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THE UNIVERSITY OF ALBERTA

MOISTURE CHARACTERISTICS OF COARSE TEXTURED SOILS AND PEAT : MINERAL MIXES

BY

TANYA D. MOSKAL

A THESIS SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE
IN
LAND RECLAMATION and REMEDIATION

DEPARTMENT OF RENEWABLE RESOURCES

EDMONTON, ALBERTA

Spring 1999

0-612-40089-1

THE UNIVERSITY OF ALBERTA RELEASE FORM

NAME OFAUTHOR: **TANYA D. MOSKAL**

TITLE OF THESIS: **MOISTURE CHARACTERISTICS OF COARSE TEXTURED SOILS AND PEAT : MINERAL MIXES**

DEGREE: **MASTER OF SCIENCE IN LAND RECLAMATION AND REMEDIATION**

YEAR THIS DEGREE GRANTED: **1999**

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Moskal

9321 95 Street
Edmonton, AB, T6C 3X1

Date: April 16/99

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled MOISTURE CHARACTERISTICS OF COARSE TEXTURED SOILS AND PEAT : MINERAL MIXES submitted by Tanya D. Moskal in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN LAND RECLAMATION AND REMEDIATION.

Dr. D. S. Chanasyk (Co-Supervisor)

M. Anne Naeth

Dr. M. A. Naeth (Co-Supervisor)

Leonard Leskiw

Mr. L. A. Leskiw

Donald J Pluth

Dr. D. J. Pluth

D C Sego

Dr. D. C. Sego

Date: April 16/99

ABSTRACT

Moisture characteristics of coarse textured soils and peat:mineral mixes were evaluated in situ on undisturbed and reclaimed sites and in the laboratory. The undisturbed sites reached field capacity (FC) within 12 h and the reclaimed sites by 24 h. Moisture contents at 0.01 MPa were significantly different from in situ FC for tailings sands; moisture contents at 0.033 MPa were similar to in situ FC for sandy loam and peaty loamy sand. Both gravimetric and volumetric laboratory available water holding capacity were altered by organic carbon in peat:mineral mixes. For in situ samples organic carbon altered gravimetric AWHC but not volumetric. Increasing depths of peat:mineral mix over tailings sand significantly increased total soil moisture (TSM) to 90 cm. Increasing peat:mineral mix ratios from 1:1 to 3:1 increased not statistically significantly TSM. TSM also increased non-significantly with changes in component texture for given peat:mineral mixes. Moisture content of peat:mineral mixes at FC was enhanced by profile interfaces.

ACKNOWLEDGEMENTS

Suncor Inc. Oil Sands Group and Syncrude Canada Ltd. jointly funded this project. Individuals from each company that made the project possible were Steve Tuttle and Leo Paquin from Suncor Inc. Oil Sands Group and Tom Coolen, Earle Anderson and Clara Qualizza from Syncrude Canada Ltd., my thanks to them. Can-Ag Enterprises Ltd. played a coordinating role in this project. Thank-you to all my committee members for their time and patience. I would especially like to thank Dr. Anne Naeth and Leonard Leskiw for their faith in my abilities and the support they provided throughout my program; without them I would not have started down this path. Special thanks to my mother (Thelma Inkson) and father (Daniel Moskal) for their numerous forms of support and encouragement; and also to Dr. David Chanasyk for his technical support, guidance and patience, without him I would have not finished. Finally, I would like to thank Pierre for his never-ending support, whether I finished or not.

There are numerous friends, at university and outside the university, who deserve thanks for their help, understanding and encouragement: Marlene Bustos, Mae Elsinger, Wendy Gardner, Pola Genoway, Darlene Howat, Emmanuel Mapfumo, Troy Moskal, The Pooles, Jilene Offord, Kelly Ostermann, Jim Schaefer, Lee Waterman

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1.0 INTRODUCTION

1.1 Background

How soil moisture characteristics of field capacity (FC), permanent wilting point (PWP) and the resultant available water holding capacity (AWHC) should be best quantified has long been debated in the soils community. There is also controversy over whether FC, PWP and AWHC measurements can be quantified through laboratory measurements (Ratliff et al. 1983). When dealing with coarse textured soils the difficulties with soil moisture characteristics and AWHC become further confounded. These coarse textured soil concerns include low AWHC and low nutrient availability for plant growth (Bennett and Entz 1989). Coarse textured soils, based on the Canadian System of Soil Classification (Soil Classification Working Group 1998), are sand, loamy sands and sandy loams. When used for reclamation or agricultural production, these coarse textured soils hold insufficient water for plant growth and development and have low levels of natural fertility (Hillel 1980).

To counteract the effects of insufficient water and low levels of natural fertility in coarse textured soils, organic matter amendments have been considered. However, the effect of such amendments on increasing AWHC of soils has been controversial since the late 1930s. Bouyoucos (1939) listed three contradictory opinions held at that time: first, organic matter will increase the water holding capacity of mineral soils; second, although the organic matter will increase FC of mineral soils, it also increases PWP equally and thus the net effect on AWHC is nil; third, organic matter plays a minor role in the water holding capacity of mineral soils. In his experiments, Bouyoucos (1938) concluded that "...organic matter increases markedly the available water [holding capacity] in light [sandy] soils, and to a less extent than in heavy [clayey] soils".

Debate continues in soil science, and in reclamation, as to whether or not FC and PWP increase in a parallel manner with increasing organic carbon (OC) and thus the AWHC remains the same (Donahue et al. 1977; Brady 1984), or whether FC increases more than

PWP as OC increases, resulting in an increased AWHC (Hudson 1994). The answer is pertinent to reclamation, as peat is readily available as an amendment for large disturbances, such as in the Oil Sands Areas of Alberta. In fact, peat:mineral mix topsoils have been used in reclaiming this region for almost 20 years (Leskiw Personal Communication).

There are over 11 000 km^2 of Athabasca Oil Sand deposits north of Township 84 in the Fort McMurray region of Alberta (Smith 1981). Oil sands are naturally occurring quartzose sands impregnated with heavy oil (Hackbarth and Nastasa 1979). They occur in the Lower Cretaceous McMurray Formation (Smith 1981). The overlying glacial drift layer is excavated and stored for future use in reclamation. Overlying sand and shale layers are also excavated and used as fill in the mined areas. Up to 8.0 m of residual material may have to be excavated to reach the oil sands system (Smith 1981). Once a pit has been established and the desired substance is reached, it is removed using a truck and shovel system (Leskiw Personal Communication).

The oil sands are fed to the extraction area of the plant where reject (oil sands with <6% oil content) are separated out as well as most of the tailings sand (Syncrude Canada Ltd. 1994). The froth that leaves the extraction plant is composed of 55 to 65% bitumen, 25 to 30% water and 8 to 10% solids. This froth may then go through various process pathways in upgrading to produce one of the end products of tail gas, sulphur or synthetic crude. The final product of the hydrocarbon removal process from oil sands is tailings sand, a fine sand material. These tailings sands, when dry, are hydrophobic and contain less than 1% OC (Macyk and Turchenek 1995).

A huge open pit remains after the oil sands have been removed. The overburden, from above the oil sands, may be stockpiled and reclaimed as is, or it may be placed directly back into the open pit. The separated tailings sand may be used to build the berms of the settling basins or stockpiled also. Once the stockpiles and berms are established, reclamation may proceed.

The goal of soil reclamation on the Suncor Oil Sands Group lease 86/17 in the Oil Sands Region is to establish vegetation on 84% of the reclaimed area, 10% may be occupied by wet lands and the remaining 6% is slated to existing disturbance, water and construction (Tuttle Personal Communication). The reclamation goals of Syncrude Canada Ltd. are to establish 70% terrestrial area and 30% water bodies, within the total 100% there are several different goals including commercial forestry 46%, traditional uses and wildlife areas 37%, human development 13% and natural and conservation areas 4% (Qualizza Personal Communication).

There are four principal types of materials that are used to create soils in the Oil Sands Region, the features of which are summarized below (Leskiw and Moskal 1997a).

Peat:mineral mix - a mixture of peat and mineral material resulting in a "mineral" soil. It may be obtained by either overstripping peat into mineral soil, or by placing peat material and then rotovating into underlying mineral material.

Direct placement material - soil or surficial geological material taken from a natural deposit and placed directly on tailings sand or overburden. This includes both upland and lowland materials high and low in organic matter. The material may be sandy or clayey in texture.

Overburden - reclamation material that may be used as subsoil. It is obtained from below the soil profile and to the oil sands that are mined. Based on 1996 observations in the Oils Sands Region the overburden is usually sandy loam, clay loam or sandy clay loam in texture, and has significant oil content (usually <2%, but sometimes as much as 6%).

Tailings sand - fine sand material which is one of the final products of the hydrocarbon removal process.

Reclamation has been conducted in the Oil Sands Region for approximately 20 years (Tuttle 1997). The process of reclamation, in its most general form, starts with the salvage of topsoil in the winter months. Topsoil salvage usually consists of removal of peat from a bog or fen, in situ, with approximately 40% (volume basis) of the underlying mineral material excavated at the same time, creating a peat:mineral mix. The preferred reclamation technique is to have this salvaged peat:mineral material placed directly on an area to be reclaimed to retain the seedbank. In the spring this material is spread to a depth of approximately 20 cm, harrowed and seeded to a barley cover. Barley is used to provide erosion control, snow capture and allows native species to emerge. Woody species are planted by hand, from collected ecotypes within an 80-km radius. Fertilizer application is conducted, by air, initially and four to five years following the initial seeding.

These subsoil bases of overburden and tailings sand within the Oil Sands Region can be reclaimed in two ways. A layer of fine textured material may be placed over the overburden or tailings sand and then a capping of peat:mineral mix would be placed on top, or a capping of peat:mineral mix may be placed directly on top of the overburden or tailings sand subsoil base.

The peat:mineral mix-tailings sands interface created when reclamation is complete may influence the moisture profile of the soil, but the exact effect remains to be determined. The answer to the reclaimed-soil-interface question becomes pertinent to ensure the peat:mineral mix placed on top of the tailings sand will not serve as a barrier to water movement, but provide a suitable growth medium, water and nutrients for vegetation, to ensure reclamation success.

1.2 Literature Review

1.2.1 Introduction

All the attributes of soils must be considered in reclamation. Coarse textured soils are characterized by large particle sizes, small surface area per unit weight, low chemical activity, low total pore space, adequate aeration, low water-holding capacity and few plant available nutrients (Naeth et al. 1991); therefore, these soils may not be the most desirable for use in reclamation. However, in some instances only coarse textured soils may be available, thus the soil moisture available to plants becomes one of the key factors in determining whether such reclaimed soils will serve as suitable plant growth media.

1.2.2 Definitions

Available water holding capacity is the measure of how much moisture the soil can retain for vegetation to establish and grow (Hausenbuiller 1985). AWHC as a specific soil moisture retention value is the mathematical difference in the amounts of water a soil holds at FC and PWP.

Field capacity is defined as the water content at which gravitational or internal drainage ceases (Hillel 1980). However, this concept has been recognized as arbitrary for many reasons. Primarily the determination of the redistribution of soil water is plagued with subjectivity and inaccuracies in measurement. These inaccuracies in measurement are found both in situ and in the laboratory, where pressure plate values of 0.033 MPa and 0.01 MPa are routinely used to approximate FC for moderately coarse and finer textured materials and coarse textured materials, respectively.

Permanent wilting point (PWP) is defined as the water content of a soil at which plants wilt and fail to recover their turgidity when placed in a dark, humid atmosphere (Powter 1994). The approximate laboratory pressure used to attain PWP is 1.5 MPa. The concept of PWP is not as controversial as FC, as at such high pressures the water remaining in the soil is not as variable as at lower pressures (McIntyre 1974).

1.2.3 FC: In Situ vs. Laboratory Pressure Estimates

Rivers and Shipp (1972) reviewed the literature and found no studies comparing laboratory pressure values with in situ FC values for coarse textured soils; however, there was a general unwritten consensus that the laboratory FC approximation for coarser textured soils was ≤0.01 MPa (Pritchett and Fisher 1987). Through their studies, Rivers and Shipp determined that 0.01 MPa underestimates the FC of sands and indicated that the values of loamy sands on the lower side of the textural triangle were also underestimated. Later (1978) the researchers further verified that none of the laboratory, low soil water suctions [0.01 MPa, 0.015 MPa, and 0.02 MPa] produced soil water values consistent with the field determined FC values. Bennett and Entz (1989) found moisture content in the field at 48 h was substantially higher than moisture content at a tension of 10 kPa in standard pressure plate laboratory procedures for estimation of field capacity in coarse-textured soils. Currently, the laboratory FC equivalent for the coarser textured soils has been set at 0.01 MPa; however, this is only a representative measurement of in situ FC.

There have been many attempts to determine how to estimate FC consistently in the laboratory to correlate it with in situ measurements in a soil profile. However, it appears that the measurements taken in the field are more accurate than those measurements taken in the laboratory. Hanks et al. (1954) found that the FC approximations based on moisture transmitting properties to be a significantly better over-all estimate of field capacity than the moisture equivalent, buchner funnel percentage and 1/3-atm. percentage. Salter and Haworth (1961a) determined that field capacity measurements involving soil sampling after irrigation or in situ were more accurate and consistent than those involving the suction-plate method (now called the pressure plate method) with undisturbed cores. Rivers and Shipp (1972) concluded that FC measured in situ is more accurate than laboratory measurements.

1.2.4 Soil Factors Affecting FC

To ensure that coarser textured soils can provide sufficient moisture to vegetation establishing and growing on reclaimed soils, the factors affecting the redistribution of moisture and the actual FC need to be examined. Soil texture, type of clay mineral, organic matter content, depth of wetting and antecedent moisture, impeding layers in the profile and evapotranspiration are factors that may be considered during reclamation to ensure that the establishing vegetation is provided for (Hillel 1971).

1.2.4.1 Texture

Soil texture plays a key role in soil moisture characteristics and therefore AWHC. Several studies have correlated texture and AWHC. Salter et al. (1966) found that available water was negatively correlated with percent coarse sand and positively correlated with percent very fine sand and silt (0.05-0.20 mm). Rivers and Shipp (1978) developed equations to estimate FC and found that the best correlation equation was based on percent very fine sand plus silt plus clay, and that equations based on percent silt and very fine sand individually were not as effective.

1.2.4.2 Depth of wetting

Colman (1944) found depth of wetting can also affect the attainment of FC, in that the moisture content of the first 30 cm was increased less by rains occurring when the soil was initially dry than when the soil was initially moist to some depth. The final outcome of in situ and laboratory studies confirmed that, depending on the soils being studied, the soils must be wetted to a depth of 30 to 90 cm before the moisture in the surface layer will be high enough to reach FC (Colman 1944). However, to moisten soil to 30 to 90 cm would require the soil above to have already reached FC, discounting Colman's theory.

1.2.4.3 Organic carbon

Organic matter effects on the redistribution of moisture in a soil profile has been in dispute for many years. Many sources of organic matter, such as manure and peat, have been studied and examined for determination of the most beneficial effects on vegetation growth. One of the earliest examinations of the effect of organic matter on the water holding capacity of mineral soils was completed by Bouyoucos in 1939. He found that the addition of organic matter increases available water in the soils. This was true whether the results are computed on the weight basis or on the volume basis. The increase in the available water is more marked in the light [coarser] textured soils than in the clays. Buoyoucos used various soil textures (S, SL, SiL, CL and C) and used muck, peat and manure as the organic matter sources (1939). These results were supported later by other researchers such as Jamison and Kroth (1958) and Salter et al. (1966).

Jamison and Kroth (1958) examined the interaction of available moisture storage capacity with the texture and organic matter content of several Missouri soils. They found trends similar to those of Bouyoucos; however, they felt that the results were attributed to different factors. They concluded that AWHC increases with silt content and decreases with clay content and that AWHC in general increases with organic matter. However, they noted the increase is due to the textural change associated with the increased coarse silt and decreased clay with the addition of organic matter. Therefore, Jamison and Kroth felt that the increase in AWHC was not due to the increased OC but due to the change of texture from organic matter addition. They acknowledged that samples with 13-20% clay show evidence of increasing AWHC with increasing organic matter. However, they attribute this increase to the possible formation of silt-sized microaggregates in the clay. In later research Salter et al. (1966) concluded by regression analysis that AWHC is approximately linearly related to the percentage of OC in the soil.

Jamison and Kroth (1958) recommended that comparisons of percent moisture be made on a volume basis rather than on a mass basis due to the lower bulk density of high organic matter or clay-containing soils. The increased volume with high organic matter or clay containing soils was again voiced by Stevenson (1974) in his research on peat moss. He felt that although soil water retention on a mass basis increased with the addition of peat, this was not consistent with the volumeteric measurements where the decreasing bulk densities " . . . more than compensate, less than compensate, or simply compensate for the changes in water retention".

There are other specific experiments that have been conducted with various sources of organic matter, to determine the effect on AWHC. Prior to the 1938 study by Boyoucous, Feustel and Byers (1936) completed a study in which the moisture-absorbing and moisture-retaining capacities of peat and soil mixtures were compared. Jamison and Kroth (1958) and Stevenson (1974) agreed with Feustel and Byers (1936), that moisture characteristics must be examined on a volumetric basis to ensure the comparisons were accurate. This held true for the comparisons Feustel and Byers (1936) were making between peat and mineral soil, and also for the comparisons between the individual types of peat. Feustel and Byers (1936) found that although soil with peat mixtures were capable of absorbing 40-50% more moisture than soil alone, when these peat:soil mixtures were made with clay loam soils, the increased evaporation rate and greater moisture content at PWP counteracted the positive moisture absorbing effects. However, the improved moisture conditions that prevailed when peat was mixed with quartz sand soils was not counteracted by increased evaporation or increased moisture at PWP. These results with the quartz sand were more noticeable with the more decomposed peat material. Due to the addition of peat, the moisture-holding capacity of quartz sand increased as much as 80%, surpassing that of the clay soil. The final evaluation of peat as a soil amendment for increased soil moisture was positive for sand and sandy soils with decomposed peat.

Salter and Haworth (1961b) concluded that farmyard manure, applied annually, increased the AWHC of a sandy loam soil. Their results were confirmed by Salter and Williams (1963), who found that over the 7- to 8-year period that farmyard manure was annually added to a SL soil, FC, PWP and apparent specific gravity had been affected and AWHC had increased. They also found that at lower tensions, manured soils, at 20 tons per acre per crop plus P and K, released more water than unmanured soil with inorganic N fertilizer. Addition of manure to soil had a beneficial effect on crops in the field (Salter and Williams 1963).

Stevenson (1974) examined the influence of peat moss on soil water retention for plants. He felt that, although the soil water retention (gravimetric) increased with the addition of peat, the positive effect was offset by the decreased bulk densities after peat additions. Furthermore, he felt that the results were due to a shift in pore size from large to small or small to large for coarse and fine textured soil, respectively. These results were similar to those found by Jamison and Kroth (1958).

To further clarify the issue of the effects of organic matter and particle size on water retention, Hollis et al. (1977) examined the effect of organic matter and particle size on the water retention properties of soils in the West Midlands of England. By using 0.05 MPa as FC (this measurement had been suggested by Webster and Beckett in 1972) and 1.5 MPa as PWP, Hollis et al. (1977) found that OC accounted for almost 70% of the variation in a linear relationship with FC and 73.5% when the relationship was curvilinear.

Clay accounted for 45% of the linear variation and 49% of the curvilinear variation in relation to FC. The researchers believed both OC and clay accounted for approximately three quarters of the variation, and that the unexplained variation could be accounted for by bulk density (Hollis et al. 1977). This opinion is similar to those expressed by Jamison and Kroth (1958) and Stevenson (1974), discussed previously. Hollis et al. (1977) also found that for AWHC only silt and OC were significantly correlated, with OC accounting for 50% of the variation in the linear relationship.

Bauer and Black (1992) examined three different textural classes with varying OC percentages to determine how OC affects the AWHC of each texture class. The texture classes set were coarse, medium and fine. The authors stated that an increase in OC concentration caused a relatively larger increase in gravimetric soil moisture at FC than at the PWP in coarse to moderately coarse soils (sandy group). But in medium and moderately fine or fine soils (medium and fine groups, respectively), an increase in OC concentration caused essentially identical increases in gravimetric soil moisture at FC and PWP (Bauer and Black 1992).

Hudson (1994) reviewed the literature over a 50 year span on the effect of organic matter on AWHC of different textured soils and analyzed the published data. He found a significant positive correlation between AWHC and increasing organic matter content, by minimizing other factors that could influence AWHC. He also found that with increasing organic matter, the water held at FC increased more rapidly than that held at PWP, therefore increasing the AWHC for all textures.

1.2.4.4 Interfaces

In general any profile discontinuity that affects pore size distribution will decrease water movement across the discontinuity boundary compared with a uniform profile (Miller 1973). Alway and McDole (1917), using six different layers of soil in a cylinder, found that it made no difference as to the order of the soil layers with the exception of dune sand. The interposition of such a sand layer in all cases greatly increased the amount of water held by the soils in the layers above it.

The water retained in soil above a coarse layer is determined by the coarseness of the layer, depth to the layer and desorption characteristics of the soil (Miller 1973). Total and available water in a sandy loam soil underlain at a 60-cm depth by sand of various size ranges increased with increasing coarseness of the sand. Increased available water in the sandy loam soil also remained above that in a uniform profile, regardless of depth to the sand layer. With an underlying sand layer, the coarser the overlying layer, the greater the increase in available water in that layer compared to a uniform soil profile of the same texture. Such soil profile discontinuities, with topsoil placed above tailings sand, occur in the Oil Sands Region of Alberta.

1.3 Study Area

The study was conducted in 1997 on plots established on reclaimed and undisturbed soils surrounding the two oil sand mines of Suncor Inc. Oil Sands Group and Syncrude Canada Ltd. Both mines are located in the northeast central area of Alberta, approximately 30 km north of Fort McMurray. The 11 000 km^2 of Athabasca Oil Sand deposits occur north of Township 84 and south of Township 104, within Ranges 6 to 20 W4.

The Fort McMurray area is characterized by long cold winters and short cool summers, with a mean annual temperature of -0.6 °C (Hackbarth and Nastas 1979). Frost occurs in the Athabasca River Valley between August 15 and August 31, and in the uplands between September 1 and September 15. The average annual precipitation is 437 mm and is about one third snow. Rain falls during June, July, August and September, with the snowfall spread evenly over the winter months. Prevailing winds are from the west.

The area covers one physiographic region: the Interior Plains (Hackbarth and Nastas 1979). Four major uplands exist within the plains area: the Birch Mountains, Muskeg Mountain, Stony Mountain and Thickwood Hills. Incised over hundred meters into the broad flat plain are the Athabasca and Clearwater Rivers. The plain slopes gradually to the other major rivers and streams.

The Clearwater and Athabasca Rivers join at Fort McMurray, and the rivers flow northward into the Athabasca Delta. Important tributaries from the west are the MacKay, Dover and Ells and from the east are the Steepbank, Muskeg and Firebag Rivers (Smith 1981). Between Fort McMurray and Embarras 75% of the gain in flow is due to the inflow of the above listed rivers and other minor tributaries (Hackbarth and Nastas 1979).

A wide array of Brunisolic, Luvisolic, Organic and Regosolic soil orders are present in the area. (Leskiw and Moskal 1997c, 1997d). The soil series of Dover and Kenzie predominate with Algar, Mildred, Muskeg and Ruth Lake representing substantial areas.

1.4 Plot Establishment and Site Soil Characteristics

Two types of field sites were chosen for study; reclaimed sites of peat:mineral mix over tailings sand within the Oils Sands disturbance and undisturbed sites consisting of coarse textured Eluviated Eutric Brunisols outside the Oil Sands disturbance (See Appendix 1 for site descriptions). The peat:mineral mix sites were chosen to represent variations in depth and textures of peat:mineral mixes over tailings sand. There are 11 peat:mineral mix sites, seven are from the 1996 research (Moskal and Leskiw 1996), the remaining four were selected in 1997. The undisturbed sites were chosen to represent variations in textures of coarse textured profiles. For coarse textured soils and comparisons, the four undisturbed sites discussed in the 1996 research (Moskal and Leskiw 1996) are used and in addition three other sites were chosen (See Appendix 1 for site maps).

Particle size distribution (PSA) was determined using the hydrometer method outlined by Day (1965), using the soils sampled from each horizon prior to experimentation. A pretreatment of hydrogen peroxide was used to remove the organic matter in the peat:mineral mixes. Sand fractions were determined using the Allen Bradley™ Sonic Sifter according to the methods discussed in Carter (1993).

Soils at the undisturbed sites had textures of sand, loamy sand and sandy loam (Table 1.1). The reclaimed sites were characterized by textures of peaty sand, peaty loamy sand and peaty sandy loam (peat:mineral mixes) over the fine sand (tailings sand). For both the coarse textured soils and the peat:mineral mixes % sand was > 70% and the % clay was < 11%. Also, the increases in % silt and clay were almost equivalent, as the % sand decreased. Very coarse (2.0-1.0 mm) and coarse sand (1.0-0.50 mm) fractions accounted for less than 17% of the sand fractions. Medium sands (0.50-0.25 mm) dominated the sand fractions of the mineral soil, S, LS, and SL, accounting for > 50% of the sample. Whereas, the medium (0.50-0.25 mm) and fine sands (0.25-0.10 mm) dominated the peaty sand, loamy sand and sandy loam groups, accounting for more than 30% in each texture. Very fine sands (0.10-0.05 mm) accounted for less than 26% of the sand fractions, except for one texture. All of the particle size analysis textural designations stayed the same after sand fraction analysis, except for tailings sand.

The tailings sand was broken down into two classes, based on the location of their origin, Suncor lease site and Syncrude lease site. All of the tailings sands were fine sands, except the Syncrude tailings sand, which contained more than 50% very fine sand (0.10-0.05 mm) and thus was categorized as such.

1.5 Objectives and Thesis Format

The objectives of this thesis and hypotheses that stem from the objectives follow.

1.5.1 Objectives

1. To evaluate the suitability of soil moisture at 48 h after saturation to represent FC or the end of free drainage under field conditions.
2. To determine what laboratory pressure best represents FC of coarse textured soils (S, LS and SL) and peat:mineral mixes under reclaimed and undisturbed conditions in the field.
3. To quantify the effect of OC (peat) on soil moisture retention of peat:mineral mixes.

4. To quantify moisture retention in a soil profile created by placing a peat:mineral mix layer over tailings sand.
5. To apply the above objectives to determine the most effective volume and depth components of peat:mineral mixes for reclamation in the Oils Sands Region of Alberta.

1.5.2 Hypotheses

1. The appropriate field measurement of FC is soil moisture at 48 h of drainage after saturation.
2. The appropriate laboratory measurement of FC is 0.01 MPa for undisturbed coarse texture soils (sand, loamy sand and sandy loam), tailings sands and peat:mineral mixes.
3. Soil moisture retention of peat:mineral mixes is not a function of % OC.
4. The soil moisture profiles created by placing a peat:mineral mix layer over top tailings sand are not influenced by layering.

1.6 References

Alway, F.J. and McDole, G.R. 1917. Relation of the water-retaining capacity of a soil to its hygroscopic coefficient. J. Agric. Res. 9:27-71.

Bauer, A. and Black, A.L. 1992. Organic carbon effects on available water capacity of three soil textural groups. Soil Sci. Soc. Am. J. 56:248-254.

Bennett, D.R. and Entz, T. 1989. Moisture-retention parameters for coarse textured soils in southern Alberta. Can. J. Soil Sci. 69:263-272.

Brady, N.C. 1984. The nature and properties of soils. 9th Edition. MacMillan. New York, NY. 750 pp.

Bouyoucos, G.J. 1939. Effect of organic matter on water-holding capacity and the wilting point of mineral soils. Soil Sci. 47:377-383.

Canadian Society of Soil Science (CSSS) Nomenclature Committee. 1976. Glossary of terms in soil science. Research Branch, Canada Department of Agriculture. Ottawa, ON. 44 pp.

Carter, M.R.(Editor) 1993. Soil sampling and methods of analysis. CRC Press/Lewis Publishers. Boca Raton, FL. Pp. 505.

Colman, E.A. 1944. The dependence of field capacity upon the depth of wetting of field soils. Soil Sci. 58:43-50

Day, P.R. 1965. Particles <2 mm - hydrometer method. In: McKeague, J.A. (ed.). 1981. Manual on soil sampling and methods of analysis. Can. Soil Survey Comm., Soil Res. Inst. Ottawa, ON. 212 pp.

Donahue, R.L., Miller, R.W. and Shickluna, J.C. 1977. Soils - An introduction to soils and plant growth. 4th Edition. Prentice-Hall. Englewood Cliffs, NJ. 626 pp.

