownish inped colors like the Bt below and exped colors similar to the Ae above. Carbonates occur in the C horizons of most PEA profiles, usually at depths below 70 or 80 cm.
- Soil structure below the B horizon is often weak and tends to be interpreted as massive when seen in hand-auger samples (as in profile described below). Generally, consistence of BC and Ck horizons is friable.
- A detailed pedon description and samples for analytical characterization were not obtained for the PEA series. Only a few grab samples were collected from PEA soils during the course of this survey. Instead, a brief description from an inspection site is provided (Table A-31). Analytical data for PEA series is available in the Alberta Soil Layers File (AG30SLF, ASIC 2001).

Table A-31. Brief description of an inspection pedon (JH733) representing PEA series.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
LFH	4-0	Litter	--	N/A	N/A
Ae	0-13	Fine sandy loam	Pale brown to brown	Granular	Very friable
AB	13-20	Sandy clay loam	--	Granular	Friable
Bt	20-40	Clay loam	--	Subangular blocky	Firm
BC	40-70	Clay loam	--	Subangular blocky	Firm
Ck	70-100	Clay loam	--	Massive	Friable

SEN – Steen Series

SEN series is classified as Solonetzic Gray Luvisol, and is commonly found in association with Dover (DOV) series on upland areas of the Upper and Lower Dover Plain land systems. Like DOV, SEN is developed on clayey glacial deposits. SEN series is described below and in Table A-32 and Table A-33.

Soil Classification (Subgroup):	Solonetzic Gray Luvisol
Parent Material; Grouping:	Clayey, calcareous lacustro-till (or till); F3 (or F4)
Drainage:	Moderately well to well
Soil Moisture Regime:	Mesic (5)
Texture:	L-SL-SiL topsoil / C subsoil
Profile Coarse Fragments:	Typically 1-10% by volume, occasionally higher in some layers
Surface Organic Material:	Mainly forest litter (LFH); averaged 6 cm thickness in area
Topsoil Thickness:	Averaged 12 cm in area – A horizon (mainly Ae) plus AB transition
Soil Capability Rating (Forestry):	52 index points; Class 3SR
Soil Sensitivity to Acid Deposition:	Medium

Comments on SEN series:

- SEN series accounted for less than 2% of all inspection sites. SEN is an intergrade between Orthic Gray Luvisol on clayey glacial material (DOV series) and Gray Solodized Solonetz on clayey glacial material (JSN series). JSN, which has a Bnt horizon with better formed, harder columnar peds than SEN, was found only sporadically in the SSA.
- Parent materials of SEN soils are clayey lacustro-till (F3) and till (F4). The two materials are similar, with the lacustro-till being somewhat more stratified and containing "grayish pink" till-like layers.
- SEN soils have a solonetzic-like upper B horizon (Btnj) with weak columnar peds that break into firm to very firm (hard) subangular blocky and blocky aggregates. Adverse subsoil structure, salinity, and sodicity cause these soils to be rated lower than their Orthic Gray Luvisol counterparts (DOV series).
- SEN soils were classified as Solonetzic Gray Luvisol based primarily on the weak columnar structure and firm to very firm consistent of the solonetzic-like B horizon. Analytical results from grab and pedon samples indicate that SEN soils had slightly lower pH in Ae horizons and slightly higher EC and SAR values in the B and C horizons than DOV soils.
- Topsoil thickness does not include the organic layer (LF or LFH) above it; leaf litter is present at all sites.
- Transition from topsoil to upper subsoil is good to moderate. SEN soils often have a thin transitional AB or BA horizon with structural peds like the Btnj below it but grayish colours like the Ae above it. In the sampled pedon (BW091P), the AB horizon was very thin and discontinuous, and therefore not sampled.
- Soil structure below the B or BC horizon is often weak and tends to be interpreted as massive when seen in hand-auger samples. High clay content in BC and C horizons contributes to relatively tough consistence (firm) in these horizons.
- A sampled SEN pedon is described in Table A-32, with selected chemical and physical data in Table A-33.

Table A-32. Description of a pedon (BW091P) representing SEN series.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
LF	5-0	Litter	10YR2/2m	--	--
Ae	0-10	Loam	10YR5/3m	Moderate, medium to coarse, platy	Very friable
AB	10-12	Clay loam	10YR5/3m	Strong, fine, blocky	Friable
Btnj	12-25	Clay	7.5YR4/4m	Weak to moderate, medium, columnar breaking to strong, medium, subangular blocky	Firm
Bt	25-45	Clay	10YR3/2m	Strong, fine to medium, subangular blocky	Friable

Table A-32. Description of a pedon (BW091P) representing SEN series.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
BCs	45-70	Clay	10YR3/3m	Moderate, fine, subangular blocky	Very friable
Cks	70-100	Clay	10YR3/3m	Weak, fine, subangular blocky	Friable

Table A-33. Selected chemical and physical properties of the SEN pedon (BW091P).

Horizon	Depth (cm)	pH	EC	OC	$CaCO_3$ Equiv.	TN	PSA (%)			Texture Class	CEC	BS %	SAR
							Sand	Silt	Clay				
LF	5-0	4.9	--	29.1	--	1.33	--	--	--	--	76.0	85	--
Ae	0-10	4.1	0.5	0.6	--	0.05	19	62	19	SiL	4.8	60	2.8
Btnj	12-25	4.5	1.6	0.7	--	0.04	20	38	42	C	21.0	75	8.0
Bt	25-45	6.8	4.5	0.7	--	0.05	18	29	53	C	24.9	116	15.8
BCs	45-70	7.5	7.5	0.5	--	0.04	23	27	50	C	17.3	284	12.0
Cks	70-100	7.9	7.0	--	6.4	--	24	29	47	C	--	--	11.4

pH – measured in $CaCl_2$ solution EC – electrical conductivity (dS/m) OC – total organic carbon (%)
CaCO3 Equiv. – calcium carbonate equivalent (%) TN – total nitrogen (%), Kjeldahl method
PSA – particle size analysis (% sand, silt, and clay separates) by the hydrometer method, with texture class
CEC – cation exchange capacity (meq/100g) BS % – base saturation percentage SAR – sodium adsorption ratio

Comments on the SEN pedon:

- Colors are specific Munsell soil color chart notations indicating hue (e.g. 10YR), value (e.g. 2/), chroma (e.g. /1), and whether taken for moist (m) or dry (d) soil.
- The BCs horizon contained nodules infused with visible gypsum crystals. Salt crystals, nodules, or veins were not visible in the Cks horizon. In most SEN and JSN profiles in the survey area, salts were not readily visible as in this pedon. With the high salt content in the sampled pedon, EC and SAR values (Table A-33) were considerably higher than in any other samples taken from similar profiles in the survey area. Consequently, lower averaged or modal values were used in calculating soil capability rating index points.
- Roots were observed throughout the entire profile – abundant, fine to medium in the upper profile; few, very fine in the Ck horizon.
- Very fine pores were observed throughout the profile.
- Clay skins were observed in the B and BC horizons – continuous thin in the Btnj and Bt horizons, many thin in the BCs.

WNFxc – Winefred-clayey subsoil Variant

WNFxc variant represents Orthic Gray Luvisols developed on L9 layered materials, namely coarse textured water-laid sediments overlying lacustro-till (or till). WNFxc soils occur mostly in the Joslyn Plain, Athabasca-Ells Valley, and Lower Dover Plain (eastern portion) land systems. Commonly associated soils include Mildred (MIL), Fort (FRT), and Peavine (PEA). Mildred-clayey subsoil (MILxc) variant is similar in profile characteristics and parent materials to WNFxc, but has a slightly different B horizon (Btj or Bm) entailing its classification as Eluviated Dystric Brunisol. WNFxc variant is described below and in Table A-11.

Soil Classification (Subgroup): Orthic Gray Luvisol
Parent Material; Grouping: Coarse textured, water-laid material overlying fine textured lacustro-till (or till); L9
Drainage: Well
Soil Moisture Regime: Mesic (5)

Texture:	SL-LS-S topsoil and upper subsoil / C lower subsoil
Profile Coarse Fragments:	Typically 1-5% by volume in lower parent material (lacustro-till)
Surface Organic Material:	Mainly forest litter (LFH); estimated at 7 cm thickness in SSA
Topsoil Thickness:	Averaged 19 cm in area – A horizon (mainly Ae) plus AB transition
Soil Capability Rating (Forestry):	37 index points; Class 4SR
Soil Sensitivity to Acid Deposition:	High

Common Winefred variants found in the SSA:

Winefred-medium subsoil (WNFxm) – similar to WNFxc but developed on L20 layered parent material – shallow (30-99 cm) coarse textured overlying medium to moderately fine textured, water-laid materials. Differences between WNFxm and WNFxc were considered insufficient to warrant separation for interpretive assessments.

Winefred-paralithic/lithic (WNFxl) – similar to WNFxc or WNFxm variants but with variable soft (paralithic) to hard (lithic) bedrock occurring within 100 cm of the mineral soil surface. The bedrock, which is partially weathered, bituminous sandstone and siltstone of the McMurray Formation (Hamilton et al. 1999), usually occurs in the lower subsoil (between 50 and 100 cm). WNFxl soils occur mainly on the eastern edge of the SSA, frequently in association with DAN, PEA, FRT, and other paralithic/lithic soils.

Comments on WNFxc and other variants:

- WNF soils were not common in the SSA, accounting for less than 1% of all inspection sites. Besides the main WNFxc and WNFxm variants, Brunisolic Gray Luvisol (WNFzb) and Gleyed Gray Luvisol (WNFgl) variants were also encountered on occasion.
- Layered soils such as WNF require 30 to 99 cm of parent material I overlying parent material II. In this case, parent material I is coarse textured, glaciofluvial material; parent material II is fine textured lacustro-till (parent material group L9, WNFxc variant) or medium to moderately fine textured, water-laid sediments (parent material group L20, WNFxm variant). Contact between the coarse and finer materials averaged 50-60 cm in the SSA.
- Topsoil thickness does not include the organic layer (LF or LFH) above it; leaf litter is present at all sites.
- Color transition from topsoil to upper subsoil is good to moderate. Transitional horizons – an AB or BA – are common in WNF soils.
- Soil structure below the B horizon is often weak and tends to be interpreted as massive when seen in hand-auger samples. High clay content in BC and C horizons contributes to relatively tough consistence (firm) in these horizons.
- A detailed pedon description and samples for analytical characterization were not obtained for the WNFxc variant. Only a few grab samples were collected from WNF soils during the course of this survey. An inspection profile (Table A-31) with selected chemical and physical data from grab samples (Table A-20) is presented below.

Table A-34. Brief description of an inspection pedon (JH135) representing WNFxc variant.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
LFH	20-0	Litter	--	--	--
Ae1	0-12	Very fine sand	--	Weak platy	Loose
Ae2	12-20	Very fine sand	--	Weak platy	Loose
AB1	20-35	Sand	--	Single grain	Loose

Table A-34. Brief description of an inspection pedon (JH135) representing WNFxc variant.

Horizon	Depth (cm)	Field Texture	Color	Structure	Consistence
AB2	35-60	Sand	--	Single grain	Loose
IIBt	60-100	Clay	--	Subangular blocky	Firm

Table A-35. Selected chemical and physical properties of the WNF pedon (JH135).

Horizon	Depth (cm)	pH	EC	OC	$CaCO_3$ Equiv.	TN	PSA (%)			Texture Class	CEC	BS %	SAR
							Sand	Silt	Clay				
LFH	20-0	--	--	--	--	--	--	--	--	--	--	--	--
Ae1	0-12	3.7	--	0.3	--	0.03	--	--	--	--	--	--	--
Ae2	12-20	3.8	--	0.3	--	0.02	--	--	--	--	3.9	23	--
AB1	20-35	4.3	--	0.2	--	<0.02	--	--	--	--	3.6	28	--
AB2	35-60	4.8	--	<0.1	--	<0.02	--	--	--	--	2.9	28	--
IIBt	60-100	5.8	--	0.3	--	0.03	--	--	--	--	15.9	89	--

pH – measured in $CaCl_2$ solution EC – electrical conductivity (dS/m) OC – total organic carbon (%)
CaCO3 Equiv. – calcium carbonate equivalent (%) TN – total nitrogen (%), Kjeldahl method
PSA – particle size analysis (% sand, silt, and clay separates) by the hydrometer method, with texture class
CEC – cation exchange capacity (meq/100g) BS % – base saturation percentage SAR – sodium adsorption ratio

Comments on the WNF pedon:

- This profile is thicker than normal in several respects. The LFH horizon would normally be less than 10 cm thick, but is unusually thick at this site likely because it occurred under an old, well developed stand of very large aspen and spruce.
- Upper solum (topsoil) horizons extend to considerable depth; often, a Bt or Btj horizon with lamellae (thin illuvial clay bands) would be present above the contact between the two parent materials, in other words replacing the AB2 horizon in the example pedon.
- The IIBt horizon in this pedon extends to over 100 cm depth. Usually transition or parent material horizons with free carbonates (IIBCk or IICk) would be encountered at about 80 to 90 cm.
- The Ae2 horizon in this profile was weakly eluviated.

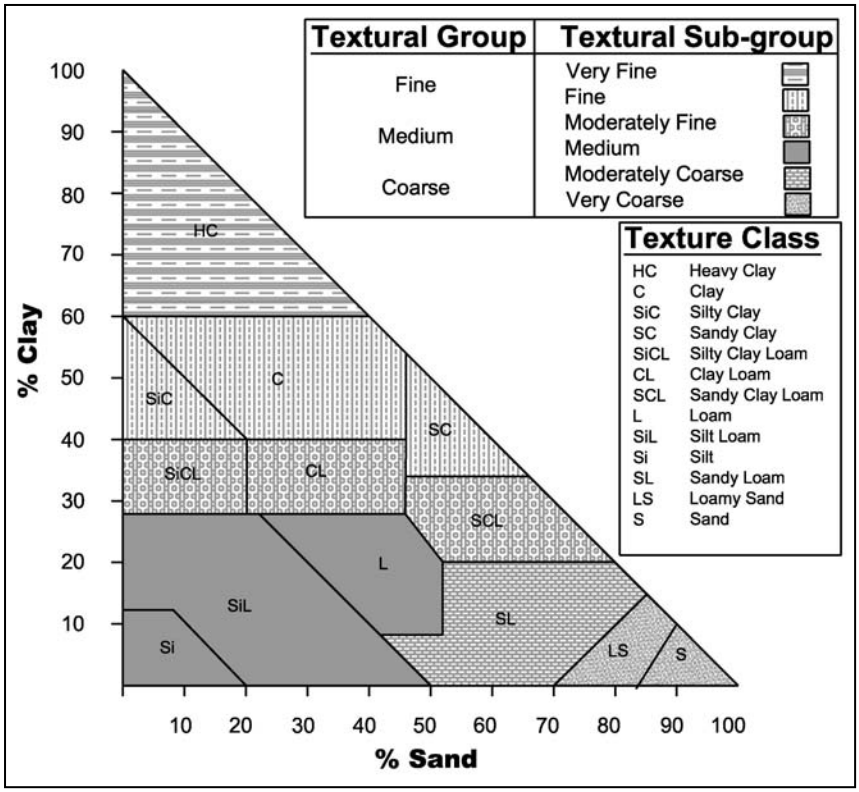


Figure A-1. Textural triangle showing classes organized into textural groups and sub-groups.

APPENDIX B

DESCRIPTIONS OF SOIL MAP UNITS

Appendix B: Descriptions of Soil Map Units

Introduction – Soil Landscape Model

Soil mapping units connect taxonomic entities (refer to Appendix A) and depict their distribution in the landscape. Soil map unit symbols are based on the AGRASID model (ASIC 2001), also referred to as the **Soil Landscape Model (SLM)**. An SLM symbol, as shown at the top of Figure B-1, consists of a numerator and a denominator. The numerator, or soil model, imparts information about soil patterns. The denominator, or landscape model, describes land surface form and topography. Appendix B defines the components of an SLM symbol, and describes the 41 soil models and 59 SLMs of the Joslyn SSA.

Soil Models

The soil model forms the numerator of the SLM symbol (Figure B-1). It consists of a three- or four-letter soil symbol, representing the dominant soil series or variants (e.g. LVK4, DOKM2), plus a one- or two-digit model number that identifies recognizable patterns of soils. As in the CNRL Horizon Project to the north (Golder Associates 2002), mineral and organic soil map units had different soil model numbering systems. Both are described in the sub-sections that follow.

Soil Models for Mineral Soils

The soil symbol uses soil name (series/variant) symbols from the Alberta Soil Names File (AG30SNF, ASIC 2001) and other sources as discussed in sub-section 4.3. A 3-letter soil symbol means that one soil series is recognized as being the dominant (Dom:) soil, occupying 60% or more of the landscape. A 4-letter soil code means that two soil names are recognized as being co-dominant (Co-dom:), each occupying >30% but <60% of the landscape.

The Soil Model number utilizes a numbering system to identify soil patterns that repeat in the landscape. The numbers identify recognizable patterns involving the dominant or co-dominant and significant soils. Significant soils occupy between 10% and 30% of the landscape and contrast appreciably from the dominant/co-dominant soils. A complete listing of the 21 soil model numbers used throughout the province can be viewed in the AGRASID website (ASIC 2001). Soil model numbers used in the Joslyn SSA are:

1 Relatively “pure” unit dominated by the named soil(s). Inclusions do occur but tend not to be extensive or important.

2 Soil model features significant wetland soils (Gleysolic and/or Organic) that occur in low-lying areas too small to map on their own. Dominant/co-dominant soils occupy drier “uplands”.

4 Soil model features significant disturbed and/or eroded soils relating to natural disturbances such as occur along steep stream course and valley walls.

5 Soil model features significant finer textured soils compared to dominant/co-dominant soils.

6 Soil model features significant coarser textured soils compared to dominant/co-dominant soils.

9 Soil model features significant coarser textured soils (as in #6), **and** significant wetland soils (Gleysolic and/or Organic) that occur in low-lying areas too small to map on their own (as in #2).

10 Soil model features significant Solonetzic or Solonetzic-like (e.g. Solonetzic Gray Luvisol) soils where the dominant/co-dominant soils are not Solonetzic, **and** significant wetland soils (Gleysolic and/or Organic) that occur in low-lying areas too small to map on their own (as in #2).

11 Soil model features significant disturbed and/or eroded soils relating to natural disturbances such as occur along steep stream course and valley walls (as in #4), and significant coarser textured soils compared to the dominant/co-dominant soils (as in #6).

21 Soil model features significant Organic soils where the dominant/co-dominant soils are Gleysolic.

Soil Models for Organic Soils

Organic soil map units were identified somewhat differently than those dominated by mineral soils. To simplify the complexity of peat-dominated areas, the naming soil series were restricted to McLelland (MLD) and Muskeg (MUS). MLD was used with fen ecosite types, MUS with bog and poor fen vegetation types. The numerical portion of the map unit symbol indicates depth of peat as follows.

1 Peat depth 40-100 cm
2 Peat depth 100-200 cm
3 Peat depth >200 cm

One of three lower case symbols, listed below, indicates the dominant texture of the mineral substratum underlying the peat in Organic soils.

c Mineral substratum below peat is predominantly clayey.
m Mineral substratum below peat is predominantly medium textured.
s Mineral substratum below peat is predominantly sandy.

Map units dominated by Organic soils but containing significant Gleysolic soils were identified with a "-G" postscript in the symbol (e.g. MLD1m-G).

Landscape Models

The landscape model (LM) forms the denominator of the SLM symbol. The LM symbol combines surface form, slope class, and surface form modifier attributes that are used to describe the topographical features of landscapes. LMs are not coupled to genetic (parent) materials, and do not include all of the traditional surface form classes. Landscape models are described in more detail in AGRASID (ASIC 2001), which includes a complete list of LMs with brief descriptions.

Table B-1 lists the landscape models used in the Joslyn SSA. In the case of H1l, HR2m, HR2l, R2l, U1h, and U1l, a complete LM symbol includes the main code (e.g. U1) plus the letter "l", "m", or "h" (for low, moderate, or high relief) that identifies the slope class. Relief classes (l, m, or h) were not used for other landscape models mapped in the SSA.

Surface form modifiers describe unique features such as channels or gullies that may affect landscape models. Table B-2 describes the five surface form modifiers as they were defined and used for AGRASID (ASIC 2001).

The only surface form modifier used in mapping soils of the Joslyn SSA was "r" (e.g. DAPE6/HR2h**r**, FRDA6/R2l**r**), which was added to specific SLMs in the format shown in Figure B-1. As used in the SSA, surface form modifier "r" indicated that bedrock was much closer to the surface than 5 m and controlled the shape (surface form or expression) of the landform. In fact, the SLMs with the modifier "r" likely have at least significant paralithic/lithic soils (refer to Table 4.2 and Appendix A).

