

FINAL REPORT

**Review and Recommended Changes to the Saturation Paste
Method to Determine Concentrations of Sodium and
Chloride in Muskeg**

**Prepared for:
BC Oil and Gas Research and Innovation Society**

SYNERGYASPEN PROJECT No. MUSK-15-RES

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EXECUTIVE SUMMARY

Muskeg (peat) is currently classified as a soil under the BC regulatory regime. The BC Ministry of Environment (MoE) analytical method for soil matrix grossly overestimates the concentration of salinity in muskeg. Muskeg behaves more like a sponge and is very moist in nature compared to mineral soils, for which the analytical methodology was designed for. Muskeg does not fit into the regulatory definition of media, which currently include water, soil, tissue, and air. As such, there is a need to develop a modified approach in the laboratory analysis for accurately quantifying concentrations of sodium and chloride, specifically for peat matrices like muskeg.

Understanding muskeg, a boreal wetland, as a matrix is an important consideration when performing an analytical characterization of a site. Canada has 35% of the world's peat with the vast majority occurring in the north, including Northeast BC. A total of 11% of Canada's surface area is covered by peat versus 9% covered by waterbodies. Given those numbers, peat is a significant matrix unto itself.

Produced water associated with upstream Oil and Gas (O&G) activity contains high levels of salinity (sodium and chloride) and is a contaminant of concern in the industry. Accurately estimating the concentrations of salinity-contaminated muskeg is critical to environmental clean-up at Oil and Gas sites in BC and elsewhere in Canada.

SynergyAspen applied for and obtained funding from the BC Oil and Gas Research and Innovation Society (BC OGRIS) to complete a review of the analytical method used to determine sodium and chloride concentrations in muskeg.

SynergyAspen Environmental, working with Maxxam Analytics (Maxxam) and CARO Analytical Services (CARO), identified a more accurate analytical method to determine sodium and chloride concentrations in muskeg. SynergyAspen calls the method "Intentional Over-Saturation" (or M4 as identified in this report). The M4 method yielded result with increased accuracy with little to no bias compared to the Saturated Paste Method currently being used by industry.

The intent of the research project was to spike sixteen (16) muskeg samples with known concentrations of produced water, analyze each using the saturated paste method, and calculate concentrations using different laboratory methods:

- Standard Saturated Paste Method (M1/M2);
- As-Received "Squeeze and Analyze" (M3);
- Intentionally Over-Saturate (M4)

It was determined that the current BC regulated laboratory standard method, Saturated Paste methodology, greatly overestimates the sodium and chloride concentrations in a muskeg sample (reported as mg/kg). Newly proposed laboratory procedures, targeting the miscible analytes in the water portion of a muskeg sample (i.e. reporting in mg/L), would eliminate this gross overestimation, and in turn, reduce the falsely identified contamination identified at many Oil and Gas Sites that are located within a muskeg setting.

The following table summarizes the rankings (from best (1) to worst (3)) based on % recovery values (standard deviation and range values).

Test Method Ranking Summary

SODIUM	Standard Saturated Paste^	M3 As-Received (mg/L)	Over Saturate M4a/b* (mg/L)
Standard Deviation	2	3	1
Range (Maximum – Minimum)	2	3	1
CHLORIDE	Standard Saturated Paste^	M3 As-Received (mg/L)	Over Saturate M4a/b* (mg/L)
Standard Deviation	3	2	1
Maximum – Minimum Range	3	2	1

Note: ^Method currently used by industry.

*Based on average values of the Over-Saturated Method (M4a and M4b) results; and,

Bold 1: Ranking as the most ideal result.

As can be observed in the Table above, the over saturated method (M4) produced the best correlation and overall the best data with respect to percent recovery for both the measured analytes (sodium and chloride).

The findings of these experiments are to encourage regulators to examine the need to recognize muskeg as a unique media and update analytical methods to represent with better accuracy salinity concentrations in a muskeg environment.

With this accuracy, SynergyAspen believes there will be enormous benefit to the upstream Oil and Gas industry, not only in cost savings by reducing the amount of muskeg being unnecessarily remediated, without compromising environmental integrity, but also by preserving the natural muskeg setting which takes thousands of years to generate.

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1. INTRODUCTION

SynergyAspen has completed the research on muskeg as presented in the letter of interest (LOI) to BC Oil and Gas Research & Innovation Society (OGRIS - formerly SCEK). A copy of the LOI is in Appendix 1.

Assessment and remediation of remote northern sites in BC have a host of challenges. One of those challenges is characterizing media that do not fit into the regulatory definition of media, which currently include water, soil, tissue, and air. Performing an analytical assessment of samples on a suspect contaminated site requires gathering representative samples and performing standardized methodology to determine if a sample is contaminated and if so, to what degree.

An analytical method that has been developed for one matrix, such as soil, is not easily applicable to different "soil" types, such as peat, which is most often analyzed using a mineral soil approach, based on the current regulatory regime in BC. The BC MoE analytical method for soil matrix grossly overestimates the concentration of salinity in muskeg. Peat samples are particularly challenging as a matrix as peat differs drastically in general characterization from samples traditionally known as mineral soil samples. Like human tissue, it is comprised of two different media. Human tissue is comprised of cells and water, while peat is comprised of water and organics. Yet, unlike human tissue, peat is not recognized as its own media.

More specifically, peat typically contains over 50% moisture content (often closer to 80% for sites SynergyAspen has worked on) compared to mineral soil which has a moisture content closer to 20%. The soil portion of muskeg contains organic matter with limited or no mineral soil. Muskeg behaves more like a sponge and is very moist in nature compared to mineral soils for which the analytical methodology was designed for. Due to these and other underlying general characteristic differences, applying current analytical methodologies developed for mineral soil to peat result in inaccurate characterization of contaminant concentration in peat at a site. Specifically, produced water associated with upstream Oil and Gas activity contains high levels of salinity and is a Contaminant of Concern for the industry. Accurately estimating the concentrations of salinity-contaminated muskeg is critical to environmental cleanup at Oil and Gas sites.

SynergyAspen prepared controlled muskeg samples of known moisture content and salinity concentrations, analyzed them using saturated paste analytical laboratory method, and reported them using four different calculations and variations of the saturated paste method calculations as outlined within this report.

There is a need to develop a modified approach to the laboratory analysis for quantifying salinity contaminant concentrations specifically for peat matrices like muskeg. In general, SynergyAspen's objectives for this research project were to:

- Identify the best analytical calculation methodology to confirm the actual contaminant; and,
- Develop a modified approach to the laboratory analysis of muskeg for quantifying salinity contaminant concentrations. The methodology may then be adapted for other contaminants in muskeg.

2. SATURATED PASTE METHOD & CALCULATION METHODS

The BC MoE Saturated Paste¹ analytical laboratory method was designed for mineral soils. The basis was to normalize all samples by bringing them to saturation prior to extraction for the analysis. The MoE, as per the BC Environmental Laboratory Manual (2013), has defined saturation as follows:

“Add sufficient deionized water while mixing to saturate the soil sample. At saturation, the soil paste glistens, flows slightly when the container is tipped, and slides cleanly from a spatula. A trench carved in the soil surface will readily close upon jarring the container”.

2.1 Saturated Paste

The approved BC MoE saturated paste method includes the following “standard” saturated paste procedure and the “as-received” saturated paste procedure, with the general steps outlined below:

“Standard Dry Saturated Paste Procedure”:

1. Dry the “as received” sample;
2. Grind and homogenize the sample;
3. Chemist hydrates sample to reach saturation to make the saturated paste;
4. Extraction of liquid;
5. Analysis of liquid to obtain a mg/L concentration; and,
6. Convert mg/L to mg/kg using the % saturation ($\text{mg/kg} = \text{mg/L} \times \% \text{ Saturation}$).

Where, % Saturation = (weight of water added / soil dry weight) x 100%.

The results are reported in mg/L and are converted to mg/kg for comparison to the BC Contaminated Sites Regulation (CSR) standards. It should be noted that the point of saturation (i.e. the amount of water added to the sample), is subjective and will vary per chemist (biased procedure), resulting in varied concentrations of the liquid extract.

“The as-received Saturated Paste Procedure”:

- Add water to the soil (as-received) until a saturated paste is created (drying of the sample is not completed);
- Extraction of the liquid;
- Moisture content of sub-sample is completed to calculate Saturation %;
- Convert mg/L to mg/kg using % saturation (if comparing to BC CSR soil standards).

The as-received method is an alternative method suggested within the Saturated Paste Methodology for soils that are over-saturated in their “as received” state. The allowance is for high moisture content soil, but these soils are defined as having a “freeboard” of water on top of the soil. This is not the case for muskeg, as it behaves like a sponge, and there is no water at its surface. The method allows for

¹ BC MoE Environmental Monitoring, Reporting & Economics, Sampling, Methods and Quality Assurance, British Columbia Environmental Laboratory Manual: 2013

bypassing the “taking the sample to saturation” step and proceeding directly with the extraction. However, based on discussions with analytical laboratories, this alternative method is not typically used on muskeg or peat soils, as they do not meet the definition of over-saturated. As such, they are treated like a mineral soil in their analysis for the Saturated Paste method. The amount of water that a muskeg can absorb is quite substantial, and to reach saturation generally requires an additional volume of water, leading to saturation typically ranging from 300-700%. This percent saturation affects the conversion to the salinity dry weight concentrations by grossly overestimating them by up to twenty times.

2.2 Calculation Methods

SynergyAspen prepared controlled samples of known moisture content and salinity concentrations and analyzed them using the BC MoE Saturated Paste analytical laboratory method or an alternative method put forth by SynergyAspen as follows:

M1 – Dry Soil Weight Method– This is the unmodified approved BC MoE analytical Saturated Paste Method as prescribed, where;

$$C_{salM1} = \frac{\text{mass of salt (mg)}}{\text{dry weight of muskeg (kg)}}$$

The mg/L salinity concentration determined through saturation paste is multiplied by % saturation to obtain a mg/kg value for comparison to the Contaminated Sites Regulation (CSR) soil standards.

M2 – Lab-Water Wet Soil Weight Method– This "wet weight" method is not currently approved by regulation. However, based on work completed by Mr. Mark Hugdahl of ALS Environmental Canada (ALS); this method is considered by industry as an alternative to the dry weight method for salinity parameters, where;

$$C_{salM2} = \frac{\text{mass of salt (mg)}}{\text{Volume of water added in lab to create the saturated paste (L)}}$$

The above equation is the mg/L concentration derived in the Saturated Paste Method and has been used in “multiple lines of evidence risk based arguments” in support of Certificate of Restoration (CoRs) applications to the OGC. The M2 result has been directly compared to the soil standard (and not multiplied by the percent saturation to obtain a mg/kg concentration as per M1) for muskeg samples where the moisture content is >50% and the percent saturation is >100%. It was thought that this would provide a more accurate representation of salinity concentration within muskeg and has been accepted as one line of evidence (in conjunction with other lines of evidence) by the Oil and Gas industry for assessing salinity in muskeg environments. Further, a presentation provided by Mark Hugdahl of ALS, “Issues with BC CSR Salt Standards in Peat Soils Related to Saline Produced Water” at the WaterTECH 2013 conference, outlines strong evidence that supports a solution based salt standard (mg/L) for sodium and chloride in peat samples.

New Methods Suggested by SynergyAspen:

M3 – Wet Soil Weight Method (“As Received Method”) - An alternative focussing on representing the water content of true sample condition with no lab intrusion. This method involves the completion of the Saturated Paste method on the sample as received and does not include bringing the sample to saturation prior to water extraction (i.e. squeeze and analyze), where:

$$C_{salM3a} = \frac{\text{mass of salt (mg)}}{\text{total muskeg sample weight (kg)}} \\ \text{(i.e. sample water and muskeg)}$$

The above equation is the new proposed calculation by SynergyAspen, which we hypothesized would be more representative of the actual sample matrix by taking into account the two matrices within muskeg (i.e. water and organics). However, during this process it was realized that this method does not account for the loss of water from the muskeg sample in the field during the sampling process (see water loss bias description below). To account for this issue, the M3a approach was updated to measure only the water concentrations of the sample. The analysis would include “squeezing” the as received sample and reporting as mg/L.

$$C_{salM3b} = \frac{\text{mass of salt (mg)}}{\text{Litre}}$$

It should be noted that a major issue with the M3b method was that water could not be “squeezed” from samples with less than approximately 80% moisture content.

Based on the results of the above methods, SynergyAspen surmised an alternate approach to the M3b analysis to determine if a better approach could be validated. The M4 approach utilizes an alternative approach for “over-saturated” soils. It assumes that all the samples were all “over-saturated” and did not require building the saturated paste, allowing for analysis to proceed directly to the extraction of the filtrate. The following M4 procedure was followed for analysis of these samples:

M4 – Intentionally Add Water Method (“Over-Saturated Method”)

The M4 method was not initially part of intended scope of work of this research project. However, upon completion of the M1, M2 and M3 methods, with lessons learned through analysis of the data, SynergyAspen hypothesized another approach with the intent to remove the inherit biases and/or shortcomings of the M1 through M3 methods.

The M4 analysis method included the addition of de-ionized water in one of two ways (“over saturate method”):

M4a – Intentionally Add Water (mg/L) – Add deionized water to achieve 90% moisture then extract the water, analyze and report eh concentration (mg/L) as undiluted; and,

M4b – Intentionally Add Water (mg/L) – Add 100 ml of deionized water to approximately 20 g of wet muskeg sample and analyze the extract, reporting the concentration (mg/L) as undiluted.

It appears that the Saturated Paste Method defined in the BC Environmental Laboratory Manual allows for the “as-received” and “over-saturated” methods to be used without a change to the Manual or to Regulation.

SynergyAspen compared results produced by all four methods and compared them to the known baseline spiked concentrations of the contaminant. This determined which method best represented the “spiked” and known contaminant concentration. At the onset of this research, SynergyAspen postulated that the third method (M3a) would produce sample concentrations closest to true concentrations, and that the current methodology (M1) would produce the furthest. However, this presumption occurred prior to the initiation of methods M3b and M4 (a & b).

2.3 Biases of the Calculation Methods

1) M1 – Dry Soil Weight Method (“kg denominator bias”)

$$C_{salM1} = \frac{\text{mass of salt (mg)}}{\text{dry weight of muskeg (kg)}}$$

Given that the denominator is based on the dry weight of the muskeg (not the actual in field wet weight), the denominator is greatly reduced when high moisture content samples are dried (i.e. sample mostly water weight). The resulting calculation grossly over estimates the concentration of contaminant for soils that have a moisture content >50%, such as muskeg. Please refer to Appendix III for a graphical representation of contaminant concentration versus soil moisture content. Referring to this graph, we can observe, as described above, the effect of measuring a contaminant on a dry weight basis (drying sample as per M1) versus using the wet weight of the sample, which would also include the water weight of the sample. For example, there is an approximate 5 time increase in contaminant concentration for a muskeg sample with a moisture content of 80% and a 10 time contaminant concentration increase for a muskeg sample with a moisture content of 90%.

2) M2 – Lab-Water Wet Soil Weight Method (Litre denominator bias)

$$C_{salM2} = \frac{\text{mass of salt (mg)}}{\text{Volume of water added in lab to create the saturated paste (L)}}$$

In the saturated paste method, the amount of water added by the chemist to the dried and ground sample to create the saturated paste is subjective, and this subjective end point forms the denominator in the equation. Additionally, the amount of water added to the sample in the lab is not related to the water content present in the sample collected in the field. Based on these two points, the laboratory measured mg/L measure is not relatable to true muskeg sample concentrations.

3) Loss of Water During Sampling

Based on the high moisture content of a typical muskeg sample, it is SynergyAspen’s experience that water from the sample can be unintentionally and unavoidably lost from muskeg during the sample collection. Due to its sponge-like qualities, any squeezing of the muskeg sample (i.e. during collection from drilling auger, placement into sample jar, etc.), could result in water loss from the sample. Further, if the moisture content is high enough, and depending on the physical characteristics of said sample, water could be lost from the sample simply due to gravity while transferring the sample into the sample jar (i.e. water drips from sample prior to placement into sample jar). If water loss does occur, the miscible parameters (such as sodium and chloride) would be lost along with the water, effectively lowering the total mass of the contaminant. In turn, the numerator in the mg/kg calculation (mg of contaminant) would be reduced, biasing the results low.

4) Percent Saturation Accuracy

Eight muskeg samples were prepared by Maxxam; two as "bone dry" and the other six at set percent moisture content values of 20%, 40%, 50%, 60% (one sample and duplicate) and 80%. Maxxam completed the standard saturated-paste saturation on each sample and reported the final jar weights at saturation. Calculating the amount of deionized water already in the sample, and the amount of deionized water added during pasting, the percent saturation was calculated and is presented in Table 13. The percent Saturation calculated, ranged from 605 to 726 % for the same muskeg sample type, with a standard deviation of over 38. Given the wide range of percent Saturation values, it is clear that muskeg is a difficult material to saturate consistently. This may also be a function of the type of muskeg. The samples collected for this experiment were stick-like and woody in nature compared to some of the more fine organics and muskegs. The sponge effect may vary in the different types of muskeg.

3. FIELD SAMPLE COLLECTION AND BACKGROUND ANALYSIS

3.1 Sample Collection

The muskeg samples were collected from two oil and gas well sites located in the Elleh field, approximately 55 km southeast of Fort Nelson and 55 km East of Fort Nelson in the Sextet field. The samples were collected off the well site in the native muskeg and are considered to be representative of native soils where no anthropogenic activities previously occurred. The produced water was obtained from a local independent gas producer in the Fort St John area.

Two independent laboratories were commissioned to assist with this research: Maxxam Analytics and CARO Analytical. They were each given a muskeg sample with a volume of one 5 gallon pail to complete the analyses detailed below. The muskeg sample depths are noted in Table A.

Table A: Muskeg and Produced Water Sample IDs

Sample ID	Location	Sample Depth (mbg ¹)	Shipped to:
S1-BH1	Site 1, Sextet Field, Background BH1	0 to 3 mbg	CARO lab
S1-BH2	Site 1, Sextet Field, Background BH2	0 to 3 mbg	Maxxam Lab
S2-BH1	Site 2, Elleh Field Background BH1	0 to 1.8 mbg	CARO lab
PW15-1	Produced Water	-	3 gallon to each lab
PW15-2	Produced Water	-	Maxxam

¹ mbg – meters below grade

3.2 Establishing Background Concentrations

A sub sample of S1-BH1 and S1-BH2 were analyzed by CARO and Maxxam, respectively. A specific scope of work was described to the two laboratories; however, the methods between the two labs were not consistent, and as such, a direct comparison was not possible. Based on our intended scope of work, the Maxxam data was most representative of our defined scope of work, and as such, Maxxam's data is discussed and the CARO data was excluded. The following parameters were analyzed by Maxxam:

- Salinity parameters (sodium, chloride, SAR, EC) using BC MoE saturated paste methodology. M1 and M2 methods concentrations; and,
- Moisture content.

The PW15-1 and PW15-2 were analyzed by Maxxam for:

- salinity parameters (sodium, chloride, SAR, EC);
- specific density and gravity; and,
- BETX, VPH, EPHw, EHW.

The following table summarizes background data for these samples. Analytical laboratory reports can be found in Appendix IV.

Table B: Summary of Background Sample Data

Parameter	Maxxam		
	S1BH1	PW15-1	PW15-2
MUSKEG			
% Saturation	627		
Sodium - M1/M3a (mg/Kg)	1,170	-	-
Sodium – M2 (mg/L)	187	-	-
Sodium – M3b/M4a/M4b (mg/L)	134		
Chloride – M1 (mg/Kg)	173	-	-
Chloride – M2(mg/L)	27.6	-	-
Chloride – M3b/M4a/M4b (mg/L)	32.3		
Sodium (mg/L)	-	52,900	39,200
Chloride (mg/L)	-	110,000	85,000

The particular muskeg sample that was used for this experiment is described as bark, mulchy, stick-like and was not homogeneous. This non-homogeneous product would account for some variability in the background concentration, and in turn the percent recovery.

Based on the above produced water results, the produced water spike concentrations used in the experiments were determined to be as follows:

Table C: Produced Water Spike Dilutions

Concentrations	Spike Strength
C1	Straight Produced water
C2	x5 dilution of C1
C3	x10 dilution of C1
C4	x25 dilution of C1

4. LABORATORY PROCEDURES – MUSKEG PREPARATION

Three iterations of tests were completed during this muskeg investigation:

1. The M1/M2/M3a analysis (April/May 2015);
2. The M3b analysis (August 2015); and,
3. The M4a and M4b analysis (September 2015).

The following methodology was completed by Maxxam (April/May test), an independent accredited BC laboratory. Muskeg Prep:

- a. Dry muskeg sample;
- b. Grind and homogenize the dry muskeg sample;
- c. Create sixteen (16) subset samples of dried muskeg;
- d. Added distilled water to each, to create four samples for each of the following moisture contents: 60%, 70%, 80% and 90%; and,
- e. Add the spike concentrations per Table D below:
 - The produced water spike added to the sample was not pre-mixed given that during the saturated paste testing, the methodology ensured a well-mixed sample (i.e. deionized water addition, vigorous stirring, further deionized, more stirring).

Table D: Proposed Sample Matrix for Salinity Analysis

Concentration (mg/L)	Moisture Content			
	60%	70%	80%	90%
C1 - Produced Water (undiluted)	Sample 1	Sample 5	Sample 9	Sample 13
C2 – 2x dilution of C1	Sample 2	Sample 6	Sample 10	Sample 14
C3 – 5x dilution of C1	Sample 3	Sample 7	Sample 11	Sample 15
C4 – 10x dilution of C1	Sample 4	Sample 8	Sample 12	Sample 16

➤ S#: Sample number

It should be noted that a second set of muskeg samples were created for the August and September test runs, where points d. and e. were combined into one step (i.e. spike and deionized water mixed together and added to muskeg sample). This update to the methodology was completed as the extensive mixing that occurs during the saturation paste testing does not occur for the M3b and M4 methods and we did not want to create a potential bias by generating a “hot spot” within the sample (i.e. poor mixing resulting in area(s) of high analyte concentration).

4.1 M1/M2/M3a Preparation

Maxxam prepared 16 muskeg samples, per the sample matrix in Table D. Details on the composition (deionized water, dry muskeg and spike volumes) of each sample is provided in Table 1, attached.

Maxxam applied a constant background concentration of salinity to all 16 samples, based on the background salinity concentration within a 20g aliquot of S1-BH1 muskeg sample prior to splitting into the subset samples. Maxxam used the background sample’s data (which potentially could be different from the other 20g aliquots used for the 16 sub samples), applying it consistently to all samples.

Maxxam presumed this would be the best unbiased way to account for the background salinity. This is further supported by the fact that the background estimates are nowhere near the saturation concentrations, and the concentrations are all higher than the grade of deionized water used.

In May 2015, Maxxam analyzed each of the 16 samples using the Saturated Paste methodology to obtain M1 and M2 concentrations. An M3a concentration was also calculated using the M1 and M2 results and composition details of the samples (See Tables 1 to 3, 8 and 9 for sample build and final results).

4.2 Alternate M3 Method – M3b Preparation

Based on the results mentioned above, SynergyAspen undertook an alternate approach for the M3 analysis. The M3b approach utilized an alternative approach and in July 2015, Maxxam created 16 new samples with the S1BH1 muskeg sample, and using the assumption that the samples did not require building the saturated paste, and proceeded directly to the extraction and subsequent analysis of the filtrate. The following M3b procedure was followed for analysis of these samples:

- Drying the muskeg
- Pre-mixing the deionized water and spike to achieve the desired moisture contents. The deionized and spike were pre-mixed to avoid any potential “contaminant hot spots” within the muskeg that may affect the concentration of the extract obtained from the samples. In comparison, during the saturated paste method, there is a lot of mixing to homogenize the spike and deionized water within the muskeg samples, compared to this alternative M3b method.
- Building the samples, as presented in Table 4, attached.
- “Pressing” the liquid out of the wet samples and analysing for parameters in mg/L concentrations. Maxxam identified that physical squeezing of the sample was a bit messy and impractical, so they subsequently used a vacuum filtration through Whatman 113 filters to collect liquid.
 - Unfortunately, the eight samples of the 60% and 70% moisture range had bound their spiked water aliquots too tightly, and no liquid could be recovered. Sufficient liquid was recovered from the 80% and 90% moisture content samples and could proceed with analysis.
- Analysis in mg/L of recovered liquid.

Maxxam identified that for the 60% and 70% moisture content samples, the 20g of dry muskeg sample completely imbibed the added liquid (spike + deionized water) and would not release more than a drop or two under strong vacuum filtration. At the moisture content of 80%, using approximately 80ml combined liquid to add to the 20g samples, only 7-10g of filtrate was obtained. This is significantly different to the M1/M2 saturated paste method as it added approximately 200-300 ml of deionized water to the 70% moisture sample, as such; there was significantly more available water to extract for analysis.

