RioTintoAlcan ESSA

Sulphur Dioxide Environmental Effects Monitoring for the Kitimat Modernization Project

2013 and 2014 Annual Reports

Prepared for:

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Summary of EEM Actions

The following tables summarize the EEM commitments for 2013 and 2014, what was done, and where to look for more information on each topic.

Year	Topic	The commitment	What was done	Where to learn more
Atmospheric Pathways				
2013	Atmospheric SO_2 concentration	Maintain existing four continuous SO_2 analysers. Assess and compare [SO_2] at Haul Road versus KMP Campsite.	Data were collected at four of five analyzers. Technical difficulties prevented SO_2 data collection at the Whitesail location and at Haul Road during the first quarter of 2013. Comparison of results from Haul Road and KMP campsite to be done during the study to optimize the ambient air monitoring network in 2015.	Section 3.1
	Wet deposition – sulphur, base cations, chloride	Maintain two rain chemistry stations (Haul Road and Lakelse Lake).	The Haul Road station operated all year. The station at Lakelse Lake began operation in March.	Section 3.1
2014	Atmospheric SO_2 concentration	Maintain existing 4 continuous SO_2 analysers.	Data were collected at 5 analyzers. There were technical difficulties with SO_2 data retrieval at the Whitesail location.	Section 3.1
		Write up 2011-2012 passive monitoring results; use to inform design of low cost pilot program with non-TEA based samplers at least 3 sites to see if they correlate well with continuous SO_2 monitors.	Passive monitoring results were analyzed, and a pilot study was designed.	Section 3.1 EEM Technical Memo P01 EEM Technical Memo P02
	Wet deposition	Maintain 2 rain chemistry stations (Haul Road and Lakelse Lake).	Both stations were operational all year.	Section 3.1
	Dry deposition	Determine entity to develop method for estimating dry deposition using existing data.	It was determined that the methodology will be developed by Trent University.	
Human Health				
No EEM activities were planned for 2013 or 2014.				

Year	Topic	The commitment	What was done	Where to learn more
Vegetation				
2014	Vegetation survey	Add checklist for presence / absence of sensitive species on field survey form; conduct visible injury survey.	The checklist has been developed. This occurred after the 2014 visual inspection survey and will be used during the 2016 survey.	The checklist is in Appendix B of the EEM Plan
		Continued vegetation sampling as per Laurence (2010).	Survey was conducted in late August 2014.	Section 3.3 Laurence (2014)
	Sulphur content in hemlock needles	Collection of hemlock needles near the end of the growing season from mid-August to mid-September.	Samples were collected in late August 2014.	Section 3.3 Stantec (2015)
	Sensitive ecosystem mapping	Review Predictive and Thematic mapping to see if there are sensitive ecosystems within the plume not covered by the existing network of vegetation, soil and surface water sampling sites.	Vegetation and lake sampling sites were overlaid with information on sensitive ecosystems.	Section 3.3 EEM Technical Memo V02
Terrestrial Ecosystems (Soils)				
2013	Review of critical limit selection	Obtain digitized vegetation map from VRI.	The data were obtained, and used to inform Bc:Al ratio discussions.	Section 3.4 EEM Technical Memo V01
2014	Soil modelling	Rio Tinto Alcan/MOE/QP collaboration on details of study design for this component. Obtain digitized surficial geology map from BC MOE; overlay with 2012 sampled soil sites.	The map layers were obtained and used to select candidate sites for additional soil sampling.	Section 3.4 EEM Technical Memo S02
		Undertake a sensitivity analysis of STAR predictions under multiple chemical criterion (Bc:Al, Ca:Al, pH, Al).	Completed as part of the Kitimat Airshed Environmental Effects Assessment	Section 3.4 ESSA et al. 2014b
	Review of critical limit selection	Collaboration with MOE on appropriate critical limit for soils, Bc:Al ratio, by vegetation type (consider use of BEC zones to derive reasonable dominant species boundaries).	Critical limits identified for vegetation types.	Section 3.4
Aquatic Ecosystems (Lakes, Streams and Aquatic Biota)				
2013	Chemistry – water sampling	Annual water sampling and laboratory analysis; sample Cecil Creek.	Completed in 2013.	Section 3.5 EEM Technical Memo W01 Perrin et al. (2013)
	Fish sampling	Sampling of 4 vulnerable lakes.	Completed in 2013 (West	Section 3.5

Year	Topic	The commitment	What was done	Where to learn more
			Lake, End Lake, Little End Lake, Finlay Lake).	EEM Technical Memo W01 Perrin et al. (2013)
2014	Steady state water modelling	Re-run acidification models to calculate CLs, to assess the effects of sampling in August (2012) versus October (2013).	Modelling was completed in 2014.	Section 3.5 EEM Technical Memo W01
	Chemistry – water sampling	Annual water sampling and laboratory analysis.	Completed in the fall of 2014.	Section 3.5 EEM Technical Memo W01 Perrin and Bennett (2015)
		More intensive sampling of 3 lakes to determine natural variability.	Completed in the fall of 2014.	Section 3.5 EEM Technical Memo W02 Perrin and Bennett (2015)
		Develop weight-of-evidence approach for assessing whether chemical change is causally related to KMP.	Completed in 2014.	Section 7 and Appendix H of the EEM Plan
	Fish sampling	Reconnaissance of habitat and water chemistry in Goose Creek – future sampling TBD based on results.	Reconnaissance and sampling conducted in the vicinity of Goose Creek in 2014. Additional reconnaissance to be conducted in 2015.	Section 3.5 EEM Technical Memo W01
	Episodic acidification	Initiate study design for snow melt and fall storm episodic acidification in Anderson Creek near KMP (gauged stream). Examine 1997 pH data for Anderson Creek as possible baseline.	Study design initiated in 2014. Continuous pH monitor installed at Anderson Creek for a pilot test in November 2014, and restarted March 2015. RTA is supporting research on acidic episodes in streams by Dr. Paul Weidman of Simon Fraser University.	Section 3.5
	Amphibians	Initiate discussion with interested party.	Discussions initiated with Ms. Jonquil Crosby of the Smithsonian Conservation Biology Institute.	Section 3.5

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1 Introduction

In 2013 a technical assessment (ESSA et al. 2013) was completed for the Kitimat Modernization Project (KMP), to determine the potential impacts of sulphur dioxide (SO_2) emissions on human health, vegetation, terrestrial ecosystems, and aquatic ecosystems. Figure 1 shows a conceptual model of the pathways of potential effect that were considered in the technical assessment.

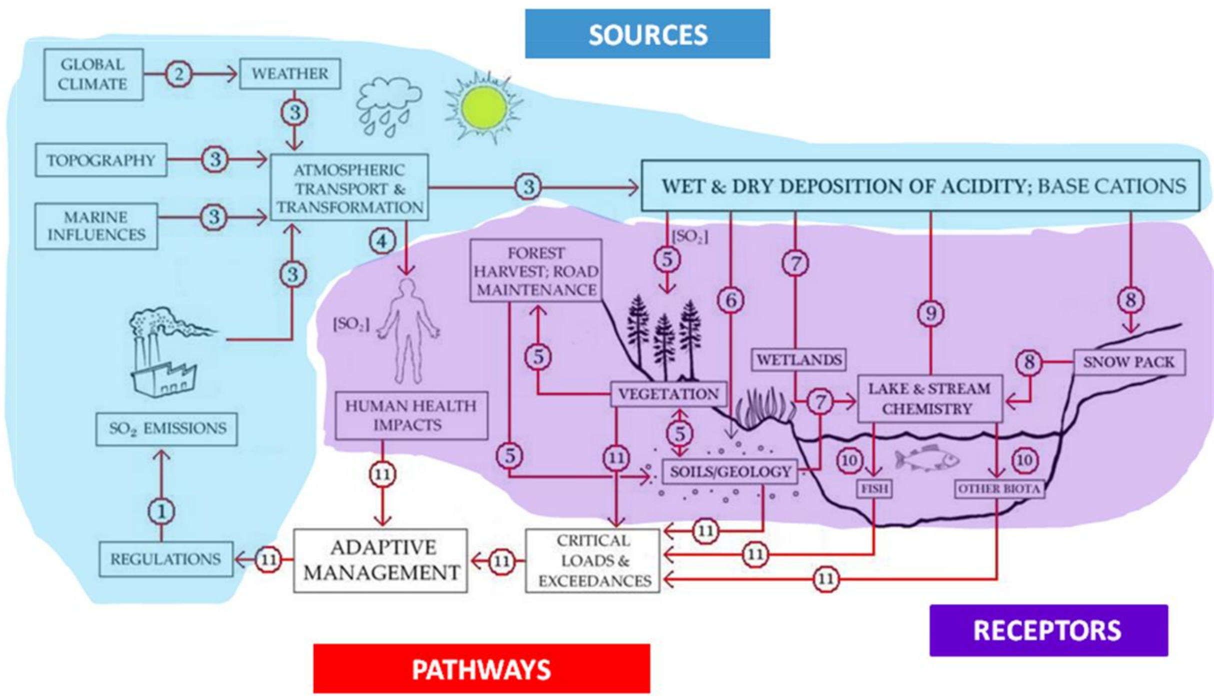


Figure 1. Source-Pathway-Receptor model of SO_2 emissions in the environment, showing linkages between sources and receptors. (Source: Figure 3.1-1 from ESSA et al. 2013)

A sulphur dioxide Environmental Effects Monitoring (EEM) Program has been designed to answer questions that arose during the technical assessment, and to monitor effects of SO_2 from the modernized smelter on human health, vegetation, and terrestrial and aquatic ecosystems. Results from this Program will inform decisions regarding the need for changes to the scale or intensity of monitoring, as well as decisions regarding the need for mitigation.

