

ANNEX XI

WATER AND SEDIMENT QUALITY BASELINE REPORT FOR THE JAY PROJECT



WATER AND SEDIMENT QUALITY BASELINE REPORT FOR THE JAY PROJECT

Prepared for: Dominion Diamond Ekati Corporation

Prepared by: Golder Associates Ltd.

September 2014

Table of Contents

1	INTRODUCTION	1-1
1.1	Background and Scope	1-1
1.2	Objectives	1-1
1.3	Study Area	1-4
1.3.1	Physical Setting	1-4
1.3.2	Baseline Study Area	1-4
1.4	Summary of Data from Other Monitoring Programs in the Baseline Study Area	1-6
1.4.1	Introduction	1-6
1.4.2	Methods	1-6
1.4.3	Results	1-9
1.4.4	Summary.....	1-13
2	2013 BASELINE FIELD PROGRAM METHODS	2-1
2.1	General Approach	2-1
2.2	Sampling Design	2-1
2.3	Basin Naming Convention	2-2
2.4	Sampling Locations.....	2-3
2.5	Field Methods.....	2-10
2.5.1	Field Measurements	2-10
2.5.2	Discrete Water Sample Collection	2-10
2.5.3	Depth-Integrated Water Sample Collection	2-12
2.5.4	Sediment Sampling.....	2-12
2.6	Sample Handling.....	2-13
2.7	Description of Parameters	2-14
2.7.1	Water Quality	2-14
2.7.2	Sediment Quality.....	2-21
2.8	Data Analysis	2-22
2.8.1	Water Quality	2-22
2.8.2	Sediment Quality.....	2-27
2.9	Quality Assurance and Quality Control	2-28
2.9.1	Quality Assurance.....	2-28
2.9.2	Quality Control	2-29
2.9.3	Quality Assurance/Quality Control Results.....	2-29
3	2013 LAKE WATER QUALITY RESULTS.....	3-1
3.1	Lac du Sauvage	3-1

3.1.1	Field-Measured Physico-Chemical Parameters	3-1
3.1.2	Defining the Euphotic Zone	3-2
3.1.3	Water Chemistry in Discrete Samples	3-3
3.1.4	Nutrients and Chlorophyll <i>a</i> in Depth-Integrated Samples	3-8
3.1.5	Trophic Status Classification	3-9
3.2	Duchess Lake	3-9
3.2.1	Field-Measured Physico-Chemical Parameters	3-10
3.2.2	Defining the Euphotic Zone	3-10
3.2.3	Water Chemistry in Discrete Samples	3-11
3.2.4	Nutrients and Chlorophyll <i>a</i> in Depth-Integrated Samples	3-15
3.2.5	Trophic Status Classification	3-15
3.3	Lake Af1	3-15
3.3.1	Field-Measured Physico-Chemical Parameters	3-16
3.3.2	Defining the Euphotic Zone	3-16
3.3.3	Water Chemistry in Discrete Samples	3-16
3.3.4	Nutrients and Chlorophyll <i>a</i> in Depth-Integrated Samples	3-20
3.3.5	Trophic Status Classification	3-21
3.4	Sub-Basin Lakes	3-21
3.4.1	Field-Measured Physico-Chemical Parameters	3-21
3.4.2	Water Chemistry in Discrete Samples	3-22
3.4.3	Chlorophyll <i>a</i> in Depth-Integrated Samples	3-26
3.4.4	Trophic Status Classification	3-26
3.5	Lake E1	3-27
3.5.1	Field-Measured Physico-Chemical Parameters	3-27
3.5.2	Defining the Euphotic Zone	3-28
3.5.3	Water Chemistry in Discrete Samples	3-28
3.5.4	Nutrients and Chlorophyll <i>a</i> in Depth-Integrated Samples	3-33
3.5.5	Trophic Status Classification	3-33
3.6	Paul Lake	3-33
3.6.1	Field-Measured Physico-Chemical Parameters	3-33
3.6.2	Defining the Euphotic Zone	3-34
3.6.3	Water Chemistry in Discrete Samples	3-34
3.6.4	Nutrients and Chlorophyll <i>a</i> in Depth-Integrated Samples	3-39
3.6.5	Trophic Status Classification	3-40
4	2013 STREAM WATER QUALITY RESULTS	4-1
4.1	Lac du Sauvage Outlet.....	4-1
4.2	Sub-Basin Streams	4-2

5	2013 LAKE SEDIMENT QUALITY RESULTS	5-1
5.1	Lac du Sauvage	5-1
5.2	Duchess Lake	5-4
5.3	Lake Af1	5-5
5.4	Sub-Basin Lakes	5-6
5.5	Lake E1	5-6
5.6	Paul Lake	5-6
6	2013 STREAM SEDIMENT QUALITY RESULTS	6-1
6.1	Lac du Sauvage Outlet.....	6-1
6.2	Sub-Basin Streams	6-1
7	SUMMARY	7-1
7.1	2013 Baseline Data.....	7-1
7.1.1	Water Quality	7-1
7.1.2	Sediment Quality.....	7-13
7.1.3	Deep and Shallow Sites.....	7-18
7.2	Overview of Historical Data and 2013 Data	7-18
8	REFERENCES	8-1
9	GLOSSARY	9-1

Maps

Map 1.1-1	Location of the Jay Project.....	1-2
Map 1.1-2	Ekati Property Map.....	1-3
Map 1.3-1	Historic Water and Sediment Quality Sampling Locations	1-5
Map 2.4-1	Water and Sediment Quality Sampling Locations, 2013	2-4

Figures

Figure 2.5-1	Discrete Water Sample Collection Strategy.....	2-11
Figure 3.1-1	Mean Chlorophyll <i>a</i> Concentrations at Deep Stations in Lac du Sauvage in Late Spring, Summer, and Fall, 2013	3-9
Figure 3.6-1	Mean Chlorophyll <i>a</i> Concentrations at Deep Stations Paul Lake in Late Spring, Summer, and Fall, 2013.....	3-39
Figure 7.1-1	Mean (\pm Standard Deviation) pH for the Baseline Study Area during the Open-Water Period, 2013	7-3
Figure 7.1-2	Mean (\pm Standard Deviation) Total Aluminum Concentrations ($\mu\text{g/L}$) for the Baseline Study Area during the Open-Water Period, 2013	7-7

Figure 7.1-3	Mean (\pm Standard Deviation) Total Iron Concentrations ($\mu\text{g/L}$) in Water for the Baseline Study Area during the Open-Water Period, 2013	7-8
Figure 7.1-4	Mean (\pm Standard Deviation) Total Chromium Concentrations ($\mu\text{g/L}$) in Water for the Baseline Study Area during the Open-Water Period, 2013	7-9
Figure 7.1-5	Mean (\pm Standard Deviation) Total Copper Concentrations ($\mu\text{g/L}$) in Water for the Baseline Study Area during the Open-Water Period, 2013	7-10
Figure 7.1-6	Mean (\pm Standard Deviation) Total Manganese Concentrations ($\mu\text{g/L}$) in Water for the Baseline Study Area during the Open-Water Period, 2013	7-11
Figure 7.1-7	Mean Particle Size Distribution in Lakes for the Jay Baseline Study Area during the Open-Water Period, 2013	7-14
Figure 7.1-8	Mean Particle Size Distribution in Streams for the Jay Baseline Study Area during the Open-Water Period, 2013	7-15
Figure 7.1-9	Mean (\pm Standard Deviation) Arsenic Concentrations (mg/kg dw) in Sediment for the Baseline Study Area during the Open-Water Period, 2013	7-17
Figure 7.1-10	Mean (\pm Standard Deviation) Chromium Concentrations (mg/kg dw) in Sediment for the Baseline Study Area during the Open-Water Period, 2013	7-17
Figure 7.1-11	Mean (\pm Standard Deviation) Copper Concentrations (mg/kg dw) in Sediment for the Baseline Study Area during the Open-Water Period, 2013	7-18

Tables

Table 1.4-1	Sources of Water and Sediment Quality Data from Other Programs	1-6
Table 2.1-1	Water and Sediment Quality Sampling Periods, 2013	2-1
Table 2.4-1	Water and Sediment Quality Sampling Summary for Lac du Sauvage, 2013	2-5
Table 2.4-2	Water and Sediment Quality Sampling Summary for Duchess Lake, 2013	2-6
Table 2.4-3	Water and Sediment Quality Sampling Summary for Lake Af1, 2013	2-6
Table 2.4-4	Water and Sediment Quality Sampling Summary for Lac du Sauvage Sub-Basins (C, D, F, G, H, I, J, K, and L), 2013	2-7
Table 2.4-5	Water and Sediment Quality Sampling Summary for Lac du Sauvage Sub-Basin E, 2013	2-8
Table 2.4-6	Water and Sediment Quality Sampling Summary for Paul Lake, 2013	2-9
Table 2.7-1	Lake Acid Sensitivity Scale	2-16
Table 2.7-2	Stream Acid Sensitivity Scale	2-16
Table 2.7-3	Water Hardness Scale	2-17
Table 2.7-4	General Trophic Status Classification of Lakes	2-19
Table 2.7-5	Trophic Classification of Canadian Lakes and Streams Based on Total Phosphorus Trigger Concentrations	2-20
Table 2.7-6	Comparison of Trophic State Index Classification and General Trophic Classification of Lakes	2-20
Table 2.8-1	Water Quality Guidelines and Site-Specific Water Quality Objectives Developed for Ekati Mine	2-23
Table 2.8-2	Sediment Quality Guidelines	2-27
Table 3.1-1	Attenuation Coefficients (K_d) at Deep Stations in Lac du Sauvage, 2013	3-2
Table 3.1-2	Water Quality in Lac du Sauvage, 2013	3-5

Table 3.2-1	Attenuation Coefficients (K_d) at Lake Bottom at Deep Stations in Duchess Lake, 2013	3-10
Table 3.2-2	Water Quality in Duchess Lake, 2013.....	3-12
Table 3.2-3	Summary of Chlorophyll <i>a</i> at Duchess Lake, 2013.....	3-15
Table 3.3-1	Water Quality in Lake Af1, 2013	3-17
Table 3.3-2	Summary of Chlorophyll <i>a</i> Concentrations at Lake Af1, 2013.....	3-21
Table 3.4-1	Water Quality in Sub-Basin Lakes, 2013	3-23
Table 3.4-2	Summary of Chlorophyll <i>a</i> in Sub-Basin Lakes C1, D3 (Counts Lake), G2, and H1, 2013.....	3-26
Table 3.5-1	Water Quality in Lake E1, 2013	3-29
Table 3.5-2	Summary of Chlorophyll <i>a</i> in Lake E1, 2013	3-33
Table 3.6-1	Attenuation Coefficients at Deep Stations in Paul Lake, 2013	3-34
Table 3.6-2	Water Quality in Paul Lake, 2013	3-36
Table 5.1-1	Sediment Chemistry at Deep and Shallow Stations in Lac du Sauvage, 2013	5-2
Table 5.2-1	Sediment Chemistry at Deep and Shallow Stations in Duchess Lake, 2013	5-4
Table 5.6-1	Sediment Chemistry at Deep Stations in Paul Lake, 2013	5-7
Table 7.1-1	Attenuation Coefficients at Deep Stations in Lakes of the Baseline Study Area, 2013	7-2
Table 7.1-2	Phosphorus, Nitrogen, and Silica in Baseline Study Area Lakes, August 2013.....	7-12
Table 7.1-3	Summary of Median Chlorophyll <i>a</i> Concentrations in Lakes in the Baseline Study Area, 2013	7-13
Table 7.1-4	Summary of Water and Sediment Quality in Lakes of the Baseline Study Area during the Open-Water Period, 2013	7-20
Table 7.1-5	Summary of Water and Sediment Quality in Streams of the Baseline Study Area during the Open-Water Period, 2013	7-22

Appendices

Appendix A	Review of Water and Sediment Quality Data From Other Programs
Appendix B	Quality Assurance and Quality Control
Appendix C	Field Profiles
Appendix D	Light Attenuation Data
Appendix E	Water Quality Data
Appendix F	Sediment Quality Data

Abbreviations

Abbreviation	Definition
AEMP	Aquatic Effects Monitoring Program
ALS	ALS Environmental
BTEX	benzene, ethylbenzene, toluene, xylene
CaCO ₃	calcium carbonate
CCME	Canadian Council of Ministers of the Environment
CDWQG	Canadian Drinking Water Quality Guideline
CFU	coliform forming units
Chl <i>a</i>	chlorophyll <i>a</i>
CWQG	Canadian Water Quality Guideline
DDMI	Diavik Diamond Mines Inc.
De Beers	De Beers Canada Inc.
Diavik Mine	Diavik Diamond Mine
DIN	depth-integrated nutrient
DL	detection limit
dw	dry weight
DO	dissolved oxygen
DOC	dissolved organic compound
Dominion Diamond	Dominion Diamond Ekati Corporation
e.g.	for example
Ekati Mine	Ekati Diamond Mine
et al.	and more than one additional author
FF	far-field
GIS	Geographic Information System
i.e.	that is
ISQG	Interim Sediment Quality Guideline
LDS	Lac du Sauvage
LN	lake number
max	maximum
MF	mid-field
mid	middle of the water column
min	minimum
N	nitrogen
NAD	North American Datum
NF	near-field
NO ₃	nitrate
NTU	nephelometric turbidity unit
NWT	Northwest Territories
n/a	not available
OECD	Organization for Economic Cooperation and Development
P	phosphorus

Abbreviation	Definition
PAR	photosynthetically active radiation
PEL	probable effects level
Project	Jay Project
QA	quality assurance
QC	quality control
QA/QC	quality assurance and quality control
RPD	relative percent difference
SD	standard deviation
SO ₄	sulphate
SQ	sediment quality
SQG	Sediment Quality Guideline
SRSi	soluble reactive silica
SSWQO	Site-Specific Water Quality Objective
TC	total carbon
TDS	total dissolved solids
TDP	total dissolved phosphorus
TIC	total inorganic carbon
TKN	total Kjeldahl nitrogen
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
TSI	trophic state index
TSS	total suspended solids

Units of Measure

Unit	Definition
%	percent
%SI	percent surface irradiance
<	less than
>	greater than
°C	degrees Celsius
µg/L	micrograms per litre
µm	micron
µmol/s/m ²	micromoles per second per square metre
µS/cm	microSiemens per centimetre
CFU/100 mL	coliform forming units per 100 millilitres
cm	centimetre
g	gram
kg	kilogram
km	kilometre
km ²	square kilometre
L	litre
m	metre
masl	metres above sea level
mg CaCO ₃ /L	milligrams calcium carbonate per litre
mg/kg dw	milligrams per kilogram dry weight
mg/L	milligrams per litre
mg N/L	milligrams per litre as nitrogen
mg P/L	milligrams per litre as phosphorus
mm	millimetre

1 INTRODUCTION

1.1 Background and Scope

Dominion Diamond Ekati Corporation (Dominion Diamond) is a Canadian-owned and Northwest Territories (NWT) based mining company that mines, processes, and markets Canadian diamonds from its Ekati Diamond Mine (Ekati Mine). The existing Ekati Mine is located approximately 200 kilometres (km) south of the Arctic Circle and 300 km northeast of Yellowknife, NWT (Map 1.1-1).

Dominion Diamond is proposing to develop the Jay kimberlite pipe (Jay pipe) located beneath Lac du Sauvage. The proposed Jay Project (Project) will be an extension of the Ekati Mine, which is a large, stable, and successful mining operation that has been operating for 16 years. Most of the facilities required to support the development of the Jay pipe and to process the kimberlite currently exist at the Ekati Mine. The Project is located in the southeastern portion of the Ekati claim block approximately 25 km from the main facilities and approximately 7 km to the northeast of the Misery Pit, in the Lac de Gras watershed (Map 1.1-2).

This water and sediment quality baseline report provides a review of existing water and sediment quality in Lac du Sauvage and downstream basins. This baseline is a component of a comprehensive baseline program that documents the natural and socio-economic environments near the Project. This baseline information from this program will be used for the environmental evaluation of Project effects on all valued components.

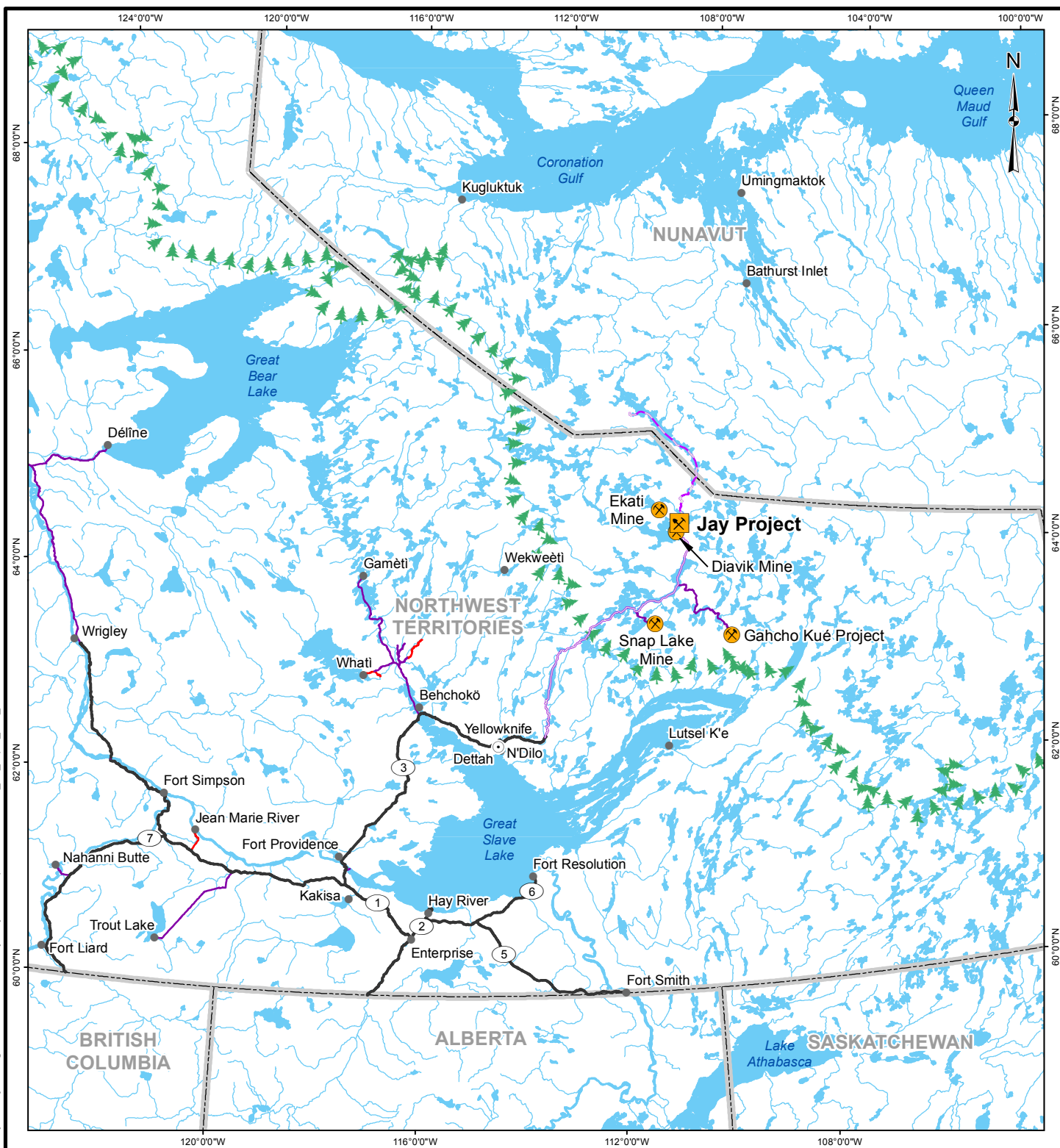
1.2 Objectives

The overall objective of this report is to summarize existing water and sediment quality in the lakes and streams of the baseline study area to support an environmental evaluation of the Project. Specifically, this report describes baseline conditions based on the 2013 open-water monitoring program. Water and sediment data collected by other monitoring programs in the baseline study area were summarized (Section 1.4 and Review of Water and Sediment Quality Data from Other Programs [Appendix A]) to place the 2013 data in context.

The specific goals of the 2013 water and sediment quality baseline program were to:

- characterize the physical limnology of the lakes in the data collection areas;
- characterize baseline water and sediment chemistry in lakes and streams within the baseline study area during open-water conditions;
- characterize spatial and seasonal variability in water and sediment quality parameters; and,
- compare baseline data to guidelines for the protection of aquatic life and for the protection of human health.

\\golder.gds\Saskatoon\GIS\CLIENTS\DOMINION\DEC Jay and Lynx Projects\Figures\13-1328-0041 Jay & Lynx EA\Aquatics\Baseline\B_JC_Aqua_043_GIS.mxd



LEGEND

- JAY PROJECT
- EXISTING MINE OR PROJECT
- TERRITORIAL CAPITAL
- POPULATED PLACE
- HIGHWAY
- ALL-SEASON ROAD
- WINTER ROAD
- TIBBITT TO CONTWOYTO WINTER ROAD
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- TERRITORIAL/PROVINCIAL BOUNDARY
- TREELINE
- WATERCOURSE
- WATERBODY

REFERENCE

WATER OBTAINED FROM ATLAS OF CANADA
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
PROJECTION: CANADA LAMBERT CONFORMAL CONIC

DOCUMENT

WATER AND SEDIMENT QUALITY BASELINE REPORT



DOMINION
DIAMOND

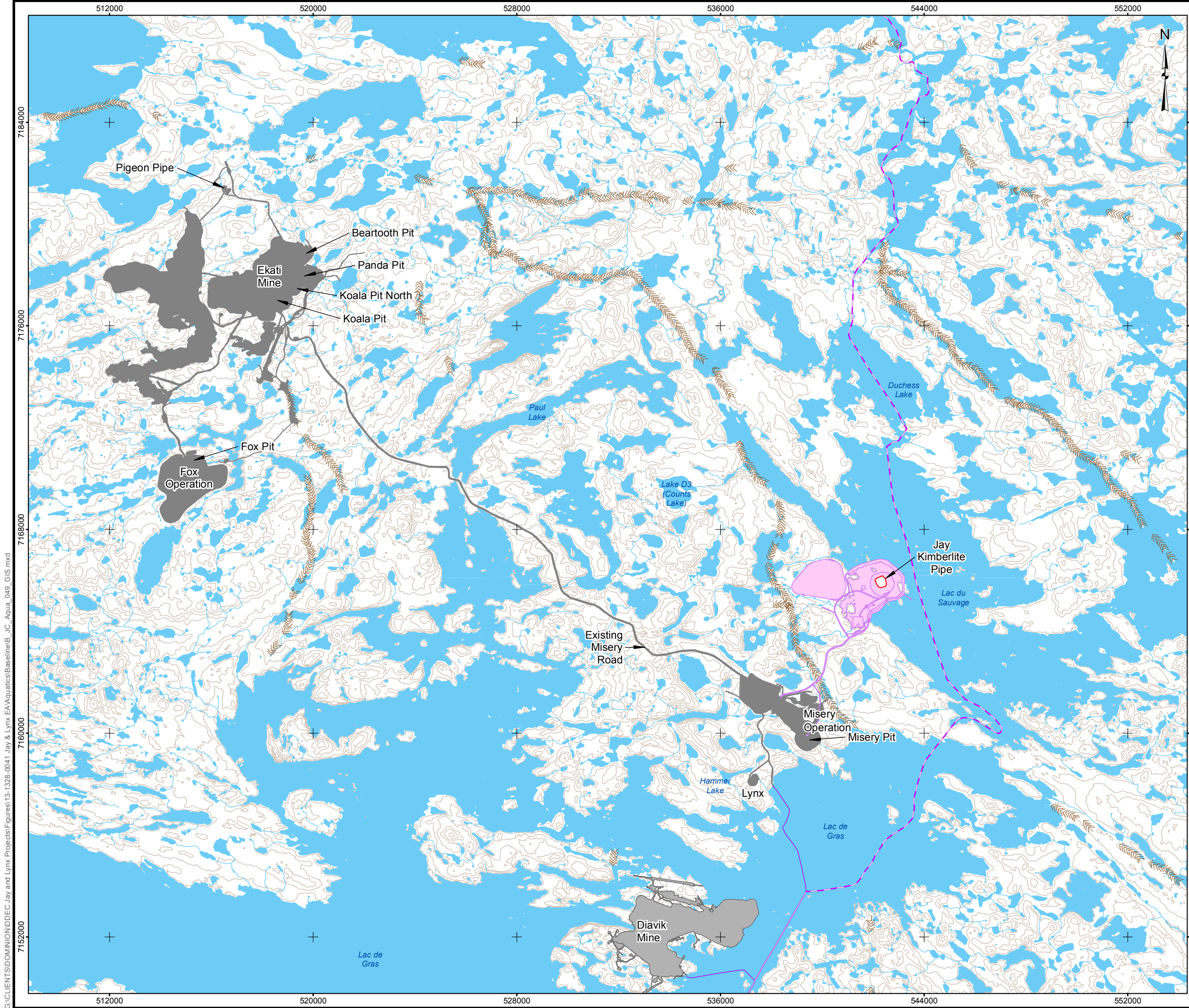
JAY PROJECT
NORTHWEST TERRITORIES, CANADA

LOCATION OF THE JAY PROJECT



PROJECT	13-1328-0041	FILE No. B_JC_Aqua_043_GIS
DESIGN	CG	24/07/14
GIS	JG	10/09/14
CHECK	CG	10/09/14
REVIEW	SM	10/09/14
SCALE AS SHOWN		REV. 0

MAP 1.1-1



LEGEND

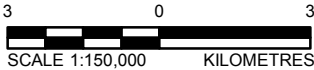
- EKATI MINE FOOTPRINT
- DIAMIK MINE FOOTPRINT
- PROPOSED JAY FOOTPRINT
- KIMBERLITE PIPE
- WINTER ROAD
- TIBBITT TO CONTWOYTO WINTER ROAD
- NORTHERN PORTION OF TIBBITT TO CONTWOYTO WINTER ROAD
- ELEVATION CONTOUR (10 m INTERVAL)
- ESKER
- WATERCOURSE
- WATERBODY



REFERENCE

CANVEC © NATURAL RESOURCES CANADA, 2012
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

WATER AND SEDIMENT QUALITY BASELINE REPORT



PROJECT		13-1328-0041		FILE No. B_JC_Aqua_049_GIS	
 DOMINION DIAMOND		JAY PROJECT NORTHWEST TERRITORIES, CANADA			
TITLE					
EKATI PROPERTY MAP					
		DESIGN	SM	12/08/14	SCALE AS SHOWN
		GIS	ANK	10/09/14	REV 0
		CHECK	CG	10/09/14	MAP 1.1-2
		REVIEW	SM	10/09/14	

Section 2 describes the methods applied to the collection and analysis of water quality and sediment quality data in the 2013 baseline program. Sections 3 to 6 discuss the results of the lake and stream water and sediment sampling.

Section 7 provides an overall summary of the 2013 results and places the 2013 data into context with relevant water and sediment quality data from other baseline and monitoring programs conducted in the baseline study area.

1.3 Study Area

1.3.1 Physical Setting

The Project is situated within the Lac du Sauvage basin, which is a component of the larger Lac de Gras drainage basin (Map 1.3-1). The Lac de Gras drainage basin has moderate topographic relief, with a maximum elevation of approximately 500 metres above sea level (masl) and a minimum elevation of approximately 416 masl along the lake shoreline. Lac de Gras, which is immediately downstream of Lac du Sauvage, possesses a large surface area, provides large inflow storage, and enables steady outflows. Outflow from this lake discharges to Coppermine River, which drains to the Arctic Ocean at Coronation Gulf.

The Lac de Gras basin is situated in the physiographic region of the Canadian Shield and has land features characteristic of glaciated terrain including crag and lee drumlins, eskers, and kettle lakes. The maze of small lakes, wetlands, and creeks in the basin indicate poorly drained conditions. The total area of these small waterbodies is approximately 1,425 square kilometres (km²); the remaining upland area is approximately 2,135 km². The upland areas are generally well-drained, although periodic ice jams at outlets of small lakes and wetlands increase downstream flood peak discharges and affect the flood characteristics.

The baseline study area lies in the sub-Arctic region of the Canadian Shield, an area of continuous permafrost characterized by typical tundra vegetation. Lichens, mosses, heather, and dwarf shrub species dominate on the higher, well-drained areas. Sedges and grasses are more predominant in the poorly drained areas, and along creeks and lakeshores.

1.3.2 Baseline Study Area

The baseline study area for this water and sediment quality report is located within the headwaters of the Coppermine drainage, and consists of sub-basins that flow directly into Lac du Sauvage or Lac de Gras. The baseline study area includes the following major basins:

- Lac du Sauvage and the Af sub-basin containing Lake Af1 and Duchess Lake;
- lakes and streams within the Lac du Sauvage basin, such as Lake D3 (Counts Lake) in D basin;
- lakes and streams within the Paul Lake basin, including Paul Lake;
- Lac de Gras and lakes in the Lac de Gras basin; and,
- tributaries to Lac de Gras.

1.4 Summary of Data from Other Monitoring Programs in the Baseline Study Area

1.4.1 Introduction

Water and sediment quality data have been collected in the baseline study area by other mines as part of their baseline or aquatic effects monitoring programs (Table 1.4-1). These data sources were reviewed and relevant data compiled to provide context for the 2013 data. The review focused on lakes that could potentially be affected by the Project, and those that are not affected by anthropogenic activities and thus represent regional baseline water and sediment natural conditions.

Lac du Sauvage and Lac de Gras are the primary lakes reviewed that could be affected by the Project, while Nanuq and Ursula lakes are the primary lakes reviewed that represent natural conditions (or water quality not affected by mining activity) (Map 1.3-1). In addition, Nanuq and Ursula lakes may also be considered as potential reference lakes in future Aquatic Effects Monitoring Programs (AEMPs). A summary of the compiled data is presented in this section; additional details are provided in Appendix A.

Table 1.4-1 Sources of Water and Sediment Quality Data from Other Programs

Program	Owner/Proponent	Sampling Years	Lakes of Interest
Ekati Diamond Mine AEMP	Dominion Diamond Ekati Corporation	1997 to 2012 ^(a)	Lac du Sauvage, Lac de Gras, Nanuq Lake
Jay Pipe Aquatic Baseline Study	Dominion Diamond Ekati Corporation	2006	Lac du Sauvage, Ursula Lake
Diavik Diamond Mine Baseline and AEMP	Diavik Diamond Mines Inc.	1994 to 2012 ^(a)	Lac de Gras

a) only water quality data from 2010 to 2012 were included for the water quality model baseline.

AEMP = Aquatic Effects Monitoring Program.

1.4.2 Methods

1.4.2.1 Ekati Mine Water Quality Monitoring

Ekati Mine is an active diamond mine in the Koala watershed (drains into the west bay of Lac de Gras) and the King-Cujo watershed (drains into the west bay of Lac du Sauvage) (ERM Rescan 2013); this mine is operated by Dominion Diamond Ekati Corporation. An AEMP has been conducted annually since 1997 to monitor for effects of mine water discharge and mining activities on the receiving environments: Koala watershed (monitored in Leslie Lake through to Lac de Gras) and Christine (sub-basin B) watershed (Cujo Lake through to Lac du Sauvage). The majority of the mining activities and mine water discharge occurs in the Koala watershed.

For the Ekati AEMP, water and sediment sample collection is focused on lakes and streams downstream of the Long Lake Containment Facility and downstream of the King Pond Settling Facility. Water released from the Long Lake Containment Facility first enters Leslie Lake, then Moose Lake, Nero Lake, Nema Lake, and Slipper Lake before entering Lac de Gras (Map 1.3-1, Stations S2 and S3). Water released from the King Pond Settling Facility first enters Cujo Lake, then Christine Lake before entering Lac du Sauvage (Map 1.3-1, Stations LDS2 and LDS1).

Samples for water quality analysis are collected annually from the various stations during ice-covered and open-water conditions. Twenty-four water quality parameters are analyzed as part of the AEMP: pH, total alkalinity, total hardness, total dissolved solids (TDS), chloride, sulphate, potassium, ammonia, nitrite, nitrate, orthophosphate, total phosphorus (TP), total organic carbon (TOC), aluminum, antimony, arsenic, copper, iron, molybdenum, nickel, selenium, strontium, uranium, and zinc. The data review was focused on the last three years of monitoring (Rescan 2011, 2012a; ERM Rescan 2013).

Samples for sediment quality analysis are collected once every three years from the downstream lakes. The most recent sediment collection was during the 2011 AEMP (Rescan 2012a). Twelve sediment quality parameters were analyzed as part of the 2011 AEMP: TOC, available phosphorus, total nitrogen, aluminum, arsenic, antimony, copper, molybdenum, nickel, selenium, strontium, and zinc.

1.4.2.2 Jay Pipe — 2006 Aquatic Baseline

Rescan conducted a study in 2006 to summarize baseline conditions of the aquatic environment near the proposed Jay kimberlite pipe (Jay Pipe) development (Rescan 2007). The study was designed as a pre-development AEMP to support post-development interpretation of potential impacts as a result of the Jay Pipe development. As such, sampling was conducted in Lac du Sauvage as the main receiving environment and Ursula Lake (in the sub-watershed draining to Lake E1) as the proposed reference lake. Sampling was also conducted in Christine Lake as a potential alternate exposure lake in the event that two of the Lac du Sauvage stations were negatively affected by construction activities due to the Jay Pipe development. For the purposes of this pre-existing baseline data review, only data from Lac du Sauvage and Ursula Lake were included. Christine Lake is downstream of the King Pond Settling Facility and is influenced by this discharge; therefore, measured water and sediment quality in Christine Lake is not representative of baseline conditions in the Project baseline study area.

Water samples were collected in Lac du Sauvage and Ursula Lake during ice-covered (February, March, and May 2006) and open-water conditions (July, August, and September 2006), and surficial sediment samples were collected during open-water conditions (August 2006). Two of the sampling locations in Lac du Sauvage (i.e., LDS1 and LDS2) were in the downstream receiving environment; the other 10 locations (LDS3 to LDS12) were located in the main basin of the lake (Map 1.3-1). In Ursula Lake, water and sediment samples were collected from three sampling locations (Map 1.3-1).

1.4.2.3 Diavik Mine Water Quality Baseline

Baseline water and sediment quality data were collected in Lac de Gras between 1994 and 2000 before the start of construction and operation of the Diavik Diamond Mine (Diavik Mine) (DDMI 2001). The number of stations, sample type (discrete or depth-integrated) and sample depth (surface, mid, depth-integrated) varied between years and sampling events (under ice or open water).

The detection limits also varied between years for many of the parameters, although detection limits generally improved over the time period. These issues limit the comparability of pre-2001 water quality data to the subsequent construction and operations water quality data from Lac de Gras. However, the data do provide an indication of pre-development water quality in Lac de Gras.

