TOWN OF RUSSELL LAGOON SLUDGE CHARACTERIZATION

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1 PROJECT SUMMARY

As part of the Town of Russell's (Town) water treatment plant (WTP) lime-softening process, the plant produces a waste stream containing a mixture of calcium carbonate and magnesium hydroxide. The waste stream, although mostly water and flocculated particles, encompasses these hydroxides in the form of a white precipitate (referred to as sludge).

The plant discharges to the Town's wastewater sewer system at a high frequency, which in turn transports a small amount of the sludge to the Town's wastewater treatment facility, "lagoon". Although the actual concentration of the precipitate (sludge) in each discharge remains very low, the cumulative effect of the lime softening process has led to a build-up of the WTP sludge within the primary cell of the Town's lagoon.

Historically, disposal has included excavation of the bulk material for transport and disposal as a cover material at the waste disposal ground, located approximately 3 kilometres away.

Manitoba Conservation and Water Stewardship (CWS) have raised concern regarding the Town's conventional disposal method to the local waste disposal ground. Of particular interest is to determine if the sludge has combined with the lagoon biosolids preventing its disposal.

CWS have requested that a consulting engineering firm evaluate the quality of the accumulated sludge in the lagoon and estimate its quantity.

1.1 PROJECT SCOPE

Based on recent discussions with the Town of Russell and with CWS the scope of this project included the following items:

- → Composite sampling of the water treatment plant sludge which mounds within the lagoon primary cell.
- → Characterization (physical, salinity, nutrient, and metals) of the composite sample by laboratory analysis to assess sludge quality.
- → Sampling of the water treatment plant waste product at the water treatment plant. This sampling will aid in the development of a characterization base line and provide further comparison of the sludge.

1.2 SLUDGE MOVEMENT TO THE LAGOON

In the lime-softening process occurring at the WTP, the pH of the water being treated is raised sufficiently to precipitate calcium carbonate and magnesium hydroxide. Typically, in small systems,

lime-softening is practiced by adding hydrated lime to the raw water to raise the pH to approximately 10 to 11, thereby precipitating calcium and magnesium as white coloured hydroxides (limestone and brucite).

The lime softening process takes place in a single reaction chamber, which discharges waste at a high flow every seven minutes to a nearby waste pit located within the WTP. The precipitates makeup a small percentage (by volume) of the total discharge waste product sludge, and slowly accumulates within the waste pit.

As the precipitate slowly builds up within the waste collection pit, the WTP operators will use treated water to clean the pit, effectively flushing additional accumulated precipitate into the wastewater sewer system. With WTP wastewater being discharged at seven minute intervals, small amounts of the lime softening precipitate enter the wastewater sewer system at a high frequency, with larger slugs occurring with the cleaning of the waste pit.

The existing wastewater treatment facility consists of a three-cell facultative stabilization pond, located approximately 600 metres from the west edge of the Community at the northeast corner of SE 04-21-28 WPM. The lagoon was originally built in 1956 and was expanded in 1968, 1985, and 2007. Wastewater is pumped from a main lift station located in the Town of Russell through a forcemain which discharges to the primary cell of the lagoon.

2 SLUDGE CHARACTERIZATION

It is anticipated that the sludge will be applied in a semi-dry state with continued dewatering as the material is deposited in its final location at the waste disposal ground. The Town reports that the material will be surface spread and incorporated into the existing waste disposal facility waste piles.

WSP completed a comprehensive sampling program on November 26, 2014 of the accumulated sludge mound located within the Town's lagoon primary cell. The Town had previously drained the cell in preparation of excavation, just prior to CWS intervention requesting a study of the mounded sludge; in turn facilitating sampling efforts.

2.1 METHOD

The Town of Russell arranged to have the necessary equipment (backhoe) and personnel available to break open the sludge mound at six locations within the primary cell. Two shovel samples were taken from each test pit at approximately 0.60 to 0.91 m below ground surface in order to collect representative samples of the material which would normally be removed. The Town's Public Works Foreman provided additional guidance demonstrating the depth and material intended to be removed.

One composite sample composed from the six pits advanced on site was assembled and submitted for analysis to ALS Laboratory Group (ALS), an accredited laboratory by the Canadian Association for

Laboratory Accreditation Inc. (CALA). The following analysis was completed to assess the sludge quality:

- Physical characteristics: moisture content, organic matter content, total carbon, mineral content and specific gravity.
- Detailed salinity (chloride, calcium, potassium, magnesium, sodium), sulfur, sodium absorption ratio (SAR), electrical conductivity (EC), and pH.
- Nutrient characteristics: nitrogen profile (total kjeldahl nitrogen, nitrate-nitrogen, ammonium-nitrogen), total and bi-carbonate phosphorus, potassium and sulfate-sulfur.
- Metals content (30 metals analyzed).

2.2 ESTIMATED SLUDGE QUANTITY

The primary cell has a total volume of 49,300 m^3 or a storage volume of 24,650 m^3, as only half of the total volume contributes to the hydraulic storage of the facility. The base of the cell has an area of approximately 28,993 m^2.

On November 26, 2014 the approximate radius of the mound from the center (outlet pipe) ranged from 25 to 28 metres with a 1.0 metre observable depth at the centre of the mound. The general shape was concentric, although not uniform. For comparison, historic aerial photography dated September 2012 provides an approximate radius from the centre of the mound of 32 to 45 metres.

Assuming a centre depth of 1.0 m, a conical frustum was used to estimate the volume present on November 26th. Should a more accurate volume calculation be required, it is recommended that the Town of Russell arrange to have the mound surveyed.

Table 1: Estimated mound volume.

Date	Frustum Parameters	Min Radii	Max Radii
November-14			
	Estimated Top Frustum Radius	5	8
	Estimated Bottom Frustum Radius	25	28
	Height	1	1
	Conical Frustum Estimate (rounded to nearest 100th) (m^3)	800	1,100
	10% Factory of Safety (m^3)	80	110
	Estimated Mound Volume (m^3)	880	1,210

Based on the November 2014 site visit, it is estimated that the volume of the mound ranges between 880 m^3 and 1,210 m^3. At a conservative estimate of 1,210 m^3 and specific gravity of 2.14 (kg/L), the mass of the mound present is estimated at approximately 2,589 tonnes. It should be noted that the volume to be removed from the primary cell may not necessarily be reflected by this estimate, as removal is often based on a function of staff availability, ease of access, budgeted funds, timing, and other municipal public works planning considerations.

2.3 SLUDGE QUALITY

2.3.1 NUTRIENT CONSIDERATIONS

An evaluation of both the WTP precipitate waste collected from the WTP's waste pit, and a composite sample from the sludge mound in the lagoon is presented below. As previously noted, CWS is concerned with the disposal of the sludge at the waste disposal ground rather than the land application of biosolids.

To determine the appropriateness of disposal to the Town's waste disposal ground, it is important to characterize the differing components of the sludge. Of particular importance is the Nutrient Management Regulation 62/2008 (registered on March 18, 2008) focusing on nutrient and biosolids application on the basis of soil agricultural suitability, ie. land application considerations. The Regulation focuses on protecting water quality by encouraging responsible nutrient planning and by regulating the application to land of substances containing nitrogen or phosphorus.

Table 2: Sludge characterization with nitrogen and phosphorus profiling.

Parameter	Description	WTP Sample	Primary Cell Sample	Unit
Physical Characteristics				
Reported Wet Volume (Table 1)	In-field	-	1,210	m^3
Specific Gravity	As Received	1.50	2.14	kg/L
Total Solids	As Received	33.4	53.5	%
Moisture	As Received	66.6	46.5	%
Dry tonnes biosolid available (wet volume x %solids)	Dried Basis	-	647	tonnes
Organic Matter	Dry Basis	3.3	7.5	%
pH	Paste	9.16	8.45	Unitless
Nitrogen Profiling				
Total Kjeldahl N	% Dried Basis	0.03	0.24	%
Total Kjeldahl N	Dried Basis	310	2,380	mg/kg
Total Kjeldahl N	Dried Basis	0.31	2.38	mg/Tonne
Ammonium - N	Dried Basis	<1.0	106.0	mg/kg
Ammonium - N	Dried Basis	<0.001	0.11	mg/Tonne
Available Nitrate-N	Dried Basis	<4.0	4.10	mg/kg
Available Nitrate-N	Dried Basis	<0.004	0.00	mg/Tonne
Organic N (TKN – Ammonium-N)	Dried Basis	310	2,274	mg/kg
Organic N	Dried Basis	0.31	2.27	mg/Tonne
Anticipated Volitization (% of initial ammonia lost; 0 to 5 days incorporation)			17%	
Available Organic N (10% of Organic N)	Dried Basis	0.03	0.23	mg/Tonne
Ammonium Nitrogen Available	Dried Basis	<0.001	0.09	mg/Tonne
Total available nitrogen (Year 1, Org.N+Amm.N.)	Dried Basis	0.03	0.23	kg/Tonne
Mineralization N (Year 1, 25%)	Dried Basis	0.08	0.57	kg/Tonne
Mineralization N (Year 2, 12%)	Dried Basis	0.04	0.27	kg/Tonne
Mineralization N (Year 3, 6%)	Dried Basis	0.02	0.14	kg/Tonne
Phosphorous Profiling				
Total Phosphorus (Acid digestion)	Dried Basis	72	857	mg/kg
Phosphorus	Dried Basis	0.07	0.86	kg/Tonne
P_2O_5 (molar equivalent)	Dried Basis	0.16	1.96	kg/Tonne
Total Available P_2O_5 (50% available of P_2O_5)	Dried Basis	0.08	0.98	kg/Tonne

Available Phosphate (Olsen)	Dried Basis	<1.0	158.00	mg/kg
Phosphorus	Dried Basis	<1.0	0.16	kg/Tonne
P_2O_5 equivalent	Dried Basis	<1.0	0.36	kg/Tonne
Total Available P_2O_5 (50% available)	Dried Basis	<1.0	0.18	kg/Tonne
Nutrient Ratio Confirmations				
Total Organic Carbon by Combustion	Dry Basis	10.7	12.4	%
C:N Ratio (Organic Carbon: Total Kjeldahl N)	Dry Basis	345	52	x:1
C:P Ratio (Organic Carbon: Total Phosphorus)	Dry Basis	1,486	145	x:1
N:P Ratio	Dry Basis	4.31	2.78	x:1

Nitrogen, present or added to the soil, is subject to several chemical changes that dictate the availability of nitrogen to plants and influence the potential movement of the final transformed product, nitrate (NO_3^-), to water supplies. Although nitrogen can be added to soil in either organic or inorganic forms, plants can only utilize inorganic nitrogen (nitrate, NO_3^- or ammonium, NH_4^+).

