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2019 East Valley Centrifuge Cake Cell Soil Assessment

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1.0 INTRODUCTION

NorthWind Land Resources Inc. (NorthWind) was commissioned by Syncrude Canada Ltd. (Syncrude) to complete soil sampling and analysis for salinity and petroleum hydrocarbon (PHC) profiling and an assessment of moisture conditions within the East Valley Centrifuge Cake Cell (EV Cake Cell). Field activities were conducted from August 13 to 16, 2019 by NorthWind field personnel alongside Syncrude Environmental Research staff.

2.0 OBJECTIVE

Cake technology is one strategy for Syncrude to meet its fine tailings reduction targets. Syncrude's goal is to understand the land capability potential of centrifuged cake (cake) as a landform substrate and evaluate potential constituents of concern (*i.e.*, salinity, sodicity and PHCs). Cake production has been underway for several years and some of the first deposits have now been reclaimed. These reclamation areas provide an opportunity to conduct field investigations to test if Syncrude's initial theories, models, and small-scale studies related to cake reclamation are accurate and if the current reclamation practices used in these areas are appropriate (*e.g.*, optimal soil capping thickness, appropriate vegetation species for site moisture conditions). This investigation is a screening-level assessment to determine if there are indications that constituents such as salts, sodium and PHCs are migrating from the cake deposit into the overlying soil reclamation cover.

The specific objective of this sampling program was to collect soil samples of the soil reclamation cover and the surface of the cake deposit at predetermined inspection points along four transects. Analysis of soil samples focused on soil pH, salinity, sodicity and PHCs as previous assessments of cake materials by Syncrude have found these constituents to be elevated. Soil moisture was also measured, as soil-water content differences in the soil can be an indicator for the potential movement of these constituents (*e.g.*, diffusion). The soil analytical results characterizing the materials were used to assist with this investigation and will subsequently be added to Syncrude's database for future use. All detailed methods and results from the 2019 EV Cake Cell sampling program are included in this report along with basic capping depth and analytical data summaries.

3.0 BACKGROUND

3.1 FLOCCULATED, CENTRIFUGED FLUID FINE TAILINGS (CAKE)

Cake consists of fluid fine tailings materials with a polymer flocculent and gypsum addition, which is spun at high speeds in a centrifuge. The polymer and gypsum promote flocculation of the fine particles and separation of the pore water from the sediment, while the centrifuge facilitates the separation of the water and sediment. The collected cake material is then transported to cake cells where it undergoes further dewatering via surface evaporation and freeze/thaw processes. The slope of the containment cell collects the water that is released, which is then pumped out of the cell to help continue the dewatering process. As the cake continues to lose pore water from its mass, it settles over time. When dewatering of the cake cell has slowed and the deposit is trafficable for equipment (during winter when a sufficient frost layer is present), the area is deemed to be ready for reclamation and soil placement and revegetation follows.

3.2 SITE HISTORY

The EV Cake Cell is located on the W1 overburden (OB) disposal area (dump). It is a containment cell constructed of Clearwater Formation OB material that is sloped from north to south, with dimensions of approximately 1.5 km (east to west) and 0.3 to 0.6 km (north to south). A map of the area is presented in Appendix I. Clearwater Formation material is fine-textured (high silt and clay) and has a low hydraulic conductivity (Meiers et al. 2011). Three berms were also constructed with Clearwater Formation OB in the EV cake cell that tie into the north containment wall and run south. The lengths of the berms vary, but each covers at least half of the total length of the cell. The addition of the berms created 4 inner cells within the EV Cake Cell, and the investigation established transects within each of these inner cells.

Cake material was poured at the EV Cake Cell over a period of approximately 4 years beginning in 2012. Cake pouring was done from the north resulting in the deposit sloping from north to south. In the winter of 2017/2018 soil reclamation material was placed on the north half of the cell. In 2018 the area was then planted to a mix of white spruce, trembling aspen and balsam poplar at a density of 1,835 stems/ha. To date the south half of the EV Cake Cell remains unreclaimed.

3.3 SOIL RECLAMATION COVER

The soil reclamation cover design at the EV Cake Cell consists of a total soil reclamation capping thickness of 1.5 m. The design consists of two soil materials, a coversoil lift of 0.3 m overlying 1.2 m of subsoil. The coversoil is mainly peat or peat-mineral mix (PTMIX), except for the west inner cell which is upland surface soil (USS). PTMIX is peat with no, or a minimal proportion of, mineral soil captured during peat salvage, when over-salvaging of the peat includes some of the underlying mineral parent material. USS is the surface forest floor (LFH), A and potentially a portion of the B horizons of upland soils, as well as peat and underlying mineral horizon(s) of transitional soils with a peat depth up to 40 cm (*i.e.* the threshold between transitional and organic soils). The subsoil (MIN) of the EV Cake Cell consists of Pleistocene glacial deposits composed of varying proportions of PG2 and PG3 (Syncrude geologic facies nomenclature) till with PL2 glaciolacustrine clay. PG2 and PG3 describes material which is typically moderately fine to fine textured (L, SCL, CL, C), poorly sorted till deposits with varying amounts of coarse fragments. PL2 is used to describe finer textured (SiC, C, HC) pink to brownish or grayish pink, stratified glaciolacustrine deposits with occasional gravel and thin silt/sand lenses.

The surface topography of the reclamation area slopes from north to south approximately 0.5 to 2%, following the slope of the cake deposit.

3.4 SITE OBSERVATIONS

In 2018 site observations after soil placement noticed surface water ponding in depressions and saturated soil reclamation covers throughout the reclaimed area. Concerns were raised whether this was due to precipitation that was unable to drain from the reclamation area and/or potential pore water release from the cake deposit, resulting from loading of the cake deposit by the reclamation cover. Cake displacement was also evident along the south margin of the soil reclamation placement. Cracks in the soil reclamation placement area were found near the margin at several locations, with cake being pushed to the surface (Photo 1). There was also evidence that the cake deposit at the margin was being pushed away from the soil reclamation placement area (Photo 2), indicating the soil cap was loading the underlying cake deposit which was being released at the margin.

Photo 1. Crack near margin of soil placement area with cake (gray material) at the surface.

Photo 2. Post installed into overburden beneath cake deposit at margin of reclamation area showing movement of cake deposit away and downslope (south) from reclamation area. Cake is also elevated (forced-up) relative to cake deposit to the south.

In the winter of 2018/19 a drainage channel was constructed in the southwest corner of the cell to improve drainage of surface water accumulating in the south half of the cake deposit. Site visits in the spring of 2019 found the soil moisture conditions to be drier than in 2018, as there were less areas with water ponding and decreased soil moisture in the soil cover. However, the soil-water content of the soil cover remained near saturation in a large portion of the reclamation area.

After the site visits it was determined that a soil quality assessment would be worthwhile to potentially confirm the source of the additional soil-water and its impact on soil quality of the soil reclamation cover. Evidence of elevated salt, sodium and/or PHC in the reclamation cover would indicate the excess moisture is coming from pore water released from the cake which may affect the capability of the reclamation area to support vegetation. Conversely, if there was no (or minimal) elevated salt, sodium and/or PHCs in the reclamation cover it would indicate that the excess moisture is coming from freshwater inputs (*i.e.*, precipitation), which has a lesser risk of impacting the soil reclamation cover (*e.g.,* salinization) and vegetation re-establishment.

4.0 METHODS

4.1 SITE SELECTION

Prior to conducting field work, Syncrude representatives selected four transects running approximately north-south across the EV Cake Cell, within each of the inner cells created by the berms. This was intended to capture variations in topography, previously observed soil moisture conditions, and soil cover designs. Depending on the length of the reclaimed area from north to south, the transects contained between five and seven sample locations with approximately 50 m spacing between each point. One inspection location on each transect extended south into the unreclaimed cake deposit. This resulted in a total of 23 sampling locations between the four transects; 19 were within the reclaimed cake cell area and four within the unreclaimed cake to the south. A site map showing each sampling location and the final coordinate list are presented in Appendices I and II, respectively.

During the field assessment it was noted that the northernmost sampling location in each transect was located either on (transects 3 and 4) or very near (transects 1 and 2) the OB berm. Therefore, the transect lengths were adjusted and the points were moved as required to field-fit the originally designed number of sampling locations in each transect into the area with known cake substrate. This maintained the total of 23 sampling locations assessed, but resulted in approximate spacing of 35 m between points in transect 4, 40 m spacing in transect 3, and the original 50 m spacing in transects 1 and 2.

4.2 SOIL SAMPLING

Soil sampling was completed using an extendable hand auger. Within the reclaimed area, a pilot hole was hand augered at each sampling location to determine the depth to the cake substrate. From this depth confirmation, a subsequent auger hole was advanced and 30 cm sampling intervals were created from the cake/subsoil interface to the soil surface, and two 30 cm sampling intervals were created below the interface and advanced into the cake. The objective for using this method was to ensure that samples directly above and below the cake interface were sampled consistently between locations for comparative purposes. The coversoil/subsoil interface did not influence the sampling intervals; therefore, most sites had one sample composed of a mixture of coversoil and subsoil, and a surface interval less than 30 cm in thickness. In addition to the 30 cm intervals, the surface (0-2 cm) was sampled separately at each location to examine salt evapo-concentration. In the unreclaimed cake area, three 30 cm sampling intervals were collected (0-30, 30-60, and 60-90 cm).

For each sampling interval, a laboratory supplied re-sealable bag and a 125 mL glass jar with a Teflon™ lined lid packed with zero headspace was collected for salinity and moisture analyses. One sampling location along each transect was selected for full soil characterization for a range of analytical parameters. In addition to the resealable bag and 125 mL jar, samples were also collected for volatile organic analyses using a Terra Core® sampler and placed into duplicate pre-weighed vials containing methanol.

The following soils information was recorded at each inspection point:

- Horizon (material type);
- Horizon depth;
- Inclusions (description of type, proportion); and,
- Additional profile notes (*e.g.,* coarse fragments, change in texture, ice/frozen, etc.).

At the time of the 2019 assessment, the cake deposit had not fully thawed at five inspection points. The ice layer was broken through and sampling was completed to depth in three of these holes, while in the remaining two holes (T2-3, T4-2) the cake was not sampled due to auger refusal from the ice.

Horizon type and depth for each auger inspection point can be found both on the figures in Appendix III and in the table in Appendix IV. This information, along with details regarding inclusions and other additional profile notes, can also be found in the scanned copies of the original field sheets provided to Syncrude.

4.3 LABORATORY ANALYSES

A total of 170 samples were collected and inventoried at NorthWind prior to submission to Element Laboratories (Element) in Edmonton, Alberta. All samples were analyzed for detailed salinity (including pH, electrical conductivity [EC], sodium adsorption ratio [SAR], major soluble cations, chloride and sulfate) and soil water content (moisture), except for the surface samples which were analyzed for detailed salinity alone.

Additional analyses were requested for all coversoil, subsoil, and substrate samples at each of the full soil characterization locations and at the unreclaimed cake locations. These included cation exchange capacity (CEC), particle size analysis (PSA), and calcium carbonate equivalent (CCE). At these locations each subsoil and substrate sample was also analyzed for PHCs, and the sample consisting of coversoil alone was analyzed for carbon and nitrogen, available nutrients, and micronutrients.

Table 4-1 provides a summary of the soil chemical analyses and the methods used for each. Detailed methods of the soil chemical analyses are present in Appendix VII.

Table 4-1. Soil chemical analyses and methods used by Element Laboratories.

Analysis	Method	Reference
Available nutrients	Modified Kelowna Test	(Exova 2018d; American Public Health Association 2012c; Maynard et al. 2008; Alberta Research Council 1996; Ashworth and Mrazek 1995)
Calcium carbonate equivalents	Calcium carbonate in soil (dual pH)	(Exova 2018a; Ashworth 1997)
Cation exchange capacity and exchangeable cations	Ammonium acetate at pH 7	(Exova 2018b; American Public Health Association 2012a; McKeague 1978)
Detailed salinity	Saturated paste extraction	(Exova 2018f; American Public Health Association 2012a, c; Miller and Curtin 2008)
Micronutrients	DTPA-TEA extractable elements	(Exova 2018c; American Public Health Association 2012a; McKeague 1981)
Moisture content	Drying at 105 °C	(Carter and Gregorich 2008; Element 2019c)
Particle size	Particle size analysis by hydrometer	(Exova 2018f; Kroetsch and Wang 2008)
Organic carbon and total nitrogen	Total organic carbon, total nitrogen and calculated organic matter (Leco Combustion)	(Exova 2018g; Bremner 1996; Nelson and Sommers 1996; Walkley and Black 1934)
Organic matter	Loss on ignition	(McKeague 1978)
Petroleum hydrocarbon fraction (F)1 – BTEX	Headspace gas chromatograph flame ionization method	(CCME 2001, 2016; Element 2019a; EPA 2014, 2017)
Petroleum hydrocarbon F2 to F4	Cold-shake method with 50:50 hexane: acetone	(CCME 2001, 2016; Element 2019b)

4.4 DATA ANALYSIS

All numerical field data and soil analytical data were grouped by material type (*e.g.*, PTMIX, MIN [subsoil], cake [substrate]) and the average and standard deviation (SD) were calculated. Soil results were compared to Alberta Tier 1 (AEP Tier 1) Guidelines (Alberta Environment and Parks [AEP] 2019) as a screening-level tool to identify elevated parameters. Soil pH, EC and SAR were compared to the AEP Tier 1 topsoil and subsoil salt remediation guidelines; PTMIX and USS were compared to topsoil guidelines and MIN and cake were compared to subsoil guidelines. Although there are currently no defined soil guidelines for chlorides and sodium, the concentrations were reported because at elevated concentrations they can impact environmental receptors. Soil PHCs were compared to the AEP Tier 1 Guidelines for natural area land use and fine-grained soils. The surface soil PHC criteria was used since it is applicable to the upper 3 m on sites without an oilfield wellhead (AEP 2019).

Cross-sections of each transect were created using the field data collected in conjunction with a digital elevation model (DEM) provided by Syncrude. The surface elevations represent real data, except for the southern portion of transects three and four. This area has hypothesized elevation data since these locations were past the southernmost edge of the DEM. The depths of coversoil and subsoil between boreholes were interpolated and do not represent real data. The soil moisture, EC, SAR and pH for each sampled depth interval at each inspection point along the transects are also displayed in the cross-section figures (Appendix III).

In the substrate characterization table (Table 6-4), the cake's chemistry is compared to other substrates present within Syncrude's EPEA Approval to provide context. For this table, only cake samples taken from the unreclaimed area were included in order to remove the potentially cross-contaminated samples from boreholes in the reclaimed area (see Section 5 for more information). The comparative substrate chemistry was retrieved from previous Syncrude assessments or from other documented literature sources.

5.0 QUALITY CONTROL

The EV Cake Cell provided a challenging environment for soil sampling. At the time of the assessment there was a significant amount of standing water across most of the study area, with saturated coversoil throughout and often saturated portions of the lower subsoil. At most sampling locations, these two zones of saturation were separated by an unsaturated zone of firm subsoil. This increased the risk of cross-contamination, caused by collapsing of the auger hole, filling-up of water and saturated sediments in the auger hole and smearing of materials during retrieval/pull-up of the auger flight.

The following steps were taken to minimize cross-contamination of the sampling:

- Prior to placement within the bag or container, the outside of each sample was shaved off with a soil knife to remove any material introduced from the perimeter of the hole. This process also removed water present on the outside of the samples.
- Separate augers were also used for coversoil/subsoil and cake samples.
- Augers were cleaned between each sampling location and interval to remove residual soil present from the auger.