Diavik Diamond Mines Inc. (DDMI) established long-term monitoring stations for the 2001 AEMP. To provide sufficient data for statistical analysis, baseline stations were matched to be as similar as possible in location and sampling depth to the long-term monitoring stations (Table 1-4 in DDMI 2001). Based on the compiled dataset, DDMI (2001) reported baseline summary statistics (number of samples, median, range, and percent of samples less than the detection limit) for the long-term monitoring stations. These stations were located in the mid-field area (LDG40, LDG41, LDG42, LDG43, LDG44, LDG45, and LDG49) and in the far-field area (LDG46, LDG48, and BHP-S) (Map 1.3-1). Station BHP-S included Stations S1, S2, and S3 from the Ekati AEMP.

Only results for water quality parameters contained in the Type A Water Licence were provided in DDMI (2001). These parameters are pH, total suspended solids (TSS), turbidity, ammonia, nitrite, TP, and total metals (aluminum, arsenic, cadmium, chromium, copper, lead, nickel, and zinc). These results were used to characterize general water quality in the Lac de Gras before development.

Baseline sediment quality samples were collected from the near-field, mid-field, and far-field areas. Only results for 11 parameters were provided (DDMI 2007): total Kjeldahl nitrogen (TKN), TOC, TP, aluminum, arsenic, cadmium, chromium, copper, lead, nickel, and zinc.

1.4.2.4 Diavik Mine Water Quality Monitoring

The Diavik Mine is an active diamond mine on Lac de Gras in the NWT. An AEMP has been conducted annually since 2000 to monitor effects of mine water discharge on the receiving environment of Lac de Gras. The average and maximum depths in Lac de Gras are 12 metres (m) and 56 m, respectively (Golder 1997; cited in Golder 2014). Based on the bathymetry data, the east basin is the deepest part of the lake.

For the Diavik Mine AEMP, collection of water and sediment quality samples is focused within Lac de Gras with occasional sample collection near the outlet of Lac du Sauvage. The AEMP was designed to evaluate five areas of Lac de Gras; each area has been defined by a distance from the diffuser (Golder 2014). The AEMP areas include the near-field (NF; near the diffuser), the far-field (FF) exposure (FF2), and three reference areas (FF1, FFA, and FFB). There are also three mid-field areas between the NF and each mid-field (MF) reference area (MF1, MF2, and MF3) (Map 1.3-1). Each area is represented by up to five individual stations, and not replicate samples, to provide adequate statistical power.

Samples for water quality analysis are collected annually from the various stations during ice-covered and open-water conditions. Twenty substances of interest in water were measured: TDS, alkalinity, calcium, magnesium, potassium, sodium, chloride, fluoride, sulphate, ammonia, TOC, total aluminum, total arsenic, total copper, total iron, total manganese, total molybdenum, total strontium, total uranium, and total zinc. Supporting variables such as bicarbonate, carbon, nitrogen, and phosphorus are also measured.

Samples for sediment quality analysis are collected every year from within the mixing zone of the diffusers in Lac de Gras under the Surveillance Network Program and once every three years from the near-field, mid-field and reference areas under the AEMP. Samples are not collected in Lac du Sauvage. Sediments were analyzed for particle size distribution, TOC, total organic matter, moisture content, total nitrogen (TN), TP, and total metals.

1.4.3 Results

1.4.3.1 *Lac du Sauvage*

Water quality trends in Lac du Sauvage are evaluated as part of the annual AEMP studies. Based on the most recent AEMP studies (Rescan 2012a; ERM Rescan 2013), there has been no change in water or sediment quality parameters in Lac du Sauvage. Thus, the water and sediment quality results from Lac du Sauvage suggest that there are no measured effects due to mine activities (i.e., concentrations in Lac du Sauvage did not show evidence of increasing temporal concentrations as compared to baseline or reference conditions) (Rescan 2012a; ERM Rescan 2013).

Water quality in Lac du Sauvage, based on various historical reports (e.g., Rescan 2007, 2012a; ERM Rescan 2013), is characterized as follows:

- clear, with Secchi depths ranging from 4 to 8 m;
- relatively cool temperatures and sufficient dissolved oxygen to support aquatic life (i.e., not below the lower bound Protection of Aquatic Life Canadian Water Quality Guideline (CWQG) of 6.5 mg/L for cold water – other life stages [CCME1999]);
- low in alkalinity (i.e., sensitive to acid inputs as per the scale in Table 2.7-1);
- low in hardness (i.e., very soft water as per the scale in Table 2.7-3);
- slightly acidic (pH was within the CWQG range in open-water samples and sometimes below the lower CWQG of pH 6.5 in under-ice samples);
- low in nutrients, with nitrogen and phosphorus concentrations being within the range for oligotrophic lakes (as per the classification schemes in Tables 2.7-4 to 2.7-6); and,
- low in metals concentrations, which were either not detected or below the CWQG, with the several exceptions where maximum concentrations for aluminum, cadmium, chromium, and lead were higher than their respective CWQGs.

In general, no spatial trends were discernable in under-ice or open-water conditions. However, higher concentrations of major ions, nutrients, and metals in the under-ice water samples compared to open-water samples. Ranges of select water quality parameters are provided in Appendix A, Table A3.1-1.

Sediments collected in Lac du Sauvage were generally dominated by clay and silt, although sand was dominant at two stations (i.e., LDS1 and LDS11). Total organic carbon content ranged from 0.35 percent (%) to 3.4% in Lac du Sauvage sediments (Rescan 2007). Mean metal concentrations were below CWQGs, with the exception of arsenic, chromium, copper, and mercury (Rescan 2007):

- Arsenic concentrations were above the Interim Sediment Quality Guideline (ISQG) of 5.9 milligrams per kilogram dry weight (mg/kg dw) at all stations and above the probable effect level (PEL) of 17 mg/kg dw at 11 Lac du Sauvage stations.
- Chromium concentrations were above the ISQG of 37.3 mg/kg dw at all stations, but below the PEL of 90 mg/kg dw at all stations.

- Copper concentration was above the ISQG of 35.7 mg/kg dw at one station (LDS8), but below the PEL of 197 mg/kg dw at all stations.
- Mercury concentrations were below the ISQG of 0.17 mg/kg dw at 11 stations, and above the PEL of 0.486 mg/kg dw at one station (LDS3).

1.4.3.2 Lac de Gras

Water quality in Lac de Gras near Diavik Mine is characterized by higher concentrations of TDS, total alkalinity, chloride, sulphate, total molybdenum, and total strontium compared to areas further away from the mine diffuser (DDMI 2013). These particular parameters have been increasing gradually over time during both the ice-cover and open-water seasons and in each exposure area (NF, MF, and FF2). Concentrations of these substances generally increased above the normal range by 2007 or thereafter, and remained above through to 2012. Total arsenic concentrations have been increasing over time in the NF area from 1996 to 2010. In 2011 and 2012, the trend was apparent in the other exposure areas reflecting the higher arsenic loadings in the Diavik Mine effluent (Appendix A, Tables A3.2-2, A3.2-3, A3.2-4, A3.2-5).

Lac de Gras also receives mining inputs from Ekati Mine via Slipper Lake Bay (Appendix A, Figure A3.1-1). Results of the 2012 AEMP noted elevated water concentrations in Slipper Lake Bay relative to baseline or reference conditions for the following parameters: pH, hardness, total dissolved solids, chloride, sulphate, potassium, total molybdenum, and total strontium (ERM Rescan 2013).

Outside of the influence of the Diavik and Ekati mines, the background water quality in Lac de Gras is characterized as follows (based on 2010 to 2012 Diavik AEMP monitoring in the FF/reference areas):

- low in alkalinity (i.e., sensitive to acid inputs as per the scale in Table 2.7-1);
- low in hardness (i.e., very soft water as per the scale in Table 2.7-3);
- slightly acidic (pH was within the CWQG range in open-water and under-ice samples with median pH ranging from 6.6 to 6.9; two samples were below pH 6.5 at Stations MF2-2 and MF2-4 during the open-water season and one sample each at Station MF2-3 and Station FFA-4 under ice);
- low in nutrients, with nitrogen and phosphorus concentrations being within the range for oligotrophic lakes (as per the classification schemes in Tables 2.7-4 to 2.7-6); and,
- low in metals concentrations, which were either not detected or were below the CWQG; however, occasionally the detection limits for cadmium and mercury were higher than the CWQG.

For this review, sediment chemistry for Diavik AEMP areas FF2 and FFA within Lac de Gras were summarized (Appendix A Table A4.2-5), because these areas were of most interest to the Project. Although influenced by Diavik Mine discharge, FF2 is a key area with respect to outflow from Lac du Sauvage because it is downstream of the Project. The FFA area is the closest reference area to the Slipper Lake outlet and mine releases from the Long Lake Containment Facility. Sediment chemistry within FF2 and FFA areas for 2007 to 2010 (DDMI 2008, 2009, 2010, and 2011) are summarized as follows:

- Sediment particle size distribution at FF2 was variable ranging from 4% to 40% clay, 58% to 90% silt, and 2% to 15% sand, and 1.9 to 2.9% TOC.
- Sediment particle size distribution at FFA was variable. It ranged from:
 - 2% to 15% clay;
 - 22% to 80% silt;
 - 7% to 76% sand; and,
 - 1% to 8% TOC.
- Median arsenic concentrations were above the PEL at all stations in both areas.
- Maximum cadmium concentrations were above the ISQG in both areas.
- Median chromium and copper concentrations were above the ISQG in both areas.
- Median lead and zinc concentrations were below the ISQG in both areas, although the maximum zinc concentration at FFA was above the ISQG.
- Lower concentrations of arsenic, cadmium, copper, and zinc were found at FF2 stations compared to the FFA stations.

Sediments at the Ekati AEMP stations S2 and S3 in Lac de Gras were dominated by silt (61% and 77%) and clay (34% and 16%), and each had a small fraction of sand (4.8% and 6.7%) (Appendix A, Table A4.2-6).

Median TOC was 5.3% and 4.2% for S2 and S3, respectively. Similar to other locations in Lac de Gras, median arsenic concentrations were above the PEL at both stations (Rescan 2012a). Median cadmium, chromium, copper, and zinc concentrations were over their respective ISQGs at both stations (i.e., S2 and S3). Median lead and mercury concentrations were below the ISQG at both stations.

Sediment quality in Lac de Gras downstream of Slipper Lake was similar to FFA in the main lake with median or maximum concentrations of arsenic, cadmium, chromium, copper, and zinc above sediment quality guidelines.

1.4.3.3 Regional Lakes – Ursula Lake and Nanuq Lake

Ursula and Nanuq lakes represent water and sediment quality of un-affected lakes, thus reflecting regional background water and sediment conditions (Appendix A, Tables A3.3-1 and A3.3-2). Ursula Lake was sampled in 2006 as a reference lake during the Jay Pipe 2006 baseline study (Rescan 2007). Nanuq Lake has been sampled as a reference lake during the Ekati Mine AEMP since 1997 (ERM Rescan 2013); data from 2010 to 2012 were collated in the historical data review.

Water quality in Ursula and Nanuq lakes are characterized as follows:

- Low in alkalinity (i.e., sensitive to acid inputs as per the scale in Table 2.7-1).
- Low in hardness (i.e., very soft water as per the scale in Table 2.7-3).

- Slightly acidic (pH was generally within the CWQG range in open water with median pH of 6.6 in Ursula Lake, and a median pH of 6.7 in Nanuq Lake, while the under ice were below the range with median pH of 6.4 in Ursula Lake and a median pH of 6.3 in Nanuq Lake).
- Low in nutrients, with nitrogen and phosphorus concentrations being within the range for oligotrophic lakes (as per the classification schemes in Tables 2.7-4 to 2.7-6).
- Low in metals concentrations, which were generally either not detected or below the CWQG. In Ursula Lake, the detection limits for cadmium were higher than the CWQG and one sample exceeded the CWQG under ice. The median lead concentration was above CWQG in the open-water season. In Nanuq Lake, the maximum aluminum concentration was above the pH-dependent CWQG in the ice-cover season.

Compared to Lac du Sauvage, Ursula Lake sediments were dominated by clay rather than silt, with little to no sand (Rescan 2007). Total nitrogen (0.9%) and TOC (11.9%) concentrations were higher in Ursula Lake compared to Lac du Sauvage (Appendix A, Table A4.3-1). Metal concentrations were generally lower in Ursula Lake but within the range measured in Lac du Sauvage, with certain notable differences:

- Median copper (63.8 mg/kg dw) and zinc (154 mg/kg dw) concentrations in Ursula Lake exceeded their respective ISQGs, but did not exceed ISQGs in Lac du Sauvage.
- The median mercury concentration (0.121 mg/kg dw) was higher than the median mercury concentration in Lac du Sauvage.
- The median arsenic concentration (24.8 mg/kg dw) exceeded PEL, but was approximately half the median arsenic concentration in Lac du Sauvage.

The particle size distribution of Nanuq Lake sediments varied between the sampled stations because samples were collected from a mid-depth water station (i.e., 5.1 to 10 m) and a deep water station (i.e., more than 10 m deep) (ERM Rescan 2013).

The particle sizes ranged from 6% to 48% clay, 48% to 63% silt, and 4% to 37% sand, with 3% to 10% TOC (Appendix A, Table A4.3-2). More sand was associated with the mid-depth station compared to the deeper water station. Total nitrogen (0.5%) and TOC (6.1%) concentrations were higher than measured in Lac du Sauvage, but slightly lower than measured in Ursula Lake.

Median metal concentrations in Nanuq Lake were generally comparable or lower than measured in Lac du Sauvage. Similar to Ursula Lake, Nanuq Lake had lower arsenic and chromium concentrations, but higher copper, mercury, and zinc concentrations compared to Lac du Sauvage. With the better detection limits for sediment analysis in 2011, median cadmium and lead concentrations were slightly higher in Nanuq Lake as compared to Lac du Sauvage.

1.4.4 Summary

1.4.4.1 Water Quality Summary

Lac du Sauvage has water quality typical of northern lakes within the Canadian Shield; that is dilute water (i.e., low TDS concentrations), circumneutral (i.e., slightly acidic to slightly basic pH), nutrient-poor, and low in metals (Pienitz et al. 1997; Rühland and Smol 1998; Golder 2012; Medeiros et al. 2012). Although discharges from Misery operations of Ekati are released to Lac du Sauvage, current water quality monitoring data suggest that Lac du Sauvage is not affected by mining operations. Lac du Sauvage possesses water quality characteristics consistent with pre-mining conditions and therefore similar to Ursula and Nanuq lakes, having low alkalinity and hardness, being slightly acidic, and having nutrients and metal concentrations generally at or below detection and/or CWQGs.

Lac de Gras water quality is typical of a northern lake but is experiencing elevated concentrations of six substances of interest (i.e., TDS, alkalinity, chloride, sulphate, total molybdenum, and total strontium) near the Diavik Mine site. Discharges from the Diavik Mine are causing increases in these parameters in the near-field monitoring locations of Lac de Gras, with elevated concentrations extending into the mid- and far-field for certain parameters. However, the concentrations of these parameters remain less than applicable CWQG and AEMP management action level benchmarks. Downstream of discharges from Ekati Mine, the stations in Slipper Lake Bay in Lac de Gras showed increases in pH, total hardness, TDS, chloride, sulphate, potassium, total molybdenum, and total strontium. The concentrations of these parameters remain below applicable CWQG and the site-specific water quality objectives (SSWQO).

1.4.4.2 Sediment Quality Summary

Sediment data from monitoring programs suggest the sediment quality in Lac du Sauvage has not changed due to mining development and is similar to non-affected lakes in the area. Concentrations of metals above sediment quality guidelines (e.g., arsenic, cadmium, chromium, copper, and zinc) in Lac du Sauvage, Nanuq Lake, and Ursula Lake indicate background sediment chemistry and are not attributable to anthropogenic influences. Mercury was generally below sediment quality guidelines in Lac du Sauvage, Nanuq Lake, and Ursula Lake. Sediments in these lakes are similar to results reported by Peramaki and Stone (2005) and Golder (2012).

Sediment quality in the western basin of Lac de Gras (FFA) is considered reflective of background concentrations and not affected by anthropogenic influences. Similar to reference lakes, concentrations of arsenic, cadmium, chromium, copper, and zinc are above sediment quality guidelines. In Lac de Gras, downstream of the Lac du Sauvage outlet (FF2), the lake is potentially influenced by treated effluent discharge from Diavik Mine with elevated bismuth concentrations.

Within the near-field and mid-field stations in the vicinity of Diavik Mine, elevated concentrations of bismuth, lead, and uranium have been measured, which suggest mine influences to sediment chemistry; these concentrations attenuate with distance from the mine. Concentrations of many parameters are higher in Lac de Gras sediments than Lac du Sauvage sediments (Table A4.5-1). The ranges reported by the Diavik and Ekati AEMP studies are similar to those reported by Peramaki and Stone (2005) for Lac de Gras.

Sediment concentrations of polychlorinated dibenzo-*p*-dioxins, polychlorinated dibenzofurans, and toxic equivalencies in Kodiak Lake exceeded the ISQG threshold of 0.85 ng toxic equivalencies /kg dw (Wilson et al. 2011). The elevated sediment concentrations of polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans in Kodiak Lake compared to Counts Lake suggested a mine influence (i.e., remote camp waste incineration activities) on the levels in Kodiak Lake.

2 2013 BASELINE FIELD PROGRAM METHODS

2.1 General Approach

The 2013 water and sediment quality baseline program was completed during the open-water season from late July to mid-September 2013. Water samples and physico-chemical water column measurements were collected during three open-water season field programs: July (late spring), August (summer), and September (fall) of 2013 (Table 2.1-1). Sediment quality samples were collected during the summer or the fall field program (Table 2.1-1).

Samples were collected at stations established in the following lakes and streams:

- Lac du Sauvage;
- Duchess Lake;
- the stream connecting Lac du Sauvage and Lac de Gras (i.e., the Lac du Sauvage outlet);
- other lakes within the Lac du Sauvage basin (i.e., Lake E1, Lake C1, Lake D1 [Counts Lake], Lake G, and Lake H);
- other streams draining to Lac du Sauvage with other lakes within its sub-basin; and,
- Paul Lake.

In situ physico-chemical measurements and water chemistry samples were collected at all stations. Samples for sediment chemistry and physical characteristics were collected at several stations in most lakes and streams.

Table 2.1-1 Water and Sediment Quality Sampling Periods, 2013

Sample Type	Timing of Sampling	Sampling Period
Water Quality	July 17 to 29	Late Spring
	August 7 to 21	Summer
	September 4 to 17	Fall
Sediment Quality	August 15 to 27	Summer
	September 12 to 16	Fall

2.2 Sampling Design

The sampling design for the 2013 open-water program involved the following components:

- field physico-chemical water column measurements of water temperature, dissolved oxygen, pH, and specific conductivity measured at 1 m depth increments at lake stations, and below the water surface at stream stations;

- field measurements of light attenuation through the water column in deep lake stations;
- discrete water chemistry samples collected in lake stations at the surface and bottom of the water column, or at mid-depth, depending on the presence of stratification;
- depth-integrated water chemistry samples collected in deep lake stations, for specific analysis of nutrients and chlorophyll *a*; and,
- composite sediment samples collected at lake and streams stations.

Depth-integrated and discrete nutrient samples were collected at the lake stations. This additional sampling was undertaken specifically for nutrient analyses to compare discrete surface water and mid-column discrete nutrient concentrations to composite samples collected through the euphotic zone. The Snap Lake AEMP (De Beers 2013) and the DDMI AEMP (Golder 2011) have shown that nutrient concentrations can be substantially different through the water column.

A depth-stratified study design was employed for three of the lakes: Lac du Sauvage, Duchess Lake, and Lake E-1. In these lakes, deep stations (target depth 10 to 15 m) and shallow stations (target depth 3 to 5 m) were sampled. In Paul Lake, lake depth was unknown, so the study design focused on a series of stations in the centre of the lake from the upper to lower reaches. Because bathymetry was not available for the small lakes within the Lac du Sauvage sub-basin, the study design focused on the centre of each of those lakes, where the deepest portion of the lake was most likely to be located. Lac du Sauvage was the focal lake of the field program, thus the largest amount of effort (i.e., number of stations) was allocated to collecting data from this lake.

The overall study design for the program was developed to optimize the collection of samples during two-week field programs, while collecting sufficient data to characterize spatial and temporal variability in water quality, and spatial variability in sediment quality.

2.3 Basin Naming Convention

The Lac du Sauvage basin has a drainage area of approximately 1,500 km² and includes Lac du Sauvage and small, direct tributaries (Basin A), 10 major tributary sub-basins (Basins B to L), and the adjacent Paul Lake basin (Basin P). To facilitate the 2013 field programs, the number of lakes and connecting channels required that a rational and easily understood naming convention be developed and applied to this large and complex basin. The naming convention was developed for use by all technical disciplines, including the other aquatic components (Hydrology Baseline Report [Annex X]; Light Attenuation Data [Appendix D]):

- Major sub-basins were identified using a capital letter (i.e., A, B, C...). The local Lac du Sauvage sub-basin was designated as the "A" basin. Tributary sub-basins identified during the basin study were designated as B through L, with the B sub-basin located immediately north of the Lac du Sauvage outlet and the sequence proceeding in a clockwise direction around Lac du Sauvage.

- The local Lac du Sauvage sub-basin was broken into internal sub-basins, designated using an additional lower case letter (i.e., Aa, Ab, Ac...). These were designated according to internal basins as identified by the available coarse bathymetry, and the sequence followed the direction generally from southeast basin to northwest.
- Lake names were designated by the basin letter and lake number (i.e., L1, L2, L3...). The sequence started at the terminal lake of each sub-basin and proceeded to the headwater lake on the mainstem of the sub-basin. The sequence then continued from the first branch on the headwater chain, upstream from the sub-basin outlet, then the second branch, and so on. Non-draining lakes were assigned numbers according to the nearest branch.
- Lake names within Lac du Sauvage sub-basins (i.e., Lake Ab1, Lake Ab2, Lake Ab3...) proceeded on a branch-by-branch basis, clockwise through each sub-basin.

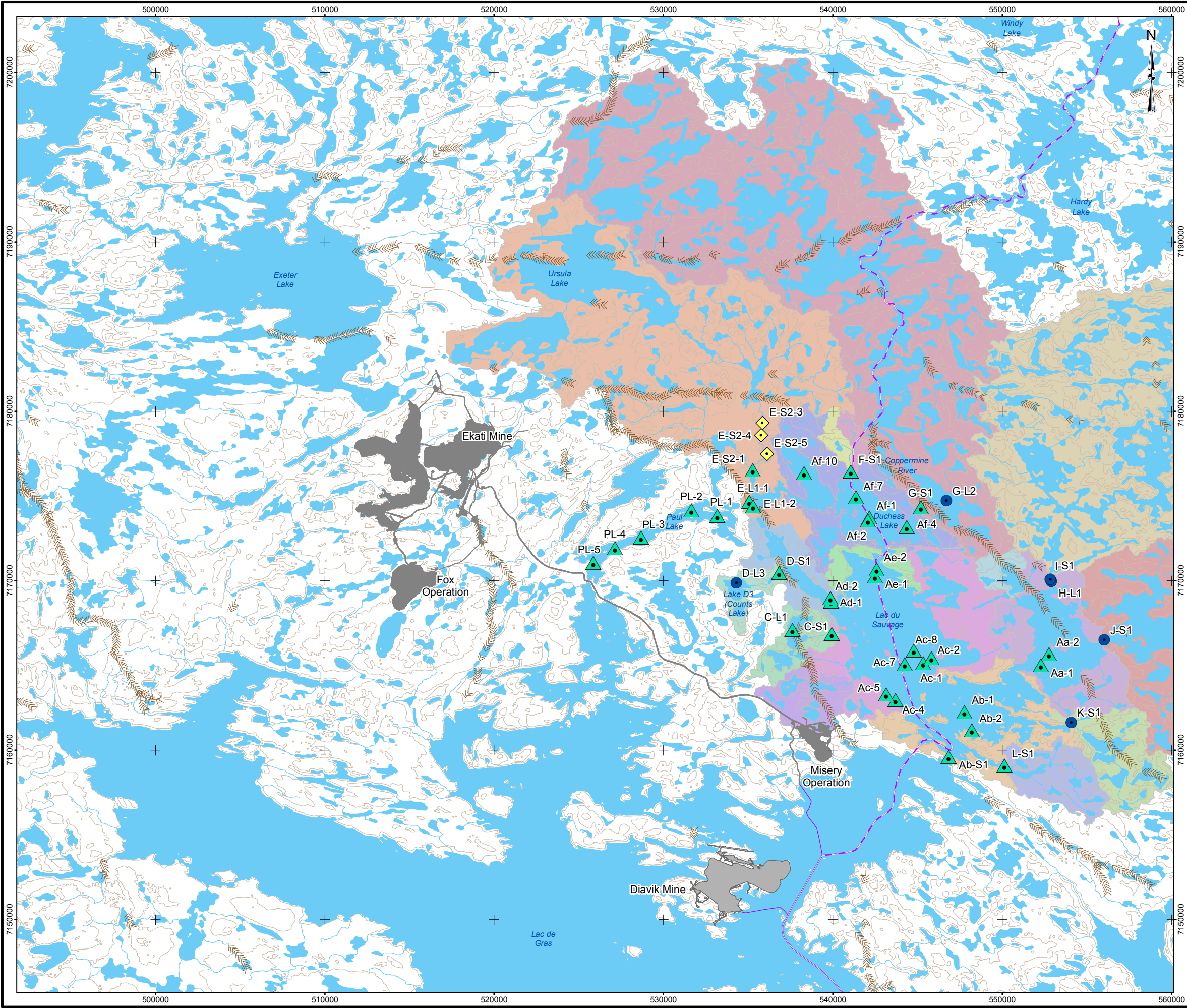
Before field studies, Duchess Lake was understood to be one continuous lake, with a narrows between the east and west portions. However, field surveys in 2013 confirmed an elevation drop of 1 m between two separate lakes (Annex X). The western lake was designated as Lake Af1, while the eastern lake, draining to Lac du Sauvage basin Ae1, continued to be designated as Duchess Lake. Both lakes (Duchess Lake and Lake Af1) are part of the Lac du Sauvage internal sub-basin Af (Map 1.3-1).

2.4 Sampling Locations

Sampling stations were established throughout the baseline study area. The 2013 sampling locations are shown, along with historical sampling locations in the baseline study area, in Map 2.4-1. Lac du Sauvage was the focus of the 2013 field program, and thus had the highest number of stations (14 stations) dispersed through internal sub-basins Aa, Ab, Ac, Ad, and Ae (Table 2.4-1). A station was also established at the Lac du Sauvage outlet (Table 2.4-1). Four stations were established in Duchess Lake (Table 2.4-2), which is part of sub-basin Af in the Lac du Sauvage basin, and one station in Lake Af1 (Table 2.4-3). Four small lakes and eight streams within the Lac du Sauvage basin were also sampled (Table 2.4-4). Two lake stations were established in Lake E1, including one stream (with four stations) (Table 2.4-5). Finally, five stations were established in Paul Lake (Table 2.4-6).

Sampling stations were only accessible by helicopter and boat and, thus, bad weather (e.g., fog, high winds) sometimes caused delays in the field programs. As such, not all stations were visited during each field program.

G:\CLIENTS\DOMINION\DEC_Jay and Lynx Projects\Figures\13-1328-0041_Jay & Lynx E&A\aquatics\Baseline\B_JC_Aqua_041_GIS.mxd



LEGEND

- EKATI MINE FOOTPRINT
- DIAMIK MINE FOOTPRINT
- WINTER ROAD
- TIBBITT TO CONTWOYT WINTER ROAD
- NORTHERN PORTION OF TIBBITT TO CONTWOYT WINTER ROAD
- ELEVATION CONTOUR (20 m INTERVAL)
- ESKER
- WATERCOURSE
- WATERBODY
- WATER SAMPLING STATION
- WATER AND SEDIMENT SAMPLING STATION
- SEDIMENT SAMPLING STATION

Basin

- Aa
- Ab
- Ac
- Ad
- Ae
- Af
- B
- C
- D
- E
- F
- F2
- G
- H
- I
- J
- K
- L

REFERENCE

NATIONAL TOPOGRAPHIC BASE DATA (NTDB) 1:250,000
NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2012
DATUM: NAD83 PROJECTION: UTM ZONE 12N

DOCUMENT

WATER AND SEDIMENT QUALITY BASELINE REPORT

5 0 5
SCALE 1:225,000 KILOMETRES

PROJECT

DOMINION DIAMOND

JAY PROJECT
NORTHWEST TERRITORIES, CANADA

TITLE

**WATER AND SEDIMENT QUALITY
SAMPLING LOCATIONS, 2013**

Golder Associates

PROJECT	13-1328-0041	FILE No. B_JC_Aqua_041_GIS
DESIGN	CC	12/06/14
GIS	TN	11/09/14
CHECK	CG	11/09/14
REVIEW	SM	11/09/14

MAP 2.4-1

Table 2.4-1 Water and Sediment Quality Sampling Summary for Lac du Sauvage, 2013

Basin	Internal Sub-Basin ID	Station ID	Station Type	NAD 83, 12W		Sampling Period ^(a)		
				Easting (m)	Northing (m)	Late Spring	Summer	Fall
Lake								
A	Aa	Aa-1	Deep	552282	7165025	Mid, Chl <i>a</i>	Top, Bottom, Chl <i>a</i> , DIN, SQ	Mid, Chl <i>a</i>
A	Aa	Aa-2	Shallow	552773	7165665	Mid	Mid, SQ	Mid
A	Ab	Ab-1	Deep	547766	7162266	Mid, Chl <i>a</i>	Top, Bottom, Chl <i>a</i> , DIN, SQ	Mid, Chl <i>a</i>
A	Ab	Ab-2	Shallow	548215	7161177	Mid	Mid, SQ	—
A	Ac	Ac-1	Deep	545339	7165138	Mid, Chl <i>a</i>	Top, Bottom, Chl <i>a</i> , DIN, SQ	Mid, Chl <i>a</i>
A	Ac	Ac-2	Shallow	545832	7165447	Mid	Mid, SQ	—
A	Ac	Ac-4	Deep	543695	7162938	Mid, Chl <i>a</i>	Top, Bottom, Chl <i>a</i> , DIN, SQ	Mid, Chl <i>a</i>
A	Ac	Ac-5	Shallow	543149	7163287	Mid	Mid, SQ	—
A	Ac	Ac-7	Deep	544247	7165068	Mid, Chl <i>a</i>	Top, Bottom, Chl <i>a</i> , DIN, SQ	Mid, Chl <i>a</i>
A	Ac	Ac-8	Shallow	544777	7165855	Mid	Mid, SQ	—
A	Ad	Ad-1	Deep	539898	7168781	Mid, Chl <i>a</i>	Top, Bottom, Chl <i>a</i> , DIN, SQ	Mid, Chl <i>a</i>
A	Ad	Ad-2	Shallow	539868	7168991	Mid	Mid, SQ	—
A	Ae	Ae-1	Deep	542494	7170252	Mid, Chl <i>a</i>	Top, Bottom, Chl <i>a</i> , DIN, SQ	Mid, Chl <i>a</i>
A	Ae	Ae-2	Shallow	542588	7170675	Mid	Mid, SQ	Mid
Streams								
A	Ab	Ab-S1	Mid-Channel	546850	7159585	—	Mid	Mid, SQ

Notes: Chl *a* = indicates that depth-integrated chlorophyll *a* samples were collected; DIN = indicates that depth-integrated nutrient samples were collected; SQ = indicates that sediment quality samples were collected; “—” = indicates the site was not sampled due to weather, environment, or schedule limitations.

a) Under stratified conditions, water samples in lakes were collected 1 m below the water surface (Top) and 1 m above the lake bed (Bottom); under mixed conditions, water samples were collected from the middle (Mid) of the water column.

ID = identification; NAD = North American Datum; m = metre.

Table 2.4-2 Water and Sediment Quality Sampling Summary for Duchess Lake, 2013

Basin	Internal Sub-Basin ID	Station ID	Type	NAD 83, 12W		Sampling Period ^(a)		
				Easting (m)	Northing (m)	Late Spring	Summer	Fall
Lake								
A	Af	Af-1	Deep	542155	7173731	Mid, Chl <i>a</i>	Mid, Chl <i>a</i> , SQ	Mid, Chl <i>a</i> , DIN
A	Af	Af-2	Shallow	542074	7173542	Mid	Mid, SQ	—
A	Af	Af-4	Shallow	544360	7173181	Mid	Mid, SQ	—
A	Af	Af-7	Deep	541367	7174902	Mid, Chl <i>a</i>	Top, Bottom, Chl <i>a</i> , SQ	Mid, Chl <i>a</i> , DIN

Notes: Chl *a* = indicates that depth-integrated chlorophyll *a* samples were collected; DIN = indicates that depth-integrated nutrient samples were collected; SQ = indicates that sediment quality samples were collected; "—"= indicates the sites were not sampled due to weather, environment, or schedule limitations.

a) Under stratified conditions, water samples in lakes were collected 1 m below the water surface (Top) and 1 m above the lake bed (Bottom); under mixed conditions, water samples were collected from the middle (Mid) of the water column.

ID = identification; NAD = North American Datum; m = metre.

Table 2.4-3 Water and Sediment Quality Sampling Summary for Lake Af1, 2013

Basin	Internal Sub-Basin ID	Station ID	Type	NAD 83, 12W		Sampling Period ^(a)		
				Easting (m)	Northing (m)	Late Spring	Summer	Fall
Lake								
A	Af	Af-10	Deep	538299	7176361	Mid, Chl	Top, Bottom, Chl a, DIN, SQ	Mid, Chl a

Notes: Chl *a* = indicates that depth-integrated chlorophyll *a* samples were collected; DIN = indicates that depth-integrated nutrient samples were collected; SQ = indicates that sediment quality samples were collected.

a) Under stratified conditions, water samples in lakes were collected 1 m below the water surface (Top) and 1 m above the lake bed (Bottom); under mixed conditions, water samples were collected from the middle (Mid) of the water column.

ID = identification; NAD = North American Datum; m = metre.

