RioTinto

Sulphur Dioxide
Environmental Effects Monitoring

For the BC Works Kitimat Aluminum Smelter

SUMMARY TERMS OF REFERENCE FOR THE
2019 COMPREHENSIVE REVIEW

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ABBREVIATIONS

AQO   Air Quality Objective

CAAQS   Canadian Ambient Air Quality Standards

CCME   Canadian Council of Ministers of the Environment

EEM   Environmental Effects Monitoring

KAEEA   Kitimat Airshed Emissions Effects Assessment

KPI   Key Performance Indicator

NADP   National Atmospheric Deposition Program

QA/QC   Quality assurance / quality control.

QPs   Qualified Professionals (for the SO_2 EEM Program and authors of the STAR report)

SO_2 EEM   Rio Tinto BC Works' SO_2 Environmental Effects Monitoring Program

STAR   Sulphur Dioxide Technical Assessment Report

ABOUT THE TERMS OF REFERENCE FOR THE 2019 COMPREHENSIVE REVIEW

The 2014 Sulphur Dioxide (SO_2) Environmental Effects Monitoring (EEM) Program for the BC Works Kitimat aluminum smelter provides for a Comprehensive Review in 2019, on the activities and findings of the EEM Program from 2013 to 2018.

As required under the EEM, the monitoring program is defined and conducted by qualified professionals (QPs) who are experts in the fields of the monitoring programs. The QPs are responsible for conducting and reporting on the Comprehensive Review.

The Detailed Terms of Reference for the 2019 Comprehensive Review has been prepared by the QPs to define the expectations for data gathering and analysis for each monitoring program, and the way the results will be communicated in the Comprehensive Review report. The Detailed Terms of Reference document sets out an outline for the Comprehensive Review analyses and report, and a draft schedule for the Comprehensive Review tasks. The Detailed Terms of Reference can be found on our website[1].

SUMMARY OF TERMS OF REFERENCE FOR THE 2019 COMPREHENSIVE REVIEW

This Summary of the Terms of Reference presents an overview of the outline for the full Comprehensive Review report that is set out by the QPs in the Detailed Terms of Reference. It also provides a brief overview of each program and a map of the monitoring sites of each program.

GENERAL SPECIFICATIONS FOR COMPREHENSIVE REVIEW CONTENT AND REPORT

The EEM Program involves monitoring the effects of SO_2 on four receptors: human health, vegetation, terrestrial ecosystems (soils) and aquatic ecosystems (lakes, streams and aquatic biota). The receptor monitoring programs are supported with airshed modelling and monitoring activities under the atmospheric pathways program; these provide information on where SO_2 moves within the Kitimat airshed, and on the concentrations of SO_2 gas and acidic deposition within the area under different emission scenarios and weather conditions. Each program is conducted by a QP or team of QPs, in accordance with the methods and standards of the relevant scientific field.

As specified in the Terms of Reference, the Comprehensive Review report will begin with an overall summary of the key results for each receptor, in terms of two sets of criteria:

- Whether any key performance indicators (KPIs) were reached or exceeded, and any action that was taken in response
    - an impact that does not exceed the KPI threshold for a facility-based mitigation is assessed as acceptable, while an exceedance of the KPI associated with a facility-based mitigation threshold is deemed unacceptable.
- The questions in the STAR or EEM that have been answered and those that remain to be answered, as well as any new questions that emerged in the course of monitoring activities.

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1   https://www.riotinto.com/documents/2019_BCWorks_SO2_environmental_effects_monitoring_program_terms_of_reference.pdf

The QPs will present the monitoring results for each receptor in greater detail, under four main headings:

- What did we set out to learn?
- What methods did we use?
- What did we learn, and did we make any adjustments to the EEM Program?
- What do we recommend for the EEM going forward?

Finally, the report will bring together all lines of evidence to describe a holistic understanding of the overall effects of SO_2 emissions from the modernized smelter on human health and the environment.

There are many technical terms used in the full Terms of Reference and in the EEM and the STAR, which are associated with the assessment and monitoring activities that are discussed in those reports. A glossary has been developed that defines these key terms and explains important scientific concepts.

The glossary is found at the end of this document, and the terms that are included in it are highlighted when they appear in the text.

REVIEW RESULTS FOR ATMOSPHERIC PATHWAYS

SUMMARY OF THE ATMOSPHERIC PATHWAYS PROGRAM

The atmospheric pathways program focuses on two types of study results: atmospheric SO_2 concentrations, and wet and dry atmospheric sulphur deposition. These studies use a combination of modelling and monitoring methods, and the results support the monitoring programs on human health and on vegetation, terrestrial ecosystems, and aquatic ecosystems.

Air dispersion modelling uses the CALPUFF model, a computer tool that forecasts the concentrations of SO_2 and deposition rates of total sulphur throughout the airshed from industrial emission sources. This model contains a grid that defines where ground level concentrations are calculated and represented by the tool, as well as weather conditions using local and regional meteorological data.

Continuous and passive SO_2 atmospheric monitoring measures concentrations of SO_2 in the air through a network of stations. The SO_2 atmospheric concentration monitoring stations at Riverlodge, Whitesail, and Kitamaat Village are used to evaluate levels relative to the human health KPI. The network also provides information on the distribution of SO_2 and related deposition rates on vegetation, soils and water throughout the study region. The locations of the different types of SO_2 air monitoring stations are shown in the map on page 11. The three residential air monitoring stations are shown on the map on page 13.

REVIEW RESULTS FOR THE ATMOSPHERIC PATHWAYS PROGRAM

The Terms of Reference provides separate directions for reporting on atmospheric concentrations and atmospheric deposition.

Atmospheric Concentrations

What did we set out to learn?

In the Comprehensive Review report we will explain that the purpose of the atmospheric concentrations program is to determine if any KPI thresholds were reached and to understand the accuracy of the CALPUFF model.

We will review the questions and hypotheses from the STAR, which primarily concern how accurately CALPUFF predicted post-smelter modernization SO_2 concentrations and sulphur deposition. The STAR also asked about the deposition rate of base cations in the study region. These questions are associated with the informative indicators for atmospheric concentrations, which are atmospheric SO_2 concentrations, atmospheric sulphur deposition, and atmospheric base cation deposition. We will describe two new informative indicators, the contribution of particulate sulphate to dry sulphur deposition, and the contribution of dry sulphur deposition to total sulphur deposition.

What methods did we use?

We will describe all of the inputs and methods in an overview, and will place additional details in an appendix.

Modelling data used for CALPUFF will be described. Modelling analyses will compare modelled SO_2 concentrations with actual atmospheric concentrations observed at monitoring stations, and will also compare modelled wet and dry deposition results with deposition monitoring observations. We will refine modelling methods if predictions are not sufficiently aligned with monitoring results.

We will describe monitoring methods, including data collection from the continuous monitoring network, the passive sampler network, the wet deposition network, and particulate monitoring using filter packs.

