Rio Tinto Alcan ESSA

Sulphur Dioxide
Environmental Effects Monitoring
for the Kitimat Modernization Project

2013 and 2014 Annual Reports

Package of Cited Reports

Compiled for:

Rio Tinto Alcan
1 Smeltersite Road, P.O. Box 1800, Kitimat, BC, Canada V8C 2H2

Compiled by:

ESSA Technologies Ltd.
Suite 600 – 2695 Granville St., Vancouver, BC, Canada V6H 3H4

The following reports are cited in the **2013 and 2014 Annual Reports**. The first three can be accessed online through the web links provided. The last four reports in the list do not have web links, and are therefore provided on the following pages, in the same order as they are listed below.

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. Volume 2: Final Technical Report. Prepared for Rio Tinto Alcan, Kitimat, B.C. 450 pp. (20.6 MB PDF file) http://www.riotintobcoperations.com/our-commitment/environment/modernization-and-the-environment/

ESSA Technologies, J. Laurence, Limnotek, Risk Sciences International, Trent University, and Trinity Consultants. 2014a. Environmental Effects Monitoring Program for the Kitimat Modernization Project. Program Plan for 2013 to 2018. Prepared for Rio Tinto Alcan, Kitimat, B.C. 67 pp. (3.0 MB PDF file) http://www.riotintobcoperations.com/our-commitment/environment/modernization-and-the-environment/

ESSA Technologies, J. Laurence, Risk Sciences International, Trent University, and Trinity Consultants. 2014b. Kitimat Airshed Emissions Effects Assessment. Report prepared for BC Ministry of Environment, Smithers, BC. 205 pp. + appendices. (31.6 MB PDF file) http://www.bcairquality.ca/airsheds/kitimat-airshed-assessment.html

Laurence, J. 2014. Report of Vegetation Inspection, August, 2014, for Rio Tinto Alcan—British Columbia Operations. 69 pp.

Perrin, C.J and S. Bennett. 2015. Rio Tinto Alcan Kitimat Modernization Project: Environmental effects monitoring of lake water quality in 2014. Data report prepared by Limnotek Research and Development Inc. for Rio Tinto Alcan Ltd. 21pp.

Perrin, C.J., E. Parkinson, and S. Bennett. 2013. Rio Tinto Alcan Kitimat Modernization Project: Environmental effects monitoring of water and aquatic Biota in 2013. Report prepared by Limnotek Research and Development Inc. for Rio Tinto Alcan Ltd. 41 pp.

Stantec. 2015. 2014 Vegetation Inspection, Monitoring and Assessment Program. 2014 Annual Report. Prepared for Rio Tinto Alcan Ltd. 17 pp.

Rio Tinto Alcan—British Columbia Operations
Report of Vegetation Inspection
August, 2014

John Laurence, Ph.D.
Consulting Plant Pathologist

SUMMARY OF FINDINGS

1. The condition of vegetation in the vicinity of the Rio Tinto Alcan (RTA-BCOPS) smelter at Kitimat, BC was about the same as that observed in 2012 although minor injury due to Fg was observed at more sites.

2. Injury to sensitive vegetation was confined to an area from about Hospital Beach to the Service Centre. Minor injury occurred on only on the most sensitive species. Injury was not substantial at any location other than the Administration Building. At other sites where injury was noted, it was at a level that would not be evident other than to a trained eye.

3. No injury to vegetation was observed at sites north of the Service Centre, south of Hospital Beach, on the east side of Minette Bay, in Kitamaat Village, or at the remote sites near Terrace.

4. In general, there were no remarkable insect outbreaks, disease epidemics, or other stress factors affecting vegetation. There is an infestation of scale insect on western hemlock in the immediate vicinity of RTA.

5. No unusual conditions were observed on ornamental vegetation in Kitimat. *Gladiolus* was observed at close range at several locations in town—none exhibited tipburn associated with exposure to fluoride.

6. I did not visit the sites accessed by helicopter (44A, 78, 81C, and 81B) due to time constraints in 2014. Photos of vegetation were taken by Nicki Veikle and provided to me. Symptoms on plants were caused by insects or growing season condition (time of year, drought conditions, etc.) and were similar to those observed at other locations on the inspection.

7. I did not visit sites 87, 88, 89, and 89A in 2014 due to logistical constraints associated with construction on the Bish Creek FS Road. Access was arranged for sampling. Nicki Veikle provided photos that did not show any unusual symptoms on vegetation.

Purpose and objectives of the inspection: Vegetation in the vicinity of the Rio Tinto Alcan Smelter at Kitimat, BC (RTA-BCOPS) was sampled and inspected during August 17-19, 2014. Western hemlock samples were collected for foliar fluoride analysis using the protocol developed during the review of the monitoring and inspection program in the winter of 2010. A visual inspection to assess the condition and health of vegetation, and to document the occurrence of injury caused by gaseous fluoride (Fg) or other significant factors, was conducted concomitantly.

The inspection was conducted by John Laurence, Ph.D., consulting plant pathologist. Nicki Veikle and Nicole Glover of Stantec, Ltd conducted sampling of western hemlock foliage.

Methodology: Inspection occurred along transects to the north, south, northeast, and west of RTA-BCOPS and along a north-south transect on the east side of Minette Bay. Sampling occurred and was observed on the same transects. A helicopter was used to access four sites to the west and northwest of RTA-BCOPS due to the lack of road or trail access. Inspection was not conducted at those sites due to time limitations in 2014. Inspection was also not conducted at sites 87, 88, 89, and 89A due to construction closure of the Bish Creek FSR road. Access was made available later in the week and sampling of western hemlock occurred. Ms. Veikle provided photos of vegetation at those locations. Inspections were also conducted at several locations that have historically been visited, but are not co-located with sampling sites. Those include neighborhoods in Kitimat and Kitamaat Village, the Service Centre, Kitimat LNG (formerly Eurocan), and East-side Overlook.

Samples of current year hemlock foliage were collected, bagged, and, at the end of the day, refrigerated until processing. After the end of the collection, processing of the samples began. Rio Tinto Alcan will analyze samples for F and S.

Results of the vegetation inspection:

General condition of vegetation in the area

The condition of vegetation with reference to Fg injury was about the same as that observed in 2012 and somewhat better than that observed in 2010, 2009, or 2008. This is likely due to a combination of reduced F emissions associated with the closure of pot rooms as part of the modernization. Injury was confined to the most sensitive vegetation, but was observed at a number of sites. However, other than the Administration Building, injury was generally slight. Thus, even though injury occurred at more sites, it was not significant in severity.

No unusual disease or insect occurrences were observed with the exception of scale insect infestation on western hemlock in the vicinity of RTA. The infestation was confined to the area south of the Service Centre and north of Site 20. On some trees it was of moderate intensity in the lower branches. The extent of the infestation should be analyzed in 2015 during the sampling to determine if it is increasing.

No unusual signs or symptoms were observed at the remote sites or on the east side of Minette Bay.

No symptoms of injury due to sulphur dioxide were observed on vegetation.

An appendix details observations at each site.

Specific observations related to the effects of Fg on vegetation: Using the F-injury Index developed during the program review, I found that values in excess of 10 (out of 100) occurred only at the Administration Building and at Site 44. Minor injury, e.g. limited tip necrosis on Scouler's willow and leaf notching, that would rate <5 out of 100 on the frequency-extent rating system occurred at sites 1, 20, 39, 43B, 44, and perhaps at site 79. The symptoms at site 79 occurred on only a few leaves of a single shrub. The pattern of the injury suggests that perhaps there was a single fumigation sometime during the growing season. No injury was observed in Kitimat, on the east side of Minette Bay, including Kitamaat Village, or at the helicopter-accessed sites.

Significant stresses to vegetation (other than Fg effects) in the area: With the exception of scale insects on western hemlock noted above, no significant stress factors affecting vegetation were observed. Conditions at the time of the inspection were very dry and Ms. Veikle reported that the summer had been pleasant and dry. The usual occurrence of insects and disease were observed, but there were no remarkable outbreaks or epidemics other than a limited occurrence of scale insects.

Interpretation of results of the inspection

1. The condition of vegetation in the vicinity of the Rio Tinto Alcan (RTA-BCOPS) smelter at Kitimat, BC was about the same as that observed in 2012 although minor injury due to Fg was observed at more sites.

2. Injury to sensitive vegetation was confined to an area from about Hospital Beach to the Service Centre. Injury was not substantial at any location other than the Administration Building. At other sites where injury was noted, it was at a level that would not be evident other than to a trained eye. Minor injury occurred on only on the most sensitive species.

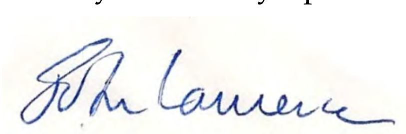
3. No injury to vegetation was observed at sites north of the Service Centre, south of Hospital Beach, on the east side of Minette Bay, in Kitamaat Village, or at the remote sites near Terrace.

4. In general, there were no remarkable insect outbreaks, disease epidemics, or other stress factors affecting vegetation. There is an infestation of scale insect on western hemlock in the immediate vicinity of RTA.

5. No unusual conditions were observed on ornamental vegetation in Kitimat. *Gladiolus* was observed at close range at several locations in town—none exhibited tipburn associated with exposure to fluoride.

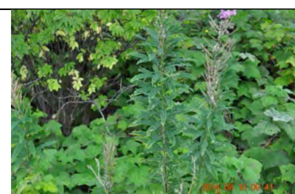
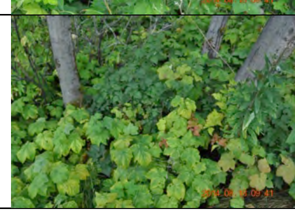
6. I did not visit the sites accessed by helicopter (44A, 78, 81C, and 81B) due to time constraints in 2014. Photos of vegetation were taken by Nicki Veikle and provided to me. Symptoms on plants were caused by insects or growing season condition (time of year, drought conditions, etc.) and were similar to those observed at other locations on the inspection.

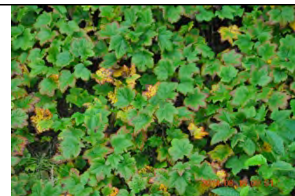
7. I did not visit sites 87, 88, 89, and 89A in 2014 due to logistical constraints associated with construction on the Bish Creek FS Road. Access was arranged for sampling. Nicki Veikle provided photos that did not show any unusual symptoms on vegetation.



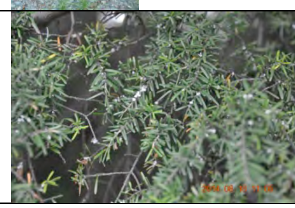
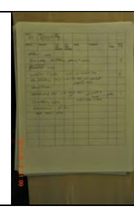
John Laurence, Ph.D.
Portland, Oregon, USA
September 13, 2014

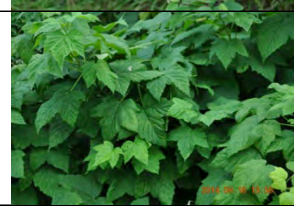
Appendix
Field Observations, Photographs, and F Concentration

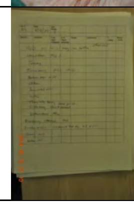
Site: 1	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
	
Western Hemlock—no unusual symptoms	
Rhododendron—no unusual symptoms	
Alberta spruce—small necrotic part due to exposed conditions	
Spirea—No unusual symptoms	
Alder trees—No unusual symptoms	
Mountain ash—No unusual symptoms	
Fireweed—Chlorosis on lower leaves	
Thimbleberry Interveinal chlorosis and necrosis in exposed site—normal in shade	
Elderberry—in shade no unusual symptoms—in sun chlorosis due to exposure	
Salmonberry—no unusual symptoms	
Sitka spruce—No unusual symptoms	

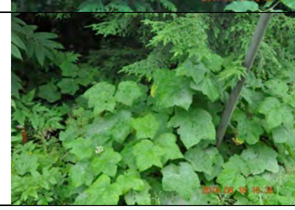
Western red cedar—No unusual symptoms	
Cottonwood—insect feeding and fungal leafspot	
Mountain ash--No unusual symptoms	
Alder—slight brown stripe	
Gooseberry—fungal leafspot and marginal anthrocyanosis, perhaps due to F	
	

Site: 20	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Thimbleberry—some anthrocyanosis on roadside plants	
Western hemlock—scale insect infestation	
Scouler willow—marginal necrosis likely caused by HF 5% leaf area on 50% of leaves=2.5	
Alder— No unusual symptoms	
Sitka spruce—No unusual symptoms	
Western hemlock—No unusual symptoms	
Mountain Ash—No unusual symptoms	
Salmonberry—occasional insect feeding and marginal necrosis but not of entire margin	
Fireweed—No unusual symptoms	
Western red cedar—No unusual symptoms	
	

Site: 37	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Fireweed—bottom leaves starting to senesce	
Western hemlock—scale insect infestation	
Alder—No unusual symptoms	
Thimbleberry—interveinal necrosis on plants growing on waste soils	
Cottonwood—severe fungal leafspot and insect feeding	
Hawkweed—No unusual symptoms	
Hardhack—No unusual symptoms	
Twinberry—No unusual symptoms	
Saskatoon—slight insect feeding	
Mountain ash—No unusual symptoms	
	

Site: 39	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site Photo	
Fireweed—No unusual symptoms	
Poplar—No unusual symptoms	
Elderberry—No unusual symptoms	
Red osier dogwood—occasional leaf with marginal necrosis or anthrocyanosis, others normal	
Thimbleberry—some general chlorosis	
Western hemlock—No unusual symptoms	
Salmonberry—slight insect feeding	
Blueberry—moderate insect feeding and fungal leafspot	
Scouler willow—occasional tip necrosis <1% of leaf on < 5% of leaves=	
Cherry—No unusual symptoms	
Balsam poplar—No unusual symptoms	
Twinberry—fungal leafspot and slight insect feeding	
Hardhack—slight fungal leafspot	
Tansy—No unusual symptoms	
Alder—No unusual symptoms	

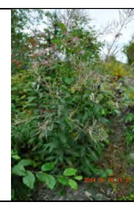
St. John's Wort—tip necrosis likely due to HF. Rating <1	
	

Site: 42	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
	
Western hemlock—No unusual symptoms	
Western red cedar—No unusual symptoms	
Mountain ash—fungal leafspot on some trees	
Thimbleberry—No unusual symptoms	
Fireweed—No unusual symptoms	
Sitka spruce—No unusual symptoms	
Alder—No unusual symptoms some brown stripe on a few plants	
Scouler's willow—No unusual symptoms	
Vaccinium sp.—No unusual symptoms	
Salmonberry—No unusual symptoms	
Hardhack—No unusual symptoms some with marginal chlorosis but minor	
Tansy—No unusual symptoms	

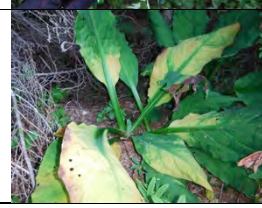
Elderberry—No unusual symptoms	
	

Site: 43A	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
	
Site photo	
Bracken fern—No unusual symptoms	
Thimbleberry—No unusual symptoms	
Salmonberry—No unusual symptoms	
Elderberry—No unusual symptoms	
Western hemlock—No unusual symptoms	
Mountain ash—No unusual symptoms	
False huckleberry—No unusual symptoms	
Blueberry—No unusual symptoms	
Devil's club—No unusual symptoms	
	

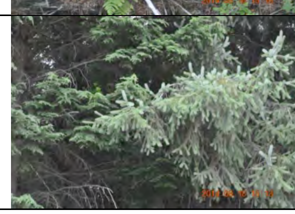
Site: 43B	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Alder—No unusual symptoms	
Fireweed—No unusual symptoms	
Salmonberry—No unusual symptoms	
Thimbleberry—Interveinal chlorosis	
Bunchberry—No unusual symptoms	
Western red cedar—No unusual symptoms	
Red osier dogwood—No unusual symptoms	
Scouler's willow—tip necrosis on less than 5% of leaf area on <5% of leaves	
Red huckleberry—No unusual symptoms	
Blueberry—fungal leafspot	
Western hemlock—No unusual symptoms	
Hawkweed—No unusual symptoms	
	

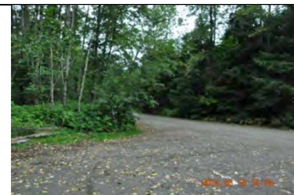
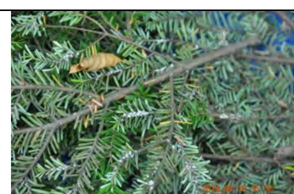
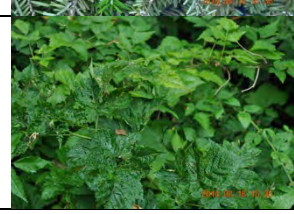
Site: 44	Date: 18/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Alder—No unusual symptoms	
Lodgepole pine—F-induced tip necrosis up to 50% of needle on less than 50% of tree. 2014 needles only. Rating <25	
Thimbleberry—No unusual symptoms	
Salmonberry—No unusual symptoms	
Goat's beard—No unusual symptoms	
Fireweed—No unusual symptoms	
Western red cedar—No unusual symptoms	
Balsam poplar—No unusual symptoms	
Mountain ash—fungal leafspot on some trees, most have no unusual symptoms	
Bracken fern—No unusual symptoms	
Mosses present on rocks	

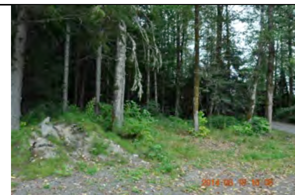
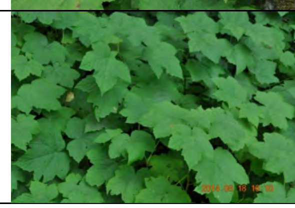
	

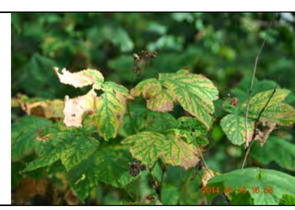
Site: 44A	Date: Not visited in 2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Photos provided by N. Veikle, Stantec, Ltd.	
Site photo	No Site Photo
Labrador tea—fungal leafspot and insect feeding	
Skunk cabbage—senescing conditions perhaps due to water shortage	

Site: 46	Date: 18/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site Photo	
Devil's club—No unusual symptoms	
Salmonberry—No unusual symptoms	
Elderberry—No unusual symptoms	
Blueberry—No unusual symptoms	
Western red cedar—No unusual symptoms	
Western hemlock—No unusual symptoms	
Sitka spruce—No unusual symptoms	
Thimbleberry—No unusual symptoms	
Alder—No unusual symptoms	
Bracken fern—No unusual symptoms	
	

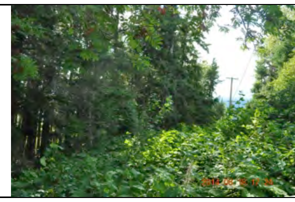
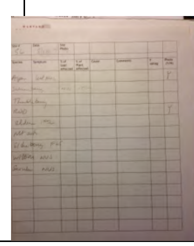
Site: 47B	Date: 18/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	No Site Photo
Alder—No unusual symptoms	
Thimbleberry—No unusual symptoms	
Red osier dogwood—No unusual symptoms	
Fireweed—No unusual symptoms	
Western hemlock—No unusual symptoms	
Elderberry—common chlorosis	
Hardhack—No unusual symptoms	
Balsam poplar—some fungal leafspot	
Bracken fern—No unusual symptoms	
Sitka spruce—No unusual symptoms	
Gooseberry—chlorotic growing on dry waste site	
	

Site: 52	Date: 18/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site Photo	
Sitka spruce—No unusual symptoms	
Thimbleberry—an occasional chlorotic leaf	
Alder tree—No unusual symptoms	
Goat's beard—No unusual symptoms	
Elderberry—chlorosis and fungal leafspot	
Saskatoon—No unusual symptoms	
Maple—mite infestation, not severe or unusual	
Western hemlock—scale insect infestation	
Salmonberry—slight insect feeding	
Red osier dogwood—slight insect feeding	
Douglas maple—slight insect feeding	

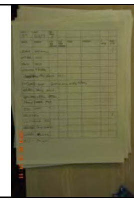
Site: 54	Date: 18/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Devil's club—minor fungal leafspot	
Thimbleberry—slight fungal leafspot	
Western hemlock—No unusual symptoms	
Douglas maple—No unusual symptoms	
Goat's beard—No unusual symptoms	
Balsam poplar—slight insect feeding and fungal leafspot	
Mint—No unusual symptoms	
Alder—No unusual symptoms	
Fireweed—some senescence of lower leaves and some tip necrosis	
Red osier dogwood—slight insect feeding	
	

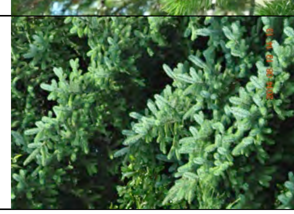
Site: 55	Date: 18/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Norway maple—mostly nus although some signs of moisture stress and some powdery mildew	
Sitka spruce—No unusual symptoms 5 or more years of needles	
Alder tree—slight insect feeding	
Mountain ash—No unusual symptoms	
Western red cedar—No unusual symptoms	
Elderberry—No unusual symptoms	
Salmonberry—No unusual symptoms	
Red osier dogwood—No unusual symptoms	
Thimbleberry—chlorotic and some interveinal necrosis—water status as other plants are wilting	
Saskatoon—No unusual symptoms	
Sitka spruce—No unusual symptoms	
Hawkweed—wilted from lack of moisture	

Douglas-fir—No unusual symptoms	
	

Site: 56	Date: 18/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Thimbleberry—No unusual symptoms	
Scouler willow—No unusual symptoms	
Alder—slight insect feeding.	
Elderberry—No unusual symptoms	
Western hemlock—No unusual symptoms	
Salmonberry—slight insect feeding	
Aspen—leaf miner	
Red osier dogwood—No unusual symptoms	
Mountain ash—No unusual symptoms	
Elderberry—fungal leafspot	
	

Site: 57	Date: 18/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Alder—slight insect feeding	
Mountain ash—No unusual symptoms	
Western hemlock—No unusual symptoms	
Red osier dogwood—No unusual symptoms	
Sitka spruce—No unusual symptoms up to 8 years of needle retention	
Hardhack—No unusual symptoms	
Lodgepole pine—No unusual symptoms	
Birch—some leaf miners, slight to moderate	
Red huckleberry—No unusual symptoms, some with fungal leafspot	
Elderberry—No unusual symptoms	
Hardhack—No unusual symptoms	
Pacific silver fir—No unusual symptoms	
Lodgepole pine—No unusual symptoms	

Mosses and club moss—No unusual symptoms	
Ornamentals in excellent condition	
	

Site: 68	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Thimbleberry—No unusual symptoms	
Red osier dogwood—No unusual symptoms	
Balsam poplar—fungal leafspot and slight insect feeding	
Hardhack—No unusual symptoms	
Scouler's willow—No unusual symptoms	
Aspen—No unusual symptoms	
Fireweed—No unusual symptoms	
Goat's beard—No unusual symptoms	
Lodgepole pine—No unusual symptoms	
Sitka spruce—No unusual symptoms	
Elderberry—No unusual symptoms	
	

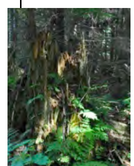
Site: 69	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Alder—No unusual symptoms	
Fireweed—No unusual symptoms	
Scouler's willow—No unusual symptoms	
Thimbleberry—No unusual symptoms, leaves in bright sun chlorotic	
Goat's beard—necrosis on leaves growing on plants in ditch	
Red osier dogwood—No unusual symptoms	
Tansy—No unusual symptoms	
Hawkweed—No unusual symptoms	
Bracken fern—No unusual symptoms	
Salmonberry—No unusual symptoms	
	

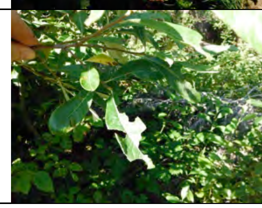
Site: 70	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Thimbleberry—No unusual symptoms on most. Some with chlorosis and necrosis due to fungal leafspot	
Western red cedar—No unusual symptoms	
Elderberry—No unusual symptoms	
Sitka spruce—No unusual symptoms	
Alder—No unusual symptoms	
Bracken fern—No unusual symptoms	
Red osier dogwood—No unusual symptoms	
Devil's club—No unusual symptoms	
	

Site: 78A	Date: Not Visited in 2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Photos provided by N. Veikle, Stantec, Ltd.	
Site photo	
Lodgepole pine—tip necrosis evident in some pictures however pattern is not characteristic of pollutant injury	

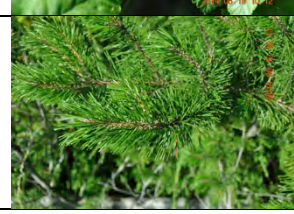
Site: 79	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Balsam poplar—No unusual symptoms	
Alder—slight insect feeding, some brown stripe	
Western hemlock—No unusual symptoms	
Salmonberry—No unusual symptoms	
Scouler's willow—necrotic tips on leaves--scattered	
Thimbleberry—No unusual symptoms	
Fireweed—chlorotic leaf tips	
Goat's beard—some insect feeding	
Devil's club—No unusual symptoms, some plants with insect feeding	
Elderberry—No unusual symptoms, some leaves chlorotic	
Bracken fern—No unusual symptoms	
Skunk cabbage—No unusual symptoms	
Alder—No unusual symptoms	
Western red cedar—No unusual symptoms	

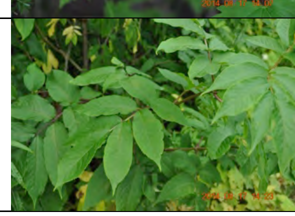
Site: 80	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Thimbleberry—No unusual symptoms	
Elderberry—some chlorotic bushes in bright sun—bushes in shade normal	
Western hemlock—No unusual symptoms	
Salmonberry—No unusual symptoms	
Alder—No unusual symptoms	
Club moss—No unusual symptoms	
Pacific silver fir—No unusual symptoms	
Blueberry—slight insect feeding	
Bunchberry—No unusual symptoms, some slight anthrocyanosis on occasional leaves	
Deer fern—No unusual symptoms	
Bracken fern—No unusual symptoms	
Mountain ash—No unusual symptoms	
Hardhack—No unusual symptoms	
	

Site: 81B	Date: Not visited in 2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Photos provided by N. Veikle, Stantec, Ltd.	
Site photo	
Devil's club—insect feeding moderate to severe	
Scouler's willow—moderate insect feeding and leafspot	

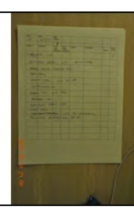
Site: 81C	Date: Not visited in 2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Photos provided by N. Veikle, Stantec, Ltd.	
Site photo	
Insect feeding on a variety of species	

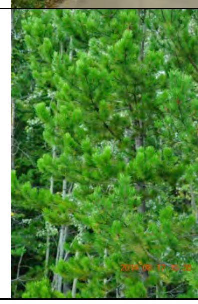
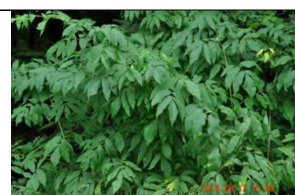
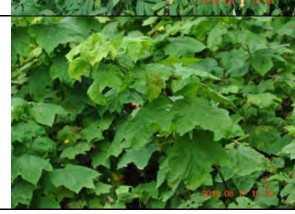
Site: 82	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Western red cedar—No unusual symptoms	
Sitka spruce—No unusual symptoms	
Salmonberry—No unusual symptoms	
Huckleberry—No unusual symptoms	
Scouler's willow—some tip and marginal chlorosis due to insects	
—No unusual symptoms	
Bitter cherry—slight insect feeding	
Hardhack—No unusual symptoms	
Alder—slight insect feeding	
Lodgepole pine—No unusual symptoms one tree with insect damage to shoots	