The scope of the EEM Program encompasses SO_2 emissions from the modernized smelter at full production capacity. An EEM Plan (ESSA et al. 2014a) that focuses on the first 6 years (2013-2018) of the EEM Program is currently underway. What is learned during this period will be applied to improve the Program in 2019. Other smelter emissions, research and development related to SO_2 impact measurement and mitigation, monitoring for non-KMP acid deposition and monitoring not specific to KMP SO_2 impacts are all outside of the scope of the SO_2 EEM Program.

SO_2 EEM reporting will occur on an annual basis. These reports will present a summary of EEM activity each year, and an overview of EEM activities that will be undertaken the following year.

Details of the results from EEM activities will be documented in technical memoranda, allowing access to more in-depth technical information for the ECC, PAC, and anyone else who is interested. A comprehensive review will be conducted in 2019 to examine results from the SO_2 EEM Plan from 2013 to 2018. The review will inform the design of EEM activities after 2018, based on what has been learned during the first six years.

This document comprises the 2013 and 2014 Annual Reports under the SO_2 EEM Plan for KMP. It is organized into sections according to the SO_2 assessment framework illustrated in Figure 2.

The Annual Report for 2015 will be prepared in the spring of 2016.

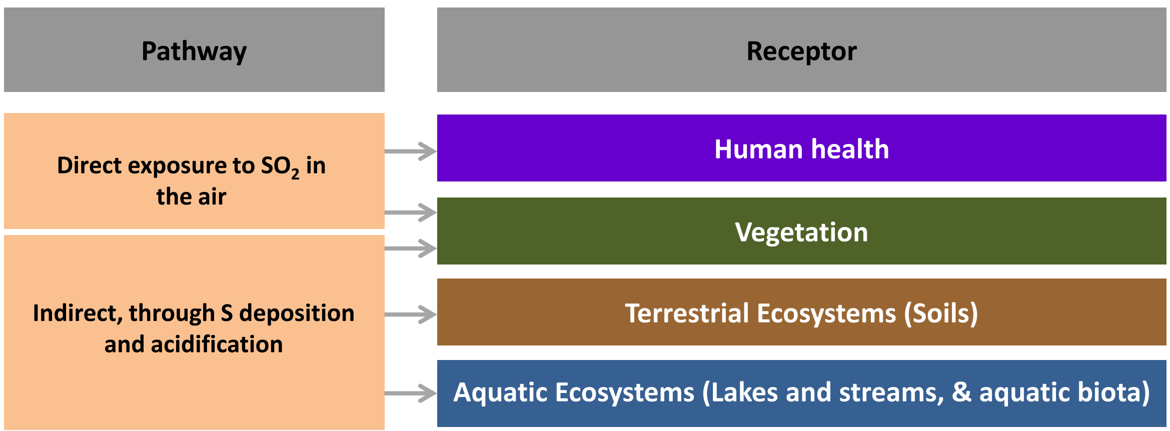


Figure 2. Framework for reporting on EEM activities.

2 Facility Production and Emissions

In April 2013 the sulfur emissions limit for the Kitimat smelter was changed from 27 tonnes per day to 42 tonnes per day. Metal production was lower in 2013 and 2014 than previous years (Figure 3), in preparation for the transition to the modernized smelter. Accordingly, emissions of SO_2 decreased from an average of 15.1 tonnes per day in 2012 to 11.6 tonnes per day in 2014 (Figure 4).

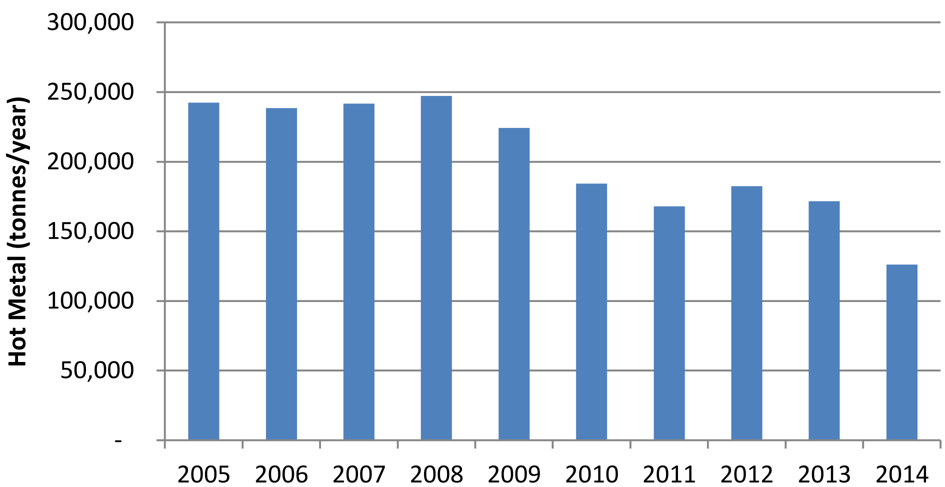
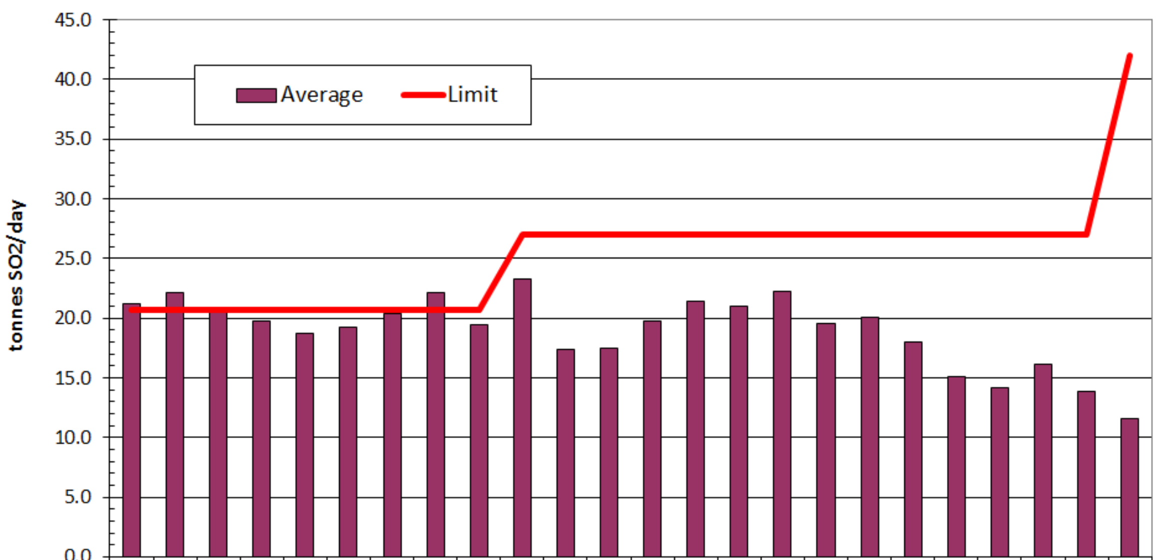


Figure 3. Hot metal production from the Kitimat smelter prior to modernization. (Source: Rio Tinto Alcan)



	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14
Average	21.2	22.1	20.9	19.8	18.7	19.2	20.4	22.1	19.5	23.3	17.4	17.5	19.8	21.4	21.0	22.2	19.6	20.1	18.0	15.1	14.2	16.1	13.9	11.6
Limit	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	42.0

Figure 4. Annual SO_2 emissions from the Kitimat smelter over the past 14 years. (Source: Rio Tinto Alcan)

3 EEM Activities

3.1 Atmospheric Pathways

2013

Activities during 2013 involved measurement of atmospheric concentrations of SO_2 using continuous analysers, and measurements of wet deposition from rain chemistry stations.

SO_2 Concentrations

For the EEM Program, SO_2 monitoring data were collected from four existing continuous analysers: Haul Road (fenceline), Riverlodge (lower Kitimat), Kitamaat Village and KMP Camp (Figure 5). There were technical issues with the SO_2 analyzer at Whitesail due to a virus in the modem's software. The continuous air quality monitoring stations (Figure 6) provide hourly observations of SO_2. They provide information on air quality in the area on an ongoing basis, and will provide important data for many EEM activities over the next five years.