In our analyses of monitoring data, we will report on the optimization of the continuous air quality monitoring network. We will also evaluate the SO_2 passive sampler results for 2016-2018 and the particulate sulphur filter pack results for 2017-2018. We will develop a framework for synthesizing passive sampler and particulate sulphate monitoring results, in order to develop an approach for spatial and temporal scaling for both programs if possible.

What did we learn, and did we make any adjustments to the EEM Program?

The Comprehensive Review report will explain general findings, including an overview of program results, a summary of what has been learned from them and any adjustments to modelling and monitoring methods, whether the questions from the EEM Plan have been answered, and whether new questions have emerged. We will also report on whether the SO_2 dispersion patterns that were predicted in the STAR for residential areas of Kitimat agree with measurements taken after the smelter modernization, and whether any changes to the monitoring network are recommended.

What do we recommend for the EEM Program going forward?

We will recommend any changes that are necessary to modelling methods and informative indicators, as well as to monitoring methods, including whether sufficient data are available on air quality south of the smelter.

Atmospheric Deposition

What did we set out to learn?
We will explain the questions and hypotheses from the STAR.

What methods did we use?
We will summarize all methods, and will describe data collected on rainfall chemistry by NADP stations.

We will analyze three main aspects of deposition data.

- Wet deposition results for Haul Road (2012- 2018) and Lakelse Lake (2013-2018). This evaluation will consider quality control of precipitation chemistry and other data; rainfall amounts and seasonal patterns in precipitation chemistry and deposition, and changes in these over time. We will compare monitoring data to results from the NADP station at Prince Rupert, and possibly beyond; produce weekly or monthly plots of sulphate deposition at the two locations; and assess base cation precipitation chemistry.

- The Big Leaf dry deposition model. We will describe the data requirements for this model for estimating dry deposition, the data sources, and the associated sensitivity and uncertainty of predictions for Kitimat and for Terrace Airport. The dry deposition velocity of SO_2 and particulate sulphate in Kitimat and Terrace will be compared.

- The dry deposition of SO_2 estimated by using SO_2 concentrations from passive samplers, and of particulate sulphate measured by filter packs. This evaluation will consist of summarizing average deposition velocity for SO_2 during the monthly passive sampler exposures periods, estimating the dry deposition during the monitoring periods, and assessing the relative importance of particulate deposition. We will evaluate total sulphur deposition at Haul Road and Lakelse Lake for the passive sampler monitoring periods, including wet sulphate deposition, dry SO_2 and dry particulate sulphate deposition.

What did we learn, and did we make any adjustments to the EEM Program?

We will provide an overview of the results and a summary of what was learned from them, noting any actions from the EEM that are incomplete, as well as questions from the EEM Plan that have been answered and any new ones that have emerged. Any changes to the informative indicators will also be noted.

Knowledge gained on a number of aspects of the program will be reported: these include the reliability of the passive samplers, variations over time and space of SO_2 and of total sulphur deposition, the contribution of dry deposition to total deposition, and the relative importance of particulate sulphate. We will describe knowledge that was gained from evaluations of modelled and observed atmospheric sulphur data.

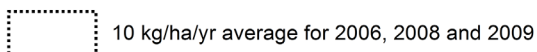## What do we recommend for the EEM Program going forward?

We will note any changes that we recommend to modelling methods and to informative indicators. In addition, any recommended changes to monitoring methods, frequency or extent will be described.

SO₂ MONITORING STATIONS

☆	Rio Tinto Site	——	Primary Road
⬚	Study Area	▭	Residential

SO₄ Deposition
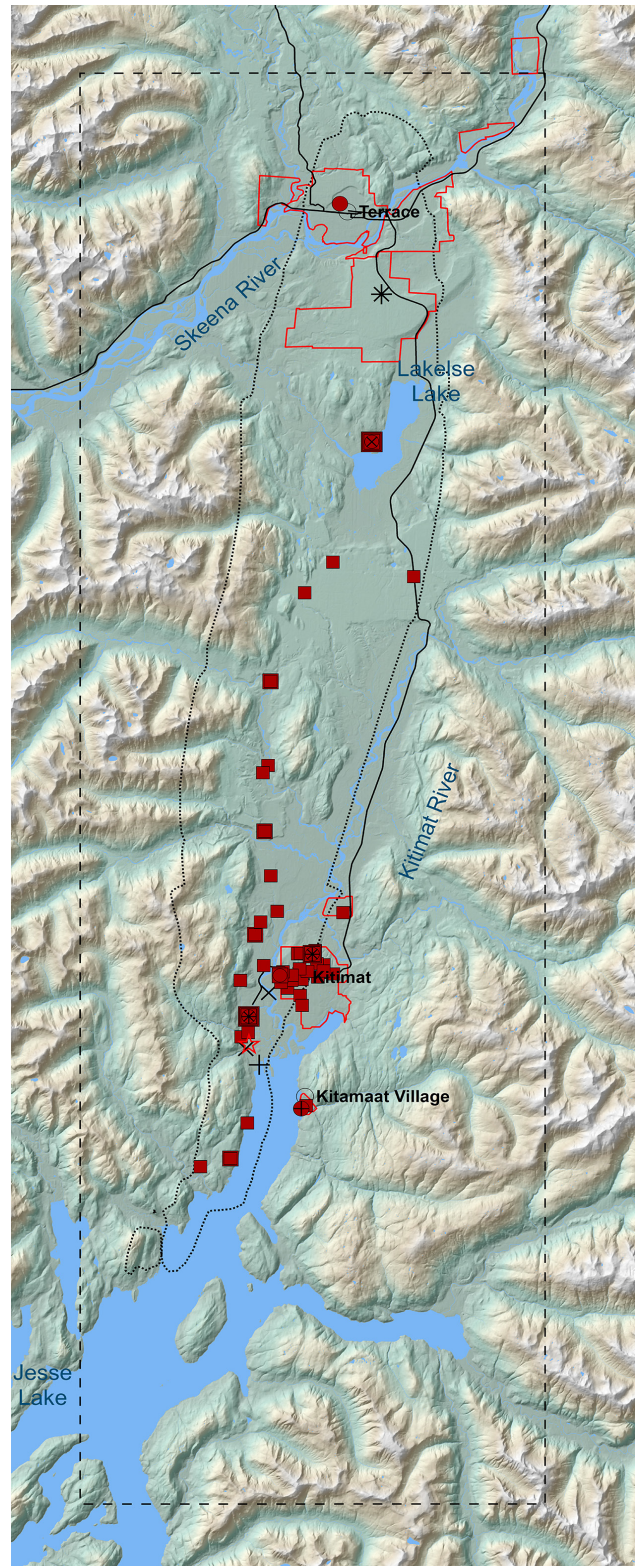
⬚ 10 kg/ha/yr average for 2006, 2008 and 2009

Atmospheric Pathway Monitoring Stations

■ SO₂ Passive Sampler Network

■ ... plus pSO₄-SO₂ Filter Pack Sampler Network

■ ... plus NADP Precipitation Chemistry Station

● Continuous SO₂ Analyzer

Meteorological Stations

✕ Used for Dry Deposition Estimates

✚ Used in Atmospheric

✳ Used in Atmospheric Modeling and for Dry Deposition

Atmospheric monitoring sites

REVIEW RESULTS FOR HUMAN HEALTH

SUMMARY OF THE HUMAN HEALTH MONITORING PROGRAM

The human health monitoring program involved monitoring SO_2 concentrations in the air and comparing them to the current KPI of 75 parts per billion (ppb). This level represents British Columbia's 1-hour interim SO_2 air quality objective, which was adopted provincially in 2016. It will be in effect through 2019.