Table 2.4-4 Water and Sediment Quality Sampling Summary for Lac du Sauvage Sub-Basins (C, D, F, G, H, I, J, K, and L), 2013

Basin	Lake/Stream	Station ID	Type	NAD 83, 12W		Sampling Period ^(a)		
				Easting (m)	Northing (m)	Late Spring	Summer	Fall
Lakes								
C	Lake C1	C-L1	Small Lake	537612	7167085	—	Top, Bottom, Chl a, SQ	—
D	Lake D3	D-L3	Small Lake	534303	7169862	—	Top, Bottom, Chl a	—
G	Lake G2	G-L2	Small Lake	546707	7174698	—	—	Mid, Chl a
H	Lake H1	H-L1	Small Lake	552899	7169950	—	—	Mid, Chl a
Streams								
C	Stream C1	C-S1	Mid-channel	539935	7166859	Mid	SQ	—
D	Stream D1	D-S1	Mid-channel	536832	7170474	Mid	SQ	—
F	Stream F1	F-S1	Mid-channel	541073	7176452	Mid	SQ	Mid
G	Stream G1	G-S1	Mid-channel	545193	7174326	Mid	SQ	Mid
I	Stream I1	I-S1	Mid-channel	552840	7170080	Mid	—	Mid
J	Stream J1	J-S1	Mid-channel	556033	7166482	Mid	—	Mid
K	Stream K1	K-S1	Mid-channel	554080	7161614	Mid	—	Mid
L	Stream L1	L-S1	Mid-channel	550131	7159101	Mid	—	Mid, SQ

Notes: Chl a = indicates that depth-integrated chlorophyll a samples were collected; SQ = indicates that sediment quality samples were collected; "—"= indicates the sites were not sampled due to weather, environment, or schedule limitations.

a) Under stratified conditions, water samples in lakes were collected 1 m below the water surface (Top) and 1 m above the lake bed (Bottom); under mixed conditions, water samples were collected from the middle (Mid) of the water column.

ID = identification; NAD = North American Datum; m = metre.

Table 2.4-5 Water and Sediment Quality Sampling Summary for Lac du Sauvage Sub-Basin E, 2013

Basin	Lake/ Stream	Station ID	Type	NAD 83, 12W		Sampling Period ^(a)		
				Easting (m)	Northing (m)	Late Spring	Summer	Fall
Lake								
E	Lake E1	E-L1-1	Deep	535065	7174657	—	Top, Bottom, Chl <i>a</i> , DIN, SQ	Mid , Chl <i>a</i>
E	Lake E1	E-L1-2	Shallow	535292	7174406	—	Mid, SQ	Mid, Chl <i>a</i>
Stream								
E	Stream E2	E-S2-1	Mid-channel	535267	7176533	Mid	—	Mid, SQ
E	Stream E2	E-S2-3	Mid-channel	535848	7179317	—	—	SQ
E	Stream E2	E-S2-4	Mid-channel	535772	7178598	—	—	SQ
E	Stream E2	E-S2-5	Mid-channel	536113	7177490	—	—	SQ

Notes: Chl *a* = indicates that depth-integrated chlorophyll *a* samples were collected; DIN = indicates that depth-integrated nutrient samples were collected; SQ = indicates that sediment quality samples were collected; “—”= indicates the sites were not sampled due to weather, environment, or schedule limitations.

a) Under stratified conditions, water samples in lakes were collected 1 m below the water surface (Top) and 1 m above the lake bed (Bottom); under mixed conditions, water samples were collected from the middle (Mid) of the water column.

ID = identification; NAD = North American Datum; m = metre.

Table 2.4-6 Water and Sediment Quality Sampling Summary for Paul Lake, 2013

Basin	Lake/ Stream	Station ID	Type	NAD 83, 12W		Sampling Period ^(a)		
				Easting (m)	Northing (m)	Late Spring	Summer	Fall
Lake								
Lac de Gras	Paul Lake	PL-1	Deep	533179	7173835	Mid, Chl a,	Top, Bottom, Chl a, DIN	SQ
Lac de Gras	Paul Lake	PL-2	Deep	531655	7174122	Mid, Chl a,	Top, Bottom, Chl a, DIN	Mid, Chl a, SQ
Lac de Gras	Paul Lake	PL-3	Deep	528681	7172550	Mid, Chl a,	Top, Bottom, Chl a, DIN	Mid, Chl a, SQ
Lac de Gras	Paul Lake	PL-4	Deep	527145	7171895	Mid, Chl a,	—	Mid, Chl a, SQ
Lac de Gras	Paul Lake	PL-5	Deep	525859	7171047	—	Top, Bottom, Chl a, DIN	Mid, Chl a, SQ

Notes: Chl a = indicates that depth-integrated chlorophyll a samples were collected; DIN = indicates that depth-integrated nutrient samples were collected; SQ = indicates that sediment quality samples were collected; "—"= indicates the sites were not sampled due to weather, environment, or schedule limitations.

a) Under stratified conditions, water samples in lakes were collected 1 m below the water surface (Top) and 1 m above the lake bed (Bottom); under mixed conditions, water samples were collected from the middle (Mid) of the water column.

ID = identification; NAD = North American Datum; m = metre.

2.5 Field Methods

2.5.1 Field Measurements

In situ physico-chemical measurements of specific conductivity, DO (concentration and percent saturation), and water temperature were taken at each lake and stream station using a multimeter (YSI 600QS, Hydrolab Series 5 MiniSonde multiprobe, and Hydrolab Series 5 DataSonde multiprobe). At the lake stations, total depth of the water column, sample depth, and Secchi depth were also measured. Total depth was measured in one of two ways: by using a sounding line, or by using a boat-mounted sonar unit (Humminbird™). Secchi depth was measured to provide a quick visual measure of water clarity and to provide a basis to determine a coarse estimate of the euphotic zone depth for the purposes of sample collection (Section 2.5.3).

At all lake stations, in situ physico-chemical measurements were taken at the surface, at 0.5 m below the surface, and every 1 m thereafter through the water column ending at 1 m above the sediments. At the stream stations, readings were taken approximately at mid-depth through the water column.

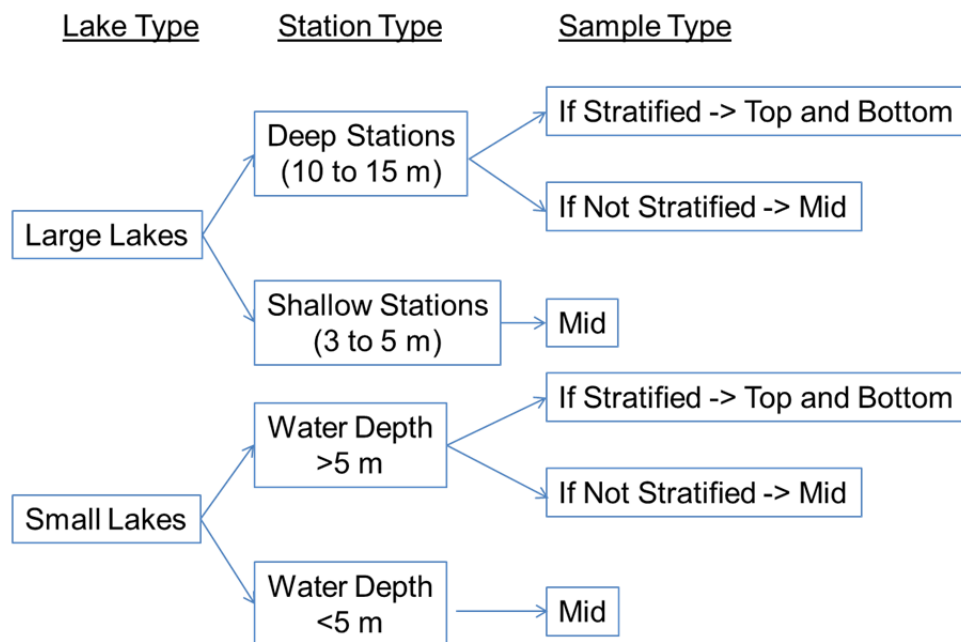
At the deep lake stations, light attenuation through the water column was measured as photosynthetically active radiation (PAR) at specific depths through the water column, using a LI-COR LI-1400 light meter. Photosynthetically active radiation is a slightly more narrow band of radiation (400 to 700 nanometres [nm]) than visible light and is the range of the light spectrum used by algae. The LI-COR light meter was equipped with a spherical light sensor to simultaneously measure upwelling (light reflected back from below the sensor) and downwelling (light entering the water from above the sensor). The sensor was lowered into the water column on a reverse T-shaped lowering arm, on the sunny side of the boat. Light measurements were recorded at the surface (considered 100 % irradiance) and lowered to specific depths (i.e., 2.5 centimetres [cm], 10 cm, 0.5 m, 1 m, and every 1 m thereafter to a depth of 1 m above the lake bed, or to a depth where the PAR measurement was approximately 1% of the light at the surface). All light measurements were re-expressed as a percentage of the surface irradiance value (%SI) and were calculated as described in Section 2.8.1.4.

2.5.2 Discrete Water Sample Collection

Discrete samples for water chemistry were collected from either Top, Mid, or Bottom depths depending on the total depth of the water column and presence of thermal stratification (Figure 2.5-1). Stratification was determined by a temperature difference of greater than or equal to 5 degrees Celsius (°C) between the surface and the bottom of the water column. If the water column was deep and stratified, discrete surface (Top) and bottom (Bottom) samples were collected. If the water column was not stratified, or at all shallow stations less than 5 m depth, a mid-column (Mid) sample was collected. The sampling stations at the remainder of the small lakes (e.g., Lake C1) were not classified deep or shallow; however, surface and bottom water samples were collected if the water was deeper than 5 m and the water column was stratified.

Lake water chemistry samples were collected using a Kemmerer sampler. At each station, the Kemmerer was triple-rinsed with lake water and then lowered to the required depth, triggered by the messenger, returned to the surface, and used to fill the lab-supplied sample bottles. This procedure was repeated until all sample bottles for the station were filled.

Figure 2.5-1 Discrete Water Sample Collection Strategy



m = metre; < = less than; > = greater than.

Stream water chemistry samples were collected from areas of observable flow. Grab samples were collected by directly filling laboratory-provided bottles, with the opening of the bottle facing upstream, at a depth ideally in the vertical middle of the water column (Mid); this depth was generally between 0.1 and 0.3 m below the water surface.

The water samples collected from all sites were analyzed by ALS Environmental (ALS), which is an analytical laboratory accredited by the Canadian Association for Laboratory Accreditation Inc. The following parameters were analyzed:

- conventional parameters (i.e., gran alkalinity, total alkalinity, conductance, hardness, laboratory pH, TDS, TSS, and turbidity);
- major ions (i.e., bicarbonate, calcium, chloride, fluoride, magnesium, potassium, sodium, and sulphate);
- nutrients (i.e., TOC, DOC, TN, TKN, total ammonia, nitrate, nitrite, TP, total dissolved phosphorus (TDP), dissolved orthophosphate, and soluble reactive silica [SRSi]);

- total and dissolved metals, metalloids, and non-metals¹ (i.e., aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, cesium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, tin, titanium, uranium, vanadium, and zinc);
- hydrocarbons (i.e., benzene, ethylbenzene, toluene, xylenes [BTEX], F1 [C₅-C₁₀], F1-BTEX, F2 [C₁₀-C₁₆], and total recoverable hydrocarbons); and,
- fecal coliforms.

2.5.3 Depth-Integrated Water Sample Collection

Depth-integrated water samples were collected for nutrient and chlorophyll *a* analyses from the euphotic zone to support the plankton component. The euphotic zone is defined as the extent of the water column that is exposed to sufficient sunlight for photosynthesis to occur (typically to a depth in the water column where 1% of the surface irradiance is measured). During the field program, the euphotic zone was calculated as two times the Secchi depth (Koenings and Edmundson 1991; AENV 2006).

A Kemmerer sampler was used to collect discrete water samples starting at the surface, and continuing every 2 m through the euphotic zone. If the total water column depth was less than two times the Secchi depth, a water sample was collected every 2 m from the surface to 2 m above the lake bed. Equal volumes of the water from each discrete depth were combined into a large clean bucket to create a composite depth-integrated sample.

Sampling using this technique was completed at Lac du Sauvage, Duchess Lake, Lake Af1, Lake E1, and Paul Lake. Depth-integrated nutrient samples were collected at deep stations during the summer sampling program in Lac du Sauvage, Lake Af1, Lake E1, and Paul Lake. Logistical issues during the sampling program prevented the collection of depth-integrated samples at Duchess Lake in the summer; therefore, two depth-integrated nutrient samples were collected at deep stations Af-1 and Af-7 in Duchess Lake during the fall sampling program (Table 2.4-4). Chlorophyll *a* samples were collected in triplicate at deep stations in Lac du Sauvage, Duchess Lake, Lake E1, and Paul Lake during the late spring, summer, and fall sampling programs, and in Lake E-L1 at an intermediate sampling station in the fall.

The depth-integrated samples were analyzed for nutrients (i.e., TN, TP, SRSi) and for chlorophyll *a*. Nutrients were analyzed by ALS Laboratories, Edmonton, Alberta. Chlorophyll *a* was analyzed, as total chlorophyll *a*, by the Biogeochemical Analytical Service Laboratory at University of Alberta, Edmonton, Alberta.

2.5.4 Sediment Sampling

To avoid disruption of the water column or potential contamination of water samples by suspended sediments, sediment samples at lake and stream sites were collected after field measurements and water quality samples were collected, or by a separate team on a different day.

¹ Henceforth, metals, metalloids (e.g., arsenic), and non-metals (e.g., selenium) will be referred to as metals.

In lakes, sediments were collected using a stainless steel 15 cm Ekman grab. Observations including colour, texture, odour, and presence of biota were recorded for each sample collected in the grab. Lake sediment was removed from the Ekman grab with a plastic trowel, taking care to remove sediments from the centre of the grab to avoid the metal sides of the Ekman, and from the upper 5 cm of the grab. The process was repeated until sufficient sediment was collected (approximately 450 grams [g] dry weight or 1.5 kilograms [kg] wet weight) for analysis of the required parameters. Each sample submitted for analysis was a composite of up to three grabs collected within close proximity around the sampling station. Sediment samples were composited by placing each of the three sub-samples into a clean, shallow, plastic pan, and mixing with a plastic spoon.

Stream sediment samples were collected using a plastic spoon because the depositional areas were not generally conducive for use of the Ekman. Surface scoops of sediment were collected at various locations in close proximity to the sampling station and composited by placing each sub-sample into a clean, shallow, plastic pan, and mixing with a plastic spoon.

Sediment samples were analyzed by ALS, an accredited analytical laboratory, for the following parameters:

- physical parameters (i.e., organic content, pH, particle size distribution [gravel, greater than 2 millimetres {mm}; coarse sand, 0.2 to 2.0 mm; fine sand, 0.063 to 0.2 mm; silt, 0.004 to 0.063 mm; and clay, less than 0.004 mm]);
- nutrients (i.e., available ammonium as nitrogen, organic nitrogen, TKN, available phosphate as phosphorus, TP, inorganic carbon, TC, and TOC); and,
- metals (i.e., aluminum, antimony, arsenic, barium, beryllium, bismuth, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, sulfur, thallium, tin, titanium, uranium, vanadium, and zinc).

2.6 Sample Handling

Sample bottles were provided by ALS. Water samples were processed (i.e., filtered and/or preserved as required, and refrigerated) according to the instructions provided by the analytical laboratory. Water samples requiring filtration were filtered through a 0.45 micron (μm) Millipore filter in a Nalgene filter tower using a hand-operated vacuum pump before being preserved with laboratory-provided preservative. Water samples were kept refrigerated before shipping; ice-packs were added to the coolers to keep the samples as cool as possible during shipping. Samples were shipped to the analytical laboratory as soon as possible after sample collection and processing.

For chlorophyll *a*, water samples were filtered through a 47 mm Whatman Glass Fiber type C (GF/C) filter in a glass filter tower using a vacuum pump under low light conditions to prevent photo-shock in the algal cells. The filters were folded in half, placed in a pre-labelled Petri dish, wrapped with aluminum foil, and frozen.

Sediment samples were placed in laboratory-provided plastic bags and kept cold during holding and transport to the analytical laboratory.

2.7 Description of Parameters

Physico-chemical (including light attenuation) and chemical (i.e., conventional, nutrient, and metals) parameters were used to describe the water and sediment quality of the different lakes and streams in the baseline study area. The major categories of parameters that were used to describe different aspects of the water or sediment are described in this section.

2.7.1 Water Quality

2.7.1.1 *Field-Measured Physico-Chemical Parameters*

Water temperature, DO, pH, and specific conductivity were measured in situ (directly in the field) using hand-held meters and submersible sondes, and then used to describe the physico-chemical characteristics of the streams and lakes.

The unique physical properties of water play an important role in structuring the annual temperature patterns in a lake. For example, water at 4°C is heavier than water that is either cooler or warmer. When the surface of a lake warms to 4°C, this denser water sinks, and the water beneath it rises and is warmed, thus continuing a pattern of mixing. Wind also plays a role in mixing the water column. In winter conditions, snow and ice cover prevent mixing so the water column tends to be more static, but with temperatures typically between 0°C to 4°C.

In the spring, when the snow and ice cover melt, the open-water column warms rapidly during the first few weeks in spring, which tends to be consistent through the whole column. In warm, calm weather during the open-water season, particularly in summer conditions, the surface water may warm up more rapidly than the deeper water and water column stratification may occur for short periods. Sub-Arctic lakes may be monomictic, meaning that the lake only experiences one main mixing period in a year, or dimictic, meaning two mixing periods during the year (i.e., in spring and fall).

Dissolved oxygen is a measure of the amount of oxygen available to aquatic organisms. The amount of oxygen that can dissolve in water depends on water temperature, elevation above sea level, air pressure, and salinity. More oxygen is soluble in cold water than in warm water; fresh water holds more oxygen than saline water, and saturation increases with increased pressure.

A measure of the acidity or alkalinity of water is expressed as pH and refers to the concentration of hydrogen ions on a negative logarithmic scale extending from 1 (acidic) to 14 (basic or alkaline). Values of pH 7 are characterized as “neutral” pH conditions. The pH is closely related to the ions available in water, which is linked to the geology and geochemistry of the catchment area.

Specific conductivity is a temperature-corrected value of the ability of the water to conduct electricity. It is strongly correlated with TDS because the presence of ions in water is directly proportional to the ability of the water to conduct electricity. The exact relationship between conductivity and TDS depends on the specific quantities of ions present, and varies among waterbodies.

2.7.1.2 Vertical Light Attenuation

Solar radiation, or sunlight, is one of the main determining factors for primary productivity in Arctic lakes. Polar regions receive less solar radiation than lower latitudes, and snow and ice cover affect light transmission through the water column (Vincent et al. 2008). The amount of light transmitted through the water column influences aquatic life, such as phytoplankton (algae) and macrophytes (plants). Surface irradiance is the amount of light that reaches the surface of the water. It is measured as PAR, which is the specific band of light wavelength (400 to 700 nm) that is used by algae and plants for photosynthesis.

The euphotic zone (the zone where photosynthesis occurs) extends from the surface of the water to a depth where PAR is approximately 1% of light measured at the surface (i.e., PAR greater than 1% of subsurface incident radiation). This is the zone where the majority of autotrophs exist (e.g., aquatic macrophytes and phytoplankton), and therefore where photosynthesis primarily occurs within the water column.

Once light enters the water, light intensity attenuates, or decreases, logarithmically with water depth (Kirk 1994; Wetzel 2001). The decrease in light intensity through the water column is quantified by the extinction or attenuation coefficient (K_d), which is a measure of the rate of vertical attenuation of light through the water column. Attenuation is a function of reflection, refraction or scattering, and absorption by water, dissolved compounds, and suspended particles (Kirk 1994; Dodds and Whiles 2010). The maximum depth of the euphotic zone depends on the extent of this light attenuation in the water column.

Water clarity, which provides an indication of light penetration into the water column, can be inferred by Secchi disk depth (i.e., the depth that the disk disappears and then reappears from view). Secchi depth can be used as a tool to estimate the euphotic zone (Koenings and Edmundson 1991; AENV 2006). Secchi depth can provide an estimate of the depth at which approximately 10% of the surface light remains (Dodds and Whiles 2010). However, a more direct, quantitative, and less subjective measure of PAR can be obtained with a LI-COR light meter.

Light meter data can also be used to evaluate the potential effects of increased TSS (also turbidity) on water transparency over time. Typically in more productive (eutrophic) waterbodies with large phytoplankton biomass or with large amounts of suspended or dissolved materials, the water contains more material to absorb or reflect light, which inhibits light transmittance to deeper depths (i.e., light attenuation is more substantial). Conversely, in less productive (oligotrophic) waterbodies with low amounts of suspended or dissolved material, light is transmitted to greater depths (i.e., lower rate of light attenuation).

2.7.1.3 Conventional Parameters

Conventional, or general water quality, parameters were measured in the laboratory: pH, total alkalinity, conductance, TDS, total hardness, TSS, and turbidity. Conventional parameters are considered indicator parameters because they indicate a trend in a larger group of substances.

Alkalinity is a measure of the capacity of water to neutralize strong acid. If alkalinity is high, pH will remain constant despite the addition of acids; if alkalinity is low, pH will be sensitive to the addition of acids. Alkalinity can also influence the form, or speciation, of trace metals in water, and thus may alter bioavailability and toxicity of the metal. The three ions that contribute to alkalinity include bicarbonate, carbonate, and hydroxide. Sub-Arctic Shield waters are typically sub-neutral to neutral, and therefore only bicarbonate is likely to contribute to any alkalinity. Arctic and sub-Arctic freshwater systems are typically low in bicarbonate, due to the constraints of low temperatures and permafrost on weathering (Lyons and Finlay 2008).

Measured total alkalinity for lakes (Table 2.7-1) and streams (Table 2.7-2) can be used to evaluate the sensitivity of surface waters to acid input. Sub-Arctic waters would be expected to have low alkalinity and thus have high sensitivity to acid input.

Table 2.7-1 Lake Acid Sensitivity Scale

Acid Sensitivity	Total Alkalinity (mg CaCO ₃ /L)
High	0 to 10
Moderate	10 to 20
Low	20 to 40
Least	>40

Source: Saffran and Trew (1996).

mg CaCO₃/L = milligrams calcium carbonate per litre; > = greater than.

Table 2.7-2 Stream Acid Sensitivity Scale

Acid Sensitivity	Total Alkalinity (mg CaCO ₃ /L)
Acidic	<0
Highly Sensitive	0 to 2.5
Sensitive	2.6 to 10
Not Sensitive	>10

Source: Boward et al. (1999).

mg CaCO₃/L = milligrams calcium carbonate per litre; < = less than; > = greater than.

Alkalinity is closely linked to water hardness, which is a measure of the amount of specific dissolved substances, primarily calcium and magnesium, in water. Hardness is important because it plays an important physiological role in the bioavailability and toxicity of metals (it is an exposure and toxicity modifying factor); the bioavailability and toxicity of a metal typically decrease as hardness increases. The qualitative scale of water hardness provided in Table 2.7-3 describes hardness of surface water.

Table 2.7-3 Water Hardness Scale

Water Hardness Scale	Total Hardness (mg CaCO ₃ /L)
Very soft	0 to 30
Soft	31 to 60
Moderately soft	61 to 120
Hard	121 to 180
Very hard	>180

Source: McNeely et al. (1979).

mg CaCO₃/L = milligrams calcium carbonate per litre; > = greater than.

Conductance, which is synonymous with conductivity, provides the same information as specific conductivity, with the exception that conductance is not a temperature-corrected value. Total dissolved solids is another measure of the total ion content of water and is strongly correlated with conductance, because the presence of ions in water is directly proportional to the ability of the water to conduct electricity. The exact relationship between conductance and TDS depends on the specific quantities of ions present and varies among waterbodies. Arctic freshwater systems typically have low concentrations of major ions, which means that conductance and TDS are low in these waters.

Total suspended solids include all solid particles suspended in the water column. Elevated TSS in the aquatic environment can affect fish behaviour, physiology, and habitat (CCME 2002; Robertson et al. 2006). Concentrations of TSS below 25 milligrams per litre (mg/L) are usually not considered harmful to aquatic life (EIFAC 1964); however, the nature and extent of adverse effects attributable to TSS is a function of concentration and exposure. For example, aquatic organisms can withstand high levels of TSS for short periods and low levels of TSS for long periods (Newcombe and MacDonald 1991; Newcombe and Jensen 1996).

Turbidity, which is measured in nephelometric turbidity units (NTU), is a measure of the cloudiness or haziness in the water caused by individual particles (e.g., total suspended or dissolved solids) that affects its clarity and how much light can be transmitted through a water sample. Turbidity is sometimes used as a surrogate measure of TSS.

2.7.1.4 Major Ions

Ions are chemicals which, when dissolved in water, separate into positively and negatively charged particles. Major ions include positively charged ions, called *cations* (e.g., calcium, magnesium, sodium, and potassium), and negatively charged ions, called *anions* (e.g., bicarbonate, chloride, fluoride, and sulphate). Arctic freshwater systems typically have low concentrations of major ions, particularly calcium, sulphate, and bicarbonate, because low temperatures and permafrost limit weathering (Lyons and Finlay 2008).

2.7.1.5 *Nutrients*

Nutrient and lake productivity parameters include carbon, nitrogen, phosphorus, and silica. Specific total and dissolved forms of these nutrients include DOC, TOC, TN, total ammonia, nitrate, nitrite, TKN, TP, TDP, dissolved orthophosphate, and SRSi. The nutrient group also includes chlorophyll *a*, which is the primary phytoplankton chlorophyll pigment, a direct correlate to phytoplankton biomass.

Organic carbon is a primary source of carbon that can be associated with natural organic matter, such as decaying plants and animals (e.g., humic acid, fulvic acid, amines, and urea). Total organic carbon includes DOC and particulate organic carbon. The form of carbon released from plants, and the form responsible for most of the yellow to brown water colour in natural water systems is DOC (e.g., humic and fulvic acids). This colouring is especially evident in muskeg and bog regions, which are naturally rich in organic matter. Total organic carbon is generally found in higher concentrations in lake sediments, because it is partly associated with suspended particles, which settle out on the lake bed. In Arctic freshwater systems, DOC is likely the dominant form of carbon, and can vary in concentration and seasonally (Lyons and Finlay 2008).

Sources of nitrogen to a lake include precipitation from the atmosphere, nitrogen fixation in the water and sediments, and inputs from surface and groundwater discharge (Wetzel 2001). Nitrogen can be present in both dissolved and particulate forms in surface water. The dissolved inorganic forms include nitrate, nitrite, and ammonia, and particulate forms include both organic and inorganic nitrogen. The dissolved forms are measured to evaluate the bioavailable nitrogen fraction.

Total phosphorus concentrations can range from approximately one microgram per litre (1 µg/L) in low productivity waters to more than 100 µg/L in high productivity waters (Vollenweider and Kerekes 1982; CCME 2004). Natural phosphorus concentrations are influenced by geology and soil characteristics, and by the presence of wetlands in the watershed of a lake or stream. Concentrations of TP are generally lower in lakes situated in Boreal regions on Precambrian Shield bedrock, and in lakes not affected by anthropogenic inputs (Wetzel 2001).

Phosphorus concentrations in Arctic freshwater systems are generally very low (Lyons and Finlay 2008). Total phosphorus measured in water includes both dissolved and particulate forms. The total dissolved fraction, TDP, includes orthophosphate or soluble reactive phosphorus, which is the form of phosphorus that is readily available for biological uptake.

Silica is moderately abundant in lakes and is generally supplied to the ecosystem through rock weathering (Wetzel 2001). Silica is a nutrient required for diatomaceous algae (diatoms), chrysophytes, and certain higher aquatic plants (e.g., sponges). Changes in silica concentration may result in changes in phytoplankton community composition; these changes can be seasonally cyclic. In particular, diatoms use inorganic silica to create biogenic silica for their cell walls.

In lakes with long residence times, silica can be depleted by diatom growth and subsequent sinking of their frustules (their hard and porous cell walls) to sediments, resulting in a selective advantage for algal groups that do not require silica for growth. The availability of silica can have a strong influence on the overall pattern of phytoplankton succession and productivity in lakes and streams. Silica is considered a limiting nutrient for diatom growth at concentrations below 0.1 mg/L (Reynolds 2006). Silica can be analyzed as SRSi to allow for evaluation of silica limitations for plankton growth.

Chlorophyll *a* is the primary photosynthetic pigment in phytoplankton and is widely used as a surrogate measure of phytoplankton biomass. A summary of chlorophyll *a* data is provided in this report as a general measure of phytoplankton biomass; details on phytoplankton species composition and biomass are provided in the Plankton Baseline Report (Annex XII).

2.7.1.6 Trophic Status Classification

Trophic status can be evaluated by examining the concentrations of nutrients (TN and TP), chlorophyll *a*, and water transparency. Chlorophyll *a* is the primary photosynthetic pigment contained in phytoplankton, which is why it is often used as a surrogate measure of phytoplankton biomass and production in lakes (Franklin et al. 2012).

The essential nutrients necessary for phytoplankton growth are TN and TP. The primary nutrient that often limits phytoplankton growth in lakes is phosphorus (Schindler 1974); therefore, phosphorus is often used to establish overall trophic status.

Nitrogen is not often the limiting nutrient in surface water although, in certain waterbodies, it is the limiting nutrient and should be considered when establishing overall trophic status (Wetzel 2001). Secchi depth (a measure of water transparency) can be used as a coarse surrogate for phytoplankton growth, because in many waterbodies, Secchi depth is inversely related to phytoplankton biomass (Dodds and Whiles 2010); therefore, it is also considered in certain cases when establishing trophic status.

The three main classes of trophic status are as follows:

- oligotrophic (nutrient-poor, unproductive systems);
- mesotrophic (moderately productive systems); and,
- eutrophic (nutrient-rich, highly productive systems).

Vollenweider (1970) developed a classification scheme for lakes using TP, TN, chlorophyll *a*, and Secchi depth (Table 2.7-4). This general classification system is an internationally accepted system based on analyses of over 200 waterbodies during the international program on eutrophication conducted by the Organization for Economic Cooperation and Development (OECD). While this general classification system is relatively simple, complications can arise due to overlap in the range of categories as well as differences in categorization between parameters.

Table 2.7-4 General Trophic Status Classification of Lakes

Trophic Status	Total Phosphorus (mg/L)		Total Nitrogen (mg/L)		Chlorophyll <i>a</i> (µg/L)		Secchi Depth (m)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Oligotrophic	0.008	0.003 to 0.018	0.661	0.307 to 1.630	1.7	0.3 to 4.5	9.9	5.4 to 28.3
Mesotrophic	0.0267	0.011 to 0.096	0.753	0.361 to 1.367	4.7	3.0 to 11.0	4.2	1.5 to 8.1
Eutrophic	0.0844	0.016 to 0.386	1.875	0.393 to 6.100	14.3	3.0 to 78.0	2.45	0.8 to 7.0

Source: Vollenweider (1970).

mg/L = milligrams per litre; µg/L = micrograms per litre; m = metre.

The Canadian Council of Ministers of Environment (CCME 2004) recommends that trophic status classification of lakes and streams be based on TP concentrations in a lake or stream, and that mesotrophic and eutrophic subdivisions should be divided further (Table 2.7-5). This additional subdivision was necessary because of considerable variation that exists in Canadian waters over the range observed by OECD (CCME 2004).

Table 2.7-5 Trophic Classification of Canadian Lakes and Streams Based on Total Phosphorus Trigger Concentrations

Trophic Status	Total Phosphorus (mg/L)	
	Lakes ^(a)	Streams ^(b)
Ultra-oligotrophic (very nutrient-poor)	<0.004	n/a
Oligotrophic (nutrient-poor)	0.004 to 0.01	<0.025
Mesotrophic (containing a moderate level of nutrients)	0.01 to 0.02	0.025 to 0.075
Meso-eutrophic (containing moderate to high levels of nutrients)	0.02 to 0.035	n/a
Eutrophic (nutrient-rich)	0.035 to 0.1	>0.075
Hyper-eutrophic (very nutrient-rich)	>0.1	n/a

a) Sources: CCME (2004); Environment Canada (2004).

b) Source: Dodds et al. (1998).

mg/L = milligrams per litre; < = less than; > = greater than; n/a = not applicable.

The trophic state index (TSI) can also be used to evaluate lake productivity. The TSI is a numerical trophic state index for lakes with a scale from 0 to 100 (Carlson 1977). Each major division (e.g., 10, 20, 30...) represents a doubling in algal biomass (Table 2.7-6). The index number is calculated from equations based on the Secchi depth, chlorophyll *a*, and TP concentrations.

An averaged TSI from the indices calculated from Secchi depth, and chlorophyll *a* and TP concentrations is used to determine a general trophic classification (Table 2.7-6).

Table 2.7-6 Comparison of Trophic State Index Classification and General Trophic Classification of Lakes

Trophic State Index	Total Phosphorus (mg/L)	Chlorophyll <i>a</i> (µg/L)	Secchi Depth (m)	General Trophic Classification
<30 to 40	0.0 to 0.012	0 to 2.6	>8.0 to 4	Oligotrophic
40 to 50	0.012 to 0.024	2.6 to 20	4 to 2	Mesotrophic
50 to 70	0.024 to 0.096	20 to 56	2 to 0.5	Eutrophic
70 to 100+	0.096 to 0.384+	56 to 155+	0.5 to <0.25	Hyper-eutrophic

Source: Carlson (1977).

mg/L = milligram per litre; µg/L = micrograms/litre; m = metre; < = less than; > = greater than; + = plus.

2.7.1.7 Total and Dissolved Metals

Metals are naturally present in surface waters in small quantities (i.e., typically less than 1 mg/L) in particulate and dissolved forms. Higher metal concentrations in natural waters are typically associated with particulate matter (i.e., elevated suspended sediments). Dissolved metals tend to be more bioavailable than particulate forms, and can be toxic to freshwater life. However, potential for toxicity is influenced by modifying factors, such as water hardness, temperature, and pH. For example, the toxicity potential of certain metals in soft, acidic waters is higher than the toxicity potential in harder, alkaline waters.

The potential effects of different metals to different receptors vary widely. For example, iron and manganese enter waterways as a result of the weathering of naturally occurring minerals and generally cause no harm other than rust stains. In fact, iron and manganese oxyhydroxides in sediments serve to bind other metals, reducing their potential bioavailability and toxicity. Other metals, such as lead and mercury, can impair the health of aquatic organisms, wildlife, and humans in relatively small quantities.

2.7.1.8 Hydrocarbons

Hydrocarbons can occur in the aquatic environment naturally, derived from the breakdown of plant matter, or through use of petroleum products. Benzene, ethylbenzene, toluene, and xylenes (BTEX) are volatile, monocyclic aromatic compounds present in coal tar, petroleum products, and various organic chemical product formulations. They are the most soluble of the major gasoline compounds and are therefore common indicators of gasoline contamination (Wilson and Moore 1998). The presence of petroleum hydrocarbon fractions F1 (C₆-C₁₀) is also indicative of gasoline, and presence of F2 (C₁₀-C₁₆) is indicative of diesel. The presence of total recoverable hydrocarbons (also known as Oil and Grease) is indicative of lubrication/motor oils (light oils), and tar/heavy oils (heavy oils). Detected concentrations of hydrocarbons in pristine northern lakes are likely linked to plant-related organic matter except where a spill has occurred.

2.7.2 Sediment Quality

Physical and chemical parameters are used to describe the sediment quality of lakes and streams. The major physical constituents of the sediment are moisture content, organic matter, and particle size distribution. The particle size distribution describes the relative proportion of sand, silt, and clay in the sediment.

The chemical character of sediments is typically associated with nutrient and metals concentrations. Sediments are sinks for certain nutrients present in surface waters, particularly phosphorus. Total phosphorus binds to sediment particles and, under certain conditions, is released back into surface waters as dissolved phosphorus. Nitrogen and carbon are two essential nutrients for primary productivity, and are usually present in much higher concentrations than phosphorus in lake water.