Eagleman, J.R. and Jamison, V.C. 1962. Soil layering and compaction effects on unsaturated moisture movement. Soil Sci. Soc. Am. Proc. 26:519-522.

Feustel, I.C. and Byers, H.G. 1936. The comparative moisture-absorbing and moisture-retaining capacities of peat and soil mixtures. Tech. Bull. No. 532, U.S. Dept. of Agric. Washington, D.C. 25 pp.

Hanks R.J., Holmes, W.E. and Tanner, C.B. 1954. Field capacity approximation based on the moisture-transmitting properties of the soil. Soil Sci. Soc. Am. Proc. 18:252-254.

Hackbarth, D. and Nastas, N. 1979. Hydrogeology of the Athabasca Oil Sands area, Alberta. Alberta Research Council. Edmonton, AB. 39 pp.

Hausenbuiller, R.L. 1985. Soil science, principles and practices, 3rd Edition. Wm. C. Brown Publishers. Dubuque, IO. 610 pp.

HBT AGRA Limited. 1992. Oil Sands soil reconstruction project five year summary. Alberta Land Conservation and Reclamation Council Report No. RRTAC 92-4. IBSN 0-7732-0875-5. Edmonton, AB. 109 pp.

Hillel, D. 1971. Soil and water: physical principles and processes. Academic Press, Inc. New York, NY. 364 pp.

Hillel, D. 1980. Introduction to soil physics. Academic Press, Inc. San Diego, CA. 364 pp.

Hollis, J.M., Jones, R.J.A. and Palmer, N. 1977. The effects of organic matter and particle size on the water retention properties of some soils in the West Midlands of England. Geoderma 17:225-238.

Hudson, B.D. 1994. Soil organic matter and available water capacity. J. Soil Water Conserv. 49:189-194.

Jamison, V.C. and Kroth, E.M. 1958. Available moisture storage capacity in relation to textural composition and organic matter content of several Missouri soils. Soil Sci. Soc. Am. Proc. 22:189-92.

Leskiw, L.A. and Moskal, T.D. 1997a. Reclaimed soils and forest ecosystem capability of Suncor Inc. Oil Sands Group. Prepared for Suncor Oil Sands Group. Edmonton, AB. 73 pp.

Leskiw, L.A. and Moskal, T.D. 1997b. Reclaimed soils and forest ecosystem capability of Syncrude Canada Ltd. Prepared for Syncrude Canada Ltd. Edmonton, AB. 82 pp.

Leskiw, L.A. and Moskal, T.D. 1997c. Predisturbance soils and forest soil capability ratings for Suncor Lease 86/17. Prepared for Suncor Oil Sands Group. Edmonton, AB. 8 pp.

Leskiw, L.A. and Moskal, T.D. 1997d. Predisturbance soils and forest soil capability ratings for Syncrude Canada Ltd. Prepared for Syncrude Canada Ltd. Edmonton, AB. 11 pp.

Leskiw, L.A. 1998. Personal Communication. President and Senior Soil Scientist, Can-Ag Enterprises Ltd. Edmonton, AB.

Macyk, T.M. and Turchenek, L.W. 1995. Tailings sand and natural soil quality at the operations of Syncrude Canada Ltd. Prepared for Syncrude Canada Ltd. Edmonton, AB. 89 pp.

McIntyre, D.S. 1974. Water retention and moisture characteristics. In: J. Loveday (ed.). Methods for analysis of irrigated soils. Tech. Commun. Commonw. Bur. Soils no. 54. CAB. Fornham Royal, England. Pp. 43-62.

Miller, D.E. 1973. Water retention and flow in layered soil profiles. In: Bruce, R.R., Flach, K.F. and Taylor, H.M.(eds.). Field soil water regime. SSSA Special Pub. Series # 5. Soil Sci. Soc. of Am Inc. Madison, WI. Pp. 107-117.

Moskal, T.D. and Leskiw, L.A. 1996. Available water holding capacity. Prepared for Suncor Inc. Oil Sands Group and Syncrude. Edmonton, AB. 14 pp.

Naeth, M.A., White, D.J., Chanasyk, D.S., Macyk, T.M., Powter, C.B. and Thacker, D.J. 1991. Soil physical properties in reclamation. Alberta Land Conservation and Reclamation Council Report No. RRTAC 91-4. ISBN o-7732-0880-1. Edmonton, AB. 216 pp.

Powter, C.B. 1994. Glossary of reclamation terms used in Alberta - 3rd Edition. Alberta Conservation and Reclamation Management Group No. RRTAC OF-1A. Edmonton, AB. 31 pp.

Pritchett, W.L. and Fisher, R.F. 1987. Properties and management of forest soils, 2nd edition. John Wiley and Sons, Inc. Toronto, ON. 494 pp.

Qualizza, C. 1999. Personal Communication. Reclamation research coordinator, Syncrude Canada Ltd. Fort Mc Murray, AB.

Ratliff, L.F., Ritchie, J.T. and Cassel, D.K. 1983. A survey of field-measured limits of soil water availability and related laboratory measured properties. Soil Sci. Soc. Am. J. 47:770-775.

Rivers, E.D. and Shipp, R.F. 1972. Available water capacity of sandy and gravelly North Dakota soils. Soil Sci. 113:74-80.

Rivers, E.D. and Shipp, R.F. 1977. Soil water retention as related to particle size in selected sands and loamy sands. Soil Sci. 126:74-80.

Salter, P.J. and Haworth, F. 1961a. The available-water capacity of a sandy loam soil, I. A critical comparison of determining moisture content of soil at field capacity and at the permanent wilting percentages. J. Soil Sci. 12:326-334.

Salter, P.J. and Haworth, F. 1961b. The available-water capacity of a sandy loam soil, II The effects of farmyard manure and different primary cultivations. J. Soil Sci. 12:334-342.

Salter, P.J. and Williams, J.B. 1963. The effect of farmyard manure on the characteristics of a sandy loam soil. J. Soil Sci. 14:73-81.

Salter, P.J., Berry, G. and Williams, J.B. 1966 The influence of texture on the moisture characteristics of soils. J. Soil Sci. 17:93-98.

Smith, S.B. 1981. Alberta Oil Sands Environmental Research Program, 1975-1980: summary report. Prepared for the Alberta Oil Sands Environmental Research Program. AOSERP Report 118. Edmonton, AB. 170 pp.

Soil Classification Working Group. 1998. The Canadian system of soil classification. Agric. and Agri-Food Canada. Publ. 1646 (Revised). Edmonton, AB 187 pp.

Stevenson, D.S. 1974. Influence of peat moss on soil water retention for plants. Can. J. Soil Sci. 54:109-111.

Syncrude Canada Ltd. 1994. The Syncrude oil extraction process overview. Extraction orientation, Syncrude Canada Ltd. Fort McMurray, AB. 42 pp.

Tuttle, S. 1997. Reclamation to native forest ecosystems in the Oil Sands Region. 34th Annual Alberta Soil Science Workshop Proceedings. Feb. 18-20. Calgary, AB. Pp. 113-116.

Tuttle, S. 1999. Personal communication. Reclamation Officier, Mine Engineering. Suncor Oil Sands Group Inc. Fort McMurray, AB.

Webster, R. and Beckett, P.H.T. 1972. Matric suctions to which soils in south central England drain. J. Agric. Sci. 78:379-387.

Table 1.1 Particle size analysis and sand fraction analysis for coarse textured soils and peat:mineral mixes.

				Sand Fraction (mm)					Final
Texture	% Sand	% Silt	% Clay	2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.050	Texture
Sand (27[a]-24[b])	92.6[c] (2.5)[d]	4.5 (2.6)	2.9 (1.3)	1.0 (0.9)	14.1 (10.9)	53.7 (7.5)	21.8 (13.9)	9.5 (4.6)	S
Loamy Sand (18-12)	82.5 (3.3)	12.6 (4.4)	4.9 (2.7)	1.1 (1.6)	10.4 (10.3)	51.6 (8.2)	20.4 (11.8)	16.5 (7.8)	LS
Sandy Loam (5-3)	70.8 (5.2)	18.5 (5.3)	10.7 (5.7)	0.7 (0.3)	7.1 (1.4)	55.9 (4.8)	19.2 (8.7)	17.2 (4.5)	SL
Fine Sand (Tailings Sand)									
Suncor (28-28)	95.8 (1.5)	2.9 (0.9)	1.3 (0.7)	1.5 (2.8)	3.7 (5.0)	10.1 (6.9)	62.3 (9.1)	22.5 (9.3)	fS
Syncrude (3-3)	94.3 (1.6)	4.3 (1.1)	1.4 (0.5)	0.2 (0.1)	1.6 (0.5)	7.6 (3.6)	32.9 (8.0)	57.7 (4.6)	vfS
Peaty Sand (3-3)	91.8 (2.3)	4.1 (1.1)	4.1 (1.8)	0.5 (0.3)	7.4 (2.8)	39.6 (25.8)	34.3 (30.0)	18.3 (5.9)	S
Peaty Loamy Sand (12-14)	84.1 (3.4)	9.1 (2.6)	6.8 (1.6)	1.9 (1.2)	12.4 (7.2)	30.6 (16.2)	33.7 (14.2)	21.5 (9.3)	LS
Peaty Sandy Loam (21-22)	69.8 (5.6)	18.9 (5.8)	11.3 (2.5)	2.3 (0.6)	14.5 (6.9)	27.3 (9.9)	32.2 (11.7)	23.7 (7.8)	SL

[a] Number of samples in particle size analysis

[b] Number of samples in sand fraction analysis

[c] Mean value

[d] Standard deviation

2.0 IN SITU SOIL MOISTURE 48 h AFTER SATURATION TO REPRESENT IN SITU FIELD CAPACITY

2.1 Introduction

In situ field capacity (FC) is defined as "... the amount of water held in the soil after excess water has drained away and the rate of downward movement of water has materially decreased, which usually takes place within 2 or 3 days after the rain or irrigation in pervious soils of uniform structure and texture" (Veihmeyer and Hendrickson 1949). This concept of FC has been recognized as arbitrary since soil profiles are rarely uniform in structure and texture throughout. Primarily though, the concept of FC is considered arbitrary because the determination of soil water redistribution is plagued with subjectivity and inaccuracies in measurement (Hillel 1980). However, Salter and Haworth (1961) determined that field capacity measurements involving soil sampling after irrigation or in situ were more accurate and consistent than the suction-plate method (now called the pressure plate method) with undisturbed cores.

Currently researchers have found that FC could occur anywhere between 24 h to 12 days after saturation (Ratliff et al. 1983). Cassel and Neilson (1986) stated that it is important to emphasize that, in reality, the hydraulic conductivity of coarser-textured soils may become 'negligible' in < 24 h, thus implying coarser textured soils may reach FC in < 48 h, even < 24 h.

2.2 Objective

The objective of this research was to evaluate the suitability of soil moisture at 48 h after saturation to represent FC or the end of free drainage under field conditions. This objective was specific to peat:mineral mixes placed over tailings sand (reclaimed sites) and coarse textured profiles consisting mostly of Ahe, Ae and Bm horizons (undisturbed sites).

2.3 Materials and Methods

2.3.1 In Situ Methods

Nineteen reclaimed and undisturbed sites were examined on and around leases belonging to Suncor Inc. Oil Sands Group and Syncrude Canada Ltd. near Fort McMurray, in northeastern Alberta. The seven undisturbed sites consisted of Eluviated Eutric Brunisols of coarse textures (sand, loamy sand and sandy loam - S, LS and SL). The reclaimed sites consisted of peat:mineral mixes of different depths over tailings sand representing normal reclamation practices in the area (See Appendix 1 for site descriptions and maps). At each of the 19 sites, three 1 x 1 m plots were delineated and bordered with 15-cm plastic garden trim, with approximately 5 cm of trim left above ground (Figure 2.1). In the center of each plot a 5-cm hole was augered and the soil removed and bagged according to horizon and sealed for laboratory analysis. An aluminum access tube for neutron probe readings was inserted into the hole and the tubes were covered with tin cans to prevent water entry. The vegetation understory within the plots was trimmed with clippers to approximately 10 cm above the soil surface. Erosion netting (coconut or straw) was placed over the plot within the garden trim and held in place by erosion netting staples, to ensure there was no soil displacement during the saturation of the plots.

Barrels, 170-L in size, were placed close to the plots and two full barrels of water were siphoned with a 1.5-cm diameter rubber hose onto each 1-m^2 plot to saturate them. Each plot was individually watered with a rubber hose to ensure the wetting front was uniform over the entire plot.

In situ soil moisture was measured within the three plots per site with Campbell Pacific Nuclear Neutron Probes, Model 503 DR, after the plots had been soaked. Neutron probe readings were taken in 10-cm increments starting at 15 cm to a depth of approximately 1 m, immediately before and after the plots were watered and every 12 h thereafter, with the last measurements taken 60 h after saturation. The reading at 15 cm was assumed to represent the upper most 20-cm of soil; all other readings represented a 10-cm depth increment. Two neutron probes were used, one (DSC) was used regularly and the other (Range) was a backup when the battery of DSC needed recharging or if there were problems in the field with the latter probe. At Site 11 both probes were used to measure the initial and saturated profiles. Between readings the plots were covered with clear industrial strength plastic held up in a tent-like position by the access tubes to prevent infiltration of precipitation.

2.3.2 Statistical Analyses

Neutron probe measurements (counts) were converted to volumetric moisture content (VM) using a calibration curve appropriate to the specific neutron probe and then compiled to determine accumulated VM (AVM) at each incremental probe depth. Based on the shallowest depths measured for all plots within a site, drainage curves were plotted using the accumulated volumetric moisture content to that depth. Readings from the Range probe were regressed against those from the DSC probe, and all subsequent readings from the Range probe were converted to DSC-equivalent moisture contents based on this regression to ensure consistency between probe readings.

AVM to a depth of 45 cm (AVM45), for each plot, was determined for each of the 12- through 60-h neutron probe measurements. This depth was the greatest in which the most sites had measurements every 12 h and therefore was used for analysis. These repeated measures data were analyzed using the general linear model analysis (GLM) and the Scheffe multiple comparisons of the Statistical Analysis System (SAS Institute Inc. 1988). The objective was to evaluate the suitability of soil moisture at 48 h after saturation to represent FC or the end of free drainage under field conditions. Theoretically, for this statement to be true, AVM45 at 12, 24, 36 and 48 h would have to be statistically different from one another and 48 and 60 h measurements would not, indicating that free drainage had stopped by 48 h. Both $P \leq 0.05$ and $P \leq 0.10$ were used to test significance.

2.3.3 Physical Interpretation

Results for both reclaimed and undisturbed sites were interpreted together, then individually by treatment. The three plot measurements for each time increment were averaged for each site. These site averages were plotted against time and the measurement for each time increment was averaged to provide a final AVM over time for reclaimed and undisturbed sites.

2.4 Results and Discussion

2.4.1 Statistical Analyses

By examining the Scheffe statistical analysis including both the reclaimed and undisturbed sites, AVM45 at the 12- and 24-h measurements were significantly different ($P \leq 0.05$) from the 60-h measurement. The only statistically different measurement ($P \leq 0.05$) from 48 h was the 12-h measurement (Table 2.1). However, by increasing the P value to ≤ 0.10 the 12- and 24-h measurements were significantly different from the 60-h and the 36- and 48-h readings were statistically different from the 12-h reading. Therefore, when the treatments are combined (reclaimed and undisturbed sites), it may be that the FC had already been reached at 24 h based on the 12- and 24-h measurements being significantly different from the 60-h AVM45 at both $P \leq 0.05$ and $P \leq 0.10$.

Analyzing the treatments on an individual basis by the Scheffe statistical test revealed even less statistical difference. The reclaimed site treatment had statistically different AVM45 between 12- and 60-h at $P \leq 0.05$, and 12- and 24- versus the 60-h AVM45 at $P \leq 0.10$. The undisturbed site treatment had no significant differences in AVM45 at all. The large amount of moisture held initially in the reclaimed soil profiles likely allowed for a huge loss of moisture between the 12- and 60-h measurements, and thus significantly different amounts of moisture were found between these measurement times. For the undisturbed sites, AVM45s were not significantly different indicating that at 12 h free drainage was complete and the profile was at FC.

2.4.2 Physical Interpretation

By examining the reclaimed and undisturbed treatments separately, trends in AVM45 for individual treatments were evident. The 5 undisturbed sites of Eluviated Eutric Brunisols consisted mainly of the coarse textures S, LS, and SL (for particle distribution see Table 1.1, page 18). AVM45 at these sites followed a general trend (Figure 2.2), decreasing from the initial 12-h through to the 60-h neutron probe measurement, with AVM45 ranging from 100 mm (12 h after saturation) to 25 mm (60 h after saturation). However, all AVM45s from the undisturbed sites were similar (Figure 2.2), with small, consistent decreases between each time period. The AVM45 plotted data for the undisturbed site treatment support the statistical result that there are no significant differences after 24 hours, as the data for the undisturbed sites seem to make their largest decrease between 12 and 24 h. These results support Cassel and Neilson's (1986) finding that in the coarse textured soils there is no further free drainage after 24 h and thus the sites have reached FC.

Differences in the initial AVM45 in the undisturbed sites (12 h and their individual plotted data) are the result of differences in finer textured material at each site, progressing from SL and SCL at the top followed by LS to S at the bottom. Site 12 has layers of SCL, SL and LS in it, while Sites 13, 10 and 15 all have LS and S in their profiles, and finally Site 11 is comprised completely of S.

Soil moisture at the eight reclaimed sites also followed a general trend, decreasing from the initial 12-h through to the 60-h neutron probe measurement, however, AVM45 ranged from 220 mm of water at the maximum (12 h after saturation) to 30 mm at the minimum (60 h after saturation). There is considerable variability among the reclaimed sites (Figure 2.2). However, by examining the average of the reclaimed sites, the plotted slope was slightly negative, with AVM45 at 60 h lower than that at 48 h (Figure 2.3). Removing

Sites 1 and 2 (two of the most erratic AVM45 curves) had no effect on the average plotted data. Therefore, according to the physical analysis, the reclaimed sites have not achieved field capacity in the 60 h monitored, as the drainage curve is not leveling off.

2.5 Conclusions

VM at 48 h would be suitable to represent FC or the end of free drainage under field conditions, however this would be largely overestimating the time it takes for coarse textured soils to reach FC and underestimating the time for reclaimed sites. Statistically, in situ FC has already been reached at 24 h when both treatments, reclaimed and natural, are analyzed together. The reclaimed sites reached FC by 24 h; however the undisturbed sites would have been at FC before the initial reading at 12 h. Results from physical analysis concur with those from the statistical analysis for the undisturbed sites. FC for the undisturbed sites had been reached prior to the initial 12-h AVM45 measurements. The reclaimed sites have a larger drop in AVM45s over time. Results for the reclaimed sites in the physical analysis differ from those from the statistical data. FC does not appear to have been achieved in the 60 h over which the sites were monitored based on the physical analysis.

2.6 References

Cassel, D.K. and Nielsen, D.R. 1986. Field capacity and available water capacity. In: A. Klute (ed.). Methods of analysis, Part 1. 2nd. Edition. Agron. Monogr. 9, ASA. Madison, WI. Pp. 901-926.

Hillel, D. 1980. Introduction to soil physics. Academic Press, Inc. San Diego, CA. 364 pp.

Ratliff, L.F., Ritchie, J.T. and Cassel, D.K. 1983. A survey of field-measured limits of soil water availability and related laboratory measured properties. Soil Sci. Soc. Am. J. 47:770-775.

SAS Institute Inc. 1988. SAS/STAT user's guide. Release 6.03 Edition. Cary, N.C. 1028 pp.

Salter, P.J. and Haworth, F. 1961. The available-water capacity of a sandy loam soil, I. A critical comparison of determining moisture content of soil at field capacity and at the permanent wilting percentages. J. Soil Sci. 12:326-334.

Veihmeyer, F.J. and Hendrickson, A.A. 1949. Methods of measuring field capacity and permanent wilting percentage of soils. Soil Sci. 61:75-94.

Table 2.1 Scheffe statistical analysis ($P \leq 0.05$ and $P \leq 0.10$) for average differences in accumulated volumetric moisture (mm) in the upper 45 cm between time increments for both treatments and reclaimed and undisturbed sites individually.

Time Comparison (h)	Difference Between Means		
	Both Treatments (n=13)	Reclaimed (n=8)	Undisturbed (n=5)
F Value	0.0001	0.0023	0.1573
R-Square	0.3127	0.1046	0.0794
12-24	10.04	11.47	1.66
12-36	30.50 *	35.45	13.66
12-48	30.11 **	34.06	11.06
12-60	41.44 **	52.75 **	18.09
24-36	20.46	23.99	9.40
24-48	20.07	22.59	12.00
24-60	31.40 **	41.28 *	16.43
36-48	-0.39	-1.40	2.60
36-60	10.93	17.29	7.02
48-60	11.32	18.69	4.42

** Indicates significance ($P \leq 0.05$)

* Indicates significance ($P \leq 0.10$)

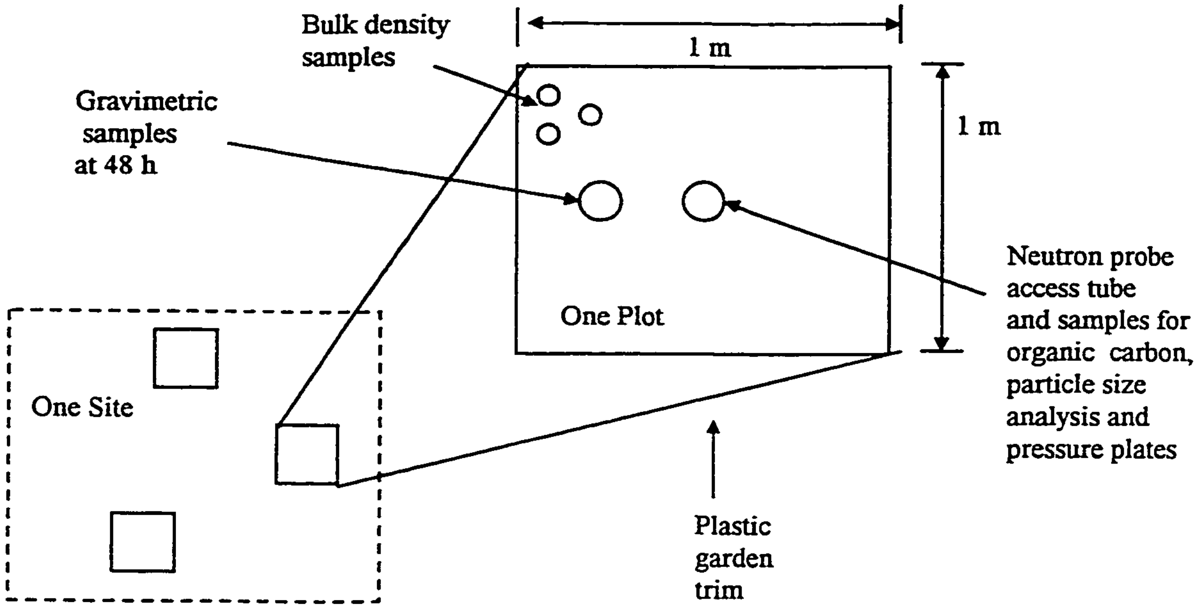


Figure 2.1 Research site layout.

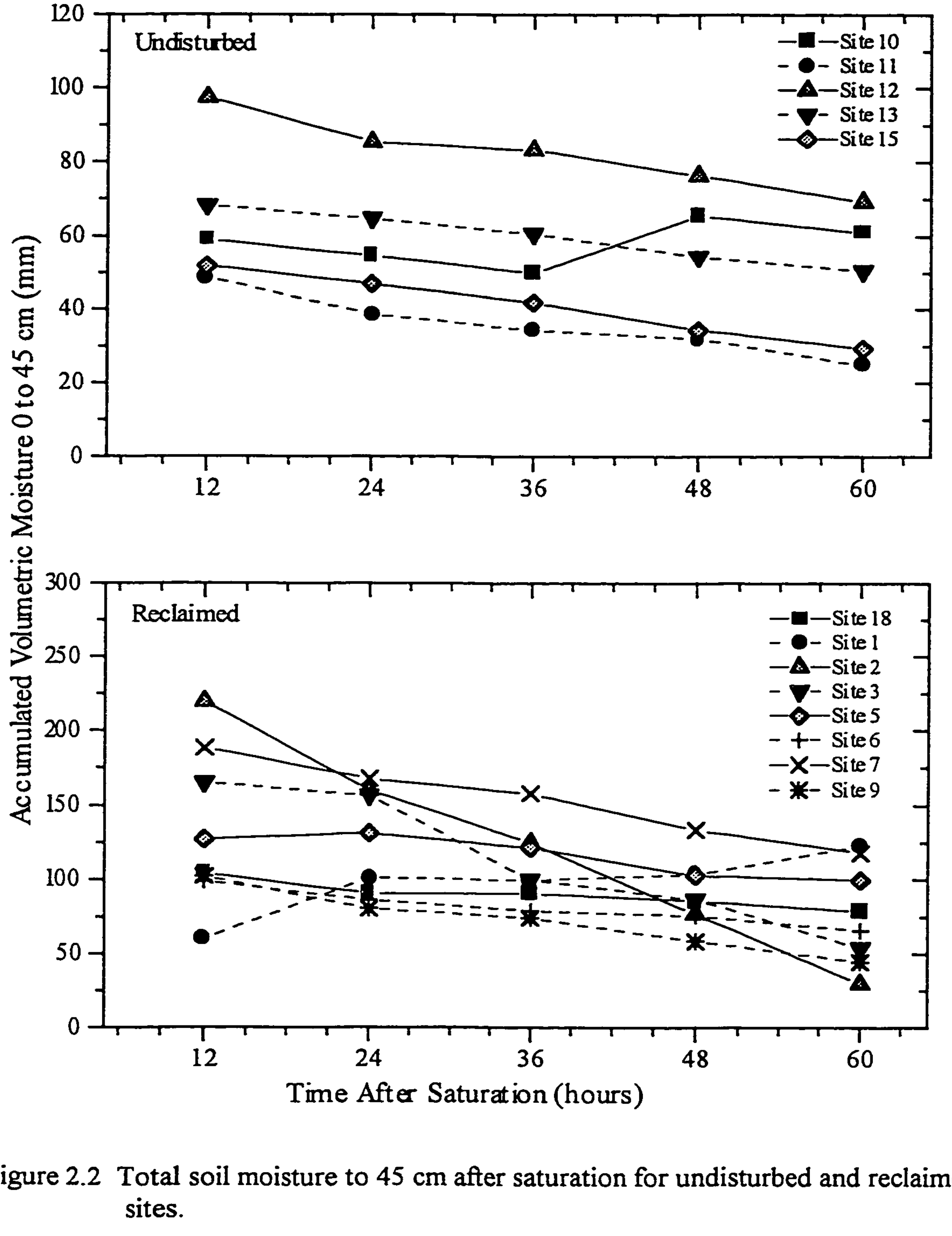


Figure 2.2 Total soil moisture to 45 cm after saturation for undisturbed and reclaimed sites.

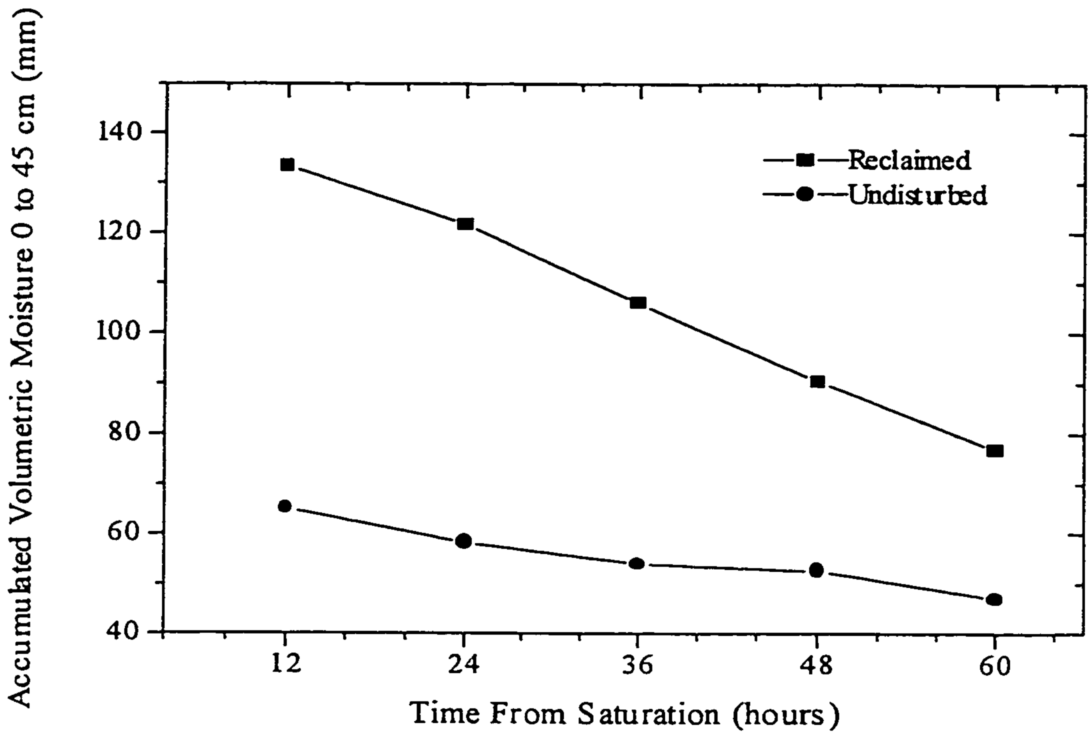


Figure 2.3 Average accumulated soil moisture to 45 cm after saturation for reclaimed and undisturbed sites.