Beginning in 2020, the Province of British Columbia will apply the Canadian Ambient Air Quality Standards (CAAQS) for SO_2 levels. The CAAQS, published by the Canadian Council of Ministers of the Environment, were based on a Health Canada risk assessment that determined that exposure to SO_2 is a respiratory irritant for asthmatics. As exposure to SO_2 below the CAAQS level is unlikely to cause asthmatic symptoms, the use of the CAAQS threshold as the human health KPI will protect the sensitive group of asthmatics. The CAAQS set out a schedule for the adoption of increasingly stringent targets; when they take effect in 2020 the SO_2 threshold will be 70 ppb, and this will drop to 65 ppb in 2025.

The air quality monitoring network includes three monitoring stations in the residential sections of the Kitimat area – in Riverlodge, Whitesail and the Haisla Village station in Kitamaat Village – that are used to evaluate the human health KPI. These stations are shown on the map on page 13.

REVIEW RESULTS FOR HUMAN HEALTH

What did we set out to learn?

The Comprehensive Review report will explain that the goal of the human health monitoring program was to learn if any KPI thresholds were reached or exceeded. It will also review the questions and hypotheses from the STAR, and consider the monitoring needs that were identified in the STAR for addressing critical uncertainties.

What methods did we use?

In this section of the Comprehensive Review report we will provide an overview of the information and methods used for the analyses, with detailed explanations placed in an appendix.

We will describe planned analyses, including an evaluation of the KPI results for 2017-2018, with an explanation of the change in the KPI with the adoption of the CAAQS. Further analyses will also assess acceptable or unacceptable impacts to human health in that period.

Continuous SO_2 monitoring station

What did we learn, and did we make any adjustments to the EEM Program?

We will summarize the results of the monitoring program, as well as what has been learned from them about the health effects of SO_2 in Kitimat.
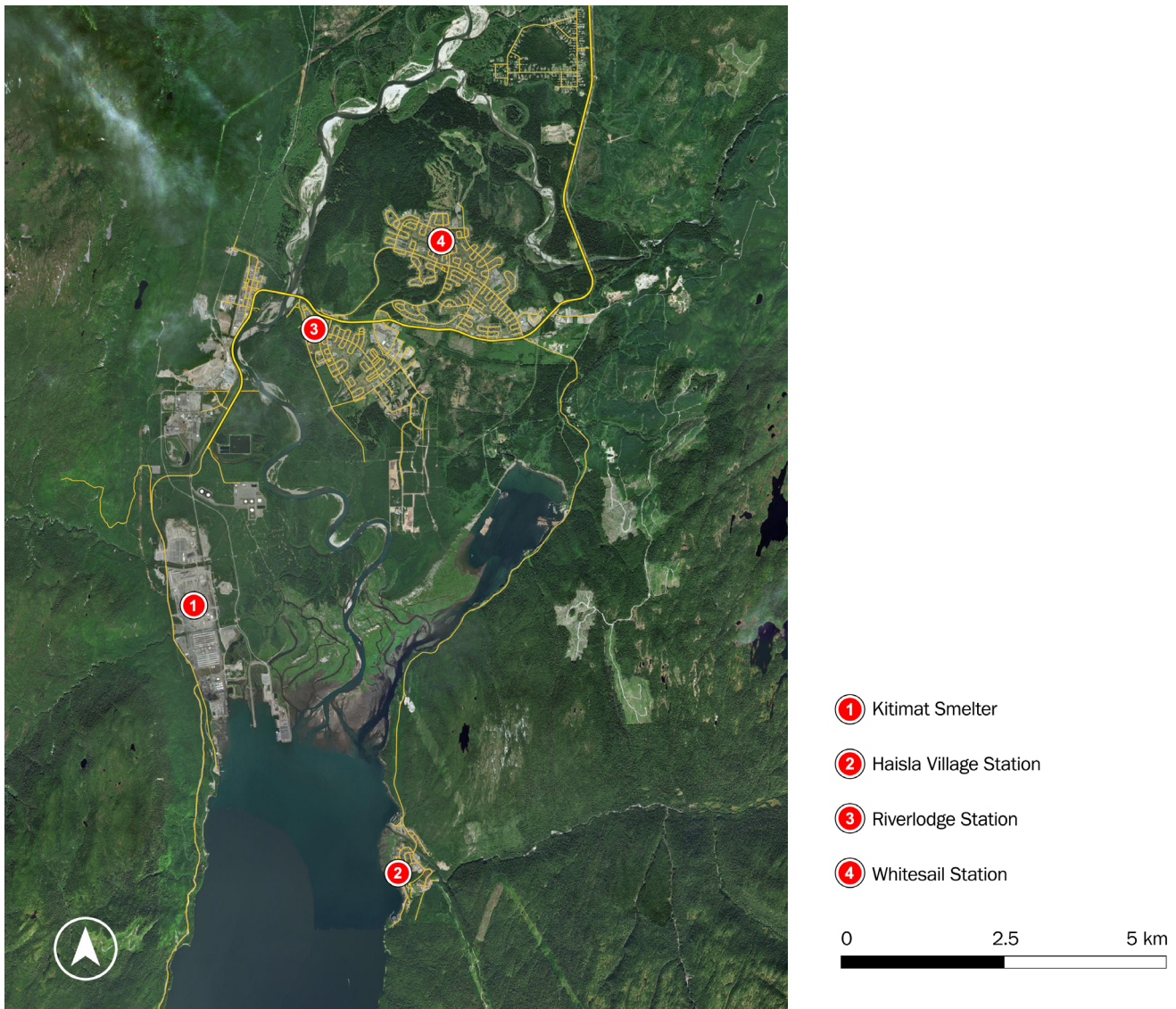
We will explain whether the questions set out in the STAR have been answered and if new ones have emerged, and whether a KPI threshold was reached, and if so what actions were taken.

Changes that have been made to the KPI, including the schedule for declining exposure limits when the CAAQS take effect as the health KPI, will be explained.

What do we recommend for the EEM Program going forward?

We will outline any changes we recommend to monitoring methods, frequency or extent, as well as any changes to the KPI and any recommended responses to exceedances of thresholds.

AIR QUALITY MONITORING STATIONS

1. Kitimat Smelter
2. Haisla Village Station
3. Riverlodge Station
4. Whitesail Station

0   2.5   5 km

REVIEW RESULTS FOR VEGETATION

SUMMARY OF THE VEGETATION MONITORING PROGRAM

The vegetation program is conducted by monitoring impacts of SO_2 and sulphur deposition on vegetation. The monitoring focuses on western hemlock trees as an indicator of the effects of sulphur deposition on vegetation. The sampling program involves inspecting all vegetation at the sampling sites every other year, and analyzing the sulphur content in western hemlock every year. A map showing the location of vegetation sampling locations is shown on page 15.

