Surface Freshwater Quality Technical Data Report

Proposed Aurora LNG Project

November 2016

Prepared for:
Aurora LNG
Calgary, Alberta

aurora LNG
COMMUNITY COMMITMENT CONNECTION

AUTHORSHIP

Mariah Arnold, Ph.D. .... Author
Lisa McCuaig, B.Tech., RB.Tech. .... Author
Karen Munro, M.Sc.. ....Quality Reviewer
Michael Browne, M.Sc., R.P.Bio. ....Quality Reviewer

TABLE OF CONTENTS

List of Tables

List of Figures

List of Appendices

EXECUTIVE SUMMARY

The Aurora LNG Project (the Project) is a proposed liquefied natural gas (LNG) facility and marine terminal on Digby Island near Prince Rupert, British Columbia (BC). The Project is owned by Aurora LNG and is currently preparing an Application for an Environmental Assessment Certificate. This technical data report presents the results of the surface freshwater acidification and eutrophication assessment including a description of field surveys, methods and baseline data describing existing conditions.

Surface water acidification is a result of acid deposition originating from sulphur dioxide and nitrogen emissions. Acidifying inputs can trigger changes in pH, causing the acidification of aquatic systems, loss of alkalinity, and ultimately adverse effects to aquatic biota. Increased nitrogen inputs can result in excess plant nutrients, causing eutrophication (algal blooms). The acidification and eutrophication assessments will evaluate the potential for these effects to occur in lakes and streams near the Project site.

To evaluate the deposition of sulphate (SO_4) and nitrogen oxides (NO_x) an air quality model was conducted to define the emissions and associated deposition under four different emission cases (Base, Project, Application and Cumulative Effects Assessment (CEA) Case). The Base Case includes existing regional emission sources and the CEA Case includes Base Case and all reasonably foreseeable future projects. Each emission case is independently evaluated under the assessment of acidification and eutrophication.

The acidification assessment was completed using the steady state water chemistry (SSWC) model in which critical loads are assessed against modelled acid deposition for individual waterbodies. The critical load is a measure of the buffering capacity of the freshwater system and exceedances to the critical load were identified. Risk categories were defined and used to assess the acidification risk to freshwater systems in the region. Low, moderate, high and critical risk categories are based on assessed pH changes and critical load exceedances. For the Base, Project and Application Case the acidification risk is considered low, where the majority of lakes and streams have no exceedances to critical load or pH changes above the threshold (0.3 units). For the CEA Case, acidification risk is considered to be critical as three of the assessed streams have a predicted pH change above the biological threshold (0.3 units). The critical risk categorization for the CEA Case can be considered a highly conservative rating as the model used to assess pH changes are largely based on lake systems (Fölster et al. 2007). Additionally, the remaining assessed waterbodies under the CEA Case fall into the low risk category with no predicted pH changes above threshold.

The eutrophication assessment was completed for lakes using the empirical nutrient nitrogen approach. Modelled nitrogen loads were assessed against recently published empirically derived nitrogen critical loads for both dystrophic and oligotrophic lakes. Since there are a range of critical load values for the representative ecosystem, effects were assessed using a range of critical load values (low, middle and high). Effects were also assessed under the four modelled air emission cases. Risk categories, similar to those used in the acidification assessment were applied. Although three levels of critical loads were assessed, the middle range is expected to provide the average result. The risk for eutrophication in lakes was estimated to be moderate for the Project and Application Case and high for the CEA Case when considering the middle range critical load.

ACRONYMS AND ABBREVIATIONS

ANC .... acid neutralizing capacity
BC .... British Columbia
BC MOE .... British Columbia Ministry of Environment
CL .... critical load
CO .... carbon monoxide
DOC .... dissolved organic carbon
DQO .... data quality objectives
ECCC .... Environment and Climate Change Canada
ICP .... International Cooperative Programme
LNG .... liquefied natural gas
LAA .... local assessment area
km .... kilometre
N .... nitrogen
NO_x .... nitrogen oxides
O_3 .... ozone
PM_5 .... particulate matter
PDA .... Project Development Area
QA/QC .... Quality Assurance/Quality Control
RAA .... regional assessment area
RPD .... relative percent difference
SO_2 .... sulphur dioxide
SO_4 .... sulphate
SSWC .... Steady State Water Chemistry
TDR .... Technical Data Report
TDS .... total dissolved solids
the Project .... the Aurora LNG Project
TOC .... total organic carbon
TK .... Traditional Knowledge
TU .... Traditional Use
VOC .... volatile organic compounds

1 INTRODUCTION

Aurora LNG is proposing to construct and operate a liquefied natural gas (LNG) facility and marine terminal on Digby Island near Prince Rupert, British Columbia (BC). The Aurora LNG Project (the Project) will convert natural gas transported from northeast BC into LNG for export to Pacific Rim markets in Asia. This Technical Data Report (TDR) describes surface freshwater quality existing conditions and methods used to evaluate the potential for acidification and eutrophication of freshwater systems assessed for Project and cumulative impacts.

Atmospheric emissions from LNG facilities generally include nitrogen oxides (NO_x), carbon monoxide (CO), sulphur dioxide (SO_2), particulate matter (PM), and volatile organic compounds (VOCs). Sulphur dioxide and NO_x compounds can react with water and oxygen in the atmosphere and potentially cause acid deposition by precipitating as sulphate (SO_4) and nitrogen compounds. Acid deposition has the potential to alter the pH in receiving aquatic environments, causing acidification and reduced alkalinity, which could cause adverse effects on aquatic biota. Increased nitrogen (N) inputs could also result in eutrophication of aquatic environments, which can result in responses ranging from small increases in primary productivity to excessive algal growth, cyanobacteria blooms, and decreases in oxygen levels. This TDR evaluates the potential for acidification and eutrophication of surface waters located within the study area.

2 STUDY AREAS

The existing conditions for surface freshwater quality are presented in the context of the local assessment area (LAA) and regional assessment area (RAA). The LAA and RAA for water quality are the same as those assessed under the Air Quality valued component (see Section 4.2 in the Application for an Environmental Assessment Certificate [the Application]). Sulphur dioxide and nitrogen deposition was modelled for the LAA and RAA and several lakes and streams were sampled to characterize existing conditions and to assess acidification and eutrophication potential.

The study area boundaries were defined considering guidance from, and through consultation with, British Columbia Ministry of Environment (BC MOE) for assessing potential acidification and eutrophication effects (BC MOE 2015a). The recommended study area boundary is defined by the 100 eq/ha/yr isopleth for acid deposition for the CEA Case shown in Figure 1. Although the modelled plume for the CEA Case extends beyond the RAA boundary (boundary in which air emissions was modelled), it is anticipated that regional effects to freshwater systems can be represented using the lakes and streams sampled within the LAA and RAA.

Digby Island, the site of the proposed LNG facility, is located within the Skeena-Queen Charlotte Regional District and the North Coast Forest District. The island is located within the Hecate Lowland ecosection, an area characterized by rocky uplands and extensive boggy lowlands (BC MOE 2015b).

3 WATER QUALITY FIELD SURVEYS

3.1 Scope

Thirty-nine waterbodies were included in the acidification and eutrophication assessment (see Table 1, Figure 1). Lakes and streams were selected to reflect a range of conditions (e.g., watershed size, proximity to the LNG facility, fish presence/absence) encountered in the region. Site selection also considered Traditional Knowledge (TK) and Traditional Use (TU) information gathered during consultation with regulators and Aboriginal Groups.

Data were obtained from a field study conducted by Stantec Consulting Ltd. (Stantec) in 12 lakes and 9 streams on Digby Island and the Tsimpsean Peninsula; sampling occurred in 2015 and 2016. Site specific historical data were obtained from Environment and Climate Change Canada[1] (ECCC) and AECOM[2]. Historical data were available for 18 lakes sampled on the Tsimpsean Peninsula, Smith Island, areas in and around Prince Rupert, Port Edward, and near Quottoon Inlet and north of Tuck Inlet. Stantec's field program focused on waterbodies on, and near, Digby Island, as this area may receive higher SO_4 and NO_x deposition based on proximity to the proposed facility. Locations of the 39 sampling stations are provided in Table 1.

Table 1 Surface Water Quality Sample Site Locations in the Project RAA

Station	Name Of Waterbody	Source	Coordinates		Years Sampled		
			Latitude	Longitude	2014	2015	2016
LAK02	Unnamed	Stantec	54.298	-130.439		✓	
LAK03	Unnamed	Stantec	54.289	-130.434		✓	
LAK04	Unnamed	Stantec	54.292	-130.428		✓	
LAK05	Unnamed	Stantec	54.287	-130.416		✓	
LAK06	Unnamed	Stantec	54.282	-130.427		✓	
LAK07	Unnamed	Stantec	54.267	-130.412		✓	
LAK08	Unnamed	Stantec	54.264	-130.407		✓	
LAK09	Unnamed	Stantec	54.262	-130.406		✓	
LAK10	Unnamed	Stantec	54.255	-130.398		✓	
LAK11	Unnamed	Stantec	54.290	-130.391		✓	
LAK12	Tsook Lake	Stantec	54.355	-130.431			✓
LAK13	Unnamed	Stantec	54.376	-130.437			✓
STR01	Unnamed	Stantec	54.305	-130.408		✓	
STR02	Unnamed	Stantec	54.309	-130.423		✓	
STR03	Unnamed	Stantec	54.305	-130.436		✓	
STR04	Unnamed	Stantec	54.290	-130.411		✓	

1 Data collected in September 2014 and provided by Patrick Shaw
2 Data collected in August 2014

Table 1 Surface Water Quality Sample Site Locations in the Project RAA

Station	Name Of Waterbody	Source	Coordinates		Years Sampled		
			Latitude	Longitude	2014	2015	2016
STR05	Unnamed	Stantec	54.268	-130.420		✓	
STR06	Unnamed	Stantec	54.271	-130.397		✓	
STR07	Unnamed	Stantec	54.272	-130.396		✓	
STR08	Unnamed	Stantec	54.349	-130.443			✓
STR09	Unnamed	Stantec	54.378	-130.458			✓
ADSW1	Wolfe Lake	AECOM	54.229	-130.270	✓		
ADSW4	Oliver Lake	AECOM	54.281	-130.272	✓		
ADSW8	Shawatlan Lake	AECOM	54.329	-130.244	✓		
ADSW9	Smith Island Lake	AECOM	54.124	-130.216	✓		
Alywn	Alywn Lake	ECCC	54.219	-130.235	✓		
Georgetown	Georgetown Lake	ECCC	54.479	-130.368	✓		
NC254	Unnamed	ECCC	54.142	-130.246	✓		
NC273	Unnamed	ECCC	54.390	-130.433	✓		
NC275	Porpoise Lake	ECCC	54.227	-130.241	✓		
NC278	Unnamed	ECCC	54.133	-130.234	✓		
NC309	Unnamed	ECCC	54.418	-130.393	✓		
NC313	Unnamed	ECCC	54.165	-130.120	✓		
NC332	Unnamed	ECCC	54.067	-130.397	✓		
NC340	Unnamed	ECCC	54.430	-130.427	✓		
NC350	Unnamed	ECCC	54.434	-130.046	✓		
NC360	Peck Lake	ECCC	54.172	-130.133	✓		
NC366	Diana Lake	ECCC	54.209	-130.148	✓		
NC374	Colonel Johnston Lake	ECCC	54.204	-130.177	✓		

3.2 Methods

Stantec collected surface water samples on Digby Island between late September and early October 2015 and from the Tsimpsean Peninsula in early April 2016. Sample collection followed protocols described in the British Columbia Field Sampling Manual (Clark 2003). Fall 2015 and spring 2016 sampling dates were chosen to reflect times when the water column was not stratified (i.e., after or before lake turnover; Lien et al. 1996) to provide data representative of annual water chemistry. Lakes sampled in 2015 were under fully mixed conditions, with the exception of LAK03, which was approximately 10 m deep and exhibited a thermocline at the time of sampling. Lakes sampled in 2016 were shallow (<2 m), with no thermocline present. For lakes, samples were collected from a boat at the center of the lake, sample bottles were submerged about a foot below surface. Streams samples were collected from mid-stream with sample bottles submerged below surface. In situ water quality parameters (temperature, conductivity, dissolved oxygen, and pH) in lakes and streams were measured using a YSI 6820 water quality meter.

Grab samples were taken from just below the water surface for chemical analysis. The list of analyzed parameters is based on guidance provided in BC MOE (2015a). A full list of analyzed parameters is provided in Appendix 1, Table 1-1. Samples were analyzed for general water chemistry parameters (e.g., hardness, conductivity, alkalinity), nutrients, anions, organic carbon and chlorophyll *a*. Samples were preserved in the field immediately after collection using sulphuric acid for applicable nutrients and dissolved organic carbon (DOC). All analyses were performed by ALS Laboratories in Burnaby, BC, which is accredited under the BC MOE Environmental Data Quality Assurance Program and the Canadian Association for Laboratory Accreditation.

Quality assurance data are provided in Appendix 1, Tables 1-4 and 1-5. The quality assurance and quality control (QA/QC) program for water quality data included the collection of field duplicates to evaluate field sampling methods. The relative percent difference (RPD) between duplicate samples was calculated for each parameter and compared to a data quality objective (DQO) of 20% for parameters with values more than five times the detection limit. Travel blanks were also collected to identify potential cross-contamination during sample collection, storage, and transport and from the addition of chemical preservatives.

3.3 Existing Conditions

The lakes sampled in 2015 and 2016 ranged in depth from 0.8 m to 3 m, with the exception of LAK03, which was approximately 10 m deep. No thermoclines were observed in any lakes except LAK03, which was the deepest lake surveyed in 2015.

Stream sites sampled in 2015 and 2016 varied in morphology. For example, STR02 had a narrow, grassy channel while STR08 was a 5 m wide, deeply incised channel containing abundant woody debris. STR09 appeared to be tidally influenced and contained seaweed, whereas STR04 was located near the mouth of a lake.

Results for in situ parameters (temperature, conductivity, dissolved oxygen and pH) are provided in Appendix 1, Table 1-2. Field and laboratory measurements were made for pH, with laboratory data reported below.

General chemistry parameters, such as pH and alkalinity, describe acidity and buffering capacity (ability to neutralize acids). The pH levels were low in the lakes sampled, ranging from 4.34 to 7.03 (average of 5.39); 28 of the 30 lakes had a pH below 6.5 (the low end of the range for the BC water quality guideline for the protection of aquatic life, BC MOE 1991). The pH of the stream sites ranged from 3.95 to 6.29, (average pH 4.78), which was also below the BC water quality guideline for aquatic life. Eleven lake sites and seven stream sites had pH values below 5.0.

In the lakes, total alkalinity ranged from <0.5 to 9.8 mg/L $CaCO_3$. In streams, total alkalinity ranged from <1.0 to 3.8 mg/L $CaCO_3$. Alkalinity in coastal BC waterbodies typically ranges from 1 to 10 mg/L (BC MOE 1998). Total phosphorus in lakes ranged from 0.0038 to 0.0083 mg/L and in streams from 0.0042 to 0.0093 mg/L. Nitrate, nitrite and ammonia levels were below detection limits (<0.005 and <0.001 and <0.005 mg/L, respectively) for all waterbodies. Total Kjeldahl nitrogen was similar for lakes and streams and ranged from 0.203 to 0.429 mg/L.

Major anion and cation concentrations are used to calculate the buffering capacity of water and are expressed in equivalent weights to facilitate acidification and eutrophication calculations. The ranges of major anion, cation and DOC concentrations are summarized in Table 2. Many of the samples collected had low ion concentrations (e.g., majority of samples had sodium and potassium concentrations below the detection limit).

Table 2 Range of Concentrations (µeq/L) for Major Ions and Dissolved Organic Carbon for Streams and Lakes

Parameter	Concentration (µeq/L unless otherwise stated)	
	Streams	Lakes
Chloride	46.9 to 80.9	0.1 to 107.2
Nitrate[1]	0.04 to 0.09	0.04 to 0.45
Sulphate	3.1 to 39.8	0.2 to 54.2
Calcium	23.3 to 102.0	17.0 to 225.6
Magnesium	21.7 to 50.8	8.2 to 68.4
Potassium[2]	2.64 to 25.6	1.4 to 25.6
Sodium[3]	43.5 to 100.0	20.9 to 161.8
Dissolved Organic Carbon	11.7 to 25.3 mg/L	2.9 to 23.0 mg/L

NOTES:

1 Nitrate concentrations were not available for the historical lake dataset so values represent 2015 and 2016 data only; all but two samples (0.09 and 0.45 µeq/L) were below the detection limit (<0.08 µeq/L).

2 All 2015 and 2016 samples except STR08 and STR09 had potassium concentrations below the detection limit (51.3 µeq/L)

3 The majority of the 2015 and 2016 samples (15 of 21) had sodium concentrations below the detection limit (<87 µeq/L)

Field duplicates were collected at two lake and two stream sites to meet the 10% quality objective (see Appendix 1). In general the RPD values calculated for the samples were below the DQO, with some exceptions (turbidity and total phosphorus for the lake duplicate and total dissolved solids (TDS), bicarbonate, total alkalinity, and chlorophyll *a* for the stream duplicate; Appendix 1 Table 1-3). All parameters in the travel blanks were below detection limits (see Appendix 1, Table 1-4). Results for the QA/QC data indicate the analytical data are of good quality.

4 ACIDIFICATION ASSESSMENT

4.1 Scope

The scope of the acidification assessment was to evaluate the acidification potential for surface waters, including a critical load assessment based on water chemistry and modelled sulphur dioxide and nitrogen emissions.

4.2 Methods

The Steady State Water Chemistry (SSWC) model of Henriksen and Posch (2001) was used to predict critical load exceedances and pH changes. Methods followed those defined in the Guidance for the Assessment of Acidification and Eutrophication of Aquatic Ecosystems (BC MOE 2015a) and the Mapping Manual for Critical Loads (Reynolds 2004).

4.2.1 Air Quality Modelling

Four air quality modelling cases were used to predict acidic deposition in the LAA and RAA: Base, Application, Project, and CEA Cases. Each case modelled different components of existing or future emissions sources; the Base Case included existing regional sources, Application Case included regional sources and the Project and the CEA Case included the Application Case plus reasonably foreseeable future projects. Detailed information regarding the air quality model and results can be found in the Air Quality TDR (see Appendix A of the Application).