Table B-1. Landscape models used in soil map units of the SSA (adapted from AGRASID, ASIC 2001).		
Code	**Description**	**Slope Class(es)**
FP3	Confined floodplain with minor active and abandoned channels	1 to 2
H1	Hummocky: **l**. low relief	 mainly 4, some 5
HR2	Hummocky and ridged: **m**. moderate relief **h**. high relief	 mainly 4, some 5 mainly 5, some 6
I4	Inclined to steep valley walls with >10% exposed bedrock (some slumping)	6 to 8
I5	Inclined, steep landforms with extensive failure slumps, small terraces in places	5 to 7
L1	Level plain	1 to 2
L3	Level and terraced (not within modern stream channels)	2 to 3, minor 4 to 5
O1	Organic – level (horizontal or plateau)	1 to 3
O2	Organic – basin (bowl)	1 to 3
O3	Organic – channelled, ribbed, or net (used in SSA to describe stream course floodplains with active channels and beaver runs)	1 to 2
O5	Organic – level with raised knolls and hummocks of mineral soils	2 to 4
R2	Ridged: **l**. low relief	 3 to 4
SC1	Valley-bottom floodplain with active and abandoned channels, some small scarps	3 to 5
SC2	Wide valley with one or more terraces (coulee and scarp slopes sometimes included)	2 to 3, minor 5 to 7
U1	Undulating: **l**. low relief **h**. high relief	 mainly 2, some 3 mainly 3

Table B-2. Surface form modifiers identified for use in AGRASID (ASIC 2001).	
Code	**Description**
c	Channelled (<50 cm, rill re-occur at the same position year after year)
d	Dissected (>50 cm, gully, same position year after year)
e	Eroded pits (specific to Solonetzic soils)
n	Concavities
r	Shallow to bedrock (within 5 m)

Soil Model (SM) and Soil Landscape Model (SLM) Descriptions

Forty-one soil models, including water and disturbed land, were mapped in the Joslyn SSA. These 41 soil models (SMs) are the focus of the map unit descriptions in this section. Combining landscape model (LM) information with the SM adds topographical characteristics that define soil landscape models (SLMs). SLMs are the actual mapping units used to depict the distribution of soils in the LSA. Fifty-nine SLMs are also described in this section.

BMT5 Soil Model

Soil Model (MU) Name:	Bitumount 5
Extent (ha / % of survey area)	82.5 ha / 0.4% of SSA
Co-dominant Soils (each 30-60%):	BMT (Bitumount) and related variants (BMT & BMTnp complex)
Significant Soils (10-30%):	Finer textured Gleysolic soils (i.e. BMTxc)
Inclusions (<10%):	Gleyed Gray Luvisol (MILgl); other Gleysolic soils (MMW series and variants); shallow organic soils (MLD1s, MUS1s); water bodies (beaver ponds and other ponded areas)
General Landform:	Low-lying level plains, in some cases including broad drainage channels
Surficial (Parent) Materials:	Mainly glaciofluvial (outwash) sands; dominantly very coarse textured (C2)
Ecosite Phase:	Various wetland types – treed (k1), shrubby (k2), and graminoid (k3) fen; treed (i1) and shrubby (i2) bog; treed poor fen (j1)
Surface Stoniness:	Non-stony
Land Use:	Wetland (various types)

Soil Landscape Models (SLMs):

BMT5 / L1 Extent – 82.5 ha; 0.4% of the SSA
L1 landscape model – level plain, sometimes associated with in-filled drainage channels; mainly slope classes 1 to 2 (0-2% slope gradient)
Amalgamated suitability rating for forestry – 4R

Comments:

- BMT5 soil model occurs only in the Joslyn Plain Land System, where it represents wetlands dominated by Gleysolic soils developed on very coarse textured glaciofluvial (outwash) deposits. Finer textured Gleysolic soils, mainly featuring sands overlying clayey sediments, are significant.
- Shallow peat deposits typically mantle BMT5 soil areas; average depth of peat was estimated at about 25 cm based on inspection sites located in BMT5/L1 SLMs. Similar looking areas with thicker (>40 cm) peat deposits were mapped as one of several organic soil units.

CHMM1 Soil Model

Soil Model (MU) Name:	Chateh-Mamawi 1
Extent (ha / % of survey area)	949.2 ha / 4.3% of SSA
Co-dominant Soils (each 30-60%):	CHT (Chateh) and MMW (Mamawi) series and variants (complexes)
Significant Soils (10-30%):	N/A
Inclusions (<10%):	Gleyed Gray Luvisols (KME, LVKgl); other Gleysolic soils (ALG series and variants); shallow organic soils (MLD1m, MUS1m); water bodies (beaver ponds and other ponded areas)
General Landform:	Confined stream course or valley floodplains or low-lying undulating plains
Surficial (Parent) Materials:	Mainly fluvial or fluviolacustrine; range from loamy (M3) to clayey (F1, F3) and include medium over fine layered deposits (L3, L10)
Ecosite Phase:	Dominantly shrubby (k2) and graminoid (k3) fens; significant Labrador tea-horsetail-spruce (h1)
Surface Stoniness:	Non-stony
Land Use:	Wetland (fen) or subhygric spruce forest

Soil Landscape Models (SLMs):

CHMM1 / FP3 Extent – 634.9 ha; 2.9% of the SSA
FP3 landscape model – confined floodplains; mainly slope classes 1 to 2 (0-3%); most areas dissected by active and abandoned stream channels and a few small ponds
Amalgamated suitability rating for forestry – 4R

CHMM1 / U1l Extent – 314.3 ha; 1.4% of the SSA
U1l landscape model – low-relief undulating; mainly slope class 2 (0.5-2% slopes)
Amalgamated suitability rating for forestry – 4R

Comments:

- CHMM1 soil model occurs in all land systems and has the greatest number of polygons (157) in the SSA. The Lower Dover Plain Land System has the most CHMM1 polygons (and area); the Joslyn Plain has the fewest polygons and area.
- CHMM1 represents wetlands dominated by Gleysolic soils developed on medium to moderately fine to fine textured, mainly water-laid deposits. The Gleysolic soils are highly variable – both CHT and MMW soil complexes are present, expressing differences in peat depth, texture and layering of parent material, and type of Gleysolic development.
- Two CHMM1 SLMs were identified based on different landscape models – CHMM1/FP3 characterized by elongated, confined, stream-course floodplains (i.e. shallow valleys), and CHMM1/U1l embodying much broader, very gently undulating, low-lying plains.

DAPE6 Soil Model

Soil Model (MU) Name:	Daphne-Peavine 6
Extent (ha / % of survey area)	112.1 ha / 0.5% of SSA
Co-dominant Soils (each 30-60%):	DAN (Daphne); PEAxl (Peavine-paralithic/lithic); PEA (Peavine)
Significant Soils (10-30%):	Coarser textured soils: FRTxl and WNFxl variants
Inclusions (<10%):	Narrow depressions between ridges & hummocks with imperfectly (gleyed subgroups) to poorly (Gleysolic or Organic) drained soils
General Landform:	Stony and rocky, bedrock-controlled hummocks and ridges
Surficial (Parent) Materials:	Stony-cobbly, medium textured drift (L19), medium textured (M2, M3), and layered (L18, L20) water-laid materials over bedrock
Ecosite Phase:	Dominantly low-bush cranberry-aspen (d1)
Surface Stoniness:	Exceedingly to very stony (S4-S3); moderately to slightly rocky (R2-R1)
Land Use:	Mainly forested (wooded), with exposed bedrock outcrops

Soil Landscape Models (SLMs):

DAPE6 / HR2hr Extent – 112.1 ha; 0.5% of the SSA
HR2hr landscape model – high-relief, hummocky and ridged terrain overlying bedrock at shallow depths (includes numerous bedrock outcrops); mainly slope class 5 (10-15%) with some 6 (15-30% slope gradients)
Amalgamated suitability rating for forestry – 4MD

Comments:

- DAPE6 soil model occurs only in the Athabasca-Ells Valley Land System, specifically on the upper wall of the Athabasca River valley in the northeast part of the SSA. The terrain is typified by hummocky to ridged topography with short, steep slopes (HR2hr); landform shape is controlled by the underlying bedrock.
- Soils of the DAPE6 soil model have been developed in a complex of shallow (<1 m) to deep (about 1-2 m), glacial drift and water-laid materials overlying partially weathered sandstone and siltstone of the McMurray Formation (Hamilton et al. 1999). The bedrock is usually oil impregnated (i.e. bitumen), and varies in hardness from friable to nearly impenetrable by shovel or hand auger. The overlying parent materials are thought to be lag deposits left behind after an early stage of the post-glacial Athabasca River eroded outwash and other glacial sediments as it down-cut its present-day valley.

- Stones, boulders, and bedrock outcrops (exposures) are common features of the DAPE6 soil model, and limit soil quality for both forest production and reclamation. Surface coarse fragments (cobbles, stones, and boulders) cover approximately 20-30% of the surface, often being concentrated in certain areas (e.g. boulder fields). Bedrock outcrops, including extremely shallow soils that are too thin to support decent tree growth, cover approximately 25% of the land surface. Combined, stoniness and rockiness affect roughly 40-50% of the ground surface of the DAPE6/HR2hr soil landscape model.
- Gentler sloping, less stony and rocky areas do occur within the DAPE6 landscape. These are usually associated with deeper (1-2 m or more) materials and soils like PEA (Peavine). Paralithic or lithic soils (e.g. PEAxl) are also fairly common in this landscape.

DOKM2 Soil Model

Soil Model (MU) Name:	Dover-Kilome 2
Extent (ha / % of survey area)	188.6 ha / 0.9% of SSA
Co-dominant Soils (each 30-60%):	DOV (Dover); KME (Kilome)
Significant Soils (10-30%):	Wetlands with Gleysolics (e.g. CHT, ALG) and Organics (e.g. MLD1m)
Inclusions (<10%):	L10 parent material soils (LVKxc, LVKgl), Solonetzic Gray Luvisols (SEN)
General Landform:	Undulating ground moraine
Surficial (Parent) Materials:	Fine textured (clayey) lacustro-till (F3) or glacial till (F4)
Ecosite Phase:	Dominantly low-bush cranberry-aspen (d1); some areas of blueberry-aspen (b2, b3); small but significant patches of f1, h1, bogs, and fens
Surface Stoniness:	Non-stony
Land Use:	Mainly forested (wooded)

Soil Landscape Models (SLMs):

DOKM2 / U1h Extent – 188.6 ha; 0.5% of the SSA
U1h landscape model – high-relief undulating; slopes mainly class 3 with some 4 (2-10% slope gradients)
Amalgamated suitability rating for forestry – 2R

Comments:

- This soil is often found in areas that are transitional between larger wetlands (e.g. MUS-based map units) and drier uplands (e.g. DOSE1, DOV10 map units). It was mapped only in the Upper Dover Plain Land System.
- DOV soils usually occur on “shedding” (i.e. convex) portions (crest, upper, and upper mid slope positions), KME on “receiving” portions (lower mid and lower slopes) of this gently undulating terrain.
- Wetlands in DOKM2 are discrete depressional areas smaller than the minimum-sized polygon (0.5 ha at 1:10,000 scale). Soils of these wetland segments range from shallow organic soils (peat of about 40-100 cm in thickness) to Gleysols related to the Chateh (CHT), Algar Lake (ALG), and Mamawi (MMW) series. For land capability and other assessments, these wetland soils were factored into the amalgamated (i.e. overall) rating for the SLM using weighted averaging, rather than using a compound rating system (i.e. 80% 2R, 20% 4R or 5OR).

DOLV6 Soil Model

Soil Model (MU) Name:	Dover-Livock 6
Extent (ha / % of survey area)	227.1 ha / 1.0% of SSA
Co-dominant Soils (each 30-60%):	DOV (Dover); LVKxc (Livock-xc)
Significant Soils (10-30%):	Coarser textured soils: WNFxc/MILxc (Winefred-xc/Mildred-xc), FRT (Fort)

Inclusions (<10%):	Imperfectly to poorly drained "wetlands"; M2 & M3 material soils (PEA)
General Landform:	Undulating plain
Surficial (Parent) Materials:	Clayey (F3) lacustro-till and layered (L10 – medium over fine, L9 – coarse over fine, L18 – medium over coarse) deposits
Ecosite Phase:	Dominantly low-bush cranberry-aspen (d1), significant blueberry-aspen (b2)
Surface Stoniness:	Non-stony
Land Use:	Mainly forested (wooded)

Soil Landscape Models (SLMs):

DOLV6 / U1h Extent – 84.4 ha; 0.4% of the SSA
U1h landscape model – high-relief undulating; mainly slope class 3 (2-5% slopes)
Amalgamated suitability rating for forestry – 2R

DOLV6 / U1l Extent – 142.8 ha; 0.7% of the SSA
U1l landscape model – low-relief undulating; mainly slope class 2 (0.5-2% slopes)
Amalgamated suitability rating for forestry – 2R

Comments:

- DOLV6 soil model occurs in the Lower Dover Plain and Joslyn Plain land systems, usually bordering the Ells River and other stream valleys in the SSA. Proximity to these valley systems accounts for the occurrence of glaciofluvial and related water-laid sediments that thinly mantle (typically a veneer <1 m thick) the lacustro-till common throughout the area.
- DOV is developed on clayey lacustro-till (F3); LVKxc is developed on medium textured water-laid material overlying the lacustro-till (L10).
- Soils that are coarser textured than DOV and LVKxc are significant in DOLV6. The coarser textured soils are developed on layered glaciofluvial deposits that overlie the lacustro-till. The main layered glaciofluvial sediments are L9 (coarse over fine) typical of both WNFxc/MILxc soils and L18 (medium over coarse) typical of FRT soils. Both Orthic Gray Luvisol and Eluviated Dystric Brunisol versions of these coarser soils occur in this soil model, e.g. FRT and FRTzb, WNFxc and MILxc.

DOLV9 Soil Model

Soil Model (MU) Name:	Dover-Livock 9
Extent (ha / % of survey area)	1,429.8 ha / 6.5% of SSA
Co-dominant Soils (each 30-60%):	DOV (Dover); LVKxc (Livock-xc)
Significant Soils (10-30%):	Imperfectly drained soils: LVKgl (Livock-gleyed); Kilome (KME) Coarser textured soils: WNFxc/MILxc (Winefred-xc/Mildred-xc); FRT (Fort); PEA (Peavine)
Inclusions (<10%):	Wetlands with Gleysolics (e.g. MMW) and Organics (e.g. MLD1m)
General Landform:	Undulating to hummocky plain
Surficial (Parent) Materials:	Clayey (F3) lacustro-till, layered (L10 – medium over fine, L9 – coarse over fine, L18 – medium over coarse), and medium (M2) textured deposits
Ecosite Phase:	Dominantly low-bush cranberry-aspen (d1, d2); significant blueberry-aspen (b2); small but significant patches of f1, g1,and h1
Surface Stoniness:	Non-stony
Land Use:	Mainly forested (wooded)

Soil Landscape Models (SLMs):

DOLV9 / H1l Extent – 61.4 ha; 0.3% of the SSA
H1l landscape model – low-relief hummocky, including donut-shaped hillocks in some areas; slopes mainly class 4 with some 5 (5-15%)
Amalgamated suitability rating for forestry – 2R

DOLV9 / U1h Extent – 590.6 ha; 2.7% of the SSA
U1h landscape model – high-relief undulating; mainly slope class 3 (2-5% slopes)
Amalgamated suitability rating for forestry – 2R

DOLV9 / U1l Extent – 777.8 ha; 3.6% of the SSA
U1l landscape model – low-relief undulating; mainly slope class 2 (0.5-2% slopes)
Amalgamated suitability rating for forestry – 2R

Comments:

- DOLV9 soil model occurs primarily in the Lower Dover Plain Land System, to a limited extent in the Upper Dover and Joslyn Plain land systems. Most polygons border either stream valleys/channels or large wetlands. Such locations account for the occurrence of glaciofluvial and related water-laid sediments that thinly mantle (typically a veneer <1 m thick) the lacustro-till common throughout the area.
- DOV and KME are developed on clayey lacustro-till (F3); LVKxc and LVKgl are developed on medium textured water-laid material overlying the lacustro-till (L10).
- Soils that are coarser textured than DOV and LVKxc are significant in DOLV9. The coarser textured soils are developed on layered glaciofluvial deposits that overlie the lacustro-till. The main layered glaciofluvial sediments are L9 (coarse over fine) typical of WNFxc/MILxc soils and L18 (medium over coarse) typical of FRT soils. Deeper medium textured water-laid materials (M2) supporting PEA soils are also common. Both Orthic Gray Luvisol and Eluviated Dystric Brunisol versions of these coarser soils occur in this soil model, e.g. FRT and FRTzb, WNFxc and MILxc, PEA and PEAzb.
- Small wetter areas are also significant in the DOLV9 soil model. Most such localities occur as discrete depressional areas smaller than the minimum-sized polygon (0.5 ha at 1:10,000 scale). Soils of these low-lying areas are mainly imperfectly drained Gleyed Gray Luvisols (KME and LVKgl), although Gleysolic and shallow Organic soils can also be found.

DOSE1 Soil Model

Soil Model (MU) Name:	Dover-Steen 1
Extent (ha / % of survey area)	2,607.6 ha / 11.9% of SSA
Co-dominant Soils (each 30-60%):	DOV (Dover); SEN (Steen)
Significant Soils (10-30%):	N/A
Inclusions (<10%):	M4 till soils (HRR); L10 material soils (LVKxc, LVKgl); Gray Solodized Solonetz (JSN); small wetlands and drainage ways with Gleysolic & Organic soils; coarser textured, layered soils (e.g. WNFxc) near stream courses
General Landform:	Hummocky (to ridged) ground moraine
Surficial (Parent) Materials:	Mainly fine textured (clayey) lacustro-till (F3) or glacial till (F4)
Ecosite Phase:	Dominantly low-bush cranberry-aspen (d1)
Surface Stoniness:	Non-stony to slightly stony
Land Use:	Mainly forested (wooded)

Soil Landscape Models (SLMs):

DOSE1 / H1l Extent – 2,607.6 ha / 11.9% of the SSA
H1l landscape model – low-relief hummocky; slopes mainly class 4 with some 5 (5-15%)
Amalgamated suitability rating for forestry – 2R

Comments:

- DOSE1 soil unit typifies the Upper Dover Plain Land System, especially along the western side of SSA. It is the most extensive soil model (and SLM) in the SSA.
- DOV soils (Orthic Gray Luvisol) usually occur on "shedding" (i.e. convex) portions (crest and upper slope positions). Similar soils developed on moderately fine textured, brownish till (Horse River series, HRR), occur in association with DOV soils in the western portion of the SSA.
- Solonetzic Gray Luvisol soils (SEN) occur mainly on mid and lower slopes; Gray Solodized Solonetz (JSN) soils are sometimes associated with SEN. Soil structures that identified SEN and JSN soils were more easily recognized as the soils dried out over the summer, and were easier to see using a shovel rather than an auger. Current vegetation (mainly aspen forest) seems to be relatively unaffected by the presence of Solonetzic-like soils in the landscape.
- The low-relief hummocky terrain of DOSE1/H1l SLM is characterized by short, irregular, complex slopes. In places, the "hummocks" coalesce into ridge-like shapes. Internal relief is typically only 2-3 m and rarely exceeds 5 m. Although slope gradients frequently exceed 5% (3°) through mid slope segments, slope lengths are short and therefore do not pose a significant erosion hazard.

DOSE2 Soil Model

Soil Model (MU) Name:	Dover-Steen 2
Extent (ha / % of survey area)	348.5 ha / 1.6% of SSA
Co-dominant Soils (each 30-60%):	DOV (Dover); SEN (Steen)
Significant Soils (10-30%):	Wetlands with Gleysolic (e.g. CHT, ALG) and Organic (e.g. MLD1m) soils
Inclusions (<10%):	M4 parent material (till) soils (HRR); L3 parent material soils (LVK); Gleyed Gray Luvisols (KME, LVKgl); Gray Solodized Solonetz (JSN)
General Landform:	Hummocky (to ridged) ground moraine
Surficial (Parent) Materials:	Mainly fine textured (clayey) lacustro-till (F3) or glacial till (F4)
Ecosite Phase:	Dominantly low-bush cranberry-aspen (d1); some areas of blueberry-aspen (b2, b3); small but significant patches of f1, h1, bogs, and fens
Surface Stoniness:	Non-stony to slightly stony
Land Use:	Mainly forested (wooded)

Soil Landscape Models (SLMs):

DOSE2 / H1l Extent – 348.5 ha / 1.6% of SSA
H1l landscape model – low-relief hummocky; slopes mainly class 4 with some 5 (5-15%)
Amalgamated suitability rating for forestry – 3SR

Comments:

- DOSE2 soil unit is similar to DOSE1 but features significant area of small wetlands. DOSE2 map unit is often found in areas that are transitional between larger wetlands (e.g. MUS-based soil units) and drier uplands (e.g. DOSE1 soil units).
- DOSE2 soil unit has upland soil patterns similar to those DOSE1, including Orthic Gray Luvisols on hilltops and Solonetzic Gray Luvisols on side slopes (see description above). Topographic

variability (H1l landscape model) is also similar for the one SLM (DOSE2/H1l) attached to this soil model.