4.3 Additional Methods – M4a & M4b Preparation

Based on the inherent biases of adding a subjective amount of deionized water to create a saturated paste, the loss of sample water during in-field sampling of the muskeg (M1, M2, M3a biases), and the issue of obtaining extract from muskeg samples with a moisture of less than 80% (M3b method), two alternative approaches were put forth; M4a and M4b.

M4a – Intentionally Add Water (mg/L) – Add deionized water to achieve 90% moisture then extract the water and analyze as undiluted; or,

M4b – Intentionally Add Water (mg/L) – Add 100 ml of deionized water to approximately 20 g of “as received” west muskeg sample, then extract the water and analyze as undiluted.

The M4 procedure included bulking two sets of the 60% and 70% test samples of the M3b procedure (no 80% or 90% moisture base samples remained). One set was bulked to 90% moisture content and the other set altered by adding 100 ml of deionized water (total of 16 samples – See Table 7 for sample “build”). The resulting samples included:

- Four 60% and four 70% moisture content samples (eight total) bulked to 90% moisture;
- Four 60% and four 70% moisture content samples (eight total) bulked by adding 100 ml water.

Both portions were then vacuum-filtered and the liquid extract analysed. This procedure, unlike the M3b procedure, would require a back calculation to report an undiluted mg/L concentration, which is easily completed as a known measured volume of water is added.

The M4a method requires the determination of the percent moisture of the sample in order to calculate the amount of deionized water needed to build the sample to the 90% moisture content. This is not required for the M4b method.

5. RESULTS

The following summarizes the three iterations of tests completed during this muskeg investigation.

1. The M1/M2/M3a analysis (April/May 2015);
2. The M3b analysis (August 2015); and,
3. The M4a and M4b analysis (September 2015).

Below is a brief outline of the results, including the standard deviation of the percent recovery and the range of percent recovery. It should be noted that the ideal data would provide 100% analyte recovery with a zero range of % recovery (see Table 12).

5.1 M1/M2/M3a Results

Table 1 outlines the initial laboratory tests completed in April and May of 2015, summarizing the Sample “Build” for the M1, M2 and M3a methods. Tables 2 and 3 identify the sodium and chloride results for the 16 samples for the Saturated Paste experiments, presenting the M1, M2 and M3a concentrations (mg/kg or mg/L).

It should be noted that the M1 and M2 reported values are based on the same laboratory procedure and are directly related as follows:

$$M1 \text{ (mg/kg)} = M2 \text{ mg/L} \times \% \text{Saturation}$$

Based on this direct relationship and that M1 and M3a are both reported in mg/kg, the relationship between M1 and M3a is appropriate for comparison. The M2 values, reported in mg/L, are not directly comparable to the M3a results.

As can be observed in Tables 2, 3, 9 and 10, the M1 data is always larger than the M3a data. As outlined in Table E below (and as outlined graphically in Appendix III), based on the moisture content of the sample, the M1 values are a specific multiple larger than the M3a values.

Table E: M1 vs. M3 - Multiples

Sample	Sodium: M1/M3a	Chloride: M1/M3a
C1/C2/C3/C4 60%M	2.7	2.7
C1/C2/C3/C4 70%M	3.6	3.6
C1/C2/C3/C4 80%M	5.2	5.2
C1/C2/C3/C4 90%M	10.2	10.2

The M1 and M3a calculated standard deviation and range of percent recovery details, for the sodium and chloride results, are summarized in Table F below and in Table 12 in the Tables Appendix.

5.2 M3b Results

Table 4 outlines the Sample “Build” for the M3b method with Tables 5 and 6 outlining the sodium and chloride results for the 8 samples of the “Squeeze and Analyze” method (M3b). A comparison of the M3b results (mg/L) will be included in the following sections, relating the other mg/L reported methods to the M3b method.

As stated previously, this “squeeze and analyze” method would not release any liquid extract during laboratory filtration for samples with 60% and 70% moisture. As such, only reported values for the 80%

and 90% moisture samples were obtained. The M3b calculated standard deviation and range of percent recovery details, for the sodium and chloride results, are summarized in Table F below.

5.3 M4a and M4b Results

Table 7 outlines the Sample “Build” for the M4a and M4b methods with Tables 10 to 11 summarizing the sodium and chloride results for all mg/L reported concentrations, including the M4a and M4b.

Referring to Table F below and Table 12 in the Tables Appendix, it can be observed that the standard deviation and range values are similar for the M4a and M4b methods, potentially indicating that both methods would consistently produce similar results. It should also be noted that in every circumstance, the reported values are most ideal for the M4 method versus the other methods.

As a summary, the following table outlines the average percent recovery, a summary of all of the standard deviations and percent recovery range values for the M1 through M4 methods (also see Table 12 in the Tables Appendix).

Table F: Test Method Summary – Standard Deviation and Ranges

SODIUM	M1/M2	M3b	M4a	M4b
Standard Deviation	19.3	30.9	16.1	15.8
Range of % Recovery	56.0 – 124.8	81.7 – 171.7	93.5 – 136.0	102.3 – 148.7
Maximum – Minimum Range	68.8	90.0	42.5	46.4
CHLORIDE	M1/M2	M3b	M4a	M4b
Standard Deviation	16.4	12.6	5.3	6.0
Range of % Recovery	63.5 – 120.4	89.2 – 131.4	86.0 – 101.9	87.8 – 106.3
Maximum – Minimum Range	56.9	42.2	15.9	18.5

Note: the M3a data is not presented on this table as the test was not completed as an individual test, but rather it was calculated based on the standard saturated paste method and M1/M2 values.

The grey shading in the table above identifies the two (2) “best” results for the standard deviation and the smallest range in percent recovery values. As can be observed, in every circumstance, Methods M4a or M4b were shaded.

All the Maxxam analytical reports are presented in Appendix IV. It is noted that Maxxam also analyzed other salinity analytes (e.g. calcium, magnesium, potassium and sulphur) during select method analysis; however, evaluation of these results was beyond the scope of this project.

6. DISCUSSION

Muskeg is currently classified as a soil under the BC regulatory regime, and as outlined within this report, the current MoE analytical method for analysis of a high moisture content “soil” matrix (i.e. muskeg), greatly overestimates contaminant concentration. The primary goal of this investigation was to identify a laboratory method for quantifying contaminant concentrations in high moisture content soil samples, specifically for peat matrices like muskeg.

To understand which of the methods described within this report are most appropriate to characterize the true concentration of an analyte in a muskeg sample, the following section examines each method, searching for issues or biases that would affect the final result.

6.1 Biases

The standard saturated paste method includes drying the sample, grinding the sample and adding deionized water until a saturated paste is achieved. The liquid is then extracted from the paste and analyzed, reporting the concentration in mg/L (M2 value), converting the mg/L to mg/kg (M1 value) via multiplication of the M2 value by percent saturation. As previously described throughout this report, there are several inherent biases with this method, as outlined below:

- 1) *M1 – Dry Soil Weight Method (kg denominator bias)* – High moisture content soil samples create a large bias (overestimation) when the lab results are reported in mg/kg;
- 2) *M2 – Lab-Water Wet Soil Weight Method (Litre denominator bias)* – The M2 method reports the mg/L concentration of the saturated paste extraction. However, this mg/L concentration is created by adding a subjective quantity of deionized water to the dried sample, resulting in an arbitrary mg/L concentration, unrelated to the original muskeg sample concentration;
- 3) Loss of water during sample collection; and,
- 4) Muskeg percent saturation accuracy.

M1 – Dry Soil Weight Method (Saturated Paste Method)

$$C_{salM1} = \frac{\text{mass of salt (mg)}}{\text{dry weight of muskeg (kg)}}$$

The M1 method is affected by all 4 of the above mentioned biases.

- Method: Dry sample, grind and homogenize sample, saturate soil, analyze extracted water (mg/L).
- The mg/L salinity concentration is multiplied by % saturation to obtain a mg/kg value. The % saturation is a subjective end point;
- The mg/kg value grossly over estimates the concentration of contaminant for soils that have a moisture content (using dry weight of sample);
- The method does not address water and salt loss during sample collection; and,

- Calculations are dependant of percent saturation values, which are difficult to complete accurately for muskeg samples.

M2 – Lab-Water Wet Soil Weight Method (Saturated Paste Method)

$$C_{salM2} = \frac{\text{mass of salt (mg)}}{\text{Volume of water added in lab to create the saturated paste (L)}}$$

The M2 method is affected by two of the above mentioned biases (#2 and #3).

- Method: Dry sample, grind and homogenize sample, saturate soil, analyze extracted water (mg/L). This is the same mg/L value from the M1 method.
- The mg/L salinity concentration obtained during saturated paste is a subjective end point; and,
- Method does not address water & salt loss during sample collection.

It should be noted that the reported units are mg/L, which are not directly comparable to the current BC mg/kg standards.

M3a – Wet Soil Weight Method (“As-Received Method”)

$$C_{salM3a} = \frac{\text{mass of salt (mg)}}{\text{total muskeg sample weight (kg) (i.e. sample water + muskeg)}}$$

- Method: Complete saturated paste on sample as received and do not bring it to saturation as per M1 and M2.

Advantages:

- Recognizes muskeg as a two media structure (water and organics);
- Removes potential bias for denominator by not using volume of water added by chemist; and,
- Units are mg/kg and can be directly compared to a soil standard.

Biases:

- Method does not address water and salt loss during sample collection.

M3b – Wet Soil Weight Method (“As-Received Method”)

To account for this water and salt loss during sample collection, the M3a approach was updated to only measure the water concentrations of the sample (mg/L). With this approach the loss of the water, which alters the mass of the salt and total sample weight, does not affect the reported concentration of the salts. The analysis included “squeezing” the sample and reporting as mg/L.

$$C_{salM3b} = \frac{\text{mass of salt (mg)}}{\text{Litre}}$$

The identified four biases are not an issue with this method. However, samples with moisture contents of less than approximately 80% could not be analyzed as the “squeezing” of the sample did not produce enough extract to analyze.

M4 – Intentionally Add Deionized Water Method (“Over-Saturated Method”)

To address muskeg samples with moisture contents less than 80%, a predetermined volume of deionized water was added in one of two methods. It should be noted, that upon initiation of this project, methods M3b, M4a and M4b were not planned for. However, through lessons learned and a more complete understanding of the biases associated with Methods M1 through M3a, we adapted to include these additional laboratory methods.

The M4 analysis method includes the addition of de-ionized water in one of two ways:

M4a – Intentionally Add Water (mg/L) – Add deionized water to achieve 90% moisture then extract the water and analyze as undiluted; or,

M4b – Intentionally Add Water (mg/L) – Add 100 ml of deionized water then extract the water and analyze as undiluted.

Given the amount of deionized water added in each of these tests is known, a back calculation is required to determine the undiluted mg/L concentration. If the analyte is miscible in water (such as sodium and chloride), an accurate measure of said analyte is measured in the extract.

The addition of the deionized water during the M4 method removes the low moisture content sample issue associated with method M3b. Further, both of the M4 methods do not appear to be susceptible to the four identified biases.

Based on the results of the above methods, SynergyAspen determined the “actual” and “theoretical” sodium and chloride concentration, and in turn the percent recovery. Tables 8 and 9 compare the sodium and chloride M1 and M3a results, which are both reported as mg/kg. Tables 10 and 11 compare the sodium and chloride results for M2, M3b, M4a and M4b, which are all reported as mg/L. A summary of the standard deviation and range of percent recovery data for all tests are summarized in Table 12.

6.2 Comparison of mg/kg Reported Methods (M1 & M3a) - Saturated Paste Method

In April and May 2015, Maxxam analyzed 16 samples using the Saturated Paste methodology to obtain M1, M2 and M3a concentrations. As previously discussed and as can be observed in Tables 2, 3, 10 and 11, the M1 results are much higher than the M3a results. The primary reason for this discrepancy is that the M1 concentrations are based on dry weight of the muskeg sample and the M3a concentrations are based on the total muskeg weight (sample water and muskeg). Therefore, the denominator of the M1 calculation (dry sample weight), would be a much smaller value than the denominator of the M3a formula. The amount of water that a muskeg can absorb is quite substantial and to reach the saturation (saturated paste method), generally requires an additional volume whereby saturations range from 300-700%. This percent saturation affects the conversion to the salinity dry weight concentrations by grossly overestimating the values.

As previously identified in Table F above and as identified in Appendix III, the M1 (dry weight) concentration will be a multiple of the M3a value. Based on our experiments, M1 concentrations range from 2.7 times higher than the M3a concentration (for the 60% moisture sample) up to 10.2 times the M3a concentration (for the 90% moisture sample). This overestimation of concentration dramatically

outlines the need for an updated laboratory methodology, as the M1 method is the approved BC MoE analytical Saturated Paste Method currently used.

6.3 Comparison of mg/L Reported Methods (M2, M3b, M4a, M4b)

SynergyAspen compared the percent recovery, final concentrations and standard deviation values for the following methods (reported in mg/L):

- M2 (Saturated Paste Method);
- M3b (As Received – Squeeze and Analyze); and,
- M4a and M4b (Over Saturate Method).

M2 to M3b Results

As noted in Tables 10, 11, and 12 and Table F above, the standard deviation and range of percent recovery was closer to ideal for the M2 method for sodium and closer to ideal for chloride using the M3b method. Based on these parameters, no clear method advantage was identified comparing M2 to M3b. However, it should be noted that even though the statistical evaluation outlined above does not clearly represent an more ideal method, for moisture contents where a extract sample can be obtained (i.e. typically > 80% moisture samples), the M3b method would be considered superior as the M3b method does not include the bias step of bringing the sample to saturation via a subjective endpoint.

In summary, the following biases are not present in the M3b method versus the M2 method:

- Water loss during sampling does not affect the measured (“As-Received”) M3b results; and,
- The subjective end point of “saturation” used in the saturated paste method is not present in the M3b method.

M2 to M4a and M4b Results

When comparing the results in Table 12 and Table F above, in every circumstance the M4a and M4b data was superior to the M2 data, with respect to standard deviation of percent recovery and range of % recovery (i.e. smaller range).

The following summarizes the rationale why the M4 method is superior to the M2 Method:

- The subjective end point of “saturation” used in the saturated paste method is not present in the M4 method;
- Water loss during sampling does not affect the M4 results;
- Muskeg percent saturation accuracy issues during the saturated paste procedure is not present in the M4 methods; and,
- In all circumstances, the standard deviation and percent recovery values and ranges were closer to ideal for the M4 method.

M3b to M4a and M4b Results

A direct statistical comparison between the M3b and M4 methods could not be completed as the tests were not completed on the same sample set. The M3b tests were completed on the 80% and 90% moisture content samples and the M4 methods were completed on the 60% and 70% moisture content samples. However, looking at the results across all sample sets and relating the data as a whole, the M4 method was considered to be more ideal based on the following:

- The M3b method could not be completed on samples with moisture contents less than approximately 80%; and,
- In every circumstance, the standard deviation and range data was superior for the M4a and M4b methods relative to the M3b method.

7. CONCLUSIONS AND RECOMMENDATIONS

It is inappropriate for a muskeg/organic sample to be considered the same as a mineral soil sample with respect to the salinity saturated paste methodology, as this type of sample does not fit into the current BC regulatory definition of media (soil, water, tissue and air). There is a need to develop a modified approach in the laboratory analysis for quantifying salinity contaminant (sodium and chloride) concentrations specifically for peat matrices like muskeg.

With reference to the three general methods outlined within this report:

- Standard Saturated Paste Method (M1/M2);
- As-Received “Squeeze and Analyze” (M3);
- Intentionally Over-Saturate (M4)

The following table summarizes the rankings (from best (1) to worst (3)) based on % recovery values (standard deviation and range values).

Table G: Test Method Ranking Summary

SODIUM	Standard Saturated Paste[^]	M3b As-Received (mg/L)	Over Saturate M4a/b* (mg/L)
Standard Deviation	2	3	1
Range (Maximum – Minimum)	2	3	1
CHLORIDE	Standard Saturated Paste[^]	M3b As-Received (mg/L)	Over Saturate M4a/b* (mg/L)
Standard Deviation	3	2	1
Maximum – Minimum Range	3	2	1

Note: [^]Method currently used by industry.

*Based on average values of the Over-Saturated Method (M4a and M4b) results; and,

Bold 1: Ranking as the most ideal result.

As can be observed in Table G above, the over saturated method (M4) produced the best correlation and overall the best data with respect to percent recovery for both the measured analytes (sodium and chloride). The standard saturated paste method was ranked second for sodium, with the as-received method ranking second for chloride.

The current BC methodology of drying, grinding and completing a saturated paste (M1/M2 method) is considered the least suitable for muskeg analysis based on the following:

- The M1 values, reported in mg/kg, grossly overestimate the analyte concentration based on the use of dry weight (kg denominator bias);
- The M2 values are calculated based on an subjective addition of deionized water which has no correlation to the actual mg/L content of the analyte in the actual sample;
- The loss of sample water is not accounted for in these analyses; and,

- The difficulty in obtaining an accurate percent saturation for muskeg samples further biases the results.

The as-received and over-saturate methods are considered more appropriate relative to the current saturated paste method used in BC for analysis of muskeg. However, the over-saturated analysis appears to show the most promise based on the following:

- The M3 method could not be completed on the samples with moisture contents of 60% and 70%; and,
- The standard deviation and range data was superior for the M4 over-saturated method relative to the M3 as-received method.

Additional recommendations and comments relating to this study are outlined below.

- Currently muskeg is regulated as a soil and the current BC CSR soil standards are listed on a mg/kg basis. However, to avoid the gross overestimation of sodium and chloride contamination reported in muskeg samples, SynergyAspen recommends the lab data be reported on a mg/L basis. This would likely require a re-evaluation of muskeg “soil” samples being classified as a media onto itself. In turn, a re-evaluation of appropriate standards would be required by regulating bodies.
- It appears that the Saturated Paste Methodology defined in the BC Environmental Laboratory Manual allows for the “as-received” and “over-saturated” methods to be used.
- The industry may require a test or method to quantify when the “as-received” or “over-saturate” method can or cannot be used, which was outside the scope of the project research. SynergyAspen’s hypothesis is the “over-saturate” method is most appropriate for organic containing soils with a moisture content greater than 50%.
- It is suspected that the point of saturation may differ with varying types of muskeg/peat. Confirmation is required by testing different types of muskeg (beyond current scope of work).
- The project findings are not limited to muskeg, likely applying to any high moisture, high organic soil.
- It would be beneficial for organizations and industry groups to continue this study. A specific opportunity presents itself for Northern Universities given their proximity to the majority of muskeg deposits.

The use of the “as-received” and/or the “over-saturated” methods will greatly reduce the overestimation of sodium and chloride contamination in muskeg. This in turn would reduce the unnecessary remediation, the high costs associated with the remediation and the negative environmental impacts of a remediation project. Benefits include:

- Reducing unnecessary remediation of muskeg by way of excavation from its natural environment, which has taken thousands of years to generate.
- Muskeg is a natural carbon sink, and removal and disposal would not only remove this carbon sink, but disposal in a landfill would add to carbon emissions.

- The carbon intensive impact of mobilization and remediation of a Site (often far from a city centre) would be eliminated.
- Costs associated with the remediation work would be significantly reduced.

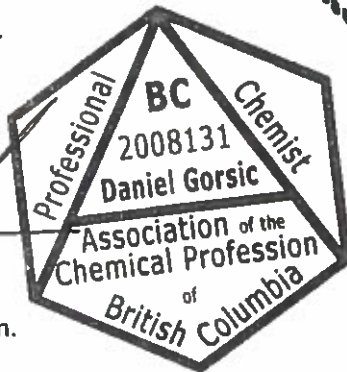
Respectfully Submitted,

Jason Chalifour, P.Ag.
Project Manager



A handwritten signature in black ink, appearing to read "Daniel Gorsic".

Daniel Gorsic, P.Chem.
CEO



Tables

Table 1: Maxxam Sample "Build" for M1/M2/M3a Experiments

Table 2: Summary of Maxxam Sodium Theoretical and Analytical Results for M1/M2/M3a Experiments

Table 3: Summary of Maxxam Chloride Theoretical and Analytical Results for M1/M2/M3a Experiments

Table 4: Maxxam Sample "Build" for M3b Experiments

Table 5: Summary of Maxxam Sodium Theoretical and Analytical Results for M3b Experiments

Table 6: Summary of Maxxam Chloride Theoretical and Analytical Results for M3b Experiments

Table 7: Maxxam Sample "Build" for M4a & M4b Experiments

Table 8: Sodium Results (M1, M3a) – (mg/kg)

Table 9: Chloride Results (M1, M3a) – (mg/kg)

Table 10: Sodium Results (M2, M3b, M4a, M4b) – (mg/L)

Table 11: Chloride Results (M2, M3b, M4a, M4b) – (mg/L)

Table 12: Percent Recovery: Standard Deviation, Average & Range

Table 13: Maxxam's Additional Testing on Wet Saturation



Table 1. Maxxam Sample "Build" for M1/M2/M3a Experiments

							Final Test-Sample Moisture	
Location	Sample ID	Dry Muskeg Weight (g)	DI Water Added (ml)	Constructed %M	PW Spike Volume (ml)	Total Sample Mass (g)	Target	Calculated
Site #1 BH2	Moisture = 60% Spike w/ C1	40.00	60	60.0	10	110.00	60	63.6
Site #1 BH2	Moisture = 60% Spike w/ C2	40.00	60	60.0	10	110.00		63.6
Site #1 BH2	Moisture = 60% Spike w/ C3	40.00	60	60.0	10	110.00		63.6
Site #1 BH2	Moisture = 60% Spike w/ C4	40.00	60	60.0	10	110.00		63.6
Site #1 BH2	Moisture = 70% Spike w/ C1	40.00	94	70.1	10	144.00	70	72.2
Site #1 BH2	Moisture = 70% Spike w/ C2	40.00	94	70.1	10	144.00		72.2
Site #1 BH2	Moisture = 70% Spike w/ C3	40.00	94	70.1	10	144.00		72.2
Site #1 BH2	Moisture = 70% Spike w/ C4	40.00	94	70.1	10	144.00		72.2
Site #1 BH2	Moisture = 80% Spike w/ C1	40.00	160	80.0	10	210.00	80	81.0
Site #1 BH2	Moisture = 80% Spike w/ C2	40.00	160	80.0	10	210.00		81.0
Site #1 BH2	Moisture = 80% Spike w/ C3	40.00	160	80.0	10	210.00		81.0
Site #1 BH2	Moisture = 80% Spike w/ C4	40.00	160	80.0	10	210.00		81.0
Site #1 BH2	Moisture = 90% Spike w/ C1	40.00	360	90.0	5	405.00	90	90.1
Site #1 BH2	Moisture = 90% Spike w/ C2	40.00	360	90.0	10	410.00		90.2
Site #1 BH2	Moisture = 90% Spike w/ C3	40.00	360	90.0	10	410.00		90.2
Site #1 BH2	Moisture = 90% Spike w/ C4	40.00	360	90.0	10	410.00		90.2

Note: DI - Deionized
 %M - Percent Moisture

Spike	Produced Water (ml)	DI Water Addition (ml)	Dilution Factor	Total Stock Volume (ml)
C1 - Straight	50	0	1	50
C2 - x5	10	40	5	50
C3 - x10	5	45	10	50
C4 - x25	2	48	25	50

Dilutions: Straight run, x5, x10, x25

Available dried/grinded muskeg (g)	1425
Averaged %Saturation	627.7
Max wt used per test sample (g)	89.0625
Ideal wt (g)	40

Table 2: Summary of Maxxam Sodium Theoretical and Analytical Results for M1/M2/M3a Experiments