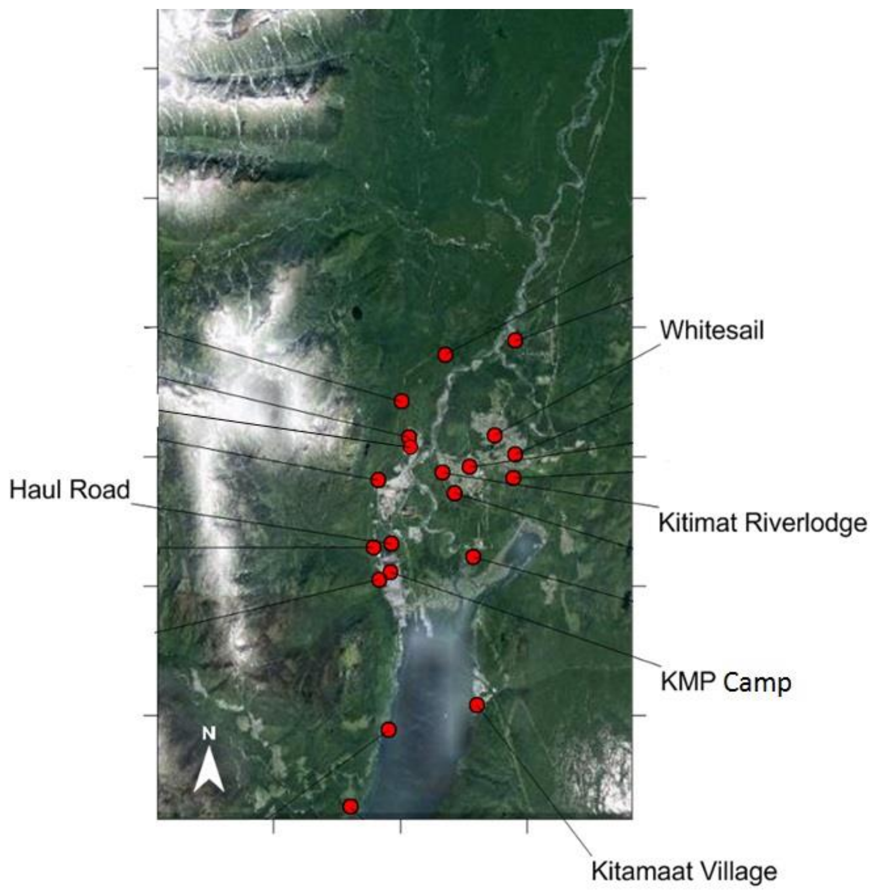


Figure 5. Locations of the four continuous SO_2 analysers (Haul Road, Whitesail, Riverlodge and Kitamaat Village) as well as the KMP Camp location.

Figure 6: Photo of continuous monitoring for air quality at the Kitamaat Village continuous monitoring station.

Wet Deposition

Wet deposition of sulphur is measured by collecting samples of precipitation, including both rain and snow. Evaluation of the wet and dry deposition data provides an estimate of total sulphur deposition. A wet deposition monitoring station at Haul Road has operating since July of 2000 (Figure 7). This station was upgraded with new equipment in September of 2012 and incorporated into the National Atmospheric Deposition Program (NADP) in September 2012. An additional monitoring location was added at Lakelse Lake in March 2013. These rain chemistry stations also monitor base cation and chloride deposition, which will be used in the recalculation of critical loads for soils and lakes.

Figure 7. Haul Road wet deposition monitoring location (Station #6, NADP ID BC22), showing electronic recording rain gauge (shown at left) and a wet deposition collector (at right).

2014

Activities during 2014 involved ongoing measurement of atmospheric SO_2 concentrations at four continuous analysers and measurements of wet deposition at two rain chemistry station, as described for 2013. The use of passive samplers was also investigated as a means of increasing spatial coverage of the measurement of SO_2 concentrations.

SO_2 Concentrations

Figure 8 shows the pattern of the monthly average SO_2 concentrations at four continuous monitoring stations during 2013 and 2014, along with monthly SO_2 emissions over the same period.

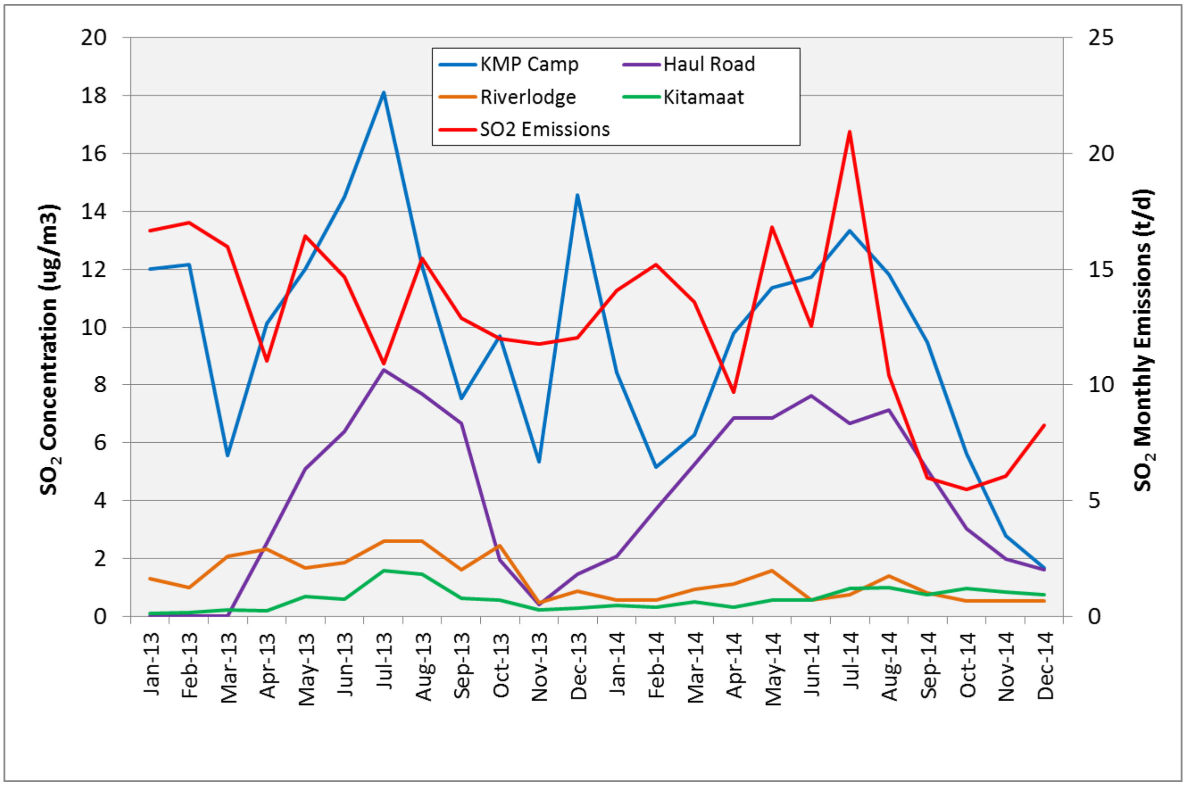


Figure 8. Monthly SO_2 emissions (red line) and monthly average ambient SO_2 concentrations at four continuous monitoring stations (blue, purple, brown and green lines). (Source: Rio Tinto Alcan)

During 2011 and 2012, Rio Tinto Alcan operated a network of passive samplers to provide empirical observations of atmospheric SO_2 concentrations. The network was composed of 19 sites during 2011 with observations for the period 04 August–20 October (11 weeks). The network expanded to 21 sites in 2012 and operated for 21 weeks (17 May–18 October).

During 2011, more than 60% of exposed samplers were reported as less than the method detection limit, i.e., they were recorded as non-valid observations. This prompted questions on the network design; to address concerns a comprehensive network review was carried out during 2012. Details on the 2011–2012 monitoring and the network review are provided in a separate Technical Memo.

The network review concluded that although the data (i.e., concentrations of SO_2 measured by passive samplers) showed a consistent gradient in air concentrations associated with the plume, the variability in replicate exposures and the limited correspondence with continuous measurement is a concern.

The review recommended that the Radiello triethanolamine passive samplers be replaced with a potassium or sodium carbonate based sampler. Sampler exposure duration be increased to two weeks (or greater). A supplemental sampler exposure pilot study should be carried out to evaluate variability and sampler performance at high air concentrations.

In 2015, data from the continuous analysers from 2013 and 2014 will be used to make a decision about whether to relocate one or more analyzers, and the passive monitoring pilot study will be implemented. Details on the proposed passive sampler pilot study are provided in a separate Technical Memo.

Wet Deposition

Figure 9 compares the amount of annual precipitation at the two wet deposition monitoring stations during 2014, and also compares annual precipitation at the Haul Rd. station in 2013 and 2014. Because the Lakelse Lake station was only in operation for part of 2013, data from that location are only shown for 2014. Figure 10 compares weekly precipitation at the two stations from April 2013 to December 2014. Precipitation chemistry for both locations is shown in Figure 11 and Figure 12.