3.0 FIELD CAPACITY OF COARSE TEXTURED SOILS AND PEAT:MINERAL MIXES

3.1 Introduction

Salter and Haworth (1961) determined that field capacity (FC) measurements involving soil sampling after irrigation or in situ were more accurate and consistent than the suction-plate method (now called the pressure plate method) with undisturbed cores. Currently, the laboratory pressure for approximating FC of coarse textured soils (sand, loamy sand and sandy loam) has been set between 0.005 MPa and 0.01 MPa, however 0.01 MPa is most commonly used (Webster and Beckett 1972). For medium textured soils, a laboratory pressure of 0.033 MPa should be used to approximate the FC, and for fine textured soils 0.05 MPa should be used (Coleman 1947; Jamison and Kroth 1958; Rivers and Shipp 1977). However, selecting the appropriate pressures to approximate FC under desorption is not straightforward. Rivers and Shipp (1977) concluded in their study that no one particle size component, or group of soil components, should be used as an indicator of the available water holding capacity of sandy soils, rather local field determinations should be carried out.

3.2 Objective

The objective of this research was to determine what laboratory pressure best represents FC of coarse textured soils and peat:mineral mixes under reclaimed and undisturbed conditions in the field. In situ moisture content 48 h after saturation is used as the reference moisture content for FC. Both 0.033 MPa and 0.01 MPa are evaluated as laboratory representative pressures of FC, using samples from peat:mineral mixes placed over tailings sand (reclaimed sites) and coarse textured profiles consisting mostly of sand, loamy sand and sandy loam (S, LS and SL) textured soils (undisturbed sites).

3.3 Materials and Methods

3.3.1 In Situ Methods

Nineteen reclaimed and undisturbed sites were examined, on and around the leases occupied Suncor Inc. Oil Sands Group and Syncrude Canada Ltd, near Fort McMurray, in northeast Alberta. The seven undisturbed sites were characterized by coarse textured Eluviated Eutric Brunisols (sand, loamy sand and sandy loam - S, LS and SL), and the twelve reclaimed sites were characterized by peat:mineral mixes of different depths over tailings sand, representing normal reclamation practices in the area (See Appendix 1 for site descriptions and maps). At each of the 19 sites, three 1 x 1 m plots were delineated and bordered with 15-cm plastic garden trim, with approximately 5 cm of the trim left above ground (Figure 2.1, Page 27). A 5-cm hole was augered in the center of each plot and the soil removed and bagged according to horizon and sealed for laboratory analysis. The vegetative understory within the plots was trimmed with clippers to within approximately 10 cm of the soil surface. Erosion netting (coconut or straw) was placed over the plot within the garden trim and held in place by erosion netting staples.

Barrels, 170-L in size, were placed close to the plots and two full barrels of water were siphoned with a 1.5-cm diameter rubber hose onto each 1-m^2 plot to saturate them. Each plot was individually watered with a rubber hose to ensure the wetting was uniform over the entire plot.

After 48 h of drainage, gravimetric samples were taken. Using an auger, samples were taken in 10-cm increments to a depth of 30 cm for each plot in Sites 1-12, inclusive. For Sites 13-19, inclusive, gravimetric samples were also taken in 10-cm increments, to a depth of 30 cm in two of the plots and to 100 cm in similar increments in one of the plots. The deeper sampling was for neutron probe correlation in related research. The 160 field gravimetric samples taken after 48 h of drainage were weighed, oven dried at 105 °C for 24 h and weighed again to determine in situ FC.

3.3.2 Laboratory Methods

Pressures of 0.01, 0.033 and 1.5 MPa were used, with modifications to the standard method, to produce moisture retention curves for each horizon (Eilers 1981). Particle size distribution (PSA) was determined using the hydrometer method outlined by Day (1965), using the soils sampled from each horizon prior to saturation. A pretreatment of hydrogen peroxide was used to remove any organic matter.

3.3.3 Statistical Analyses

The gravimetric in situ moisture contents within each horizon were averaged. Samples including horizon interfaces were excluded from the analysis. Moisture contents at pressures of 0.01 and 0.033 MPa were compared to those at 0.1 and 1.5 MPa; any samples that did not demonstrate a uniform decrease in moisture content from 0.01 to 1.5 MPa were also excluded from the analysis. The data were divided into textural classes of tailings sand, sand, loamy sand, sandy loam, peaty loamy sand and peaty sandy loam. The mean value, standard deviation and numbers of samples were calculated for each texture within the three categories of in situ FC, 0.01 MPa and 0.033 MPa. The in situ data were compared to the two laboratory measurements using the T-test for independent samples in the Microcal Origin Version:3.5 Scientific and Technical Graphics in Windows package (Microcal Software, Inc. 1991-94).

3.4 Results and Discussion

Percent sand varied from 70% in the sandy loam and peaty sandy loam to over 95% in the tailings sand (Table 1.1). The percent silt and clay were lowest in the tailings sand (3.0% and 1.4%, respectively) and highest in the sandy loam and peaty sandy loam.

For sand and loamy sand, the 0.033 MPa laboratory approximation was significantly different from the in situ measurements, whereas the 0.01 MPa laboratory approximation more closely matches the measurements (Table 1.1). Therefore, for sands and loamy sands, moisture content at 0.01 MPa provides the better laboratory approximation for FC. This was also revealed through visual examination of the mean values. For both sand and loamy sand, the mean values for the in situ FC were similar to the laboratory approximations at 0.01 MPa while the laboratory approximations at 0.033 MPa were only half those of the in situ FC. These results support the use of 0.01 MPa as the laboratory approximation for sands and loamy sands.

However, for sandy loams, the P values of 0.29 and 0.14, for 0.01 MPa and 0.033 MPa, respectively, indicate there were no significant differences between either laboratory approximation and the in situ measurement (See Appendix 2 for detailed statistical analysis). The in situ mean value of the sandy loam (14.0 g/g*100) is nearly half way between the 0.01 MPa (17.0 g/g*100) and 0.033 MPa (10.6 g/g*100) laboratory approximations. Therefore, neither laboratory approximation was better for determining the FC of sandy loam. There may be two explanations for this result. There are substantially fewer samples for sandy loam than there were for loamy sand and sand, in most cases less than a third as many, thus this may not be an adequate sample set. Secondly, this may be the location in the textural triangle where a transition from coarse textured soils to finer textured soils begins from a FC perspective, therefore moving into the textures that need FC to be approximated in the laboratory at 0.033 MPa. This result indicates the need for further research to determine what laboratory approximation for FC between 0.01 and 0.033 MPa would be best for sandy loams.

For tailings sands, of fine sand texture (Table 1.1), both 0.033 MPa and 0.01 MPa laboratory approximations for FC are significantly different from the in situ measurements for FC. However, the FC value at 0.01 MPa is much closer to the in situ value (56% of the in situ value compared to only 27% of the in situ value for the 0.033 MPa value). There are two cautionary notes about these results. First, the sample size for the in situ measurements is a third of that for the laboratory approximations. Second, tailings sand are slightly hydrophobic and therefore may not act as normal soils do in the pressure chambers used for pressure plate measurements. This latter factor may have lowered the

FC moisture contents of the pressure plate compared to the moisture contents found in situ.

For peaty loamy sand both 0.033 MPa and 0.01 MPa laboratory approximations for FC were not significantly different from the in situ measurements for FC. Therefore, either would be a good laboratory approximation for FC. In fact, the laboratory approximations were closer to each other than they were to the in situ measurements. Again these results might be due to a small sample size (n=9-13).

The peaty sandy loams had the largest sample size of the peat mineral mixes. For them the 0.033 MPa laboratory approximation was significantly different from the in situ measurements, whereas the 0.01 MPa laboratory approximation was not. Therefore, for peaty sandy loams the best laboratory approximation for FC would be 0.01 MPa.

There are two explanations for the unique results in the peaty loamy sand approximations. The primary treatment for pressure plates is to dry, grind and sieve the soil samples through a 2-mm sieve. This procedure might change the composition of the peat:mineral mix from the field affecting the laboratory approximation of FC. The peat component of the mix may decrease the sample to pressure plate contact and decrease the accuracy of the laboratory approximations. Therefore, the results from the peaty sandy loams may be more valid than the other peat:mineral mix results as there are more fine-textured particles which could increase the contact with pressure plates. Also, due to the smaller number of samples for peaty loamy sands versus the peaty sandy loams, the results from the peaty sandy loams may be most representative of the peat:mineral mixes and therefore would encourage the use of 0.01 MPa as the laboratory approximation for FC for peat:mineral mixes.

3.5 Conclusions

The laboratory approximation of 0.01 MPa provides a better approximation of in situ FC for sands and loamy sands, versus 0.033 MPa. For sandy loams 0.01 or 0.033 MPa provide appropriate laboratory approximations. Both laboratory approximations for FC of tailings sand were significantly different and both mean values were lower than that of the in situ measurement. Therefore, the laboratory approximation for FC of tailings sand may be even < 0.01 MPa and requires more research. For peaty loamy sand, both 0.033 MPa and 0.01 MPa laboratory approximations for FC were not significantly different from the in situ measurements of FC, perhaps be due to the change in composition in preparation for pressure plates analysis, or poor pressure plate contact due to a small amount of fines in the peat:mineral mix. The laboratory approximation for peaty sandy loams was statistically better with 0.01 MPa than 0.033 MPa. Overall, it appears that 0.01 MPa best represents FC of coarse textured soils and peat:mineral mixes under reclaimed and undisturbed conditions in the field.

3.6 References

Coleman, E.A. 1947. A laboratory procedure for determining the field capacity of soils. Soil Sci. 63:277-283.

Eilers, R.G. 1981. Water content and water retention. In: McKeague, J.A. (ed.). 1981. Manual on soil sampling and methods of analysis. Can. Soil Survey Comm., Soil Res. Inst. Ottawa, ON. 212 pp.

Jamison, V.C. and Kroth, E.M. 1958. Available moisture storage capacity in relation to textural composition and organic matter content of several Missouri soils. Soil Sci. Soc. Am. Proc. 22:189-92.

Microcal Software, Inc. 1991 to 1994. Scientific and Technical Graphics in Windows. Version 3.5. Cary, N.C.

Rivers, E.D. and Shipp, R.F. 1977. Soil water retention as related to particle size in selected sands and loamy sands. Soil Sci. 126:74-80.

Salter, P.J. and Haworth, F. 1961. The available-water capacity of a sandy loam soil, I. A critical comparison of determining moisture content of soil at field capacity and at the permanent wilting percentages. J. Soil Sci. 12:326-334.

Webster, R. and Beckett, P.H.T. 1972. Matric suctions to which soils in south central England drain. J. Agric. Sci. 78:379-387.

Table 3.1 T Test for independent sample P values for field capacity (FC) moisture measurements in situ vs laboratory pressures.

Texture	In Situ Moisture Content at FC (g/g*100)	Laboratory Moisture Content at 0.01 MPa (g/g*100)	P Value (In Situ vs 0.01 MPa)	Laboratory Moisture Content at 0.033 MPa (g/g*100)	P Value (In Situ vs 0.033 MPa)
Sand	7.8[a] (2.2)[b] 16[c]	7.2 (2.5) 30	0.37	4.5 (2.1) 29	7.9810^{-6} ***
Loamy Sand	11.9 (3.8) 8	11.2 (2.9) 18	0.60	6.7 (2.3) 18	$1.9*10^{-4}$ ***
Sandy Loam	14.0 (3.4) 3	17.0 (3.8) 5	0.29	10.6 (2.3) 5	0.14
Fine Sand (Tailings Sand)	10.7 (5.1) 8	6.0 (2.4) 31	$5.6*10^{-4}$ ***	2.9 (0.9) 27	$6.7*10^{-9}$ ***
Peaty Loamy Sand	42.1 (37.3) 10	48.6 (30.4) 13	0.65	47.5 (24.9) 9	0.72
Peaty Sandy Loam	43.7 (30.7) 19	39.3 (16.7) 23	0.56	28.3 (13.3) 23	0.04 **

[a] Mean value
[b] Standard deviation
[c] Number of samples
** Indicates significance ($P \leq 0.05$)
*** Indicates significance ($P \leq 0.01$)

4.0 EFFECT OF ORGANIC CARBON (PEAT) ON SOIL MOISTURE RETENTION OF PEAT:MINERAL MIXES

4.1 Introduction

Many sources of organic matter, such as manure and peat, have been studied to determine their effects on soil properties and vegetation growth and development. One of the earliest examinations of the effect of organic matter on the available water holding capacity (AWHC) of mineral soils was completed by Bouyoucos in 1939, who used various soils (S, SL, SiL, CL and C) and used muck, peat and manure as the organic matter sources. He found that the addition of organic matter increases available water in soils. He found this was true whether the results were computed on a mass or volume basis. The increase in the available water was more marked in the coarser textured soils than in the finer textured soils (Bouyoucos 1939). These results were supported later by other research.

Jamison and Kroth (1958) examined the interaction of available moisture storage capacity with the texture and organic matter content of several Missouri soils. They found trends similar to those of Bouyoucos, but attributed the results to different factors. They concluded that AWHC increases were due to the textural change associated with increased coarse silt and decreased clay as a result of the addition of organic matter. The researchers concluded that the increase in AWHC was not due to the increased organic carbon (OC) but to the change of texture from organic matter addition. They acknowledged that samples with 13 to 20% clay showed evidence of increasing AWHC with increasing organic matter. However, they attributed this increase to the possible formation of silt-sized microaggregates in the clay. In later research Salter et al. (1966) concluded through regression analysis that AWHC is linearly related to the percentage of OC in the soil.

Other experiments have been conducted with various sources of organic matter, to determine the effect of organic matter (OM) on AWHC. Feustel and Byers (1936) found that although soil with peat mixtures were capable of absorbing 40 to 50% more moisture than soil alone when these peat:soil mixtures were made with clay loam soils; an increased evaporation rate and greater moisture content at permanent wilting point (PWP) counteracted the positive moisture absorbing effects. However, the improved moisture conditions that prevailed when peat was mixed with quartz sand soils was not counteracted by increased evaporation or increased moisture at PWP; these results were more noticeable with more decomposed peat material. Due to the addition of peat, the moisture-holding capacity of quartz sand increased as much as 80%, surpassing that of a clay soil. The final evaluation of decomposed peat as a soil amendment for increased soil moisture retention was positive for sand and sandy soils.

Hollis et al. (1977) examined the effect of organic matter and particle size on the water retention properties of soils in the West Midlands of England. By using 0.05 MPa as field capacity (FC) (this measurement had been suggested by Webster and Beckett in 1972) and 1.5 MPa as PWP, the researchers found that OC accounted for almost 70% of the variation in a linear relationship with FC and 73.5% when the relationship was curvilinear. Clay accounted for 45% of the linear variation and 49% of the curvilinear variation in relation to FC. The researchers believed both OC and clay accounted for approximately three quarters of the variation, and that the unexplained variation could be accounted for by bulk density (Hollis et al. 1977). They also found that for AWHC only silt and OC were significantly correlated, with OC accounting for 50% of the variation in the linear relationship.

Bauer and Black (1992) found that increase in OC concentration caused a relatively larger increase in gravimetric moisture content at FC than at the PWP in coarse to moderately coarse soils (sandy group). But in medium and fine textured groups, respectively, an increase in OC concentration caused essentially identical increases in gravimetric moisture content at FC and PWP.

Hudson (1994) reviewed the literature on the effect of organic matter on AWHC of different textured soils over a 50-year span and analyzed the published data. He found a significant positive correlation between AWHC and organic matter content, by minimizing other factors that could influence AWHC. He also found that with increasing organic matter, the water held at FC increased more rapidly than that held at PWP, therefore increasing the AWHC for all textures.

Jamison and Kroth (1958) and Stevenson (1974) agreed with Feustel and Byers (1936) that moisture characteristics of OC-amended soils must be examined on a volumetric basis to ensure the comparisons were accurate. This held true for the comparisons Feustel and Byers (1936) were making between peat and mineral soil, and also for the comparisons between the individual types of peat. Jamison and Kroth (1958) recommended that comparisons of percent moisture be made on a volume basis due to the lower bulk density of high organic matter or clay-containing soils. Stevenson (1974) found that although soil water retention on a mass basis increased with the addition of peat, this was not consistent with the volumetric measurements where the decreasing bulk densities " . . . more than compensate, less than compensate, or simply compensate for the changes in water retention".

Two other organic amendment factors have been identified as potential influences on AWHC. Firstly, Hollis et al. (1977) discussed discrepancies that may result from differences in the approach of experimentalists; the laboratory technique of adding organic matter to air-dry soil in varying amounts compared to the field one of studying additions of organic matter to an already stablized, or partly stablilized organo-mineral system. Secondly, soil texture plays a key role in soil moisture characteristics and therefore AWHC, where through the addition of soil amendments soil texture can be modified. There have been several studies which correlated texture and AWHC. Salter et al. (1966) found that available water was negatively correlated with percent coarse sand and positively correlated with percent very fine sand and silt (0.05-0.02 mm). Rivers and Shipp (1978) developed equations to estimate FC and found that the best correlation equation was based on percent very fine sand plus silt plus clay, and that equations based on percent silt and very fine sand individually were not as effective.

4.2 Objective

The objective of this research was to quantify the effect of OC (peat) on soil moisture retention of peat:mineral mixes and coarse textured soils. It was hypothesized that the addition of peat would increase FC more that PWP and hence would increase AWHC. The effects of OC on water retention would be evaluated on both a gravimetric and volumetric basis.

4.3 Materials and Methods

4.3.1 In Situ Methods

Nineteen reclaimed and undisturbed sites were examined on and around the leases occupied by Suncor Inc. Oil Sands Group (Suncor) and Syncrude Canada Ltd (Syncrude), near Fort McMurray, in northeast Alberta. Eluviated Eutric Brunisols characterized the seven undisturbed sites of coarse textures (sand, loamy sand and sandy loam - S, LS and SL). The 12 reclaimed sites were characterized by peat:mineral mixes of different depths over tailings sand representing normal reclamation practices in the area (See Appendix 1 for site descriptions and maps). At each of the 19 sites, three 1 x 1 m plots were delineated and a 5-cm hole was augered in the center of each plot and the soil removed and bagged according to horizon and sealed for laboratory analysis.

4.3.2 Laboratory Methods

Laboratory peat:mineral mixes were produced using peat from the Suncor Inc. Oil Sands Group lease site. The peat had been salvaged from the Muskeg Soil Series (Leskiw and Moskal 1997) at the north end of the Suncor lease site and had been stockpiled for one year. In the laboratory it was determined that the peat material was a 5 on the von Post scale of decomposition (von Post and Granlund 1926). This determination was due to the recognizable but not distinct plant structure, the strongly turbid expressed fluid, with some portion of peat extruding from the hand and somewhat mushy nature of the residue. The moist colors for natural, pressed and rubbed were 2.5/1 10YR, 3/1 10YR and 3/1 10YR, respectively and the material had a rubbed fiber content of 30%. Therefore, the organic material was classified as mesic (SCWG 1998). Very dry peat tends to be hydrophobic, so it was kept moist in the laboratory to ensure it would take up moisture once mixed with the mineral soil. The mineral component of the peat:mineral mixes was obtained from Brunisolic B horizons of the undisturbed sites: the sand from Site 11, the loamy sand from Site 10 and the sandy loam from Site 12 (See Appendix 1 for site maps and descriptions).

The peat:mineral mixes were constructed on a volume basis, with three peat to mineral ratios of 1:3, 1:1 and 3:1. These ratios were constructed with each of the soil textures of sand, loamy sand and sandy loam, creating nine peat:mineral mixes. The peat:mineral mixes were hand mixed and passed through a 9.5-mm sieve for pressure plate analysis to assure sufficient contact was made between the peat and the pressure plate.

Particle size distribution was determined using the hydrometer method outlined by Day (1965), for the soils sampled from each horizon prior to saturation and the constructed peat:mineral mixes along with their individual components of peat and mineral soil. A pretreatment of hydrogen peroxide was used to remove any organic matter; sand fractions were determined using the Allen Bradley™ Sonic Sifter (Carter 1993).

Pressure plate values of 0.01 and 1.5 MPa were conducted in triplicate, with modifications to the standard method, due to small sample sizes available (Eilers 1981). Soil organic matter was determined in triplicate by the Walkley-Black method (Nelson and Sommers 1986). This method was chosen over the Leco Furnace Method which identifies organic carbon, as any hydrocarbon contamination from the oil sands would cause increases in the Leco values and thus not truly represent non oil sand hydrocarbons. In situ bulk densities were determined with a Uhland core (66.7 cm^3) taken in triplicate (Blake and Hartge

1986). The bulk densities of the peat:mineral mixes were determined from constructed soil profiles in related research.

4.3.3 Statistical Analyses

Pressure plate moisture contents at 0.01 MPa (FC) and 1.5 MPa (PWP), resultant AWHC (FC-PWP), OC, particle size and bulk density of the in situ samples were used in the statistical analysis. Moisture retention at 0.01 MPa and 1.5 MPa and resultant AWHC determined both gravimetrically and volumetrically, were linearly regressed against OC, using the Microcal Origin Version:3.5 Scientific and Technical Graphics in Windows package (Microcal Software, Inc. 1991-1994). The same procedure was used for the peat:mineral mixes. Then the moisture retention at 0.01 MPa and 1.5 MPa and resultant AWHC of the peat:mineral mixes was linearly regressed against peat. P and R^2 values were obtained for all the computations.

AWHC (cm^3/cm^3*100) was regressed against the particle size percentages and OC using the multiple regression procedure from the Statistical Analysis System (SAS Institute Inc. 1988) with the option for backwards elimination. The best model was found by eliminating whichever independent variable had the highest P value, until all the remaining P values were significant ($P \leq 0.05$).

4.4 Results And Discussion

Organic carbon for the sand, loamy sand, sandy loam and tailings sand, in situ samples was very low (< 0.5%) and similar in magnitude (Table 4.1). For the mineral textures, gravimetrically, FC, PWP and AWHC increased in the order tailings sand < sand < loamy sand < sandy loam. Volumetric AWHC for these soils followed the same ranking, as the bulk densities for these soils were similar. Both FC and PWP varied for these soils even though OC was static. The increases in FC, PWP and AWHC for the mineral soils may be explained by an increase in both clay and silt as sand decreased.

The OC of the in situ peat:mineral mixes decreased from peaty sand (18.9%) to peaty loamy sand (11.1%) to peaty sandy loam (7.0%) (Table 4.1). Gravimetric FC, PWP and AWHC also decreased from peaty sand to peaty sandy loam, coupled with a decrease in sand and increases in silt and clay. However, volumetric AWHC increased as OC decreased due to dramatic increases in bulk density.

For all the mineral soils (S, LS, SL and tailings sand) trends in volumetric AWHC were similar to those for gravimetric AWHC as the bulk densities were all similar (1.31 to 1.43 Mg/m^3). However, dissimilar trends occurred with the peat:mineral mixes, where the bulk densities were all below 1.00 Mg/m^3 (0.39 to 0.87 Mg/m^3). For the peat:mineral mixes gravimetric AWHC decreased, but volumetric AWHC increased, as OC decreased. This result supports the claims of Jamison and Kroth (1958) and Stevenson (1974), that comparisons of percent moisture should be made on a volume basis rather than on a weight basis due to the lower bulk density of high organic matter soils.

Trends in AWHC and its magnitude for the mineral components used in the laboratory study (Table 4.2) paralleled those obtained for in situ samples (Table 4.1), except for the sandy loam in the laboratory, which had both a low FC and PWP and hence AWHC relative to the in situ samples. This decrease for the sandy loam was evident for both the gravimetric and volumetric AWHCs.

The OC for the mineral component of the peat:mineral mixes increased only slightly from sand (0.2%) to sandy loam (0.3%) to loamy sand (0.5%) (Table 4.2). The in situ mineral soils had similar OC values between 0.4 to 0.5% (Table 4.1). The bulk densities used in the mineral component peat:mineral mixes were similar to those found in situ, ranging from 1.41 to 1.45 Mg/m^3 (Table 4.2).

For all the peat:mineral mixes OC, FC, PWP and AWHC (g/g*100) increased with an increase in the amount of peat (from 1:3 to 1:1 to 3:1) for all mineral components (S, LS and SL) (Table 4.2). The volumetric AWHC increased slightly from the 1:1 ratio of peat to sand (8.7%) to the 3:1 ratio of peat to sand (10.8%). However, this trend was not evident for the sandy loam, with volumetric AWHC decreasing from 14.9% for the 1:1 ratio to 13.5% for the 3:1 ratio of peat to sandy loam.

Changes in the particle size were < 2.5% (absolute) due to the addition of peat for the sands and the loamy sands (Table 4.3). This was not the case for the sandy loams, which had an increase of 8.4% sand (absolute) and a 6.6% decrease in clay (absolute). Hence for the sand and loamy sand, changes in AWHC as a result of changes in OC are not confounded by changes in texture; this is not true for sandy loam. Jamison and Kroth (1958) found AWHC increases due to a textural change from the addition of OM.

For all three textures the 0.50-0.25 and 0.25-0.10 mm sand fractions dominated the samples. The addition of peat to the loamy sand increased the 0.50 to 0.10 mm fraction and the addition to sandy loam had little effect on its sand fraction distribution.

Gravimetric moisture retention parameters were all very highly significantly related to OC (Table 4.4) for both the in situ and laboratory produced mixes (See Appendix 3 for detailed statistical analysis). When these parameters were considered on a volumetric basis this significance was lost for the in situ samples, but remained for the laboratory peat:mineral mixes. For the peat:mineral mixes the volumetric 0.01 MPa relationship with OC was very highly significant ($P \leq 0.01$), 1.5 MPa was highly significant ($P \leq 0.05$) and AWHC was significant ($P \leq 0.10$).

The general trend in the linear regressions between FC, PWP and AWHC and % peat was similar for each of the three soil textures (Table 4.5) (See Appendix 3 for detailed statistical analysis). The values for FC (0.01 MPa) and AWHC were significant, whereas those for PWP (1.5 MPa) were not. One difference between the textures is that for sand and loamy sand, 0.01 MPa is significant ($P \leq 0.10$) and AWHC is highly significant ($P \leq 0.05$), whereas the corresponding values for sandy loam were very highly significant ($P \leq 0.01$) in both cases. Thus increases in peat increased the AWHC due to increases in FC, with no effect on PWP.

Multiple regressions were conducted with each textural group with enough samples for validity in OC and particle size percentages against volumetric AWHC as the dependent variable (Table 4.6) (See Appendix 3 for detailed statistical analysis). For the mineral materials, particle size was the significant factor in determining AWHC: sand, silt and clay were highly significant ($P \leq 0.05$) in determining sand textured AWHC, and clay was very highly significant ($P \leq 0.01$) in determining loamy sand textured AWHC. The OC was very highly significant ($P \leq 0.01$) in determining the AWHC of tailings sand; however, sand and silt were also highly significant ($P \leq 0.05$). For peaty loamy sand, silt was the only significant factor in determining its AWHC, whereas sand, silt and clay were significant factors in the determination of the AWHC of peaty sandy loams AWHC.

4.5 Conclusions

The effect of OC (peat) on soil moisture retention of peat:mineral mixes and coarse textured soils depended on whether in situ or laboratory produced mixes were used, whether the retention parameters were expressed on a mass or volume basis and on the texture of the mineral soil. Both gravimetric and volumetric AWHC were altered by the OC in peat:mineral mixes produced in the laboratory. For the in situ samples, OC altered gravimetric AWHC, but not volumetric AWHC. Bulk density had an effect on the volumetric AWHC of peat:mineral soils in situ. For laboratory constructed peat:mineral mixes, FC and AWHC were significantly impacted by peat, however PWP was not. Thus results were inconclusive on the impact of OC on AWHC, with a different trend from laboratory constructed peat:mineral mixes than for in situ measurements.