Sediments are sinks for the metals present in surface waters. Higher metal concentrations in surface water are usually associated with suspended sediments, which tend to settle out and accumulate on the lake bottom over time. If they are bioavailable, metals in sediments can be toxic to aquatic organisms. Baseline metal concentrations also reflect the geochemistry of the watershed.

2.8 Data Analysis

2.8.1 Water Quality

2.8.1.1 Comparison to Guidelines

Water quality data were compared to the following water quality guidelines and objectives (Table 2.8-1):

- Canadian Council of Ministers of the Environment (CCME) CWQGs for the protection of aquatic life (CCME 1999);
- Health Canada's Canadian Drinking Water Quality Guidelines (CDWQGs) (Health Canada 2012); and,
- Ekati Mine's short- and long-term SSWQO for chloride, potassium, sulphate, nitrate, molybdenum, and vanadium (Elphick et al. 2011; Rescan 2012 b,c,d,e,f).

Guidelines are numerical limits or narrative statements based on the most current, scientifically defensible toxicological data available for the parameter of interest. They are designed to be protective of all forms of aquatic life and all aspects of the aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term. Ambient water quality guidelines developed for the protection of aquatic life provide the science-based benchmark for a nationally consistent level of protection for aquatic life in Canada (CCME 1999). As such, the guidelines are generic and intended for use across a wide range of aquatic systems throughout Canada. An exceedance of a guideline does not necessarily imply the likelihood of an adverse environmental effect. Exceedances of guidelines under baseline conditions indicate naturally elevated concentrations relative to other sites in Canada, and suggest that resident aquatic biota have adapted to these concentrations.

For the Ekati Mine, SSWQO were developed for certain constituents for use as benchmarks for monitoring in the receiving environment (Table 2.8-1). The SSWQO were developed following CCME guidance, have undergone internal and third-party technical peer review, and are now incorporated into the current Water Licence, #W2012L2-0001, for the Ekati Mine (WLWB 2014).

Table 2.8-1 Water Quality Guidelines and Site-Specific Water Quality Objectives Developed for Ekati Mine

Parameter	Unit	Guidelines			Ekati Mine Site-Specific Water Quality Objectives	
		Aquatic Life		Drinking Water ^(b)	Short Term ^(c,d,e,f,g,h)	Long Term ^(c,d,e,f,g,h)
		Acute ^(a)	Chronic ^(a)			
Conventional Parameters						
pH	—	—	6.5 to 9	6.5 to 8.5	—	—
Total dissolved solids	mg/L	—	—	500	—	—
Major Ions						
Chloride	mg/L	640	120	250	—	64.5 ^(c,i)
Fluoride	mg/L	—	0.12	1.5	—	—
Potassium	mg/L	—	—	—	112 ^(d)	41 ^(d)
Sodium	mg/L	—	—	200	—	—
Sulphate	mg/L	—	—	500	250 ^(e,i)	22.7 ^(e,i)
Nutrients						
Total ammonia	mg N/L	—	2.7 to 139 ^(k)	—	—	—
Nitrate	mg N/L	124	2.9	10	—	0.57 ^(f,i)
Nitrite	mg N/L	—	0.06	1.0	—	—
Other Parameters						
Benzene	µg/L	—	370	5.0	—	—
Ethylbenzene	µg/L	—	90	2.4	—	—
Toluene	µg/L	—	2	24	—	—
Xylene	µg/L	—	—	300	—	—
Total Metals						
Aluminum	µg/L	—	5 or 100 ^(k)	100	—	—
Antimony	µg/L	—	—	6.0	—	—
Arsenic	µg/L	—	5	10	—	—
Barium	µg/L	—	—	1,000	—	—
Boron	µg/L	29,000	1,500	5,000	—	—
Cadmium	µg/L	0.11 to 7.7	0.04 to 0.37	5.0	—	—
Chromium	µg/L	—	1	50	—	—
Chromium (VI)	µg/L	—	1	—	—	—
Copper	µg/L	—	2 ^(k)	1,000	—	—
Iron	µg/L	—	300	300	—	—
Lead	µg/L	—	1 ^(k)	10	—	—
Manganese	µg/L	—	—	50	—	—
Mercury	µg/L	—	0.026	1.0	—	—
Molybdenum	µg/L	—	73	—	223,000 ^(g)	19,000 ^(g)
Nickel	µg/L	—	25 ^(k)	—	—	—

Table 2.8-1 Water Quality Guidelines and Site-Specific Water Quality Objectives Developed for Ekati Mine

Parameter	Unit	Guidelines			Ekati Mine Site-Specific Water Quality Objectives	
		Aquatic Life		Drinking Water ^(b)	Short Term ^(c,d,e,f,g,h)	Long Term ^(c,d,e,f,g,h)
		Acute ^(a)	Chronic ^(a)			
Selenium	µg/L	—	1	10	—	—
Silver	µg/L	—	0.1	—	—	—
Thallium	µg/L	—	0.8	—	—	—
Uranium	µg/L	33	15	20	—	—
Vanadium	µg/L	—	—	—	300 ^(h)	30 ^(h)
Zinc	µg/L	—	30	5,000	—	—

a) CCME (1999).

b) Health Canada (2012).

c) Elphick et al. (2011).

d) Rescan (2012b).

e) Rescan (2012c).

f) Rescan (2012d).

g) Rescan (2012e).

h) Rescan (2012f).

i) Guidelines based on hardness of 4.7 milligrams calcium carbonate per litre (mg CaCO₃/L).

j) Guidelines based on hardness of 10 mg CaCO₃/L.

k) Guidelines based on pH of 6.0 to 7.2, water temperature of 4.4 degrees Celsius (°C) to 20.4°C, and water hardness of 3.6 to 7.4 mg/L.

mg/L = milligrams per litre; mg N/L = milligrams nitrogen per litre; µg/L = micrograms per litre; — = no guideline.

Parameter concentrations above guideline or objective values during baseline investigations may be a result of naturally occurring conditions.

2.8.1.2 Seasonality

Seasonality is an important feature in lakes of northern Canada. During open-water conditions, runoff from snowmelt and precipitation (which is usually low in dissolved substances) decreases TDS in surface waters. The high flows generated by spring melt can result in scouring of river beds and banks, which in turn results in elevated concentrations of TSS and parameters associated with particulate matter (e.g., aluminum, iron, phosphorus). Mid- to late-summer water quality is usually characterized by low flow in rivers and streams. Depending on nutrient concentrations, algal growth can increase during the summer. Dissolved oxygen concentrations also decline in the summer because oxygen solubility decreases with increasing temperatures.

The open-water season in the Lac de Gras watershed can extend from June to October (Golder 2014); thus, during the majority of the year, the surfaces of the waterbodies are frozen and, in the case of the smaller lakes, may be isolated from one another. The build-up of ice on these lakes and streams can cause lakes to become isolated through freezing of channels to the bottom, and can lead to increased concentration of dissolved substances in the unfrozen water. During under-ice (winter) conditions, water quality is typically characterized by higher TDS compared to open-water conditions. Metals present in the water will not be completely incorporated into the ice, resulting in higher metals concentrations in the water column compared to the open-water season. Such *cryo-concentration* of solutes under ice-cover is a common observation in Arctic lakes (Pieters and Lawrence 2009; Golder 2012).

Within the baseline study area, samples were collected seasonally (three times during the open-water season) to understand temporal variability over the open-water period.

2.8.1.3 *Spatial Variability*

Spatial variability of typical water quality features in lakes within the baseline area originate from differences in position within the watershed, lake morphometry, the intensity of surface water and groundwater interactions, the amount of surface inflow and outflow from streams, and other factors. Seasonal effects also contribute to spatial differences, particularly in vertical distribution of water quality parameters (e.g., stratification effects).

Water quality of lakes in the baseline study area is strongly influenced by watershed geomorphology and drainage to streams and lakes from direct precipitation to the watershed during open-water and winter conditions. During open-water conditions, precipitation moves directly from the watershed to the streams and lakes via runoff, whereas snow and ice that accumulate over winter enter streams and lakes during the snowmelt period. Initial spring runoff occurs mostly as flow on top of the frozen ground, thus limiting the amount of dissolved and particulate substances that can enter a waterbody.

Locations for sampling stations were selected to gather information from all of the Lac du Sauvage internal sub-basins, several small lakes in the surrounding sub-basins, and the Lac du Sauvage inlet streams to understand spatial variability in water quality among these lakes and streams. Samples were collected from multiple stations within the larger lakes, and from various depths (i.e., Top, Mid, and Bottom) within the water column to investigate spatial variability within lakes.

2.8.1.4 *Light Attenuation*

Light measurements were expressed as a percentage of the surface irradiance value (%SI) and were calculated as follows:

Equation 2.8-1 Surface Irradiance Equation

$$\% SI = \left(\frac{I_d}{I_0} \right) \times 100$$

where:

%SI = surface irradiance as a percentage;
 I_d = irradiance ($\mu\text{mol photons/s/m}^2$) at depth d (metres); and,
 I_0 = irradiance ($\mu\text{mol photons/s/m}^2$) at the surface.

The vertical light attenuation coefficient (k_z) was also calculated to compare light attenuation through the water column at different stations and on different sampling occasions. Light attenuation was calculated using the transformed Beer-Lambert equation (Dodd and Whiles 2010) as follows:

Equation 2.8-2 Beer-Lambert Equation

$$K_d = - \frac{\ln \left(\frac{I_d}{I_0} \right)}{d}$$

where:

K_d = the attenuation coefficient (m^{-1});
 I_d = irradiance ($\mu\text{mol photons/s/m}^2$) at depth d (metres);
 I_0 = irradiance ($\mu\text{mol photons/s/m}^2$) at the surface; and,
 d = depth (metres).

2.8.1.5 Trophic Status

Trophic status in monitored lakes and streams was determined using: Vollenweider (1970) trophic classification scheme for lakes (using TP, TN, chlorophyll a , and Secchi depth); CCME (2004) trophic classification scheme for Canadian lakes and streams (using TP); and the TSI developed by Carlson (1977) (Section 2.7.1.6). The TSI is a numerical trophic state index for lakes that classifies lakes on a scale from 0 to 100 (Carlson 1977). The index number was generated as a rounded average from the TSI values calculated from Secchi depth, chlorophyll a , and TP measurements, using the following equations (Carlson 1977):

Equation 2.8-3 Trophic State Index Equations

$$TSI (TP) = 10 \left(6 - \frac{\ln \frac{48}{TP}}{\ln 2} \right)$$

$$TSI (Chl) = 10 \left(6 - \frac{2.04 - 0.68 \ln Chl}{\ln 2} \right)$$

$$TSI (Secchi) = 10 \left(6 - \frac{\ln SD}{\ln 2} \right)$$

where:

TSI = trophic state index;
TP = total phosphorus;
ln = natural logarithm;
Chl = chlorophyll *a*;
SD = standard deviation; and,
Secchi = Secchi depth.

The values are multiplied by 10 to give the scale a range of 0 to 100.

2.8.2 Sediment Quality

2.8.2.1 Comparison to Guidelines

Sediment chemistry was compared to the ISQGs and PEL guidelines for the protection of aquatic life (CCME 2001; Table 2.8-2). At concentrations below the ISQG adverse biological effects are not expected to occur. At concentrations above the ISQG adverse biological effects may occur. At concentrations above the PEL, adverse biological effects are likely, but not certain, to occur.

Table 2.8-2 Sediment Quality Guidelines

Parameter	Unit	Canadian Council of Ministers of the Environment Sediment Quality Guidelines ^(a)	
		Interim Sediment Quality Guidelines	Probable Effect Level
Total Metals			
Arsenic	mg/kg dw	5.9	17
Cadmium	mg/kg dw	0.6	3.5
Chromium	mg/kg dw	37.3	90
Copper	mg/kg dw	35.7	197
Lead	mg/kg dw	35	91.3
Mercury	mg/kg dw	0.17	0.486
Zinc	mg/kg dw	123	315

a) Source: CCME (2001).

mg/kg/dw = milligrams per kilogram dry weight.

2.8.2.2 *Spatial and Temporal Variability*

Sediment quality can vary spatially due to differences in lake and basin morphology, composition of bedrock, the intensity of surface and groundwater interactions, the amount of surface inflow and outflow from streams, as well as other factors. Sediment quality can also vary temporally, but because sedimentation rates in Arctic ecosystems are so low (e.g., Peramaki and Stone 2005), inter-annual variation in sediment quality is also expected to be low.

Sediment samples were collected at the majority of the water quality sampling locations, which were selected to gather information from all of the Lac du Sauvage internal sub-basins, several small lakes in the surrounding sub-basins, and all of the Lac du Sauvage inlet streams. Samples were also collected from multiple stations (deep and shallow) within the larger lakes, to investigate spatial variability within lakes.

2.9 Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) practices determine data integrity and are relevant to all aspects of a study, from sample collection to data analysis and reporting. Quality assurance (QA) encompasses management and technical practices designed to make sure that the data generated are of consistent high quality. Quality control (QC) is an aspect of QA and includes the procedures used to measure and evaluate data quality, and the corrective actions to be taken when data quality objectives are not met. The QA/QC practices that were applied during this study are described in more detail in Appendix B, Quality Assurance and Quality Control. An evaluation of the QC data, and a description of the implications of QC results to the interpretation of study results, are also provided in Appendix B. Brief summaries of the principal components of the QA/QC practices, and an assessment of overall data quality, are presented in this section.

2.9.1 Quality Assurance

Quality assurance encompasses management and technical practices designed so that the data generated are of consistent high quality, including appropriate training of sampling personnel, use of standard operating procedures when collecting samples, appropriate sample handling and storage, use of accredited analytical laboratories, and data management systems.

The field programs used the following QA procedures:

- following appropriate sampling and sample handling procedures;
- maintaining field equipment (e.g., Kemmerer water sampler, water quality multi-meters) by regular servicing;
- regularly calibrating field equipment, as appropriate, according to manufacturer's instructions;
- using appropriately trained staff to collect data;
- collecting required samples for the program;
- completing all paperwork including field data sheets and chain of custody forms;
- delivering samples to approved laboratories within the accepted hold time;

- using laboratories accredited by the Canadian Association for Laboratory Accreditation Inc.;
- maintaining clear communication records; and,
- following a defined data screening and validation procedure.

2.9.2 Quality Control

Quality control includes the procedures used to measure and evaluate data quality, and the corrective actions to be taken when data quality objectives are not met. The QC processes in this program involved:

- following procedures during the various field programs such as using alternate methods (e.g., the Winkler titration method for DO) to test the reliability of readings from field meters;
- checking the field measurements for evidence of unacceptable data and/or variation;
- checking field and trip blanks for evidence of contamination;
- checking field duplicate samples for evidence of unacceptable variation;
- checking field triplicate chlorophyll *a* samples for evidence of unacceptable collection and processing variation, and laboratory triplicate chlorophyll *a* samples for unacceptable analytical variation; and,
- checking laboratory QC data (i.e., sample temperature and integrity of containers upon receipt, review laboratory qualifiers, holding times, internal duplicates, ion balance, and % recovery of spiked analytes).

Five blank water samples, nine duplicate water samples, and four duplicate sediment samples (distributed among each sampling event) were collected.

2.9.3 Quality Assurance/Quality Control Results

The Project QA/QC program included: a review of field data; assessment of water quality blank samples, water and sediment quality duplicate samples, a comparison of dissolved and total parameter concentrations; and assessment of chlorophyll *a* triplicate samples.

Review of field physico-chemical data indicated that the field-measured pH data were unreliable. Different multi-meters were used throughout the sampling program because there were multiple crews in the field at the same time. Certain multi-meters did not function reliably (e.g., periodically reading pH and DO parameters at levels that were not plausible), despite successful calibrations and servicing of the field meters. The results suggested equipment (probe) malfunction; thus, the pH data were considered suspect using best professional judgement. Dissolved oxygen data that did not pass the quality control review are not included in this report.

Although appropriate steps were taken in the field to achieve the highest quality of field data possible, the field-measured pH data were considered unreliable and therefore were not included in the baseline report. Laboratory-measured pH was used as a surrogate measurement. However, the measurement of laboratory pH was completed outside of the holding time requirement. Therefore, the laboratory pH data are associated with certain level of uncertainty.

Samples for laboratory analyses were submitted as soon as possible after collection to maintain sample integrity. Analytical holding time (i.e., time between collection of the sample and start of the analyses) was met for all samples except for pH, certain nutrient parameters in the unpreserved samples (i.e., nitrate, nitrite, and orthophosphate), certain bacteria samples, and the turbidity samples. Exceedance of holding time for pH is due to the very short holding time (i.e., 15 minutes) and the exceedance of holding time for nutrients, bacteria, and turbidity was a function of the availability of scheduled charter flights; if the charter flight was available the day after sample collection, holding time was met.

The overall quality of the water and sediment quality data was determined to be high. Evaluation of the water and sediment quality QC samples indicated that, across the entire dataset, there were detectable parameters in 0.2% of the blank samples, 4.2% of the values differed by more than 20% between water quality duplicates, 4.7% of the values differed by more than 20% between sediment quality duplicates, and 0.2% of the values differed by more than 20% between dissolved and total water quality parameters.

The results of the evaluation of field and laboratory chlorophyll *a* triplicate samples indicated that there was an acceptable level of reproducibility in field data collection and the level of precision in the laboratory duplicates for the chlorophyll *a* data was high. Further details of the QC review are provided in Appendix B.

3 2013 LAKE WATER QUALITY RESULTS

This section of the report presents an evaluation of water quality data collected for lakes in the baseline study area. Detailed results are provided in the following appendices:

- field water column profile measurements (i.e., water temperature and DO) are provided in Appendix C, Field Profiles;
- light attenuation data are provided in Appendix D; and,
- field and laboratory water quality data are provided in Appendix E, Water Quality Data.

3.1 Lac du Sauvage

Sampling stations in Lac du Sauvage included seven deep (10 to 15 m deep) stations (Aa-1, Ab-1, Ac-1, Ac-4, Ac-7, Ad-1, and Ae-1) and seven shallow (3 to 5 m deep) stations (Aa-2, Ab-2, Ac-2, Ac-5, Ac-8, Ad-2, and Ae-2) (Map 2.4-1). Forty-five samples were collected from Lac du Sauvage during the 2013 baseline program, and 38 field physico-chemical water column profiles were recorded. Stations Ab-2, Ac-2, Ac-5, and Ac-8 were not sampled in the fall due to inclement weather.

3.1.1 Field-Measured Physico-Chemical Parameters

Summer thermal stratification within the water column was evident at all deep Lac du Sauvage stations, and was beginning at Stations Aa-1, Ad-1, and Ae-1 in the late spring (Appendix C, Figure C-1a and Figure C-2a). Certain stations that were stratified in early to mid-August when the water quality sampling was conducted had already turned over by the time the benthic invertebrate sampling crew sampled in late August.

Dissolved oxygen concentrations at the Lac du Sauvage stations were higher than the CWQG of 6.5 mg/L at all depths on all three open-water sampling events. The DO profiles showed no evidence of oxic stratification (Appendix C, Figure C-1b and Figure C-2b). Dissolved oxygen concentrations were lower in the summer than in the late spring and fall, but the waters were well oxygenated throughout the water column, with oxygen saturation ranging from 72% to 107% (Appendix E, Table E-1).

Field-measured specific conductivity was similar among the stations and sampling events with the exception of deep Lac du Sauvage stations in the fall. Specific conductivity was similar throughout the water column and generally ranged from 11 to 15 microSiemens per centimetre ($\mu\text{S}/\text{cm}$) (Appendix E, Table E-1). In the fall, several deep stations (i.e., Aa-1, Ab-1, Ac-1, Ac-4, Ac-7, and Ad-1) had higher specific conductivity of 23 to 24 $\mu\text{S}/\text{cm}$, which was consistent with depth.

3.1.2 Defining the Euphotic Zone

During the field program, Secchi depth was measured to provide an estimate of the euphotic zone for the purpose of collecting depth-integrated samples for nutrients and chlorophyll *a*. Secchi depths at the deep sampling stations in Lac du Sauvage ranged from 4.7 to 10.3 m (Appendix E, Table E-2).

The corresponding range of total depth at the Lac du Sauvage deep sampling stations was 10.8 to 14.0 m (Appendix E, Table E-2). Mean Secchi depth in Lac du Sauvage was higher in the summer sampling period (average = 8.8 m), intermediate in the fall sampling period (average = 6.6 m), and lowest in the late spring sampling period (average = 6.4 m). This trend suggests that the depth of the euphotic zone in Lac du Sauvage increased during the summer sampling period; these results are contrary to what has been observed in other northern lakes such as Lac de Gras (Golder 2011) and Snap Lake (De Beers 2013).

The euphotic zone is better defined from vertical light attenuation measurements, as compared to Secchi depth measurements, because light attenuation measurements can be used to determine the depth in the water column where 1% ambient light is achieved. Therefore, irradiance as PAR was measured to refine the extent of the euphotic zone, and to provide supporting information for the phytoplankton component.

The attenuation coefficient (K_d) was similar among all stations in Lac du Sauvage during late spring (Appendix D, Figure D-1), and ranged from 0.36 to 0.53. This range characterizes Lac du Sauvage as a clear water lake; the range of K_d values was similar to 44 clear water lakes in Alaska with a mean of 0.31 ± 0.12 (standard deviation [SD]) (Kirk 1994). On average, across the three sampling events, light attenuated more rapidly with depth at Station Ab-1 and least at Station Ac-4 (Table 3.1-1). The light profile data confirm the observations made with the Secchi depth data, that light penetrated deeper into the water column during the summer compared to the late spring and fall (i.e., the euphotic zone was deeper in summer).

Table 3.1-1 Attenuation Coefficients (K_d) at Deep Stations in Lac du Sauvage, 2013

Station	Sampling Event		
	Late Spring	Summer	Fall
Aa-1	0.40	0.44	0.53
Ab-1	0.45	0.36	0.49
Ac-1	0.41	0.36	0.46
Ac-4	0.42	0.36	0.43
Ac-7	0.43	0.38	0.48
Ad-1	0.49	0.39	0.32
Ae-1	0.46	0.36	0.41

3.1.3 Water Chemistry in Discrete Samples

Concentrations of conventional water quality parameters were similar among stations and sampling events (Table 3.1-2). The range of values for total alkalinity and total hardness indicated that Lac du Sauvage is a very soft water lake (Table 2.7-3), and has a high potential sensitivity to acid deposition (Table 2.7-1). The range of laboratory-measured pH values (pH 6.1 to 6.8, with a median of pH 6.4) indicated that the lake water may be slightly acidic². Most (69%) of the water samples had pH values that were below the CWQG and CDWQG lower bound of pH 6.5. Total dissolved solids ranged from less than 10 mg/L to 25 mg/L (median = 15 mg/L). Concentrations of TSS and turbidity were below the laboratory detection limit (DL).

Major ions concentrations were similar among stations and sampling events (Table 3.1-2). The dominant major ions were bicarbonate, calcium, and sulphate (Table 3.1-2). Detection limits and measured concentrations of major ions were below the associated guidelines and objectives.

Nutrient concentrations measured in the discrete water samples from Lac du Sauvage were similar among stations and sampling events (Table 3.1-2):

- Total ammonia concentrations ranged from less than 0.005 to 0.03 milligrams per litre as nitrogen (mg N/L) and were below the CWQG.
- Total Kjeldahl nitrogen concentrations ranged from less than 0.05 to 0.25 mg N/L.
- Nitrate and nitrite were not detected (DL of 0.006 mg N/L and 0.002 mg N/L, respectively).
- Concentrations of TP and TDP ranged from 0.0026 to 0.014 milligrams per litre as phosphorus (mg P/L) and from less than 0.001 to 0.004 mg P/L, respectively; dissolved orthophosphate concentrations were always below the laboratory DL (less than 0.001 mg/L).
- Concentrations of SRSi ranged from 0.091 to 0.15 mg/L.
- Organic carbon occurred primarily in the dissolved form, with DOC concentrations ranging from 2.6 to 6.3 mg/L.

Concentrations of total and dissolved metals were either below the DLs or below guidelines and objectives, with the exception of aluminum (Table 3.1-2). Total aluminum concentrations were above the chronic CWQG of 5 micrograms per litre (µg/L) in 28 samples (62%) where laboratory-measured pH values for the corresponding samples were less than pH 6.5. Total aluminum concentrations in these samples ranged from 2.2 to 40 µg/L. Dissolved aluminum concentrations ranged from less than 0.30 to 7.3 µg/L; thus, the dissolved fraction represented, on average, less than 50% of the total concentration.

² Measurement of laboratory pH was completed outside of the holding time requirement and thus are associated with a level of uncertainty, but are included in the dataset as a characterization of conditions in 2013. Due to probe malfunction, the field-measured pH values were deemed unreliable and were therefore not included in this report. Laboratory pH was used as a surrogate measure of field pH.



Concentrations of hydrocarbons (BTEX, total recoverable hydrocarbons, and petroleum hydrocarbons F1 (C₆-C₁₀), F1 (C₆-C₁₀)-BTEX, and F2 (C₁₀-C₁₆) fractions were not detected in any sample (Appendix E, Table E-2). Fecal coliform concentrations were also below the laboratory DL (less than 1 coliform forming units per 100 millilitres [CFU/100 mL]; Appendix E, Table E-2).

Table 3.1-2 Water Quality in Lac du Sauvage, 2013

Parameter	Unit	Guidelines			Objectives		Count	Measured Range	Median
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO			
Conventional Parameters									
Total alkalinity	mg/L	—	—	—	—	—	45	3.7 to 5.4	4.1
Specific Conductivity	µS/cm	—	—	—	—	—	45	13 to 16	14
Hardness	mg/L	—	—	—	—	—	45	4.4 to 5.0	4.7
pH	-	—	6.5 to 9.0	6.5 to 8.5	—	—	45	6.1 to 6.8	6.4
Total dissolved solids	mg/L	—	—	500	—	—	43	<10 to 25	15
Total suspended solids	mg/L	—	—	—	—	—	45	<3.0	<3.0
Turbidity	NTU	—	—	—	—	—	45	0.30 to 0.86	0.50
Major Ions									
Bicarbonate	mg/L	—	—	—	—	—	45	<5.0 to 6.6	<5
Calcium	mg/L	—	—	—	—	—	45	0.77 to 0.94	0.86
Chloride	mg/L	640	120	250	—	64.5	45	<0.50 to 0.63	<0.50
Fluoride	mg/L	—	0.12	1.5	—	—	45	<0.020 to 0.027	<0.02
Magnesium	mg/L	—	—	—	—	—	45	0.57 to 0.65	0.62
Potassium	mg/L	—	—	—	112	41	45	0.48 to 0.65	0.53
Sodium	mg/L	—	—	200	—	—	45	0.54 to 0.71	0.60
Sulphate	mg/L	—	—	500	250	22.7	45	1.0 to 1.7	1.2
Nutrients									
Total organic carbon	mg/L	—	—	—	—	—	44	2.7 to 3.8	3.4
Dissolved organic carbon	mg/L	—	—	—	—	—	44	2.6 to 6.3	3.4
Total Kjeldahl Nitrogen	mg N/L	—	—	—	—	—	45	<0.05 to 0.25	0.13
Total ammonia	mg N/L	—	2.7 to 139	—	—	—	45	<0.005 to 0.030	0.0092
Nitrate	mg N/L	124	2.9	10	—	0.57	45	<0.006	<0.006
Nitrite	mg N/L	—	0.06	1	—	—	45	<0.002	<0.002

Table 3.1-2 Water Quality in Lac du Sauvage, 2013

Parameter	Unit	Guidelines			Objectives		Count	Measured Range	Median
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO			
Nutrients (Continued)									
Total phosphorus	mg P/L	—	—	—	—	—	45	0.0026 to 0.014	0.0059
Total dissolved phosphorus	mg P/L	—	—	—	—	—	45	<0.001 to 0.004	0.0021
Dissolved orthophosphate	mg/L	—	—	—	—	—	41	<0.001 to <0.010	<0.001
Silica, reactive	mg/L	—	—	—	—	—	44	0.091 to 0.15	0.11
Total Metals									
Aluminum	µg/L	—	5 or 100	100	—	—	45	2.2 to 40	7.1
Antimony	µg/L	—	—	6	—	—	45	<0.02	<0.02
Arsenic	µg/L	—	5	10	—	—	45	0.14 to 1.2	0.31
Barium	µg/L	—	—	1,000	—	—	45	0.44 to 2.3	1.1
Beryllium	µg/L	—	—	—	—	—	45	<0.01	<0.01
Bismuth	µg/L	—	—	—	—	—	45	<0.01	<0.01
Boron	µg/L	29,000	1,500	5,000	—	—	45	1.9 to 4.8	2.9
Cadmium	µg/L	0.11	0.04	5	—	—	45	<0.005	<0.005
Cesium	µg/L	—	—	—	—	—	45	<0.1	<0.1
Chromium	µg/L	—	1	50	—	—	45	<0.06 to 0.15	<0.06
Cobalt	µg/L	—	—	—	—	—	45	<0.01 to 0.053	0.015
Copper	µg/L	—	2	1,000	—	—	45	0.24 to 0.76	0.58
Iron	µg/L	—	300	300	—	—	45	4.8 to 267	13
Lead	µg/L	—	1	10	—	—	45	<0.01 to 0.032	<0.01
Lithium	µg/L	—	—	—	—	—	45	<0.5 to 1.3	1.2
Manganese	µg/L	—	—	50	—	—	45	0.99 to 15	3.6
Mercury	µg/L	—	0.026	1	—	—	45	<0.0005 to 0.005	<0.0005
Molybdenum	µg/L	—	73	—	223,000	19,000	45	<0.05	<0.05
Nickel	µg/L	—	25	—	—	—	45	0.12 to 0.36	0.30

Table 3.1-2 Water Quality in Lac du Sauvage, 2013

Parameter	Unit	Guidelines			Objectives		Count	Measured Range	Median
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO			
Total Metals (Continued)									
Selenium	µg/L	—	1	10	—	—	45	<0.04	<0.04
Silver	µg/L	—	0.1	—	—	—	45	<0.005	<0.005
Strontium	µg/L	—	—	—	—	—	45	4.8 to 5.7	5.3
Thallium	µg/L	—	0.8	—	—	—	45	<0.01	<0.01
Tin	µg/L	—	—	—	—	—	45	<0.05	<0.05
Titanium	µg/L	—	—	—	—	—	45	<0.1 to 3.2	0.32
Uranium	µg/L	33	15	20	—	—	45	0.016 to 0.026	0.022
Vanadium	µg/L	—	—	—	300	30	45	<0.05 to 0.15	<0.05
Zinc	µg/L	—	30	5,000	—	—	45	<0.8 to 2.9	<0.8

Notes: **Bolded** concentrations are higher than relevant water quality guidelines or objectives; for pH, **bolded** values are outside the guideline range.

CWQG = Canadian Council of Ministers of Environment (CCME) water quality guidelines for the protection of aquatic life (CCME 1999); CDWQG = Canadian Drinking Water Quality Guideline (Health Canada 2012); SSWQO = site-specific water quality objectives (Elphick et al. 2011; Rescan, 2012b,c,d,e,f).

mg/L = milligrams per litre; “—” = no guideline or objective; µS/cm = microSiemens per centimetre; < = less than; NTU = nephelometric turbidity units; mg N/L = milligrams nitrogen per litre; mg P/L = milligrams phosphorus per litre; µg/L = micrograms per litre.

3.1.4 Nutrients and Chlorophyll *a* in Depth-Integrated Samples

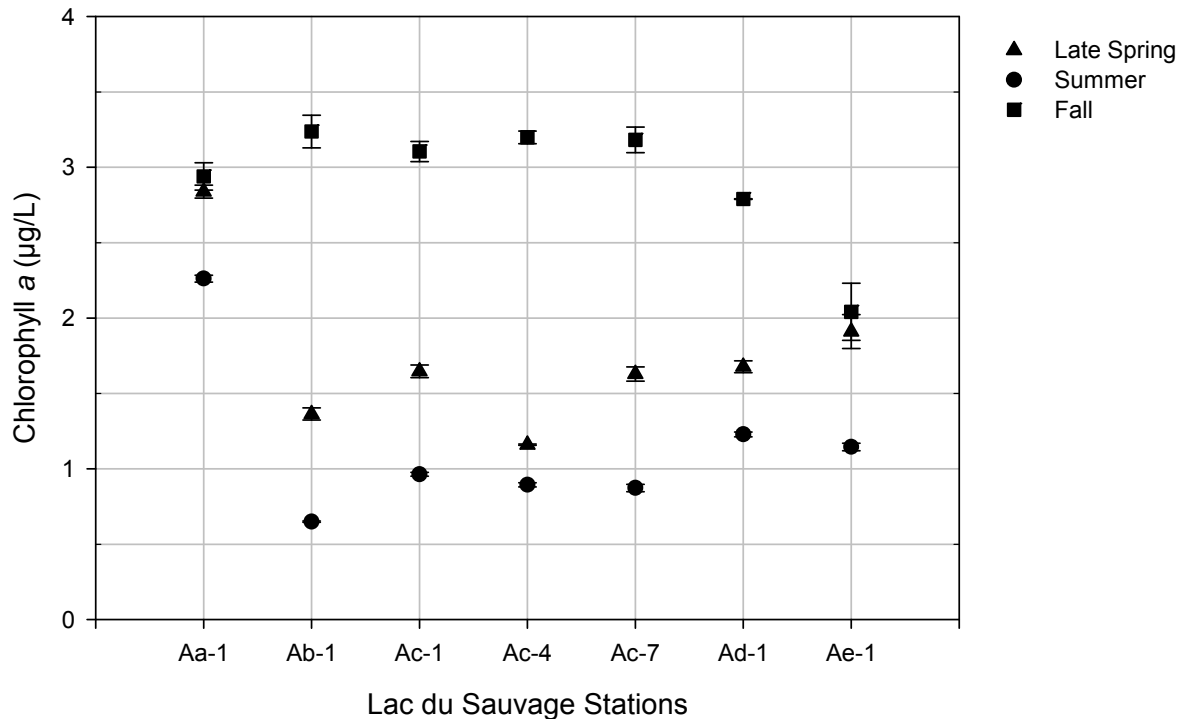
The summer TP concentrations in the depth-integrated samples from Lac du Sauvage were higher than those in the discrete samples (top and mid samples).

This observation is based on a limited number of samples. However, monitoring programs at other northern mines have observed similar differences in nutrient concentrations between discrete and depth-integrated samples (e.g., Snap Lake Diamond Mine, De Beers 2013; Diavik Mine, Golder 2011). Concentrations of TP ranged from 0.006 to 0.010 mg P/L (median = 0.008 mg P/L) in the depth-integrated samples (Appendix E, Table E-15) compared to 0.003 to 0.007 mg P/L (median = 0.004 mg P/L) in the corresponding discrete samples. Total nitrogen was not measured in the depth-integrated samples from Lac du Sauvage.