This last step was particularly difficult near the subsoil/cake interface and within the cake because of the high moisture content and often sticky consistence. Since the subsoil above the cake was often saturated, it was difficult to physically separate these two materials from one another. The difference in soil colour and PHC odour was used to help discern the two, but discrete sampling at this boundary proved difficult in most cases and may have affected the analytical results.

Even after implementing the above measures it is apparent that cross-contamination could be minimized but not eliminated. The cake samples that were collected in the unreclaimed area can be used for comparative purposes with the cake samples collected in the reclamation area to provide an indication of potential cross-contamination. Therefore, any soil pH, salinity, sodicity and/or PHC increase in the MIN subsoil or decrease in the cake near the cake/subsoil interface may be due (in part) to cross-contamination of the different materials.

6.0 RESULTS AND DISCUSSION

A Site Map and Coordinate List are presented in Appendices I and II. Transect cross-sections and Figures are presented in Appendix III where profiles for moisture, salinity, sodicity and pH can be observed. Soil capping depth by transect is presented in Appendix IV. The full salinity results (main soluble ions, pH, EC, SAR) and moisture content are provided in Appendix V. All PHC results as well as supplemental chemical and physical analyses results are presented in Appendix VI.

6.1 SOIL RECLAMATION CAPPING DEPTH

A total of 19 plots were assessed in the reclaimed portion of the EV Cake Cell. The mean coversoil capping depth was 42 cm (standard deviation [SD] = 16 cm) and the mean total capping thickness was 159 cm (SD = 25 cm; Table 6-1). The minimum depth of coversoil was 15 cm and the maximum depth of coversoil was 80 cm at plot T1-5 and T2-4, respectively (Table 6-1; Appendix IV). The minimum total cap was 102 cm (inspection point T2-5) and the maximum was >203 cm (T4-2).

Table 6-1. Mean, minimum and maximum coversoil and total reclamation capping depths of inspection points within the EV Cake Cell. (Note: Standard deviation in parentheses)

	n	Average Depth (cm)	Minimum Depth (cm)	Maximum Depth (cm)
Coversoil	19	42 (16)	15	80
Total Reclamation Capping Depth	19	159 (25) *	102	>203*

* Data from all inspection points used in average depth calculations. Maximum depth to auger refusal (ice) used at two sites (T2-3, T4-2) where cake was not reached.

One location (T2-5 Anomaly) was not sampled because the depth to the cake was >3.2 m. The location was noted, and an alternate hole was advanced within 5 m (T2-5) (Appendix I).

6.2 GENERAL SOIL QUALITY/CHARACTERISTICS

Soil results for moisture, pH, salinity (EC), sodicity (SAR) and PHCs were compiled for all inspection points of the study and are presented below. Additional soil analysis (available nutrients, micronutrients, cation exchange capacity, organic carbon and nitrogen and particle size analysis) were performed on select samples and they are presented in Appendix VI.

6.2.1 Soil Moisture

Coversoil PTMIX and USS had the highest mean moisture (56 and 46%, respectively) (Table 6-2). The range of moisture for PTMIX was 24 to 77% and 25 to 78% for USS. The mean MIN subsoil moisture content was 21%, with a range of 15 to 33%. The cake mean moisture content was 28%, ranging from 18 to 34%. The higher moisture content of the coversoil reflects the higher organic matter content relative to the MIN subsoil and cake. The higher moisture of the cake relative to the

MIN subsoil reflects the high residual moisture content that remains after centrifugation and post-deposition water loss (evaporation and freeze/thaw).

Table 6-2. Mean and standard deviation of select soil parameters for soil reclamation materials and cake substrate.

Material Type	*n*	Soil Parameter							
		Moisture (% m/m)		pH (H_2O)		Electrical Conductivity (dS/m)		Sodium Adsorption Ratio	
		Mean (std)	Range	Mean (std)	Range	Mean (std)	Range	Mean (std)	Range
Alberta Tier 1 (Topsoil)		--	--	*6.0-8.5*	--	*2-4 (Fair)*	--	*4-8 (Fair)*	--
Alberta Tier 1 (Subsoil)		--	--	*6.0-8.5*	--	*3-5 (Fair)*	--	*4-8 (Fair)*	
Surface (0-2 cm)	19	--	--	5.2 (0.66)	4.0 - 6.9	1.3 (0.79)	0.4 - 3.2	2.3 (0.73)	0.5 - 5.5
PTMIX	17	56 (14)	24 - 77	5.0 (0.32)	4.4 - 5.5	1.4 (0.78)	0.5 - 3.5	1.3 (0.95)	0.4 - 4.1
PTMIX/MIN	12[1]	37 (21)	16 - 72	6.8 (0.75)	5.6 - 7.7	1.3 (0.52)	0.8 - 2.4	1.5 (1.20)	0.4 - 4.3
USS	6	46 (20)	25 - 78	5.9 (0.70)	5.0 - 6.6	1.9 (0.42)	1.2 - 2.5	1.9 (0.48)	1.1 - 2.4
USS/MIN	6[2]	20 (3)	16 - 23	7.7 (0.14)	7.4 - 7.8	1.7 (0.39)	1.0 - 2.2	2.3 (0.73)	1.8 - 3.6
MIN	65[3]	21 (3)	15 - 33	7.7 (0.46)	5.1 - 8.2	1.5 (0.69)	0.4 - 3.0	2.7 (1.92)	0.3 - 8.1
Cake	45[4]	28 (3)	18 - 34	8.2 (0.29)	7.4 - 8.7	3.3 (1.50)	1.2 - 8.3	22.2 (9.86)	4.4 - 44.0

1 10 samples analysed for moisture content and 12 for other soil parameters.
2 5 samples analysed for moisture content and 6 for other soil parameters.
3 64 samples analysed for moisture content and 65 for other soil parameters.
4 All cake samples (includes exposed cake samples) were used in summary statistics.

6.2.2 Soil pH

PTMIX had the lowest mean soil pH (5.0) followed by the surface 0-2 cm (5.2), USS (5.9), MIN (7.7), and cake (8.2) (Table 6-2). As expected, the mixtures of coversoil (PTMIX and USS) and MIN had a soil pH between the coversoil and the pure MIN values. The range of pH for PTMIX was 4.4 to 5.5 and for USS it was 5.0 to 6.6. The MIN subsoil pH range was 5.1 to 8.2 and for cake it was 7.4 to 8.7.

Comparison of the mean pH values for the materials to AEP Tier 1 guidelines finds the subsoil MIN and cake are within the acceptable range pH range (6.0-8.5). There were no MIN subsoil samples that were above the acceptable pH range; however, there were occasionally cake materials that exceeded 8.5 (highest value of 8.7), spread across transects 1, 3 and 4 (Appendix V). The average pH for PTMIX and USS was below 6.0, but they are not a cause for concern because they are within the normal range of surface pH for soils in the region.

6.2.3 Soil Salinity

The mean EC for PTMIX, USS, MIN and all mixed profiles of these materials were similar, ranging from 1.3 to 1.9 dS/m (Table 6-2). The range of EC for PTMIX was 0.5 to 3.5 and for USS it was 1.2 to 2.5. The MIN subsoil EC range was 0.4 to 3.0. Comparison of the mean EC values for all the soil reclamation materials to AEP Tier 1 guidelines confirms that PTMIX, USS and MIN are classified as Good for both topsoil (<2 dS/m) and subsoil (<3 dS/m). Some individual PTMIX and USS samples exceeded the Good topsoil rating (2 dS/m) and fell into the Fair category (2-4 dS/m; Appendix V). Only the highest individual MIN subsoil sample (3.0 dS/m) fell into the Fair subsoil category (3-5 dS/m).

The mean EC for cake was 3.3 dS/m, with a range of 1.2 to 8.3. The mean EC for cake is classified as Fair; however, some of the elevated EC values are in the Poor category.

6.2.4 Soil Sodicity

The mean SAR for PTMIX, USS, MIN and all mixed profiles of these materials were similar, ranging from 1.3 to 2.7 (Table 6-2). The range of SAR for PTMIX was 0.4 to 4.1 and for USS it was 1.1 to 2.4. The MIN subsoil SAR range was 0.3 to 8.1. Comparison of the mean SAR values for all the soil reclamation materials to AEP Tier 1 guidelines confirms that PTMIX, USS and MIN are classified as Good for topsoil and subsoil (<4). There were no individual USS samples that exceeded the Good category and only the highest individual PTMIX samples exceeded Good and fell into the Fair category (4 to 8; Appendix V). A number of individual MIN samples exceeded the Good category and fell into the Fair category (4 to 8), with one individual sample in the Poor category (8 to 12).

The mean SAR for cake was 22.2, with a range of 4.4 to 44.0. The mean SAR for cake is classified as Unsuitable, with select individuals in the Fair (4 to 8) and Poor (8 to 12) categories.

6.2.5 Soil Petroleum Hydrocarbons

In the samples analyzed for PHCs, only the cake samples exceeded the AEP Tier 1 guidelines for surface soil (Appendix VI). In the cake samples, exceedances were identified for benzene, ethylbenzene, xylenes, and PHC fraction (F)1 to F4. Out of the 20 cake samples, the following summary of PHC results were found when compared to AEP Tier 1 guidelines:

- All exceeded PHC F2, with exceedances ranging from 1,110 to 5,940 mg/kg (AEP Tier 1 guideline is 150 mg/kg);
- All exceeded PHC F3, with exceedances ranging from 8,730 to 31,100 mg/kg (AEP Tier 1 guideline is 1,300 mg/kg);
- Seventeen exceeded PHC F4, with exceedances ranging from 5,820 to 13,100 mg/kg (AEP Tier 1 guideline is 5,600 mg/kg);
- Fifteen exceeded ethylbenzene, with exceedances ranging from 0.102 to 2.560 mg/kg (AEP Tier 1 guideline is 0.073 mg/kg);
- Thirteen exceeded PHC F1, with exceedances ranging from 212 to 1,440 mg/kg (AEP Tier 1 guideline is 210 mg/kg);
- Twelve exceeded xylenes, with exceedances ranging from 1.43 to 7.28 mg/kg (AEP Tier 1 guideline is 0.99 mg/kg);

- Eleven exceeded benzene, with exceedances ranging from 0.063 to 0.581 mg/kg (AEP Tier 1 guideline is 0.046 mg/kg); and,
- There were no exceedances for toluene (AEP Tier 1 guideline is 0.52 mg/kg).

6.3 SOIL QUALITY CHANGES AND CHARACTERISTICS AT SUBSOIL/CAKE INTERFACE

Changes in soil quality above and below the MIN subsoil and cake interface were assessed to determine if salt, sodium, PHC migration and/or transformations may be occurring in the reclamation cover and cake. Mean pH, EC, SAR and PHCs for each depth interval from the MIN subsoil/cake interface and their range are provided in Table 6-3. Cake samples from the unreclaimed cake deposit (exposed cake) are also presented to compare with capped cake in the reclamation area. The coversoil/subsoil interface was not assessed, because any changes to date would be most evident at the subsoil/cake interface. However, it should be noted that the exposed cake has been exposed to the atmosphere for a longer period than the capped cake, resulting in different weathering rates and potentially different soil quality characteristics.

Comparison of the MIN subsoil pH, EC, SAR and PHC concentrations for the various depth intervals suggests that to date there has been no substantial migration in salinity, sodicity and PHCs from the cake into the overlying subsoil. This is evidenced by no dramatic changes in the subsoil chemistry of the MIN subsoil at the cake interface relative to overlying MIN subsoil sample depth intervals (Table 6-3). The soil pH of the 0-30 cm subsoil interval (7.6) is similar to the above depth intervals (7.7 to 7.8). The EC of the 0-30 cm MIN subsoil interval (1.6 dS/m) is similar to the above depth intervals (1.4 to 1.5 dS/m) and the SAR of the 0-30 cm subsoil interval is only marginally higher (3.4) than the above depth intervals (2.3 to 2.4).

While there is a slight EC and SAR increase in the MIN near the cake interface, it has not resulted in a substantial change in soil quality. The mean pH, EC and SAR of the MIN subsoil 0-30 cm depth interval are rated as Good with respect to AEP Tier 1 Subsoil guidelines. Only the highest EC concentration of an individual sample (3.01 dS/m; T3-1, 80-110 cm) fell into the Fair category for Subsoil (3 to 5 dS/m), while a number of MIN subsoil 0-30 cm samples were in the SAR Fair Subsoil category (4 to 8) and one sample (8.1 dS/m; T3-1, 80-110 cm) fell into the Poor category.

There was also no apparent change in the PHC concentrations in the subsoil. BTEX, F1-BTEX and F2 PHC concentrations were non-detect for all subsoil MIN samples and there was no apparent increase or decrease in PHC concentration in F3 and F4 fractions for all subsoil depth intervals. All MIN subsoil samples were below AEP Tier 1 guidelines.

Changes were evident in the cake deposit; however, the changes were confined to the surface of the cake deposit (0 to -30 cm). Soil pH within the reclaimed area was comparable in the 0 to -30 and -30 to -60 cm depth intervals in the cake, but EC and SAR were lower in the 0 to -30 cm interval (Table

6-3). These results are consistent with the exposed cake samples with the exception of EC. The mean EC of the 0 to -30 cm interval of exposed cake (4.3 dS/m) was higher than the underlying depth intervals (3.4 and 3.0 dS/m for -30 to -60 and -60 to -90 cm depth intervals, respectively). It is unclear if the decrease in EC and SAR in the 0 to -30 cm interval is the result of a change at this depth, or the result of cross-contamination with the overlying MIN subsoil which has lower EC and SAR. The increase in EC and decrease of SAR in the surface 0 to -30 cm of the exposed cake may be an indication that extended exposure of the cake to the atmosphere results in more rapid geochemical transformations than the cake that is capped with the reclamation cover.

The mean pH for all cake depth intervals is below the AEP Tier 1 guideline. The mean EC of the 0 to -30 cm cake interval in the reclaimed area is rated as Good, but the -30 to -60 cm interval and all depth intervals of the exposed cake samples are in the Fair category. Although there was a drop in the 0 to -30 cm interval, the mean SAR for the cake in the reclamation and exposed cake areas are still in the Unsuitable category (>12).

Comparison of the PHC concentrations in the cake depth intervals suggests some degradation of hydrocarbons in the cake deposit has occurred post-pouring. All PHC compounds and fractions were lower in concentration in the 0 to -30 cm interval in both the reclaimed and exposed cake compared to the intervals sampled below (Table 6-3). In the exposed cake there was little difference in the PHCs between the -30 to -60 and -60 to -90 cm intervals, suggesting the only changes to date are limited to the surface 30 cm of the cake deposit. Surprisingly, there was a drop in the heavy PHC fraction ranges (F3 and F4HTGC), which are considered to be relatively resistant to degradation. The 0 to -30 cm cake interval in the reclamation area was 31% and 34% lower in F3 and F4HTGC concentrations than the -30 to -60 cm depth interval. Some of this decrease could be attributable to cross-contamination with the overlying MIN subsoil which has a lower PHC concentration; however, this decrease was also evident in the exposed cake deposit. The exposed cake 0 to -30 cm F3 and F4HTGC concentrations were 21% and 22% lower than the -30 to -60 cm depth interval, which suggests some degradation of the heavy-end PHC fractions has occurred.

Although there was a decrease in the PHC concentrations of the cake in the EV reclamation area, all PHC compounds and fractions (except Toluene) still exceed AEP Tier 1 guidelines. However, the exposed cake had greater losses in BTEX and F1-BTEX, resulting in the mean and range of Benzene, Xylenes and F1-BTEX being below Alberta Tier 1 guidelines. This suggests that additional exposure of the cake deposit to the atmosphere allows for further degradation of light-end PHCs via processes such as photodegradation and volatilization.