Tailings sand AWHC was affected by OC, however, sand and silt also were factors in determining the amount of water held. The fact that OC is a significant factor would support the placement of peat on tailings sand and incorporation as a topsoil amendment, however it would require further research, as a potential field study.

The addition of peat material changed texture imperceptibly for sand and loamy sand; hence the change in texture could not be responsible for the increases in AWHC as the result of peat additions, as other researchers have found. The results for sandy loam are less clear.

4.6 References

Bauer, A. and Black, A.L. 1992. Organic carbon effects on available water capacity of three soil textural groups. Soil Sci. Soc. Am. J. 56:248-254.

Black, C.A., Evans, D.D., White, J.L., Ensminger, L.E. and Clark, F.E. 1965. Walkey-Black Method. In: Methods of soil analysis: Chemical and microbiological properties. Vol. 2. Am. Soc. Agron. Madison, WN. Pp. 1372-1376.

Blake, G.R. and Hartge, K.H. 1986. Bulk density. In: Klute, A. (ed.). Methods of soil analysis Part 1 - Physical and mineralogical methods 2nd edition. Agronomy Monograph # 9. Soil Sci. Soc. of Am. Madison, WI. Pp. 364-367.

Bouyoucos, G.J. 1939. Effect of organic matter on water-hoiding capacity and the wilting point of mineral soils. Soil Sci. 47:377-383.

Carter, M.R. (ed.). 1993. Soil sampling and methods of analysis. CRC Press/Lewis Publishers. Boca Raton, FL. Pp. 505.

Day, P.R. 1965. Particles <2 mm - hydrometer method. In: McKeague, J.A. (ed.). 1981. Manual on soil sampling and methods of analysis. Can. Soil Survey Comm., Soil Res. Inst. Ottawa, ON. 212 pp.

Eilers, R.G. 1981. Water content and water retention. In: McKeague, J.A. (ed.). 1981. Manual on soil sampling and methods of analysis. Can. Soil Survey Comm., Soil Res. Inst. Ottawa, ON. 212 pp.

Feustel, I.C. and Byers, H.G. 1936. The comparative moisture-absorbing and moisture-retaining capacities of peat and soil mixtures. Tech. Bull. No. 532, U.S. Dept. of Agric. Washington, D.C. 25 pp.

Hollis, J.M., Jones, R.J.A. and Palmer, N. 1977. The effects of organic matter and particle size on the water retention properties of some soils in the West Midlands of England. Geoderma 17:225-238.

Hudson, B.D. 1994. Soil organic matter and available water capacity. J. Soil Water Conserv. 49:189-194.

Jamison, V.C. and Kroth, E.M. 1958. Available moisture storage capacity in relation to textural composition and organic matter content of several Missouri soils. Soil Sci. Soc. Am. Proc. 22:189-92.

Leskiw, L.A. and Moskal, T.D. 1997. Predisturbance soils and forest soil capability ratings for Suncor lease 86/17. Prepared. for Suncor Oil Sands Group. 8 pp.

Microcal Software Inc. 1991 to 1994. Scientific and technical graphics in windows. Version 3.5. Cary, NC

Nelson, D.N. and Sommers, L.E. 1986. Total carbon, organic carbon and organic matter. In: Page, A.L. (ed.). Methods of soil analysis Part 2 - Chemical and microbiological properties 2nd edition. Agronomy Monograph # 9. Soil Sci. Soc. of Am. Madison, WI. Pp. 539-579.

Rivers, E.D. and Shipp, R.F. 1977. Soil water retention as related to particle size in selected sands and loamy sands. Soil Sci. 126:74-80.

Salter, P.J., Berry, G. and Williams, J.B. 1966. The influence of texture on the moisture characteristics of soils. J. Soil Sci. 17:93-98.

SAS Institute Inc. 1988. SAS/STAT user's guide. Release 6.03 Edition. Cary, N.C. 1028 pp.

Soil Classification Working Group (SCWG). 1998. The Canadian system of soil classification. Agric. and Agri-Food Can. Publ. 1646 (Revised). Ottawa, ON. 187 pp.

Stevenson, D.S. 1974. Influence of peat moss on soil water retention for plants. Can. J. Soil Sci. 54:109-111.

von Post, L. and Granlund, E. 1926. Sodra sveriges torvtilgaangar (Peat resources in southern Sweden). Sveriges Geologiska Undersokning. Yearbook 19, Vol. 2, Series C, No. 355. 127 pp.

Webster, R. and Beckett, P.H.T. 1972. Matric suctions to which soils in south central England drain. J. Agric. Sci. 78:379-387.

Table 4.1 Moisture retention characteristics and select soil properties of in situ coarse textured soils and peat:mineral mixes.

Texture	Organic Carbon (%)	Laboratory Moisture Content at 0.01 MPa (g/g*100)	Laboratory Moisture Content at 1.5 MPa (g/g*100)	Laboratory Moisture Content AWHC[†] (g/g*100)	Particle Size Analysis			Bulk Density (Mg/m^3)	Laboratory Moisture Content AWHC[†] (cm^3/cm^3*100)
					% Sand	% Silt	% Clay		
Sand (22[a]-27[b]-20[c])	0.5[d] (0.4)[e]	7.8 (2.4)	2.5 (1.4)	5.3 (1.8)	92.6 (2.5)	4.5 (2.6)	2.9 (1.3)	1.34 (0.1)	6.9 (2.5)
Loamy Sand (15-18-18)	0.4 (0.2)	10.4 (2.1)	2.8 (1.1)	7.7 (2.3)	82.5 (3.3)	12.6 (4.4)	4.9 (2.7)	1.31 (0.29)	10.6 (3.3)
Sandy Loam (4-5-4)	0.4 (0.3)	16.9 (4.3)	4.3 (4.5)	12.7 (3.7)	70.8 (5.2)	18.5 (5.3)	10.7 (5.7)	1.43 (0.07)	17.9 (6.1)
Fine Sand (27-31-32) (Tailings Sand)	0.4 (0.2)	5.9 (2.4)	1.3 (0.7)	4.6 (2.0)	95.6 (1.5)	3.0 (1.0)	1.4 (0.7)	1.40 (0.05)	6.5 (2.8)
Peaty Sand (6-3-6))	18.9 (13.6)	107.3 (76.4)	60.9 (48.9)	46.3 (28.9)	91.8 (2.3)	4.1 (1.1)	4.1 (1.8)	0.39 (0.28)	11.6 (2.9)
Peaty Loamy Sand (12-12-13)	11.1 (5.5)	51.6 (29.7)	26.7 (18.5)	24.9 (11.6)	84.1 (3.4)	9.1 (2.6)	6.8 (1.6)	0.63 (0.24)	14.5 (5.1)
Peaty Sandy Loam (20-21-22)	7.0 (2.9)	42.4 (15.6)	20.5 (9.7)	21.9 (7.2)	69.8 (5.6)	18.9 (5.8)	11.3 (2.5)	0.87 (0.31)	18.0 (5.4)

[a] Number of samples for OC, soil moisture content (gravimetric and volumetric)
[b] Number of samples for particle size analysis
[c] Number of samples for bulk density
[d] Mean value
[e] Standard deviation
[†] Available water holding capacity

Table 4.2 Moisture retention characteristics and select soil properties of laboratory produced peat:mineral mixes and their mineral components.

Mineral Textures and Peat:mineral Ratios	Organic Carbon (%)[+]	Laboratory Moisture Content at 0.01 MPa (g/g*100)[+]	Laboratory Moisture Content at 1.5 MPa (g/g*100)[+]	Laboratory Moisture Content AWHC[†] (g/g*100)[+]	Bulk Density (Mg/m^3)	Laboratory Moisture Content AWHC[†] (cm^3/cm^3*100)
Sand	0.2[a] (0.02[b])	5.2 (0.4)	2.2 (0.1)	3.0 (0.4)	1.45 (-)[#] (n=1)	4.4
1:3 Sand	1.0 (0.15)	10.3 (0.7)	5.5 (0.5)	4.7 (1.2)	-	-
1:1 Sand	1.9 (0.09)	13.9 (1.7)	5.5 (1.1)	8.4 (2.6)	1.03 (0.08)[†] (n=15)	8.7
3:1 Sand	3.5 (0.04)	37.3 (2.6)	20.7 (8.7)	16.6 (6.2)	0.65 (0.09)[†] (n=9)	10.8
Loamy Sand	0.3 (0.01)	9.7 (1.4)	2.8 (0.2)	6.9 (1.2)	1.41 (-)[#] (n=1)	9.7
1:3 Loamy Sand	1.2 (0.02)	11.5 (2.7)	3.7 (0.4)	7.8 (3.1)	-	-
1:1 Loamy Sand	1.9 (0.13)	19.5 (3.0)	5.7 (0.4)	13.8 (3.3)	-	-
3:1 Loamy Sand	6.0 (0.37)	38.5 (4.8)	18.9 (2.3)	19.5 (6.3)	-	-
Sandy Loam	0.5 (0.02)	9.8 (0.8)	6.1 (0.4)	3.8 (1.2)	1.43 (-)[#] (n=1)	5.3
1:3 Sandy Loam	1.4 (0.06)	18.4 (2.5)	9.7 (4.3)	8.7 (3.8)	-	-
1:1 Sandy Loam	2.2 (0.09)	26.3 (3.4)	9.0 (0.9)	17.3 (3.4)	0.86 (0.03)[†] (n=15)	14.9
3:1 Sandy Loam	6.7 (0.47)	43.2 (11.8)	20.7 (5.1)	22.6 (7.8)	0.60 (0.03)[†] (n=9)	13.5

[+] Samples examined in triplicate
- Data unavailable or could not be determined
[†] Bulk density assumed from related soil profile construction research
[#] Bulk density assumed from in situ Uhland Core measurements
[†] Available water holding capacity
[a] Mean value
[b] Standard deviation

Table 4.3 Particle size analysis and sand fraction analysis of laboratory produced peat:mineral mixes and their mineral components.

Mineral Textures and Peat:mineral Ratios	% Sand	% Silt	% Clay	Sand Fraction (mm)					Final Texture
				2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Sand (3[a]- 3[b])	90.3[c]	6.0	3.8	0.1	3.4	48.4	37.9	10.2	S
	(0.5[d])	(1.6)	(2.1)	(0.1)	(1.5)	(9.3)	(6.2)	(4.4)	
1:3 Sand [+]	88.4	6.2	5.4	-	-	-	-	-	-
1:1 Sand [+]	88.9	6.0	5.1	0.0	1.7	39.5	37.8	21.0	S
3:1 Sand [+]	87.9	6.2	5.9	-	-	-	-	-	-
Loamy Sand (4-3)	82.9	11.2	5.9	0.0	1.3	40.6	38.3	19.8	LS
	(0.6)	(0.8)	(1.1)	(0.0)	(0.1)	(1.8)	(2.5)	(3.9)	
1:3 Loamy Sand [+]	82.4	11.0	6.6	0.3	4.0	40.5	41.1	14.1	LS
1:1 Loamy Sand [+]	83.7	10.3	6.0	1.2	2.7	47.7	39.5	8.9	LS
3:1 Loamy Sand [+]	80.4	12.4	7.2	1.1	5.9	51.1	31.2	10.7	LS
Sandy Loam (4-3)	69.7	16.5	13.9	0.1	2.0	53.2	31.3	13.4	SL
	(2.6)	(3.7)	(6.2)	(0.1)	(0.5)	(1.6)	(3.4)	(3.8)	
1:3 Sandy Loam [+]	71.9	15.5	12.6	0.6	2.7	52.2	32.5	12.0	SL
1:1 Sandy Loam [+]	74.6	14.8	10.6	0.6	3.2	55.2	26.8	14.2	SL
3:1 Sandy Loam [+]	78.1	14.6	7.3	0.3	3.3	51.1	32.6	12.7	SL

[a] Number of samples for particle size analysis
[b] Number of samples for sand fraction analysis
[c] Mean value
[d] Standard deviation
[+] Sample size = 1
- Data unavailable or could not be determined

Table 4.4 Linear regression P and R^2 values for moisture retention parameters vs percent organic carbon (OC).

Comparisons$^+$	Gravimetric (g/g*100)			Volumetric (cm^3/cm^3*100)		
	P Value		R^2 Value	P Value		R^2 Value
In Situ						
0.01 MPa vs % OC	0.002	***	0.92	0.57	ns	0.26
1.5 MPa vs % OC	0.001	***	0.93	0.15	ns	0.59
AWHC† vs % OC	0.004	***	0.90	0.91	ns	0.05
Peat:Mineral Mixes						
0.01 MPa vs % OC	$5*10^{-6}$	***	0.94	0.01	***	0.84
1.5 MPa vs % OC	$6*10^{-5}$	***	0.90	0.03	**	0.78
AWHC† vs % OC	$6*10^{-5}$	***	0.90	0.09	*	0.67

*Indicates significance ($P \le 0.10$)
** Indicates significance ($P \le 0.05$)
*** Indicates significance ($P \le 0.01$)
† Available water holding capacity
ns Indicates no significance
$^+$ All correlation coefficients were positive

Table 4.5 Linear regression R^2 and P values for gravimetric moisture retention parameters (g/g*100) vs %peat for peat:mineral mixes.

Comparisons	Sand		Loamy Sand		Sandy Loam	
	P Value	R^2 Value	P Value	R^2 Value	P Value	R^2 Value
0.01 MPa vs %Peat	0.09 *	0.90	0.07 *	0.92	0.01 ***	0.98
1.5 MPa vs %Peat	0.13 ns	0.86	0.13 ns	0.86	0.13 ns	0.86
AWHC[†] vs %Peat	0.05 **	0.94	0.03 **	0.96	0.00 ***	0.99

* Indicates significance (P≤0.10)

** Indicates significance (P≤0.05)

*** Indicates significance (P≤0.01)

[†] Available water holding capacity

ns Indicates no significance

Table 4.6 Multiple regression P and R^2 values for volumetric available water holding capacity (cm^3/cm^3*100) vs percent organic carbon and particle size distribution percentages.

In Situ Textures	%Organic Carbon P Value		% Sand P Value		% Silt P Value		% Clay P Value		R^2 Value
Sand	ns		0.020	**	0.020	**	0.019	**	0.29
Loamy Sand	ns		ns		ns		0.000	***	0.94
Fine Sand (Tailings Sand)	0.000	***	0.024	**	0.026	**	ns		0.54
Peaty Loamy Sand	ns		ns		0.046	**	ns		0.34
Peaty Sandy Loam	ns		0.034	**	0.034	**	0.034	**	0.35

** Indicates significance ($P \leq 0.05$)
*** Indicates significance ($P \leq 0.01$)
ns Not significant

5.0 SOIL MOISTURE RETENTION IN A PEAT:MINERAL MIX OVER TAILINGS SAND PROFILE

5.1 Introduction

In general any profile discontinuity that affects pore size distribution will decrease water movement across the discontinuity boundary compared with a uniform profile (Miller 1973). Alway and McDole (1917), using six different layers of soil in a cylinder, found that the order of the soil layers did not affect water retention, with the exception of dune sand. The interposition of such a sand layer in all cases greatly increased the amount of water held by the soils in the layers above it.

The water retained in soil above a coarse layer is determined by the coarseness of the layer, depth to the layer and desorption characteristics of the soil (Miller 1973). Total and available water in a sandy loam soil underlain at a 60-cm depth by sand of various size ranges increased with increasing coarseness of the sand. Increased available water in the sandy loam soil also remained above that in a uniform profile, regardless of depth to the sand layer. With an underlying sand layer, the coarser the overlying layer, the greater the increase in available water in that layer compared to a uniform soil profile of the same texture. Such soil profile discontinuities, with topsoil placed above tailings sand, occur in the Oil Sands Region of Alberta.

5.2 Objective

The study objective was to quantify moisture retention in a soil profile created by placing a peat:mineral mix layer over tailings sand. Different peat:mineral mix ratios (1:1 and 3:1, on a volume basis), mineral components (sand and sandy loam) and depths of peat:mineral mixes (20, 35 and 50 cm) were examined.

5.3 Materials and Methods

5.3.1 Creation of Peat:mineral Mixes

Peat:mineral mixes were produced in the laboratory using peat from the Suncor Inc. Oil Sands Group lease site. The peat had been salvaged from the Muskeg Soil Series (Leskiw and Moskal 1997) at the north end of the Suncor lease site and had been stockpiled for one year. The peat material had a von Post scale of decomposition of 5 due to the recognizable but not distinct plant structure, the strongly turbid expressed fluid, with some portion of peat extruding from the hand and somewhat mushy nature of the residue (von Post and Granlund 1926). The colors for the moist organic material as natural, pressed and rubbed were 2.5/1 10YR, 3/1 10YR and 3/1 10YR, respectively and the material had a rubbed fiber content of 30%. Therefore, based on the von Post scale of decomposition, the colors and the rubbed fiber content the organic material was classified as mesic (SCWG 1998). Very dry peat tends to be hydrophobic, so the peat was kept moist in the laboratory to ensure it would take up moisture once mixed with the mineral soil. The mineral component of the peat:mineral mixes was obtained from Brunisolic B horizons of the undisturbed sites: the sand from Site 11, the loamy sand from Site 10 and the sandy loam from Site 12 (See Appendix 1 for site descriptions and maps).

The peat:mineral mixes were constructed on a volume basis, with two peat to mineral ratios of 1:1 and 3:1. These ratios were constructed by hand mixing, with two soil textures of sand and sandy loam, creating four peat:mineral mixes.

For the Suncor tailings sand three replicate columns were created with each of the three depths of peat:mineral mix (20, 35 and 50 cm), with two peat mineral ratios (1:1 and 3:1) of the two different mineral components (sand and sandy loam). These 12 different amendments were placed over the tailing sands from the Suncor site to create soil profiles of 100 cm. Over Syncrude tailings sand three depths of peat:mineral mix (20, 35 and 50 cm) were applied with one peat mineral ratio (1:1) made of the two different mineral components (sand and sandy loam). The soil profiles were created in plexiglass columns

10 cm deep, 15 cm wide and 125 cm high. The columns had a spigot at the bottom through which the drainage water could run, and once the profiles were drained they could be laid down, the removable face taken off and the soil profile cut into sections.

The process of saturation and drainage was as follows. Cleaned columns were placed on a bench approximately 30 cm off the ground; to allow drainage into a beaker below. Gravel was placed at the bottom of the column, approximately 5.0 cm deep, to at least 1.0 cm above the spigot to ensure the tailings sand did not plug the spigot. Then the tailing sands were placed in the column to the required depth (these tailings sands had been dried and any lumps were hand crushed to ensure even settling). The column was then tapped gently two or three times with a rubber mallet to settle the material. The peat:mineral mix was placed on top of the tailings sand, to the required depth, and again the column was tapped gently two or three times The laboratory produced peat:mineral mixes were dried and sieved through a 12.5-mm sieve to ensure there was a standard aggregate size, as the peat would sometimes stay in large clumps of matted material and was broken up by hand. The columns were constructed with 2 to 3 cm extra height in each profile peat:mineral mix so that after saturation, settling and subsequent drainage, the thickness of the peat:mineral mixes were as close as possible to the desired depths of 20, 35 and 50 cm.

The profiles of peat:mineral mix over Suncor tailings sands were saturated via the pressure of the distilled water tap. Hoses were attached to the column spigots and the taps and a standard pressure was used to saturate the profiles from the bottom. Complications with this method for the Syncrude tailings sand profiles necessitated a different method of saturation. Plastic hoses were connected to the soil column spigots and then taped into a large plastic container of water. The container was elevated in small increments and finally placed on containers higher than the level of the soil in the column, thereby saturating the entire column slowly.

The columns were considered saturated when there was a water film present to the top of the soil profile within the column. Once all three of the columns were saturated, they were covered at the top with stretchy wax paper to prevent evaporation and drainage was started. At 48 h the drainage spigots were turned off, the columns were placed on the workbench and the faces removed. The peat:mineral mix depth was measured again and the profile was divided into one 2-cm increment above and below the interface, two 5-cm increments above and below that with the remaining profile was divided into 10-cm increments. Samples from each of these increments were weighed, oven dried at 105 °C for 24 h and weighed again to determine soil moisture.

5.3.2 Statistical Analyses

Gravimetric moisture was determined from the incremental measurements at 48 h for the entire profiles. From measurements taken during the construction of the profiles, bulk density was determined and used to convert moisture contents to a volumetric basis. Total soil moisture (TSM, mm of water in a 90-cm profile) for each column was then calculated. Scheffe multiple comparisons of the Statistical Analysis System (SAS Institute Inc. 1988) were conducted on the different combinations of peat:mineral mix ratios, depths and tailings sand subsoil (3 replications for each combination). Comparisons of TSM were made between different textures of the same peat:mineral ratio, different ratios of the same texture and different depths of peat:mineral mixes.

5.4 Results and Discussion

There was noticeable settling in the deeper peat:mineral mixes, but not in the 20-cm peat:mineral mixes (Table 5.1). The 35-cm peat:mineral mixes settled 4 to 6 cm and the 50-cm profiles 4 to 12 cm.

TSM increased with increasing peat:mineral depth in the profile, with 20 cm < 35 cm < 50 cm, for all but one of the different combinations of mineral components and ratios (Table 5.1). The 20-cm, 1:1 sandy loam peat:mineral mix over Syncrude tailings sand combination did not follow this sequence having a higher TSM for the 20-cm depth (268 mm) than for the 35-cm depth (250 mm). The 20-cm profile remained very wet even after 48 h of drainage, indicated by the water flowing out the top of the column when the profile was laid on the counter. However, the TSMs for the three depth increments for all combinations were significantly different ($P \leq 0.05$) (See Appendix 4 for detailed statistical analysis).

TSM consistently increased from 1:1 to 3:1 peat:mineral ratios for each texture. These differences were not statistically significant, although some of them were large (>50 mm of water).

TSM increased with changes in component texture for a given peat:mineral ratio. However, the only significant difference was the sand 1:1 ratio versus the sandy loam 1:1 ratio over Suncor tailings sand. TSM decreased from sand to sandy loam for the 50-cm peat:mineral mix over Syncrude tailings sand (Table 5.1) (See Appendix 4 for detailed statistical analysis). This profile was noted to be exceptionally wet after 48 h of drainage, indicated by free water during incremental slicing.

The effect of the interface on soil moisture distribution within the 90-cm profile was clearly evident (Figures 5.1 and 5.2), with soil moisture decreasing dramatically below the interface. Soil moisture distribution within the peat:mineral mix was generally uniform with depth. There was no consistent order in soil moisture within the peat:mineral mixes among depths of 20, 35 and 50 cm. Moisture content in the 70 to 80 cm depth interval for all Suncor profiles was uniform, averaging 32.0 cm^3/cm^3*100 (standard deviation of 3.4 cm^3/cm^3*100, for a coefficient of variation of 10.6%).

Moisture contents of peat:mineral mixes at FC as determined from the column experiments ranged from 2.01 to 2.78 times those determined via pressure plate analysis (Table 5.2). The increase in FC was greater for the sand than the sandy loam. This increase in FC can be attributed to the presence the profile interface.

5.5 Conclusions

Increasing the depth of peat:mineral mix over tailings sand significantly increased TSM. Increasing the peat:mineral mix ratio from 1:1 to 3:1 also increased TSM but not significantly. TSM increased non-significantly with changes in component texture for a given peat:mineral ratio. Moisture content at FC within the peat:mineral mixes was more than doubled by the presence of a profile interface.

5.6 References

Alway, F.J. and McDole, G.R. 1917. Relation of the water-retaining capacity of a soil to its hygroscopic coeffeicient. J. Agric. Res. 9:27-71.

Leskiw, L.A. and Moskal, T.D. 1997. Predisturbance soils and forest soil capability ratings for Suncor lease 86/17. Prep. for Suncor Oil Sands Group. Edmonton, AB. 8 pp.

Miller, D.E. 1973. Water retention and flow in layered soil profiles. In: Bruce, R.R., Flach, K.F. and Taylor, H.M.(eds.). Field soil water regime. SSSA Special Pub. Series # 5. Soil Sci. Soc. of Am Inc. Madison, WI. Pp. 107-117.

SAS Institute Inc. 1988. SAS/STAT user's guide. Release 6.03 Edition. Cary, N.C. 1028 pp.

Soil Classification Working Group (SCWG). 1998. The Canadian system of soil classification. Agric. and Agri-Food Can. Publ. 1646 (Revised).Ottawa, ON. 187 pp.

Von Post, L. and Granlund, E. 1926. Sodra sveriges torvtilgaangar (Peat resources in southern Sweden). Sveriges Geologiska Undersokning. Yearbook 19, Vol. 2, Series C, No. 355. 127 pp.

Table 5.1 Average total moisture (mm) to 90 cm after 48 h drainage (field capacity) of laboratory soil profiles and Scheffe multiple-comparison results.

Tailings Sand Source	Mineral Component	Peat:Mineral Mix Ratio	Depth of Peat:Mineral Mix[A]		
			20 cm	35 cm	50 cm
Suncor	Sand	1:1 [a]	157 (23)[†]	190 (33)	204 (46)
	Sand	3:1	161 (23)	245 (31)	267 (38)
	Sandy loam	1:1[a]	198 (20)	235 (31)	270 (40)
	Sandy loam	3:1	214 (21)	246 (29)	304 (42)
Syncrude	Sand	1:1	229 (20)	240 (31)	324 (43)*
	Sandy loam	1:1	268 (16)*	250 (31)	319 (46)

[A] All depth comparisons are significantly different ($P \leq 0.05$)

[†] Actual average depth of peat:mineral mixes after saturation and drainage

[a] Similar lower case letter indicates significant difference between different textures of the same peat:mineral mix ratios ($P \leq 0.05$)

*These profiles may have had air pockets or other blockages in drainage

Table 5.2 Field capacity (cm^3/cm^3*100) of peat:mineral mixes as determined by pressure plate analysis and column experiments.

	Moisture Content (cm^3/cm^3*100)	
Peat:mineral Mix	Pressure Plate[†]	Column[+]
Sand 1:1	8.7	24.2
Sand 3:1	10.8	26.9
Sandy loam 1:1	14.9	29.9
Sandy loam 3:1	13.5	31.8

[†] Data taken from Table 4.2

[+] Average moisture content for 0-20 cm of the profiles having a 20-cm thick peat:mineral mix overlying Suncor sand

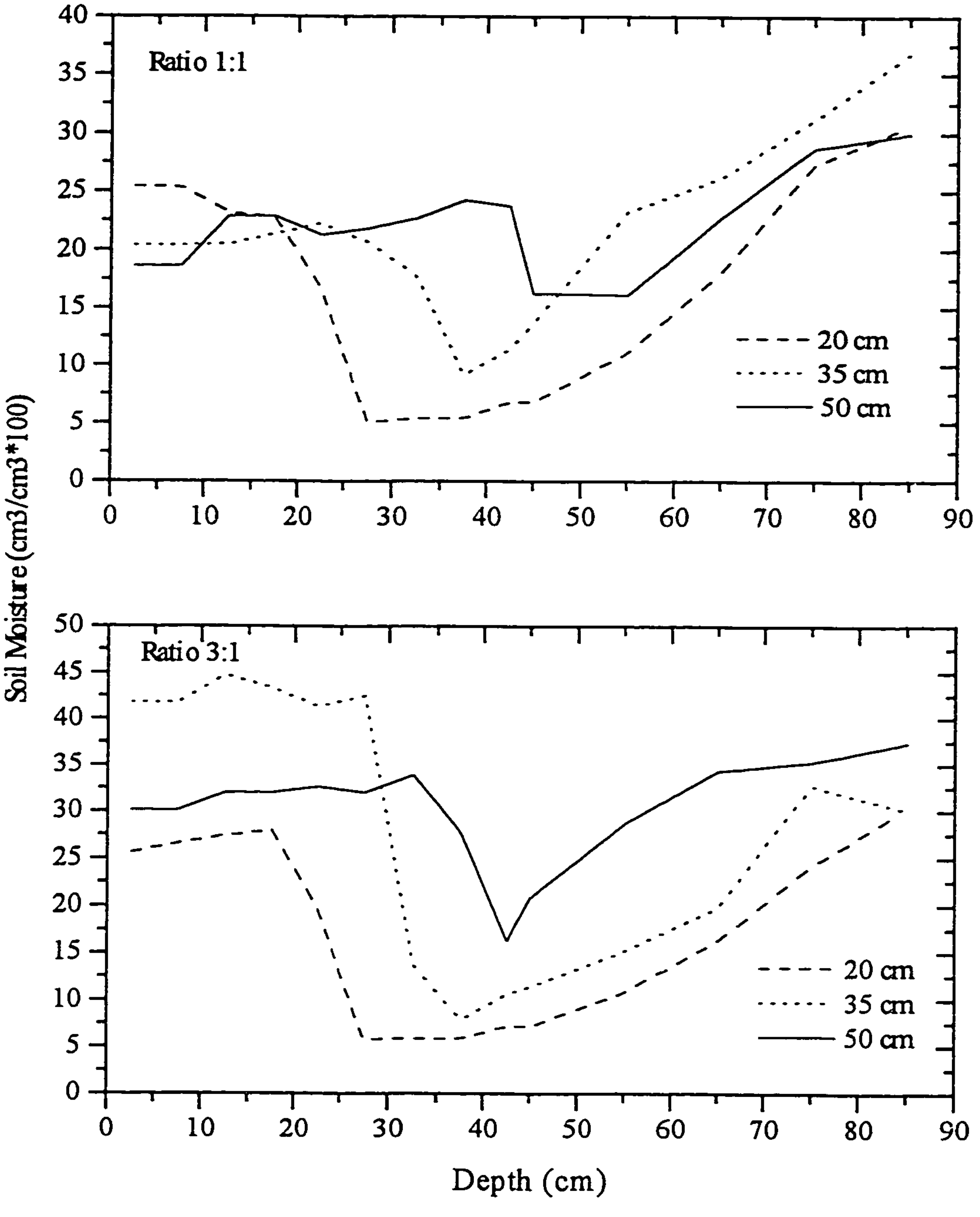


Figure 5.1 Soil moisture (cm^3/cm^3*100) for sand component ratios (1:1 and 1:3) at 20, 35 and 50 cm depths over Suncor tailings sand at 48 h drainage.