In contrast, SRSi concentrations were generally lower in the depth-integrated samples than in the discrete samples from Lac du Sauvage. Concentrations of SRSi ranged from 0.03 to 0.12 mg/L (median = 0.04 mg/L) in the depth-integrated samples (Appendix E, Table E-15) compared to 0.11 to 0.14 mg/L (median = 0.12 mg/L) in the discrete samples in the summer (top and mid samples; Appendix E, Table E-2). Most of the SRSi concentrations in the depth-integrated samples were less than 0.1 mg/L, which suggests that silica may be limiting for diatom growth (Reynolds 2006).

Chlorophyll *a* concentrations in Lac du Sauvage ranged from a minimum of 0.65 µg/L at Station Ab-1 during the summer sampling event to a maximum of 3.24 µg/L at Station Ab-1 during the fall sampling event (Figure 3.1-1; Appendix E, Table D-16). Overall, chlorophyll *a* concentrations were higher during the fall sampling period, ranging from 2.04 to 3.24 µg/L (mean = 2.93 µg/L), compared to the late spring (1.17 to 2.84 µg/L; mean = 1.75 µg/L) or summer (0.65 to 2.26 µg/L; mean = 1.15 µg/L) sampling periods. Based on measured chlorophyll *a* concentrations, peak phytoplankton biomass occurred during the fall sampling period at most stations in Lac du Sauvage.

Figure 3.1-1 Mean Chlorophyll a Concentrations at Deep Stations in Lac du Sauvage in Late Spring, Summer, and Fall, 2013



Note: Error bars = standard error.
µg/L = micrograms per litre.

3.1.5 Trophic Status Classification

Trophic status was evaluated by examining the concentrations of TP, chlorophyll a, and water transparency (Secchi depth) (Section 2.8.1.5). The discrete water sampling program for Lac du Sauvage yielded mean annual concentrations of 0.0057 mg P/L for TP and 6.5 m for Secchi depth. The corresponding TSI values were 29.3 using TP and 33 using Secchi depth, for a rounded average of 31. The depth-integrated sampling program yielded mean annual concentrations of 0.0080 mg P/L for TP, 7.3 m for Secchi depth, and 1.94 µg/L for chlorophyll a. The corresponding TSI values were 37.1 using chlorophyll a, 33.6 using TP, and 31.3 using Secchi depth, for a rounded average of 34. Based on these values, and the classification systems of Vollenweider (1970), CCME (2004), and Carlson (1977), Lac du Sauvage is classified as an oligotrophic lake.

3.2 Duchess Lake

Sampling stations in Duchess Lake included two deep (10 to 15 m deep) stations (Af-1 and Af-7) and two shallow (3 to 5 m deep) stations (Af-2 and Af-4) (Map 2.4-1). Eleven samples were collected and 10 field water column profile measurements were recorded from Duchess Lake during the 2013 baseline program. Stations Af-2 and Af-4 were not sampled in the fall due to inclement weather.

3.2.1 Field-Measured Physico-Chemical Parameters

Temperature profile measurements of the water column showed that Duchess Lake deep stations were weakly stratified in the late spring, with stronger thermal stratification evident during the summer (Appendix C, Figure C-3a and Figure C-4a). Stations that were stratified in early to mid-August had already turned over by the time they were sampled in late August.

Dissolved oxygen (DO) concentrations at the Duchess Lake stations were higher than the CWQG of 6.5 mg/L at all depths in the late spring and summer sampling events; DO data were unavailable for the fall (Appendix C, Figure C-3b and Figure C-4b). The DO profiles in the deep stations were uniform with depth in late spring, and varied with depth in the summer such that DO concentrations declined from approximately 10.5 mg/L at 6 m to a low of 8.4 mg/L. Dissolved oxygen concentrations were lower in the summer than in the late spring, but the waters were well oxygenated throughout the water column, with saturation ranging from 80% to 108% (Appendix E, Table E-3).

Field-measured specific conductivity was similar among the stations and sampling events with the exception of deep stations in the fall. Specific conductivity was similar throughout the water column and generally ranged from 10 to 13 $\mu\text{S}/\text{cm}$ (Appendix E, Table E-3). In the fall, the deep stations (i.e., Af-1 and Af-7) had higher specific conductivity values of 20 $\mu\text{S}/\text{cm}$, which was consistent with depth.

3.2.2 Defining the Euphotic Zone

Secchi depths at the deep stations in Duchess Lake ranged from 3.6 to 6.0 m (Appendix E, Table E-3). Total depth at the deep stations ranged from 11.0 to 14.0 m (Appendix E, Table E-4). Secchi depth was similar between stations and among sampling events (3.6 to 4.8 m), except for Station Af-1 in the summer, where the Secchi depth was 6.0 m.

Vertical light attenuation through the water column was similar among all stations in Duchess Lake during late spring and summer, indicating a uniform light regime (Appendix D, Figure D-2). Light attenuation coefficients (ranging from 0.35 to 0.50) characterize Duchess Lake as a clear water lake. Light attenuated less rapidly into the water column during the fall, in contrast to Lac du Sauvage, where the deeper euphotic depth was measured in summer (Table 3.2-1).

Table 3.2-1 Attenuation Coefficients (K_d) at Lake Bottom at Deep Stations in Duchess Lake, 2013

Station	Sampling Event		
	Late Spring	Summer	Fall
Af-1	0.50	0.50	0.44
Af-7	0.50	0.48	0.35

3.2.3 Water Chemistry in Discrete Samples

Concentrations of conventional water quality parameters were similar among stations and sampling events (Table 3.2-2). The range of values for total alkalinity and total hardness indicated that Duchess Lake has a high sensitivity to acid deposition (Table 2.7-1) and is a very soft-water lake (Table 2.7-3). The range of laboratory-measured pH values (pH 6.2 to 6.8, with a median of pH 6.4), in lieu of available field pH data, indicated that the lake water may be slightly acidic. Most water samples (8 of the 11) had laboratory pH values that were below the CWQG and CDWQG lower limits of pH 6.5. Total dissolved solids ranged from 11 to 25 mg/L (median = 19 mg/L). The concentrations of TSS ranged from below the laboratory DL (less than 3 mg/L) to 6 mg/L, and turbidity was less than 1 NTU.

Major ions concentrations were similar among stations and sampling events (Table 3.2-2). The dominant major ions were magnesium, sodium, and sulphate (Table 3.2-2). Detection limits and measured concentrations of major ions were below associated guidelines and objectives.

Nutrient concentrations measured in the discrete water samples from Duchess Lake were similar among stations and sampling events (Table 3.2-2):

- Total ammonia concentrations ranged from 0.0067 to 0.017 mg N/L and were below the CWQG.
- Total Kjeldahl nitrogen concentrations ranged from 0.080 to 0.25 mg N/L.
- Nitrate and nitrite were not detected.
- Concentrations of TP and TDP ranged from 0.0065 to 0.013 mg P/L and from 0.0017 to 0.0041 mg P/L, respectively; dissolved orthophosphate concentrations were always below the laboratory DL.
- Concentrations of SRSi ranged from 0.12 to 0.21 mg/L.
- Organic carbon occurred primarily in the dissolved form, with DOC concentrations ranging from 3.5 to 4.3 mg/L.

Concentrations of total and dissolved metals were either below DLs or below guidelines and objectives, with the exception of aluminum (Table 3.2-2). Total aluminum concentrations were above the chronic CWQG in eight samples (the same samples with laboratory-measured pH value of less than 6.5). The guideline for aluminum is determined by pH value of a sample; if pH is less than 6.5, the aluminum guideline is 5 µg/L; if the pH value is equal to or greater than 6.5, the aluminum guideline is 100 µg/L.

Concentrations of BTEX, petroleum hydrocarbons F1 (C₆-C₁₀), F1 (C₆-C₁₀)-BTEX, and F2 (C₁₀-C₁₆) fractions, and fecal coliforms were not detected in any samples (Appendix E, Table E-4). Total recoverable hydrocarbons ranged from less than 1 to 1.4 mg/L (median = less than 1 mg/L).

Table 3.2-2 Water Quality in Duchess Lake, 2013

Parameter	Unit	Guidelines			Objectives		Range			
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO	Count	Deep Stations	Shallow Stations	Median
Conventional Parameters										
Total alkalinity	mg/L	—	—	—	—	—	11	3.1 to 4.1	3.3 to 3.5	3.3
Specific conductivity	µS/cm	—	—	—	—	—	11	12 to 15	12 to 13	12
Hardness	mg/L	—	—	—	—	—	11	3.7 to 4.1	3.7 to 4.1	3.7
pH	—	—	6.5 to 9.0	6.5 to 8.5	—	—	11	6.2 to 6.8	6.3 to 6.4	6.4
Total dissolved solids	mg/L	—	—	500	—	—	11	11 to 25	15 to 21	19
Total suspended solids	mg/L	—	—	—	—	—	11	<3.0 to 6.0	<3.0 to 3.0	<3.0
Turbidity	NTU	—	—	—	—	—	11	0.7 to 1.0	0.62 to 0.93	0.79
Major Ions										
Bicarbonate	mg/L	—	—	—	—	—	11	<5.0 to 5.1	<5.0	<5.0
Calcium	mg/L	—	—	—	—	—	11	0.64 to 0.74	0.67 to 0.72	0.68
Chloride	mg/L	640	120	250	—	64.5	11	<0.5	<0.5	<0.5
Fluoride	mg/L	—	0.12	1.5	—	—	11	<0.02	<0.02	<0.02
Magnesium	mg/L	—	—	—	—	—	11	0.49 to 0.55	0.49 to 0.55	0.5
Potassium	mg/L	—	—	—	112	41	11	0.42 to 0.49	0.42 to 0.47	0.45
Sodium	mg/L	—	—	200	—	—	11	0.531 to 0.64	0.52 to 0.62	0.59
Sulphate	mg/L	—	—	500	250	22.7	11	0.34 to 0.91	0.86 to 1.00	0.86
Nutrients										
Total organic carbon	mg/L	—	—	—	—	—	11	3.2 to 4.1	2.9 to 4.2	3.9
Dissolved organic carbon	mg/L	—	—	—	—	—	11	3.7 to 4.3	3.5 to 4.2	4.1
Total Kjeldahl Nitrogen	mg N/L	—	—	—	—	—	11	0.091 to 0.25	0.080 to 0.24	0.2
Total ammonia	mg N/L	—	2.7 to 139	—	—	—	11	0.009 to 0.017	0.0067 to 0.014	0.014
Nitrate	mg N/L	124	2.9	10		0.57	11	<0.006	<0.006	<0.006
Nitrite	mg N/L	—	0.06	1	—	—	11	<0.002	<0.002	<0.002

Table 3.2-2 Water Quality in Duchess Lake, 2013

Parameter	Unit	Guidelines			Objectives		Range			
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO	Count	Deep Stations	Shallow Stations	Median
Nutrients (Continued)										
Total phosphorus	mg P/L	—	—	—	—	—	11	0.0075 to 0.013	0.0065 to 0.0090	0.0088
Total dissolved phosphorus	mg P/L	—	—	—	—	—	11	0.002 to 0.0041	0.0017 to 0.0033	0.0029
Dissolved orthophosphate	mg/L	—	—	—	—	—	11	<0.001	<0.001	<0.001
Silica, reactive	mg/L	—	—	—	—	—	11	0.15 to 0.21	0.12 to 0.16	0.16
Total Metals										
Aluminum	µg/L	—	5 or 100	100	—	—	11	7.2 to 17	10 to 27 ^(a)	10
Antimony	µg/L	—	—	6	—	—	11	<0.02	<0.02	<0.02
Arsenic	µg/L	—	5	10	—	—	11	0.49 to 0.56	0.34 to 0.51	0.5
Barium	µg/L	—	—	1,000	—	—	11	1.8 to 2.1	1.7 to 2.1	1.9
Boron	µg/L	29,000	1,500	5,000	—	—	11	2.2 to 5.1	1.8 to 2.8	2.8
Cadmium	µg/L	0.11	0.04	5	—	—	11	<0.005 to 0.0063	<0.005 to <0.005	<0.005
Chromium	µg/L	—	1	50	—	—	11	0.075 to 0.075	<0.06 to 0.13	<0.06
Cobalt	µg/L	—	—	—	—	—	11	0.027 to 0.034	0.025 to 0.037	0.031
Copper	µg/L	—	2	1,000	—	—	11	0.57 to 0.78	0.54 to 1.2	0.65
Iron	µg/L	—	300	300	—	—	11	36 to 61	33 to 61	41
Lead	µg/L	—	1	10	—	—	11	<0.01 to 0.022	<0.01 to 0.016	<0.01
Manganese	µg/L	—	—	50	—	—	11	3.6 to 5.1	2.9 to 5.1	3.9
Mercury	µg/L	—	0.026	1	—	—	11	<0.0005 to 0.005	<0.0005 to 0.00062	0.00053
Molybdenum	µg/L	—	73	—	223,000	19,000	11	<0.05	<0.05	<0.05
Nickel	µg/L	—	25	—	—	—	11	0.29 to 0.35	0.25 to 0.35	0.3
Selenium	µg/L	—	1	10	—	—	11	<0.04	<0.04	<0.04
Silver	µg/L	—	0.1	—	—	—	11	<0.005	<0.005	0.0025
Strontium	µg/L	—	—	—	—	—	11	4.5 to 4.8	4.5 to 4.8	4.6
Thallium	µg/L	—	0.8	—	—	—	11	<0.01	<0.01	<0.01

Table 3.2-2 Water Quality in Duchess Lake, 2013

Parameter	Unit	Guidelines			Objectives		Range			
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO	Count	Deep Stations	Shallow Stations	Median
Total Metals (Continued)										
Uranium	µg/L	33	15	20	—	—	11	0.032 to 0.038	0.025 to 0.037	0.034
Vanadium	µg/L	—	—	—	300	30	11	<0.05 to 0.065	<0.05 to 0.075	<0.05
Zinc	µg/L	—	30	5,000	—	—	11	<0.8 to 4.1	<0.8 to 1.1	<0.8

Note: **Bolded** concentrations are higher than water quality guidelines or objectives.

a) Exceedances of aluminum CWQG occurred in samples with laboratory-measured pH value of <6.5.

CWQG = Canada Council of Ministers of the Environment (CCME) water quality guidelines for the protection of aquatic life (CCME 1999); CDWQG = Canadian Drinking Water Quality Guideline (Health Canada 2012); SSWQO = site-specific water quality objectives (Elphick et al. 2011; Rescan, 2012a,b,c,d,e).

mg/L = milligrams per litre; — = no guideline or objective; µS/cm = microSiemens per centimetre; < = less than; NTU = nephelometric turbidity units; mg N/L = milligrams nitrogen per litre; mg P/L = milligrams phosphorus per litre; µg/L = micrograms per litre.

3.2.4 Nutrients and Chlorophyll *a* in Depth-Integrated Samples

In the fall, concentrations of SRSi in discrete samples (mid depth) and depth-integrated samples from Duchess Lake were similar across all samples. Concentrations of TP were similar at Af-7 for discrete and depth-integrated samples, but at Af-1 the concentration of TP was higher in the depth-integrated sample (0.044 mg P/L) than the discrete sample (0.011 mg P/L) (Appendix E, Table E-4 and Table E-15). The median SRSi concentration was 0.15 mg/L in all samples, which is higher than the threshold of 0.1 mg/L that would be limiting for diatom growth (Reynolds 2006). Due to an analytical laboratory error, total nitrogen was not analyzed in the depth-integrated samples from Duchess Lake.

Chlorophyll *a* concentrations in Duchess Lake ranged from a minimum of 2.54 µg/L at Station Af-1 during the summer sampling event to a maximum of 5.21 µg/L at Station Af-7 during the fall sampling event (Table 3.2-3). Overall, chlorophyll *a* concentrations were higher in the fall. Based on measured chlorophyll *a* concentrations, peak phytoplankton biomass occurred during the fall sampling period at all sampled stations in Duchess Lake.

Table 3.2-3 Summary of Chlorophyll *a* at Duchess Lake, 2013

Sampling Event	Chlorophyll <i>a</i> (µg/L)	
	Station Af-1	Station Af-7
Late Spring	3.04 ± 0.11	2.80 ± 0.06
Summer	2.54 ± 0.09	3.59 ± 0.15
Fall	5.12 ± 0.08	5.21 ± 0.03

Note: Concentrations are mean ± standard error.

µg/L= micrograms per litre; ± = plus or minus.

3.2.5 Trophic Status Classification

The discrete water sampling program for Duchess Lake yielded mean annual concentrations of 0.0091 mg P/L for TP and 4.2 m for Secchi depth. The corresponding TSI values were 36 using TP and 39.3 using Secchi depth, for a rounded average of 38. The depth-integrated sampling program yielded mean annual concentrations of 0.027 mg P/L for TP, 4.1 m for Secchi depth, and 3.72 µg/L for chlorophyll *a*. The corresponding TSI values were 51.7 using chlorophyll *a*, 39.6 using TP, and 43.5 using Secchi depth, for a rounded average of 45. Based on the concentrations of nutrients and chlorophyll *a*, Duchess Lake is classified as oligotrophic to mesotrophic using Vollenweider (1970) and mesotrophic using CCME (2004). Based on the TSI values of Carlson (1977), Duchess Lake is classified as mesotrophic.

3.3 Lake Af1

Sampling stations in Lake Af1 were one deep (10 to 15 m deep) station (Af-10), and no shallow stations (Map 2.4-1). Four samples were collected and three field profile measurements were recorded from Lake Af1 during the 2013 baseline program.

3.3.1 Field-Measured Physico-Chemical Parameters

Thermal stratification was evident in the summer at Station Af-10, but the water column was well mixed in the late spring and fall (Appendix C, Figure C-5a).

Dissolved oxygen concentrations at Station Af-10 were uniform with depth during the late spring and fall sampling events, but declined with depth during the summer event (Appendix C, Figure C-5b), from 9.7 mg/L at 5 m to 1.1 mg/L at 8 m (just above the sediments). Summer DO concentrations were below the CWQG of 6.5 mg/L at depths between 6 and 8 m. In the late spring and fall, and in the surface 5 m in the summer, DO saturation ranged from 90% to 104% (Appendix E, Table E-5). Below 5 m in the summer, DO saturation declined from 60% at 6 m to 6% at 8 m.

Field-measured specific conductivity was slightly lower in the fall at 8.4 to 8.5 $\mu\text{S}/\text{cm}$, compared to 10 to 13 $\mu\text{S}/\text{cm}$ in the late spring and summer (Appendix E, Table E-5). Specific conductivity was consistent throughout the water column, although the highest conductivity value was measured near lake bottom during the summer (13 $\mu\text{S}/\text{cm}$; rest of water column was 10 to 11 $\mu\text{S}/\text{cm}$).

3.3.2 Defining the Euphotic Zone

Secchi depth at Station Af-10 ranged from 1.8 to 2.6 m (Appendix E, Table E-6). The deepest Secchi depth was measured in late spring (2.6 m), with similar depths measured in summer and fall (i.e., 1.8 m and 2.0 m, respectively). Total depth at Station Af-10 ranged from 8.2 to 8.5 m (Appendix E, Table E-6).

Vertical light attenuation through the water column was similar in Lake Af1 during late spring and summer, indicating a uniform light regime (Appendix D, Figure D-3). Light attenuation coefficients determined for Lake Af1 indicate a clear water lake, with slightly more attenuation in the water column than Lac du Sauvage and Duchess Lake. Light penetrated deeper into the water column during the late spring ($K_d = 0.71$) and fall ($K_d = 0.74$), compared to summer ($K_d = 0.83$).

3.3.3 Water Chemistry in Discrete Samples

Concentrations of conventional water quality parameters were similar among sampling events (Table 3.3-1). The range of values for total alkalinity and total hardness indicated that Lake Af1 has a high sensitivity to acid deposition (Table 2.7-1) and is a very soft-water lake (Table 2.7-3). The range of laboratory-measured pH values (pH 6.0 to 6.4, with a median of pH 6.3) indicated that the lake water is slightly acidic. All water samples had pH values that were below the CWQG and CDWQG lower limits of pH 6.5. Total dissolved solids ranged from 11 to 26 mg/L (median = 15 mg/L). The concentrations of TSS ranged from below the laboratory DL (less than 3 mg/L) to 4 mg/L, and turbidity ranged from 1.3 to 2.7 NTU.

Table 3.3-1 Water Quality in Lake Af1, 2013

Parameter	Unit	Guidelines			Objectives		Count	Range	Median
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO			
Conventional Parameters									
Total alkalinity	mg/L	—	—	—	—	—	4	3.0 to 3.5	3.1
Specific conductivity	µS/cm	—	—	—	—	—	4	11 to 13	12
Hardness	mg/L	—	—	—	—	—	4	3.7 to 3.8	3.8
pH	—	—	6.5 to 9.0	6.5 to 8.5	—	—	4	6.0 to 6.4	6.3
Total dissolved solids	mg/L	—	—	500	—	—	4	11 to 26	15
Total suspended solids	mg/L	—	—	—	—	—	4	<3.0 to 4.0	2.3
Turbidity	NTU	—	—	—	—	—	4	1.3 to 2.7	1.8
Major Ions									
Bicarbonate	mg/L	—	—	—	—	—	4	<5	<5
Calcium	mg/L	—	—	—	—	—	4	0.65 to 0.68	0.68
Chloride	mg/L	640	120	250	—	64.5	4	<0.5	<0.5
Fluoride	mg/L	—	0.12	1.5	—	—	4	<0.02	<0.02
Magnesium	mg/L	—	—	—	—	—	4	0.51 to 0.52	0.52
Potassium	mg/L	—	—	—	112	41	4	0.43 to 0.47	0.44
Sodium	mg/L	—	—	200	—	—	4	0.58 to 0.94	0.72
Sulphate	mg/L	—	—	500	250	22.7	4	0.85 to 1	0.95
Nutrients									
Total organic carbon	mg/L	—	—	—	—	—	4	4.2 to 6.3	5.2
Dissolved organic carbon	mg/L	—	—	—	—	—	4	4.6 to 5.8	5.2
Total Kjeldahl Nitrogen	mg N/L	—	—	—	—	—	4	0.25 to 0.48	0.32
Total ammonia	mg N/L	—	2.7 to 139	—	—	—	4	<0.005 to 0.013	0.0078
Nitrate	mg N/L	124	2.9	10	—	0.57	4	<0.006 to <0.006	<0.006
Nitrite	mg N/L	—	0.06	1	—	—	4	<0.002 to <0.002	<0.002

Table 3.3-1 Water Quality in Lake Af1, 2013

Parameter	Unit	Guidelines			Objectives		Count	Range	Median
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO			
Nutrients (Continued)									
Total phosphorus	mg P/L	—	—	—	—	—	4	0.016 to 0.024	0.02
Total dissolved phosphorus	mg P/L	—	—	—	—	—	4	0.0017 to 0.0048	0.0028
Dissolved orthophosphate	mg/L	—	—	—	—	—	4	<0.001 to <0.001	<0.001
Silica, reactive	mg/L	—	—	—	—	—	4	0.12 to 0.31	0.19
Total Metals									
Aluminum	µg/L	—	5 or 100	100	—	—	4	22 to 60 ^(a)	31
Antimony	µg/L	—	—	6	—	—	4	<0.02 to 0.14	0.09
Arsenic	µg/L	—	5	10	—	—	4	0.48 to 0.67	0.59
Barium	µg/L	—	—	1,000	—	—	4	2.3 to 2.9	2.4
Beryllium	µg/L	—	—	—	—	—	4	<0.01 to <0.01	<0.01
Bismuth	µg/L	—	—	—	—	—	4	<0.01 to <0.05	<0.05
Boron	µg/L	29,000	1,500	5,000	—	—	4	2.6 to <10	<10
Cadmium	µg/L	0.11	0.04	5	—	—	4	<0.005 to 0.013	<0.01
Cesium	µg/L	—	—	—	—	—	3	<0.1 to <0.1	<0.1
Chromium	µg/L	—	1	50	—	—	4	0.084 to 0.26	0.15
Cobalt	µg/L	—	—	—	—	—	3	0.072 to 0.14	0.14
Copper	µg/L	—	2	1,000	—	—	4	1 to 1.4	1.4
Iron	µg/L	—	300	300	—	—	4	113 to 241	170
Lead	µg/L	—	1	10	—	—	4	0.02 to 0.053	<0.05
Lithium	µg/L	—	—	—	—	—	4	1.4 to 2.5	2.5
Manganese	µg/L	—	—	50	—	—	4	6.3 to 19	13
Mercury	µg/L	—	0.026	1	—	—	4	0.0006 to 0.01	0.00065
Molybdenum	µg/L	—	73	—	223,000	19,000	4	<0.05 to 0.063	0.058
Nickel	µg/L	—	25	—	—	—	4	0.58 to 0.76	0.71

Table 3.3-1 Water Quality in Lake Af1, 2013

Parameter	Unit	Guidelines			Objectives		Count	Range	Median
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO			
Total Metals (Continued)									
Selenium	µg/L	—	1	10	—	—	4	<0.04 to <0.1	<0.1
Silver	µg/L	—	0.1	—	—	—	4	<0.005 to <0.01	<0.01
Strontium	µg/L	—	—	—	—	—	4	4.6 to 5.7	5.3
Thallium	µg/L	—	0.8	—	—	—	4	<0.01 to <0.05	<0.05
Tin	µg/L	—	—	—	—	—	4	<0.05 to <0.1	<0.1
Titanium	µg/L	—	—	—	—	—	4	0.89 to 2.5	1.0
Uranium	µg/L	33	15	20	—	—	4	0.074 to 0.085	0.082
Vanadium	µg/L	—	—	—	300	30	4	0.16 to 0.31	0.23
Zinc	µg/L	—	30	5,000	—	—	4	1.2 to 3	<3

Notes: **Bolded** concentrations are higher than water quality guidelines or objectives.

a) Exceedances of aluminum CWQG occurred in samples with laboratory-measured pH value of <6.5.

CWQG = Canadian Council of Ministers of the Environment (CCME) water quality guidelines for the protection of aquatic life (CCME 1999); CDWQG = Canadian Drinking Water Quality Guideline (Health Canada 2012); SSWQO = site-specific water quality objectives (Elphick et al. 2011; Rescan, 2012b,c,d,e,f).

mg/L = milligrams per litre; — = no guideline or objective; µS/cm = microSiemens per centimetre; < = less than; NTU = nephelometric turbidity units; mg N/L = milligrams nitrogen per litre; mg P/L = milligrams phosphorus per litre; µg/L = micrograms per litre.

Major ions concentrations were similar among sampling events (Table 3.3-1). The dominant major ions were magnesium, sodium, and sulphate (Table 3.3-1). Detection limits and measured concentrations of major ions were below associated guidelines and objectives.

Nutrient concentrations measured in the discrete water samples from Lake Af1 were similar among sampling events (Table 3.3-1):

- Total ammonia concentrations ranged from less than 0.005 to 0.013 mg N/L, and were below the CWQG.
- Total Kjeldahl nitrogen concentrations ranged from 0.25 to 0.48 mg N/L.
- Nitrate and nitrite were not detected.
- Concentrations of TP and TDP ranged from 0.0016 to 0.024 mg P/L and from 0.0017 to 0.0048 mg P/L, respectively; dissolved orthophosphate concentrations were always below the laboratory DL.
- Concentrations of SRSi ranged from 0.12 to 0.31 mg/L.
- Organic carbon occurred primarily in the dissolved form, with DOC concentrations ranging from 4.6 to 5.8 mg/L.

Concentrations of total and dissolved metals were either below the DLs or below guidelines and objectives, with the exception of aluminum (Table 3.3-1). Total aluminum concentrations ranged from 22 to 60 µg/L, above the chronic CWQG in all samples; laboratory-measured pH values in the corresponding samples were less than pH 6.5. Dissolved aluminum concentrations ranged from 6.6 to 13 µg/L; the dissolved fraction represented, on average, less than 50% of the total concentration.

Concentrations of hydrocarbons (BTEX, total recoverable hydrocarbons, and petroleum hydrocarbons F1 (C₆-C₁₀), F1 (C₆-C₁₀)-BTEX, and F2 (C₁₀-C₁₆) fractions) were not detected in any samples (Appendix E, Table E-6). Fecal coliform concentrations were also below the laboratory DL (less than 1 CFU/100 mL; Appendix E, Table E-6).

3.3.4 Nutrients and Chlorophyll *a* in Depth-Integrated Samples

Concentrations of TN, TP, and SRSi were 0.48 mg N/L, 0.024 mg P/L, and 0.12 mg/L, respectively, in the discrete sample collected at Station Af-10 in the summer (Appendix E, Table E-6). In comparison, concentrations of TN, TP, and SRSi in the depth-integrated sample collected at the same time were 0.38 mg N/L, 0.021 mg P/L, and 0.14 mg/L, respectively. Concentrations of SRSi in both samples were higher than the threshold of 0.1 mg/L that would be limiting for diatom growth (Reynolds 2006).

Chlorophyll *a* concentrations in Lake Af1 ranged from a minimum of 8.95 µg/L in the fall to a maximum of 13.45 µg/L in the summer (Appendix E, Table E-16). Based on measured chlorophyll *a* concentrations, peak phytoplankton biomass occurred during the summer sampling period at Lake Af1 (Table 3.3-2).

Table 3.3-2 Summary of Chlorophyll a Concentrations at Lake Af1, 2013

Sampling Event	Chlorophyll a (µg/L)
Late Spring	9.49 ± 0.10
Summer	13.45 ± 0.23
Fall	8.95 ± 0.28

Note: Concentrations are mean ± standard error.
µg/L = micrograms per litre; ± = plus or minus.

3.3.5 Trophic Status Classification

The discrete water sampling program for Lake Af1 yielded mean annual concentrations of 0.020 mg P/L for TP, and 2.1 m for Secchi depth. The corresponding TSI values were 47.4 using TP and 49.3 using Secchi depth, for a rounded average of 48. The depth-integrated sampling program yielded concentrations of 0.021 mg P/L for TP, 1.8 m for Secchi depth, and a mean annual concentration of 10.6 µg/L for chlorophyll a. The corresponding TSI values were 51.5 using chlorophyll a, 48.1 using TP, and 53.7 using Secchi depth, for a rounded average of 51. Based on the concentrations of nutrients and chlorophyll a, Lake Af1 is classified as mesotrophic to eutrophic using Vollenweider (1970) and mesotrophic using CCME (2004). Based on the TSI values (Carlson 1977), Lake Af1 is classified as mesotrophic.

3.4 Sub-Basin Lakes

One station was sampled from each of four sub-basin lakes (C1, D3 [Counts Lake], G2, and H1; Map 2.4-1). Bathymetry was not available for all of the lakes before the first field program, thus sampling stations were chosen in the field from a deep site near the centre of each of the lakes.

The focus of the field program was to sample each lake at least once during the open-water season; therefore, these lakes were not sampled during each seasonal sampling event. Lakes C1 and D3 (Counts Lake) were sampled during the summer event, and lakes G2 and H1 were sampled during the fall event; the lakes were not sampled during the late spring event.

Six samples were collected from the sub-basin lakes during the 2013 baseline program, and four field water column profiles were recorded.

3.4.1 Field-Measured Physico-Chemical Parameters

Thermal stratification occurred in the summer at Stations C-L1 and D-L3, but did not occur in the fall at Stations G-L2, H-L1, and C-L1 (Appendix C, Figure C-6).

The dissolved oxygen profiles were uniform with depth in the fall at Station C-L1, and decreased with depth in the summer at Stations C-L1 and D-L3. Concentrations of DO were above the CWQG of 6.5 mg/L (Appendix C, Figure C-6). Dissolved oxygen saturation generally ranged from 86% to 106%, with the exception of Station C-L1 in the summer, where DO saturation declined with depth from 81% at 12 m to 66% at 19 m (Appendix E, Table E-7).

Field-measured specific conductivity was similar among the four sub-basin lakes and did not vary with depth (Appendix E, Table E-7). Overall, specific conductivity ranged from 11 to 20 $\mu\text{S}/\text{cm}$, with the lowest values observed in Lake D3 (Counts Lake; 11 to 12 $\mu\text{S}/\text{cm}$) and the highest values in Lake G2 (19 to 20 $\mu\text{S}/\text{cm}$).

3.4.2 Water Chemistry in Discrete Samples

Concentrations of conventional parameters were similar among stations in the four sub-basin lakes (Table 3.4-1). The range of values for total alkalinity and total hardness indicated that the sub-basin lakes have a high sensitivity to acid deposition (Table 2.7-1) and are very soft-water lakes (Table 2.7-3). The range of laboratory-measured pH values (pH 6.5 to 6.9, with a median of pH 6.7) indicated that the lake water is slightly acidic to neutral. Total dissolved solids ranged from less than 10 to 21 mg/L (median = 16 mg/L). The concentrations of TSS ranged from less than 3 to 5 mg/L (median = less than 3 mg/L) and turbidity was less than 1 NTU.

Major ions concentrations were similar among stations (Table 3.4-1). The dominant major ions were bicarbonate, magnesium, and sulphate (Table 3.4-1). Detection limits and measured concentrations of major ions were below the associated guidelines and objectives.

Nutrient concentrations measured in the discrete water samples were slightly higher in samples from Lake C1 and Lake H1 (Appendix E, Table E-8), with the exception of SRSi:

- Total ammonia concentrations ranged from 0.011 to 0.032 mg N/L in lakes C1 and H1, compared to 0.0064 to 0.013 mg/L in lakes D3 (Counts Lake) and G2; all concentrations were below the CWQG.
- Total Kjeldahl nitrogen concentrations ranged from 0.21 to 0.38 mg/L in lakes C1 and H1, compared to 0.13 to 0.16 mg/L in lakes D3 (Counts Lake) and G2.
- Nitrate and nitrite were not detected.
- Concentrations of TP and TDP ranged from 0.0067 to 0.011 mg P/L and from 0.0021 to 0.0034 mg P/L, respectively, in lakes C1 and H1, compared to 0.0052 to 0.0065 mg P/L and less than 0.001 to 0.0026 mg P/L, respectively in lakes D3 (Counts Lake) and G2; dissolved orthophosphate concentrations were below the laboratory DL.
- Concentrations of SRSi ranged from 0.094 to 0.26 mg/L, with the highest concentrations in Lake D3 (Counts Lake).
- Organic carbon occurred primarily in the dissolved form, with DOC concentrations ranging from 4.1 to 4.8 mg/L in lakes C1 and H1, compared to 2.9 to 3.1 mg/L in lakes D3 (Counts Lake) and G2.