4.2.2 Critical Load Assessment

The SSWC model described by Henriksen and Posch (2001), Henriksen et al. (2002), and Reynolds (2004) is used to assess critical load exceedances in waterbodies. The critical load is a quantitative estimate of the maximum amount of acid input an aquatic system may receive without expecting adverse biological effects (Posch 2004, Henriksen et al. 2002). Critical loads were calculated following methods described in the International Cooperative Programme (ICP) Mapping Manual (Reynolds 2004) using the following equation:

$$Critical\ Load = Q\ ([BC_0] - [ANC_{limit}])$$

where:

- Q ($m^3/y/m^2$) is the long-term mean annual catchment runoff (see Appendix 2 for details on the hydrology method used to determine Q in lakes and streams)
- BC_0 is the sum of the non-marine base cations (in µeq/L)
- ANC_{limit} is 40 µeq/L; the ANC_{limit} is typically between 20 and 50 µeq/L (BC MOE 2015) and an ANC_{limit} of 26 µeq/L, roughly corresponding to a pH of 6.0, was applied to the Rio Tinto Alcan Sulfur Dioxide Technical Assessment and to the Kitimat Airshed Emissions Effects Assessment (ESSA et al. 2013, 2014). The higher ANC_{limit} of 40 µeq/L provides a more conservative estimate of critical load and errs on the side of higher acid sensitivity.

Water quality parameters, including anions and cation concentrations, were used to calculate the acid neutralizing capacity (ANC). The ANC is a measure of the buffering capacity of the water to acidic input and is calculated as the difference between base cations ($[Ca^{2+}] + [Mg^{2+}] + [K^{+}] + [Na^{+}]$) and strong acid anions ($[SO_4^{2-}] + [NO_3^{-}] + [Cl^{-}]$) (Henriksen and Posch 2001). Organic acids contribute to the buffering capacity of waterbodies and are included in the ANC calculation by using the total organic carbon (TOC) concentration. The organic acid adjusted ANC (ANC_{oaa}) can be calculated using the following equation from Lydersen et al. (2003) and Reynolds (2004):

$$ANC_{oaa} = ([Ca^{2+}] + [Mg^{2+}] + [K^{+}] + [Na^{+}]) - ([SO_4^{2-}] + [NO_3^{-}] + [Cl^{-}] + 1/3 * m * TOC)$$

Where:

- TOC is total organic carbon (mg/L)
- *m* is the charge density of organic matter (set to 10.2 μeq/mg, based on Hruska et al. 2001).

Concentrations of TOC were not available for the historical datasets; therefore, DOC concentrations were used in the calculation.

Existing acid sensitivity in the waterbodies was classified according to Table 3 and was developed by ESSA Technologies (ESSA et al. 2013).

Table 3 Categories of Acid Sensitivity and Existing Conditions for Lakes and Streams in the Regional Study Area

Acid Sensitivity	Critical load ($meq/m^2/year$)
Acidic	≤0[1]
High	0 to 20
Sensitive	20 to 40
Moderate	40 to 60
Low	60 to 100
Very Low	> 100

NOTE:

[1] In addition to the critical load criteria, acidic waterbodies have an ANC value <0, while acid sensitive waterbodies have an ANC value >0.

SOURCE:

ESSA 2013

Dispersion modelling described in further detail in the Air Quality Technical Data Report (see Appendix A) provided sulphur dioxide and nitrogen deposition rates, which were compared to critical load values to calculate exceedances. An exceedance to the critical load can be defined as acid input levels exceeding the natural buffering capacity of the water body. Critical load exceedances were identified based on methods detailed in Chapter 7 of the ICP Mapping Manual (Reynolds 2004). The critical load exceedance was calculated using the following equation:

$$Exceedance = S_{dep} + N_{dep} - Critical\ Load$$

Where

- S_{dep} is the sulphur deposition in meq/m/yr
- N_{dep} is the nitrogen deposition in meq/m/yr

4.2.3 Prediction of pH changes

The prediction of changes in pH caused by acidifying inputs allows for the evaluation of potential effects to aquatic organisms. A model proposed by Small and Sutton (1986) relates the ANC and pH in each waterbody and provides an estimated pH change, which is evaluated under the four different emission cases described in Section 4.2.1. As part of the model, the change in ANC (ΔANC) is estimated using the ESSA/Fisheries and Oceans Canada (DFO) model (ESSA et al 2013) modified from Marmorek et al. (1990). Fölster et al. (2007) suggests a 0.4 unit change in pH to be protective of aquatic biota; however, previous airshed studies have used a more conservative threshold of 0.3 units. To remain consistent and comparative to previous studies a 0.3 unit threshold is used in this assessment.

There are some limitations to this model, including a lower statistical robustness when there are fewer waterbodies in the dataset, which introduces bias. The model assumes the relationship between ANC and pH is constant; however, naturally occurring pH and anion concentrations readily fluctuate and are influenced by a variety of factors (e.g., precipitation, and oceanic salt input).

The model for evaluating pH change uses an inverse hyperbolic sine function (arcsinh), as shown below. Laboratory measured pH and calculated ANC_{oaa} were plotted and a best fit curve (RStudio Software Version 0.99.491) was applied to estimate equation constants *a*, *c*, and *d*:

$$pH = a + \frac{1}{Ln(10)} arcsinh\left[\frac{(ANC - d)}{c}\right]$$

The change in ANC (ΔANC) was estimated using the ESSA/DFO model (ESSA 2013) modified from Marmorek et al. (1990):

$$\Delta\mathrm{ANC} = -1 * (1 - \mathrm{F}) * (\mathrm{DEP_{cumulative}})/\mathrm{Q}$$

Where

- F is the F-factor describing the proportion of acidity neutralized by cation exchange
- $DEP_{cumulative}$ is the sulphur dioxide and nitrogen deposition modeled under the CEA Case
- Q is the long-term mean annual catchment runoff

To model cumulative effects, the acidic deposition from the Project and all other current and reasonably foreseeable industry sources ($DEP_{cumulative}$) was used to predict pH changes. Detailed information relating to air quality modelling is described in the Air Quality TDR (Stantec 2016).

The F-factor estimates the flux of cation exchange due to strong acid anions (Henriksen and Posch 2001). An empirical estimate for the F factor was calculated using the equation provided by Henriksen et al. (2002) and Reynolds (2004):

$$F = \sin\left(\frac{\frac{\pi}{2} * Q * [BC^*]_t}{S}\right)$$

Where

- $[BC^*]_t$ is the present concentration of non-marine base cations
- S is the base cation flux, estimated to be 400 meq $m^{-2}yr^{-1}$ based on a previously published value (Henriksen et al. 2002)
- Q is the runoff value, determined using the hydrology-water balance approach

The steady state ANC value (ANC_∞), representing the predicted future ANC value, was then calculated from the sum of the current ANC (ANC_{oaa}) and ΔANC:

$$ANC_\infty = ANC_{oaa} + \Delta ANC$$

The steady state ANC is used to estimate steady state pH (pH_∞) using the relationship described by the Small and Sutton (1986) equation above. The steady state pH is an estimate of future pH of a waterbody under the CEA Case. The best-fit curve used in the assessment is shown in Figure 2.

4.2.4 Uncertainties

The acidification assessment has an inherent degree of uncertainty due to assumptions in the modelling, some of which are described below:

- The models used for pH predictions assume that the parameters relating to CO_2 and weak acids (a, c, and d) are the same for all sites throughout the year, but these values could change temporally, seasonally, or due to other unknown factors.
- For the ANC-pH model, the 95% confidence intervals around the parameter estimates calculated as ±2 standard deviations were such that there would be relatively large differences in the calculated pH using the best fit estimate versus the upper or lower confidence interval. The lack of confidence in the parameter estimates was likely due to low sample size (39) and data variability.
- Natural variability and measurement errors for anion and cation balance could affect ANC_{oaa} calculations; in an effort to decrease this uncertainty, organic acids are included in the ANC calculations to represent a more realistic and relevant alkalinity value for each of the sites.
- Concentrations for several anions and cations used in the charge balance and anion composition calculations were below detection limits; use of a value of one-half the detection limit in these calculations increases the uncertainty in these calculations.
- The original sulphur dioxide concentration was estimated with the assumption that the background sulphate level in the Prince Rupert area is 10 meq/m^2/yr
- Nitrate concentrations were not available for the AECOM or ECCC historical lakes dataset; therefore, a concentration equivalent to the average of the lakes sampled in 2015 and 2016 (one-half the detection limit) was selected for calculations.

4.3 Risk Categorization

The BC MOE has developed a risk assessment process to evaluate the potential effects of acidification on freshwater lakes, based on the Canadian Acid Rain Strategy for Post-2000 (CCME 1998) and work done by Fölster et al. (2007). These documents suggest that, for the protection of aquatic biota, pH should not change more than 0.4 units, and that 95% of lakes in the region should maintain a pH above 6. To add further conservativism and to stay consistent with previous airshed studies completed in the region, the biological threshold value for pH used in this assessment is 0.3 units. This threshold was also used in the risk assessment framework for the Kitimat Airshed Emissions Effects Assessment (ESSA et al 2014).

Combining critical load exceedance assessments with the pH prediction model creates four possible categories of concern for acidification effects to aquatic biota (see Table 4). Categories range from no concern (the critical load is not exceeded and the pH change is not biologically significant [ΔpH < 0.3 units]) to high concern (both the critical load is exceeded and a biologically significant pH change is predicted [ΔpH ≥ 0.3 units]).

Table 4 Acidification Categories of Concern

	ΔpH < 0.3 units	**ΔpH ≥ 0.3 units**
Critical Load not Exceeded	**Category 1** No concern (critical load not exceeded, ΔpH < 0.3 units)	**Category 3** Intermediate concern (critical load not exceeded but ΔpH ≥ 0.3 units)
Critical Load Exceeded	**Category 2** Low concern (critical load exceeded but ΔpH < 0.3 units)	**Category 4** High concern (critical load exceeded and ΔpH ≥ 0.3 units)

NOTES:
ΔpH – change in pH
SOURCE:
ESSA Technologies 2014

Four risk categories were developed for the acidification assessment based on The Canada-Wide Acid Rain Strategy for Post-2000 and Supporting Document (CCME 1998), which aims to protect 95% of lakes by maintaining a pH above 6 following deposition of sulphur. Although efforts were made to meet the benchmark of 95%, the small sample size limits the practicality of the proposed risk categories. To develop risk categories representing whole lake/stream systems, the framework was modified as described in Table 5.

Table 5 Risk Categories for Waterbodies with Biologically Significant Changes in pH and Critical Load of Acidity Exceedances

Risk Category	Category Description
Low	0% lakes/streams with ΔpH ≥ 0.3 units and all lakes/streams are in Categories 1 and 2 (0 lakes/stream)
Moderate	0-2.5% lakes/streams with ΔpH ≥ 0.3 units and lakes/streams are in Categories 3 or 4 (1 lake/stream)
High	2.5-5.1% lakes/streams with ΔpH ≥ 0.3 units and lakes/streams are in Categories 3 or 4 (2 lakes/streams)
Critical	5.1-7.5% lakes/streams with ΔpH ≥ 0.3 units and lakes/streams are in Categories 3 or 4 (3 lakes/streams)

4.4 Data Results

The definitions of acid sensitivities in relation to critical loads and the number of lakes and streams in each category for existing conditions (Base Case) are provided in Table 6.

Table 6 Number of Lakes and Streams per Category of Acid Sensitivity in the Regional Study Area, Existing Conditions

Acid Sensitivity	Critical load ($meq/m^2/year$)	Lake Sites	Stream Sites
Acidic	≤0[1]	2	0
High	0 to 20	5	0
Sensitive	20 to 40	3	0
Moderate	40 to 60	4	1
Low	60 to 100	4	4
Very Low	> 100	12	4
Total Sampled Sites		**30**	**9**

NOTES:

[1] In addition to the critical load criteria, acidic waterbodies have an ANC value <0, while acid sensitive waterbodies have an ANC value >0.

Of the 39 waterbodies assessed, 24 (62%) were categorized as having low to very low acid sensitivity. Two lakes (LAK12 and ADSW9) were identified as acidic, with pH values of 4.69 and 5.51 and ANC_{oaa} of 1.0 and 5.2 meq/m^3, respectively. Five lakes (LAK13, NC309, NC350, NC360, NC366) were categorized as having high acid sensitivities, with ANC_{oaa} values <22 meq/m^3 and three lakes (LAK09, NC254, NC313) were categorized as sensitive to acid input.

Critical load exceedances, predicted pH changes, and associated categories were determined for each waterbody under the four emissions cases, as shown in Table 7. Locations of lakes and streams with critical load exceedances and changes in pH above 0.3 units are shown in Figure 3 and Figure 4.

For the Base, Project, and Application Cases, 92% (36 of 39) of the lakes and streams are considered to have no concern for acidification (Category 1: Table 3), while three lakes (ADSW9, LAK12 and LAK13) exceed the critical loads, but are not expected to have a pH change over the biological threshold (0.3 units). No waterbodies assessed under the Base, Project or Application Cases exceed the pH change threshold of 0.3 units. Overall the risk is rated as low concern for acidification for the Base, Project and Application Cases, as no changes in pH are predicted above 0.3, and only three critical load exceedances are predicted, but are not anticipated to result in a pH change above the biological threshold.

For the CEA Case, two additional lakes (NC309, NC366) have critical load exceedances and three streams (STR01, STR04, STR06) have a predicted pH change greater than 0.3 units, but less than or equal to 0.4 units, with no critical load exceedance. Although a change in pH is predicted for these streams using the biological model, the threshold (0.3 units) was originally developed to assess lakes and does not incorporate stream data (Fölster et al. 2007). The pH in streams naturally fluctuates seasonally and the system is recharged (i.e., buffering capacity recovery) more readily than for lakes. These streams are located on Digby Island, either inside the Project Development Area (PDA) (STR06) or just beyond the PDA border (STR01 and STR04), and are expected to receive high levels of nitrogen and sulphur input due to their proximity to the proposed facility (see Appendix 1, Table 1-6). At the time of sampling, STR01, STR04 and STR06 had pH values of 4.64, 4.43 and 4.45, respectively, but were categorized as having low to very low acid sensitivity. Despite having low pH values, STR01 and STR06 are known to support commercial, recreational, and Aboriginal fish species (e.g., coho salmon, Dolly Varden). Additionally, salmon redds were observed near the confluence of STR06 and STR07 (Khtada 2015).

The overall risk for the CEA Case is rated as a critical concern for acidification due to three streams with a pH change above the biological threshold, but this is considered overly conservative, given the inclusion of these streams with a predicted pH change above 0.3 (but not above 0.4 units, which is still considered to be protective of aquatic systems; Section 4.3). The remaining assessed lakes and streams have no concern (no critical load exceedance and no pH exceedance) or low concern (a critical load exceedance and no pH exceedance) for acidification, and would fall under the low risk category for acidification.

A critical load exceedance was shown for lakes LAK12, LAK13, and ADSW9 for all emission cases including Base Case. These lakes were categorized as acidic (LAK12 and ADSW9), or highly acid sensitive (LAK13), using baseline water chemistry data. LAK12 and LAK13, located on the Tsimpsean Peninsula in Metlakatla First Nation territory, had existing pH values of 4.34 and 4.69, respectively, which is below water quality guidelines for aquatic life (BC MOE 1991). Tsook Lake (LAK12) has been identified as a drinking water source and recreational lake for the Metlakatla First Nation, and is expected to contain fish species including rainbow trout (*Oncorhynchus mykiss*), cutthroat trout (*O. clarkii*) and sockeye salmon (*O. nerka*) (BC MOE 2016). Although pH measurements in lakes were lower than water quality guidelines at the time of sampling, pH is expected to fluctuate seasonally and with influence from precipitation events. Modelled changes in pH for these lakes are expected to be below the threshold value (0.3 units) and therefore be protective of aquatic biota.