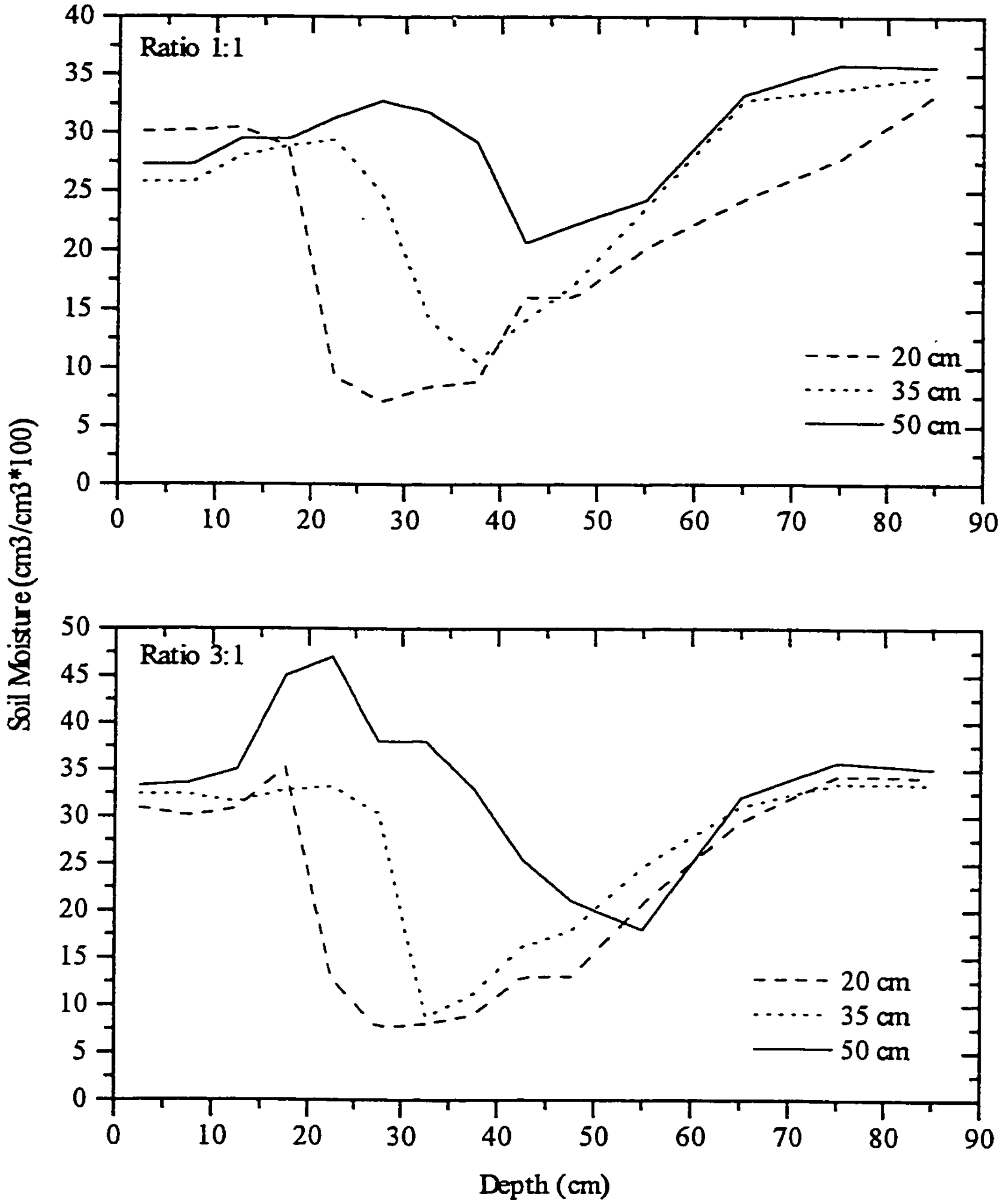


Figure 5.2 Soil moisture (cm^3/cm^3*100) for sandy loam component ratios (1:1 and 1:3) at 20, 35 and 50 cm depths over Suncor tailings sand at 48 h drainage.

6.0 SYNTHESIS - VOLUME AND DEPTH COMPONENTS FOR PEAT:MINERAL MIXES FOR RECLAMATION IN THE OIL SANDS REGION

To ensure reclamation in the Oil Sands Region is effective, the soil amendment used must provide adequate moisture for vegetation to grow and develop, as the underlying material of tailings sand is low in moisture holding capacity. The use of the muskeg salvaged from above the oil sands as an amendment is cost effective. There have been different application methods used to apply peat as topsoil: the current method is over-stripping the muskeg areas into the mineral component below then placing it on tailings sand as peat:mineral mix. Management issues become the different qualities of peat:mineral mix obtained with different depths of peat versus mineral material, and effect of different textured mineral components. To manage these reclamation issues, and others required to run large operations like that of Suncor Inc. Oil Sands Group and Syncrude Canada Ltd., a standard evaluation tool, The Land Capability Classification for Forest Ecosystems in the Oil Sands Region (Leskiw 1998), has been developed. This type of manual puts government and industry on the same footing to evaluate reclaimed soils and to bring consistency to the evaluation, and success to reclamation. The research reported in this thesis can be used to clarify some of the questions that arose in the development of the manual.

Many of the questions that arose pertained to the evaluation of the physical characteristics of a soil. Table 6 Available water holding capacity based on texture (Leskiw 1998) became a concern and needed verification (Table 6.1). It was uncertain whether a pressure of 0.01 or 0.033 MPa should be used to determine FC of the mineral components of reclamation in the Oil Sands Region. Available water holding capacity (AWHC), which is calculated by subtracting permanent wilting point (PWP) from FC, is a key parameter in the Land Capability Classification for Forest Ecosystems. Hence, accurate determination of FC is key to use of the classification.

For the coarse textured soils of sand and loamy sand 0.01 MPa is definitely a better approximation of FC in the laboratory than 0.033 MPa. The AWHCs listed for sand and loamy sand in Table 6 of the Land Capability Classification System (Table 6.1) are similar to those reported in this study (Tables 3.1, 4.1 and 5.1).

Sandy loam seems to be the location within the textural triangle where the appropriate laboratory pressure for the determination of FC may change from 0.01 to 0.033 MPa. However, such a change would create a discontinuity in the graph of FC versus texture. This discontinuity needs to be further researched. However, the AWHC for sandy loam in Table 6 of the Land Capability Classification System (Table 6.1) is similar to those in this study (Tables 3.1, 4.1 and 5.1).

Tailings sand appears to retain moisture in field situations. However, laboratory measurements of FC at 0.01 and 0.033 MPa for tailings sand indicate that it holds little moisture, as both 0.01 and 0.033 MPa laboratory measurements were significantly lower than in situ measurements. This may be due to the unique characteristics of this processed material, so even lower pressures than 0.01 MPa in the laboratory may be needed to represent this material's FC. Under laboratory conditions, tailings sand is closest to sand in moisture retention; however, the in situ measurements indicate it is closest to loamy sand in water retention. The AWHC provided in Table 6 of the Land Capability Classification System (Table 6.1) is likely appropriate, based on in situ measurements (Tables 3.1, 4.1 and 5.1).

One of the problems with measuring FC of peat:mineral mixes in the laboratory is adequate contact between the peat:mineral material and the pressure plate due to the highly fibrous nature of the peat:mineral material. For peaty sandy loam, the FC for peat:mineral mixes found in situ were significantly different than those attained at 0.033 MPa. This was not the case for peaty loamy sand where moisture retentions at 0.01 and 0.033 MPa were not significantly different from in situ measurements. The peaty sandy loam sample set had almost twice as many points as the peaty loamy sand sample set and therefore the estimate of FC for peaty sandy loam is likely more accurate. Hence, peat:mineral mixes should be measured in the laboratory using the 0.01 MPa and more research specifically on peat:mineral mixes should be conducted. Given the variability in the FC of the peat:mineral mixes, it would be best to measure FC of these soils in the field. Hovwever, the values of AWHC in Table 6 in the Land Capability Classification for Forest Ecosystems in the Oil Sands Region are appropriate for all textures discussed in this thesis.

One concern with Table 6 in the Land Capability Classification for Forest Ecosystems (Table 6.1) is the classification of peat:mineral mixes by their mineral component, determined by particle size analysis, after the organic matter has been digested. The results from in situ and constructed peat:mineral mix particle size determinations and AWHC show no consistent trends. Although, the AWHCs provided in Table 6 of the Land Capability Classification (Table 6.1) are similar to those reported in this study, the classification might be better determined by records kept of the reclamation peat:mineral mix ratios.

The timeframe for determining FC in the field ranges from 2 to 12 days; this was found to be inaccurate for the Oil Sands Region. In the undisturbed sandy Eluviated Eutric Brunisols, FC was attained prior to 12 h and statistically the reclaimed soils had reached their FC at 24 h. The 12-h time for undisturbed soils can be justified, but the reclaimed soils may still be draining at 48 h. This 12-h measurement may hold true not only for coarse textured soils in the Oil Sands Region, but in other coarse textured soils as well. If the measurements of FC are made at 48 h, they will be conservative.

Another question that needed to be addressed in reclamation was whether organic carbon (OC) had an effect on the AWHC of peat:mineral mixes. Under controlled laboratory conditions, OC affected gravitmetric AWHC. However, this was not true when moisture contents were considered on a volumetric basis. In fact, in situ, none of the moisture retention parameters on a volumetric basis were significantly correlated to OC. The laboratory produced peat:mineral mixes retained some statistical significance on a volumetric basis. The different results obtained under in situ versus laboratory conditions could be due to several factors. Soils are variable in the field; generally unlike the controlled, consistent laboratory situation. OC in the field may have already broken down and established a stablized, or partly stablilized organo-mineral system. Such systems are not created in the fresh laboratory mixes.

Some of the in situ measurement procedures are of concern. The one of greatest relevance to this study is the use of the Uhland core to determine bulk density. In measuring bulk density of peat:mineral mixes, for which the material is quite fibrous, filling the core completely is difficult. Any such problems with the Uhland core could adversely affect the accuracy of the bulk densities so determined. Since volumetric moisture contents are calculated using bulk densities, any errors in determining the bulk densities translate into errors in the determination of volumetric moisture content.

For the coarse textured soils studied, it appears that soil texture affects AWHC more than OC does. When volumetric AWHC was regressed against all three textural components (% clay, silt and sand) and OC, the AWHCs of two textures, sand and peat sandy loam, were affected more by the three textural components than OC. The AWHC of loamy sand was most related to clay while for peat loamy sand AWHC varied with silt. The only texture for which AWHC varied with OC was tailings sand; however, sand and silt also were factors in determining the amount of water held. These results support the placement of peat on tailings sand and incorporation as a topsoil amendment, because as peat is added to tailings sand, there is an increase in OC and therefore an increase in AWHC.

Several studies in the literature indicated that the addition of peat material would alter soil texture, and in that way be responsible for the increases in AWHC. This was not the case in this study as the addition of peat changed the texture imperceptibly for sand and loamy sand. The results for sandy loam were less clear.

Generally, soil moisture was higher moving from a ratio of 1:1 to 3:1 within one textural component of a peat mineral mix. Soil moisture in a peat:mineral mix was also generally higher when the mineral of the peat:mineral mix component was sandy loam compared to a sand. However, the values were not significantly different. Increasing moisture (retained in a 90-cm profile after 48 h of drainage) with increasing depth of peat:mineral mix was significant for all profiles. Therefore soil moisture will increase with more peat in the peat:mineral mix and going to a finer textured soil as the mineral component, increasing the depth will significantly increase soil moisture. Extrapolation of these results to the field, however, needs to be made carefully as the differences between the laboratory produced peat:mineral mixes and stabilized organo-mineral systems in situ need to be more thoroughly researched.

Soil moisture retained after 48 h of drainage in any layer overlying the coarse textured tailings sands increased due to the presence of the textural discontinuity (interface). The coarser the mineral component of the peat:mineral mix in the overlying layer, the greater the impact of that interface. So trade-offs might be made: for example, using sand as the peat:mineral mix base at a greater depth may give the equivalent moisture content as a peat:mineral mix with a sandy loam mineral component at a shallower depth. However, an increase in AWHC will be found if the different peat:mineral mix components and ratios are placed over tailings sand.

The magnitude of AWHC increases are due to the presence of an interface and can be determined from the results of this study. The contribution of tailings sand to the AWHC of a reclaimed profile can be determined from using data from Table 4.1,while the contributions for the values of peat:mineral mixes can be determined from Table 4.2. The interface effect on AWHC can be calculated by subtracting the sum of the tailings sand contribution and the peat:mineral mix contribution from the total AWHC as determined in the column study (Table 5.1). Results are given in Figure 6.1. In all cases, the interface effect dominated the AWHC of the profile. This may partially explain why in situ AWHCs are greater than those calculated from laboratory measurements.

6.1 References

Leskiw, L.A. 1998. Land capability classification for forest ecosystems in the Oil Sands region (Revised edition). Tailings sand reclamation practices working group. Edmonton, AB. 93 pp.

Table 6.1 Land capability classification for forest ecosystems in the Oil Sands region (Revised edition) Table 6 Available water holding capacity based on texture. †

Texture		AWHC(mm)			
Natural and Reclaimed Soils			Topsoil	Upper Subsoil	Lower Subsoil
		mm/cm	mm/20 cm	mm/30 cm	mm/50 cm
0.01 MPa FC*	Sand	0.8	16	24	40
	Loamy sand	1.1	22	33	55
	Sandy loam	1.4	28	42	70
0.01 MPa FC*	Tailings sand	1.0	20	30	50
Peat:mineral Mixes	peat+LS orS	1.2	24	36	60
0.01 MPa FC*	peat+SL or finer	1.7	34	51	85

†Adapted from Leskiw 1998

* Field capacity

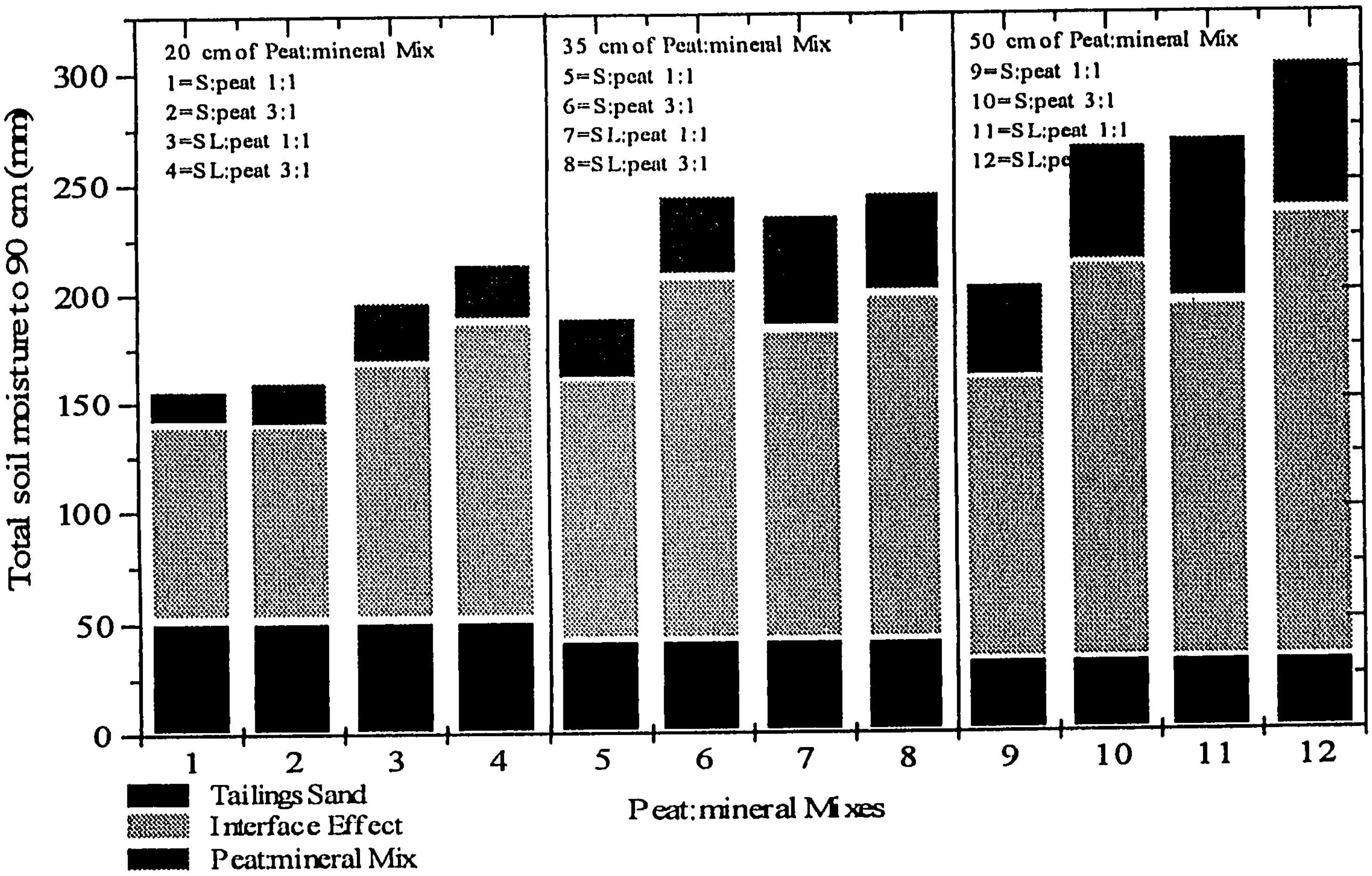


Figure 6.1 Effect of an interface on water retention within a soil profile created by placing a peat:mineral mix over tailing sand.

7.0 DEFINITIONS

Available Water Holding Capacity - In general terms, that portion of soil water that can be readily absorbed by plant roots, but as a specific soil value, the mathematical difference in the amounts of water a soil holds at the field capacity and the permanent wilting point (Hausenbuiller 1985).

Bulk Density - The mass of dry soil per unit of bulk volume (CSSS 1976).

Coarse Textured Soils - The texture exhibited by sands, loamy sands and sandy loams, except very fine sandy loam (CSSS 1976).

Field Capacity - The amount of water remaining in a field soil that has been thoroughly wetted and drained until free drainage has practically ceased (Hausenbuiller 1985).

In Situ - In the natural or original position (Webster's New Collegiate Dictionary, 1981).

Moisture Retention - The relationship between matric potential and soil moisture content, is represented as the soil moisture characteristic curve (Modified from Powter 1994).

Peat:Mineral Mix - A mixture of peat and mineral material resulting in a "mineral" soil used in reclamation. It may be obtained by either overstripping peat in the mineral material, or by placing peat material and then rotovating into underlying mineral material (Leskiw and Moskal 1997a and 1997b).

> **Peaty Sand (PtS)** - A peat:mineral mix with more than 4% organic carbon. After hydrogen peroxide digestion of all organic matter the remaining soil particle size analysis indicates sand as the texture.
>
> **Peaty Loamy Sand (PtLS)** - A peat:mineral mix with more than 4% organic carbon. After hydrogen peroxide digestion of all organic matter the remaining soil particle size analysis indicates loamy sand as the texture.
>
> **Peaty Sandy Loam (PtSL)** - A peat:mineral mix with more than 4% organic carbon. After hydrogen peroxide digestion of all organic matter the remaining soil particle size analysis indicates sandy loam as the texture.

Permanent Wilting Point - The moisture content of the soil at which plants (specifically sunflower plants) wilt and fail to recover their turgidity when placed in a dark, humid atmosphere. The wilting point is commonly estimated by measuring the 15-bar percentage of a soil (CSSS 1976).

Reclaimed Soil - The original soil has been disturbed by humans, and after the completion of the disturbance a modified soil has been laid down to allow the soil to return to its former or other productive uses.

Soil Moisture - Water contained in the soil (CSSS 1976).

Tailings Sand - A fine sand material which is one of the final products of the hydrocarbon removal process from oil sands (Leskiw and Moskal 1997a and 1997b).

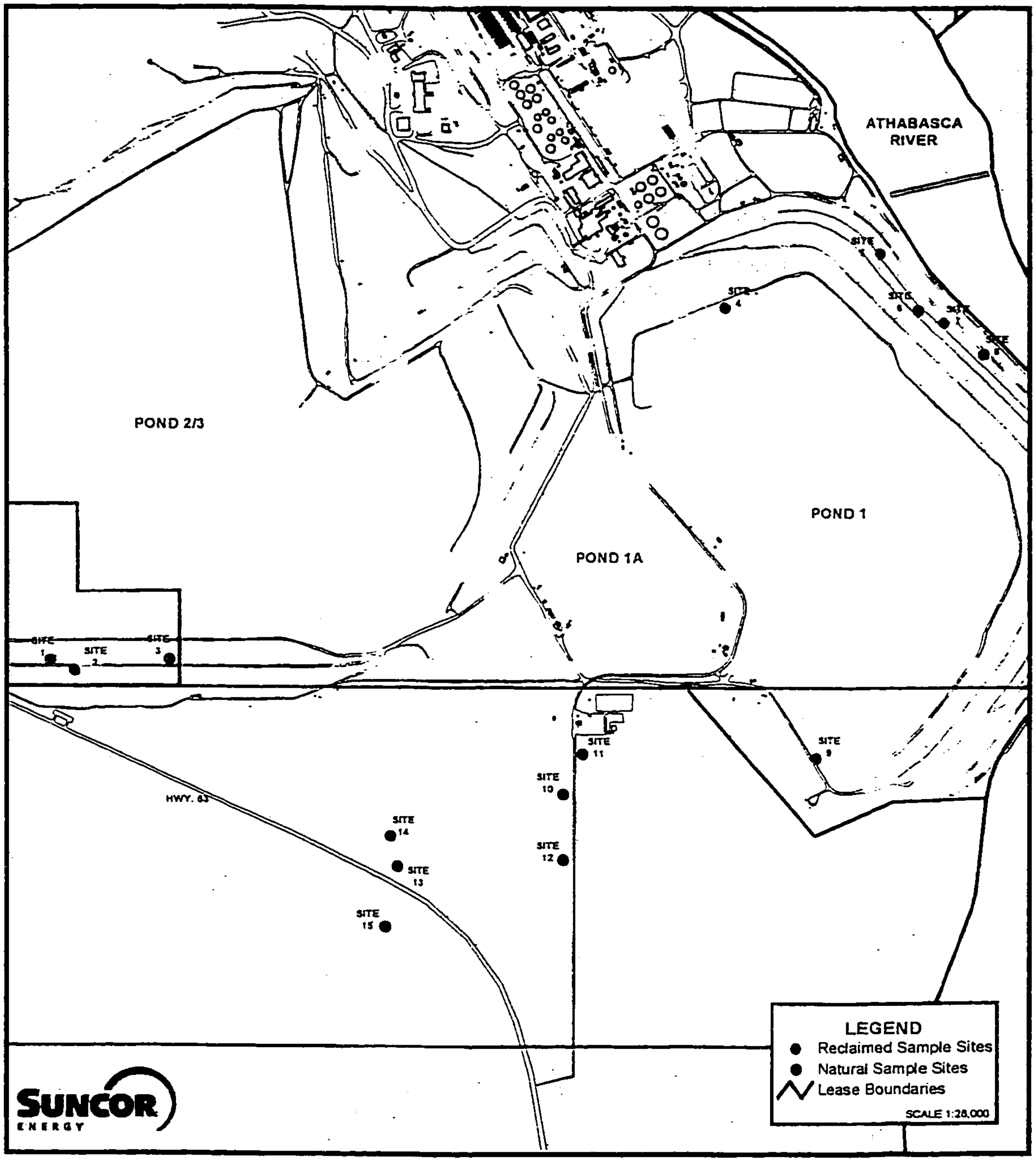
Topsoil - The uppermost part of the soil, ordinarily moved in tillage or its equivalent in uncultivated soils, and normally ranging in depth from 5-45 cm (Powter 1994).

Undisturbed Soils - Soils that have not been disturbed or replaced, but have existed in situ over an extended period of time.

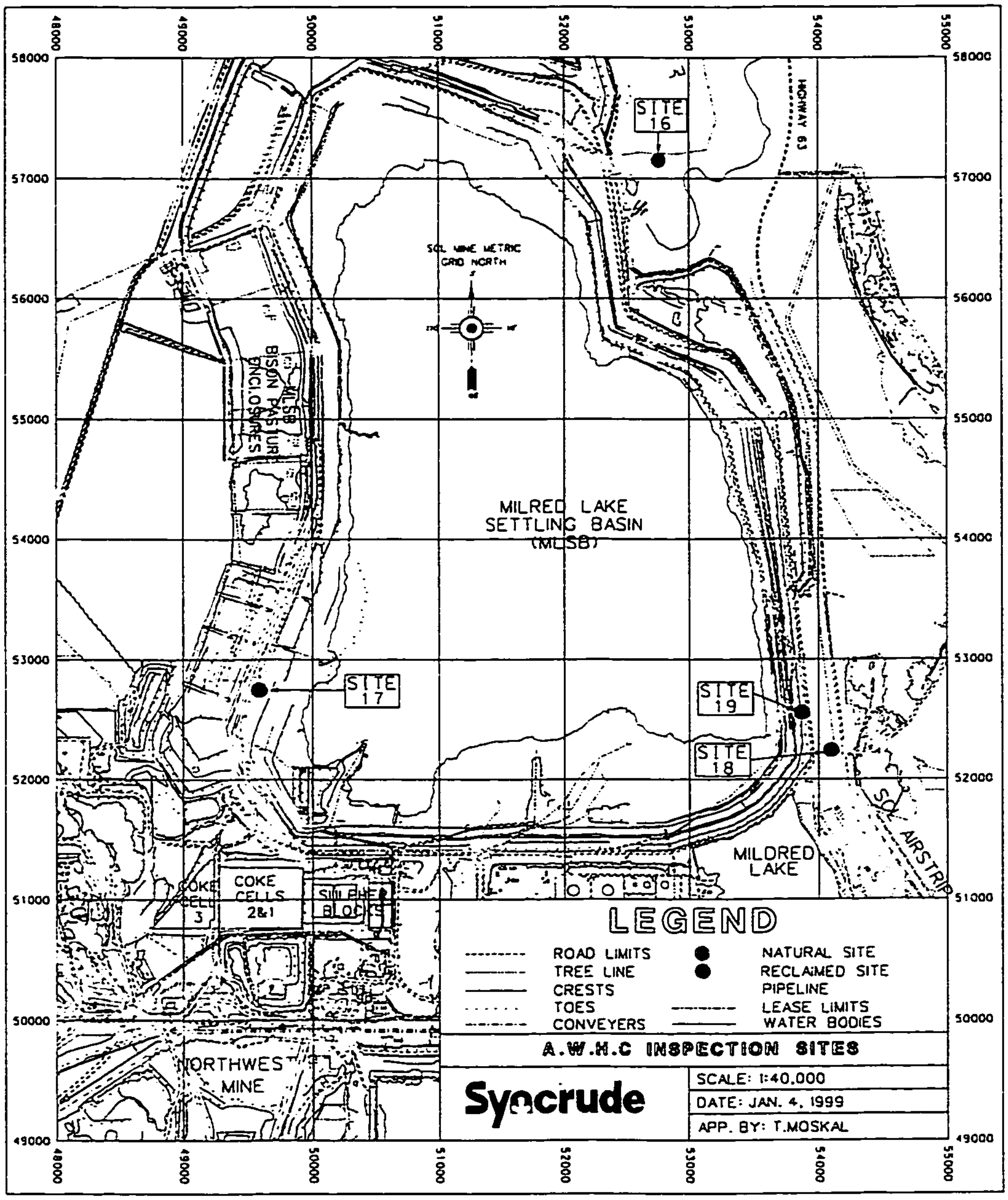
Volumetric Moisture Content - Percentage of soil volume occupied by water (% volume/volume) (Powter 1994).