Table 6-3. Mean and (range) of select soil parameters for depth intervals from the MIN subsoil/cake interface.

Material Type	Depth from interface (cm)	Soil Parameter												
		n	pH (H_2O)	EC (dS/m)	SAR	PHCs (mg/kg)								
						n	Benzene	Toluene	Ethylbenzene	Xylenes$_{(m,p,o)}$	F1-BTEX	F2$_{(C10-16)}$	F3$_{(C16-34)}$	F4HTGC$_{(C34-50+)}$
			Mean (Range)				Mean (Range)							
Alberta Tier 1 (Subsoil)		*--*	*6.0-8.5*	*3-5 (Fair)*	*4-8 (Fair)*	*--*	*0.046*	*0.52*	*0.073*	*0.99*	*210*	*150*	*1,300*	*5,600*
MIN	+90 - 120	10	7.8 (7.6 - 8.2)	1.4 (0.4 - 2.5)	2.3 (0.4 - 6.1)	2	<0.005 (n/a)	<0.002 (n/a)	<0.005 (n/a)	<0.03 (n/a)	<10 (n/a)	<25 (n/a)	230 (106 - 354)	260 (120 - 400)
MIN	+60 - 90	17	7.8 (7.3 - 8.1)	1.4 (0.4 - 2.6)	2.4 (0.3 - 6.4)	4	<0.005 (n/a)	<0.002 (n/a)	<0.005 (n/a)	<0.03 (n/a)	<10 (n/a)	<25 (n/a)	572 (284 - 794)	761 (335 - 1170)
MIN	+30 - 60	18	7.7 (6.4 - 8.0)	1.5 (0.6 - 2.6)	2.4 (0.4 - 6.6)	4	<0.005 (n/a)	<0.002 (n/a)	<0.005 (n/a)	<0.03 (n/a)	<10 (n/a)	<25 (n/a)	385 (146 - 848)	483 (187 - 985)
MIN	0 - 30	19	7.6 (5.1 - 8.1)	1.6 (0.6 - 3.0)	3.4 (0.6 - 8.1)	4	<0.005 (n/a)	<0.002 (n/a)	<0.005 (n/a)	<0.03 (n/a)	<10 (n/a)	<25 (n/a)	388 (73 - 825)	715 (260 - 1410)
Cake	0 - -30	17	8.2 (7.6 - 8.7)	2.9 (1.4 - 7.7)	17.5 (4.4 - 40.0)	4	0.129 (0.008 - 0.365)	0.065 (0.030 - 0.100)	0.254 (0.037 - 0.757)	1.46 (0.12 - 5.17)	471 (231 - 711)	2,633 (1,710 - 4,810)	15,158 (8,730 - 24,700)	12,748 (6,690 - 21,300)
Cake	-30 - -60	16	8.2 (7.4 - 8.7)	3.4 (1.2 - 8.3)	20.0 (11.0 - 35.0)	4	0.290 (0.115 - 0.406)	0.100 (0.090 - 0.110)	0.618 (0.102 - 1.580)	3.49 (0.28 - 7.28)	613 (166 - 1,230)	4,225 (2,440 - 5,790)	21,850 (12,100 - 31,100)	19,275 (10,600 - 28,500)
Exposed Cake	0 - -30	4	8.2 (7.7 - 8.6)	4.3 (2.9 - 5.7)	26.3 (16.5 - 40.0)	4	0.035 (0.018 - 0.063)	0.053 (0.020 - 0.090)	0.141 (0.048 - 0.252)	0.34 (0.20 - 0.53)	135 (87 - 177)	3,123 (1,110 - 4,400)	18,633 (9,630 - 22,700)	16,670 (8,980 - 21,600)
Exposed Cake	-30 - -60	4	8.3 (8.2 - 8.4)	3.4 (2.8 - 4.5)	32.8 (29.0 - 36.1)	4	0.225 (0.040 - 0.581)	0.077 (0.040 - 0.150)	1.453 (1.170 - 1.860)	4.42 (2.79 - 6.24)	818 (472 - 1,310)	4,448 (3,070 - 5,940)	23,550 (16,600 - 30,700)	21,350 (14,100 - 27,900)
Exposed Cake	-60 - -90	4	8.4 (8.3 - 8.4)	3.0 (2.7 - 3.4)	36.8 (30.0 - 44.0)	4	0.245 (0.012 - 0.563)	0.110 (0.040 - 0.180)	0.982 (0.287 - 2.560)	4.81 (1.43 - 6.61)	1,013 (212 - 1,440)	4,603 (3,710 - 5,540)	23,575 (19,700 - 29,300)	22,025 (18,400 - 27,800)

6.4 EFFECT OF TOPOGRAPHY ON SOIL QUALITY/CHARACTERISTICS

Soil quality and characteristics were qualitatively assessed with each transect as related to changes in topographic position. Figures for each transect showing the location of each inspection point and the moisture, EC, SAR and pH are shown in Figures 1 to 4 of Appendix III. Comparing each of the soil parameters of each inspection point across each transect did not identify any clear pattern or trend with different topographic positions. Variation in the results for each parameter is present but the differences can't be attributed to a specific topographic location or condition (upslope vs downslope, localized depression vs localized crest). This does not suggest that topographic position is not or will not have an impact on increasing or decreasing concentrations of these parameters. In the case of the EV reclamation area there may be no discernible trend because the reclamation area is nearly level (0.5 to 2% slopes). The design of EV with minimal slope will be consistent for other cake deposition areas due to construction techniques (pour placement in cells) and geotechnical stability requirements, but if cake reclamation areas with greater relief are constructed they may provide an opportunity to assess the effect of topography on these soil quality parameters.

6.5 COMPARISON OF CAKE CHARACTERISTICS TO OTHER SUBSTRATES

Select soil parameters for the unreclaimed cake samples have been compared to other reclaimed substrates to provide additional context for the land reclamation capability of cake (Table 6-4). A centrifuge cake sample from a previous test pilot confirms the general soil quality characteristics of the cake substrate in the EV cell is consistent with other cake material that has been produced by Syncrude. Although there is variation in the values, both cake materials have elevated SAR and PHCs. Comparison to the other substrates presented finds the pH of cake is generally higher than most other substrates with the exception of hydraulically placed tailings in East In-Pit. The EC of cake is higher than most of the substrates, but is significantly lower than the EC of Clearwater OB substrate. The SAR of Clearwater OB is elevated relative to other substrates; however, cake SAR values generally exceed those of Clearwater OB.

The PHCs within cake are unique among Syncrude's substrates, with a PHC concentration significantly higher than most other substrates. Although cake has similar heavy-fraction PHCs (F3 and F4HTGC) as lean oil sand OB, the light-end concentrations (BTEX, F1-BTEX and F2) are substantially higher. The lower light-end PHC concentrations in lean oil sand OB indicates that the substrate has undergone weathering and hydrocarbon degradation prior to mining activities. PHC concentrations have not been provided for Clearwater OB and tailings sand, but they are expected to be significantly lower than the cake concentrations.

Comparison of cake to other substrates highlights that cake is unique in its high SAR and PHC concentrations, particularly the light-end compounds and fractions. To date Syncrude has not reclaimed a substrate with light-end PHC compounds and SAR values like that of cake material. These two soil quality parameters stand out as constituents of concern that merit further assessment.

Table 6-4. Comparison of select soil parameters of East Valley cake substrate with other substrates.

		Substrate Material					
		East Valley Cake Deposit	**Centrifuge Cake**	**Hydraulically Placed Tailings**	**Lean Oil Sand Overburden**	**Clearwater Overburden**	**Tailings Sand**
Reference		**Mean of exposed cake inspection points (bottom depth interval)**	**Mean of MLSB centrifuge cake test trial (Unpub. Data)**	**East In-Pit (Unpub. Data)**	**Visser (2008)**	**Kessler (2007)**	**Sandhill Fen (Unpub. Data)**
Parameter	**Unit**						
pH	-	8.4	8.1	8.0-9.3	6.8	6.1 - 7.7	7.6
Electrical Conductivity	dS/m	3.0	2.6	0.63 - 2.76	1.7	3.9 - 16.7	0.9
Sodium Adsorption Ratio	-	36.8	22.3	--[1]	0.4	2.9 - 35.0	2.8
Petroleum Hydrocarbons							
Benzene	mg/kg	0.245	0.285	<0.005 - 0.006	<0.004	--	--
Toluene	mg/kg	0.110	0.025	<0.02 - 0.07	<0.005	--	--
Ethylbenzene	mg/kg	0.982	2.09	<0.005	<0.01	--	--
Xylenes$_{(m,p,o)}$	mg/kg	4.81	2.53	<0.03 - 0.06	<0.01	--	--
F1-BTEX	mg/kg	1,013	226	11	90	--	--
F2$_{(C10-16)}$	mg/kg	4,603	3,681	62 - 302	5923	--	--
F3$_{(C16-34)}$	mg/kg	23,575	17,976	661 - 1,510	22,800	--	--
F4HTGC$_{(C34-50)}$	mg/kg	22,025	12,550	289 - 709	24,500	--	--

1 Unable to accurately calculate SAR because calcium and magnesium concentrations below detection limit.

7.0 KEY FINDINGS

The soil quality assessment of the EV Cake Cell had the following key findings:

1. PHC concentrations and SAR appear to be the constituents of greatest concern for reclamation, while soil pH and EC are generally rated as Good according to AEP Tier 1 guidelines and are within or below the range of concentrations for other substrates being reclaimed. Cake exceeds most of the light and heavy-end PHC fraction AEP Tier 1 guidelines and are generally rated as Unsuitable with respect to SAR. The combination of these two parameters being elevated is unique among the substrates that Syncrude is currently reclaiming.
2. Light and heavy-end fraction PHC concentrations at the surface of the cake deposit (0 to 30 cm) have been reduced, suggesting there is some ability for degradation of hydrocarbons present in the cake.
3. Changes in the SAR and EC of the surface 30 cm of cake suggest the deposit will continue to undergo geochemical transformations over time. Salt and soluble ion generation through redox processes may continue to alter the SAR and EC in the cake and transport of salts and ions into the reclamation cover and to downstream receptors.
4. There has been little movement of constituents (*i.e.*, salts, sodium and PHCs) from the cake into the soil reclamation cover. Constituent concentrations of the MIN subsoil directly above the cake interface have not changed substantially relative to the MIN subsoil higher in the soil profile.
5. Constituent concentrations do not appear to be correlated with the topographic position. There were no apparent trends in constituent concentration with the different topographic positions. However, it should be noted that the slope of the EV Cake Cell is approximately 0.5 to 2%, which is a nearly level landform.
6. The additional soil moisture present in the reclamation cover at the EV Cake Cell is primarily from precipitation and snowmelt inputs. The constituent concentrations (*e.g.*, salts, sodium and PHCs) in the reclamation cover generally do not show an increase at the interface of the cake and have a suitable soil quality rating. This indicates there has not been a rapid release of pore water from the cake deposit into the reclamation cover.

8.0 CONCLUSION

This research study was initiated to assess the soil quality of the reclamation cover and cake at the EV Cake Cell. Preliminary reconnaissance by Syncrude identified significantly more water in the area than was initially expected. The objective of the investigation was to evaluate the soil quality of the reclamation cover and near surface cake deposit to determine if the excess soil moisture present is the result of freshwater inputs (*i.e.*, precipitation and snowmelt) or the result of pore water release from the cake deposit.

Coversoil and total capping depths were assessed along four transects within the EV Cake Cell. On average, the coversoil and total cap exceeded the targeted depth. Coversoil had the highest mean moisture content followed by cake and MIN. When compared to the AEP Tier 1 guidelines, cake had the most salinity exceedances and was the only material type that had PHC concentrations exceeding guidelines. Soil pH was within the AEP Tier 1 guidelines except for some cake samples and most coversoil samples; however, low pH in coversoil is typical in this region and is not a concern. The mean soil EC was rated Good in all horizons except for the cake, which was Fair. Mean SAR was rated Good for all horizons except for the cake, which was Unsuitable. Most cake samples exceeded the Alberta Tier 1 guidelines for PHCs for all fractions and compounds except toluene.

The MIN subsoil quality at the cake interface was found to be relatively similar to overlying sample depth intervals and the soil quality ratings are generally suitable (Good rating). This suggests that there has not been substantial migration of salinity, sodicity and PHCs from the cake into the overlying subsoil. As the area was only reclaimed approximately two years ago, and the site is in its early stages, the chemistry may be subject to change over time. The concentration of PHCs were significantly lower in the surface of the cake in both the reclaimed and unreclaimed areas than the intervals below. This suggests that all fractions of PHCs are degraded by various means when exposed to the atmosphere.

Compared to other reclamation substrates at Syncrude, cake is unique due to its high SAR and light-end PHC concentrations. Heavy-fraction PHCs (F3 and F4HTGC) of the cake assessed in the program had similar values to those of lean oil sand OB. Due to the gentle slope within the EV Cake Cell, variations in chemistry and moisture content could not be attributed to changes in topographic positions for this assessment.

The EV Cake Cell provides an opportunity to assess the reclamation capability of a cake landform deposit. Cake reclamation will play a more prominent role in future reclamation at Syncrude, and the learnings from this investigation will assist in understanding the dynamics of constituent transport, transformation and degradation expected to occur in reclaimed cake landforms.

9.0 CLOSURE

We trust that the content of this report meets your current requirements. Should you have any questions or require further information, please contact the undersigned at 780-481-9777.

Respectfully,

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10.0 REFERENCES

Alberta Agriculture, Food and Rural Development (AAFRD). 1987. Soil Quality Criteria Relative to Disturbance and Reclamation. Conservation and Development Branch. 51 pp.

Alberta Environment and Parks (AEP). 2019. *Alberta Tier 1 Soil and Groundwater Remediation Guidelines*. Edmonton, Alberta. January 2019.

Alberta Research Council. 1996. Method 19103 565, Potassium, Dissolved Automated Flame Photometry Method. Methods Manual for Chemical Analysis of Water and Wastes.

American Public Health Association. 2012a. 3120B Inductively Coupled Plasma (ICP) Method. Standard Methods for the Examination of Water and Wastewater, 21st edition. 1368 pp.

American Public Health Association. 2012b. 3500-Cr B, Colorimetric Method. Standard Methods for the Examination of Water and Wastewater, 21st edition. 1368 pp.

American Public Health Association. 2012c. 4500-P D, Stannous Chloride Method. Methods for the Examination of Water and Wastewater, 21st edition. 1368 pp.

Ashworth, J. 1997. Improvement to Two Routine Methods for Calcium Carbonate in Soils. Commun. Soil Sci. Plant Anal. **28:** 841-848.

Ashworth, J., and Mrazek, K. 1995. Modified Kelowna Soil Test. Commun. Soil Sci. Plant Anal. **26:** 431-439.

Bremner, J.M. 1996. Nitrogen – Total. In D.L. Sparks et al., Ed.'s. Methods of Soil Analysis Part 3 – Chemical Methods. SSSA Book Series No. 5. SSSA and ASA, Madison, WI. 1085-1121 pp.

Canadian Council of Ministers of the Environment (CCME). 2001. Reference Method for the Canada Wide Standard for Petroleum Hydrocarbons in Soil – Tier 1 Method including Addendum 1. April 2001.

Canadian Council of Ministers of the Environment (CCME). 2016. Guidance Manual for Environmental Site Characterization in Support of Environmental and Human Health Risk Assessment. Volume 4.

Carter, M.R., and Gregorich, E.G. 2008. Method 4.4, Sample Moisture Content. In Soil Sampling and Methods of Analysis, 2nd Ed. CRC Press, Taylor & Francis Group, Boca Raton, FL.