One form is not more important than the other and all sources of nitrogen can be converted to nitrate. Organic nitrogen is converted to inorganic nitrogen through the process of mineralization. With any potential land application of the sludge, only an initial portion of the total nitrogen would be available immediately. A portion of the total nitrogen present in the organic form will undergo mineralization, transforming it to inorganic nitrogen (specifically ammonium).

Table 2 applies an anticipated mineralization rate of 25% for year one, 12% for year two and 6% for year three, demonstrating the mineralization amount.

The carbon:nitrogen (C:N) ratio of organic matter, along with environmental conditions, can regulate microbial population growth. This ratio will effectively control the amount of inorganic nitrogen available for plant uptake, or other less desirable fates (leaching, denitrification).

Stable organic matter has a C:N ratio from approximately 10:1 to 12:1, while soil organisms have ratios from approximately 5:1 to 8:1. A C:N ratio of approximately 25:1 commonly indicates mineralization and immobilization are in balance; whereas greater ratios such as >30:1 indicate a rapid increase in microbial biomass and depletion of available nitrogen (immobilization) in soil. Both samples exceed a 30:1 ratio, inferring nitrogen immobilization; meaning the conversion of inorganic nitrogen to organic compounds is prevented (and thereby preventing plant accessible nitrogen).

Similar to nitrogen, organic phosphorus is converted to inorganic phosphate through the process of mineralization. The immobilization of inorganic phosphate, in contrast, is the reverse reaction of mineralization. During immobilization, microbial populations convert inorganic forms to organic phosphate, which are then incorporated into microbial biomass. Mineralization and immobilization of phosphorus occur simultaneously in the soil, with the C:P ratio determining whether there is net mineralization or net immobilization.

With a carbon:phosphorus (C:P) ratio of <200:1, net mineralization occurs indicating sufficient phosphorus present to promote plant and microbial growth. At ratios >300:1, net immobilization occurs and thus not enough phosphorus is present to sustain plant or microbial growth. Lab results (C:P ratio of 145:1) suggest that based upon the phosphorous concentration, the sludge sample could support plant and microbial growth, whereas the WTP sample could not.

When wastes have nitrogen:phosphorus (N:P) ratio's within a range of 0.5:1 to 1:1, and are being applied based upon pre-existing nitrogen conditions present in soil, over time phosphorus will tend to accumulate. Both the WTP and sludge samples have elevated N:P ratios and thus it is anticipated that phosphorus will not accumulate (agreeing with the high C:P ratio).

Organic matter content is an important measurement of the samples, as it generally consists of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by soil organisms. In essence, organic matter content is largely regarded as a critical component of soil function and soil quality. The Manitoba Agricultural Resources section evaluated natural soil organic matter content for the Russell area in 1997. Their survey concluded the Russell area had organic matter content between 6.8 to 8.4%. The sludge sample analyzed has organic matter content within this range and is consequently not anticipated to provide any net benefit to a land application disposal.

2.3.2 SALINITY CONSIDERATIONS

Soil salinity is a soil condition where water soluble salts in the soils can impede vegetative growth. The WTP sample had an electrical conductivity (EC) of 3.53 dS/m and the sludge sample had an EC of 5.5 dS/m. Manitoba Agriculture, Food and Rural Initiatives (MAFRI) consider an EC of 0 to 2 dS/m as "non-saline", where a EC of 2 to 4 dS/m is considered "slightly saline" with a "low hazard to crop growth". An EC between 4 and 8 dS/m is noted to be "moderately saline", having a "medium hazard to crop growth".

Addition consideration can also be given to the sodium absorption ratio (SAR). The SAR is the ratio of sodium to the beneficial soil structural cations, calcium and magnesium. When the SAR value exceeds 13, the soil is "sodic". If the SAR exceeds 13 and the EC is greater than 4, it is considered a "saline-sodic" soil.

Both the WTP sample and the sludge sample would therefore be considered slightly to moderately saline with little to medium hazard to soils. The SAR is considered low and does not pose a risk to the soil becoming sodic.

Table 3: Sample salinity results.

Parameter Name (Saturated Paste)	WTP	Lagoon Sample	Unit
Electrical Conductivity	3.53	5.5	dS/m
Sodium Absorption Ratio	1.02	0.83	
% Saturation	Oversaturated	45.9	mg/kg
Calcium (Wet)	242.00	<20	mg/kg
Chloride (Wet)	215.00	-	mg/kg
Magnesium (Wet)	188.00	940	mg/kg
Potassium (Wet)	5.80	22	mg/kg
Sodium (Wet)	71.00	118	mg/kg
Sulfate-SO4 (Wet)	1160.00	1700	mg/kg

2.3.3 TRACE METALS CONSIDERATIONS

In Manitoba, biosolids are typically applied to agricultural land with licensing under the Manitoba Environment Act that sets out conditions for application. Key conditions are the maximum application rate and the cumulative addition of specified metals to the land. Using land application standards, the suitability of disposal via land application can be considered.

Metals of principal concern to agriculture commonly include, arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc. The cumulative weight per hectare of each heavy metal in the soil is calculated by adding the amount of each metal in the samples at the guideline rate, to a previously established soil concentration.

Given that establishing pre-existing soil considerations of typical farmland in the area and at the waste disposal ground is beyond the scope of the project, mean metal farmland concentrations for the Town of Russell area were obtained from Haluschak and Mills[1]. Using an application rate of 5.5 tonne per hectare, the mean concentration of the trace elements sampled remains below guidelines. Table 5 on the following page reports the trace element concentrations for the WTP and lagoon sludge sample.

2.4 SAMPLE COMPARISON

Biosolids are mainly a mix of water and organic materials that are a by-product of the sewage treatment processes. Most wastewater comes from household, kitchens, laundries and bathrooms, as such can be described as the following:

- Macronutrients, such as nitrogen, phosphorus, potassium and sulphur; and
- Micronutrients, such as copper, zinc, calcium, magnesium, iron, boron, molybdenum and manganese.

Biosolids may also contain traces of synthetic organic compounds and metals, including arsenic, cadmium, chromium, lead, mercury, nickel and selenium.

By summarizing the above constituents, an opinion of the integration of the sludge mound into the general lagoon biosolid content can be made. As previously mentioned, the Town's Public Works

[1] Haluschak, P., R. G. Eilers, G. F. Mills and S. Grift. 1998. Status of Selected Trace Elements in Agricultural Soils of Southern Manitoba. Technical Report 1998-6E Land Resource Unit, Brandon Research Centre, Research Branch, Agriculture and Agri-Food Canada.

Foreman provided additional guidance demonstrating the depth and material to be removed. Samples were mixed into a composite sample intended to remain representative of the sludge to be excavated.

Table 4: WTP and lagoon sample comparison.

	WTP	Lagoon	% Difference	Detection Limit	Units
Macronutrients					
Nitrogen (TKN)	0.031	0.238	668%		%
Phosphorus	72	857	1090%		mg/kg
Potassium	-	150		100	mg/kg
Sulphur (Sat)	1750	1700	-3%		mg/kg
Micronutrients					
Copper	1.4	27.1	1836%		mg/kg
Zinc	-	29.4		5	mg/kg
Calcium	237,000	197,000	-17%		mg/kg
Magnesium	19,800	7,760	-61%		mg/kg
Iron	2,270	2,020	-11%		mg/kg
Boron (Hot Water)	1.73	8.73	405%		mg/kg
Molybdenum	-	-		<1.0	mg/kg
Manganese	261	215	-18%		mg/kg
Other					
Organic Matter	3.3	7.5	127%		%
Total Carbon (Combustion)	10.7	12.4	16%		%
Arsenic	17.2	8.05	-53%		mg/kg
Cadmium	-	0.11		0.1	mg/kg
Chromium	1.84	2.92	59%		mg/kg
Lead	-	2.6		1	mg/kg
Mercury	-	0.23		0.1	mg/kg
Nickel	2	1.7	-15%		mg/kg
Selenium	-	-		0.2	mg/kg

It is observable that constituents from both the macronutrients and micronutrient categories have increased when compared to the WTP sample. When considering substantial increases (>25% of the highest increase), items of notable mention are nitrogen (TKN), phosphorus, and copper.

As previously mentioned nitrogen and phosphorus are regulated nutrients and have been previously discussed.

Copper may occur in natural waters and wastewaters, as soluble copper salts or as copper compounds precipitated on suspended solids. The copper concentration may be significantly higher in the lagoon when compared to the WTP sample, in part due to copper's ability to integrate well within the wastewater constituents.

Calcium and magnesium, being the main metals produced in the WTP waste remain significantly high in concentration when compared to other constituents (several orders of magnitude). On a parts per million basis, calcium and magnesium compose 97% of the all the metals analyzed, for both the WTP and lagoon sample.

Given the mound's general opaque appearance, remaining high concentrations of calcium and magnesium, and pH, WSP is of the opinion that no significant mixing has occurred. The bulk of the material remains characteristic of the WTP waste.

Table 5: Metal concentrations and their cumulative loading concentration.

	WTP Sample		Sludge Sample		Assumed Existing Soil Concentration (mg/kg)		Loading Rate based on 5.5 Tonne/ha (dry)		Cumulative Metal Concentration by Average Existing Soil Concentration		Manitoba Maximum loading kilograms per hectare* (kg/ha)
	mg/kg	kg/Tonne	mg/kg	kg/Tonne	Min.	Max	WTP (kg/ha)	Sludge Sample (kg/ha)	WTP (kg/ha)	Sludge Sample (kg/ha)	
Arsenic	17.2	0.01720	8.05	0.00805	4	8	0.095	0.044	0.34	0.29	21.6
Barium	14.3	0.01430	32.7	0.0327	-		0.079	0.180	-	-	
Beryllium	<0.50	<0.0005	<0.50	<0.0005	-		-	-	-	-	
Cadmium	<0.1	<0.0001	0.11	0.00011	<0.2		-	0.001	-	-	2.5
Chromium	1.84	0.00184	2.92	0.00292	31	65	0.010	0.016	2.00	2.00	115.2
Cobalt	<1.0	<0.001	<1.0	<0.001	13	22	-	-	-	-	
Copper	1.4	0.00140	27.1	0.0271	19	35	0.008	0.149	1.13	1.27	113.4
Lead	<1.0	<0.001	2.6	0.0026	9	15	-	0.014	-	0.51	126
Mercury	<0.005	<0.000005	0.23	0.00023	31	90	-	0.001	-	**2.51**	11.9
Molybdenum	<1.0	<0.0001	<1.0	<0.001	3	4	-	-	-	-	
Nickel	2	0.00200	1.7	0.0017	22	40	0.011	0.009	1.29	1.29	
Selenium	<0.20	<0.0002	<0.20	<0.0002	0	1	-	-	-	-	
Silver	<0.20	<0.0002	0.73	0.00073	0		-	0.004	-	0.01	
Thallium	<0.10	<0.0001	<0.10	<0.001	-		-	-	-	-	
Zinc	<5.0	<0.005	29.4	0.0294	66	110	-	0.162	-	3.80	360

*Where calculated values shall be based on a soil bulk density of 1,200 kilograms per cubic metre and a soil depth of 15 centimetres. Analysis for heavy metals carried out in accordance with specific methods (for biosolids and soil analyses).