8.0 APPENDICES

8.1 Appendix 1 - Site Descriptions and Maps



Map 1. Sites present on and around Suncor Inc. Oil Sands Group lease.



Map 2. Sites on the Syncrude Canada Ltd lease.

Site Descriptions
Site Number # 1 - Suncor - Reclaimed

Site Parameters

Site Location	Dyke 2 East and West top (Suncor Site # 61)
Exact Location	3 km from Tar Island Drive off landfill entrance to Dyke 2
Slope Class	25-30 %
Position	Mid slope on 2nd berm up from the wetlands
Stoniness	10-20%
Drainage	Rapid
Erosion	Slight
Average Topsoil Depth	22 cm

Vegetation Parameters

Overstory	**Understory**
Lodgepole pine *(Pinus contorta)* 30 cm tall with 5-10 cm growth Northwest poplar *(Populus* sp.*)* 1.5-2 m	White sweet clover *(Melilotus alba)* Common dandelion *(Taraxacum officinale)* Fireweed *(Epilobium angustifolium)* Red raspberry *(Rubus idaeus)* Dead vegetation, with moss in areas

Comments
Reclaimed in 1992, 29 cm of topsoil (peat:mineral mix) over tailings sand 1992-Harrowed, and planted to barley, afforested with lodgepole pine *(Pinus contorta)*, northwest poplar *(Populus* sp.*)*, red osier dogwood *(Cornus stolonifera)* and red raspberry *(Rubus idaeus)* South aspect, Red Belt effect Moderate infiltration, some ponding

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-22	3/210YR	m	ptSL	granular	friable
US	22-100	5/310YR	m	fS	single grain	loose - TSS
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-21	3/210YR	m	ptSL	granular	friable
US	21-100	5/310YR	m	fS	single grain	loose - TSS
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-22	3/210YR	m	ptSL	granular	friable
US	22-100	5/310YR	m	fS	single grain	loose - TSS

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
TS	32.0	21.0	21.5	13.8	18.2	4.5	0.86
US	3.3	1.7	1.3	0.9	2.4	0.2	1.46
Plot 2							
TS	48.6	47.0	41.0	23.5	25.1	8.3	0.70
US	3.9	2.9	2.4	1.3	2.6	0.3	1.46
Plot 3							
TS	44.2	37.4	35.2	21.8	22.4	9.2	0.42
US	4.4	2.8	2.3	1.6	2.8	0.4	1.46

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm)					Texture
					2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
TS	69	20	11	SL	2	12	19	47	20	SL
US	97	2	1	S	2	4	12	69	13	fS
Plot 2										
TS	61	33	6	SL	3	13	28	38	18	SL
US	97	2	1	S	1	7	16	61	15	fS
Plot 3										
TS	64	30	6	SL	2	14	32	31	21	SL
US	97	2	1	S	2	5	14	64	15	fS

Site Number # 2 - Suncor - Reclaimed

Site Parameters

Site Location	Dyke 2 West (Suncor Site # 44)
Exact Location	2.9 km from Tar Island Drive off landfill entrance to Dyke 2
Slope Class	29-34 %
Position	Mid slope on 1st berm up from the wetlands
Stoniness	0%
Drainage	Rapid
Erosion	Slight
Average Topsoil Depth	15 cm

Vegetation Parameters

Overstory	Understory
White spruce *(Picea glauca)* 50-75 cm	Grasses *(Poaceae)*
Northwest poplar *(Populus* sp.*)* 1.5 m	Saskatoon *(Amelanchier alnifolia)*

Comments

Reclaimed 1988, 21 cm of topsoil (peat:mineral mix) over tailings sand

1988-Harrowed, and planted to seed mix and barley-Seed Mix-violet wheat grass *(Agropyron violaceum)* 48%, sheep fescue *(Festuca ovina)* 10%, hair grass *(Agrostis scabra)* 9%, fowl bluegrass *(Poa palustris)* 9%, meadow fox tail *(Alopecurus pratensis)* 9%, alsike clover *(Trifolium hybridum)* 5%, red top *(Agrostis alba)* 5% at 50 kg/ha, with barley *(Hordeum* sp.*)* at 50kg/ha

1988-Afforested with white spruce *(Picea glauca)*, northwest poplar *(Populus* sp.*)*, red osier dogwood *(Cornus stolonifera)*, saskatoon *(Amelanchier alnifolia)*, prickly rose *(Rosa acicularis)* and willow *(Salix* sp.*)*, planted four more times 1998

1998-Jack pine *(Pinus banksiana)* also planted

South aspect, very dry

Fast infiltration, no ponding

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
OL	0-5	5/310YR	d	fS	single grain	loose - TSS
TS	5-35	3/310YR	m	pt	granular	friable
US	35-100	6/310YR	m	fS	single grain	loose - TSS
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
OL	0-3	5/310YR	d	fS	single grain	loose - TSS
TS	3-17	3/310YR	m	pt	granular	friable
US	17-100	6/310YR	m	fS	single grain	loose - TSS
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
OL	0-3	5/310YR	d	fS	single grain	loose - TSS
TS	3-5	3/210YR	d/m	pt	granular	friable
US	5-100	6/310YR	m	fS	single grain	loose - TSS

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
TS	45.2	33.8	32.3	26.1	19.1	10.5	0.85
US	8.0	4.0	3.3	3.4	4.6	0.6	1.47
Plot 2							
TS	27.3	14.8	13.3	11.2	16.1	5.3	0.96
US	4.7	2.9	2.2	0.5	4.2	0.4	1.47
Plot 3							
TS	13.2	8.0	6.9	4.1	9.1	2.8	0.89
US	4.3	2.6	2.1	0.6	3.7	0.3	1.47

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm)					Texture
					2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
TS	66	19	15	SL	2	9	24	39	26	SL
US	95	3	2	S	1	2	4	62	31	fS
Plot 2										
TS	77	13	10	SL	2	9	19	44	26	fSL
US	97	2	1	S	1	4	9	66	20	fS
Plot 3										
TS	88	4	8	S	1	4	10	69	16	LS
US	97	2	1	S	1	3	7	72	17	fS

Site Number # 3 - Suncor - Reclaimed

Site Parameters

Site Location	Dyke 2 West (Suncor Site # 61)
Exact Location	2.5 km from Tar Island Drive off landfill entrance to Dyke 2
Slope Class	29-34 %
Position	Mid slope on 2nd berm up from the wetlands
Stoniness	2 % - Hard to auger
Drainage	Well
Erosion	Slight
Average Topsoil Depth	32 cm

Vegetation Parameters

Overstory	**Understory**
Lodgepole pine *(Pinus contorta)* 50-70 cm	Grasses *(Poaceae)*
Northwestern poplar *(Populus* sp.*)* 1.5-2 m	White sweet clover *(Melilotus alba)*
	Red raspberry *(Rubus idaeus)*
	Common dandelion *(Taraxacum officinale)*
	American vetch *(Vicia americana)*

Comments

Reclaimed in 1992, 29 cm of topsoil (peat:mineral mix) over tailings sand

1992-Harrowed, and planted to barley, afforested with lodgepole pine *(Pinus contorta)*, northwest poplar *(Populus* sp.*)*, red osier dogwood *(Cornus stolonifera)* and red raspberry *(Rubus idaeus)*

South aspect, very dry, Red Belt effect

Very slow infiltration, ponding, surface soil powdery and stayed on surface of the water.

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-28	4/610YR	d/m	ptS	granular	friable
US	28-100	6/310YR	m	fS	single grain	loose - TSS
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-41	4/410YR	d/m	PtS	granular	friable
US	41-100	6/310YR	m	FS	single grain	loose - TSS
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-27	4/410YR	d/m	pt	granular	friable
US	27-100	6/310YR	m	fS	single grain	loose - TSS

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
TS	13.0	11.3	9.6	3.8	9.1	1.5	1.15
US	3.2	2.4	1.8	5.3	na	0.3	1.33
Plot 2							
TS	17.9	13.5	11.6	5.4	12.4	3.7	1.66
US	3.6	2.2	2.0	1.2	2.4	0.2	1.33
Plot 3							
TS	na	na	na	na	na	2.0	na
US	3.2	2.0	1.8	0.7	2.4	0.3	1.33

na Information not available

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm)					Texture
					2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
TS	73	16	11	SL	3	16	27	31	23	SL
US	97	2	1	S	0	2	5	70	23	fS
Plot 2										
TS	73	16	11	SL	2	17	26	33	22	SL
US	97	2	1	S	0	4	9	61	26	fS
Plot 3										
TS	72	16	12	SL	2	18	28	27	25	SL
US	97	2	1	S	0	5	9	72	14	fS

Site Number # 4 - Suncor - Reclaimed

Site Parameters

Site Location	North end of Tar Island Dyke (Suncor Site # 68)
Exact Location	1.7 km from Tar Island Drive top berm facing plant site
Slope Class	29-34 %
Position	Mid slope on top berm
Stoniness	1 %
Drainage	Well
Erosion	Slight
Average Topsoil Depth	27 cm

Vegetation Parameters

Overstory	**Understory**
Lodgepole pine *(Pinus contorta)* 40-50 cm with 5-15 cm new growth	Grasses *(Poaceae)*
White spruce *(Picea glauca)* 100-110 cm with 10-20 cm new growth	White sweet clover *(Melilotus alba)*
	Fireweed *(Epilobium angustifolium)*
	Common dandelion *(Taraxacum officinale)*

Comments

Reclaimed in 1991, 26 cm of topsoil (peat:mineral mix) over tailings sand
1991-Harrowed, and planted to barley 62 kg/ha, afforested with white spruce *(Picea glauca)*, lodgepole pine *(Pinus contorta)*, northwest poplar *(Populus* sp.*)*, red osier dogwood *(Cornus stolonifera)*
Red Belt effect - very high in the landscape
Good infiltration, some ponding on Plot 3

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-23	3/210YR	d/m	ptSL	granular	friable
US	23-100	5/310YR	m	fS	single grain	loose - TSS
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-32	3/210YR	d/m	ptSL	granular	friable
US	32-100	5/310YR	m	fS	single grain	loose - TSS
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-26	3/210YR	d/m	ptSL	granular	friable
US	26-100	5/310YR	m	fS	single grain	loose - TSS

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
TS	24.3	21.8	18.7	9.3	15.1	4.1	1.00
US	3.1	2.0	2.3	0.7	2.3	0.4	1.41
Plot 2							
TS	21.3	20.8	17.9	na	na	4.8	1.20
US	6.3	2.5	2.0	1.9	4.4	0.3	1.41
Plot 3							
TS	33.2	22.1	20.2	11.4	21.8	4.4	1.38
US	3.5	1.9	1.7	0.9	2.7	0.4	1.41

na Information not available

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm) 2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	Texture
Plot 1										
TS	62	22	16	SL	2	12	30	37	19	SL
US	97	2	1	S	3	13	25	51	8	fS
Plot 2										
TS	61	25	14	SL	2	11	29	34	24	SL
US	97	2	1	S	5	14	19	55	7	fS
Plot 3										
TS	na	na	na	na	na	na	na	na	na	na
US	96	3	1	S	14	21	26	34	5	S

na Information not available

Site Number # 5 - Suncor - Reclaimed

Site Parameters

Site Location	Northeastern Tar Island Dyke (Suncor Site # 20)
Exact Location	2.3 km from Tar Island Drive, east side access road TID, 2nd berm up from river, approach from above
Slope Class	26-30 %
Position	Upper slope on 2nd berm up from the river
Stoniness	0 %
Drainage	Well
Erosion	Slight
Average Topsoil Depth	15 cm

Vegetation Parameters

Overstory	**Understory**
Jack pine *(Pinus banksiana)* 3.5 m, with 8 cm new growth White spruce *(Picea glauca)* 3.5-4 m, with 30 cm new growth Trembling aspen *(Populus tremuloides)* 5 m	Grasses *(Poaceae)* Mosses

Comments
Reclaimed 1971, 10 cm of topsoil (peat:mineral mix) over tailings sand 1971-Unknown seed mix 1994-Fill in planted with white spruce *(Picea glauca)*, trembling aspen *(Populus tremuloides)*, red osier dogwood *(Cornus stolonifera)* and prickly rose *(Rosa acicularis)* Healthy looking trees, with good ground cover of moss and grass Fast infiltration, no ponding

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
OL	0-8	6/310YR	m	fS	single grain	loose - TSS
TS	8-26	3/210YR	m	pt	granular	friable
US	26-100	6/310YR	m	fS	single grain	loose - TSS
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
OL	0-10	6/310YR	m	fS	single grain	loose - TSS
TS	10-28	3/210YR	m	pt	granular	friable
US	28-100	6/310YR	m	fS	single grain	loose - TSS
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
OL	0-9	6/310YR	m	fS	single grain	loose - TSS
TS	9-19	3/210YR	m	pt	granular	friable
US	19-100	6/310YR	m	fS	single grain	loose - TSS

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
OL	8.5	4.7	4.4	17.9	na	1.2	1.29
TS	49.1	40.0	39.1	24.2	24.8	9.6	0.36
US	8.2	4.0	3.2	1.3	6.8	0.6	1.45
Plot 2							
OL	10.7	5.5	5.1	5.8	4.9	1.4	1.14
TS	53.2	44.4	36.6	24.7	28.5	9.5	0.86
US	9.5	4.3	3.1	1.9	7.7	0.6	1.45
Plot 3							
OL	6.1	2.6	1.9	1.2	4.9	0.3	1.16
TS	58.3	45.9	37.5	30.7	27.6	10.1	0.48
US	7.8	3.8	2.5	1.1	6.7	0.5	1.45

na Information not available

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm)					Texture
					2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
OL	94	5	1	S	0	3	12	66	19	fS
TS	86	8	6	LS	3	12	20	35	30	LS
US	95	4	1	S	0	1	4	64	31	fS
Plot 2										
OL	91	8	1	S	1	3	12	56	28	fS
TS	78	15	7	LS	2	12	21	41	24	LS
US	94	4	2	S	0	4	9	61	26	fS
Plot 3										
OL	97	2	1	S	1	4	7	59	29	fS
TS	80	13	7	LS	4	17	28	26	25	LS
US	95	4	1	S	2	2	21	54	21	fS

Site Number # 6 - Suncor - Reclaimed

Site Parameters

Site Location	Northeast Tar Island Dyke (Suncor Site # 25)
Exact Location	2.0 km from Tar Island Drive, east side access road TID, 3nd berm up from river, approach from below
Slope Class	26-30 %
Position	Lower slope on 3rd berm up from the river
Stoniness	0 %
Drainage	Well
Erosion	Slight
Average Topsoil Depth	22 cm

Vegetation Parameters

Overstory	**Understory**
Lodgepole pine *(Pinus contorta)* 5-7 m, with 25 cm new growth	Grasses *(Poaceae)*
White spruce *(Picea glauca)* 3-5 m, with 10 cm new growth	Mosses White sweet clover *(Melilotus alba)*
Trembling aspen *(Populus tremuloides)* 5 m	Fireweed *(Epilobium angustifolium)* Willow *(Salix* sp.*)*, bottom of slope

Comments
Reclaimed in 1972, 10 cm of topsoil (peat:mineral mix) over tailings sand
1972-Seedmix-grass and legume mix
Grass mix-crested wheatgrass *(Agropyron pectiniforme)* 22%, streambank wheatgrass *(Agropyron riparium)* 22%, brome grass *(Bromus* sp.*)* 39%, creeping red fescue *(Festuca rubra var. rubra)* 17%, at 27 kg/ha
Legume mix-alfalfa *(Medicago* sp.*)* 33%, white sweet clover *(Melilotus alba)* 25%, alsike clover *(Trifolium hybridum)* 42% at 18 kg/ha
1976-Planted with non native tree species
1995-Fill planted with lodgepole pine *(Pinus contorta)* and white spruce *(Picea glauca)*
Plot 3 - hit rocky overburden layer 2 - 5 cm thick at approx. 70 cm
Healthy looking trees, with good ground cover of moss and grass
Fast infiltration, no ponding, may have been primed by weekend rain

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-27	3/210YR	m	ptS	granular	friable
US	27-100	5/310YR	m	fS	single grain	loose - TSS
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-10	3/210YR	m	ptS	granular	friable
US	10-100	5/310YR	m	fS	single grain	loose - TSS
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-28	3/210YR	m	ptS	granular	friable
US	28-100	5/310YR	m	fS	single grain	loose - TSS

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
TS	74.0	60.8	50.9	40.7	33.3	10.5	0.40
US	8.8	na	na	1.1	7.7	0.5	1.35
Plot 2							
TS	29.4	na	na	11.2	18.2	11.2	0.57
US	6.0	3.3	2.7	1.1	4.9	0.4	1.35
Plot 3							
TS	31.5	22.9	22.5	16.7	14.7	8.4	0.57
US	8.2	3.8	2.7	2.0	6.2	0.5	1.35

na Information not available

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm)					Texture
					2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
TS	79	8	13	SL	2	3	8	56	31	vfSL
US	94	4	2	S	0	0	3	63	34	fS
Plot 2										
TS	88	8	4	LS	0	1	6	53	40	LfS
US	95	3	2	S	2	1	4	73	20	fS
Plot 3										
TS	90	5	5	S	4	17	28	26	25	S
US	93	4	3	S	2	2	21	54	21	fS

Site Number # 7 - Suncor - Reclaimed

Site Parameters

Site Location	Northeast Tar Island Dyke (Suncor Site # 20)
Exact Location	1.9 km from Tar Island Drive, east side access road TID, 2nd berm up from river, approach from above
Slope Class	29-34 %
Position	Upper slope on 2rd berm up from the river
Stoniness	0 %
Drainage	Well
Erosion	None
Average Topsoil Depth	34 cm

Vegetation Parameters

Overstory	**Understory**
White spruce *(Picea glauca)* 1 m, with 30 cm new growth Balsam poplar *(Populus balsamifera)*	Grasses *(Poaceae)* Common dandelion *(Taraxacum officinale)* White sweet clover *(Melilotus alba)* Fireweed *(Epilobium angustifolium)*

Comments
Reclaimed 1971, 10 cm of topsoil (peat:mineral mix) over tailings sand
1971-Unknown seed mix (May be same mix as Site 6)
1994- Fill in planted with white spruce *(Picea glauca)*, balsam poplar *(Populus balsamifera)*, red osier dogwood *(Cornus stolonifera)* and prickly rose *(Rosa acicularis)*
Fast infiltration, some ponding from the last quarter of the barrel

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-37	3/310YR	m	ptL	granular	friable
US	37-100	5/310YR	m	fS	single grain	loose - TSS
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-32	3/310YR	m	ptL	granular	friable
US	32-100	5/310YR	m	fS	single grain	loose - TSS
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-32	3/310YR	m	ptL	granular	friable
US	32-100	5/310YR	m	fS	single grain	loose - TSS

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
TS	44.2	24.1	20.2	18.8	25.4	5.7	0.62
US	9.1	4.8	3.8	2.6	6.5	0.9	1.60
Plot 2							
TS	49.0	36.1	35.8	27.8	21.2	6.7	0.70
US	7.0	4.3	na	1.8	5.1	0.6	1.39
Plot 3							
TS	51.7	31.9	na	30.9	20.7	6.3	1.02
US	32.8	2.4	na	28.8	4.1	0.4	1.39

na Information not available

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm)					Texture
					2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
TS	73	16	11	SL	3	13	30	33	21	SL
US	93	4	3	S	1	3	19	54	23	fS
Plot 2										
TS	68	21	11	SL	2	3	8	56	31	vfSL
US	94	3	3	S	0	7	13	56	24	fS
Plot 3										
TS	69	18	13	SL	3	14	33	19	31	SL
US	95	3	2	S	3	0	8	62	27	fS

Site Number # 8 - Suncor - Reclaimed

Site Parameters

Site Location	Northest corner of Tar Island Dyke (Suncor Site # 20)
Exact Location	4 km from Tar Island Drive, east side access road TID, 1st berm up from river, approach from below
Slope Class	24-30 %
Position	Lower slope on 2nd berm up from the river
Stoniness	0 %
Drainage	Moderately well, high water table
Erosion	Slight
Average Topsoil Depth	14 cm

Vegetation Parameters

Overstory	Understory
Balsam poplar *(Populus balsamifera)* 8-10 m	Grasses *(Poaceae)* Caragana (*Caragana arborescens*) Russian thistle *(Cirsium* sp.*)* Willow *(Salix* sp.*)* - 4 m

Comments
Reclaimed 1971, 10 cm of topsoil (peat:mineral mix) over tailings sand 1971-Unknown seed mix (May be same mix as Site 6) 1994- Fill in planted with white spruce *(Picea glauca)*, balsam poplar *(Populus balsamifera)*, red osier dogwood *(Cornus stolonifera*) and prickly rose *(Rosa acicularis)* Mottles in US Soils are moist from 80 cm

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-22	3/210YR	m	ptS	granular	friable
US	22-100	5/310YR	m	fS	single grain	loose - TSS
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-12	3/210YR	m	ptS	granular	friable
US	12-100	5/310YR	m	fS	single grain	loose - TSS
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-7	3/210YR	m	ptS	granular	friable
US	7-100	5/310YR	m	fS	single grain	loose - TSS

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
TS	45.3	43.4	na	27.3	17.9	13.3	0.75
US	4.6	2.5	na	1.0	3.6	0.5	1.43
Plot 2							
TS	12.5	22.2	na	13.7	na	9.4	0.50
US	6.0	3.5	3.1	1.4	4.6	0.6	1.43
Plot 3							
TS	19.4	16.4	17.0	8.9	10.5	4.2	0.78
US	5.6	3.0	2.3	0.8	4.9	0.4	1.43

na Information not available

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm)					Texture
					2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
TS	82	8	10	LS	3	16	27	29	25	LS
US	94	4	2	S	0	1	12	57	30	fS
Plot 2										
TS	85	8	7	LS	1	7	15	48	29	LS
US	95	3	2	S	0	0	5	61	34	fS
Plot 3										
TS	80	13	7	LS	2	5	40	42	11	LS
US	95	4	1	S	0	0	3	61	36	fS

Site Number # 9 - Suncor - Reclaimed

Site Parameters

Site Location	South end of Tar Island Dyke (Suncor Site # 66)
Exact Location	0.6 km from Tar Island Drive, south side access road TID, approach from below
Slope Class	24-30 %
Position	Mid slope on only berm
Stoniness	1 %
Drainage	Well
Erosion	Slight
Average Topsoil Depth	22 cm

Vegetation Parameters

Overstory	**Understory**
Lodgepole pine *(Pinus contorta)* 40 cm	Grasses *(Poaceae)*
White spruce *(Picea glauca)* 30 cm	Common dandelion *(Taraxacum officinale)*
Trembling aspen *(Populus tremuloides)* 1.5-2 m	

Comments

Reclaimed in 1991, 26 cm of topsoil (peat:mineral mix) over tailings sand
1991-Seeded to barley at 62 kg/ha
1991-(Fall planted) with white spruce *(Picea glauca)*, balsam poplar *(Populus balsamifera)*, lodgepole pine *(Pinus contorta)* and red osier dogwood *(Cornus stolonifera)*
Trees small and very spread out
Soils dry when set up, after a day of rain?

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-10	3/210YR	d	pt	granular	friable
US	10-100	6/310YR	d	fS	single grain	loose - TSS
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-28	3/210YR	d	pt	granular	friable
US	28-100	6/310YR	d	fS	single grain	loose - TSS
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-27	3/210YR	d	pt	granular	friable
US	27-100	6/310YR	d	fS	single grain	loose - TSS

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
TS	59.6	46.6	40.6	31.6	28.0	11.0	0.66
US	5.3	2.3	1.7	0.8	4.6	0.4	1.40
Plot 2							
TS	57.6	36.7	33.1	22.1	35.6	7.8	0.63
US	2.4	2.4	2.3	0.8	1.6	0.2	1.40
Plot 3							
TS	52.2	37.8	31.0	24.0	28.2	10.2	0.80
US	2.5	1.7	0.9	0.9	1.6	0.1	1.40

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm)					Texture
					2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
TS	81	9	10	LS	3	9	30	36	22	LS
US	96	3	1	S	0	1	12	57	30	fS
Plot 2										
TS	65	21	14	SL	1	13	29	22	35	SL
US	98	1	1	S	0	0	5	79	16	fS
Plot 3										
TS	69	19	12	SL	2	12	28	18	40	SL
US	98	1	1	S	0	0	5	79	16	fS

Site Number #10 - Undisturbed

Site Parameters

Site Location	Along of Suncor access road
Exact Location	1.7 km from Suncor exit off Highway 63 on west side of road
Slope Class	2-3% with microtopographic variation
Position	Level in natural ecosystem
Stoniness	0-1%
Drainage	Well drained
Erosion	0
Average Topsoil Depth	Ae -8 cm
Soil Subgroup	Eluviated Eutric Bruinsol

Vegetation Parameters

Overstory	**Understory**
Jack pine *(Pinus banksiana)* 8-10 m Trembling aspen *(Populus tremuloides)* 8-10 m	Prickly rose *(Rosa acicularis)* Fireweed *(Epilobium angustifolium)* Brome grass *(Bromus* sp.*)* Blueberry *(Vaccinium* sp.*)* Solomon's seal *(Smilacina racemosa)* Sarsaparilla *(Aralia nudicaulis)* Alder *(Alnus* sp.*)* 2-3 m Moss and lichens

Comments
Rapid infiltration of water Site 2 is upland dry microsite vs sites 1 and 3 are low microsite and definitely wetter

Plots

Plot 1

Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	5-0					
Ae	0-10	6/2 10YR	m	S	single grain	loose
Bm	13-100	5/6 10YR	m	S	single grain	loose

Plot 2

Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	4-0					
Ae	0-5	6/4 10YR	m	S	single grain	loose
Bm	5-100	5/6 10YR	m	S	single grain	loose

Plot 3

Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	4-0					
Ae	0-10	6/2 10YR	m	S	single grain	loose
Bm	10-100	5/6 10YR	m	LS	single grain	loose

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
Ae	7.6	4.7	4.5	3.8	3.8	1.1	1.27
Bm	7.3	4.5	4.1	2.8	4.6	0.3	1.33
Plot 2							
Ae	6.7	3.2	2.5	2.6	4.1	0.5	1.38
Bm	4.6	3.4	2.7	1.8	2.8	0.3	1.49
Plot 3							
Ae	10.6	5.6	3.5	2.0	8.7	0.6	1.29
Bm	13.3	7.4	6.3	4.0	9.2	0.2	1.41

Horizon	%	%	%	Textural	Sand Fraction (mm)					Texture
	Sand	Silt	Clay	Class	2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
Ae	93	5	2	S	na	na	na	na	na	S
Bm	89	5	6	S	na	na	na	na	na	S
Plot 2										
Ae	84	13	3	LS	1	4	54	23	18	LS
Bm	96	1	3	S	0	1	42	47	10	S
Plot 3										
Ae	89	8	3	S	0	3	48	41	8	S
Bm	83	6	11	LS	0	2	38	48	12	LS

na Information not available

Site Number #11 - Undisturbed

Site Parameters

Site Location	Along of Suncor access road
Exact Location	1.8 km from Suncor exit off Highway 63 on east side of road
Slope Class	2-3% with microtopographic variation
Position	level in natural ecosystem
Stoniness	0%
Drainage	Well drained
Erosion	0
Average Topsoil Depth	Ae -9 cm
Soil Subgroup	Eluviated Eutric Bruinsol