Environmental Protection Agency (EPA). 1994. Method 200.8 Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma – Mass Spectrometry, Revision 5.4. Environmental Monitoring Systems Laboratory Office of Research and Development U.S. Environmental Protection Agency.

Environmental Protection Agency (EPA). 2014. Volatile Organic Compounds in Various Sample Matrices Using Equilibrium Headspace Analysis. Method 5021A. Revision 2. July 2014.

Environmental Protection Agency (EPA). 2017. Volatile Organic Compounds by Gas Chromatography/Mass Spectroscopy (GC/MS). Method 8260D. Revision 4. February 2017.

Element. 2019a. Analysis of C6-16 Compounds, F1 and F2 by Headspace GC/MSD/FID Method Summary. Received November 7, 2019.

Element. 2019b. Extractable hydrocarbons in water and CCME Hydrocarbons in Soil (Benchmark and Alternative Method) by GC/FID Method Summary. Received November 7, 2019.

Element. 2019c. Moisture Content. Received February 14, 2020.

Exova. 2018a. Calcium Carbonate in Water by Dual pH. Received February 16, 2018.

Exova. 2018b. Exchangeable Cations and Cation Exchange Capacity in Soil by Ammonium Acetate Extraction. Received February 16, 2018.

Exova. 2018c. Extractable Micronutrients in Soil by ICP. Received February 16, 2018.

Exova. 2018d. Extractable Nitrate, Phosphate and Potassium in Soil by Continuous Flow Colorimetry. Received February 16, 2018.

Exova. 2018e. Particle Size Analysis of Soil by Hydrometer. Received February 16, 2018.

Exova. 2018f. Sodium Adsorption Ratio (SAR), pH and EC in Soil by Saturated Paste. Received February 20, 2018.

Exova. 2018g. Total Nitrogen, Total Carbon, Inorganic Carbon by Combustion Method Summary. Received February 16, 2018.

Kessler, S. 2007. Salinity profiles in reconstructed soils over saline-sodic waste from the oil sands industry. M.Sc. Thesis. University of Saskatchewan, Saskatoon, Saskatchewan. 90 pp.

Kroetsch, D. and Wang, C. 2008. Particle Size Distribution. In Carter et al., Ed.'s. Soil Sampling and Methods of Analysis, 2nd Edition. Canadian Society of Soil Science, CRC Press, Boca Raton, FL. 713-725 pp.

Maynard, D.G., Kalra, Y.P., and Crumabugh, J.A. 2008. Soil Sampling and Methods of Analysis, 2nd Edition. Canadian Soil Science Society, CRC Press, Boca Raton, FL. 71-80 pp.

Meiers, G.P, Barbour, S.L., Qualizza, C.V. and Dobchuk, B.S. 2011. Evolution of the Hydraulic Conductivity of Reclamation Covers over Sodic/Saline Mining Overburden. Journal of Geotechnical and Geoenvironmental Engineering. Vol. 137, Issue 10.

Miller, J.J., and Curtin, D. 2008. Electrical Conductivity and Soluble Ions. In Carter et al., Ed.'s. Soil Sampling and Methods of Analysis, 2nd Edition. Canadian Society of Soil Science, CRC Press, Boca Raton, FL. 161-171 pp.

McKeague, J.A. 1978. Manual on Soil Sampling and Methods of Analysis, Second Edition. Canadian Soil Science Society. Suite 907, 151 Slater St., Ottawa, ON. 212 pp.

McKeague, J.A. 1981. Method 4.65, DTPA-TEA Extractable Elements. In Manual on Soil Sampling and Methods of Analysis, Second Edition 1978. Canadian Society of Soil Science. 212 pp.

Nelson, D.W. and Sommers, L.E. 1996. Total Carbon, Organic Carbon, and Organic Matter. In D.L Sparks et al., Ed.'s. Methods of Soil Analysis Part 3 – Chemical Methods. SSSA Book Series No. 5. SSSA and ASA, Madison, WI. 961-1010 pp.

Visser, S. 2008. Petroleum Hydrocarbons (PHCs) in Lean Oil Sand (LOS): Degradation Potential and Toxicity to Ecological Receptors. Prepared for the CEMA Reclamation Working Group. 120 pp.

Walkley, A. and Black, I.A. 1934. An Examination of the Degtjareff Method for Determining Soil Organic Matter, and a Proposed Modification of the Chromic Acid Titration Method. Soil Sci. **37:** 29–38.

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APPENDIX I – SITE MAP

Appendix I. **EV Centrifuge Cake Cell sampling locations.**

APPENDIX II – COORDINATE LIST

Transect	Site	Easting	Northing
1	T1-1	453028	6318580
1	T1-2	453017	6318532
1	T1-3	453004	6318485
1	T1-4	452989	6318440
1	T1-5	452971	6318381
1	T1-6	452967	6318343
1	T1-7	452966	6318303
2	T2-1	453376	6318497
2	T2-2	453373	6318448
2	T2-3	453361	6318401
2	T2-4	453351	6318353
2	T2-5	453355	6318313
2	T2-5 Anomaly*	453345	6318305
2	T2-6	453341	6318259
3	T3-1	453768	6318395
3	T3-2	453760	6318365
3	T3-3	453760	6318325
3	T3-4	453759	6318288
3	T3-5	453753	6318242
4	T4-1	454147	6318413
4	T4-2	454144	6318373
4	T4-3	454144	6318330
4	T4-4	454141	6318289
4	T4-5	454141	6318225

Note: * denotes location not sampled

APPENDIX III – TRANSECT CROSS-SECTIONS AND FIGURES

Figure 1. Transect 1 soil cross section and associated chemistry (moisture, electrical conductivity (EC), sodium adsorption ratio (SAR) and pH).

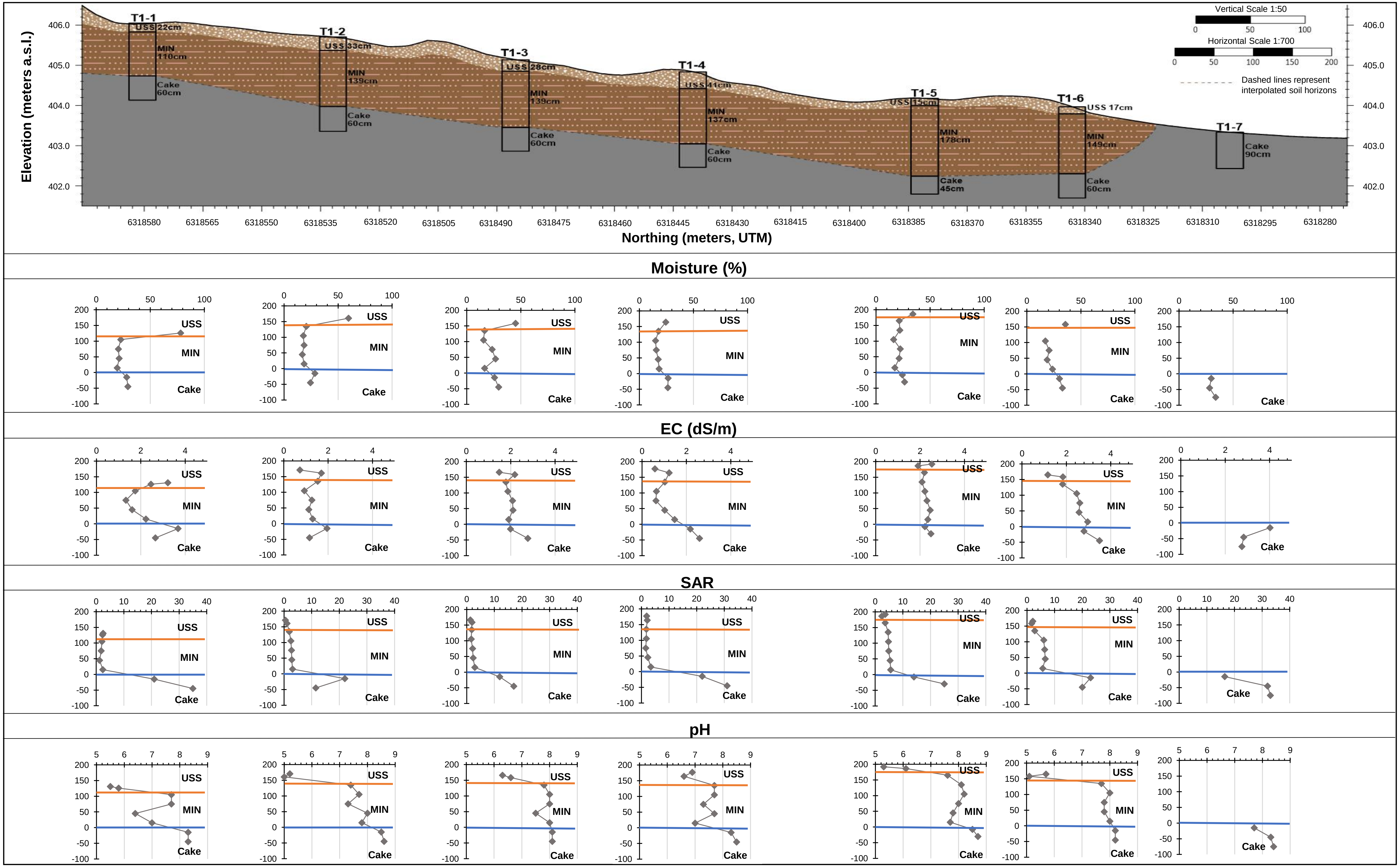


Figure 2. Transect 2 soil cross section and associated chemistry (moisture, electrical conductivity (EC), sodium adsorption ratio (SAR) and pH).

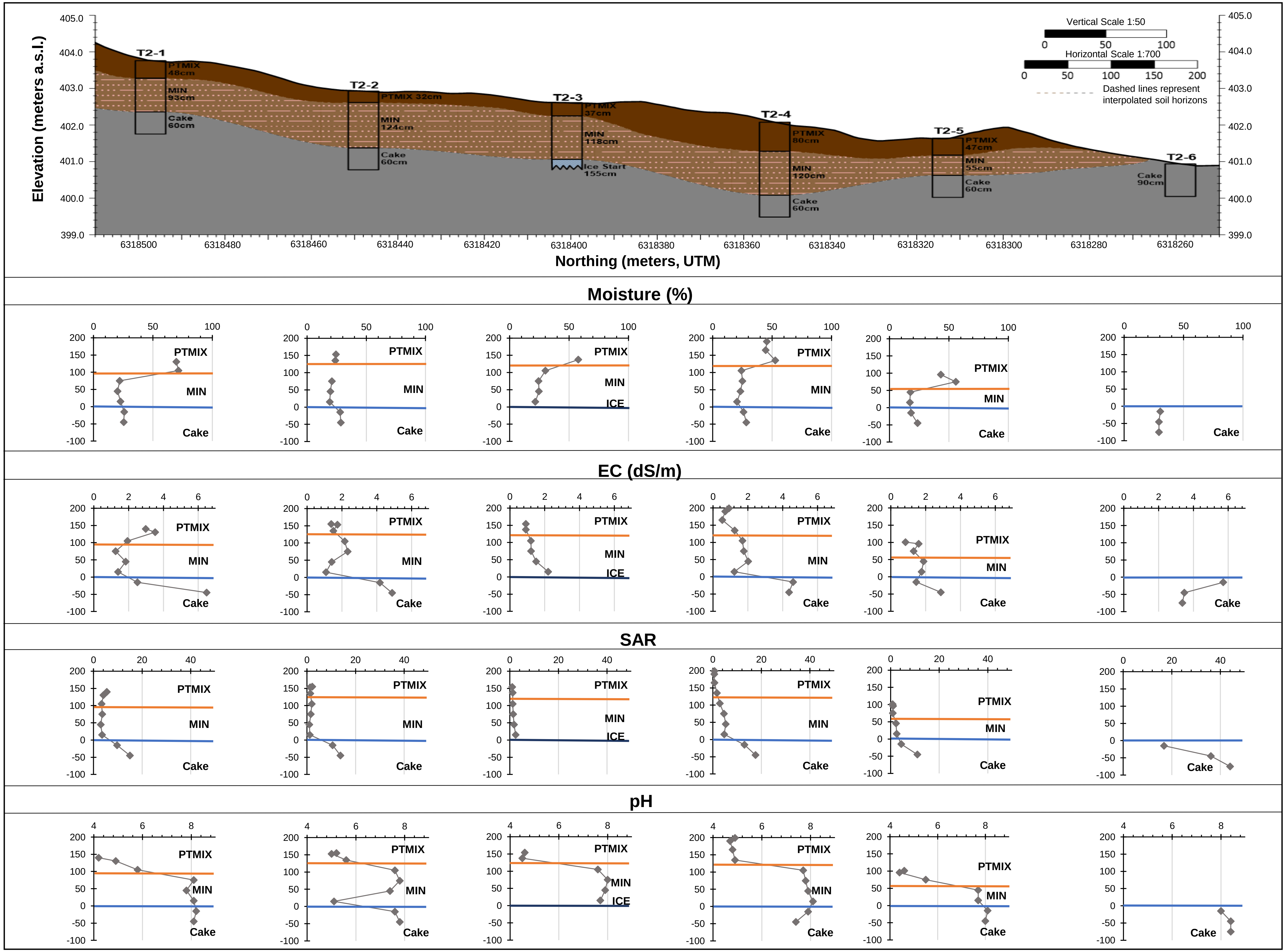


Figure 3. Transect 3 soil cross section and associated chemistry (moisture, electrical conductivity (EC), sodium adsorption ratio (SAR) and pH).