3 CONCLUSION

3.1 MANAGEMENT OF NITROGEN AND PHOSPHORUS

Of major concern associated with its removal and disposal is nutrient leaching and run-off. Specifically, the leaching and/or surface runoff of nitrogen and phosphorus into the ground or surface water is a concern if disposal exceeds natural removal rates and natural soil attenuation. This can be mitigated if the sludge is encapsulated in clay pits at the waste disposal ground, thereby preventing leeching and run-off. If applied to farmland in a typical land application, these concerns are not alleviated.

Typically, for biosolid land applications, the amount of plant available nitrogen added to the land from the sludge should not exceed 100 kg per hectare during any year. Plant available nitrogen is defined as the amount of nitrogen which is readily available to plants by uptake through the roots and is determined by adding 20% of the organic nitrogen (as nitrogen), 100% of the ammonium (as nitrogen), and 100% of the nitrate (as nitrogen). The lagoon sample has a plant available nitrogen of 0.564 mg/tonne.

Using this guideline as a comparison basis with a land application rate of 5.5 tonne per hectare, the plant available nitrogen is calculated as $3.1x10^{-6}$ kg/hectare, and does not exceed plant available nitrogen guidelines. For additional context, if 80% of the estimated dry mass (being approximately 518 tonnes) is excavated; the plant available nitrogen would be approximately 292 mg, far less than the 100 kg per hectare allowance.

CWS also provides soil nitrate-nitrogen thresholds for all soil classifications (N1 to N3). The residual soil nitrate-nitrogen limits within the top 60 cm of soil ranges from 157.1 kg/ha for N1, 101 kg/ha N2, and 33.6 kg/ha for N3 zones. Using the same land application rate as above or excavation volume, the nitrate-nitrogen threshold is not triggered for any of the soil classification zones.

At a total phosphorus concentration of 857 mg/kg, the sludge cannot be placed in a nutrient management area zoned N1, N2, or N3; with the N3 zone having an upper application threshold of 180 ppm at 15 cm depth.

3.2 SALINITY

Using Manitoba's Soil Fertility Guide, both the WTP sample and the sludge sample would be considered "slightly to moderately saline" with "little to medium hazard" to soils. As such, the sludge poses a slight environmental risk for soil salinization, as soil EC, soluble ions, and SAR increase directly with land application. The risk of soil salinization, where previously not occurring, would be minimized if disposed to the waste disposal ground as opposed to a traditional land application.

3.3 TRACE METALS

The loading rates for heavy metals in the sludge from the lagoon were determined based on the theoretical maximum application of 5.5 dry tonnes per hectare. These calculated heavy metal loading rates remain below the cumulative weight criteria as set by Manitoba Agriculture. If 80% of the estimated dry mass is deposited, the following estimates the bulk trace metal concentrations.

Table 6: Bulk trace metal masses contributed at 80% of the mound being deposited to the waste disposal ground.

	80% Dry Mass Deposited in a Single Hectare – Sludge (kg/1 ha)	Manitoba Maximum loading kilograms per hectare* (kg/ha)
		-
Arsenic	4.17	21.6
Barium	16.93	-
Beryllium		-
Cadmium	0.06	2.5
Chromium	1.51	115.2
Cobalt		-
Copper	14.03	113.4
Lead	1.35	126
Mercury	0.12	11.9
Molybdenum		-
Nickel	0.88	-
Selenium		-
Silver	0.38	-
Thallium		-
Zinc	15.23	360

*Where calculated values shall be based on a soil bulk density of 1,200 kilograms per cubic metre and a soil depth of 15 centimetres. Analysis for heavy metals carried out in accordance with specific methods (for biosolids and soil analyses).

3.4 DISPOSAL

In order to prevent potential for order nuisances and to reduce vector related problems, the sludge should be buried and capped at the waste disposal ground.

Pre-existing buffer zones associated with the waste disposal ground have a well-established setback distance from residential areas, residences, groundwater wells, and surface water drainage systems. In addition, the waste disposal ground has been designed to minimize surface runoff, thereby facilitating burying into winter soil.

Given the phosphorus concentrations observed, land application at a 5.5 tonne per hectare rate would not satisfy Manitoba regulations; thereby limiting land application at this rate and concentration.

As the sludge presents an elevated pH (the material was originally generated as calcium or magnesium hydroxide), the material should be buried into existing soil so as to ensure that it does not remain uncovered (ie. wind moving potentially caustic particulate into the air may pose a hazard).

With nutrient conditions limiting land application, metal loadings remaining well below fertilizer application, and considering the pre-established buffer zones associated with the waste disposal ground, burying at the waste disposal ground is considered the recommended suitable disposal option.

3.5 FINDINGS SUMMARY

- As part of the lime-softening process occurring at the WTP, a small amount of precipitated calcium hydroxide and magnesium as a high frequency waste product is collected by the sewer system.
- The waste, due to long-term operation, has accumulated in the primary cell of the lagoon as sludge. Assuming a centre depth of 1.0 m, a conical frustum was used to estimate a volume between 880 to 1,210 m^3.
- Using an anticipated nitrogen mineralization rate of 25% for year one, 12% for year two and 6% for year three, plant available nitrogen within the sludge mound ranges from 0.57 to 0.02 kg/tonne.
- Within the mound sludge, the C:N ratio indicates little conversion of inorganic nitrogen to organic compounds, and thereby prevents nitrogen being accessible to plants.
- Within the mound sludge, the C:P ratio indicates mineralization of phosphorous, making phosphorus accessible to plants for growth.
- The organic matter content of the sludge remains within background levels and is anticipated to provide little benefit the soil via land application.
- Using Manitoba's Soil Fertility Guide, the sludge sample is considered "slightly to moderately saline" with "little to medium hazard" to soils.
- On a parts per million basis, calcium and magnesium compose 97% of the all the metals analyzed in the sludge.

If applied to farmland in a typical land application, the high phosphorus concentration remains a concern, there remains potential for nutrient leeching and run-off, and the sludge is not anticipated to benefit the land.

As such, it is recommended that the sludge be encapsulated in clay pits with clay covers at the waste disposal ground, thereby limiting potential for nutrient leeching and run-off.

4 LIMITATIONS

The findings and recommendations provided in this report were prepared by WSP (the Consultant) in accordance with generally accepted professional engineering principles and practices. The information contained in this report represents the professional opinion of the Consultant and their best judgment under the natural limitations imposed by the Scope of Work.

This report is limited in scope to only those items that are specifically referenced in this report. There may be existing conditions that were not recorded in this report. Such conditions were not apparent to the Consultant due to the limitations imposed by the scope of work. The Consultant, therefore, accepts no liability for any costs incurred by the Client for subsequent discovery, manifestation or rectification of such conditions.

This report is intended solely for the Client named as a general indication of the visible or reported condition of the items addressed in the report at the time of the assessment. The material in this report reflects the Consultant's best judgment in light of the information available to it at the time of preparation.

This report and the information and data contained herein are to be treated as confidential and may be used only by the Client and its officers and employees in relation to the specific project that it was prepared for. Any use a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. The Consultant accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

The report has been written to be read in its entirety, do not use any part of this report as a separate entity.

All files, notes, source data, test results and master files are retained by WSP and remain the property of the Consultant.

Appendix A

ANALYTICAL LAB RESULT

WSP Canada Inc.
ATTN: JUSTIN RAK-BANVILLE
1600 Buffalo Place
Winnipeg MB R3T 6B8

Date Received: 27-NOV-14
Report Date: 09-DEC-14 15:56 (MT)
Version: FINAL

Client Phone: 204-477-6650

Certificate of Analysis

Lab Work Order #: L1551947

Project P.O. #: NOT SUBMITTED
Job Reference: RUSSELL LAGOON SLUDGE TESTING
C of C Numbers:
Legal Site Desc:

Craig Riddell
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1551947-1 WTP SAMPLE							
Sampled By: JRB on 27-NOV-14 @ 10:00							
Matrix: OTHER							
Miscellaneous Parameters							
Boron (B), Hot Water Ext.	1.73	DLM	0.40	mg/kg	04-DEC-14	04-DEC-14	R3115323
Available Phosphate-P	<1.0		1.0	mg/kg	05-DEC-14	05-DEC-14	R3116046
Available Potassium	22		20	mg/kg	04-DEC-14	04-DEC-14	R3115132
Available Sulfate-S	703	DLM	6.0	mg/kg	04-DEC-14	04-DEC-14	R3115310
Mercury (Hg)	<0.0050		0.0050	mg/kg	03-DEC-14	04-DEC-14	R3115147
% Moisture	66.6		0.10	%	03-DEC-14	03-DEC-14	R3113039
% Saturation	Oversat		1.0	%	03-DEC-14	04-DEC-14	R3115354
Special Request	See Attached					09-DEC-14	R3117309
Specific Gravity	1.50		0.010	kg/L		08-DEC-14	R3116802
Total Carbon by Combustion	10.7		0.1	%	05-DEC-14	05-DEC-14	R3116576
Total Kjeldahl Nitrogen	0.031		0.020	%	01-DEC-14	03-DEC-14	R3114563
Organic Matter by LOI at 375 deg C.							
Organic Matter	3.3		1.0	%	03-DEC-14	04-DEC-14	R3114978
Loss on Ignition @ 375 C	3.8		1.0	%	03-DEC-14	04-DEC-14	R3114978
Detailed Salinity in dry-weight mg/kg							
Chloride (Cl)	644		20	mg/kg dwt		05-DEC-14	
Calcium (Ca)	724		20	mg/kg dwt		05-DEC-14	
Magnesium (Mg)	562		20	mg/kg dwt		05-DEC-14	
Potassium (K)	18		10	mg/kg dwt		05-DEC-14	
Sodium (Na)	212		40	mg/kg dwt		05-DEC-14	
Sulfur (as SO4)	3480		50	mg/kg dwt		05-DEC-14	
Detailed Salinity in wet-weight mg/kg							
Chloride (Cl)	215		6.7	mg/kg wwt		05-DEC-14	
Calcium (Ca)	242		6.7	mg/kg wwt		05-DEC-14	
Magnesium (Mg)	188		6.7	mg/kg wwt		05-DEC-14	
Potassium (K)	5.8		3.3	mg/kg wwt		05-DEC-14	
Sodium (Na)	71		13	mg/kg wwt		05-DEC-14	
Sulfur (as SO4)	1160		17	mg/kg wwt		05-DEC-14	
Metals in Soil by CRC ICPMS							
Aluminum (Al)	3920		50	mg/kg	03-DEC-14	04-DEC-14	R3115353
Antimony (Sb)	<0.10		0.10	mg/kg	03-DEC-14	04-DEC-14	R3115353
Arsenic (As)	17.2		0.10	mg/kg	03-DEC-14	04-DEC-14	R3115353
Barium (Ba)	14.3		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Beryllium (Be)	<0.50		0.50	mg/kg	03-DEC-14	04-DEC-14	R3115353
Bismuth (Bi)	<0.20		0.20	mg/kg	03-DEC-14	04-DEC-14	R3115353
Cadmium (Cd)	<0.10		0.10	mg/kg	03-DEC-14	04-DEC-14	R3115353
Calcium (Ca)	237000	DLA	500	mg/kg	03-DEC-14	04-DEC-14	R3115353
Chromium (Cr)	1.84		0.50	mg/kg	03-DEC-14	04-DEC-14	R3115353
Cobalt (Co)	<1.0		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Copper (Cu)	1.4		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Iron (Fe)	2270		50	mg/kg	03-DEC-14	04-DEC-14	R3115353
Lead (Pb)	<1.0		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Lithium (Li)	4.8		2.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Magnesium (Mg)	19800		100	mg/kg	03-DEC-14	04-DEC-14	R3115353
Manganese (Mn)	261		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Molybdenum (Mo)	<1.0		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Nickel (Ni)	2.0		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Phosphorus (P)	72		50	mg/kg	03-DEC-14	04-DEC-14	R3115353
Potassium (K)	<100		100	mg/kg	03-DEC-14	04-DEC-14	R3115353
Selenium (Se)	<0.20		0.20	mg/kg	03-DEC-14	04-DEC-14	R3115353
Silver (Ag)	<0.20		0.20	mg/kg	03-DEC-14	04-DEC-14	R3115353

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1551947-1 WTP SAMPLE							
Sampled By: JRB on 27-NOV-14 @ 10:00							
Matrix: OTHER							
Metals in Soil by CRC ICPMS							
Sodium (Na)	580		100	mg/kg	03-DEC-14	04-DEC-14	R3115353
Strontium (Sr)	322		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Thallium (Tl)	<0.10		0.10	mg/kg	03-DEC-14	04-DEC-14	R3115353
Tin (Sn)	<2.0		2.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Titanium (Ti)	37.5		5.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Uranium (U)	2.35		0.10	mg/kg	03-DEC-14	04-DEC-14	R3115353
Vanadium (V)	<1.0		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Zinc (Zn)	<5.0		5.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Available Ammonia-N & Nitrate-N (2N KCl)							
Available Ammonium-N							
Available Ammonium-N	<1.0		1.0	mg/kg	04-DEC-14	04-DEC-14	R3115813
Available Nitrate-N (2N KCl)							
Available Nitrate-N	<4.0	DLM	4.0	mg/kg	04-DEC-14	04-DEC-14	R3116064
Detailed Salinity -over sat'd waste							
Chloride (Cl)							
Chloride (Cl)	323	DLA	10	mg/L	04-DEC-14	04-DEC-14	R3115033
SAR and Cations (over sat'd)							
Calcium (Ca)	363	DLA	10	mg/L	04-DEC-14	04-DEC-14	R3115016
Potassium (K)	8.8	DLA	5.0	mg/L	04-DEC-14	04-DEC-14	R3115016
Magnesium (Mg)	282	DLA	10	mg/L	04-DEC-14	04-DEC-14	R3115016
Sodium (Na)	106	DLA	20	mg/L	04-DEC-14	04-DEC-14	R3115016
Sulfur (as SO4)	1750	DLA	25	mg/L	04-DEC-14	04-DEC-14	R3115016
SAR	1.02		0.10	SAR	04-DEC-14	04-DEC-14	R3115016
pH and Conductivity							
pH	9.16		0.10	pH	03-DEC-14	04-DEC-14	R3115354
Conductivity (EC)	3.53		0.010	dS m-1	03-DEC-14	04-DEC-14	R3115354
L1551947-2 LAGOON SAMPLE							
Sampled By: JRB on 27-NOV-14 @ 11:30							
Matrix: WASTE							
Miscellaneous Parameters							
Boron (B), Hot Water Ext.	8.73	DLM	0.20	mg/kg	04-DEC-14	04-DEC-14	R3115323
Available Phosphate-P	158		1.0	mg/kg	05-DEC-14	05-DEC-14	R3116046
Available Potassium	84		20	mg/kg	04-DEC-14	04-DEC-14	R3115132
Available Sulfate-S	377	DLM	6.0	mg/kg	04-DEC-14	04-DEC-14	R3115310
Chloride (Cl)	134	DLA	20	mg/L	04-DEC-14	04-DEC-14	R3115033
Mercury (Hg)	0.23	DLA	0.10	mg/kg	03-DEC-14	04-DEC-14	R3115147
% Moisture	46.5		0.10	%	03-DEC-14	03-DEC-14	R3113039
Special Request	See Attached					09-DEC-14	R3117309
Specific Gravity	2.14		0.010	kg/L		08-DEC-14	R3116802
Total Carbon by Combustion	12.4		0.1	%	05-DEC-14	05-DEC-14	R3116576
Total Kjeldahl Nitrogen	0.238		0.020	%	01-DEC-14	03-DEC-14	R3114563
Organic Matter by LOI at 375 deg C.							
Organic Matter	7.5		1.0	%	03-DEC-14	04-DEC-14	R3114978
Loss on Ignition @ 375 C	9.2		1.0	%	03-DEC-14	04-DEC-14	R3114978
Metals in Soil by CRC ICPMS							
Aluminum (Al)	1580		50	mg/kg	03-DEC-14	04-DEC-14	R3115353
Antimony (Sb)	<0.10		0.10	mg/kg	03-DEC-14	04-DEC-14	R3115353
Arsenic (As)	8.05		0.10	mg/kg	03-DEC-14	04-DEC-14	R3115353
Barium (Ba)	32.7		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Beryllium (Be)	<0.50		0.50	mg/kg	03-DEC-14	04-DEC-14	R3115353

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1551947-2 LAGOON SAMPLE							
Sampled By: JRB on 27-NOV-14 @ 11:30							
Matrix: WASTE							
Metals in Soil by CRC ICPMS							
Bismuth (Bi)	0.87		0.20	mg/kg	03-DEC-14	04-DEC-14	R3115353
Cadmium (Cd)	0.11		0.10	mg/kg	03-DEC-14	04-DEC-14	R3115353
Calcium (Ca)	197000	DLA	500	mg/kg	03-DEC-14	04-DEC-14	R3115353
Chromium (Cr)	2.92		0.50	mg/kg	03-DEC-14	04-DEC-14	R3115353
Cobalt (Co)	<1.0		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Copper (Cu)	27.1		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Iron (Fe)	2020		50	mg/kg	03-DEC-14	04-DEC-14	R3115353
Lead (Pb)	2.6		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Lithium (Li)	4.0		2.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Magnesium (Mg)	7760		100	mg/kg	03-DEC-14	04-DEC-14	R3115353
Manganese (Mn)	215		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Molybdenum (Mo)	<1.0		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Nickel (Ni)	1.7		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Phosphorus (P)	857		50	mg/kg	03-DEC-14	04-DEC-14	R3115353
Potassium (K)	150		100	mg/kg	03-DEC-14	04-DEC-14	R3115353
Selenium (Se)	<0.20		0.20	mg/kg	03-DEC-14	04-DEC-14	R3115353
Silver (Ag)	0.73		0.20	mg/kg	03-DEC-14	04-DEC-14	R3115353
Sodium (Na)	520		100	mg/kg	03-DEC-14	04-DEC-14	R3115353
Strontium (Sr)	260		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Thallium (Tl)	<0.10		0.10	mg/kg	03-DEC-14	04-DEC-14	R3115353
Tin (Sn)	2.8		2.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Titanium (Ti)	24.0		5.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Uranium (U)	1.94		0.10	mg/kg	03-DEC-14	04-DEC-14	R3115353
Vanadium (V)	1.5		1.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Zinc (Zn)	29.4		5.0	mg/kg	03-DEC-14	04-DEC-14	R3115353
Available Ammonia-N & Nitrate-N (2N KCl)							
Available Ammonium-N							
Available Ammonium-N	106		1.0	mg/kg	04-DEC-14	04-DEC-14	R3115813
Available Nitrate-N (2N KCl)							
Available Nitrate-N	4.1	DLM	4.0	mg/kg	04-DEC-14	04-DEC-14	R3116064
Detailed Salinity							
Detail Salinity in mg/kg							
Chloride (Cl)	61.6	DLA	9.2	mg/kg		05-DEC-14	
Calcium (Ca)	<9.2	DLA	9.2	mg/kg		05-DEC-14	
Magnesium (Mg)	431	DLA	9.2	mg/kg		05-DEC-14	
Potassium (K)	10.1	DLA	4.6	mg/kg		05-DEC-14	
Sodium (Na)	54	DLA	18	mg/kg		05-DEC-14	
Sulfur (as SO4)	778	DLA	23	mg/kg		05-DEC-14	
SAR, Cations and SO4 in saturated soil							
Calcium (Ca)	<20	DLA	20	mg/L	04-DEC-14	04-DEC-14	R3115016
Potassium (K)	22	DLA	10	mg/L	04-DEC-14	04-DEC-14	R3115016
Magnesium (Mg)	940	DLA	20	mg/L	04-DEC-14	04-DEC-14	R3115016
Sodium (Na)	118	DLA	40	mg/L	04-DEC-14	04-DEC-14	R3115016
SAR	0.83	SAR:M	0.10	SAR	04-DEC-14	04-DEC-14	R3115016
Sulfur (as SO4)	1700	DLA	50	mg/L	04-DEC-14	04-DEC-14	R3115016
Theoretical Gypsum Requirement							
TGR(brine)	<0.10		0.10	t/ha		05-DEC-14	
TGR(sodic)	<0.10		0.10	t/ha		05-DEC-14	
pH and EC (Saturated Paste)							
% Saturation	45.9		1.0	%	03-DEC-14	04-DEC-14	R3115354
pH in Saturated Paste	8.45		0.10	pH	03-DEC-14	04-DEC-14	R3115354
Conductivity Sat. Paste	5.53		0.10	dS m-1	03-DEC-14	04-DEC-14	R3115354