Vegetation Parameters

Overstory	**Understory**
Jack pine *(Pinus banksiana)* 8 m Trembling aspen *(Populus tremuloides)* 6-8 m	Kinnickinnick *(Arctostaphylos uva-ursi)* Blueberry *(Vaccinium* sp.*)* Brome grass *(Bromus* sp.*)* Pin cherry *(Prunus pensylvanica)* Solomon's seal *(Smilacina racemosa)* Trembling aspen *(Populus tremuloides)* seedlings 1.5 m

Comments
Rapid infiltration Dwarf Mistletoe on Pine

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	5-0					
Ae	0-5	6/2 10YR	d/m	S	single grain	loose
Bm	5-100	5/7 10YR	m	S	single grain	loose
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	5-0					
Ae	0-15	6/2 10YR	d	S	single grain	loose
Bm	15-100	5/7 10YR	d	S	single grain	loose
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	4-0					
Ahe	0-8	3/1 10YR	d	S	single grain	loose
Ae	8-15	6/2 10YR	d/m	S	single grain	loose
Bm	15-100	5/6 10YR	m	S	single grain	loose

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
Ac	9.4	4.3	2.8	2.5	7.0	0.6	1.3
Bm	7.9	4.2	3.4	1.8	6.1	0.2	1.39
Plot 2							
Ae	9.4	4.1	3.4	2.2	7.2	0.44	1.21
Bm	1.3	3.2	2.7	na	2.9	0.2	1.36
Plot 3							
Ahe	8.3	na	4.8	2.5	5.8	1.4	0.64
Ae	6.7	4.3	3.3	1.2	58.5	0.4	1.22
Bm	5.4	3.5	2.9	1.7	3.7	0.2	1.45

na Information not available

Horizon	%	%	%	Textural	Sand Fraction (mm)					Texture
	Sand	Silt	Clay	Class	2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
Ae	93	5	2	S	0	8	60	26	6	S
Bm	88	8	4	S	0	5	54	34	7	S
Plot 2										
Ae	92	6	2	S	0	6	58	27	9	S
Bm	93	4	3	S	0	3	53	35	9	S
Plot 3										
Ahe	95	4	1	S	0	5	51	31	13	S
Ae	89	9	2	S	0	5	48	37	10	S
Bm	90	6	4	S	0	2	38	45	15	S

Site Number #12 - Undisturbed

Site Parameters

Site Location	Along of Suncor access road
Exact Location	1.1 km from Suncor exit off Highway 63 on west side of road
Slope Class	2-3% with microtopographic variation
Position	level in natural ecosystem
Stoniness	0%
Drainage	Well drained
Erosion	0
Average Topsoil Depth	Ae -14 cm
Soil Subgroup	Eluviated Eutric Bruinsol

Vegetation Parameters

Overstory	**Understory**
Jack pine *(Pinus banksiana)* 10-12 m Trembling aspen *(Populus tremuloides)* 5-10 m Sparse black spruce *(Picea mariana)* 7 m	Green alder *(Alnus crispa)* 1-2 m Kinnickinnick *(Arctostaphylos uva-ursi)* Trembling aspen *(Populus tremuloides)* seedlings 2-3 m Bunchberry *(Cornus canadensis)* Twinflower *(Linnaea borealis)* Sarsaparilla *(Aralia nudicaulis)* Bog cranberry *(Vaccinium oxycoccos)*

Comments
Wide range of plant species

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	5-0					
Ae	0-16	6/2 10YR	d/m	S	single grain	loose
Bm	16-50	5/6 10YR	m	SL	granular	friable
Bm2	50-100	5/4 10YR	d	SL	granular	friable
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	6-0					
Ae	0-16	6/1 10YR	d/m	S	single grain	loose
Bm	16-50	6/4 10YR	m	SL	granular	friable
Bm2	50-100	5/4 10YR	m	S	single grain	loose
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	6-0					
Ae	0-10	5/3 10YR	d/m	S	single grain	loose
Btj	10-25	4/6 5YR	m	SL	granular	friable
Bm	25-50	6/3 10YR	m	SL	granular	friable
Bm2	50-100	5/6 10YR	m	S	single grain	loose

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
Ac	10.1	6.9	4.1	1.8	8.3	0.3	1.26
Bm	12.8	7.1	5.5	3.2	9.5	0.1	1.43
Bm2	na	na	na	na	na	na	na
Plot 2							
Ac	12.8	8.7	6.3	2.1	10.7	0.6	1.43
Bm	9.1	3.8	2.5	2.6	6.5	0.2	1.30
Bm2	8.0	3.3	1.5	1.6	6.4	0.1	1.42
Plot 3							
Ac	16.2	9.4	5.7	3.0	13.2	1.5	1.14
Btj	na	na	na	na	na	0.7	na
Bm	22.7	13.4	1.0	5.2	17.6	0.3	1.36
Bm2	9.6	2.9	na	1.4	8.2	0.1	1.42

na Information not available

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm)					Texture
					2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
Ae	82	16	2	LS	0	5	53	20	22	LS
Bm	78	12	10	SL	0	6	57	24	13	SL
Bm2	na	na	na	na	na	na	na	na	na	na
Plot 2										
Ae	75	22	3	LS	1	4	48	22	25	LS
Bm	84	9	7	LS	0	3	52	30	15	LS
Bm2	93	3	4	S	0	2	55	23	20	S
Plot 3										
Ae	79	16	5	LS	1	7	55	24	13	LS
Btj	63	20	17	SL	1	8	60	9	22	SL
Bm	59	20	21	SCL	1	9	55	12	23	SCL
Bm2	93	2	5	S	0	4	58	30	8	S

na Information not available

Site Number #13 - Undisturbed

Site Parameters

Site Location	Northwest of Suncor on Highway 63
Exact Location	0.8 km from Suncor exit on right side of Highway 63 heading north, 0.3 km in ditch heading north
Slope Class	2-3% with microtopographic variation
Position	Level in natural ecosystem
Stoniness	1%
Drainage	Well drained
Erosion	0
Average Topsoil Depth	Ae -13 cm
Soil Subgroup	Eluviated Eutric Bruinsol

Vegetation Parameters

Overstory	**Understory**
Jack pine *(Pinus banksiana)* 13-15 m	Mosses
Trembling aspen *(Populus tremuloides)* 5 m	Kinnickinnick *(Arctostaphylos uva-ursi)*
	Green alder *(Alnus crispa)*
	Blueberry *(Vaccinium* sp.*)*
	Sarsaparilla *(Aralia nudicaulis)*

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	5-0					
Ae	0-15	7/1 10YR	d	LS	single grain	loose
Bm	15-60	5/6 10YR	d	LS	single grain	loose
Bm2	60-100	5/4 10YR	d	S	single grain	loose
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	7-0					
Ae	0-15	7/1 10YR	d	LS	single grain	loose
Bm	15-70	5/6 10YR	d	LS	single grain	loose
Bm2	70-100	5/4 10YR	d	S	single grain	loose
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	7-0					
Ae	0-10	7/1 10YR	d	S	single grain	loose
Bm	10-70	6/6 10YR	d	LS	single grain	loose
Bm2	70-100	5/6 10YR	d	S	single grain	loose

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
Ac	8.5	5.1	3.8	1.7	6.8	0.3	1.22
Bm	11.5	6.7	5.5	3.6	8.0	0.3	1.32
Bm2	na	na	na	na	na	0.1	na
Plot 2							
Ac	8.3	6.2	5.2	2.8	5.4	0.7	1.36
Bm	10.4	5.8	4.6	2.6	7.8	0.3	1.41
Plot 3							
Ac	17.5	10.3	8.2	4.0	13.5	0.8	1.41
Bm	11.4	5.6	4.4	3.5	7.9	0.5	1.38
Bm2	na	na	na	na	na	0.2	na

na Information not available

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm)					Texture
					2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
Ac	84	14	2	LS	na	na	na	na	na	na
Bm	81	11	8	LS	na	na	na	na	na	na
Bm2	94	3	3	S	na	na	na	na	na	na
Plot 2					na	na	na	na	na	na
Ac	89	10	1	LS	na	na	na	na	na	na
Bm	83	11	6	LS	na	na	na	na	na	na
Plot 3					na	na	na	na	na	na
Ac	71	26	3	SL	na	na	na	na	na	na
Bm	81	11	8	LS	na	na	na	na	na	na
Bm2	94	2	4	S	na	na	na	na	na	na

na Information not available

Site Number #14 - Undisturbed

Site Parameters

Site Location	Northwest of Suncor on Highway 63
Exact Location	0.8 km from Suncor exit on right side of Highway 63 heading north, 0.3 km in ditch heading north, NE of Site 13
Slope Class	2-3% with microtopographic variation
Position	level in natural ecosystem
Stoniness	0%
Drainage	Well drained
Erosion	0
Average Topsoil Depth	Ae -12 cm
Soil Subgroup	Eluviated Eutric Bruinsol

Vegetation Parameters

Overstory	**Understory**
Jack pine *(Pinus banksiana)* 13-15 m Trembling aspen *(Populus tremuloides)* 7-10 m	Alder *(Alnus* sp.*)* Kinnickinnick *(Arctostaphylos uva-ursi)* Labrador tea *(Ledum groenlandicum)* Blueberry *(Vaccinium* sp.*)* Twinflower *(Linnaea borealis)* Sarsaparilla *(Aralia nudicaulis)* Mosses Horse tails *(Equisetum* sp.*)*

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	8-0					
Ae	0-5	6/2 10YR	d	S	single grain	loose
Bm	5-75	5/4 10YR	m	SL	granular	friable
Bm2	75-100	5/4 10YR	m	S	single grain	loose
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	7-0					
Ae	0-12	5/3 10YR	d	S	single grain	loose
Bm	12-75	5/6 10YR	m	SL	granular	friable
Bm2	75-100	5/6 10YR	m	S	single grain	loose
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	6-0					
Ae	0-20	6/2 10YR	d	S	single grain	loose
Bm	20-50	5/8 2.5YR	m	SL	granular	friable
Bm2	50-100	5/8 2.5YR	m	S	single grain	loose

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
Ac	12.1	8.0	6.8	na	na	0.8	1.46
Bm	14.8	11.1	8.3	4.8	10.0	0.4	1.52
Bm2	na	na	na	na	na	0.1	na
Plot 2							
Ac	12.7	6.0	4.9	2.5	9.6	0.8	1.43
Bm	12.7	6.2	5.0	3.9	8.8	0.3	1.54
Bm2	na	na	na	na	na	0.2	na
Plot 3							
Ac	12.1	5.8	5.1	0.3	11.8	0.4	1.33
Bm	12.1	10.0	6.6	4.9	7.2	0.4	1.49
Bm2	na	na	na	na	na	0.1	na

na Information not available

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm)					Texture
					2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
Ac	82	16	2	LS	na	na	na	na	na	na
Bm	72	20	8	SL	na	na	na	na	na	na
Bm2	95	1	4	S	na	na	na	na	na	na
Plot 2										
Ac	85	14	1	LS	na	na	na	na	na	na
Bm	82	11	7	LS	0	6	66	14	14	
Bm2	95	2	3	S	1	11	52	24	12	
Plot 3										
Ae	79	19	2	LS	0	7	36	27	30	
Bm	na	na	na	na	na	na	na	na	Na	na
Bm2	96	1	3	S	1	15	67	11	6	

na Information not available

Site Number #15 - Undisturbed - (Macyk's site)

Site Parameters

Site Location	off Highway 63
Exact Location	0.9 km from suncor exit on left side of Highway 63 heading north, road into bush
Slope Class	2% with microtopographic variation
Position	level in natural ecosystem
Stoniness	0%
Drainage	rapidly drained
Erosion	0
Average Topsoil Depth	Ae -12 cm
Soil Subgroup	Eluviated Eutric Bruinsol

Vegetation Parameters

Overstory	**Understory**
Jack pine *(Pinus banksiana)* 12-15 m Trembling aspen *(Populus tremuloides)* 7-8 m	Grasses *(Poaceae)* Kinnickinnick *(Arctostaphylos uva-ursi)* Trembling aspen *(Populus tremuloides)* seedlings Blueberry *(Vaccinium* sp.*)* Solomon's seal *(Smilacina racemosa)* Sarsaparilla *(Aralia nudicaulis)* Alder *(Alnus* sp.*)* <3m

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	6-0					
Ae	0-15	6/2 10YR	d	S	single grain	loose
Bm	15-100	5/6 10YR	m	S	single grain	loose
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	4-0					
Ae	0-20	6/2 10YR	d	S	single grain	loose
Bm	20-100	5/6 10YR	m	S	single grain	loose
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	7-0					
Ae	0-2	6/2 10YR	d	S	single grain	loose
Bm	2-100	5/6 10YR	m	S	single grain	loose

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
Ae	7.7	5.6	2.5	2.0	5.7	0.5	1.30
Bm	9.8	5.0	3.8	4.1	5.7	0.2	1.64
Plot 2							
Ae	6.7	5.1	3.2	2.3	4.4	0.5	1.28
Bm	9.3	7.4	3.7	2.8	6.4	0.2	1.44
Plot 3							
Bm	7.4	7.3	3.0	2.1	5.3	0.4	1.28

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm)					Texture
					2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
Ae	88	6	6	LS	2	21	60	5	12	LS
Bm	88	6	6	LS	4	26	50	11	9	LcS
Plot 2										
Ae	88	10	2	S	2	22	49	20	7	S
Bm	90	5	5	S	2	27	56	7	8	S
Plot 3										
Bm	93	3	4	S	0	12	68	8	12	S

Site Number #16 - Undisturbed

Site Parameters

Site Location	Syncrude S-Pit
Exact Location	Site was GPSed
Slope Class	2-3% with microtopographic variation
Position	level in natural ecosystem
Stoniness	0%
Drainage	Rapidly drained
Erosion	0
Average Topsoil Depth	Ae -10 cm
Soil Subgroup	Eluviated Eutric Bruinsol

Vegetation Parameters

Overstory	**Understory**
Jack pine *(Pinus banksiana)* (one) 17 m	Green alder *(Alnus* sp.*)*
White spruce *(Picea glauca)* 8-12 m	Prickly rose *(Rosa acicularis)*
Trembling aspen *(Populus tremuloides)* 8-10 m	Bog cranberry *(Vaccinium oxycoccos)*
	Bunchberry *(Cornus canadensis)*
	Saskatoon *(Amelanchier alnifolia)*
	Sarsaparilla *(Aralia nudicaulis)*

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	4-0					
Ae	0-10	5/4 7.5YR	d	cS	single grain	loose
Bm	10-100	6/4 10YR	d/m	cS	single grain	loose
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	4-0					
Ae	0-10	5/4 7.5YR	d	cS	single grain	loose
Bm	10-100	4/6 7.5YR	d/m	cS	single grain	loose
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
LFH	4-0					
Ae	0-10	5/4 7.5YR	d	cS	single grain	loose
Bm	10-100	5/6 10YR	d/m	cS	single grain	loose

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
Ac	13.4	9.4	3.9	7.4	5.9	1.2	1.10
Bm	6.3	na	2.4	2.1	4.1	0.2	1.33
Plot 2							
Ac	4.9	4.1	3.0	2.1	2.8	0.4	1.08
Bm	4.4	2.5	2.0	1.6	2.8	0.3	1.38
Plot 3							
Ae	7.9	7.7	3.6	4.0	3.8	0.9	1.34
Bm	4.9	2.9	2.9	1.6	3.4	0.3	1.50

na Information not available

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm)					Texture
					2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
Ac	95	3	2	S	2	28	60	4	6	cS
Bm	94	4	2	S	2	30	58	6	4	cS
Plot 2										
Ac	95	4	1	S	2	33	56	4	5	cS
Bm	95	3	2	S	2	30	61	5	2	cS
Plot 3										
Ae	80	15	5	LS	4	33	55	5	3	LcS
Bm	93	5	2	S	3	30	57	3	7	cS

Site Number # 17 - Syncrude - Reclaimed

Site Parameters

Site Location	South west Mildred Lake Settling Basin
Exact Location	Site was GPSed
Slope Class	2-3%
Position	Level
Stoniness	0-1 %
Drainage	Moderately Well
Erosion	None
Average Topsoil Depth	> 100 cm of peat

Vegetation Parameters

Overstory	**Understory**
Larch *(Larix laricina)*- recently planted seedlings	Grasses*(Poaceae)*
White spruce *(Picea glauca)* - recently planted seedlings	Common dandelion *(Taraxacum officinale)*
	Fireweed *(Epilobium angustifolium)*
	Very sparse willow *(Salix* sp.*)*

Comments

Reclaimed in 1992, 150 cm topsoil (peat:mineral mix) over tailings sand
1996-Planted to white spruce *(Picea glauca)* and larch *(Larix laricina)*
Water infiltrated freely in Plots 1 and 2, Plot 3 ponded
More than 100 cm peat as topsoil

Plots

Plot 1

Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-100	2/310YR	m	pt	granular	friable

Plot 2

Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-100	2/310YR	m	pt	granular	friable

Plot 3

Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-100	2/310YR	m	pt	granular	friable

Physical Characteristics

Horizon (depth)	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
0-20 cm	113.7	94.9	75.3	68.1	45.6	20.6	0.40
20-50 cm	103.0	79.3	70.0	56.5	46.4	19.1	0.40
50-100cm	149.9	109.1	96.0	75.7	74.2	21.4	0.40
Plot 2							
0-20 cm	47.9	38.8	33.6	25.8	22.1	14.6	0.45
20-50 cm	64.4	49.6	44.6	33.0	31.3	11.3	0.45
50-100cm	59.9	40.0	34.4	28.6	31.2	17.3	0.45
Plot 3							
0-20 cm	55.0	33.1	31.0	25.3	29.7	9.5	0.90
20-50 cm	52.3	37.1	32.1	24.0	28.3	9.4	0.90
50-100cm	42.9	26.9	23.9	27.6	15.3	7.4	0.90

Horizon	%	%	%	Textural	Sand Fraction (mm)					Texture
(depth)	Sand	Silt	Clay	Class	2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
0-20 cm	87	7	6	LS	1	14	45	34	6	LS
20-50 cm	84	10	6	LS	1	18	63	8	10	LS
50-100cm	76	14	10	SL	1	22	57	13	7	SL
Plot 2										
0-20 cm	91	5	4	S	0	9	53	13	25	S
20-50 cm	92	4	4	S	0	9	56	21	14	S
50-100cm	84	9	7	LS	1	11	51	24	13	LS
Plot 3										
0-20 cm	67	22	11	SL	3	21	31	29	16	SL
20-50 cm	72	17	11	SL	3	29	30	19	19	cSL
50-100cm	71	19	10	SL	3	29	32	22	14	cSL

Site Number # 18 - Syncrude - Reclaimed

Site Parameters

Site Location	South east of Mildred Lake Settling Basin
Exact Location	Left hand side of east exit to highway 63, Site was GPSed
Slope Class	1-5 %
Position	Mid slope
Stoniness	0 %
Drainage	Well
Erosion	None
Average Topsoil Depth	11 cm

Vegetation Parameters

Overstory	**Understory**
Trembling aspen *(Populus tremuloides)*	Grasses *(Poaceae)*
Willow *(Salix* sp.*)* <5% cover	Common dandelion *(Taraxacum officinale)*
	Fireweed *(Epilobium angustifolium)*
	White sweet clover *(Melilotus alba)*
	Alfalfa *(Medicago* sp.*)*
	Red raspberry *(Rubus idaeus)*

Comments
Reclaimed in 1993, 8 cm topsoil (peat:mineral mix) over burrow pit sand
Temporary reclamation

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-10	3/310YR	d	pt	granular	friable
US	10-100	4/310YR	m	S	single grain	loose
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-8	3/310YR	d	pt	granular	friable
US	8-100	4/310YR	m	S	single grain	loose
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
TS	0-15	3/310YR	d	pt	granular	friable
US	15-100	4/310YR	m	S	single grain	loose

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
TS	144.0	na	97.4	71.2	72.8	13.4	0.18
US	7.2	na	4.4	2.5	4.6	1.4	1.50
Plot 2							
TS	208.5	na	139.2	132.6	75.9	38.8	0.20
US	6.6	na	na	2.8	3.7	3.2	1.44
Plot 3							
TS	165.6	na	123.2	98.9	66.7	31.9	0.14
US	9.9	na	na	3.5	6.4	2.3	1.30

na Information not available

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm)					Texture
					2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
TS	58	23	19	SL	1	9	18	38	34	vfSL
US	94	3	3	S	1	23	46	18	12	S
Plot 2										
TS	56	20	24	SCL	na	na	na	na	na	SCL
US	94	3	3	S	1	15	46	26	12	S
Plot 3										
TS	52	20	28	SCL	2	2	40	27	29	SCL
US	91	6	3	S	2	20	45	12	21	S

Site Number # 19 - Syncrude - Reclaimed

Site Parameters

Site Location	South east corner of Mildred Lake Settling Basin
Exact Location	Adjacent to erosion study, Site was GPSed
Slope Class	24-30 %
Position	Upper slope on 1st berm up from main haul road, access from above
Stoniness	0 %
Drainage	Well
Erosion	Slight
Average Topsoil Depth	42 cm

Vegetation Parameters

Overstory	**Understory**
Caragana (*Caragana arborescens*) 1.5-2 m	Grasses *(Poaceae)*
White spruce *(Picea glauca)* - 40 cm	Saskatoon *(Amelanchier alnifolia)*
	Alfalfa *(Medicago* sp.*)*
	Common dandelion *(Taraxacum officinale)*

Comments
Reclaimed in 1980, 23 cm topsoil (peat:mineral mix) over 15 cm of clay over tailings sand
1980-Planted to caragana (*Caragana arborescens*)) and saskatoon *(Amelanchier alnifolia)*
Water infiltrated freely in Plots 1 and 2, Plot 3 ponded

Plots

Plot 1	Highest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
OL	0-25	6/310YR	d	fS	single grain	loose - TSS
TS	25-55	3/210YR	m	ptSL	granular	friable
US	55-100	6/310YR	m	fS	single grain	loose - TSS
Plot 2						
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
OL	0-10	6/310YR	d	fS	single grain	loose - TSS
TS	10-55	3/210YR	m	ptSL	granular	friable
US	55-100	6/310YR	m	fS	single grain	loose - TSS
Plot 3	Lowest on slope					
Horizon	Depth (cm)	Color	dry / moist	Texture	Structure	Consistence
OL	0-8	6/310YR	d	fS	single grain	loose - TSS
TS	8-60	3/210YR	m	ptSL	granular	friable
US	60-100	6/310YR	m	fS	single grain	loose - TSS

Physical Characteristics

Horizon	-0.01 MPa (g /g*100)	-0.33 MPa (g /g*100)	-0.1 MPa (g /g*100)	-1.5 MPa (g /g*100)	AWHC % (wt)	% OC	Bulk Density (Mg/m^3)
Plot 1							
OL	na	3.5	1.8	1.6	na	0.5	1.30
TS	28.4	na	na	12.6	15.8	5.6	1.07
US	7.3	na	na	0.7	6.6	0.4	1.32
Plot 2							
OL	9.3	na	4.1	1.7	7.6	0.6	1.21
TS	28.2	na	17.3	10.2	18.0	4.2	1.05
US	8.2	na	na	1.5	6.7	0.5	1.32
Plot 3							
OL	19.5	na	8.5	3.5	16.0	1.7	1.24
TS	24.3	15.8	11.2	11.2	13.2	2.8	1.10
US	10.3	3.2	na	1.4	8.9	0.4	1.32

na Information not available

Horizon	% Sand	% Silt	% Clay	Textural Class	Sand Fraction (mm)					Texture
					2.0-1.0	1.0-0.50	0.50-0.25	0.25-0.10	0.10-0.05	
Plot 1										
OL	88	10	2	S	0	1	7	32	60	vfS
TS	82	10	8	LS	3	25	34	20	18	LS
US	94	5	1	S	0	1	8	29	62	vfS
Plot 2										
OL	90	9	1	S	0	1	12	20	67	vfS
TS	86	7	7	LS	2	23	38	18	19	LS
US	93	5	2	S	0	2	11	28	59	vfS
Plot 3										
OL	74	23	3	LS	0	1	5	25	69	LvfS
TS	79	11	10	SL	2	19	36	23	20	SL
US	96	3	1	S	0	1	4	42	53	vfS

8.2 Appendix 2 - Statistics for Chapter 3

Linear Regression Summaries

Linear Regression of LS

```
Y = A + B * X
Param   Value   sd
A       5.26175 0.92416
B       0.2943  0.07426
R  = 0.85064
SD = 0.73901, N = 8
P = 0.00742
```

```
Independent t-Test on Data1 col(FCinsitu) and col(Lab0.01)
          mean     variance N
-----------------------------------------
FCinsitu 11.9375 14.14839         8
Lab0.01 11.23333          8.18941 18
-----------------------------------------
t = -0.52596
p = 0.60374
At the 0.05 level The two means are
not significantly different
```

```
Independent t-Test on Data1 col(FCinsitu) and col(Lab0.033)
          mean     variance N
-----------------------------------------
FCinsitu 11.9375 14.14839         8
Lab0.033          6.68333 5.31088 18
-----------------------------------------
t = -4.40252
p = 0.00019
At the 0.05 level The two means are
significantly different
```

Linear Regression of PtLS

```
Y = A + B * X
Param   Value   sd
A       22.11053        4.89483
B       0.31821 0.08899
R  = 0.78431
SD = 9.94839, N = 10
P = 0.00723
```

```
Independent t-Test on Data1 col(FCinsitu) and col(Lab0.01)
          mean     variance N
-----------------------------------------
A         42.14    1388.66044      10
B         48.6     924.435 13
```

```
----------------------------------------
t = 0.45822
p = 0.6515
At the 0.05 level The two means are
not significantly different

Independent t-Test on Data1 col(FCinsitu) and col(Lab0.033)
          mean     variance N
----------------------------------------
A         42.14    1388.66044       10
C         47.46667         621.48   9
----------------------------------------
t = 0.36164
p = 0.72207
At the 0.05 level The two means are
not significantly different
```

Linear Regression of PtSL

```
Y = A + B * X
Param    Value    sd
A        19.60651         3.85918
B        0.34318 0.07288
SD = 9.49155, N = 19
R  = 0.75237
P = 0.0002

Independent t-Test on Data1 col((FCinsitu) and col(Lab0.01)
          mean     variance N
----------------------------------------
A         43.72105          942.41953      19
B         39.29565          279.30498      23
----------------------------------------
t = -0.5939
p = 0.55592
At the 0.05 level The two means are
not significantly different

Independent t-Test on Data1 col(FCinsitu) and col(Lab0.033)
          mean     variance N
----------------------------------------
A         43.72105          942.41953      19
C         28.28261          178.17605      23
----------------------------------------
t = -2.17946
p = 0.03524
At the 0.05 level The two means are
significantly different
```

Linear Regression of S

```
Y = A + B * X
Param    Value    sd
```

```
A        1.72783 1.02086
B        0.46652 0.12585
SD = 1.06497, N = 16
R  = 0.70382
P = 0.00234

Independent t-Test on Data1 col(InsituFC) and col(Lab.0.01)
         mean     variance N
---------------------------------------
InsituFC7.83125 4.77429 16
Lab.0.01          7.15667 6.27426 30
---------------------------------------
t = -0.90773
p = 0.36897
At the 0.05 level The two means are
not significantly different

Independent t-Test on Data1 col(InsituFC) and col(Lab.0.033)
         mean     variance N
---------------------------------------
InsituFC7.83125 4.77429 16
Lab.0.033         4.47241 4.38564 29
---------------------------------------
t = -5.0724
p = 7.9828E-6
At the 0.05 level The two means are
significantly different
```

Linear Regression of SL

```
Y = A + B * X
Param   Value    sd
A       11.073   3.1177
B       0.39334 0.21894
SD = 1.05289, N = 3
R  = 0.87376
P = 0.32335

Independent t-Test on Data1 col(InsituFC) and col(Lab.0.01)
         mean     variance N
---------------------------------------
InsituFC13.96667          11.56333          3
Lab.0.01          17.04     13.843   5
---------------------------------------
t = 1.16347
p = 0.28881
At the 0.05 level The two means are
not significantly different

Independent t-Test on Data1 col(InsituFC) and col(Lab.0.033)
         mean     variance N
---------------------------------------
InsituFC13.96667          11.56333          3
```

```
Lab.0.033          10.62    5.197    5
----------------------------------------
t = -1.69389
p = 0.14123
At the 0.05 level The two means are
not significantly different
```