		Muskeg (background)		Produced Water		DI Water	THEORETICAL Sodium	Actual Sodium	% Sodium Recovery	Analytical Result Sodium		
Sample ID :	Prep Details :	Sodium As Analyzed (mg/kg)	Sodium Sample Amount (mg)	Sodium As Analyzed (mg/L)	Sodium PW Contribution (mg)	DI water (mL)	Total Na in sample (mg)	Total Na Recovered in Analysis (mg)		M1: Dry Weigh Conversion (mg/kg)	M2: Wet Soluble Na (mg/L)	M3: As received weight (mg/kg)
MG5789	Moisture = 60% Spike w/ C1	1170	46.8	52900	529.0	217.0	575.8	469	81.4	11700	2160	4261.7
MG5793	Moisture = 60% Spike w/ C2		46.8		105.8	215.9	152.6	127	83.5	3190	590	1158.2
MG5795	Moisture = 60% Spike w/ C3		46.8		52.9	216.1	99.7	98	98.4	2450	454	891.7
MG5796	Moisture = 60% Spike w/ C4		46.8		21.2	215.3	68.0	76	111.2	1890	351	686.9
MG5797	Moisture = 70% Spike w/ C1		46.8		529.0	222.5	575.8	449	78.1	11200	2020	3121.0
MG5798	Moisture = 70% Spike w/ C2		46.8		105.8	223.2	152.6	151	98.9	3770	676	1047.6
MG5799	Moisture = 70% Spike w/ C3		46.8		52.9	222.3	99.7	84	84.7	2110	380	586.7
MG5800	Moisture = 70% Spike w/ C4		46.8		21.2	222.5	68.0	63	92.7	1580	283	437.3
MG5801	Moisture = 80% Spike w/ C1		46.8		529.0	250.7	575.8	399	69.2	9950	1590	1898.3
MG5802	Moisture = 80% Spike w/ C2		46.8		105.8	251.2	152.6	103	67.7	2580	411	491.7
MG5803	Moisture = 80% Spike w/ C3		46.8		52.9	250.6	99.7	58	57.8	1440	230	274.5
MG5804	Moisture = 80% Spike w/ C4		46.8		21.2	250.2	68.0	85	124.8	2120	339	403.8
MG5805	Moisture = 90% Spike w/ C1		46.8		264.5	299.4	311.3	174	56.0	4360	582	430.3
MG5806	Moisture = 90% Spike w/ C2		46.8		105.8	299.6	152.6	163	106.6	4060	543	396.7
MG5807	Moisture = 90% Spike w/ C3		46.8		52.9	301.3	99.7	71	70.7	1770	234	172.0
MG5808	Moisture = 90% Spike w/ C4		46.8		21.2	298.8	68.0	56	81.7	1390	186	135.5

Notes: DI - Deionized
Based on 40.00g sample size

Table 3: Summary of Maxxam Chloride Theoretical and Analytical Results for M1/M2/M3 Experiments

Sample ID :	Prep Details :	Muskeg (background)		Produced Water		DI Water Added	THEORETICAL Chloride	ACTUAL Chloride	% Chloride Recovery	Analytical Result Chloride		
		Chloride As Analyzed (mg/kg)	Chloride Sample Amount (mg)	Chloride As Analyzed (mg/L)	Chloride PW Contribution (mg)	DI water (mL)	Total Cl in sample (mg)	Total Chloride Recovered in Analysis (mg)		M1: Dry Weigh Conversion (mg/kg)	M2: Wet Soluble Na (mg/L)	M3: As received weight (mg/kg)
MG5789	Moisture = 60% Spike w/ C1	173	6.9	110000	1100.0	217.0	1106.9	1055	95.3	26400	4860	9589
MG5793	Moisture = 60% Spike w/ C2		6.9		220.0	215.9	226.9	214	94.1	5340	989	1941
MG5795	Moisture = 60% Spike w/ C3		6.9		110.0	216.1	116.9	126	107.4	3140	581	1141
MG5796	Moisture = 60% Spike w/ C4		6.9		44.0	215.3	50.9	57	111.2	1420	263	515
MG5797	Moisture = 70% Spike w/ C1		6.9		1100.0	222.5	1106.9	1032	93.3	25800	4640	7169
MG5798	Moisture = 70% Spike w/ C2		6.9		220.0	223.2	226.9	250	110.1	6240	1120	1736
MG5799	Moisture = 70% Spike w/ C3		6.9		110.0	222.3	116.9	108	92.6	2710	487	752
MG5800	Moisture = 70% Spike w/ C4		6.9		44.0	222.5	50.9	51	100.9	1280	231	357
MG5801	Moisture = 80% Spike w/ C1		6.9		1100.0	250.7	1106.9	860	77.7	21500	3430	4095
MG5802	Moisture = 80% Spike w/ C2		6.9		220.0	251.2	226.9	199	87.8	4980	793	949
MG5803	Moisture = 80% Spike w/ C3		6.9		110.0	250.6	116.9	78	66.9	1960	312	372
MG5804	Moisture = 80% Spike w/ C4		6.9		44.0	250.2	50.9	61	120.4	1530	245	292
MG5805	Moisture = 90% Spike w/ C1		6.9		550.0	299.4	556.9	353	63.4	8800	1180	872
MG5806	Moisture = 90% Spike w/ C2		6.9		220.0	299.6	226.9	160	70.6	4010	535	391
MG5807	Moisture = 90% Spike w/ C3		6.9		110.0	301.3	116.9	97	83.0	2430	322	237
MG5808	Moisture = 90% Spike w/ C4		6.9		44.0	298.8	50.9	47	92.7	1180	158	115

Notes: DI - Deionized
Based on 40.00g sample size

Table 4. Maxxam Sample "Build" for M3b Experiments

Maxxam ID	Sample ID	Dry Muskeg Weight (g)	DI Water Added (ml)	Constructed %M	PW Spike Volume (ml)	Total Sample Mass (g)	Final Test-Sample Moisture		
							Target	Calculated	Recovery (ml)
MW3621	Moisture = 80% Spike w/ C1	20.00	75	78.9	5	100.00	80	80.0	~10 mls
MW3622	Moisture = 80% Spike w/ C2	20.00	75	78.9	5	100.00		80.0	~7.5 mls
MW3623	Moisture = 80% Spike w/ C3	20.00	75	78.9	5	100.00		80.0	~6 mls
MW3624	Moisture = 80% Spike w/ C4	20.00	75	78.9	5	100.00		80.0	~7.5 mls
MW3625	Moisture = 90% Spike w/ C1	20.00	175	89.7	5	200.00	90	90.0	~26 mls
MW3626	Moisture = 90% Spike w/ C2	20.00	175	89.7	5	200.00		90.0	~35 mls
MW3627	Moisture = 90% Spike w/ C3	20.00	175	89.7	5	200.00		90.0	~25 mls
MW3628	Moisture = 90% Spike w/ C4	20.00	175	89.7	5	200.00		90.0	~32 mls

Note: Liquid extract could not be recovered from the 60% and 70% Moisture Content Samples

%M - Percent Moisture

Spike	Produced Water (ml)	DI Water Addition (ml)	Dilution Factor	Total Stock Volume (ml)
C1 - Straight	50	0	1	50
C2 - x5	10	40	5	50
C3 - x10	5	45	10	50
C4 - x25	2	48	25	50

Dilutions: Straight run, x5, x10, x25

Table 5: Summary of Maxxam SODIUM Theoretical and Analytical Results for M3b Experiments

Maxxam ID	Sample ID	Constructed %M	Spike	Produced Water Spike Volume	DI Water Added	Spike Contribution (mg)	Background Contribution (mg)	Theoretical Expected Value (mg/L)	Recovered Value (mg/L)	% Recovery
MW3621	Moisture = 80% Spike w/ C1	80	C1	5	75	196	11	2584.0	2110.0	81.7
MW3622	Moisture = 80% Spike w/ C2		C2	5	75	39.2	11	624.0	600.0	96.2
MW3623	Moisture = 80% Spike w/ C3		C3	5	75	19.6	11	379.0	447.0	117.9
MW3624	Moisture = 80% Spike w/ C4		C4	5	75	7.84	11	232.0	349.0	150.4
MW3625	Moisture = 90% Spike w/ C1	90	C1	5	175	196	11	1148.4	1100.0	95.8
MW3626	Moisture = 90% Spike w/ C2		C2	5	175	39.2	11	277.3	346.0	124.8
MW3627	Moisture = 90% Spike w/ C3		C3	5	175	19.6	11	168.4	240.0	142.5
MW3628	Moisture = 90% Spike w/ C4		C4	5	175	7.84	11	103.1	177.0	171.7

Note: DI - Deionized
%M - Percent Moisture

Table 6: Summary of Maxxam CHLORIDE Theoretical and Analytical Results for M3b Experiments

Maxxam ID	Sample ID	Constructed %M	Spike ID	Produced Water Spike Volume (ml)	DI Water Added (ml)	Spike Contribution (mg)	Background Contribution (mg)	Theoretical Expected Value (mg/L)	Recovered Value (mg/L)	% Recovery
MW3621	Moisture = 80% Spike w/ C1	80	C1	5	75	425	3	5344.8	5470.0	102.3
MW3622	Moisture = 80% Spike w/ C2		C2	5	75	85	3	1094.8	1130.0	103.2
MW3623	Moisture = 80% Spike w/ C3		C3	5	75	42.5	3	563.6	623.0	110.5
MW3624	Moisture = 80% Spike w/ C4		C4	5	75	17	3	244.8	295.0	120.5
MW3625	Moisture = 90% Spike w/ C1	90	C1	5	175	425	3	2375.5	2120.0	89.2
MW3626	Moisture = 90% Spike w/ C2		C2	5	175	85	3	486.6	529.0	108.7
MW3627	Moisture = 90% Spike w/ C3		C3	5	175	42.5	3	250.5	275.0	109.8
MW3628	Moisture = 90% Spike w/ C4		C4	5	175	17	3	108.8	143.0	131.4

Note: DI - Deionized
%M - Percent Moisture



Table 7. Maxxam Sample "Build" for M4a & M4b Experiments

		Original Dry Muskeg Weight (g)	Total liquid [DI + spike] added (ml)	Constructed %M	Wet Muskeg Weight Used (g)	Equivalent Liquid Content (mls)	DI Water to add for %M=90 (ml)	DI Water "leaching dose"
Maxxam ID	Sample ID							
ND1406	60%M C1 90%	20.00	30	60	6	4	20	
ND1407	60%M C1 ADD 100ML				3	2		100
ND1408	60%M C2 90%	20.00	30		20	12	60	
ND1409	60%M C2 ADD 100ML							100
ND1410	60%M C3 90%	20.00	30				60	
ND1411	60%M C3 ADD 100ML							100
ND1412	60%M C4 90%	20.00	30				60	
ND1413	60%M C4 ADD 100ML							100
ND1414	70%M C1 90%	20.00	47	70	3	2	6	
ND1415	70%M C1 ADD 100ML				4	3		100
ND1416	70%M C2 90%	20.00	47		20	14	40	
ND1417	70%M C2 ADD 100ML							100
ND1418	70%M C3 90%	20.00	47				40	
ND1419	70%M C3 ADD 100ML							100
ND1420	70%M C4 90%	20.00	47				40	
ND1421	70%M C4 ADD 100ML							100

Note: DI - Deionized
%M - Percent Moisture

Spike :	Produced Water (ml)	DI Water Addition (ml)	Dilution Factor	Total Stock Volume (ml)
C1 - Straight	50	0	1	50
C2 - x5	10	40	5	50
C3 - x10	5	45	10	50
C4 - x25	2	48	25	50

Dilutions: Straight run, x5, x10, x25



Table 8a: Sodium Results (Methods M1, M3a) - [mg/kg]

C1 Spike (Straight Produced Water)

Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/kg)	% Recovery	Standard Deviation of % Recovery
%M = 60, C1 spike, sat pasted	MG5789	M1	C1	60	11700	81.4	11.4
		M3a	C1		4262		
%M = 70, C1 spike, sat pasted	MG5797	M1	C1	70	11200	78.1	
		M3a	C1		3121		
%M = 80, C1 spike, sat pasted	MG5801	M1	C1	80	9950	69.2	
		M3a	C1		1898		
%M = 90, C1 spike, sat pasted	MG5805	M1	C1	90	4360	56	
		M3a	C1		430		

Table 8b: Sodium Results (Methods M1, M3a) - [mg/kg]

C2 Spike (1:5 Dilution of Produced Water)

Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/kg)	% Recovery	Standard Deviation of % Recovery
%M = 60, C2 spike, sat pasted	MG5793	M1	C2	60	3190	83.5	17.2
		M3a	C2		1158		
%M = 70, C2 spike, sat pasted	MG5798	M1	C2	70	3770	98.9	
		M3a	C2		1048		
%M = 80, C2 spike, sat pasted	MG5802	M1	C2	80	2580	67.7	
		M3a	C2		492		
%M = 90, C2 spike, sat pasted	MG5806	M1	C2	90	4060	106.6	
		M3a	C2		397		

Table 8c: Sodium Results (Methods M1, M3a) - [mg/kg]

C3 Spike (1:10 Dilution of Produced Water)

Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/kg)	% Recovery	Standard Deviation of % Recovery
%M = 60, C3 spike, sat pasted	MG5795	M1	C3	60	2450	98.4	17.5
		M3a	C3		892		
%M = 70, C3 spike, sat pasted	MG5799	M1	C3	70	2110	84.7	
		M3a	C3		587		
%M = 80, C3 spike, sat pasted	MG5803	M1	C3	80	1440	57.8	
		M3a	C3		275		
%M = 90, C3 spike, sat pasted	MG5807	M1	C3	90	1770	70.7	
		M3a	C3		172		

Table 8d: Sodium Results (Methods M1, M3a) - [mg/kg]

C4 Spike (1:25 Dilution of Produced Water)

Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/kg)	% Recovery	Standard Deviation of % Recovery
%M = 60, C4 spike, sat pasted	MG5796	M1	C4	60	1890	111.2	19.2
		M3a	C4		687		
%M = 70, C4 spike, sat pasted	MG5800	M1	C4	70	1580	92.7	
		M3a	C4		437		
%M = 80, C4 spike, sat pasted	MG5804	M1	C4	80	2120	124.8	
		M3a	C4		404		
%M = 90, C4 spike, sat pasted	MG5808	M1	C4	90	1390	81.7	
		M3a	C4		136		

Standard Deviation of % Recovery for all M1/M3a Data	19.3
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Table 9a: Chloride Results (Methods M1, M3a) - [mg/kg]

C1 Spike (Straight Produced Water)

Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/kg)	% Recovery	Standard Deviation of %Recovery
%M = 60, C1 spike, sat pasted	MG5789	M1	C1	60	26400	95.3	14.9
		M3a	C1		9589		
%M = 70, C1 spike, sat pasted	MG5797	M1	C1	70	25800	93.3	
		M3a	C1		7169		
%M = 80, C1 spike, sat pasted	MG5801	M1	C1	80	21500	77.7	
		M3a	C1		4095		
%M = 90, C1 spike, sat pasted	MG5805	M1	C1	90	8800	63.4	
		M3a	C1		872		

Table 9b: Chloride Results (Methods M1, M3a) - [mg/kg]

C2 Spike (1:5 Dilution of Produced Water)

Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/kg)	% Recovery	Standard Deviation of %Recovery
%M = 60, C2 spike, sat pasted	MG5793	M1	C2	60	5340	94.1	16.3
		M3a	C2		1941		
%M = 70, C2 spike, sat pasted	MG5798	M1	C2	70	6240	110.1	
		M3a	C2		1736		
%M = 80, C2 spike, sat pasted	MG5802	M1	C2	80	4980	87.8	
		M3a	C2		949		
%M = 90, C2 spike, sat pasted	MG5806	M1	C2	90	4010	70.6	
		M3a	C2		391		

Table 9c: Chloride Results (Methods M1, M3a) - [mg/kg]

C3 Spike (1:10 Dilution of Produced Water)

Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/kg)	% Recovery	Standard Deviation of %Recovery
%M = 60, C3 spike, sat pasted	MG5795	M1	C3	60	3140	107.4	17.0
		M3a	C3		1141		
%M = 70, C3 spike, sat pasted	MG5799	M1	C3	70	2710	92.6	
		M3a	C3		752		
%M = 80, C3 spike, sat pasted	MG5803	M1	C3	80	1960	66.9	
		M3a	C3		372		
%M = 90, C3 spike, sat pasted	MG5807	M1	C3	90	2430	82.9	
		M3a	C3		237		

Table 9d: Chloride Results (Methods M1, M3a) - [mg/kg]

C4 Spike (1:25 Dilution of Produced Water)

Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/kg)	% Recovery	Standard Deviation of %Recovery
%M = 60, C4 spike, sat pasted	MG5796	M1	C4	60	1420	111.2	12.0
		M3a	C4		515		
%M = 70, C4 spike, sat pasted	MG5800	M1	C4	70	1280	100.9	
		M3a	C4		357		
%M = 80, C4 spike, sat pasted	MG5804	M1	C4	80	1530	120.4	
		M3a	C4		292		
%M = 90, C4 spike, sat pasted	MG5808	M1	C4	90	1180	92.8	
		M3a	C4		115		

Standard Deviation of % Recovery for all M1/M3a	16.4
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Table 10a: Sodium Results (Methods M2, M3b, M4a, M4b) - [mg/L]							
C1 Spike (Straight Produced Water)							
Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/L)	% Recovery	Adjusted Analytical Result (mg/L)
%M = 60, C1 spike, sat pasted	MG5789	M2	C1	60	2160	81.4	2160
%M = 60, C1 spike, filtered as-is	NA	M3b	C1		no filtrate obtained		
%M = 60, C1 spike, made to %M = 90	ND1406	M4a	C1		983	93.5	5898
%M = 60, C1 spike, 100mls added	ND1407	M4b	C1		139	114.1	7089
%M = 70, C1 spike, sat pasted	MG5797	M2	C1	70	2020	77.9	2020
%M = 70, C1 spike, filtered as-is	NA	M3b	C1		no filtrate obtained		
%M = 70, C1 spike, made to %M = 90	ND1414	M4a	C1		1110	96.4	4440
%M = 70, C1 spike, 100mls added	ND1415	M4b	C1		141	116.6	4841
%M = 80, C1 spike, sat pasted	MG5801	M2	C1	80	1590	69.3	1590
%M = 80, C1 spike, filtered as-is	MW3621	M3b	C1		2110	81.7	2110
%M = 80, C1 spike, made to %M = 90	NA	M4a	C1		NA		
%M = 80, C1 spike, 100mls added	NA	M4b	C1		NA		
%M = 90, C1 spike, sat pasted	MG5805	M2	C1	90	582	56	582
%M = 90, C1 spike, filtered as-is	MW3625	M3b	C1		1100	95.8	1100
%M = 90, C1 spike, made to %M = 90	NA	M4a	C1		NA		
%M = 90, C1 spike, 100mls added	NA	M4b	C1		NA		
Table 10b: Sodium Results (Methods M2, M3b, M4a, M4b) - [mg/L]							
C2 Spike (1:5 Dilution Produced Water)							
Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/L)	% Recovery	Adjusted Analytical Result (mg/L)
%M = 60, C2 spike, sat pasted	MG5793	M2	C2	60	590	83.5	590
%M = 60, C2 spike, filtered as-is	NA	M3b	C2		no filtrate obtained		
%M = 60, C2 spike, made to %M = 90	ND1408	M4a	C2		313	111.3	1878
%M = 60, C2 spike, 100mls added	ND1409	M4b	C2		184	102.3	1717
%M = 70, C2 spike, sat pasted	MG5798	M2	C2	70	676	98.8	676
%M = 70, C2 spike, filtered as-is	NA	M3b	C2		no filtrate obtained		
%M = 70, C2 spike, made to %M = 90	ND1416	M4a	C2		282	101.4	1088
%M = 70, C2 spike, 100mls added	ND1417	M4b	C2		138	105.2	1124
%M = 80, C2 spike, sat pasted	MG5802	M2	C2	80	411	67.6	411
%M = 80, C2 spike, filtered as-is	MW3622	M3b	C2		600	96.2	600
%M = 80, C2 spike, made to %M = 90	NA	M4a	C2		NA		
%M = 80, C2 spike, 100mls added	NA	M4b	C2		NA		
%M = 90, C2 spike, sat pasted	MG5806	M2	C2	90	543	106.6	543
%M = 90, C2 spike, filtered as-is	MW3626	M3b	C2		346	124.8	346
%M = 90, C2 spike, made to %M = 90	NA	M4a	C2		NA		
%M = 90, C2 spike, 100mls added	NA	M4b	C2		NA		

Table 10c: Sodium Results (Methods M2, M3b, M4a, M4b) - [mg/L]							
C3 Spike (1:10 dilution Produced Water)							
Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/L)	% Recovery	Adjusted Analytical Result (mg/L)
%M = 60, C3 spike, sat pasted	MG5795	M2	C3	60	454	98.4	454
%M = 60, C3 spike, filtered as-is	NA	M3b	C3		no filtrate obtained		
%M = 60, C3 spike, made to %M = 90	ND1410	M4a	C3		198	115.6	1188
%M = 60, C3 spike, 100mls added	ND1411	M4b	C3		129	117.9	1204
%M = 70, C3 spike, sat pasted	MG5799	M2	C3	70	380	84.6	380
%M = 70, C3 spike, filtered as-is	NA	M3b	C3		no filtrate obtained		
%M = 70, C3 spike, made to %M = 90	ND1418	M4a	C3		198	119	764
%M = 70, C3 spike, 100mls added	ND1419	M4b	C3		94.5	119.4	770
%M = 80, C3 spike, sat pasted	MG5803	M2	C3	80	230	57.9	230
%M = 80, C3 spike, filtered as-is	MW3623	M3b	C3		447	117.9	447
%M = 80, C3 spike, made to %M = 90	NA	M4a	C3		NA		
%M = 80, C3 spike, 100mls added	NA	M4b	C3		NA		
%M = 90, C3 spike, sat pasted	MG5807	M2	C3	90	234	70.7	234
%M = 90, C3 spike, filtered as-is	MW3627	M3b	C3		240	142.5	240
%M = 90, C3 spike, made to %M = 90	NA	M4a	C3		NA		
%M = 90, C3 spike, 100mls added	NA	M4b	C3		NA		

Table 10d: Sodium Results (Methods M2, M3b, M4a, M4b) - [mg/L]							
C4 Spike (1:25 dilution Produced Water)							
Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/L)	% Recovery	Adjusted Analytical Result (mg/L)
%M = 60, C4 spike, sat pasted	MG5796	M2	C4	60	351	111	351
%M = 60, C4 spike, filtered as-is	NA	M3b	C4		no filtrate obtained		
%M = 60, C4 spike, made to %M = 90	ND1412	M4a	C4		141	136	846
%M = 60, C4 spike, 100mls added	ND1413	M4b	C4		92.2	138.6	861
%M = 70, C4 spike, sat pasted	MG5800	M2	C4	70	283	92.9	283
%M = 70, C4 spike, filtered as-is	NA	M3b	C4		no filtrate obtained		
%M = 70, C4 spike, made to %M = 90	ND1420	M4a	C4		138	134	532
%M = 70, C4 spike, 100mls added	ND1421	M4b	C4		72.4	148.7	590
%M = 80, C4 spike, sat pasted	MG5804	M2	C4	80	339	124.7	339
%M = 80, C4 spike, filtered as-is	MW3624	M3b	C4		349	150.4	349
%M = 80, C4 spike, made to %M = 90	NA	M4a	C4		NA		
%M = 80, C4 spike, 100mls added	NA	M4b	C4		NA		
%M = 90, C4 spike, sat pasted	MG5808	M2	C4	90	186	81.7	186
%M = 90, C4 spike, filtered as-is	MW3628	M3b	C4		177	171.7	177
%M = 90, C4 spike, made to %M = 90	NA	M4a	C4		NA		
%M = 90, C4 spike, 100mls added	NA	M4b	C4		NA		



Table 11a: Sodium Results (Methods M2, M3b, M4a, M4b) - [mg/L]							
C1 Spike (Straight Produced Water)							
Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/L)	% Recovery	Adjusted Analytical Result (mg/L)
%M = 60, C1 spike, sat pasted	MG5789	M2	C1	60	4860	95.3	4860
%M = 60, C1 spike, filtered as-is	NA	M3b	C1		no filtrate obtained		
%M = 60, C1 spike, made to %M = 90	ND1406	M4a	C1		1870	86	11220
%M = 60, C1 spike, 100mls added	ND1407	M4b	C1		256	101.6	13056
%M = 70, C1 spike, sat pasted	MG5797	M2	C1	70	4640	93.3	4640
%M = 70, C1 spike, filtered as-is	NA	M3b	C1		no filtrate obtained		
%M = 70, C1 spike, made to %M = 90	ND1414	M4a	C1		2230	93.6	8920
%M = 70, C1 spike, 100mls added	ND1415	M4b	C1		266	106.3	9133
%M = 80, C1 spike, sat pasted	MG5801	M2	C1	80	3430	77.7	3430
%M = 80, C1 spike, filtered as-is	MW3621	M3b	C1		5470	102.3	5470
%M = 80, C1 spike, made to %M = 90	NA	M4a	C1		NA		
%M = 80, C1 spike, 100mls added	NA	M4b	C1		NA		
%M = 90, C1 spike, sat pasted	MG5805	M2	C1	90	1180	63.4	1180
%M = 90, C1 spike, filtered as-is	MW3625	M3b	C1		2120	89.2	2120
%M = 90, C1 spike, made to %M = 90	NA	M4a	C1		NA		
%M = 90, C1 spike, 100mls added	NA	M4b	C1		NA		
Table 11b: Sodium Results (Methods M2, M3b, M4a, M4b) - [mg/L]							
C2 Spike (1:5 Dilution Produced Water)							
Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/L)	% Recovery	Adjusted Analytical Result (mg/L)
%M = 60, C2 spike, sat pasted	MG5793	M2	C2	60	989	94.1	989
%M = 60, C2 spike, filtered as-is	NA	M3b	C2		no filtrate obtained		
%M = 60, C2 spike, made to %M = 90	ND1408	M4a	C2		501	101.5	3006
%M = 60, C2 spike, 100mls added	ND1409	M4b	C2		277	87.8	2585
%M = 70, C2 spike, sat pasted	MG5798	M2	C2	70	1120	110.1	1120
%M = 70, C2 spike, filtered as-is	NA	M3b	C2		no filtrate obtained		
%M = 70, C2 spike, made to %M = 90	ND1416	M4a	C2		468	95.9	1805
%M = 70, C2 spike, 100mls added	ND1417	M4b	C2		212	92.1	1726
%M = 80, C2 spike, sat pasted	MG5802	M2	C2	80	793	87.7	793
%M = 80, C2 spike, filtered as-is	MW3622	M3b	C2		1130	103.2	1130
%M = 80, C2 spike, made to %M = 90	NA	M4a	C2		NA		
%M = 80, C2 spike, 100mls added	NA	M4b	C2		NA		
%M = 90, C2 spike, sat pasted	MG5806	M2	C2	90	535	70.6	535
%M = 90, C2 spike, filtered as-is	MW3626	M3b	C2		529	108.7	529
%M = 90, C2 spike, made to %M = 90	NA	M4a	C2		NA		
%M = 90, C2 spike, 100mls added	NA	M4b	C2		NA		