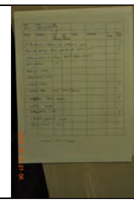
		

Site: 84A	Date: 17/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Western hemlock—No unusual symptoms	
Thimbleberry—No unusual symptoms	
Fireweed—No unusual symptoms	
Bracken fern—No unusual symptoms	
Hardhack—No unusual symptoms	
Red osier dogwood—No unusual symptoms	
Elderberry—No unusual symptoms	
Balsam poplar—slight fungal leafspot	
Alder—slight insect feeding	
Sitka spruce—No unusual symptoms	
Western red cedar—No unusual symptoms	
Blueberry—slight insect feeding and fungal leafspot	
Balsam poplar—minor leaf miner	
Douglas maple—some chlorosis but others nus	
Elderberry—No unusual symptoms	

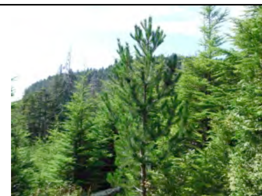
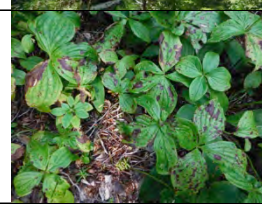
Site: 85	Date: 17/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Lodgepole pine—No unusual symptoms	
Balsam poplar—No unusual symptoms	
Western hemlock—No unusual symptoms	
Red huckleberry—No unusual symptoms	
Alder—some brown stripe	
Bracken fern—No unusual symptoms	
Aspen—No unusual symptoms, some minor fungal leafspot	
Mountain ash—fungal leafspot and slight insect feeding	
Fireweed—slight insect feeding	
	

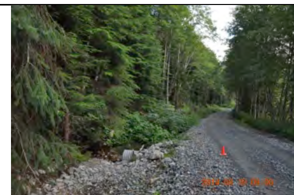
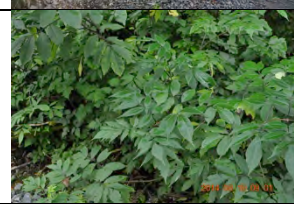
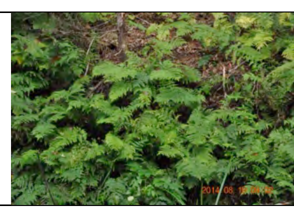
Site: 86	Date: 17/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Lodgepole pine—No unusual symptoms	
Alder—slight insect feeding	
Hardhack—No unusual symptoms	
Fireweed—No unusual symptoms	
Elderberry—some bushes with chlorosis, otherwise nus	
Thimbleberry—some plants with minor chlorosis	
Western hemlock—No unusual symptoms	
Sitka spruce—No unusual symptoms	
Salmonberry—plants had been mowed on the roadside	
Red osier dogwood—No unusual	

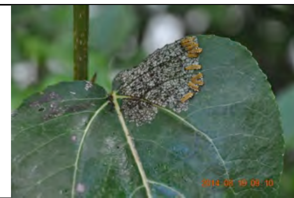
symptoms	
Aspen—leaf miner	
Western red cedar—No unusual symptoms	
	

Site: 87	Date: Not visited in 2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Photos provided by N. Veikle, Stantec, Ltd.	
Site photo	
Devil's club—insect feeding moderate to severe	

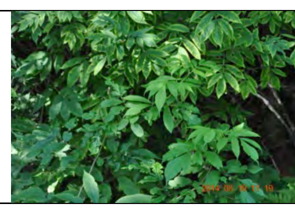
Site: 88	Date: Not visited in 2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Photos provided by N. Veikle, Stantec, Ltd.	
Moderate insect feeding on some species	

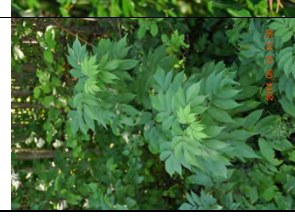
Site: 89A	Date: Not visited in 2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Photos provided by N. Veikle, Stantec, Ltd.	
Site photo	
Lodgepole pine—No unusual symptoms	
Bunchberry—fungal leafspot	

Site: 90	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Elderberry—No unusual symptoms some fungal leafspot	
Red osier dogwood—slight insect feeding	
Sitka spruce—No unusual symptoms	
Devil's club—No unusual symptoms	
Western hemlock—No unusual symptoms	
Alder—slight insect feeding	
Bracken fern—No unusual symptoms	
Goat's beard—slight insect feeding	
Thimbleberry—No unusual symptoms to some slight insect feeding	
Fireweed—insect feeding	

Balsam poplar—moderate insect feeding by skeletonizers	
Scouler’s willow—No unusual symptoms	
	

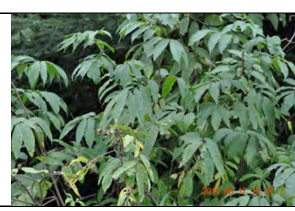
Site: 91A	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Western hemlock—No unusual symptoms	
Alder—slight insect feeding	
Goats beard—insect feeding and some severe fungal leafspots	
Salmonberry—slight insect feeding	
Elderberry—slight insect feeding and fungal leafspot Some marginal chlorosis but not widespread	
Thimbleberry—insect feeding and fungal leafspot	
Red osier dogwood—fungal leafspot	
Mountain ash—No unusual symptoms	
Bracken—No unusual symptoms	
Alder tree—insect feeding	
Devil's club—No unusual symptoms	

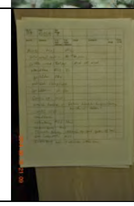
Site: 92	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Alder—No unusual symptoms	
Sitka spruce—No unusual symptoms	
Western hemlock—No unusual symptoms	
Western red cedar—No unusual symptoms	
Thimbleberry—No unusual symptoms	
Hardhack—No unusual symptoms	
Salmonberry—slight insect feeding	
Bracken fern—No unusual symptoms	
Blueberry—slight insect feeding	
Mountain ash—slight insect feeding	
Elderberry—some chlorotic bushes in exposed areas	
Fireweed—No unusual symptoms	
	

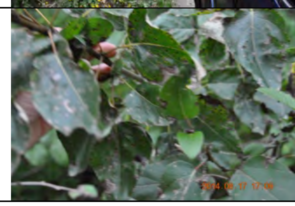
Site: 95	Date: 19/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Alder—slight insect feeding and fungal leafspot	
Sitka spruce—No unusual symptoms	
Western hemlock—No unusual symptoms	
Western red cedar—No unusual symptoms	
Thimbleberry—plants in exposed area chlorotic—otherwise fine	
Red osier dogwood—No unusual symptoms	
Salmonberry—some insect feeding and fungal leafspot	
Scouler's willow—No unusual symptoms, some insect feeding	
Balsam poplar—No unusual symptoms	
Elderberry—No unusual symptoms	
Saskatoon—slight insect feeding	
Goat's beard—No unusual symptoms	

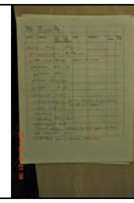
	

Site: 97	Date: 17/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock:	
Observation	Photograph
Site photo	
Hardhack—slight insect feeding	
Alder—slight insect feeding	
Western hemlock—No unusual symptoms	
Sitka spruce—No unusual symptoms	
Fireweed—No unusual symptoms on most, some with minor anthrocyanosis	
Thimbleberry—some plants with chlorosis on roadside—most No unusual symptoms	
Yarrow—No unusual symptoms	
Western red cedar—No unusual symptoms	
Elderberry—No unusual symptoms	
Lodgepole pine—No unusual symptoms	
	

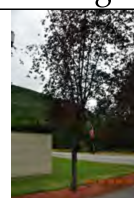
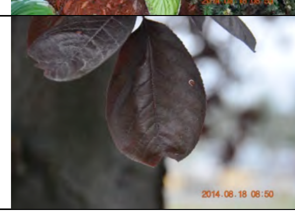
Site: 97	Date: 17/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Balsam poplar—moderate fungal leafspot and slight insect feeding	
Alder—slight insect feeding	
Mountain ash—No unusual symptoms	
Fireweed—some insect feeding	
Red osier dogwood—insect feeding	
Hardhack—slight fungal leafspot and dust deposits from road	
Western hemlock—No unusual symptoms	
Thimbleberry—No unusual symptoms	
Alder tree—slight insect feeding	
Elderberry—some fungal leafspot	

Salmonberry—slight insect feeding	
Spruce—No unusual symptoms	
	

Site: 98A	Date: 17/8/2014
F concentration in hemlock: ppm	
S concentration in hemlock: %	
Observation	Photograph
Site photo	
Balsam poplar—moderate fungal leafspot and insect feeding	
Alder—slight insect feeding	
Mountain ash—No unusual symptoms	
Fireweed—No unusual symptoms some with chlorosis at the bottom of the plant from senescence	
Red osier dogwood—No unusual symptoms some insect feeding	
Hardhack—slight fungal leafspot	
Western hemlock—No unusual symptoms but some needle drop on shaded branches	
Salmonberry—No unusual symptoms	
Blueberry—moderate fungal leafspot	
Western red cedar—No unusual symptoms	
Thimbleberry—No unusual symptoms	
Lodgepole pine—No unusual symptoms	

Elderberry—nus, some individuals chlorotic	
	

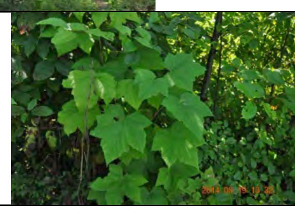
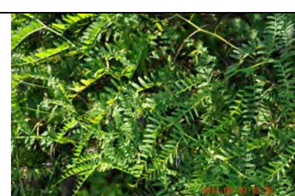
Inspection Sites (No foliage collection)

Site: Administration Building	Date: 18/8/2014
54° 0'34.88"N 128°42'21.60"W	
F concentration in hemlock: NA	
S concentration in hemlock: NA	
Observation	Photograph
Site photo	
Cherry—F tip necrosis and notching <5 on 30%=1.5	
Mugo pine—F tip necrosis 25 on 70=17.5	
Hosta—marginal necrosis 20 on 100=20	
Purple plum—leaf notching and stem cankers on trees. Cankered trees should be removed	
Spirea—anthrocyanosis	
Contorted alder—No unusual symptoms	
Yew—No unusual symptoms	
Sitka spruce—No unusual symptoms	

Western red cedar—No unusual symptoms—no flagging	
White pine—No unusual symptoms	
Austrian pine—No unusual symptoms	
Saskatoon—marginal chlorosis	
Alpine currant—some tip necrosis, bushes pruned way back	
Potentilla—No unusual symptoms	
Red osier dogwood—marginal necrosis and leaf spotting less than 5 on 5=0.25	
Mountain ash—No unusual symptoms	
Cottonwood—slight insect feeding and fungal leafspot	
Alder—sooty mold	

Site: Anderson Creek Road Crossing	Date: Not visited due to construction
54° 1'9.62"N 128°42'33.85"W	
F concentration in hemlock: NA	
S concentration in hemlock: NA	
Observation	Photograph
Site not visited due to construction of KMP	

Site: Kitimat LNG	Date: 18/8/2014
54° 2'33.22"N 128°41'43.92"W	
F concentration in hemlock: NA	
S concentration in hemlock: NA	
Observation	Photograph
Site photo	No photo
Hydrangea—No unusual symptoms	
Mugo pine—No unusual symptoms	
Plantings are not maintained.	

Site: Kitamaat Village	Date:
53°57'57.86"N 128°39'8.68"W	
F concentration in hemlock: NA	
S concentration in hemlock: NA	
Observation	Photograph
Site photo	
Thimbleberry—No unusual symptoms	
Fireweed—No unusual symptoms	
Red osier dogwood—fungal leafspot	
Western hemlock—No unusual symptoms	
Bracken fern—No unusual symptoms	
Rose—No unusual symptoms	
Western red cedar—No unusual symptoms	
Blueberry—slight insect feeding	
Bunchberry—slight insect feeding	
Tansy—No unusual symptoms	
Vetch—No unusual symptoms	
	

Site: Kitimat Town Site	Date: 18/8/2014
54° 3'14.50"N 128°38'14.50"W	
F concentration in hemlock: NA	
S concentration in hemlock: NA	
Observation	Photograph
Ornamental vegetation was in excellent condition for the time of year. No injury was observed on *Gladiolus* in town.	No photos taken

Site: Eastside Overlook	Date: 19/8/2014
53°59'55.55"N 128°39'0.62"W	
F concentration in hemlock: NA	
S concentration in hemlock: NA	
Observation	Photograph
Site photo	None taken
Thimbleberry—No unusual symptoms	
Fireweed—No unusual symptoms	
Red osier dogwood—No unusual symptoms	
Lodgepole pine—No unusual symptoms	

Site: Service Centre	Date: 18/8/2014
54° 3'20.01"N 128°41'18.55"W	
F concentration in hemlock: NA	
S concentration in hemlock: NA	
Observation	Photograph
Mugo pines at Service Centre Chevron removed	

Site: Top of Sand Hill	Date: Not visited in 2014
54° 3'4.14"N 128°42'34.08"W	
F concentration in hemlock: NA	
S concentration in hemlock: NA	
Observation	Photograph
Not visited in 2014	

Rio Tinto Alcan Kitimat Modernization Project: Environmental Effects Monitoring of Lake Water Quality in 2014

DRAFT DATA REPORT

January 23, 2015

LIMNOTEK

Rio Tinto Alcan Kitimat Modernization Project: Environmental Effects Monitoring of Lake Water Quality in 2014

DRAFT DATA REPORT

Submitted to

Rio Tinto Alcan Ltd.
Kitimat, B.C.

Prepared by

C.J. Perrin, MSc., RPBio and S. Bennett, MSc., RPBio

January 23, 2015

Citation: Perrin, C.J and S. Bennett 2015. Rio Tinto Alcan Kitimat Modernization Project: Environmental effects monitoring of lake water quality in 2014. Data report prepared by Limnotek Research and Development Inc. for Rio Tinto Alcan Ltd. 20p.

Cover photo: Aerial view of the End Lakes in the Kitimat River valley, October 2, 2014. Photo credit, Chris Perrin.

EXECUTIVE SUMMARY

Measurements of water chemistry among selected lakes between Kitimat and Terrace occurred in October 2014 as part of the ongoing environmental effects monitoring plan (EEMP) for the Kitimat Modernization Project by Rio Tinto Alcan (RTA). The EEMP was developed in consultation with representatives of RTA, the Haisla First Nation, and the BC Ministry of Environment. There were three objectives in 2014 as follows: measure a suite of chemical properties in seven acid sensitive and three acid insensitive lakes for later recalculation of critical load of acidity, measure the same chemical properties in two additional lakes as requested by the BC Ministry of Environment, and provide results from quality assurance testing of chemical measurements that were made in 2014.

All samples for chemical analysis were successfully collected on October 2, 2014, with follow-up lab work and data compilation completed in October through December, 2014. The data were compiled with similar data from 2012 and 2013 to provide an up-to-date compilation of data for all EEMP years. The 2014 data will be used in 2015 for recalculation of critical load of acidity (CL) among lakes to examine variability among estimates of CL. Quality assurance testing showed high precision and accuracy in the 2014 field and lab procedures. Further quality assurance testing of pH measurement was done in 2014 because of the importance of pH in the ongoing EEMP. Testing of four different pH meters used in the field and lab showed no instrument effect on pH within ranges of precision reported by instrument manufacturers and laboratories. This finding shows that within the specifications of pH meters, any of the instruments or labs can be used for routine pH measurement in future years. We noted that repeatability of measurements from pH meters or pH measurement from labs is typically ±0.2 to 0.3 pH units. This range is the same amount of change in pH in one or more lakes that would trigger more intensive monitoring and decisions about mitigation within the EEMP. It may be difficult to resolve this amount of change in pH (0.3 pH units) when instrument precision is the same amount. This interaction between the amount of critical change in pH that triggers management actions and the precision of instruments used to measure pH needs to be further investigated to remove uncertainty in criteria for change in monitoring or mitigation activities within the EEMP.

ACKNOWLEDGEMENTS

Several people from different companies contributed to the collection of data that are described in this report. Safety planning and preparations with the field crew were managed by James Mathers of LaPointe Engineering Ltd. The authors thank Shawn Zettler (Rio Tinto Alcan), James Mathers (LaPointe Engineering) and Donna Gasper (Rio Tinto Alcan) for expediting preparation of the Permit to Work as required by Rio Tinto Alcan before field activities could begin. Mapping and GIS support was provided by Simon Casley and Nick Ochoski. The authors were assisted in the field by Dani Ramos and Fred Seiler. Helicopter services were provided by Canadian Helicopters Ltd. from their base in Terrace. Chris Hampton was the pilot of the twinstar helicopter that was used for all the lake water sampling. Water lab analytical services were provided by Kevin Adkinson and Dr. Julian Aherne of Trent University, and ALS Environmental in Burnaby, B.C. The account manager at ALS was Courtney Duncan. Safety check-in personnel included Jason Bennett and Alex Ramos (LaPointe Engineering). Special thanks goes to David Marmorek (ESSA Technologies Ltd.), Shawn Zettler (Rio Tinto Alcan), Nathalie Fortin (Rio Tinto Alcan), Helene Pinard (Rio Tinto Alcan), Patrick Williston (Ministry of Environment), Frazer McKenzie (Ministry of Environment), Ian Sharpe (Ministry of Environment), Carol Murray (ESSA Technologies Ltd.), and Julian Aherne (Trent University) for their continued development of the environmental effects monitoring plan and ongoing communications with the authors during 2014.

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1 INTRODUCTION

Rio Tinto Alcan (RTA) is modernizing the Kitimat aluminum smelter to increase the production of aluminum. The modernization, hereafter called the Kitimat Modernization Project or KMP, will increase emissions of SO_2 and potentially result in acidification of precipitation affecting watersheds between the communities of Terrace and Kitimat. ESSA et al. (2013a) estimated that the acid deposition may exceed the critical load for some lakes where critical load (CL) is defined as “a quantitative estimate of an exposure to one of more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge” (Nilsson and Grennfelt, 1988). An environmental effects monitoring plan (EEMP) was developed by ESSA et al. (2013b) in consultation with representatives of RTA, the Haisla First Nation, and the BC Ministry of Environment. The monitoring requirements included indicators of atmospheric SO_2 and acid deposition, human health, vegetation, soils, and water and aquatic biota. Various indicators will be used to routinely track the condition of each of these environmental components. In the water and aquatic biota component, indicators include atmospheric sulphur deposition related to KMP emissions, pH in 7 acid sensitive lakes and 3 acid insensitive control lakes, and the presence or absence of fish in 4 acid sensitive lakes and 3 acid insensitive control lakes. The pH measurements and a suite of chemical analytes to assist with interpreting temporal variation among acid sensitive and control lakes will be measured annually in the 7 acid sensitive lakes and 3 acid insensitive control lakes.

Fishes were selected as an indicator because of their known sensitivity to acidification (Jackson and Harvey 1995, Tammi et al 2003). Fish response to acidification varies through interactions between acid loading and sensitivity to acidification between species and life history stages (Korman et al. 1994, McCormick and Leino, 1999). Fish presence/absence was measured in the acid sensitive lakes in 2013 and it will be measured in the acid insensitive lakes in 2015 to establish baseline knowledge of what fish species are present. Thereafter, inference of fish condition will be made from established relationships between fish condition and pH (e.g. Baker et al. 1991). If the annual chemical monitoring detects more than a 0.3 decline in pH at a future time from a present benchmark, the fish sampling will be repeated to determine if presence/absence of fish species has changed with the change in pH. Those observations will be used to determine need for mitigation as laid out by ESSA et al. (2013b).

Monitoring of water chemistry in the acid sensitive and acid insensitive lakes occurred in 2014. The measurements in 2014 will be appended to that collected in 2012 and 2013 (ESSA et al. 2013a). At the request of the Ministry of Environment, two other lakes (MOE6 and Lakelse Lake) were also sampled in 2014.

Early in 2014, a decision was made by RTA to begin continuous monitoring of pH in each of End Lake (LAK006), Little End Lake (LAK012) and West Lake (LAK023) during the fall period when the EEM sampling typically occurs. The objective was to document variability in pH and related chemistry in each of the three lakes over the fall season. Limnotek set up and installed instrumentation and conducted routine maintenance and calibration of the instruments and associated water sampling during a period of deployment from August 29, 2014 through November 25, 2014. Results are reported in a memo from Limnotek to RTA dated January 19, 2015. They are not repeated in this report.

Similarly, a reconnaissance survey of water chemistry in Goose Creek that is thought to drain one of the acid sensitive lakes called LAK028 was conducted on October 5, 2014. This survey followed a request by MOE to obtain water quality information to assist with understanding conditions of Cutthroat trout spawning habitat in lower Goose Creek. Results are reported in a memo from Limnotek to RTA dated December 1, 2014. They are not repeated in this report.

Quality assurance samples from the fall sampling in LAK006, LAK012, and LAK023 and from the Goose Creek sampling are included in this report to provide evidence of the quality of chemical data for all water sampling that was conducted for RTA in 2014 in relation to the KMP environmental effects monitoring project.

In summary, this report presents the following results:

- Measurements of lake water chemistry in the 10 EEM lakes that were sampled in 2014,
- Measurements of lake water chemistry in the two lakes that were added in 2014 at the request of MOE (Lakelse Lake, MOE6), and
- Quality assurance results from the sampling of the above 12 lakes, the intensive sampling in LAK006, LAK012, and LAK023 and the sampling in Goose Creek in 2014.

2 METHODS

2.1 Sampling sites

Twelve lakes were selected for sampling of water chemistry in 2014 using criteria outlined by ESSA et al. (2013a and b) (Table 1, Figure 1). Using nomenclature from 2012, the lakes included seven acid-sensitive lakes (LAK006 (End Lake), LAK012, LAK022, LAK023 (West Lake), LAK028, LAK042, and LAK044), three control lakes having no risk of exceedence of CL (LAK007, LAK016 and LAK034), and two lakes that the BC Ministry of Environment requested for sampling (MOE6 and Lakelse Lake). MOE6 was to be sampled in 2013 but due to poor visibility in persistent fog which prevented access by helicopter on repeated attempts, sampling of MOE6 was deferred to 2014. It was successfully sampled in 2014.

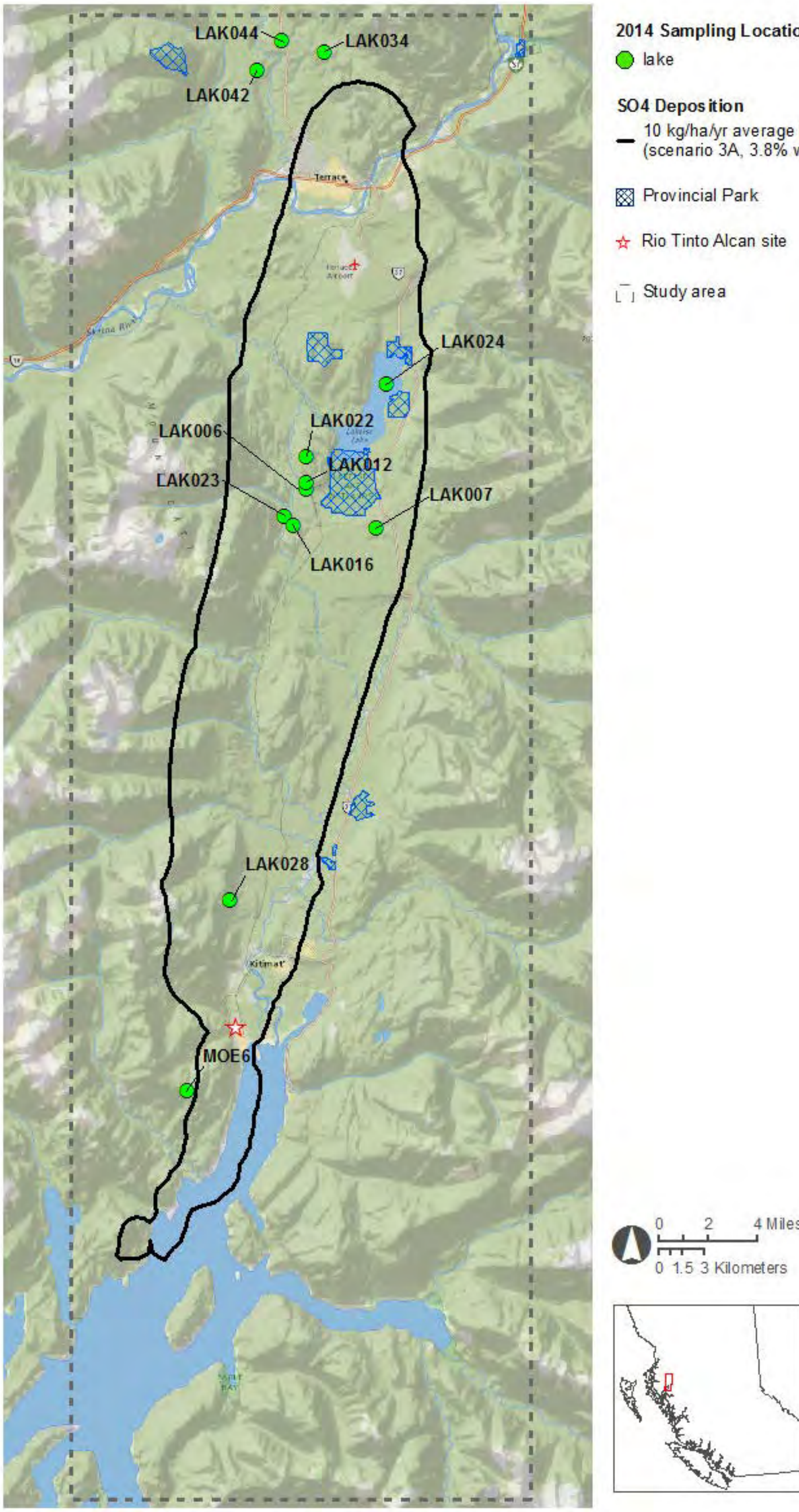

Figure 1. Location of lakes that were sampled in 2014. The area within the black line was predicted by ESSA (2013a) to receive more than 10 kg $SO_4 \cdot ha^{-1} \cdot yr^{-1}$ under KMP. Based on studies elsewhere in North America, lakes receiving less than 10 kg $SO_4 \cdot ha^{-1} \cdot yr^{-1}$ are not likely to acidify.

Table 1. List of lakes and stream sites sampled in 2014 along with planned sample activity in future years.