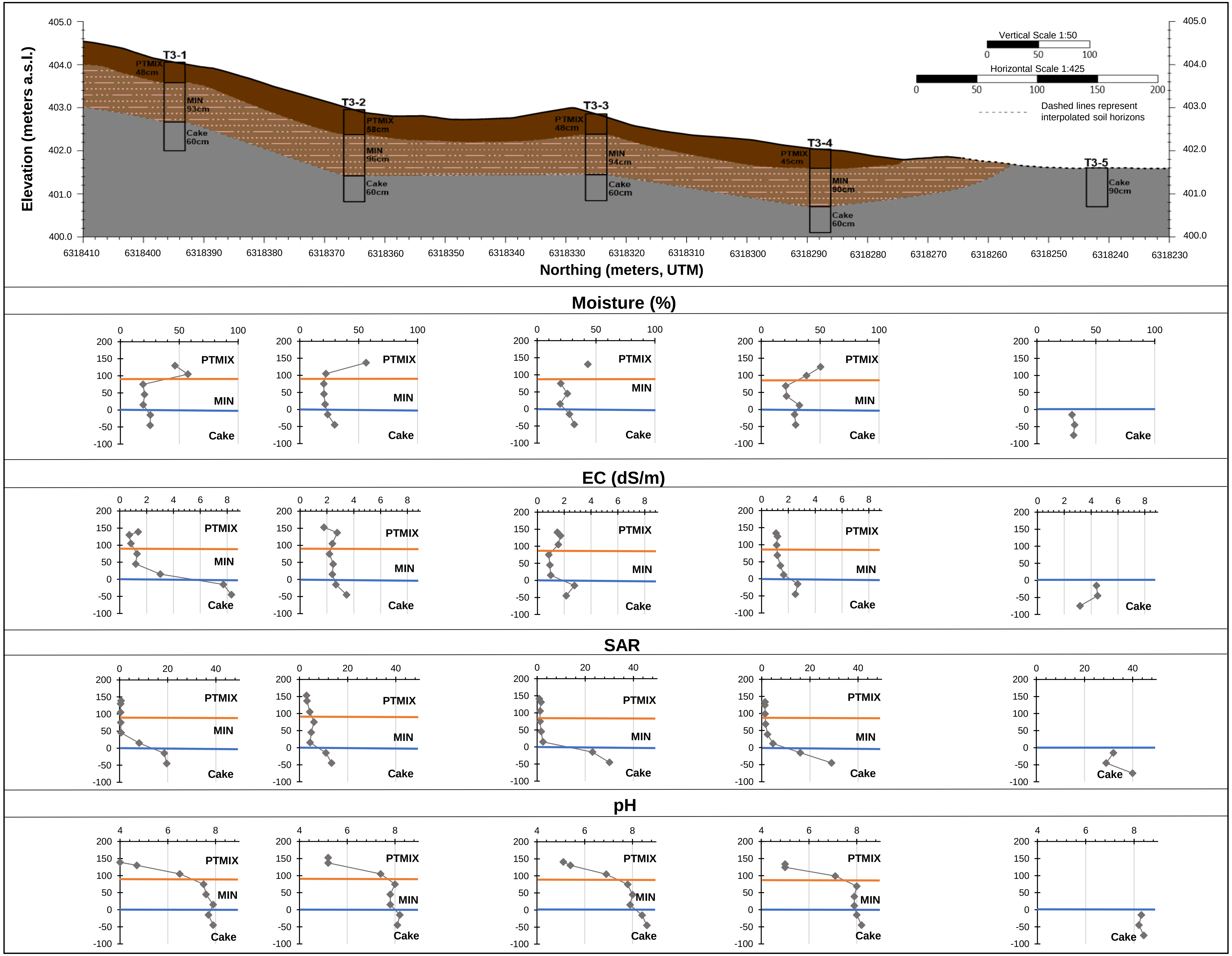
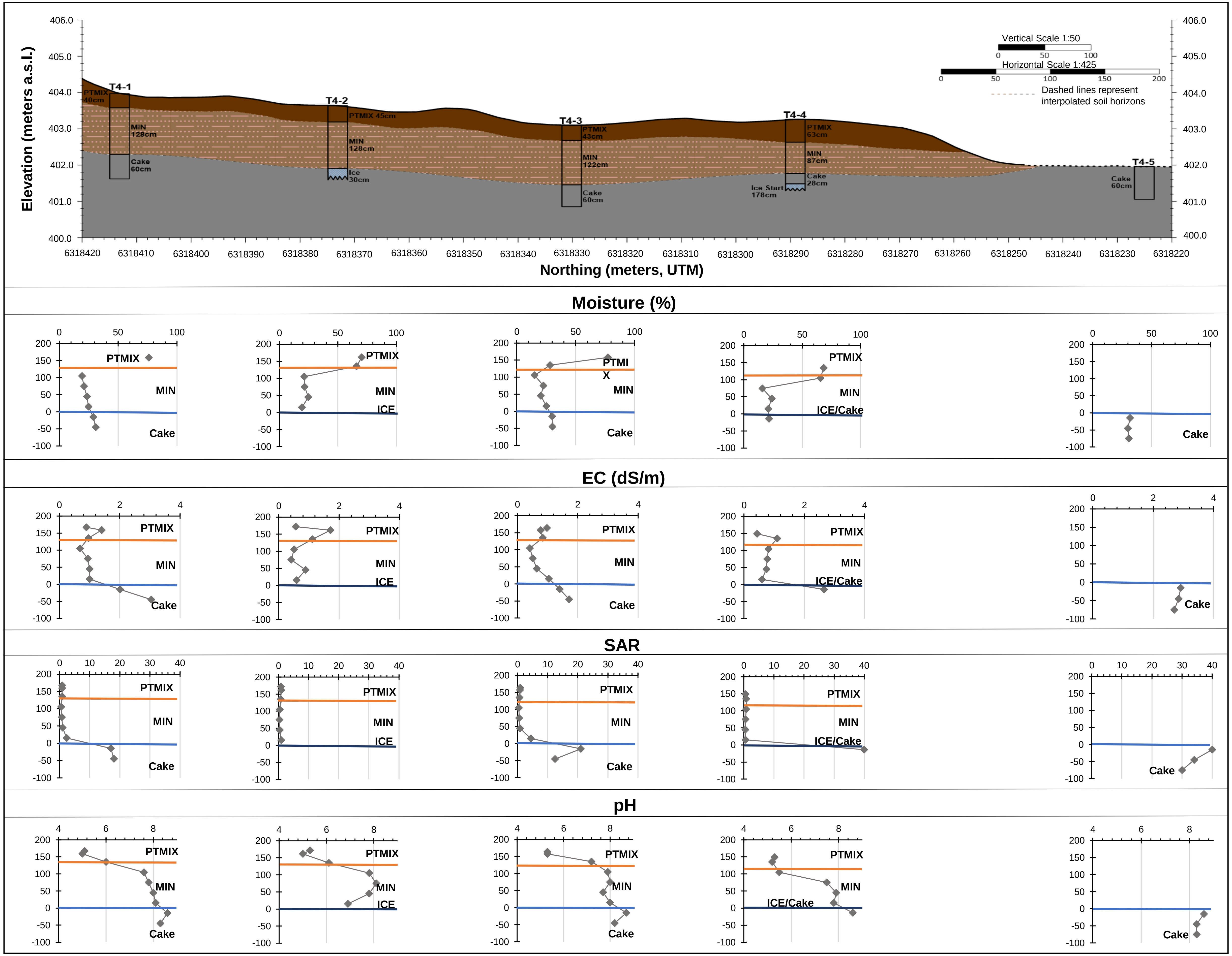


Figure 4. Transect 4 soil cross section and associated chemistry (moisture, electrical conductivity (EC), sodium adsorption ratio (SAR) and pH).



APPENDIX IV – EV CAKE CELL CAPPING DEPTHS

Site	Easting	Northing	Material Type	Capping Depths (cm)			Depth to Ice (cm)
				Coversoil	Mineral	Total Cap	
T1-1	453028	6318580	USS/MIN/Cake	22	110	132	--
T1-2	453017	6318532	USS/MIN/Cake	33	139	172	--
T1-3	453004	6318485	USS/MIN/Cake	28	139	167	--
T1-4	452989	6318440	USS/MIN/Cake	41	137	178	--
T1-5	452971	6318381	USS/MIN/Cake	15	178	193	--
T1-6	452967	6318343	USS/MIN/Cake	17	149	166	--
T1-7	452966	6318303	Cake	--	--	--	--
T2-1	453376	6318497	PTMIX/MIN/Cake	48	93	141	--
T2-2	453373	6318448	PTMIX/MIN/Cake	32	124	156	--
T2-3	453361	6318401	PTMIX/MIN/Cake	37	>118*	>155*	155
T2-4	453351	6318353	PTMIX/MIN/Cake	80	120	200	160
T2-5	453355	6318313	PTMIX/MIN/Cake	47	55	102	--
T2-6	453341	6318259	Cake	--	--	--	--
T3-1	453768	6318395	PTMIX/MIN/Cake	48	92	140	--
T3-2	453760	6318365	PTMIX/MIN/Cake	58	96	154	--
T3-3	453760	6318325	PTMIX/MIN/Cake	48	94	142	--
T3-4	453759	6318288	PTMIX/MIN/Cake	45	90	135	--
T3-5	453753	6318242	Cake	--	--	--	--
T4-1	454147	6318413	PTMIX/MIN/Cake	40	128	168	168
T4-2	454144	6318373	PTMIX/MIN/Cake	45	>158*	>203*	173-203+
T4-3	454144	6318330	PTMIX/MIN/Cake	43	122	165	--
T4-4	454141	6318289	PTMIX/MIN/Cake	63	87	150	178
T4-5	454141	6318225	Cake	--	--	--	--

NOTES: -- denotes parameter not analyzed or not applicable.
* denotes that Cake was not reached due to impenetrable ice

APPENDIX V – DETAILED SALINITY ANALYTICAL RESULTS

			Detailed Salinity (Saturated Paste)																		
			Calcium		Chloride			Magnesium		Potassium		Sodium		Sulfate (SO4)		Sulfate-S		pH	EC	SAR	Moisture
			meq/L	mg/kg	meq/L	mg/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg		dS/m		%
		Detection Limit	0.01		0.06			0.02		0.03		0.04		0.06		0.06			0.01		
		Alberta Tier 1[1] (topsoil)				120*												6.0-8.5	2-4 *(fair)*	4-8 *(fair)*	
		(subsoil)				120*												6.0-8.5	3-5 *(fair)*	4-8 *(fair)*	
Site ID	Sample Description	Depth (cm)																			
T1-1	Surface	0-2	22.2	626	4.00	142*	200	16.5	282	0.30	16	11.0	356	45.1	3060	45.1	1020	5.5	3.22	2.5	--
T1-1	USS	0-12	16.1	681	2.83	100	212	10.1	259	0.27	22	8.4	405	31.2	3160	31.2	1050	5.8	2.46	2.3	78.1
T1-1	USS/MIN	12-42	11.2	137	2.26	80	49	4.87	36	0.10	2	6.0	84	18.1	530	18.1	177	7.7	1.75	2.1	22.7
T1-1	MIN	42-72	7.89	93.8	2.05	73	43	3.43	24.7	0.11	3	4.3	58	12.0	343	12.0	114	7.7	1.33	1.8	20.5
T1-1	MIN	72-102	10.9	130	4.01	142*	85	5.01	36.4	0.13	3	3.5	48	14.8	427	14.8	142	6.4	1.61	1.2	21.2
T1-1	MIN	102-132	14.4	187	4.23	150*	98	6.3	49	<0.26	<7	7.7	116	22.8	712	22.8	237	7.0	2.23	2.4	19.4
T1-1	Cake	132-162	3.5	58	8.01	284*	232	2.7	26	0.60	19	36.7	689	31.3	1230	31.4	409	8.3	3.68	21.0	28.2
T1-1	Cake	162-192	0.74	13	9.00	319*	278	0.6	6	0.38	13	28.9	580	18.4	770	18.4	257	8.3	2.66	35.0	29.2
T1-2	Surface	0-2	3.56	217	2.07	73	225	2.54	93.9	0.90	108	0.9	64	4.7	691	4.7	230	5.2	0.73	0.5	--
T1-2	USS	0-22	11.2	518	2.20	78	181	8.42	236	0.59	53	3.4	183	19.0	2120	19.0	706	5.0	1.70	1.1	59.7
T1-2	USS/MIN	22-52	9.57	117	3.89	138*	84	3.91	28.8	0.21	5	4.9	69	11.3	331	11.3	110	7.4	1.53	1.9	20.6
T1-2	MIN	52-82	3.96	43.8	2.79	99	55	1.41	9.4	0.27	6	4.1	53	4.8	126	4.8	42.1	7.7	0.93	2.5	17.9
T1-2	MIN	82-112	6.08	72.9	4.28	152*	91	2.22	16.1	0.29	7	5.4	75	7.4	214	7.4	71.2	7.3	1.27	2.7	18.6
T1-2	MIN	112-142	4.82	48.3	4.19	149*	74	1.68	10.2	0.31	6	5.1	59	6.1	148	6.1	49.2	8.0	1.13	2.8	16.9
T1-2	MIN	142-172	5.74	61.4	5.04	179*	95	1.97	12.7	0.29	6	6.1	75	6.7	173	6.7	57.6	7.8	1.30	3.1	18.5
T1-2	Cake	172-202	0.83	13.7	6.36	225*	187	0.5	5.1	0.34	11	17.9	342	10.2	409	10.3	136	8.5	1.95	22.0	28.6
T1-2	Cake	202-232	1.04	23.9	3.58	127*	146	0.46	6.4	0.25	11	9.9	262	5.5	305	5.5	102	8.6	1.16	11.5	24.4
T1-3	Surface	0-2	9	182	2.48	88	89	5.78	70.7	0.39	15	3.6	84	14.3	696	14.3	232	6.3	1.48	1.3	--
T1-3	USS	0-17	14.6	310	3.21	114	121	8.93	115	<0.26	<9	6.6	162	25.0	1280	25.0	425	6.6	2.18	1.9	45.1
T1-3	USS/MIN	17-47	12.5	158	2.42	86	54	4.89	37.5	0.26	6	5.3	77	18.5	562	18.5	187	7.8	1.78	1.8	16.4
T1-3	MIN	47-77	13.5	142	2.50	89	47	5.02	32	0.50	10	4.8	58	20.3	515	20.3	172	8.0	1.87	1.6	15.5
T1-3	MIN	77-107	14.2	181	3.61	128*	82	5.5	43	0.42	11	6.7	99	22.4	687	22.4	229	8.0	2.08	2.1	23.4
T1-3	MIN	107-137	13.3	188	4.72	167*	118	5.2	44	0.46	13	7.0	114	19.7	665	19.7	222	7.5	2.10	2.3	26.6
T1-3	MIN	137-167	10.3	120	5.60	199*	116	3.76	26.6	0.53	12	7.7	103	16.4	460	16.4	153	8.0	1.91	2.9	16.4
T1-3	Cake	167-197	2.55	38.8	5.67	201*	153	1.28	11.8	0.38	11	16.5	289	12.3	451	12.4	150	8.1	1.99	11.9	25.7
T1-3	Cake	197-227	2.5	37	8.53	302*	217	1.6	14	0.52	14	24.9	411	20.0	687	20.0	229	8.1	2.77	17.0	29.5
T1-4	Surface	0-2	2.8	39.4	0.64	23	16	1.73	14.7	0.09	3	2.8	46	2.7	91.9	2.7	30.6	6.9	0.58	1.9	--
T1-4	USS	0-28	5.9	82.2	2.44	87	60	4.21	35.5	0.11	3	4.7	76	9.8	329	9.8	110	6.6	1.22	2.1	24.5
T1-4	USS/MIN	28-58	5.84	66.1	1.37	49	28	2.54	17.4	0.18	4	3.6	47	8.5	230	8.5	76.6	7.7	1.03	1.8	17.7
T1-4	MIN	58-88	2.99	34.8	0.83	29	17	1.48	10.4	0.18	4	2.8	37	4.0	111	4.0	37	7.7	0.65	1.8	15
T1-4	MIN	88-118	3.08	34.3	0.70	25	14	1.53	10.3	0.08	2	2.4	31	4.0	106	4.0	35.4	7.3	0.63	1.6	15.6
T1-4	MIN	118-148	4.76	54.2	2.98	106	60	2.00	13.8	0.22	5	4.2	56	5.8	157	5.8	52.5	7.7	1.02	2.3	17.5
T1-4	MIN	148-178	6.1	65	5.47	194*	103	3.10	20	0.10	2	7.4	90	7.2	184	7.2	61.4	7.0	1.47	3.4	18.3
T1-4	Cake	178-208	1.2	23	9.83	349*	330	0.83	9.5	0.31	12	21.6	471	8.8	402	8.8	134	8.3	2.18	22.0	26.6
T1-4	Cake	208-238	0.88	18	10.2	362*	362	0.70	9	0.44	17	27.5	636	16.2	782	16.2	261	8.5	2.59	31.0	26.4
T1-5	Surface	0-2	16.4	284	2.45	87	75	10.4	108	<0.26	<9	13.2	261	33.8	1400	33.8	467	5.3	2.53	3.6	--
T1-5	USS	0-13	12.5	211	1.75	62	52	5.95	61.1	0.16	5	7.3	143	20.6	840	20.7	280	6.1	1.91	2.4	34.1
T1-5	USS/MIN	13-43	14.6	201	1.97	70	48	7.6	63	<0.26	<7	11.8	187	26.5	878	26.6	293	7.6	2.20	3.6	21.4
T1-5	MIN	43-73	9.73	137	1.01	36	25	5.5	47	<0.26	<7	13.0	211	24.1	816	24.1	272	8.1	2.09	4.7	22
T1-5	MIN	73-103	9.67	126	1.01	36	23	5.2	41	<0.26	<7	13.1	196	24.8	777	24.9	259	8.2	2.22	4.8	16.3
T1-5	MIN	103-133	9.85	149	2.56	91	69	5.6	51	<0.26	<8	13.7	239	24.8	901	24.8	300	8.0	2.31	4.9	22.4
T1-5	MIN	133-163	10.5	185	2.01	71	63	6.5	69	<0.26	<9	15.8	320	28.0	1190	28.0	396	7.8	2.46	5.4	21.3
T1-5	MIN	163-193	8.76	138	2.83	100	79	5.8	56	<0.26	<8	15.2	276	23.8	903	23.9	301	7.7	2.35	5.6	17.4
T1-5	Cake	193-208	2.3	35	7.24	257*	191	1.5	14	<0.26	<7	20.0	342	13.5	481	13.5	160	8.5	2.22	14.0	24.4
T1-5	Cake	208-238	1.1	23	8.47	300*	334	0.8	10	0.33	14	24.3	623	15.0	804	15.0	268	8.7	2.49	25.0	26.4