Table 11c: Sodium Results (Methods M2, M3b, M4a, M4b) - [mg/L]							
C3 Spike (1:10 dilution Produced Water)							
Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/L)	% Recovery	Adjusted Analytical Result (mg/L)
%M = 60, C3 spike, sat pasted	MG5795	M2	C3	60	581	107.4	581
%M = 60, C3 spike, filtered as-is	NA	M3b	C3		no filtrate obtained		
%M = 60, C3 spike, made to %M = 90	ND1410	M4a	C3		234	91.9	1404
%M = 60, C3 spike, 100mls added	ND1411	M4b	C3		152	93.4	1419
%M = 70, C3 spike, sat pasted	MG5799	M2	C3	70	487	92.6	487
%M = 70, C3 spike, filtered as-is	NA	M3b	C3		no filtrate obtained		
%M = 70, C3 spike, made to %M = 90	ND1418	M4a	C3		252	101.9	972
%M = 70, C3 spike, 100mls added	ND1419	M4b	C3		111	94.4	904
%M = 80, C3 spike, sat pasted	MG5803	M2	C3	80	312	66.9	312
%M = 80, C3 spike, filtered as-is	MW3623	M3b	C3		623	110.5	623
%M = 80, C3 spike, made to %M = 90	NA	M4a	C3		NA		
%M = 80, C3 spike, 100mls added	NA	M4b	C3		NA		
%M = 90, C3 spike, sat pasted	MG5807	M2	C3	90	322	83	322
%M = 90, C3 spike, filtered as-is	MW3627	M3b	C3		275	109.8	275
%M = 90, C3 spike, made to %M = 90	NA	M4a	C3		NA		
%M = 90, C3 spike, 100mls added	NA	M4b	C3		NA		
Table 11d: Sodium Results (Methods M2, M3b, M4a, M4b) - [mg/L]							
C4 Spike (1:25 dilution Produced Water)							
Sample Identifier	Maxxam Sample ID	Method	Spike	%Moisture	Analytical Result (mg/L)	% Recovery	Adjusted Analytical Result (mg/L)
%M = 60, C4 spike, sat pasted	MG5796	M2	C4	60	263	111.2	263
%M = 60, C4 spike, filtered as-is	NA	M3b	C4		no filtrate obtained		
%M = 60, C4 spike, made to %M = 90	ND1412	M4a	C4		107	97.8	642
%M = 60, C4 spike, 100mls added	ND1413	M4b	C4		64.7	92.2	604
%M = 70, C4 spike, sat pasted	MG5800	M2	C4	70	231	100.9	231
%M = 70, C4 spike, filtered as-is	NA	M3b	C4		no filtrate obtained		
%M = 70, C4 spike, made to %M = 90	ND1420	M4a	C4		101	92.9	390
%M = 70, C4 spike, 100mls added	ND1421	M4b	C4		47	91.5	383
%M = 80, C4 spike, sat pasted	MG5804	M2	C4	80	245	120.4	245
%M = 80, C4 spike, filtered as-is	MW3624	M3b	C4		295	120.5	295
%M = 80, C4 spike, made to %M = 90	NA	M4a	C4		NA		
%M = 80, C4 spike, 100mls added	NA	M4b	C4		NA		
%M = 90, C4 spike, sat pasted	MG5808	M2	C4	90	158	92.7	158
%M = 90, C4 spike, filtered as-is	MW3628	M3b	C4		143	131.4	143
%M = 90, C4 spike, made to %M = 90	NA	M4a	C4		NA		
%M = 90, C4 spike, 100mls added	NA	M4b	C4		NA		

Table 12. Percent Recovery: Standard Deviation, Average and Range

SODIUM				
Prep Details :	M1/M2/M3a	M3b	M4a	M4b
	% Recovery	% Recovery	% Recovery	% Recovery
Moisture = 60% Spike w/ C1	81.4	-	93.5	114.1
Moisture = 60% Spike w/ C2	83.5	-	111.3	102.3
Moisture = 60% Spike w/ C3	98.4	-	115.6	117.9
Moisture = 60% Spike w/ C4	111.2	-	136.0	138.6
Moisture = 70% Spike w/ C1	78.1	-	96.4	116.6
Moisture = 70% Spike w/ C2	98.9	-	101.4	105.2
Moisture = 70% Spike w/ C3	84.7	-	119.0	119.4
Moisture = 70% Spike w/ C4	92.7	-	134.0	148.7
Moisture = 80% Spike w/ C1	69.2	81.7	-	-
Moisture = 80% Spike w/ C2	67.7	96.2	-	-
Moisture = 80% Spike w/ C3	57.8	117.9	-	-
Moisture = 80% Spike w/ C4	124.8	150.4	-	-
Moisture = 90% Spike w/ C1	56.0	95.8	-	-
Moisture = 90% Spike w/ C2	106.6	124.8	-	-
Moisture = 90% Spike w/ C3	70.7	142.5	-	-
Moisture = 90% Spike w/ C4	81.7	171.7	-	-
Standard Deviation	19.3	30.9	16.1	15.8
Average	85.2	122.6	113.4	120.4
Range of % Recovery	56.0 - 124.8	81.7 - 171.7	93.5 - 136.0	102.3 - 148.7
Max. - Min. Range	68.8	90.0	42.5	46.4

CHLORIDE				
Prep Details :	M1/M2/M3a	M3b	M4a	M4b
	% Recovery	% Recovery	% Recovery	% Recovery
Moisture = 60% Spike w/ C1	95.3	-	86	101.6
Moisture = 60% Spike w/ C2	94.1	-	101.5	87.8
Moisture = 60% Spike w/ C3	107.4	-	91.9	93.4
Moisture = 60% Spike w/ C4	111.2	-	97.8	92.2
Moisture = 70% Spike w/ C1	93.3	-	93.6	106.3
Moisture = 70% Spike w/ C2	110.1	-	95.9	92.1
Moisture = 70% Spike w/ C3	92.6	-	101.9	94.4
Moisture = 70% Spike w/ C4	100.9	-	92.9	91.5
Moisture = 80% Spike w/ C1	77.7	102.3	-	-
Moisture = 80% Spike w/ C2	87.8	103.2	-	-
Moisture = 80% Spike w/ C3	66.9	110.5	-	-
Moisture = 80% Spike w/ C4	120.4	120.5	-	-
Moisture = 90% Spike w/ C1	63.4	89.2	-	-
Moisture = 90% Spike w/ C2	70.6	108.7	-	-
Moisture = 90% Spike w/ C3	83.0	109.8	-	-
Moisture = 90% Spike w/ C4	92.7	131.4	-	-
Standard Deviation	16.4	12.6	5.3	6.0
Average	91.7	109.5	95.2	94.9
Range of % Recovery	63.5 - 120.4	89.2 - 131.4	86.0 - 101.9	87.8 - 106.3
Max. - Min. Range	56.9	42.2	15.9	18.5

Table 13: Maxxam's Additional Testing on Wet Saturation

Jar ID	Sample ID	Jar wt (g)	Jar + dry sample (g)	Dry sample (g)	DI Water Added (mls)	Initial Sample wt (g)	Final Sample Wt (g)	Weight of DI Water Added (g)	% Saturation	Average Dry Material %M
6	Dry material (0%)	33.22	53.22	20.00	0	53.22	180.03	126.81	634.1	619.4
3	Dry material (0%)	33.33	53.33	20.00	0	53.33	174.27	120.94	604.7	
1	20% Moisture	33.51	53.51	20.00	5	58.51	181.97	123.46	642.3	
5	40% Moisture	33.98	53.98	20.00	13.4	67.38	176.42	109.04	612.2	
7	50% Moisture	32.67	52.69	20.02	20	72.69	181.30	108.61	642.4	
4	60% Moisture	32.55	52.55	20.00	30	82.55	187.65	105.10	675.5	
8	60% Moisture DUP	33.48	53.49	20.01	30	83.49	198.80	115.31	726.2	
2	80% Moisture	32.51	52.53	20.02	80	132.53	182.62	50.09	649.8	
Note: DI - Deionized									Average Saturation % :	648.4
%M - Percent Moisture									Standard Deviation:	38.3

- Saturated Paste analysis was completed on eight (8) muskeg samples: two as "bone dry" and the other six at set %M values outlined above.
- Calculating the amount of DI water already in the sample and the amount of DI water added during pasting, the % Saturation is calculated, as shown above.
- Given the wide range of %Saturation values achieved, it is clear that muskeg is a difficult material to saturate consistently.

Appendix I

Letter of Intent to BC OGRIS

Fund Manager: Howard Madill
300-398 Harbour Road
Victoria, BC V9A 0B7
Phone: 250-220-1418

Recipient Agreement

July 3, 2015

Michelle Uyeda
SynergyAspen Environmental Strategies
1214 Austin Ave.
Coquitlam, B.C., V3K 3P5

Dear Michelle:

**Re: Recipient Agreement EI-2016-03
for Salinity Analytical Method Review for Characterization in Muskeg**

This letter confirms that the BC Oil and Gas Research and Innovation Society (the "BC OGRIS") has agreed to provide funding to SynergyAspen Environmental Strategies (the "Recipient"), for conducting a salinity analytical method review for characterization in muskeg (the "Project"), upon and subject to the terms and conditions specified below and set out in *Appendix I—Terms and Conditions*.

The Fund Manager ("Fund Manager") is the designated representative of the BC OGRIS with respect to all matters arising under this Agreement and relating to the Project.

1 Purpose

The BC OGRIS contribution is to be used solely for the purpose of the Recipient carrying out and completing the Project as described in the proposal (the "Proposal") attached as Appendix II to this letter.

The Recipient will not make any material alteration to the Project or the Workplan described in the Proposal without the prior written consent of the Fund Manager, not to be unreasonably withheld.

2 Amount

The BC OGRIS will provide a grant to the Recipient in the amount of \$ 48,440 (Canadian dollars)—inclusive of all fees, expenses and taxes. Funds provided by the BC OGRIS that the

Recipient does not use in the Project will be returned to the BC OGRIS at the end of the Project. The BC OGRIS reserves the right to audit expenses or receive copies of invoices, as it deems appropriate, including those of any parties not at arm's length that will incur expenses on behalf of the Recipient.

The BC OGRIS is primarily a funding organization for research that is in the public domain. It is our view that we are exempt from the requirement to collect GST. The amount contributed to the Recipient in this agreement is considered a contribution in order for the Recipient to carry out the Project described in the Proposal (Appendix II). The BC OGRIS will not receive a direct benefit from this contribution. The deliverables from this research will be provided to the BC OGRIS for extension to the oil and gas industry, regulators, government agencies, other applicable stakeholders and the general public.

3 Disbursements

The BC OGRIS will disburse funds to the Recipient based on the schedule of payments listed below. Payments will be issued upon receipt of an invoice containing the following information:

- Recipient contact information (name, address, phone, email) and payment information (addressee for cheque);
- Fund Manager contact information (name, address);
- Project information associated with the invoice (recipient agreement number, name of project and any applicable milestones and deliverables);
- Invoice amount and date;
- GST component of the invoice amount, if applicable; and
- Supporting list of expenses, and amounts, incurred in the invoice period

The BC OGRIS will pay the Recipient within 45 days following receipt of the submitted invoice and the completion of the corresponding accountability for each milestone listed in the table below

The schedule of payments is as follows (all funds in Canadian dollars and inclusive of all fees, expenses and taxes):

Milestone	Description / Accountability	Contribution Amount	Estimated Date
1. Project started	• Signed Funding Agreement. • Fund Manager's acceptance of: • Project Profile. • Status report of project's activities and findings to-date and plans for remainder of project. A summary of the presentation at the federal	\$21,000	July 31, 2015

DH

Milestone	Description / Accountability	Contribution Amount	Estimated Date
	RPIC Workshop will be included (e.g , date, location, number of participants, presenter). • Copy of presentation file to the federal RPIC Workshop		
2. Research Complete	• Fund Manager's acceptance of: • Final Report— summarizing activities and findings in Project, including all relevant data. • Executive Summary of Final Report. • Final Administration Report confirming funds spent as per the Proposal. • Presentation to BC OGRIS and invited guests. • Photographs of field activities • Extension and communication plan for disseminating project findings.	\$21,000	September 30, 2015
3. Presentation to BC regulators	• Fund Manager's acceptance of: • A summary of the presentation to BC regulators (MoE and OGC) (e g , date, location, names and organizations of participants, presenter). • Copy of presentation file to the BC regulators (MoE and OGC).	\$6,440	November 30, 2015
Total		\$ 48,440	

4 Deliverables

All deliverables must be edited for completeness, readability and consistent format before submission to the BC OGRIS. The BC OGRIS may not accept a deliverable if there is any readability or comprehension issues with the deliverable

Each deliverable will have a short executive summary of the deliverable's content.

The Fund Manager may request a verbal or written status report at periodic intervals through the Project.

The Recipient will supply the Fund Manager with the deliverables listed in the deliverables section of the Proposal and will provide:

- One (1) hard copy and one (1) electronic copy of any and all interim and final reports, maps, or other deliverables specified in this Agreement.
- One (1) complete set of data collected in the execution of the Project, with accompanying metadata in digital (CD) format.

Final Administration Report

The Recipient will provide the Fund Manager with a Final Administration Report containing:

- Summary of project revenues and expenditures. This statement must detail all funds received from other sources and the use of those funds.
- a brief report on "lessons learned" for *internal* use of the BC OGRIS. The lessons learned report will not be posted to the BC OGRIS's website. The Lessons Learned will contain the following:
 - a) reflecting on variances between what was planned and what actually occurred, and recommending ways to improve future projects of a similar nature, and
 - b) providing advice on how to improve the effectiveness of the program, the quality of project deliverables, and the experience of recipients.

Project Profile

The Recipient will provide the Fund Manager with a Project Profile—for posting on the Active Projects page of the BC OGRIS website and summarizing the Project's objectives, methodology and deliverables. A template will be provided by the Fund Manager.

5 Project Initiation and Completion Dates

The Recipient will commence the Project on or before April 15, 2015 with completion on or before December 31, 2015

6 Other Terms and Conditions

Extension Activities

Recipient will notify the Program Manager of all extension activities related to the project. This includes presentations, media coverage and publications. Copies of extension



Recipient Agreement EI-2016-03
Salinity Analytical Method Review
(SynergyAspen)

**BC Oil and Gas Research and
Innovation Society (BC OGRIS)**

activities will be provided to the Program Manager. Participation in any extension activity that results in revenue or payment to the Recipient must be approved, in writing, in advance by the Fund Manager.

7 Acceptance

Please confirm your agreement with the foregoing terms and conditions by dating and executing all copies of this agreement in the space and manner indicated below and return it to the BC OGRIS, free of any conditions.

Agreed to this:
30 day of July, 2015



Fund Manager

Howard Madill

Fund Manager

300-398 Harbour Road
Victoria, BC V9A 0B7
250-419-4424

Howard.madill@bcogc.ca

Agreed to this:
29 day of JULY, 2015



Authorized Recipient Representative

Name: DANIEL GORSIC, CEO/DIRECTOR

Company: SYNERGY ASPEN ENVIRONMENTAL INC

Address: 1214 AUSTIN AVENUE, COQUITLAM, BC

Tel: 604.931.1026 EXT. 101 V3K 3P5

Email: dgorsic@synergyspen.ca

Recipient Agreement EI-2016-03—Appendices
Salinity Analytical Method Review for Characterization in Muskeg
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AI-1 Project Management

The Recipient is expected to manage the Project prudently, use funds cost-effectively, and ensure timely completion to a standard of care in a manner consistent with that level of care and skill ordinarily exercised by other professionals currently practicing under similar conditions, according to the terms of this Agreement.

The Recipient will ensure the Fund Manager is advised, as soon as reasonably practical, of any expected cost overruns and/or delays in completing the Project. The Recipient will also provide status updates, verbal and/or written, upon reasonable request by the Fund Manager.

The Recipient will notify the Fund Manager, in writing, of any change in project leadership or governance processes. A change in project leadership must be accompanied by a meeting with the Fund Manager to reconfirm the Project and Workplan outlined in this funding agreement.

The Recipient will maintain proper work, personnel, and financial records. Financial records are to clearly separate and identify the receipt and expenditure of contributions from the BC OGRIS, cash contributions from other sources, and in-kind contributions from all sources.

The Recipient will permit the Fund Manager at all reasonable times to inspect, examine, review, and copy any and all layouts, copy, prints, specifications, drawings, working papers, reports, documents, and all audio, visual, and print material—whether complete or otherwise—(collectively called the "Material") that have been produced, received, or acquired by the Recipient in connection with the Project, unless such Material is subject to written confidentiality obligations imposed on the Recipient by another party.

AI-2 Insurance

The Recipient, and its subcontractors, shall ensure they have appropriate insurance to operate and address potential liabilities resulting from the Project.

AI-3 Acknowledgement

In all publications and other forms of release or communication pertaining to the Project, the Recipient and its subcontractor(s) shall acknowledge the assistance provided by the BC OGRIS.

AI-4 Ownership of Technology and Intellectual Property

The BC OGRIS will retain any Intellectual Property (IP) rights on the data and reports developed under the Project

The BC OGRIS's use of the IP is solely for the purposes of providing the research findings to the oil and gas industry, regulators, applicable government agencies, other applicable stakeholders and the general public.



AI-5 Subcontractors

The Recipient must provide the Fund Manager with prior notice in writing of any intended or actual use of subcontractors in carrying out the Project or change in the use of subcontractors. No subcontract, whether consented to or not, relieves the Recipient from any obligations under this Agreement. The Recipient must ensure that:

- (a) Any person retained by the Recipient to perform obligations under this Agreement fully complies with this Agreement in performing the subcontracted obligation; and
- (b) Any person retained by a person described in paragraph (a) to perform those obligations fully complies with this Agreement in performing the subcontracted obligation

AI-6 Audit

The Fund Manager may engage an auditor or conduct an audit to review the Workplan and any records, reports, accounting procedures, and other information of the Recipient as may be desirable in its opinion relating to the Project, its disbursements, or this Agreement, provided that such auditor is subject to confidentiality obligations similar to those contained in AI-14 below.

The Fund Manager shall have the right to request specific and general information from the Recipient that is reasonably necessary or desirable under generally accepted auditing standards; the Recipient will provide such information in a timely fashion.

The Recipient will assist the audit by whatever means are necessary and reasonable to facilitate any such audit or request for information. Where the Fund Manager or an auditor requires access to, or copies of, information, data, or documents for the requirements set out in this Agreement or other related documents, the Recipient (and its Subcontractor(s)) will, at no cost to the Fund Manager or the auditor, ensure that the person who has control of such information, data, or documents provides full access to them; and provides appropriate space for the BC OGRIS or the auditor to carry out the audit at reasonable times during business hours.

Any obligation imposed on the Recipient under AI-6 to provide or cause to be provided certain information, data or documents is subject to such information, data and documents not being subject to written confidentiality obligations imposed on the Recipient or other person who has control over such materials, by another person.

The Fund Manager may use its findings from an audit or the findings of the auditor as one means to assess the performance of the Recipient under this Agreement.

The Recipient acknowledges that, in addition to the audits conducted by and on behalf of the Fund Manager, other types of audits may be conducted on the BC OGRIS. In these cases, the Recipient will assist in the audit of the BC OGRIS by providing information as requested by the auditor, subject to the terms and conditions of this funding agreement. All audits shall be subject to thirty days prior written notice to the Recipient before commencement, save and except where otherwise required by law.

AI-7 Assignment of Rights or Responsibilities

The Recipient is not to transfer to any person any rights or responsibilities of this Agreement without the written consent of the Fund Manager. The Recipient must ensure that subcontractors comply with the Agreement.

AI-8 Confidentiality and Freedom of Information

All material, information and reports produced under this agreement may be subject to disclosure in accordance with the *Freedom of Information and Protection of Privacy Act*. Any party required to disclose any material information or reports pursuant to the Act will first notify the other party of such requirement and will cooperate with the other party to only disclose information to the extent required by the Act

AI-9 Conflict of Interest

The Recipient will, concurrently with the delivery of this Agreement, disclose to the Fund Manager the existence of any conflicts of interest between the obligations of the Recipient to the BC OGRIS under this Agreement and the obligations of the Recipient to another person ("Conflicts") and will, during the term of the Agreement, notify the Fund Manager in the event that any Conflicts arise.

AI-10 Termination

The Fund Manager may terminate this Agreement:

1. Immediately—if the Recipient has failed to comply with this Agreement and has not within 5 days of notice from the BC OGRIS of such non-compliance, addressed such non-compliance. Written notice of termination must be given to the Recipient, and
2. With at least 30 days' notice—for any other reason. Written notice of termination must be given to the Recipient.

The Recipient may terminate this Agreement on giving at least 30 days' written notice of termination to the Fund Manager.

This Agreement may also be terminated immediately, by written notice of the other party, if such party becomes bankrupt, insolvent, makes a general assignment for the benefit of creditors or has a receiver appointed

If we terminate this Agreement under AI-10(2) above, the BC OGRIS will pay the Recipient that portion of the fees and expenses detailed in the Proposal (Appendix II) representing the portion of the services that were completed to our reasonable satisfaction before termination. Such payment will discharge the BC OGRIS from all liability to the Recipient under this Agreement. The Recipient will return that portion of any pre-payments made by the BC OGRIS that is above the fees and expenses for services listed in the Proposal that are completed.

Upon termination, the other party may attempt to undertake the remainder of the Project on their own or with other parties.

Notwithstanding any termination of this Agreement, the obligations set out in AI-14 [Confidentiality] below shall survive and continue to bind the parties and their successors and assigns for a period of six years following any termination of this agreement.

AI-11 Failure to Complete

If, for any reason, the Project is not completed, the BC OGRIS will pay the Recipient that portion of the fees and expenses detailed in the Proposal (Appendix II) representing the portion of the services that were completed to our reasonable satisfaction. The Recipient will return that portion of any pre-payments made by the BC OGRIS that is above the fees and expenses for services completed.

The BC OGRIS will not entertain future proposals from organizations where previous projects were incomplete or deliverable(s) not received. This refers to situations in which the organization failed to complete the Project.

AI-12 Settlement of any Disputes

All disputes arising out of or in connection with this Agreement or in respect of any defined legal relationship derived from it must, unless the parties otherwise agree, be referred to and finally resolved by arbitration administered by the British Columbia International Commercial Arbitration Centre under its rules

AI-13 Governing Laws

This agreement will be governed by and construed in accordance with the laws of the Province of British Columbia and the laws of Canada applicable therein, and, subject to AI-12 above, the Parties hereto hereby submit to attorn to the non-exclusive jurisdiction of the Courts within the Province of British Columbia.

AI-14 Confidentiality

Both parties agree that all confidential information communicated by one party to the other party for the purpose of this Agreement, including but not limited to the terms of this Agreement, will be held in strict confidence and will be used only for the purposes of this Agreement, and that no such confidential information will be disclosed by the receiving party, agents or employees without the prior written consent of the disclosing party or unless disclosure of such confidential information is compelled by judicial process or otherwise by law, or if the information has been made public without any action by the receiving party. Both parties will exercise due diligence not to use or commercialize, or to disclose the other party's confidential information to any person or

entity, except to its own employees having a “need to know” and other recipients approved by owner in writing. Neither party will alter or remove from such confidential information any confidential or proprietary rights legend.