Table 7 Critical Load Exceedances for Acidification, Predicted Change in pH (ΔpH) and Risk Categories for Assessed Streams and Lakes

Site ID	Runoff (m^3/year/m^2)	ANCoaa (meq/m^3)	Critical Load (meq/m^2/year)	Base Case			Project Case			Application Case			Cumulative Effects Assessment Case		
				Critical Load Exceedance (meq/m^2/year)	ΔpH	Cat	Critical Load Exceedance (meq/m^2/year)	ΔpH	Cat	Critical Load Exceedance (meq/m^2/year)	ΔpH	Cat	Critical Load Exceedance (meq/m^2/year)	ΔpH	Cat
AD-SW1	2.4	195.5	720.0	-719	0.00	1	-717	0.00	1	-716	0.00	1	-704	0.00	1
AD-SW4	2.1	222.5	435.3	-434	0.00	1	-431	0.00	1	-430	0.00	1	-420	0.00	1
AD-SW8	2.6	45.4	51.4	-51	0.00	1	-49	-0.01	1	-48	-0.01	1	-34	-0.06	1
AD-SW9	2.2	5.2	-75.0	75	0.00	2	76	-0.02	2	77	-0.02	2	81	-0.07	2
Alywn	2.3	57.3	117.8	-117	0.00	1	-115	-0.01	1	-114	-0.01	1	-106	-0.03	1
Georgetown	2.8	95.3	319.3	-319	0.00	1	-317	0.00	1	-316	0.00	1	-305	-0.01	1
LAK02	1.8	33.9	225.9	-224	-0.01	1	-212	-0.05	1	-210	-0.06	1	-201	-0.09	1
LAK03	1.8	80.0	225.7	-224	0.00	1	-214	-0.02	1	-212	-0.02	1	-202	-0.03	1
LAK04	1.8	60.3	308.0	-306	0.00	1	-290	-0.02	1	-288	-0.02	1	-277	-0.04	1
LAK05	1.8	-6.0	86.9	-85	-0.02	1	-58	-0.17	1	-55	-0.18	1	-43	-0.24	1
LAK06	1.8	39.8	259.0	-257	0.00	1	-247	-0.03	1	-245	-0.04	1	-236	-0.06	1
LAK07	1.8	-12.1	42.0	-40	-0.01	1	-36	-0.04	1	-35	-0.05	1	-26	-0.09	1
LAK08	1.8	-13.4	42.4	-41	-0.01	1	-37	-0.03	1	-35	-0.04	1	-26	-0.09	1
LAK09	1.7	-17.2	37.1	-35	-0.01	1	-32	-0.03	1	-30	-0.04	1	-21	-0.09	1
LAK10	1.8	-2.8	53.3	-51	-0.02	1	-48	-0.04	1	-46	-0.06	1	-37	-0.13	1
LAK11	1.8	-12.7	69.6	-67	-0.02	1	-31	-0.19	1	-28	-0.20	1	-9	-0.27	1
LAK12	1.7	1.0	-8.8	11	-0.03	2	21	-0.13	2	23	-0.15	2	35	-0.26	2
LAK13	1.7	1.4	0.7	1	-0.02	2	9	-0.11	2	11	-0.13	2	21	-0.23	2
NC254	2.5	20.4	25.2	-25	0.00	1	-23	-0.02	1	-23	-0.02	1	-18	-0.06	1
NC273	2.5	28.7	63.9	-62	-0.01	1	-56	-0.05	1	-55	-0.06	1	-44	-0.12	1
NC275	2.5	285.7	555.2	-555	0.00	1	-552	0.00	1	-552	0.00	1	-543	0.00	1
NC278	2.3	32.9	69.9	-70	0.00	1	-68	-0.01	1	-68	-0.01	1	-64	-0.03	1

Table 7 Critical Load Exceedances for Acidification, Predicted Change in pH (ΔpH) and Risk Categories for Assessed Streams and Lakes

Site ID	Runoff (m^3/year/m^2)	ANCoaa (meq/m^3)	Critical Load (meq/m^2/year)	Base Case			Project Case			Application Case			Cumulative Effects Assessment Case		
				Critical Load Exceedance (meq/m^2/year)	ΔpH	Cat	Critical Load Exceedance (meq/m^2/year)	ΔpH	Cat	Critical Load Exceedance (meq/m^2/year)	ΔpH	Cat	Critical Load Exceedance (meq/m^2/year)	ΔpH	Cat
NC309	2.0	6.0	10.2	-9	-0.01	1	-6	-0.05	1	-5	-0.06	1	6	-0.17	2
NC313	2.1	19.0	35.4	-35	0.00	1	-34	-0.01	1	-34	-0.01	1	-30	-0.05	1
NC332	2.2	56.9	149.8	-150	0.00	1	-149	0.00	1	-149	0.00	1	-149	0.00	1
NC340	1.8	59.5	109.8	-109	0.00	1	-105	-0.01	1	-104	-0.02	1	-94	-0.04	1
NC350	3.8	15.0	7.4	-7	0.00	1	-7	-0.01	1	-6	-0.01	1	-2	-0.07	1
NC360	2.2	15.5	11.1	-11	0.00	1	-10	-0.01	1	-10	-0.02	1	-6	-0.06	1
NC366	2.2	21.5	5.8	-5	0.00	1	-4	-0.01	1	-4	-0.01	1	1	-0.04	2
NC374	2.8	70.0	149.2	-149	0.00	1	-147	0.00	1	-147	-0.01	1	-140	-0.02	1
STR01	1.7	15.5	175.8	-173	-0.02	1	-142	-0.27	1	-139	-0.29	1	-124	-0.40	3
STR02	1.8	-24.1	75.5	-73	-0.01	1	-46	-0.09	1	-44	-0.10	1	-32	-0.13	1
STR03	1.8	-5.1	92.5	-91	-0.01	1	-72	-0.09	1	-70	-0.09	1	-60	-0.13	1
STR04	1.8	-3.9	89.8	-88	-0.02	1	-47	-0.26	1	-45	-0.27	1	-33	-0.33	3
STR05	1.7	29.3	228.9	-228	-0.01	1	-224	-0.02	1	-223	-0.02	1	-216	-0.05	1
STR06	1.8	32.1	100.6	-98	-0.01	1	-71	-0.20	1	-69	-0.22	1	-56	-0.34	3
STR07	1.8	-27.1	53.4	-51	-0.01	1	-17	-0.13	1	-15	-0.14	1	-2	-0.18	1
STR08	1.8	59.6	74.6	-73	-0.01	1	-60	-0.05	1	-58	-0.06	1	-46	-0.11	1
STR09	1.9	98.1	154.8	-153	0.00	1	-144	-0.02	1	-142	-0.02	1	-132	-0.03	1

NOTES:
Green highlighting represents waterbodies in category 1 with no concern for acidification
Yellow highlighting represents waterbodies in category 1 with low concern for acidification
Orange highlighting represents waterbodies in category 3 with moderate concern for acidification
Red highlighting represents a critical load exceedance
Grey highlighting represents a predicted change in pH above the biological threshold (>0.3)
No waterbodies were identified as category 4 with high concern for acidification

5 EUTROPHICATION ASSESSMENT

5.1 Scope

The scope of the eutrophication assessment was to compare the modelled nitrogen (N) deposition with empirically derived nutrient-nitrogen critical loads for the protection of surface waters from eutrophication.

Anthropogenic activities may increase atmospheric nitrogen deposition, leading to nutrient enrichment (eutrophication) and, ultimately, changes in primary productivity (e.g., algal biomass). For example, nitrogen enrichment increased phytoplankton biomass in acid-sensitive, northern Minnesota lakes categorized as oligotrophic to eutrophic (Axler et al. 1994). Gradual eutrophication leading to increased phytoplankton biomass was also observed during the summer in oligotrophic Swedish lakes receiving atmospheric N deposition less than 500 kg N/km^2/yr; phytoplankton in lakes receiving higher atmospheric nitrogen deposition were likely saturated with nitrogen (Bergström et al. 2005). Phytoplankton in oligotrophic lakes receiving high amounts of nitrogen deposition may switch from being nitrogen limited to phosphorus limited (Bergström 2010). Paleolimnological evidence (diatom composition in sediment cores) from alpine lakes in Colorado suggested that nitrogen deposition of 3 to 5 kg N/ha/yr caused shifts from oligotrophic to mesotrophic status (Wolfe et al. 2001). Excessive algal growth from increased nutrient inputs may consequently decrease oxygen concentrations, increase cyanobacteria growth, and decrease biodiversity of affected waterbodies.

A trophic state designation is used to describe the current, expected, or measured amount of algal biomass in a targeted watershed. For example, oligotrophic lakes are generally low in nutrient concentrations, with low algal growth. Coastal lakes in British Columbia typically have low concentrations of both nitrogen and phosphorus (P) (Stockner and MacIsaac 1996). Dystrophic lakes may or may not be low in nutrients and typically have brown colored water from high concentrations of humic materials and organic acids (Hansen 1962). The Project may result in increased NO_x deposition into aquatic environments located in the LAA and RAA, with the potential to lead to alterations in trophic status.

5.2 Methods

The eutrophication assessment was conducted for the same 30 lakes evaluated in the acidification assessment. Methods followed those defined in the Guidance for the Assessment of Acidification and Eutrophication of Aquatic Ecosystems, which provides guidance for eutrophication assessment for lakes only (BC MOE 2015a). Streams were not assessed for eutrophication because, with constant flow and recharge, eutrophication is anticipated to be a lesser concern. Lakes were categorized by trophic status after estimating charge balance and anion composition for each site using water chemistry data. Nutrient-nitrogen critical load ranges were assigned to each lake based on classification. Exceedances were estimated under the four modeled emissions cases (i.e., Base, Project, Application, and CEA Cases).

5.2.1 Analysis of Charge Balance

An analysis of charge balance (the difference between the sum of the major cations and major anions) and anion composition was completed for each lake to assess data quality and categorize each lake as either dystrophic or oligotrophic. The following data were used for these analyses:

- Major cations: calcium, magnesium, sodium, potassium, and hydrogen (pH)
- Major anions: chloride, fluoride, nitrate, calcium carbonate, sulphate, and DOC.

Total concentrations were used for each parameter. For ion concentrations below the analytical detection limit, the concentration was calculated as half the detection limit. All measurements of cations and anions were converted from mg/L to µeq/L based on molar mass and charge.

Organic anions such as DOC contribute to the charge balance equation. The charge of organic anions is dependent on the types of organic acids present, and the pH; the charge density of DOC may be estimated using pH and the DOC concentration (Oliver et al. 1983). The charge density of organic anions in data from the 2015 and 2016 field surveys and the historically sampled lakes were optimized separately using an iterative approach for achieving charge balance. The estimated charge density that provided the optimal charge balance (i.e., the smallest difference in anion and cation concentrations), and the lowest number of lakes with a charge balance deviating by >10% from a 1:1 line, was selected.

Once the charge density of DOC was estimated, anion composition was calculated for each lake. The percentages of chloride, calcium carbonate, sulphate, organic anions, and other anions (fluoride and nitrate) out of the total anions were calculated for each lake. Lakes with pH < 6 and organic anions comprising >50% of total anions were categorized as dystrophic.

5.2.1.1 Critical Load Exceedance and Eutrophication

Empirically-derived critical load values for nutrient-nitrogen were obtained from the International Cooperative Programme Waters Report Nutrient Enrichment Effects of Atmospheric Nitrogen Deposition on Biology in Oligotrophic Surface Waters (de Wit and Lindholm 2010). Empirical nutrient-nitrogen critical load values have been derived based on a review of existing scientific literature (e.g., Bobbink et al. 2010, Bobbink et al. 1995, Achermann and Bobbink 2003) and are available for specific ecosystem types.

A range of nutrient-nitrogen critical load values was chosen for temperate dystrophic and oligotrophic lakes based on the values suggested by de Wit and Lindholm (2010). The upper bound, mid-point, and lower bound values of the nutrient-nitrogen critical load range, as appropriate to the designated nutrient class (i.e., oligotrophic or dystrophic), were compared to modeled N deposition for each lake. Modeled N deposition rates were compared to the nutrient-nitrogen critical loads for each lake type in Table 8. An exceedance was identified when the modeled N deposition was greater than the nutrient-nitrogen critical load.

Table 8 Nutrient-nitrogen Critical Loads for Oligotrophic and Dystrophic Lakes

Trophic Status	Nutrient-nitrogen Critical Load (kg N/ha/yr)		
	Lower Bound	Mid-Point	Upper Bound
Oligotrophic	5	7.5	10
Dystrophic	3	4	5

NOTE:
Source: de Wit and Lindholm (2010)

5.2.2 Uncertainties

The eutrophication assessment had an inherent degree of uncertainty due to assumptions in the modelling, some of which are described below:

- Concentrations for several anions and cations used in the charge balance and anion composition calculations were below detection limits; therefore, one half the detection limit was used in these calculations, which may have biased the concentrations upward.
- The charge balance calculation assumes a constant charge density for DOC and a charge balance of 1:1 but natural variability and limitations in the measurements of low concentrations of some anions and cations can increase uncertainty.
- Fluoride and nitrate concentrations were not available for the lakes sampled by AECOM and nitrate concentrations were not available for the lakes sampled by ECCC; therefore, concentrations equivalent to the average of the 2015 and 2016 sampled lakes (one half the detection limit) were selected for calculations.

5.2.3 Risk Categorization

For eutrophication, a risk assessment categorization system similar to that used in the acidification assessment, aiming to protect 95% of the aquatic ecosystems, was applied (see Table 9).

Table 9 Risk Categories for Lakes with Nutrient-nitrogen Critical Load Exceedances

Risk Category	Number of Lakes out of 30 Total with Nutrient-nitrogen Critical Load Exceedances
Low	0 (0% of 30 lakes total)
Moderate	1 (3.3% of 30 lakes total)
High	2 (6.7% of 30 lakes total)
Critical	3 (10% of 30 lakes total)

Risk categories were assigned for each emissions case (i.e., Base, Project, Application, and CEA Case) under each of the three nutrient-nitrogen critical load values (i.e., lower bound, mid-point, and upper bound).

5.3 Data Results

5.3.1.1 Analysis of Charge Balance

Charge balance (sum of the major cations and anions) was determined for modelled lakes. The calculated charge balance should be approximately neutral, with a 1:1 ratio of anions to cations. Typically, however, calculated charge balance is not perfectly neutral due to measurement errors and variation in charge of organic anions due to the effects of water chemistry parameters (e.g., pH).

The calculated charge balance for the 2015 and 2016 lakes (4.75 µeq/mg) was reasonably close to the desired 1:1 ratio (R^2 = 0.94), with an average percent difference of 0.82% (see Figure 5, Table 10). The charge balance for the historically sampled lakes was slightly higher (5.0 µeq/mg, R^2 = 0.95) with an average percent difference of 1.2% (see Table 11). Half the lakes had a negative charge balance, indicating higher concentrations of anions, while the remaining half had higher concentrations of cations.

The optimization of the organic anion charge density was based on the effect of the selected charge density on the overall charge balance (see Table 10 and Table 11).

Table 10 Effect of DOC Charge Density on Charge Balance for Lakes Sampled in 2015 and 2016

DOC Charge Density (µeq/mg)	Mean% Diff	Mean ABS%	Mean Diff	Mean Abs Diff	# of Lakes>10% off Charge Balance
5.00	-1.61	5.15	-1.41	9.98	1
4.75	0.82	4.31	2.93	8.95	1
4.50	3.33	4.38	7.27	9.32	1
4.25	5.89	6.07	11.61	12.00	2

NOTES:
Mean % Diff = mean % charge density
Mean ABS % = mean of the absolute value of the deviations from neutral charge balance
Mean Diff = mean deviation from neutral charge balance
Mean Abs Diff = mean of the absolute value of the deviations from neutral charge balance
The grey highlight indicates the chosen charge density value (4.75 µeq/mg)

Table 11 Effect of DOC Charge Density on Charge Balance for Historically Sampled Lakes

Charge Density (µeq/mg)	Mean% Diff	Mean ABS%	Mean Diff	Mean Abs Diff	# of Lakes>10% off Charge Balance
5.25	-0.75	8.69	5.06	19.27	6
5.00	1.23	8.60	8.26	19.26	5
4.75	3.27	9.19	11.47	20.41	5
4.50	5.34	10.09	14.67	21.89	6

NOTES:
Mean % Diff = mean % charge density
Mean ABS % = mean of the absolute value of the deviations from neutral charge balance
Mean Diff = mean deviation from neutral charge balance
Mean Abs Diff = mean of the absolute value of the deviations from neutral charge balance
The grey highlight indicates the chosen charge density value (5.0 µeq/mg)

All 12 lakes sampled in 2015 and 2016 had laboratory pH < 6.0, whereas 10 of the 18 historically sampled lakes had pH < 6.0. The anion composition of the 30 lakes is shown in Table 12. Six lakes sampled in 2015 and 2016 (LAK05, LAK07, LAK08, LAK09, LAK13, and LAK11) were identified as dystrophic, with organic anions comprising 50.4% to 56.6% of the total anions. Five historically-sampled lakes (NC278, NC313, NC332, NC360, and ADSW9) were also identified as dystrophic, with organic anions comprising 50.6% to 63.7% of the total anions. All the lakes sampled in 2015 and 2016, and 15 of 18 of the historically sampled lakes, were chloride-influenced (≥25% total anions). The remaining lakes were characterized as oligotrophic, with organic anions comprising <50% of the total anions.

Table 12 Anion Composition in Lakes

Lake ID	DOC (mg/L)	pH (lab)	Chloride	Alkalinity as $CaCO_3$	Sulphate	Organics
LAK08	17.2	4.38	38%	7%	2%	**53%**
LAK09	17.7	4.35	37%	6%	2%	**54%**
LAK02	22.2	4.86	31%	5%	16%	48%
LAK04	21.1	5.37	26%	17%	20%	36%
LAK05	20.9	4.41	33%	6%	4%	**57%**
LAK06	21.4	5.03	31%	4%	20%	45%
LAK07	17.4	4.35	37%	7%	2%	**54%**
LAK 11	18.7	4.34	34%	6%	5%	**54%**
LAK 10	13.7	4.60	46%	7%	2%	44%
LAK 03	16.2	5.29	38%	11%	18%	34%
LAK 12	8.29	4.69	56%	8%	3%	33%
LAK 13	13.5	4.58	39%	8%	2%	**50%**
Alywn	9.3	6.32	24%	35%	10%	30%
Georgetown	8.6	6.78	17%	44%	19%	19%
NC254	11.2	5.26	41%	4%	5%	49%
NC273	10.2	6.05	38%	21%	5%	36%
NC275	11.7	7.03	0%	77%	0%	23%
NC278	17.3	5.07	35%	3%	3%	**58%**
NC309	10	5.12	40%	5%	5%	49%
NC313	16	4.84	29%	4%	3%	**64%**
NC332	19.1	5.64	27%	15%	7%	**51%**
NC340	16.6	5.81	27%	20%	5%	48%
NC350	2.9	6.21	36%	32%	6%	24%
NC360	12.2	4.91	33%	4%	7%	**54%**
NC366	8.6	5.49	35%	6%	10%	48%
NC374	4.7	6.73	25%	47%	11%	17%
AD-SW1	23	6.13	35%	25%	2%	38%
AD-SW4	23	6.47	31%	34%	2%	33%

Table 12 Anion Composition in Lakes

Lake ID	DOC (mg/L)	pH (lab)	Chloride	Alkalinity as $CaCO_3$	Sulphate	Organics
AD-SW8	7.39	5.98	33%	28%	5%	33%
AD-SW9	18.8	5.51	31%	13%	3%	**52%**

NOTES:
Dystrophic lakes are highlighted in grey (>50% organic anions)
Bolded values are ≥50%

5.3.1.2 Nutrient-nitrogen Critical Load Exceedance and Eutrophication

The empirical critical load thresholds for nutrient-nitrogen described in Section 5.2.1.1 were compared to the expected nitrogen deposition values (kg N/ha/yr) under the four emission cases. The nutrient-nitrogen critical load range was applied to each lake based on its classification as dystrophic or oligotrophic. Nitrogen deposition values were compared to the upper, mid-point, and lower bound critical load values. Critical load ranges are conservative, as it is assumed almost all of the nitrogen deposited on a waterbody will contribute to eutrophication. The mid-point value represents the average of the critical load range and, therefore, may be most representative of expected conditions.

The full results for the nutrient-nitrogen eutrophication analysis under the lower, mid-point, and upper bound critical loads are presented in Appendix 1, Table 1-5. Of the 30 lakes analyzed, only two (LAK05 and LAK11, 6.7% of lakes) showed exceedances for the Project, Application, and CEA nitrogen emission cases using the lower bound nutrient-nitrogen critical load threshold, resulting in a high risk for eutrophication for lakes in the RAA (see Table 13).