- Wetlands in DOSE2 are discrete depressional areas smaller than the minimum-sized polygon (0.25 ha at 1:10,000 scale). Soils of the wetland segments range from shallow Organic soils (peat of about 40-100 cm in thickness) to Gleysols related to the Chateh (CHT), Algar (ALG), and Mamawi (MMW) series. small wetlands (20% 4R or 5OR) included
- Wetlands in DOSE2 are discrete depressional areas smaller than the minimum-sized polygon (0.5 ha at 1:10,000 scale). Soils of these wetland segments range from shallow organic soils (peat of about 40-100 cm in thickness) to Gleysols related to the Chateh (CHT), Algar Lake (ALG), and Mamawi (MMW) series. For land capability and other assessments, these wetland soils were factored into the amalgamated (i.e. overall) rating for the SLM using weighted averaging, rather than using a compound rating system (i.e. 80% 2R, 20% 4R or 5OR).

DOV10 Soil Model

Soil Model (MU) Name:	Dover 10
Extent (ha / % of survey area)	1,602.7 ha / 7.3% of SSA
Dominant Soil (60% or more):	DOV (Dover)
Significant Soils (10-30%):	KME (Kilome); LVKgl (LVK-gleyed); SEN (Steen)
Inclusions (<10%):	L10 parent material soils (LVKxc); small wetlands and drainages; Gray Solodized Solonetz (JSN); M3 parent material soils (TAR)
General Landform:	Undulating plain (or ground moraine)
Surficial (Parent) Materials:	Fine textured (clayey) lacustro-till (F3), overlain in places by medium textured, water-laid veneer (L10)
Ecosite Phase:	Mainly low-bush cranberry-aspen (d1); some areas of blueberry-aspen (b3)
Surface Stoniness:	Non-stony
Land Use:	Mainly forested (wooded)

Soil Landscape Models (SLMs):

DOV10 / U1h	Extent – 1,377.6 ha; 6.3% of the SSA U1h landscape model – high-relief undulating; mainly slope class 3 (2-5% slopes) Amalgamated suitability rating for forestry – 2R
DOV10 / U1l	Extent – 225.1 ha; 1.0% of the SSA U1l landscape model – low-relief undulating; mainly slope class 2 (0.5-2% slopes) Amalgamated suitability rating for forestry – 2R

Comments:

- DOV10 soil model was mapped most extensively in an area spanning the boundary between the Lower and Upper Dover Plain land systems.
- DOV (Orthic Gray Luvisol) soils usually occur on “shedding” (i.e. convex) portions of the landscape (crest and upper slope positions). Other major soil series/variants (KME, LVKgl, SEN) generally occur on mid and lower slope positions, but are otherwise unpredictable in their distribution within the landscape.
- Gleyed Gray Luvisols (KME, LVKgl) are significant in the DOV10 soil model. While not actually occurring under wetland vegetation, these soils favour subhygric conditions, possibly relating to lateral seepage, and are prevalent in lower slope positions. Small discrete depressional areas with wetland vegetation and Gleysolic and Organic soils occur as inclusions.

- Solonetzic Gray Luvisols (SEN) occur mainly on mid slopes. Soil structures that identified SEN and JSN (Gray Solodized Solonetz) soils were more easily recognized as the soils dried out over the summer, and were easier to see using a shovel rather than an auger. Current vegetation (mainly aspen forest) seems to be relatively unaffected by the presence of Solonetzic-like soils in the landscape.
- DOV10/U1h SLM often contains minor elements of rougher (H1l) topography.

FRDA6 Soil Model

Soil Model (MU) Name:	Fort-Daphne 6
Extent (ha / % of survey area)	60.0 ha / 0.3% of SSA
Co-dominant Soils (each 30-60%):	FRT (Fort); FRTxl (Fort-paralithic/lithic); DAN (Daphne)
Significant Soils (10-30%):	Coarser textured soils: WNFxl and MILfi variants
Inclusions (<10%):	Narrow depressions between ridges & hummocks with imperfectly (gleyed subgroups) to poorly (Gleysolic or Organic) drained soils
General Landform:	Stony and rocky, bedrock-controlled ridges
Surficial (Parent) Materials:	Layered (L18, L20), stony to cobbly, medium textured drift (L19), and other water-laid deposits (C3) commonly overlying bedrock
Ecosite Phase:	Dominantly low-bush cranberry-aspen (d1); some low-bush cranberry-aspen-white spruce (d2)
Surface Stoniness:	Very to exceedingly stony (S3-S4); slightly to moderately rocky (R1-R2)
Land Use:	Mainly forested (wooded), with exposed bedrock outcrops

Soil Landscape Models (SLMs):

FRDA6 / R2lr Extent – 60.0 ha; 0.3% of the SSA
R2lr landscape model – low-relief, ridged terrain overlying bedrock at shallow depths (includes some bedrock outcrops); mainly slope classes 3-4 (5-10% slope gradients)
Amalgamated suitability rating for forestry – 4MD

Comments:

- FRDA6 soil model only occurs in the Athabasca-Ells Valley Land System, specifically on the upper wall of the Athabasca River valley in the northeast part of the SSA, often in proximity to polygons mapped as DAPE6 soil models. The terrain is typified by ridged topography with short, moderate slopes (R2lr); landform shape is partially controlled by the underlying bedrock.
- Soils of the FRDA6 soil model have been developed in a complex of shallow (<1 m) to deep (about 1-2 m), glacial drift and water-laid materials overlying partially weathered sandstone and siltstone of the McMurray Formation (Hamilton et al. 1999). The bedrock is usually oil impregnated (i.e. bitumen), and varies in hardness from friable to nearly impenetrable by shovel or hand auger. The overlying parent materials are thought to be lag deposits left behind after an early stage of the post-glacial Athabasca River eroded outwash and other glacial sediments as it down-cut its present-day valley.
- Stones, boulders, and bedrock outcrops (exposures) are common features of the FRDA6 soil model, and limit soil quality for both forest production and reclamation. Surface coarse fragments (cobbles, stones, and boulders) cover approximately 10-30% of the surface, often being concentrated in certain areas (e.g. boulder fields). Bedrock outcrops, including extremely shallow soils that are too thin to support decent tree growth, cover approximately 10-20% of the land surface. Combined, stoniness and rockiness affect roughly 25-40% of the ground surface of the FRDA6/R2lr soil landscape model.

- Gentler sloping, less stony and rocky areas of the FRDA6 landscape are usually associated with deeper (1-2 m or more) materials and soils like FRT (Fort). Other common soils related to FRT are paralithic or lithic variant (e.g. FRTxl) and Eluviated Dystric Brunisol variant (FRTzb).

FRLV2 Soil Model

Soil Model (MU) Name:	Fort-Livock 2
Extent (ha / % of survey area)	132.9 ha / 0.6% of SSA
Co-dominant Soils (each 30-60%):	FRT (Fort); LVK (Livock-xc)
Significant Soils (10-30%):	Wetlands with Gleysolic (e.g. MMW) and Organic (e.g. MLD1m) soils
Inclusions (<10%):	Gleyed Gray Luvisols (FRTgl); M2 & M3 parent material soils (PEA)
General Landform:	Undulating plain
Surficial (Parent) Materials:	Layered (L18 – medium over coarse, L10 – medium over fine) deposits
Ecosite Phase:	Mainly low-bush cranberry (d1, d2, d3) with blueberry-jack pine-aspen (b1); small but significant patches of f3, g1, bogs, and fens
Surface Stoniness:	Non-stony
Land Use:	Mainly forested (wooded)

Soil Landscape Models (SLMs):

FRLV2 / U1h Extent – 66.1 ha; 0.3% of the SSA
U1h landscape model – high-relief undulating; mainly slope class 3 (2-5% slopes)
Amalgamated suitability rating for forestry – 3R

FRLV2 / U1l Extent – 66.8 ha; 0.3% of the SSA
U1l landscape model – low-relief undulating; mainly slope class 2 (0.5-2% slopes)
Amalgamated suitability rating for forestry – 3R

Comments:

- FRLV2 soil model occurs only in the Joslyn Plain Land System, primarily in locations that are transitional between wetlands (e.g. MUS-based map units) and sand-dominated uplands (e.g. MIFR5, MIL5 soil units). Some FRLV2 polygons also border stream valleys/channels. Such locations account for the occurrence of glaciofluvial and related water-laid sediments that thinly mantle (typically a veneer <1 m thick) the terrain.
- FRT and LVKxc are the “upland” soils in this model, and typically occur on crest, upper, and mid slope positions within the landscape. Eluviated Dystric Brunisol variants (FRTzb) are also common.
- Wetlands in FRLV2 are discrete depressional areas smaller than the minimum-sized polygon (0.5 ha at 1:10,000 scale). Soils of these wetland segments range from shallow organic soils (peat of about 40-100 cm in thickness) to Gleysols related mainly to the Mamawi (MMW) series. For land capability and other assessments, these wetland soils were factored into the amalgamated (i.e. overall) rating for the SLM using weighted averaging, rather than using a compound rating system (i.e. 80% 2R, 20% 4R or 5OR).

KMLV1 Soil Model

Soil Model (MU) Name:	Kilome-Livock-gleyed 1
Extent (ha / % of survey area)	1,169.4 ha / 5.4% of SSA
Co-dominant Soils (each 30-60%):	KME (Kilome); LVKgl (Livock-gleyed)
Significant Soils (10-30%):	Drier Luvisols – DOV (Dover) and LVKxc (Livock-xc)
Inclusions (<10%):	Wetlands with Gleysolics (e.g. CHT, MMW); Solonetzic Gray Luvisol (SEN)

Landscape Model:	U1l – low-relief undulating; slopes mainly class 2, some 3 (0.5-3%)
General Landform:	Undulating plain (or ground moraine)
Surficial (Parent) Materials:	Fine textured (clayey) lacustro-till (F3), frequently overlain by medium textured, water-laid veneer (L10)
Ecosite Phase:	Dominantly low-bush cranberry-aspen (d1, d2) grading to blueberry-jack pine-aspen (b1, b2)
Surface Stoniness:	Non-stony
Land Use:	Mainly forested (wooded)
Soil Capability Rating (Forestry):	Amalgamated – Class 1

Soil Landscape Models (SLMs):

KMLV1 / U1h Extent – 583.4 ha; 2.7% of the SSA
U1h landscape model – high-relief undulating; mainly slope class 3 (2-5% slopes)
Amalgamated suitability rating for forestry – 1

KMLV1 / U1l Extent – 586.0 ha; 2.7% of the SSA
U1l landscape model – low-relief undulating; mainly slope class 2 (0.5-2% slopes)
Amalgamated suitability rating for forestry – 1

Comments:

- KMLV1 soil model occurs almost exclusively in the Joslyn Plain Land System, and is typified by imperfectly drained soils.
- The co-dominant soils (KME and LVKgl) are affected by seepage waters and seasonally high water tables perched on somewhat impervious underlying fine textured materials. They are quite wet after thaw in the spring, and dry out to some degree through the summer season. In terms of land capability assessment, these conditions were considered to produce optimum water availability, thereby generating an overall rating of Class 1.
- Vegetation associated with the imperfectly drained soils is classed as aspen or mixed wood forest, but often contains somewhat unusual combinations of dryland and wetland plants. Consequently, moisture regime is gauged to be subhygric. Large conifers are often present but are scattered across the landscape.
- Drier soils (DOV and LVKxc) occur on slightly elevated "shedding" (i.e. convex) portions of the landscape.
- Solonetzic-like soils (SEN) occur as inclusions, generally association with the drier soils.
- Narrow, elongated, drainage channels with wetland vegetation and Gleysolic and Organic soils occur as inclusions.

KMLV2 Soil Model

Soil Model (MU) Name:	Kilome-Livock-gleyed 2
Extent (ha / % of survey area)	797.8 ha / 3.7% of SSA
Co-dominant Soils (each 30-60%):	KME (Kilome); LVKgl (Livock-gleyed)
Significant Soils (10-30%):	Wetlands with Gleysolic (e.g. ALG, CHT, MMW) and shallow Organic (e.g. MLD1m) soils Drier Luvisols – DOV (Dover) and LVKxc (Livock-xc)
Inclusions (<10%):	M2 & M3 material soils (PEA, PEAgl); Solonetzic Gray Luvisol (SEN)
General Landform:	Undulating plain (or ground moraine)
Surficial (Parent) Materials:	Fine textured (clayey) lacustro-till (F3), frequently overlain by medium textured, water-laid veneer (L10)
Ecosite Phase:	Dominantly low-bush cranberry (d1, d2, d3) grading to blueberry-jack pine-

	aspen (b1, b2); small but significant patches of rich fen (k1), Labrador tea-horsetail-spruce (h1), and other wetland types
Surface Stoniness:	Non-stony
Land Use:	Mainly forested (wooded)

Soil Landscape Models (SLMs):

KMLV2 / U1h Extent – 315.1 ha; 1.4% of the SSA
U1h landscape model – high-relief undulating; mainly slope class 3 (2-5% slopes)
Amalgamated suitability rating for forestry – 2R

KMLV2 / U1l Extent – 482.7 ha; 2.2% of the SSA
U1l landscape model – low-relief undulating; mainly slope class 2 (0.5-2% slopes)
Amalgamated suitability rating for forestry – 2R

Comments:

- KMLV1 soil model occurs mostly in the Joslyn Plain Land System, to a limited extent in the Upper Dover Plain Land System, and is typified by imperfectly drained soils. It often occupies land areas that are transitional between true upland soil types (DOSE1 and DOV10 soil models) and wetland landscapes.
- The co-dominant soils (KME and LVKgl) are affected by seepage waters and seasonally high water tables perched on somewhat impervious underlying fine textured materials. They are quite wet after thaw in the spring, and dry out to some degree through the summer season.
- Vegetation associated with the imperfectly drained soils is classed as aspen, spruce, or mixed wood forest, but often contains somewhat unusual combinations of dryland and wetland plants. Consequently, moisture regime is gauged to be subhygric. Large conifers are often present but are scattered across the landscape.
- KMLV2 soil model differs from KMLV1 by having significant wetland areas that are smaller than the minimum-sized polygon (0.5 ha at 1:10,000 scale). The wetland areas commonly occur as narrow, elongated, drainage channels with treed rich fen (k1), Labrador tea/horsetail-spruce (h1), or related vegetation. Soils of the wetland segments are frequently Gleysolic (ALG, CHT, and MMW series and variants); shallow Organic soils (peat of about 40-100 cm in thickness) also occur. For land capability and other assessments, these wetland soils were factored into the amalgamated (i.e. overall) rating for the SLM using weighted averaging, rather than using a compound rating system (i.e. 80% 1, 20% 4R or 5OR).
- Drier soils (DOV and LVK) occur on slightly elevated “shedding” (i.e. convex) portions of the landscape.
- Solonetzic-like soils (SEN) occur as inclusions, generally in association with the drier soils.

LVK4 Soil Model

Soil Model (MU) Name:	Livock 4
Extent (ha / % of survey area)	185.0 ha / 0.8% of SSA
Dominant Soil (60% or more):	LVKxc (Livock-xc)
Significant Soils (10-30%):	Naturally disturbed soils – Brunisols and Regosols
Inclusions (<10%):	Gleyed Gray Luvisols (LVKgl); M2 & M3 parent material soils (PEA); clayey soils (e.g. DOV), including Solonetzic Gray Luvisol (SEN); coarser textured soils on L18 and other layered parent materials (FRT)
General Landform:	Steep, stream-cut slopes that mark upper reaches of the Ells River and Joslyn Creek valleys; rotational slump features are common in several areas; shallow

	gullies (inactive) occur in a few areas
Surficial (Parent) Materials:	Shallow, medium textured, water-laid material overlying clayey material (L10)
Ecosite Phase:	Mainly low-bush cranberry-aspen (d1); some shrubby-bare areas
Surface Stoniness:	Non-stony to slightly stony
Land Use:	Mainly forested (wooded); some bare (i.e. disturbed) areas

Soil Landscape Models (SLMs):

LVK4 / I5 Extent – 185.0 ha; 0.8% of the SSA
I5 landscape model – inclined to steep valley walls with failure slumps in some areas, dissections in others; slope classes 5-7 (10-45% slope gradients)
Amalgamated suitability rating for forestry – 3T

Comments:

- LVK4 soil model represents the steep scarps that mark the edges of the post-glacial (non-modern) upper Ells River and Joslyn Creek valleys where they have been down-cut by the erosive action of major streams.
- Rotational failure slumps are a common feature of this landscape. There was no provision for rotational failure slumps in rating this landform for land capability; consequently severity of slope steepness was increased from 30% to 45% (40 point deduction) to compensate. It is difficult to know how to rate this soil landscape – slumping doesn't seem to be active where it is visible on air photos and hillshade models since tree cover seems good. However, under the right conditions failure slumps might occur in places where the slopes are still steep.
- In areas where there are no slump features, gullied (dissected) slopes frequently occur. Gullied areas are generally no longer active, thus were rated as zero impact in the landscape capability classification.
- The significant soils in this landscape commonly have naturally disturbed (eroded) upper and middle sola. Topsoil horizons (e.g. Ae) may be absent, weakly developed, or mixed with underlying horizons due to tree throw and natural erosion. Some soils have a thin Ah or AB horizon at the mineral surface. In other places, B horizons are absent and the soils show signs of natural disturbance (i.e. soil creep) throughout the upper parts of their profiles.
- Forest vegetation that is reasonably stable covers these slopes in most places. Low-bush cranberry-aspen ecosite phase (d1) predominates, but blueberry-jack pine-aspen (b1, b2) and related vegetation types with white spruce (d2, d3, b3) also occur. Minor amounts of wetland are sometimes trapped in depressional sites created by the rotational slumping.
- Because these landscapes border elongated valleys that have been cut through a variety of geomorphic materials, soils developed in other types of parent materials may also occur. In places the medium textured veneer is absent exposing clayey soils (DOV, SEN); in other places the medium textured material exceeds 1 m thickness (PEA soils). Stratified materials with coarse textured layers also occur in a few localities.

LVK11 Soil Model

Soil Model (MU) Name:	Livock 11
Extent (ha / % of survey area)	660.3 ha / 3.0% of SSA
Dominant Soil (60% or more):	LVKxc (Livock-xc)
Significant Soils (10-30%):	Naturally disturbed soils – Regosols and Brunisols Coarser textured soils: WNFxc (Winefred-xc), MILfi (Mildred-fine) Paralithic/lithic variants of above soils (LVK11/I4 only)
Inclusions (<10%):	Gleyed soils (LVKgl, MMYgl); M2 & M3 parent material soils (PEA, MMY); F3 parent material soils (mainly DOV, DOVzr)
General Landform:	Steep, stream-cut slopes that mark lower reaches of the Ells, MacKay, and

	Joslyn valleys; rotational slump features are common in several areas; shallow gullies (inactive) occur in a few areas; some polygons have exposed bedrock
Surficial (Parent) Materials:	Layered (L10 – medium over fine, L9 – coarse over fine, L20 – coarse over medium) deposits
Ecosite Phase:	Mainly low-bush cranberry types (d1, d2, d3); significant blueberry-jack pine-aspen (b1) and horsetail-balsam poplar-aspen (f1); some shrubby-bare areas
Surface Stoniness:	Non-stony to slightly stony; moderately rocky (R1) in LVK11/I4 SLM
Land Use:	Mainly forested (wooded); some bare (i.e. disturbed) areas

Soil Landscape Models (SLMs):

LVK11 / I4 Extent – 132.6 ha; 0.6% of the SSA
I4 landscape model – inclined to steep valley walls with >10% exposed bedrock; some failure slumps and dissections; slope classes mainly 6-8 (15-70% slope gradients)
Amalgamated suitability rating for forestry – 4TP

LVK11 / I5 Extent – 527.8 ha; 2.4% of the SSA
I5 landscape model – inclined to steep valley walls with failure slumps in some areas, dissections in others; slope classes 5-7 (10-45% slope gradients)
Amalgamated suitability rating for forestry – 3T

Comments:

- LVK11 soil model represents the steep scarps that mark the edges of the post-glacial (non-modern) Ells River, MacKay River, and Joslyn Creek valleys, below (east of) the Upper Dover Plain Land System. The walls of these deeply incised valleys have been formed by the down-cutting, erosive action of the major streams that they contain.
- Rotational failure slumps are a common feature of these landscapes. There was no provision for rotational failure slumps in rating the landforms for land capability; consequently slope steepness severity was increased from 30% to 45% (I5) or 50% (I4) to compensate. It is difficult to know how to rate these soil landscapes – slumping doesn't seem to be active where it is visible on air photos and hillshade models since tree cover seems good. However, under the right conditions failure slumps might occur in places where the slopes are still steep.
- In areas where there are no slump features, gullied (dissected) slopes frequently occur. Gullied areas are generally no longer active, thus were rated as zero impact in the landscape capability classification.
- Exposed bedrock is common (>10%) in the LVK11/I4 SLM where it usually associated with the steepest of slopes. Paralithic/lithic variants of the other major soils are also common in this SLM.
- The significant Regosolic/Brunisolic soils in this landscape commonly have naturally disturbed (eroded) upper and middle sola. Topsoil horizons (e.g. Ae) may be absent, weakly developed, or mixed with underlying horizons due to tree throw and natural erosion. Some soils have a thin Ah or AB horizon at the mineral surface. In other places, B horizons are absent and the soils show signs of natural disturbance (i.e. soil creep) throughout the upper parts of their profiles.
- Forest vegetation that is reasonably stable covers these slopes in most places. Low-bush cranberry types (d1, d2, d3) predominate, but blueberry-jack pine-aspen (b1), horsetail-balsam poplar-aspen (f1), and related vegetation types with white spruce (b2, b3, f2, f3) also occur. Minor amounts of wetland are sometimes trapped in depressional sites created by the rotational slumping.