Both parties agree that any information encountered by either party to this Agreement where such information is the property of the other party shall be treated as being confidential and shall be safeguarded in the same manner as each party to this Agreement safeguards information regarding its own business

The Recipient may communicate with the BC OGRIS or others via telephone, facsimile, post, courier and e-mail transmission. As all communications can be intercepted or otherwise used or communicated by an unintended third party, or may not be delivered to each of the parties to whom they are directed and only to such parties, the Recipient cannot guarantee or warrant that communications from the Recipient will be properly delivered only to the addressee. Therefore, Recipient specifically disclaims and waives any liability or responsibility whatsoever for interception or unintentional disclosure of communications transmitted by the Recipient in connection with the performance of this agreement. The BC OGRIS acknowledges and agrees that the Recipient shall have no liability for any loss or damage to any person or entity resulting from the interception or unintentional disclosure of communications, including any consequential, incidental, direct, indirect, or special damages, such as loss of revenues or anticipated profits, or disclosure or communication of confidential or proprietary information.

AI-15 Indemnity and Limitation of Liability

Each party shall indemnify, defend and hold harmless the other and each of their respective directors, officers, servants, employees and agents from and against, and shall be responsible for, all actions, suits, claims, demands, losses, costs, charges, damages and expenses, including reasonable legal fees incurred, suffered, sustained by or claimed against the other party, arising out of or resulting from any negligent acts or omissions of such indemnifying party or its directors, officers, servants, employees or agents or such other persons for whom it is in law responsible in connection with the subject matter of this Agreement and from breaches of the covenants and obligations of such party under this Agreement, except to the extent caused by the negligence or willful act of the other party or persons for whom such other party is in law responsible.

Each party's total cumulative liability, if any, to the other party, or any third party for direct damages arising out of or in connection with this Agreement will in no event exceed the cash portion of the fees payable by the BC OGRIS under this Agreement. Each party's entire liability, regardless of the form of action, whether based in contract or tort, including negligence, shall be for direct damages only. In no event shall one party be liable to the other party for damages under or related to or arising from this Agreement for special, incidental or consequential damages (even if the party has been advised of the possibility of such loss) including lost business revenue, loss of profits, loss of data, failure to realize expected profits or savings or other commercial or economic loss of any kind or any claim against any party by any other person.

AI-16 Other Terms and Conditions

The relationship of the parties is that of independent contractors. Nothing herein contained shall be deemed to constitute a joint venture relationship or partnership among the parties. Neither party shall have any authority to assume or create any obligation whatsoever, express or implied, in the name of the other party nor to bind the other party in any manner whatsoever, except as herein specifically provided.

This Agreement contains the entire understanding of the parties relating to the subject matter herein contained. Any amendment to this Agreement must be in writing and executed by the proper officers of the parties.

Each provision of this Agreement is intended to be severable. If a court determines that any provision is unenforceable for any reason, that provision will be severed from this Agreement and will not affect the enforceability of the remainder or any other provision of this Agreement.

Waiver by any party of any provision of this Agreement in one instance shall not constitute a waiver as to any other instance and any waiver must be in writing to be effective.

If the performance of this Agreement is interfered with, in whole or in part, by circumstances beyond the reasonable control of any party such as fires, labour unrest such as strikes and picketing, floods, acts of God or war, the party affected shall be excused from performance of its obligations on a day-by-day basis provided that the party so affected shall use reasonable efforts to remove the cause of non-performance

Both parties agree not to assign or otherwise dispose of any of their rights, obligations or interests in this Agreement without the prior written consent of the other party, which consent may not unreasonably or arbitrarily be withheld. This Agreement shall be binding upon and enure to the benefit of the parties hereto and their successors and permitted assigns



APPENDIX II – LOI Application

A handwritten signature in black ink, located in the bottom right corner of the page. The signature is stylized and appears to be a combination of initials and a surname.

Proponent Information

Proponent Name:	Michelle Uyeda
Proponent Organization	SynergyAspen Environmental Strategies
Mailing Address:	1214 Austin Ave. Coquitlam, BC V3K3P5
Physical Address:	Same as above
Email Address:	muyeda@synergyaspen.ca
Telephone:	Off.604-931-1026- ext 103, cell. 604-803-8346

Project Information

Project Title:	Salinity Analytical Method Review for Characterization in Muskeg
Proposed start and finish dates:	April 15, 2015 – August 31, 2015
Project Rationale:	Understanding muskeg, a boreal wetland, as a matrix is an important consideration when performing an analytical characterization of a site. Canada has 35% of the world's peat accumulating wetlands with a vast majority of it in the north, including NE BC. Produced water associated with upstream O&G activity, contains high levels of salinity and is a contaminant of concern in the industry. Accurately estimating the volume of salinity contaminated muskeg is critical in environmental cleanup at O&G sites. Muskeg is currently classified as a soil under the BC regulatory regime. However, the BC MoE analytical method for soil matrix grossly overestimates the concentration of salinity in muskeg. Muskeg behaves more like a sponge and is very moist nature compared to mineral soils for which the analytical methodology was designed for. As such, there is a need to develop a modified approach in the laboratory analysis for quantifying salinity contaminant concentrations specifically for peat matrices like muskeg. This project differs to the recent SCEK project awarded to Hemmera. SynergyAspen Environmental (SA) is looking at modifying the analytical methodology for salinity parameters for muskeg samples while Hemmera is looking to establish revised salinity standards for boreal wetlands, such as muskeg based on toxicity, using the pre-defined soil analytical methodology.
Project Description:	SA intends to prepare controlled samples of known moisture content and salinity concentrations and analyze them using the BC MoE Saturated Paste¹ analytical laboratory method, but reporting them using three different calculations: 1) M1 – Dry Soil Weight Method– This is the unmodified approved BC MoE analytical method as prescribed, where;

¹ BC MoE Environmental Monitoring, Reporting & Economics, Sampling, Methods and Quality Assurance, British Columbia Environmental Laboratory Manual: 2013

Project Description (cont'd):	$C_{salM1} = \frac{\text{mass of salt (mg)}}{\text{dry weight of muskeg (kg)}}$ The mg/L salinity concentration determined through saturation paste is multiplied by % saturation to obtain a mg/kg value. It grossly over estimates the concentration of contaminant for soils that have a moisture content >50% (such as muskeg) by a factor of up to twenty. 2) M2 – Lab-Water Wet Soil Weight Method– This "wet weight" method, being accepted in industry as an alternative to the dry weight method for salinity parameters, where; $C_{salM2} = \frac{\text{mass of salt (mg)}}{\text{Volume of water added in lab to create the saturated paste (L)}}$ The above equation is the mg/L concentration derived in the Saturated Paste Method and is used in "multiple lines of evidence risk based arguments" in support of CoRs and is directly compared to the soil standard (and not multiplied by the %saturation to obtain a mg/kg concentration as per M1). This provides a more accurate representation of salinity concentration within muskeg. However, the limitation is that it is biased by the amount of water the lab chemist adds to the dried sample to make a saturated paste, which forms the denominator in the equation. There is no prescriptive methodology for the volumes used to obtain a saturated paste; it is up to the chemist's discretion. 3) M3 – Wet Soil Weight Method- An alternative focussing on representing the water content of true sample condition and not lab intrusion, where: $C_{salM3} = \frac{\text{mass of salt (mg)}}{\text{total muskeg sample weight (kg) (i.e. sample water and muskeg)}}$ The above equation is the new proposed calculation by SA, which may be more representative of the actual sample matrix by taking into account the two matrices within muskeg, i.e. water and organics. SA will compare results produced by all three methods and compare them to the known baseline concentrations of the contaminant. This will determine which of the three methods best represents the "spiked" contaminant concentration. SA postulates that the third method will provide sample concentrations to be closest to the true concentrations, and the current methodology (M1) to be the furthest.
Project Methodology:	Muskeg samples are collected in the native muskeg along the perimeter of an oil and gas well site in NE BC, where no known anthropogenic activity occurred. Produced water was obtained from a local producer in the FSJ area. The intent of the research project is to spike 16 muskeg samples with known concentrations of produced water and analyze each using the saturated paste method, and calculate concentrations using three different methods, M1, M2 and M3, per the Table 1, below.

Project Methodology (cont'd):	The methodology will be completed by two independent accredited BC laboratories. This will provide opportunity to identify consistency in the methodologies between different laboratories. Forty eight samples points will be obtained from each lab and interpreted.				
	Table 1: Proposed Sample Matrix for Salinity Analysis				
	Concentration (mg/L)	Moisture Content			
		60%	70%	80%	90%
	C1 – 2x dilution of C4	Sample 1: M1: M2: M3:	Sample 5: M1: M2: M3:	Sample 9: M1: M2: M3:	Sample 13: M1: M2: M3:
	C2 – 5x dilution of C4	Sample 2 M1: M2: M3:	Sample 6: M1: M2: M3:	Sample 10: M1: M2: M3:	Sample 14: M1: M2: M3:
C3 – 10x dilution of C4	Sample 3 M1: M2: M3:	Sample 7: M1: M2: M3:	Sample 11: M1: M2: M3:	Sample 15: M1: M2: M3:	
C4 – Produced Water	Sample 4 M1: M2: M3:	Sample 8: M1: M2: M3:	Sample 12: M1: M2: M3:	Sample 16: M1: M2: M3:	
S#: Sample number					
Project Objectives:	- Identifying the analytical calculation methodology best confirming the actual contaminant concentration within the samples. - SA and both laboratories will demonstrate the need to develop a modified approach in the laboratory analysis of muskeg for quantifying salinity contaminant concentrations. The methodology may then be adapted for other contaminants in muskeg.				
Project Deliverables:	- Summary report of data with all relevant data - Presentation of findings (power point format) - Final Administrative Report - Photographs of field activities				
Project Outcomes, benefits:	- The findings of these experiments are to encourage regulators to examine the need to recognize muskeg as a unique media and update analytical methods to represent with better accuracy salinity concentrations in a muskeg environment. - With this accuracy, SA believes there will be huge benefit to the upstream O&G industry, not only in cost savings by reducing the amount of muskeg being unnecessarily remediated, but also preserving the natural muskeg setting which takes thousands of years to generate.				
Project Extension:	Extension activities will include: - Presentation of project findings to SCEK fund and invited guests - Final report and executive summary to be posted on SCEK website - Project Profile (1-2 pages in length, using SCEK template) for posting on SCEK website - Presentation at the federal RPIC Workshop in June 2015 - Presentation of findings to BC regulators: MoE and OGC - Completing the same analysis on two additional sites to obtain increased reliability and confirmation of data				

Project Team

Name	Role	Skills/Qualification
Michelle Uyeda, MSc., P.Eng., CSAP SynergyAspen Environmental	Project Director; coordinate and manage project; liaise with client, senior data review and interpretation, report review, responsible for presentation of data	BC Contaminated Sites Approved Professional (CSAP), >20 years in environmental consulting for contaminated sites, including 7 specifically working with the upstream O&G industry

Daniel Gorsic, B.Sc., P.Chem. SynergyAspen	Senior Technical Advisor, senior data review and interpretation, report review	>20 years in environmental consulting for contaminated sites, including 7 specifically working with the upstream O&G industry
Steve Hait, B.A.Sc., EIT SynergyAspen Environmental	Data interpretation and report writing	4 years in environmental consulting for contaminated sites with the upstream O&G industry. Completed investigation and remediation programs, data interpretation and technical reporting
Patrick Novak, B.Sc., P.Chem. CARO Analytical Services	Laboratory Project Manager; coordinate and manage laboratory testing, data review	>15 years in the environmental analytical laboratory industry. Has expertise in project management for contaminated sites soil, water and air analysis. Participated in design and management of several environmental study programs
Rob Gilbert, Maxxam Laboratory	Laboratory Project Manager; coordinate and manage laboratory testing, data review	>20 years in the analytical laboratory industry. Has expertise in project management for contaminated sites soil, water and air analysis

Project Governance

Project Director:	Ms. Michelle Uyeda, M.Sc., P.Eng., CSAP
Project Management Process:	Timing for results is dictated by the confirmed RPIC Federal Contaminated Sites Workshop Presentation of this topic on June 2, 2015. Kickoff meeting to occur with each lab and timeline to be detailed at that time. The Project Director will complete regular check-ins with lab to confirm targeted timelines.
Quality Assurance of Deliverables	- QA/QC involves analyses being completed by two independent accredited laboratories. Each laboratory has its own standard QA/QC procedures which will be followed during analysis - SA has its own internal Quality Management System which will be followed through the project life cycle. - All deliverables will be edited for comprehension, completeness and format prior to submission to SCEK fund - SCEK fund will have opportunity to review all deliverables before finalization

Funding Request for Proposed Salinity Analytical Method Review Project

Year	Fees	Expenses	Request to SCEK	Other Partner Contributions
Year 1 research project	\$34,800	\$500	\$35,300	\$0
Extension Work – - Presentation at RPIC workshop - Presentation to MoE and/or OGC	\$8,000	\$3,000	\$11,000	\$0
Extension Work – Sample analysis and interpretation for up to two additional muskeg sites			Year 2 request, based on contributions	Will apply to BC MoE and CSAP Society for funding
Total	\$42,800	\$3500	\$46,300	-

References

Mr. Devin Scheck, Oil and Gas Commission	T. 250 794-5232, Devin.Scheck@bcogc.ca
Ms. Joanne Germaine, Whitecap Resources	T. 403 817-2306, JGermaine@wcap.ca

Appendix II

Photographs



PHOTO 1: View of drill rig during collection of muskeg samples.



PHOTO 2: View of one of the muskeg samples collected (S2-BH1 –muskeg sample not used during investigation).
Note high moisture content of sample.



PHOTO 3: View of one of the muskeg samples collected (S3-BH1 – muskeg sample not used during investigation).
Note drier and more stick like nature of muskeg sample relative to Photo 2.

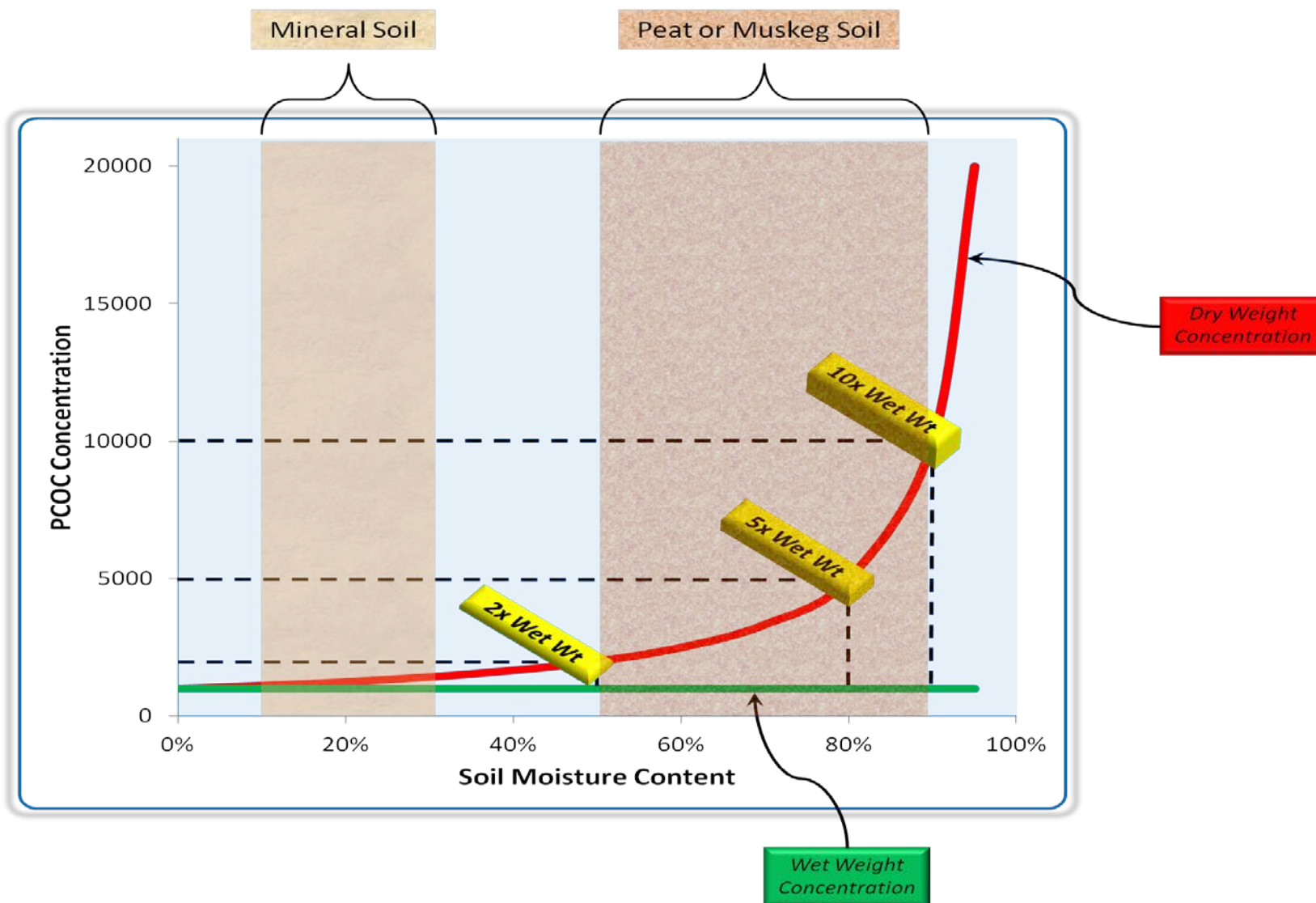


PHOTO 4: View of muskeg samples in the laboratory.

Appendix III

Effect of Moisture Content on Peat/Muskeg Samples

Appendix III: Effect of Moisture Content on Peat/Muskeg (mg/kg)



Appendix IV

Maxxam Analytical Results

Your Project #: MAXXAM - WATER TEMPLATE
Your C.O.C. #: A9E0408A01

Attention:Michelle Uyeda

SynergyAspen Environmental Inc.
1214 Austin Avenue
Coquitlam, BC
CANADA V3K 3P5

Report Date: 2015/04/16

Report #: R1846368

Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B528565

Received: 2015/04/09, 10:40

Sample Matrix: Water
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
BTEX/MTBE LH, VH, F1 SIM/MS	1	2015/04/15	2015/04/15	BBY8SOP-00010/11	EPA 8260c R3 m
Chloride by Automated Colourimetry	1	N/A	2015/04/15	BBY6SOP-00011	SM 22 4500-Cl- G m
Conductance - water	1	N/A	2015/04/15	BBY6SOP-00026	SM 22 2510 B m
Hardness Total (calculated as CaCO3)	1	N/A	2015/04/15	BBY7SOP-00002	EPA 6020a R1 m
ICP-AES Total Metals in Water	1	2015/04/15	2015/04/15	BBY7SOP-00018	EPA 6010c R3 m
Absolute Density @ 15°C on Water Sample (1)	1	2015/04/16	2015/04/16	PTC SOP-00099	ASTM D4052
Relative Density @15 °C on Water Sample (1)	1	2015/04/16	2015/04/16	PTC SOP-00099	ASTM D4052
Sodium Adsorption Ratio	1	N/A	2015/04/15	BBY WI-00033	SSMA 15.4.4
EPH in Water by GC/FID	1	2015/04/15	2015/04/15	BBY8SOP-00029	BCMOE EPH w 07/99 m
Volatile HC-BTEX	1	N/A	2015/04/15	BBY WI-00033	Auto Calc

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

(1) This test was performed by Maxxam Edmonton Petroleum

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Stefanie Teo, Project Manager

Email: STEO@maxxam.ca

Phone# (604)638-5019

=====

This report has been generated and distributed using a secure automated process.

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B528565
Report Date: 2015/04/16

SynergyAspen Environmental Inc.
Client Project #: MAXXAM - WATER TEMPLATE

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		MA4066		
Sampling Date		2015/03/06		
COC Number		A9E0408A01		
	Units	PW-15-1	RDL	QC Batch
Calculated Parameters				
Sodium Adsorption Ratio	N/A	140	0.10	7865418
Anions				
Dissolved Chloride (Cl)	mg/L	110000	500	7865557
Physical Properties				
Water Absolute Density @ 15°C	kg/m3	1100	0.10	7866704
Conductivity	uS/cm	192000	1.0	7865220
Water Relative Density @ 15 °C	N/A	1.1	0.00010	7866706
RDL = Reportable Detection Limit				

Maxxam Job #: B528565
Report Date: 2015/04/16

SynergyAspen Environmental Inc.
Client Project #: MAXXAM - WATER TEMPLATE

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID		MA4066		
Sampling Date		2015/03/06		
COC Number		A9E0408A01		
	Units	PW-15-1	RDL	QC Batch
Total Metals by ICP				
Total Aluminum (Al)	mg/L	<5.0	5.0	7865582
Total Antimony (Sb)	mg/L	<5.0	5.0	7865582
Total Arsenic (As)	mg/L	<3.0	3.0	7865582
Total Barium (Ba)	mg/L	176	0.10	7865582
Total Beryllium (Be)	mg/L	<0.30	0.30	7865582
Total Bismuth (Bi)	mg/L	<5.0	5.0	7865582
Total Boron (B)	mg/L	14.3	1.0	7865582
Total Cadmium (Cd)	mg/L	<0.50	0.50	7865582
Total Chromium (Cr)	mg/L	<1.0	1.0	7865582
Total Cobalt (Co)	mg/L	<2.0	2.0	7865582
Total Copper (Cu)	mg/L	<2.0	2.0	7865582
Total Iron (Fe)	mg/L	55.2	1.0	7865582
Total Lead (Pb)	mg/L	<3.0	3.0	7865582
Total Lithium (Li)	mg/L	54.5	2.0	7865582
Total Manganese (Mn)	mg/L	3.98	0.30	7865582
Total Molybdenum (Mo)	mg/L	<2.0	2.0	7865582
Total Nickel (Ni)	mg/L	<2.0	2.0	7865582
Total Phosphorus (P)	mg/L	7.6	5.0	7865582
Total Selenium (Se)	mg/L	<10	10	7865582
Total Silicon (Si)	mg/L	11.3	5.0	7865582
Total Silver (Ag)	mg/L	<1.0	1.0	7865582
Total Strontium (Sr)	mg/L	1530	0.10	7865582
Total Tin (Sn)	mg/L	<3.0	3.0	7865582
Total Titanium (Ti)	mg/L	<0.50	0.50	7865582
Total Vanadium (V)	mg/L	<1.0	1.0	7865582
Total Zinc (Zn)	mg/L	<0.50	0.50	7865582
Total Zirconium (Zr)	mg/L	<2.0	2.0	7865582
Total Calcium (Ca)	mg/L	9120	5.0	7865582
Total Magnesium (Mg)	mg/L	1190	5.0	7865582
Total Potassium (K)	mg/L	2150	30	7865582
Total Sodium (Na)	mg/L	52900	10	7865582
Total Sulphur (S)	mg/L	<10	10	7865582
RDL = Reportable Detection Limit				

Maxxam Job #: B528565
Report Date: 2015/04/16

SynergyAspen Environmental Inc.
Client Project #: MAXXAM - WATER TEMPLATE

TOTAL PETROLEUM HYDROCARBONS (WATER)

Maxxam ID		MA4066		
Sampling Date		2015/03/06		
COC Number		A9E0408A01		
	Units	PW-15-1	RDL	QC Batch
Ext. Pet. Hydrocarbon				
EPH (C10-C19)	mg/L	2.6	0.20	7865652
EPH (C19-C32)	mg/L	0.51	0.20	7865652
Surrogate Recovery (%)				
O-TERPHENYL (sur.)	%	100		7865652
RDL = Reportable Detection Limit				

Maxxam Job #: B528565
Report Date: 2015/04/16

SynergyAspen Environmental Inc.
Client Project #: MAXXAM - WATER TEMPLATE

BCCSR BTEX/VPH IN WATER (WATER)

Maxxam ID		MA4066		
Sampling Date		2015/03/06		
COC Number		A9E0408A01		
	Units	PW-15-1	RDL	QC Batch
Volatiles				
VPH (VH6 to 10 - BTEX)	ug/L	1100	300	7864984
Methyl-tert-butylether (MTBE)	ug/L	<4.0	4.0	7864995
Benzene	ug/L	630	0.40	7864995
Toluene	ug/L	150	0.40	7864995
Ethylbenzene	ug/L	0.98	0.40	7864995
m & p-Xylene	ug/L	7.7	0.40	7864995
o-Xylene	ug/L	2.7	0.40	7864995
Styrene	ug/L	<0.40	0.40	7864995
Xylenes (Total)	ug/L	10	0.40	7864995
VH C6-C10	ug/L	1900	300	7864995
Surrogate Recovery (%)				
1,4-Difluorobenzene (sur.)	%	98		7864995
4-Bromofluorobenzene (sur.)	%	100		7864995
D4-1,2-Dichloroethane (sur.)	%	99		7864995
RDL = Reportable Detection Limit				

Maxxam Job #: B528565
Report Date: 2015/04/16

SynergyAspen Environmental Inc.
Client Project #: MAXXAM - WATER TEMPLATE

CSR TOTAL METALS IN WATER (WATER)

Maxxam ID		MA4066		
Sampling Date		2015/03/06		
COC Number		A9E0408A01		
	Units	PW-15-1	RDL	QC Batch
Calculated Parameters				
Total Hardness (CaCO ₃)	mg/L	27700	0.50	7864910
RDL = Reportable Detection Limit				

Maxxam Job #: B528565
Report Date: 2015/04/16

SynergyAspen Environmental Inc.
Client Project #: MAXXAM - WATER TEMPLATE

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	2.3°C
Package 2	2.0°C
Package 3	2.7°C
Package 4	2.0°C

Sample conductivity value was outside the calibration range. Linearity verified using a 111,900 uS/cm conductivity standard.