LAK05 and LAK11 were classified as dystrophic, meaning empirically-derived nutrient-nitrogen critical load values of 3, 4, and 5 kg N/ha/yr were applied for the assessment. Both lakes had low pH values at 4.41 and 4.34 for LAK05 and LAK11, respectively. LAK05 was approximately 1.25 m deep. No fish were captured in LAK05 during fish surveys although it feeds streams with known commercial, recreational, and Aboriginal valued fish species, including coho salmon and Dolly Varden (Khtada 2015). LAK11 acts as the water reservoir for the community of Dodge Cove, which has been under a boil water advisory since 1988, due to the abandonment of the water treatment facility. Both lakes (LAK05 and LAK11) are also located close to the boundary of the PDA on Digby Island and are modeled to receive the highest nitrogen deposition.

Table 13 Eutrophication Risk Categorization for Nutrient-nitrogen Critical Load Exceedances for 30 Lakes Under Base, Project, Application, and CEA Nitrogen Oxide Emissions Cases

Nutrient-nitrogen Critical Load	Risk Categories per Emissions Case (Number of Lakes with Exceedances)			
	Base	Project	Application	Cumulative
Lower Bound	Low (0)	High (2)	High (2)	High (2)
Mid-Point	Low (0)	Moderate (1)	Moderate (1)	High (2)
Upper Bound	Low (0)	Low (0)	Low (0)	High (2)

Evaluation using the mid-point nutrient-nitrogen critical load value resulted in only one lake (LAK11) with a nutrient-nitrogen moderate load exceedance under the Project and Application Cases and lakes in the RAA were therefore classified with a moderate risk for eutrophication (3.3% of lakes exceed nutrient-nitrogen critical load). Under the CEA Case, two lakes (LAK11 and LAK05) had a nutrient-nitrogen exceedance resulting in a high risk for eutrophication for lakes in the RAA (6.7% of lakes exceed the nutrient-nitrogen critical load). Results for the mid-point critical load assessment are shown in Table 14.

Table 14 Results of the Eutrophication Nutrient-nitrogen Analysis for 30 Lakes under the Mid-Point Nutrient-nitrogen Critical Loads

Lake ID	pH	Organic anions	N Exceedances per Emissions Case			
			Base (kg N/ha/yr)	Project (kg N/ha/yr)	Application (kg N/ha/yr)	Cumulative (kg N/ha/yr)
LAK08	4.38	53%	-3.744	-3.382	-3.126	-2.037
LAK09	4.35	54%	-3.741	-3.413	-3.154	-2.082
LAK02	4.86	48%	-7.258	-5.914	-5.672	-4.544
LAK04	5.37	36%	-7.227	-5.419	-5.146	-3.844
LAK05	4.41	57%	-3.705	-0.533	-0.238	**1.231**
LAK06	5.03	45%	-7.256	-6.150	-5.906	-4.752
LAK07	4.35	54%	-3.774	-3.375	-3.149	-2.145
LAK 11	4.34	54%	-3.597	**0.377**	**0.780**	**2.946**
LAK 10	4.60	44%	-7.185	-6.883	-6.568	-5.460
LAK 03	5.29	34%	-7.250	-6.142	-5.891	-4.737
LAK12	4.69	33%	-7.219	-6.076	-5.795	-4.264
LAK13	4.58	50%	-3.758	-2.870	-2.628	-1.300
Alywn	6.32	30%	-7.416	-7.205	-7.121	-6.096
Georgetown	6.78	19%	-7.425	-7.222	-7.147	-5.814
NC254	5.26	49%	-7.441	-7.290	-7.231	-6.682
NC273	6.05	36%	-7.281	-6.581	-6.362	-5.098
NC275	7.03	23%	-7.416	-7.190	-7.106	-6.047
NC278	5.07	58%	-3.950	-3.846	-3.796	-3.383
NC309	5.12	49%	-7.357	-6.999	-6.855	-5.502
NC313	4.84	64%	-3.963	-3.861	-3.824	-3.372
NC332	5.64	51%	-3.980	-3.960	-3.940	-3.873
NC340	5.81	48%	-7.352	-6.914	-6.765	-5.541
NC350	6.21	24%	-7.472	-7.372	-7.344	-6.785
NC360	4.91	54%	-3.963	-3.861	-3.824	-3.372
NC366	5.49	48%	-7.453	-7.325	-7.278	-6.674
NC374	6.73	17%	-7.446	-7.268	-7.215	-6.408
AD-SW1	6.13	38%	-7.386	-7.152	-7.038	-5.545
AD-SW4	6.47	33%	-7.381	-7.052	-6.933	-5.691

Table 14 Results of the Eutrophication Nutrient-nitrogen Analysis for 30 Lakes under the Mid-Point Nutrient-nitrogen Critical Loads

Lake ID	pH	Organic anions	N Exceedances per Emissions Case			
			Base (kg N/ha/yr)	Project (kg N/ha/yr)	Application (kg N/ha/yr)	Cumulative (kg N/ha/yr)
AD-SW8	5.98	33%	-7.400	-7.180	-7.081	-5.487
AD-SW9	5.51	52%	-3.954	-3.853	-3.807	-3.361

NOTES:
Grey shading indicates dystrophic lakes
Bold text indicates N exceedances for eutrophication

Using the upper bound nutrient-nitrogen critical load, no lakes showed exceedances of the nutrient-nitrogen critical load under the Project and Application Cases. The result is a low risk classification for eutrophication for lakes in the RAA; however, for the CEA Case LAK11 and LAK05 exceeded the upper bound critical load, resulting in a high risk for lakes in the RAA. For the CEA Case, there was a high risk for eutrophication for lakes in the RAA for the full range of critical loads applied.

6 SUMMARY

For acidification, a low risk was predicted for the Project and Application Cases because no waterbodies showed exceedances of the biological threshold for ∆pH and only three lakes had a critical load exceedance. Three streams exceeded the conservative biological effects threshold of 0.3 units for the CEA Case and five lakes had a critical load exceedance, indicating critical risk for acidification. Although a critical risk is identified for the CEA Case it is largely due to the three streams predicted to have a pH change above 0.3 units. The biological model applied to calculate pH changes in streams was originally developed to assess lakes and does not incorporate stream data (Fölster et al. 2007). The pH in streams naturally fluctuates seasonally and the system is recharged (i.e., buffering capacity recovery) more readily than for lakes. The remaining assessed lakes and streams under the CEA Case have no concern (no critical load exceedance and no pH exceedance) or low concern (a critical load exceedance and no pH exceedance) for acidification, and would fall under the low risk category for acidification.

For eutrophication, modelled nitrogen deposition under the Base, Project, Application, and CEA Cases was compared to a range of critical loads (lower bound, mid-point, and upper bound). Two dystrophic lakes (LAK05 and LAK11) were identified as having exceedances of the nutrient-nitrogen critical load under various emission cases, resulting in risk ratings of low, moderate, or high. This included high risk ratings (i.e., 2 of 30 lakes) using the most conservative lower bound critical load values, for the Project and Application Cases; moderate risk ratings (i.e., 1 of 30 lakes) under the Project and Application Cases using the mid-point critical load values; and low risk for the Project and Application Cases using the upper bound critical load values. For the CEA Case, a risk rating of high (i.e., 2 of 30 lakes) was identified, regardless of the critical range applied (lower bound, mid-point, or upper bound).

7 CLOSURE

Respectfully submitted,

STANTEC CONSULTING LTD.

Mariah Arnold, Ph.D.
Report Author

Karen Munro, MSc.
Technical Reviewer

Lisa McCuaig, B. Tech, RB. Tech.
Report Author

Michael Browne, M.Sc., R.P.Bio
Technical Reviewer

8 REFERENCES

8.1 Literature Cited

Achermann, B. and R. Bobbink (eds.). 2003. Empirical critical loads for nitrogen. Expert Workshop, Berne. Swiss Agency for the Environment, Forests and Landscape (SAEFL).

Axler, R.P., Rose, C., and Tikkanen, C.A. 1994. Phytoplankton nutrient deficiency as related to atmospheric nitrogen deposition in northern Minnesota acid-sensitive lakes. *Canadian Journal of Fisheries and Aquatic Sciences* 51-: 1281-1296.

Bergström, A.-K., Blomqvist, P., Jansson, M. 2005. Effects of atmospheric nitrogen deposition on nutrient limitation and phytoplankton biomass in unproductive Swedish lakes. *Limnology and Oceanography* 50: 987-994.

Bergström, A.-K. 2010. The use of Tn-TP and DIN/TP ratios as indicators for phytoplankton nutrient limitation in oligotrophic lakes affected by N deposition. *Aquatic Sciences* 72: 277-281.

Bobbink, R., Hicks, K., Galloway, J., Spranger, T., Alkemade, R., Ashmore, M., Bustamante, M., Cinderby, S., Davidson, E., Dentener, F., Emmett, B., Erisman, J.-W., Fenn, M., Gilliam, F., Nordin, A., Pardo, L., De Vries, W. 2010. Global assessment of nitrogen deposition effects on terrestrial plant diversity: a synthesis. *Ecological Applications* 20: 30-59.

Bobbink, R. and Roelofs, J.G.M. 1995. Nitrogen critical loads for the natural and semi-natural ecosystems: The empirical approach. *Water, Air, and Soil Pollution* 85: 2413-2418.

British Columbia Ministry of Environment (BC MOE). 1991. Ambient Water Quality Criteria for pH. Technical Appendix. Water Quality Branch. URL: http://www.env.gov.bc.ca/wat/wq/BCguidelines/phtech.pdf. Accessed: June 2016.

British Columbia Ministry of Environment (BC MOE). 1998. Guidelines for Interpreting Water Quality Data. Prepared by the Ministry of Environment, Lands and Parks, LandDataBC, Geographic Data BC for the Land Use Task Force Resources Inventory Committee. URL: https://www.for.gov.bc.ca/hts/risc/pubs/aquatic/interp/index.htm. Accessed: July 2016.

British Columbia Ministry of Environment (BC MOE). 2015a. Guidance for the Assessment of Acidification and Eutrophication of Aquatic Ecosystems. British Columbia Ministry of Environment Air Emissions Impact Assessment for Liquefied Natural Gas Export Terminal Facilities.

British Columbia Ministry of Environment (BC MOE). 2015b. *Part II: Ecoregion Unit Descriptions*. URL: http://www.env.gov.bc.ca/ecology/ecoregions/humidtemp.html#coast. Accessed: February 2016.

BC MOE (British Columbia Ministry of Environment). 2016. HabitatWizard. URL: http://www.env.gov.bc.ca/habwiz/. Accessed: May 2016.

Canadian Council of Ministers of the Environment (CCME). 1998. The Canada-Wide Acid Rain Strategy for Post-2000. Strategy and Supporting Document. Federal/Provincial/Territorial Ministers of Energy and Environment. Halifax, Nova Scotia. URL: http://www.ccme.ca/files/Resources/air/acid_rain/1998_acid_rain_strategy_e.pdf. Accessed: June 2016.

Clark, M.J.R. 2003. *British Columbia Field Sampling Manual*. Water, Air and Climate Change Branch, Ministry of Water, Land and Air Protection, Victoria, BC, Canada. 312 pp.

Davies, J.-M., Nowlin, W.H., Mazumder, A. 2004. Temporal changes in nitrogen and phosphorus codeficiency of plankton in lakes of coastal and interior British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences* 61: 1538-1551.

Environment Canada. 2004. Canadian Acid Deposition Science Assessment. Meteorological Service of Canada Branch, Ottawa, ON.

ESSA Technologies, Laurence, J. Limnotek, Risk Sciences International, Rio Tinto Alcan, Tren University, Trinity Consultants, University of Illinois (ESSA). 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, BC. 450 pp.

ESSA Technologies, Laurence, J., Risk Sciences International, Trent University, and Trinity Consultants. 2014. Kitimat Airshed Emissions Effects Assessment.

Fölster, J., Andrén, C., Bishop, K., Buffam, I., Cory, N., Goedkoop, W., Holmgren, K., Johnson, R., Laudon, H., Wilander, A. 2007. A novel environmental quality criterion for acidification in Swedish lakes—An application of studies on the relationship between biota and water chemistry. *Water Air Soil Pollution: Focus* 7:331-338.

Hansen, K. 1962. The dystrophic lake type. *Hydrobiologia* 19: 183-190.

Henriksen, A., and Posch, M. 2001. Steady-state models for calculation critical loads of acidity for surface waters. *Water, Air, and Soil Pollution Focus* 1: 375–398.

Henriksen, A., Dillon, P.J., Aherne, J. 2002. Critical Loads of acidity for surface waters in south-central Ontario, Canada: regional application of the steady-state water chemistry (SSWC) model. *Canadian Journal of Fish and Aquatic Science* 59: 1287–1295.

Hruska, J., Laudon, H., Johnson, C.E., Kohler, S., Bishop, K. 2001. Acid/base character of organic acids in a boreal stream during snowmelt. *Water Resources Research* 37: 1043-1056.

Khtada Environmental Services LP (Khtada). 2015. Aurora LNG Freshwater Fish and Fish Habitat Final Report 2014-2015. Prepared for Nexen Energy ULC.

Lien, L. G. Raddum, A. Fjellheim, Henriksen, A. 1996. A critical limit for acid neutralizing capacity in Norwegian surface waters, based on the new analysis of fish and invertebrate responses. *Science of the Total Environment* 177: 173–193.

Lydersen, E., Larssen, T., Fjeld, T. 2003. The influence of total organic carbon on the relationship between acid neutralizing capacity and fish status in Norwegian Lakes. *Science of the Total Environment* 326: 63–69.

Marmorek, D.R., Jones, M.L., Minns, C.K., Elder, F.C. 1990. Assessing the potential extent of damage to inland lakes in eastern Canada due to acidic deposition. I. Development and evaluation of a simple “site” model. *Canadian Journal of Fisheries and Aquatic Sciences* 47: 55-66.

Oliver, B.G., E.M. Thurman, and R.L, Malcolm. 1983. The contribution of humic substances to the acidity of colored natural waters. Geochim. Cosmochim. Acta 47, 2031.

Posch, M. 2004. Manual on methodologies and criteria for Modelling and Mapping Critical Loads and Levels and Air Pollution Effects, Risk and Trends. Chapter 7, Exceedance Calculations. Federal Environmental Agency (Umweltbundesamt).

Reynolds, B. 2004. Critical loads for aquatic ecosystems. In Convention on Long-Range Transboundary Air Pollution (CLRTAP). Manual on Methodologies and Criteria for Modelling and Mapping Critical Loads and Levels and Air Pollution Effects, Risks and Trends. UNECE Convention on Longrange Transboundary Air Pollution.

Saffran, K. and Trew, D. 1996. *Sensitivity of Alberta Lakes to Acidifying Deposition: An Update of Sensitivity Maps with Emphasis on 109 Northern Lakes*. Water Science Branch, Alberta Environmental Protection.

Small, M.J. and Sutton, M.C. 1986. A regional pH-alkalinity relationship. *Water Resources* 20: 335-343.

Stantec Consulting Ltd. 2016. Air Quality Technical Data Report. Prepared for Aurora LNG.

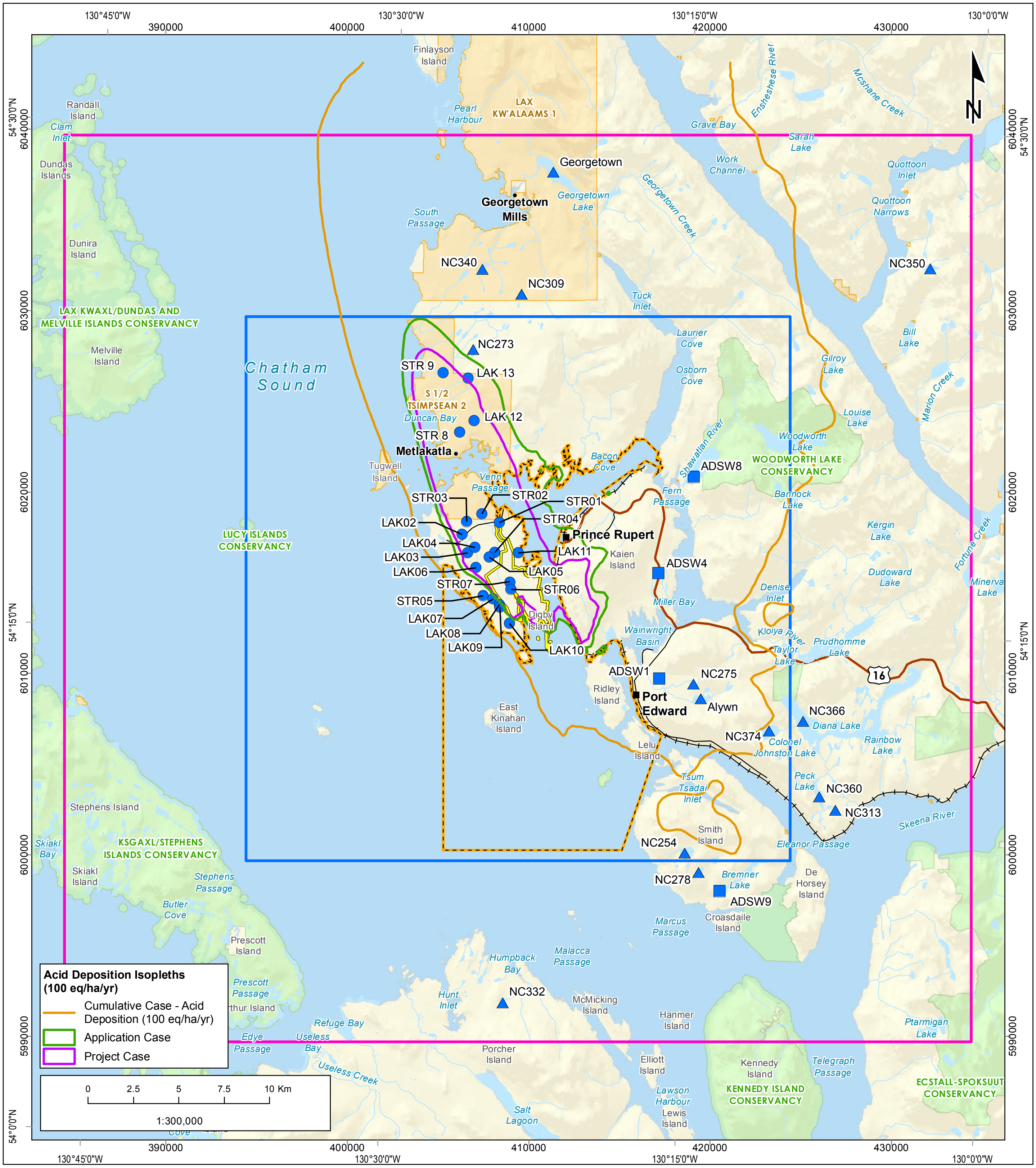
Stockner, J.G. and MacIsaac, E.A. 1996. British Columbia lake enrichment programme: Two decades of habitat enhancement for sockeye salmon. *Regulated Rivers: Research & Management* 12: 547-56.

de Wit, H.A. and Lindholm, M. 2010. Nutrient enrichment effects of atmospheric N deposition on biology in oligotrophic surface waters—a review. Norwegian Institute of Water Research. ICP Waters report 101/2010. 39 pp.