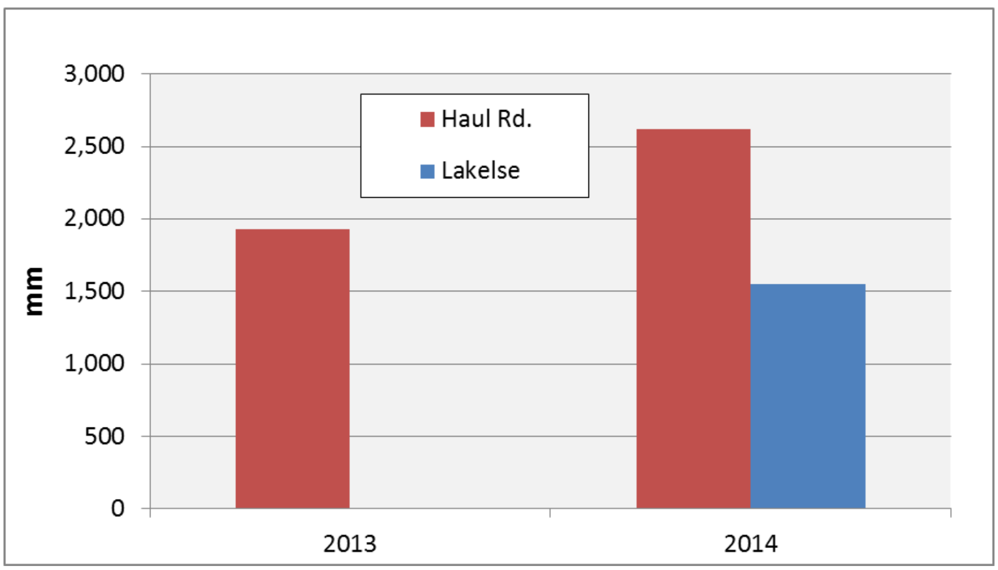


Figure 9. Annual precipitation for 2013 and 2014 at the Haul Road and Lakelse Lake wet deposition monitoring stations. (Source: Rio Tinto Alcan)

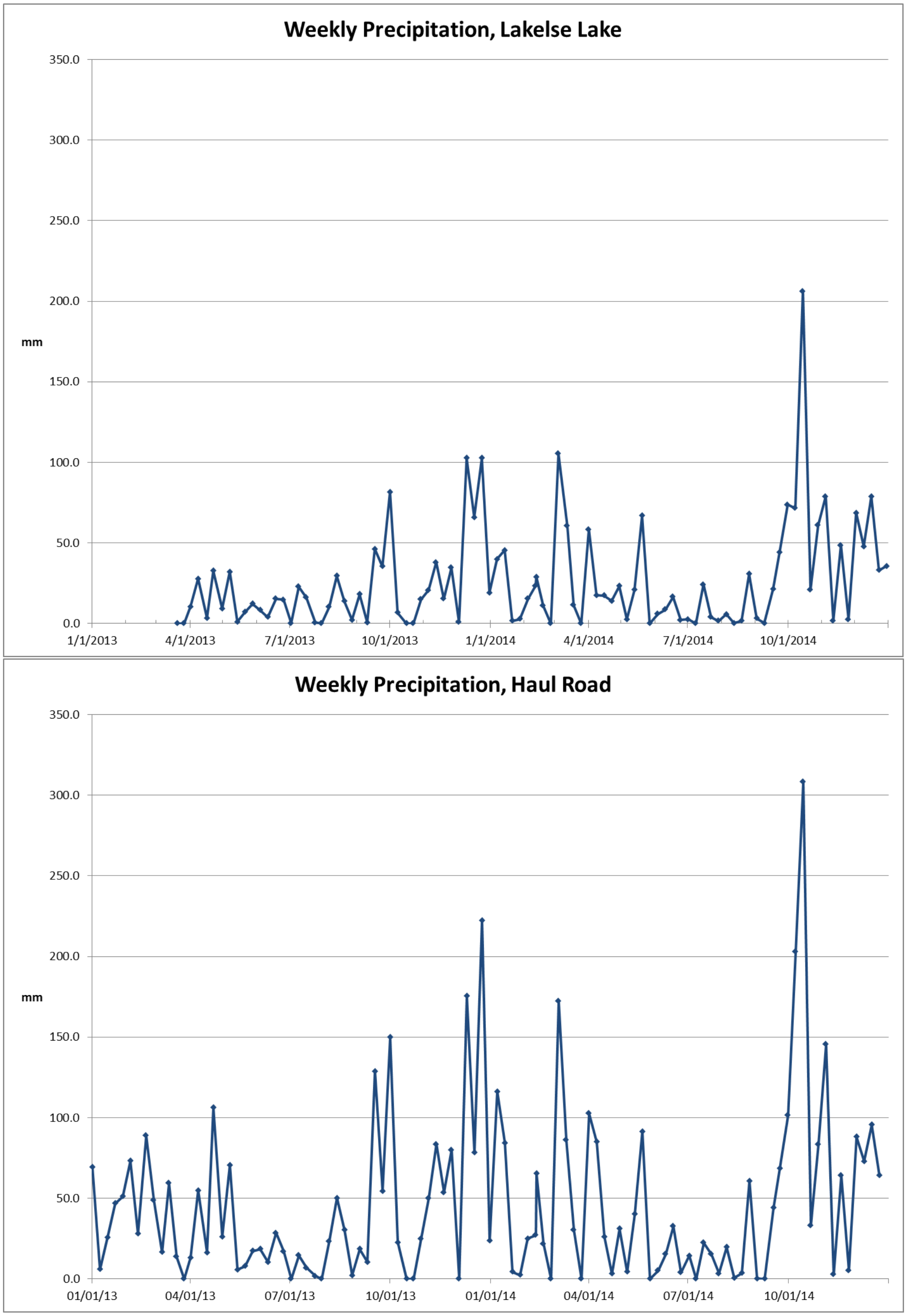


Figure 10. Weekly precipitation from April 2013 to December 2014 at the Lakelse Lake (upper graph) and Haul Road (lower graph) wet deposition monitoring stations. (Source: Rio Tinto Alcan)

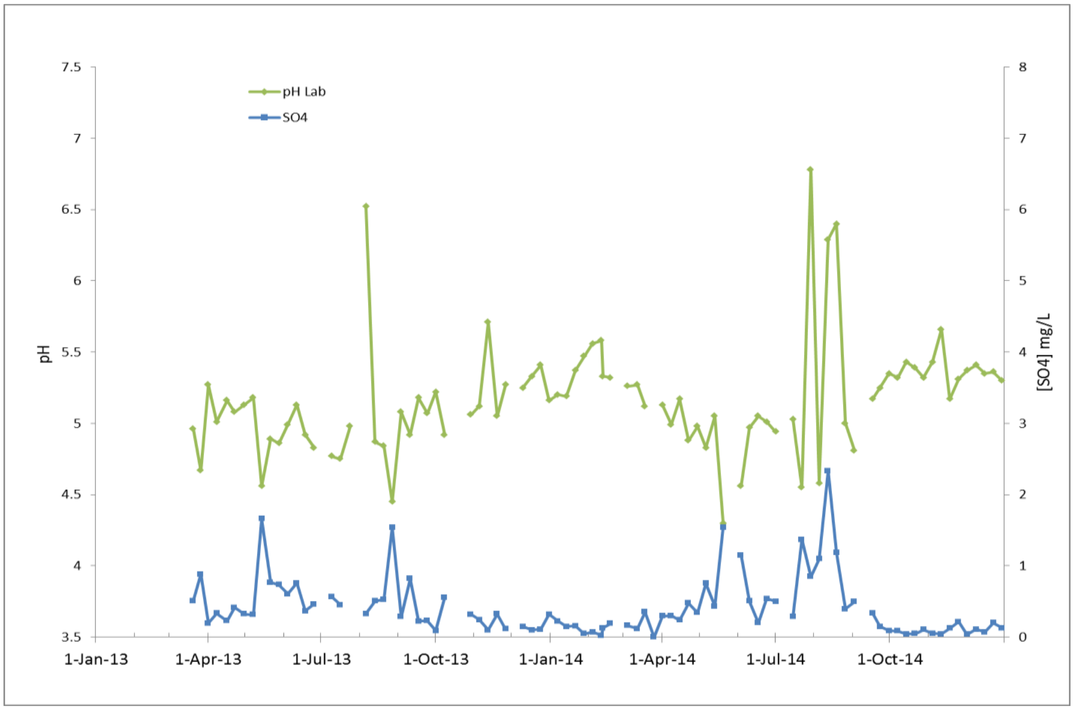


Figure 11. Precipitation chemistry from April 2013 to December 2014 at the Lakelse Lake wet deposition monitoring station. (Source: Rio Tinto Alcan)