Sample MA4066-01 : Sample received past recommended hold time for all organic tests.

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER) Comments

Sample MA4066-03 ICP-AES Total Metals in Water: Detection limits raised due to matrix interference.

Results relate only to the items tested.

Maxxam Job #: B528565
Report Date: 2015/04/16

QUALITY ASSURANCE REPORT

SynergyAspen Environmental Inc.
Client Project #: MAXXAM - WATER TEMPLATE

QC Batch	Parameter	Date	Matrix Spike		Spiked Blank		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	Units	Value (%)	QC Limits
7864995	1,4-Difluorobenzene (sur.)	2015/04/15	102	70 - 130	99	70 - 130	105	%		
7864995	4-Bromofluorobenzene (sur.)	2015/04/15	99	70 - 130	97	70 - 130	99	%		
7864995	D4-1,2-Dichloroethane (sur.)	2015/04/15	100	70 - 130	94	70 - 130	99	%		
7865652	O-TERPHENYL (sur.)	2015/04/15			102	50 - 130	103	%		
7864995	Benzene	2015/04/15	98	70 - 130	97	70 - 130	<0.40	ug/L	NC	30
7864995	Ethylbenzene	2015/04/15	107	70 - 130	105	70 - 130	<0.40	ug/L	NC	30
7864995	m & p-Xylene	2015/04/15	100	70 - 130	100	70 - 130	<0.40	ug/L	NC	30
7864995	Methyl-tert-butylether (MTBE)	2015/04/15	94	70 - 130	93	70 - 130	<4.0	ug/L		
7864995	o-Xylene	2015/04/15	105	70 - 130	104	70 - 130	<0.40	ug/L	NC	30
7864995	Styrene	2015/04/15	118	70 - 130	116	70 - 130	<0.40	ug/L		
7864995	Toluene	2015/04/15	98	70 - 130	97	70 - 130	<0.40	ug/L	NC	30
7864995	VH C6-C10	2015/04/15			90	70 - 130	<300	ug/L		
7864995	Xylenes (Total)	2015/04/15					<0.40	ug/L	NC	30
7865220	Conductivity	2015/04/15			99	80 - 120	<1.0	uS/cm		
7865557	Dissolved Chloride (Cl)	2015/04/15			100	80 - 120	<0.50	mg/L		
7865652	EPH (C10-C19)	2015/04/15			102	50 - 130	<0.20	mg/L		
7865652	EPH (C19-C32)	2015/04/15			103	50 - 130	<0.20	mg/L		

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

Surrogate: A pure or isotopically labeled compound whose behavior mirrors the analytes of interest. Used to evaluate extraction efficiency.

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (one or both samples < 5x RDL).

Maxxam Job #: B528565
Report Date: 2015/04/16

SynergyAspen Environmental Inc.
Client Project #: MAXXAM - WATER TEMPLATE

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).



Andy Lu, Data Validation Coordinator

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.



Burnaby: 4606 Canada Way, Burnaby, BC V5G 1K5 Ph: (604) 734-7276 Fax: (604) 731-2386, Toll Free: (800) 665-8566

CHAIN OF CUSTODY RECORD

Maxxam Job #:

B528565

COC #:

A9E0408A01

Page: 1 of 1

Invoice To: Require Report?

Yes ☐ No ☒

Report To:

Company Name: SynergyAspen c/o SynergyAspen
Contact Name: Michelle Uyeda ph: 604-803-8346
Address: 1214 Austin Ave
Coquitlam, BC PC: V3K 3P5
Phone / Fax#: Ph: 604-931-1026 Fax: 604-931-1046
E-mail: projectcoordinator@synergyaspen.ca

Company Name: SynergyAspen Environmental
Contact Name: Project Manager - Michelle Uyeda
Address: 1214 Austin Ave
Coquitlam, BC PC: V3K 3P5
Phone / Fax#: Ph: 604-931-1026 Fax: 604-931-1046
E-mail: projectcoordinator@synergyaspen.ca
E-mail 2: muyeda@synergyaspen.ca

PO #: n/a
Project #: Maxxam - Water Template
Location: n/a
Sampled by: Painted Pony Petroleum

COC Relinquished by: MPU
Date: 8-Apr-15 Time: 12:00 AM

REGULATORY REQUIREMENTS: SERVICE REQUESTED:

- ☒ CSR ☒ Regular Turn Around Time (TAT)
☐ CCME (5 days for most tests)
☐ BC Water Quality **RUSH** (Please contact the lab)
☐ Other ☐ 1 Day ☐ 2 Day ☐ Day
☐ DRINKING WATER Rush Results Due Date: DD-MMM-YY

SPECIAL INSTRUCTIONS:

Return Cooler ☐ Ship Sample Bottles (please specify) ☐

Deliver and hold in Burnaby lab for special project approved by Rob Gilbert

ANALYSIS REQUESTED

Sample Identification	Lab Identification	HSVC (ppm or %LEL)	# containers	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	SYN - BTEX/VPH	SYN - EPH	SYN - PAH	SYN - LEPH/HEPH	SYN - General Chemistry	SYN - Detailed Salinity	SYN - D.Metals	SYN - MERCURY	pH (not filtered, not preserved)	Turbidity	Metals: Field Filtered	Metals: Field Preserved	HOLD	Rush Sample
1 PW-15-1	MD4066	n/a	6	04-Apr-15																X
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				

ARRIVED AT DEPOT:

APR 4 2015

TEMP: 16/L6, LC

17100 ILO



B528565

Print name and sign

Print name and sign

Laboratory Use Only

*Relinquished By:	Date (yy/mm/dd):	Time (24hr):	Received by:	Date (yy/mm/dd):	Time (24 hr):	Time Sensitive	Temperature on Receipt (°C)	Custody Seal	Yes	No
Painted Pony Petrole	##	##	Amelaine Berthier	2015/04/09	10:41	☐	A) 2 B) 2 C) 3	Present?	☒	☐
							Just sampled & rec'd on ice:	Intact?	☒	☐

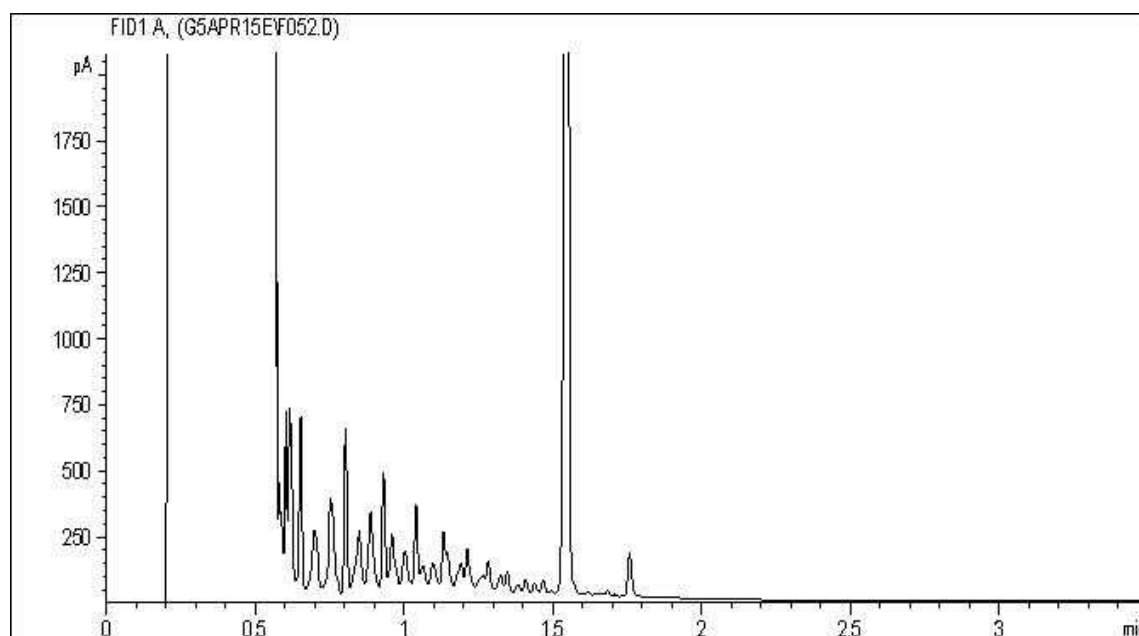
IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORDS. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

BBY FCD-00077R1_C

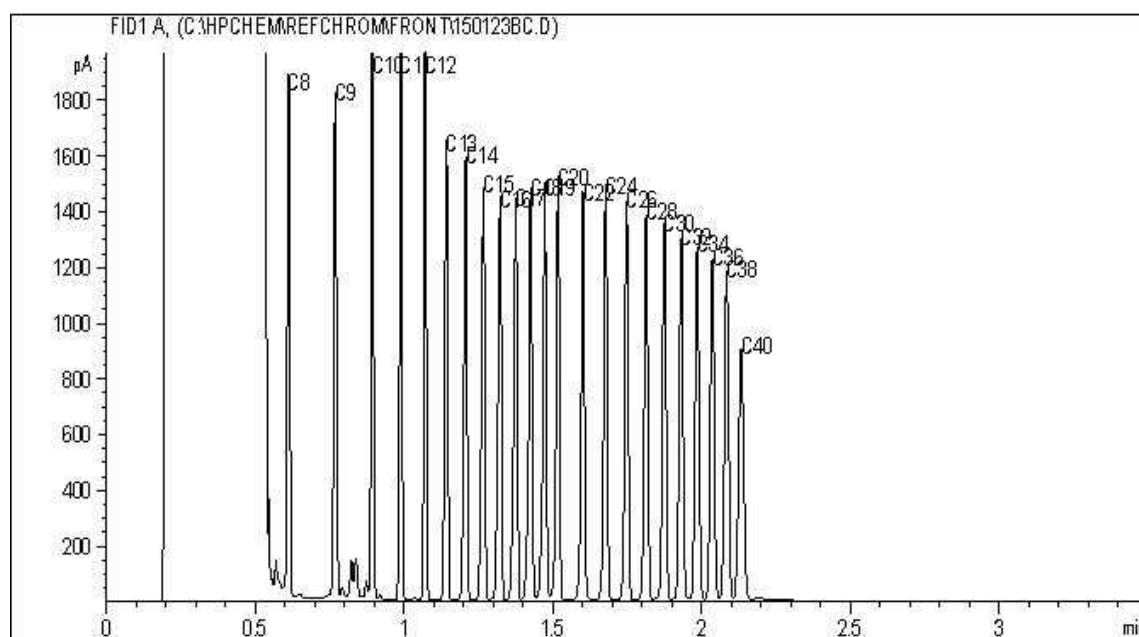
Maxxam Analytics Success Through Science ©

22,2/233/22,2

EPH in Water by GC/FID Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Note: This information is provided for reference purposes only. Should detailed chemist interpretation or fingerprinting be required, please contact the laboratory.

Your Project #: MUSK-15-RES
Your C.O.C. #: G083969

Attention:Michelle Uyeda

SynergyAspen Environmental Inc.
1214 Austin Avenue
Coquitlam, BC
CANADA V3K 3P5

Report Date: 2015/08/19

Report #: R2026737

Version: 1 - Final

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B569014

Received: 2015/08/12, 08:10

Sample Matrix: Water
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
BTEX/MTBE LH, VH, F1 SIM/MS	1	2015/08/13	2015/08/13	BBY8SOP-00010/11	EPA 8260c R3 m
Chloride by Automated Colourimetry	1	N/A	2015/08/14	BBY6SOP-00011	SM 22 4500-Cl- G m
Conductance - water	1	N/A	2015/08/13	BBY6SOP-00026	SM 22 2510 B m
Hardness Total (calculated as CaCO3)	1	N/A	2015/08/17	BBY7SOP-00002	EPA 6020a R1 m
ICP-AES Total Metals in Water	1	2015/08/14	2015/08/17	BBY7SOP-00018	EPA 6010c R3 m
Absolute Density @ 15°C on Water Sample (1)	1	2015/08/12	2015/08/14	PTC SOP-00099	ASTM D4052
Relative Density @15 °C on Water Sample (1)	1	2015/08/12	2015/08/14	PTC SOP-00099	ASTM D4052
Sodium Adsorption Ratio	1	N/A	2015/08/17	BBY WI-00033	SSMA 15.4.4
EPH in Water by GC/FID	1	2015/08/17	2015/08/17	BBY8SOP-00029	BCMOE EPH w 07/99 m
Volatile HC-BTEX	1	N/A	2015/08/14	BBY WI-00033	Auto Calc

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

(1) This test was performed by Maxxam Edmonton Petroleum

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Stefanie Teo, Project Manager

Email: STeo@maxxam.ca

Phone# (604)638-5019

=====

This report has been generated and distributed using a secure automated process.

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B569014
Report Date: 2015/08/19

SynergyAspen Environmental Inc.
Client Project #: MUSK-15-RES

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		MW3037		
Sampling Date				
COC Number		G083969		
	UNITS	PRODUCE WATER	RDL	QC Batch
Calculated Parameters				
Total Hardness (CaCO ₃)	mg/L	21600	0.50	7999300
Sodium Adsorption Ratio	N/A	120	0.10	7999923
Anions				
Dissolved Chloride (Cl)	mg/L	85000	500	8004869
Physical Properties				
Water Absolute Density @ 15°C	kg/m ³	1100	0.10	7999887
Conductivity	uS/cm	160000	1.0	8002007
Water Relative Density @ 15 °C	N/A	1.1	0.00010	7999889
RDL = Reportable Detection Limit				

Maxxam Job #: B569014
Report Date: 2015/08/19

SynergyAspen Environmental Inc.
Client Project #: MUSK-15-RES

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID		MW3037		
Sampling Date				
COC Number		G083969		
	UNITS	PRODUCE WATER	RDL	QC Batch
Total Metals by ICP				
Total Aluminum (Al)	mg/L	1.4	1.0	8002291
Total Antimony (Sb)	mg/L	<1.0	1.0	8002291
Total Arsenic (As)	mg/L	<0.60	0.60	8002291
Total Barium (Ba)	mg/L	201	0.020	8002291
Total Beryllium (Be)	mg/L	<0.060	0.060	8002291
Total Bismuth (Bi)	mg/L	<1.0	1.0	8002291
Total Boron (B)	mg/L	14.6	0.20	8002291
Total Cadmium (Cd)	mg/L	<0.10	0.10	8002291
Total Chromium (Cr)	mg/L	<0.20	0.20	8002291
Total Cobalt (Co)	mg/L	<0.40	0.40	8002291
Total Copper (Cu)	mg/L	<0.40	0.40	8002291
Total Iron (Fe)	mg/L	69.4	0.20	8002291
Total Lead (Pb)	mg/L	<0.60	0.60	8002291
Total Lithium (Li)	mg/L	37.2	0.40	8002291
Total Manganese (Mn)	mg/L	3.45	0.060	8002291
Total Molybdenum (Mo)	mg/L	<0.40	0.40	8002291
Total Nickel (Ni)	mg/L	<0.40	0.40	8002291
Total Phosphorus (P)	mg/L	10.8	1.0	8002291
Total Selenium (Se)	mg/L	<2.0	2.0	8002291
Total Silicon (Si)	mg/L	12.7	1.0	8002291
Total Silver (Ag)	mg/L	<0.20	0.20	8002291
Total Strontium (Sr)	mg/L	1300	0.020	8002291
Total Tin (Sn)	mg/L	<0.60	0.60	8002291
Total Titanium (Ti)	mg/L	<0.10	0.10	8002291
Total Vanadium (V)	mg/L	<0.20	0.20	8002291
Total Zinc (Zn)	mg/L	<0.10	0.10	8002291
Total Zirconium (Zr)	mg/L	<0.40	0.40	8002291
Total Calcium (Ca)	mg/L	7140	1.0	8002291
Total Magnesium (Mg)	mg/L	925	1.0	8002291
Total Potassium (K)	mg/L	1970	6.0	8002291
Total Sodium (Na)	mg/L	39200	2.0	8002291
Total Sulphur (S)	mg/L	9.0	2.0	8002291
RDL = Reportable Detection Limit				

Maxxam Job #: B569014
Report Date: 2015/08/19

SynergyAspen Environmental Inc.
Client Project #: MUSK-15-RES

TOTAL PETROLEUM HYDROCARBONS (WATER)

Maxxam ID		MW3037		
Sampling Date				
COC Number		G083969		
	UNITS	PRODUCE WATER	RDL	QC Batch
Ext. Pet. Hydrocarbon				
EPH (C10-C19)	mg/L	0.29	0.20	8005167
EPH (C19-C32)	mg/L	<0.20	0.20	8005167
Surrogate Recovery (%)				
O-TERPHENYL (sur.)	%	119		8005167
RDL = Reportable Detection Limit				

Maxxam Job #: B569014
Report Date: 2015/08/19

SynergyAspen Environmental Inc.
Client Project #: MUSK-15-RES

BCCSR BTEX/VPH IN WATER (WATER)

Maxxam ID		MW3037		
Sampling Date				
COC Number		G083969		
	UNITS	PRODUCE WATER	RDL	QC Batch
Volatiles				
VPH (VH6 to 10 - BTEX)	ug/L	320	300	7999086
Methyl-tert-butylether (MTBE)	ug/L	<4.0	4.0	8000954
Benzene	ug/L	1200	0.40	8000954
Toluene	ug/L	360	0.40	8000954
Ethylbenzene	ug/L	2.4	0.40	8000954
m & p-Xylene	ug/L	21	0.40	8000954
o-Xylene	ug/L	6.6	0.40	8000954
Styrene	ug/L	<0.40	0.40	8000954
Xylenes (Total)	ug/L	27	0.40	8000954
VH C6-C10	ug/L	1900	300	8000954
Surrogate Recovery (%)				
1,4-Difluorobenzene (sur.)	%	101		8000954
4-Bromofluorobenzene (sur.)	%	100		8000954
D4-1,2-Dichloroethane (sur.)	%	94		8000954
RDL = Reportable Detection Limit				

Maxxam Job #: B569014
Report Date: 2015/08/19

SynergyAspen Environmental Inc.
Client Project #: MUSK-15-RES

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	5.3°C
Package 2	7.0°C
Package 3	6.7°C

Sample conductivity value was outside the calibration range. Linearity verified using a 111,900 uS/cm conductivity standard.

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER) Comments

Sample MW3037-03 ICP-AES Total Metals in Water: Detection limits raised due to matrix interference.

Results relate only to the items tested.

Maxxam Job #: B569014
Report Date: 2015/08/19

QUALITY ASSURANCE REPORT

SynergyAspen Environmental Inc.
Client Project #: MUSK-15-RES

QC Batch	Parameter	Date	Matrix Spike		Spiked Blank		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
8000954	1,4-Difluorobenzene (sur.)	2015/08/13	107	70 - 130	107	70 - 130	108	%		
8000954	4-Bromofluorobenzene (sur.)	2015/08/13	96	70 - 130	100	70 - 130	98	%		
8000954	D4-1,2-Dichloroethane (sur.)	2015/08/13	92	70 - 130	95	70 - 130	98	%		
8005167	O-TERPHENYL (sur.)	2015/08/17	120	50 - 130	119	50 - 130	113	%		
8000954	Benzene	2015/08/18	92	70 - 130	92	70 - 130	<0.40	ug/L	1.2 (1)	30
8000954	Ethylbenzene	2015/08/13	92	70 - 130	91	70 - 130	<0.40	ug/L		
8000954	m & p-Xylene	2015/08/13	96	70 - 130	95	70 - 130	<0.40	ug/L		
8000954	Methyl-tert-butylether (MTBE)	2015/08/13	91	70 - 130	91	70 - 130	<4.0	ug/L		
8000954	o-Xylene	2015/08/13	94	70 - 130	94	70 - 130	<0.40	ug/L		
8000954	Styrene	2015/08/13	99	70 - 130	95	70 - 130	<0.40	ug/L		
8000954	Toluene	2015/08/13	89	70 - 130	89	70 - 130	<0.40	ug/L		
8000954	VH C6-C10	2015/08/13			108	70 - 130	<300	ug/L		
8000954	Xylenes (Total)	2015/08/13					<0.40	ug/L		
8002007	Conductivity	2015/08/13			101	80 - 120	<1.0	uS/cm	1.1	20
8002291	Total Aluminum (Al)	2015/08/17	110	80 - 120	114	80 - 120	<0.050	mg/L		
8002291	Total Antimony (Sb)	2015/08/17	96	80 - 120	100	80 - 120	<0.050	mg/L		
8002291	Total Arsenic (As)	2015/08/17	97	80 - 120	98	80 - 120	<0.030	mg/L		
8002291	Total Barium (Ba)	2015/08/17	107	80 - 120	110	80 - 120	<0.0010	mg/L		
8002291	Total Beryllium (Be)	2015/08/17	109	80 - 120	109	80 - 120	<0.0030	mg/L		
8002291	Total Bismuth (Bi)	2015/08/17					<0.050	mg/L		
8002291	Total Boron (B)	2015/08/17	105	80 - 120	106	80 - 120	<0.010	mg/L		
8002291	Total Cadmium (Cd)	2015/08/17	103	80 - 120	104	80 - 120	<0.0050	mg/L		
8002291	Total Calcium (Ca)	2015/08/17	NC	80 - 120	107	80 - 120	<0.050	mg/L	2.1	20
8002291	Total Chromium (Cr)	2015/08/17	104	80 - 120	106	80 - 120	<0.010	mg/L		
8002291	Total Cobalt (Co)	2015/08/17	103	80 - 120	105	80 - 120	<0.020	mg/L		
8002291	Total Copper (Cu)	2015/08/17	101	80 - 120	103	80 - 120	<0.020	mg/L		
8002291	Total Iron (Fe)	2015/08/17	NC	80 - 120	109	80 - 120	<0.010	mg/L		
8002291	Total Lead (Pb)	2015/08/17	101	80 - 120	104	80 - 120	<0.030	mg/L		
8002291	Total Lithium (Li)	2015/08/17	111	80 - 120	113	80 - 120	<0.020	mg/L		
8002291	Total Magnesium (Mg)	2015/08/17	NC	80 - 120	109	80 - 120	<0.050	mg/L		
8002291	Total Manganese (Mn)	2015/08/17	102	80 - 120	108	80 - 120	<0.0030	mg/L		
8002291	Total Molybdenum (Mo)	2015/08/17	103	80 - 120	104	80 - 120	<0.020	mg/L		

Maxxam Job #: B569014
Report Date: 2015/08/19

QUALITY ASSURANCE REPORT(CONT'D)

SynergyAspen Environmental Inc.
Client Project #: MUSK-15-RES

QC Batch	Parameter	Date	Matrix Spike		Spiked Blank		Method Blank		RPD	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits
8002291	Total Nickel (Ni)	2015/08/17	106	80 - 120	106	80 - 120	<0.020	mg/L		
8002291	Total Phosphorus (P)	2015/08/17	103	80 - 120	104	80 - 120	<0.050	mg/L		
8002291	Total Potassium (K)	2015/08/17	105	80 - 120	105	80 - 120	<0.30	mg/L		
8002291	Total Selenium (Se)	2015/08/17	102	80 - 120	103	80 - 120	<0.10	mg/L		
8002291	Total Silicon (Si)	2015/08/17	NC	80 - 120	92	80 - 120	<0.050	mg/L		
8002291	Total Silver (Ag)	2015/08/17	7.2 (2)	80 - 120	104	80 - 120	<0.010	mg/L		
8002291	Total Sodium (Na)	2015/08/17	NC	80 - 120	111	80 - 120	<0.10	mg/L		
8002291	Total Strontium (Sr)	2015/08/17	106	80 - 120	108	80 - 120	<0.0010	mg/L		
8002291	Total Sulphur (S)	2015/08/17	NC	80 - 120	103	80 - 120	<0.10	mg/L		
8002291	Total Tin (Sn)	2015/08/17	101	80 - 120	102	80 - 120	<0.030	mg/L		
8002291	Total Titanium (Ti)	2015/08/17	107	80 - 120	108	80 - 120	<0.0050	mg/L		
8002291	Total Vanadium (V)	2015/08/17	103	80 - 120	105	80 - 120	<0.010	mg/L		
8002291	Total Zinc (Zn)	2015/08/17	106	80 - 120	107	80 - 120	<0.0050	mg/L		
8002291	Total Zirconium (Zr)	2015/08/17	106	80 - 120	108	80 - 120	<0.020	mg/L		
8004869	Dissolved Chloride (Cl)	2015/08/14			103	80 - 120	<0.50	mg/L	1.3	20
8005167	EPH (C10-C19)	2015/08/17	109	50 - 130	101	50 - 130	<0.20	mg/L	NC	30
8005167	EPH (C19-C32)	2015/08/17	115	50 - 130	107	50 - 130	<0.20	mg/L	NC	30

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

Surrogate: A pure or isotopically labeled compound whose behavior mirrors the analytes of interest. Used to evaluate extraction efficiency.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than 2x that of the native sample concentration).