Number of water body	Lake or stream name	Lake surface area (ha)	Lake designation[a]	UTM zone	Easting	Northing	Sample Date in 2014	Water depth at sampling station (m)	Sampling activity in the EEM plan[b]
MOE6	MOE6	2.44	na	9U	516262	5980766	2-Oct-14	2.6	To be determined
LAK006	End Lake	10.25	Acid sensitive	9U	524155	6020661	2-Oct-14	10.4	SWC, F
LAK012		2.30	Acid sensitive	9U	524145	6021028	2-Oct-14	5.0	SWC, F
LAK022		5.74	LTM	9U	524185	6022796	2-Oct-14	7.7	SWC
LAK023	West Lake	6.77	Acid sensitive	9U	522751	6018850	2-Oct-14	10.0	SWC, F
LAK028		1.02	LTM	9U	519139	5993425	2-Oct-14	9.0	SWC
LAK042		1.46	LTM	9U	520911	6048362	2-Oct-14	10.2	SWC
LAK044	Finlay Lake	2.01	Acid sensitive	9U	522542	6050321	2-Oct-14	6.8	SWC, F
LAK007	Clearwater Lakes	2.62	Control	9U	528771	6018028	2-Oct-14	4.6	SWC, F
LAK016		2.58	Control	9U	523347	6018243	2-Oct-14	9.0	SWC, F
LAK034		8.62	Control	9U	525386	6049589	2-Oct-14	4.0	SWC, F
LAK024	Lakelse Lake	1374.4	na	9U	529485	6027587	2-Oct-14	14.8	To be determined

Notes:

a. There are four lake designations: ***control lakes*** are those having no risk of exceedance of CL, ***acid sensitive lakes*** are those in which CL may be exceeded. The ***na*** lakes are those not included in long term monitoring but water chemistry was measured from these sites in 2014 at the request of the Ministry of Environment. ***LTM lakes*** are sensitive to acid loading and will be included in long term monitoring of water chemistry but not fish. Water chemistry will be sampled annually from all control lakes, all acid sensitive lakes, and all LTM lakes.

b. Sampling activities are surface water chemistry (SWC) and fish (F). Fish sampling of acid sensitive lakes was conducted for the first time in 2013 and fish sampling of acid insensitive lakes will be conducted for the first time in 2015.

2.2 Safety

Prior to the start of field activities, a health and safety plan (HASP) was submitted and approved by LaPointe Engineering for Rio Tinto Alcan. The safety plan included protocols developed by Limnotek as general practice with modifications from RTA, LaPointe Engineering Ltd., and Canadian Helicopters to ensure the safety of the crew while sampling lakes by deploying instruments and sampling devices from a helicopter while hovering. A twin engine A-Star AS355 helicopter was used for the water sampling at all lakes. Payload and fuel load was managed to balance engine performance with practical execution of the water sampling plan. The plan was based on WorkSafe BC standards and safety procedures developed by Limnotek. Identification of potential hazards and procedures for hazard prevention were reviewed by each person operating in the field and acknowledged by signing a Hazard Analysis Acknowledgement Form.

Helicopter safety protocols were as follows. All personal on board the helicopter wore life jackets as required by Canadian Helicopters Ltd. and the flights were actively tracked using a satellite tracking system. All Limnotek personnel were certified with working at heights training and technicians in the back seats wore fall restraint gear at all times. Fall restraint protocols were required because sampling gear and instruments were deployed from the back seats with doors ajar. Only essential gear and crew were on board. Before the sampling flight, the pilot reviewed load limit, egress, toe-in and ditching procedures. In addition to working at heights training, all Limnotek crew were trained in Emergency First Aid for Industry and had passed the RTA Safety Induction.

Prior to flight, the Limnotek crew and pilot completed an on-ground mock deployment of all instruments and gear while wearing all required safety gear. Small adjustments to procedures and placement of gear were made to ensure the pilot and crew were satisfied that all procedures were safe before flight commenced.

On each day of field work a Daily Trip and Check-in Log form was completed by a check-in contact person. Once the field day was successfully completed, the completed form was saved electronically to the project file. The crew had cell phones and a satellite phone with them at all times for checking in with the check-in person at regular intervals. In addition, the helicopter pilot checked in with the Terrace base regularly using the helicopter radio.

2.3 Water sampling and analyses in laboratories

Water sampling and measurements were completed on October 2, 2014. Instruments were deployed and water was collected from the helicopter in a hover position, approximately 4 m above the water surface using a three person crew plus pilot. The crew leader in the front seat recorded data on a standard field sheet (Appendix

A), took site photos, double-checked the global positioning system (GPS) waypoint location, and provided overall direction of sampling activities. The other two crew members worked together in the back seat to take instrument readings and collect the water samples. The pilot made all decisions related to safety. Crew members and the pilot were in communication via headsets at all times. Nitrile gloves were worn by crew members handling the instruments and water bottles.

The following procedure was followed at each of the lakes. As the helicopter approached a lake, the dissolved oxygen sensor on a Yellow Springs Instrument (YSI) multiparameter Sonde (model 6920) was calibrated. The crew leader (front seat) provided the pilot with general guidelines about where the sampling station should be located, which was usually at an expected deep point, based on lake morphometry. The pilot decided on the actual location. Station location coordinates from the helicopter GPS were logged on the field form. Once on station in stable hover, the sliding back door of the helicopter was opened, a weighted transducer was lowered to an elevation just under the water surface and the water depth was measured using a Lowrance Mark-5X portable depth sounder. The sounder transducer was retrieved. The YSI that was calibrated for conductivity, pH, and turbidity during the evening before sampling was lowered to the water surface and the pressure transducer was calibrated to zero to accommodate the changing barometric pressure at each lake. The probe was lowered to 1m below the surface, held in place for approximately two minutes while sensors stabilized, and all sensor measurements were recorded into Sonde memory. Measurements included Sonde depth, water temperature, pH, specific conductivity, total dissolved solids concentration, turbidity, and dissolved oxygen concentration. The data were recorded on a field sheet as backup (Table 2, Appendix A). The Sonde was retrieved and stowed. A 5L VanDorn water bottle (Wildlife Supply Co. Yulee, FL) was lowered to a depth of 1m, triggered with a messenger to collect a water sample and retrieved. Sample water was dispensed from the VanDorn bottle into each of two 250 mL pre-rinsed polyethylene bottles, one 125 mL pre-rinsed amber glass bottle, and two 1L pre-rinsed polyethylene bottles. Pre-rinsing involved rinsing twice with deionized water and then capped on the day before sampling. After filling all bottles at a given lake, the bottles were placed in a plastic bag labelled with the lake number. Time on station to complete the measurements and water collections was 8 – 18 minutes.

At the end of the day of sample collections, the water samples from each site were handled as follows. Sample in the 125 mL amber glass bottle was preserved with H_2SO_4, packed on ice, and shipped to ALS Environmental in Burnaby, B.C. for fluorometric analysis of ammonium concentration. One of the 250 mL polyethylene bottles was preserved with HNO_3, packed on ice, and shipped to ALS for analysis of total base cation (Ca, K, Mg, Na, Sr, Al, Mn, Fe) concentrations using inductively coupled plasma – mass spectrometry. The other 250 mL polyethylene bottle was packed on ice and shipped to Trent University for analysis of Gran ANC by titration on a PC-titration Plus system and pH using an automated bench top pH meter. One of the 1L polyethylene bottles was packed on ice and shipped to ALS for analysis of anion (HCO_3, Cl, SO_4, F, NO_3-N) concentrations by ion chromatography and pH by using an automated bench top pH meter. From the other 1L polyethylene bottle, a 250 mL aliquot was filtered using a syringe filtering system, preserved with HNO_3, packed on ice, and shipped to ALS for analysis of dissolved base cation (Ca, K, Mg, Na, Sr, Al, Mn, Fe) concentrations using inductively coupled plasma – mass spectrometry. Another 125 mL aliquot was filtered, packed on ice, and shipped to ALS for analysis of dissolved inorganic carbon (DIC) concentration by CO_2 purge. Another 125 mL aliquot was filtered, preserved with H_2SO_4, packed on ice, and shipped to ALS Environmental in Burnaby, B.C. for analysis of dissolved organic carbon (DOC) concentration. All lab procedures followed standard methods in APHA (2011).

2.4 Lake attributes

Measurements of descriptive variables were compiled on a field data form (Appendix A) at each lake. The listing of these variables and how they were measured is provided in Table 2. These data provided supportive evidence of lake conditions that may later assist with interpretation of lake chemistry and the data included chemical measurements from the YSI Sonde as backup to data logged into Sonde memory.

Table 2. List of descriptive variables and associated methods of calculation that were recorded on the field data sheet (Appendix A) at each lake.

Habitat or other descriptive variable	**Units**	**Description and method**
Lake name	No units	Station label
Site ID		Preassigned site identification number
Date		Date of sampling
Time on station		Time of arrival at station
Time off station		Time of departure from station
Field Crew		Names of field crew
Northing	UTM	UTM northing recorded with a Garmin GPSmap 76CSx GPS receiver
Easting	UTM	UTM easting recorded with a Garmin GPSmap 76CSx GPS receiver
Weather	No units	Coding for present conditions and conditions in past 24 hours and past week
Riparian Vegetation	%	Estimate (%) of each type, totaling 100% including: unvegetated, grasses/ferns/herbs, shrubs, deciduous forest, coniferous forest, and wetland
Water depth at sampling station	m	Water depth at the sampling station measured using the Lowrance Mark-5XDSI portable depth sounder.
Water sample depth	m	Depth of sample collection recorded from the calibrated line used to deploy the VanDorn water bottle.
Temperature	ºC	Instantaneous surface temperature in all lakes measured with the YSI model 6920 Sonde
pH	Relative units	Surface measurement in all lakes measured with the YSI model 6920 Sonde calibrated with fresh pH buffers on the evening before or day of measurement
Specific conductivity	$\mu S \cdot cm^{-1}$	Surface measurement in all lakes measured with the YSI model 6920 Sonde that was calibrated with fresh conductivity standards on the evening prior to or day of measurement
Dissolved oxygen	$mg \cdot L^{-1}$	Surface measurement in all lakes measured with the YSI model 6920 Sonde that was air calibrated at each station prior to measurement
Turbidity	NTU	Surface measurement in all lakes measured with the YSI model 6920 Sonde that was calibrated with fresh turbidity standards on the evening before or day of measurement
TDS	$mg \cdot L^{-1}$	Surface measurement in all lakes measured with the YSI model 6920 Sonde that was calibrated with fresh TDS standards on the evening before or day of measurement

2.5 Quality of chemical data

On the day of sampling the 12 EEM lakes (October 2, 2014), one blank sample was processed to provide information on contamination from handling and one blind duplicate sample (no site label) was collected from a lake to estimate field sampling precision. One blank and one duplicate sample was also collected during the sampling of Goose Creek on October 5, 2014. In addition, one blank and one duplicate sample was collected during each visit to End Lake (LAK006), Little End Lake (LAK012) and West Lake (LAK023) during fall, 2014. The dates when these samples were analyzed for all analytes were October 9, 16, 23, and November 11.A duplicate sample for pH measurement was also collected on September 14 and November 25 when pH was the only measurement made on the lakes. On all other dates the full suite of analytes that were measured in the lakes (NH_4-N, total and dissolved base cations (Ca, K, Mg, Na, Sr, Al, Mn, Fe), Gran ANC, anions (HCO_3, Cl, SO_4, F, NO_3-N), DIC, DOC) was also measured in the blanks and duplicates. Blanks were deionized water samples provided by ALS Environmental and handled the same way as all test samples including water transfers to sample bottles, filtrations, storage, and shipping. The presence of cations and anions in the blank samples indicated contamination during sample processing and the chemical concentration showed the amount of contamination. Precision (D_f) was calculated as relative percent difference of an analyte concentration between a sample and its corresponding duplicate using the following equation recommended by the Ministry of Environment Lands and Parks (1988):

$$D_f = \left(\frac{A-B}{(A+B)/2}\right) * 100 \qquad \text{Equation 1}$$

where A is the concentration of an analyte in sample A and B is the concentration of the same analyte in the duplicate sample. The measurement of precision was associated with field and lab processes because it integrated sample collection, processing in the field, transport to the lab, and processing of samples in the labs.

Lab accuracy was tested by calculating percent recovery on solutions of known concentrations. Accuracy was determined as percent recovery (R_p) according to the following equation:

$$R_p = \left(\frac{B}{A}\right) * 100 \qquad \text{Equation 2}$$

where B is the recovered concentration and A is the known concentration of a given analyte in a solution. The solution containing the known analyte concentration was prepared in each lab using inorganic standards. The average value from up to 9 separate spiked samples was used to show average percent recovery from known standards of each cation and anion. Tests of percent recovery were limited to analytical values that were more than five times greater than the method detection limit, where the method detection limit was the concentration above which there was a high probability that a substance could be detected, following procedures reported by the Ministry of Environment Lands and Parks (1988).

2.6 Comparison of pH results between instruments and labs

The pH of the suite of acid sensitive and acid insensitive lakes will be measured annually as part of the EEMP to provide an indication of acidification of surface waters. This measurement can be done in the field using a pH metre or in labs following holding of sample water, typically in polyethylene bottles, between times of collection and measurement. Use of field instruments avoids potential drift of pH associated with CO_2 degassing from sample bottles as water is held over time. However, resolution and accuracy of pH can be lower on field instruments than on lab instruments. The pH can also vary during measurement in the field due to time associated with sensor stabilization (takes up to 2 minutes) and water movement past a sensor, which introduces uncertainty about what is the actual pH. CO_2 degassing can be minimized in sample bottles by ensuring no air space and by keeping the samples cool. There can also be time course change in pH during the assigned time window for annual monitoring as recently shown in the memo from Limnotek to RTA dated January 19, 2015. All of these variables lead to uncertainty about detection of a 0.3 pH change that is required in the EEMP as a threshold for addition of monitoring requirements and decisions on mitigation.

In 2014, pH was measured using four different instruments and sample handling procedures as follows:

- YSI Sonde deployed from the helicopter,
- WTW ProfilLine 3210 portable pH meter (http://www.wtw.de/en/products/lab/ph/portable-meters.html) used to measure pH at the end of the day of sampling from a sample collected from each lake,
- Bench top automated pH meter in the lab at ALS Environmental located in Burnaby within 3 days after sampling,
- Autotitrator at Trent University within 14 days after sampling.

Resulting data supported a test of an “instrument effect” on pH wherein the effect had four levels (pH measured using the YSI deployed from the helicopter, pH measured using the WTW at the end of the day of sampling on October 2, pH measured at ALS within 3 days after sampling, and pH measured at Trent 14 days after sampling). For the measurements at ALS and Trent, all sample bottles were filled with no air space, which would minimize effects of CO_2 degassing on pH.

A repeated measures design was used to test the hypothesis that a pH measurement by a given instrument at a lake was more similar to its corresponding measurement by one of the other instruments than to samples from other lakes. Measurements from the four instruments were compared using a series of paired t-tests. The paired contrasts were WTW versus YSI, WTW versus Trent, WTW versus ALS, YSI versus Trent, YSI versus ALS, Trent versus ALS. The usual significance level for a single contrast was adjusted using the Bonferroni correction to account for random effects, resulting in conservative control over Type I error (probability of rejecting the null hypothesis of no difference in pH between a pair of instruments when the null hypothesis is actually true). The Bonferroni correction was α/c where α is the nominal significance level (e.g. 0.05) and c is the number of paired contrasts, which in this case was 6, resulting in the corrected significance level of 0.008.

The equation for calculating the t value for each paired test was as follows:

$$t = \frac{Mean\ differences}{SE\ of\ differences}$$ Equation 3

If the P value for a paired t-test was less than 0.008, the mean difference between paired values reported by the two instruments that were contrasted was considered significant.

We also hypothesized that if an instrument effect was present, the effect would be less than the range of repeatability for the pH instruments (± 0.2 pH units on the YSI and WTW, ± 0.2 pH units at Trent, and ±0.3 pH units at ALS). If this finding is true, a conclusion will be that no instrument effect is actually present because the mean of differences in pH between a pair of instruments is less than the range of repeatability of the two instruments based on factory or lab specifications. If an instrument effect is present and the mean of differences in pH between a pair of instruments is greater than the range of repeatability of the two instruments based on factory or lab specifications, then an instrument effect will be considered present.

3 RESULTS

3.1 Overview

All water sampling and measurements were completed as planned. There were no safety incidences and all work was completed on time within the planned schedule. A photographic record of each lake is available in the project Dropbox and can be used as reference material. All field and laboratory data were compiled into an Excel workbook that accompanies this report.

3.2 Quality of Chemical Data

No positive blanks (those having an analyte concentration greater than the method detection limit) were found in any of the 2014 analyses (Table 3).

Table 3. Incidence of positive blanks (blanks having an analyte concentration above the method detection limit) and comparison of analyte concentrations in positive blanks with those in stream and lake samples.

Analyte	Method detection limit ($mg \cdot L^{-1}$)	Number of positive blanks (maximum possible is 5)	Average concentration in positive blanks ($mg \cdot L^{-1}$)	Average concentration in lake samples in 2014 ($mg \cdot L^{-1}$)
Aluminum, dissolved	0.001	0	Not applicable	0.104
Aluminum, total	0.003	0	Not applicable	0.116
Calcium	0.02	0	Not applicable	4.22
Chloride	0.1	0	Not applicable	0.512
Dissolved Organic Carbon	0.5	0	Not applicable	4.45
Dissolved Inorganic Carbon	0.5	0	Not applicable	2.48
Fluoride	0.02	0	Not applicable	0.122
Iron, dissolved	0.01	0	Not applicable	0.08
Iron, total	0.01	0	Not applicable	0.132
Magnesium, dissolved	0.005	0	Not applicable	0.458
Magnesium, total	0.005	0	Not applicable	0.468
Manganese, dissolved	0.00005	0	Not applicable	0.009
Manganese, total	0.00005	0	Not applicable	0.013
Potassium	0.05	0	Not applicable	0.302
Sodium, total	0.05	0	Not applicable	0.9216
Strontium, dissolved	0.0002	0	Not applicable	0.024
Strontium, total	0.0002	0	Not applicable	0.024
Sulphate	0.2	0	Not applicable	1.557
Ammonium-N	0.005	0	Not applicable	0.003
Nitrate-N	0.005	0	Not applicable	0.024

Precision measured as relative percent differences between replicate pairs of samples ranged between 1% and 10% (Table 4). Precision is considered high when relative percent difference is less than 25% (Ministry of Environment Lands and Parks (1988)). It was high among all tests.

Table 4. Relative percent differences of analyte concentrations between replicates. Data are shown only for sample pairs having analyte concentrations greater than five times the method detection limit (except pH), following protocols reported by the Ministry of Environment Lands and Parks (1988).

Analyte	**Average value of relative percent differences between replicate pairs of samples (%)**
Alkalinity	10 (n=4)
Aluminum, dissolved	3 (n=5)
Aluminum, total	6 (n=5)
Calcium	5 (n=5)
Chloride	no values > 5x MDL
Dissolved Organic Carbon	no values > 5x MDL
Dissolved Inorganic Carbon	no values > 5x MDL
Conductivity	1 (n=5)
Fluoride	1 (n=3)
Iron, dissolved	4 (n=3)
Iron, total	6 (n=3)
Magnesium, dissolved	2 (n=5)
Magnesium, total	2 (n=5)
Manganese, dissolved	2 (n=5)
Manganese, total	3 (n=5)
Potassium	1 (n=2)
Sodium	3 (n=5)
Strontium, dissolved	2 (n=5)
Strontium, total	5 (n=5)
Sulphate	<1 (n=3)
Ammonium-N	no values > 5x MDL
Nitrate-N	3 (n=1)
pH	0.02[a] pH units (n=7)

Notes:

a. Differences in pH between replicates were calculated in pH units.

Percent recovery in spiked samples within the two labs ranged from 87% to 114% with an average of 98% among analytes (Table 5). These results show very high accuracy in both of the labs.

Table 5. Percent recovery of analyte concentrations in spiked samples for the test of lab accuracy.

Analyte	Known concentration ($mg \cdot L^{-1}$ unless otherwise noted)	Average recovered concentration ($mg \cdot L^{-1}$ unless otherwise noted)	Sample size	Average percent recovery
Alkalinity	10.4	9.1	2	87
Alkalinity	102.7	98.1	3	96
Gran Alkalinity	10.38	9	2	87
Gran Alkalinity	102.7	97.1	3	95
Conductivity	33.12*	37.85*	2	114
Conductivity	354.94*	356*	3	100
Aluminum, dissolved	2	1.98	6	100
Aluminum, dissolved	0.241	0.28	10	96
Aluminum, total	2	2.05	8	103
Aluminum, total	0.3	0.28	5	101
Ammonia	0.2	0.202	8	101
Calcium	50	48.617	6	97
Calcium	4.648	4.473	4	98
Chloride	100	102.83	20	103
Dissolved Iorganic Carbon	8	8.055	9	101
Dissolved Iorganic Carbon	5	6.943	3	98
Fluoride	1.016	1.096	46	109
Iron, dissolved	1.526	1.533	15	95
Iron, total	1.296	1.44	13	97
Magnesium, dissolved	1.375	1.335	2	95
Magnesium, total	1.308	1.253	4	91
Manganese, dissolved	0.0236	0.0242	7	97
Manganese, total	0.03	0.29	2	93

Analyte	Known concentration (mg·L^{-1} unless otherwise noted)	Average recovered concentration (mg·L^{-1} unless otherwise noted)	Sample size	Average percent recovery
Nitrate (as N)	2.564	2.621	47	102
Potassium, total	4.14	3.96	4	94
Sodium, dissolved	2.85	2.80	8	95
Sodium, total	2.52	2.50	4	94
Strontium, dissolved	0.03	0.0276	5	100
Sulfate	100	103	20	103

* Units are uS/cm

3.3 Comparison of pH results between instruments

Among mean differences in pH between instrument and lab pairs, only pH between the WTW field pH meter and the ALS lab was found to be significantly different ($p<0.008$; Bonferroni corrected from 0.05) (Figure 2). Among the instrument pairs in which the mean difference in pH was not significant, the mean difference was always <0.2 pH units. The mean difference between the WTW and ALS pair was 0.27 pH units. In all these cases the mean difference in pH between instruments was less than the range of repeatability of the instruments based on factory or lab specifications (± 0.2 pH units on the YSI and WTW, ± 0.2 pH units at Trent, and ±0.3 pH units at ALS). Based on these specifications, no difference in pH measurement was found among the four instruments and labs.

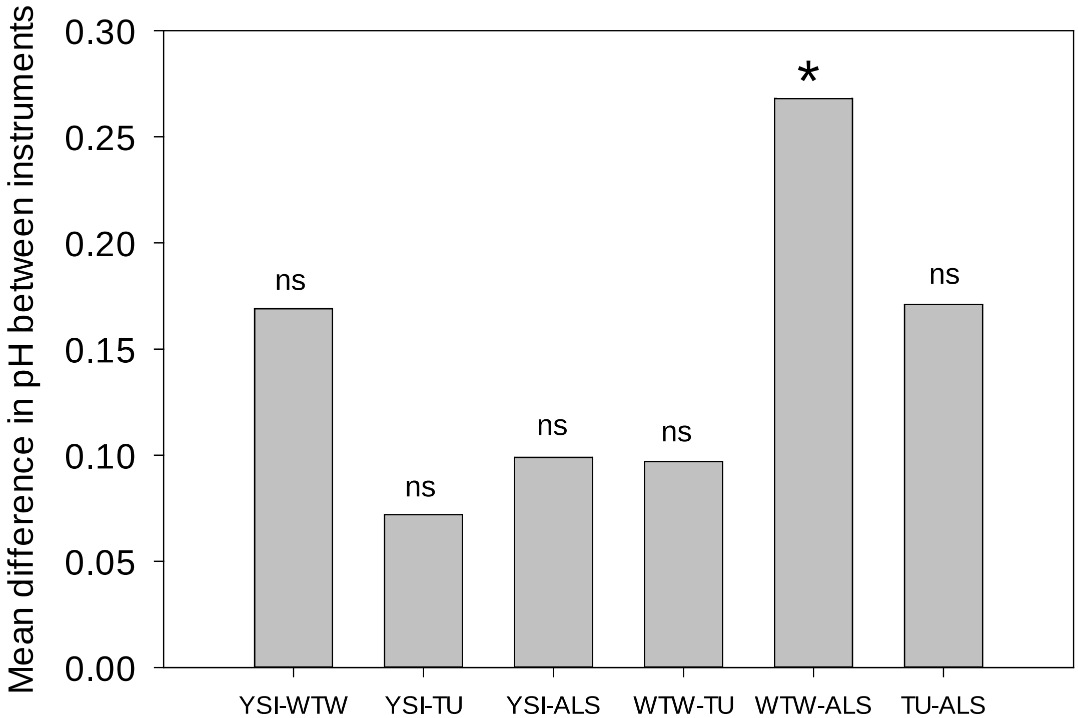

Figure 2 Mean difference in pH between all combinations of instrument pairs among all lakes that were sampled on Oct 2, 2014. Acronyms joined by a hyphen below each bar indicate the instrument or lab pair being tested where YSI is the YSI Sonde that directly measured pH in the lake by deployment from the helicopter, WTW is a handheld pH meter that was used to measure pH at the end of the day of sampling from a water sample, ALS is the ALS lab in Burnaby, and TU is Trent University. The * indicates a significant mean difference ($p<0.008$; Bonferroni corrected from 0.05) and "ns" indicates no significant difference in pH between paired instruments.

4 DISCUSSION AND CONCLUSIONS

Data from 2014 were appended to those from 2012 (ESSA et al. 2013a) and 2013 to provide an up-to-date compilation of chemical and other descriptive information for calculations of CL in 2014. Those calculations will be run by ESSA Technologies Ltd. This process of continuous updates to a single database will be essential for purposes of review, analysis, and reporting over time.

The following findings from the 2014 water sampling are important as part of review of ongoing procedures within the EEMP:

1. Procedures for the collection and analysis of water samples were acceptable. No contamination of samples was detected in 2014, which was an improvement over that found in 2013. The difference may be due to less sample handling in 2014

compared to that in 2013 when sample fractionations were done in the field for certain cation analyses at Trent University and separate aliquots were prepared for tests of bottle type effects on cation concentrations. None of those tests were run in 2014. Precision was high among analytes, indicating excellent repeatability of sample handling and analysis procedures in 2014. Percent recovery in the laboratories was excellent, showing high accuracy of procedures at each of ALS and Trent University labs.

2. pH will be a critical measurement in lakes as part of the ongoing EEMP because it will be used as a criterion to determine need for more intensive monitoring than is occurring at present and it will contribute to decisions on need for mitigation of acidification. No instrument or lab effect on pH was found, which shows that within the specifications of field and lab pH meters, any of the instruments or labs that were tested can be used for routine pH measurement in future years. It is essential that samples sent to a lab for analysis of pH must be filled without air space as was done during the test of instrument and lab effects in 2014.
3. At best, precision on pH measurement using a field instrument or at a lab is 0.2 pH units. It is 0.3 pH units at ALS. These values are essentially the same as the amount of change in pH that is to trigger more intensive monitoring and decisions about mitigation within the EEMP (0.3 pH units, ESSA et al. 2013b). It may be difficult to resolve this amount of change in pH when instrument precision is the same amount. For example, if a lake pH is found to be 5.6, the actual pH is within a minimum range of 5.4 – 5.8. If pH in that same lake at a future date is found to be 5.3, corresponding with a change of 0.3 pH units that would trigger change in monitoring or application of mitigation, the actual pH range at that new level would be 5.0 – 5.6, resulting in overlap of possible variance between the two measurements and uncertainty about whether the two pH values were different. Only a change of more than 0.6 pH units would provide confidence that a change had occurred because it would exceed the range of possible values associated with instrument precision. This interaction between the amount of critical change in pH that triggers alterative actions and precision of the instruments used to measure pH needs to be further investigated to remove uncertainty in criteria for change in monitoring or mitigation activities.
4. A recommendation from the water monitoring in 2013 was that redundancy of pH measurement is important to ensure backup of pH data in case an instrument fails or faulty readings are found. Redundancy means measurement of pH from each lake using at least two different instruments in the field or lab. Another recommendation from the 2013 work was that pH sensors must always be checked and replaced as needed. On some instruments, replacement is needed approximately once every three months. Daily calibration with fresh standards is a basic requirement among all measurements. These recommendations remain in effect and should be followed in future years of monitoring.