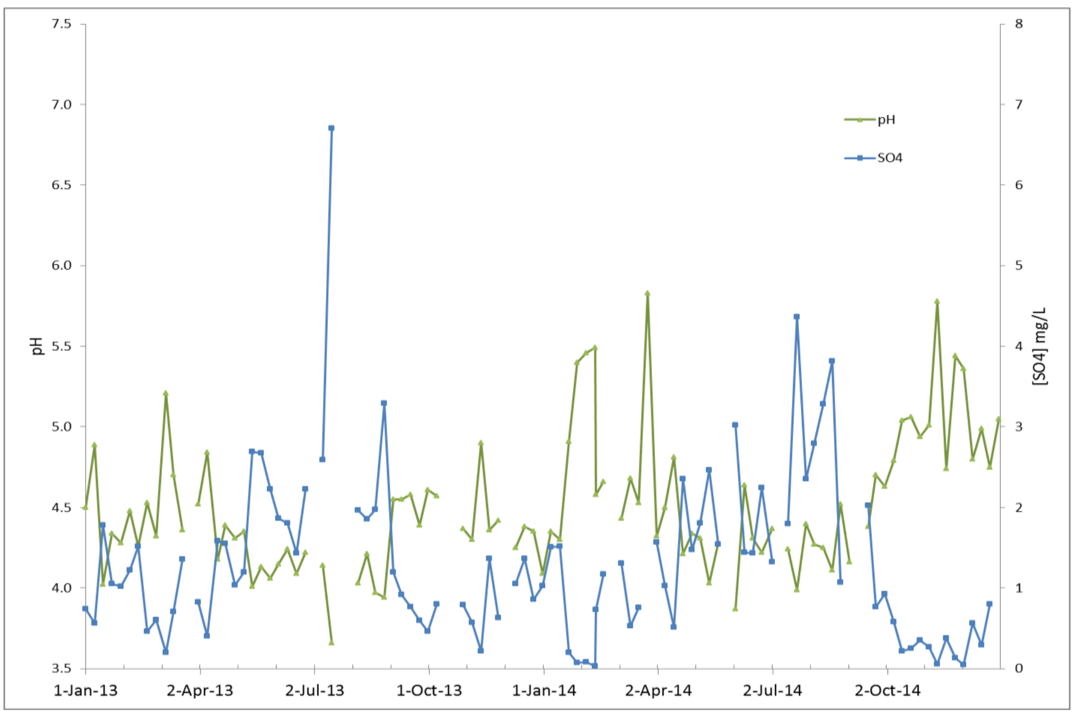


Figure 12. Precipitation chemistry for 2013 and 2014 at the Haul Road wet deposition monitoring station. (Source: Rio Tinto Alcan)

In 2015, a method will be developed for estimating dry deposition to determine the relative contribution of wet and dry deposition to total sulphur deposition, based on a modelling approach developed by Dr. Leiming Zhang of Environment Canada. Figure 13 shows preliminary estimates of the amount of dry and wet deposition at the Haul Road NADP monitoring station, using the same methods that were applied in the STAR (ESSA et al. 2013). The equipment at the Haul Road site was updated to the NADP standard during the fall of 2012, which explains the gap in wet deposition data during this period. The NADP equipment provides better estimates of precipitation, which may be partly responsible for the observed trends in wet deposition. The peak in estimated wet deposition during December 2013 is likely related to very high precipitation during that month (475.7 mm). Problems with the SO_2 data logger explain the gap in dry deposition estimates during the latter half of 2012 and first quarter of 2013.

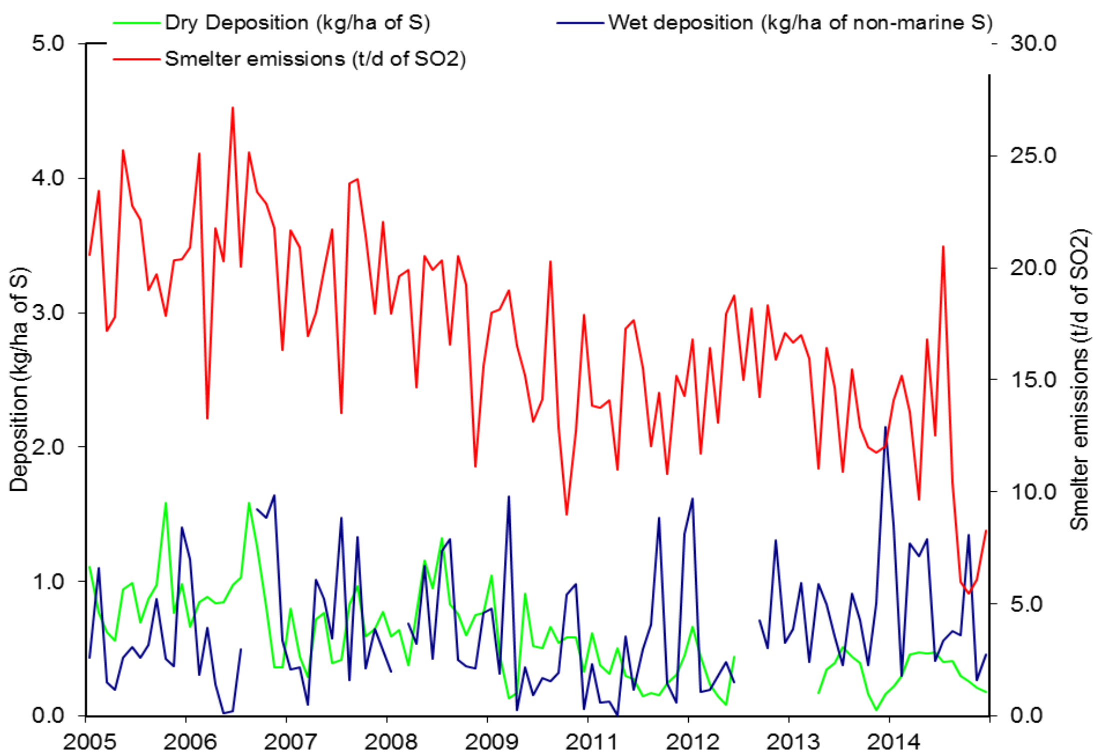


Figure 13. Trends in monthly smelter emissions of SO_2, preliminary estimates of dry deposition of sulphur (S), and wet deposition of sulphur (S). (Source: Dr. Julian Aherne, Trent University)

3.2 Human Health

There were no actions during 2013 or 2014 for this component of the EEM Plan.

In 2015, work will focus on increasing accessibility of ambient air quality data, and predicting the annual number of SO_2-associated respiratory responses.

3.3 Vegetation

2013

There were no actions during for 2013 for this component of the EEM Plan.

2014

Vegetation Survey and Sampling

Two types of vegetation sampling occurred in August 2014: a visual survey for signs of SO_2 injury, and collection of hemlock needles for subsequent sampling for S content. The locations are shown in Figure 14.

No symptoms of visual injury due to SO_2 were observed, and no unusual conditions were observed in ornamental vegetation in Kitimat. An infestation of scale insect on western hemlock was noted in the immediate vicinity of Rio Tinto Alcan, but there were otherwise no remarkable insect outbreaks, disease epidemics or other stress factors affecting vegetation. No unusual signs or symptoms were observed at the remote sites or on the east side of Minette Bay. More information can be obtained in the vegetation survey results report (Laurence 2014).

Concentrations of sulphur in hemlock needles sampled in 2014 averaged 0.08%. This is the same average concentration found in 2011 and 2013, and is the lowest average recorded since the Vegetation Inspection and Monitoring Program began in 1970. Concentrations in 2014 ranged from 0.05% (sites 52, 54, 57, 69 and 85 in Figure 14) to 0.14% (site 43B). More information can be obtained in the 2014 Vegetation Inspection, Monitoring and Assessment Program report (Stantec 2015).

Sensitive Ecosystems

The EEM Plan called for investigation into whether there are sensitive ecosystems in the SO_2 assessment study area, and if so, whether they occur in areas already covered by the existing EEM sampling network for vegetation, soil and water. Two sensitive ecosystems occur in the study area, according to the BC Conservation Data Centre (CDC): black cottonwood-red alder/salmonberry, and wet submaritime Sitka spruce/salmonberry. Both are located along the Skeena River.

None of the lake or stream sampling sites under the EEM Plan are located near these ecosystems, although one vegetation sampling site (#84A in Figure 14) is located very close by. Some EEM sampling sites do overlap polygons from the VRI that contain Sitka spruce, cottonwood or alder, but these polygons are along other waterways near Kitimat, not in the areas explicitly identified as sensitive ecosystems. Further investigation would be needed to determine if some of these sites might be adequate surrogates for the CDC-listed ecosystems, or whether EEM sampling locations might need to be added in those sensitive ecosystems.

Additional information about the results of this investigation is provided in a separate Sensitive Ecosystems Technical Memo.