MIFR5 Soil Model

Soil Model (MU) Name:	Mildred-Fort 5
Extent (ha / % of survey area)	365.0 ha / 1.7% of SSA
Co-dominant Soils (each 30-60%):	MIL (Mildred); FRT (Fort) & FRTzb (Fort-brunisolic)
Significant Soils (10-30%):	Finer textured (including layered) soils (PEA, MILfi, WNFxc, MILxc)
Inclusions (<10%):	Gleyed soils (e.g. FRTgl, MILgl, PEAgl)
General Landform:	Undulating plain
Surficial (Parent) Materials:	Coarse (C2, C3), layered (L18 – medium over coarse, L9 – coarse over fine to medium), and medium (M2, M3) water-laid deposits
Ecosite Phase:	Mainly low-bush cranberry-aspen (d1) and blueberry-aspen-white birch (b2) with significant patches of d2, b1, and other relatively dry forest types
Surface Stoniness:	Non-stony
Land Use:	Mainly forested (wooded)

Soil Landscape Models (SLMs):

MIFR5 / U1h Extent – 287.6 ha; 1.3% of the SSA
U1h landscape model – high-relief undulating; mainly slope class 3 (2-5% slopes)
Amalgamated suitability rating for forestry – 3MR

MIFR5 / U1l Extent – 77.4 ha; 0.4% of the SSA
U1l landscape model – low-relief undulating; mainly slope class 2 (0.5-2% slopes)
Amalgamated suitability rating for forestry – 3MR

Comments:

- MIFR5 soil model occurs almost exclusively in the Joslyn Plain Land System, and is part of the widespread sandy outwash landscapes that typify this area. Two polygons, associated with the Athabasca-Ells Valley Land System, are located high on the valley wall at the confluence of the Ells and Athabasca rivers.
- A complex array of stratified water-laid materials typifies this landscape. Sandy glaciofluvial materials are considered the core materials; they may be overlain or underlain by medium textured strata, and in places are replaced by medium to moderately fine textured sediments.
- Both Orthic Gray Luvisol and Eluviated Dystric Brunisol versions of soils developed on the same types of water-laid materials occur in this soil model, e.g. FRT and FRTzb, PEA and PEAzb, WNFxc and MILxc.

MIL1 Soil Model

Soil Model (MU) Name:	Mildred 1
Extent (ha / % of survey area)	316.7 ha / 1.4% of SSA
Dominant Soil (60% or more):	MIL (Mildred)
Significant Soils (10-30%):	N/A
Inclusions (<10%):	Orthic Dystric Brunisol (MILzo); Finer textured soils (FRTzb, MILxc, PEA)
General Landform:	Undulating (to ridged) plain
Surficial (Parent) Materials:	Very coarse textured glaciofluvial (outwash) material (C2)
Ecosite Phase:	Lichen-jack pine (a1)
Surface Stoniness:	Non-stony
Land Use:	Mainly forested (wooded)

Soil Landscape Models (SLMs):

MIL1 / U1h Extent – 316.7 ha; 1.4% of the SSA
U1h landscape model – high-relief undulating with some ridges (dunes) and

hummocks; slopes mainly class 3 with some 4 (2-10% slope gradients)
Amalgamated suitability rating for forestry – 4MK

Comments:

- MIL1 soil model typifies the sandy outwash landscapes of the Joslyn Plain Land System.
- The undulating glaciofluvial landforms of MIL1/U1h SLM include small, elongated ridges in places. Some of these ridges are likely shallow dunes formed by eolian (wind) re-working of the outwash sands.

MIL5 Soil Model

Soil Model (MU) Name:	Mildred 5
Extent (ha / % of survey area)	329.6 ha / 1.5% of SSA
Dominant Soil (60% or more):	MIL (Mildred)
Significant Soils (10-30%):	Finer textured & layered soils (FRT, MILfi, WNFxc, MILxc)
Inclusions (<10%):	Orthic Dystric Brunisol (MILzo); M2 parent material soils (PEA, PEAzb)
General Landform:	Undulating (to ridged) plain
Surficial (Parent) Materials:	Very coarse glaciofluvial (C2); significant layered (L9, L18) and coarse (C3)
Ecosite Phase:	Mainly blueberry-jack pine-aspen (b1); some other blueberry types (b2, b3, b4)
Surface Stoniness:	Non-stony
Land Use:	Mainly forested (wooded)

Soil Landscape Models (SLMs):

MIL5 / U1h Extent – 329.6 ha; 1.5% of the SSA
U1h landscape model – high-relief undulating with some ridges (dunes) and hummocks; slopes mainly class 3 with some 4 (2-10% slope gradients)
Amalgamated suitability rating for forestry – 4MK

Comments:

- MIL5 soil model occurs only in the Joslyn Plain Land System, and is part of the widespread sandy outwash landscapes that typify this area.
- MIL5 is similar to MIL1 soil model but contains significant amounts of soils that are finer textured than MIL. These finer soils are developed on coarse (SL, C3 type) and layered (L18 – medium over coarse, L9 – coarse over fine to medium) materials. Both Orthic Gray Luvisol and Eluviated Dystric Brunisol versions of the finer soils occur, e.g. FRT and FRTzb, WNFxc and MILxc, PEA and PEAzb.
- The undulating glaciofluvial landforms of MIL5/U1h SLM include small, elongated ridges in places. Some of these ridges are likely shallow dunes formed by eolian (wind) re-working of the outwash sands.

MLD1c-G Soil Model

Soil Model (MU) Name:	McLelland 1c-G
Extent (ha / % of survey area)	180.0 ha / 0.8% of SSA
Dominant Soil (60% or more):	MLD1c (McLelland-shallow over clayey substrate)
Significant Soils (10-30%):	Gleysolic soils, both peaty and non-peaty (e.g. ALG, CHT, MMW)
Inclusions (<10%):	Organic soils with thicker (100-200 cm) peat deposits; water bodies
General Landform:	Shallow peat fens on confined floodplains or low-lying, nearly level plains
Surficial (Parent) Materials:	Shallow (40-100 cm) fen peat over clayey, water-laid and glacial materials (L13)
Ecosite Phase:	Shrubby and graminoid rich fen (k2, k3); some treed rich fen (k1)
Surface Stoniness:	Non-stony
Land Use:	Wetland (fen)

Soil Landscape Models (SLMs):

MLD1c-G / O3 Extent – 98.0 ha; 0.4% of the SSA
O3 landscape model – confined floodplain with channels; slope classes 1-2 (0-3% slopes)
Amalgamated suitability rating for forestry – 5OR

MLD1c-G / O5 Extent – 82.1 ha; 0.4% of the SSA
O5 landscape model – "level" organic landform with small raised knolls and hummocks of mineral soils; slope classes 2-4 (0.5-10% slopes)
Amalgamated suitability rating for forestry – 5OR

Comments:

- MLD1c-G soil model occurs only in the Lower and Upper Dover Plain land systems, and represents wetlands dominated by shallow fen peat overlying clayey mineral substrate. Textures of the underlying mineral substrate commonly fit the fine textural group (refer to Figure A-1).
- Current vegetation is fen, and fen peat dominates the surface organic materials of these soils. Organic soils dominate. Gleysolic soils occur where the peat deposits are not as thick and well developed.
- While being quite variable across the landscape, peat thickness was interpreted as mainly between 40 and 100 cm for the dominant Organic soils.
- MLD1c-G soil model was fairly restricted in its application to polygons where site inspection data indicated the predominance of clayey substrate beneath the organic materials. Where the nature of the substrate was uncertain or where medium, coarse, or fine textured materials were mixed or layered, MLD1m-G (see next description) was usually applied as the "default" soil model.

MLD1m-G Soil Model

Soil Model (MU) Name:	McLelland 1m-G
Extent (ha / % of survey area)	858.8 ha / 3.9% of SSA
Dominant Soil (60% or more):	MLD1m (McLelland-shallow over medium textured mineral substrate)
Significant Soils (10-30%):	Gleysolic soils, both peaty and non-peaty (e.g. mainly MMW variants)
Inclusions (<10%):	Organic soils with thicker (100-200 cm) peat deposits; shallow Organic soils with clayey mineral substrate; other Gleysolic soils (e.g. ALG, BMT, CHT); Gleyed Gray Luvisols; water bodies
General Landform:	Shallow peat fens on confined floodplains or low-lying, nearly level plains
Surficial (Parent) Materials:	Shallow (40-100 cm) fen peat over medium textured, water-laid materials (L12)
Ecosite Phase:	Mainly treed and shrubby rich fen (k1, k2); significant graminoid rich fen (k3) and Labrador tea/horsetail-spruce (h1); some horsetail types (f3, f1)
Surface Stoniness:	Non-stony
Land Use:	Wetland (fen)

Soil Landscape Models (SLMs):

MLD1m-G / O3 Extent – 517.3 ha; 2.4% of the SSA
O3 landscape model – confined floodplain with channels; slope classes 1-2 (0-3% slopes)
Amalgamated suitability rating for forestry – 5OR

MLD1m-G / O5 Extent – 341.4 ha; 1.6% of the SSA
O5 landscape model – "level" organic landform with small raised knolls and hummocks of mineral soils; slope classes 2-4 (0.5-10% slopes)
Amalgamated suitability rating for forestry – 5OR

Comments:

- MLD1m-G soil model occurs in all land systems and represents wetlands dominated by shallow fen peat overlying medium textured mineral substrate. Textures of the underlying mineral substrate commonly fit the medium textural group (refer to Figure A-1).
- Organic soils dominate this soil model, and fen peat dominates the surface organic materials of these soils. Gleysolic soils occur where the peat deposits are not as thick and well developed.
- While being quite variable across the landscape, peat thickness was interpreted as mainly between 40 and 100 cm for the dominant Organic soils.
- Current vegetation is predominantly rich fen. Relatively wet forest vegetation types (h1, f3, f1) occur at the margins of MLD1m-G polygons and on slightly raised knolls and hummocks where the soils may not be as water-logged.
- MLD1m-G was the most widely applied soil model for fen-dominated landscapes with shallow Organic soils. While characterized by medium textured mineral materials underlying the peat, layered mineral materials (medium overlying clayey) were also covered by this map unit. In polygons where the nature of the mineral substratum was uncertain, or where medium, coarse, or fine textured materials were mixed or layered, MLD1m-G was usually applied as the "default" soil model.

MLD1s-G Soil Model

Soil Model (MU) Name:	McLelland 1s-G
Extent (ha / % of survey area)	25.9 ha / 0.1% of SSA
Dominant Soil (60% or more):	MLD1m (McLelland-shallow over coarse textured mineral substrate)
Significant Soils (10-30%):	Gleysolic soils, both peaty and non-peaty (e.g. mainly BMT variants)
Inclusions (<10%):	Organic soils with thicker (100-200 cm) peat deposits; shallow Organic soils with medium mineral substrate; other Gleysolic soils (e.g. MMW); water bodies
General Landform:	Shallow peat fens on low-lying, nearly level plains
Surficial (Parent) Materials:	Shallow (40-100 cm) fen peat over coarse textured, water-laid materials (L11)
Ecosite Phase:	Mainly treed & shrubby rich fen (k1, k2); some Labrador tea/horsetail-spruce (h1)
Surface Stoniness:	Non-stony
Land Use:	Wetland (fen)

Soil Landscape Models (SLMs):

MLD1s-G / O5 Extent – 25.9 ha; 0.1% of the SSA
O5 landscape model – "level" organic landform with small raised knolls and hummocks of mineral soils; slope classes 2-4 (0.5-10% slopes)
Amalgamated suitability rating for forestry – 5OR

Comments:

- MLD1s-G soil model occurs only in the Joslyn Plain Land System, and represents wetlands dominated by shallow fen peat overlying coarse textured mineral substrate. Textures of the underlying mineral substrate commonly fit the coarse textural group (refer to Figure A-1).
- Organic soils dominate this soil model, and fen peat dominates the surface organic materials of these soils. Gleysolic soils occur where the peat deposits are not as thick and well developed.
- While being quite variable across the landscape, peat thickness was interpreted as mainly between 40 and 100 cm for the dominant Organic soils.
- Current vegetation is predominantly rich fen. Relatively wet forest vegetation types (h1) occur at the margins of MLD1s-G polygons and on slightly raised knolls and hummocks where the soils may not be as water-logged.

- MLD1s-G soil model was fairly restricted in its application to polygons where site inspection data indicated the predominance of coarse textured substrate beneath the organic materials. Where the nature of the substrate was uncertain or where medium, coarse, or fine textured materials were mixed or layered, MLD1m-G (see previous description) was usually applied as the "default" soil model.

MLD2c Soil Model

Soil Model (MU) Name:	McLelland 2c
Extent (ha / % of survey area)	10.8 ha / 0.05% of SSA
Dominant Soil (60% or more):	MLD (McLelland) series and variants (peat 100-200 cm thick)
Significant Soils (10-30%):	N/A
Inclusions (<10%):	Organic soils with thinner (40-100) and thicker (>200 cm) peat; Organic soils with medium textured mineral substrate; Gleysolic soils
General Landform:	Fen wetlands occupying broad, low-lying areas
Surficial (Parent) Materials:	Moderately deep (100-200 cm) fen or mixed peat overlying fine textured, water-laid and glacial materials (mainly P2)
Ecosite Phase:	Mainly shrubby and graminoid rich fen (k2, k3)
Surface Stoniness:	Non-stony
Land Use:	Wetland (fen)

Soil Landscape Models (SLMs):

MLD2c / O1 Extent – 10.8 ha; 0.05% of the SSA
O1 landscape model – level wetland with internal undulations; slope classes 1-3 (0-5%)
Amalgamated suitability rating for forestry – 5OR

Comments:

- MLD2c soil model occurs only in the Lower and Upper Dover Plain land systems and accounts for the smallest area (10.8 ha, 0.05%) of the SSA. MLD2c SM represents wetlands dominated by moderately thick fen peat overlying clayey mineral substrate. Textures of the underlying mineral substrate commonly fit the fine textural group (refer to Figure A-1).
- Current vegetation is rich fen, and fen peat dominates the surface organic materials of these soils. While being quite variable across the landscape, peat thickness was interpreted as mainly between 100 and 200 cm for the dominant Organic soils. The undulating peat surface often reflects varying peat thickness.
- MLD2c soil model was fairly restricted in its application to polygons where site inspection data indicated the predominance of clayey substrate beneath moderately thick organic materials. Where the nature of the substrate was uncertain, or where medium, coarse, or fine textured materials were mixed or layered, MLD2m (see next description) was usually applied as the "default" soil model.

MLD2m Soil Model

Soil Model (MU) Name:	McLelland 2m
Extent (ha / % of survey area)	377.7 ha / 1.7% of SSA
Dominant Soil (60% or more):	MLD (McLelland) series and variants (peat 100-200 cm thick)
Significant Soils (10-30%):	N/A
Inclusions (<10%):	Organic soils with thinner (40-100) and thicker (>200 cm) peat deposits; Organic soils with clayey or sandy mineral substrate; Gleysolic soils
General Landform:	Fen wetlands occupying broad, low-lying areas
Surficial (Parent) Materials:	Moderately deep (100-200 cm) fen or mixed peat overlying medium textured water-laid materials (mainly P2)

Ecosite Phase:	Mainly shrubby rich fen (k2); significant treed and graminoid rich fen (k1, k3)
Surface Stoniness:	Non-stony
Land Use:	Wetland (fen)

Soil Landscape Models (SLMs):

MLD2m / O1 Extent – 377.7 ha; 1.7% of the SSA
O1 landscape model – level wetland with internal undulations; slope classes 1-3 (0-5%)
Amalgamated suitability rating for forestry – 5OR

Comments:

- MLD2m soil model occurs in the Upper and Lower Dover Plain and Joslyn Plain land systems, and represents wetlands dominated by moderately thick fen peat overlying medium textured mineral substrate. Textures of the underlying mineral substrate commonly fit the medium textural group (refer to Figure A-1).
- Current vegetation is rich fen, and fen peat dominates the surface organic materials of these soils. While being quite variable across the landscape, peat thickness was interpreted as mainly between 100 and 200 cm for the dominant Organic soils. The undulating peat surface often reflects varying peat thickness.
- MLD2m was the most widely applied soil model for fen-dominated landscapes with moderately deep Organic soils. While characterized by medium textured mineral materials underlying the peat, layered mineral materials (medium overlying clayey) were also covered by this map unit. Actually, MLD2c soil model was the most common inclusion in polygons mapped as MLD2m. In polygons where the nature of the mineral substratum was uncertain, or where medium, coarse, or fine textured materials were mixed or layered, MLD2m was usually applied as the "default" soil model.
- MLD2m soil model was mapped only with the O1 LM (level Organic wetlands). However, a few polygons with the same soil pattern were basin-like (O2) or had somewhat rougher surfaces (O5).

MLD2s Soil Model

Soil Model (MU) Name:	McLelland 2s
Extent (ha / % of survey area)	34.3 ha / 0.2% of SSA
Dominant Soil (60% or more):	MLD (McLelland) series and variants (peat 100-200 cm thick)
Significant Soils (10-30%):	N/A
Inclusions (<10%):	Organic soils with thinner (40-100) and thicker (>200 cm) peat deposits; Organic soils with medium textured mineral substrate; Gleysolic soils
General Landform:	Fen wetlands occupying broad, low-lying areas
Surficial (Parent) Materials:	Moderately deep (100-200 cm) fen or mixed peat overlying coarse textured, water-laid materials (mainly P2)
Ecosite Phase:	Mainly shrubby rich fen (k2); significant treed and graminoid rich fen (k1, k3)
Surface Stoniness:	Non-stony
Land Use:	Wetland (fen)

Soil Landscape Models (SLMs):

MLD2s / O1 Extent – 34.3 ha; 0.2% of the SSA
O1 landscape model – level wetland with internal undulations; slope classes 1-3 (0-5%)
Amalgamated suitability rating for forestry – 5OR

Comments:

- MLD2s soil model occurs only in the Joslyn Plain Land System, and represents wetlands dominated by moderately thick fen peat overlying coarse textured mineral substrate. Textures of the underlying mineral substrate commonly fit the coarse textural group (refer to Figure A-1).
- Current vegetation is rich fen, and fen peat dominates the surface organic materials of these soils. While being quite variable across the landscape, peat thickness was interpreted as mainly between 100 and 200 cm for the dominant Organic soils. The undulating peat surface often reflects varying peat thickness.
- MLD2s soil model was fairly restricted in its application to polygons where site inspection data indicated the predominance of coarse textured substrate beneath moderately deep organic materials. Where the nature of the substrate was uncertain, or where medium, coarse, or fine textured materials were mixed or layered, MLD2m (see previous description) was usually applied as the "default" soil model.

MLD3 Soil Model

Soil Model (MU) Name:	McLelland 3
Extent (ha / % of survey area)	29.9 ha / 0.1% of SSA
Dominant Soil (60% or more):	MLD (McLelland) series and variants (peat >200 cm thick)
Significant Soils (10-30%):	N/A
Inclusions (<10%):	Organic soils with thinner (40-200 cm) peat deposits; minor Organic Cryosols
General Landform:	Mainly confined depressions within rougher upland terrain that dominates the western part of SSA
Surficial (Parent) Materials:	Deep (>200 cm) fen or mixed peat (P2)
Ecosite Phase:	Shrubby and graminoid rich fen (k2, k3)
Surface Stoniness:	Non-stony
Land Use:	Wetland (fen)

Soil Landscape Models (SLMs):

MLD3 / O2 Extent – 29.9 ha; 0.1% of the SSA
O2 landscape model – basin-like (bowl) depressions; peat surface often undulating, occasionally hummocky; slope classes 1-3 (0-5%)
Amalgamated suitability rating for forestry – 5OR

Comments:

- MLD3 soil model occurs only in the Upper Dover Plain Land System, and represents wetlands dominated by thick (>200 cm) fen peat. MLD3 polygons occur as small, discrete basins scattered throughout the hummocky uplands of this land system, or as larger basin-like wetlands that border two distinctive lakes in the area.
- Current vegetation is rich fen, and fen peat dominates the surface organic materials of these soils. Other types of peat (bog peat, organic material high in wood fragments) may occur deeper in the soil profile.
- While being quite variable across the landscape, peat thickness was interpreted as exceeding 200 cm for the dominant Organic soils. The undulating, occasionally hummocky, peat surface often reflects varying peat thickness. Soils with thinner peat deposits do occur, especially near margins of these "peat basins".
- The fringes of these wetland depressions may have soils with shallower peat (peaty Gleysols and shallow Organics) and different vegetation.
- Some elevated mounds in these basins occasionally have permanently frozen peat soils, classified at the Great Group level as Organic Cryosols. Organic soils with permanently frozen layers

below 100 cm also occur. Organic soils with permafrost layers are more common under bog vegetation (MUS3, see below).