Linear Regression of TSS

```
Y = A + B * X
Param   Value   sd
A       2.35068 0.22674
B       0.07028 0.0194
SD = 0.26272, N = 8
R  = 0.82841
P = 0.01106
```

```
Independent t-Test on Data1 col(FCInSitu) and col(FC.0.01Lab)
           mean     variance N
----------------------------------------
FCInSitu          10.6625 26.20268          8
FC.0.01Lab        5.9871  5.88849 31
----------------------------------------
t = -3.77936
p = 0.00056
At the 0.05 level The two means are
significantly different
```

```
Independent t-Test on Data1 col(FCInSitu) and col(FC.0.033Lab)
           mean     variance N
----------------------------------------
FCInSitu          10.6625 26.20268          8
FC.0.033Lab       2.95185 0.74644 27
----------------------------------------
t = -7.72643
p = 6.7169E-9
At the 0.05 level The two means are
significantly different
```

8.3 Appendix 3 - Statistics for Chapter 4

Statistics for Table 4.4

Linear Regressions for In Situ Gravimetric Values

```
Linear Regression for Data1_A.0.01MPa:
Y = A + B * X
Param  Value   sd
A      13.64041     6.80832
B      4.58231      0.82414
SD = 14.99552, N = 7
R  = 0.92778
P = 0.00259
```

```
Linear Regression for Data1_A.1.5MPa:
Y = A + B * X
Param  Value   sd
A      4.41363      3.7976
B      2.74983      0.4597
SD = 8.36432, N = 7
R  = 0.9367
P = 0.00187
```

```
Linear Regression for Data1_AWHC:
Y = A + B * X
Param  Value   sd
A      9.27226      3.10803
B      1.82566      0.37622
SD = 6.84552, N = 7
R  = 0.90821
P = 0.00466
```

Linear Regressions for In Situ Volumetric Values

```
Linear Regression for Data1_A.0.01MPa:
Y = A + B * X
Param  Value   sd
A      20.06761     5.77489
B      0.42218      0.69905
SD = 12.71936, N = 7
R  = 0.26075
P = 0.57223
```

```
Linear Regression for Data1_A.1.5MPa:
Y = A + B * X
Param  Value   sd
A       6.26911        2.44397
B       0.49364        0.29584
SD = 5.38291, N = 7
R  = 0.59806
P = 0.15607

Linear Regression for Data1_AWHC:
Y = A + B * X
Param  Value   sd
A       12.13694       2.35497
B       0.0325 0.28507
SD = 5.18688, N = 7
R  = 0.05092
P = 0.91366
```

Linear Regressions for Laboratory Peat:mineral Mixes Gravimetric Values

```
Linear Regression for Data1_A.0.01MPA:
Y = A + B * X
Param  Value   sd
A       7.59352        1.97201
B       5.71078        0.65224
SD = 4.62523, N = 12
R  = 0.94054
P = 5.2965E-6

Linear Regression for Data1_A.1.5MPa:
Y = A + B * X
Param  Value   sd
A       2.70417        1.33893
B       2.92322        0.44285
SD = 3.14039, N = 12
R  = 0.90185
P = 0.00006

Linear Regression for Data1_AWHC:
Y = A + B * X
Param  Value   sd
A       4.88895        1.27501
B       2.78774        0.42171
```

```
SD = 2.99047, N = 12
R  = 0.9021
P = 0.00006
```

Linear Regressions for Laboratory Peat:mineral Mixes Volumetric Values

```
Linear Regression for Data1_A.0.01MPa:
Y = A + B * X
Param  Value   sd
A      12.10884     2.13597
B      2.46628      0.69771
SD = 3.98896, N = 7
R  = 0.84511
P = 0.01665
```

```
Linear Regression for Data1_A.1.5MPa:
Y = A + B * X
Param  Value   sd
A      4.96692      1.43506
B      1.34207      0.46876
SD = 2.68, N = 7
R  = 0.78811
P = 0.03528
```

```
Linear Regression for Data1_B:
Y = A + B * X
Param  Value   sd
A      7.17434      1.68837
B      1.12514      0.5515
SD = 3.15306, N = 7
R  = 0.674
P = 0.09685
```

Statistics for Table 4.5

Linear Regressions for Sand

```
Linear Regression for Data1_A.0.01MPa:
Y = A + B * X
Param  Value   sd
A      1.69   6.10266
B      0.3996 0.13048
SD = 7.29407, N = 4
R  = 0.90788
```

```
P = 0.09212

Linear Regression for Data1_A.1.5MPa:
Y = A + B * X
Param  Value  sd
A      0.15   4.28722
B      0.222  0.09166
SD = 5.12421, N = 4
R  = 0.86355
P = 0.13645

Linear Regression for Data1_AWHC:
Y = A + B * X
Param  Value  sd
A      1.5    1.95096
B      0.178  0.04171
SD = 2.33184, N = 4
R  = 0.94923
P = 0.05077
```

Linear Regressions for Sandy loam

```
Linear Regression for Data1_A.0.01MPa:
Y = A + B * X
Param  Value  sd
A      5.64   5.1273
B      0.3776 0.10963
SD = 6.1283, N = 4
R  = 0.92506
P = 0.07494

Linear Regression for Data1_A.1.5MPa:
Y = A + B * X
Param  Value  sd
A      0.23   3.87596
B      0.2012 0.08287
SD = 4.63266, N = 4
R  = 0.86409
P = 0.13591

Linear Regression for Data1_AWHC:
Y = A + B * X
Param  Value  sd
A      5.43   1.58943
B      0.1752 0.03398
```

```
SD = 1.89974, N = 4
R  = 0.96437
P = 0.03563
```

Linear Regressions for Loamy sand

```
Linear Regression for Data1_A.0.01MPa:
Y = A + B * X
Param  Value   sd
A      8.21    2.77028
B      0.4324  0.05923
SD = 3.31112, N = 4
R  = 0.98175
P = 0.01825
```

```
Linear Regression for Data1_A.1.5MPa:
Y = A + B * X
Param  Value   sd
A      4.91    3.25906
B      0.1724  0.06968
SD = 3.89532, N = 4
R  = 0.86818
P = 0.13182
```

```
Linear Regression for Data1_AWHC:
Y = A + B * X
Param  Value   sd
A      3.35    0.93354
B      0.26    0.01996
SD = 1.1158, N = 4
R  = 0.99416
P = 0.00584
```

Statistics for Table 4.6

Regression of S AWHC against % OC and PSA Classes

```
Model: MODEL1
Dependent Variable: AWHC

                    Analysis of Variance

                     Sum of        Mean
Source        DF    Squares      Square    F Value    Prob>F

Model          4   39.92926     9.98232      1.819    0.1716
Error         17   93.27437     5.48673
```

```
    C Total       21   133.20364

       Root MSE      2.34238   R-square     0.2998
       Dep Mean      6.92727   Adj R-sq     0.1350
       C.V.         33.81383

                      Parameter Estimates

                 Parameter     Standard   T for H0:
    Variable  DF    Estimate        Error  Parameter=0   Prob > |T|

    INTERCEP   1      -21726  9886.0729068       -2.198      0.0421
    OC         1   -0.639333    1.56047380       -0.410      0.6871
    CLAY       1  217.793428   98.97368503        2.201      0.0419
    SILT       1  217.294857   98.86536556        2.198      0.0421
    SAND       1  217.324019   98.85547831        2.198      0.0421

Model: MODEL2
Dependent Variable: AWHC

                      Analysis of Variance

                         Sum of        Mean
    Source        DF      Squares       Square     F Value      Prob>F

    Model          3     39.00828     13.00276       2.485      0.0936
    Error         18     94.19536      5.23308
    C Total       21    133.20364

       Root MSE      2.28759   R-square     0.2928
       Dep Mean      6.92727   Adj R-sq     0.1750
       C.V.         33.02298

                      Parameter Estimates

                 Parameter     Standard   T for H0:
    Variable  DF    Estimate        Error  Parameter=0   Prob > |T|

    INTERCEP   1      -23121  9064.6769567       -2.551      0.0201
    CLAY       1  231.794510   90.71429053        2.555      0.0199
    SILT       1  231.248377   90.64324633        2.551      0.0200
    SAND       1  231.262588   90.64603156        2.551      0.0200
```

Regression of LS AWHC against % OC and PSA Classes

```
Model: MODEL1
Dependent Variable: AWHC

                      Analysis of Variance

                         Sum of        Mean
    Source        DF      Squares       Square     F Value      Prob>F

    Model          4    141.80091     35.45023      50.698      0.0001
    Error         10      6.99242      0.69924
    C Total       14    148.79333

       Root MSE      0.83621   R-square     0.9530
       Dep Mean     10.56667   Adj R-sq     0.9342
       C.V.          7.91363

                      Parameter Estimates

                 Parameter     Standard   T for H0:
    Variable  DF    Estimate        Error  Parameter=0   Prob > |T|

    INTERCEP   1   -0.973255    1.81186257       -0.537      0.6029
    OC         1    0.629139    1.16079253        0.542      0.5997
```

```
        CLAY    1    1.386298  0.10088868     13.741     0.0001
        SILT    1   0.122870  0.11170240     1.100    0.2971
        SAND    1    0.007460  0.07849686     0.095     0.9262

Model: MODEL2
Dependent Variable: AWHC

                    Analysis of Variance

                       Sum of        Mean
        Source      DF    Squares      Square    F Value     Prob>F

        Model        3   141.79459    47.26486    74.287     0.0001
        Error       11    6.99874    0.63625
        C Total     14   148.79333

          Root MSE     0.79765    R-square      0.9530
          Dep Mean    10.56667    Adj R-sq      0.9401
          C.V.      7.54876

                    Parameter Estimates

                Parameter     Standard   T for H0:
       Variable DF   Estimate        Error  Parameter=0   Prob > |T|

       INTERCEP  1   -0.834887  1.02876547     -0.812     0.4343
       OC        1   0.637417  1.10415075     0.577     0.5754
       CLAY       1    1.385187  0.09558925     14.491     0.0001
       SILT      1   0.115749  0.07902190     1.465     0.1710


Model: MODEL3
Dependent Variable: AWHC

                    Analysis of Variance

                       Sum of        Mean
        Source      DF    Squares      Square    F Value     Prob>F

        Model        2   141.58255    70.79128    117.809     0.0001
        Error       12    7.21078    0.60090
        C Total     14   148.79333

          Root MSE     0.77518    R-square      0.9515
          Dep Mean    10.56667    Adj R-sq      0.9435
          C.V.      7.33605

                    Parameter Estimates

                Parameter     Standard   T for H0:
       Variable DF   Estimate        Error  Parameter=0   Prob > |T|

       INTERCEP  1   -0.451705  0.76384462     -0.591     0.5653
       CLAY       1    1.380150  0.09250796     14.919     0.0001
       SILT      1   0.098536  0.07111869     1.386     0.1911
Model: MODEL4
Dependent Variable: AWHC

                    Analysis of Variance

                       Sum of        Mean
        Source      DF    Squares      Square    F Value     Prob>F

        Model        1   140.42904   140.42904    218.258     0.0001
        Error       13    8.36429    0.64341
        C Total     14   148.79333
```

```
    Root MSE       0.80213     R-square      0.9438
    Dep Mean      10.56667     Adj R-sq      0.9395
    C.V.         7.59110

                  Parameter Estimates

           Parameter      Standard    T for H0:
Variable  DF   Estimate        Error  Parameter=0  Prob > |T|

INTERCEP   1   -0.130468  0.75310983       -0.173      0.8651
CLAY       1    1.398928  0.09469123       14.774      0.0001
```

Regression of TAILINGS AWHC against % OC and PSA Classes

```
Model: MODEL1
Dependent Variable: AWHC

                 Analysis of Variance

                   Sum of       Mean
      Source     DF    Squares       Square    F Value    Prob>F

      Model       4   123.99899   30.99975     8.278     0.0003
      Error      22   82.38620    3.74483
      C Total    26   206.38519

        Root MSE      1.93516    R-square     0.6008
        Dep Mean      6.44074    Adj R-sq     0.5282
        C.V.       30.04554

                 Parameter Estimates

             Parameter     Standard    T for H0:
    Variable  DF    Estimate        Error   Parameter=0    Prob > |T|

    INTERCEP  1      -15623  8727.5662246     -1.790      0.0872
    OC        1    9.234304   2.31328070     3.992      0.0006
    CLAY      1  154.610527  87.37391931      1.770      0.0907
    SILT      1  157.317058  87.34783163     1.801      0.0854
    SAND      1   156.244483  87.27608314      1.790      0.0872

Model: MODEL2
Dependent Variable: AWHC

                 Analysis of Variance

                   Sum of       Mean
      Source     DF    Squares       Square    F Value    Prob>F

      Model       3   112.27308   37.42436     9.146     0.0004
      Error      23   94.11210    4.09183
      C Total    26   206.38519

        Root MSE      2.02283    R-square     0.5440
        Dep Mean      6.44074    Adj R-sq     0.4845
        C.V.       31.40675

                 Parameter Estimates

             Parameter     Standard    T for H0:
    Variable  DF    Estimate        Error   Parameter=0    Prob > |T|

    INTERCEP  1  -179.489127  75.03080347     -2.392      0.0253
    OC        1   10.244301   2.34332214     4.372     0.0002
    SILT      1    2.765334   1.16768928     2.368     0.0267
    SAND      1     1.812298   0.74998050      2.416     0.0240
```

Regression of PtLS AWHC against % OC and PSA Classes

```
Model: MODEL1
Dependent Variable: AWHC

                        Analysis of Variance

                        Sum of        Mean
        Source     DF   Squares       Square     F Value     Prob>F

        Model       4   145.44590    36.36148     1.837      0.2265
        Error       7   138.54326    19.79189
        C Total    11   283.98917

          Root MSE     4.44881    R-square     0.5122
          Dep Mean    14.49167    Adj R-sq     0.2334
          C.V.        30.69908

                        Parameter Estimates

                  Parameter       Standard     T for H0:
      Variable DF   Estimate         Error    Parameter=0   Prob > |T|

      INTERCEP  1      -43029  34080.504258      -1.263      0.2472
      OC        1   -0.022249    0.31110468      -0.072      0.9450
      CLAY      1  430.839093  340.95879325       1.264      0.2468
      SILT      1  430.946483  340.47568400       1.266      0.2461
      SAND      1  430.346790  340.84678040       1.263      0.2472

Model: MODEL2
Dependent Variable: AWHC

                        Analysis of Variance

                        Sum of        Mean
        Source     DF   Squares       Square     F Value     Prob>F

        Model       3   145.34468    48.44823     2.796      0.1089
        Error       8   138.64449    17.33056
        C Total    11   283.98917

          Root MSE     4.16300    R-square     0.5118
          Dep Mean    14.49167    Adj R-sq     0.3287
          C.V.        28.72685

                        Parameter Estimates

                  Parameter       Standard     T for H0:
      Variable DF   Estimate         Error    Parameter=0   Prob > |T|

      INTERCEP  1      -41530  25138.985202      -1.652      0.1371
      CLAY      1  415.840440  251.55531801       1.653      0.1369
      SILT      1  415.960633  251.11260046       1.656      0.1362
      SAND      1  415.346104  251.40159021       1.652      0.1371

Model: MODEL3
Dependent Variable: AWHC

                        Analysis of Variance

                        Sum of        Mean
        Source     DF   Squares       Square     F Value     Prob>F

        Model       2    98.04079    49.02040     2.373      0.1487
        Error       9   185.94838    20.66093
        C Total    11   283.98917
```

```
    Root MSE       4.54543     R-square       0.3452
    Dep Mean      14.49167     Adj R-sq       0.1997
    C.V.          31.36582

                    Parameter Estimates

               Parameter      Standard    T for H0:
Variable  DF    Estimate         Error   Parameter=0    Prob > |T|

INTERCEP   1    2.923866    6.95350009         0.420        0.6840
CLAY       1    0.242704    0.92265347         0.263        0.7984
SILT       1    1.092794    0.54468361         2.006        0.0758
```

```
Model: MODEL4
Dependent Variable: AWHC

                    Analysis of Variance

                     Sum of         Mean
Source       DF     Squares       Square      F Value       Prob>F

Model         1    96.61115     96.61115        5.156       0.0465
Error        10   187.37801     18.73780
C Total      11   283.98917

    Root MSE       4.32872     R-square       0.3402
    Dep Mean      14.49167     Adj R-sq       0.2742
    C.V.          29.87040

                    Parameter Estimates

               Parameter      Standard    T for H0:
Variable  DF    Estimate         Error   Parameter=0    Prob > |T|

INTERCEP   1    4.213553    4.69578126         0.897        0.3906
SILT       1    1.132263    0.49864657         2.271        0.0465
```

Regression of PTSL AWHC against % OC and PSA Classes

```
Model: MODEL1
Dependent Variable: AWHC

                    Analysis of Variance

                     Sum of         Mean
Source       DF     Squares       Square      F Value       Prob>F

Model         4   211.26871     52.81718        2.284       0.1083
Error        15   346.81329     23.12089
C Total      19   558.08200

    Root MSE       4.80842     R-square       0.3786
    Dep Mean      17.97000     Adj R-sq       0.2128
    C.V.          26.75803

                    Parameter Estimates

               Parameter      Standard    T for H0:
Variable  DF    Estimate         Error   Parameter=0    Prob > |T|

INTERCEP   1      -43639  18664.057463        -2.338        0.0336
OC         1    0.321050    0.42622127         0.753        0.4630
CLAY       1  437.082659  186.56545931         2.343        0.0333
SILT       1  436.453708  186.61312844         2.339        0.0336
SAND       1  436.489699  186.65498769         2.338        0.0336
```

```
Model: MODEL2
Dependent Variable: AWHC

                        Analysis of Variance

                         Sum of       Mean
        Source      DF   Squares      Square     F Value    Prob>F

        Model        3  198.15031    66.05010     2.936     0.0651
        Error       16  359.93169    22.49573
        C Total     19  558.08200

          Root MSE      4.74297   R-square     0.3551
          Dep Mean     17.97000   Adj R-sq     0.2341
          C.V.        26.39380

                        Parameter Estimates

                  Parameter     Standard    T for H0:
       Variable DF    Estimate        Error   Parameter=0   Prob > |T|

       INTERCEP  1      -42226 18316.735155      -2.305      0.0349
       CLAY      1  423.049868 183.10616100       2.310      0.0345
       SILT      1  422.390261 183.14938520       2.306      0.0348
       SAND      1  422.352533 183.18115228       2.306      0.0349
```

8.4 Appendix 4 - Statistics for Chapter 5

```
                                  The SAS System
                    General Linear Models Procedure
                      Class Level Information

          Class   Levels   Vaiues
          TRT        6   Sunsand1 Sunsand3 Sunsl1 Sunsl3 Synsand1 Synsl1
          DEP        3   1 2 3
          REP        3   1 2 3

                Number of observations in data set = 54
NOTE: Due to missing values, only 53 observations can be used in this analysis.


                        The SAS System
                                    General Linear Models Procedure

Dependent Variable: TOTMOIST

Source              DF       Sum of Squares      Mean Square   F Value    Pr > F
Model               17     110714.24908805    6512.60288753     10.19    0.0001
Error              35      22370.59166667     639.15976190
Corrected Total       52      133084.84075472

R-Square             C.V.         Root MSE        TOTMOIST Mean
0.831907          10.60084      25.28160916        238.48679245


Source              DF          Type I SS      Mean Square   F Value     Pr > F
TRT                 5      48494.71644916   9698.94328983     15.17     0.0001
DEP                 2      50329.27472826  25164.63736413     39.37     0.0001
TRT*DEP               10      11890.25791063   1189.02579106      1.86     0.0857

Source              DF         Type III SS     Mean Square   F Value     Pr > F

TRT                 5      50900.72318428  10180.14463686     15.93     0.0001
DEP                 2      51549.68285088  25774.84142544     40.33     0.0001
TRT*DEP               10      11890.25791063   1189.02579106      1.86     0.0857
```

```
                  The SAS System
             General Linear Models Procedure
           Scheffe's test for variable: TOTMOIST
NOTE: This test controls the type I experimentwise error rate but generally
has a higher type II error rate than Tukey's for all pairwise comparisons.

    Alpha= 0.05  Confidence= 0.95  df= 35  MSE= 639.1598
           Critical Value of F= 2.48514

Comparisons significant at the 0.05 level are indicated by '***'.

                    Simultaneous          Simultaneous
                      Lower   Difference    Upper
       TRT          Confidence  Between  Confidence
    Comparison         Limit     Means      Limit

 Synsl1   - Synsand1    -21.26     22.05     65.35
 Synsl1   - Sunsl3     -17.87     24.14     66.16
 Synsl1   - Sunsl1       2.41     44.42     86.43  ***
 Synsl1   - Sunsand3     12.44     54.46     96.47  ***
 Synsl1   - Sunsand1     52.97     94.98    136.99  ***

 Synsand1 - Synsl1      -65.35    -22.05     21.26
 Synsand1 - Sunsl3      -41.20      2.10     45.40
 Synsand1 - Sunsl1      -20.93     22.38     65.68
 Synsand1 - Sunsand3     -10.89     32.41     75.71
 Synsand1 - Sunsand1      29.63     72.93    116.24  ***

 Sunsl3   - Synsl1     -66.16    -24.14     17.87
 Sunsl3   - Synsand1    -45.40     -2.10     41.20
 Sunsl3   - Sunsl1     -21.73     20.28     62.29
 Sunsl3   - Sunsand3    -11.70     30.31     72.32
 Sunsl3   - Sunsand1     28.82     70.83    112.84  ***

 Sunsl1   - Synsl1     -86.43    -44.42     -2.41  ***
 Sunsl1   - Synsand1    -65.68    -22.38     20.93
 Sunsl1   - Sunsl3     -62.29    -20.28     21.73
 Sunsl1   - Sunsand3    -31.98     10.03     52.04
 Sunsl1   - Sunsand1      8.54     50.56     92.57  ***

 Sunsand3 - Synsl1      -96.47    -54.46    -12.44  ***
 Sunsand3 - Synsand1     -75.71    -32.41     10.89
 Sunsand3 - Sunsl3      -72.32    -30.31     11.70
 Sunsand3 - Sunsl1      -52.04    -10.03     31.98
 Sunsand3 - Sunsand1      -1.49     40.52     82.53

 Sunsand1 - Synsl1     -136.99    -94.98    -52.97  ***
 Sunsand1 - Synsand1    -116.24    -72.93    -29.63  ***
 Sunsand1 - Sunsl3     -112.84    -70.83    -28.82  ***
 Sunsand1 - Sunsl1      -92.57    -50.56     -8.54  ***
 Sunsand1 - Sunsand3     -82.53    -40.52      1.49
```

```
                 The SAS System
             General Linear Models Procedure
            Scheffe's test for variable: TOTMOIST
NOTE: This test controls the type I experimentwise error rate but generally
 has a higher type II error rate than Tukey's for all pairwise comparisons.

    Alpha= 0.05  Confidence= 0.95  df= 35  MSE= 639.1598
          Critical Value of F= 3.26742

 Comparisons significant at the 0.05 level are indicated by '***'.

             Simultaneous         Simultaneous
               Lower   Difference    Upper
       DEP     Confidence  Between  Confidence
    Comparison     Limit    Means     Limit

    3  - 2     22.746    44.603    66.460  ***
    3  - 1     52.396    74.253    96.110  ***

    2  - 3    -66.460   -44.603   -22.746  ***
    2  - 1      8.107    29.650    51.193  ***

    1  - 3    -96.110   -74.253   -52.396  ***
    1  - 2    -51.193   -29.650    -8.107  ***


                The SAS System     16:06
             General Linear Models Procedure
               Least Squares Means

TRT         TOTMOIST  Pr > |T| H0: LSMEAN(i)=LSMEAN(j)
           LSMEAN  i/j   1     2     3     4     5     6

Sunsand1  183.855556  1  .     0.0017 0.0002 0.0001 0.0001 0.0001
Sunsand3  224.377778  2 0.0017  .     0.4056 0.0156 0.0028 0.0001
Sunsl1    234.411111  3 0.0002 0.4056  .     0.0977 0.0214 0.0007
Sunsl3    254.688889  4 0.0001 0.0156 0.0977  .     0.4439 0.0505
Synsand1  264.294444  5 0.0001 0.0028 0.0214 0.4439  .     0.2491
Synsl1    278.833333  6 0.0001 0.0001 0.0007 0.0505 0.2491  .

NOTE: To ensure overall protection level, only probabilities associated with pre-planned
   comparisons should be used.


    DEP    TOTMOIST  Pr > |T| H0: LSMEAN(i)=LSMEAN(j)
           LSMEAN  i/j   1     2     3

    1   204.600000  1  .     0.0012 0.0001
    2   234.250000  2 0.0012  .     0.0001
    3   281.380556  3 0.0001 0.0001  .

NOTE: To ensure overall protection level, only probabilities associated with pre-planned
   comparisons should be used.
```

8.5 Appendix 5 - Soil Moisture Distributions for Chapter 5

Average soil moisture for each depth and combination of mineral component, ratio and tailings sand.

Sand 1:1 Peat:min Mix
Over Suncor TSS

Depth (cm)	20 cm	35cm	50cm
0-5	25.4	20.4	18.6
5-10	25.4	20.4	18.6
10-15	23.2	20.5	22.9
15-20	22.8	21.4	22.9
20-25	16.8	22.3	21.3
25-30	5.1	20.7	21.9
30-35	5.4	17.8	22.7
35-40	5.4	9.2	24.3
40-45	6.8	11.4	23.8
45-50	6.8	13.7	16.3
50-60	11.1	23.3	16.1
60-70	18.1	26.2	22.8
70-80	27.3	31.2	28.7
80-90	30.7	36.8	30.0

Sand 3:1 Peat:min Mix
Over Suncor TSS

Depth (cm)	20 cm	35cm	50cm
0-5	25.6	41.8	30.1
5-10	26.6	41.8	30.1
10-15	27.4	44.8	32.0
15-20	28.0	43.4	32.0
20-25	19.7	41.4	32.6
25-30	5.8	42.5	32.0
30-35	5.9	13.8	33.9
35-40	5.9	7.9	27.7
40-45	7.2	10.6	16.3
45-50	7.2	11.4	20.9
50-60	10.8	15.2	28.7
60-70	16.3	19.8	34.3
70-80	24.2	32.7	35.3
80-90	30.3	30.1	37.4

SL 1:1 Peat:min Mix
Over Suncor TSS

Depth (cm)	20 cm	35cm	50cm
0-5	30.1	25.8	27.3
5-10	30.2	25.8	27.3
10-15	30.5	28.0	29.5
15-20	28.8	28.9	29.5
20-25	9.3	29.4	31.3
25-30	7.1	24.9	32.8
30-35	8.4	14.2	31.8
35-40	8.8	10.5	29.2
40-45	16.0	14.1	20.7
45-50	16.0	17.1	22.2
50-60	20.2	23.7	24.3
60-70	24.4	32.8	33.3
70-80	27.8	33.8	35.9
80-90	33.3	34.9	35.7

SL 3:1 Peat:min Mix
Over Suncor TSS

Depth (cm)	20 cm	35cm	50cm
0-5	30.9	32.4	33.3
5-10	30.1	32.4	33.6
10-15	30.9	31.6	35.1
15-20	35.3	32.8	45.1
20-25	12.8	33.2	47.1
25-30	7.7	30.4	38.0
30-35	8.1	8.8	38.0
35-40	9.0	11.2	33.0
40-45	13.0	16.2	25.5
45-50	13.0	17.9	21.1
50-60	20.8	24.7	18.0
60-70	29.5	31.1	32.1
70-80	34.3	33.5	35.8
80-90	34.2	33.4	35.1

Sand 1:1 Peat:min Mix
Over Syncrude TSS

Depth (cm)	20 cm	35cm	50cm
0-5	21.2	22.2	36.8
5-10	21.2	22.2	36.8
10-15	21.9	25.9	41.8
15-20	22.7	24.2	41.8
20-25	11.4	21.2	42.8
25-30	10.9	20.8	42.8
30-35	12.2	17.4	41.5
35-40	13.3	17.6	36.8
40-45	20.9	21.5	36.0
45-50	20.9	18.8	35.8
50-60	27.8	26.1	36.6
60-70	38.1	34.0	38.1
70-80	37.2	37.5	38.7
80-90	37.3	37.0	38.2

SL 1:1 Peat:min Mix
Over Syncrude TSS

Depth (cm)	20 cm	35cm	50cm
0-5	33.1	25.4	29.3
5-10	33.5	25.4	29.5
10-15	36.0	26.5	31.3
15-20	18.3	26.4	22.4
20-25	16.4	26.3	21.4
25-30	19.8	26.9	23.4
30-35	22.7	16.9	19.8
35-40	22.7	14.3	18.5
40-45	28.0	16.3	22.2
45-50	28.0	18.6	23.3
50-60	31.0	26.2	28.6
60-70	34.4	34.8	34.6
70-80	35.1	38.6	36.9
80-90	38.0	39.6	38.8