			Detailed Salinity (Saturated Paste)																		
			Calcium		Chloride			Magnesium		Potassium		Sodium		Sulfate (SO4)		Sulfate-S		pH	EC	SAR	Moisture
			meq/L	mg/kg	meq/L	mg/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg		dS/m		%
		Detection Limit	0.01		0.06			0.02		0.03		0.04		0.06		0.06			0.01		
		Alberta Tier 1[1] (topsoil)				120*												6.0-8.5	2-4 *(fair)*	4-8 *(fair)*	
		(subsoil)				120*												6.0-8.5	3-5 *(fair)*	4-8 *(fair)*	
Site ID	Sample Description	Depth (cm)																			
T1-6	Surface	0-2	6.22	148	1.12	40	47	2.67	38.5	0.16	8	4.5	124	11.3	649	11.3	216	5.7	1.16	2.1	--
T1-6	USS	0-16	12.6	366	0.98	35	50	6.56	115	0.22	12	5.2	174	22.4	1560	22.4	519	5.1	1.84	1.7	35.7
T1-6	USS/MIN	16-46	10.7	144	1.21	43	29	4.71	38.3	0.12	3	7.6	118	19.1	619	19.1	206	7.7	1.83	2.8	--
T1-6	MIN	46-76	9.33	141	0.97	34	26	5.7	52	<0.26	<8	16.6	288	28.4	1030	28.4	343	8.0	2.46	6.1	17.2
T1-6	MIN	76-106	9.12	128	0.93	33	23	6	51	<0.26	<7	17.5	282	29.4	991	29.4	330	7.8	2.60	6.4	20.6
T1-6	MIN	106-136	9.05	108	1.41	50	30	5.8	42	<0.26	<6	18.1	250	29.2	840	29.2	280	7.8	2.57	6.6	18.8
T1-6	MIN	136-166	13.5	160	3.76	133*	79	7.6	55	<0.26	<6	18.5	251	33.3	948	33.4	316	8.0	2.96	5.7	23.8
T1-6	Cake	166-196	1.6	31	10.4	369*	353	1.2	14	0.32	12	26.8	590	14.7	677	14.7	226	8.2	2.79	23.0	30.2
T1-6	Cake	196-226	3.2	58	10.0	355*	317	2.2	24	0.37	13	33.7	692	27.3	1170	27.3	390	8.2	3.49	20.0	32.9
T1-7	Cake	0-30	6.61	105	11.3	401*	319	3.8	37	0.62	19	37.6	691	32.5	1240	32.5	415	7.7	4.02	16.5	29.8
T1-7	Cake	30-60	0.92	19	11.4	404*	421	0.7	9	0.49	20	29.0	693	17.1	853	17.1	284	8.3	2.83	32.0	28.3
T1-7	Cake	60-90	0.78	9.9	13.3	472*	300	0.6	4	0.41	10	26.9	394	13.6	417	13.6	139	8.4	2.75	33.0	33.9
T2-1	Surface	0-2	12.3	1470	2.90	103	615	9.46	683	<0.26	<60	18.0	2470	36.0	10300	36.0	3440	4.2	2.98	5.5	--
T2-1	PTMIX	0-21	23.7	945	6.14	218*	433	11.8	285	<0.26	<20	17.4	798	45.3	4330	45.4	1440	4.9	3.53	4.1	69.7
T2-1	PTMIX/MIN	21-51	9.98	744	2.46	87	325	5.47	247	0.15	22	9.1	778	20.8	3720	20.8	1240	5.8	1.94	3.3	71.5
T2-1	MIN	51-81	4.67	78	1.76	62	52	2.64	26.7	0.05	2	6.9	133	10.5	419	10.5	140	8.1	1.25	3.6	22
T2-1	MIN	81-111	10	130	2.57	91	59	5.09	40.1	0.08	2	8.2	123	18.5	579	18.5	193	7.8	1.83	3.0	20.3
T2-1	MIN	111-141	5.86	87.1	1.66	59	44	2.96	26.6	0.08	2	7.4	127	12.6	450	12.6	150	8.1	1.39	3.5	22.7
T2-1	Cake	141-171	6.17	100	3.67	130*	105	3.2	31	0.37	12	21.0	391	23.7	921	23.7	307	8.2	2.51	9.7	25.9
T2-1	Cake	171-201	17.8	256	13.7	486*	349	8.83	76.9	0.65	18	54.8	907	64.4	2220	64.5	742	8.1	6.48	15.0	25.5
T2-2	Surface	0-2	6.83	205	1.24	44	66	4.43	80.4	0.13	8	5.3	184	14.4	1040	14.4	345	5.2	1.38	2.2	--
T2-2	PTMIX	0-6	11.8	153	1.36	48	31	6.91	54.2	0.08	2	4.1	61	21.1	657	21.1	219	5.0	1.74	1.3	24.3
T2-2	PTMIX/MIN	6-36	9.25	118	1.77	63	40	5.54	42.8	0.09	2	3.9	57	16.4	503	16.4	168	5.6	1.50	1.4	23.7
T2-2	MIN	36-66	15.2	231	5.74	204*	154	7.1	65	<0.26	<8	6.7	117	20.8	757	20.8	252	7.6	2.16	2.0	--
T2-2	MIN	66-96	20.2	272	0.68	24	16	8.36	68.1	<0.26	<7	5.9	92	31.5	1020	31.5	340	7.8	2.33	1.6	20.9
T2-2	MIN	96-126	9.96	149	0.71	25	19	5.66	51.3	<0.26	<1	2.7	47	14.8	533	14.8	178	7.4	1.41	1.0	19.6
T2-2	MIN	126-156	5.88	72.2	1.53	54	33	3.77	28.1	0.12	3	2.6	37	10.6	312	10.6	104	5.1	1.08	1.2	19.1
T2-2	Cake	156-186	13.5	227	10.1	358*	301	7	71	0.52	17	34.0	656	41.9	1690	42.0	564	7.6	4.18	10.6	27.9
T2-2	Cake	186-216	11.5	184	12.4	440*	350	6.2	59	0.40	12	41.0	754	44.1	1690	44.1	564	7.8	4.88	13.8	28.4
T2-3	Surface	0-2	5.23	360	0.56	20	68	3.37	140	0.12	16	2.1	164	9.5	1570	9.5	522	4.6	0.92	1.0	--
T2-3	PTMIX	0-35	4.8	270	0.49	17	49	3.26	111	0.20	22	2.4	152	9.4	1270	9.4	425	4.5	0.92	1.2	57.8
T2-3	PTMIX/MIN	35-65	8.33	135	0.53	19	15	3.76	36.8	0.12	4	3.0	55	11.3	439	11.3	146	7.6	1.21	1.2	30.2
T2-3	MIN	65-95	8.06	122	0.47	17	13	3.73	34.2	0.09	3	3.5	61	12.7	462	12.7	154	8.0	1.22	1.4	24.4
T2-3	MIN	95-125	9.09	148	0.34	12	10	5.03	49.5	0.07	2	4.6	86	16.6	649	16.6	216	7.9	1.51	1.7	24.7
T2-3	MIN	125-155	14.5	258	0.35	12	11	8.95	96.1	<0.26	<9	8.4	171	29.8	1270	29.8	424	7.7	2.20	2.4	21.7
T2-4	Surface	0-2	5.28	200	0.99	35	66	3.64	83.4	0.20	14	1.4	62	8.9	809	8.9	270	4.9	0.91	0.7	--
T2-4	PTMIX	0-20	3.97	179	0.42	15	34	2.48	67.8	0.15	13	1.1	59	6.9	743	6.9	248	4.7	0.70	0.6	45.6
T2-4	PTMIX	20-50	2.58	180	0.88	31	109	1.61	67.9	0.15	20	1.1	85	4.0	669	4.0	223	4.8	0.53	0.7	44.7
T2-4	PTMIX	50-80	5.54	667	2.95	105	631	4.07	297	0.20	47	3.8	521	10.5	3040	10.5	1010	4.9	1.24	1.7	52.7
T2-4	MIN	80-110	9.15	135	3.48	123*	91	3.27	29.2	0.08	2	7.1	121	14.6	517	14.6	172	7.7	1.69	2.9	24.2
T2-4	MIN	110-140	6.85	125	3.47	123*	112	3	33.1	0.12	4	10.3	216	15.5	680	15.5	227	7.8	1.77	4.6	25.1
T2-4	MIN	140-170	7.33	119	4.09	145*	118	3.4	33	<0.26	<8	12.3	229	17.9	699	18.0	233	7.9	2.02	5.3	23.4
T2-4	MIN	170-200	3.66	59.3	2.33	83	67	1.6	15.6	0.12	4	7.6	142	9.0	349	9.0	116	8.1	1.22	4.7	20.6
T2-4	Cake	200-230	10.7	213	9.76	346*	346	6.1	74	0.79	31	37.8	869	43.1	2070	43.1	689	7.9	4.60	13.0	26
T2-4	Cake	230-260	6.81	131	11.1	394*	378	3.9	46	0.73	27	40.8	902	38.9	1800	38.9	599	7.4	4.37	17.6	28.4

			Detailed Salinity (Saturated Paste)																		
			Calcium		Chloride			Magnesium		Potassium		Sodium		Sulfate (SO4)		Sulfate-S		pH	EC	SAR	Moisture
			meq/L	mg/kg	meq/L	mg/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg		dS/m		%
		Detection Limit	0.01		0.06			0.02		0.03		0.04		0.06		0.06			0.01		
		Alberta Tier 1[1] (topsoil)				120*												6.0-8.5	2-4 *(fair)*	4-8 *(fair)*	
		(subsoil)				120*												6.0-8.5	3-5 *(fair)*	4-8 *(fair)*	
Site ID	Sample Description	Depth (cm)																			
T2-5	Surface	0-2	4.64	137	1.74	62	91	2.89	51.6	0.08	4	1.5	51	7.0	496	7.0	165	4.6	0.84	0.8	--
T2-5	PTMIX	0-12	10.1	318	3.20	113	179	6.7	128	0.17	10	2.9	104	16.3	1230	16.3	411	4.4	1.60	1.0	43.2
T2-5	PTMIX	12-42	7.66	390	3.44	122*	310	4.88	150	0.25	25	2.2	130	11.3	1380	11.3	461	5.5	1.31	0.9	55.8
T2-5	PTMIX/MIN	42-72	12.3	135	4.56	162*	88	3.86	25.6	0.23	5	6.2	78	17.0	447	17.0	149	7.7	1.88	2.2	17.5
T2-5	MIN	72-102	10.4	110	4.22	150*	79	3.36	21.5	0.19	4	6.5	79	15.4	391	15.4	130	7.7	1.76	2.5	17.2
T2-5	Cake	102-132	5.38	68.1	3.06	108	69	1.57	12.1	0.18	4	8.3	121	11.2	342	11.2	114	8.1	1.46	4.4	18.1
T2-5	Cake	132-162	6.48	73.6	6.35	225*	128	2.7	19	0.27	6	22.9	299	24.5	669	24.5	223	8.0	2.87	11.0	23.6
T2-6	Cake	0-30	10.3	217	17.0	603*	633	6.5	82	0.79	33	48.7	1180	48.5	2450	48.6	817	8.0	5.72	16.8	30.3
T2-6	Cake	30-60	0.92	22	11.9	422*	508	0.84	12	0.55	26	33.8	939	20.9	1220	21.0	405	8.4	3.48	36.1	29.3
T2-6	Cake	60-90	0.61	14	14.0	496*	585	0.5	8	0.48	22	33.1	894	19.0	1070	19.1	358	8.4	3.37	44.0	29.2
T3-1	Surface	0-2	9.75	508	0.50	18	46	5.3	167	0.33	34	1.7	100	15.6	1950	15.6	651	4.0	1.36	0.6	--
T3-1	PTMIX	0-20	4.6	203	0.28	10	22	2.45	65.4	0.16	14	0.7	36	6.9	733	6.9	244	4.7	0.70	0.4	46.4
T3-1	PTMIX/MIN	20-50	6.22	120	0.43	15	15	2.44	28.7	0.18	7	0.9	20	4.3	200	4.3	66.5	6.5	0.83	0.4	57.4
T3-1	MIN	50-80	10.9	129	1.43	51	30	3.49	25	0.15	3	1.3	17	12.1	345	12.2	115	7.5	1.28	0.5	19.3
T3-1	MIN	80-110	9.64	121	1.42	50	31	2.93	22.2	0.17	4	1.6	23	11.2	336	11.2	112	7.6	1.19	0.6	20.6
T3-1	MIN	110-140	11.5	153	3.11	110	73	4	32	<0.26	<7	22.5	343	33.2	1060	33.2	353	7.9	3.01	8.1	19.4
T3-1	Cake	140-170	18.1	449	3.89	138*	171	12.2	183	1.30	63	72.6	2070	100.0	5960	100.0	1990	7.7	7.72	18.6	25.5
T3-1	Cake	170-200	20	458	6.14	218*	249	13	180	1.40	63	79.5	2090	107.0	5890	107.0	1960	7.9	8.32	19.6	25.4
T3-2	Surface	0-2	8.2	590	2.76	98	352	5.59	244	0.21	30	7.6	633	18.3	3160	18.3	1050	5.2	1.78	2.9	--
T3-2	PTMIX	0-34	15.3	292	6.64	235*	225	10.9	126	0.30	11	11.4	250	30.7	1410	30.7	469	5.2	2.77	3.1	56.3
T3-2	PTMIX/MIN	34-64	13.2	188	4.51	160*	114	4	35	<0.26	<7	12.5	206	23.6	808	23.6	269	7.4	2.40	4.3	22.1
T3-2	MIN	64-94	10.2	136	3.36	119	79	2.8	22	<0.26	<7	15.3	234	21.3	684	21.3	228	8.0	2.19	6.0	20.4
T3-2	MIN	94-124	12.9	162	4.28	152*	95	3.5	27	<0.26	<6	14.0	202	25.5	769	25.6	256	7.8	2.46	4.9	20.5
T3-2	MIN	124-154	13.8	194	3.80	135*	94	3.7	31	<0.26	<7	13.0	210	25.6	862	25.6	287	7.8	2.41	4.4	21.5
T3-2	Cake	154-184	6.1	92.4	5.33	189*	143	2.5	23	0.34	10	22.2	386	23.3	850	23.4	283	8.2	2.67	11.0	23.6
T3-2	Cake	184-214	7.18	106	9.98	354*	262	3.1	28	0.43	13	30.0	512	29.2	1040	29.2	347	8.1	3.46	13.3	29.6
T3-3	Surface	0-2	9.53	603	0.46	16	51	7.03	269	0.11	14	2.6	188	18.4	2800	18.4	933	5.1	1.49	0.9	--
T3-3	PTMIX	0-22	9.6	518	3.15	112	300	7.2	235	0.54	57	4.5	280	18.3	2370	18.3	789	5.4	1.73	1.6	43.1
T3-3	PTMIX/MIN	22-52	10.9	263	3.82	135*	163	4.62	67.2	0.20	9	3.3	90	11.4	656	11.4	219	6.9	1.56	1.2	--
T3-3	MIN	52-82	4.92	59.9	2.33	83	50	1.87	13.7	0.13	3	2.2	31	5.1	149	5.1	49.6	7.8	0.85	1.2	20
T3-3	MIN	82-112	4.65	63.1	2.53	90	61	1.84	15.1	0.12	3	3.1	49	6.0	194	6.0	64.8	8.0	0.93	1.7	25.7
T3-3	MIN	112-142	4.64	62	2.45	87	58	1.65	13.3	0.10	3	4.2	64	6.5	209	6.5	69.6	7.9	0.99	2.4	19.5
T3-3	Cake	142-172	1.4	20	7.22	256*	188	0.97	8.7	0.37	11	25.2	426	19.0	671	19.0	224	8.4	2.76	23.0	27.4
T3-3	Cake	172-202	0.56	12	8.17	290*	304	0.4	5	0.36	15	20.4	492	13.0	657	13.0	219	8.6	2.14	30.0	31.5
T3-4	Surface	0-2	5.44	234	2.12	75	162	3.53	91.9	0.18	15	2.9	144	9.9	1020	9.9	341	5.0	1.08	1.4	--
T3-4	PTMIX	0-21	6.26	166	2.44	87	115	4	64.2	0.10	5	2.9	88	11.1	710	11.2	237	5.0	1.19	1.3	50.4
T3-4	PTMIX/MIN	21-51	7.1	135	3.24	115	109	2.45	28.2	0.12	5	3.1	68	7.1	321	7.1	107	7.1	1.13	1.4	38.5
T3-4	MIN	51-81	6.86	89.2	4.51	160*	104	2.13	16.8	0.14	4	3.3	49	7.1	220	7.1	73.3	8.0	1.18	1.6	20.8
T3-4	MIN	81-111	7.9	96.1	6.07	215*	131	2.27	16.7	0.13	3	5.5	77	8.0	234	8.0	77.9	7.9	1.41	2.4	21.5
T3-4	MIN	111-135	6.35	87.3	6.16	218*	150	1.76	14.6	0.10	3	9.5	150	9.9	328	10.0	109	7.9	1.65	4.7	32.5
T3-4	Cake	135-165	3	41	9.84	349*	232	1.3	10	<0.26	<7	24.1	369	16.1	515	16.1	172	8.0	2.70	16.0	28.3
T3-4	Cake	165-195	0.76	15	10.2	362*	358	0.5	6	0.32	12	23.1	525	15.9	756	16.0	252	8.2	2.53	29.0	29.3
T3-5	Cake	0-30	2.1	44	19.9	706*	736	1.8	22	0.47	19	45.3	1090	25.0	1260	25.0	419	8.3	4.40	32.0	29.7
T3-5	Cake	30-60	2.4	51	19.1	677*	717	2	25	0.60	25	43.0	1050	27.8	1410	27.8	471	8.2	4.49	29.0	31.9
T3-5	Cake	60-90	0.6	13	13.4	475*	523	0.5	7	0.47	20	29.8	757	18.9	999	18.9	333	8.4	3.17	40.0	31.2