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1551947-2 LAGOON SAMPLE Sampled By: JRB on 27-NOV-14 @ 11:30 Matrix: WASTE							

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Sample Parameter Qualifier Key:

Qualifier	Description
DLA	Detection Limit adjusted for required dilution
DLM	Detection Limit Adjusted due to sample matrix effects.
SAR:M	Reported SAR represents a maximum value. Actual SAR would be lower if all cations were detectable.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
B-HOTW-SK	Soil	Available Boron, Hot Water	SSSA (1996) P. 610-611
Hot water is used to extract the plant-available and potentially plant-available boron from soil. Boron in the extract is determined by ICP-OES.			
C-TOT-LECO-SK	Soil	Total Carbon by combustion method	SSSA (1996) P. 973-974
The sample is ignited in a combustion analyzer where carbon in the reduced CO2 gas is determined using a thermal conductivity detector.			
CL-COL-SK	Waste	Chloride (Cl)	APHA 4110B
CL-PASTE-COL-SK	Soil	Chloride (Cl) (Saturated Paste)	CSSS(1993) 18.2.2/APHA 4500-CL E
Chloride in a saturated soil extract is determined colorimetrically by auto-analyzer.			
HG-200.2-CVAF-SK	Soil	Mercury on Soil by CVAFS	EPA 200.2/EPA 245.7
A representative portion of dry < 2mm soil is digested with concentrated nitric and hydrochloric acids for 2 hours in an open vessel digestor at 95 degrees. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometer.			
K-AVAIL-SK	Soil	Available Potassium	Comm. Soil Sci. Plant, 25 (5&6)
Plant available potassium is extracted from the soil using Modified Kelowna solution. Potassium in the soil extract is determined by flame emission at 770 nm.			
MET-200.2-CCMS-SK	Soil	Metals in Soil by CRC ICPMS	EPA 200.2/6020A
This analysis is carried out using procedures from CSR Analytical Method: "Strong Acid Leachable Metals (SALM) in Soil", BC Ministry of Environment, 26 June 2009, and procedures adapted from EPA Method 200.2. The sample is dried at 40 C, then ground to < 2 mm particle size using a stainless steel flail grinder. A representative portion is digested with concentrated nitric and hydrochloric acids for 2 hours in an open vessel digestor at 95 degrees. Instrumental analysis of the digested extract is by collision cell inductively coupled plasma - mass spectrometry (modifed from EPA Method 6020A).			
MOIST-SK	Soil	Moisture Content	ASTM D2216-80
The weighed portion of soil is placed in a 105°C oven overnight. The dried soil is allowed to cooled to room temperature, weighed and the % moisture is calculated. Reference: ASTM D2216-80			
N-TOTKJ-COL-SK	Soil	Total Kjeldahl Nitrogen	CSSS (1993) 22.2.3
The soil is digested with sulfuric acid in the presence of CuSO4 and K2SO4 catalysts. Ammonia in the soil extract is determined colrimetrically at 660 nm.			
NH4-AVAIL-SK	Soil	Available Ammonium-N	CSSS(1993) 4.2/COMM SOIL SCI 19(6)
Ammonium (NH4-N) is extracted from the soil using 2 N KCl. Ammonium in the extract is mixed with hypochlorite and salicylate to form indophenol blue, which is determined colorimetrically by auto analysis at 660 nm.			
NO3-AVAIL-KCL-SK	Soil	Available Nitrate-N (2N KCl)	CSSS (1993) 4.2, 4.3
Available Nitrate and Nitrite are extracted from the soil using a 2N KCl solution. Nitrate is quantitatively reduced to nitrite by passage of the sample through a copperized cadmium column. The nitrite (reduced nitrate plus original nitrite) is then determined by diazotizing with sulfanilamide followed by coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. The resulting water soluble dye has a magenta color which is measured at colorimetrically at 520nm. Reference: Carter, Martin. Soil Sampling and Methods of Analysis. Can. Soc. Soil Sci.(1993) methods 4.2, 4.3			
OM-LOI-SK	Soil	Organic Matter by LOI at 375 deg C.	CSSS (1978) p. 160
The dry-ash method involves the removal of organic matter by combustion at 375 degrees C for a minimum of 16 hours. Samples are dried prior to combustion. Reference: McKeague, J.A. Soil Sampling and Methods of Analysis. Can. Soc. Soil Sci.(1978) method 4.23			
PH/EC-SK	Waste	pH and Conductivity	APHA 4500-H,2510
PO4-AVAIL-OLSEN-SK	Soil	Available Phosphate-P by Olsen	CSSS (1993) 7.2,7.3.1

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
Plant available phosphorus is extracted from the sample with sodium bicarbonate. PO4-P in the filtered extract is determined colorimetrically at 880 nm.			
SAL-D50-DRYCALC-SK	Waste	Detailed Salinity in dry-weight mg/kg	Calculation
Conversion of Saturation Extract soluble ions from units of mg/L to dry-weight mg/kg. For over-saturated wastes: mg/kg dwt = mg/L * % Moisture / (100% - % Moisture) For under-saturated wastes: mg/kg dwt = mg/L * (% Saturation / 100%)			
SAL-D50-WETCALC-SK	Waste	Detailed Salinity in wet-weight mg/kg	Calculation
Conversion of Saturation Extract soluble ions from units of mg/L to wet-weight mg/kg. For over-saturated wastes: mg/kg wwt = mg/L * % Moisture / 100% For under-saturated wastes: mg/kg wwt = mg/L * (% Saturation / 100%) * (100% - % Moisture) / 100%			
SAL-MG/KG-CALC-SK	Soil	Detail Salinity in mg/kg	Manual Calculation
SALINITY-INTCHECK-SK	Soil		CSSS 18.4-Calculation
SAR-CALC-SK	Waste	SAR and Cations (over sat'd)	APHA 3120B
SAR-CALC-SO4-SK	Soil	SAR, Cations and SO4 in saturated soil	APHA 3120B
Ca, Mg, Na, K and SO4 in a saturated soil extract are determined by ICP-OES.			
SAT-PCNT-SK	Soil	Saturated Paste	CSSS (1993) 18.2.2
SAT/PH/EC-SK	Soil	pH and EC (Saturated Paste)	CSSS 18.2.2/CSSC 3.14/CSSS 18.3.1
pH of a saturated soil paste is measured using a pH meter. After equilibration, an extract is obtained by vacuum filtration with conductivity of the extract measured by a conductivity meter.			
SO4-AVAIL-SK	Soil	Available Sulfate-S	REC METH SOIL ANAL - AB. AG(1988)
Plant available sulfur in the soil is extracted with a weak calcium chloride solution. Total S in the extract is then determined by ICP-OES.			
SPECGRAV-ED	Soil	Specific Gravity	CSSS-Gravimetric
A portion of air-dried sample is weighed in a container that is calibrated for volume. Specific Gravity is reported as the mass of sample per mass of an equal volume of pure water, where the density of pure water is taken to be 1.00 g/mL.			
SPECIAL REQUEST-SK	Misc.	Special Request Sask Lab	SEE SUBLET LAB RESULTS
TGR2-CALC-SK	Soil	Theoretical Gypsum Requirement	J. Ashworth et al (1999)
Theoretical Gypsum Requirement is an estimate of the gypsum amendment required to remediate brine-contaminated or sodic soils, and is provided in units of tonnes per hectare (t/ha) for a treatment depth of 15cm. TGR(brine), intended for brine-contaminated soils, is calculated using Method A from "A Comparison of Methods for Gypsum Requirement of Brine-Contaminated Soils", by J. Ashworth (Cdn J. of Soil Science, 1999), available at www.alsglobal.com. TGR(sodic), intended for naturally sodic soils, uses the Oster and Frenkel method (Method B) from the same paper. Reported TGR values are capped at 50 t/ha, considered the maximum practical gypsum amendment. To convert TGR from t/ha to tons/acre, multiply by 0.446. To determine a TGR value for an alternate treatment depth, multiply by [desired treatment depth (cm) / 15 cm].			

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
SK	ALS ENVIRONMENTAL - SASKATOON, SASKATCHEWAN, CANADA
ED	ALS ENVIRONMENTAL - EDMONTON, ALBERTA, CANADA

Chain of Custody Numbers:

Reference Information

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Workorder: L1551947 Report Date: 09-DEC-14

Client: WSP Canada Inc.
1600 Buffalo Place
Winnipeg MB R3T 6B8
Contact: JUSTIN RAK-BANVILLE

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
B-HOTW-SK	**Soil**							
Batch R3115323								
WG2007522-2 IRM		**SAL814**						
Boron (B), Hot Water Ext.			102.6		%		70-130	04-DEC-14
WG2007522-1 MB								
Boron (B), Hot Water Ext.			<0.20		mg/kg		0.2	04-DEC-14
C-TOT-LECO-SK	**Soil**							
Batch R3116576								
WG2005887-1 DUP		**L1551947-1**						
Total Carbon by Combustion		10.7	10.4		%	2.7	20	05-DEC-14
WG2005887-2 IRM		**08-109_SOIL**						
Total Carbon by Combustion			98.3		%		80-120	05-DEC-14
WG2005887-3 MB								
Total Carbon by Combustion			<0.1		%		0.1	05-DEC-14
CL-PASTE-COL-SK	**Soil**							
Batch R3115033								
WG2006213-3 IRM		**SAL814**						
Chloride (Cl)			93.1		%		70-130	04-DEC-14
WG2006213-2 MB								
Chloride (Cl)			<5.0		mg/L		5	04-DEC-14
HG-200.2-CVAF-SK	**Soil**							
Batch R3115147								
WG2006305-3 CRM		**TILL-1**						
Mercury (Hg)			105.0		%		70-130	04-DEC-14
WG2006305-2 DUP		**L1552939-10**						
Mercury (Hg)		0.0097	0.0099		mg/kg	2.2	40	04-DEC-14
WG2006305-4 IRM		**ALS MET IRM1**						
Mercury (Hg)			94.3		%		70-130	04-DEC-14
WG2006305-1 MB								
Mercury (Hg)			<0.0050		mg/kg		0.005	04-DEC-14
K-AVAIL-SK	**Soil**							
Batch R3115132								
WG2006229-1 DUP		**L1551947-1**						
Available Potassium		22	20		mg/kg	10	30	04-DEC-14
WG2006229-3 IRM		**FARM2005**						
Available Potassium			106.5		%		70-130	04-DEC-14
WG2006229-2 MB								
Available Potassium			<20		mg/kg		20	04-DEC-14
MET-200.2-CCMS-SK	**Soil**							