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (one or both samples < 5x RDL).

(1) Detection limits raised due to dilution to bring analyte within the calibrated range.

(2) Recovery or RPD for this parameter is outside control limits. The overall quality control for this analysis meets acceptability criteria.

Maxxam Job #: B569014
Report Date: 2015/08/19

SynergyAspen Environmental Inc.
Client Project #: MUSK-15-RES

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).



Rob Reinert, Data Validation Coordinator

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.



Page: of

Maxxam Job#: RS69014

Invoice To: Require Report? Yes ☐ No ☐

E-mail

Report To:

PO #:

Quotation #:

Project #: MUKK-15-RES

Proj. Name:

Location:

Sampled By:

☐ CSR ☐ Regular Turn Around Time (TAT)
☐ CCME (5 days for most tests)
☐ BC Water Quality ☐ RUSH (Please contact the lab)
☐ Other ☐ 1 Day ☐ 2 Day ☐ 3 Day
 DRINKING WATER Date Required: _____

Return Cooler ☐ Ship Sample Bottles (please specify) ☐

Sample Identification	Lab Identification	Sample Type	Date/Time Sampled	BTEX/PH	VOC/PH	EPH	PAH	CCME-PHC	CCME-PHC	CCME-BTB	PCB	Phenols by	TOG	Dissolved Metals	Total Metals	Nitrate	Chloride	Total Susp	pH	BOD	COO	Coliform, T	Asbestos	HOLD	YES
1	MW3037																								YES
2																									YES
3																									
4																									
5																									
6																									
7																									
8																									
9																									
10																									
11																									
12																									

RECEIVED IN FT ST JOHN

By: D. Malmgren - 15:30

2015 AUG 07

Temp: / /

B569014

Samples are from a Drinking Water Source?

Does source supply multiple households?

RECEIVED IN FT ST JOHN
By: D. Malinoff - 15:30
2015 AUG 07

Temp: 1 1

Samples are from a Drinking Water Source?
Does source supply multiple households?

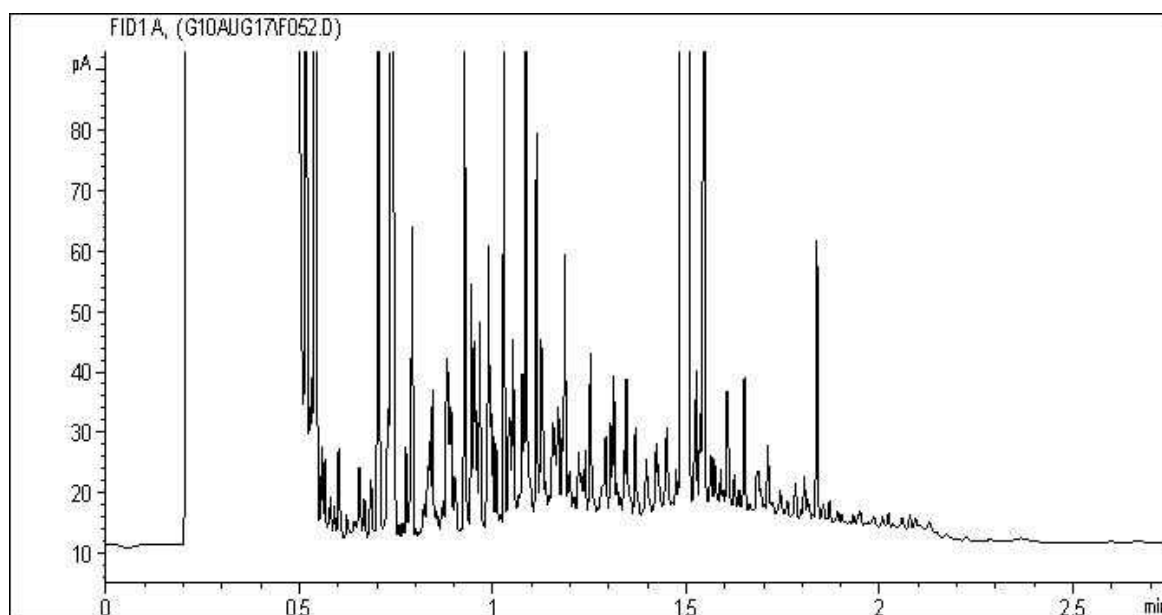
*Relinquished by:	Date (YY/MM/DD):	Time:	Received by:	Date (YY/MM/DD):	Time:	Time Sensitive	Temperature on Receipt (°C)	Custody Seal Intact on Cooler?
Fernando Villegas	15/08/107	3:43pm	Uma Laurel Hernandez	2015/08/12	08:10	☐	55.6/77.7	Yes ☒ No ☐
IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORD. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.							Whiter: Maximum Yellow: Client	

COC-1020 (05/10)

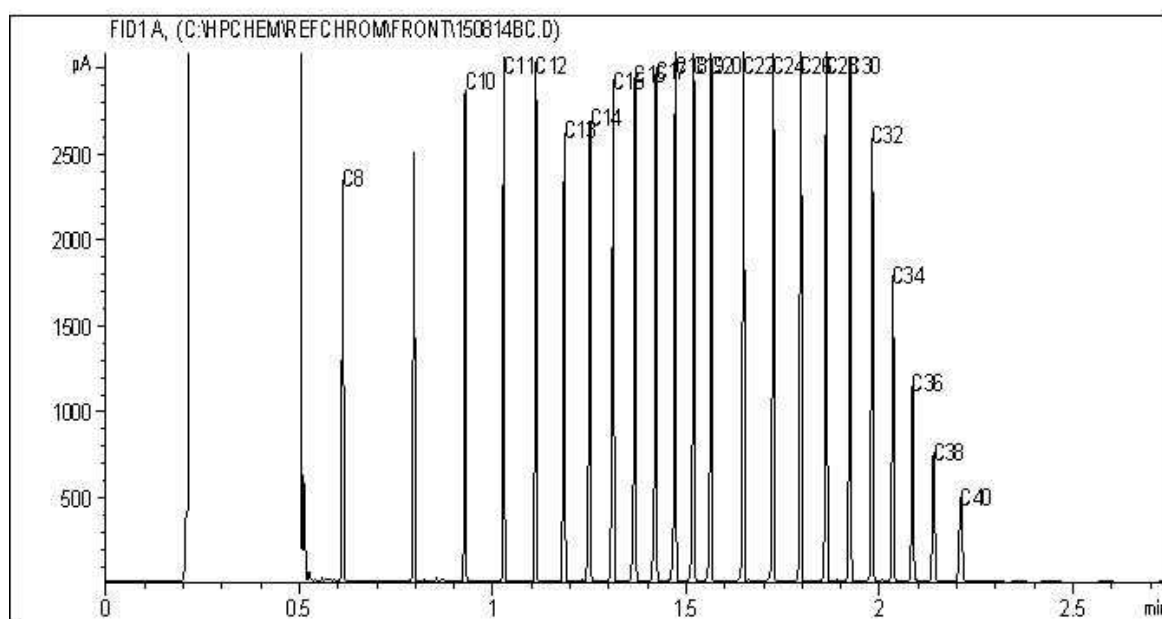
Maxxam International Corporation o/a Maxxam Analytics

White; Maxxam Yellow; Client

EPH in Water by GC/FID Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Gasoline:	C4 - C12	Diesel:	C8 - C22
Varsol:	C8 - C12	Lubricating Oils:	C20 - C40

Note: This information is provided for reference purposes only. Should detailed chemist interpretation or fingerprinting be required, please contact the laboratory.

Your C.O.C. #: A9E0408A01

Attention:Michelle Uyeda

SynergyAspen Environmental Inc.
1214 Austin Avenue
Coquitlam, BC
CANADA V3K 3P5

Report Date: 2015/05/27

Report #: R1965479

Version: 3 - Revision

CERTIFICATE OF ANALYSIS – REVISED REPORT

MAXXAM JOB #: B528565

Received: 2015/04/09, 10:40

Sample Matrix: Soil
Samples Received: 17

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Chloride (soluble)	1	2015/04/28	2015/04/28	BBY6SOP-00011	SM 22 4500-Cl- G m
Chloride (soluble)	16	2015/05/26	2015/05/27	BBY6SOP-00011	SM 22 4500-Cl- G m
Conductivity (Soluble)	1	2015/04/28	2015/04/29	BBY6SOP-00029	SM 22 2510 B
Conductivity (Soluble)	16	2015/05/26	2015/05/27	BBY6SOP-00029	SM 22 2510 B
pH (Soluble)	1	2015/04/28	2015/04/28	BBY6SOP-00025	SM 22 4500-H+ B
pH (Soluble)	16	2015/05/26	2015/05/26	BBY6SOP-00025	SM 22 4500-H+ B
Sodium Adsorption Ratio SP	1	N/A	2015/04/28	BBY6SOP-00030	Carter 2nd 15.2.1 m
Sodium Adsorption Ratio SP	16	N/A	2015/05/26	BBY6SOP-00030	Carter 2nd 15.2.1 m
Saturated Paste	1	2015/04/28	2015/04/28	BBY6SOP-00030	Carter 2nd 15.2.1 m
Saturated Paste	16	2015/05/26	2015/05/26	BBY6SOP-00030	Carter 2nd 15.2.1 m
Soluble Ions Calculation (mg/kg)	1	N/A	2015/04/28	BBY WI-00033	Auto Calc
Soluble Ions Calculation (mg/kg)	16	N/A	2015/05/27	BBY WI-00033	Auto Calc
Sulphate (soluble) (soil)	1	2015/04/28	2015/04/28	BBY6SOP-00017	SM 22 4500-SO42- E m
Sulphate (soluble) (soil)	16	2015/05/26	2015/05/27	BBY6SOP-00017	SM 22 4500-SO42- E m
Soluble Cations (Ca,K,Mg,Na,S)	1	N/A	2015/04/28	BBY7SOP-00018	EPA 6010c R3 m
Soluble Cations (Ca,K,Mg,Na,S)	16	N/A	2015/05/26	BBY7SOP-00018	EPA 6010c R3 m

Sample Matrix: Water
Samples Received: 1

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
BTEX/MTBE LH, VH, F1 SIM/MS	1	2015/04/15	2015/04/15	BBY8SOP-00010/11	EPA 8260c R3 m
Chloride by Automated Colourimetry	1	N/A	2015/04/15	BBY6SOP-00011	SM 22 4500-Cl- G m
Conductance - water	1	N/A	2015/04/15	BBY6SOP-00026	SM 22 2510 B m
Hardness Total (calculated as CaCO3)	1	N/A	2015/04/15	BBY7SOP-00002	EPA 6020a R1 m
ICP-AES Total Metals in Water	1	2015/04/15	2015/04/15	BBY7SOP-00018	EPA 6010c R3 m
Absolute Density @ 15°C on Water Sample (1)	1	2015/04/16	2015/04/16	PTC SOP-00099	ASTM D4052
Relative Density @15 °C on Water Sample (1)	1	2015/04/16	2015/04/16	PTC SOP-00099	ASTM D4052
Sodium Adsorption Ratio	1	N/A	2015/04/15	BBY WI-00033	SSMA 15.4.4
EPH in Water by GC/FID	1	2015/04/15	2015/04/15	BBY8SOP-00029	BCMOE EPH w 07/99 m
Volatile HC-BTEX	1	N/A	2015/04/15	BBY WI-00033	Auto Calc

Your C.O.C. #: A9E0408A01

Attention:Michelle Uyeda

SynergyAspen Environmental Inc.
1214 Austin Avenue
Coquitlam, BC
CANADA V3K 3P5

Report Date: 2015/05/27

Report #: R1965479

Version: 3 - Revision

CERTIFICATE OF ANALYSIS – REVISED REPORT

MAXXAM JOB #: B528565

Received: 2015/04/09, 10:40

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

(1) This test was performed by Maxxam Edmonton Petroleum

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Stefanie Teo, Project Manager

Email: STeo@maxxam.ca

Phone# (604)638-5019

=====

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B528565
Report Date: 2015/05/27

SynergyAspen Environmental Inc.

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		MA4066		
Sampling Date		2015/03/06		
COC Number		A9E0408A01		
	Units	PW-15-1	RDL	QC Batch
Calculated Parameters				
Total Hardness (CaCO ₃)	mg/L	27700	0.50	7864910
Sodium Adsorption Ratio	N/A	140	0.10	7865418
Anions				
Dissolved Chloride (Cl)	mg/L	110000	500	7865557
Physical Properties				
Water Absolute Density @ 15°C	kg/m ³	1100	0.10	7866704
Conductivity	uS/cm	192000	1.0	7865220
Water Relative Density @ 15 °C	N/A	1.1	0.00010	7866706
RDL = Reportable Detection Limit				

Maxxam Job #: B528565
Report Date: 2015/05/27

SynergyAspen Environmental Inc.

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER)

Maxxam ID		MA4066		
Sampling Date		2015/03/06		
COC Number		A9E0408A01		
	Units	PW-15-1	RDL	QC Batch
Total Metals by ICP				
Total Aluminum (Al)	mg/L	<5.0	5.0	7865582
Total Antimony (Sb)	mg/L	<5.0	5.0	7865582
Total Arsenic (As)	mg/L	<3.0	3.0	7865582
Total Barium (Ba)	mg/L	176	0.10	7865582
Total Beryllium (Be)	mg/L	<0.30	0.30	7865582
Total Bismuth (Bi)	mg/L	<5.0	5.0	7865582
Total Boron (B)	mg/L	14.3	1.0	7865582
Total Cadmium (Cd)	mg/L	<0.50	0.50	7865582
Total Chromium (Cr)	mg/L	<1.0	1.0	7865582
Total Cobalt (Co)	mg/L	<2.0	2.0	7865582
Total Copper (Cu)	mg/L	<2.0	2.0	7865582
Total Iron (Fe)	mg/L	55.2	1.0	7865582
Total Lead (Pb)	mg/L	<3.0	3.0	7865582
Total Lithium (Li)	mg/L	54.5	2.0	7865582
Total Manganese (Mn)	mg/L	3.98	0.30	7865582
Total Molybdenum (Mo)	mg/L	<2.0	2.0	7865582
Total Nickel (Ni)	mg/L	<2.0	2.0	7865582
Total Phosphorus (P)	mg/L	7.6	5.0	7865582
Total Selenium (Se)	mg/L	<10	10	7865582
Total Silicon (Si)	mg/L	11.3	5.0	7865582
Total Silver (Ag)	mg/L	<1.0	1.0	7865582
Total Strontium (Sr)	mg/L	1530	0.10	7865582
Total Tin (Sn)	mg/L	<3.0	3.0	7865582
Total Titanium (Ti)	mg/L	<0.50	0.50	7865582
Total Vanadium (V)	mg/L	<1.0	1.0	7865582
Total Zinc (Zn)	mg/L	<0.50	0.50	7865582
Total Zirconium (Zr)	mg/L	<2.0	2.0	7865582
Total Calcium (Ca)	mg/L	9120	5.0	7865582
Total Magnesium (Mg)	mg/L	1190	5.0	7865582
Total Potassium (K)	mg/L	2150	30	7865582
Total Sodium (Na)	mg/L	52900	10	7865582
Total Sulphur (S)	mg/L	<10	10	7865582
RDL = Reportable Detection Limit				

Maxxam Job #: B528565
Report Date: 2015/05/27

SynergyAspen Environmental Inc.

TOTAL PETROLEUM HYDROCARBONS (WATER)

Maxxam ID		MA4066		
Sampling Date		2015/03/06		
COC Number		A9E0408A01		
	Units	PW-15-1	RDL	QC Batch
Ext. Pet. Hydrocarbon				
EPH (C10-C19)	mg/L	2.6	0.20	7865652
EPH (C19-C32)	mg/L	0.51	0.20	7865652
Surrogate Recovery (%)				
O-TERPHENYL (sur.)	%	100		7865652
RDL = Reportable Detection Limit				

Maxxam Job #: B528565
Report Date: 2015/05/27

SynergyAspen Environmental Inc.

BCCSR BTEX/VPH IN WATER (WATER)

Maxxam ID		MA4066		
Sampling Date		2015/03/06		
COC Number		A9E0408A01		
	Units	PW-15-1	RDL	QC Batch
Volatiles				
VPH (VH6 to 10 - BTEX)	ug/L	1100	300	7864984
Methyl-tert-butylether (MTBE)	ug/L	<4.0	4.0	7864995
Benzene	ug/L	630	0.40	7864995
Toluene	ug/L	150	0.40	7864995
Ethylbenzene	ug/L	0.98	0.40	7864995
m & p-Xylene	ug/L	7.7	0.40	7864995
o-Xylene	ug/L	2.7	0.40	7864995
Styrene	ug/L	<0.40	0.40	7864995
Xylenes (Total)	ug/L	10	0.40	7864995
VH C6-C10	ug/L	1900	300	7864995
Surrogate Recovery (%)				
1,4-Difluorobenzene (sur.)	%	98		7864995
4-Bromofluorobenzene (sur.)	%	100		7864995
D4-1,2-Dichloroethane (sur.)	%	99		7864995
RDL = Reportable Detection Limit				

Maxxam Job #: B528565
Report Date: 2015/05/27

SynergyAspen Environmental Inc.

SALINITY 4 PACKAGE FOR SOIL (SOIL)

Maxxam ID		MC9570			MG5789		MG5793		
Sampling Date									
COC Number		A9E0408A01			A9E0408A01		A9E0408A01		
	Units	S1-BH2 BACKGROUND	RDL	QC Batch	MOISTURE = 60%, SPIKE W/C1	RDL	MOISTURE = 60%, SPIKE W/C2	RDL	QC Batch

ANIONS									
Soluble Sulphate (SO4)	mg/L	554	10	7884994	249	10	181	10	7914387
Soluble Chloride (Cl)	mg/L	27.6	5.0	7884993	4860	50	989	5.0	7914386

Calculated Parameters									
Soluble Chloride (Cl)	mg/kg	173	31	7883818	26400	270	5340	27	7906055
Soluble Sodium (Na)	mg/kg	1170	31	7883818	11700	27	3190	27	7906055
Soluble Calcium (Ca)	mg/kg	1350	31	7883818	3560	27	778	27	7906055
Soluble Magnesium (Mg)	mg/kg	323	31	7883818	1030	27	307	27	7906055
Soluble Potassium (K)	mg/kg	<130	130	7883818	422	110	129	110	7906055
Soluble Sulphur (S)	mg/kg	1290	190	7883818	465	160	385	160	7906055
Soluble Sulphate (SO4)	mg/kg	3470	63	7883818	1350	54	979	54	7906055

Soluble Parameters									
Soluble Conductivity	dS/m	1.57	0.0010	7884372	14.0 (1)	0.0010	3.47	0.0010	7912452
Soluble pH	pH	4.82	N/A	7884363	4.35	N/A	4.68	N/A	7912408
Wet Soluble Calcium (Ca)	mg/L	215	5.0	7884686	655	5.0	144	5.0	7912707
Saturation %	%	627	1.0	7884360	543	1.0	540	1.0	7912399
Wet Soluble Magnesium (Mg)	mg/L	51.5	5.0	7884686	190	5.0	56.9	5.0	7912707
Wet Soluble Potassium (K)	mg/L	<20	20	7884686	78	20	24	20	7912707
Wet Soluble Sodium (Na)	mg/L	187	5.0	7884686	2160	5.0	590	5.0	7912707
Wet Soluble Sulphur (S)	mg/L	205	30	7884686	86	30	71	30	7912707
Sodium Adsorption Ratio	N/A	2.97	0.10	7883816	19.1	0.10	10.5	0.10	7906054

RDL = Reportable Detection Limit

N/A = Not Applicable

(1) Conductivity result is greater than the highest standard (12900 uS/cm).

Maxxam Job #: B528565
Report Date: 2015/05/27

SynergyAspen Environmental Inc.

SALINITY 4 PACKAGE FOR SOIL (SOIL)

Maxxam ID		MG5795	MG5796		MG5797		MG5798		
Sampling Date									
COC Number		A9E0408A01	A9E0408A01		A9E0408A01		A9E0408A01		
	Units	MOISTURE = 60%, SPIKE W/C3	MOISTURE = 60%, SPIKE W/C4	RDL	MOISTURE = 70%, SPIKE W/C1	RDL	MOISTURE = 70%, SPIKE W/C2	RDL	QC Batch

ANIONS

Soluble Sulphate (SO4)	mg/L	194	187	10	734	10	72	10	7914387
Soluble Chloride (Cl)	mg/L	581	263	5.0	4640	50	1120	5.0	7914386

Calculated Parameters

Soluble Chloride (Cl)	mg/kg	3140	1420	27	25800	280	6240	28	7906055
Soluble Sodium (Na)	mg/kg	2450	1890	27	11200	28	3770	28	7906055
Soluble Calcium (Ca)	mg/kg	626	445	27	5400	28	537	28	7906055
Soluble Magnesium (Mg)	mg/kg	245	173	27	1110	28	283	28	7906055
Soluble Potassium (K)	mg/kg	<110	<110	110	380	110	149	110	7906055
Soluble Sulphur (S)	mg/kg	459	485	160	1270	170	262	170	7906055
Soluble Sulphate (SO4)	mg/kg	1050	1000	54	4080	56	404	56	7906055

Soluble Parameters

Soluble Conductivity	dS/m	2.51	1.61	0.0010	13.6 (1)	0.0010	3.67	0.0010	7912452
Soluble pH	pH	4.74	4.81	N/A	4.29	N/A	4.68	N/A	7912408
Wet Soluble Calcium (Ca)	mg/L	116	82.8	5.0	971	5.0	96.2	5.0	7912707
Saturation %	%	540	538	1.0	556	1.0	558	1.0	7912399
Wet Soluble Magnesium (Mg)	mg/L	45.4	32.1	5.0	200	5.0	50.8	5.0	7912707
Wet Soluble Potassium (K)	mg/L	<20	<20	20	68	20	27	20	7912707
Wet Soluble Sodium (Na)	mg/L	454	351	5.0	2020	5.0	676	5.0	7912707
Wet Soluble Sulphur (S)	mg/L	85	90	30	228	30	47	30	7912707
Sodium Adsorption Ratio	N/A	9.05	8.29	0.10	15.4	0.10	13.9	0.10	7906054

RDL = Reportable Detection Limit

N/A = Not Applicable

(1) Conductivity result is greater than the highest standard (12900 uS/cm).

Maxxam Job #: B528565
Report Date: 2015/05/27

SynergyAspen Environmental Inc.

SALINITY 4 PACKAGE FOR SOIL (SOIL)

Maxxam ID		MG5799	MG5800		MG5801		MG5802		
Sampling Date									
COC Number		A9E0408A01	A9E0408A01		A9E0408A01		A9E0408A01		
	Units	MOISTURE = 70%, SPIKE W/C3	MOISTURE = 70%, SPIKE W/C4	RDL	MOISTURE = 80%, SPIKE W/C1	RDL	MOISTURE = 80%, SPIKE W/C2	RDL	QC Batch

ANIONS

Soluble Sulphate (SO4)	mg/L	205	144	10	512	10	441	10	7914387
Soluble Chloride (Cl)	mg/L	487	231	5.0	3430	50	793	5.0	7914386

Calculated Parameters

Soluble Chloride (Cl)	mg/kg	2710	1280	28	21500	310	4980	31	7906055
Soluble Sodium (Na)	mg/kg	2110	1580	28	9950	31	2580	31	7906055
Soluble Calcium (Ca)	mg/kg	614	376	28	4320	31	1710	31	7906055
Soluble Magnesium (Mg)	mg/kg	221	143	28	922	31	428	31	7906055
Soluble Potassium (K)	mg/kg	<110	<110	110	330	130	<130	130	7906055
Soluble Sulphur (S)	mg/kg	467	428	170	1050	190	940	190	7906055
Soluble Sulphate (SO4)	mg/kg	1140	802	56	3210	63	2770	63	7906055

Soluble Parameters

Soluble Conductivity	dS/m	2.25	1.42	0.0010	10.8	0.0010	3.23	0.0010	7912452
Soluble pH	pH	4.75	4.85	N/A	4.37	N/A	4.57	N/A	7912408
Wet Soluble Calcium (Ca)	mg/L	110	67.6	5.0	690	5.0	272	5.0	7912707
Saturation %	%	556	556	1.0	627	1.0	628	1.0	7912399
Wet Soluble Magnesium (Mg)	mg/L	39.7	25.6	5.0	147	5.0	68.1	5.0	7912707
Wet Soluble Potassium (K)	mg/L	<20	<20	20	53	20	<20	20	7912707
Wet Soluble Sodium (Na)	mg/L	380	283	5.0	1590	5.0	411	5.0	7912707
Wet Soluble Sulphur (S)	mg/L	84	77	30	168	30	150	30	7912707
Sodium Adsorption Ratio	N/A	7.88	7.45	0.10	14.3	0.10	5.77	0.10	7906054

RDL = Reportable Detection Limit

N/A = Not Applicable

Maxxam Job #: B528565
Report Date: 2015/05/27

SynergyAspen Environmental Inc.