Site ID	Sample Description	Depth (cm)	Detailed Salinity (Saturated Paste)																		Moisture
			Calcium		Chloride			Magnesium		Potassium		Sodium		Sulfate (SO4)		Sulfate-S		pH	EC	SAR	
			meq/L	mg/kg	meq/L	mg/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg	meq/L	mg/kg		dS/m		%
		Detection Limit	0.01		0.06			0.02		0.03		0.04		0.06		0.06			0.01		
		Alberta Tier 1[1] (topsoil)				120*												6.0-8.5	2-4 *(fair)*	4-8 *(fair)*	
		(subsoil)				120*												6.0-8.5	3-5 *(fair)*	4-8 *(fair)*	
T4-1	Surface	0-2	5.02	251	0.29	10	26	3.56	108	0.15	15	1.7	95	9.9	1180	9.9	395	5.1	0.89	0.8	--
T4-1	PTMIX	0-18	9.2	633	0.34	12	42	6.56	273	0.11	14	2.2	177	16.9	2800	16.9	934	5.0	1.40	0.8	76.1
T4-1	PTMIX/MIN	18-48	5.16	176	1.00	35	60	3.89	80.3	0.21	14	1.8	69	8.0	658	8.0	219	6.0	0.96	0.8	--
T4-1	MIN	48-78	4.54	65.2	1.42	50	36	1.84	16	0.04	1	0.8	14	4.0	136	4.0	45.5	7.6	0.68	0.5	19.3
T4-1	MIN	78-108	6.32	87.4	2.60	92	64	2.36	19.7	0.12	3	1.4	23	6.6	218	6.6	72.6	7.8	0.94	0.7	21
T4-1	MIN	108-138	6.34	86.9	2.73	97	66	2.24	18.5	0.15	4	2.0	32	7.0	231	7.0	76.9	8.0	1.00	1.0	23.6
T4-1	MIN	138-168	4.8	66.5	2.36	84	58	1.64	13.7	0.12	3	4.1	66	7.1	237	7.1	79.1	8.1	1.00	2.3	24.8
T4-1	Cake	168-198	1.4	28	5.09	180*	180	0.87	11	<0.26	<10	18.6	428	13.0	626	13.0	209	8.6	2.01	17.0	28.9
T4-1	Cake	198-228	2.8	48	10.7	379*	326	1.6	17	0.40	13	27.1	536	19.1	786	19.1	262	8.3	3.04	18.0	31
T4-2	Surface	0-2	3.16	112	0.30	11	19	2.05	44	0.05	4	1.3	52	5.5	470	5.5	157	5.3	0.56	0.8	--
T4-2	PTMIX	0-23	12.3	686	0.26	9	25	8.26	278	0.13	14	2.8	180	22.9	3070	23.0	1020	5.0	1.71	0.9	70.4
T4-2	PTMIX/MIN	23-53	7.46	184	0.93	33	41	4.11	61.4	0.16	8	1.7	48	11.0	652	11.0	217	6.1	1.11	0.7	66
T4-2	MIN	53-83	3.31	42.4	0.43	15	10	1.24	9.6	0.11	3	0.6	9	2.8	85	2.8	28.3	7.8	0.51	0.4	21.2
T4-2	MIN	83-113	2.84	31.3	0.53	19	10	0.93	6.2	0.11	2	0.5	6	2.2	57.9	2.2	19.3	8.1	0.41	0.3	21.5
T4-2	MIN	113-143	6.17	96	2.99	106	83	2.3	21.6	0.13	4	0.9	15	5.1	191	5.1	63.5	7.8	0.89	0.4	24.7
T4-2	MIN	143-173	3.48	43.7	1.50	53	33	1.2	9.2	0.09	2	1.3	19	3.0	89.9	3.0	30	6.9	0.59	0.9	19.3
T4-3	Surface	0-2	5.94	223	1.48	52	99	3.73	84.6	0.10	8	2.0	84	9.7	869	9.7	290	5.3	0.98	0.9	--
T4-3	PTMIX	0-15	4.42	169	0.65	23	44	2.77	64	0.10	7	1.6	69	7.8	718	7.8	239	5.3	0.77	0.8	77.3
T4-3	PTMIX/MIN	15-45	5.85	82.4	1.72	61	43	2.3	19.6	0.12	3	1.1	18	4.4	149	4.4	49.8	7.2	0.84	0.6	28.1
T4-3	MIN	45-75	2.75	31.9	1.02	36	21	0.93	6.6	0.07	2	0.6	7	1.6	43.6	1.6	14.5	7.9	0.41	0.4	15
T4-3	MIN	75-105	3.23	36.7	1.32	47	27	1.12	7.7	0.09	2	0.7	9	2.2	59.2	2.2	19.7	8.0	0.51	0.5	22.6
T4-3	MIN	105-135	4.17	49	2.33	83	49	1.28	9.1	0.12	3	1.3	17	2.2	62.6	2.2	20.9	7.7	0.64	0.8	20.3
T4-3	MIN	135-165	3.14	38.5	3.89	138*	85	1.01	7.5	0.11	3	6.4	90	3.8	112	3.8	37.5	8.0	1.04	4.4	25
T4-3	Cake	165-195	0.48	11	4.86	172*	193	0.26	3.5	0.20	9	12.7	326	6.0	323	6.0	108	8.7	1.40	21.0	30
T4-3	Cake	195-225	1.86	32.7	4.54	161*	142	0.75	8	0.23	8	14.2	286	9.8	413	9.8	138	8.2	1.71	12.4	30.2
T4-4	Surface	0-2	2.42	98.7	0.47	17	34	1.43	35.2	0.18	14	0.9	41	3.6	352	3.6	117	5.3	0.43	0.6	--
T4-4	PTMIX	0-30	7.3	285	0.37	13	26	4.5	106	0.13	10	2.0	89	12.4	1160	12.4	388	5.2	1.10	0.8	68.3
T4-4	PTMIX	30-60	4.65	235	0.67	24	60	3.03	92.5	0.14	13	1.5	86	7.9	959	7.9	320	5.5	0.81	0.8	65.6
T4-4	PTMIX/MIN	60-90	5.15	68.4	2.90	103	68	1.74	14	0.18	5	1.0	16	2.9	91.7	2.9	30.6	7.5	0.77	0.6	15.9
T4-4	MIN	90-120	5.15	61.8	3.09	110	66	1.59	11.6	0.16	4	1.0	13	3.1	88.6	3.1	29.5	7.9	0.74	0.5	23.9
T4-4	MIN	120-150	3.81	58.5	1.91	68	52	1.17	10.8	0.14	4	0.9	16	2.1	78.7	2.1	26.2	7.8	0.59	0.6	21
T4-4	Cake	150-178	0.52	9.9	10.10	358*	338	0.4	4	0.27	10	25.4	551	11.9	539	11.9	180	8.6	2.65	40.0	21.6
T4-5	Cake	0-30	0.53	11	10.50	372*	374	0.4	5	0.36	14	28.0	647	14.4	696	14.4	232	8.6	2.91	40.0	31.8
T4-5	Cake	30-60	0.68	15	8.36	296*	315	0.6	7	0.46	19	27.2	665	16.6	850	16.7	283	8.3	2.84	34.0	30.1
T4-5	Cake	60-90	0.78	16	8.72	309*	324	0.6	8	0.46	19	25.2	607	18.7	939	18.7	313	8.3	2.70	30.0	30.8

NOTES: -- denotes parameter not analyzed or not applicable.

* According to Alberta Tier 1 Guidelines, chloride must be considered when the concentration is greater than 120 mg/L for natural areas.

Highlighting indicates parameter above (or outside the range of) screening level guidelines or established background values but is justified based on Site considerations.

Highlighting indicates parameter above (or outside the range of) screening level guidelines or established background values.

[1] Alberta Environment and Parks (AEP 2019). Alberta Tier 1 Soil and Groundwater Remediation Guidelines.

APPENDIX VI – FULL CHARACTERIZATION ANALYTICAL RESULTS

Site ID	Sample Description	Depth (cm)	Available Nutrients					Micronutrients				CEC	Carbon/Nitrogen				Particle Size Analysis			
			Ammonium - N	Nitrate - N	Phosphorus	Potassium	Sulfate-S	Copper	Iron	Manganese	Zinc	CEC	C:N Ratio	TN	OM	TOC	Texture	Sand	Silt	Clay
			mg/kg	µg/g	µg/g	µg/g	mg/kg	mg/kg				meq/100 g		%				% by weight		
		Detection Limit	0.3	2	5	25	1	0.1	2	0.1	0.5	4	0.1	0.02	0.04	0.04		0.1	0.1	0.1
		Alberta Tier 1[1] (surface)																		
T1-6	USS	0-16	1	<2	6	100	539	1	357	17	<4.9	60	43	0.32	27	13.52	Loam	43	36	21
T1-6	USS/MIN	16-46	--	--	--	--	--	--	--	--	--	13	--	--	--	--	Clay Loam	37	25	38
T1-6	MIN	46-76	--	--	--	--	--	--	--	--	--	20	--	--	--	--	Clay	24	22	54
T1-6	MIN	76-106	--	--	--	--	--	--	--	--	--	20	--	--	--	--	Clay	35	17	48
T1-6	MIN	106-136	--	--	--	--	--	--	--	--	--	19	--	--	--	--	Sandy Clay	47	15	38
T1-6	MIN	136-166	--	--	--	--	--	--	--	--	--	22	--	--	--	--	Clay Loam	38	23	38
T1-6	Cake	166-196	--	--	--	--	--	--	--	--	--	14	--	--	--	--	Clay Loam	20	48	32
T1-6	Cake	196-226	--	--	--	--	--	--	--	--	--	13	--	--	--	--	Clay	18	37	45
T1-7	Cake	0-30	--	--	--	--	--	--	--	--	--	15	--	--	--	--	Silty Clay Loam	18	46	36
T1-7	Cake	30-60	--	--	--	--	--	--	--	--	--	13	--	--	--	--	Silty Clay	11	42	46
T1-7	Cake	60-90	--	--	--	--	--	--	--	--	--	13	--	--	--	--	Clay	16	34	50
T2-2	PTMIX	0-6	0.8	<2	15	45	227	0.9	519	16.9	13	24	24	0.11	4.97	2.49	Sandy Clay Loam	49	21	30
T2-2	PTMIX/MIN	6-36	--	--	--	--	--	--	--	--	--	22	--	--	--	--	Clay Loam	41	22	37
T2-2	MIN	36-66	--	--	--	--	--	--	--	--	--	19	--	--	--	--	Clay	27	30	42
T2-2	MIN	66-96	--	--	--	--	--	--	--	--	--	17	--	--	--	--	Clay Loam	32	30	38
T2-2	MIN	96-126	--	--	--	--	--	--	--	--	--	20	--	--	--	--	Clay	26	18	56
T2-2	MIN	126-156	--	--	--	--	--	--	--	--	--	17	--	--	--	--	Clay	26	22	52
T2-2	Cake	156-186	--	--	--	--	--	--	--	--	--	14	--	--	--	--	Silty Clay Loam	16	46	38
T2-2	Cake	186-216	--	--	--	--	--	--	--	--	--	16	--	--	--	--	Silty Clay	15	42	42
T2-6	Cake	0-30	--	--	--	--	--	--	--	--	--	14	--	--	--	--	Silty Clay Loam	8	56	35
T2-6	Cake	30-60	--	--	--	--	--	--	--	--	--	13	--	--	--	--	Silty Clay	6	44	50
T2-6	Cake	60-90	--	--	--	--	--	--	--	--	--	12	--	--	--	--	Silty Clay	6	49	45
T3-3	PTMIX	0-22	12	<2	6	177	765	2	1070	112	21.2	100	22.7	1.49	67.6	33.8	Loam	50	40	10
T3-3	PTMIX/MIN	22-52	--	--	--	--	--	--	--	--	--	32	--	--	--	--	Clay Loam	34	36	30
T3-3	MIN	52-82	--	--	--	--	--	--	--	--	--	12	--	--	--	--	Clay Loam	38	30	32
T3-3	MIN	82-112	--	--	--	--	--	--	--	--	--	18	--	--	--	--	Clay	28	26	46
T3-3	MIN	112-142	--	--	--	--	--	--	--	--	--	13	--	--	--	--	Clay Loam	36	28	36
T3-3	Cake	142-172	--	--	--	--	--	--	--	--	--	14	--	--	--	--	Clay Loam	28	33	38
T3-3	Cake	172-202	--	--	--	--	--	--	--	--	--	13	--	--	--	--	Clay	24	31	45
T3-5	Cake	0-30	--	--	--	--	--	--	--	--	--	17	--	--	--	--	Silty Clay Loam	15	50	35
T3-5	Cake	30-60	--	--	--	--	--	--	--	--	--	14	--	--	--	--	Clay	21	36	42
T3-5	Cake	60-90	--	--	--	--	--	--	--	--	--	14	--	--	--	--	Silty Clay	15	40	45
T4-1	PTMIX	0-18	2	3	19	64	710	3.1	1130	59.8	52.8	110	22.8	1.6	73	36.48	--	--	--	--
T4-1	PTMIX/MIN	18-48	--	--	--	--	--	--	--	--	--	71	--	--	--	--	Clay Loam	35	35	30
T4-1	MIN	48-78	--	--	--	--	--	--	--	--	--	18	--	--	--	--	Clay	27	30	43
T4-1	MIN	78-108	--	--	--	--	--	--	--	--	--	14	--	--	--	--	Clay	37	23	40
T4-1	MIN	108-138	--	--	--	--	--	--	--	--	--	12	--	--	--	--	Clay Loam	35	27	38
T4-1	MIN	138-168	--	--	--	--	--	--	--	--	--	11	--	--	--	--	Clay Loam	36	28	36
T4-1	Cake	168-198	--	--	--	--	--	--	--	--	--	22	--	--	--	--	Clay	26	33	41
T4-1	Cake	198-228	--	--	--	--	--	--	--	--	--	13	--	--	--	--	Clay	28	32	40
T4-5	Cake	0-30	--	--	--	--	--	--	--	--	--	16	--	--	--	--	Silty Clay	18	42	40
T4-5	Cake	30-60	--	--	--	--	--	--	--	--	--	16	--	--	--	--	Clay	21	39	40
T4-5	Cake	60-90	--	--	--	--	--	--	--	--	--	14	--	--	--	--	Silty Clay	16	43	41

NOTES: -- denotes parameter not analyzed or not applicable.