REVIEW RESULTS FOR VEGETATION

What did we set out to learn?

In the Comprehensive Review report we will explain that the monitoring activities were intended to answer the questions in the STAR on sampling locations, and on the health of vegetation where critical loads in soils or water may be exceeded. We will also explain if any KPI and informative indicators were exceeded, and if these indicators are appropriate. We will identify any new questions that have emerged on the indicators, or on sampling methods.

What methods did we use?

We will describe the data collected from the CALPUFF simulations and from field observations, the data that was evaluated to confirm that sampling locations are appropriate, and the extent of sulphur deposition that might affect sensitive vegetation. We will compare results of vegetation injury inspections from pre-smelter modernization to post-smelter modernization inspections, and evaluate inspection results from 2014 to 2018.

Sampling Western Hemlock

Recommended analyses for the next EEM phase will be outlined, including the extent of any insect or disease outbreaks, the sulphur content in vegetation, and any change in the presence of species sensitive to SO_2. We will relate monitoring results to CALPUFF models, integrate vegetation monitoring results with results of soils monitoring, and evaluate if the KPI and informative indicators are suitable to assess SO_2 impacts on vegetation.

What did we learn, and did we make any adjustments to the EEM Program?

We will summarize the knowledge gained from the monitoring, including updated scientific information; a comparison of sulphur concentrations and a synthesis of vegetation injury inspection results pre- and post- smelter modernization, and an analysis of the suitability of sampling sites. We will describe any modifications we made to the EEM Program, including to the KPI and informative indicator, and possible measures to support the inspection and sampling program.
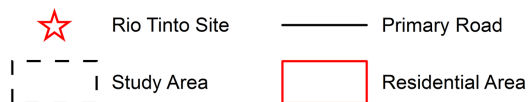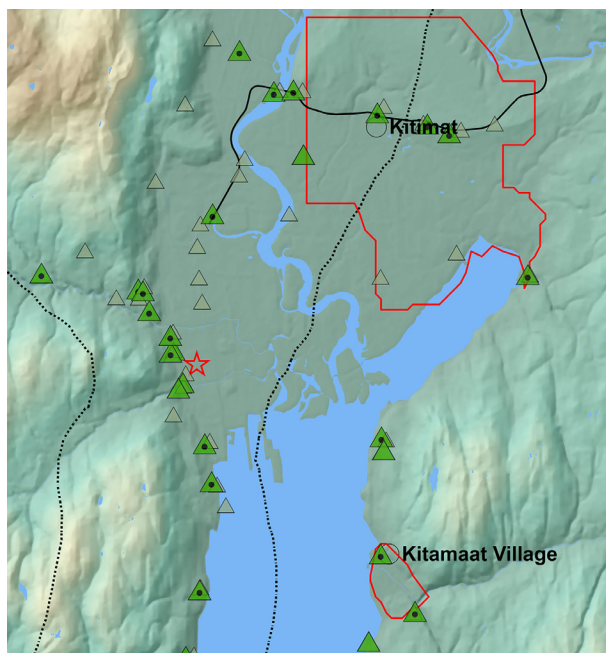
A comprehensive synthesis will relate vegetation monitoring results to those of the soils and aquatic studies, with a map showing vegetation sampling sites, overlaid with areas of sensitive soils and SO_2 concentrations.
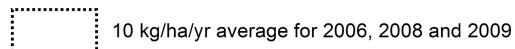
We will note any necessary adjustments to monitoring sites.

Conclusions will be presented on any changes in the risks to vegetation from the modernized smelter, the utility of the KPI and informative indicator, and any uncertainties and changes to levels or indicators.

What do we recommend for the EEM Program going forward?

We will discuss any recommendations regarding the KPI and informative indicator, and the inspection and sampling program.

	Rio Tinto Site	—	Primary Road
- - -	Study Area	▭	Residential Area

SO$_4$ Deposition

▭ 10 kg/ha/yr average for 2006, 2008 and 2009

Vegetation Receptor Monitoring Station

▲ With Hemlock needle sampling

▲ Without Hemlock needle sampling

▲ Additional supporting vegetation data for STAR and EEM
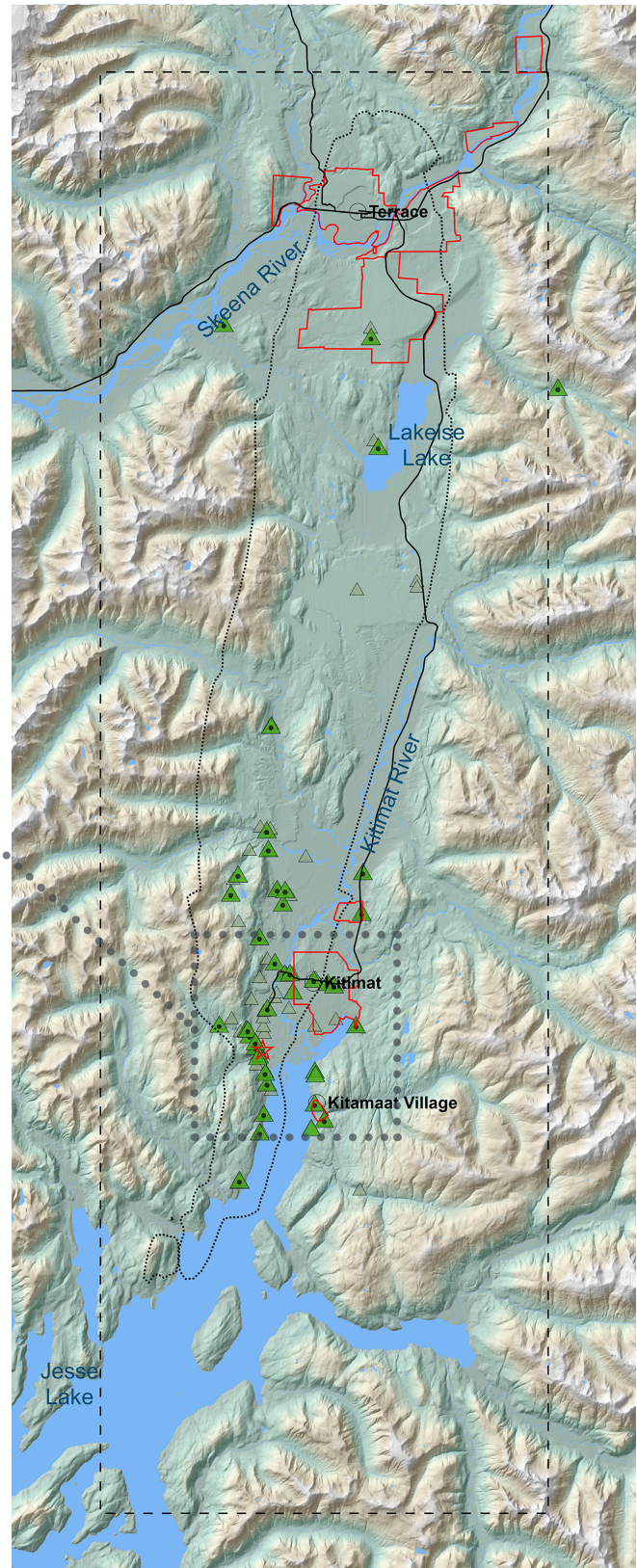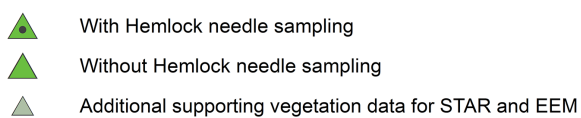
Vegetation monitoring sites