Quality Control Report

Client: WSP Canada Inc.
1600 Buffalo Place
Winnipeg MB R3T 6B8
Contact: JUSTIN RAK-BANVILLE

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-CCMS-SK	**Soil**							
Batch R3115353								
WG2006305-2 DUP		**L1552939-10**						
Aluminum (Al)		33200	34100		mg/kg	2.9	30	04-DEC-14
Antimony (Sb)		<0.10	<0.10	RPD-NA	mg/kg	N/A	30	04-DEC-14
Arsenic (As)		4.58	4.71		mg/kg	2.8	30	04-DEC-14
Barium (Ba)		291	297		mg/kg	2.0	30	04-DEC-14
Beryllium (Be)		1.59	1.62		mg/kg	1.3	30	04-DEC-14
Bismuth (Bi)		0.50	0.50		mg/kg	0.5	30	04-DEC-14
Cadmium (Cd)		0.16	0.16		mg/kg	4.2	30	04-DEC-14
Calcium (Ca)		4880	4710		mg/kg	3.5	30	04-DEC-14
Chromium (Cr)		74.1	74.8		mg/kg	1.0	30	04-DEC-14
Cobalt (Co)		107	109		mg/kg	2.4	30	04-DEC-14
Copper (Cu)		795	811		mg/kg	1.9	30	04-DEC-14
Iron (Fe)		43600	43100		mg/kg	1.2	30	04-DEC-14
Lead (Pb)		14.1	14.1		mg/kg	0.2	40	04-DEC-14
Lithium (Li)		54.9	55.3		mg/kg	0.7	30	04-DEC-14
Magnesium (Mg)		15700	15300		mg/kg	2.7	30	04-DEC-14
Manganese (Mn)		690	695		mg/kg	0.7	30	04-DEC-14
Molybdenum (Mo)		<1.0	<1.0	RPD-NA	mg/kg	N/A	30	04-DEC-14
Nickel (Ni)		2600	2740		mg/kg	5.1	30	04-DEC-14
Phosphorus (P)		586	582		mg/kg	0.7	30	04-DEC-14
Potassium (K)		7860	7800		mg/kg	0.8	30	04-DEC-14
Selenium (Se)		0.40	0.34		mg/kg	18	30	04-DEC-14
Silver (Ag)		0.25	0.24		mg/kg	3.4	30	04-DEC-14
Sodium (Na)		740	730		mg/kg	1.1	30	04-DEC-14
Strontium (Sr)		55.4	55.2		mg/kg	0.5	30	04-DEC-14
Thallium (Tl)		0.52	0.52		mg/kg	1.5	30	04-DEC-14
Tin (Sn)		3.4	2.2	J	mg/kg	1.1	4	04-DEC-14
Titanium (Ti)		1810	1880		mg/kg	3.3	30	04-DEC-14
Uranium (U)		5.65	5.85		mg/kg	3.5	30	04-DEC-14
Vanadium (V)		81.4	81.8		mg/kg	0.6	30	04-DEC-14
Zinc (Zn)		108	108		mg/kg	0.4	30	04-DEC-14
WG2006305-4 IRM		**ALS MET IRM1**						
Aluminum (Al)			99.6		%		70-130	04-DEC-14
Antimony (Sb)			97.9		%		70-130	04-DEC-14

Quality Control Report

Client: WSP Canada Inc.
1600 Buffalo Place
Winnipeg MB R3T 6B8
Contact: JUSTIN RAK-BANVILLE

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-CCMS-SK	**Soil**							
Batch R3115353								
WG2006305-4 IRM		**ALS MET IRM1**						
Arsenic (As)			111.2		%		70-130	04-DEC-14
Barium (Ba)			93.6		%		70-130	04-DEC-14
Beryllium (Be)			107.3		%		70-130	04-DEC-14
Cadmium (Cd)			100.5		%		70-130	04-DEC-14
Calcium (Ca)			97.9		%		70-130	04-DEC-14
Chromium (Cr)			103.4		%		70-130	04-DEC-14
Cobalt (Co)			106.2		%		70-130	04-DEC-14
Copper (Cu)			103.2		%		70-130	04-DEC-14
Iron (Fe)			105.3		%		70-130	04-DEC-14
Lead (Pb)			103.6		%		70-130	04-DEC-14
Lithium (Li)			100.2		%		70-130	04-DEC-14
Magnesium (Mg)			99.2		%		70-130	04-DEC-14
Manganese (Mn)			103.3		%		70-130	04-DEC-14
Molybdenum (Mo)			93.4		%		70-130	04-DEC-14
Nickel (Ni)			105.0		%		70-130	04-DEC-14
Phosphorus (P)			100.5		%		70-130	04-DEC-14
Potassium (K)			106.9		%		70-130	04-DEC-14
Selenium (Se)			108.3		%		70-130	04-DEC-14
Silver (Ag)			110.3		%		70-130	04-DEC-14
Sodium (Na)			180		mg/kg		70-270	04-DEC-14
Strontium (Sr)			94.8		%		70-130	04-DEC-14
Thallium (Tl)			103.7		%		70-130	04-DEC-14
Tin (Sn)			104.2		%		70-130	04-DEC-14
Titanium (Ti)			103.8		%		70-130	04-DEC-14
Uranium (U)			106.4		%		70-130	04-DEC-14
Vanadium (V)			107.2		%		70-130	04-DEC-14
Zinc (Zn)			107.4		%		70-130	04-DEC-14
WG2006305-1 MB								
Aluminum (Al)			<50		mg/kg		50	04-DEC-14
Antimony (Sb)			<0.10		mg/kg		0.1	04-DEC-14
Arsenic (As)			<0.10		mg/kg		0.1	04-DEC-14
Barium (Ba)			<1.0		mg/kg		1	04-DEC-14
Beryllium (Be)			<0.50		mg/kg		0.5	04-DEC-14
Bismuth (Bi)			<0.20		mg/kg		0.2	04-DEC-14

Quality Control Report

Client: WSP Canada Inc.
1600 Buffalo Place
Winnipeg MB R3T 6B8
Contact: JUSTIN RAK-BANVILLE

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-200.2-CCMS-SK	**Soil**							
Batch R3115353								
WG2006305-1 MB								
Cadmium (Cd)			<0.10		mg/kg		0.1	04-DEC-14
Calcium (Ca)			<100		mg/kg		100	04-DEC-14
Chromium (Cr)			<0.50		mg/kg		0.5	04-DEC-14
Cobalt (Co)			<1.0		mg/kg		1	04-DEC-14
Copper (Cu)			<1.0		mg/kg		1	04-DEC-14
Iron (Fe)			<50		mg/kg		50	04-DEC-14
Lead (Pb)			<1.0		mg/kg		1	04-DEC-14
Lithium (Li)			<2.0		mg/kg		2	04-DEC-14
Magnesium (Mg)			<100		mg/kg		100	04-DEC-14
Manganese (Mn)			<1.0		mg/kg		1	04-DEC-14
Molybdenum (Mo)			<1.0		mg/kg		1	04-DEC-14
Nickel (Ni)			<1.0		mg/kg		1	04-DEC-14
Phosphorus (P)			<50		mg/kg		50	04-DEC-14
Potassium (K)			<100		mg/kg		100	04-DEC-14
Selenium (Se)			<0.20		mg/kg		0.2	04-DEC-14
Silver (Ag)			<0.20		mg/kg		0.2	04-DEC-14
Sodium (Na)			<100		mg/kg		100	04-DEC-14
Strontium (Sr)			<1.0		mg/kg		1	04-DEC-14
Thallium (Tl)			<0.10		mg/kg		0.1	04-DEC-14
Tin (Sn)			<2.0		mg/kg		2	04-DEC-14
Titanium (Ti)			<5.0		mg/kg		5	04-DEC-14
Uranium (U)			<0.10		mg/kg		0.1	04-DEC-14
Vanadium (V)			<1.0		mg/kg		1	04-DEC-14
Zinc (Zn)			<5.0		mg/kg		5	04-DEC-14
MOIST-SK	**Soil**							
Batch R3113039								
WG2006232-1 DUP		**L1551947-2**						
% Moisture		46.5	44.8		%	3.6	20	03-DEC-14
N-TOTKJ-COL-SK	**Soil**							
Batch R3114563								
WG2005877-1 DUP								
Total Kjeldahl Nitrogen		N/A	0.031		%	0.0	20	03-DEC-14
WG2005877-2 IRM		**08-109_SOIL**						

Quality Control Report

Client: WSP Canada Inc.
1600 Buffalo Place
Winnipeg MB R3T 6B8
Contact: JUSTIN RAK-BANVILLE

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
N-TOTKJ-COL-SK	**Soil**							
Batch R3114563								
WG2005877-2 IRM		**08-109_SOIL**						
Total Kjeldahl Nitrogen			81.2		%		80-120	03-DEC-14
WG2005877-3 MB								
Total Kjeldahl Nitrogen			<0.020		%		0.02	03-DEC-14
WG2005877-4 RB								
Total Kjeldahl Nitrogen			<0.020		%			03-DEC-14
NH4-AVAIL-SK	**Soil**							
Batch R3115813								
WG2006237-3 IRM		**SAL814**						
Available Ammonium-N			111.3		%		70-130	04-DEC-14
WG2006237-2 MB								
Available Ammonium-N			<1.0		mg/kg		1	04-DEC-14
NO3-AVAIL-KCL-SK	**Soil**							
Batch R3116064								
WG2006240-3 IRM		**SAL814**						
Available Nitrate-N			106.7		%		70-130	04-DEC-14
WG2006240-2 MB								
Available Nitrate-N			<2.0		mg/kg		2	04-DEC-14
OM-LOI-SK	**Soil**							
Batch R3114978								
WG2007406-1 DUP		**L1551947-2**						
Organic Matter		7.5	7.2		%	3.6	20	04-DEC-14
Loss on Ignition @ 375 C		9.2	8.9		%	3.7	25	04-DEC-14
WG2007406-3 IRM		**FARM2009**						
Organic Matter			4.8		%		3-5	04-DEC-14
Loss on Ignition @ 375 C			5.8		%		4.2-6.2	04-DEC-14
WG2007406-2 MB								
Organic Matter			<1.0		%		1	04-DEC-14
Loss on Ignition @ 375 C			<1.0		%		1	04-DEC-14
PO4-AVAIL-OLSEN-SK	**Soil**							
Batch R3116046								
WG2006248-1 DUP		**L1551947-1**						
Available Phosphate-P		<1.0	<1.0	RPD-NA	mg/kg	N/A	30	05-DEC-14
WG2006248-3 IRM		**FARM2005**						
Available Phosphate-P			82.9		%		70-130	05-DEC-14
WG2006248-2 MB								
Available Phosphate-P			<1.0		mg/kg		1	05-DEC-14