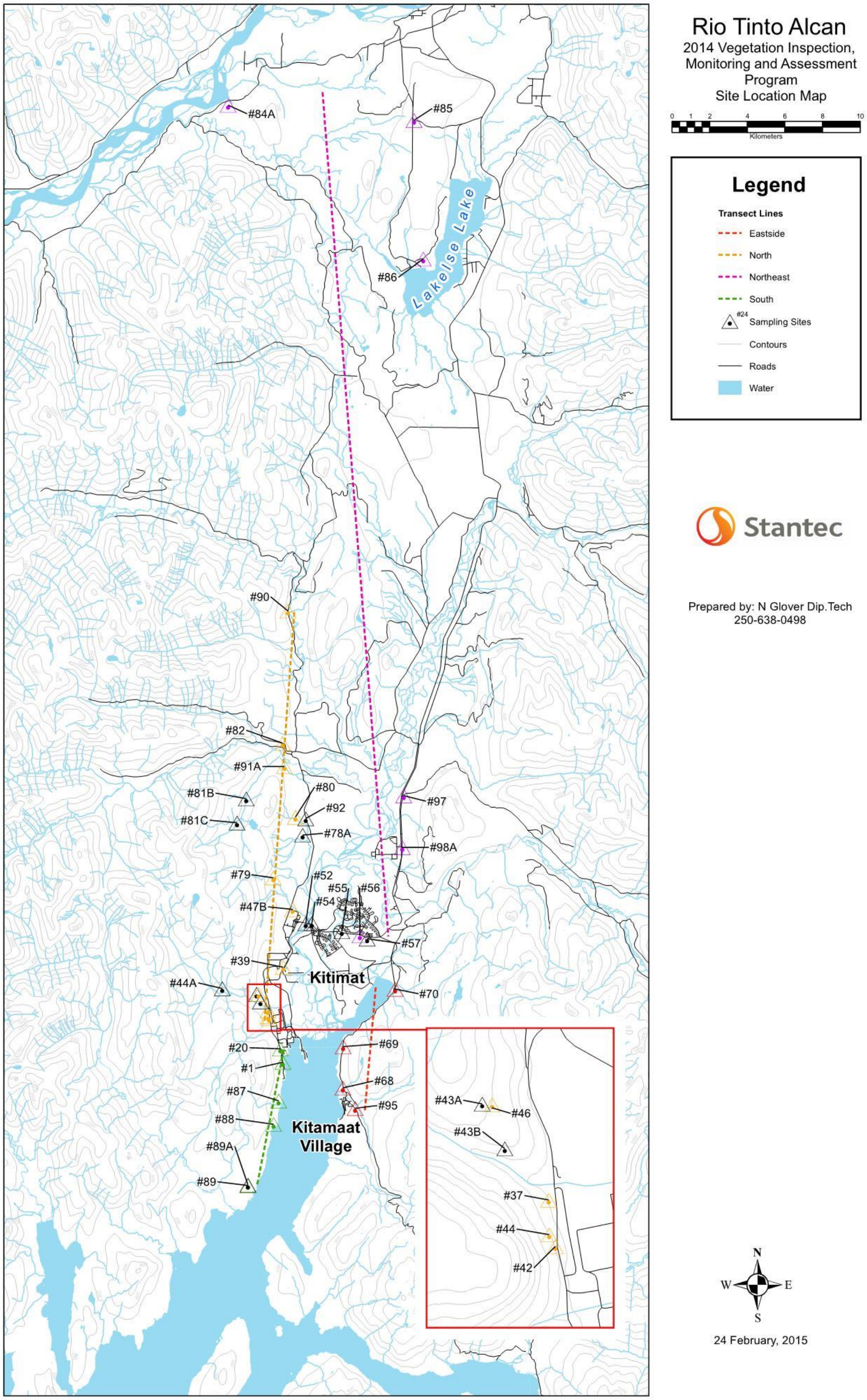


Figure 14. Location of vegetation sampling (denoted by triangles). (Source: Figure 1 in Stantec 2015)

3.4 Terrestrial Ecosystems (Soils)

2013

A digitized vegetation map was obtained for the study area from the Vegetation Resource Inventory. These data will support work in 2014 to identify the most appropriate Bc:Al critical limit in soils with different forest cover types in the study area. The critical limit for Bc:Al is one of the inputs required when running the steady state mass balance model to re-calculate one of the KPIs for soils: atmospheric S deposition and critical load (CL) exceedance risk. The re-calculation will be done in 2017, and will incorporate the revised Bc:Al critical limit information as well as other modelling and monitoring data from various EEM activities over the next three years.

A brief description of the VRI data, including a listing of VRI attributes, is provided in a separate VRI Technical Memo.

2014

The soils component of the EEM program includes two KPIs: critical load exceedance risk and observed change in base cation pool over time. The latter requires the establishment of long-term soil monitoring plots; discussions regarding the soil plots will be undertaken during a 2015.

Under the EEM program, critical loads of acidity for (upland) forest soils will be revised during 2017 to support the KPI 'critical load exceedance risk'. Revised modelling and mapping of terrestrial critical loads will incorporate additional (new) observational data, improved regionalisation methods and updated model parameters as recommended under the STAR (ESSA et al., 2013) or following the Kitimat Airshed Emissions Effect Assessment (ESSA et al., 2014). Details are provided in a separate Technical Memo.

A sensitivity analysis of the STAR predictions under multiple chemical criterion (Bc:Al, Ca:Al, pH, Al) confirmed that the outcome of the STAR was not biased by the use of the Bc:Al ratio. Further details on this assessment will be described in a Technical Memo during 2015. Collaboration with the MOE on appropriate limits for the Bc:Al ratio by vegetation type will be continued during 2015 and 2016, and incorporated into the revised critical loads during 2017.

The STAR (ESSA et al., 2013) identified spatial variability in estimated soil base cation weathering rate as a critical uncertainty. As such, the EEM program identified several broad regions for supplemental soil sampling during 2015 to expand weathering estimates. Details on the proposed 2015 supplemental soil sampling are provided in a separate Technical Memo. A list of 17 potential plots was selected from five broad regions; it is recommended that at least 12 plots are sampled following field sampling procedures used under the STAR.

3.5 Aquatic Ecosystems (Lakes, Streams and Aquatic Biota)

2013

The EEM Plan calls for three activities in 2013: annual water sampling and analysis, sampling of Cecil Creek, and sampling fish presence in four vulnerable lakes.

Water Sampling

Water chemistry and acidification is the KPI for aquatic ecosystems. Ten lakes in the study area were determined by the SO_2 technical assessment to be sensitive to acidification (Figure 15). The EEM Plan calls for monitoring 7 of these lakes through annual water sampling and laboratory analyses.

Eleven lakes were sampled in October 2013. Seven of the sampled lakes are acid-sensitive: End Lake (LAK006), Little End Lake (LAK012), LAK022, West Lake (LAK023), LAK028, LAK042, and Finlay Lake (LAK044). Three are acid-insensitive lakes: LAK007, LAK016 and LAK034. Lake MOE3 was also sampled. All of these lakes are shown on Figure 16. Lake 15 is the only one in Figure 15 not considered vulnerable, because its original pH was below 6.0 and it is not expected to experience a pH decrease or a critical load exceedance. Lakes 012, 022, 006, 023, 028, 042 and 044 are included in the EEM program (Source: ESSA et al. 2014a). We intended to sample Lake MOE6 as well but this was not possible due to deteriorating weather conditions in 2013.

Cecil Creek receives drainage from West Lake (LAK023), and was also sampled in three locations.

The information will be used to re-calculate critical loads of acidity in these lakes (described under the 2014 subheading below).

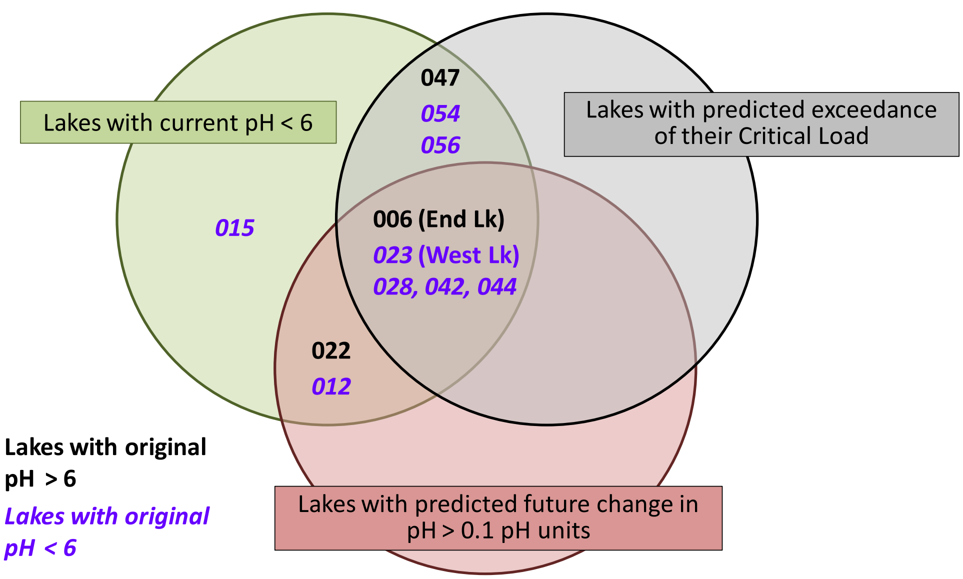


Figure 15. Conceptual diagram of criteria for lake vulnerability.