REVIEW RESULTS FOR TERRESTRIAL ECOSYSTEMS (SOILS)

SUMMARY OF THE TERRESTRIAL ECOSYSTEMS (SOILS) MONITORING PROGRAM

The soils monitoring program involves the analysis of soil samples collected at more than 75 locations throughout the valley, to improve critical load estimates and to establish three long-term soil monitoring plots. Critical loads are used to predict whether unacceptable soil acidification will occur under various emission scenarios. The long-term soil plots will be sampled periodically to determine actual changes in acidity over time. The map on page 17 shows the soil sampling locations.

REVIEW RESULTS FOR TERRESTRIAL ECOSYSTEMS (SOILS)

What did we set out to learn?

We will review the questions on soils from the STAR, and the monitoring needs described in the STAR in relation to critical uncertainties.

We will report if any KPI thresholds were reached. The soils KPIs refer to whether unacceptable soil acidification is predicted to occur due to sulphur deposition or whether significant losses of base cations are detected from the soil exchangeable pool at the long-term monitoring plots. The informative indicators are soil base cation weathering rates, and the size of the exchangeable cation pools.

What methods did we use?

The Comprehensive Review report will review all data and methods used in the analyses, including the regional soil sampling, the establishment of long-term plots and the rationale for the sampling and analysis of different long-term soil plots.

We will describe analytic processes, including those related to:

- Critical loads, which will be recalculated using an updated methodology and additional soil and updated atmospheric deposition data.

- Long-term soil plots: soil chemistry from the 2015 and 2018 field sampling campaigns will be presented and described.

- Assessment of acceptable or unacceptable impacts to soils causally related to the smelter modernization.

What did we learn, and did we make any adjustments to the EEM Program?

We will summarize data, including the regional mapping of soil critical loads and their exceedances under various deposition scenarios. The ability to detect changes in soil chemistry will be presented, and major knowledge gaps that add uncertainty in results will be identified.

The comprehensive synthesis will summarize changes in soil critical loads, and the linking of changes in soil chemistry to potential effects to sensitive receptors. In our conclusion we will include an evaluation of the contribution of smelter SO_2 emissions to the risk of acidification of terrestrial ecosystems, a summary of uncertainties, and an assessment of acceptable or unacceptable impacts.
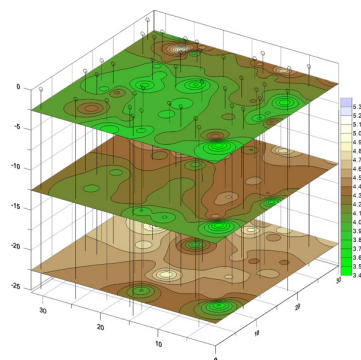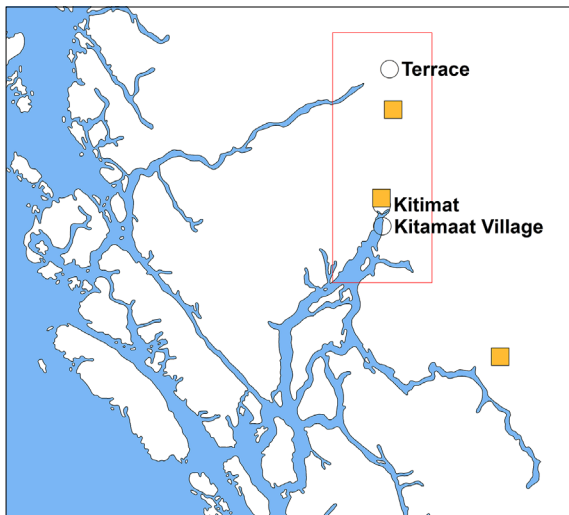

Example of soil profile mapping at a permanent plot

What do we recommend for the EEM Program going forward?

Recommendations will be made related to any necessary changes in monitoring methods, frequency or extent. We may also make recommendations on the KPIs or informative indicators, on thresholds, or responses to exceedances of thresholds.

PERMANENT PLOTS

Location of the two permanent plots in the study area (Lakelse Lake and Coho Flats, Kitimat Valley) and the reference plot established at Kemano.

☆   Rio Tinto Site   ———   Primary Road

⌐ ⌐ ⌐ Study Area   ▢   Residential Area
⌐ — — ⌐

SO$_4$ Deposition

⋯⋯⋯   10 kg/ha/yr average for 2006, 2008 and 2009
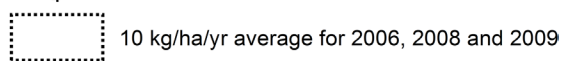
Soils/Terrestrial Monitoring Stations

▢   Permanent/long-term plot

▢   Soil sampling (EEM program)

▢   Soil sampling (KAEEA program)

▢   Soil sampling (LNG program)

▢   Soil sampling (STAR program)

Terrestrial monitoring sites

REVIEW RESULTS FOR AQUATIC ECOSYSTEMS
(LAKES, STREAMS, AND AQUATIC BIOTA)