Wolfe, A.P., Baron, J.S., and Cornett, R.J. 2001. Anthropogenic nitrogen deposition induces rapid ecological changes in alpine lakes of the Colorado Front Range (USA). *Journal of Paleolimnology* 25: 1-7.

9 FIGURES

Please see the following pages.



- City, Municipality, or Town
- Community, Locality, or Village
- Highway
- Road
- Railway
- Watercourse
- Park, Protected Area, Ecological Reserve, or Conservancy
- First Nation Reserve
- Waterbody
- Prince Rupert Port Authority Boundary
- Project Development Area
- Surface Water Acidification and Eutrophication Local Assessment Area
- Surface Water Acidification and Eutrophication Regional Assessment Area

Water Quality Site

- Stantec
- Environment Canada
- AECOM

Data Sources: Government of British Columbia: DataBC, Terrain Resource Information Management, National Topographic System, BC Stats, BC Oil & Gas Commission. Government of Canada: CanVec v12, National Hydrology Network, Atlas of Canada National Framework, Fisheries and Oceans Canada, Environment Canada, Natural Resources Canada. INPEX Gas British Columbia Ltd. Nexen Energy ULC.Service Layer Credits: Copyright:© 2014 Esri

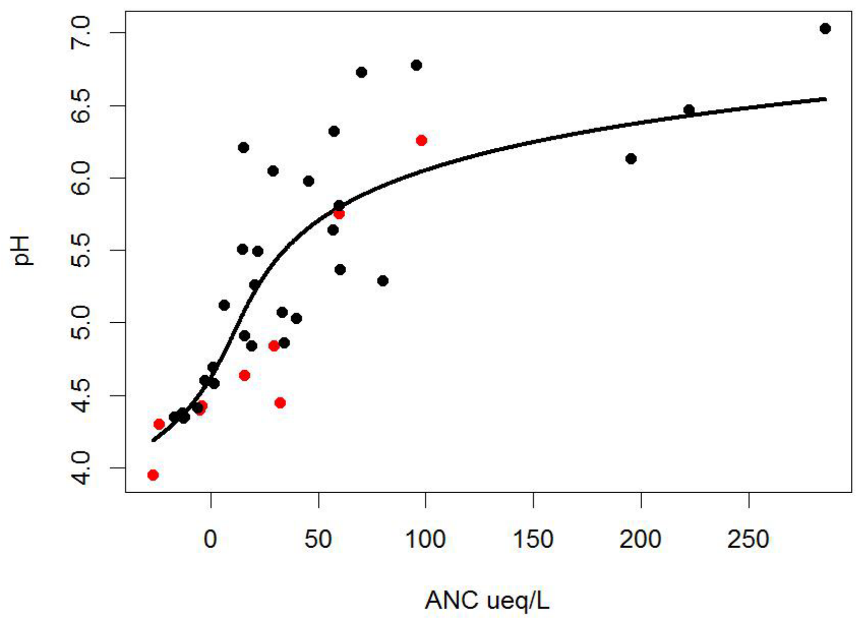
Disclaimer: Contains information licensed under the Open Government License – British Columbia, Canada. Although there is no reason to believe that there are any errors associated with the data used to generate this product or in the product itself, users of these data are advised that errors in the data may be present. Use of this map is strictly at user's own risk. Nexen Energy ULC (Nexen) and INPEX Gas British Columbia Ltd. (IGBC) and each of their affiliates make no representation, warranty or guaranty about this map or its contents, including, without limitation, accuracy, completeness, or fitness for any purpose. Nexen and IGBC shall have no liability for any errors, omissions, or inaccuracies in the information provided. Nexen and IGBC assumes no liability for any decisions made or actions taken or not taken in reliance upon the data furnished on this map. Usage, manipulation, or reproduction, in any form, of the data and information contained herein is prohibited without permission of Nexen and IGBC.

aurora LNG
COMMUNITY COMMITMENT CONNECTION

SURFACE WATER QUALITY TECHNICAL DATA REPORT

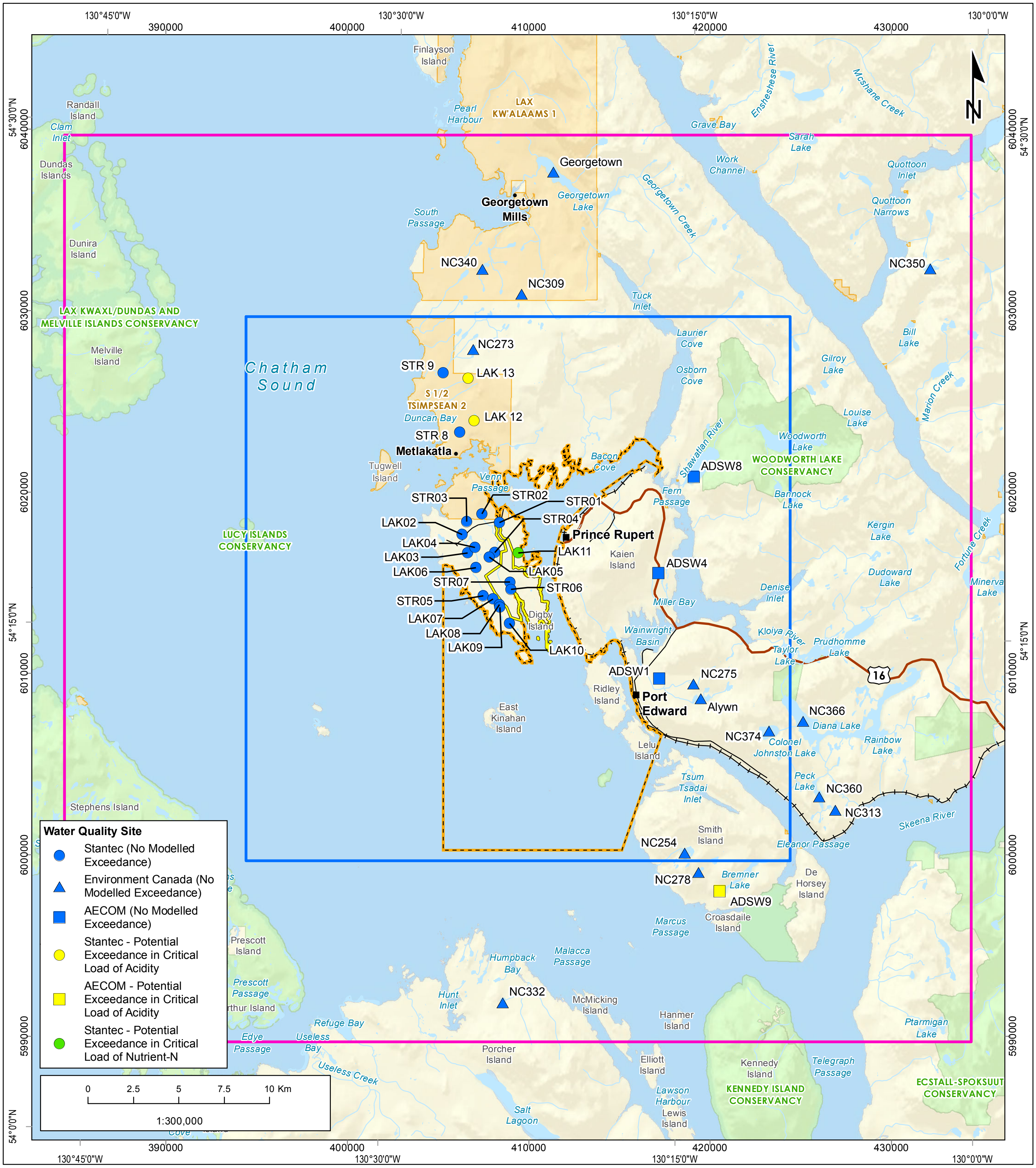
FRESHWATER ACIDIFICATION AND EUTROPHICATION SURVEY SITES AND AIR QUALITY ISOPLETHS (EQ/HA/YR)

Projection: UTM Zone 9 Datum: NAD 83	Fig. ID: 123220054 Date: Oct 26, 2016	Drawn By: RC Checked By: MA	FIGURE NO: 1



NOTE:
Black data points represent lakes and red data points represent stream sites.

Figure 2 **ANC_{oaa} (ANC) and pH curve to fit the Small and Sutton (1986) Equation for 30 Lakes and 9 Streams in the Regional Assessment Area (R Studio)**



- City, Municipality, or Town
- Community, Locality, or Village
- Highway
- Road
- Railway
- Watercourse
- Park, Protected Area, Ecological Reserve, or Conservancy
- First Nation Reserve
- Waterbody
- Prince Rupert Port Authority Boundary
- Project Development Area
- Surface Water Acidification and Eutrophication Local Assessment Area
- Surface Water Acidification and Eutrophication Regional Assessment Area

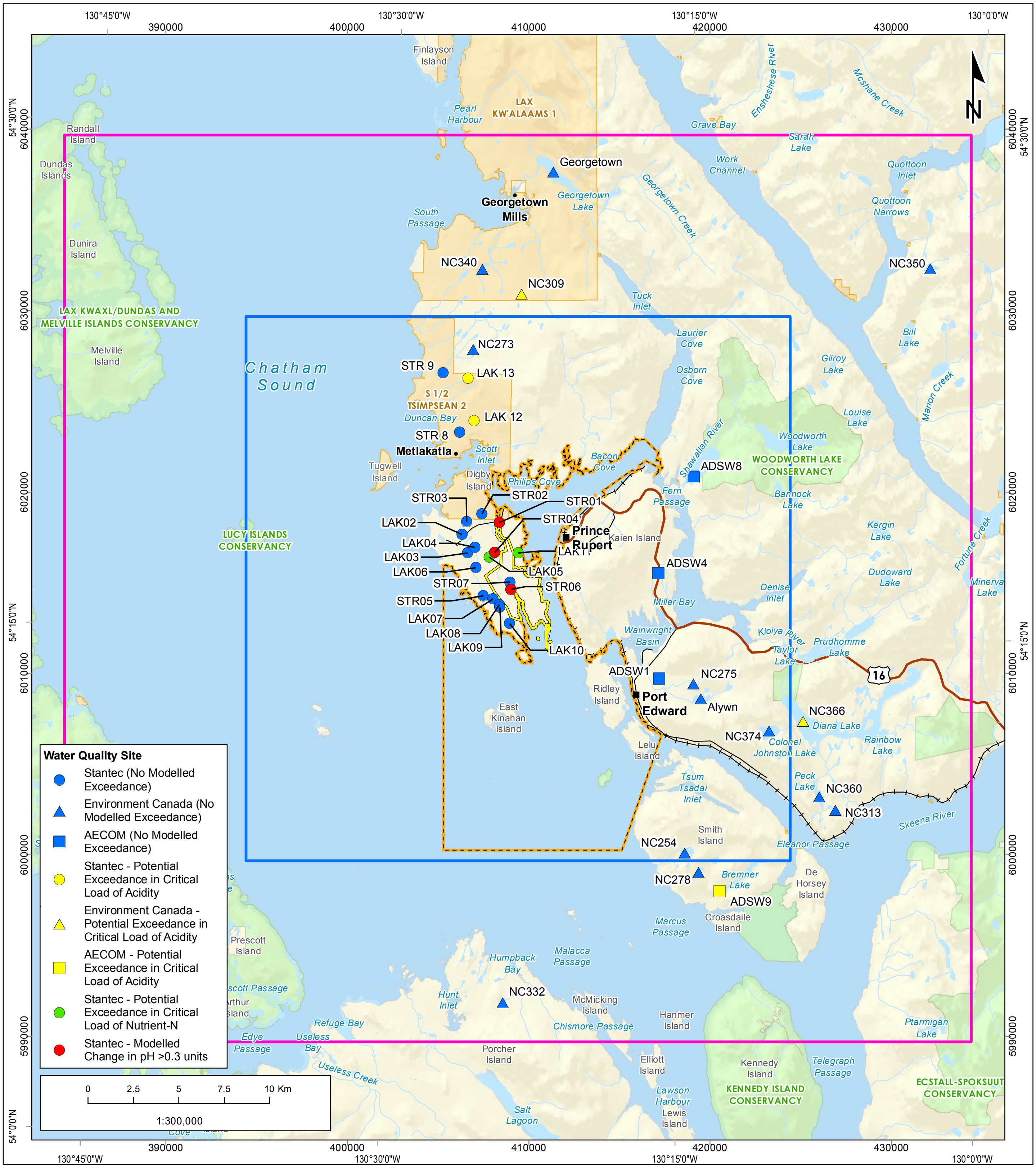
Data Sources: Government of British Columbia: DataBC, Terrain Resource Information Management, National Topographic System, BC Stats, BC Oil & Gas Commission. Government of Canada: CanVec v12, National Hydrology Network, Atlas of Canada National Framework, Fisheries and Oceans Canada, Environment Canada, Natural Resources Canada. INPEX Gas British Columbia Ltd. Nexen Energy ULC.Service Layer Credits: Copyright:© 2014 Esri

aurora LNG

SURFACE WATER QUALITY TECHNICAL DATA REPORT

APPLICATION CASE: WATERBODIES THAT ARE POTENTIALLY ABOVE CRITICAL LOAD

Projection: UTM Zone 9 Datum: NAD 83	Fig. ID: 123220054 Date: Oct 27, 2016	Drawn By: RC Checked By: MA	FIGURE NO: 3



- City, Municipality, or Town
- Community, Locality, or Village
- Highway
- Road
- Railway
- Watercourse
- Park, Protected Area, Ecological Reserve, or Conservancy
- First Nation Reserve
- Waterbody
- Prince Rupert Port Authority Boundary
- Project Development Area
- Surface Water Acidification and Eutrophication Local Assessment Area
- Surface Water Acidification and Eutrophication Regional Assessment Area

aurora LNG

COMMUNITY COMMITMENT CONNECTION

SURCACE WATER QUALITY TECHNICAL DATA REPORT

CUMULATIVE EFFECTS ASSESSMENT CASE: WATERBODIES THAT ARE POTENTIALLY ABOVE CRITICAL LOAD

Data Sources: Government of British Columbia: DataBC, Terrain Resource Information Management, National Topographic System, BC Stats, BC Oil & Gas Commission. Government of Canada: CanVec v12, National Hydrology Network, Atlas of Canada National Framework, Fisheries and Oceans Canada, Environment Canada, Natural Resources Canada. INPEX Gas British Columbia Ltd. Nexen Energy ULC.Service Layer Credits: Copyright:© 2014 Esri

Projection: UTM Zone 9 Datum: NAD 83	Fig. ID:123220054 Date: Oct 27, 2016	Drawn By: RC Checked By: MA	FIGURE NO: 4

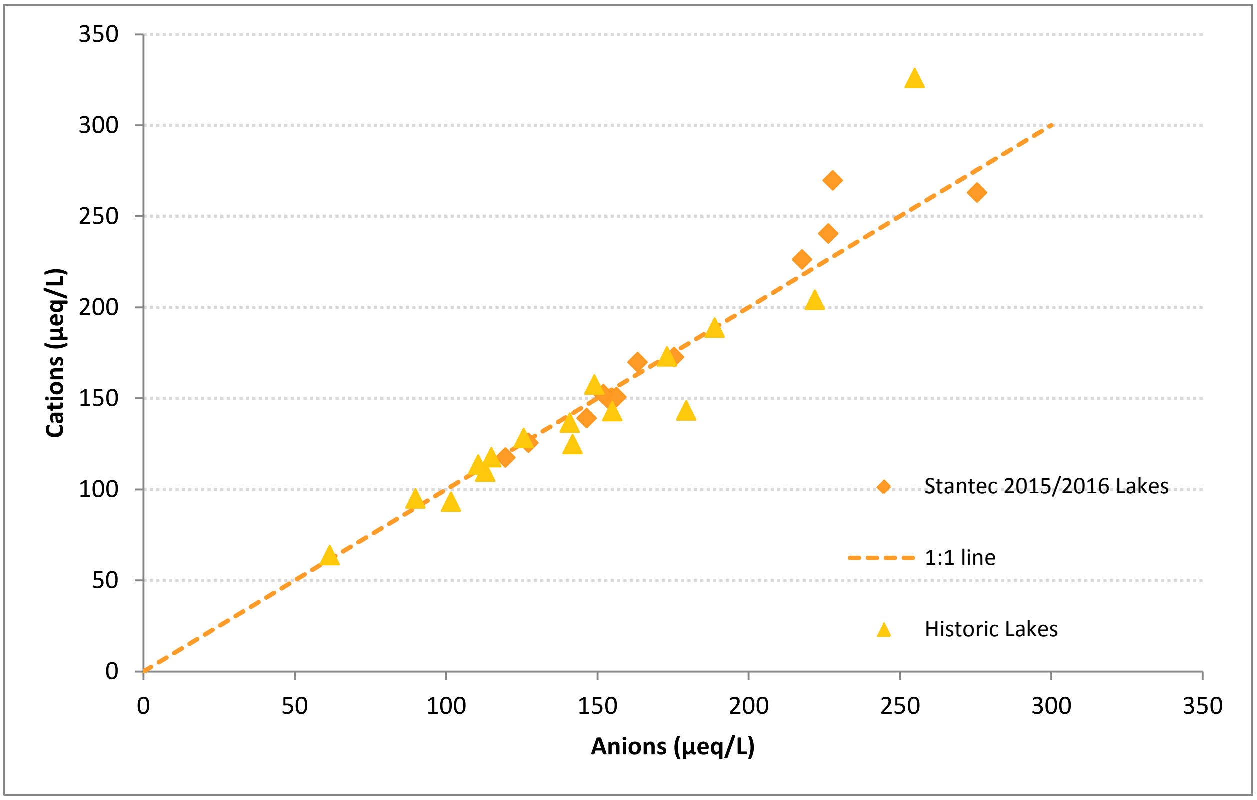


Figure 5 Charge Balance for the 2015 and 2016 Stantec and Historically Sampled Lakes