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6 APPENDIX A: STANDARD FIELD SHEET FOR RTA WATER SAMPLING

Rio Tinto Alcan EEM Water Component 2014: Field Data Sheet (Site ID_________________)

A: Location

Lake or Stream Name		Site ID (eg.lak053):
Date:	Time on station:	Time off station:
Field crew:		
GPS Unit #	Elevation on GPS receiver (m)	
Northing	Easting	

Was a water sample collected from this site? ☐ Y ☐ N
If No, give reasons for not sampling:

Lake Photos
facing north ☐ facing south ☐ facing east ☐ facing west ☐
aerial view ☐ Other ______________________________ ☐

B: Weather

Now: ☐ storm (heavy rain) ☐ rain (steady rain) ☐ showers (intermittent) ☐ overcast ☐ clear/ sunny

Past 24 hours: ☐ storm (heavy rain) ☐ rain (steady rain) ☐ showers (intermittent) ☐ overcast ☐ clear/ sunny

Has there been a heavy rain in the past 7 days? ☐ Y ☐ N

C. Riparian Vegetation (estimate the % of each type, totaling 100%)

Unvegetated (bare soil or bedrock)	%	Deciduous Forest (trees >5m tall)	%
Grasses/Ferns/Herbs	%	Coniferous Forest	%
Shrub (may include grasses/herbs growing beneath	%	wetland	%

D. Lake Site Description

Water depth at sampling station (m):	Instrument used for depth measurement :
Water sampling depth: Surface grab ☐	Other (m):

E. Water Quality

Field Measurements

Make and model of Sonde	Depth of sample collection (m)	Water Temperature (°C)	pH	Spec. Conductance (µS/cm)	D.O. (mg/L)	Turbidity (NTU)	TDS (mg/L)
YSI model 6920							
WTW pH meter (used back at base after helicopter sampling)	n/a	n/a		n/a	n/a	n/a	n/a

Water Samples (check the box once sample is collected on board the helicopter):

☐ 250 mL poly for total cations (metals) (ALS bottle)

☐ 125 mL amber glass for NH_4-N (ALS bottle)

☐ 1 L poly to supply water for filtrations at base (Limnotek bottle)

☐ 1 L poly for anions and pH (ALS bottle)

☐ 250 mL square poly for Gran ANC (Limnotek bottle)

Rio Tinto Alcan Kitimat Modernization Project: Environmental Effects Monitoring of Water and Aquatic Biota in 2013

DRAFT REPORT

December 24, 2013

LIMNOTEK

Rio Tinto Alcan Kitimat Modernization Project: Environmental Effects Monitoring of Water and Aquatic Biota in 2013

DRAFT REPORT

Submitted to

Rio Tinto Alcan Ltd.
Kitimat, B.C.

Prepared by

C.J. Perrin, MSc., RPBio, E. Parkinson MSc.
and S. Bennett, MSc., RPBio

December 24, 2013

Citation: Perrin, C.J., E. Parkinson and S. Bennett 2013. Rio Tinto Alcan Kitimat Modernization Project: Environmental effects monitoring of water and aquatic Biota in 2013. Report prepared by Limnotek Research and Development Inc. for Rio Tinto Alcan Ltd. 41p.

Cover photo: Kitimat Modernization Project site view October 8, 2013. Photo credit, Chris Perrin.

EXECUTIVE SUMMARY

Monitoring of water and fish started in 2013 as part of the environmental effects monitoring plan (EEMP) for the Kitimat Modernization Project by Rio Tinto Alcan (RTA). The EEMP is being developed in consultation with representatives of RTA, the Haisla First Nation, and the BC Ministry of Environment. There were three objectives in 2013 as follows: determine options for access to control lakes from which fish will be sampled in 2014, measure a suite of chemical properties of acid sensitive and acid insensitive lakes for recalculation of critical load of acidity that was first done in 2012, and measure presence/absence of fish from four acid sensitive lakes. A reconnaissance in August 2013 showed that all three control lakes could be accessed by truck, all-terrain vehicle (ATV), and hiking along trails. Water sampling of 11 lakes and three sites on Cecil Creek was completed in early October 2013. Fish were sampled, also in early October, from West Lake (LAK023), End Lake (LAK006), Little End Lake (LAK012), and Finlay Lake (LAK044) using standard gill netting techniques.

All chemical data were successfully collected and were compiled with similar data from 2012. The 2013 data will be used in 2014 for recalculation of critical load of acidity (CL) among lakes to examine variability among estimates of CL. Quality assurance testing showed high precision and accuracy in the field and lab procedures. Annual measurement of pH will be part of the ongoing EEMP to determine temporal change. Quality assurance testing showed no effect of sample holding time on pH as long as sample bottles had no air space and were kept cool, within the ranges of precision at both a commercial lab (ALS Environmental) and University lab (Trent University). Redundancy of pH measurement using both field instruments and measurement in a lab is recommended in future sampling. Power analysis is recommended to determine the number of samples that must be collected in future sampling to correctly detect a change in pH beyond a threshold of 0.3 pH units that is specified in the EEMP to trigger additional monitoring and mitigation needs.

Three of the four lakes sampled using gill nets contained fish. Finlay Lake had no inlets or outlets and no fish were caught. Stickleback (*Gasterosteus aculeatus*, TSB) were common in the other three lakes. Both of the End Lakes had coastal cutthroat trout (*Oncorhynchus clarkii clarkii*, CCT), coho salmon (*Oncorhynchus kisutch*, CO), and Dolly Varden char (*Salvelinus malma*, DV) whereas West Lake only had CO and TSB. The CO in West Lake had morphologies indicating residualism (fish did not migrate out of the lake after rearing as juveniles), which is rare in coastal lakes. DNA analysis of tissue from the CO in 2014 will be used to confirm species identification 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 DV may result in difficulty detecting the presence of this species in future sampling.

ACKNOWLEDGEMENTS

Several people from different companies contributed to the collection of data that are described in this report. Safety planning and preparations with the field crew were managed by James Mathers of LaPointe Engineering Ltd. The authors thank Shawn Zettler (Rio Tinto Alcan), James Mathers (LaPointe Engineering) and Donna Gasper (Rio Tinto Alcan) for expediting preparation of the Permit to Work as required by Rio Tinto Alcan before field activities could begin. Mapping and GIS support was provided by Simon Casley. The authors were assisted in the field by Dani Ramos and Fred Seiler. Helicopter services were provided by Canadian Helicopters Ltd. from their base in Terrace. Chris Hampton was the pilot of the twinstar helicopter that was used for all the lake water sampling. Logistics support for the fish sampling was provided by Fred Seiler. Water lab analytical services were provided by Kevin Adkinson and Dr. Julian Aherne of Trent University, and ALS Environmental in Burnaby, B.C. The account manager at ALS was Selam Worku. Fish scale aging was completed by Robert Hamaguchi. We thank Dean Peard (BC Ministry of Environment, Smithers) for his detailed review of fish collection methods and issuance of the fish collection permit. We thank Michael Gordon for his assistance in coordinating review of the application for the fish collection permit by representatives of the Haisla First Nation. Safety check-in personnel included Jason Bennett and Alex Ramos (LaPointe Engineering). Special thanks goes to David Marmorek (ESSA Technologies Ltd.), Shawn Zettler (Rio Tinto Alcan), Nathalie Fortin (Rio Tinto Alcan), Helene Pinard (Rio Tinto Alcan), Patrick Williston (Ministry of Environment), Frazer McKenzie (Ministry of Environment), Carol Murray (ESSA Technologies Ltd.), and Julian Aherne (Trent University) for their tireless development of the environmental effects monitoring plan and ongoing communications with the authors during its implementation in 2013.

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1 INTRODUCTION

Rio Tinto Alcan (RTA) is modernizing the Kitimat aluminum smelter to increase the production of aluminum. The modernization, hereafter called the Kitimat Modernization Project or KMP, will increase emissions of SO_2 and potentially result in acidification of precipitation affecting watersheds between the communities of Terrace and Kitimat. ESSA et al. (2013a) estimated that the acid deposition may exceed the critical load for some lakes where critical load (CL) is defined as "a quantitative estimate of an exposure to one of more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge" (Nilsson and Grennfelt, 1988). An environmental effects monitoring plan (EEMP) was developed by ESSA et al. (2013b) in consultation with representatives of RTA, the Haisla First Nation, and the BC Ministry of Environment. The monitoring requirements included indicators of atmospheric SO_2 and acid deposition, human health, vegetation, soils, and water and aquatic biota. Various indicators will be used to routinely track the condition of each of these environmental components. In the water and aquatic biota component, indicators include atmospheric sulphur deposition related to KMP emissions, pH in acid sensitive lakes and a group of acid insensitive control lakes, and the presence or absence of fish in acid sensitive lakes and acid insensitive control lakes. Fishes were selected as an indicator because of their known sensitivity to acidification (Jackson and Harvey 1995, Tammi et al 2003). Fish response to acidification varies through interactions between acid loading and sensitivity to acidification between species and life history stages (Korman et al. 1994, McCormick and Leino, 1999). The pH and a suite of chemical analytes will be measured annually to calculate critical load of acidity to lakes. Fish presence/absence will be measured in the acid sensitive lakes in 2013 and in the acid insensitive lakes in 2014 to establish baseline knowledge of what fish species are present. Thereafter, inference of fish condition will be made from established relationships between fish condition and pH (e.g. Baker et al. 1991). If the annual chemical monitoring detects more than a 0.3 decline in pH at a future time from a present benchmark, the fish sampling will be repeated to determine if presence/absence of fish species has changed with the change in pH. Those observations will be used to determine need for mitigation as laid out by ESSA et al. (2013b).

Monitoring of water chemistry and fish presence/absence started in 2013. There were three objectives as follows:

1. Examine constraints for accessing the three acid insensitive lakes and determine access improvements that will be required for sampling those lakes in 2014.

2. Measure pH and a suite of chemical analytes to support recalculation of CL from ten lakes that were first sampled in 2012 (ESSA et al. 2013a). Recalculation of CL will support estimates of precision of CL measurements among lakes. At the request of the Ministry of Environment, three sites on Cecil Creek that receives drainage from West Lake (one of the ten lakes to be sampled) and two new lakes

were added. Based on interpretation of the 2012 water chemistry (ESSA et al. 2013a), seven of the lakes were considered sensitive to acid loading and three were considered insensitive to acid loading.

3. Measure presence/absence of fish from four of the seven acid sensitive lakes.

This report presents results from the 2013 sampling activities. The chemical data were appended to that collected in 2012 for later calculation of CL by ESSA Technologies Ltd. in 2014. Measurement of fish presence/absence was summarized and interpreted in this report. Observations of access constraints for sampling the control lakes in 2014 are presented. This report is the first of annual reports related to water and aquatic biota to be prepared for the EEMP.

2 METHODS

2.1 Sampling Sites

Twelve lakes and three sites on Cecil Creek were selected for sampling of water chemistry in 2013 using criteria outlined by ESSA et al. (2013a and b) (Table 1, Figure 1). Using nomenclature from 2012, the lakes included seven acid-sensitive lakes (LAK006 (End Lake), LAK012, LAK022, LAK023 (West Lake), LAK028, LAK042, and LAK044), three control lakes having no risk of exceedence of CL (LAK007, LAK016 and LAK034), and two lakes that the BC Ministry of Environment requested for sampling (MOE3 and MOE6). Only MOE6 was not sampled due to poor visibility in persistent fog which prevented access by helicopter on repeated attempts. All three sites on Cecil Creek were sampled at road crossings with easy vehicle access.

Fish species presence/absence was measured in LAK006 (End Lake), LAK012, LAK023 (West Lake), and LAK044, again using criteria established in the EEMP (ESSA et al 2013b). All of these lakes were easily accessible by truck and all-terrain vehicle off of paved highways and logging roads. LAK044, located north of Terrace, had no inlets or outlets. The other lakes were south of Terrace in close proximity to each other (Figure 1). All three lakes had mapped outlets but End Lake and West Lake had no inlets. These three lakes were on the edge of a gravel plateau with no visible stream channels (Figure 1), which suggests that most inflow to these lakes was from groundwater.

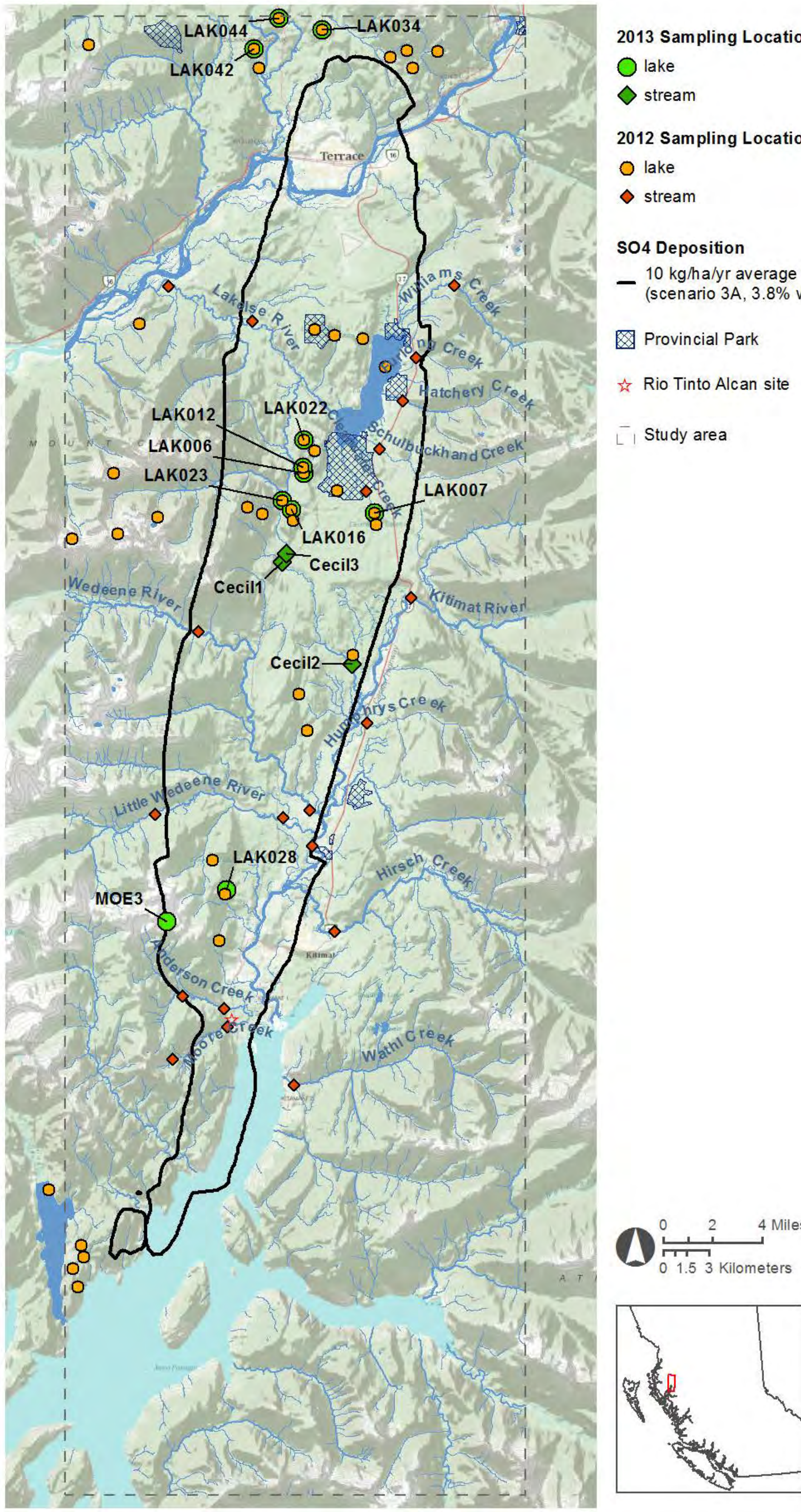

Figure 1. Location of lakes and stream sites that were sampled in 2013. The 2012 sampling sites are shown for reference. The area within the black line was predicted by ESSA (2013a) to receive more than 10 kg $SO_4 \cdot ha^{-1} \cdot yr^{-1}$ under KMP. Based on studies elsewhere in North America, lakes receiving less than 10 kg $SO_4 \cdot ha^{-1} \cdot yr^{-1}$ are not likely to acidify.

Table 1. List of lakes and stream sites sampled in 2013 along with planned sample activity in future years.

Number of water body	Lake or stream name	Lake surface area (ha)	Lake designation [a]	UTM zone	Easting	Northing	Sampling activity in 2013[b]	Sample Date in 2013	Water depth at sampling station (m)	Sampling activity in future years[b]
Lake MOE3	MOE3	14.2	na	9U	515229	5991369	SWC	8-Oct-13	7	To be determined after 2013
Lake MOE6	MOE6	2.44	na	9U	516262	5980766	SWC	Not sampled in 2013 due to weather	Not sampled in 2013 due to weather	To be determined after 2013
LAK006	End Lake	10.25	Acid sensitive	9U	524155	6020661	SWC,F	9-Oct-13	6	SWC, F
LAK012		2.30	Acid sensitive	9U	524145	6021028	SWC, F	9-Oct-13	3.4	SWC, F
LAK022		5.74	LTM	9U	524185	6022796	SWC	9-Oct-13	9.6	SWC
LAK023	West Lake	6.77	Acid sensitive	9U	522751	6018850	SWC, F	9-Oct-13	4.5	SWC, F
LAK028		1.02	LTM	9U	519139	5993425	SWC	9-Oct-13	10.4	SWC
LAK042		1.46	LTM	9U	520911	6048362	SWC	9-Oct-13	11.2	SWC
LAK044	Finlay Lake	2.01	Acid sensitive	9U	522542	6050321	SWC,F	11-Oct-13	14.5	SWC, F
LAK007	Clearwater Lakes	2.62	Control	9U	528771	6018028	SWC	9-Oct-13	4.5	SWC, F
LAK016		2.58	Control	9U	523347	6018243	SWC	9-Oct-13	3.7	SWC, F
LAK034		8.62	Control	9U	525386	6049589	SWC	9-Oct-13	6	SWC, F
Cecil1	Cecil Creek West tributary	na	na	9U	522786	6014866	SWC	10-Oct-13	0.15	To be determined after 2013
Cecil2	Cecil Creek downstream	na	na	9U	527311	6008163	SWC	10-Oct-13	0.1	To be determined after 2013
Cecil3	Cecil Creek East tributary	na	na	9U	523067	6015402	SWC	10-Oct-13	0.2	To be determined after 2013

Notes:

a. There are four lake designations: ***control lakes*** are those having no risk of exceedence of CL, ***acid sensitive lakes*** are those in which CL may be exceeded and fish were sampled in 2013. Water chemistry will be sampled annually from all lakes. Fish presence/absence was determined in the acid sensitive lakes in 2013 and will be determined in the control lakes in 2014. The ***na lakes and streams*** are those not included in long term monitoring but water chemistry was measured from these sites in 2013 at the request of the Ministry of Environment. ***LTM lakes*** are sensitive to acid loading and will be included in long term monitoring of water chemistry but not fish.

b. Sampling activities are surface water chemistry (SWC) and fish (F).

2.2 Safety

Prior to the start of field activities, a health and safety plan (HASP) was submitted and approved by LaPointe Engineering for Rio Tinto Alcan. The safety plan included protocols developed by Limnotek as general practice with modifications from RTA, LaPointe Engineering Ltd., and Canadian Helicopters to ensure the safety of the crew while sampling lakes by deploying instruments and sampling devices from a helicopter while hovering. A twin engine A-Star AS355 helicopter was used for the water sampling at all lakes. Payload and fuel load was managed to balance engine performance with practical execution of the water sampling plan. The safety plan also included protocols for sampling fish from a small boat on lakes. The plan was based on WorkSafe BC standards and safety procedures developed by Limnotek. Identification of potential hazards and procedures for hazard prevention were reviewed by each person operating in the field and acknowledged by signing a Hazard Analysis Acknowledgement Form.

Helicopter safety protocols were as follows. All personal on board the helicopter wore life jackets as required by Canadian Helicopters Ltd. and the flights were actively tracked using a Satellite tracking system. All Limnotek personnel were certified with working at heights training and technicians in the back seats wore fall restraint gear at all times. Fall restraint protocols were required because sampling gear and instruments were deployed from the back seats with doors ajar. Only essential gear and crew were on board and the pilot reviewed load limit, egress, toe-in and ditching procedures daily. In addition to working at heights training, all Limnotek crew were trained in Emergency First Aid for Industry, RTA Induction, and as Swiftwater Rescue Technicians.

Prior to flight, the Limnotek crew and pilot completed an on-ground mock deployment of all instruments and gear while wearing all required safety gear. Small adjustments to procedures and placement of gear were made to ensure the pilot and crew were satisfied that all procedures were safe before flight commenced.

On each day of field work a Daily Trip and Check-in Log form was completed by a check-in contact person. Once the field day was successfully completed, the completed form was saved electronically to the project file. The crew had cell phones and a satellite phone with them at all times for checking in with the check-in person at regular intervals. In addition, the helicopter pilot checked in with the Terrace base regularly using the helicopter radio.

2.3 Survey of Access to Lakes for Fish Sampling in 2014

A survey of access to control lakes to be sampled for fish presence/absence in 2014 was completed on August 29, 2013. Two crew members traveled by truck to close access points and then by ATV and hiking on trails to review options for access. For each of the three lakes, a field data sheet was filled out noting the access route, coordinates at the start and end of trails to each lake, potential need to sling gear in by helicopter, and availability of a helicopter landing spot (if no close road access).

2.4 Water Sampling and Analyses in Laboratories

Water sampling and measurements were completed during October 8 – 11, 2013. Instruments were deployed and water was collected from the helicopter in a hover position, approximately 4 m above the water surface using a three person crew plus pilot. The crew leader in the front seat recorded data on a standard field sheet (Appendix A), took site photos, double-checked the global positioning system (GPS) waypoint location, and provided overall direction of sampling activities. The other two crew members worked together in the back seat to take instrument readings and collect the water samples. The pilot made all decisions related to safety. Crew members and the pilot were in communication via headsets at all times. Nitrile gloves were worn by crew members handling the instruments and water bottles.

The following procedure was followed at each of the lakes. As the helicopter approached a lake, the dissolved oxygen sensor on the YSI instrument was calibrated. The crew leader (front seat) provided the pilot with general guidelines about where the sampling station should be located, which was usually at an expected deep point, based on lake morphometry. The pilot decided on the actual location, keeping within 50 m from shore as required in safety protocols. Station location coordinates from the helicopter GPS were logged on the field form. Once on station in stable hover, the sliding back door of the helicopter was opened, a weighted transducer was lowered to an elevation just under the water surface and the water depth was measured using a Lowrance Mark-5X portable depth sounder. The sounder transducer was retrieved. A Yellow Springs Instrument (YSI) multiparameter Sonde (model 6920) that was calibrated during the evening before sampling was lowered to the water surface and the pressure transducer was calibrated to zero to accommodate the changing barometric pressure at each lake. The probe was lowered to 1m below the surface, held in place for approximately two minutes while sensors stabilized, and all sensor measurements were recorded into Sonde memory. Measurements included Sonde depth, water temperature, pH, specific conductivity, total dissolved solids concentration, turbidity, and dissolved oxygen concentration. The data were recorded on the field sheet as backup. The Sonde was retrieved and stowed. A 5L VanDorn water bottle (Wildlife Supply Co. Yulee, FL) was lowered to a depth of 1m, triggered with a messenger to collect a water sample and retrieved. Sample water was dispensed from the VanDorn bottle into each of two 500 mL polyethylene bottles, one 250 mL amber glass bottle, and one 250 mL polyethylene bottle. Each bottle was rinsed twice with the sample water and then filled, capped, placed in labelled plastic bag, and packed on ice in a cooler. Time on station to complete the measurements and water collections was 8 – 12 minutes.

At the end of each field day the water samples were handled as follows. Sample in the amber glass bottle from each site was preserved with sulphuric acid, packed on ice, and shipped to ALS Environmental in Burnaby, B.C. for analysis of ammonium concentration. One of the 500 mL polyethylene bottles was packed with the glass bottle from each site for analysis at ALS for nitrate, pH, and conductivity. The 250 mL polyethylene bottles were packed on ice and shipped to the lab of Dr. Julian Aherne at Trent University for analysis of dissolved organic carbon, Gran ANC, alkalinity, pH, conductivity, total base cations (Ca, K, Mg, Na, Sr, Al, Mn, Fe) and anions (HCO_3, Cl, SO4, F). A 15 mL aliquot from the 500 mL polyethylene bottle from every second site was dispensed into a teflon vial for analysis of base cations (Ca, K, Mg, Na, Sr, Al, Mn, Fe). Data from these vials was compared to that in bulk water collected in polyethylene bottles to test sample bottle effects on base cation concentrations as described in Section 2.8. Another aliquot from the 500 mL polyethylene bottle, this time from every site, was passed through a solid phase extraction (SPE) column (Bond Elut SCX from Agilent Technologies Ltd., Mississauga Ontario) and into a 15 mL standard round Teflon vial (catalogue number 200-015-20 (vial) and 600-033-01 (cap), PFA vials from Delta Scientific (supplier for Savillex Labware), Mississauga Ontario) for analysis of fractionated Al and Fe following the procedure recommended by Tangen et al. (2002). The SPE was attached to the end of a 20 mL syringe. Water from the bulk sample bottle was dispensed into the syringe after washing the syringe with sample water. A slow constant pressure was applied to the syringe to pass sample water through the SPE at a rate of about 5 mL per minute to allow fractionation to occur in the column. The first 15 mL that passed through the column was discarded to condition the column and equilibrate the pH. The next 5 mL was used to rinse the Teflon sample vial. The vial was then filled with 15 mL of fractionated sample water. The difference between Al or Fe concentration in the bulk water sample and the Al or Fe concentration in water from the fractionated sample in the Teflon vial was the inorganic fraction of Al or Fe. Chemical analyses at ALS occurred within 3.5 – 7.5 days after sampling and analyses at Trent occurred within 46 – 59 days after sampling. This difference in time of analysis allowed for a test of time effects on pH that can change in association with CO_2 degassing from sample bottles. All sample bottles were filled with no air space to minimize this effect but the bottles were opened for sample processing at Trent before final pH analyses were run, which would have allowed for some CO_2 degassing to occur.

Chemical analyses were run at ALS Environmental in Burnaby, B.C. (ammonium and nitrate) and the lab of Dr. Julian Aherne at Trent University in Peterborough, Ontario (all other analyses). The pH was measured at both labs for the test of time effects on pH measurement. ANC was measured with GRAN titration on a PC-titration Plus system. Sulphate, fluoride and chloride was measured by ion chromatography on a Dionex IC. Total base cations (calcium, potassium, magnesium, sodium, aluminum, manganese, and iron) was measured using PerkinElmer inductively coupled plasma – optical emission spectroscopy (ICP-OES). Dissolved organic carbon was measured by combustion with a Shimadzu TOC-V CPH carbon analyzer using standard methods reported in APHA (2011). At ALS, nitrate was determined by ion chromatography and ammonium was determined by fluorescence.