Table 3.4-1 Water Quality in Sub-Basin Lakes, 2013

Parameter	Unit	Guidelines			Objectives		Count	Range	Median
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO			
Conventional Parameters									
Total alkalinity	mg/L	—	—	—	—	—	6	3.9 to 6.5	5.0
Specific conductivity	µS/cm	—	—	—	—	—	6	12 to 20	15
Hardness	mg/L	—	—	—	—	—	6	3.8 to 6.1	5.0
pH	—	—	6.5 to 9.0	6.5 to 8.5	—	—	6	6.5 to 6.9	6.7
Total dissolved solids	mg/L	—	—	500	—	—	6	<10 to 21	16
Total suspended solids	mg/L	—	—	—	—	—	6	<3 to 5	<3
Turbidity	NTU	—	—	—	—	—	6	0.46 to 0.78	0.54
Major Ions									
Bicarbonate	mg/L	—	—	—	—	—	6	<5 to 8	6.1
Calcium	mg/L	—	—	—	—	—	6	0.6 to 0.92	0.75
Chloride	mg/L	640	120	250	—	64.5	6	<0.5	<0.5
Fluoride	mg/L	—	0.12	1.5	—	—	6	<0.02 to 0.032	0.023
Magnesium	mg/L	—	—	—	—	—	6	0.56 to 0.93	0.72
Potassium	mg/L	—	—	—	112	41	6	0.45 to 0.8	0.62
Sodium	mg/L	—	—	200	—	—	6	0.63 to 0.9	0.67
Sulphate	mg/L	—	—	500	250	22.7	6	0.93 to 2.1	1.3
Nutrients									
Total organic carbon	mg/L	—	—	—	—	—	6	3 to 5	3.6
Dissolved organic carbon	mg/L	—	—	—	—	—	6	2.9 to 4.8	3.6
Total Kjeldahl Nitrogen	mg N/L	—	—	—	—	—	6	0.13 to 0.38	0.18
Total ammonia	mg N/L	—	2.7 to 139	—	—	—	6	0.0064 to 0.032	0.012
Nitrate	mg N/L	124	2.9	10	—	0.57	6	<0.006	<0.006
Nitrite	mg N/L	—	0.06	1	—	—	6	<0.002	<0.002

Table 3.4-1 Water Quality in Sub-Basin Lakes, 2013

Parameter	Unit	Guidelines			Objectives		Count	Range	Median
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO			
Nutrients (Continued)									
Total phosphorus	mg P/L	—	—	—	—	—	6	0.0052 to 0.011	0.0066
Total dissolved phosphorus	mg P/L	—	—	—	—	—	6	<0.001 to 0.0034	0.0016
Dissolved orthophosphate	mg/L	—	—	—	—	—	6	<0.001	<0.001
Silica, reactive	mg/L	—	—	—	—	—	6	0.094 to 0.26	0.2
Total Metals									
Aluminum	µg/L	—	5 or 100	100	—	—	6	5.6 to 21	8.6
Antimony	µg/L	—	—	6	—	—	6	<0.02	<0.02
Arsenic	µg/L	—	5	10	—	—	6	0.27 to 0.6	0.44
Barium	µg/L	—	—	1,000	—	—	6	1.4 to 3.1	2.0
Beryllium	µg/L	—	—	—	—	—	6	<0.01	<0.01
Bismuth	µg/L	—	—	—	—	—	6	<0.01	<0.01
Boron	µg/L	29,000	1,500	5,000	—	—	6	2.2 to 5.7	3.6
Cadmium	µg/L	0.11	0.04	5	—	—	6	<0.005	<0.005
Cesium	µg/L	—	—	—	—	—	6	<0.1	<0.1
Chromium	µg/L	—	1	50	—	—	6	<0.06 to 0.12	<0.06
Chromium VI	µg/L	—	1	—	—	—	6	<1.0	<1.0
Cobalt	µg/L	—	—	—	—	—	6	0.019 to 0.084	0.033
Copper	µg/L	—	2	1,000	—	—	6	0.44 to 1.5	0.73
Iron	µg/L	—	300	300	—	—	6	20 to 229	36
Lead	µg/L	—	1	10	—	—	6	<0.010 to 0.014	0.011
Lithium	µg/L	—	—	—	—	—	6	0.81 to 1.6	1.1
Manganese	µg/L	—	—	50	—	—	6	2.6 to 46	5.6
Mercury	µg/L	—	0.026	1	—	—	6	<0.0005 to 0.00061	<0.0005
Molybdenum	µg/L	—	73	—	223,000	19,000	6	<0.05 to 0.063	<0.05
Nickel	µg/L	—	25	—	—	—	6	0.17 to 0.98	0.41

Table 3.4-1 Water Quality in Sub-Basin Lakes, 2013

Parameter	Unit	Guidelines			Objectives		Count	Range	Median
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO			
Total Metals (Continued)									
Selenium	µg/L	—	1	10	—	—	6	<0.04	<0.04
Silver	µg/L	—	0.1	—	—	—	6	<0.005	<0.005
Strontium	µg/L	—	—	—	—	—	6	4.3 to 7.4	5.7
Thallium	µg/L	—	0.8	—	—	—	6	<0.01	<0.01
Tin	µg/L	—	—	—	—	—	6	<0.05	<0.05
Titanium	µg/L	—	—	—	—	—	6	<0.1 to 0.32	0.2
Uranium	µg/L	33	15	20	—	—	6	<0.01 to 0.039	0.013
Vanadium	µg/L	—	—	—	300	30	6	<0.05 to 0.098	<0.05
Zinc	µg/L	—	30	5,000	—	—	6	0.82 to 3.2	1.4

Note: **Bolded** concentrations are higher than water quality guidelines or objectives.

CWQG = Canadian Council of Ministers of the Environment (CCME) water quality guidelines for the protection of aquatic life (CCME 1999); CDWQG = Canadian Drinking Water Quality Guideline (Health Canada 2012); SSWQO = site-specific water quality objectives (Elphick et al. 2011; Rescan, 2012a,b,c,d,e).

mg/L = milligrams per litre; — = no guideline or objective; µS/cm = microSiemens per centimetre; < = less than; NTU = nephelometric turbidity units; mg N/L = milligrams nitrogen per litre; mg P/L = milligrams phosphorus per litre; µg/L = micrograms per litre.

Concentrations of total and dissolved metals were either below laboratory DLs or below guidelines and objectives, with the exception of aluminum (Table 3.4-1). Total aluminum concentrations ranged from 5.6 to 21 µg/L. Dissolved aluminum concentrations ranged from 1.4 to 5.6 µg/L; the dissolved fraction represented, on average, less than 50% of the total concentration.

Concentrations of hydrocarbons (BTEX, total recoverable hydrocarbons, and petroleum hydrocarbons F1 (C₆-C₁₀), F1 (C₆-C₁₀)-BTEX, and F2 (C₁₀-C₁₆) fractions) were not detected in any samples from the sub-basin lakes (Appendix E, Table E-8). Fecal coliform concentrations in the sub-basin lakes ranged from below the laboratory DL (less than 1 CFU/100 mL) to 1 CFU/100 mL (Appendix E, Table E-8).

3.4.3 Chlorophyll *a* in Depth-Integrated Samples

Chlorophyll *a* concentrations in the sub-basin lakes ranged from a minimum of 1.99 µg/L at Lake C1 during the summer to a maximum of 5.45 µg/L at Lake H1 during the fall (Table 3.4-2; Appendix E, Table E-16). Overall, chlorophyll *a* concentrations were higher during the fall sampling period (mean = 2.49 µg/L) compared to the summer (mean = 4.88 µg/L) sampling period. Based on measured chlorophyll *a* concentrations, peak phytoplankton biomass occurred during the fall sampling period at the sub-basin lakes.

Table 3.4-2 Summary of Chlorophyll *a* in Sub-Basin Lakes C1, D3 (Counts Lake), G2, and H1, 2013

Sub-Basin	Lake	Summer	Fall
C	C1	2.99 ± 0.13	—
D	D3 (Counts Lake)	1.99 ± 0.03	—
G	G2	—	4.31 ± 0.11
H	H1	—	5.45 ± 0.09

Notes: Concentrations are mean ± standard error; units are µg/L = micrograms per litre.

— = not sampled; ± = plus or minus.

3.4.4 Trophic Status Classification

Trophic status was individually calculated for each of the sub-basin lakes based on discrete samples:

- Lake C1 is classified as oligotrophic to mesotrophic based on TSI values for TP (33) and Secchi depth (41.9), for a rounded average of 37.
- Lake D3 (Counts Lake) is classified as oligotrophic based on TSI values for TP (34.9) and Secchi depth (38.3), for a rounded average of 37.
- Lake H1 is classified as oligotrophic based on the TSI value for TP (37.9) and Secchi depth (41.5), for a rounded average of 40.
- Lake G2 is classified as oligotrophic based on TSI values for TP (38.7) and Secchi depth (42.3), for a rounded average of 41.

These classifications are consistent with classifications based on Vollenweider (1970) and CCME (2004).

Trophic status classification of the sub-basin lakes using depth-integrated samples (excluding TP results) was less variable than the classification based on discrete samples:

- Lake C1 is classified as mesotrophic based on TSI values for chlorophyll *a* (41.3) and Secchi depth (41.9), for a rounded average of 42.
- Lake D3 (Counts Lake) is classified as oligotrophic based on TSI values for chlorophyll *a* (37.3) and Secchi depth (38.3), for a rounded average of 38.
- Lake H1 is classified as mesotrophic based on TSI values for chlorophyll *a* (47.2) and Secchi depth (41.5), for a rounded average of 44.
- Lake G2 varies from oligotrophic to mesotrophic based on TSI values for chlorophyll *a* (44.9) and Secchi depth (38.9), for a rounded average of 42.

Trophic classifications based on TSI values for these four sub-basin lakes are consistent with classifications based on Vollenweider (1970). The CCME (2004) classification could not be applied to the sub-basin lakes because depth-integrated phosphorus data were unavailable.

3.5 Lake E1

Sampling stations in Lake E1 were one deep (10 to 15 m deep) station (E-L1-1) and one shallow (3 to 5 m deep) station (E-L1-2) (Map 2.4-1). Five water samples were collected and four field water column profiles were recorded from Lake E1 during the 2013 baseline program. Lake E1 was not sampled in the fall due to inclement weather.

3.5.1 Field-Measured Physico-Chemical Parameters

Thermal stratification was evident in the summer in Lake E1, but not in the fall (Appendix C, Figure C-7a).

Oxic stratification was evident in Lake E1 during the summer sampling event; DO concentrations at the deep station (Station E-L1-1) declined sharply with depth (Appendix C, Figure C-7b), from 8.4 mg/L (76% saturation) at 8 m to 1.8 mg/L (17% saturation) at 11 m. Dissolved oxygen concentrations were below the CWQG of 6.5 mg/L below 9 m. In the summer and fall, and at above 8 m depths in the summer, DO saturation ranged from 86% to 103% (Appendix E, Table E-9).

The total depth at Station E-L1-1 differed between summer (12 m) and fall (7 m) events. This variability in station depth between sampling events was attributed to boat drift during fall sampling because of high wind conditions at the time of sampling. Thus, lake turnover by the fall sampling event cannot be confirmed.

Field-measured specific conductivity was lower in the fall at 8.1 to 8.5 $\mu\text{S}/\text{cm}$, compared to 12 to 15 $\mu\text{S}/\text{cm}$ in the summer (Appendix E, Table E-9). Specific conductivity was consistent throughout the water column, although a slight increase in conductivity with depth was observed in the deep station (Station E-L1-1) during the summer sampling event. For example, specific conductivity increased from 12 $\mu\text{S}/\text{cm}$ as measured between surface and 7 m depth, to a high of 15 $\mu\text{S}/\text{cm}$ at 11 m.

3.5.2 Defining the Euphotic Zone

Secchi depth in Lake E1 was consistent among sampling events (3.5 to 4.0 m; Appendix E, Table E-10), despite variability in station depth. Total depth at the deep station was 12.0 m in the summer and 7.3 m in the fall (Appendix E, Table E-10).

Vertical light attenuation coefficients determined for Lake E1 indicate a clear water lake, with more attenuation in the water column than Lac du Sauvage and Duchess Lake, but less attenuation than Lake Af1. Light penetrated deeper into the water column in the summer ($K_d = 0.61$) than in the fall ($K_d = 0.67$) (Appendix D, Figure D-4).

3.5.3 Water Chemistry in Discrete Samples

Concentrations of conventional parameters were similar among stations and sampling events (Table 3.5-1). The range of values for total alkalinity and total hardness indicated that Lake E1 has a high sensitivity potential to acid deposition (Table 2.7-1) and is a very soft-water lake (Table 2.7-3). The range of laboratory-measured pH values (pH 6.0 to 6.3, with a median of pH 6.3), indicated that the lake water is slightly acidic. All of the water samples collected in Lake E1 had pH values that were below the CWQG and CDWQG lower limits of pH 6.5. Total dissolved solids ranged from less than 10 to 13 mg/L (median = 10 mg/L). The concentrations of TSS were always below the laboratory DL (less than 3 mg/L) and turbidity ranged from 0.59 to 1.2 NTU.

Table 3.5-1 Water Quality in Lake E1, 2013

Parameter	Unit	Guidelines			Objectives		Count	Range	Median
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO			
Conventional Parameters									
Total Alkalinity	mg/L	—	—	—	—	—	5	2.6 to 3.1	2.8
Specific conductivity	µS/cm	—	—	—	—	—	5	11 to 13	11
Hardness	mg/L	—	—	—	—	—	5	3.6 to 4	3.6
pH	—	—	6.5 to 9.0	6.5 to 8.5	—	—	5	6.0 to 6.3	6.3
Total dissolved solids	mg/L	—	—	500	—	—	5	<10 to 13	10
Total suspended solids	mg/L	—	—	—	—	—	5	<3	<3
Turbidity	NTU	—	—	—	—	—	5	0.59 to 1.2	0.89
Major Ions									
Bicarbonate	mg/L	—	—	—	—	—	5	<5	<5
Calcium	mg/L	—	—	—	—	—	5	0.62 to 0.75	0.65
Chloride	mg/L	640	120	250	—	64.5	5	<0.5	<0.5
Fluoride	mg/L	—	0.12	1.5	—	—	5	<0.02	<0.02
Magnesium	mg/L	—	—	—	—	—	5	0.49 to 0.52	0.5
Potassium	mg/L	—	—	—	112	41	5	0.35 to 0.44	0.36
Sodium	mg/L	—	—	200	—	—	5	0.52 to 0.56	0.54
Sulphate	mg/L	—	—	500	250	22.7	5	1 to 1.3	1.1
Nutrients									
Total organic carbon	mg/L	—	—	—	—	—	5	3.6 to 4.1	4.0
Dissolved organic carbon	mg/L	—	—	—	—	—	5	3.8 to 4.5	4.2
Total Kjeldahl Nitrogen	mg N/L	—	—	—	—	—	5	0.24 to 0.41	0.3
Total ammonia	mg N/L	—	2.7 to 139	—	—	—	5	<0.005 to 0.034	<0.005
Nitrate	mg N/L	124	2.9	10	—	0.57	5	<0.006 to 0.013	<0.006
Nitrite	mg N/L	—	0.06	1	—	—	5	<0.002	<0.002

Table 3.5-1 Water Quality in Lake E1, 2013

Parameter	Unit	Guidelines			Objectives		Count	Range	Median
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO			
Nutrients (Continued)									
Total phosphorus	mg P/L	—	—	—	—	—	5	0.0074 to 0.021	0.0091
Total dissolved phosphorus	mg P/L	—	—	—	—	—	5	0.0014 to 0.0066	0.0028
Dissolved orthophosphate	mg/L	—	—	—	—	—	5	<0.001 to 0.0027	<0.001
Silica, reactive	mg/L	—	—	—	—	—	5	0.15 to 0.44	0.15
Total Metals									
Aluminum	µg/L	—	5 or 100	100	—	—	5	15 to 183	18
Antimony	µg/L	—	—	6	—	—	5	<0.02	<0.02
Arsenic	µg/L	—	5	10	—	—	5	0.29 to 1.1	0.37
Barium	µg/L	—	—	1,000	—	—	5	1.8 to 3.5	1.9
Beryllium	µg/L	—	—	—	—	—	5	<0.01	<0.01
Bismuth	µg/L	—	—	—	—	—	5	<0.01	<0.01
Boron	µg/L	29,000	1,500	5,000	—	—	5	2.4 to 3.3	3
Cadmium	µg/L	0.11	0.04	5	—	—	5	<0.005 to 0.0069	<0.005
Cesium	µg/L	—	—	—	—	—	5	<0.1	<0.1
Chromium	µg/L	—	1	50	—	—	5	<0.06 to 0.11	0.097
Cobalt	µg/L	—	—	—	—	—	5	0.04 to 0.41	0.053
Copper	µg/L	—	2	1,000	—	—	5	0.74 to 1.2	0.78
Iron	µg/L	—	300	300	—	—	5	60 to 695	67
Lead	µg/L	—	1	10	—	—	5	<0.01 to 0.067	0.011
Lithium	µg/L	—	—	—	—	—	5	0.81 to 1.5	1.3
Manganese	µg/L	—	—	50	—	—	5	1.6 to 27	2.3
Mercury	µg/L	—	0.026	1	—	—	5	<0.0005 to 0.00095	0.00058
Molybdenum	µg/L	—	73	—	223,000	19,000	5	<0.05	<0.05
Nickel	µg/L	—	25	—	—	—	5	0.36 to 0.64	0.38

Table 3.5-1 Water Quality in Lake E1, 2013

Parameter	Unit	Guidelines			Objectives		Count	Range	Median
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO			
Total Metals									
Selenium	µg/L	—	1	10	—	—	5	<0.04	<0.04
Silver	µg/L	—	0.1	—	—	—	5	<0.005	<0.005
Strontium	µg/L	—	—	—	—	—	5	4.9 to 5.7	5
Thallium	µg/L	—	0.8	—	—	—	5	<0.01	<0.01
Tin	µg/L	—	—	—	—	—	5	<0.05	<0.05
Titanium	µg/L	—	—	—	—	—	5	0.24 to 1.3	0.53
Uranium	µg/L	33	15	20	—	—	5	0.038 to 0.098	0.046
Vanadium	µg/L	—	—	—	300	30	5	0.098 to 0.47	0.11
Zinc	µg/L	—	30	5,000	—	—	5	1.4 to 4.1	1.5

Note: **Bolded** concentrations are higher than water quality guidelines or objectives.

CWQG = Canadian Council of Ministers of the Environment (CCME) water quality guidelines for the protection of aquatic life (CCME 1999); CDWQG = Canadian Drinking Water Quality Guideline (Health Canada 2012); SSWQO = site-specific water quality objectives (Elphick et al. 2011; Rescan, 2012b,c,d,e,f).

mg/L = milligrams per litre; — = no guideline or objective; µS/cm = microSiemens per centimetre; < = less than; NTU = nephelometric turbidity units; mg N/L = milligrams nitrogen per litre; mg P/L = milligrams phosphorus per litre; µg/L = micrograms per litre.

Major ions concentrations were similar among stations and sampling events (Table 3.5-1). The dominant major ions were calcium, magnesium, and sulphate (Table 3.5-1). Detection limits and measured concentrations of major ions were below associated guidelines and objectives.

Nutrient concentrations measured in the discrete water samples from Lake E1 were similar among stations and sampling events (Table 3.5-1):

- Total ammonia concentrations ranged from less than 0.005 to 0.034 mg N/L and were below the CWQG.
- Total Kjeldahl nitrogen concentrations ranged from 0.24 to 0.41 mg/L.
- Nitrate was detected in one bottom sample from Station E-L1-1 in the summer (0.013 mg N/L), but not detected in any other sample (laboratory DL = 0.006 mg N/L).
- Nitrite was not detected in any sample (laboratory DL = 0.002 mg N/L).
- Concentrations of TP and TDP ranged from 0.0074 to 0.021 mg P/L and 0.0014 to 0.0066 mg P/L, respectively.
- Dissolved orthophosphate concentrations were below the laboratory DL (0.001 mg/L) in all samples the bottom sample from Station E-L1-1 in the summer (0.0027 mg P/L).
- Concentrations of SRSi ranged from 0.15 to 0.44 mg/L.
- Organic carbon occurred primarily in the dissolved form, with DOC concentrations ranging from 3.8 to 4.5 mg/L.

Concentrations of total and dissolved metals were either below DLs or below guidelines and objectives with the exception of aluminum and iron concentrations (Table 3.5-1). Total aluminum concentrations were above the chronic CWQG of 5 µg/L in all samples (applicable to pH values less than 6.5) and above the CDWQG of 100 µg/L in one sample. Total aluminum concentrations ranged from 15 to 183 µg/L. Dissolved aluminum concentrations ranged from 7.5 to 20 µg/L; the dissolved fraction represented, on average, less than 50% of the total concentration. Total iron concentrations ranged from 60 to 75 µg/L, with the exception of the bottom sample from station E-L1-1 in the summer (695 µg/L), which was above the chronic CWQG and the CDWQG of 300 µg/L. Dissolved iron concentrations ranged from 16 to 117 µg/L; the dissolved fraction represented, on average, less than 50% of the total concentration.

Concentrations of hydrocarbons (BTEX, total recoverable hydrocarbons, and petroleum hydrocarbons F1 (C₆-C₁₀), F1 (C₆-C₁₀)-BTEX, and F2 (C₁₀-C₁₆) fractions) were not detected in any sample from Lake E1 (Appendix E, Table E-10). Fecal coliform concentrations were also below the laboratory DL (less than 1 CFU/100 mL; Appendix E, Table E-10).

3.5.4 Nutrients and Chlorophyll *a* in Depth-Integrated Samples

One discrete sample was collected from the top of the deep station (E-L1-1) and one discrete sample from the mid depth of the shallow station (E-L1-2) in the summer. In these discrete samples, concentrations of TN were variable at 0.41 mg N/L at Station E-L1-1 and 0.24 mg N/L at Station E-L1-2 (Appendix E, Table E-10). Additionally, concentrations of TP (0.010 and 0.007 mg P/L, respectively) and SRSi (0.15 mg/L and 0.12 mg/L, respectively) were similar between samples. In comparison, concentrations of TN, TP, and SRSi in the depth-integrated sample collected at the same time were 0.32 mg N/L, 0.015 mg P/L, and 0.21 mg/L, respectively. The concentrations of SRSi in both samples were higher than the threshold of 0.1 mg/L that would be limiting for diatom growth (Reynolds 2006).

Depth-integrated chlorophyll *a* samples were collected in both sampling periods (summer and fall) at Station E-L1-1 and in fall at Station E-L1-2. Chlorophyll *a* concentrations were similar among the stations and sampling events (Table 3.5-2; Appendix E, Table E-16). Overall, chlorophyll *a* concentrations were slightly higher during the summer compared to the fall. Based on measured chlorophyll *a* concentrations, peak phytoplankton biomass occurred during the summer sampling period in Lake E1.

Table 3.5-2 Summary of Chlorophyll *a* in Lake E1, 2013

Station	Summer	Fall
E-L1-1	4.25 ± 0.09	4.01 ± 0.07
E-L1-2	—	3.15 ± 0.23

Notes: Concentrations are mean ± standard error; units are µg/L = micrograms per litre.

— = not sampled; ± = plus or minus.

3.5.5 Trophic Status Classification

The discrete water sampling program for Lake E1 yielded mean annual concentrations of 0.011 mg/L for TP and 3.4 m for Secchi depth. The TSI values were 38.7 using TP and 42.3 using Secchi depth, for a rounded average of 41. The depth-integrated sampling program yielded a concentration of 0.015 mg/L for TP, 4.0 m for Secchi depth, and an annual mean concentration of 3.80 µg/L for chlorophyll *a*. The TSI values were 43.7 using chlorophyll *a*, 38.7 using TP, and 42.3 using Secchi depth, for a rounded average of 42. Based on these values, and the classification systems of Vollenweider (1970), CCME (2004), and Carlson (1977), Lake E-L1 is classified as a mesotrophic lake.

3.6 Paul Lake

Sampling stations in Paul Lake were five deep (10 to 15 m deep) stations (PL-1, PL-2, PL-3, PL-4, and PL-5) (Map 2.4-1), at which 16 water samples and 11 water column field profile measurements were recorded during the 2013 baseline program. Station PL-5 (late spring), Station PL-4 (summer), and Station PL-1 (fall) were not sampled due to inclement weather.

3.6.1 Field-Measured Physico-Chemical Parameters

Thermal stratification was evident in the summer at three stations in Paul Lake (i.e., PL-1, PL-2, PL-3), but was not evident in the late spring or fall at any stations (Appendix C, Figure C-8a).

In the late spring and fall sampling events, DO concentrations remained uniform with depth. In the summer, DO varied with depth (Appendix C, Figure C-8b). Surface water DO concentrations were highest in the summer (11.1 to 13.3 mg/L or 93% to 112% saturation) compared to the late spring (10.1 to 10.3 mg/L or 94% to 97%) (Appendix E, Table E-11).

Field-measured specific conductivity throughout the water column was similar among the stations and sampling events, ranging from 13 to 16 $\mu\text{S}/\text{cm}$ (Appendix E, Table E-11).

3.6.2 Defining the Euphotic Zone

Secchi depths at the Paul Lake stations ranged from 3.0 to 5.9 m (Appendix E, Table E-12); the total depth at the sampling stations ranged from 6.0 to 14.0 m (Appendix E, Table E-12). Mean Secchi depth in Paul Lake was greater in the late spring (mean = 4.7 m) than in the summer (mean = 3.7 m) and fall (mean = 3.4 m).

Vertical light attenuation through the water column was similar among all stations in Paul Lake during late spring, summer, and fall, indicating a relatively uniform light regime (Appendix D, Figure D-5). Light attenuation coefficients (K_d) ranged from 0.48 to 0.66) characterize Paul Lake as a clear water lake. Light penetrated deeper into the water column during the fall (Table 3.6-1). The light profile data are therefore in slight contrast with the observations made with the Secchi depth data (i.e., the Secchi depth was greater during the late spring compared to summer and fall).

Table 3.6-1 Attenuation Coefficients at Deep Stations in Paul Lake, 2013

Station	Sampling Event		
	Late Spring	Summer	Fall
PL-1	0.57	0.61	—
PL-2	0.55	0.66	0.63
PL-3	0.62	0.50	0.48
PL-4	0.55	—	0.50
PL-5	—	0.56	0.54

Notes: Station PL-5 was not sampled in the late spring, Station PL-4 was not sampled in the summer, and Station PL-1 was not sampled in the fall due to inclement weather.

— = not sampled.

3.6.3 Water Chemistry in Discrete Samples

Concentrations of conventional water quality parameters in Paul Lake were similar among stations and sampling events, with the exception of pH (Table 3.6-2). Laboratory-measured pH was consistently lower in the late spring samples, and these values were below the CWQG and CDWQG lower limits of pH 6.5. The range of values for total alkalinity and total hardness indicated that Paul Lake has a high potential sensitivity to acid deposition (Table 2.7-1) and is a very soft-water lake (Table 2.7-3). The range of laboratory-measured pH values (pH 6.4 to 7.2, with a median of pH 6.7) indicated that the lake water may be slightly acidic to pH-neutral. Field-measured specific conductivity ranged from 16 to 32 $\mu\text{S}/\text{cm}$ (median = 18 $\mu\text{S}/\text{cm}$). Total dissolved solids ranged from less than 10 to 28 mg/L (median = 14 mg/L).

The concentrations of TSS were always below the laboratory DL (less than 3 mg/L) and turbidity ranged from 0.66 to 1.5 NTU.

Major ions concentrations were similar among stations and sampling events in Paul Lake (Table 3.6-2). The dominant major ions were bicarbonate, magnesium, and sulphate (Table 3.6-2). Detection limits and measured concentrations of major ions were below associated guidelines and objectives.

Nutrient concentrations measured in the discrete water samples from Paul Lake were similar among stations and sampling events (Table 3.6-2):

- Total ammonia concentrations ranged from less than 0.005 to 0.015 mg N/L, and were below the CWQG.
- Total Kjeldahl nitrogen concentrations ranged from 0.12 to 0.30 mg/L.
- Nitrate and nitrite were not detected.
- Concentrations of TP and TDP ranged from 0.0067 to 0.017 mg P/L and 0.0021 to 0.0044 mg P/L, respectively; dissolved orthophosphate concentrations were below the laboratory DL.
- Concentrations of SRSi ranged from 0.12 to 0.20 mg/L.
- Organic carbon occurred primarily in the dissolved form, with DOC concentrations ranging from 4.2 to 5.1 mg/L.

Concentrations of total and dissolved metals were either below DLs or below guidelines and objectives, with the exception of aluminum (Table 3.6-2). Total aluminum concentrations were above the CWQG and CDWQG in three samples from Paul Lake, specifically, the late spring samples that had laboratory-measured pH values of less than 6.5. In samples where total aluminum was above the CWQG, dissolved aluminum was also above the CWQG in two of the three samples.

Concentrations of hydrocarbons (BTEX, total recoverable hydrocarbons, petroleum hydrocarbons F1 (C₆-C₁₀), F1 (C₆-C₁₀)-BTEX, and F2 (C₁₀-C₁₆)) were not detected in any samples from Paul Lake. Fecal coliform concentrations ranged from below the laboratory DL (1 CFU/100 mL) to 5 CFU/100 mL (Appendix D, Table D-1).

Table 3.6-2 Water Quality in Paul Lake, 2013

Parameter	Unit	Guidelines			SSWQO		Count	Range	Median
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO			
Conventional Parameters									
Total alkalinity	mg/L	—	—	—	—	—	16	4.4 to 6.5	5.3
Specific conductivity	µS/cm	—	—	—	—	—	16	16 to 32	18
Hardness	mg/L	—	—	—	—	—	16	5.7 to 6.1	6
pH	pH units	—	6.5 to 9.0	6.5 to 8.5	—	—	16	6.4 to 7.2	6.7
Total dissolved solids	mg/L	—	—	500	—	—	16	<10 to 28	14
Total suspended solids	mg/L	—	—	—	—	—	16	<3	<3
Turbidity	NTU	—	—	—	—	—	16	0.66 to 1.5	0.74
Major Ions									
Bicarbonate	mg/L	—	—	—	—	—	16	5.4 to 7.9	6.4
Calcium	mg/L	—	—	—	—	—	16	0.9 to 1	0.96
Chloride	mg/L	640	120	250	—	64.5	16	<0.5	<0.5
Fluoride	mg/L	—	0.12	1.5	—	—	16	<0.02 to 0.029	<0.02
Magnesium	mg/L	—	—	—	—	—	16	0.82 to 0.88	0.86
Potassium	mg/L	—	—	—	112	41	16	0.57 to 0.64	0.62
Sodium	mg/L	—	—	200	—	—	16	0.67 to 0.73	0.69
Sulphate	mg/L	—	—	500	250	22.7	16	1.1 to 2	1.7
Nutrients									
Total organic carbon	mg/L	—	—	—	—	—	16	3.7 to 5.2	4.6
Dissolved organic carbon	mg/L	—	—	—	—	—	16	4.2 to 5.1	4.6
Total Kjeldahl Nitrogen	mg N/L	—	—	—	—	—	16	0.12 to 0.3	0.18
Total ammonia	mg N/L	—	2.7 to 139	—	—	—	16	<0.005 to 0.015	0.0089
Nitrate	mg N/L	124	2.9	10	—	0.57	16	<0.006	<0.006
Nitrite	mg N/L	—	0.06	1	—	—	16	<0.002	<0.002

Table 3.6-2 Water Quality in Paul Lake, 2013

Parameter	Unit	Guidelines			SSWQO		Count	Range	Median
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO			
Nutrients (Continued)									
Total phosphorus	mg P/L	—	—	—	—	—	16	0.0067 to 0.017	0.0090
Total dissolved phosphorus	mg P/L	—	—	—	—	—	16	0.0021 to 0.0044	0.0028
Dissolved orthophosphate	mg/L	—	—	—	—	—	15	<0.001 to <0.01	<0.001
Silica, reactive	mg/L	—	—	—	—	—	16	0.12 to 0.2	0.17
Total Metals									
Aluminum	µg/L	—	5 or 100	100	—	—	16	9.3 to 39 ^(a)	13
Antimony	µg/L	—	—	6	—	—	16	<0.02 to <0.1	<0.02
Arsenic	µg/L	—	5	10	—	—	16	0.43 to 1	0.6
Barium	µg/L	—	—	1,000	—	—	16	1.4 to 1.9	1.7
Beryllium	µg/L	—	—	—	—	—	16	<0.01 to <0.5	<0.01
Bismuth	µg/L	—	—	—	—	—	16	<0.01 to <0.05	<0.01
Boron	µg/L	29,000	1,500	5,000	—	—	16	2.6 to <10	3.9
Cadmium	µg/L	0.11	0.04	5	—	—	16	<0.005 to 0.011	<0.005
Cesium	µg/L	—	—	—	—	—	15	<0.1	<0.1
Chromium	µg/L	—	1	50	—	—	16	<0.06 to 0.17	0.079
Cobalt	µg/L	—	—	—	—	—	16	0.027 to <0.1	0.04
Copper	µg/L	—	2	1,000	—	—	16	0.96 to 1.5	1.1
Iron	µg/L	—	300	300	—	—	16	36 to 79	50
Lead	µg/L	—	1	10	—	—	16	<0.01 to <0.05	0.014
Lithium	µg/L	—	—	—	—	—	16	1.1 to <5	1.5
Manganese	µg/L	—	—	50	—	—	16	3.4 to 12	6.3
Mercury	µg/L	—	0.026	1	—	—	16	<0.0005 to 0.01	0.00054
Molybdenum	µg/L	—	73	—	223,000	19,000	16	<0.050 to 0.095	0.05
Nickel	µg/L	—	25	—	—	—	16	0.49 to 0.89	0.57

Table 3.6-2 Water Quality in Paul Lake, 2013

Parameter	Unit	Guidelines			SSWQO		Count	Range	Median
		Acute CWQG	Chronic CWQG	CDWQG	Short-Term SSWQO	Long-Term SSWQO			
Total Metals									
Selenium	µg/L	—	1	10	—	—	16	<0.04 to <0.1	<0.04
Silver	µg/L	—	0.1	—	—	—	16	<0.005 to <0.01	<0.005
Strontium	µg/L	—	—	—	—	—	16	6 to 6.9	6.7
Thallium	µg/L	—	0.8	—	—	—	16	<0.01 to <0.05	<0.01
Tin	µg/L	—	—	—	—	—	16	<0.05 to <0.1	<0.05
Titanium	µg/L	—	—	—	—	—	16	0.15 to 1.2	0.49
Uranium	µg/L	33	15	20	—	—	16	0.033 to 0.052	0.038
Vanadium	µg/L	—	—	—	300	30	16	0.064 to 0.23	0.076
Zinc	µg/L	—	30	5,000	—	—	16	<0.8 to 4.4	1.4

Note: **Bolded** concentrations are higher than relevant water quality guidelines or objectives.

CWQG = Canadian Council of Ministers of the Environment (CCME) water quality guidelines for the protection of aquatic life (CCME 1999); CDWQG = Canadian Drinking Water Quality Guideline (Health Canada 2012); SSWQO = site-specific water quality objectives (Elphick et al. 2011; Rescan, 2012b,c,d,e,f).

a) Aluminum was above the guideline of 5 µg/L in 19% of samples due to pH values in those samples less than 6.5; in all other samples, aluminum was below the guideline of 100 µg/L in all other samples due to pH in those samples above 6.5.

mg/L = milligrams per litre; — = no guideline or objective; µS/cm = microSiemens per centimetre; < = less than; NTU = nephelometric turbidity units; mg N/L = milligrams nitrogen per litre; mg P/L = milligrams phosphorus per litre; µg/L = micrograms per litre.