APPENDIX 1

Aurora LNG – Freshwater Quality Data

Appendix 1 Table 1-1 - Water Chemistry Data

Parameter	Units	LAK02	LAK03	LAK04	LAK05	LAK06	LAK07	LAK08
		1-Oct-15	2-Oct-15	1-Oct-15	1-Oct-15	1-Oct-15	1-Oct-15	30-Sep-15
Conductivity (µS/cm)	uS/cm	28.4	27	28.7	28.4	28.1	28.2	28
Hardness (as CaCO3)	mg/L	7.16	7.14	9.45	3.21	8.07	1.91	1.93
pH (pH units)	pH	4.86	5.29	5.37	4.41	5.03	4.35	4.38
Total Suspended Solids	mg/L	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Total Dissolved Solids	mg/L	61	45	59	54	63	46	43
Turbidity (NTU)	NTU	0.57	0.72	0.59	0.84	0.62	0.95	0.56
Gran Alkalinity (as -H+) (meq/L)	meq/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Alkalinity, Bicarbonate (as CaCO3)	mg/L	<1.0	1.2	2.4	<1.0	<1.0	<1.0	<1.0
Alkalinity, Carbonate (as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Alkalinity, Hydroxide (as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Alkalinity, Total (as CaCO3)	mg/L	<1.0	1.2	2.4	<1.0	<1.0	<1.0	<1.0
Ammonia, Total (as N)	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bromide (Br)	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	mg/L	2.34	3.02	2.54	2.04	2.45	1.95	2.04
Fluoride (F)	mg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Nitrate (as N)	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Nitrite (as N)	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Total Kjeldahl Nitrogen	mg/L	0.429	0.302	0.382	0.363	0.348	0.327	0.332
Orthophosphate-Dissolved (as P)	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Phosphorus (P)-Total Dissolved	mg/L	0.0066	0.005	0.0065	0.0063	0.0081	0.0039	0.0036
Phosphorus (P)-Total	mg/L	0.0083	0.0079	0.0046	0.0044	0.0079	0.0042	0.0042
Sulfate (SO4)	mg/L	1.67	1.92	2.6	0.35	2.12	<0.30	<0.30
Anion Sum (meq/L)	meq/L	0.1	0.15	0.17	<0.10	0.11	<0.10	<0.10
Cation Sum (meq/L)	meq/L	0.19	0.27	0.22	0.13	0.2	<0.10	<0.10
Cation - Anion Balance (%)	%	30.7	28.1	12.5	33.2	28.1	25.5	22.7
Dissolved Organic Carbon	mg/L	22.2	16.2	21.1	20.9	21.4	17.4	17.2
Total Organic Carbon	mg/L	22.6	17.1	21.1	21.8	22.7	17.9	17.6
Aluminum (Al)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony (Sb)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic (As)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium (Ba)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Beryllium (Be)-Total	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth (Bi)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron (B)-Total	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium (Cd)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium (Ca)-Total	mg/L	1.9	1.83	2.61	0.775	2.19	0.37	0.358
Chromium (Cr)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt (Co)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Copper (Cu)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron (Fe)-Total	mg/L	0.615	0.448	0.556	0.478	0.569	0.18	0.206
Lead (Pb)-Total	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium (Li)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium (Mg)-Total	mg/L	0.58	0.62	0.71	0.31	0.63	0.24	0.25
Manganese (Mn)-Total	mg/L	0.0153	0.0154	0.0149	0.0073	0.0134	<0.0050	<0.0050
Molybdenum (Mo)-Total	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel (Ni)-Total	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus (P)-Total	mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)-Total	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Selenium (Se)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon (Si)-Total	mg/L	0.65	0.531	0.666	0.376	0.632	0.098	0.105
Silver (Ag)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium (Na)-Total	mg/L	<2.0	2.2	<2.0	<2.0	<2.0	<2.0	<2.0
Strontium (Sr)-Total	mg/L	0.0113	0.0115	0.0147	0.0058	0.0129	<0.0050	<0.0050
Thallium (Tl)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin (Sn)-Total	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium (Ti)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium (V)-Total	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc (Zn)-Total	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
BOD	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
COD	mg/L	73	46	66	61	72	56	54
Chlorophyll a (µg/L)	ug/L	0.444	2.25	0.154	1.22	0.542	1.02	0.932

Appendix 1 Table 1-1 - Water Chemistry Data

Parameter	Units	LAK09	LAK10	LAK11	LAK12	LAK13	STR01	STR02
		30-Sep-15	2-Oct-15	26-Oct-15	4-Apr-16	4-Apr-16	30-Sep-15	2-Oct-15
Conductivity (µS/cm)	uS/cm	28.4	24.3	28.9	18.1	20.1	29.7	32.5
Hardness (as CaCO3)	mg/L	1.85	2.24	2.73	1.64	1.97	6.02	2.91
pH (pH units)	pH	4.35	4.6	4.34	4.69	4.58	4.64	4.3
Total Suspended Solids	mg/L	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Total Dissolved Solids	mg/L	41	34	51	24	23	64	52
Turbidity (NTU)	NTU	0.68	1.09	0.65	0.71	0.65	0.77	0.53
Gran Alkalinity (as -H+) (meq/L)	meq/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Alkalinity, Bicarbonate (as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Alkalinity, Carbonate (as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Alkalinity, Hydroxide (as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Alkalinity, Total (as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ammonia, Total (as N)	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bromide (Br)	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	mg/L	2.05	2.37	1.96	2.33	1.73	2.08	1.81
Fluoride (F)	mg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Nitrate (as N)	mg/L	<0.0050	<0.0050	0.0278	<0.0050	<0.0050	0.0056	<0.0050
Nitrite (as N)	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Total Kjeldahl Nitrogen	mg/L	0.33	0.352	0.354	0.203	0.268	0.36	0.418
Orthophosphate-Dissolved (as P)	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Phosphorus (P)-Total Dissolved	mg/L	0.0036	0.0028	0.0043	0.0024	<0.0020	0.0078	0.0075
Phosphorus (P)-Total	mg/L	0.0043	0.0048	0.0038	0.0063	0.006	0.0061	0.0078
Sulfate (SO4)	mg/L	<0.30	<0.30	0.36	<0.30	<0.30	1.56	0.31
Anion Sum (meq/L)	meq/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cation Sum (meq/L)	meq/L	<0.10	<0.10	0.13	0.13	0.15	0.18	0.14
Cation - Anion Balance (%)	%	23	8.3	32.1	32.9	51.6	32.2	40.5
Dissolved Organic Carbon	mg/L	17.7	13.7	18.7	8.29	13.5	23.8	25.3
Total Organic Carbon	mg/L	18.1	13.5	21.4	7.75	13.3	24.3	27.4
Aluminum (Al)-Total	mg/L	<0.20	<0.20	<0.20	0.0452	0.0826	<0.20	<0.20
Antimony (Sb)-Total	mg/L	<0.20	<0.20	<0.20	<0.00010	<0.00010	<0.20	<0.20
Arsenic (As)-Total	mg/L	<0.20	<0.20	<0.20	<0.00010	<0.00010	<0.20	<0.20
Barium (Ba)-Total	mg/L	<0.010	<0.010	<0.010	0.00079	0.0013	<0.010	<0.010
Beryllium (Be)-Total	mg/L	<0.0050	<0.0050	<0.0050	<0.00010	<0.00010	<0.0050	<0.0050
Bismuth (Bi)-Total	mg/L	<0.20	<0.20	<0.20	<0.000050	<0.000050	<0.20	<0.20
Boron (B)-Total	mg/L	<0.10	<0.10	<0.10	<0.010	<0.010	<0.10	<0.10
Cadmium (Cd)-Total	mg/L	<0.010	<0.010	<0.010	<0.0000050	<0.0000050	<0.010	<0.010
Calcium (Ca)-Total	mg/L	0.339	0.447	0.648	0.342	0.506	1.62	0.696
Chromium (Cr)-Total	mg/L	<0.010	<0.010	<0.010	0.00013	<0.00010	<0.010	<0.010
Cobalt (Co)-Total	mg/L	<0.010	<0.010	<0.010	<0.00010	<0.00010	<0.010	<0.010
Copper (Cu)-Total	mg/L	<0.010	<0.010	<0.010	<0.00050	0.00106	<0.010	<0.010
Iron (Fe)-Total	mg/L	0.194	0.17	0.471	0.151	0.334	0.643	0.506
Lead (Pb)-Total	mg/L	<0.050	<0.050	<0.050	0.000118	0.00056	<0.050	<0.050
Lithium (Li)-Total	mg/L	<0.010	<0.010	<0.010	<0.0010	<0.0010	<0.010	<0.010
Magnesium (Mg)-Total	mg/L	0.24	0.27	0.27	0.19	0.17	0.48	0.28
Manganese (Mn)-Total	mg/L	<0.0050	<0.0050	0.0061	0.00554	0.00489	0.0142	0.0064
Molybdenum (Mo)-Total	mg/L	<0.030	<0.030	<0.030	<0.000050	<0.000050	<0.030	<0.030
Nickel (Ni)-Total	mg/L	<0.050	<0.050	<0.050	<0.00050	<0.00050	<0.050	<0.050
Phosphorus (P)-Total	mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)-Total	mg/L	<2.0	<2.0	<2.0	0.092	0.056	<2.0	<2.0
Selenium (Se)-Total	mg/L	<0.20	<0.20	<0.20	<0.000050	<0.000050	<0.20	<0.20
Silicon (Si)-Total	mg/L	0.106	<0.050	0.43	0.058	0.124	0.643	0.57
Silver (Ag)-Total	mg/L	<0.010	<0.010	<0.010	<0.000010	<0.000010	<0.010	<0.010
Sodium (Na)-Total	mg/L	<2.0	<2.0	<2.0	1.42	1.34	<2.0	<2.0
Strontium (Sr)-Total	mg/L	<0.0050	<0.0050	<0.0050	0.00223	0.00365	0.0097	0.0061
Thallium (Tl)-Total	mg/L	<0.20	<0.20	<0.20	<0.000010	<0.000010	<0.20	<0.20
Tin (Sn)-Total	mg/L	<0.030	<0.030	<0.030	<0.00010	<0.00010	<0.030	<0.030
Titanium (Ti)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium (V)-Total	mg/L	<0.030	<0.030	<0.030	<0.000010	<0.000010	<0.030	<0.030
Zinc (Zn)-Total	mg/L	<0.0050	<0.0050	<0.0050	<0.00050	<0.00050	<0.0050	<0.0050
BOD	mg/L	<2.0	2.1	<2.0	<2.0	<2.0	<2.0	<2.0
COD	mg/L	58	48	65	24	38	71	81
Chlorophyll a (µg/L)	ug/L	0.965	1.87	0.677	1.95	3.69	0.066	0.064

Appendix 1 Table 1-1 - Water Chemistry Data

Parameter	Units	STR03	STR04	STR05	STR06	STR07	STR8	STR9
		30-Sep-15	30-Sep-15	29-Sep-15	29-Sep-15	29-Sep-15	3-Apr-16	3-Apr-16
Conductivity (µS/cm)	uS/cm	29.4	28.9	34.6	33	74.8	17	18.8
Hardness (as CaCO3)	mg/L	3.31	3.31	7.61	3.61	2.23	3.99	5.97
pH (pH units)	pH	4.4	4.43	4.84	4.45	3.95	5.75	6.26
Total Suspended Solids	mg/L	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0	<3.0
Total Dissolved Solids	mg/L	60	45	64	55	53	30	42
Turbidity (NTU)	NTU	0.83	0.72	0.72	0.78	0.76	0.5	0.67
Gran Alkalinity (as -H+) (meq/L)	meq/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Alkalinity, Bicarbonate (as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	1.8	3.8
Alkalinity, Carbonate (as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Alkalinity, Hydroxide (as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Alkalinity, Total (as CaCO3)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	1.8	3.8
Ammonia, Total (as N)	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bromide (Br)	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Chloride (Cl)	mg/L	1.96	2.04	2.53	2.83	1.83	2.25	1.64
Fluoride (F)	mg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Nitrate (as N)	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Nitrite (as N)	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Total Kjeldahl Nitrogen	mg/L	0.36	0.353	0.393	0.351	0.411	0.208	0.209
Orthophosphate-Dissolved (as P)	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	0.0013	<0.0010	<0.0010
Phosphorus (P)-Total Dissolved	mg/L	0.0062	0.0041	0.0074	0.0051	0.0066	0.0043	0.005
Phosphorus (P)-Total	mg/L	0.0083	0.0042	0.0076	0.0053	0.006	0.0093	0.0088
Sulfate (SO4)	mg/L	<0.30	0.33	1.91	0.41	<0.30	<0.30	<0.30
Anion Sum (meq/L)	meq/L	<0.10	<0.10	0.11	<0.10	<0.10	<0.10	0.12
Cation Sum (meq/L)	meq/L	0.14	0.13	0.2	0.23	0.18	0.21	0.25
Cation - Anion Balance (%)	%	43.4	33.4	28	45	55.8	35.6	34.1
Dissolved Organic Carbon	mg/L	23.4	21.5	22.7	21.2	24.3	11.7	12.2
Total Organic Carbon	mg/L	24.1	21.8	23.7	22.5	25.2	11.7	13.7
Aluminum (Al)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	0.137	0.154
Antimony (Sb)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.00010	<0.00010
Arsenic (As)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	0.00012	0.00015
Barium (Ba)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	0.0018	0.00276
Beryllium (Be)-Total	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.00010	<0.00010
Bismuth (Bi)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.000050	<0.000050
Boron (B)-Total	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.010	<0.010
Cadmium (Cd)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.0000050	<0.0000050
Calcium (Ca)-Total	mg/L	0.888	0.808	2.04	0.83	0.465	1.13	1.8
Chromium (Cr)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	0.00014	0.00019
Cobalt (Co)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.00010	<0.00010
Copper (Cu)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.00050	<0.00050
Iron (Fe)-Total	mg/L	0.618	0.476	0.567	0.489	0.471	0.476	0.68
Lead (Pb)-Total	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	0.000085	0.000058
Lithium (Li)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.0010	<0.0010
Magnesium (Mg)-Total	mg/L	0.27	0.31	0.61	0.37	0.26	0.28	0.36
Manganese (Mn)-Total	mg/L	0.0143	0.0085	0.0128	0.0065	<0.0050	0.0127	0.00642
Molybdenum (Mo)-Total	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.000050	<0.000050
Nickel (Ni)-Total	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.00050	<0.00050
Phosphorus (P)-Total	mg/L	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium (K)-Total	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	0.103	0.114
Selenium (Se)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.000050	<0.000050
Silicon (Si)-Total	mg/L	0.506	0.36	0.654	0.449	0.376	0.787	1.32
Silver (Ag)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.000010	0.000011
Sodium (Na)-Total	mg/L	<2.0	<2.0	<2.0	2.3	<2.0	1.94	1.65
Strontium (Sr)-Total	mg/L	0.0071	0.0059	0.0122	0.0063	<0.0050	0.00674	0.0112
Thallium (Tl)-Total	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20	<0.000010	<0.000010
Tin (Sn)-Total	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.00010	<0.00010
Titanium (Ti)-Total	mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium (V)-Total	mg/L	<0.030	<0.030	<0.030	<0.030	<0.030	<0.000010	<0.000010
Zinc (Zn)-Total	mg/L	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.00050	<0.00050
BOD	mg/L	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	6
COD	mg/L	71	63	68	69	78	39	33
Chlorophyll a (µg/L)	ug/L	<0.010	0.59	0.097	0.272	0.053	0.584	0.113

Appendix 1, Table 1-2 - In situ Data

Site ID	Date	Temperature (˚C)	Specific Conductivity (mS/cm)	pH	DO (mg/L)	ORP (mV)
LAK02	1-Oct-15	11.5	0.028	4.14	9.2	173
LAK03	2-Oct-15	12	0.026	5.13	9.1	164
LAK04	1-Oct-15	11	0.028	4.96	7.9	150
LAK05	1-Oct-15	11.7	0.029	4.03	8.9	230
LAK06	1-Oct-15	11.6	0.027	4.75	8.8	210
LAK07	26-Oct-15	12	0.029	4.08	9.9	254
LAK08	30-Sep-15	12.5	0.028	4.05	9.3	218
LAK09	1-Oct-15	12.4	0.028	4.14	9.9	110
LAK10	2-Oct-15	10.7	0.026	4.08	7.5	248
LAK11	2-Oct-15	—	—	—	—	—
LAK12	4-Apr-16	10.6	0.025	4.03	11.8	196
LAK13	4-Apr-16	10.9	0.033	3.95	11.9	190
STR01	30-Sep-15	10.7	0.030	3.96	11.5	156
STR02	30-Sep-15	9.8	0.035	3.43	9.3	288
STR03	30-Sep-15	10.7	0.032	3.54	10.0	233
STR04	30-Sep-15	11.9	0.030	3.98	8.8	214
STR05	29-Sep-15	11.2	0.028	4.25	9.0	229
STR06	29-Sep-15	11.2	0.032	3.71	11.2	233
STR07	29-Sep-15	10.7	0.037	3.52	11.1	272
STR08	3-Apr-16	7.8	0.016	5.16	12.6	30
STR09	3-Apr-16	7.1	0.033	5.68	14.8	72

NOTE:

— = no data available

Appendix 1, Table 1-3 - Quality Control Field Duplicate Data

Sample ID		LAK10	Field Duplicate	RPD (%)	STR08	Field Duplicate	RPD (%)
Date Sampled		2-Oct-15			3-Apr-16		
ALS Sample ID		L1683162-1	L1683162-3		L1751475-2	L1751475-3	
Parameter	Units	Rep 1	Rep 2		Rep 1	Rep 2	
Physical Tests							
Conductivity (µS/cm)	uS/cm	24.3	24.4	0.4	17.0	17.0	0
Hardness (as $CaCO_3$)	mg/L	2.24	2.18	2.7	3.99	3.83	4.1
pH (pH units)	pH	4.60	4.52	1.8	5.75	5.74	0.2
Total Suspended Solids	mg/L	<3.0	<3.0	n/a	<3.0	<3.0	n/a
Total Dissolved Solids	mg/L	34	34	0	30	38	23.5
Turbidity (NTU)	NTU	1.09	0.62	55	0.50	0.61	19.8
Ions and Nutrients							
Gran Alkalinity (as -H+) (meq/L)	meq/L	<0.10	<0.10	n/a	<0.10	<0.10	n/a
Alkalinity, Bicarbonate (as $CaCO_3$)	mg/L	<1.0	<1.0	n/a	1.8	1.3	32.3
Alkalinity, Carbonate (as $CaCO_3$)	mg/L	<1.0	<1.0	n/a	<1.0	<1.0	n/a
Alkalinity, Hydroxide (as $CaCO_3$)	mg/L	<1.0	<1.0	n/a	<1.0	<1.0	n/a
Alkalinity, Total (as $CaCO_3$)	mg/L	<1.0	<1.0	n/a	1.8	1.3	32.3
Ammonia, Total (as N)	mg/L	<0.0050	<0.0050	n/a	<0.0050	<0.0050	n/a
Bromide (Br)	mg/L	<0.050	<0.050	n/a	<0.050	<0.050	n/a
Chloride (Cl)	mg/L	2.37	2.37	0.0	2.25	2.24	0.4
Fluoride (F)	mg/L	<0.020	<0.020	n/a	<0.020	<0.020	n/a
Nitrate (as N)	mg/L	<0.0050	<0.0050	n/a	<0.0050	<0.0050	n/a
Nitrite (as N)	mg/L	<0.0010	<0.0010	n/a	<0.0010	<0.0010	n/a
Total Kjeldahl Nitrogen	mg/L	0.352	0.330	6.5	0.208	0.211	1.4
Orthophosphate-Dissolved (as P)	mg/L	<0.0010	<0.0010	n/a	<0.0010	<0.0010	n/a
Phosphorus (P)-Total Dissolved	mg/L	0.0028	0.0026	7.4	0.0043	0.0048	11.0
Phosphorus (P)-Total	mg/L	0.0048	0.0039	20.7	0.0093	0.0083	11.4
Sulfate (SO_4)	mg/L	<0.30	<0.30	n/a	<0.30	<0.30	n/a
Organic Carbon							
Dissolved Organic Carbon	mg/L	13.7	13.6	0.7	11.7	11.5	1.7
Total Organic Carbon	mg/L	13.5	14.9	9.9	11.7	12.3	5.0
Total Metals							
Aluminum (Al)-Total	mg/L	<0.20	<0.20	n/a	0.137	0.131	4.5
Antimony (Sb)-Total	mg/L	<0.20	<0.20	n/a	<0.00010	<0.00010	n/a
Arsenic (As)-Total	mg/L	<0.20	<0.20	n/a	0.00012	0.00011	8.7
Barium (Ba)-Total	mg/L	<0.010	<0.010	n/a	0.0018	0.00171	5.1
Beryllium (Be)-Total	mg/L	<0.0050	<0.0050	n/a	<0.00010	<0.00010	n/a
Bismuth (Bi)-Total	mg/L	<0.20	<0.20	n/a	<0.000050	<0.000050	n/a
Boron (B)-Total	mg/L	<0.10	<0.10	n/a	<0.010	<0.010	n/a
Cadmium (Cd)-Total	mg/L	<0.010	<0.010	n/a	<0.0000050	<0.0000050	n/a
Calcium (Ca)-Total	mg/L	0.447	0.432	3.4	1.130	1.090	3.6
Chromium (Cr)-Total	mg/L	<0.010	<0.010	n/a	0.00014	0.00014	0.0
Cobalt (Co)-Total	mg/L	<0.010	<0.010	n/a	<0.00010	<0.00010	n/a
Copper (Cu)-Total	mg/L	<0.010	<0.010	n/a	<0.00050	<0.00050	n/a
Iron (Fe)-Total	mg/L	0.170	0.166	2.4	0.476	0.458	3.9
Lead (Pb)-Total	mg/L	<0.050	<0.050	n/a	0.000085	0.000081	4.8
Lithium (Li)-Total	mg/L	<0.010	<0.010	n/a	<0.0010	<0.0010	n/a
Magnesium (Mg)-Total	mg/L	0.27	0.27	0.0	0.28	0.27	3.6
Manganese (Mn)-Total	mg/L	<0.0050	<0.0050	n/a	0.0127	0.0125	1.6
Molybdenum (Mo)-Total	mg/L	<0.030	<0.030	n/a	<0.000050	<0.000050	n/a
Nickel (Ni)-Total	mg/L	<0.050	<0.050	n/a	<0.00050	<0.00050	n/a
Phosphorus (P)-Total	mg/L	<0.30	<0.30	n/a	<0.30	<0.30	n/a
Potassium (K)-Total	mg/L	<2.0	<2.0	n/a	0.103	0.093	10.2
Selenium (Se)-Total	mg/L	<0.20	<0.20	n/a	<0.000050	<0.000050	n/a
Silicon (Si)-Total	mg/L	<0.050	<0.050	n/a	0.787	0.755	4.2
Silver (Ag)-Total	mg/L	<0.010	<0.010	n/a	<0.000010	<0.000010	n/a
Sodium (Na)-Total	mg/L	<2.0	<2.0	n/a	1.94	1.87	3.7
Strontium (Sr)-Total	mg/L	<0.0050	<0.0050	n/a	0.00674	0.00647	4.1
Thallium (Tl)-Total	mg/L	<0.20	<0.20	n/a	<0.000010	<0.000010	n/a
Tin (Sn)-Total	mg/L	<0.030	<0.030	n/a	<0.00010	<0.00010	n/a
Titanium (Ti)-Total	mg/L	<0.010	<0.010	n/a	<0.010	<0.010	n/a
Vanadium (V)-Total	mg/L	<0.030	<0.030	n/a	<0.000010	<0.000010	n/a
Zinc (Zn)-Total	mg/L	<0.0050	<0.0050	n/a	<0.00050	<0.00050	n/a
Aggregate Organics							
BOD	mg/L	2.1	<2.0	n/a	<2.0	<2.0	n/a
COD	mg/L	48	41	15.7	39	33	16.7
Plant Pigments							
Chlorophyll a (µg/L)	ug/L	1.87	1.74	7.2	0.584	0.42	32.7

NOTE:

LDL = lowest detection limit

n/a = not applicable

— = no data available

< = below detection limit

RPD = relative percent difference

RPD =(|Rep 2 - Rep 1|)/((Rep 1 + Rep 2)/2) x 100

Grey shaded values indicate the RPD is greater than 20% and both replicates are more than 5 times the detection limit

Dark grey shaded values indicate the RPD is greater than 50% and both replicates are more than 5 times the detection limit

Appendix 1, Table 1-4 - Quality Control Travel Blank Data

Sample ID	Units	Detection Limit	TRAVEL BLANK	TRAVEL BLANK
Date Sampled			n/a	4-Apr-16
ALS Sample ID			L1683162-6	L1752048-1
Physical Tests				
Conductivity (µS/cm)	uS/cm	2	<2.0	<2.0
Hardness (as $CaCO_3$)	mg/L	0.5	<0.50	<0.50
pH (pH units)	pH	0.1	5.57	5.45
Total Suspended Solids	mg/L	3	<3.0	<3.0
Total Dissolved Solids	mg/L	10	<10	<10
Turbidity (NTU)	NTU	0.1	<0.10	<0.10
Ions and Nutrients				
Gran Alkalinity (as -H+) (meq/L)	meq/L	0.1	<0.10	<0.10
Alkalinity, Bicarbonate (as $CaCO_3$)	mg/L	1	<1.0	<1.0
Alkalinity, Carbonate (as $CaCO_3$)	mg/L	1	<1.0	<1.0
Alkalinity, Hydroxide (as $CaCO_3$)	mg/L	1	<1.0	<1.0
Alkalinity, Total (as $CaCO_3$)	mg/L	1	<1.0	<1.0
Ammonia, Total (as N)	mg/L	0.005	<0.0050	<0.0050
Bromide (Br)	mg/L	0.05	<0.050	<0.050
Chloride (Cl)	mg/L	0.5	<0.50	<0.50
Fluoride (F)	mg/L	0.02	<0.020	<0.020
Nitrate (as N)	mg/L	0.005	<0.0050	<0.0050
Nitrite (as N)	mg/L	0.001	<0.0010	<0.0010
Total Kjeldahl Nitrogen	mg/L	0.05	<0.050	<0.050
Orthophosphate-Dissolved (as P)	mg/L	0.001	<0.0010	<0.0010
Phosphorus (P)-Total Dissolved	mg/L	0.002	<0.0020	<0.0020
Phosphorus (P)-Total	mg/L	0.002	<0.0020	<0.0020
Sulfate (SO_4)	mg/L	0.3	<0.30	<0.30
Anion Sum (meq/L)	meq/L	—	<0.10	<0.10
Cation Sum (meq/L)	meq/L	—	<0.10	<0.10
Organic Carbon				
Total Organic Carbon	mg/L	1	<0.50	<0.50
Total Metals				
Aluminum (Al)-Total	mg/L	0.2	<0.20	<0.0030
Antimony (Sb)-Total	mg/L	0.2	<0.20	<0.00010
Arsenic (As)-Total	mg/L	0.2	<0.20	<0.00010
Barium (Ba)-Total	mg/L	0.01	<0.010	<0.000050
Beryllium (Be)-Total	mg/L	0.005	<0.0050	<0.00010
Bismuth (Bi)-Total	mg/L	0.2	<0.20	<0.000050
Boron (B)-Total	mg/L	0.1	<0.10	<0.010
Cadmium (Cd)-Total	mg/L	0.01	<0.010	<0.0000050
Calcium (Ca)-Total	mg/L	0.05	<0.050	<0.050
Chromium (Cr)-Total	mg/L	0.01	<0.010	<0.00010
Cobalt (Co)-Total	mg/L	0.01	<0.010	<0.00010
Copper (Cu)-Total	mg/L	0.01	<0.010	<0.00050
Iron (Fe)-Total	mg/L	0.03	<0.030	<0.010
Lead (Pb)-Total	mg/L	0.05	<0.050	<0.000050

Appendix 1, Table 1-4 - Quality Control Travel Blank Data

Lithium (Li)-Total	mg/L	0.01	<0.010	<0.0010
Magnesium (Mg)-Total	mg/L	0.1	<0.10	<0.10
Manganese (Mn)-Total	mg/L	0.005	<0.0050	<0.00010
Molybdenum (Mo)-Total	mg/L	0.03	<0.030	<0.000050
Nickel (Ni)-Total	mg/L	0.05	<0.050	<0.00050
Phosphorus (P)-Total	mg/L	0.3	<0.30	<0.30
Potassium (K)-Total	mg/L	2	<2.0	<0.050
Selenium (Se)-Total	mg/L	0.2	<0.20	<0.000050
Silicon (Si)-Total	mg/L	0.05	<0.050	<0.050
Silver (Ag)-Total	mg/L	0.01	<0.010	<0.000010
Sodium (Na)-Total	mg/L	2	<2.0	<0.050
Strontium (Sr)-Total	mg/L	0.005	<0.0050	<0.00020
Thallium (Tl)-Total	mg/L	0.2	<0.20	<0.000010
Tin (Sn)-Total	mg/L	0.03	<0.030	<0.00010
Titanium (Ti)-Total	mg/L	0.01	<0.010	<0.010
Vanadium (V)-Total	mg/L	0.03	<0.030	<0.00050
Zinc (Zn)-Total	mg/L	0.005	<0.0050	<0.0030
Aggregate Organics				
BOD	mg/L	2	<2.0	<2.0
COD	mg/L	20	<20	<20

NOTE:

— = no data available

< = below detection limit

n/a = not applicable

Appendix 1, Table 1-5 - Nutrient Nitrogen Critical Load Exceedances

Station	Source	Lake Classification	Emperical Critical Load			Base Case			Project Case			Application Case			Cumulative Case		
			Lower Bound	Mid-Point	Upper Bound	Exceedance Lower Bound	Exceedance Mid-Point	Exceedance Upper Bound	Exceedance Lower Bound	Exceedance Mid-Point	Exceedance Upper Bound	Exceedance Lower Bound	Exceedance Mid-Point	Exceedance Upper Bound	Exceedance Lower Bound	Exceedance Mid-Point	Exceedance Upper Bound
AD-SW1	AECOM	Oligo	5.0	7.5	10.0	-4.886	-7.386	-9.886	-4.652	-7.152	-9.652	-4.538	-7.038	-9.538	-3.045	-5.545	-8.045
AD-SW4	AECOM	Oligo	5.0	7.5	10.0	-4.881	-7.381	-9.881	-4.552	-7.052	-9.552	-4.433	-6.933	-9.433	-3.191	-5.691	-8.191
AD-SW8	AECOM	Oligo	5.0	7.5	10.0	-4.900	-7.400	-9.900	-4.680	-7.180	-9.680	-4.581	-7.081	-9.581	-2.987	-5.487	-7.987
AD-SW9	AECOM	Dystr	3.0	4.0	5.0	-2.954	-3.954	-4.954	-2.853	-3.853	-4.853	-2.807	-3.807	-4.807	-2.361	-3.361	-4.361
LAK02	L1682773-1	Oligo	5.0	7.5	10.0	-4.758	-7.258	-9.758	-3.414	-5.914	-8.414	-3.172	-5.672	-8.172	-2.044	-4.544	-7.044
LAK03	L1683162-4	Oligo	5.0	7.5	10.0	-4.750	-7.250	-9.750	-3.642	-6.142	-8.642	-3.391	-5.891	-8.391	-2.237	-4.737	-7.237
LAK04	L1682773-2	Oligo	5.0	7.5	10.0	-4.727	-7.227	-9.727	-2.919	-5.419	-7.919	-2.646	-5.146	-7.646	-1.344	-3.844	-6.344
LAK05	L1682773-3	Dystr	3.0	4.0	5.0	-2.705	-3.705	-4.705	**0.467**	-0.533	-1.533	**0.762**	-0.238	-1.238	**2.231**	**1.231**	**0.231**
LAK06	L1682773-4	Oligo	5.0	7.5	10.0	-4.756	-7.256	-9.756	-3.650	-6.150	-8.650	-3.406	-5.906	-8.406	-2.252	-4.752	-7.252
LAK07	L1682773-5	Dystr	3.0	4.0	5.0	-2.774	-3.774	-4.774	-2.375	-3.375	-4.375	-2.149	-3.149	-4.149	-1.145	-2.145	-3.145
LAK08	L1682772-7	Dystr	3.0	4.0	5.0	-2.744	-3.744	-4.744	-2.382	-3.382	-4.382	-2.126	-3.126	-4.126	-1.037	-2.037	-3.037
LAK09	L1682772-8	Dystr	3.0	4.0	5.0	-2.741	-3.741	-4.741	-2.413	-3.413	-4.413	-2.154	-3.154	-4.154	-1.082	-2.082	-3.082
LAK10	L1683162-1	Oligo	5.0	7.5	10.0	-4.685	-7.185	-9.685	-4.383	-6.883	-9.383	-4.068	-6.568	-9.068	-2.960	-5.460	-7.960
LAK11	L1694769-1	Dystr	3.0	4.0	5.0	-2.597	-3.597	-4.597	**1.377**	**0.377**	-0.623	**1.780**	**0.780**	-0.220	**3.946**	**2.946**	**1.946**
LAK12	L1752048-2	Oligo	5.0	7.5	10.0	-4.719	-7.219	-9.719	-3.576	-6.076	-8.576	-3.295	-5.795	-8.295	-1.764	-4.264	-6.764
LAK13	L1752048-3	Dystr	3.0	4.0	5.0	-2.758	-3.758	-4.758	-1.870	-2.870	-3.870	-1.628	-2.628	-3.628	-0.300	-1.300	-2.300
Alywn	EC	Oligo	5.0	7.5	10.0	-4.916	-7.416	-9.916	-4.705	-7.205	-9.705	-4.621	-7.121	-9.621	-3.596	-6.096	-8.596
Georgetown	EC	Oligo	5.0	7.5	10.0	-4.925	-7.425	-9.925	-4.722	-7.222	-9.722	-4.647	-7.147	-9.647	-3.314	-5.814	-8.314
NC254	EC	Oligo	5.0	7.5	10.0	-4.941	-7.441	-9.941	-4.790	-7.290	-9.790	-4.731	-7.231	-9.731	-4.182	-6.682	-9.182
NC273	EC	Oligo	5.0	7.5	10.0	-4.781	-7.281	-9.781	-4.081	-6.581	-9.081	-3.862	-6.362	-8.862	-2.598	-5.098	-7.598
NC275	EC	Oligo	5.0	7.5	10.0	-4.916	-7.416	-9.916	-4.690	-7.190	-9.690	-4.606	-7.106	-9.606	-3.547	-6.047	-8.547
NC278	EC	Dystr	3.0	4.0	5.0	-2.950	-3.950	-4.950	-2.846	-3.846	-4.846	-2.796	-3.796	-4.796	-2.383	-3.383	-4.383
NC309	EC	Oligo	5.0	7.5	10.0	-4.857	-7.357	-9.857	-4.499	-6.999	-9.499	-4.355	-6.855	-9.355	-3.002	-5.502	-8.002
NC313	EC	Dystr	3.0	4.0	5.0	-2.963	-3.963	-4.963	-2.861	-3.861	-4.861	-2.824	-3.824	-4.824	-2.372	-3.372	-4.372
NC332	EC	Dystr	3.0	4.0	5.0	-2.980	-3.980	-4.980	-2.960	-3.960	-4.960	-2.940	-3.940	-4.940	-2.873	-3.873	-4.873
NC340	EC	Oligo	5.0	7.5	10.0	-4.852	-7.352	-9.852	-4.414	-6.914	-9.414	-4.265	-6.765	-9.265	-3.041	-5.541	-8.041
NC350	EC	Oligo	5.0	7.5	10.0	-4.972	-7.472	-9.972	-4.872	-7.372	-9.872	-4.844	-7.344	-9.844	-4.285	-6.785	-9.285
NC360	EC	Dystr	3.0	4.0	5.0	-2.963	-3.963	-4.963	-2.861	-3.861	-4.861	-2.824	-3.824	-4.824	-2.372	-3.372	-4.372
NC366	EC	Oligo	5.0	7.5	10.0	-4.953	-7.453	-9.953	-4.825	-7.325	-9.825	-4.778	-7.278	-9.778	-4.174	-6.674	-9.174
NC374	EC	Oligo	5.0	7.5	10.0	-4.946	-7.446	-9.946	-4.768	-7.268	-9.768	-4.715	-7.215	-9.715	-3.908	-6.408	-8.908