2.5 Habitat Attributes

Measurements of descriptive habitat variables were compiled on the field data form (Appendix A) at each lake and stream site. The listing of these variables and how they were measured is provided in Table 2. Some were chemical measurements that will contribute to calculation of CL but others provided supportive evidence of site conditions to assist with interpretation of CL among and between lakes and streams.

Table 2. List of descriptive variables and associated methods of calculation that were recorded on the field data sheet (Appendix A).

Habitat or other descriptive variable	**Units**	**Description and method**	**Habitat type**
Lake or stream name	No units	Station label	Lakes and streams
Site ID		Preassigned site identification number	Lakes and streams
Date		Date of sampling	Lakes and streams
Time on station		Time of arrival at station	Lakes and streams
Time off station		Time of departure from station	Lakes and streams
Field Crew		Names of field crew	Lakes and streams
Northing	UTM	UTM northing recorded with a Garmin GPSmap 76CSx GPS receiver	Lakes and streams
Easting	UTM	UTM easting recorded with a Garmin GPSmap 76CSx GPS receiver	Lakes and streams
Elevation	m	Elevation of a sample station in meters above mean sea level	Lakes and streams
Riparian Vegetation	%	Estimate (%) of each type, totaling 100% including: unvegetated, grasses/ferns/herbs, shrubs, deciduous forest, coniferous forest, and wetland	Lakes and streams
Water depth at sampling station	m	Water depth at the sampling station measured using the Lowrance Mark-5XDSI portable depth sounder.	Lakes
Water sample depth	m	Depth of sample collection recorded from the calibrated line used to deploy the VanDorn water bottle. Sample depth in streams was always 0.1 m, which was the depth of grab sample collections.	Lakes and streams
Temperature	ºC	Instantaneous surface temperature in all lakes and streams measured with the YSI model 6920 Sonde	Lakes and streams
pH	Relative units	Surface measurement in all lakes and streams measured with the YSI model 6920 Sonde calibrated with fresh pH buffers on the evening before or day of measurement	Lakes and streams
Specific conductivity	$\mu S \cdot cm^{-1}$	Surface measurement in all lakes and streams measured with the YSI model 6920 Sonde that was calibrated with fresh conductivity standards on the evening prior to or day of measurement	Lakes and streams
Dissolved	$mg \cdot L^{-1}$	Surface measurement in all lakes and streams measured with the YSI model	Lakes and streams

Habitat or other descriptive variable	Units	Description and method	Habitat type
oxygen		6920 Sonde that was air calibrated at each station prior to measurement	
Turbidity	NTU	Surface measurement in all lakes and streams measured with the YSI model 6920 Sonde that was calibrated with fresh turbidity standards on the evening before or day of measurement	Lakes and streams
TDS	$mg \cdot L^{-1}$	Surface measurement in all lakes and streams and vertical profiles in selected lakes measured with the YSI model 6920 Sonde that was calibrated with fresh TDS standards on the evening before or day of measurement	Lakes and streams
Water Colour	Numeric code	Water colour determined visually in surface water of streams or in the VanDorn bottle during lake water collections. Coded as 1=clear, 2=light staining, 3=moderate staining, 4= heavy staining, 5=very heavy staining	Lakes and streams
Water clarity	Checkbox	Clarity of water determined visually as glacial, clear, stained or other	Streams
Stream Bankfull width	m	Bankfull width estimated or measured using survey tape	Streams
% composition of streambed	%	Visual estimate of areal coverage by particle size representing sand (<2 mm), gravel (2 to 4 mm), pebble (4 mm to 6 cm), cobble (6 to 26 cm), boulder (> 26 cm) and bedrock.	Streams
Stream Disturbance Indicators – Bed Characteristics	Checkbox	Presence / absence of the following disturbance indicators: Extensive areas of scour, large extensive sediment wedges, extensive riffle zones, extensive areas of unvegetated bar, elevated mid-channel bars or limited pool frequency and extent	Streams
Stream Disturbance Indicators – Channel Pattern	Checkbox	Presence / absence of multiple channels / braiding	Streams
Stream Disturbance	Checkbox	Presence / absence of eroding banks, and isolated side or back channels	Streams

Habitat or other descriptive variable	Units	Description and method	Habitat type
Indicators – Banks			
Stream Disturbance Indicators – Large Woody Structures	Checkbox	Presence / absence of large woody debris mostly parallel to banks, or recently formed debris jams	Streams
Stream Disturbance Indicators – Odours	Checkbox	Check off any odours present in the following categories: Sewage, petroleum, anaerobic (H_2S), chemical, other, or none	Streams
Predominant surrounding land use	Checkbox	Check off all predominant land use types observed at the sampling site including forest, cut-block logging, selective logging, fields/pasture, agriculture, mining, urban, rural residential, commercial/industrial, recreational (Park), or other	Streams
Erosion	Numeric code	Local watershed erosion visible at the site coded as 1=none, 2=light, 3=moderate, 4=heavy	Streams
Non-point source pollution	Numeric code	Evidence of non-point-source pollution visible at the site coded as 1=no evidence, 2=some potential sources, 3=obvious sources	Streams

2.6 Quality of Chemical Data

On each of four days of sampling, one blank sample was processed to provide information on contamination from handling and one blind duplicate sample (no site label) was collected from a stream or lake site to estimate field sampling precision. Each of the four blanks and four duplicates were analysed for each chemical parameter. Blanks were deionized water samples provided by ALS Environmental and handled the same way as all test samples including water transfers to sample bottles, fractionation, storage, and shipping. The presence of cations and anions in the blank samples indicated contamination during sample processing and the chemical concentration showed the amount of contamination. Precision (D_f) was calculated as relative percent difference of an analyte concentration between a sample and its corresponding duplicate using the following equation recommended by the Ministry of Environment Lands and Parks (1988):

$$D_f = \left(\frac{A-B}{(A+B)/2}\right) * 100 \qquad \text{Equation 1}$$

where A is the concentration of an analyte in sample A and B is the concentration of the same analyte in the duplicate sample. The measurement of precision was associated with field and lab processes because it integrated sample collection, processing in the field, transport to the lab, and processing of samples in the labs.

Lab accuracy was tested by calculating percent recovery on solutions of known concentrations. Accuracy was determined as percent recovery (R_p) according to the following equation:

$$R_p = \left(\frac{B}{A}\right) * 100 \qquad \text{Equation 2}$$

where B is the recovered concentration and A is the known concentration of a given analyte in a solution. The solution containing the known analyte concentration was prepared in each lab using inorganic standards. The average value from up to 9 separate spiked samples was used to show average percent recovery from known standards of each cation and anion. Tests of percent recovery were limited to analytical values that were more than five times greater than the method detection limit, where the method detection limit was the concentration above which there was a high probability that a substance could be detected, following procedures reported by the Ministry of Environment Lands and Parks (1988).

2.7 Comparison of pH Results Between Laboratories

The pH of a suite of acid sensitive and acid insensitive lakes will be measured annually as part of the EEMP to provide an indication of acidification of surface waters. This measurement can be done in the field using a pH metre or multi-sensor instrument, or in labs following holding of sample water, typically in polyethylene bottles, between times of collection and measurement. Use of field instruments avoids potential drift of pH associated with CO_2 degassing from sample bottles as water is held over time. However, resolution and accuracy of pH can be lower on field instruments than on lab instruments. The pH can also vary during measurement in the field due to time associated with sensor stabilization (takes up to 2 minutes) and water movement past a sensor, which introduces uncertainty about what is the actual pH. CO_2 degassing can be minimized in sample bottles by ensuring no air space and by keeping the samples cool. All of these variables lead to uncertainty about detection of a 0.3 pH change that is required in the EEMP as a threshold for addition of monitoring requirements and decisions on mitigation.

In 2013, pH was measured in the field during instrument deployment from the helicopter, in the lab at ALS Environmental within 3.5 – 7.5 days after sampling, and at Trent University within 46 – 59 days after sampling. The difference in time of analysis between measurements allowed for a test of time effects on pH measurement. All sample bottles were filled with no air space, which would minimize effects of CO_2 degassing on pH but the bottles were opened for sample processing at Trent before final pH analyses were run, which would have allowed for some CO_2 degassing to occur.

There were three main differences potentially being tested; the length of time the samples were held prior to processing (in situ measurement using the field instrument, 3.5 – 7.5 days until measurement at ALS and 46 – 59 days until measurement at Trent), whether or not samples were exposed to air prior to pH analysis (no exposure at ALS and several occurrences of exposure at Trent), and the lab instrument used (benchtop metre at ALS, auto-titrator at Trent). Pairs of samples for analysis of pH in the two labs were treated identically in the field and during transit. Differences in pH between the instruments were expected to be less than the range of repeatability at each lab or known for the field instrument (± 0.2 pH units on the YSI (resolution listed in specifications for YSI pH sensor), ± 0.2 pH units at Trent (J. Aherne, Trent University (personal communication, November 26 EEMP meeting, Vancouver, B.C.) and ±0.3 pH units at ALS (QA data sheet for pH supplied with results)), which would make an instrument effect a non-issue. Hence, the hypothesis was really a test of the effect of time of measurement and incidence of exposure of the sample to air on pH. The pH would be expected to increase with holding time due to risk of CO_2 degassing that would shift carbonate equilibria to the right.

A repeated measures design was used to test the hypothesis that a pH measurement (in the field or at ALS or Trent) was expected to be more similar to its corresponding measurement than to samples from other lakes. Review of field notes showed that the pH sensor on the YSI Sonde was taking longer than the standard 2 minutes to stabilize, which indicated sensor failure or variable conditions during sampling. In some cases the sensor took longer than 5 minutes to stabilize despite acceptable readings during calibration. This variability introduced uncertainty into the field pH data, resulting in it being considered faulty and not further used in the comparison test. The ALS and Trent pH data were compared using a paired t-test. The equation used for calculating the t value was as follows:

$$t = \frac{Mean\ differences}{SE\ of\ differences}$$ Equation 3

If the P value was less than 0.05, the mean differences between values reported by the two labs was considered significant. A 95% confidence interval was calculated for mean differences between pairs using the critical value of t (based on the degrees of freedom) from a table (not the calculated value of t) using equation 4.

$$Mean\ difference\ \pm t_{critical} * SE\ of\ differences$$ Equation 4

2.8 Test of Sample Bottle Effects on Base Cation Concentrations

The concentrations of base cations in the Teflon vials were compared to concentrations of the same cations in the polyethylene bottles to determine if there was a sample bottle effect on base cation concentrations. An hypothesis is that polyethylene attracts cations and may result in lower concentrations in sample water than is actually present in the lake or stream water. Teflon does not attract cations, making it a suitable control for the test.

A repeated measures design was again used to test the hypothesis that base cation concentrations in sample water between paired polyethylene and Teflon containers was more similar than to samples from other lakes. The analysis was a paired t-test as described above for pH in equations 3 and 4.

2.9 Fish Sampling

Fish were sampled from LAK006, LAK012, LAK023, and LAK044 (acid sensitive lakes) in 2013. An application for fish collections was submitted to the BC Ministry of Forests, Lands and Natural Resource Operations on August 7, 2013 and the permit was received on September 19, 2013, a processing period of 43 days. In the application, the lakes were identified using the 1:20000 Provincial watershed atlas WBID identifier and a local lake number identifier.

Fish sampling was done during October 7-11, 2013 when surface water temperature was in the range of 9.7-11.5°C, which was close to the optimal temperature for gill netting as estimated by Ward et al. (2012).

Four nets were fished in each lake as shown in Figures 2 and 3. Two were sinking RIC standard gill nets (RIC 1997), 91.2 m long and 2.4 m deep with six panels of different mesh sizes (25, 89, 51, 76, 38, and 64 mm stretched mesh). The other two were sinking fine mesh gill nets, 12.4 m long and 1.8 m deep with four equal length panels of different mesh sizes (12.5, 19, 16, 25 mm stretched mesh). The fine mesh was uncoloured monofilament <0.13 mm for the three smallest meshes and 0.18 mm for the largest mesh size The fine mesh nets were used to target small fish and the RIC nets were used to target larger fish. All nets were installed in late afternoon and recovered the following morning in littoral areas 1.5-6m deep. The characteristics of each net set were recorded on a field form at the time of sampling (lake, unique set code, date, start and end time in 24 hour clock, geo-coordinates). Each captured fish was identified with lake number, date, unique set code, mesh size where the capture occurred, unique fish code, species code, and scale number. Each fish was measured to the nearest mm (fork length), and weighed to the nearest gram on an Ohaus Scout Pro SP4001 top loading balance. Otoliths were removed from the head of each fish and scales were removed from a location between the posterior end of the dorsal fin and the lateral line. Both were stored in labeled envelopes for later aging.   If no fish were captured in a set, then lake, date, set code, and a label called “NFC” for species code was entered on the fish data form. This procedure followed standard methods for gill netting by Lester et al (2009), Appelberg (2000), and Morgan and Snucins (2005).

Each fish was identified to species using the dichotomous field key to BC Fish reported by McPhail and Carveth (1993). For more details on salmonid identification this key was supplemented with keys by McPhail (2007), Phillips (1977), and Trautmann (1973).

Fish density was estimated from gillnet catch per unit of effort (CPUE) using a model, which is based on mark-recapture population estimates in 12 lakes in southern BC (Ward et al. 2012). The lake area used in the fish density calculations was obtained from the 1:20K version of the BC Watershed Atlas.

In addition to the conventional numerical and biomass measures, densities were also expressed as effective densities ($\sum length^2$) to facilitate future modeling efforts (Parkinson et al. 2004, Askey 2007). Littoral area proportions were not available for the sampled lakes, so we assumed a value of 100% because depth at the limnologic sampling station was 6m or less in all three lakes.

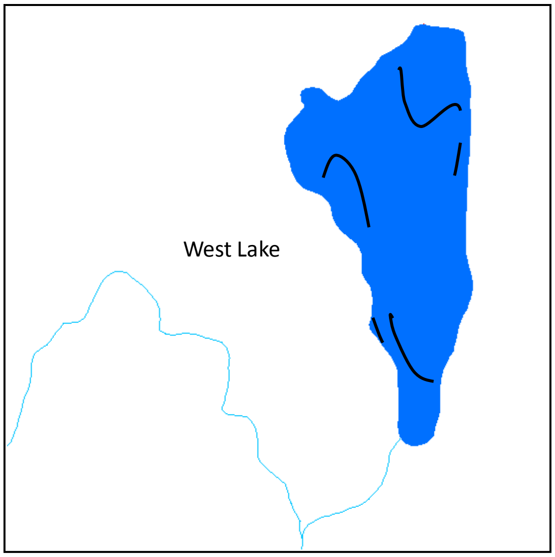

Figure 2. West Lake (LAK023) showing drainage and approximate location of gill net sets. Black lines are approximate locations for gillnet sets.

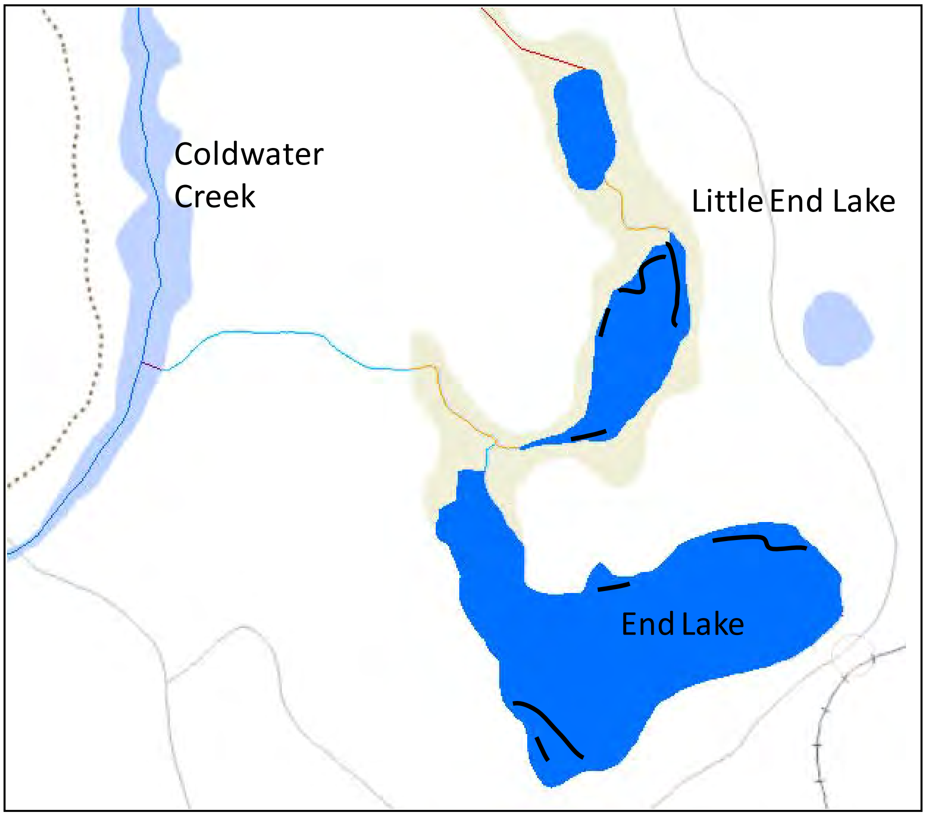

Figure 3. End Lake (LAK006) and Little End Lake (LAK012) showing drainage to Coldwater Creek. Black lines are approximate locations for gillnet sets.

3 RESULTS

3.1 Overview

All water and fish sampling and measurements were completed as planned. There were no safety incidences and all work was completed on time within the planned schedule. A photographic record of every lake and stream site is available in the project Dropbox and can be used as reference material. All field and laboratory data were compiled into an Excel workbook that accompanies this report. As noted in Section 2.7, the pH sensor on the YSI Sonde took longer than the standard 2 minutes to stabilize at many lake sites, which indicated sensor failure or variable conditions during sampling. Other sensors on the instrument responded correctly. This unusual behaviour of the pH sensor introduced uncertainty into the field pH data, resulting in it being considered faulty and not further used. Those field pH data were omitted from the raw data appendix. Later lab testing of the sensor showed slow response time, thus supporting the decision to omit field pH from the data record.

3.2 Survey of Lake Access for Sampling in 2014

The access survey on August 29, 2013 showed that all three control lakes can be accessed for fish sampling in 2014 using combinations of truck and ATV (Table 3). LAK034 can be accessed by truck on the Spring Creek road to kilometer 6, and then by ATV for an additional 2.8 km right to the lake. LAK007 can be accessed by ATV from 2 km on the Wedeene Forest Service Road (FSR). The ATV can take equipment another 2.2 km closer to the lake, and then access is on foot over the Clearwater Lakes hiking trail for roughly 100 m. This route will require wheelbarrows to move equipment from the ATV to the lake. Helicopter access is also an option at this lake. For LAK016, there is road access right to the lake. Communications will be via satellite phone because there is no cell phone service in the area of any of the control lakes.

Table 3. Summary of access information for each of the control lakes from which fish will be sampled in 2014.

Lake Number	Distance from closest road (km)	Is ATV needed from end of the road?	Trail length from end of ATV access	Is helicopter needed to sling in fish sampling gear
LAK034	2.8	Yes	25m	No
LAK007	2.2	Yes	Approximately 1 hour hike in	Is an option and there is a landing area
LAK016	<0.1	no	25m	no

3.3 Quality of Chemical Data

Positive blanks (those having an analyte concentration greater than the method detection limit) were found in analyses for sulphate, calcium, potassium, magnesium and iron (Table 4). For sulphate, calcium, and magnesium, only one out of three blank samples was positive. Potassium was positive in all three blanks, consistent with results from 2012 (ESSA et al. 2013a). The mean concentrations of each analyte in the positive blanks were 13 to 250 times lower than corresponding concentrations in the stream and lake samples.

Table 4. Incidence of positive blanks (blanks having an analyte concentration above the method detection limit) and comparison of analyte concentrations in positive blanks with those in stream and lake samples.

Analyte	**Method detection limit ($mg \cdot L^{-1}$)**	**Number of positive blanks (maximum possible is 3)**	**Average concentration in positive blanks ($mg \cdot L^{-1}$)**	**Average concentration in lake and stream samples in 2013 ($mg \cdot L^{-1}$)**
Chloride	0.05	0		0.785
Sulphate	0.005	1	0.0057	1.444
Fluoride	0.0005	0		0.066
Calcium	0.002	1	0.012	2.649
Potassium	0.005	3	0.02	0.259
Magnesium	0.001	1	0.002	0.301
Sodium	0.003	0		0.660
Aluminum	0.009	0		0.071
Manganese	0.004	0		0.003
Iron	0.004			0.054
Aluminum	0.009	0		0.064
Iron	0.004	2	0.01	0.069
Dissolved organic carbon	0.2	0		2.94
Dissolved inorganic carbon	0.2	0		1.89
Nitrate-N	0.005	0		0.025
Ammonium-N	0.005	0		0.006

Precision measured as relative percent differences between replicate pairs of samples ranged between 1% and 49% (Table 5). Precision is considered high when relative percent difference is less than 25% (Ministry of Environment Lands and Parks (1988)). It was high among all tests except for iron following fractionation (49%). Given that the relative percent difference for iron in bulk water was only 12%, the high value for fractionated iron suggests inconsistency in retention of inorganic iron in the fractionation column between samples. All came from one sample, which shows the effect was not generally associated with the analysis for iron. This difference was not found for aluminum that was also analysed in bulk water and fractionated water. Some variability between replicate water samples is expected not only related to sample handling and processing but due to natural variability captured in the separate water samples.

Table 5. Relative percent differences of analyte concentrations between replicates. Data are shown only for sample pairs having analyte concentrations greater than five times the method detection limit (except pH), following protocols reported by the Ministry of Environment Lands and Parks (1988).

Analyte	**Average value of relative percent differences between replicate pairs of samples (%)**
Alkalinity	5 (n=4)
Aluminum after fractionation	9 (n=2)
Aluminum in bulk water	3 (n=2)
Calcium	3 (n=4)
Chloride	11 (n=3)
Dissolved Organic Carbon	13 (n=5)
Dissolved Inorganic Carbon	3 (n=2)
Conductivity	1 (n=2)
Fluoride	16 (n=2)
Iron after fractionation	49 (n=1)
Iron in bulk water	12 (n=1)
Magnesium	3 (n=4)
Manganese	no values > 5x MDL
Potassium	6 (n=4)
Sodium	6 (n=4)
Sulphate	4 (n=4)
Ammonium-N	5 (n=1)
Nitrate-N	1 (n=1)
pH	0.17[a] pH units (n=4)

Notes:

a. Differences in pH between replicates were calculated in pH units.

Percent recovery in spiked samples within the two labs ranged from 90% to 102% among all analytes (Table 6). These results show very high accuracy in both of the labs. It is possible that accuracy may differ at lower concentrations for some of the analytes found in the lake and stream samples (Table 1), however, the testing was done at concentrations more than 5 times the method detection limit as recommended by Ministry of Environment Lands and Parks (1988).

Table 6. Percent recovery of analyte concentrations in spiked samples for the test of lab accuracy.

Analyte	**Known concentration ($mg \cdot L^{-1}$)**	**Average recovered concentration ($mg \cdot L^{-1}$)**	**Sample size**	**Average percent recovery**
Aluminum	5	5.03	1	101
Calcium	2.5	2.59	3	103
Calcium	5	5.21	1	104
Calcium	10	9.79	3	98
Chloride	1	0.90	3	90
Fluoride	1	0.94	3	94
Iron	2.5	2.76	3	110
Iron	5	3.94	1	79
Iron	10	10.25	3	102
Magnesium	2.5	2.46	3	98
Magnesium	5	5.13	1	103
Magnesium	10	10	3	100
Manganese	2.5	2.58	3	103
Manganese	5	5.13	1	103
Manganese	10	9.81	3	98
Potassium	5	5.09	1	102
Sodium	5	5.02	1	100
Sulphate	1	0.98	3	98
Ammonium-N	0.2	0.19	3	95
Nitrate-N	2.5	2.53	6	101

3.4 Comparison of pH Results Between Laboratories

A frequency distribution of differences in pH between ALS and Trent (ALS pH minus Trent pH) is shown in Figure 4. The peak is centered over zero, which indicates no difference but there is a right tail to the distribution. ALS reported higher pH values than Trent among 37 out of 48 samples. This result was opposite of what was expected to be higher pH values at Trent due to periodic CO_2 degassing that could have occurred more at Trent than at ALS. The differences in pH between the two labs ranged from -0.15 to 0.57, with a mean difference of 0.17 and a standard deviation of the differences of 0.2. This difference was found to be statistically significant (paired t-test, DF=47, t=-5.69, $p<0.001$). However, the 95% confidence interval of the differences (±0.06 or a range of 0.11 to 0.23) was less than laboratory precision known at Trent (± 0.2 pH units, J. Aherne, Trent University, personal communication, November 26 EEMP meeting, Vancouver, B.C.) and at ALS (±0.3 pH units, QA data sheet for pH supplied with results). The confidence interval is also less than the measured precision (0.17 pH units, Table 5), suggesting that there was no change in pH due to differences in holding time.

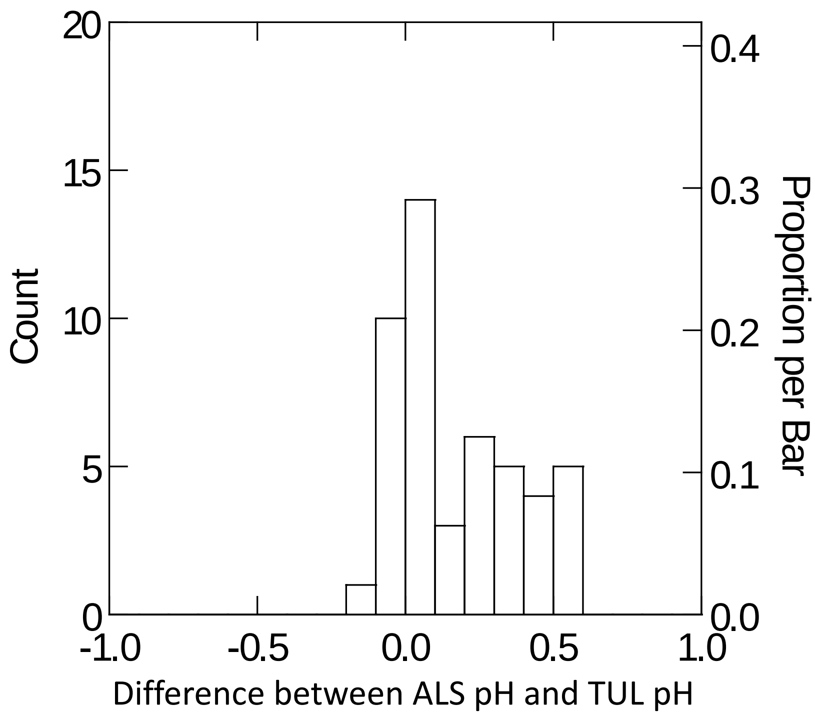

Figure 4 Frequency distribution of differences in pH measurement between sample pairs made at the ALS lab and Trent University lab.