SUMMARY OF THE AQUATIC ECOSYSTEMS MONITORING PROGRAM

The surface water studies have involved measurements of the water chemistry in 41 lakes and 20 streams (as part of the STAR), and 14 lakes that were selected for the 2013-2018 EEM Program (7 acid-se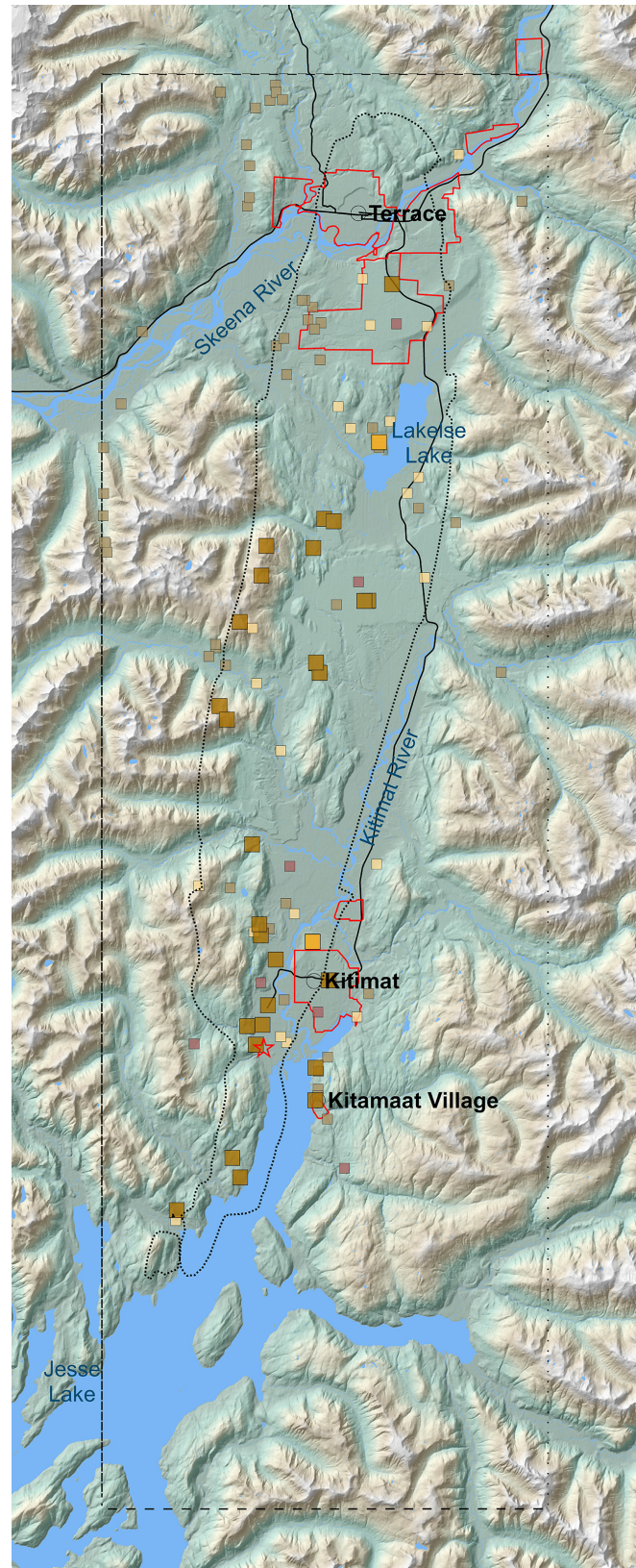nsitive lakes, 4 less sensitive lakes and 3 control lakes outside of the zone of acidic deposition). Water chemistry data track sulphate levels, the pH (level of acidity) of the water, and other parameters that determine the ability of lakes to neutralize acidic deposition. Three of the sensitive lakes have been intensively monitored, with pH measurements every half hour. Baseline fish sampling has been completed in five of the sensitive lakes, and three of the less sensitive lakes. The map on page 19 shows the water monitoring sites and the locations of the sensitive and less sensitive lakes. For reasons of scale, the control lakes are not shown.

REVIEW RESULTS FOR AQUATIC ECOSYSTEMS

What did we set out to learn?

The Comprehensive Review report will explain the questions and hypotheses from the STAR, and review questions from the STAR and EEM. These include determining whether changes in lake chemistry since 2012 suggest that acidification has occurred within individual lakes, and if so, the most likely causes of this acidification (e.g., the smelter, natural organic acids, unusual weather). The three control lakes provide a valuable means of tracking changes in lake chemistry caused by variation in weather that is unrelated to the smelter.

The Comprehensive Review report will explain if any KPI or informative indicators were exceeded. The KPIs refer to observed acidification in lakes (a decrease in pH of more than 0.3 units below pre-smelter modernization conditions), with a causal relation to the smelter modernization. The informative indicators consider atmospheric sulphur deposition and the risk of exceeding critical loads; the causes of pH changes; the presence or absence of fish in sensitive lakes; and amphibians.

New questions that have emerged over the course of the six years of the EEM will be discussed, including potential changes to monitoring methods.

We will assess how natural and smelter-driven processes have interacted to determine observed changes in lake chemistry, following the path of sulphur from the smelter through vegetation and soils to aquatic ecosystems.

What methods did we use?

The core of the EEM Program is monitoring of lake chemistry in the set of 14 lakes. We analyze monitoring data to determine how the chemical composition has changed over time and space, using both statistical and acidification models.

The Comprehensive Review will assess whether or not the impacts to lakes are acceptable, using a number of specific analyses:

- Modelling of critical loads, exceedances and predicted changes in pH

- Statistical methods to determine the strength of evidence for changes in water chemistry

- Weight-of-evidence approach for assessing whether observed changes are related to sulphur emissions from the smelter

- Studies of acidic episodes, particularly during rainstorms

- Monitoring and evaluation of the quality of domestic water supplies obtained from the Kitimat River

- Biological information, including fish sampling, and reviews of available data and literature on amphibian studies

- The strengths and weaknesses of three different measures for estimating the capacity of surface waters to neutralize acids.

What did we learn, and did we make any adjustments to the EEM Program?

Knowledge gained will be summarized, including the ability to detect changes in water chemistry;

spatial and temporal patterns in water chemistry; critical loads, exceedances and predicted changes in pH; episodic acidification studies; Kitimat River water quality; and results from previously reported analyses.

