Rio Tinto Alcan

KMP SO_2 EEM Program – Technical Memo S02

Steady-State Soil Modelling
Supplemental Soil Sampling

March 2015

Prepared for:

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1 Overview

This memo describes the selection of supplemental soil sampling sites to address critical uncertainties and data gaps identified under the STAR (ESSA et al., 2013).

A list of 17 potential plots is provided (Figure 1 and Table 1); it is recommended that at least 12 plots are sampled (Table 1). The STAR recommended a maximum of 10–15 sites, and the EEM program recommended a maximum of 12–18 sites.

2 Supplemental Soil Sampling Plots

The STAR (ESSA et al., 2013) identified spatial variability in estimated soil base cation weathering rate as a critical uncertainty. Weathering rates were estimated using a limited number of soil plots (4–6) assigned to each bedrock category, irrespective of overlying surficial geology. As such, the STAR noted that weathering rates may have been underestimated in certain regions.

The STAR and the EEM program identified several broad regions for supplemental soil sampling to expand weathering estimates. These regions were revised to accommodate additional soil sampling carried out in the STAR study domain under several external projects, and proposed revisions to the regionalisation methodology (see Technical Memo: Revised Modelling and Mapping of Terrestrial Critical Loads, March 2015). A list of 17 potential plots were selected from five regions (Figure 1 and Table 1), it is recommended that at least 12 plots are sampled (Table 1), and that field sampling procedures follow the STAR (see Appendix A).

1. Exceeded [E] area soil plots. The STAR identified areas with exceedance of critical loads close to the RTA smelter and areas with potential exceedance further north. Four E plots were identified, all accessible by road. It is recommended that at least two E plots area sampled (near and far from the smelter).

2. South-western [S] region soil plots. Under the STAR, soil plot selection and subsequent sampling were based on an initial study domain that incorporated limited area south of the RTA smelter. Following field sampling, the study domain was expanded to accommodate emissions plumes that moved south of the smelter. As such, there are few soil plots in the southern portion of the study domain.

Three S plots were identified in the southern portion of the study domain, located on primarily acid-sensitive bedrock geology and in regions with high predicted post-KMP modelled sulphur deposition. It is recommended that at least two S plots are sampled, all road accessible. The S plots could be further supplemented with an additional plot (further south) that requires air access.

3. Alpine [A] soil plots. Soil sampling under the STAR focused primarily on road accessible plots. As such, few alpine or high elevation soil plots were sampled. The BC MOE have raised concerns with respect to the representivity of alpine acid-sensitive ecosystems in regional soil base cation weathering estimates.

Four A plots were identified along the western portion of the Kitimat valley, within the modelled post-KMP 10 kg SO_4^{2-} ha^{-1} yr^{-1} deposition plume. In addition all proposed plots were co-located with soil chemistry plots sampled under the LNG Canada Project (URL: lngcanada.ca). It is recommended that all four A plots are sampled. All sites are only accessible by air; however, soil sub-samples may potentially be obtained from LNG Canada.

4. Acid-sensitive lake [L] catchment soil plots. The STAR noted potential spatial inconsistencies between estimated soil base cation weathering rates and study lakes with low base cation concentrations. As such, the STAR recommended that supplemental soil sampling be co-located within the catchments of acid sensitive lakes.

Five acid-sensitive lakes are routinetly sampled under the EEM program, all lakes were identified as L plots. It is recommended that at least three L plots are sampled (Table 1), including one site that is only air accessible (L28; Figure 1).

5. Lodgepole Pine [P] stands. The BC MOE requested that supplemental soil sampling include plots with dominant Lodgepole pine (*Pinus contorta*) stands. One plot location, close to Terrace Airport, was provided by the BC MOE (Figure 1 and Table 1). It is recommended that this P plot be sampled and potentially be amended with additional road accessible P plots, as requested by the BC MOE.