NOTE:

Oligo: oligotrophic

Dystr: dystrophic

Dystrophic lakes (pH<6.0, %ORG>50%)

Bold text indicates N exceedances for eutrophication

all units are listed as kg N/ha/yr

Appendix 1, Table 1-6 - Nitrogen and Sulphate Deposition for Sampled Lakes and Streams

	Base meq/m²/yr			Project meq/m²/yr			Application meq/m²/yr			Cumulative meq/m²/yr		
Station ID	**Nitrogen**	**Sulphate**	**N+S**	**Nitrogen**	**Sulphate**	**N+S**	**Nitrogen**	**Sulphate**	**N+S**	**Nitrogen**	**Sulphate**	**N+S**
AD-SW1	0.813	0.042	0.856	2.485	0.766	3.250	3.298	0.808	4.106	13.965	2.276	16.241
AD-SW4	0.853	0.051	0.904	3.199	0.823	4.022	4.053	0.874	4.926	12.919	2.077	14.996
AD-SW8	0.712	0.039	0.751	2.284	0.475	2.759	2.996	0.514	3.510	14.377	3.272	17.649
AD-SW9	0.328	0.022	0.350	1.052	0.341	1.393	1.381	0.363	1.744	4.563	1.045	5.608
Alywn	0.598	0.035	0.632	2.106	0.650	2.756	2.704	0.685	3.389	10.031	2.035	12.066
Georgetown	0.532	0.028	0.561	1.987	0.366	2.353	2.519	0.394	2.913	12.041	1.842	13.883
LAK02	1.728	0.077	1.805	11.326	2.350	13.676	13.054	2.427	15.481	21.116	3.728	24.844
LAK03	1.787	0.079	1.867	9.703	2.101	11.804	11.490	2.180	13.670	19.737	3.490	23.227
LAK04	1.952	0.085	2.037	14.866	3.058	17.924	16.818	3.143	19.961	26.111	4.615	30.726
LAK05	2.105	0.089	2.193	24.766	4.623	29.388	26.871	4.711	31.582	37.366	6.360	43.726
LAK06	1.741	0.075	1.816	9.642	2.169	11.811	11.383	2.244	13.627	19.629	3.550	23.179
LAK07	1.617	0.067	1.684	4.464	1.148	5.611	6.081	1.215	7.296	13.249	2.396	15.645
LAK08	1.828	0.074	1.902	4.415	0.968	5.382	6.242	1.041	7.284	14.024	2.351	16.375
LAK09	1.849	0.075	1.924	4.194	0.863	5.057	6.043	0.938	6.981	13.701	2.236	15.937
LAK10	2.252	0.089	2.341	4.408	0.737	5.146	6.660	0.827	7.487	14.572	2.166	16.738
LAK11	2.879	0.144	3.023	31.266	7.689	38.955	34.144	7.833	41.978	49.611	10.710	60.322
LAK12	2.009	0.098	2.106	10.171	1.748	11.920	12.180	1.846	14.026	23.115	3.338	26.453
LAK13	1.729	0.088	1.817	8.073	1.393	9.466	9.802	1.481	11.283	19.284	2.722	22.006
NC254	0.423	0.029	0.452	1.497	0.456	1.953	1.920	0.485	2.405	5.839	1.357	7.196
NC273	1.565	0.081	1.646	6.565	1.160	7.724	8.130	1.241	9.371	17.160	2.398	19.559
NC275	0.600	0.036	0.636	2.215	0.673	2.888	2.816	0.709	3.524	10.380	2.016	12.396
NC278	0.358	0.025	0.384	1.099	0.365	1.463	1.457	0.390	1.847	4.410	1.059	5.468
NC309	1.024	0.055	1.079	3.580	0.659	4.239	4.604	0.715	5.318	14.268	2.177	16.446
NC313	0.262	0.016	0.279	0.991	0.302	1.293	1.254	0.319	1.572	4.486	1.024	5.510
NC332	0.145	0.009	0.154	0.283	0.092	0.375	0.428	0.101	0.529	0.905	0.226	1.131
NC340	1.060	0.057	1.117	4.189	0.753	4.942	5.249	0.811	6.059	13.993	2.048	16.041
NC350	0.198	0.009	0.208	0.917	0.147	1.064	1.115	0.156	1.272	5.105	0.666	5.770
NC360	0.262	0.016	0.279	0.991	0.302	1.293	1.254	0.319	1.572	4.486	1.024	5.510
NC366	0.336	0.019	0.355	1.252	0.323	1.576	1.589	0.342	1.931	5.898	1.131	7.030
NC374	0.385	0.022	0.407	1.654	0.449	2.103	2.039	0.472	2.511	7.799	1.603	9.401
STR01	2.386	0.103	2.489	28.235	5.584	33.819	30.621	5.687	36.308	44.148	7.788	51.936
STR02	2.089	0.090	2.180	24.963	4.658	29.620	27.052	4.748	31.800	37.652	6.411	44.063
STR03	1.871	0.082	1.954	17.432	3.333	20.765	19.303	3.416	22.719	28.126	4.852	32.978
STR04	2.152	0.089	2.241	36.079	6.257	42.336	38.231	6.346	44.577	49.229	8.075	57.304
STR05	1.322	0.059	1.382	3.759	0.961	4.720	5.082	1.020	6.102	11.067	2.015	13.083
STR06	2.256	0.089	2.345	24.492	4.658	29.150	26.747	4.748	31.495	37.566	6.563	44.128
STR07	2.328	0.092	2.419	30.469	5.522	35.992	32.797	5.614	38.411	43.856	7.478	51.334
STR08	1.894	0.098	1.992	12.642	2.413	15.056	14.537	2.511	17.047	24.801	4.088	28.888
STR09	1.510	0.075	1.585	9.128	1.560	10.688	10.637	1.635	12.273	19.337	2.855	22.192

Note:

N+S = nitrogen plus sulphate

APPENDIX 2

Technical Memorandum:
Aurora LNG – Water Balance Estimates for Selected Waterbodies

Stantec

Memo

To:	Lisa McCuaig, Dip.T., B.Tech. Natalie Tashe, P.Ag.	From:	Michael Trudell, P.Eng.
File:	123220054	Date:	November 1, 2016

Reference: Aurora LNG – Water Balance Estimates for Selected Waterbodies

INTRODUCTION

An acidification assessment is a requirement of the Environmental Assessment for the Aurora LNG Project. The assessment requires knowledge of the long term mean annual values for certain hydrological parameters in the watersheds being studied. The purpose of this memo is to provide estimates of these hydrological parameters utilizing a water balance approach. A water balance is an accounting approach balancing inputs, precipitation, and outputs, water losses through evapotranspiration, groundwater recharge and streamflow. This relationship can be represented as follows:

$$P = Q + ET + R \qquad \text{Eq. 1}$$

Where:

- P is precipitation (mm/yr)
- Q is streamflow (mm/yr)
- ET is evapotranspiration (mm/yr)
- R is the groundwater recharge (mm/yr)

Eq. 1 does not include a water storage component. This is because, as long term mean annual values are of interest, water storage fluctuation can be assumed to be negligible; hence the change in long term mean annual watershed storage is minimal.

This memo provides estimated water balance variables for the watersheds of 32 subject lakes and nine subject streams. The sites were selected for water quality sampling by the Stantec Aquatics team who are conducting the acidification assessment. All of these waterbodies are contained in the Study Area which is comprised of Digby Island and the surrounding area (Figures 1 and 2).

APPROACH

Long-term hydrologic information is not available for the subject watersheds. The approach used for each water balance variable in Eq. 1 is presented below.

Long term precipitation data (P) was obtained from ClimateBC online tool (v.5.21; Wang et. al., 2013). This tool generates unique mean annual precipitation values at coordinates based on historical climate station data over various time frames. The 1981-2010 Climate Normal period was selected for this study. The tool also adjusts its output to elevation using a digital elevation map.

The coordinates of each subject watershed centroid was used as the geographic coordinate input. Watershed elevation inputs included either a watershed median elevation (where LiDAR-generated Digital Elevation Models existed) or the elevation at the centroids was used. Using this process, a unique long term mean annual precipitation value was produced for each watershed.

Reference: Aurora LNG – Water Balance Estimates for selected Waterbodies

Streamflow (Q) was calculated as a percentage of precipitation. The percentage selected was based on published sources and professional judgement. Summarizing a seven year research program in watershed hydrology in watersheds near Prince Rupert, Smith Island and Diana Lake, Banner et al (2005) estimated that streamflow accounted for 67% and 77.6% of annual precipitation. The Banner et al. (2005) study expanded on earlier work by Beaudry and Sagar (1995), who calculated streamflow in a watershed north of Prince Rupert as 75% of annual precipitation. Mean annual streamflow was calculated for the Kloiya River (Station ID: 08E016; Watershed area = 104 km^2) Water Survey of Canada hydrometric station for the period between 1981 and 2010 as 2,352 mm. Precipitation for the Kloiya River watershed was determined using ClimateBC and was determined to be 3,431 mm, resulting in streamflow of 68% of the mean annual precipitation. This study will apply a runoff coefficient of 70% of mean annual precipitation; therefore 70% of the precipitation will be assumed to be streamflow.

Mean annual evapotranspiration (ET) varies across different landforms, soil types, rainfall distribution and vegetation types. A representative value was selected from sources to characterize the overall Study Area. Beaudry and Sagar (1995) found that for coastal cedar-hemlock ecosystems in the area, annual evapotranspiration was 25% of annual precipitation. The same proportion of annual precipitation (25%) assigned to evapotranspiration was also estimated for Prince Rupert by the BC Ministry of Environment (BC 2013). The proportion of 25% mean annual precipitation assigned to evapotranspiration was chosen for this study.

There is little information available on groundwater recharge (R) in the area. The HyP^3 Project (Banner et al 2005) stated that only a small proportion of new water inputs reached the lower groundwater zone (recharge) in hyper-maritime forests of northern British Columbia due to the low hydraulic conductivity. Referring to Eq. 1, three of the four variables of the water balance have been determined. The equation can be rearranged to solve for the groundwater recharge component as follows:

$$\mathrm{R} = \mathrm{P} - \mathrm{Q} - E\mathrm{T} \qquad \text{Eq. 2}$$

Streamflow (Q) has been established as 0.70**P*, and *ET* as 0.25**P;* groundwater recharge is therefore estimated to be 0.05**P*, or 5% of mean annual precipitation.

Watershed areas for each of the 41 watersheds were digitally delineated using ArcGIS software. The best available topographic information of either LiDAR (1 m resolution), TRIM (20 m resolution) or CanVec (50 m resolution) was used as base data to delineate each of the individual watersheds.

RESULTS

Annual streamflow, evapotranspiration and groundwater recharge are estimated as fractions of annual precipitation for the 1981-2010 Climate Normal period. The estimates of these water balance variables for the subject waterbodies are presented in the attached Table 1.

Reference: Aurora LNG – Water Balance Estimates for selected Waterbodies

CLOSURE

The above results are generated to inform acidification studies for the Aurora LNG Environmental Assessment. Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Do not hesitate to contact the undersigned Author with any questions.

STANTEC CONSULTING LTD.

Michael Trudell, P.Eng.
Water Resources Engineer
Phone: (604) 412-3041
Fax: (604) 436-3752
Michael.Trudell@stantec.com

Attachment: Table 1: Aurora LNG Water Balance Estimates

Reference: Aurora LNG – Water Balance Estimates for selected Waterbodies

REFERENCES

BC Ministry of Environment, 2013. *Soil Landscapes of BC*. Available at: http://www.env.gov.bc.ca/soils/landscape/1.2climate.html. Accessed: February, 2015

Banner, A., P. LePage, J. Moran and A. de Groot (editors). 2005. *The HyP^3 Project: pattern, process, and productivity in hypermaritime forests of coastal British Columbia – a synthesis of 7-year results.* B.C. Min. For., Res. Br., Victoria, B.C. Spec. Rep. 10. Available at: http://www.for.gov.bc.ca/hfd/pubs/Docs/Srs/Srs10.htm

Beaudry, P.G. and Sagar, R.M. 1995. The water balance of a coastal cedar hemlock ecosystem. *In Mountain hydrology, peaks and valleys in research applications*. B.T Guy and J. Barnard (eds.) Can. Water Resour. Assoc., Cambridge, Ont. pp. 3–16.

Environment Canada, 2016. *Water Survey of Canada – Kloiya River (08EG016)*. Available at: http://wateroffice.ec.gc.ca/search/search_e.html?sType=h2oArc. Accessed April 21, 2016

Wang, T., Hamann, and A. Spittlehouse, D.L.. 2013. *ClimateBC – A program to generate climate normal, annual, seasonal and monthly data for genecology and climate change studies in British Columbia (BC), BC*.

Reference: Aurora LNG – Water Balance Estimates for selected Waterbodies

Table 1 Aurora LNG Water Balance Estimates

Waterbody Code	Geographic Name	Latitude	Longitude	Watershed Area (m^2)	Mean Annual Precipitation (mm)	Streamflow		Evapo-transpiration (mm)	Groundwater Recharge (mm)
						Runoff (10^3 m^3/yr)	Unit Area Mean Annual Q (m^3/yr/m^2)		
LAK_01		54.309	-130.402	20867	2505	37	1.8	626	125
LAK_02		54.298	-130.439	1218713	2507	2139	1.8	627	125
LAK_03		54.289	-130.434	2016759	2510	3543	1.8	628	126
LAK_04		54.292	-130.428	2741269	2507	4811	1.8	627	125
LAK_05		54.287	-130.416	937883	2537	1666	1.8	634	127
LAK_06		54.282	-130.427	3614757	2570	6503	1.8	643	129
LAK_07		54.267	-130.412	163561	2521	289	1.8	630	126
LAK_08		54.264	-130.407	324539	2505	569	1.8	626	125
LAK_09		54.262	-130.406	525168	2498	918	1.7	625	125
LAK_10		54.255	-130.398	325620	2515	573	1.8	629	126
LAK_11		54.290	-130.391	242215	2501	424	1.8	625	125
LAK_12	Tsook Lake	54.352	-130.430	526477	2493	919	1.7	623	125
LAK_13		54.374	-130.438	439873	2494	768	1.7	624	125
STR_01		54.305	-130.408	3277993	2497	5730	1.7	624	125
STR_02		54.309	-130.423	331581	2507	582	1.8	627	125
STR_03		54.305	-130.436	64031	2539	114	1.8	635	127
STR_04		54.290	-130.411	33976	2558	61	1.8	640	128
STR_05		54.268	-130.420	4553846	2490	7937	1.7	623	125
STR_06		54.271	-130.397	2727570	2511	4794	1.8	628	126
STR_07		54.272	-130.396	1209998	2539	2151	1.8	635	127

Reference: Aurora LNG – Water Balance Estimates for selected Waterbodies

Table 1 Aurora LNG Water Balance Estimates

Waterbody Code	Geographic Name	Latitude	Longitude	Watershed Area (m^2)	Mean Annual Precipitation (mm)	Streamflow		Evapo-transpiration (mm)	Groundwater Recharge (mm)
						Runoff (10^3 m^3/yr)	Unit Area Mean Annual Q (m^3/yr/m^2)		
STR_08		54.344	-130.455	5551404	2629	10216	1.8	657	131
STR_09		54.378	-130.472	17077392	2715	32456	1.9	679	136
AD_SW4	Oliver Lake	54.281	-130.272	323646	3019	684	2.1	755	151
AD_SW8	Shawatlan Lake	54.329	-130.244	47322074	3750	124220	2.6	938	188
AD_SW9	Bremmer Lake	54.124	-130.216	5699920	2754	10988	1.9	689	138
Alywn	Alwyn Lake	54.219	-130.235	8228254	3291	18955	2.3	823	165
Georgetown	Georgetown Lake	54.479	-130.368	59121840	3940	163058	2.8	985	197
NC254		54.142	-130.246	2625532	3596	6609	2.5	899	180
NC275		54.227	-130.241	1994735	3600	5027	2.5	900	180
NC278		54.133	-130.234	5020392	3344	11752	2.3	836	167
NC332		54.067	-130.397	3574268	3200	8006	2.2	800	160
NC344		54.042	-130.023	1461069	4979	5092	3.5	1245	249
NC350		54.434	-130.046	2450234	5385	9236	3.8	1346	269
NC360	Peck Lake	54.172	-130.133	3320596	3137	7292	2.2	784	157
NC366	Diana Lake	54.209	-130.148	56594648	3158	125108	2.2	790	158
NC374	Colonel Johnston Lake	54.204	-130.176	3567728	3934	9825	2.8	984	197
NC273		54.390	-130.433	599165	2675	1122	1.9	669	134
NC309		54.417	-130.393	212257	2911	433	2.0	728	146

Reference: Aurora LNG – Water Balance Estimates for selected Waterbodies

Table 1 Aurora LNG Water Balance Estimates

Waterbody Code	Geographic Name	Latitude	Longitude	Watershed Area (m^2)	Mean Annual Precipitation (mm)	Streamflow		Evapo-transpiration (mm)	Groundwater Recharge (mm)
						Runoff (10^3 m^3/yr)	Unit Area Mean Annual Q (m^3/yr/m^2)		
NC313		54.166	-130.120	639886	2966	1329	2.1	742	148
NC339		53.906	-130.520	1191013	2484	2071	1.7	621	124
NC340		54.431	-130.426	1381029	2599	2513	1.8	650	130