We will describe the changes that were made to the EEM Program between 2013 and 2018, and the reason they were made.
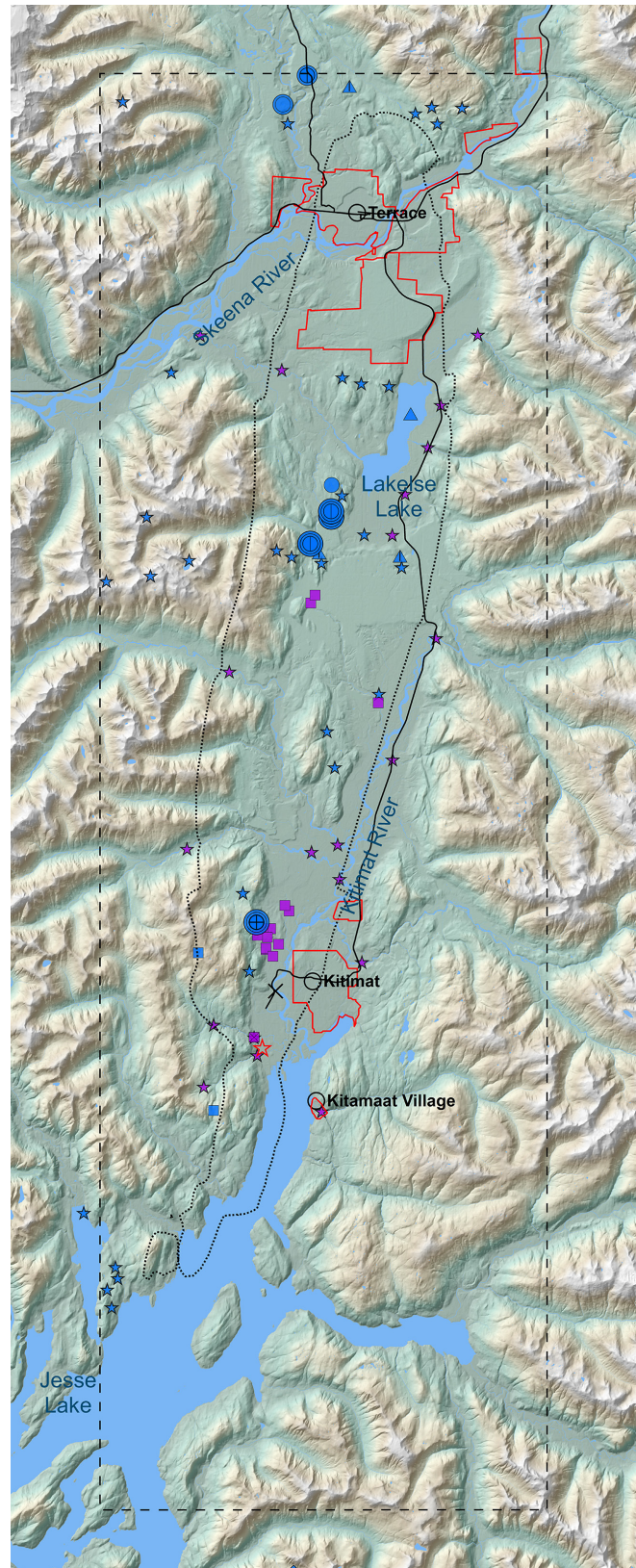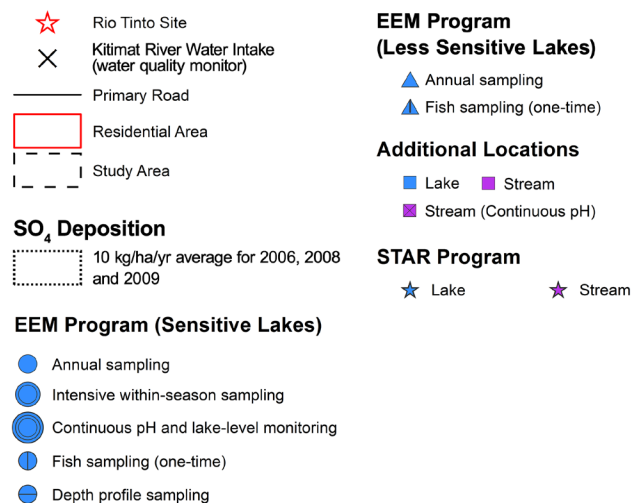
The Comprehensive Review will compare monitoring data to model predictions made in the STAR, to learn whether sulphur moved through the air and watersheds as we had expected, or whether outcomes were different from our expectations. We will also compare the results of models applied to lake water with models applied to forest soils.

Our conclusions will address key questions, including: Has acidification occurred? If so, does the weight of evidence indicate that such acidification was caused by the smelter? Is the level of acidification likely to cause unacceptable damage to aquatic biota?

We will address questions posed in the STAR and EEM, describe outstanding questions that still require further or ongoing investigation; and pose new questions that have emerged.

What do we recommend for the EEM Program going forward?

Recommendations could be made on several aspects of the program, including potential changes to monitoring methods, frequency or extent; KPIs or informative indicators and thresholds, including alternative KPIs and thresholds; and the form of future EEM analyses (both statistical and modelling analyses). Recommendations may also be made regarding lakes that are not part of the EEM monitoring program, but which were sampled as part of the regional Kitimat Airshed Assessment in 2013.

Legend

☆ Rio Tinto Site
✕ Kitimat River Water Intake (water quality monitor)
— Primary Road
▭ Residential Area
▯ Study Area

SO₄ Deposition
⬓ 10 kg/ha/yr average for 2006, 2008 and 2009

EEM Program (Sensitive Lakes)
● Annual sampling
◉ Intensive within-season sampling
◎ Continuous pH and lake-level monitoring
◖ Fish sampling (one-time)
◑ Depth profile sampling

EEM Program (Less Sensitive Lakes)
▲ Annual sampling
◮ Fish sampling (one-time)

Additional Locations
■ Lake   ■ Stream
■ Stream (Continuous pH)

STAR Program
★ Lake   ★ Stream

Aquatic ecosystem monitoring sites

HOLISTIC UNDERSTANDING OF EFFECTS OF SMELTER MODERNIZATION ON THE ENVIRONMENT AND HUMAN HEALTH ACROSS ALL LINES OF EVIDENCE

After reviewing the results of the atmospheric pathways modelling and monitoring activities, and the of the evidence gathered for each receptor type, we will describe an integrated understanding of the effects of SO_2 from the smelter modernization.

The Comprehensive Review report will present a map of all sampling and monitoring locations across all pathways and receptors.

We will summarize what is known about the links between SO_2, human health and ecosystems, based on the evidence gained from the air dispersion models and monitoring, and the monitoring programs on the four receptors. This summary may show results in the matrix shown below.

From: \ To:	Atmosphere	Human Health	Vegetation	Soils	Surface Waters
Atmosphere		$[SO_2]$ vs. KPI & respiratory responses	$[SO_2]$ vs. vegetation thresholds	Deposition vs CL, and vs. soil base saturation	Deposition vs CL, and vs. acidic episodes
Human Health					
Vegetation	$[S]$ in needles vs. observed / predicted $[SO_2]$ in air				
Soils			Soil CL exceedance vs. Vegetation observations		Soil CL exceedance vs. Lake CL exceedance
Surface Waters	Use Δ lake $[SO_4]$ to inform CALPUFF	Water quality in Kitimat River near water treatment plant		BC weathering rate from [BC] and runoff vs. soil estimates	

GLOSSARY OF TECHNICAL TERMS

A

Acid: Water-based solution with a pH value less than 7 and neutralizes alkalis.

Acid deposition: The transfer of acids from the air to soils and water, through precipitation (wet deposition - rain, snow, sleet, hail, fog droplets); or via particles (dry deposition).

Acid Neutralizing Capacity (ANC): Capacity of a solution to neutralize strong acids; alkaline solution that neutralizes strong acids.

Acidification: The process by which something becomes acidic or is converted into an acid.

The decrease of acid neutralizing capacity in water, or base saturation in soil, by natural or anthropogenic processes.

Airshed: A geographic area where the movement of air, and air pollutants, can be confined or channelled by local features such as mountains, and by weather conditions, such that all parts of the area have similar air quality conditions.

Alkaline / Alkalinity: A base with the ability to neutralize acids.

Alkalinity is a measure of the ability of a solution to neutralize acids; often used interchangeably with ANC.

Ambient: Of the surrounding area or environment. Ambient air refers to the air in an area, as opposed to the air emitted at a specific source.

B

Base: A substance or solution with a pH value greater than 7 and neutralizes an acid.

Base cation: The most prevalent and weak acid cations in the soil. These include alkaline earth metal ions such as calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+) and sodium (Na^+). Base cations are able to counteract acidity in soils, and thus provide acid neutralizing capacity (ANC).

Base cation exchange: The replacement of hydrogen ions (acidic) in the soil water by base cations from soil particles, leading to reduction of acidity.

Baseline: defined starting point value or condition, used as a basis for comparison or for measuring change.

Big-leaf dry deposition model: Analytical model for estimating the dry deposition of SO_2 and particulate sulphate, giving the amounts deposited per hour.

Uses measurements from continuous and passive air samplers, as well as weather conditions such as temperature, wind speed, relative humidity and precipitation.