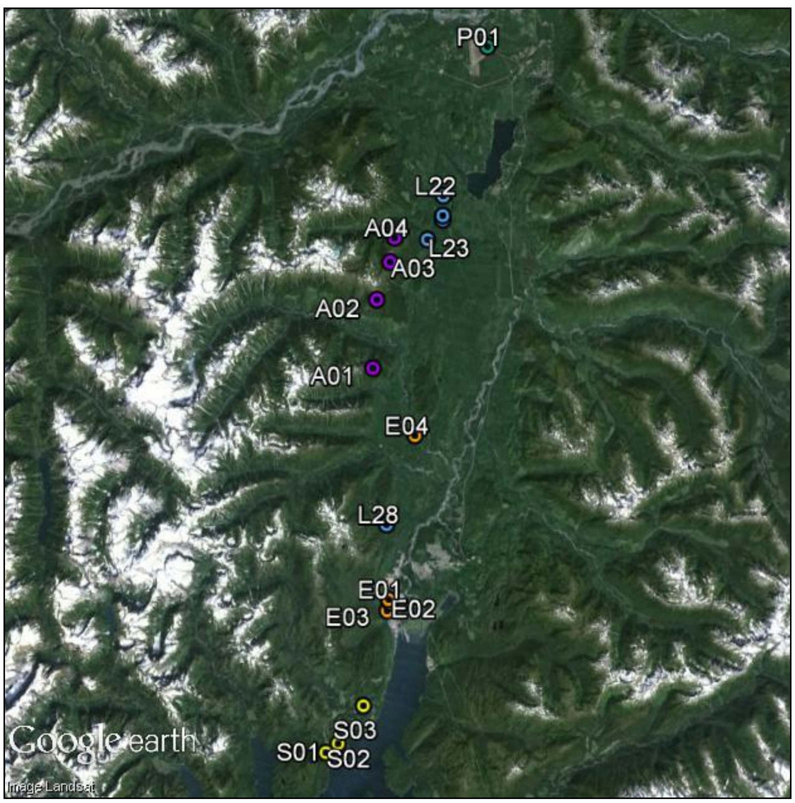

Figure 1. Location of proposed supplemental soil sampling plots (n = 17) in the EEM study domain. The site IDs denote plots in the southern [S] portion of the study area, plots with predicted exceedance [E] of critical load, plots located within the catchments of acid sensitive lakes [L], plots in alpine [A] or upland regions and a lodgepole pine [P] plot. The co-ordinates for each plot are given in Table 1.

Table 1: Proposed supplemental soil sampling plots (n = 17). The easting and northern co-ordinates area referenced under UTM Zone 9, Datum WGS84. The location of each plot is shown in Figure 1.

#	ID	Easting	Northing	Notes
1	E01	519351	5986688	On RTA property
2	E02$	519521	5986396	On RTA property
3	E03	519231	5985660	On RTA property
4	E04$	521693	6001365	
5	S01$	514798	5973743	
6	S02	513671	5972936	
7	S03$	517099	5977208	
8	A01$	517869	6007327	LNG Canada soil chemistry plot. Air access
9	A02$	518176	6013397	LNG Canada soil chemistry plot. Air access
10	A03$	519367	6016711	LNG Canada soil chemistry plot. Air access
11	A04$	519771	6018828	LNG Canada soil chemistry plot. Air access
12	L06	524155	6020661	EEM monitored lake.
13	L12$	524145	6021028	EEM monitored lake.
14	L22	524185	6022796	EEM monitored lake. Air access
15	L23$	522750	6018850	EEM monitored lake.
16	L28$	519139	5993425	EEM monitored lake. Air access
17	P01$	528172	6036227	Lodgepole pine plot requested by BC MOE

$ Recommended or preferential soil sampling plots

3 Literature Cited

ESSA Technologies, J. Laurence, Limnotek, Risk Sciences International, Rio Tinto Alcan, Trent University, Trinity Consultants and University of Illinois. 2013. Sulphur Dioxide Technical Assessment Report in Support of the 2013 Application to Amend the P2-00001 Multimedia Permit for the Kitimat Modernization Project. Vol.2: Final Technical Report. Prepared for RTA, Kitimat, BC. 450 pp.

Technical Memo: Revised Modelling and Mapping of Terrestrial Critical Loads, March 2015. In, Sulphur Dioxide Environmental Effects Monitoring for the Kitimat Modernization Project, 2013 and 2014 Annual Reports. ESSA Technologies Ltd, Vancouver, Canada.

Appendi A. STAR soil sampling procedures.

Soil survey field sheet: 2012 Kitimat
RTA | ESSA | TRENTU

Site ID ☐

Site check list

Soil samples for chemistry
Five auger pits sampled ☐
Composite samples at 3 depths ☐

Centre auger pit
Forest floor sample ☐
Bulk density at 3 depths ☐
Site observations recorded ☐

Verified by (initial here):

On-site observations (centre auger pit)

Date: ________ ☐ JUN ☐ JUL ☐ AUG 2012

Time: ________ 24 hour clock (Pacific)

Coordinates: ________ lat. ________ lon.