3.6.4 Nutrients and Chlorophyll *a* in Depth-Integrated Samples

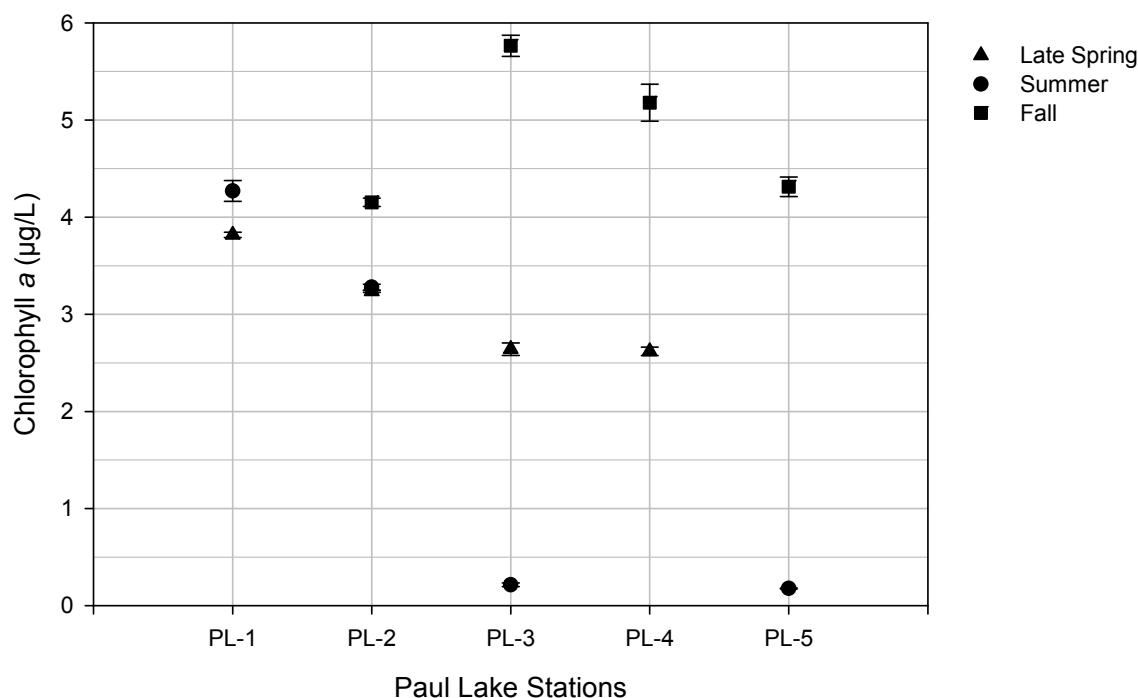
Summer concentrations of TN concentrations in the depth-integrated samples from Paul Lake were higher than those in the discrete samples collected (top samples). Concentrations of TN ranged from 0.19 to 0.57 mg N/L (median = 0.24 mg N/L) in the depth-integrated samples (Appendix E, Table E-15) compared to 0.12 to 0.16 mg N/L (median = 0.14 mg N/L) in the discrete samples.

In contrast, TP and SRSi concentrations in Paul Lake were similar between depth-integrated and discrete samples:

- Concentrations of TP ranged from 0.009 to 0.020 mg P/L (median = 0.010 mg P/L) in the depth-integrated samples (Appendix E, Table E-15) compared to 0.007 to 0.013 mg P/L (median = 0.009 mg P/L) in the discrete samples.
- Concentrations of SRSi ranged from 0.16 to 0.19 mg/L (0.16 mg/L) in the depth-integrated samples (Appendix E, Table E-15) compared to 0.16 to 0.18 mg/L (median = 0.17 mg/L) in the discrete samples in the summer (top samples; Appendix E, Table E-12). Concentrations of SRSi were higher than the threshold of 0.1 mg/L considered limiting for diatom growth (Reynolds 2006).

Chlorophyll *a* concentrations ranged from 0.18 µg/L at Station PL-5 during the summer to a maximum of 5.77 at Station PL-3 during the fall (Appendix E, Table E-16). Overall, higher chlorophyll *a* concentrations were observed during the fall sampling period (Figure 3.6-1). Based on measured chlorophyll *a* concentrations, peak phytoplankton biomass occurred during the fall at most stations in Paul Lake.

Figure 3.6-1 Mean Chlorophyll *a* Concentrations at Deep Stations Paul Lake in Late Spring, Summer, and Fall, 2013



Notes: Error bars = standard error; µg/L = micrograms per litre.

3.6.5 Trophic Status Classification

The discrete water sampling program for Paul Lake yielded mean annual concentrations of 0.010 mg/L mg P/L for TP and 3.9 m for Secchi depth. The TSI values were 37.4 using TP and 40.4 using Secchi depth, for a rounded average of 39. The depth-integrated sampling program yielded mean annual concentrations of 0.012 mg P/L for TP, 3.9 m for Secchi depth, and 3.31 µg/L for chlorophyll *a*. The TSI values were 42.8 using chlorophyll *a*, 41.3 using TP, and 40.3 using Secchi depth, for a rounded average of 41. Based on these values and the classification systems of Vollenweider (1970), CCME (2004), and Carlson (1977), Paul Lake would be classified as an oligotrophic to mesotrophic lake.

4 2013 STREAM WATER QUALITY RESULTS

4.1 Lac du Sauvage Outlet

Water samples were collected at Station Ab-S1 (Lac du Sauvage outlet) during the summer and fall (Map 2.4-1).

Field-measured physico-chemical parameters varied slightly between sampling events (Appendix E, Table E-13). Stream water temperature was higher in the summer (16.7°C) than in the fall (10.5°C), and stream temperatures were generally similar to surface water temperatures observed in the lake during the same seasonal sampling events. Stream flow was well oxygenated during both sampling events at 10.5 mg/L (109% saturation) in the summer and 11.1 mg/L (99% saturation) in the fall. Dissolved oxygen concentrations were within CWQG and CDWQG. Specific conductivity was similar between sampling events (11 to 15 µS/cm).

Values for conventional chemistry parameters were similar between the sampling events at the Lac du Sauvage outlet (Appendix E, Table E-14). Total alkalinity was 3.9 and 4.5 mg/L in the summer and fall, respectively. Based on the acid sensitivity scale for streams (Table 2.7-2), the Lac du Sauvage outlet has potential to be sensitive to acid deposition. The water hardness was 4.5 and 4.9 mg/L; based on the water hardness scale (Table 2.7-3), water at Lac du Sauvage outlet is very soft water. The laboratory-measured pH value indicates that the stream water is slightly acidic, similar to Lac du Sauvage (half of the laboratory-measured pH values were below the CWQG and CDWQG of pH 6.5). Concentrations of total dissolved solids ranged from 14 to 17 mg/L. Total suspended solids concentrations were below the DL (less than 3 mg/L) and turbidity was less than 1 NTU.

Major ions concentrations were also similar between sampling events at the Lac du Sauvage outlet. The dominant ions were bicarbonate, calcium, and sulphate (Appendix E, Table E-13), which were also the dominant ions observed in Lac du Sauvage (Section 3.1.3). All concentrations of major ions were below CWQG and CDWQG.

Concentrations of most nutrients were similar between sampling events at the Lac du Sauvage outlet, with the exception of total ammonia and phosphorus, which were higher in the fall sample (Appendix E, Table E-13):

- Total ammonia concentrations were 0.0065 mg N/L in the summer and 0.012 mg N/L in the fall, with both values below sample-specific CWQG.
- Total Kjeldahl nitrogen concentrations were 0.13 mg/L in the summer and 0.14 mg/L in the fall.
- Nitrate and nitrite concentrations were below their respective DLs (i.e., less than 0.006 mg N/L and 0.002 mg N/L, respectively).
- Total phosphorus concentrations were 0.0036 mg P/L in the summer and 0.0083 mg P/L in the fall. The TDP concentration was also higher in the fall (i.e., 0.0029 mg P/L, compared to below the DL in the summer). Dissolved orthophosphate concentrations were below the DL (i.e., less than 0.001 mg P/L).
- Concentrations of SRSi were 0.11 mg/L in both samples.

- Most of the organic carbon measured in the samples was present as DOC; concentrations were 3.5 mg/L in the summer and 3.6 mg/L in the fall.

Based on the CCME (2004) trophic classification of streams (Table 2.7-5), the TP concentrations measured in the Lac du Sauvage outlet would classify the stream as oligotrophic.

Total and dissolved metals concentrations were either below DLs or below guidelines and objectives, with the exception of aluminum collected in the summer event (Appendix E, Table E-13). The total aluminum concentration of 5.8 µg/L in the summer sample exceeded the lower bound CWQG, as the corresponding laboratory pH value was below 6.5. The dissolved aluminum concentration in this sample was 3.1 µg/L.

Hydrocarbons and fecal coliforms were not detected in the summer stream sample, but were detected in the fall sample (Appendix E, Table E-13). Total recoverable hydrocarbon was measured just above the DL in the fall sample (1.1 mg/L), as was the fecal coliform concentration (1 CFU/100 mL).

4.2 Sub-Basin Streams

Other stream stations in the Lac du Sauvage basin sampled as part of this baseline program included Stations C-S1, D-S1, E-S2, F-S1, G-S1, I-S1, J-S1, K-S1, and L-S1 (Map 2.4-1). In total, 20 stream samples were collected during late spring and fall sampling events.

Of the field-measured physico-chemical parameters, stream water temperatures varied between sampling events; DO concentrations and conductivity were more consistent (Appendix E, Table E-14). Stream water temperatures were higher in late spring (9.8°C to 13.4°C) than in fall (4.4°C to 9.0°C). Sub-basin streams were well oxygenated (9.7 to 12.2 mg/L, and 83% to 110% saturation) during both sampling events. Specific conductivity was variable among samples, but showed no discernible pattern with season (i.e., 7 to 18 µS/cm in late spring compared to 10 to 16 µS/cm in fall) or among streams.

Values for conventional chemistry parameters were similar between the sampling events and among streams (Appendix E, Table E-14). Total alkalinity concentrations (2.8 to 6.9 mg/L) indicated that the streams had low alkalinity and thus were potentially sensitive to acid deposition. Based on the water hardness scale (Table 2.7-3), water in the streams is characterized as very soft (i.e., the total hardness ranged from 3.8 to 7.4 mg/L). Laboratory-measured pH values ranged from 6.2 to 7.0 (median = 6.4) and 80% of samples had values below the CWQG and CDWQG of pH 6.5. Total dissolved solids ranged from 11 to 55 mg/L (median = 19 mg/L). Concentrations of TSS were generally below the DL of 3 mg/L, with two samples yielding higher values: 5 mg/L in the late spring sample from Station G-S1, and 14 mg/L in a fall sample from Station L-S1. Turbidity was variable (0.22 to 3.7 NTU), and was not obviously correlated to TSS concentrations.

Major ions concentrations were similar between sampling events and streams (Appendix E, Table E-14). The dominant ions were bicarbonate, calcium, and sulphate, which were also the dominant ions observed in the Lac du Sauvage outlet water samples (Section 4.1). All concentrations of major ions were below CWQG and CDWQG.

Concentrations of most nutrients were similar between sampling events and stations in the sub-basin streams, with the exception of samples from Station L-S1 where the highest concentrations of TN and TKN were measured in the fall sample (Appendix E, Table E-14):

- Total ammonia concentrations were variable among sampling events and stations, but were below CWQG. Concentrations ranged from less than 0.005 to 0.024 mg N/L, with the highest concentration measured in the fall sample from Station L-S1.
- Total Kjeldahl nitrogen concentrations ranged from 0.14 to 0.31 mg/L with the exception of the fall sample from Station L-S1, which had a TKN concentration of 1.4 mg/L.
- Nitrate and nitrite concentrations were generally below their respective DLs (i.e., less than 0.006 mg N/L and less than 0.002 mg N/L), with the exception of samples from Stations C-S1, D-S1, I-S1, and K-S1 that had nitrate concentrations ranging from 0.0078 to 0.059 mg N/L.
- Total phosphorus and TDP concentrations were similar among sampling events and stations, with the exception of Station L-S1. The fall sample from Station L-S1 had higher TP and TDP concentrations in the fall (0.095 mg P/L for TP and 0.05 mg P/L for TDP), compared to late spring concentrations of 0.011 mg P/L for TP and 0.0056 mg P/L for TDP. Dissolved orthophosphate concentrations were below the DL (less than 0.001 mg P/L).
- Concentrations of SRSi were similar among most samples (i.e., 0.095 to 0.38 mg/L), with the exception of notably higher concentrations measured in fall samples from Stations E-S2 (0.87 mg/L), F-S1 (1.8 mg/L), and K-S1 (0.75 mg/L).
- Most of the organic carbon measured in the samples was present as DOC; concentrations ranged from 2.4 to 12 mg/L and TOC concentrations ranged from 2.6 to 13 mg/L, with the highest concentration measured in the fall sample from Station L-S1.

Based on the CCME (2004) trophic classification of streams (Table 2.7-5), the TP concentrations measured in the sub-basin streams would classify the streams as oligotrophic, except for Stream L-S1 which would be classified as eutrophic.

Total and dissolved metals concentrations in the sub-basin streams were either below their method detection limits or below guidelines and objectives with exception of the following metals (Appendix E, Table E-14):

- Total aluminum concentrations ranged from 6.9 to 34 µg/L in 15 of the 16 samples; 10 of these 15 samples had laboratory-measured pH of less than 6.5, and thus had total aluminum concentrations that were above the chronic pH-dependent CWQG of 5 µg/L. One sample collected during the fall event from Station L-S1 had a total aluminum concentration of 227 µg/L, which is higher than the associated CWQG of 100 µg/L (laboratory-measured pH in this sample was pH 6.7). Dissolved aluminum concentrations ranged from 3.4 to 113 µg/L in all 16 samples; the dissolved fraction represented, on average, less than 65% of the total fraction.

- Most total chromium concentrations ranged from less than 0.06 to 0.26 µg/L; the fall sample from Station L-S1 had a total chromium concentration of 1.3 µg/L, which was above the chronic CWQG for hexavalent chromium of 1 µg/L (note that concentrations of hexavalent chromium were not determined).
- Total copper concentrations ranged from 0.38 to 0.83 µg/L in most stream samples. However, the late spring and fall samples from Station L-S1 had concentrations of 2.1 and 3.3 µg/L, respectively, which were above the chronic hardness-dependent CWQG of 2 µg/L. Dissolved copper concentrations ranged from 0.39 to 2.1 µg/L; the dissolved copper concentration in the fall sample from Station L-S1 was above the CWQG.
- Total iron concentrations ranged from 21 to 290 µg/L in most samples, with the exception of the fall sample from Station L-S1, which had a total iron concentration of 1,290 µg/L. This result was an unusual value for the dataset and may be an anomaly. This concentration was above the chronic CWQG and CDWQG of 300 µg/L. The proportion of dissolved iron varied among samples (i.e., 29% to 91%); dissolved iron concentrations ranged from 9.0 to 1,120 µg/L.
- Total manganese concentrations ranged from 1.7 to 15 µg/L in most samples, with the exception of the fall sample from Station L-S1, which had a total manganese concentration of 96 µg/L. This value was above the chronic CDWQG of 50 µg/L; dissolved manganese concentrations ranged from 1.4 to 73 µg/L.

Concentrations of hydrocarbons were below the DLs in all samples from the sub-basin streams with the exception of one: the total recoverable hydrocarbon concentration in the fall sample collected at Station I-S1 was 1 mg/L, which is equal to the DL (Appendix E, Table E-14).

Fecal coliform concentrations in the sub-basin streams ranged from below the laboratory DL (1 CFU/100 mL) to 12 CFU/100 mL (Appendix E, Table E-14); fecal coliforms were detected in almost half of the samples collected. Fecal coliforms were detected in several late spring samples from Stations C-S1, D-S1, G-S1, I-S1, and L-S1, and two fall samples from Stations F-S1 and L-S1.

5 2013 LAKE SEDIMENT QUALITY RESULTS

5.1 Lac du Sauvage

Fourteen sediment samples were collected during the summer sampling event in Lac du Sauvage. These samples were collected from seven deep stations (Aa-1, Ab-1, Ac-1, Ac-4, Ac-7, Ad-1, and Ae-1), and seven shallow stations (Aa-2, Ab-2, Ac-2, Ac-5, Ac-8, Ad-2, and Ae-2). The deep stations had sample depths of 11.2 to 12.8 m and the shallow stations had sample depths of 3.5 to 5.3 m.

Particle size distribution, organic matter content, and pH were similar in deep and shallow stations (Table 5.1-1). The sediments were predominantly silt (median = 78%), with the exception of the sample from Station Ac-5, which had a higher proportion of sand (49%) (Sediment Quality Data [Appendix F, Table F-1]). Organic matter content ranged from 1.7% to 3.7% (median = 2.7%). The pH of the sediments ranged from pH 5.7 to 8.5 (median = pH 6.2).

Overall, nutrient concentrations were variable, but median concentrations were similar in deep and shallow stations (Table 5.1-1). Total Kjeldahl nitrogen concentrations ranged from 0.075% to 0.21%, with an overall median concentration of 0.14%. Concentrations of TP ranged from 511 to 1,850 milligrams per kilogram dry weight (mg/kg dw), with an overall median concentration of 1,020 mg/kg dw. Total organic carbon ranged from 0.75% to 1.8%, with an overall median of 1.2%.

Total metals concentrations were generally below sediment quality guidelines (SQGs), with the exception of arsenic, chromium, and copper (Table 5.1-1; Appendix F, Table F-1). Total arsenic concentrations were above the CCME (2001) ISQG of 5.9 mg/kg dw in 13 of the 14 samples, and above the PEL of 17 mg/kg dw in 11 samples. Total chromium concentrations were above the ISQG of 37.3 mg/kg dw, but below the PEL of 90 mg/kg dw in all samples. Total copper concentration was above the ISQG of 35.7 mg/kg dw in one sample; no samples had concentrations above the PEL of 197 mg/kg dw.

The range and median values of metals were mostly similar between the deep and shallow stations in Lac du Sauvage (Table 5.1-1) with the exception of arsenic, copper, iron, and manganese. For these four metals, median concentrations were higher in the deep stations.

Table 5.1-1 Sediment Chemistry at Deep and Shallow Stations in Lac du Sauvage, 2013

Parameter	Unit	CCME SQG		Deep Stations		Shallow Stations	
		ISQG	PEL	Range	Median	Range	Median
Physical Characteristics							
Organic matter	%	—	—	1.8 to 3.7	3	1.7 to 3.4	2.6
pH	pH units	—	—	5.7 to 7.1	6.4	5.7 to 8.5	6.1
Clay (<4 μm)	%	—	—	11 to 22	21	7.4 to 20	14
Silt (4 μm to 0.063 mm)	%	—	—	76 to 84	78	40 to 87	77
Fine sand (0.063 mm to 0.2 mm)	%	—	—	0.29 to 4.4	1.2	0.79 to 27	2.9
Coarse sand (0.2 mm to 2.0 mm)	%	—	—	<0.1 to 0.52	0.11	0.25 to 22	1.3
Gravel (>2 mm)	%	—	—	<0.1 to <0.1	<0.1	<0.1 to 3.3	<0.1
Nutrients							
Available ammonium-N	mg/kg dw	—	—	11 to 16	13	9 to 51	14
Nitrogen, Organic	%	—	—	0.01 to 0.15	0.14	0.074 to 0.2	0.13
Nitrogen, Total Kjeldahl	%	—	—	0.098 to 0.16	0.14	0.075 to 0.21	0.14
Phosphate, Available-P	mg/kg dw	—	—	9.2 to 25	15	5.2 to 101	16
Phosphorus	mg/kg dw	—	—	599 to 1,850	1,090	511 to 1,170	1,010
Carbon, Total	%	—	—	1.0 to 1.6	1.5	0.8 to 2	1.3
Carbon, Inorganic	%	—	—	0.14 to 0.27	0.21	<0.1 to 0.2	0.15
Carbon, Total Organic	%	—	—	0.76 to 1.4	1.2	0.75 to 1.8	1.2
Total Metals							
Aluminum	mg/kg dw	—	—	11,600 to 19,000	17,400	11,900 to 19,400	14,900
Arsenic	mg/kg dw	5.9	17	4.2 to <u>196</u>	<u>81</u>	7 to <u>61</u>	<u>32</u>
Barium	mg/kg dw	—	—	83 to 178	151	98 to 144	121
Beryllium	mg/kg dw	—	—	<0.5 to 0.57	0.51	<0.5 to 0.56	<0.5
Cadmium	mg/kg dw	0.6	3.5	<0.1 to 0.2	0.16	<0.1 to 0.16	<0.1
Chromium	mg/kg dw	37.3	90	45 to 72	66	45 to 69	59
Cobalt	mg/kg dw	—	—	7.3 to 26	20	12 to 18	13
Copper	mg/kg dw	35.7	197	23 to 36	31	16 to 29	23
Iron	mg/kg dw	—	—	16,100 to 55,500	39,800	21,100 to 35,600	28,600

Table 5.1-1 Sediment Chemistry at Deep and Shallow Stations in Lac du Sauvage, 2013

Parameter	Unit	CCME SQG		Deep Stations		Shallow Stations	
		ISQG	PEL	Range	Median	Range	Median
Total Metals (Continued)							
Lead	mg/kg dw	35	91.3	3.3 to 5.1	4.7	2.9 to 5.1	4.1
Lithium	mg/kg dw	—	—	28 to 49	41	28 to 50	41
Manganese	mg/kg dw	—	—	199 to 3,490	2,080	396 to 932	614
Mercury	mg/kg dw	0.17	0.486	0.014 to 0.036	0.024	0.0064 to 0.031	0.012
Molybdenum	mg/kg dw	—	—	<1 to 3.4	2.6	<1 to 2	1.2
Nickel	mg/kg dw	—	—	23 to 52	43	28 to 46	35
Strontium	mg/kg dw	—	—	10 to 15	13	7.9 to 16	12
Sulfur	mg/kg dw	—	—	<500 to 700	700	<500 to 1,100	600
Thallium	mg/kg dw	—	—	0.16 to 0.31	0.28	0.17 to 0.31	0.24
Titanium	mg/kg dw	—	—	835 to 1,260	1150	794 to 1,250	1,020
Uranium	mg/kg dw	—	—	1.7 to 2.9	2.7	1.6 to 2.8	2.2
Vanadium	mg/kg dw	—	—	36 to 60	54	38 to 57	47
Zinc	mg/kg dw	123	315	42 to 80	69	44 to 73	60

Notes: Antimony, bismuth, selenium, silver, and tin data were not included in the table, as all reported concentrations were below the detection limit.

Values above ISQG are **bolded**; values above PEL are **bolded and underlined**.

CCME SQG = Canadian Council of Ministers of the Environment (CCME) Sediment Quality Guideline (SQG) (CCME 2001); ISQG = Interim Sediment Quality Guideline; PEL = Probable Effect Level; % = percent; < = less than; µm = micrometre; mm = millimetre; > = greater than; mg/kg dw = milligrams per kilogram as dry weight; "—" = no guideline available.

5.2 Duchess Lake

Sediment samples were collected in Duchess Lake during the summer sampling event at four stations: two deep stations (Af-1 and Af-7, 13.5 m and 12.4 m deep, respectively), and two shallow stations (Af-2 and Af-4, 4.3 and 3.1 m deep, respectively).

Physical characteristics of the sediments were similar among deep and shallow stations (Table 5.2-1). The sediments in Duchess Lake were predominantly silt (median = 81%) (Appendix F, Table F-2). Organic matter content ranged from 2.3% to 3.4% (median = 2.4%). The pH of the sediments ranged from pH 5.4 to 6.2 (median = pH 5.7).

Nutrient concentrations were also similar among deep and shallow stations in Duchess Lake (Table 5.2-1). Concentrations of TKN in the sediments at Duchess Lake ranged from 0.091% to 0.22%, with an overall median of 0.13%. Concentration of TP ranged from 585 to 1,640 mg/kg dw (median = 882 mg/kg dw). Concentrations of TOC ranged from 0.75% to 2.1% (median = 1.2%).

Total metal concentrations in Duchess Lake were below SQGs, with the exception of arsenic and chromium (Table 5.2-1). Arsenic concentrations ranged from 5.7 to 87 mg/kg dw and were above the ISQG of 5.9 mg/kg dw in three of the four samples, and above the PEL of 17 mg/kg dw in one sample (Appendix F, Table F-2). Chromium concentrations ranged from 59 to 64 mg/kg dw and were above the ISQG (i.e., 37.3 mg/kg dw) in all samples.

Table 5.2-1 Sediment Chemistry at Deep and Shallow Stations in Duchess Lake, 2013

Parameter	Unit	CCME SQG		Deep Stations	Shallow Stations
		ISQG	PEL	Range	Range
Physical Characteristics					
Organic matter	%	—	—	2.3 to 3.4	2.3 to 2.5
pH	pH units	—	—	5.4 to 6.2	5.7 to 5.9
Clay content (<4 µm)	%	—	—	14 to 18	13 to 17
Silt content (4 µm to 0.063 mm)	%	—	—	81 to 84	81 to 82
Fine sand (0.063 mm to 0.2 mm)	%	—	—	0.23 to 2	1.3 to 4.6
Coarse sand (0.2 mm to 2.0 mm)	%	—	—	<0.1 to 0.3	0.11 to 0.37
Gravel (>2 mm)	%	—	—	<0.1	<0.1
Nutrients					
Available ammonium-N	mg/kg dw	—	—	18 to 21	11 to 18
Nitrogen, Organic	%	—	—	0.12 to 0.21	0.09 to 0.15
Nitrogen, Total Kjeldahl	%	—	—	0.13 to 0.21	0.09 to 0.15
Phosphate, Available-P	mg/kg dw	—	—	9.7 to 27	12 to 21
Phosphorus	mg/kg dw	—	—	692 to 1,010	585 to 1,640
Carbon, Total	%	—	—	1.2 to 2.1	0.9 to 1.4
Carbon, Inorganic	%	—	—	<0.1	0.13 to 0.18
Carbon, Total Organic	%	—	—	1.2 to 2.1	0.75 to 1.3

Table 5.2-1 Sediment Chemistry at Deep and Shallow Stations in Duchess Lake, 2013

Parameter	Unit	CCME SQG		Deep Stations	Shallow Stations
		ISQG	PEL	Range	Range
Metals					
Aluminum	mg/kg dw	—	—	14,800 to 17,500	16,100 to 16,800
Arsenic	mg/kg dw	5.9	17	5.7 to 17	8 to 87
Barium	mg/kg dw	—	—	93 to 128	120 to 121
Beryllium	mg/kg dw	—	—	0.48 to 0.51	<0.5 to 0.6
Bismuth	mg/kg dw	0.6	3.5	0.32 to <1	<1
Chromium	mg/kg dw	37.3	90	53 to 64	62 to 63
Cobalt	mg/kg dw	—	—	11 to 12	11 to 17
Copper	mg/kg dw	35.7	197	20 to 28	18 to 21
Iron	mg/kg dw	—	—	24,600 to 28,200	24,900 to 53,700
Lead	mg/kg dw	35	91.3	4.3 to 4.5	4 to 4.3
Lithium	mg/kg dw	—	—	39 to 45	41 to 42
Manganese	mg/kg dw	—	—	236 to 286	260 to 667
Mercury	mg/kg dw	0.17	0.486	0.014 to 0.020	0.0084 to 0.012
Molybdenum	mg/kg dw	—	—	<1 to 1.6	<1 to 3.2
Nickel	mg/kg dw	—	—	29 to 34	32 to 32
Strontium	mg/kg dw	—	—	12 to 14	11 to 13
Sulfur	mg/kg dw	—	—	<500 to 1,100	<500 to 600
Thallium	mg/kg dw	—	—	0.21 to 0.26	<0.5
Titanium	mg/kg dw	—	—	970 to 1,210	1,100 to 1,130
Uranium	mg/kg dw	—	—	2.6 to 3	2.3 to 2.5
Vanadium	mg/kg dw	—	—	47 to 53	49 to 52
Zinc	mg/kg dw	123	315	58 to 64	62 to 62

Notes: Antimony, cadmium, selenium, silver, and tin data were not included in the table as all reported concentrations were below the detection limit.

Values above ISQG are **bolded**; values above PEL are **bolded and underlined**.

CCME SQG = Canadian Council of Ministers of the Environment (CCME) Sediment Quality Guideline (SQG) (CCME 2001);

ISQG = Interim Sediment Quality Guideline; PEL = Probable Effect Level; % = percent; < = less

than; µm = micrometre; mm = millimetre; > = greater than; mg/kg dw = milligrams per kilogram as dry weight; — = no guideline available.

5.3 Lake Af1

A sediment sample was collected in Lake Af1 during the summer sampling event (from a deep station (Station Af-10), which had a depth of 7.3 m (Appendix F, Table F-3).

The sediment was predominantly silt (81%) and clay (18%). Organic matter content was 3.4% and the sediment pH was 5.4. Nutrient concentrations were 0.22% for TKN, 1,010 mg/kg dw for TP, and 2.1% for TOC.

Total metal concentrations were below SQGs, with the exception of arsenic and chromium; the arsenic concentration was 6.7 mg/kg dw (above the ISQG of 5.9 mg/kg dw), and the chromium concentration was 53 mg/kg dw (above the ISQG of 37.3 mg/kg dw).

5.4 Sub-Basin Lakes

Sediment sampling was limited to one sub-basin lake (Lake C1) during the fall sampling event (Appendix F, Table F-4).

The sediment at Lake C1 was predominantly silt (76%) and clay (22%), with relatively higher organic matter content (9.1%). The pH of the Lake C1 sediment was pH 5.4. Nutrient concentrations in the sediment were 0.32% TKN, 947 mg/kg dw TP, and 5.8% TOC.

Total metals concentrations were below SQGs with the exception of arsenic, chromium, and copper (Appendix F, Table F-4). The arsenic concentration was 15 mg/kg dw (above the ISQG of 5.9 mg/kg dw), the chromium concentration was 60 mg/kg dw (above the ISQG of 37.3 mg/kg dw), and the copper concentration was 54 mg/kg dw (above the ISQG of 35.7 mg/kg dw).

5.5 Lake E1

Sediment samples were collected in Lake E1 from two stations during the summer event: Station E-L1-1 with a depth of 11.6 m (deep station), and Station E-L1-2 with a depth of 3.5 m (shallow station).

Sediment physical characteristics were similar between the deep and shallow stations in Lake E1 (Appendix F, Table F-5), with the sediment predominantly silt (78% and 79%, respectively), and clay (17%). Both sediments had a low proportion of sand (4% and 3%, respectively), but a small amount of gravel was measured at the deep station (0.85%). Organic matter content was similar (6.3% and 6.4%, respectively), and sediment pH was higher at the deeper station (pH 6.2, compared to pH 5.8).

Nutrient concentrations were similar in deep and shallow stations in Lake E1 (Appendix F, Table F-5). Concentrations of TKN were 0.34% and 0.36%, respectively, and TOC concentrations were 3.4% and 3.7%, respectively. Total phosphorus concentrations were more variable: 1,010 mg/kg dw in the deep station and 715 mg/kg dw in the shallow station.

Total metals concentrations in Lake E1 were similar between the deep and shallow stations. Concentrations were below SQGs, with the exception of arsenic and chromium (Appendix F, Table F-5). Arsenic (9.3 and 6.9 mg/kg) and chromium (66 and 64 mg/kg) concentrations in samples E-L1-1 and E-L1-2, respectively, were above their corresponding ISQG (arsenic: 5.9 mg/kg dw, and chromium: 37.3 mg/kg dw).

5.6 Paul Lake

Sediment samples were collected in Paul Lake from five deep stations during the fall sampling event (i.e., PL-1, PL-2, PL-3, PL-4, and PL-5). The deep stations had depths between 8.0 and 13.0 m; Station PL-3 had a depth of 13.0 m (Appendix F, Table F-6).

Paul Lake sediments were similar in physical characteristics. The sediments were predominantly silt (median = 73%) and clay (median = 27%), with a sediment pH range of 5.2 to 5.6 (Table 5.6-1).

Nutrient concentrations were similar among the stations (Table 5.6-1). Concentrations of TKN in the Paul Lake sediments ranged from 0.17% to 0.28% (median = 0.23%); the concentrations of TP ranged from 759 to 1,340 mg/kg dw (median = 1,150 mg/kg dw), and TOC concentrations ranged from 2.0% to 2.6% (median = 2.4%).

Total metals concentrations in Paul Lake were below SQGs, with the exception of arsenic, chromium, and copper (Table 5.6-1; Appendix F, Table F-6). Arsenic concentrations were above the ISQG of 5.9 mg/kg dw in all five samples, and above the PEL of 17 mg/kg dw in two samples. Chromium concentrations were above the ISQG of 37.3 mg/kg dw in all samples, and copper concentrations were above the ISQG of 35.7 mg/kg dw in three samples.

Table 5.6-1 Sediment Chemistry at Deep Stations in Paul Lake, 2013

Parameter	Unit	CCME SQG		Range	Median
		ISQG	PEL		
Physical Characteristics					
Organic matter	%	—	—	3.4 to 4.2	3.8
pH	pH units	—	—	5.24 to 5.59	5.5
Clay content (<4 µm)	%	—	—	21.8 to 29.7	27
Silt content (4 µm to 0.063 mm)	%	—	—	70.2 to 77.8	73
Fine sand (0.063 mm to 0.2 mm)	%	—	—	<0.1 to 0.3	<0.1
Coarse sand (0.2 mm to 2.0 mm)	%	—	—	<0.1 to 0.12	<0.1
Gravel (>2 mm)	%	—	—	<0.1	<0.1
Nutrients					
Available ammonium-N	mg/kg dw	—	—	12.8 to 21.5	17
Nitrogen, Organic	%	—	—	0.163 to 0.278	0.22
Nitrogen, Total Kjeldahl	%	—	—	0.166 to 0.28	0.23
Phosphate, Available-P	mg/kg dw	—	—	8.8 to 70.5	13
Phosphorus	mg/kg dw	—	—	759 to 1,340	1,150
Carbon, Total	%	—	—	2 to 2.6	2.4
Carbon, Inorganic	%	—	—	<0.1	<0.1
Carbon, Total Organic	%	—	—	2.02 to 2.61	2.4
Total Metals					
Aluminum	mg/kg dw	—	—	18,700 to 21,700	20,700
Arsenic	mg/kg dw	5.9	17	8.4 to <u>33</u>	15
Barium	mg/kg dw	—	—	122 to 149	143
Beryllium	mg/kg dw	—	—	0.6 to 0.71	0.68
Bismuth	mg/kg dw	—	—	0.37 to 0.53	0.48
Cadmium	mg/kg dw	0.6	3.5	0.11 to 0.13	0.13
Chromium	mg/kg dw	37.3	90	68 to 78	74
Cobalt	mg/kg dw	—	—	14 to 22.8	15
Copper	mg/kg dw	35.7	197	29.3 to 41	36
Iron	mg/kg dw	—	—	29,000 to 41,000	34,000
Lead	mg/kg dw	35	91.3	5.01 to 5.91	5.8

Table 5.6-1 Sediment Chemistry at Deep Stations in Paul Lake, 2013

Parameter	Unit	CCME SQG		Range	Median
		ISQG	PEL		
Total Metals (Continued)					
Lithium	mg/kg dw	—	—	48.6 to 56.1	52
Manganese	mg/kg dw	—	—	324 to 566	372
Mercury	mg/kg dw	0.17	0.486	0.0218 to 0.0323	0.026
Molybdenum	mg/kg dw	—	—	0.77 to 2.02	1.3
Nickel	mg/kg dw	—	—	41.2 to 50.5	45
Selenium	mg/kg dw	—	—	<0.2 to 0.25	0.21
Strontium	mg/kg dw	—	—	14.4 to 15.9	15
Sulfur	mg/kg dw	—	—	1,100 to 6,100	1,600
Thallium	mg/kg dw	—	—	0.257 to 0.305	0.29
Titanium	mg/kg dw	—	—	1,110 to 1,300	1,210
Uranium	mg/kg dw	—	—	3.03 to 3.85	3.5
Vanadium	mg/kg dw	—	—	56.6 to 65.2	60
Zinc	mg/kg dw	123	315	77 to 89.5	86

Notes: Antimony, silver, and tin data were not included in the table, as all reported concentrations were below the detection limit.