Biota: The total collection of all plant and animal life (in a region, or used more generically).

C

CALPUFF: An advanced software-based modeling system for the simulation of atmospheric pollution dispersion, used for assessing long- range transport of pollutants and their impacts.

Uses information on local physical characteristics, weather data and monitoring results to represent the movement of SO_2 in the air through the study region.

Cation: An ion with a positive charge, (has fewer electrons than protons, giving it a positive charge).

Causality: The effect of a factor or process in producing another state or effect.

To determine the causality of an effect, evidence for attributing the effect to a specific cause is analyzed. This will be specific to the system and factors involved.

The EEM describes an "evidentiary framework" for evaluating if an observed effect (such as acidification) is causally related to KMP, with factors set out for each pathway and receptor. The evaluation of causality is done if thresholds reach or exceed the applicable KPI. (See 'weight of evidence').

CL; critical load: A quantitative estimate of a receptor's exposure to one or more pollutants, below which no significant harmful effects occur. Specific critical loads will apply to individual receptors and pollutants.

Continuous samplers: SO_2 air samplers that take measurements of SO_2 in the ambient air each hour, located in five stations in Kitimat, Kitamaat Village and Lakelse Lake. Also referred to as continuous analysers or active samplers.

Control: In scientific studies, the inclusion of a group of samples that are not affected by the factors (variables) that are under study, to clarify that effects observed in the main samples result from the studied factors.

The aquatic ecosystems study includes some control lakes that do not receive acid deposition from KMP, to increase confidence in attributing changes in acidity of the main study lakes to KMP emissions.

Critical uncertainties: A category of uncertainty in knowledge or findings from the 2013 SO_2 Technical Assessment Report.

A 'critical' uncertainty is one that, when resolved, may shift a predicted effect into another risk category (in the risk assessment framework). This could result in a different impact category; or could change a decision about mitigation actions.

Other uncertainties that are not expected to change the impact category or mitigation actions may be 'nice to know' but are not deemed 'critical'.

D

Deposition: The transfer of substances from the atmosphere to terrestrial or aquatic environments. May occur as dry or wet deposition.

Dry deposition involves the settling of large particles and the transfer of smaller particles and trace gases.

Wet deposition involves the transfer of particles through precipitation such as rain, snow or fog droplets.

E

Episode / Episodic: Related to a specific event or occurrence; may be irregular or related to other events.

An acidic episode is an event in which surface water increases in acidity; may be due to an irregular or seasonal event, such as an influx of acidic rainwater or spring meltwater.

F

Facility-based mitigation: A response to an unacceptable impact to a receptor that is caused by smelter SO_2 emissions, defined as an exceedance of a specified KPI threshold. A facility-based mitigation would reduce SO_2 emissions from the smelting operation sufficiently to reduce the unacceptable impact, and could be episodic or permanent as determined to be appropriate.

KPIs define thresholds at up to three levels: the vegetation, soils and water KPIs define threshold levels for increased monitoring, receptor-based mitigation, and facility-based mitigation, while the human health KPI only defines a facility-based mitigation strategy.

Receptor-based mitigation refers to measures that can be applied to the receptor to protect it from the impacts of SO_2; an example is adding lime to soil to reduce acidity levels.

H

H_2SO_4: Sulphuric acid. Created from SO_2 when it dissolves in water.

Hypothesis: A proposed or preliminary explanation made on the basis of limited evidence, as a basis for further investigation or reasoning.

I

Informative indicator: In the monitoring program, observable and measurable factors associated with the development of key performance indicators (KPIs).

Ion: Atom or molecule in which the total number of electrons is not equal to the total number of protons, giving it a positive or negative electric charge. (See: cation)

K

KPI; Key performance indicator: A quantitative level of harm that can be associated with thresholds (of acidity or other factors) that trigger additional monitoring or mitigation measures.

M

Mitigation: Actions taken to reduce the severity of an effect.

N

NADP: National Atmospheric Deposition Program. The NADP is a US-based network of stations in the United States and a few locations in western Canada that measure the atmospheric deposition of acids, nutrients, and base cations in precipitation. Included in the NADP network are stations at Haul Road and Lakelse Lake; data from these stations can be viewed at https://nadp.slh.wisc.edu/data/sites/map/?net=NTN

P

Particulate: microscopic matter suspended in the air; can be fine or coarse. $PM_{2.5}$ (fine particulate) is up to 2.5 micrometers in diameter. PM_{10} (coarse particulate) can be up to 10 micrometers in diameter.

Passive sampler: Passive SO_2 air concentration monitors. They sample SO_2 in one-month exposure periods.

Pathway: The means or route by which a receptor comes in contact with a substance; may be direct or indirect.

pH: Measure of how acidic or basic (alkaline) a substance is when it is in a water solution.

Lower numbers (0-6) are more acidic, while higher numbers (8-14) are basic (alkaline). A neutral solution has a pH of 7.

R

Receptor: Something that is exposed to a hazard and may be at risk of associated effects.

Four receptors studied under the EEM are humans, vegetation, soils and surface waters.

S

S: Sulphur, a natural chemical element.

Sampling: The selection of examples from a population to include in a scientific study. The selection process may be random, to represent the larger population or system; or it may be targeted, to focus on individuals or types of interest.

Scenario: A hypothetical situation or sequence of events, defined and analyzed for the purpose of understanding the outcomes of different conditions or inputs.

Sometimes referred to as 'alternative worlds'; and contrasted with 'actual', an existing situation or event that has occurred.

SO_2: Sulphur dioxide; a compound of sulphur and oxygen.

SO_4: Sulphate; compound of sulphuric acid.

Solar irradiance: the amount of light energy from the sun as measured at a defined location on the earth.

Solar irradiance varies with the seasons, and also throughout the day. Measurements of solar irradiance are used in weather forecasting.

STAR: Sulphur Dioxide Technical Assessment Report. The STAR was completed in 2013 as part of the regulatory process to amend the P2-00001 Multimedia Permit to increase the smelter's SO_2 emissions from 27 t/d to 42 t/d. The STAR reported on studies of the potential impacts of SO_2 emissions from the modernized Kitimat aluminum smelter on human health, vegetation, soils and aquatic ecosystems.   It defined the criteria for the assessment of impacts to the receptors, and led to the establishment of the longer term EEM.

T

Threshold. A boundary level or magnitude at which an effect reaches a different or significant state; and / or at which a specified action begins or changes.

W

Watershed: A geographic area that catches rain and snow and drains into a particular lake or point along a stream.

Weathering: The breaking down of rocks, soils and minerals through the action of wind, water and biological organisms.

Weathering occurs in place, and is different from erosion, which involves rocks and soils being displaced by water, ice or wind.

Weight-of-evidence: A systematic evaluation of the quality and amount of evidence for a conclusion or analysis of findings.

The EEM evidentiary framework (Chapter 7) describes the systematic weight of evidence assessment for determining if observed effects are causally related to KMP, in terms relevant to each pathway and receptor.

RioTinto

SUMMARY TERMS OF REFERENCE FOR THE
2019 COMPREHENSIVE REVIEW

RSI