Fish Sampling

Sampling was also done in October to determine presence/absence of fish in four of the acid sensitive lakes: West Lake (LAK023), End Lake (LAK006), Little End Lake (LAK012), and Finlay Lake (LAK044), all shown in Figure 15 and Figure 16. Sampling was done using standard gill netting techniques. Fish were caught in three of the four lakes. No fish were caught in Finlay Lake, which also had no inlets or outlets. Stickleback were common in the other three lakes. Both End Lake and Little End Lake had coastal cutthroat trout, coho salmon (coho), and Dolly Varden char whereas West Lake only had coho and Stickleback. The coho in West Lake had characteristics indicating residualism (fish that do not migrate out of the lake after rearing as juveniles), which is rare in coastal lakes.

DNA analysis of tissue from these coho has confirmed that they are indeed coho salmon and the apparent occurrence of coho residualism. The condition may be caused by intermittent access to West Lake between wet and dry years. In dry years, lack of wetted channels may have prevented smolts from outmigrating. Very low numbers of Dolly Varden may result in difficulty detecting the presence of this species in future sampling.

Reconnaissance in August 2013 for feasibility of fish sampling in three acid-insensitive lakes showed that all three lakes could be accessed by truck, all-terrain vehicle (ATV), and hiking along trails.

More information on sampling methods and results can be found in the detailed sampling results report (Perrin et al. 2013).

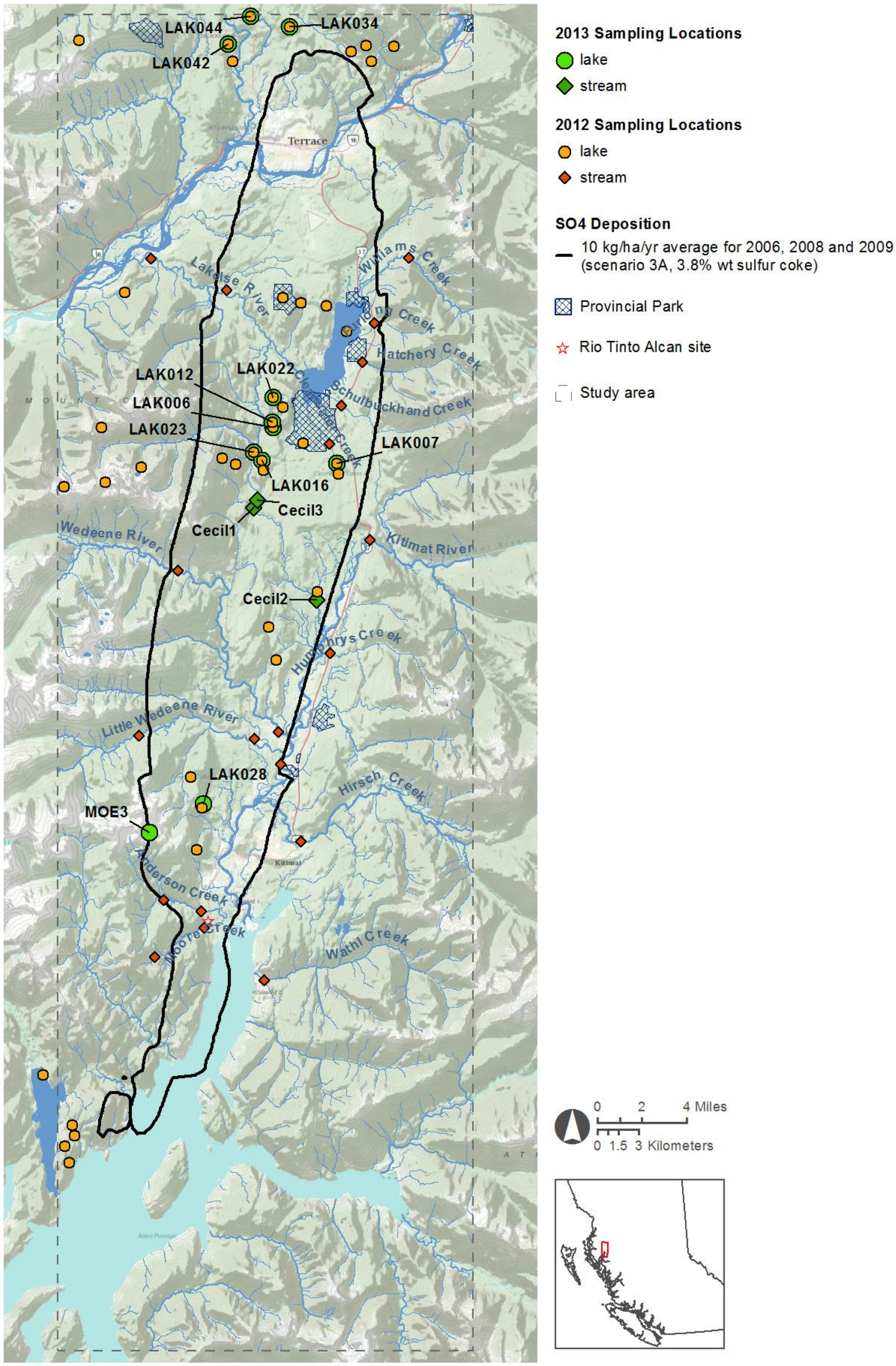


Figure 16. Location of lakes and stream sites that were sampled in 2013. The 2012 sampling sites are shown for reference. The area within the black line was predicted by ESSA et al. (2013) to receive more than 10 kg SO_4 per hectare per year under KMP. Lakelse Lake is LAK 024. (Source: Perrin et al. 2013)

2014

The following three sub-sections contain a condensed summary of the work described in a separate Freshwater Chemistry Analyses Technical Memo focusing on the actions that were performed, the knowledge gained from conducting those actions, and the recommended next steps to take as a result of those learnings. Each action, learning/conclusion, and next step is presented as a short bullet. The Freshwater Chemistry Analyses Technical Memo provides extensive details on the methods and results that support these statements.

Actions Taken in 2014

- Annual sampling and lab analyses of water chemistry for the seven sensitive EEM lakes and three less sensitive EEM lakes, plus the addition of Lakelse Lake in 2014 (Perrin and Bennett 2015).
- Additional sampling of non-EEM lakes and stream identified as being potentially sensitive to increased emissions, including Lake MOE6 and six sites within the Goose Creek watershed (2014). Lake MOE3 and three sites along Cecil Creek were sampled in 2013.
- Intensive monitoring of pH in the three accessible sensitive EEM lakes. Monitoring included the implementation of continuous pH monitors and multiple within-season samples collected for field and lab analyses of pH.
- Continuous monitoring of stream pH was initiated in Anderson Creek in the fall of 2014 for a 10-day trial period (November 19-28), and was restarted on March 31, 2015.
- Development of a weight-of-evidence approach for assessing causality associated with observed changes in water chemistry (i.e., the Evidentiary Framework). The Evidentiary Framework has been incorporated into the EEM plan (See Section 7.0 and Appendix H of the EEM plan).
- Critical loads and exceedances were recalculated using the KAA approach for defining watershed area (a more accurate approach) for EEM lakes based on the 2012 STAR data, in order to compare with the original results (using the STAR approach) and therefore assess the effect of changing to the improved methodology.
- Critical loads and exceedances were calculated for EEM lakes with the new 2013 data in order to assess the effects of sampling in August 2012 versus October 2013.
- Critical loads and exceedances were calculated for the non-EEM sites (MOE3, MOE6, and Cecil Creek) in order to determine if they are sensitive to increased emissions of SO_2.
- A preliminary assessment of the sensitivity of the Goose Creek sites was conducted based on the water chemistry samples collected and analyzed in 2014. Critical loads were not calculated in 2014.
- Inter-annual changes in water chemistry parameters were examined, especially in the context of the Evidentiary Framework. The examination focused on changes between 2013 and 2014 as changes from 2012 are more difficult to interpret due to the mixed effects of changing season and changing year.