MMW2 Soil Model

Soil Model (MU) Name:	Mamawi 2
Extent (ha / % of survey area)	231.3 ha / 1.1% of SSA
Co-dominant Soils (each 30-60%):	MMW (Mamawi) soil complex (both peaty and non-peaty); Water bodies
Significant Soils (10-30%):	N/A
Inclusions (<10%):	Shallow Organic soils (MLD1m); Other Gleysolic soils (ALG and CHT)
General Landform:	Confined stream course/valley floodplains with ponded areas
Surficial (Parent) Materials:	Medium textured (M3) and medium overlying fine textured (L10) water-laid deposits (fluvial, fluviolacustrine, or lacustrine origin)
Ecosite Phase:	Marsh (l1), graminoid and shrubby fen (k3, k2), and flooded areas (NWF)
Surface Stoniness:	Non-stony
Land Use:	Wetland (marsh, fen, and water)

Soil Landscape Models (SLMs):

MMW2 / FP3 Extent – 231.3 ha; 1.1% of the SSA
FP3 landscape model – confined floodplains; mainly slope classes 1 to 2 (0-3%); most areas dissected by active and abandoned stream channels and ponds
Amalgamated suitability rating for forestry – 5R

Comments:

- MMW2 soil model occurs in all land systems. The Lower Dover Plain Land System has the most MMW2 polygons; the Joslyn Plain and Athabasca-Ells Valley each have only a few polygons.
- MMW2/FP3 characterizes very low-lying segments of confined stream courses (i.e. shallow valleys). It consists of wetlands dominated by Gleysolic soils and water. Water bodies (sloughs, ponds, and small lakes) are an important part of this map unit. Water bodies include areas ponded by damming, especially through the activities of beaver.
- Each tract (i.e. polygon) typically contains one main meandering stream, which is usually permanent. The stream occupies a distinctive channel cut into the floodplain. Other old and often abandoned channels may also be present. Beaver "runs" may also dissect the floodplain.
- Gleysolic soils are highly variable – MMW soil complexes dominate, with series and variants expressing differences in peat depth, layering of parent material, and type of Gleysolic development. Algar Lake (ALG) and Chateh (CHT) soil complexes may also be found (inclusions).
- In some localities, peat has had a chance to build up to thicknesses exceeding 40 cm. Consequently, shallow Organic soils (MLD1m complex) are considered common inclusions (i.e. 5-10% of the soil model).
- MMW2 and "Water" soil models are similar, except that "Water" is dominated by water bodies.

MMW21 Soil Model

Soil Model (MU) Name:	Mamawi 21
Extent (ha / % of survey area)	113.6 ha / 0.5% of SSA
Co-dominant Soils (each 30-60%):	MMW (Mamawi) soil complex (both peaty and non-peaty)
Significant Soils (10-30%):	Shallow Organic soils (MLD1m); finer (ALG & CHT complexes) and coarser (BMTxc complex) textured Gleysolic soils
Inclusions (<10%):	Gleyed Gray Luvisols (e.g. PEAgl)
General Landform:	Low-lying level plains, in some cases including broad drainage channels
Surficial (Parent) Materials:	Medium textured (M2, M3), layered (L9, L10), and fine textured (F1, F3)

	deposits with areas of shallow (40-100 cm) peat
Ecosite Phase:	Mainly Labrador tea/horsetail-spruce (h1) and treed poor fen (j1); other relatively wet types (i1, f1, f3, k3) may also occur
Surface Stoniness:	Non-stony
Land Use:	Wetland (various types)

Soil Landscape Models (SLMs):

MMW21 / U1h Extent – 28.4 ha; 0.1% of the SSA
U1h landscape model – high-relief undulating; mainly slope class 3 (2-5% slopes)
Amalgamated suitability rating for forestry – 4R

MMW21 / U1l Extent – 85.1 ha; 0.4% of the SSA
U1l landscape model – low-relief undulating; mainly slope class 2 (0.5-2% slopes)
Amalgamated suitability rating for forestry – 4R

Comments:

- MMW21 soil model occurs only in the Joslyn Plain Land System, where it represents wetlands dominated by various Gleysolic soils with significant shallow Organic soils.
- Gleysolic soils are highly variable – MMW soil complexes dominate, with series and variants expressing differences in peat depth, layering of parent material, and type of Gleysolic development. Algar Lake (ALG), Bitumount-clayey subsoil (BMTxc), and Chateh (CHT) soil complexes are also reasonably common (listed collectively as significant soils).
- In some localities, peat has had a chance to build up to thicknesses exceeding 40 cm. Consequently, shallow Organic soils (MLD1m complex) are also considered as significant soils (i.e. 10-30% of the SM).
- Vegetation patterns associated with the MMW21 soil model are, like the soils, highly complex. Most polygons (i.e. map delineations) have some combination of forest cover and wetland vegetation.

MMY2 Soil Model

Soil Model (MU) Name:	McMurray 2
Extent (ha / % of survey area)	732.5 ha / 3.4% of SSA
Co-dominant Soils (each 30-60%):	MMY (McMurray); Gleyed, humic variants of MMY (MMYzhgl, MMYgl)
Significant Soils (10-30%):	Wetlands with Gleysolic soils (e.g. CHT, MMW variants)
Inclusions (<10%):	Other Regosols, Luvisolic soils on stable, elevated slopes; shallow Organic soils (MLD1m)
General Landform:	Confined stream course/valley floodplains associated with major streams
Surficial (Parent) Materials:	Medium textured (M2, M3) and layered (L10, L20) fluvial deposits
Ecosite Phase:	Mainly horsetail-balsam poplar-aspen (f1) or low-bush cranberry-white spruce (d3); significant shrubby rich fen (k2) and other wetland types; dogwood (e1, e2, e3) and other horsetail (f2, f3) types also occur
Surface Stoniness:	Mainly non-stony; some areas slightly stony (mostly in MMY2/SC2 SLM)
Land Use:	Mainly forested (wooded) riparian habitat

Soil Landscape Models (SLMs):

MMY2 / SC1 Extent – 516.3 ha; 2.4% of the SSA
SC1 landscape model – valley-bottom floodplain with channels, including small scarps & valley walls in places; slope classes 3-5 (2-15% slope gradients)
Amalgamated suitability rating for forestry – 2V

MMY2 / SC2 Extent – 216.2 ha; 1.0% of the SSA
SC2 landscape model – terraced valley bottom with risers and channels; slopes mainly classes 2-3 with some 4-5 (overall slope gradient range 0.5-15%)
Amalgamated suitability rating for forestry – 2V

Comments:

- MMY2 soil model occurs in all land systems, and represents relatively dry, modern floodplains associated with Joslyn Creek, Ells River, MacKay River, and some of their major tributaries. "Relatively dry" refers to the prevailing subhygric to mesic moisture regime and imperfectly to moderately well drained soils. "Modern" implies that MMY2 landforms are still actively changing and forming.
- The soils in this type of terrain are highly variable – most fall within the Regosolic Order (poorly developed), mainly because of frequent deposition of fluvial materials on the floodplain. Parent material textures are predominantly medium (SiL-L), but coarser (SL) and finer (SiCL, CL, SCL) layers also occur.
- Most of the Regosolic soils are layered – former surfaces appear as buried organo-mineral layers – hence the term "Cumulic". The mineral soil surface (topsoil) typically has high organic matter (1% or more organic carbon content), even if Ah horizons are not present.
- The main soils (MMY complex) seem quite acidic in the Joslyn Lease area, based on analytical results for the sampled MMYzhgl pedon (refer to Appendix A). Free carbonates are found only occasionally in these soils, most often on the east side of the SSA. These soil characteristics imply that the fluvial sediments were derived by erosion of surface mineral layers in adjacent upland areas.
- Poorly drained wetlands in MMY2 are small (less than 0.5 ha), and often occur in oxbow channels. Soils of these wetland segments, mostly fens (k2), are dominated by a variety of Gleysolic soils (mainly variants of CHT and MMW). A few shallow Organic soils also occur. For land capability and other assessments, these wetland soils were factored into the amalgamated (i.e. overall) rating using weighted averaging, rather than using a compound rating system (i.e. 80% 2V, 20% 4R).
- Landscape model SC1 (MMY2/SC1 SLM) features irregular, complex surfaces typified by active and abandoned channels, small terraces, and even some small scarps. Steep side slopes that border these floodplains were mapped as LVK4 or LVK11 soil models if large enough. In some MMY2/SC1 polygons however, small remnants of the steep side slopes were included because they were too small to map independently.
- Landscape model SC2 (MMY2/SC2 SLM) is typified by terraced terrain, and occurs only within the Ells, MacKay, and Athabasca river valleys. A terrace is a land surface form consisting of a lower or front slope (the riser) and a broad, relatively level surface (the tread); the tread may be bounded by another terrace or a steep ascending valley wall slope. In the Joslyn SSA, MMY2/SC2 polygons normally contain multiple terraces, truncated in places by oxbow channels. The steep valley walls that bound these prominent valleys commonly occur above the MMY2/SC2 terraces, and were usually mapped as LVK11 soil model.

MMY6 Soil Model

Soil Model (MU) Name:	McMurray 6
Extent (ha / % of survey area)	50.9 ha / 0.2% of SSA
Dominant Soil (60% or more):	Mainly Cumulic Regosols (MMY)
Significant Soils (10-30%):	Coarser textured soils: MILxm (Mildred-xm), MILfi (Mildred-fine); Paralithic/lithic variants (MMYxl, MILxl)
Inclusions (<10%):	Gleyed & Humic Regosols (MMYgl, MMYzhgl)
General Landform:	Terraced and channelled bottomland within the Ells & Athabasca river valleys
Surficial (Parent) Materials:	Medium (M2, M3) and coarse (C2, C3) textured fluvial sediments, in places shallow over bedrock
Ecosite Phase:	Mainly low-bush cranberry-aspen types (d1, d2); some spruce types (d3, f1)
Surface Stoniness:	Non-stony to slightly stony (buried gravels in places)
Land Use:	Mainly forested (wooded) riparian habitat

Soil Landscape Models (SLMs):

MMY6 / SC2r Extent – 50.9 ha; 0.2% of the SSA
SC2r landscape model – terraced valley bottom with risers and channels, in places overlying bedrock at shallow depths; slopes mainly classes 2-3 (0.5-5%)with minor 4-5 (risers and small scarps)
Amalgamated suitability rating for forestry – 3SR

Comments:

- MMY6 soil model occurs only in the Athabasca-Ells Valley Land System at the eastern margin of the SSA, and represents dry, terraced, valley bottom. Moisture regime is mainly mesic, associated with well to moderately well drained soils. MMY6 landforms are considered "modern" in that they are still actively changing and forming.
- The soils in this type of terrain are highly variable – most fall within the Regosolic Order (poorly developed), mainly because of frequent deposition of fluvial materials on the floodplain. Parent material textures are predominantly medium (SiL-L) to coarse (SL-LS), but finer (SiCL, CL, SCL) layers also occur.
- Most of the Regosolic soils are layered – former surfaces appear as buried organo-mineral layers – hence the term "Cumulic". The mineral soil surface (topsoil) typically has high organic matter (1% or more organic carbon content), even if Ah horizons are not present.
- Soils that are coarser textured than MMY soils are significant in MMY6. The coarser textured soils are developed mainly on sandy loam fluvial deposits (C3, MILfi variant) that may include coarser (LS-S) layers. In some places, the coarse textured material overlies medium textured (FSL-L-SiL) layers (L20, MILxm).
- In about 30% of MMY6 landscape, the fluvial materials are shallow (<1 m), overlying partially weathered sandstone and siltstone of the McMurray Formation (Hamilton et al. 1999). The bedrock is often oil impregnated, and varies in hardness from friable to nearly impenetrable by shovel or hand auger.
- Landscape model SC2r (MMY6/SC2r SLM) is typified by terraced terrain. A terrace is a land surface form consisting of a lower or front slope (the riser) and a broad, relatively level surface (the tread); the tread may be bounded by another terrace or a steep ascending valley wall slope. In the Joslyn SSA, MMY6/SC2r polygons normally contain multiple terraces, truncated in places by channels. Steep valley walls, likely mapped as LVK11 soil model, usually occur above the MMY6/SC2r terraces. The "r" modifier of SC2r LM denotes shallow depth to bedrock, which is particularly true in some portions of the landscape.
- MMY6 and PELV11 soil models are similar in that they occur on terraced terrain comprised of water-laid parent materials situated on the valley floors of the Ells, MacKay, and Joslyn water

courses. There is substantial difference in degree of soil development however – MMY6 is dominated by Regosolic soils whereas PELV1 (see below) is dominated by Luvisolic soils. Regosolic soil development (MMY6) implies young and possibly still evolving landscape. Luvisolic soil development implies much older, geomorphically more stable terrain. In addition, MMY6 occurs only along the lower reaches of Joslyn Creek and Ells River, and along the Athabasca River; most terraced terrain upstream from these locations were mapped as PELV11 soil model.

MUS1c-G Soil Model

Soil Model (MU) Name:	Muskeg 1c-G
Extent (ha / % of survey area)	1,970.9 ha / 9.0% of SSA
Dominant Soil (60% or more):	MUS1c (Muskeg-shallow over clayey substrate)
Significant Soils (10-30%):	Gleysolic soils, both peaty and non-peaty (e.g. ALG, CHT, MMW)
Inclusions (<10%):	Organic soils with thicker (100-200 cm) peat deposits; shallow Organic soils with medium textured mineral substrate
General Landform:	Shallow peat bogs and poor fens on low-lying, nearly level plains
Surficial (Parent) Materials:	Shallow (40-100 cm) bog peat over clayey, water-laid and glacial materials (L13)
Ecosite Phase:	Treed and shrubby bog (i1, i2); treed and shrubby poor fen (j1, j2)
Surface Stoniness:	Non-stony
Land Use:	Wetland (bog or poor fen)

Soil Landscape Models (SLMs):

MUS1c-G / O5 Extent – 1,970.9 ha / 9.0% of the SSA
O5 landscape model – "level" organic landform with small raised knolls and hummocks of mineral soils; slope classes 2-4 (0.5-10% slopes)
Amalgamated suitability rating for forestry – 5SR

Comments:

- MUS1c-G soil model occurs extensively in the Lower Dover Plain Land System, with a few polygons in the Upper Dover Plain and Joslyn Plain land systems. It represents wetlands dominated by shallow bog peat overlying clayey mineral substrate. Textures of the underlying mineral substrate commonly fit the fine textural group (refer to Figure A-1).
- Current vegetation is bog or poor fen; bog peat dominates the surface organic layers of these soils. Other types of peat (fen peat, organic material high in wood fragments) may occur deeper in the soil profile.
- Organic soils dominate. Gleysolic soils occur where the peat deposits are not as thick and well developed.
- While being quite variable across the landscape, peat thickness was interpreted as mainly between 40 and 100 cm for the dominant Organic soils.
- MUS1c-G soil model was fairly restricted in its application to polygons where site inspection data indicated the predominance of clayey substrate beneath the organic materials. Where the nature of the substrate was uncertain, or where medium, coarse, or fine textured materials were mixed or layered, MUS1m-G (see next description) was usually applied as the "default" soil model.

MUS1m-G Soil Model

Soil Model (MU) Name:	Muskeg 1m-G
Extent (ha / % of survey area)	1,384.5 ha / 6.3% of SSA
Dominant Soil (60% or more):	MUS1m (Muskeg-shallow over medium textured substrate)
Significant Soils (10-30%):	Gleysolic soils, both peaty and non-peaty (e.g. ALG, BMT, CHT, MMW)
Inclusions (<10%):	Organic soils with thicker (100-200 cm) peat deposits; shallow Organic soils with

	clayey or sandy mineral substrate; Organic Cryosol soils
General Landform:	Shallow peat bogs and poor fens on low-lying, nearly level plains
Surficial (Parent) Materials:	Shallow (40-100 cm) bog peat over medium textured, water-laid materials (L12)
Ecosite Phase:	Treed and shrubby bog (i1, i2); treed and shrubby poor fen (j1, j2)
Surface Stoniness:	Typically non-stony; stony-bouldery patches in polygons along Athabasca River
Land Use:	Wetland (bog or poor fen)

Soil Landscape Models (SLMs):

MUS1m-G / O5 Extent – 1,384.5 ha / 6.3% of the SSA
O5 landscape model – "level" organic landform with small raised knolls and hummocks of mineral soils; slope classes 2-4 (0.5-10% slopes)
Amalgamated suitability rating for forestry – 5SR

Comments:

- MUS1c-G soil model occurs in all land systems and represents wetlands dominated by shallow bog peat overlying medium textured mineral substrate. Textures of the underlying mineral substrate commonly fit the medium textural group (refer to Figure A-1).
- Current vegetation is bog or poor fen; bog peat dominates the surface organic layers of these soils. Other types of peat (fen peat, organic material high in wood fragments) may occur deeper in the soil profile.
- Organic soils dominate. Gleysolic soils occur where the peat deposits are not as thick and well developed.
- While being quite variable across the landscape, peat thickness was interpreted as mainly between 40 and 100 cm for the dominant Organic soils.
- MUS1m-G was the most widely applied soil model for bog-dominated landscapes with shallow Organic soils. While characterized by medium textured mineral materials underlying the peat, layered mineral materials (medium overlying clayey) were also covered by this map unit. In polygons where the nature of the mineral substratum was uncertain, or where medium, coarse, or fine textured materials were mixed or layered, MUS1m-G was usually applied as the "default" soil model.
- MUS1m-G is typically non-stony. However, several polygons located along the upper wall of the Athabasca River valley contain patches (e.g. boulder fields) where coarse fragments (cobbles, stones, and boulders) cover approximately 10-30% of the ground surface.

MUS1s-G Soil Model

Soil Model (MU) Name:	Muskeg 1s-G
Extent (ha / % of survey area)	131.9 ha / 0.6% of SSA
Dominant Soil (60% or more):	MUS1m (Muskeg-shallow over coarse textured substrate)
Significant Soils (10-30%):	Gleysolic soils, both peaty and non-peaty (e.g. mainly BMT variants)
Inclusions (<10%):	Organic soils with thicker (100-200 cm) peat deposits; shallow Organic soils with medium or fine mineral substrate; other Gleysolic soils (e.g. MMW)
General Landform:	Shallow peat bogs and poor fens on low-lying, nearly level plains
Surficial (Parent) Materials:	Shallow (40-100 cm) bog peat over coarse textured, water-laid materials (L11)
Ecosite Phase:	Treed and shrubby bog (i1, i2); treed and shrubby poor fen (j1, j2)
Surface Stoniness:	Non-stony
Land Use:	Wetland (bog or poor fen)

Soil Landscape Models (SLMs):

MUS1s-G / O5 Extent – 131.9 ha; 0.6% of the SSA
O5 landscape model – "level" organic landform with small raised knolls and

hummocks of mineral soils; slope classes 2-4 (0.5-10% slopes)
Amalgamated suitability rating for forestry – 5SR

Comments:

- MUS1s-G soil model occurs only in the Joslyn Plain Land System, and represents wetlands dominated by shallow fen peat overlying coarse textured mineral substrate. Textures of the underlying mineral substrate commonly fit the coarse textural group (refer to Figure A-1).
- Current vegetation is bog or poor fen; bog peat dominates the surface organic layers of these soils. Other types of peat (fen peat, organic material high in wood fragments) may occur deeper in the soil profile.
- Organic soils dominate. Gleysolic soils occur where the peat deposits are not as thick and well developed.
- While being quite variable across the landscape, peat thickness was interpreted as mainly between 40 and 100 cm for the dominant Organic soils.
- MUS1s-G soil model was fairly restricted in its application to polygons where site inspection data indicated the predominance of coarse textured substrate beneath the organic materials. Where the nature of the substrate was uncertain, or where medium, coarse, or fine textured materials were mixed or layered, MUS1m-G (see previous description) was usually applied as the "default" soil model.