3.5 Sample Bottle Effects on Base Cation Concentrations

There was no sample bottle effect on base cation concentrations except for potassium (Table 7). This finding means that with the possible exception of potassium, attraction of base cations to polyethylene was not enough to cause change in concentrations of base cations in samples that were collected in polyethylene bottles. Potassium concentrations were significantly lower in samples from Teflon vials compared to those from polyethylene containers. However, the 95% confidence interval (0.002 to 0.013 $mg \cdot L^{-1}$) of the mean difference between the two container types (0.008 $mg \cdot L^{-1}$, Table 7) was less than sampling and analytical precision (6% or ±0.02 $mg \cdot L^{-1}$, Tables 5 and 4) for potassium. This outcome means that the bottle effect was not enough to cause change in potassium concentrations resulting from all field and lab procedures.

Table 7 Summary statistics for total cation concentrations reported for replicate water samples in polyethylene bottles and Teflon vials. Results of a paired t-test are shown where a P value less than 0.05 indicates a statistically significant difference in total cation concentrations in paired samples between different bottle types. The total number of sample pairs was 17 (DF=16) for each test.

Analyte	**Mean concentration in polyethylene bottles ($mg \cdot L^{-1}$)**	**Mean concentration in Teflon vials ($mg \cdot L^{-1}$)**	**Mean difference ± SD ($mg \cdot L^{-1}$)**	**95% CI of mean difference ($mg \cdot L^{-1}$)**	**P value**
Aluminum	0.082	0.087	-0.005 ± 0.021	-0.015 to 0.006	0.381
Calcium	2.361	2.340	0.021 ± 0.119	-0.041 to 0.082	0.484
Iron	0.060	0.066	-0.006 ± 0.020	-0.016 to 0.004	0.233
Magnesium	0.276	0.271	0.004 ± 0.009	0 to 0.009	0.057
Manganese	0.004	0.007	-0.002 ± 0.006	-0.006 to 0.001	0.129
Potassium	0.252	0.244	0.008 ± 0.011	0.002 to 0.013	**0.010**
Sodium	0.794	0.792	0.002 ± 0.041	-0.019 to 0.023	0.846

3.6 Fish

3.6.1 Species presence

The four lakes were sampled on sequential nights with 2 RIC and 2 fine mesh gillnets set in each lake (Table 8). A RIC net was set in West Lake for one additional night in an effort to obtain additional samples to confirm species identification. End Lake was connected to Little End Lake by a common outlet channel. That channel was 1 m deep and 2 m wide and edged with floating bog over its entire length. Water exchange between the two lakes is probably minimal, but fish can move freely between the lakes.

Only three of the lakes contained fish (Table 9). Finlay Lake had no inlets or outlets and overnight gillnet sets caught no fish. Only four species were found in the other three lakes. Stickleback (*Gasterosteus aculeatus*, TSB) were common in the12-18 mm stretch mesh panels in all three lakes. Both of the End Lakes had coastal cutthroat trout (*Oncorhynchus clarkii clarkii*, CCT), coho salmon (*Oncorhynchus kisutch*, CO), and Dolly Varden char (*Salvelinus malma*, DV) whereas West Lake only had CO and TSB.

The presence of coho up to 360 mm in length was not expected and triggered a more intensive examination of their morphology to confirm the species identification. The length of the anal fin base confirmed that these fish were not CCT or rainbow trout, the length and number of the gillrakers ruled out kokanee, branchiostegal ray counts ruled out chinook and therefore these fish were identified as coho. Smaller individuals resembled typical coho with obvious parr marks and falcate (sickle-shaped) anal fins with black and sometimes white edges (Figure 5). Larger individuals superficially resembled kokanee with clear anal fins, silvery, deciduous scales, no visible parr marks and only very faint spotting on tails (Figure 6). However, gillraker length, spacing and counts clearly ruled out kokanee (Figure 7).

Although 13 mature CO were captured, all of these were from West Lake and only 1 was a female (Figure 8).

3.6.2 Fish size, age and growth

Sizes of CTT were typical for small lakes in coastal BC. CTT ranged from 119 to 518 mm (Table 10) but most were 250-350 mm in length (Figure 9). The smallest CCT was 237 mm in length and age-0+ CCT were completely missing from the sample (Table 11).

CO ranged in size from 119 to 362 mm across the three lakes. CO were generally larger (Table 10) and older (Table 11) in West Lake than in End Lake and Little End Lake.

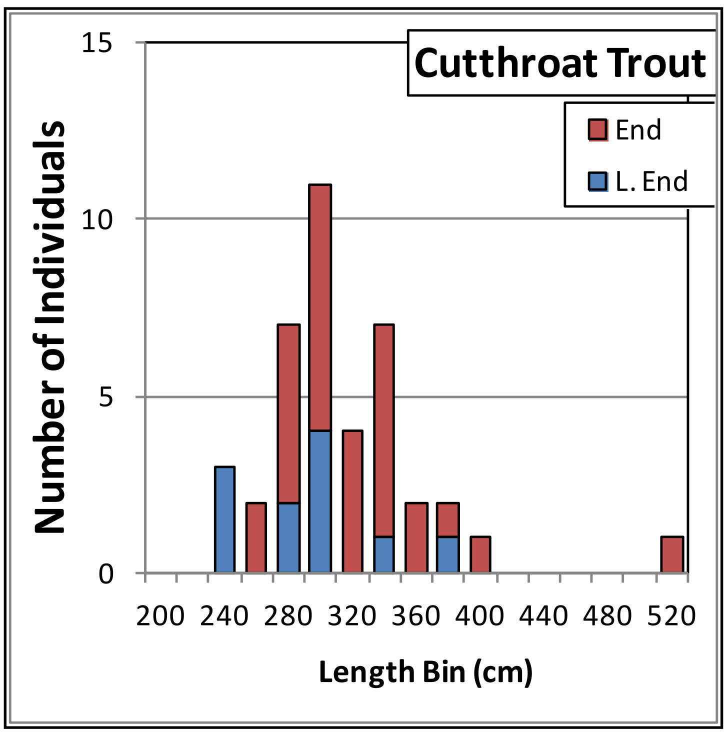

Figure 9. Length frequency distribution of CCT in End and Little End lakes. No CCT <200 mm were captured. No CCT were captured in West Lake.

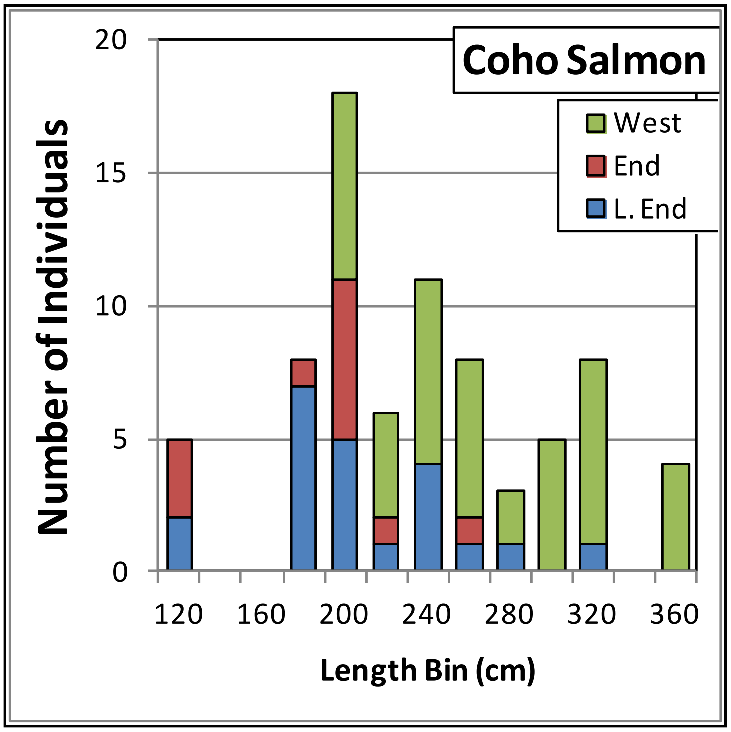

Figure 10. Length frequency distribution of CO in West, End and Little End lakes. No coho <119 mm were captured.

A few age-0 and age-1 CCT and CO were captured but, in general, smaller and younger salmonids were not present in the samples from any of the lakes. The five DV that were captured were also all adults or sub-adults. TSB were similar in size across the three lakes and were not aged.

3.6.3 Catch per unit effort (CPUE)

Catch in the RIC nets and numerical density varied by ±10% between lakes (Table 12). Variation in biomass density was much larger, ±50% and variation in effective density was ±25%.

Table 8. Types, timing and locations of gillnets set in each of the 4 lakes.

Lake name and number	Date In	Date Out	Set #	Net type	Net length (m)	Time in	Time Out	UTM Zone	Position at start of net	
									Easting	Northing
West, LAK023	07-Oct	08-Oct	1	RIC_Sink	91	1507	950	10	132,557	6,033,573
West, LAK023	07-Oct	08-Oct	2	Fine	9	1509	1012	10	132,709	6,033,575
West, LAK023	07-Oct	08-Oct	3	Fine	9	1519	1025	10	132,616	6,033,350
West, LAK023	07-Oct	08-Oct	4	RIC_Sink	91	1540	1040	10	132,671	6,033,330
West, LAK023	10-Oct	11-Oct	5	RIC_Sink	91	1247	1154	10	132,639	6,033,700
Big End Lake, LAK006	08-Oct	09-Oct	1	RIC_Sink	91	1445	945	10	135,179	6,065,615
Big End Lake, LAK006	08-Oct	09-Oct	2	Fine	9	1455	1000	10	135,200	6,065,652
Big End Lake, LAK006	08-Oct	09-Oct	3	Fine	9	1457	1015	10	135,254	6,065,702
Big End Lake, LAK006	08-Oct	09-Oct	4	RIC_Sink	91	1505	1030	10	135,147	6,065,468
Little End Lake, LAK012	09-Oct	10-Oct	1	Fine	9	1315	958	10	135,430	6,065,299
Little End Lake, LAK012	09-Oct	10-Oct	2	RIC_Sink	91	1320	1003	10	135,162	6,065,272
Little End Lake, LAK012	09-Oct	10-Oct	3	RIC_Sink	91	1328	1038	10	135,066	6,065,068
Little End Lake, LAK012	09-Oct	10-Oct	4	Fine	9	1334	1105	10	135,125	6,065,045
Finlay Lake, LAK044	10-Oct	11-Oct	1	RIC_Sink	91	920	1625	10	135,059	6,065,998
Finlay Lake, LAK044	10-Oct	11-Oct	2	Fine	9	930	1634	10	135,193	6,065,962
Finlay Lake, LAK044	10-Oct	11-Oct	3	Fine	9	935	1640	10	135,105	6,065,884
Finlay Lake, LAK044	10-Oct	11-Oct	4	RIC_Sink	91	940	1700	10	135,154	6,064,009

Table 9. Fish catch by species and gillnet set for each of the study lakes.

Name, WB_ID, and Lake number	Net Type	Set #	Coastal Cutthroat Trout (CCT)	Coho Salmon (CO)	Dolly Varden Char (DV)	Threespine Stickeback (TSB)
West Lake, 00012KITR, LAK023	RIC	1		22		
	Fine	2		1		14
	Fine	3				11
	RIC	4		13		
	RIC	5		3		
Little End Lake 00144LKEL, LAK012	Fine	1		1		4
	RIC	2	7	10	1	
	RIC	3	4	10	3	
	Fine	4		1		3
End Lake 00146LKEL, LAK006	RIC	1	14	1	1	
	Fine	2				6
	Fine	3				23
	RIC	4	15	11		
Finlay Lake, 00737KLUM, LAK044	RIC	1	No fish caught			
	Fine	2	No fish caught			
	Fine	3	No fish caught			
	RIC	4	No fish caught			
		Total Number	40	73	5	61
		% of total	22%	40%	3%	33%

Figure 5. Two of the smaller coho from End Lake. Note obvious parr marks on the bottom fish.

Figure 6. Three large coho from West Lake. The middle fish is a mature male, the top and the bottom fishes are immature females. The measuring board is 30 cm in length.

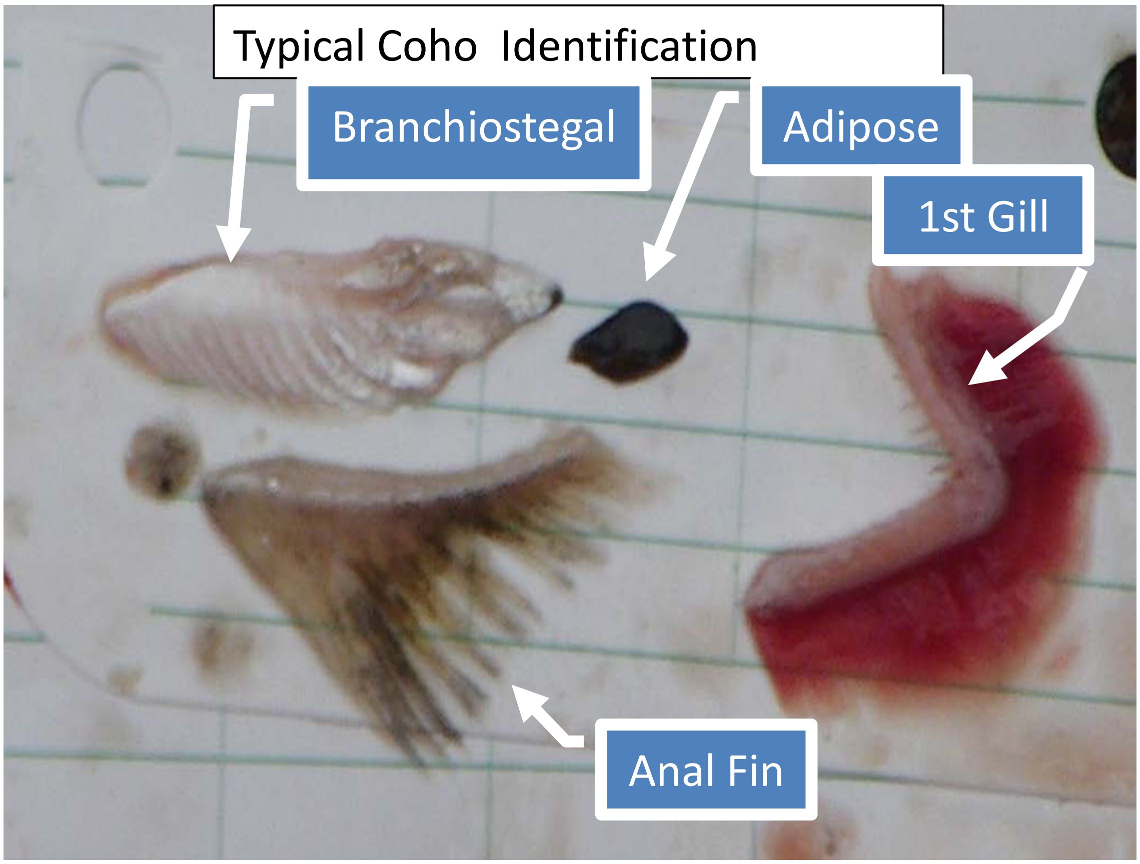

Figure 7. Typical identification structures from a coho from End Lake. Note the heavily pigmented adipose fin, short gillrakers, long anal fin with short leading edge and the low branchiostegal ray count.

Figure 8. The single mature female coho salmon, which was from West Lake. Note the short, widely spaced gillrakers that are just visible under the operculum.

Table 10. Average size and weights of each fish species in each lake.

Fish species	Lake name	N	Average length (mm)	Standard deviation of length (mm)	Minimum length (mm)	Maximum length (mm)	Average weight (g)	Standard deviation of weight (g)
CCT	End	29	321	51.7	252	518	505	341.5
	Little End	11	291	43.2	237	385	300	183.3
CO	End	12	183	41.7	121	265	76	45.0
	Little End	22	206	44.7	119	310	103	53.9
	West	42	267	49.8	193	362	224	122.4
DV	End	1	270		270	270	228	
	Little End	4	252	40.1	198	290	200	109.8
TSB	End	29	56	4.5	50	67	Not measured	
	Little End	7	62	4.1	57	68	Not measured	
	West	25	63	7.9	49	76	Not measured	

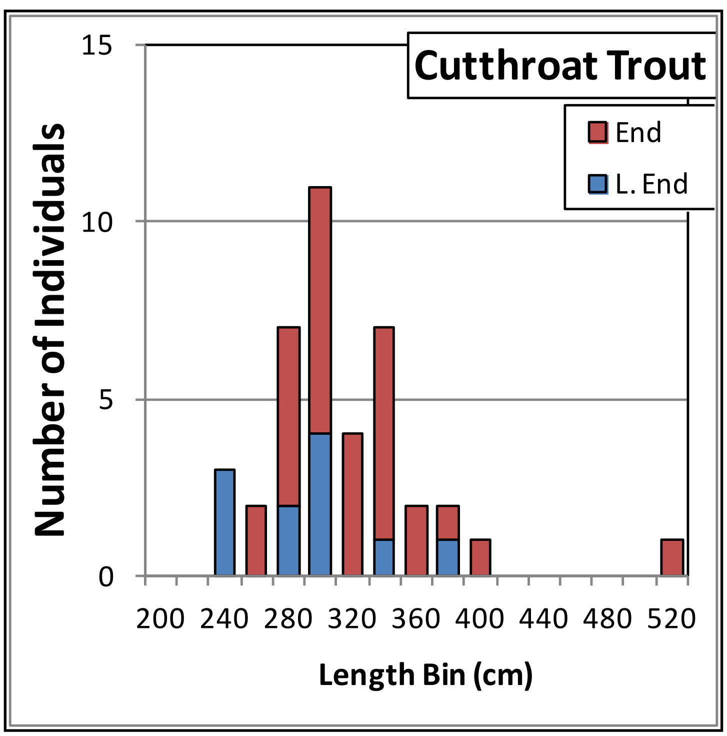

Figure 9. Length frequency distribution of CCT in End and Little End lakes. No CCT <200 mm were captured. No CCT were captured in West Lake.

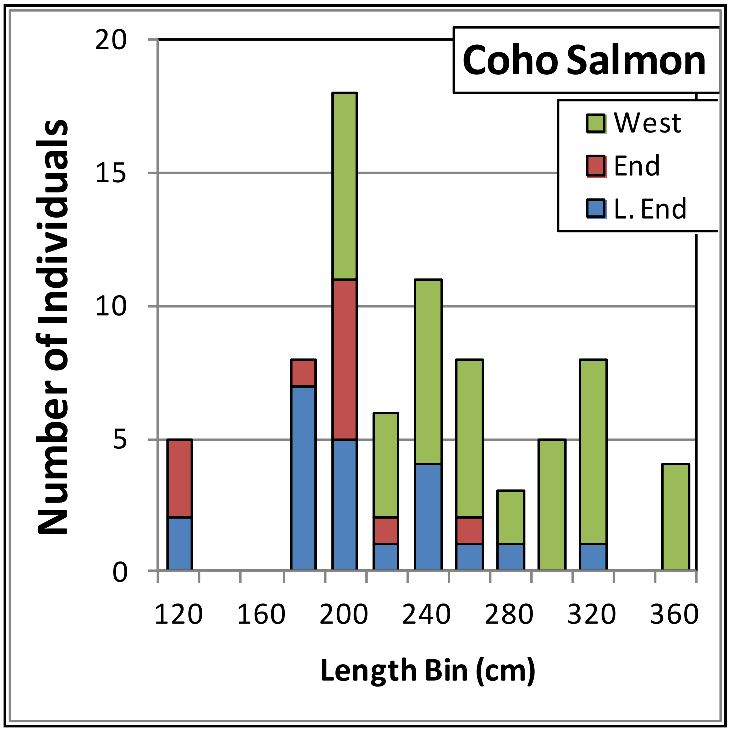

Figure 10. Length frequency distribution of CO in West, End and Little End lakes. No coho <119 mm were captured.

Table 11. Length and weight at age of salmonids in each lake.

Name WB_ID	Fish species	Age	N	Average length (mm)	Standard deviation of length (mm)	Minimum length (mm)	Maximum length (mm)	Average weight (g)	Standard deviation of weight (g)
West (LAK023)	CO	1+	2	203	14.1	193	213	94.7	16.1
		2+	15	225	21.9	195	258	127.5	35.9
		3+	10	258	29.7	198	302	187.3	61.9
		4+	10	326	20.8	302	362	366.4	71.2
		5+	5	314	22.7	290	351	355.4	99.9
Little End (LAK012)	CCT	1+	8	279	26.5	237	305	239.1	101.0
		2+	1	245		245	245	185.0	
		3+	2	359	37.5	332	385	602.0	198.0
	CO	0+	2	120	0.7	119	120	43.2	33.7
		1+	11	193	16.0	178	230	76.8	19.1
		2+	8	232	29.6	191	278	136.1	42.4
		3+	1	310		310	310	245.0	
	DV	NA	4	252	40.1	198	290	200.3	109.8
Big End (LAK006)	CCT	1+	2	280	16.3	268	291	254.5	41.7
		2+	16	311	33.2	252	380	412.1	168.4
		3+	10	325	39.2	273	395	558.6	221.0
		4+	1	518		518	518	1956.0	
	CO	0+	1	121		121	121	20.6	
		1+	8	176	33.0	123	213	64.5	27.6
		2+	2	200	6.4	195	204	92.3	3.0
		3+	1	265		265	265	187.0	

Name WB_ID	Fish species	Age	N	Average length (mm)	Standard deviation of length (mm)	Minimum length (mm)	Maximum length (mm)	Average weight (g)	Standard deviation of weight (g)
	DV	NA	1	270		270	270	228.0	

Table 12. Estimates of fish density for West Lake, End Lake, and Little End Lake. Methods for calculating density are from Ward et al. (2012). Modeling growth and survival using effective density is discussed in Walters and Post (1993) and Parkinson et al. (2004).

Name	Little End Lake	Big End Lake	West Lake	Average
Lake#	LAK012	LAK006	LAK023	
WB_ID	00144LKEL	00146LKEL	00012KITR	
Area (ha)	2.3	10.2	6.8	
Catch	35	42	38	
Q_{max}	0.209	0.047	0.071	
Total population estimate	167	890	537	
Average weight (g)	173	376	227	258
Average length^2(cm^2)	591	845	741	726
Numerical density (fish·ha^{-1})	73	87	79	80
Biomass density (kg·ha^{-1})	12.6	32.8	17.9	21.1
Effective density (cm^2·ha^{-1})	42,945	73,686	58,463	58,364

4 DISCUSSION AND CONCLUSIONS

4.1 Water Chemistry

Data from 2013 were appended to those from 2012 (ESSA et al. 2013a) to provide an up to date compilation of chemical and other descriptive information to be used to update calculations of CL in 2014. Those calculations will be run by ESSA Technologies. This process of continuous updates to a single database will be essential for purposes of review, analysis, and reporting over time.

The following findings from the 2013 water sampling are important for defining ongoing procedures within the EEMP:

1. Procedures for the collection and analysis of water samples were acceptable. Contamination of some samples was detected but it was 13 to 250 times less than analyte concentrations in the samples. Such low level contamination will not affect interpretations of the chemical data and can be expected in even the cleanest of procedures in the field. Precision was high among analytes from all samples except iron in water passed through the fractionation column. Cause of this anomaly is unknown. It potentially can be avoided in the future by taking due care and attention to fractionation procedures in the field. Most important is that a slow and constant pressure be applied to the syringe used to pass water through

the fractionation column. The rate guideline is 5 mL per minute. Percent recovery in the laboratories was excellent, showing high accuracy of procedures at each of ALS and Trent University labs. No sample bottle effects were found on measurement of base cations, which shows that standard polyethylene bottles can continue to be used for the collection and shipment of water samples.

2. pH will be a critical measurement in lakes as part of the ongoing EEMP because it will be used as a criterion to determine need for more intensive monitoring than is occurring at present and it will contribute to decisions on need for mitigation of acidification . No effect of sample holding time on pH was found. While degassing of CO_2 from sample water can occur and shift pH upwards, the attention to ensuring no air space in sample bottles and keeping the samples cool avoided these degassing effects in 2013. There was no difference in pH measurement between labs at the within-lab level of precision. At best, precision on pH measurement at a lab is 0.2 pH units. This value is close to the amount of change that is being applied as a threshold for implementing more intensive monitoring and decisions about mitigation within the EEMP (0.3 pH units, ESSA et al. 2013b). It is recommended that a power analysis be run to determine the number of samples that must be collected from a given lake or group of lakes to determine if a 0.3 pH change has occurred in future samples at a given probability level and precision of 0.2 pH units.
3. Anomalous readings from the field pH meter in 2013 showed the importance of having redundancy built into the annual water sampling activities. The field data were backed up with redundant measurements in the lab. It is recommended that pH continue to be measured in the field and labs and that pH sensors be less than 3 months old. If there is uncertainty about sensor age, it should be replaced as a precaution to avoid slow response time that can introduce uncertainty into pH values. Daily calibration with fresh standards is a basic requirement among all measurements.

4.2 Fish

The presence of large coho salmon that have not migrated to the ocean is the most unusual aspect of the fish fauna in these lakes. Coho rearing in lakes as age-0+ is relatively common, but their size in the fall is rarely >100mm and most emigrate to the ocean as age-1+ smolts (Irvine and Johnston 1992). The coho salmon in these lakes appear to resemble other lake-rearing age-0+ coho, which have duller fin colors and a less falcate anal fin than their stream-rearing counterparts (Swain and Holtby 1989). Stream rearing coho were also more aggressive, which is consistent with their brighter display coloration.

The mature coho were all from West Lake and only one of these fish was a female. Non-anadromous coho salmon populations are common in the Great Lakes (Rand and Stewart 1998), which indicates that there is no physiological reason that coho salmon must migrate to the ocean to mature. Maturation of non-andromous chinook males is common (e.g. Johnson et al. 2012), but observations of non-anadromous coho maturation within their native range are rare. DNA samples from scales will be used to confirm the identification of these fish.

The absence of age-0+ CCT and CO is puzzling. Previous experience suggests that rainbow trout >50 mm are vulnerable to the fine mesh nets (Askey et al. 2007) and their absence suggests that they may spend the first year or two in tributary streams. However, these lakes are at the edge of a flat gravel plateau where streams are noticeably absent in air photos and the 1:20,000 provincial watershed atlas. All three lakes have outlet streams and the outlet of West Lake has a second order tributary that enters just below the lake. However, access in and out of these lakes may be limited by drought or beaver dams, which raises the possibility that some species in some of the lakes may not be present in all years.

Dolly Varden char in End Lake and Little End Lake are the only species that may be difficult to detect, or confirm the absence of, in future sampling. Only 5 out of 79 (6%) salmonids were DV, which suggests that the total adult population in the two lakes is well under 100 fish. However, if the number observed is a Poisson variable and the probability of observing zero fish in a future sample is also a Poisson variable, then the joint probability of observing zero fish is only 0.04. This probability can be lowered to close to zero if a doubling in sampling effort is triggered by the observation of zero fish in a future sample.

The large size of age-1+ CTT, combined with typical size at age-3+ CTT in Table 11 suggests that the age-1+ size at age is an anomaly. Average size at age 2 (equivalent to 1+) of CCT did not exceed 200 mm in 8 coastal lakes in southern BC (Nilsson and Northcote 1981) but it was 279 mm and 280 mm in Little End and Big End Lakes respectively. Similarly, rainbow trout from 2 strains that were stocked into a very productive, southern-interior lake at 5-7 g (~85 mm) , reached a maximum average size 233 mm at age- 1+ (Hume and Tsumura 1992). Age-1+ trout in two less productive lakes both averaged <200 mm. One likely cause of this anomaly is the inability to detect the first annulus, which is a common problem with aging salmonids from western North America (Lentsch and Griffith 1987).