Quality Control Report

Client: WSP Canada Inc.
1600 Buffalo Place
Winnipeg MB R3T 6B8
Contact: JUSTIN RAK-BANVILLE

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
SAR-CALC-SO4-SK	**Soil**							
Batch R3115016								
WG2006213-3 IRM		**SAL814**						
Calcium (Ca)			106.0		%		70-130	04-DEC-14
Potassium (K)			98.2		%		70-130	04-DEC-14
Magnesium (Mg)			111.4		%		70-130	04-DEC-14
Sodium (Na)			99.9		%		70-130	04-DEC-14
Sulfur (as SO4)			112.0		%		70-130	04-DEC-14
WG2006213-2 MB								
Calcium (Ca)			<2.0		mg/L		2	04-DEC-14
Potassium (K)			<1.0		mg/L		1	04-DEC-14
Magnesium (Mg)			<2.0		mg/L		2	04-DEC-14
Sodium (Na)			<4.0		mg/L		4	04-DEC-14
Sulfur (as SO4)			<5.0		mg/L		5	04-DEC-14
SAT-PCNT-SK	**Soil**							
Batch R3115354								
WG2006213-3 IRM		**SAL814**						
% Saturation			45.2		%		37-47	04-DEC-14
SAT/PH/EC-SK	**Soil**							
Batch R3115354								
WG2006213-3 IRM		**SAL814**						
% Saturation			45.2		%		37-47	04-DEC-14
pH in Saturated Paste			7.81		pH		7.4-8	04-DEC-14
Conductivity Sat. Paste			103.1		%		80-120	04-DEC-14
WG2006213-2 MB								
Conductivity Sat. Paste			<0.10		dS m-1		0.1	04-DEC-14
SO4-AVAIL-SK	**Soil**							
Batch R3115310								
WG2006246-3 IRM		**SAL814**						
Available Sulfate-S			99.5		%		70-130	04-DEC-14
WG2006246-2 MB								
Available Sulfate-S			<3.0		mg/kg		3	04-DEC-14
SPECGRAV-ED	**Soil**							
Batch R3116802								
WG2010183-1 DUP		**L1551947-2**						
Specific Gravity		2.14	1.90		kg/L	12	13	08-DEC-14

Quality Control Report

Client: WSP Canada Inc.
1600 Buffalo Place
Winnipeg MB R3T 6B8
Contact: JUSTIN RAK-BANVILLE

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
CL-COL-SK	**Waste**							
Batch R3115033								
WG2006213-2 MB								
Chloride (Cl)			<1.0		mg/L		1	04-DEC-14
PH/EC-SK	**Waste**							
Batch R3115354								
WG2006213-2 MB								
Conductivity (EC)			<0.010		dS m-1		0.01	04-DEC-14
SAR-CALC-SK	**Waste**							
Batch R3115016								
WG2006213-3 IRM		**SAL814**						
Sulfur (as SO4)			112.0		%		70-130	04-DEC-14
WG2006213-2 MB								
Calcium (Ca)			<2.0		mg/L		2	04-DEC-14
Potassium (K)			<1.0		mg/L		1	04-DEC-14
Magnesium (Mg)			<2.0		mg/L		2	04-DEC-14
Sodium (Na)			<4.0		mg/L		4	04-DEC-14
Sulfur (as SO4)			<5.0		mg/L		5	04-DEC-14

Quality Control Report

Workorder: L1551947 Report Date: 09-DEC-14

Client: WSP Canada Inc.
1600 Buffalo Place
Winnipeg MB R3T 6B8
Contact: JUSTIN RAK-BANVILLE

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
DLA	Detection Limit adjusted for required dilution
J	Duplicate results and limits are expressed in terms of absolute difference.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Quality Control Report

Workorder: L1551947 Report Date: 09-DEC-14

Client: WSP Canada Inc.
1600 Buffalo Place
Winnipeg MB R3T 6B8
Contact: JUSTIN RAK-BANVILLE

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Leachable Metals							
Available Boron, Hot Water							
	1	27-NOV-14 10:00	04-DEC-14	5	7	days	EHT
	2	27-NOV-14 11:30	04-DEC-14	5	7	days	EHT

Legend & Qualifier Definitions:

EHTR-FM: Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR: Exceeded ALS recommended hold time prior to sample receipt.
EHTL: Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT: Exceeded ALS recommended hold time prior to analysis.
Rec. HT: ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1551947 were received on 27-NOV-14 13:00.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

Work Order	Sample	Client ID	Analyte	Result (Dry)	Result (Wet)	Qualifier	Units	LOR (dry)
L1551947	L1551947-1	WTP SAMPLE	Conductivity (EC)		3.53		dS m-1	0.010
L1551947	L1551947-1	WTP SAMPLE	Loss on Ignition @ 375 C	3.8	70.4		%	1.0
L1551947	L1551947-1	WTP SAMPLE	% Moisture		66.6		%	0.10
L1551947	L1551947-1	WTP SAMPLE	Organic Matter	3.3	1.1		%	1.0
L1551947	L1551947-1	WTP SAMPLE	pH	9.16	9.16		pH	0.10
L1551947	L1551947-1	WTP SAMPLE	Total Kjeldahl Nitrogen	0.031	0.010		%	0.020
L1551947	L1551947-1	WTP SAMPLE	Total Carbon by Combustion	10.7	3.6		%	0.1
L1551947	L1551947-1	WTP SAMPLE	Available Ammonium-N	<1.0	<0.3		mg/kg	1.0
L1551947	L1551947-1	WTP SAMPLE	Available Nitrate-N	<4.0	<1	DLM	mg/kg	4.0
L1551947	L1551947-1	WTP SAMPLE	Available Phosphate-P	<1.0	<0.3		mg/kg	1.0
L1551947	L1551947-1	WTP SAMPLE	Available Potassium	22	7.3		mg/kg	20
L1551947	L1551947-1	WTP SAMPLE	Available Sulfate-S	703	235	DLM	mg/kg	6.0
L1551947	L1551947-1	WTP SAMPLE	SAR	1.02	1.02		SAR	0.10
L1551947	L1551947-1	WTP SAMPLE	Calcium (Ca)	724	242		mg/kg	20
L1551947	L1551947-1	WTP SAMPLE	Chloride (Cl)	644	215		mg/kg	20
L1551947	L1551947-1	WTP SAMPLE	Magnesium (Mg)	562	188		mg/kg	20
L1551947	L1551947-1	WTP SAMPLE	Potassium (K)	18	6.0		mg/kg	10
L1551947	L1551947-1	WTP SAMPLE	% Saturation	Oversat	Oversat		%	1.0
L1551947	L1551947-1	WTP SAMPLE	Sodium (Na)	212	71		mg/kg	40
L1551947	L1551947-1	WTP SAMPLE	Sulfur (as SO4)	3480	1160		mg/kg	50
L1551947	L1551947-1	WTP SAMPLE	Aluminum (Al)	3920	1309		mg/kg	50
L1551947	L1551947-1	WTP SAMPLE	Antimony (Sb)	<0.10	<0.03		mg/kg	0.10
L1551947	L1551947-1	WTP SAMPLE	Arsenic (As)	17.2	5.7		mg/kg	0.10
L1551947	L1551947-1	WTP SAMPLE	Barium (Ba)	14.3	4.8		mg/kg	1.0
L1551947	L1551947-1	WTP SAMPLE	Beryllium (Be)	<0.50	<0.2		mg/kg	0.50
L1551947	L1551947-1	WTP SAMPLE	Bismuth (Bi)	<0.20	<0.07		mg/kg	0.20
L1551947	L1551947-1	WTP SAMPLE	Cadmium (Cd)	<0.10	<0.03		mg/kg	0.10
L1551947	L1551947-1	WTP SAMPLE	Calcium (Ca)	237000	79158	DLA	mg/kg	500
L1551947	L1551947-1	WTP SAMPLE	Chromium (Cr)	1.84	0.61		mg/kg	0.50
L1551947	L1551947-1	WTP SAMPLE	Cobalt (Co)	<1.0	<0.3		mg/kg	1.0
L1551947	L1551947-1	WTP SAMPLE	Copper (Cu)	1.4	0.47		mg/kg	1.0
L1551947	L1551947-1	WTP SAMPLE	Iron (Fe)	2270	758		mg/kg	50
L1551947	L1551947-1	WTP SAMPLE	Lead (Pb)	<1.0	<0.3		mg/kg	1.0