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[1] Alberta Environment and Parks (AEP 2019). Alberta Tier 1 Soil and Groundwater Remediation Guidelines.

Site ID	Sample Description	Depth (cm)	$CaCO_3$ Equivalent	Petroleum Hydrocarbons									
				Benzene	Toluene	Ethylbenzene	Xylenes (m,p,o)	F1 -BTEX	F2c C10-C16	F3c C16-C34	F4c C34-C50	F4HTGCc C34-C50+	C50+
			%	mg/kg									%
		Detection Limit	0.2	0.005	0.02	0.005	0.03	10	25	50	100	100	
		Alberta Tier 1[1] (surface)		0.046	0.52	0.073	0.99	210	150	1,300	5,600		
T1-6	USS	0-16	0.33	--	--	--	--	--	--	--	--	--	--
T1-6	USS/MIN	16-46	4.44	--	--	--	--	--	--	--	--	--	--
T1-6	MIN	46-76	0.88	<0.005	<0.02	<0.005	<0.03	<10	<25	106	<100	120	13.6
T1-6	MIN	76-106	0.3	<0.005	<0.02	<0.005	<0.03	<10	<25	<50	<100	<100	<5
T1-6	MIN	106-136	0.22	<0.005	<0.02	<0.005	<0.03	<10	<25	<50	<100	<100	<5
T1-6	MIN	136-166	0.94	<0.005	<0.02	<0.005	<0.03	<10	<25	227	152	260	15.1
T1-6	Cake	166-196	1.22	0.365	0.10	0.757	5.17	711	4,810	24,700	10,400	21,300	14.4
T1-6	Cake	196-226	1.69	0.406	0.10	0.225	4.91	646	5,790	31,100	13,100	28,500	15.9
T1-7	Cake	0-30	0.75	0.063	0.09	0.252	0.53	142	4,400	22,700	9,570	21,600	16.8
T1-7	Cake	30-60	0.94	0.581	0.15	1.860	6.24	1,010	5,940	30,700	13,100	27,900	15.5
T1-7	Cake	60-90	1.1	0.563	0.18	0.421	6.61	980	5,540	29,300	12,500	27,800	16.6
T2-2	PTMIX	0-6	<0.20	--	--	--	--	--	--	--	--	--	--
T2-2	PTMIX/MIN	6-36	0.22	<0.005	<0.02	<0.005	<0.03	<10	<25	156	123	213	17.1
T2-2	MIN	36-66	1.57	--	--	--	--	--	--	--	--	--	--
T2-2	MIN	66-96	2.81	<0.005	<0.02	<0.005	<0.03	<10	<25	284	201	335	14.8
T2-2	MIN	96-126	0.51	<0.005	<0.02	<0.005	<0.03	<10	<25	161	148	277	21.6
T2-2	MIN	126-156	<0.20	<0.005	<0.02	<0.005	<0.03	<10	<25	73	<100	<100	15.2
T2-2	Cake	156-186	0.84	0.014	<0.02	0.063	0.20	<10	1,840	14,200	5,850	10,200	10.7
T2-2	Cake	186-216	1.02	0.115	0.11	1.580	1.50	411	4,220	21,600	9,020	17,500	13
T2-6	Cake	0-30	1.02	0.018	0.05	0.048	0.24	<10	2,810	21,200	8,860	16,100	11.8
T2-6	Cake	30-60	1.31	0.040	<0.02	1.400	3.05	472	4,440	25,700	10,900	22,200	14.5
T2-6	Cake	60-90	1.22	0.012	<0.02	0.660	1.43	212	4,100	21,100	9,490	19,700	15.5
T3-3	PTMIX	0-22	0.98	--	--	--	--	--	--	--	--	--	--
T3-3	PTMIX/MIN	22-52	3.64	--	--	--	--	--	--	--	--	--	--
T3-3	MIN	52-82	3.96	<0.005	<0.02	<0.005	<0.03	<10	<25	794	585	1,170	21.2
T3-3	MIN	82-112	2.58	<0.005	<0.02	<0.005	<0.03	<10	<25	146	116	187	14.8
T3-3	MIN	112-142	3.64	<0.005	<0.02	<0.005	<0.03	<10	<25	825	666	1,410	24.3
T3-3	Cake	142-172	2.89	0.008	0.03	0.037	0.12	<10	2,170	13,000	5,820	12,800	17.1
T3-3	Cake	172-202	1.31	0.349	0.09	0.564	7.28	1,230	4,450	22,600	10,000	20,500	14.9
T3-5	Cake	0-30	0.91	0.025	0.02	0.120	0.20	87	1,110	9,630	4,730	8,980	14.5
T3-5	Cake	30-60	0.81	0.145	0.04	1.380	2.79	481	3,070	16,600	7,280	14,100	13.6
T3-5	Cake	60-90	0.78	0.258	<0.02	2.560	5.57	1,440	3,710	19,700	8,730	18,400	15.7
T4-1	PTMIX	0-18	0.7	--	--	--	--	--	--	--	--	--	--
T4-1	PTMIX/MIN	18-48	1.06	--	--	--	--	--	--	--	--	--	--
T4-1	MIN	48-78	1.02	<0.005	<0.02	<0.005	<0.03	<10	<25	354	246	400	13.9
T4-1	MIN	78-108	1.02	<0.005	<0.02	<0.005	<0.03	<10	<25	639	434	779	16.8
T4-1	MIN	108-138	3.64	<0.005	<0.02	<0.005	<0.03	<10	<25	848	549	985	16.3
T4-1	MIN	138-168	3.34	<0.005	<0.02	<0.005	<0.03	<10	<25	428	280	475	14.7
T4-1	Cake	168-198	1.63	<0.005	<0.02	0.158	0.36	231	1,710	8,730	3,730	6,690	11.5
T4-1	Cake	198-228	2.73	<0.005	<0.02	0.102	0.28	166	2,440	12,100	5,240	10,600	14.5
T4-5	Cake	0-30	1.36	<0.005	<0.02	0.145	0.40	177	4,170	21,000	9,480	20,000	15.9
T4-5	Cake	30-60	0.81	0.134	0.04	1.170	5.61	1,310	4,340	21,200	9,410	21,200	17.3
T4-5	Cake	60-90	0.78	0.145	0.04	0.287	5.61	1,420	5,060	24,200	10,800	22,200	15.1

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APPENDIX VII – ANALYTICAL METHODS

Appendix VII. Analytical Methods

All analyses were performed by Element laboratories (Element) and the following methods represent the modified methods utilized by Element.

Detailed Salinity

Saturated paste extraction was used to determine the pH, electrical conductivity (EC), and soluble ion concentrations in each soil sample. The soluble ion concentrations were used to calculate the sodium adsorption ratio (SAR). A minimum of 50 g (50-200 g depending on sample volume) of dried and ground soil was used for the analysis (Exova 2018f; Miller and Curtin 2008). Deionized water was used to saturate each soil sample; typically, at a 2:1 soil to water ratio. Saturated pastes were re-examined after 1 hour to ensure the samples were still at saturation. The saturated paste was allowed to equilibrate for a minimum of four hours, generally overnight. The pH was measured for each sample after thorough mixing using a pH meter. Following pH measurement, the saturated paste was extracted using vacuum filtration through highly retentive filter paper until sufficient filtrate was collected. Electrical conductivity was measured on the filtrate using a conductivity meter. Calcium, magnesium, sodium, K and sulfate concentrations were analyzed on each extract using inductively coupled plasma optical emission spectrometry (ICP-OES; American Public Health Association 2012a; 2012c). Chloride ions were measured using colorimetric techniques on the extract (Exova 2018f; Miller and Curtin 2008). The extracts were stored at 4°C between analyses.

Particle Size Distribution

The hydrometer method was used to determine the particle size distribution in all mineral samples with less than ten percent organic matter (Exova 2018e; Kroetsch et al. 2008). Fifty grams of soil were placed in a graduated cylinder with deionized water and a chemical dispersing agent (Calgon®). The samples were soaked overnight. Each sample was mechanically agitated for two minutes followed by hydrometer readings at 40 seconds and six hours, to determine the percent of sand and clay, respectively (Exova 2018e; Kroetsch et al. 2008).

Carbon and Nitrogen in Soil

Total C and N were determined using the LECO Truspec analyzer using infrared absorption to measure the quantity of the combustion gases; CO2, NOx and N2 (Exova 2018g; Bremner 1996; Nelson et al. 1996). Total N is the sum of the nitrogen compounds that are oxidized in the combustion process to NO2 gas. To determine the organic C concentration within a sample, the quantity of inorganic C must first be determined and is subsequently used to calculate organic C (Total C – Inorganic C = Organic C; Walkey and Black 1934). To determine inorganic C, a separate soil sample was placed in a muffle furnace at 500°C for 2 hours to burn off the organic C (Walkley and Black 1934). The sample was then analyzed for inorganic C colorimetrically.

Organic C was calculated as the difference between total C (determined using the LECO analyzer) and inorganic C. Organic matter concentration was calculated by multiplying the total organic C by two (Exova 2018g; Bremner 1996; Nelson et al. 1996).

Available Nutrients

Exchangeable sulfate, ammonium, nitrate, phosphorus (P) and potassium (K) were analysed to assess the nutrient status of the soils in this program. Sulfate was extracted from 10 g of sample using 20 ml 0.001 N $CaCl_2$ (Exova 2018d; McKeague 1978). Samples were filtered through Whatman #40 filter paper and centrifuged. The analysis was performed using ICP-OES (Exova 2018f; American Public Health Association 2012a; McKeague 1978). Ammonium was extracted from 5 g of sample using 50 ml of 1 N KCl (Exova 2018b; Maynard et al. 2008). The extract was then shaken for 30 minutes followed by centrifugation. Ammonium was measured colorimetrically (Exova 2018b; American Public Health Association 2012b; Maynard et al. 2008).

Exchangeable nitrate, P and K was determined using the Modified Kelowna method (Exova 2018e; American Public Health Association 2012c; Maynard et al. 2008; Alberta Research Council 1996; Ashworth and Mrazek 1995). For nitrate, P and K analysis, 5 g of soil was extracted using a solution of ammonium fluoride, ammonium acetate and acetic acid. In this procedure, all nitrate is reduced to nitrite using granular cadmium coated with copper (Exova 2018e; Maynard et al. 2008). Nitrate and P concentrations were determined colorimetrically (Maynard et al. 2008; American Public Health Association 2012c), whereas K was analyzed using the Automated Flame Photometry Method (Exova 2018e; Alberta Research Council 1996).

Micronutrients in Soil

Micronutrients concentrations of copper, iron, manganese and zinc were determined by extracting 10 g of soil with 20 mL of extracting solution (DTPA [0.005 N diethylenetriamine pentacetic acid, pentasodium salt] -TEA [triethanolamine] in 0.01 N $CaCl_2$ adjusted to pH of 7.30 with HCl; Exova 2018c; McKeague 1981). Samples were shaken continuously for two hours and filtered. The trace element concentrations were determined by ICP-OES (Exova 2018c; American Public Health Association 2012a; McKeague 1981).

Calcium Carbonate Equivalent in Soil

Calcium carbonate equivalent was determined by adding dilute acetic acid to a known weight of soil and measuring the pH after equilibration (Exova 2018a; Ashworth 1997). The carbonate within the soil neutralizes the acid and causes the pH to increase. The final pH of the mixture is converted to a calcium carbonate equivalent (CCE) based on calibrations done using soils with known calcium carbonate concentrations (Exova 2018a; Ashworth 1997).

Cation Exchange Capacity

The exchangeable cation concentrations within soil was determined using the Ammonium Acetate method where 1M ammonium acetate was used to displace exchangeable cations (Exova 2018c; McKeague 1978). The cation exchange capacity was determined by displacing the sorbed ammonium from the first step using 1 N sodium chloride solution and the remained extractant was analyzed for N (Exova 2018c; American Public Health Association 2012a). The quantity of N within the extractant represents the number of sites within the soil sample for the sorption of cations (Exova 2018c; McKeague 1978).

Petroleum Hydrocarbon Fraction 1 (BTEX)

Petroleum hydrocarbon fraction (F) 1 (C6-C10) including benzene, toluene, ethylbenzene and xylenes (BTEX) were determined using the headspace gas chromatograph flame ionization detector (GC-FID) method (CCME 2001; 2016; Element 2019a; EPA 2014; 2017). Approximately 5 g of soil was placed in a vial containing 10 mL of methanol using a Terra Core© sampler in the field. In the laboratory, the samples were heated in the GC-FID to separate the organic compounds. A reference standard was run for comparison. The area counts were integrated to determine the concentration of each constituent.

Petroleum Hydrocarbon Fractions 2 Through 4

Petroleum hydrocarbon F2 through 4 (C10-C50) were determined using a modified version of the Canadian Council of Ministers of the Environment method for hydrocarbons in soil (CCME 2001; 2016). Element utilized the cold-shake method extracted with 50:50 hexane: acetone (Element 2019b). Prior to extraction, the samples were dried with methanol. After extraction, water was used to remove excess acetone. Activated silica gel was used to remove polar material prior to analysis with the GC-FID. If hydrocarbons greater than C50 were identified, high temperature gas chromatography was performed to determine the total concentration of hydrocarbons greater than C34 (F4HTGC).

Soil Moisture

Soil moisture content was determined by weighing out a 10 g sample and placing it in a forced air oven at 105°C for a minimum of 4 hours, or until constant weight (Carter and Gregorich 2008; Element 2019c). The sample was weighed after drying. The difference in weight before and after drying is the moisture (g) and is used to calculate the water content (% by weight).