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6 APPENDIX A: STANDARD FIELD SHEET FOR RTA WATER SAMPLING

Rio Tinto Alcan SO2 Permit Study-Water Component 2013: Field Data Sheet (Site ID________________)

A: Location

Lake or Stream Name		Site ID (eg.lak053):
Date:	Time on station:	Time off station:
Field crew:		
GPS Unit #	Elevation on GPS receiver (m)	
Northing	Easting	

Was a water sample collected from this site? ☐ Y ☐ N
If No, give reasons for not sampling:

Lake Photos
field sheet ☐ facing north ☐ facing south ☐ facing east ☐ facing west ☐ aerial view ☐
Other ______________________ ☐

Stream Photos
field sheet ☐ upstream ☐ downstream ☐ across site ☐ aerial view ☐
Other ______________________ ☐

B: Weather

Now: ☐ storm (heavy rain) **Past 24 hours:** ☐ storm (heavy rain)
☐ rain (steady rain) ☐ rain (steady rain)
☐ showers (intermittent) ☐ showers
(intermittent)
☐ overcast ☐ overcast
☐ clear/ sunny ☐ clear/ sunny

Has there been a heavy rain in the past 7 days? ☐ Y ☐ N

C. Riparian Vegetation (estimate the % of each type, totaling 100%)

Unvegetated (bare soil or bedrock)	%	Deciduous Forest (trees >5m tall)	%
Grasses/Ferns/Herbs	%	Coniferous Forest	%
Shrub (may include grasses/herbs growing beneath	%	wetland	%

D. Lake Site Description

Water depth at sampling station (m):	Instrument used for depth measurement :
Water sampling depth: Surface grab ☐	Other (m):

E. Water Quality

Field Measurements

Make and model of Sonde	Depth of sample collection (m)	Water Temperature (°C)	pH	Spec. Conductance (µS/cm)	D.O. (mg/L)	Turbidity (NTU)	TDS (mg/L)
YSI model 6920							

Water Samples (check the box once sample is collected on board the helicopter):

☐ 500 mL poly for Teflon vials (vial 1 receives fractionated sample, vial 2 receives bulk sample) and backup sample water

☐ 250 mL poly bulk sample for Trent

☐ 250 mL amber glass for NH_4-N to be preserved with acid and sent to ALS

☐ 500 mL for NO_3-N and sent to ALS

F. Stream Channel Characteristics

1. Stream Clarity: ☐ Glacial ☐ Clear ☐ Stained ☐ Other________________________

2. Stream Bankfull Widths (measure wetted width and channel width at 3 different locations within the 6x bankfull using Google Earth)

Position at site	Bankfull Width (m)
Downstream	
Middle	
Upstream	
Average	

G. Stream Substrate Characteristics

1. % Composition (**estimate %** composition of each substrate type within the reach – Wentworth Scale)

_____sand (<2mm)	_____gravel	_____pebble (2-4mm)	_____cobble (4mm-6cm)	_____boulder (6-26cm)	_____bedrock (>26cm)

H. Stream Disturbance Indicators: (USEPA Habitat Assessment Info)

Indicate the presence of the following disturbance indicators at the site:

1. Bed Characteristics

☐ Extensive areas of scour ☐ Extensive areas of (unvegetated) bar
☐ Large extensive sediment wedges ☐ Elevated mid-channel bars
☐ Extensive riffle zones ☐ Limited pool frequency and extent

2. Channel Pattern

☐ Multiple channels (braiding)

3. Banks

☐ Eroding banks ☐ Isolated side channels or backchannels

4. Large Woody Structure

☐ Most parallel to banks ☐ Recently formed jams

5. Odours (indicate the presence of the following in the substrate)

☐ None ☐ Sewage ☐ Petroleum ☐ Anaerobic (H_2S) ☐ Chemical
☐ Other____

I. Land Use

1. **Predominant Surrounding Land Use** (consider what is visible from the sample site, or known/suspected to be occurring upstream; tick all that apply)

☐ Forest (undisturbed)	☐ Field / Pasture	☐ Urban
☐ Recreational (Park)	☐ Cut-Block Logging	☐ Agriculture
☐ Rural Residential	☐ Other	☐ Selective Logging
☐ Mining	☐ Commercial / Industrial	(describe):

2. Erosion (visible at sample site)

☐ Heavy ☐ None
☐ Moderate
☐ Light

3. **Local Watershed NPS Pollution**

☐ Obvious sources
☐ Some potential sources
☐ No evidence
Possible Sources (if present):

2014 Vegetation Inspection, Monitoring and Assessment Program

2014 Annual Report

Prepared for:
Rio Tinto Alcan
PO Box 1800, 1 Smeltersite Road,
Kitimat, BC V8C 2H2

Prepared by:
Stantec Consulting Ltd.
4623 Park Ave.,
Terrace, BC V8G 1V5

March 20, 2015

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Stantec

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Executive Summary

The Vegetation Inspection, Monitoring and Assessment Program is an assessment of air emissions from industrial processes at Rio Tinto Alcan's (RTA) Kitimat Operations. This program has been conducted annually for 45 years. Gaseous air emissions from RTA Kitimat Operations are dispersed across the landscape according to prevailing winds, thereby exposing receptors to gaseous fluoride and sulphur dioxide emissions. Chemical analysis for fluoride and sulphur in the foliage of a bioindicator vegetation species, western hemlock (*Tsuga heterophylla*), is an indicator of the dispersion of air emissions within the Kitimat Valley and airshed (the study area).

Stantec Consulting Ltd. (Stantec) was retained by RTA to carry out the 2014 Vegetation Inspection, Monitoring and Assessment Program. Western hemlock foliage was collected from 38 pre-established sample sites and analyzed for fluoride and sulphur content. The field component was carried out from August 17 to 20, 2014, and lab samples were processed August 22 to September 10, 2014 and sent for analysis on September 11, 2014 to Rio Tinto Alcan Centre Analytique (Vaudreuil). Laboratory results were received on November 21, 2014.

The 2014 average gaseous fluoride emission rate was 2.21 kilograms of gaseous fluoride per tonne of aluminum produced (kg F_g/tonne Al). The lowest emissions were recorded in November, at 1.58 kg F_g/tonne Al, and the highest in August at 2.56 kg F_g/tonne Al. The annual rate is 16% higher than the pre-2008 permit limit of 1.9 kg F_g/tonne Al, and 12% lower than the 2013 annual emissions rate of 2.5 kg F_g/tonne Al. A permit compliance threshold does not exist for emission rates post 2008. Compliance is currently measured by fluoride loading.

The 2014 annual average gaseous fluoride loadings were 24.3 tonnes of gaseous fluoride per month (tonnes F_g/month). The highest loadings were recorded in January and May, at 35.3 tonnes F_g/month and 32.9 tonnes F_g/month, respectively. The growing season average loading was 25.3 tonnes F_g/month. The growing season loading is 1% higher than the annual average monthly loading. The monthly gaseous fluoride loadings are in compliance with the permit limit of 50 tonnes Fg/month, with the annual average loading at 51% below the permit threshold.

The 2014 sulphur dioxide (SO_2) annual emission rate was 11.6 tonnes of SO_2/day. This is 17% below the 2013 rate of 13.9 tonnes of SO_2/day. The SO_2 emissions are in compliance with the permit limit of 27.0 tonnes of SO_2/day, and are 57% below the permit threshold.

The 2014 average foliar fluoride concentration in western hemlock was 28.9 parts-per-million (ppm), with a maximum of 98.0 ppm and a minimum of 14.0 ppm. The 2014 average concentration is 4% higher than the 2013 average foliar concentration of 27.8 ppm.

The 2014 average foliar sulphur concentration was 0.08%. This concentration is identical to the 2011 and 2013 concentrations of 0.08%.

Abbreviations

%	percent
Al	aluminum
F_g	gaseous fluoride
F-injury index	foliage injury index
FSR	Forest Service Road
g	gram
GPS	global positioning satellite
kg	kilogram
km	kilometer
m	metre
ppm	parts-per-million
RTA	Rio Tinto Alcan
SO_2	sulphur dioxide

1.0 INTRODUCTION

The Vegetation Inspection, Monitoring and Assessment Program is an annual assessment of air emissions from industrial processes at Rio Tinto Alcan's (RTA) Kitimat Operations. Chemical analysis for fluoride and sulphur in the foliage of western hemlock (*Tsuga heterophylla*) is used to determine the dispersion of air emissions within the Kitimat Valley and airshed (the study area).

1.1 RATIONALE

Gaseous air emissions from RTA Kitimat Operations are dispersed across the landscape according to prevailing winds, thereby exposing receptors to gaseous fluoride and sulphur dioxide emissions. With chronic exposure, these airborne contaminants can result in toxicity to exposed vegetation receptors. Fluoride can accumulate to toxic levels in leaves, resulting in chlorosis or foliar necrosis (death of leaf tissue), which leads to reduced plant growth and yield (Yu, Tsunoda, & Tsunoda, 2011). Chronic exposure to sulphur dioxide can also result in chlorosis or foliar necrosis, increased senescence (hardening), and may result in reduced growth and yield (World Health Organization, 2000).

1.2 PURPOSE AND OBJECTIVES

The purpose of the Vegetation Inspection, Monitoring and Assessment Program is to determine the dispersion of fluoride and sulphur dioxide air emissions using foliar fluoride and sulphur concentrations. The objectives of this program were to:

- Collect western hemlock foliage from 38 sample sites throughout the Kitimat Valley and analyze for fluoride and sulphur content
- Document the extent and severity of vegetation injury resulting from gaseous fluoride emissions
- Graphically correlate current and historical concentrations of fluoride and sulphur in western hemlock foliage to RTA Kitimat Operations' annual air emission rates (foliar fluoride analysis has occurred since 1970; foliar sulphur analysis since 1990)
- Estimate the extent of the dispersion of gaseous fluoride through an interpolated isoconcentration map
- Document areas unaffected by emissions from Kitimat Operations. As fluoride occurs naturally at low concentrations in vegetation, with background concentrations in plant tissues ranging from 2 to 20 ppm (Braen & Weinstein, 1984), the results of the analysis may identify areas which are outside the area of gaseous fluoride deposition.

1.3 EMISSIONS AT THE SOURCE

The major sources of emissions at the RTA Kitimat Operations smelter are the potroom roofs and exhaust stacks. The two main gaseous emissions monitored are fluoride and sulphur dioxide. Emission rates refer to the mass of pollutant emitted per unit of production. Emission loadings refer to the total mass of a pollutant emitted in a given time period. Emission rates and loading data of gaseous fluoride and loading data of sulphur dioxide from RTA (formerly Alcan) Kitimat Operations have been recorded since 1974 and 1990, respectively.

1.3.1 Multi-Media Permit

RTA Kitimat Operations holds a permit for multi-media emissions under the *Environmental Management Act*. This permit has undergone multiple amendments since its inception. This has affected the method of reporting air emissions from the site.

Prior to 2008, the permit for gaseous fluoride emissions was reported as an emission rate with a permit limit of 1.9 kilograms gaseous fluoride per tonne of aluminum (kg F_g/tonne Al). In 2008, a permit amendment was introduced changing the reporting method from emission rate to monthly emission loading. As of December 20, 2007, the monthly fluoride emission loading limit is 50 tonnes gaseous fluoride per month (tonnes F_g/month). However, for the purpose of this program, the pre-2008 permit limit is used to illustrate relative fluoride emissions over time and will be referred to as the "pre-2008 permit limit".

In 1999, the permit limit for sulphur dioxide emissions loading was increased from 20.7 to 27.0 tonnes of sulphur dioxide (SO_2) per day. The sulphur dioxide emissions loading limit was further increased on April 23, 2013 to 42.0 tonnes of SO_2 per day.

1.4 VEGETATION MONITORING PROGRAM

RTA Kitimat Operations initiated the Vegetation Inspection and Monitoring Program in 1970. The program consists of two parts: an annual collection of current-year western hemlock foliage from pre-established sample sites followed by fluoride and sulphur analysis of needle tissue and a biennial inspection of vegetation in the Kitimat area. The biennial inspection is a qualitative analysis documenting the visible effects of fluoride on vegetation and other factors that affected vegetation in the area (such as insect outbreaks, wind-throw, disease, and common lawn and garden problems). Since 2010, a quantitative assessment methodology has been used to document the extent of the symptoms related to foliage injury index (F-injury index). This index is based on the percentage of leaf area affected multiplied by the percentage of the plant affected. The biennial vegetation inspection was conducted by Dr. John Laurence, concurrently with the foliar sample collection, during the 2014 Vegetation Inspection and Monitoring Program.

1.4.1 Uptake of Airborne Contaminants

Vegetation uptakes gaseous fluoride and sulphur dioxide through stomata during the process of photosynthesis and associated transpiration of water. When plants are actively growing, during daylight hours and favourable moisture conditions, gaseous fluoride accumulates in the leaf with carbon dioxide. There it enters the transpiration stream and accumulates in leaf tissue. The plant cannot metabolize gaseous fluoride. Thus, the biology of the plant and the process of photosynthesis allows the plant to become vulnerable to gaseous fluoride accumulation during a large portion of the growing season; however, when conditions are unfavourable to plant growth (at night or during drought), stomata remain closed and minimal gaseous fluoride is absorbed.

Vegetation also varies in the uptake of gaseous air emissions over the course of the growing season, which is typically described as beginning in May and ending in September. At the beginning of the growing season uptake begins slowly. Maximum uptake occurs as leaves reach maturity and continues until the photosynthetic rate drops in preparation for winter. The leaves begin to senesce (harden) in fall, and both photosynthesis and uptake of gaseous fluoride slow until cessation.

1.4.2 Bioindicator: Western Hemlock

Bioindicators, or biological indicators, are processes, species or communities used to monitor the health of an environment or ecosystem (Holt & Miller, 2011). For the purposes of this program, a bioindicator vegetation species was used to determine the concentration of gaseous air emissions uptaken during the growing season. This method provides a low-tech, inexpensive system for monitoring air emissions.

Western hemlock was chosen as the bioindicator species for this program as it grows ubiquitously throughout the study area and is indicative of air emission concentrations at various distances from the emission source. Western hemlock trees accumulate gaseous fluoride when they are actively growing throughout the growing season. Therefore, the fluoride content in the new (current year) growth of western hemlock tissue provides a representation, or indicator, of biological integration of the ecosystem from exposure to gaseous fluoride and sulphur.

2.0 METHODOLOGY

2.1 SOURCE EMISSION MONITORING

The rate and loading of gaseous fluoride and loading of sulphur dioxide emissions from the RTA smelter site have been monitored and reported by RTA or Alcan since 1974 and 1990 respectively. Fluoride emissions are monitored at six locations on four representative potroom buildings using cassette sampling technology (total of 24 gaseous fluoride monitoring stations). Sulphur dioxide emissions are determined using mass balance calculations.

As discussed in Section 1.3.1, in 2008, the multi-media emissions permit limit changed from 1.9 kg F_g/tonne Al to 50 tonnes F_g/month. To illustrate relative fluoride emissions over time, the pre-2008 permit limit and the current permit limit are both reported graphically in the results below.

In 1999, the permit limit for sulphur dioxide emissions loading was increased from 20.7 to 27.0 tonnes of sulphur dioxide (SO_2) per day. The sulphur dioxide emissions loading limit was further increased on April 23, 2013 to 42.0 tonnes of SO_2 per day.

These permit limits are shown graphically in the results below.

2.2 VEGETATION MONITORING PROGRAM

The vegetation monitoring program commenced in 1970. Foliar fluoride analysis has occurred since 1970; sulphur analysis since 1990. Results of foliar fluoride analysis have been graphically correlated to fluoride emission data from the smelter site. As available emissions data begins in 1974, these results are presented from 1974 to present. Sulphur dioxide emission data and foliar sulphur analysis are presented graphically from 1990 to present.

2.2.1 Study Area

The 2014 Vegetation Inspection and Monitoring Program study area includes 38 annual sample sites located throughout the Kitimat Valley and north to the Lakelse Lake area in British Columbia. These pre-determined sample site locations were historically selected by Alcan to determine the concentration gradient of fluoride and sulphur in western hemlock radiating outward from the source. Locations of the 38 sample sites are presented in Figure 1.

2.2.2 Sample Collection

Sample sites were located using a GPS receiver and satellite imagery base maps. Each sample tree has been marked in previous years with a metal tree tag to facilitate locating the precise site. At each site approximately 10 to 12 boughs were collected from two to three western hemlock trees. Hand and pole pruners were used to cut boughs ranging from 1 to 5 m above the ground on each tree. Selected boughs were specifically targeted to maximize the amount of current year's growth collected. The boughs (the sample) were then placed on a tarpaulin and photographed. Each sample was put into a large paper bag, sealed, and labelled with the site number, date and time.

Sample collection occurred on August 17, 18, 19, and 20, 2014. All samples were refrigerated in paper collection bags until processed. Sample site coordinates and site information are provided in Appendix A.

At each site, photos of the samples, sample tree, sampler, and four cardinal directions were collected to record signs of fluoride injury or insect defoliation, and to document the general condition of the surrounding landscape. Appendix B contains site photos and general site observations.

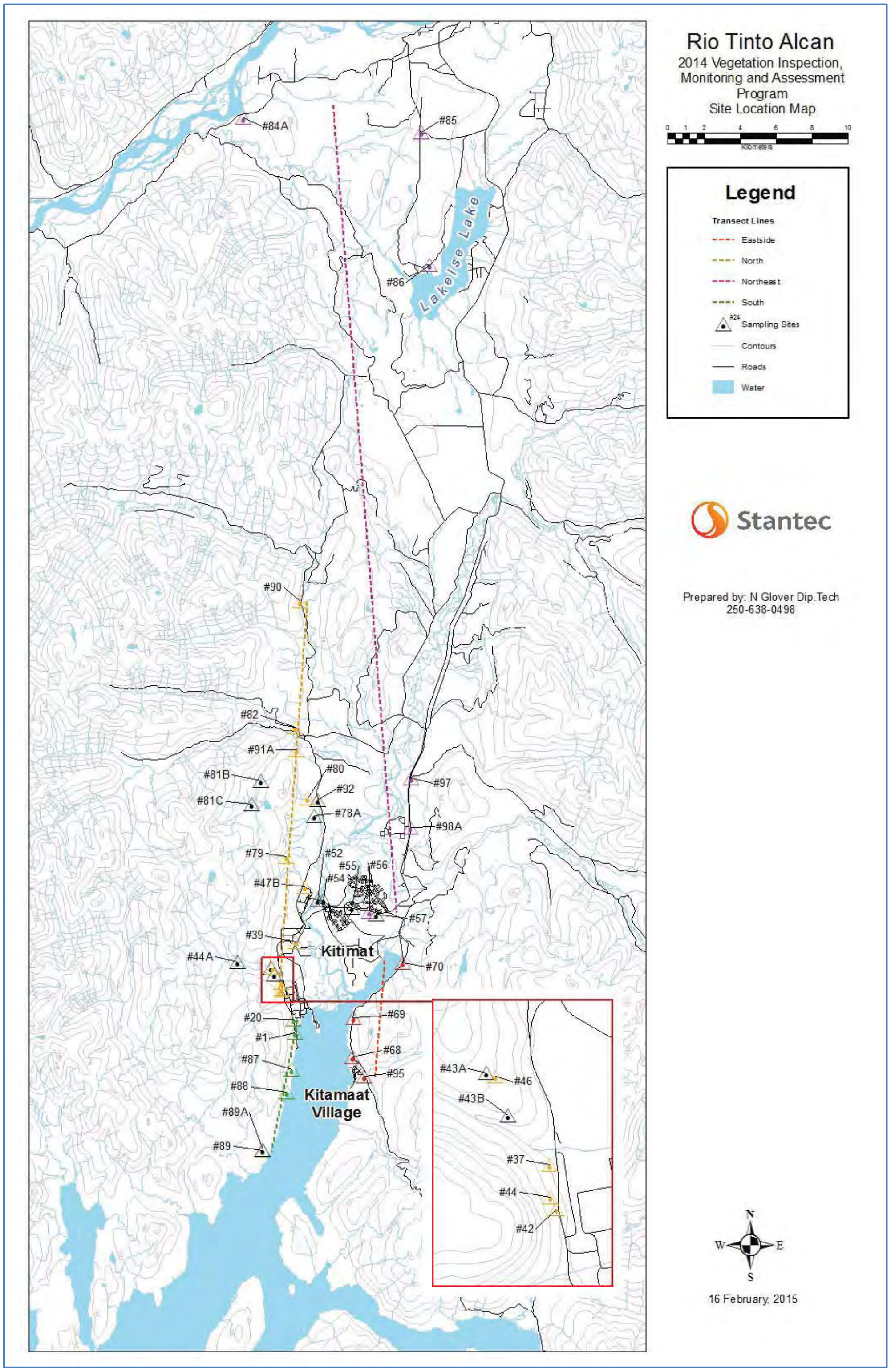

Figure 1 2014 Sample Site Locations and Transects

Modifications to the 2014 sample program include moving Site 46 across the road from its current location due to a lack of boughs to sample from.

2.2.3 Transects

Four transects were established in 2010 to assess the change in fluoride and sulphur concentration in western hemlock at varying distances from the RTA Kitimat Operations smelter site. These transects are:

- East Transect, located on the east side of the Douglas Channel between the Kitimat town site and Kitamaat Village
- North Transect, located between the Kitimat town site and north of Lakelse Lake
- Northeast Transect, located between the RTA smelter site north to a location on the Wedeene Forest Service Road (FSR)
- South Transect, located between the RTA smelter site south to a site near Bish Cove

Transects and sample site locations are shown in Figure 1.

2.2.4 Sample Processing

The processing component of sample preparation began in the lab with clipping the present year's annual growth (ends of the boughs) and placing them into a labelled glass dish. The sample was then desiccated in a commercial drying oven at temperatures of 95–105°F for approximately 24 hours. Each sample was weighed before and after desiccation; wet and dry weights were recorded.

Samples were then sorted to remove stems and the needles were ground into a fine powder using a standard coffee grinder. Each powdered sample was divided in two parts: a 10 g portion to be sent for laboratory analysis, and the remainder (approximately 15 g portion) to be retained by Stantec. Each sample portion was placed into a small Ziploc bag and labelled with site number, date and time collected; date processed, and sample portion weight. The sample processing occurred from August 22 to September 10, 2014.

A total of 38 samples in10 g sample portions were sent to the RTA Centre Analytique (Vaudreuil) in Jonquiere, Quebec on September 11, 2014. 38 samples portions of approximately 15 g portions were retained at the Stantec office as a contingency.

Each of the 10 g sample portions were analyzed for fluoride (ppm) and sulphur (%) concentration. These results were received from the laboratory on November 21, 2014.

2.2.5 Isoconcentration Map

The concentration of fluoride (ppm) in western hemlock was used to develop an isoconcentration map. Each sample site was assigned to a zone, depicted by the different coloured isopleths, based on the fluoride concentration in the foliage. Isopleths connecting sites in the same range were interpolated, and the area within each isopleth was assigned a color, as follows:

- Yellow: moderate, 60.1 ppm to 100 ppm
- Yellow-Green: moderate-low, 30.1 ppm to 60 ppm
- Green: low, 10.1 ppm to 30 ppm
- No color: background concentrations, ≤10 ppm

3.0 RESULTS AND DISCUSSION

3.1 SOURCE EMISSION RATES AND LOADINGS

Emissions rates and loadings have been provided by RTA. Gaseous fluoride emission data are available from 1974 to present; sulphur dioxide emission data are available from 1990 to present.

3.1.1 Fluoride Emissions

Figure 2 presents the 2014 monthly F_g emission rates in kilograms per tonne of aluminum compared to the pre-2008 permit limit.

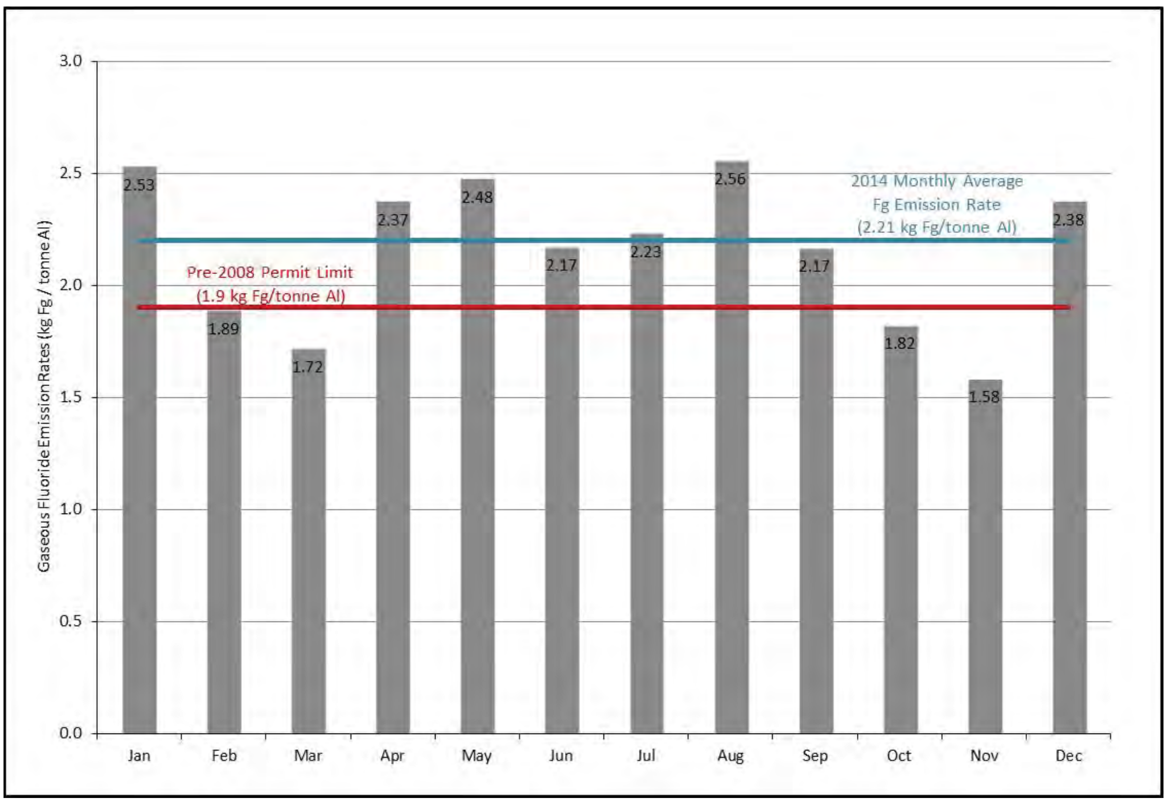

Figure 2 2014 Monthly Fluoride Emission Rates

The gaseous fluoride emission rate for 2014 averaged 2.21 kg F_g/tonne Al produced. This is 16% higher than the pre-2008 permit limit and 12% lower than the 2013 average emission rate of 2.5 kg F_g/tonne Al produced.

Figure 3 presents the 2014 monthly gaseous fluoride (Fg) emission loadings in tonnes per month compared to the current permit limit. It also presents the average gaseous fluoride loadings during the growing season, from May to September 2014.