MUS2c Soil Model

Soil Model (MU) Name:	Muskeg 2c
Extent (ha / % of survey area)	628.9 ha / 2.9% of SSA
Dominant Soil (60% or more):	MUS (Muskeg) series and variants (peat 100-200 cm thick)
Significant Soils (10-30%):	N/A
Inclusions (<10%):	Organic soils with thinner (40-100) and thicker (>200 cm) peat deposits; Organic soils with medium textured mineral substrate; Gleysolic soils; Organic Cryosols
General Landform:	Bog or poor fen wetlands occupying broad, low-lying areas
Surficial (Parent) Materials:	Moderately deep (100-200 cm) bog or mixed peat overlying fine textured water-laid and glacial materials (mainly P1)
Ecosite Phase:	Mainly treed & shrubby bog (i1, i2); significant treed & shrubby poor fen (j1, j2)
Surface Stoniness:	Non-stony
Land Use:	Wetland (bog or poor fen)

Soil Landscape Models (SLMs):

MUS2c / O1 Extent – 628.9 ha; 2.9% of the SSA
O1 landscape model – level wetland with internal undulations; slope classes 1-3 (0-5%)
Amalgamated suitability rating for forestry – 5SR

Comments:

- MUS2c soil model occurs only in the Lower and Upper Dover Plain land systems, and represents wetlands dominated by moderately thick bog peat overlying clayey mineral substrate. Textures of the underlying mineral substrate commonly fit the fine textural group (refer to Figure A-1).
- Current vegetation is bog or poor fen; bog peat dominates the surface organic layers of these soils. Other types of peat (fen peat, organic material high in wood fragments) may occur deeper in the soil profile.
- While being quite variable across the landscape, peat thickness was interpreted as mainly between 100 and 200 cm for the dominant Organic soils. The undulating peat surface often reflects varying peat thickness.

- Fringes of these wetland depressions often have soils with shallower peat (peaty Gleysols and shallow Organics) and different vegetation.
- Some elevated mounds in these basins may have permanently frozen peat soils, classed at the Great Group level as Organic Cryosols.
- MUS2c soil model was fairly restricted in its application to polygons where site inspection data indicated the predominance of clayey substrate beneath moderately thick organic materials. Where the nature of the substrate was uncertain, or where medium, coarse, or fine textured materials were mixed or layered, MUS2m (see next description) was usually applied as the "default" soil model.
- MUS2c soil model was mapped only with the O1 LM (level Organic wetlands). However, a few polygons with the same soil pattern were basin-like (O2) or had somewhat rougher surfaces (O5).

MUS2m Soil Model

Soil Model (MU) Name:	Muskeg 2c
Extent (ha / % of survey area)	926.2 ha / 4.2% of SSA
Dominant Soil (60% or more):	MUS (Muskeg) series and variants (peat 100-200 cm thick)
Significant Soils (10-30%):	N/A
Inclusions (<10%):	Organic soils with thinner (40-100) and thicker (>200 cm) peat deposits; Organic soils with clayey or sandy mineral substrate; Gleysolic soils; Organic Cryosols
General Landform:	Bog or poor fen wetlands occupying broad, low-lying areas
Surficial (Parent) Materials:	Moderately deep (100-200 cm) bog or mixed peat overlying medium textured water-laid materials (mainly P1)
Ecosite Phase:	Mainly treed & shrubby bog (i1, i2); significant treed & shrubby poor fen (j1, j2)
Surface Stoniness:	Non-stony
Land Use:	Wetland (bog or poor fen)

Soil Landscape Models (SLMs):

MUS2m / O1 Extent – 926.2 ha / 4.2% of the SSA
O1 landscape model – level wetland with internal undulations; slope classes 1-3 (0-5%)
Amalgamated suitability rating for forestry – 5SR

Comments:

- MUS2m soil model occurs extensively in the Upper and Lower Dover Plain and Joslyn Plain land systems, only sporadically in the Athabasca-Ells Valley. MUS2m SM represents wetlands dominated by moderately thick fen peat overlying medium textured mineral substrate. Textures of the underlying mineral substrate commonly fit the medium textural group (refer to Figure A-1).
- Current vegetation is bog or poor fen; bog peat dominates the surface organic layers of these soils. Other types of peat (fen peat, organic material high in wood fragments) may occur deeper in the soil profile.
- While being quite variable across the landscape, peat thickness was interpreted as mainly between 100 and 200 cm for the dominant Organic soils. The undulating peat surface often reflects varying peat thickness.
- Fringes of these wetland depressions often have soils with shallower peat (peaty Gleysols and shallow Organics) and different vegetation.
- Some elevated mounds in these basins may have permanently frozen peat soils, classed at the Great Group level as Organic Cryosols.

- MUS2m was the most widely applied soil model for fen-dominated landscapes with moderately deep Organic soils. While characterized by medium textured mineral materials underlying the peat, layered mineral materials (medium overlying clayey) were also covered by this map unit. In polygons where the nature of the mineral substratum was uncertain, or where medium, coarse, or fine textured materials were mixed or layered, MUS2m was usually applied as the "default" soil model. In the Joslyn Plain Land System, MUS2m soil model represented a few areas where the mineral substratum was believed to be mainly sandy, because a MUS2s soil model was not identified for this survey.
- MUS2m soil model was mapped only with the O1 LM (level Organic wetlands). However, a few polygons with the same soil pattern were basin-like (O2) or had somewhat rougher surfaces (O5).

MUS3 Soil Model

Soil Model (MU) Name:	Muskeg 3
Extent (ha / % of survey area)	465.0 ha / 2.1% of SSA
Dominant Soil (60% or more):	MUS (Muskeg) series and variants (peat >200 cm thick)
Significant Soils (10-30%):	N/A
Inclusions (<10%):	Organic soils with thinner (40-200 cm) peat deposits; Organic Cryosols
General Landform:	Mainly confined depressions within rougher upland terrain that dominates the western part of SSA
Surficial (Parent) Materials:	Deep (>200 cm) bog or mixed peats (P1)
Ecosite Phase:	Dominantly shrubby bog (i2); significant treed bog (i1)
Surface Stoniness:	Non-stony
Land Use:	Wetland (bog)

Soil Landscape Models (SLMs):

MUS3 / O2 Extent – 465.0 ha; 2.1% of the SSA
O2 landscape model – basin-like (bowl) depressions; peat surface often undulating, occasionally hummocky; slope classes 1-3 (0-5%)
Amalgamated suitability rating for forestry – 5SR

Comments:

- The majority of MUS3 polygons occur in the Upper Dover Plain Land System; several others are located in the adjacent Lower Dover Plain Land System and one polygon in the Joslyn Plain area. MUS3 represents wetlands dominated by thick (>200 cm) bog peat. Most polygons occur as small, discrete basins scattered throughout the hummocky uplands in the western part of the SSA.
- Current vegetation is bog or poor fen; bog peat dominates the surface organic layers of these soils. Other types of peat (fen peat, organic material high in wood fragments) may occur deeper in the soil profile.
- While being quite variable across the landscape, peat thickness was interpreted as exceeding 200 cm for the dominant Organic soils. The undulating, occasionally hummocky, peat surface often reflects varying peat thickness. Soils with thinner peat deposits do occur, especially near margins of these "peat basins".
- Fringes of these wetland depressions may have soils with shallower peat (peaty Gleysols and shallow Organics) and different vegetation.
- Some elevated mounds in these basins occasionally have permanently frozen peat soils, classified at the Great Group level as Organic Cryosols. Organic soils with permanently frozen layers below 100 cm also occur. Organic soils with permafrost layers are most common in the MUS3 soil model. In a few polygons, peat soils with permafrost layers are quite common to the level of being considered "significant" (10-30%) within those particular polygons.

PEA9 Soil Model

Soil Model (MU) Name:	Peavine 9
Extent (ha / % of survey area)	103.8 ha / 0.5% of SSA
Dominant Soil (60% or more):	PEA (Peavine)
Significant Soils (10-30%):	Coarser textured soils: WNFxc/MILxc (Winefred-xc/Mildred-xc), FRT (Fort) Wetlands with Gleysolic soils (e.g. MMW)
Inclusions (<10%):	Gleyed Gray Luvisols (PEAgl, FRTgl); shallow Organic soils (e.g. MLD1m)
General Landform:	Relatively small areas of undulating plain
Surficial (Parent) Materials:	Medium textured (M2, M3) and layered (L18 – medium over coarse; L9 – coarse over fine to medium), water-laid deposits
Ecosite Phase:	Mainly low-bush cranberry-aspen-spruce (d2, d3) with significant patches of wetter vegetation types (h1, f1, f3, bogs, and fens)
Surface Stoniness:	Typically non-stony; stony-bouldery patches in polygons along Athabasca River
Land Use:	Mainly forested (wooded)

Soil Landscape Models (SLMs):

PEA9 / U1h Extent – 51.6 ha; 0.2% of the SSA
U1h landscape model – high-relief undulating; slopes mainly class 3 with some 4 (2-10% slope gradients)
Amalgamated suitability rating for forestry – 3R

PEA9 / U1l Extent – 52.2 ha; 0.2% of the SSA
U1l landscape model – low-relief undulating; mainly slope class 2 (0.5-2% slopes)
Amalgamated suitability rating for forestry – 3R

Comments:

- PEA9 soil model occurs only in the Joslyn Plain and Athabasca-Ells Valley land systems, primarily on the eastern edge of the SSA. Many polygons occur in association with medium-coarse textured uplands (e.g. PEWN1 soil units), sometimes in locations that are transitional to wetlands (e.g. MUS-based map units).
- PEA (Peavine) and its closely related Eluviated Dystric Brunisol variant (PEAzb) are the "upland" soils that dominate this model. Soils that are coarser textured than PEA are significant. The coarser textured soils are developed on layered glaciofluvial deposits – L9 (coarse over fine lacustro-till) typical of WNFxc/MILxc soils and L18 (medium over coarse) typical of FRT soils. Both Orthic Gray Luvisol and Eluviated Dystric Brunisol versions of the coarser soils occur, e.g. FRT and FRTzb, WNFxc and MILxc.
- Small wet areas are also significant in the PEA9 soil model. Most such localities occur as discrete depressional areas smaller than the minimum-sized polygon (0.5 ha at 1:10,000 scale). Soils of these wetland segments are mainly Gleysols related to the Mamawi (MMW) series.
- For land capability and other assessments, both sandy textured and wetland soils with their low index ratings were factored into the amalgamated (i.e. overall) rating for the SLM.

- PEA9 is usually non-stony. However, several polygons located along the upper wall of the Athabasca River valley contain patches (e.g. boulder fields) where coarse fragments (cobbles, stones, and boulders) cover approximately 10-30% of the ground surface.

PELV1 Soil Model

Soil Model (MU) Name:	Peavine-Livock 1
Extent (ha / % of survey area)	318.8 ha / 1.5% of SSA

Co-dominant Soils (each 30-60%):	PEA (Peavine); LVKxc (Livock-xc)
Significant Soils (10-30%):	N/A
Inclusions (<10%):	Gleyed Gray Luvisols (LVKgl, PEAgl); small Gleysolic wetlands; F3 parent material soils (DOV, KME); coarser textured soils on L18 (WNFxc) and L20 (FRT) parent materials
General Landform:	Terraced and undulating landforms that flank modern stream course valleys like Joslyn Creek and Ells River
Surficial (Parent) Materials:	Medium textured (M2, M3) and layered (L10 – medium over fine) deposits
Ecosite Phase:	Mainly low-bush cranberry-aspen (d1); minor areas of b2 and b3
Surface Stoniness:	Non-stony
Land Use:	Mainly forested (wooded)

Soil Landscape Models (SLMs):

PELV1 / L3 Extent – 127.3 ha; 0.6% of the SSA
L3 landscape model – Level and terraced (not within modern stream channels); slope classes mainly 2-3 (0.5-5%) with minor 4-5 (terrace risers, small bordering scarps)
Amalgamated suitability rating for forestry – 2R

PELV1 / U1h Extent – 191.5 ha; 0.9% of the SSA
U1h landscape model – high-relief undulating; slopes mainly class 3 with some 4 (2-10% slope gradients)
Amalgamated suitability rating for forestry – 2R

Comments:

- PELV1 soil model occurs mainly in the Upper and Lower Dover Plain land systems, usually bordering the Ells River and some of its major tributaries like Joslyn Creek. Proximity to these valley systems accounts for the occurrence of glaciofluvial and related water-laid sediments that thinly mantle the lacustro-till common throughout the area.
- PEA soils are developed on relatively thick (>1 m) medium to moderately fine textured water-laid materials (M2, M3); LVKxc is developed on the same medium textured water-laid materials that overlie fine textured lacustro-till (L10) at shallow depths (30-99 cm).
- The L3 landscape model (PELV1/L3 SLM) denotes level to terraced terrain associated mainly with Joslyn Creek where it cuts through the Upper Dover Plain. It represents old floodplains formed in times when these streams were much larger. PELV1/L3 polygons usually occur within (below) the steep valley walls (LVK4/I5 map unit) but above the modern stream course floodplain (MMY2/SC1 map unit). L3 as used in this SLM is typified by level to terraced landforms dominated by slope classes 2-3 (0.5-5% slopes). Short risers with steeper slopes (classes 4-5) connect different terrace levels where terraced landforms are well developed. Small steep scarps that resemble the LVK4/I5 SLM are included in a few polygons.
- The PELV1/U1h SLM polygons tend to be much larger than PELV1/L3 polygons. The former occur in upland areas that border major stream valleys like the Ells River, or occur within the confluence areas of major tributary streams. Such locations imply immediate post-glacial formation of the U1h landform.
- A variety of soil inclusions related to stratified parent materials (with coarse textured layers) and variations in drainage can be found in this soil model. Small, narrow, wetland areas associated with old channels and oxbows are numbered amongst these inclusions.

PELV11 Soil Model

Soil Model (MU) Name:	Peavine-Livock 11
Extent (ha / % of survey area)	632.7 ha / 2.9% of SSA

Co-dominant Soils (each 30-60%):	PEA (Peavine); LVKxc (Livock-xc)
Significant Soils (10-30%):	Coarser textured soils: MILfi, MILxc/xm, WNFxc/xm Regosolic soils (e.g. MMY and variants)
Inclusions (<10%):	Gleyed Gray Luvisols (PEAgl, LVKgl); small wetlands with Gleysolic soils (in old channels)
General Landform:	Terraced and channelled bottomland in the Ells, MacKay, & Joslyn valleys
Surficial (Parent) Materials:	Medium (M2, M3), layered (L10 – medium over fine; L9 – coarse over fine to medium), and coarse (C2, C3) water-laid (glaciofluvial or fluvial) deposits
Ecosite Phase:	Mainly low-bush cranberry-aspen (d1); minor areas of b1, b2, d2, and e1
Surface Stoniness:	Non-stony to slightly stony (buried gravels in places)
Land Use:	Mainly forested (wooded)

Soil Landscape Models (SLMs):

PELV11 / SC2 Extent – 50.9 ha; 0.2% of the SSA
SC2 landscape model – terraced valley bottom with risers and channels; slopes mainly classes 2-3 (0.5-5%) with minor 4-5 (risers and scarps)
Amalgamated suitability rating for forestry – 3SR

Comments:

- PELV11 soil model occurs mainly in the Athabasca-Ells Valley Land System, but extends along the Joslyn Creek valley into the Joslyn Plain and Lower Dover Plain areas. It represents dry, terraced, valley bottom landforms dominated by Luvisolic soils. Moisture regime is mainly mesic, associated with well to moderately well drained soils.
- Stratified, mainly medium textured, water-laid deposits (i.e. glaciofluvial or fluvial) typify the parent materials of this soil model. PEA soils are developed on relatively thick (>1 m) medium to moderately fine textured water-laid materials (M2, M3); LVKxc is developed on the same medium textured water-laid materials that overlie fine textured lacustro-till (L10) at shallow depths (30-99 cm).
- Soils that are coarser textured than PEA and LVKxc soils are significant in PELV11. The coarser textured soils are developed mainly on sandy loam deposits (C3, MILfi variant) that may include coarser (LS-S) layers. In some places, the coarse textured materials overlie fine (C-SiC-SC; L9; MILxc/WNFxc) or medium (FSL-L-SiL; L20; MILxm/WNFxm) textured layers.
- Landscape model SC2 (PELV11/SC2 SLM) is typified by terraced terrain. A terrace is a land surface form consisting of a lower or front slope (the riser) and a broad, relatively level surface (the tread); the tread may be bounded by another terrace or a steep ascending valley wall slope. In the Joslyn SSA, PELV11/SC2 polygons normally contain multiple terraces, truncated in places by channels. Steep valley walls, likely mapped as LVK11 soil model, usually occur above the PELV11/SC2 terraces.
- PELV11 and MMY6 soil models are similar in that they occur on terraced terrain comprised of water-laid parent materials situated on the valley floors of the Ells, MacKay, and Joslyn water courses. There is substantial difference in degree of soil development however – PELV1 is dominated by Luvisolic soils whereas MMY6 (see above) is dominated by Regosolic soils. Regosolic soil development (MMY6) implies young and possibly still evolving landscape. Luvisolic soil development implies much older, geomorphically more stable terrain. Moreover, MMY6 occurs only along the lower reaches of Joslyn Creek and Ells River, and along the Athabasca River; most terraced terrain upstream from these locations were mapped as PELV11 soil model.

PEWN1 Soil Model

Soil Model (MU) Name:	Peavine-Livock 11
Extent (ha / % of survey area)	495.2 ha / 2.3% of SSA
Co-dominant Soils (each 30-60%):	PEA (Peavine); PEAzb (Peavine-brunisolic); WNFxc (Winefred-xc); MILxc (Mildred-xc); paralithic/lithic variants (only in PEWN1/HR2mr)
Significant Soils (10-30%):	N/A
Inclusions (<10%):	Small wetter patches with Gleyed Gray Luvisols (PEAgl, LVKgl) or Gleysols; L10 parent material soils (LVKxc); paralithic/lithic variants and Regosolic soils in polygons located near the Athabasca River
General Landform:	Undulating plain with areas of bedrock-controlled hummocks and ridges
Surficial (Parent) Materials:	Medium (M2, M3) and layered (L9 – coarse over fine to medium) deposits; in places shallow over bedrock (in PEWN1/HR2mr SLM)
Ecosite Phase:	Mainly low-bush cranberry-aspen (d1); minor areas of d2 and h1
Surface Stoniness:	Typically non-stony; stony-bouldery patches in places along Athabasca River
Land Use:	Mainly forested (wooded)

Soil Landscape Models (SLMs):

PEWN1 / HR2mr Extent – 122.7 ha; 0.6% of the SSA
HR2mr landscape model – moderate-relief, hummocky and ridged terrain overlying bedrock at shallow depths; mainly slope class 4 (5-10%) with some 5 (10-15% slopes)
Amalgamated suitability rating for forestry – 3SR

PEWN1 / U1h Extent – 171.5 ha; 0.8% of the SSA
U1h landscape model – high-relief undulating; slopes mainly class 3 with some 4 (2-10% slope gradients)
Amalgamated suitability rating for forestry – 3SR

PEWN1 / U1l Extent – 201.0 ha; 0.9% of the SSA
U1l landscape model – low-relief undulating; mainly slope class 2 (0.5-2% slopes)
Amalgamated suitability rating for forestry – 3SR

Comments:

- PEWN1 soil model occurs only in the Joslyn Plain and Athabasca-Ells Valley land systems, primarily on the eastern most edge of the SSA close to the Athabasca River. The area in which PEWN1 occurs may have been shaped by an early post-glacial stage of the Athabasca River.
- Stratified, medium to coarse textured, water-laid deposits (i.e. glaciofluvial) typify the parent materials of this soil model. PEA soils are developed on relatively thick (>1 m) medium to moderately fine textured water-laid materials (M2, M3). WNFxc and MILxc soils are developed on coarse textured (LS-S-SL)
  water-laid materials that overlie fine textured lacustro-till (L9) at shallow depths (30-99 cm). In some places, the coarse textured sediments overlie medium textured (L-SCL-CL) water-laid materials.
- PEWN1/HR2mr SLM differs substantially from the other two PEWN1 SLMs because it contains roughly 50% paralithic/lithic soils. In the paralithic/lithic variants, stratified water-laid parent materials often overlie partially weathered sandstone and siltstone of the McMurray Formation (Hamilton et al. 1999) at shallow depths (30-99 cm). The bedrock is usually oil impregnated (i.e. bitumen), and varies in hardness from friable to nearly impenetrable by shovel or hand auger.
- HR2mr landscape model (PEWN1/HR2mr SLM) is typified by hummocky to ridged topography with short, moderate slopes; landform shape is partially controlled by the underlying bedrock. The U1h and U1l landscapes have gentler slopes and substantially thicker surficial materials that

mask the underlying bedrock surface. However, a few instances of shallow parent materials were found in undulating polygons located just above the Athabasca River.

- Both Orthic Gray Luvisol and Eluviated Dystric Brunisol versions of soils developed on the same types of water-laid materials occur in this soil model, e.g. PEA and PEAzb, WNFxc and MILxc.
- PEWN1 is usually non-stony or slightly stony. However, several polygons located along the wall of the Athabasca River valley contain patches (e.g. boulder fields) where coarse fragments (cobbles, stones, and boulders) cover approximately 10-30% of the ground surface.