SALINITY 4 PACKAGE FOR SOIL (SOIL)

Maxxam ID		MG5803	MG5804		MG5805	MG5806		
Sampling Date								
COC Number		A9E0408A01	A9E0408A01		A9E0408A01	A9E0408A01		
	Units	MOISTURE = 80%, SPIKE W/C3	MOISTURE = 80%, SPIKE W/C4	RDL	MOISTURE = 90%, SPIKE W/C1	MOISTURE = 90%, SPIKE W/C2	RDL	QC Batch

ANIONS

Soluble Sulphate (SO4)	mg/L	321	327	10	357	607	10	7914387
Soluble Chloride (Cl)	mg/L	312	245	5.0	1180	535	5.0	7914386

Calculated Parameters

Soluble Chloride (Cl)	mg/kg	1960	1530	31	8800	4010	37	7906055
Soluble Sodium (Na)	mg/kg	1440	2120	31	4360	4060	37	7906055
Soluble Calcium (Ca)	mg/kg	996	419	31	2280	952	37	7906055
Soluble Magnesium (Mg)	mg/kg	263	168	31	507	347	37	7906055
Soluble Potassium (K)	mg/kg	<130	<130	130	151	<150	150	7906055
Soluble Sulphur (S)	mg/kg	703	759	190	964	1500	220	7906055
Soluble Sulphate (SO4)	mg/kg	2010	2040	63	2670	4550	75	7906055

Soluble Parameters

Soluble Conductivity	dS/m	1.80	1.70	0.0010	4.30	2.76	0.0010	7912452
Soluble pH	pH	4.69	4.85	N/A	4.34	4.79	N/A	7912408
Wet Soluble Calcium (Ca)	mg/L	159	67.0	5.0	304	127	5.0	7912707
Saturation %	%	627	625	1.0	749	749	1.0	7912399
Wet Soluble Magnesium (Mg)	mg/L	42.0	26.8	5.0	67.7	46.3	5.0	7912707
Wet Soluble Potassium (K)	mg/L	<20	<20	20	20	<20	20	7912707
Wet Soluble Sodium (Na)	mg/L	230	339	5.0	582	543	5.0	7912707
Wet Soluble Sulphur (S)	mg/L	112	121	30	129	201	30	7912707
Sodium Adsorption Ratio	N/A	4.20	8.85	0.10	7.86	10.5	0.10	7906054

RDL = Reportable Detection Limit

N/A = Not Applicable

Maxxam Job #: B528565
Report Date: 2015/05/27

SynergyAspen Environmental Inc.

SALINITY 4 PACKAGE FOR SOIL (SOIL)

Maxxam ID		MG5807		MG5808		
Sampling Date						
COC Number		A9E0408A01		A9E0408A01		
	Units	MOISTURE = 90%, SPIKE W/C3	RDL	MOISTURE = 90%, SPIKE W/C4	RDL	QC Batch
ANIONS						
Soluble Sulphate (SO ₄)	mg/L	399	10	61	10	7914387
Soluble Chloride (Cl)	mg/L	322	5.0	158	5.0	7914386
Calculated Parameters						
Soluble Chloride (Cl)	mg/kg	2430	38	1180	37	7906055
Soluble Sodium (Na)	mg/kg	1770	38	1390	37	7906055
Soluble Calcium (Ca)	mg/kg	1470	38	358	37	7906055
Soluble Magnesium (Mg)	mg/kg	363	38	126	37	7906055
Soluble Potassium (K)	mg/kg	<150	150	<150	150	7906055
Soluble Sulphur (S)	mg/kg	1070	230	414	220	7906055
Soluble Sulphate (SO ₄)	mg/kg	3010	75	455	75	7906055
Soluble Parameters						
Soluble Conductivity	dS/m	1.95	0.0010	0.915	0.0010	7912452
Soluble pH	pH	4.61	N/A	4.88	N/A	7912408
Wet Soluble Calcium (Ca)	mg/L	196	5.0	47.9	5.0	7912707
Saturation %	%	753	1.0	747	1.0	7912399
Wet Soluble Magnesium (Mg)	mg/L	48.1	5.0	16.8	5.0	7912707
Wet Soluble Potassium (K)	mg/L	<20	20	<20	20	7912707
Wet Soluble Sodium (Na)	mg/L	234	5.0	186	5.0	7912707
Wet Soluble Sulphur (S)	mg/L	143	30	55	30	7912707
Sodium Adsorption Ratio	N/A	3.89	0.10	5.89	0.10	7906054
RDL = Reportable Detection Limit						
N/A = Not Applicable						

Maxxam Job #: B528565
Report Date: 2015/05/27

SynergyAspen Environmental Inc.

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	2.3°C
Package 2	2.0°C
Package 3	2.7°C
Package 4	2.0°C

Sample conductivity value was outside the calibration range. Linearity verified using a 111,900 uS/cm conductivity standard.

Sample MA4066-01 : Sample received past recommended hold time for all organic tests and for chloride and conductivity analysis.

Sample MG5805-01 : Sample spiked with 5mls of straight Produced Water instead of 10mls.

ELEMENTS BY ATOMIC SPECTROSCOPY (WATER) Comments

Sample MA4066-03 ICP-AES Total Metals in Water: Detection limits raised due to matrix interference.

Results relate only to the items tested.

Maxxam Job #: B528565
Report Date: 2015/05/27

QUALITY ASSURANCE REPORT

SynergyAspen Environmental Inc.

QC Batch	Parameter	Date	Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	Units	Value (%)	QC Limits	% Recovery	QC Limits
7864995	1,4-Difluorobenzene (sur.)	2015/04/15	102	70 - 130	99	70 - 130	105	%				
7864995	4-Bromofluorobenzene (sur.)	2015/04/15	99	70 - 130	97	70 - 130	99	%				
7864995	D4-1,2-Dichloroethane (sur.)	2015/04/15	100	70 - 130	94	70 - 130	99	%				
7865652	O-TERPHENYL (sur.)	2015/04/15			102	50 - 130	103	%				
7864995	Benzene	2015/04/15	98	70 - 130	97	70 - 130	<0.40	ug/L	NC	30		
7864995	Ethylbenzene	2015/04/15	107	70 - 130	105	70 - 130	<0.40	ug/L	NC	30		
7864995	m & p-Xylene	2015/04/15	100	70 - 130	100	70 - 130	<0.40	ug/L	NC	30		
7864995	Methyl-tert-butylether (MTBE)	2015/04/15	94	70 - 130	93	70 - 130	<4.0	ug/L				
7864995	o-Xylene	2015/04/15	105	70 - 130	104	70 - 130	<0.40	ug/L	NC	30		
7864995	Styrene	2015/04/15	118	70 - 130	116	70 - 130	<0.40	ug/L				
7864995	Toluene	2015/04/15	98	70 - 130	97	70 - 130	<0.40	ug/L	NC	30		
7864995	VH C6-C10	2015/04/15			90	70 - 130	<300	ug/L				
7864995	Xylenes (Total)	2015/04/15					<0.40	ug/L	NC	30		
7865220	Conductivity	2015/04/15			99	80 - 120	<1.0	uS/cm				
7865557	Dissolved Chloride (Cl)	2015/04/15			100	80 - 120	<0.50	mg/L				
7865652	EPH (C10-C19)	2015/04/15			102	50 - 130	<0.20	mg/L				
7865652	EPH (C19-C32)	2015/04/15			103	50 - 130	<0.20	mg/L				
7884360	Saturation %	2015/04/28					<1.0	%	0.19	30	104	75 - 125
7884363	Soluble pH	2015/04/28			101	97 - 103			3.2	N/A	101	97 - 103
7884372	Soluble Conductivity	2015/04/29			98	80 - 120	<0.0010	dS/m	1.3	35		
7884686	Wet Soluble Calcium (Ca)	2015/04/28					<5.0	mg/L	0.26	30	95	75 - 125
7884686	Wet Soluble Magnesium (Mg)	2015/04/28					<5.0	mg/L	0	30	90	75 - 125
7884686	Wet Soluble Potassium (K)	2015/04/28					<20	mg/L	NC	30	89	75 - 125
7884686	Wet Soluble Sodium (Na)	2015/04/28					<5.0	mg/L	0.14	30	95	75 - 125
7884686	Wet Soluble Sulphur (S)	2015/04/28					<30	mg/L	0.72	30		
7884993	Soluble Chloride (Cl)	2015/04/28	121	75 - 125	103	80 - 120	<5.0	mg/L	0.29	30	90	75 - 125
7884994	Soluble Sulphate (SO4)	2015/04/28	NC	75 - 125	98	80 - 120	<10	mg/L	2.5	30	109	75 - 125
7912399	Saturation %	2015/05/26					<1.0	%			106	75 - 125
7912408	Soluble pH	2015/05/26			100	97 - 103					101	97 - 103
7912452	Soluble Conductivity	2015/05/27			95	80 - 120	<0.0010	dS/m				
7912707	Wet Soluble Calcium (Ca)	2015/05/26					<5.0	mg/L			93	75 - 125
7912707	Wet Soluble Magnesium (Mg)	2015/05/26					<5.0	mg/L			90	75 - 125

Maxxam Job #: B528565
Report Date: 2015/05/27

QUALITY ASSURANCE REPORT(CONT'D)

SynergyAspen Environmental Inc.

QC Batch	Parameter	Date	Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
			% Recovery	QC Limits	% Recovery	QC Limits	Value	Units	Value (%)	QC Limits	% Recovery	QC Limits
7912707	Wet Soluble Potassium (K)	2015/05/26					<20	mg/L			79	75 - 125
7912707	Wet Soluble Sodium (Na)	2015/05/26					<5.0	mg/L			89	75 - 125
7912707	Wet Soluble Sulphur (S)	2015/05/26					<30	mg/L				
7914386	Soluble Chloride (Cl)	2015/05/27	NC	75 - 125	105	80 - 120	<5.0	mg/L			85	75 - 125
7914387	Soluble Sulphate (SO4)	2015/05/27			96	80 - 120	<10	mg/L			105	75 - 125

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

Surrogate: A pure or isotopically labeled compound whose behavior mirrors the analytes of interest. Used to evaluate extraction efficiency.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spiked amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than 2x that of the native sample concentration).

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (one or both samples < 5x RDL).

Maxxam Job #: B528565
Report Date: 2015/05/27

SynergyAspen Environmental Inc.

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).



Andy Lu, Data Validation Coordinator



Rob Reinert, Data Validation Coordinator

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Burnaby: 4606 Canada Way, Burnaby, BC V5G 1K5 Ph: (604) 734-7276 Fax: (604) 731-2386, Toll Free: (800) 665-8566

CHAIN OF CUSTODY RECORD

Maxxam Job #:

B528565

COC #:

A9E0408A01

Page: 1 of 1

Invoice To: Require Report?

Yes ☐ No ☒

Report To:

Company Name: SynergyAspen c/o SynergyAspen
Contact Name: Michelle Uyeda ph: 604-803-8346
Address: 1214 Austin Ave
Coquitlam, BC PC: V3K 3P5
Phone / Fax#: Ph: 604-931-1026 Fax: 604-931-1046
E-mail: projectcoordinator@synergyaspen.ca

Company Name: SynergyAspen Environmental
Contact Name: Project Manager - Michelle Uyeda
Address: 1214 Austin Ave
Coquitlam, BC PC: V3K 3P5
Phone / Fax#: Ph: 604-931-1026 Fax: 604-931-1046
E-mail: projectcoordinator@synergyaspen.ca
E-mail 2: muyeda@synergyaspen.ca

PO #: n/a
Project #: Maxxam - Water Template
Location: n/a
Sampled by: Painted Pony Petroleum

COC Relinquished by: MPU
Date: 8-Apr-15 Time: 12:00 AM

REGULATORY REQUIREMENTS: SERVICE REQUESTED:

- ☒ CSR ☒ Regular Turn Around Time (TAT)
☐ CCME (5 days for most tests)
☐ BC Water Quality **RUSH** (Please contact the lab)
☐ Other ☐ 1 Day ☐ 2 Day ☐ Day
☐ DRINKING WATER Rush Results Due Date: DD-MMM-YY

SPECIAL INSTRUCTIONS:

Return Cooler ☐ Ship Sample Bottles (please specify) ☐

Deliver and hold in Burnaby lab for special project approved by Rob Gilbert

ANALYSIS REQUESTED

Sample Identification	Lab Identification	HSVC (ppm or %LEL)	# containers	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	SYN - BTEX/PH	SYN - EPH	SYN - PAH	SYN - LEPH/HEPH	SYN - General Chemistry	SYN - Detailed Salinity	SYN - D.Metals	SYN - MERCURY	pH (not filtered, not preserved)	Turbidity	Metals: Field Filtered	Metals: Field Preserved	HOLD	Rush Sample
1 PW-15-1	MD4066	n/a	6	04-Apr-15																X
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				

ARRIVED AT DEPOT:

APR 4 2015

TEMP: 16/L6/LC

17100 ILO



B528565

Print name and sign

Print name and sign

Laboratory Use Only

*Relinquished By:	Date (yy/mm/dd):	Time (24hr):	Received by:	Date (yy/mm/dd):	Time (24 hr):	Time Sensitive	Temperature on Receipt (°C)	Custody Seal	Yes	No
Painted Pony Petrole	##	##	<i>Amelaine Berthier</i>	2015/04/09	10:41	☐	A) 2 B) 2 C) 3	Present?	☒	☐
							Just sampled & rec'd on ice: ☐	Intact?	☒	☐

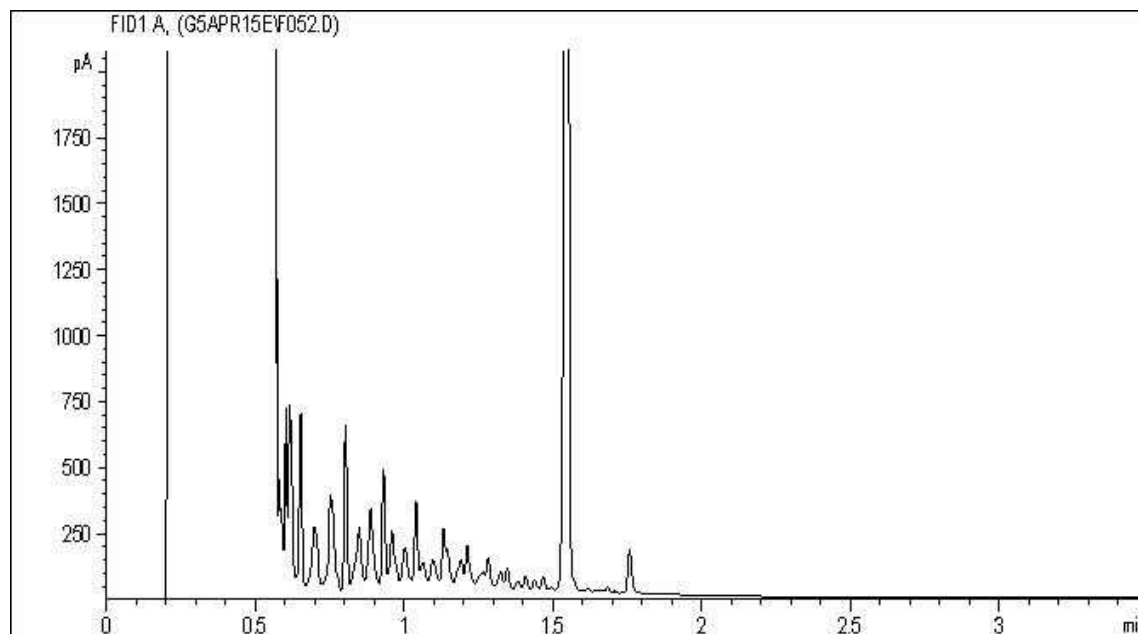
IT IS THE RESPONSIBILITY OF THE RELINQUISHER TO ENSURE THE ACCURACY OF THE CHAIN OF CUSTODY RECORDS. AN INCOMPLETE CHAIN OF CUSTODY MAY RESULT IN ANALYTICAL TAT DELAYS.

BBY FCD-00077R1_C

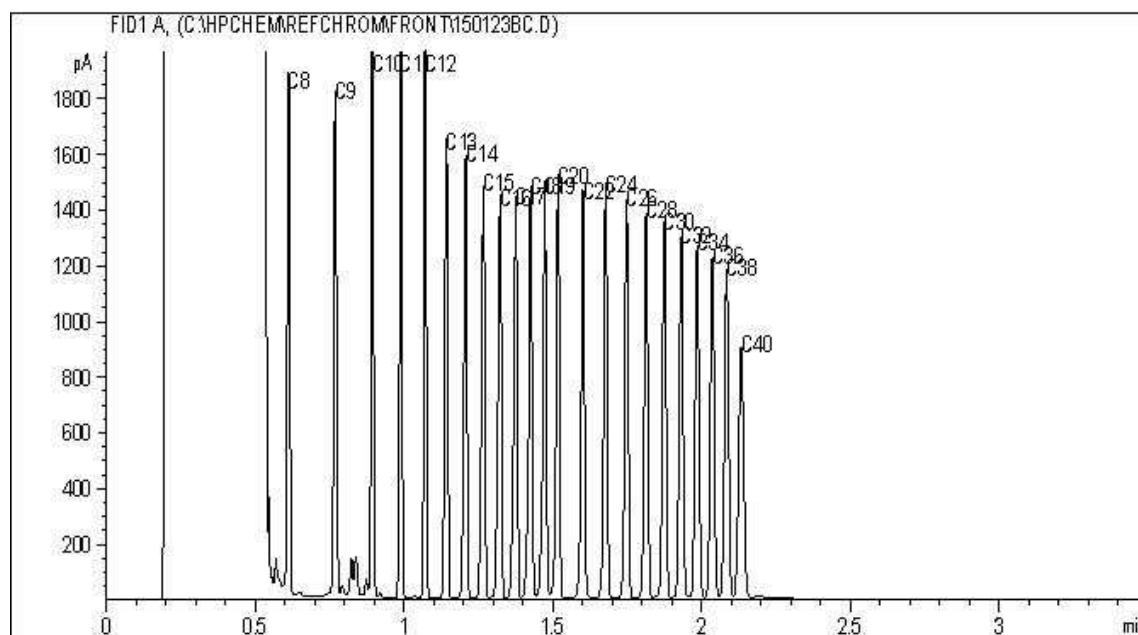
Maxxam Analytics Success Through Science ©

22,2/233/22,2

EPH in Water by GC/FID Chromatogram



Carbon Range Distribution - Reference Chromatogram



TYPICAL PRODUCT CARBON NUMBER RANGES

Note: This information is provided for reference purposes only. Should detailed chemist interpretation or fingerprinting be required, please contact the laboratory.

Attention:Michelle Uyeda

SynergyAspen Environmental Inc.
1214 Austin Avenue
Coquitlam, BC
CANADA V3K 3P5

Report Date: 2015/08/28

Report #: R2032256

Version: 2 - Revision

CERTIFICATE OF ANALYSIS – REVISED REPORT

MAXXAM JOB #: B569110

Received: 2015/08/12, 15:39

Sample Matrix: Solid
Samples Received: 12

Analyses	Date		Laboratory Method	Analytical Method
	Quantity	Extracted		
Chloride (soluble)	12	2015/08/28	2015/08/28 BBY6SOP-00011	SM 22 4500-Cl- G m
Soluble Cations (Ca,K,Mg,Na,S)	12	N/A	2015/08/19 BBY7SOP-00001/18	EPA 6010c/6020A m

Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.

* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

Stefanie Teo, Project Manager

Email: STeo@maxxam.ca

Phone# (604)638-5019

=====

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Maxxam Job #: B569110
Report Date: 2015/08/28

SynergyAspen Environmental Inc.

RESULTS OF CHEMICAL ANALYSES OF SOLID

Maxxam ID		MW3618	MW3619		MW3620		
Sampling Date							
	UNITS	70%M C1 SPIKE AFTER	80%M C1 SPIKE AFTER	RDL	MUSKEG SATURATION C1	RDL	QC Batch
ANIONS							
Soluble Chloride (Cl)	mg/L	9710	6300	50	42100	5000	8019771
Soluble Parameters							
Wet Soluble Calcium (Ca)	mg/L	2220	1320	5.0	4560	5.0	8007621
Wet Soluble Magnesium (Mg)	mg/L	358	214	5.0	665	5.0	8007621
Wet Soluble Potassium (K)	mg/L	106	78	20	608	20	8007621
Wet Soluble Sodium (Na)	mg/L	3540	2370	5.0	14900	5.0	8007621
Wet Soluble Sulphur (S)	mg/L	442	298	30	285	30	8007621
RDL = Reportable Detection Limit							

Maxxam ID		MW3621		MW3622	MW3623	MW3624		MW3625		
Sampling Date										
	UNITS	MOISTURE=80% SPIKE W/ C1	RDL	MOISTURE=80% SPIKE W/ C2	MOISTURE=80% SPIKE W/ C3	MOISTURE=80% SPIKE W/ C4	RDL	MOISTURE=90% SPIKE W/ C1	RDL	QC Batch
ANIONS										
Soluble Chloride (Cl)	mg/L	5470	50	1130	623	295	5.0	2120	50	8019771
Soluble Parameters										
Wet Soluble Calcium (Ca)	mg/L	798	5.0	242	148	102	5.0	251	5.0	8007621
Wet Soluble Magnesium (Mg)	mg/L	220	5.0	75.0	47.9	31.0	5.0	90.4	5.0	8007621
Wet Soluble Potassium (K)	mg/L	73	20	21	<20	<20	20	39	20	8007621
Wet Soluble Sodium (Na)	mg/L	2110	5.0	600	447	349	5.0	1100	5.0	8007621
Wet Soluble Sulphur (S)	mg/L	133	30	135	125	117	30	39	30	8007621
RDL = Reportable Detection Limit										

Maxxam ID		MW3626	MW3627	MW3628	MW3629		
Sampling Date							
	UNITS	MOISTURE=90% SPIKE W/ C2	MOISTURE=90% SPIKE W/ C3	MOISTURE=90% SPIKE W/ C4	MUSKEG BACKGROUND	RDL	QC Batch
ANIONS							
Soluble Chloride (Cl)	mg/L	529	275	143	32.3	5.0	8019771
Soluble Parameters							
Wet Soluble Calcium (Ca)	mg/L	65.6	44.4	36.5	394	5.0	8007621
Wet Soluble Magnesium (Mg)	mg/L	24.5	15.6	11.3	79.0	5.0	8007621
Wet Soluble Potassium (K)	mg/L	<20	<20	<20	<20	20	8007621
Wet Soluble Sodium (Na)	mg/L	346	240	177	134	5.0	8007621
Wet Soluble Sulphur (S)	mg/L	43	44	47	351	30	8007621
RDL = Reportable Detection Limit							

Maxxam Job #: B569110
Report Date: 2015/08/28

SynergyAspen Environmental Inc.

GENERAL COMMENTS

Results relate only to the items tested.

Maxxam Job #: B569110
Report Date: 2015/08/28

QUALITY ASSURANCE REPORT

SynergyAspen Environmental Inc.

QC Batch	Parameter	Date	Spiked Blank		Method Blank	
			% Recovery	QC Limits	Value	UNITS
8007621	Wet Soluble Calcium (Ca)	2015/08/19			<5.0	mg/L
8007621	Wet Soluble Magnesium (Mg)	2015/08/19			<5.0	mg/L
8007621	Wet Soluble Potassium (K)	2015/08/19			<20	mg/L
8007621	Wet Soluble Sodium (Na)	2015/08/19			<5.0	mg/L
8007621	Wet Soluble Sulphur (S)	2015/08/19			<30	mg/L
8019771	Soluble Chloride (Cl)	2015/08/28	105	80 - 120	<5.0	mg/L
Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy. Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.						

Maxxam Job #: B569110
Report Date: 2015/08/28

SynergyAspen Environmental Inc.

VALIDATION SIGNATURE PAGE

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Rob Reinert, Data Validation Coordinator

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