Knowledge Gained from Actions taken in 2014

- The intensive monitoring of the three accessible EEM lakes showed that there is high variability in pH, substantially higher than previously expected. For each of the lakes there is variability in pH over time, between the continuous monitors and lab measures, between other field measures and lab measures, and between measures from different labs. This variability has important implications for the design of the EEM program, including:
    - The need to maintain continuous monitoring of pH at these lakes, as well as frequent collection of samples for lab analyses until we get a good understanding of this natural variability.
    - The need to strengthen the EEM threshold for change in pH by jointly evaluating the patterns of change in pH, ANC and SO_4.
    - The need to analyze the within-season samples for ANC and SO_4 in addition to pH
    - The need to conduct power analyses to rigorously assess the ability to correctly identify changes in water chemistry given the high levels of variability.
- Critical loads – 2012 vs. 2013. When assessed using the October 2013 sampling data, the sensitivity of the EEM lakes predominantly appears to be similar or lower than when previously assessed using the August 2012 sampling data. This supports the idea, as described in the STAR, that sampling done in the summer (which was necessary due to logistical constraints during the STAR work) would be more conservative than sampling done in the fall.
- The non-EEM sites MOE3, MOE6 and Cecil Creek have very high critical loads (multiple times higher than the threshold for the "very low sensitivity" class) and are therefore not sensitive to increased emissions and do not need to be added to annual EEM sampling.
- The preliminary assessment of the Goose Creek sites suggest that three of the sites are highly insensitive, two sites are likely insensitive and one site could potentially be sensitive. Site #4 has water chemistry properties that suggest it was likely a naturally acidic stream, and could potentially show an exceedance if its deposition is high and its runoff is low relative to nearby sites.
- Inter-annual changes in water chemistry properties:
    - It is difficult to interpret the changes from August 2012 to October 2013 due to the mixed effect of changing season and changing year. Therefore the assessment of inter-annual changes with respect to the expectations associated with decreasing S emissions was focussed on 2013-2014
    - The observed changes between 2013 and 2014 mostly agreed with the expectations associated with decreasing S emissions and therefore decreasing SO_4 deposition:
        - SO_4 concentration decreased in all EEM lakes
        - ANC increased in most of the sensitive EEM lakes
        - ANC exhibited less change in the less sensitive EEM lakes
        - pH increased in most of the sensitive EEM lakes
        - DOC remained similar or increased in most lakes

- In general, changes from 2013 to 2014 show apparent responses of the lakes to reductions in SO_2 emissions over the last several years (going back to 2008, and continuing to decline over the 2013-14 period – Figure 4), which implies that future reductions in emissions (if required) would also result in changes in the water chemistry of lakes within a few years. pH and ANC both predominantly show increases from 2012 to 2013 and 2013 to 2014.
- Changes in pH, ANC and SO_4 for 2013-2014 are shown in Table 1 and Figure 17.

Table 1. Changes in pH, ANC and SO_4 for EEM lakes, 2013 to 2014.

	pH	Gran ANC (ueq/L)	SO_4* (μeq/L)
From	2013	2013	2013
To	2014	2014	2014
Lak006	0.08	7.8	-3.4
Lak012	-0.02	16.8	-5.5
Lak022	0.11	10.5	-9.3
Lak023	0.11	11.7	-7.4
Lak028	0.12	17.8	-33.7
Lak042	-0.35	-8.5	-1.8
Lak044	0.09	-2.7	-1.6
Average (Sensitive Lakes)	**0.02**	**7.6**	**-8.9**
Lak007	0.14	-16.4	-35.8
Lak016	0.04	8.8	-8.7
LAK024			
Lak034	-0.12	-5.4	-21.1
Average (Less Sensitive Lakes)	**0.02**	**-4.3**	**-21.9**

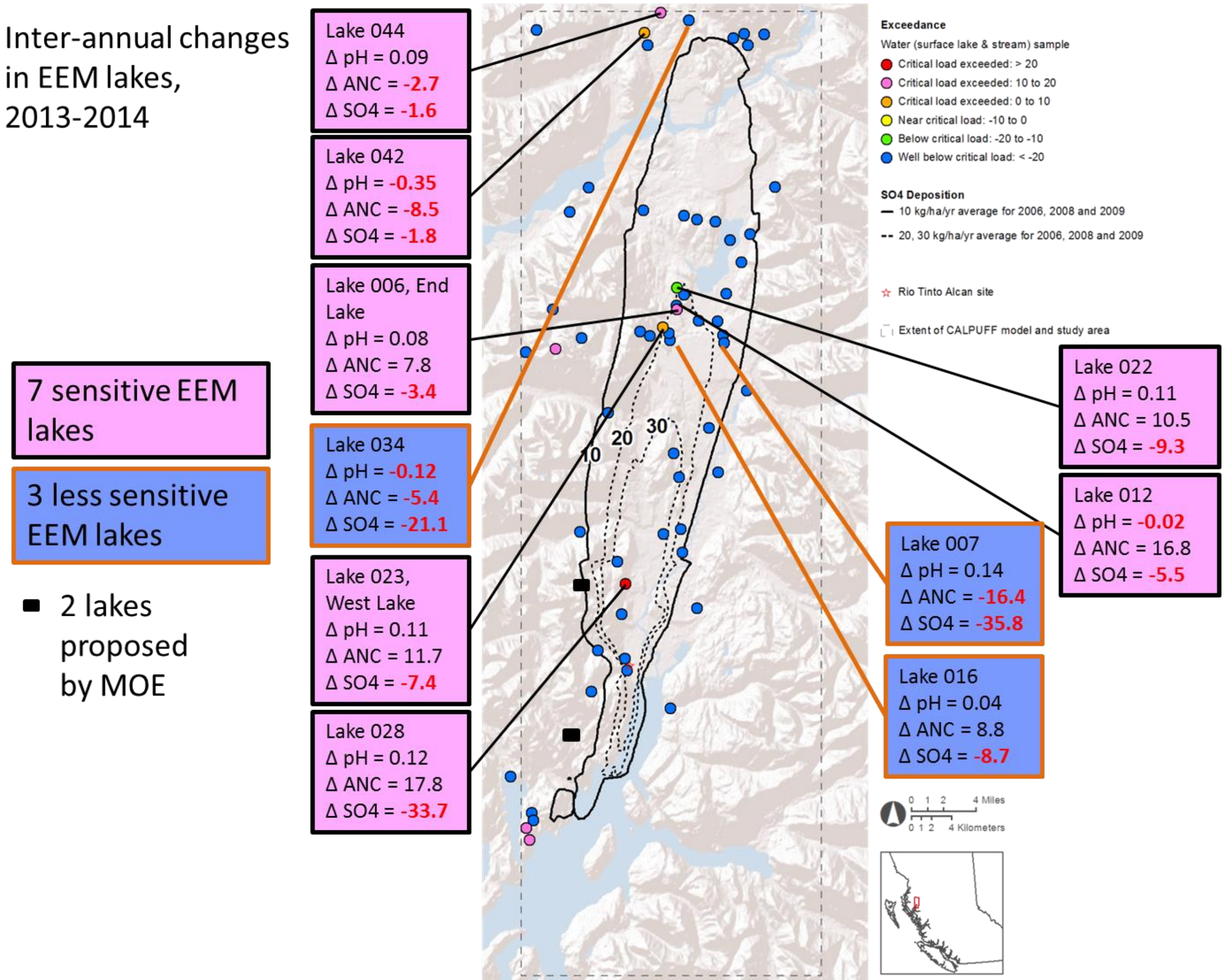


Figure 17. Map of EEM lakes, with inter-annual changes (2013-2014) in pH, ANC and SO_4. Underlying map shows all STAR sample sites and calculated critical loads. The 2 lakes proposed by MOE (MOE3, MOE6; black squares) are shown for additional context.

Next Steps for 2015

- Continue annual sampling of EEM lakes.
    - Include addition of Lakelse Lake (LAK024).
    - Do not include MOE3, MOE6, or Cecil Creek.
- Maintain continuous monitoring of pH at three accessible lakes during 2015, as done in 2014. Decide at the end of 2015 whether or not to maintain the continuous monitoring.
- Sample three accessible lakes four times during the fall sampling period for lab analyses of water chemistry parameters.
- Conduct power analyses to determine ability to correctly detect changes in pH, ANC and SO_4 given the high levels of variability (as observed in pH in particular).
- Calculate critical loads for Goose Creek sites.

Amphibians

Rio Tinto Alcan is having preliminary discussions with Ms. Jonquil Crosby (Researcher at the Center for Conservation Education and Sustainability at the Smithsonian Conservation Biology Institute). Possible actions include exploring ways in which stakeholders could get involved in an EEM effort on amphibians.

4 Cited Reports

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5 Cited EEM Technical Memos

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Technical Memo P02. Atmospheric Sulphur Dioxide – Passive Diffusive Sampler Network: Pilot Study (March 2015, Trent University)

Technical Memo V01. Vegetation Resource Inventory Metadata (December 2014, ESSA Technologies Ltd.)

Technical Memo V02. Sensitive Ecosystems (March 2015, ESSA Technologies Ltd.)

Technical Memo S01. Steady-State Soil Modelling – Revised Modelling and Mapping of Terrestrial Critical Loads (March 2015, Trent University)

Technical Memo S02. Steady-State Soil Modelling - Supplemental Soil Sampling (March 2015, Trent University)

Technical Memo W01. Freshwater Chemistry Analyses (March 2015, ESSA Technologies Ltd.)

Technical Memo W02. Continuous Monitoring of pH in West Lake, End Lake and Little End Lake in Fall, 2014. (January 2015, Limnotek Research and Development Inc.)