Water

Soil Model (MU) Name:	Water bodies
Extent (ha / % of survey area)	112.4 ha / 1.0% of SAGD-RSA
Dominant Soil (60% or more):	Non-soil – Water
Significant Soils (10-30%):	N/A
Inclusions (<10%):	Gleysolic soils (e.g. MMW and CHT variants); shallow Organic soils (e.g. MLD1c and MLD1m variants)
General Landform:	Low-lying areas dominated by ponds, lakes and sloughs; including floodplain areas flooded due to beaver activities
Surficial (Parent) Materials:	N/A
Ecosite Phase:	Flooded areas (NWF)
Surface Stoniness:	N/A
Land Use:	Wetland (water bodies and marsh)

Soil Landscape Models (SLMs): None (Not applicable)

Comments:

- Most polygons mapped as "Water" occur in ponded or flooded portions of stream course channels/valleys. Other polygons occupy relatively large circular depressions.
- This map unit is often comprised of one large water body (lake) or a string of smaller ponds or sloughs set in a "marshy matrix" with Gleysolic (e.g. MMW and CHT) or shallow Organic (e.g. MLD1c and MLD1m) soils. The water table is usually at or near the surface in the marshy fringes.
- "Water" and MMW2/FP3 landscapes may resemble each other in some cases; however, water bodies are co-dominant (i.e. 30-60% of the area) with Gleysolic soils in polygons mapped as MMW2/FP3.

ZDL

Soil Model (MU) Name:	Disturbed Land
Extent (ha / % of survey area)	321.8 ha / 1.5% of SSA
Dominant Soils (>60%):	Undifferentiated disturbed and reconstructed soil materials
Significant Soils (10-30%):	N/A
Inclusions (<10%):	N/A
General Landform:	Terrain that is considered built-up or shaped by human activities
Surficial (Parent) Materials:	Undifferentiated disturbed and reconstructed materials
Ecosite Phase:	N/A
Surface Stoniness:	N/A
Land Use:	Industrial/transportation

Soil Landscape Models (SLMs): None (Not applicable)

Comments:

- CNRL Road and intersecting Deer Creek Energy Limited facility access roads.

- Fort MacKay road along Athabasca River valley.
- DCEL Joslyn Phase 1 Plant Site.
- DCEL field camp and well sites located in the North Mine LSA.
- ATCO power line right-of-way.
- Larger borrow pits along roadways.
- Other disturbed areas, mainly well sites, were ignored assuming that their soils were not markedly disturbed.

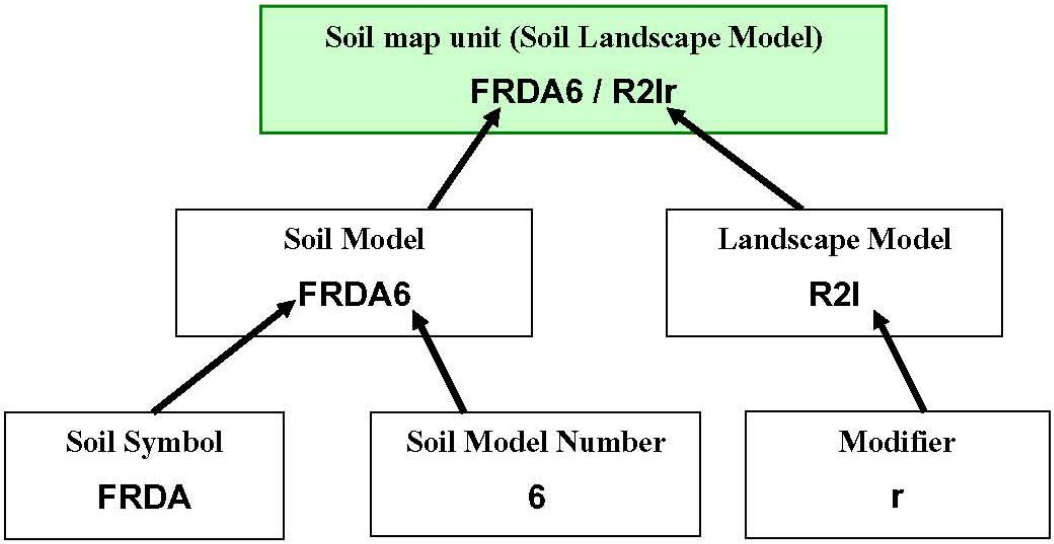


Figure B-1. Components of a Soil Landscape Model (map unit) symbol.

Adapted from AGRASID (ASIC, 2001)

APPENDIX C

Borehole Logs and Analytical Results

Terracon Geotechnique Ltd.
10208 Centennial Drive
FortMcMurray AB T9H 1Y5
Telephone: 780 743-9343
Fax: 780 743-2420

BOREHOLE NUMBER 1AA/01-33-095-11W4/00

CLIENT Deer Creek Energy Ltd. **PROJECT NAME** Winter Overburden Drilling Project

PROJECT NUMBER 3995 **PROJECT LOCATION** Joslyn Creek Lease 24

DATE STARTED 8/2/04 **COMPLETED** 8/2/04 **GROUND ELEVATION** 292.33 m **HOLE SIZE** 6 inch

DRILLING CONTRACTOR Beck Drilling and Environmental

COORDINATES E 456901.501m N 6348930.462m

DRILLING METHOD Solid Stem Auger

LOGGED BY Katherine Stasiuk **CHECKED BY** **NOTES**

DEPTH (m)	SAMPLE TYPE NUMBER	FACIES DESCRIPTOR	GRAPHIC LOG	MATERIAL DESCRIPTION	
1		Ho		MUSKEG Black organic soil, some silt and clay, moist, fine, low to intermediate plasticity.	
				1.06 ▽	291.27
		Pfs		FLUVIAL SAND Rusty brown fine to medium grained sand, moderately sorted, isolated coarse sand to fine gravel size, saturated, oxidized, loose.	
				1.52	290.81
2		Pl		LACUSTRINE Pinkish grey clay, some silt, rare coarse sand to fine gravel, firm, moisture content greater than plastic limit, intermediate to high plasticity, rare till clumps towards bottom of run.	
3				3.05	289.28
4	GB MEM - 1	Pgtc		CLAYEY TILL Medium brown-grey silty clay, 3-5% coarse sand to fine gravel, firm, moisture content much greater than plastic limit, low to intermediate plasticity.	
				4.57	287.76
5		Pgtc		As above, increasing clay percent downhole, local high plasticity Kc rich zones, isolated millimeter scale glauconitic sand lenses.	
6				6.10	286.23
7		Km (MB)		McMURRAY FORMATION Pink-brown fine sand, some silt, dark grey to black centimeter scale clay beds and lenses, est. 4-6% bitumen.	
				7.62	284.71
				Bottom of hole at 7.62 m.	

GENERAL BH / TP / WELL 3995 DEER CREEK OVERBURDEN PROGRAM.GPJ GINT CANADA.GDT 14/5/04

Terracon Geotechnique Ltd.
10208 Centennial Drive
FortMcMurray AB T9H 1Y5
Telephone: 780 743-9343
Fax: 780 743-2420

BOREHOLE NUMBER 1AA/06-03-096-11W4/00

CLIENT Deer Creek Energy Ltd. **PROJECT NAME** Winter Overburden Drilling Project

PROJECT NUMBER 3995 **PROJECT LOCATION** Joslyn Creek Lease 24

DATE STARTED 7/2/04 **COMPLETED** 7/2/04 **GROUND ELEVATION** 285.96 m **HOLE SIZE** 6 inch

DRILLING CONTRACTOR Beck Drilling and Environmental

COORDINATES E 457493.848m N 6350708.627m

DRILLING METHOD Solid Stem Auger

LOGGED BY Katherine Stasiuk **CHECKED BY** **NOTES**

DEPTH (m)	SAMPLE TYPE NUMBER	FACIES DESCRIPTOR	GRAPHIC LOG	MATERIAL DESCRIPTION	
1		Pfs		FLUVIAL SAND Buff to orange fine to coarse grained sand, occasional fine gravel, well graded, moist, compact.	
				0.91 ▽	285.05
		Pfs		Buff to light orange fine sand, silty, trace of thin clay lenses, moist to wet, compact, well sorted.	
				1.52	284.44
2		Pgtc/Pgt		SILTY CLAY TILL Dark brown to grey/brown, trace of sand, 3-5% coarse sand to fine gravel, stiff, silt percent increases down hole, low plasticity, moist.	
3				3.05	282.91
4		Kc		CLEARWATER FORMATION Dark grey clay, silty lenses and burrows, high plasticity, moisture content greater than plastic limit, stiff, top ~30cm is disturbed.	
				4.57	281.39
5	GB MEM - 1	Kc		CLEARWATER FORMATION As above, very stiff, waxy, crumbles off auger, moisture content greater than plastic limit.	
6				6.10	279.86
7		Kc		As above, increasing silt %.	
				7.62	278.34
				Bottom of hole at 7.62 m.	

GENERAL BH / TP / WELL 3995 DEER CREEK OVERBURDEN PROGRAM.GPJ GINT CANADA.GDT 14/5/04

Terracon Geotechnique Ltd.
10208 Centennial Drive
FortMcMurray AB T9H 1Y5
Telephone: 780 743-9343
Fax: 780 743-2420

BOREHOLE NUMBER 1AA/07-30-095-11W4/00

CLIENT Deer Creek Energy Ltd. **PROJECT NAME** Winter Overburden Drilling Project

PROJECT NUMBER 3995 **PROJECT LOCATION** Joslyn Creek Lease 24

DATE STARTED 9/2/04 **COMPLETED** 9/2/04 **GROUND ELEVATION** 304.92 m **HOLE SIZE** 6 inch

DRILLING CONTRACTOR Beck Drilling and Environmental **COORDINATES** E 453303.211m N 6347514.351m

DRILLING METHOD Solid Stem Auger

LOGGED BY Katherine Stasiuk **CHECKED BY** **NOTES**

DEPTH (m)	SAMPLE TYPE NUMBER	FACIES DESCRIPTOR	GRAPHIC LOG	MATERIAL DESCRIPTION	
		Ho		MUSKEG	
				0.45 Black organic soil with brown peat, rootlets, wood debris, frozen.	304.47
		Pfs		FLUVIAL SAND	
1				Buff to rusty orange, fine sand, silty, occasional buff clay clasts (possible Lacustrine from below), compact, frozen.	
				1.22	303.70
		Pl		LACUSTRINE	
2				Greyish pink clay, some silt, slightly mottled, intermediate to high plasticity, moisture content greater than plastic limit, firm to stiff.	
				2.75	302.17
		Pgtc		CLAYEY TILL	
3				3.05	301.87
				Medium to dark brown silty clay, trace of sand, low to intermediate plasticity, 3-5% fine gravel, moisture content greater than plastic limit, firm to stiff.	
4	GB MEM - 1	Pgtc		As above, occasional high plasticity Kc derived clay pockets, intermediate plasticity.	
5					
6				6.10	298.82
		Kca		CLEARWATER FORMATION	
7				Dark grey clay, trace of silt, occasional siderite and glauconitic silt burrows, high plasticity, moisture content is approximately equal to plastic limit, stiff.	
				7.32	297.60
		Kcw		CLEARWATER FORMATION - WABISKAW MEMBER	
				7.62	297.30
				Glauconitic fine sand with dark grey clay interbeds, mild bitumen odour, non to low plasticity.	
				Bottom of hole at 7.62 m.	

GENERAL BH / TP / WELL 3995 DEER CREEK OVERBURDEN PROGRAM.GPJ GINT CANADA.GDT 14/5/04

Terracon Geotechnique Ltd.
10208 Centennial Drive
FortMcMurray AB T9H 1Y5
Telephone: 780 743-9343
Fax: 780 743-2420

BOREHOLE NUMBER 1AA/12-05-096-11W4/00

CLIENT Deer Creek Energy Ltd. **PROJECT NAME** Winter Overburden Drilling Project

PROJECT NUMBER 3995 **PROJECT LOCATION** Joslyn Creek Lease 24

DATE STARTED 7/2/04 **COMPLETED** 7/2/04 **GROUND ELEVATION** 298.32 m **HOLE SIZE** 6 inch

DRILLING CONTRACTOR Beck Drilling and Environmental

DRILLING METHOD Solid Stem Auger **COORDINATES** E 454109.652m N 6351189.225m

LOGGED BY Katherine Stasiuk **CHECKED BY** **NOTES**

DEPTH (m)	SAMPLE TYPE NUMBER	FACIES DESCRIPTOR	GRAPHIC LOG	MATERIAL DESCRIPTION	
		Ho		MUSKEG	
			0.45	Black organic soil, peat, rootlets, frozen.	297.87
		Pfs		FLUVIAL SAND Light to medium grey, predominantly fine sand with trace of medium grained component, frozen, compact, moist, grey Kc-like clumps, well sorted.	
			1.52		296.80
2		Pfs		As above, numerous dark grey Kc-like clumps, moist, frozen patches to 2.73.	
			3.05		295.27
		Pgtc/PgKc		CLAYEY TILL	
			3.66 ▽	Dark grey clay, some silt, coarse sand to fine gravel, intermediate to high plasticity, Kc matrix, greasy, stiff, moisture content greater than plastic limit.	294.66
4	GB MEM - 1	Pgtc/PgKc		Dark grey silty clay, some sand, rare coarse sand to fine gravel, saturated, moisture content greater than liquid limit, low plasticity.	
			4.57		293.75
		Pl		LACUSTRINE Pink grading to mottled grey clay, some silt, isolated fine gravel, greasy, high plasticity, moisture content greater than plastic limit.	
6			6.10		292.22
		Pgtc		CLAYEY TILL Dark grey-brown, silty clay, trace of sand, 5-8% coarse sand to fine gravel, low to intermediate plasticity, moisture content greater than plastic limit, predominately gritty with occasional high plasticity clay zones.	
			7.62		290.70
8	GB MEM - 2	Kca		CLEARWATER FORMATION Dark grey clay, some silt, isolated glauconitic/siderite silt burrows, very stiff, high plasticity, moisture content greater than plastic limit.	
			9.14		289.18
10		Kcw		CLEARWATER FORMATION - WABISKAW MEMBER Dark grey clay with glauconitic fine sand pockets, brown fine sand lenses starting from 10.0m, very stiff, intermediate to high plasticity, rubbly zone (siltstone?) at 9.81m, mild bitumen odour.	
			10.67		287.65
		Km		McMURRAY FORMATION Medium to dark brown fine sand, silty with black high plastic clay interbeds, 2-4% bitumen saturation, medium dense.	
12			12.19		286.13
				Bottom of hole at 12.19 m.	

GENERAL BH / TP / WELL 3995 DEER CREEK OVERBURDEN PROGRAM.GPJ GINT CANADA.GDT 14/5/04

Terracon Geotechnique Ltd.
10208 Centennial Drive
FortMcMurray AB T9H 1Y5
Telephone: 780 743-9343
Fax: 780 743-2420

BOREHOLE NUMBER 1AA/14-20-095-11W4/00

CLIENT Deer Creek Energy Ltd. **PROJECT NAME** Winter Overburden Drilling Project

PROJECT NUMBER 3995 **PROJECT LOCATION** Joslyn Creek Lease 24

DATE STARTED 11/2/04 **COMPLETED** 11/2/04 **GROUND ELEVATION** 302.66 m **HOLE SIZE** 6 inch

DRILLING CONTRACTOR Beck Drilling and Environmental **COORDINATES** E 454489.699m N 6347005.417m

DRILLING METHOD Solid Stem Auger

LOGGED BY Katherine Stasiuk **CHECKED BY** **NOTES**

DEPTH (m)	SAMPLE TYPE NUMBER	TESTS	FACIES DESCRIPTOR	GRAPHIC LOG	MATERIAL DESCRIPTION	
			Ho		0.31 MUSKEG	302.35
					Black organic soil, rootlets, frozen.	
			Pfsg		FLUVIAL GRAVEL Rusty orange fine to coarse sand, trace of silt and buff clay clasts, 15-20% fine to coarse gravel, isolated cobbles, moist to wet, compact, stony, difficult drilling, good road material.	
					1.52	301.14
2			Pfsg		As above, slight increase in clay percent above contact.	
					2.43	300.23
			Pl		LACUSTRINE Pinkish grey clay, some silt, trace of fine gravel, mottled, intermediate to high plasticity, moisture content much greater than plastic limit, soft to firm.	
4	GB 1 MEM - 1	MC=10.5% Fines=15%			3.96	298.70
			Pgtc		CLAYEY TILL Grey-brown silty clay, trace of fine sand, grey high plastic lenses, intermediate plasticity, 3-5% coarse sand to fine gravel, moisture content greater than plastic limit, firm.	
6					6.10	296.56
			Pgtc		Medium to dark grey-brown silty clay, some fine sand increasing with depth, 5-8% fine gravel, low plasticity, moisture content greater than plastic limit, firm, mild bitumen odour.	
					6.92	295.74
			Km		McMURRAY FORMATION Medium grey fine sand, some silt, dark grey to black clay lenses, lean (less than or equal to 2% bitumen saturated).	
					7.62	295.04
8			Km		Light to medium brown fine sand, silty, light brown to grey clay lenses and burrow infills, dense, lean (less than or equal to 2% bitumen saturated).	
					9.14	293.52
					Bottom of hole at 9.14 m.	

GENERAL BH / TP / WELL 3995 DEER CREEK OVERBURDEN PROGRAM.GPJ GINT CANADA.GDT 14/5/04

ETL Enviro-Test LABORATORIES
A DIVISION OF ETL CHEMSPEC ANALYTICAL LIMITED

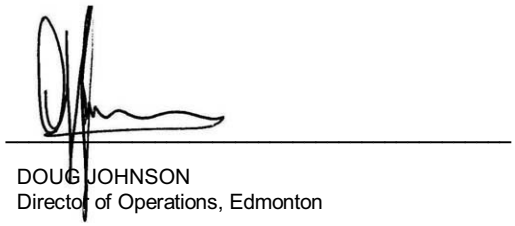
PRELIMINARY RESULTS

MILLENNIUM
ATTN: DANE MCCOY
208 4207 98 ST
EDMONTON AB T6E 5R7

DATE: 06-APR-04 09:16 AM Revision: 1

Lab Work Order #: L152714 **Sampled By:** KS **Date Received:** 09-MAR-04
Project P.O. #:
Project Reference: 03-019

Comments: ADDITIONAL 30-MAR-04 09:44 26-FEB-04 L152714-8,9,*-10,-11,-13 water-hold-cap-sk cancelled due to high clay content of the sample
16-MAR-04 Water Holding Capacity cancelled on -17 due to high clay content



DOUG JOHNSON
Director of Operations, Edmonton

KAREN HUEBNER
Client Service Specialist

THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL WITHOUT THE WRITTEN AUTHORITY OF THE LABORATORY.
ANY REMAINING SAMPLES WILL BE DISPOSED OF AFTER 30 DAYS FOLLOWING ANALYSIS. PLEASE CONTACT THE LAB IF YOU REQUIRE ADDITIONAL SAMPLE STORAGE TIME.