L1551947	L1551947-1	WTP SAMPLE	Lithium (Li)	4.8	2		mg/kg	2.0
L1551947	L1551947-1	WTP SAMPLE	Magnesium (Mg)	19800	6613		mg/kg	100
L1551947	L1551947-1	WTP SAMPLE	Manganese (Mn)	261	87		mg/kg	1.0
L1551947	L1551947-1	WTP SAMPLE	Mercury (Hg)	<0.0050	<0.002		mg/kg	0.0050
L1551947	L1551947-1	WTP SAMPLE	Molybdenum (Mo)	<1.0	<0.3		mg/kg	1.0
L1551947	L1551947-1	WTP SAMPLE	Nickel (Ni)	2.0	0.7		mg/kg	1.0
L1551947	L1551947-1	WTP SAMPLE	Phosphorus (P)	72	24		mg/kg	50
L1551947	L1551947-1	WTP SAMPLE	Potassium (K)	<100	<30		mg/kg	100
L1551947	L1551947-1	WTP SAMPLE	Selenium (Se)	<0.20	<0.07		mg/kg	0.20
L1551947	L1551947-1	WTP SAMPLE	Silver (Ag)	<0.20	<0.07		mg/kg	0.20
L1551947	L1551947-1	WTP SAMPLE	Sodium (Na)	580	194		mg/kg	100
L1551947	L1551947-1	WTP SAMPLE	Strontium (Sr)	322	108		mg/kg	1.0
L1551947	L1551947-1	WTP SAMPLE	Thallium (Tl)	<0.10	<0.03		mg/kg	0.10
L1551947	L1551947-1	WTP SAMPLE	Tin (Sn)	<2.0	<0.7		mg/kg	2.0
L1551947	L1551947-1	WTP SAMPLE	Titanium (Ti)	37.5	13		mg/kg	5.0
L1551947	L1551947-1	WTP SAMPLE	Uranium (U)	2.35	1		mg/kg	0.10
L1551947	L1551947-1	WTP SAMPLE	Vanadium (V)	<1.0	<0.3		mg/kg	1.0
L1551947	L1551947-1	WTP SAMPLE	Zinc (Zn)	<5.0	<2.0		mg/kg	5.0
L1551947	L1551947-1	WTP SAMPLE	Boron (B), Hot Water Ext.	1.73	0.6	DLM	mg/kg	0.40
L1551947	L1551947-2	LAGOON SAMPLE	Loss on Ignition @ 375 C	9.2	55.7		%	1.0
L1551947	L1551947-2	LAGOON SAMPLE	% Moisture		46.5		%	0.10
L1551947	L1551947-2	LAGOON SAMPLE	Organic Matter	7.5	4.0		%	1.0
L1551947	L1551947-2	LAGOON SAMPLE	Total Kjeldahl Nitrogen	0.238	0.13		%	0.020
L1551947	L1551947-2	LAGOON SAMPLE	Total Carbon by Combustion	12.4	6.6		%	0.1
L1551947	L1551947-2	LAGOON SAMPLE	Available Ammonium-N	106	56.7		mg/kg	1.0
L1551947	L1551947-2	LAGOON SAMPLE	Available Nitrate-N	4.1	2.2	DLM	mg/kg	4.0
L1551947	L1551947-2	LAGOON SAMPLE	Available Phosphate-P	158	84.5		mg/kg	1.0
L1551947	L1551947-2	LAGOON SAMPLE	Available Potassium	84	44.9		mg/kg	20
L1551947	L1551947-2	LAGOON SAMPLE	Available Sulfate-S	377	202	DLM	mg/kg	6.0
L1551947	L1551947-2	LAGOON SAMPLE	SAR	0.83	0.83	SAR:M	SAR	0.10
L1551947	L1551947-2	LAGOON SAMPLE	Calcium (Ca)	<9.2	<5	DLA	mg/kg	9.2
L1551947	L1551947-2	LAGOON SAMPLE	Chloride (Cl)	61.6	33.0	DLA	mg/kg	9.2
L1551947	L1551947-2	LAGOON SAMPLE	Conductivity Sat. Paste		5.53		dS m-1	0.10
L1551947	L1551947-2	LAGOON SAMPLE	Magnesium (Mg)	431	230.6	DLA	mg/kg	9.2

L1551947	L1551947-2	LAGOON SAMPLE	pH in Saturated Paste	8.45	8.45		pH	0.10
L1551947	L1551947-2	LAGOON SAMPLE	Potassium (K)	10.1	5.4	DLA	mg/kg	4.6
L1551947	L1551947-2	LAGOON SAMPLE	% Saturation	45.9			%	1.0
L1551947	L1551947-2	LAGOON SAMPLE	Sodium (Na)	54	28.9	DLA	mg/kg	18
L1551947	L1551947-2	LAGOON SAMPLE	Sulfur (as SO4)	778	416.2	DLA	mg/kg	23
L1551947	L1551947-2	LAGOON SAMPLE	TGR(sodic)	<0.10	<0.05		t/ha	0.10
L1551947	L1551947-2	LAGOON SAMPLE	TGR(brine)	<0.10	<0.05		t/ha	0.10
L1551947	L1551947-2	LAGOON SAMPLE	Aluminum (Al)	1580	845.3		mg/kg	50
L1551947	L1551947-2	LAGOON SAMPLE	Antimony (Sb)	<0.10	<0.05		mg/kg	0.10
L1551947	L1551947-2	LAGOON SAMPLE	Arsenic (As)	8.05	4.3		mg/kg	0.10
L1551947	L1551947-2	LAGOON SAMPLE	Barium (Ba)	32.7	17.5		mg/kg	1.0
L1551947	L1551947-2	LAGOON SAMPLE	Beryllium (Be)	<0.50	<0.3		mg/kg	0.50
L1551947	L1551947-2	LAGOON SAMPLE	Bismuth (Bi)	0.87	0.5		mg/kg	0.20
L1551947	L1551947-2	LAGOON SAMPLE	Cadmium (Cd)	0.11	0.1		mg/kg	0.10
L1551947	L1551947-2	LAGOON SAMPLE	Calcium (Ca)	197000	105395.0	DLA	mg/kg	500
L1551947	L1551947-2	LAGOON SAMPLE	Chromium (Cr)	2.92	1.6		mg/kg	0.50
L1551947	L1551947-2	LAGOON SAMPLE	Cobalt (Co)	<1.0	<0.5		mg/kg	1.0
L1551947	L1551947-2	LAGOON SAMPLE	Copper (Cu)	27.1	14.5		mg/kg	1.0
L1551947	L1551947-2	LAGOON SAMPLE	Iron (Fe)	2020	1080.7		mg/kg	50
L1551947	L1551947-2	LAGOON SAMPLE	Lead (Pb)	2.6	1.4		mg/kg	1.0
L1551947	L1551947-2	LAGOON SAMPLE	Lithium (Li)	4.0	2.1		mg/kg	2.0
L1551947	L1551947-2	LAGOON SAMPLE	Magnesium (Mg)	7760	4151.6		mg/kg	100
L1551947	L1551947-2	LAGOON SAMPLE	Manganese (Mn)	215	115.0		mg/kg	1.0
L1551947	L1551947-2	LAGOON SAMPLE	Mercury (Hg)	0.23	0.1	DLA	mg/kg	0.10
L1551947	L1551947-2	LAGOON SAMPLE	Molybdenum (Mo)	<1.0	<0.5		mg/kg	1.0
L1551947	L1551947-2	LAGOON SAMPLE	Nickel (Ni)	1.7	0.9		mg/kg	1.0
L1551947	L1551947-2	LAGOON SAMPLE	Phosphorus (P)	857	458.5		mg/kg	50
L1551947	L1551947-2	LAGOON SAMPLE	Potassium (K)	150	80.3		mg/kg	100
L1551947	L1551947-2	LAGOON SAMPLE	Selenium (Se)	<0.20	<0.1		mg/kg	0.20
L1551947	L1551947-2	LAGOON SAMPLE	Silver (Ag)	0.73	0.4		mg/kg	0.20
L1551947	L1551947-2	LAGOON SAMPLE	Sodium (Na)	520	278.2		mg/kg	100
L1551947	L1551947-2	LAGOON SAMPLE	Strontium (Sr)	260	139.1		mg/kg	1.0
L1551947	L1551947-2	LAGOON SAMPLE	Thallium (Tl)	<0.10	<0.05		mg/kg	0.10
L1551947	L1551947-2	LAGOON SAMPLE	Tin (Sn)	2.8	1.5		mg/kg	2.0

L1551947	L1551947-2	LAGOON SAMPLE	Titanium (Ti)	24.0	12.8	mg/kg	5.0
L1551947	L1551947-2	LAGOON SAMPLE	Uranium (U)	1.94	1.0	mg/kg	0.10
L1551947	L1551947-2	LAGOON SAMPLE	Vanadium (V)	1.5	0.8	mg/kg	1.0
L1551947	L1551947-2	LAGOON SAMPLE	Zinc (Zn)	29.4	15.7	mg/kg	5.0
L1551947	L1551947-2	LAGOON SAMPLE	Boron (B), Hot Water Ext.	8.73	4.7 DLM	mg/kg	0.20

DLM Detection Limit Adjusted due to sample matrix effects.
DLA Detection Limit adjusted for required dilution
SAR:M Reported SAR represents a maximum value. Actual SAR would be lower if all cations were detectable.

ALS Environmental

L1551947-COFC

COC # _____

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Report To		Report Format / Distribution		Service Requested (Rush for routine analysis subject to availability)
Company:	WSP	☐ Standard ☐ Other		◉ Regular (Standard Turnaround Times - Business Days)
Contact:	JUSTIN RAK-BANVILLE	☑ PDF ☑ Excel ☐ Digital ☐ Fax		○ Priority (2-4 Business Days) - 50% Surcharge - Contact ALS to Confirm TAT
Address:	1600 BUFFALO PLACE	Email 1:	JUSTIN.RAK.BANVILLE@WSPGROUP.COM	○ Emergency (1-2 Bus. Days) - 100% Surcharge - Contact ALS to Confirm TAT
	WINNIPEG, MANITOBA R3T 6B8	Email 2:		○ Same Day or Weekend Emergency - Contact ALS to Confirm TAT
Phone:	204-477-6650 x37 Fax:	Email 3:		
Invoice To	Same as Report ? ☑ Yes ☐ No	**Client / Project Information**		**Analysis Request**
Hardcopy of Invoice with Report?	☑ Yes ☐ No	Job #:	Russell Lagoon Sludge Testing	Please indicate below Filtered, Preserved or both (F, P, F/P)
Company:		PO / AFE:		
Contact:		LSD:		
Address:				
Phone:	Fax:	Quote #:	Q48093	
Lab Work Order # (lab use only)		**ALS Contact:**	Bouchard **Sampler:** JRB	

Sample #	Sample Identification (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	See Quote	Number of Containers
1	WTP Sample	27-Nov-14	10:00am	Other	X	1
2	Lagon Sample	27-Nov-14	11:30am	Waste	X	3

Special Instructions / Regulations with water or land use (CCME-Freshwater Aquatic Life/BC CSR - Commercial/AB Tier 1 - Natural, etc) / Hazardous Details

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY.

By the use of this form the user acknowledges and agrees with the Terms and Conditions as provided on a separate Excel tab.

Also provided on another Excel tab are the ALS location addresses, phone numbers and sample container / preservation / holding time table for common analyses.

SHIPMENT RELEASE (client use)			SHIPMENT RECEPTION (lab use only)				SHIPMENT VERIFICATION (lab use only)			
Released by:	Date (dd-mmm-yy)	Time (hh-mm)	Received by:	Date:	Time:	Temperature:	Verified by:	Date:	Time:	Observations: Yes / No ? If Yes add SIF
			LD	Nov 27/14	1:00	-2. °C				

GENF 18.01 Front