GPS elevation (m): ________ Site photograph: ☐ Y ☐ N

Mineral soil depth (cm)[$]: ________ Distance from road or trail (m): ________

Forest floor depth (cm)[$]: ________ Site gradient (slope): ☐ steep ☐ moderate ☐ flat

Site position: ☐ crest ☐ upper slope ☐ middle slope ☐ lower slope ☐ depression ☐ level

Dominant vegetation[$$]: ________ Outcropping rock (%): ________

Recent rainfall ☐ Y ☐ N Snow on ground ☐ Y ☐ N

	Depth: 0–10 cm	Depth 15–25 cm	Depth 40–50 cm
Moisture regime: Dry [D] Moist [M] Wet [W]	☐ D ☐ M ☐ W	☐ D ☐ M ☐ W	☐ D ☐ M ☐ W
Roots present:	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
Size of stones:	☐ Small ☐ Medium ☐ Large	☐ Small ☐ Medium ☐ Large	☐ Small ☐ Medium ☐ Large
Volume of stones:	________ %	________ %	________ %

Recorded by:

Comments and notes:

See overleaf for sampling protocol and description of required observations

[$] Average depth of mineral soil and forest floor for all auger pits (in addition, list the depth of the centre auger pit for mineral and forest floor). [$$] List all tree dominant species (use comment box if needed)

Soil sampling protocol: 2012 Kitimat

Equipment: GPS, soil auger (AMS Dutch auger head with bayonet connector), soil core sampler (AMS 404.02 2" x 2" SCS complete), measuring tape, sharp knife, forest floor quadrate, Zip-lock bags, sharpie, digital camera, additional core liner (404.28 2" X 2" SST liner)…

Objective: Collection of mineral soil from 50 sites following rapid protocol using soil auger and corer. Mineral soil should be sampled at three (fixed) depths from five auger pits and composited by depth ('composite' samples), at one auger pit fixed volume soil cores should be sampled at the three (fixed) depths ('bulk density' samples), and a fixed area sample of forest floor should also be collected from one pit ('forest floor' sample). In total seven sample bags should be collected at each site (assuming mineral soil is > 50 cm).

1. Site location: Potential sampling sites represent the centre co-ordinates of a 500 m × 500 m grid with assumed 'homogenous' geological rock type, i.e., soil parent material. Only grids accessible from (or close to) trails are listed. If you are within 250 m of the co-ordinates, you are 'in the sampling grid'.

2. Site selection: The soil sampling location should reflect the general vegetated landscape, i.e., avoid the unique clearing in the sun. The site should be undisturbed (i.e., not recently harvested, > 50 m from trail, etc). If the landscape is irregular, give preference to upland locations between lower slope (or depression) and crest. If significant disturbance, do not sample (go to next site). Use digital camera to record sites.

3. Soil sampling: At each site, establish an ~ 20 m × 20 m grid; using a soil auger collect soils at each grid corner and the grid centre, giving a total of five auger points. Collect soils from three fixed depths (0-10 cm, 15-25 cm and 40-50 cm) at each of the five points. If forest floor is present, remove prior to collection of auger samples (i.e., the 0-10 cm depth starts at the bottom of the forest floor layer). The five samples from each common depth should be composited, giving three 'composite' samples per site, i.e., put all 0-10 cm samples into one Zip-lock, etc. Approximately 150–200 g of soil should be collected for each depth-composite. Collect samples using a Dutch-style auger (mark auger stem with coloured tape to delineate sampling depths). Label zip-lock bags for each depth-composite, i.e., Sxxxx-0-10, Sxxx-15-25 and Sxxx-40-50. Finally, record the average soil depth (average of the maximum depth at each pit, estimated using the soil auger).

4. Collect bulk density samples from the grid centre point using steel cylinders of fixed volume; use a dedicated ring holder (AMS soil corer) for core sampling after application of a soil auger to prepare a sampling platform at the predetermined depth (0-10 cm, 15-25 cm and 40-50 cm). If forest floor is present, remove prior to collection of bulk density samples. Carefully remove soil-filled cylinder from the ring holder and trim soil extending beyond both cylinder ends using a sharp knife. Resample cylinders with large stones, or large roots extending beyond the core. Store soils in zip-lock freezer bags and label for each bulk density depth, i.e., Sxxxx-0-10-DB, Sxxx-15-25-DB and Sxxx-40-50-DB.

5. A fixed area forest floor sample should be collected for bulk density. At the centre pit, use a small quadrate (e.g., 20 cm × 20 cm) to collect the forest floor layer, cut around the inner circumference of quadrate to remove material, and measure the average depth (average of four sides [record on field sheet]). Store forest floor in a zip-lock freezer bag and label, i.e., Sxxxx-DB-FF.

6. Complete field sheet (overleaf): Site ID, location and elevation are important. Observations are based on the centre auger pit or the site area. Use comments box for additional notes.

Soil depth: use auger to record the maximum depth of the mineral soil, or indicated '> 1 m'.
Dominant vegetation: record tree species (use comments box if additional space is required).
Outcropping rock: record the percent area of outcropping rock across the study location.
Moisture regime: is the soil wet at centre pit? Record for each sample (fixed) depth.
Roots present: are roots visible in auger soil (at each sample depth) at centre pit?
Size of stones: record size of stones encountered during auger use (at each sample depth for centre pit).
Volume of stones: based on the frequency of stones, estimated the fraction of the soil pit occupied by stones.

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