LABORATORY ACCREDITATIONS:
- **STANDARDS COUNCIL OF CANADA IN COOPERATION WITH THE CANADIAN ASSOCIATION FOR ENVIRONMENTAL ANALYTICAL LABORATORIES (CAEAL)** FOR SPECIFIC TESTS AS REGISTERED BY THE COUNCIL (EDMONTON, CALGARY, GRANDE PRAIRIE, SASKATOON, WINNIPEG, THUNDER BAY, WATERLOO)
- **AMERICAN INDUSTRIAL HYGIENE ASSOCIATION (AIHA)** IN THE INDUSTRIAL HYGIENE PROGRAM (EDMONTON, WINNIPEG)
- **STANDARDS COUNCIL OF CANADA IN COOPERATION WITH THE CANADIAN FOOD INSPECTION AGENCY (CFIA)** FOR FERTILIZER AND FEED TESTING (SASKATOON) AND FOR MICROBIOLOGICAL TESTING IN FOOD (WINNIPEG)

LABORATORY RECOGNITIONS:
- **STANDARDS COUNCIL OF CANADA** - GLP COMPLIANT FACILITY (EDMONTON, OTTAWA)

ENVIRO-TEST ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier	D.L.	Units	Extracted	Analyzed	By	Batch
L152714-1 06-03 (2-7.6M)								
Sample Date:								
Matrix: SOIL								
Cation Exchange Capacity	9.6		0.2	meq/100g	16-FEB-04	16-FEB-04	IGH	R167875
Loss On Ignition @ 420 C	2.5		0	%		17-FEB-04	SR	R168082
Lime	MEDIUM		0		16-FEB-04	16-FEB-04	NLM	R167963
Special Request	SEE ATTACHED					01-MAR-04	AS	R170103
Water Holding Capacity	26.1		0.1	%	13-FEB-04	17-FEB-04	MJW	R167945
Particle Size								
% Sand	32		1	%		13-FEB-04	SR	R167936
% Silt	40		1	%		13-FEB-04	SR	R167936
% Clay	28		1	%		13-FEB-04	SR	R167936
Texture	Clay loam					13-FEB-04	SR	R167936
Metals in Soil - CCME List								
Silver (Ag)	<1		1	mg/kg		12-FEB-04	MX	R167509
Arsenic (As)	8.6		0.2	mg/kg		12-FEB-04	MX	R167509
Barium (Ba)	64		5	mg/kg		12-FEB-04	MX	R167509
Beryllium (Be)	<1		1	mg/kg		12-FEB-04	MX	R167509
Cadmium (Cd)	<0.5		0.5	mg/kg		12-FEB-04	MX	R167509
Cobalt (Co)	9		1	mg/kg		12-FEB-04	MX	R167509
Chromium (Cr)	13.9		0.5	mg/kg		12-FEB-04	MX	R167509
Copper (Cu)	23		2	mg/kg		12-FEB-04	MX	R167509
Mercury (Hg)	<0.05		0.05	mg/kg		12-FEB-04	MX	R167509
Molybdenum (Mo)	<1		1	mg/kg		12-FEB-04	MX	R167509
Nickel (Ni)	24		2	mg/kg		12-FEB-04	MX	R167509
Lead (Pb)	10		5	mg/kg		12-FEB-04	MX	R167509
Antimony (Sb)	<0.2		0.2	mg/kg		12-FEB-04	MX	R167509
Selenium (Se)	0.9		0.2	mg/kg		12-FEB-04	MX	R167509
Tin (Sn)	<5		5	mg/kg		12-FEB-04	MX	R167509
Thallium (Tl)	<1		1	mg/kg		12-FEB-04	MX	R167509
Uranium (U)	<40		40	mg/kg		12-FEB-04	MX	R167509
Vanadium (V)	19		1	mg/kg		12-FEB-04	MX	R167509
Zinc (Zn)	70		10	mg/kg		12-FEB-04	MX	R167509
Detailed Salinity								
Chloride (Cl)	144		1	mg/L		13-FEB-04	SHC	R167934
Sulphate (SO4)	955		0.5	mg/L		13-FEB-04	EOC	R167674
pH and EC (Saturated Paste)								
% Saturation	66.3		0.1	%		13-FEB-04	NKC	R167625
pH in Saturated Paste	8.4		0.1	pH		13-FEB-04	NKC	R167625
Conductivity Sat. Paste	1.49		0.01	dS m-1		13-FEB-04	NKC	R167625
SAR								
Calcium (Ca)	22.9		0.5	mg/L		13-FEB-04	EOC	R167674
Potassium (K)	17.2		0.5	mg/L		13-FEB-04	EOC	R167674
Magnesium (Mg)	8.1		0.1	mg/L		13-FEB-04	EOC	R167674
Sodium (Na)	477		1	mg/L		13-FEB-04	EOC	R167674
SAR	21.9			SAR		13-FEB-04	EOC	R167674
L152714-2 12-05 (2-7M)								
Sample Date:								
Matrix: SOIL								
Cation Exchange Capacity	6.9		0.2	meq/100g	16-FEB-04	16-FEB-04	IGH	R167875
Loss On Ignition @ 420 C	2.5		0	%		17-FEB-04	SR	R168082
Lime	MEDIUM		0		16-FEB-04	16-FEB-04	NLM	R167963

ENVIRO-TEST ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier	D.L.	Units	Extracted	Analyzed	By	Batch
L152714-2 12-05 (2-7M)								
Sample Date:								
Matrix: SOIL								
Special Request	SEE ATTACHED					01-MAR-04	AS	R170103
Water Holding Capacity	23.3		0.1	%	13-FEB-04	17-FEB-04	MJW	R167945
Particle Size								
% Sand	47		1	%		13-FEB-04	SR	R167936
% Silt	29		1	%		13-FEB-04	SR	R167936
% Clay	24		1	%		13-FEB-04	SR	R167936
Texture	Loam					13-FEB-04	SR	R167936
Metals in Soil - CCME List								
Silver (Ag)	<1		1	mg/kg		12-FEB-04	MX	R167509
Arsenic (As)	4.7		0.2	mg/kg		12-FEB-04	MX	R167509
Barium (Ba)	86		5	mg/kg		12-FEB-04	MX	R167509
Beryllium (Be)	<1		1	mg/kg		12-FEB-04	MX	R167509
Cadmium (Cd)	<0.5		0.5	mg/kg		12-FEB-04	MX	R167509
Cobalt (Co)	6		1	mg/kg		12-FEB-04	MX	R167509
Chromium (Cr)	10.2		0.5	mg/kg		12-FEB-04	MX	R167509
Copper (Cu)	11		2	mg/kg		12-FEB-04	MX	R167509
Mercury (Hg)	<0.05		0.05	mg/kg		12-FEB-04	MX	R167509
Molybdenum (Mo)	<1		1	mg/kg		12-FEB-04	MX	R167509
Nickel (Ni)	15		2	mg/kg		12-FEB-04	MX	R167509
Lead (Pb)	6		5	mg/kg		12-FEB-04	MX	R167509
Antimony (Sb)	<0.2		0.2	mg/kg		12-FEB-04	MX	R167509
Selenium (Se)	0.4		0.2	mg/kg		12-FEB-04	MX	R167509
Tin (Sn)	<5		5	mg/kg		12-FEB-04	MX	R167509
Thallium (Tl)	<1		1	mg/kg		12-FEB-04	MX	R167509
Uranium (U)	<40		40	mg/kg		12-FEB-04	MX	R167509
Vanadium (V)	15		1	mg/kg		12-FEB-04	MX	R167509
Zinc (Zn)	40		10	mg/kg		12-FEB-04	MX	R167509
Detailed Salinity								
Chloride (Cl)	45		1	mg/L		13-FEB-04	SHC	R167934
Sulphate (SO4)	1190		0.5	mg/L		13-FEB-04	EOC	R167674
pH and EC (Saturated Paste)								
% Saturation	46.5		0.1	%		13-FEB-04	NKC	R167625
pH in Saturated Paste	7.8		0.1	pH		13-FEB-04	NKC	R167625
Conductivity Sat. Paste	1.89		0.01	dS m-1		13-FEB-04	NKC	R167625
SAR								
Calcium (Ca)	250		0.5	mg/L		13-FEB-04	EOC	R167674
Potassium (K)	20.6		0.5	mg/L		13-FEB-04	EOC	R167674
Magnesium (Mg)	46.2		0.1	mg/L		13-FEB-04	EOC	R167674
Sodium (Na)	273		1	mg/L		13-FEB-04	EOC	R167674
SAR	4.2			SAR		13-FEB-04	EOC	R167674
L152714-3 12-05 (7-9.8M)								
Sample Date:								
Matrix: SOIL								
Cation Exchange Capacity	20.3		0.2	meq/100g	16-FEB-04	16-FEB-04	IGH	R167875
Loss On Ignition @ 420 C	2.7		0	%		17-FEB-04	SR	R168082
Lime	MEDIUM		0		16-FEB-04	16-FEB-04	NLM	R167963
Special Request	SEE ATTACHED					01-MAR-04	AS	R170103
Water Holding Capacity	67.3		0.1	%	13-FEB-04	17-FEB-04	MJW	R167945
Particle Size								

ENVIRO-TEST ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier	D.L.	Units	Extracted	Analyzed	By	Batch
L152714-3 12-05 (7-9.8M)								
Sample Date:								
Matrix: SOIL								
Particle Size								
% Sand	28		1	%		13-FEB-04	SR	R167936
% Silt	28		1	%		13-FEB-04	SR	R167936
% Clay	44		1	%		13-FEB-04	SR	R167936
Texture	Clay					13-FEB-04	SR	R167936
Metals in Soil - CCME List								
Silver (Ag)	<1		1	mg/kg		12-FEB-04	MX	R167509
Arsenic (As)	8.5		0.2	mg/kg		12-FEB-04	MX	R167509
Barium (Ba)	502		5	mg/kg		12-FEB-04	MX	R167509
Beryllium (Be)	<1		1	mg/kg		12-FEB-04	MX	R167509
Cadmium (Cd)	<0.5		0.5	mg/kg		12-FEB-04	MX	R167509
Cobalt (Co)	10		1	mg/kg		12-FEB-04	MX	R167509
Chromium (Cr)	11.1		0.5	mg/kg		12-FEB-04	MX	R167509
Copper (Cu)	27		2	mg/kg		12-FEB-04	MX	R167509
Mercury (Hg)	<0.05		0.05	mg/kg		12-FEB-04	MX	R167509
Molybdenum (Mo)	<1		1	mg/kg		12-FEB-04	MX	R167509
Nickel (Ni)	23		2	mg/kg		12-FEB-04	MX	R167509
Lead (Pb)	13		5	mg/kg		12-FEB-04	MX	R167509
Antimony (Sb)	<0.2		0.2	mg/kg		12-FEB-04	MX	R167509
Selenium (Se)	1.1		0.2	mg/kg		12-FEB-04	MX	R167509
Tin (Sn)	<5		5	mg/kg		12-FEB-04	MX	R167509
Thallium (Tl)	<1		1	mg/kg		12-FEB-04	MX	R167509
Uranium (U)	<40		40	mg/kg		12-FEB-04	MX	R167509
Vanadium (V)	13		1	mg/kg		12-FEB-04	MX	R167509
Zinc (Zn)	80		10	mg/kg		12-FEB-04	MX	R167509
Detailed Salinity								
Chloride (Cl)	81		1	mg/L		13-FEB-04	SHC	R167934
Sulphate (SO4)	273		0.5	mg/L		13-FEB-04	EOC	R167674
pH and EC (Saturated Paste)								
% Saturation	90.6		0.1	%		13-FEB-04	NKC	R167625
pH in Saturated Paste	9.0		0.1	pH		13-FEB-04	NKC	R167625
Conductivity Sat. Paste	1.09		0.01	dS m-1		13-FEB-04	NKC	R167625
SAR								
Calcium (Ca)	13.5		0.5	mg/L		13-FEB-04	EOC	R167674
Potassium (K)	13.0		0.5	mg/L		13-FEB-04	EOC	R167674
Magnesium (Mg)	4.9		0.1	mg/L		13-FEB-04	EOC	R167674
Sodium (Na)	349		1	mg/L		13-FEB-04	EOC	R167674
SAR	20.7			SAR		13-FEB-04	EOC	R167674
L152714-4 7-30 (2-7M)								
Sample Date:								
Matrix: SOIL								
Cation Exchange Capacity	12.7		0.2	meq/100g	16-FEB-04	16-FEB-04	IGH	R167875
Loss On Ignition @ 420 C	2.9		0	%		17-FEB-04	SR	R168082
Lime	MEDIUM		0		16-FEB-04	16-FEB-04	NLM	R167963
Special Request	SEE ATTACHED					01-MAR-04	AS	R170103
Water Holding Capacity	43.3		0.1	%	13-FEB-04	17-FEB-04	MJW	R167945
Particle Size								
% Sand	38		1	%		13-FEB-04	SR	R167936
% Silt	28		1	%		13-FEB-04	SR	R167936

ENVIRO-TEST ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier	D.L.	Units	Extracted	Analyzed	By	Batch
L152714-4 7-30 (2-7M)								
Sample Date:								
Matrix: SOIL								
Particle Size								
% Clay	34		1	%		13-FEB-04	SR	R167936
Texture	Clay loam					13-FEB-04	SR	R167936
Metals in Soil - CCME List								
Silver (Ag)	<1		1	mg/kg		12-FEB-04	MX	R167509
Arsenic (As)	4.6		0.2	mg/kg		12-FEB-04	MX	R167509
Barium (Ba)	214		5	mg/kg		12-FEB-04	MX	R167509
Beryllium (Be)	<1		1	mg/kg		12-FEB-04	MX	R167509
Cadmium (Cd)	<0.5		0.5	mg/kg		12-FEB-04	MX	R167509
Cobalt (Co)	7		1	mg/kg		12-FEB-04	MX	R167509
Chromium (Cr)	10.9		0.5	mg/kg		12-FEB-04	MX	R167509
Copper (Cu)	17		2	mg/kg		12-FEB-04	MX	R167509
Mercury (Hg)	<0.05		0.05	mg/kg		12-FEB-04	MX	R167509
Molybdenum (Mo)	<1		1	mg/kg		12-FEB-04	MX	R167509
Nickel (Ni)	16		2	mg/kg		12-FEB-04	MX	R167509
Lead (Pb)	8		5	mg/kg		12-FEB-04	MX	R167509
Antimony (Sb)	<0.2		0.2	mg/kg		12-FEB-04	MX	R167509
Selenium (Se)	0.5		0.2	mg/kg		12-FEB-04	MX	R167509
Tin (Sn)	<5		5	mg/kg		12-FEB-04	MX	R167509
Thallium (Tl)	<1		1	mg/kg		12-FEB-04	MX	R167509
Uranium (U)	<40		40	mg/kg		12-FEB-04	MX	R167509
Vanadium (V)	12		1	mg/kg		12-FEB-04	MX	R167509
Zinc (Zn)	40		10	mg/kg		12-FEB-04	MX	R167509
Detailed Salinity								
Chloride (Cl)	74		1	mg/L		13-FEB-04	SHC	R167934
Sulphate (SO4)	619		0.5	mg/L		13-FEB-04	EOC	R167674
pH and EC (Saturated Paste)								
% Saturation	74.8		0.1	%		13-FEB-04	NKC	R167625
pH in Saturated Paste	9.0		0.1	pH		13-FEB-04	NKC	R167625
Conductivity Sat. Paste	1.10		0.01	dS m-1		13-FEB-04	NKC	R167625
SAR								
Calcium (Ca)	12.6		0.5	mg/L		13-FEB-04	EOC	R167674
Potassium (K)	9.3		0.5	mg/L		13-FEB-04	EOC	R167674
Magnesium (Mg)	3.9		0.1	mg/L		13-FEB-04	EOC	R167674
Sodium (Na)	379		1	mg/L		13-FEB-04	EOC	R167674
SAR	23.9			SAR		13-FEB-04	EOC	R167674
L152714-5 14-20 (2-6.1M)								
Sample Date:								
Matrix: SOIL								
Cation Exchange Capacity	6.6		0.2	meq/100g	16-FEB-04	16-FEB-04	IGH	R167875
Loss On Ignition @ 420 C	2.7		0	%		17-FEB-04	SR	R168082
Lime	MEDIUM		0		16-FEB-04	16-FEB-04	NLM	R167963
Special Request	SEE ATTACHED					01-MAR-04	AS	R170103
Water Holding Capacity	13.6		0.1	%	13-FEB-04	17-FEB-04	MJW	R167945
Particle Size								
% Sand	44		1	%		13-FEB-04	SR	R167936
% Silt	30		1	%		13-FEB-04	SR	R167936
% Clay	26		1	%		13-FEB-04	SR	R167936
Texture	Loam					13-FEB-04	SR	R167936

ENVIRO-TEST ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier	D.L.	Units	Extracted	Analyzed	By	Batch
L152714-5 14-20 (2-6.1M)								
Sample Date:								
Matrix: SOIL								
Metals in Soil - CCME List								
Silver (Ag)	<1		1	mg/kg		12-FEB-04	MX	R167509
Arsenic (As)	2.4		0.2	mg/kg		12-FEB-04	MX	R167509
Barium (Ba)	95		5	mg/kg		12-FEB-04	MX	R167509
Beryllium (Be)	<1		1	mg/kg		12-FEB-04	MX	R167509
Cadmium (Cd)	<0.5		0.5	mg/kg		12-FEB-04	MX	R167509
Cobalt (Co)	5		1	mg/kg		12-FEB-04	MX	R167509
Chromium (Cr)	10.5		0.5	mg/kg		12-FEB-04	MX	R167509
Copper (Cu)	9		2	mg/kg		12-FEB-04	MX	R167509
Mercury (Hg)	<0.05		0.05	mg/kg		12-FEB-04	MX	R167509
Molybdenum (Mo)	<1		1	mg/kg		12-FEB-04	MX	R167509
Nickel (Ni)	13		2	mg/kg		12-FEB-04	MX	R167509
Lead (Pb)	6		5	mg/kg		12-FEB-04	MX	R167509
Antimony (Sb)	<0.2		0.2	mg/kg		12-FEB-04	MX	R167509
Selenium (Se)	0.3		0.2	mg/kg		12-FEB-04	MX	R167509
Tin (Sn)	<5		5	mg/kg		12-FEB-04	MX	R167509
Thallium (Tl)	<1		1	mg/kg		12-FEB-04	MX	R167509
Uranium (U)	<40		40	mg/kg		12-FEB-04	MX	R167509
Vanadium (V)	15		1	mg/kg		12-FEB-04	MX	R167509
Zinc (Zn)	30		10	mg/kg		12-FEB-04	MX	R167509
Detailed Salinity								
Chloride (Cl)	32		1	mg/L		13-FEB-04	SHC	R167934
Sulphate (SO4)	210		0.5	mg/L		13-FEB-04	EOC	R167674
pH and EC (Saturated Paste)								
% Saturation	43.9		0.1	%		13-FEB-04	NKC	R167625
pH in Saturated Paste	8.0		0.1	pH		13-FEB-04	NKC	R167625
Conductivity Sat. Paste	0.47		0.01	dS m-1		13-FEB-04	NKC	R167625
SAR								
Calcium (Ca)	52.5		0.5	mg/L		13-FEB-04	EOC	R167674
Potassium (K)	11.3		0.5	mg/L		13-FEB-04	EOC	R167674
Magnesium (Mg)	12.9		0.1	mg/L		13-FEB-04	EOC	R167674
Sodium (Na)	50		1	mg/L		13-FEB-04	EOC	R167674
SAR	1.6			SAR		13-FEB-04	EOC	R167674
L152714-6 1-33 (2-6.1M)								
Sample Date:								
Matrix: SOIL								
Cation Exchange Capacity	6.8		0.2	meq/100g	16-FEB-04	16-FEB-04	IGH	R167875
Loss On Ignition @ 420 C	2.2		0	%		17-FEB-04	SR	R168082
Lime	LOW		0		16-FEB-04	16-FEB-04	NLM	R167963
Special Request	SEE ATTACHED					01-MAR-04	AS	R170103
Water Holding Capacity	12.9		0.1	%	13-FEB-04	17-FEB-04	MJW	R167945
Particle Size								
% Sand	43		1	%		13-FEB-04	SR	R167936
% Silt	39		1	%		13-FEB-04	SR	R167936
% Clay	18		1	%		13-FEB-04	SR	R167936
Texture	Loam					13-FEB-04	SR	R167936
Metals in Soil - CCME List								
Silver (Ag)	<1		1	mg/kg		12-FEB-04	MX	R167509
Arsenic (As)	2.4		0.2	mg/kg		12-FEB-04	MX	R167509

ENVIRO-TEST ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier	D.L.	Units	Extracted	Analyzed	By	Batch
L152714-6 1-33 (2-6.1M)								
Sample Date:								
Matrix: SOIL								
Metals in Soil - CCME List								
Barium (Ba)	74		5	mg/kg		12-FEB-04	MX	R167509
Beryllium (Be)	<1		1	mg/kg		12-FEB-04	MX	R167509
Cadmium (Cd)	<0.5		0.5	mg/kg		12-FEB-04	MX	R167509
Cobalt (Co)	5		1	mg/kg		12-FEB-04	MX	R167509
Chromium (Cr)	9.4		0.5	mg/kg		12-FEB-04	MX	R167509
Copper (Cu)	9		2	mg/kg		12-FEB-04	MX	R167509
Mercury (Hg)	<0.05		0.05	mg/kg		12-FEB-04	MX	R167509
Molybdenum (Mo)	<1		1	mg/kg		12-FEB-04	MX	R167509
Nickel (Ni)	12		2	mg/kg		12-FEB-04	MX	R167509
Lead (Pb)	<5		5	mg/kg		12-FEB-04	MX	R167509
Antimony (Sb)	<0.2		0.2	mg/kg		12-FEB-04	MX	R167509
Selenium (Se)	0.3		0.2	mg/kg		12-FEB-04	MX	R167509
Tin (Sn)	<5		5	mg/kg		12-FEB-04	MX	R167509
Thallium (Tl)	<1		1	mg/kg		12-FEB-04	MX	R167509
Uranium (U)	<40		40	mg/kg		12-FEB-04	MX	R167509
Vanadium (V)	12		1	mg/kg		12-FEB-04	MX	R167509
Zinc (Zn)	30		10	mg/kg		12-FEB-04	MX	R167509
Detailed Salinity								
Chloride (Cl)	15		1	mg/L		13-FEB-04	SHC	R167934
Sulphate (SO4)	130		0.5	mg/L		13-FEB-04	EOC	R167674
pH and EC (Saturated Paste)								
% Saturation	43.1		0.1	%		13-FEB-04	NKC	R167625
pH in Saturated Paste	7.3		0.1	pH		13-FEB-04	NKC	R167625
Conductivity Sat. Paste	0.48		0.01	dS m-1		13-FEB-04	NKC	R167625
SAR								
Calcium (Ca)	67.2		0.5	mg/L		13-FEB-04	EOC	R167674
Potassium (K)	16.4		0.5	mg/L		13-FEB-04	EOC	R167674
Magnesium (Mg)	19.2		0.1	mg/L		13-FEB-04	EOC	R167674
Sodium (Na)	28		1	mg/L		13-FEB-04	EOC	R167674
SAR	0.8			SAR		13-FEB-04	EOC	R167674