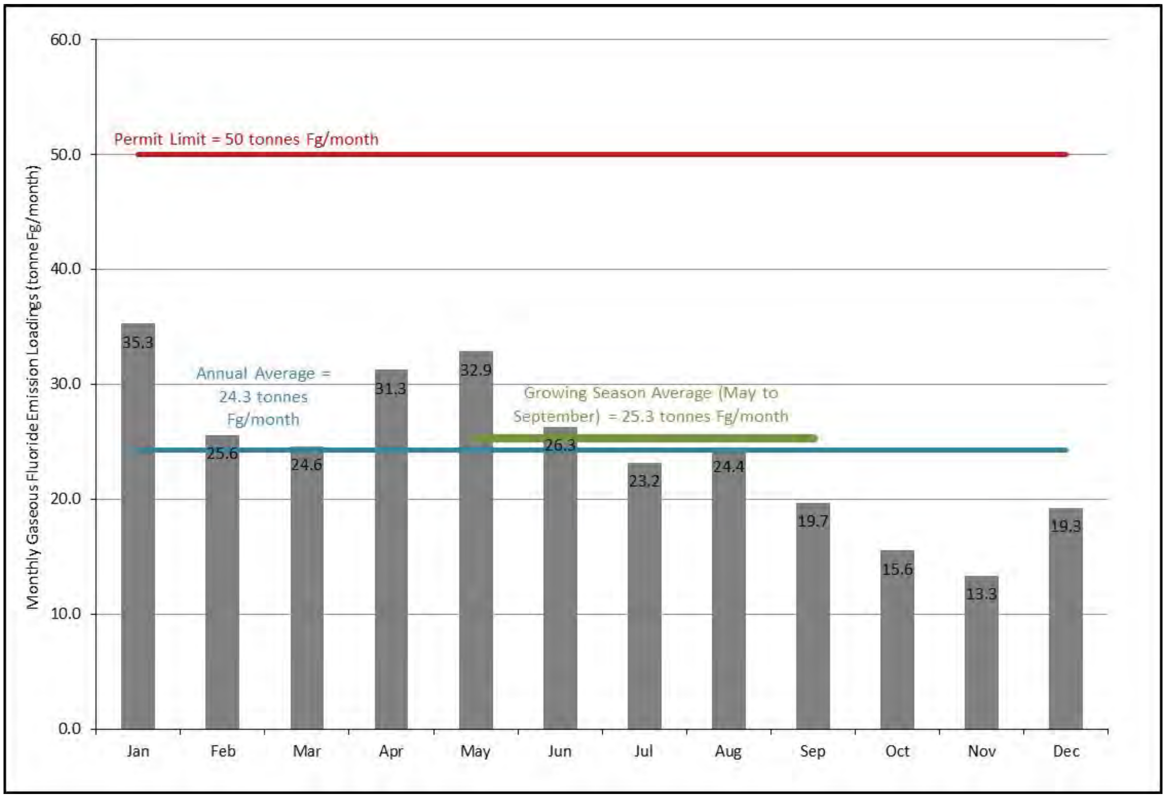

Figure 3 2014 Monthly Fluoride Emission Loadings

The 2014 monthly Fg loadings did not exceed the permit limit during the year. The two highest monthly loadings in 2014 occurred in January and May (35.3 and 32.9 tonnes of Fg). These two peaks are lower than the highest months in 2013, which occurred in September and November, each at 45.1 tonnes of Fg.

Throughout the months of the growing season (May to September) the average loading of 25.3 tonnes Fg/month was 38% lower than the 2013 annual average of 41.0 tonnes of Fg/month of the growing season.

The total annual loading in 2014 was 291.5 tonnes of Fg. The 2014 total annual Fg loading was 35% lower than the 2013 annual loading of 453.7 tonnes of Fg.

Figure 4 presents historical fluoride emission data from 1974 to 2014 relative to the pre-2008 permit limit.

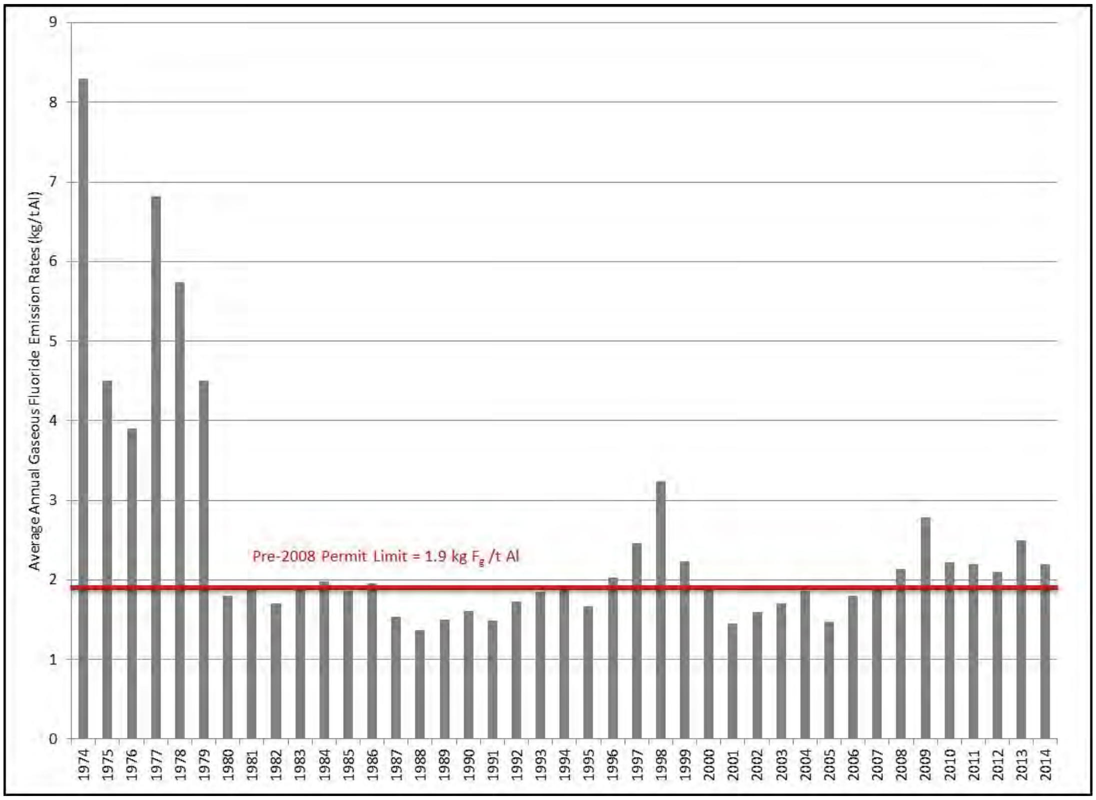

Figure 4 Historic Average Annual Gaseous Fluoride Emissions, 1974 to 2014

Forty-one years of historical data presents the trend in gaseous fluoride emission rates. Between 1980–1995 and 2000–2007, the average Fg emissions were equal to or less than the pre-2008 limit. However, between 1997 and 1999 and from 2008 to present, emissions exceeded this limit, with a high recorded in 1998 at 3.3 kg Fg/tonne Al. The 2014 emission rate exceeded the pre-2008 permit limit; however, the 2014 emission loading was below the current permit limit of 50 tonnes of Fg/month.

3.1.2 Sulphur Dioxide Emissions

The Sulphur dioxide (SO_2) limit was increased to 42.0 tonnes of SO_2 per day (SO_2/day) on April 23, 2013. The previous limits were 20.7 tonnes of SO_2/day from 1990 to 1999 and 27.0 tonnes of SO_2/ day from 2000 to 2013. Figure 5 presents the sulphur emissions for the last 25 years compared to the pre- and post-1999 and 2013 permit limits changes.

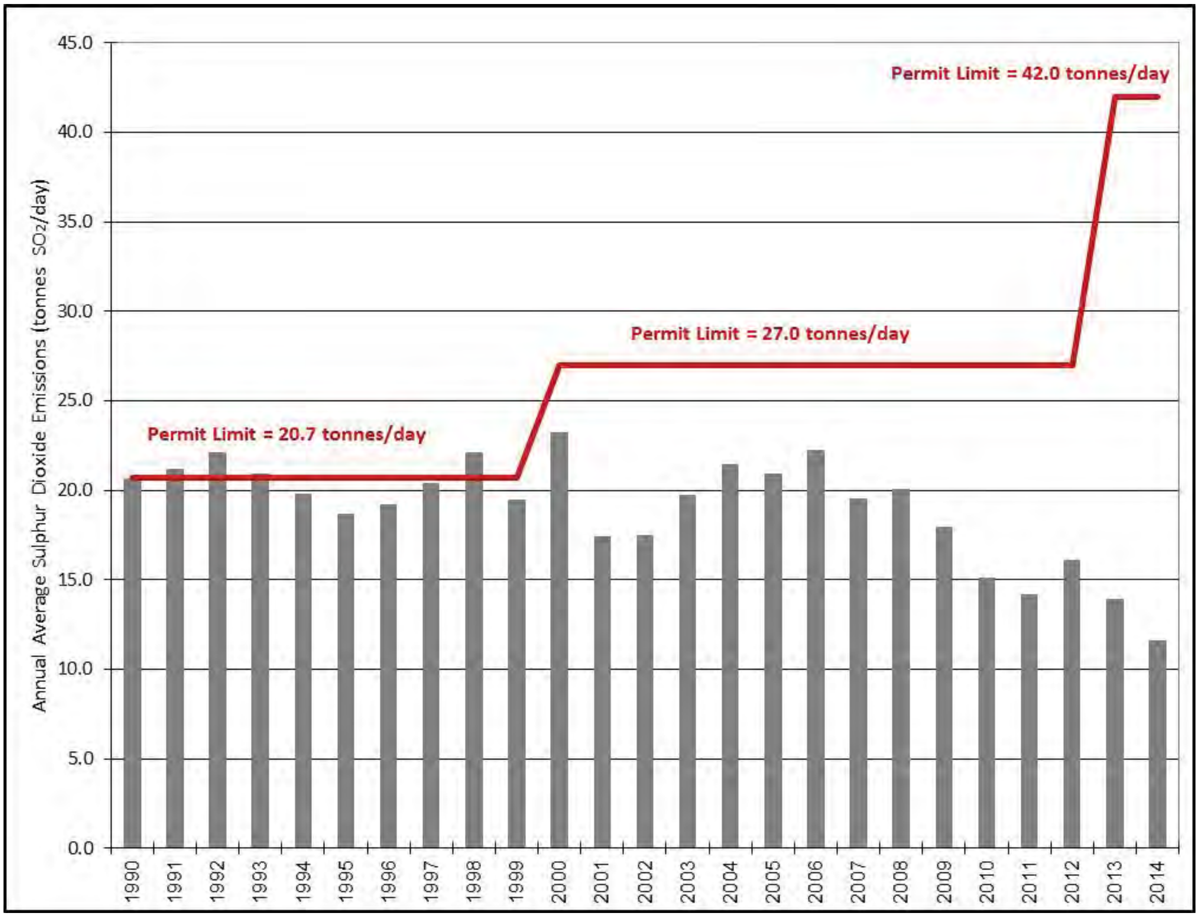

Figure 5 Historic Average Daily Sulphur Dioxide Emissions, 1990–2014

Sulphur dioxide emissions in 2014 averaged 11.6 tonnes/day, 17% lower than the 2013 average of 13.9 tonnes/day. Sulphur dioxide emissions have declined in recent years from a high of 23.3 tonnes/day in 2000. The 2014 emissions are 57% lower than the permit limit of 27.0 tonnes/day.

3.2 FOLIAR FLUORIDE AND SULPHUR

Results of chemical analysis of foliar fluoride and sulphur are available from 1970 and 1990 respectively. These data are graphically correlated to RTA emission rates in Figure 6 and Figure 7. As gaseous fluoride emission data are only available from 1974 to present, foliar fluoride results for 1970 to 1973 have been omitted from Figure 6. The current and historical results of foliar concentrations recorded at each of the 38 sample sites are presented in Appendix C.

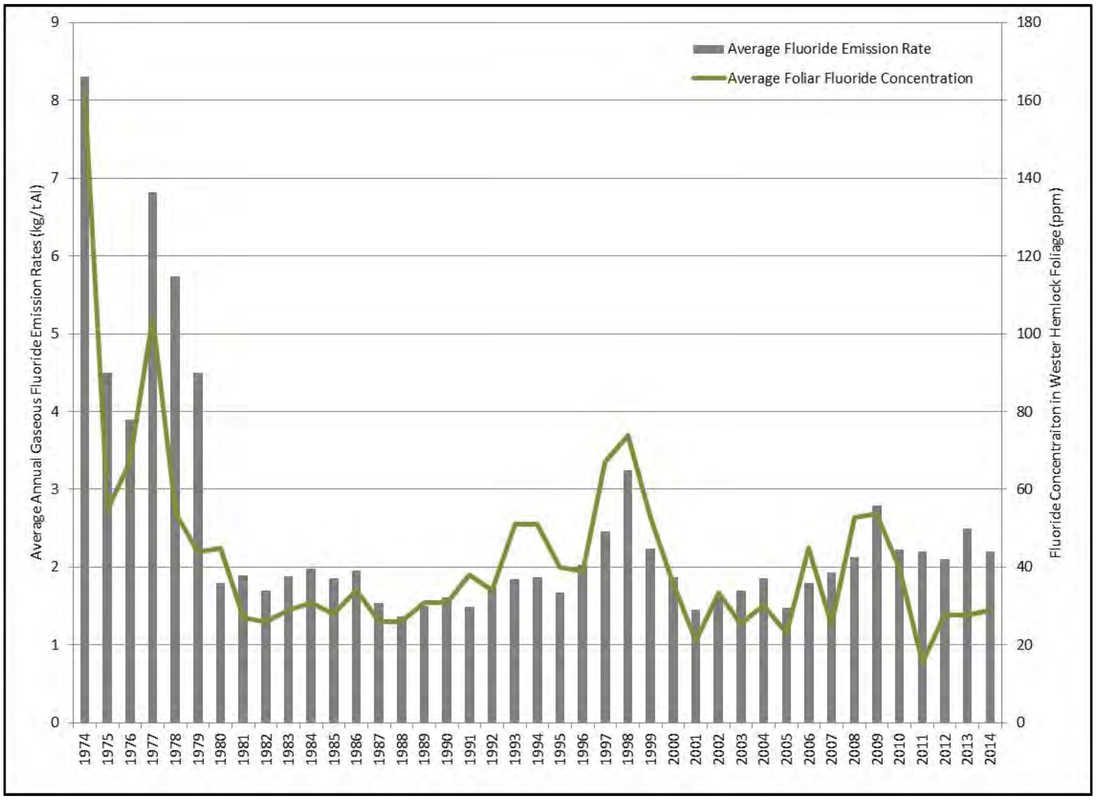

Figure 6 Gaseous Fluoride Emissions and Concentration of Foliar Fluoride, 1974–2014

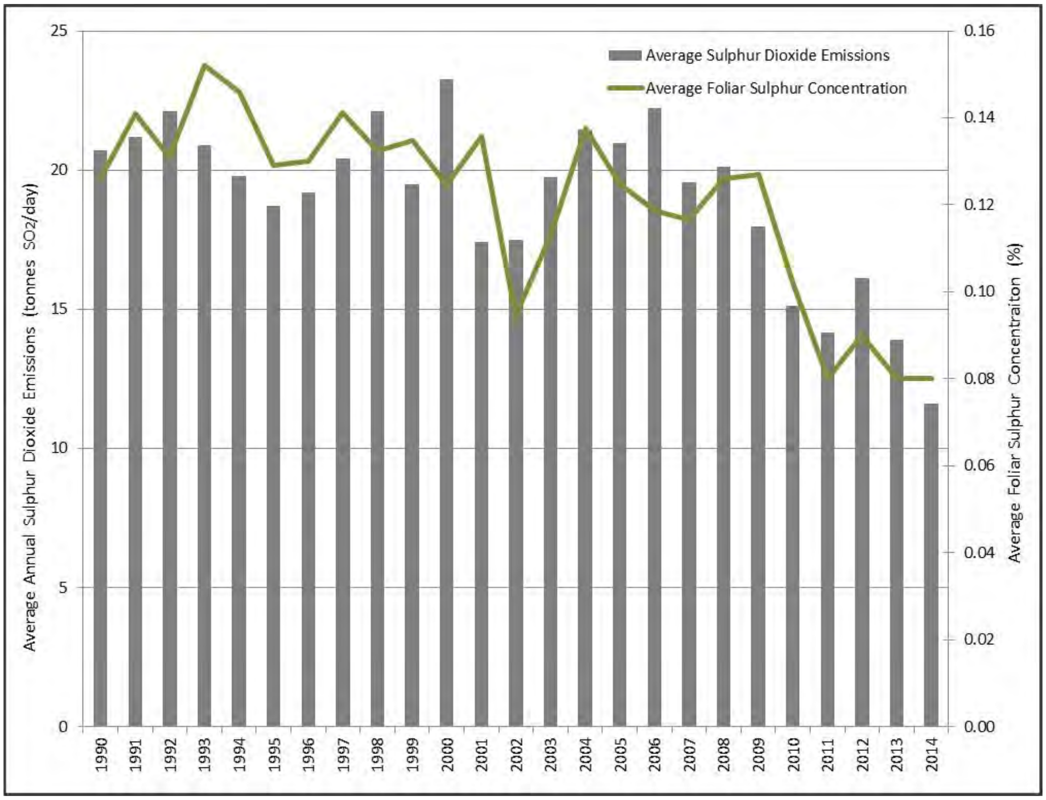

Figure 7 Sulphur Dioxide Emissions and Concentration of Sulphur in Western Hemlock, 1990–2014

3.2.1 Laboratory Results

The results of foliar analysis of fluoride and sulphur in western hemlock for the 38 sites sampled in 2014 are presented in Table 1. The analysis report provided by RTA Centre Analytique (Vaudreuil) is presented in Appendix D. Historical results of laboratory analysis of western hemlock (1974–2014) are presented graphically in Appendix C.

Table 1 2014 Results of Foliar Analysis of Fluoride and Sulphur in Western Hemlock

Site Number	Fluoride (ppm)	Sulphur (%)
1	22.0	0.07
20	23.0	0.06
37	81.9	0.12
39	50.9	0.10
42	42.0	0.09

Table 1 2014 Results of Foliar Analysis of Fluoride and Sulphur in Western Hemlock

Site Number	Fluoride (ppm)	Sulphur (%)
43A	53.9	0.11
43B	98.0	0.14
44	84.9	0.11
44A	27.0	0.12
46	30.0	0.08
47B	34.9	0.09
52	16.0	0.05
54	17.0	0.05
55	20.0	0.06
56	21.0	0.07
57	16.0	0.05
68	17.0	0.06
69	21.0	0.05
70	14.0	0.06
78A	25.0	0.09
79	18.0	0.08
80	22.0	0.10
81B	18.0	0.07
81C	21.0	0.09
82	16.0	0.08
84A	20.0	0.07
85	35.0	0.05
86	18.0	0.06
87	24.0	0.09
88	21.0	0.12
89	45.0	0.11
89A	24.0	0.11
90	17.0	0.06
91A	16.0	0.08
92	20.0	0.11
95	18.0	0.07
97	15.0	0.06
98A	14.0	0.07

Table 1 2014 Results of Foliar Analysis of Fluoride and Sulphur in Western Hemlock

Site Number	Fluoride (ppm)	Sulphur (%)
Total Plots	38.0	38.00
Mean	28.9	0.08
Median	21.0	0.08
Minimum	14.0	0.05
Maximum	98.0	0.14
Standard Deviation	20.3	0.02

3.2.2 Field Results

It was observed that the condition of western hemlock and surrounding vegetation during the sample collection program varied at each site. The vegetation at sites located within close proximity to the smelter site (within 1 to 2 km) appeared not to be thriving, with some specimens in poor condition. Stress on hemlock vegetation included needle necrosis, chlorosis, and insect infestation. Needle necrosis was observed as hemlock boughs which had shed, or were carrying dead chloratic needles. Chlorosis was observed on many hemlock trees in varying proximities from the smelter site, characterized by boughs with chloratic needles turning red. Chlorisis was often noted on the under branches, or near the tips of the boughs. Insect infestation by a scale insect, which was also found on some of the sample clippings, was observed at sites 37, 42, 52 and 88. These sites are all found close to the smelter site, (within 2 km), with the exception of site 52, which is just outside of the high fluoride concentration plume of 30.1 to 100 ppm (Figure 8).

Stresses on other vegetation observed during collection include conically-shaped cedar trees displaying inhibited growth patterns, predation of *Rhibes spp.* by defoliating insects, leaf rusts on false azalea, *Pinus contorta* with chloratic needle tips, *Alnus rubra* with signs of leaf predation, *Salex spp.* with brown curled leaves, and encroachment from invasive and exotic shrub and grass species. Exotic and invasive species observed include *Teraxacum spp.*, *Sonchus spp.*, and *Dactylis glomerata* being prevalent at many sites found adjacent to disturbed areas or roads.

Appendix B contains photographs and field observations recorded at each sample site during the 2014 field sampling program.

No sample collection issues were encountered during the 2014 sampling program. One site, 46, was moved approximately 10 m, due to lack of sufficient boughs to sample from (over sampling).

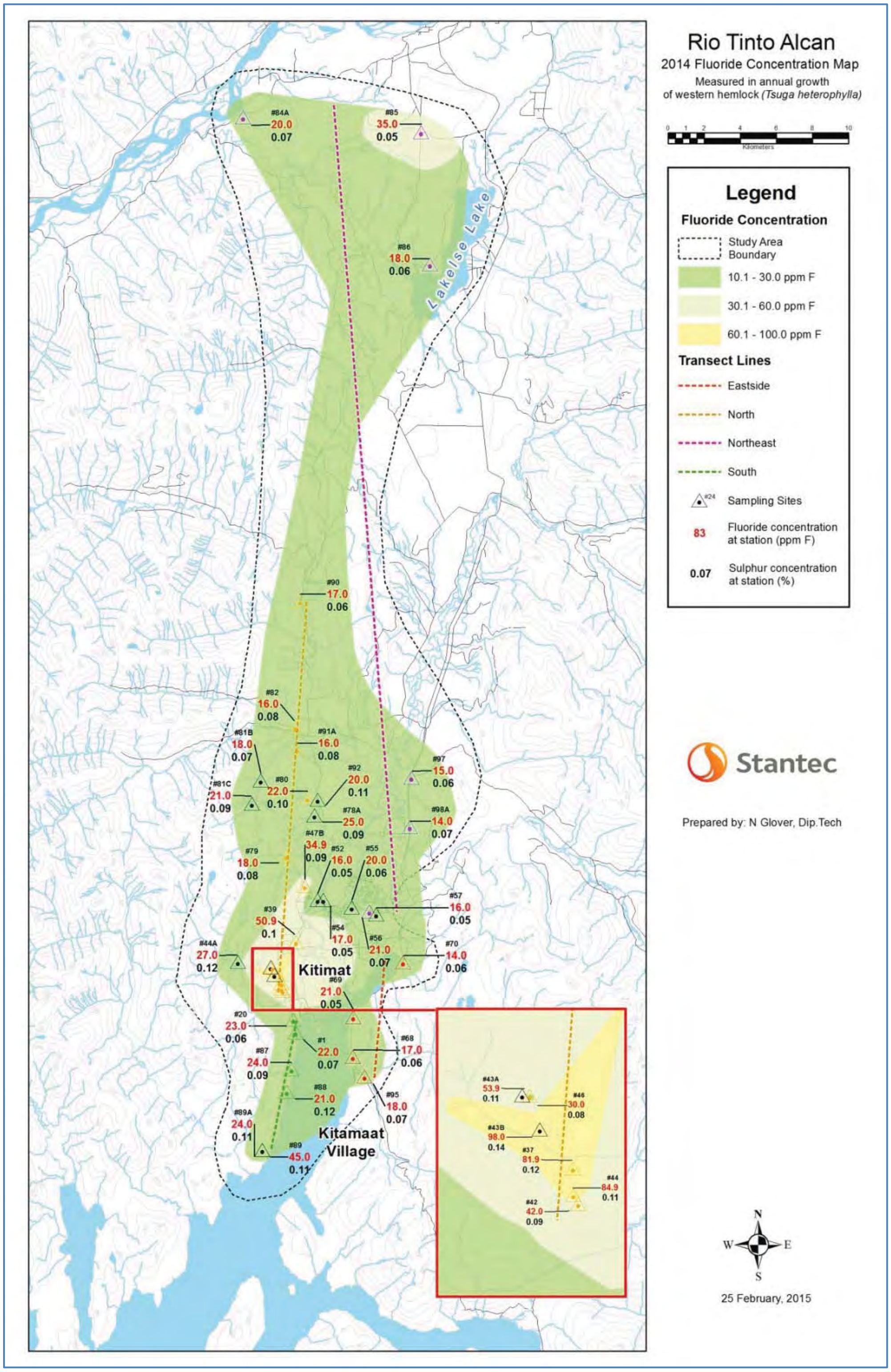

Figure 8 2014 Fluoride Isoconcentration Map

Stantec

3.2.3 Foliar Fluoride

Figure 6 illustrates the foliar fluoride concentration in western hemlock compared to smelter fluoride emission rates over a 41-year period (1974 to 2014).

The 2014 average concentration of fluoride in western hemlock was 28.9 ppm. This average concentration is 4% higher than the 2013 average of 27.8 ppm. The foliar fluoride concentrations ranged from a minimum of 14.0 ppm at sites 70 and 98A, to a maximum of 98.0 ppm at site 43B.

The foliar concentrations were highest at three samples sites located within close proximity to the smelter site. Sites 43B, 44, and 37 had concentrations of 98, 84.9 and 81.9 ppm respectively. These three sites are located within 1 to 2 km northwest of the smelter site, and are directly downwind of the prevailing wind direction. Site 42, located approximately 100 m south of the smelter site, upwind from the prevailing winds, had a much lower concentration of 42 ppm.

3.2.4 Foliar Sulphur

Figure 7 illustrates the foliar sulphur concentration in western hemlock compared to smelter sulphur dioxide emissions over a 25 year period (1990 to 2014).

The average foliar sulphur concentration in 2014 was 0.08%. This is equal to the 2011 and 2013 average of 0.08%, and is the lowest level on record. Foliar sulphur concentrations in 2014 ranged from a minimum of 0.05% at sites 52, 54, 57, 69, and 85, to a maximum of 0.14% at site 43B.

3.2.5 Fluoride Isoconcentration Map

The geographic distribution of fluoride in western hemlock foliage (foliar fluoride) is presented in parts-per-million on the fluoride isoconcentration map in Figure 8. Figure 8 also presents foliar sulphur concentrations at each site, but does not depict sulphur concentration isobars.

This map shows the range of accumulated foliar fluoride at sample plots, and extrapolated between sample plots, with colour-coded polygons representing concentration ranges. Elevation, alpine and de-vegetated areas have not been factored in.

The concentration levels of fluoride recorded in 2014 are as follows:

- High fluoride concentrations (>100 ppm) were not documented in 2014.
- Moderate fluoride concentrations (60.1 ppm to 100 ppm) were measured at three sample sites: 37, 43B and 44.
- Moderate-low fluoride concentrations (30.1 ppm to 60 ppm) were measured at six sites: 39, 42, 43A, 47, 85 and 89. This zone includes an outlier in the northern most extent of the map, near Lakelse Lake (Site 85).
- Low fluoride concentrations (10.1 ppm to 30 ppm) were measured at 29 sample sites: 1, 20,44A, 46, 52, 54, 55, 56, 57, 68, 69, 70, 78A, 79, 80, 81B, 81C, 82, 84A, 86, 87, 88, 89A, 90, 91A, 92, 95, 97and 98A. This zone includes the residential areas of Kitimat (Sites 54 and 87).