Values above ISQG are **bolded**; values above PEL are **bolded and underlined**.

CCME SQG = Canadian Council of Minister of the Environment (CCME) Sediment Quality Guideline (SQG) (CCME 2001);
ISQG = Interim Sediment Quality Guideline; PEL = Probable Effect Level; % = percent; < = less than; µm = micrometre; mm = millimetre; > = greater than; mg/kg dw = milligrams per kilogram dry weight; — = no guideline available.

6 2013 STREAM SEDIMENT QUALITY RESULTS

6.1 Lac du Sauvage Outlet

A sediment sample was collected at Station Ab-S1 (Lac du Sauvage outlet) during the fall sampling program (Appendix F, Table F-7). The sediment was predominantly sand (58%) and gravel (33%); the amount of silt (8.3%) and clay (0.88%) was low. Because of the higher proportion of sand, organic matter and nutrient contents were low. Organic matter content and nitrogen concentrations were not detected (i.e., less than 1% organic matter and less than 0.02% TKN), the TP concentration was 471 mg/kg dw, and TOC concentration was 0.22%. The pH of Station Ab-S1 sediment was pH 6.7.

Total metals concentrations were below SQGs, with the exception of chromium (Appendix F, Table F-7). The chromium concentration was 56 mg/kg dw, which was above the CCME (2001) ISQG of 37.3 mg/kg dw.

6.2 Sub-Basin Streams

Sediment samples were collected from six other streams in the Lac du Sauvage basin: Streams C1, D1, E2, F1, G1, and L1. One sediment sample was collected at each stream, with the exception of Stream E2, which had four stations established along the length of the stream between Lake E1 and Lake E2 (Appendix F, Table F-8). In total, nine samples were collected from the streams during summer or fall sampling events.

Physical characteristics of the sediments differed among the streams:

- Sediment from Stations C-S1 and F-S1 was predominantly sand, with low clay content and low organic matter content (Appendix F, Table F-8).
- Sediment from Stations D-S1 and L-S1 was sandy-silty, with the highest organic matter content measured in the stream sediments (9.5%).
- Stream G1 sediment was very coarse, with 45% gravel and 50% sand, and organic matter content below the DL of 1%.
- Sediment from Stream E2 comprised a silty to silty-sandy composition, with organic matter content ranging from 3.5% to 9.5%. Sediment pH ranged from pH 5.3 to pH 6.8, with the highest pH measured in the sediment with gravel (i.e., Stream G1).

Nutrient concentrations were variable among stream samples, and were generally higher in sediments with high organic matter content. Sediments from Stations D-S1, L-S1, and E-S2-3 had the highest TOC content (9.5%), and the highest concentrations of TKN and TP (Appendix F, Table F-8). For example, TKN concentrations ranged from 0.25% to 0.36% in these three sediment samples, compared to 0.03% to 0.16% in the other stream sediments. Similarly, TOC ranged from less than 0.1% to 6.5% in these samples, compared to less than 0.1 to 2.9 mg/L in the other samples.



Total metals concentrations were below SQGs, with the exception of arsenic and chromium (Appendix F, Table F-8). Arsenic concentrations ranged from 0.17 to 5.7 mg/kg dw in most samples, with the exception of Station D-S1 (7.1 mg/kg dw, which is higher than the ISQG of 5.9 mg/kg dw). Chromium concentrations ranged from 1.3 to 35.3 mg/kg dw in all but two samples. Samples from Stations G-S1 and E-S2 had chromium concentrations of 96 mg/kg dw and 42 mg/kg dw, respectively, higher than the ISQG of 37.3 mg/kg dw. Chromium concentration in sediment from Station G-S1 was also above the PEL of 90 mg/kg dw.

7 SUMMARY

7.1 2013 Baseline Data

Baseline water and sediment quality programs were conducted in the baseline study area during open-water conditions in 2013. Thirty lake stations and seven stream stations were sampled for field and laboratory water quality parameters across nine lakes (Lac du Sauvage, Duchess Lake, Lake Af1, Lake E1, Paul Lake, and lakes of the Lac du Sauvage sub-basin, which include Lakes C1, D3 [Counts Lake], G2, H1), and seven streams (Lac du Sauvage outlet and streams of the Lac du Sauvage sub-basin [streams C1, D1, F1, G1, L1, E2]). Sediment samples were collected from 22 lake stations across 6 lakes (Lac du Sauvage, Duchess Lake, Lake Af1, Lake C1, Lake E1, Paul Lake) and 10 stream stations across 7 streams (Lac du Sauvage outlet and streams of the Lac du Sauvage sub-basin [Streams C1, D1, F1, G1, L1, E2]).

7.1.1 Water Quality

Profile measurements of the water column and water samples were collected from each lake and stream monitoring station at least once during the open-water season (i.e., late spring, summer, and fall) in 2013.

7.1.1.1 *Field-Measured Physico-Chemical Parameters*

All deep lake stations across the baseline study area that were sampled in the summer, including Lac du Sauvage, Duchess Lake, Paul Lake, and Lac du Sauvage sub-basin Lakes C1, D3 (Counts Lake), and E1, showed evidence of thermal stratification at depth. In general, these stations tended to be well-mixed (isothermal) in the late spring and fall, and certain stations in Lac du Sauvage were well-mixed by the end of August. However, certain Lac du Sauvage and Duchess Lake stations (i.e., Aa-1, Ae-1, Ad-1, Af-7, and Af-10), showed the onset of thermal stratification in late spring. Similar to the deep stations, shallow stations in Lac du Sauvage and Duchess Lake that were deeper than 3 m tended to be stratified in the summer and well mixed in the late spring and fall.

Stream temperatures (as measured at 0.3 m below the surface) across the baseline study area during the three sampling events varied from 4.4°C to 16.7°C (median = 10.2°C). Temperatures were higher at the Lac du Sauvage outlet (Station Ab-S1) (median = 13.6°C) than in the sub-basin streams (median = 10.0°C). Temperature measurements were highest in the summer and lowest in the fall.

Dissolved oxygen concentrations in the lakes were generally higher than the CCME (1999) CWQG of 6.5 mg/L at all depths in all three open-water sampling events, with two exceptions:

- Dissolved oxygen concentrations at Station Af-10 (Lake Af1) in the summer declined from 6.3 mg/L (60% saturation) at 6 m to 1.1 mg/L (6% saturation) at 8 m.
- In Lake E1 during the summer sampling event, DO concentrations at the deep station (Station E-L1-1) declined sharply with depth, from 8.4 mg/L (76% saturation) at 8 m to 1.8 mg/L (17% saturation) at 11 m.

No evidence of oxic stratification was observed at any other lake station. Dissolved oxygen in streams across the baseline study area varied from 9.7 to 12.2 mg/L (median = 10.7 mg/L) (83% to 110%; median = 97%) and was marginally higher at the Lac du Sauvage outlet (median = 10.8 mg/L; 104%) than in the Lac du Sauvage sub-basin streams (median = 10.7 mg/L; 95%).

Field-measured specific conductivity was similar among lakes and did not vary with depth. Stations in Lac du Sauvage and Duchess Lake tended to have slightly higher specific conductivity in the fall (i.e., 20 to 24 $\mu\text{S}/\text{cm}$) than in the late spring or summer (i.e., 10 to 15 $\mu\text{S}/\text{cm}$). In contrast, stations in Lake Af1 and Lake E1 had lower conductivity in the fall (i.e., 8.1 to 8.5 $\mu\text{S}/\text{cm}$) compared to other sampling periods (i.e., 10 to 15 $\mu\text{S}/\text{cm}$). Specific conductivity ranged from 11 to 20 $\mu\text{S}/\text{cm}$ in the sub-basin lakes (Lake C1, Lake D3 [Counts Lake], Lake G2, and Lake H1), and in Paul Lake.

7.1.1.2 Defining the Euphotic Zone

During the field program, Secchi depth was measured to provide an estimate of the euphotic zone for the purpose of collecting depth-integrated samples for nutrients and chlorophyll *a*. Throughout the open-water season, mean Secchi depths were deepest in Lac du Sauvage, ranging between 6.4 and 8.8 m. Mean Secchi depths in the remaining waterbodies were lower, ranging between 2.0 and 4.7 m. Secchi depths in Lac du Sauvage, Duchess Lake, and Lake E1 were deepest during the summer; Paul Lake had the deepest Secchi depth reading in the late spring. Seasonal variability in Secchi depths was not discernible in the sub-basin Lakes C1, D3 (Counts Lake), G2, and H1. Typically, at the shallow stations in Lac du Sauvage, Duchess Lake, and Lake E1, the lakebed was visible from the surface (i.e., the Secchi depth was greater than the water column depth).

The euphotic zone is better defined from vertical light attenuation measurements, because these measurements allow more accurate determination of the depth at which 1% ambient light occurs. Light profile measurements indicated well mixed surface water systems with uniform light regimes; however, the rate of attenuation through the surface water column, as provided by the attenuation coefficient (K_d), indicated variability among the lake stations (Table 7.1-1). All lakes sampled during the 2013 field program can be characterized as clear water lakes, with deep euphotic zones. Lac du Sauvage and Duchess Lake had a lower K_d range (and therefore deeper light penetration) compared to Lake Af1, Lake E1, and Paul Lake. The light profile data were generally consistent with the Secchi depth.

Table 7.1-1 Attenuation Coefficients at Deep Stations in Lakes of the Baseline Study Area, 2013

Lake	Sampling Event		
	Late Spring	Summer	Fall
Lac du Sauvage ^(a)	0.44	0.38	0.45
Duchess Lake ^(a)	0.50	0.49	0.40
Lake Af1	0.71	0.83	0.74
Lake E1	—	0.61	0.67
Paul Lake ^(a)	0.57	0.58	0.54

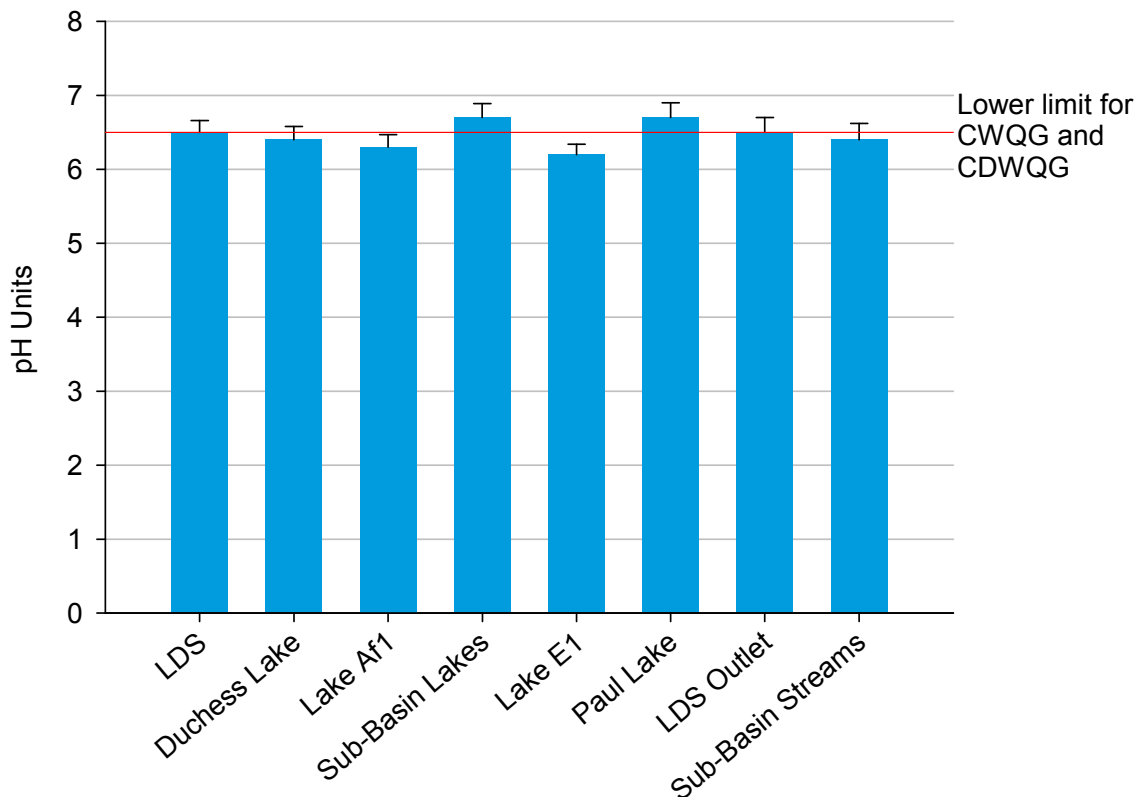
a) Average K_d (attenuation coefficient) values are presented.

— = not measured.

7.1.1.3 Water Chemistry in Discrete Samples

Due to the absence of reliable field pH data, laboratory pH was used to characterize pH in the lakes and streams of the baseline study area. Laboratory pH measurements indicated slightly acidic conditions, frequently at pH values below the lower limit of the CWQGs (i.e., pH 6.5). The mean pH value for the majority of the lakes and streams was just below the lower limit of the chronic CWQG and the CDWQG (Figure 7.1-1).

Figure 7.1-1 Mean (\pm Standard Deviation) pH for the Baseline Study Area during the Open-Water Period, 2013



CWQG = Canadian Water Quality Guideline; CDWQG = Canadian Drinking Water Quality Guideline; LDS = Lac du Sauvage.

Water hardness, as classified by the qualitative scale of lake hardness (McNeely et al. 1979), was very soft across the entire baseline study area. Total hardness ranged from 3.6 to 6.1 mg/L in the lakes (median = 4.7 mg/L), and 3.8 to 7.4 mg/L in the streams (median = 4.7 mg/L). Potential sensitivity of the waterbodies to acid deposition was classified based on the measured alkalinity values, the lake acid sensitivity scale (Saffran and Trew 1996), and the stream acid sensitivity scales (Boward et al. 1996). Total alkalinity ranged from 2.6 to 6.5 mg/L in the lakes (median = 4.1 mg/L), and from 2.8 to 6.9 mg/L in the streams (median = 3.9 mg/L). Lakes across the baseline study area were classified as highly sensitive to acid deposition; the streams were classified as sensitive to acid deposition.

Total dissolved solids concentrations were low and similar in lakes and streams of the baseline study area. In lakes, TDS concentrations ranged from less than 10 to 28 mg/L (median = 15 mg/L); in streams, TDS ranged from 11 to 55 mg/L (median = 18 mg/L).

Total suspended solids and turbidity were also low in the lakes and streams. The TSS ranged from less than 3 to 6 mg/L (median = less than 3 mg/L) in the lakes, and from less than 3 to 14 mg/L (median = less than 3 mg/L) in the streams. Turbidity ranged from 0.3 to 2.7 NTU (median = 0.6 NTU) in the lakes, and 0.2 to 3.7 NTU (median = 0.5 NTU) in the streams.

7.1.1.4 Major Ions

Across the baseline study area, the range of major ion concentrations was narrow, with little difference in median concentrations between the areas. Overall, the major ions concentrations were similar across the baseline study area, and below CWQGs and CDWQGs. Major ion concentrations were typically highest in Paul Lake and the Lac du Sauvage sub-basin lakes, and lowest in Lake E1.

Across the baseline study area, bicarbonate, calcium, and sulphate were the dominant major ions in water. Ranges of major ion concentrations were as follows:

- bicarbonate concentrations ranged from less than 0.5 to 8.4 mg/L (median = 6.6 mg/L);
- calcium concentrations ranged from 0.6 to 1.3 mg/L (median = 0.79 mg/L);
- sulphate concentrations ranged from 0.34 to 2.9 mg/L (median = 1.1 mg/L);
- chloride concentrations ranged from less than 0.5 to 0.63 mg/L (median = less than 0.5 mg/L);
- fluoride concentrations ranged from less than 0.02 to 0.034 mg/L (median = less than 0.02 mg/L);
- magnesium concentrations ranged from 0.49 to 1.1 mg/L (median = 0.59 mg/L);
- potassium concentrations ranged from 0.14 to 0.83 mg/L (median = 0.50 mg/L); and,
- sodium concentrations ranged from 0.52 to 1.1 mg/L (median = 0.65 mg/L).

Bicarbonate, calcium, magnesium, sodium, and sulphate concentrations were highest overall in Paul Lake (median = 8.4 mg/L, 0.96 mg/L, 0.86 mg/L, 0.69 mg/L, and 1.7 mg/L, respectively).

Fluoride was highest overall in the sub-basin lakes (median = 0.023 mg/L); potassium was highest overall in the Lac du Sauvage sub-basin lakes and Paul Lake (median = 0.62 mg/L). Bicarbonate concentrations were lowest overall in the sub-basin lakes (median = less than 5 mg/L). Calcium, magnesium, potassium, and sodium were lowest in Lake E1 (median values = 0.65 mg/L, 0.5 mg/L, 0.36 mg/L, and 0.54 mg/L, respectively). Sulphate concentrations were lowest overall in Duchess Lake (median = 0.83 mg/L).

Median fluoride concentrations were below the DL (less than 0.02 mg/L) in all areas except the Lac du Sauvage sub-basin lakes and Paul Lake. Median chloride concentration was the same in all areas (0.5 mg/L).

7.1.1.5 *Nutrients*

Nutrient concentrations in the baseline study area were low:

- Ammonia, nitrate, and nitrite concentrations were often below the laboratory DLs, and consistently below guidelines:
 - Ammonia concentrations ranged from less than 0.005 to 0.034 mg N/L (median = 0.0093 mg N/L);
 - Nitrate concentrations ranged from less than 0.006 to 0.059 mg N/L (median = less than 0.006 mg N/L); and,
 - Nitrite concentrations ranged from less than 0.002 to 0.002 mg N/L (median = less than 0.002 mg N/L).
- TKN concentrations ranged from 0.0026 to 1.4 mg N/L (median = 0.15 mg N/L); concentrations were highest in Lake E1 and Duchess Lake (medians = 0.31 and 0.20 mg N/L, respectively) and lowest in Lac du Sauvage (median = 0.14 mg N/L) and the Lac du Sauvage outlet (Station Ab-S1; median = 0.14 mg N/L).
- TP concentrations ranged from 0.0031 to 0.095 mg P/L (median = 0.013 mg P/L); median concentrations were highest in Lake Af1 (0.021 mg/L) and lowest in Lac du Sauvage (median = 0.0057 mg P/L) and the Lac du Sauvage outlet (median = 0.0060 mg P/L).
- Median concentrations of TDP were similar among lakes and streams, ranging from 0.0016 mg P/L in the sub-basin lakes to 0.0029 mg P/L in Duchess Lake. The overall median concentration was 0.0025 mg P/L.
- Concentrations of SRSi ranged from 0.091 to 1.8 mg/L, with an overall median of 0.14 mg/L.
- Organic content occurred mainly in the dissolved fraction as opposed to the particulate fraction; DOC concentrations ranged 2.4 to 12 mg/L, with an overall median of 3.7 mg/L and TOC concentrations ranged from 2.6 to 13 mg/L.

7.1.1.6 *Metals*

Total aluminum, iron, chromium, copper, and manganese concentrations in lakes and streams were above CWQGs in one or more samples collected in the baseline study area. All other metals were either below CWQGs or below the analytical DLs.

Mean total aluminum concentrations for all lake and stream stations, with the exception of the Lac du Sauvage outlet, were above the lowest chronic pH-dependent CWQG of 5 µg/L (based on pH less than 6.5) (Figure 7.1-2). As illustrated in Figure 7.1-1, mean laboratory-measured pH was below pH 6.5 for most lakes and streams, with the exception of the sub-basin lakes and Paul Lake. Total aluminum concentrations were below the highest chronic CWQG of 100 µg/L (based on pH 6.5 or greater) in most lakes and streams with the exception of Lake E1.

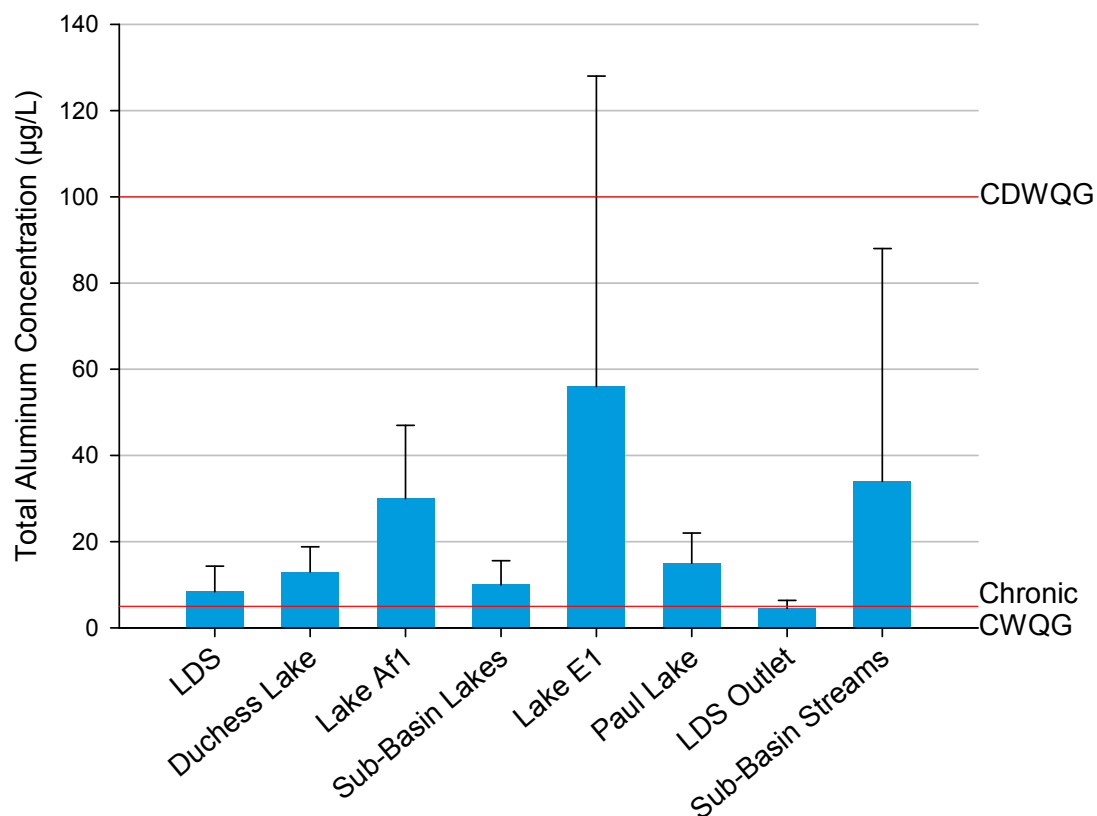
Concentrations of aluminum were above the chronic pH-dependent CWQG of 5 µg/L (based on laboratory pH values less than 6.5) in the following:

- Lac du Sauvage (62% of samples from 14 stations);
- Duchess Lake (80% of samples from four stations);
- Lac du Sauvage sub-basin lakes (17% of samples from four stations);
- Lake E1 (100% of samples from two stations);
- Paul Lake (19% of samples from five stations, but exceedances were limited to three stations);
- the Lac du Sauvage outlet (50% of samples from one station); and,
- the Lac du Sauvage sub-basin streams (69% of samples from nine stations, but exceedances were limited to seven stations).

Concentrations of aluminum were above the chronic pH-dependent CWQG of 100 µg/L (based on laboratory pH values more than 6.5) in Stream L1 (the fall sample) and in Lake E1 (20% of samples from two stations, but exceedances were limited to one station).

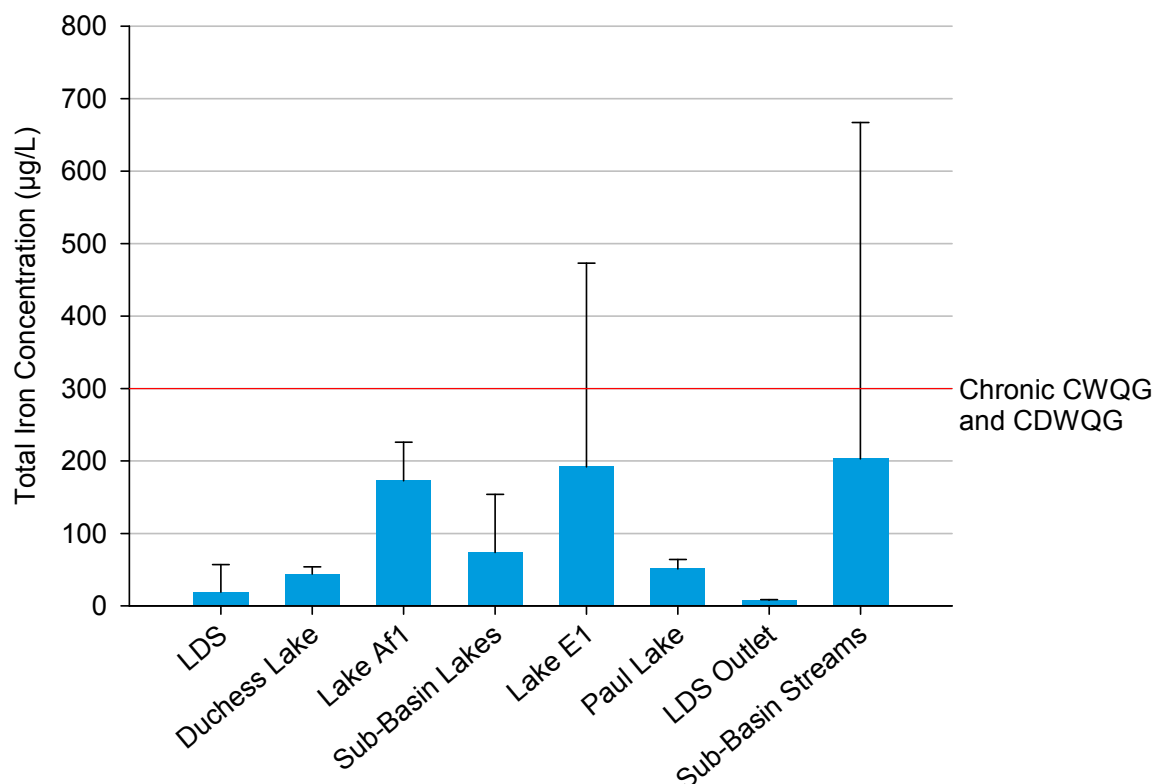
Mean total iron concentrations were below the chronic CWQG and CDWQG of 300 µg/L in all lakes and streams (Figure 7.1-3). However, individual concentrations were above the chronic CWQG and CDWQG at stations in Lake E1 (20% of samples from two stations, but exceedances were limited to one station) and at Stream Station L-S1.

Figure 7.1-2 Mean (\pm Standard Deviation) Total Aluminum Concentrations ($\mu\text{g/L}$) for the Baseline Study Area during the Open-Water Period, 2013



CWQG = Canadian Water Quality Guideline; CDWQG = Canadian Drinking Water Quality Guideline; LDS = Lac du Sauvage; $\mu\text{g/L}$ = micrograms per litre.

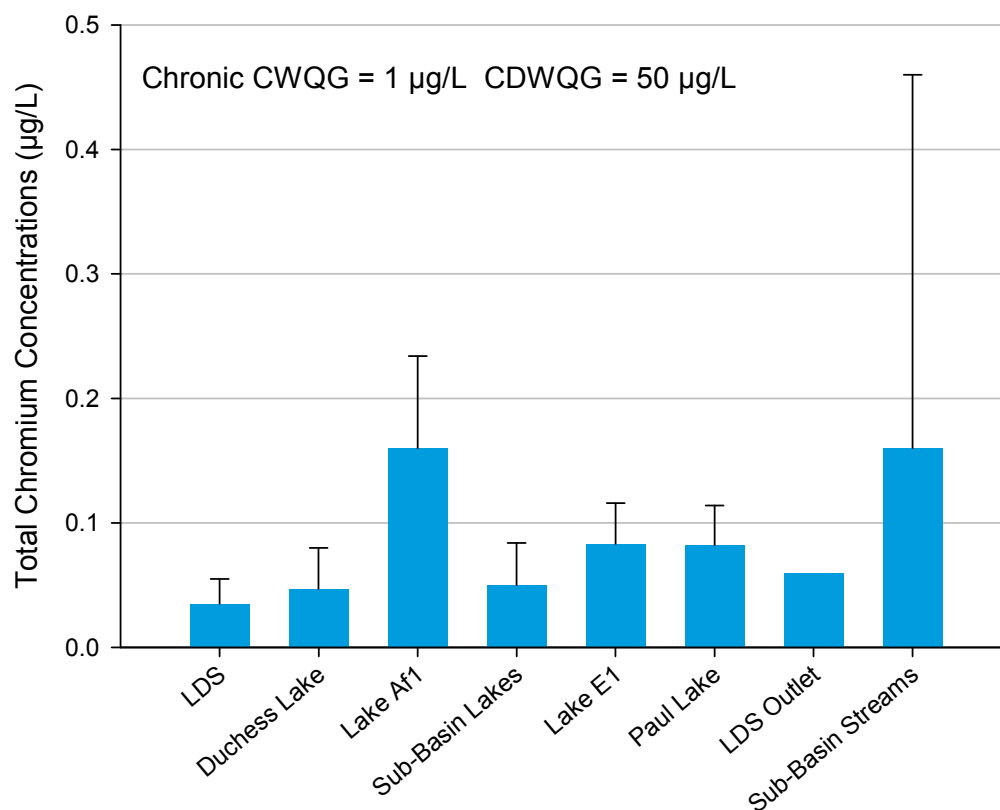
Figure 7.1-3 Mean (\pm Standard Deviation) Total Iron Concentrations ($\mu\text{g/L}$) in Water for the Baseline Study Area during the Open-Water Period, 2013



CWQG = Canadian Water Quality Guideline; CDWQG = Canadian Drinking Water Quality Guideline; LDS = Lac du Sauvage; $\mu\text{g/L}$ = micrograms per litre.

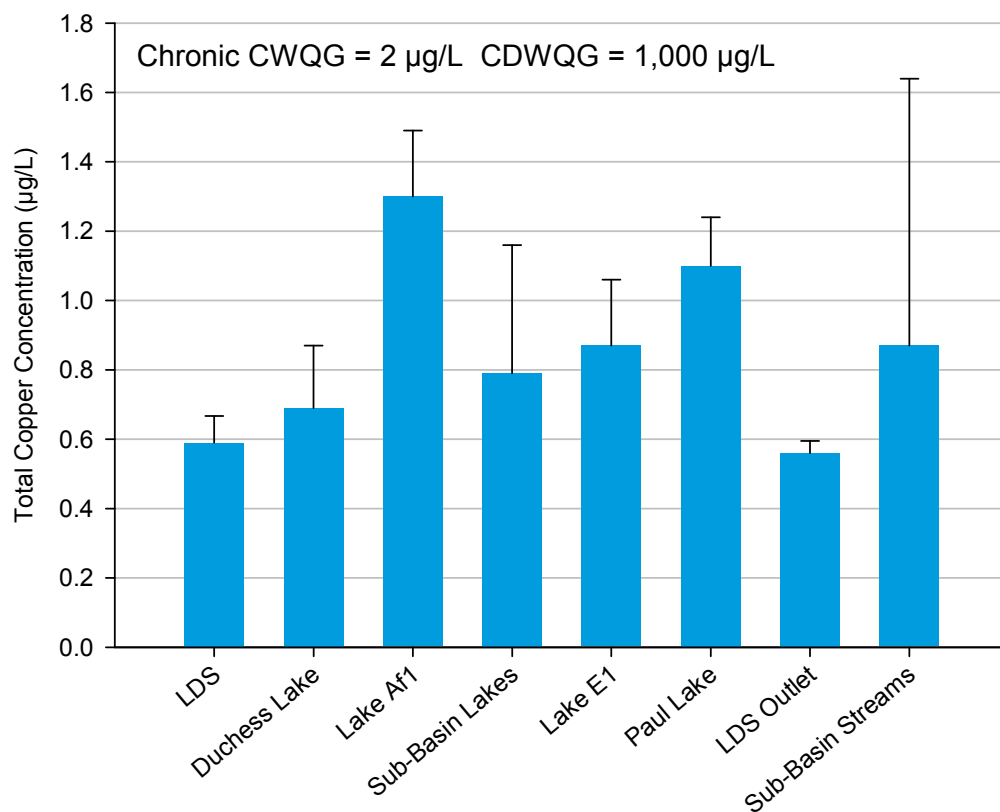
In the fall sample from Station L-S1, concentrations of chromium ($1.3 \mu\text{g/L}$), manganese ($96 \mu\text{g/L}$), and copper ($3.3 \mu\text{g/L}$) were above the chronic CWQG (i.e., $1 \mu\text{g/L}$ for chromium, and $2 \mu\text{g/L}$ for copper) and CDWQG ($50 \mu\text{g/L}$ for manganese) guidelines. The results from Stream L-S1, including the elevated aluminum and iron concentrations described above, may indicate the influence of metal inputs from sub-surface or groundwater flows. However, one sample is insufficient to determine such a trend. Average concentrations of total chromium, copper, and manganese were relatively similar among lakes and streams (Figures 7.1-4 to 7.1-6).

Figure 7.1-4 Mean (\pm Standard Deviation) Total Chromium Concentrations ($\mu\text{g/L}$) in Water for the Baseline Study Area during the Open-Water Period, 2013



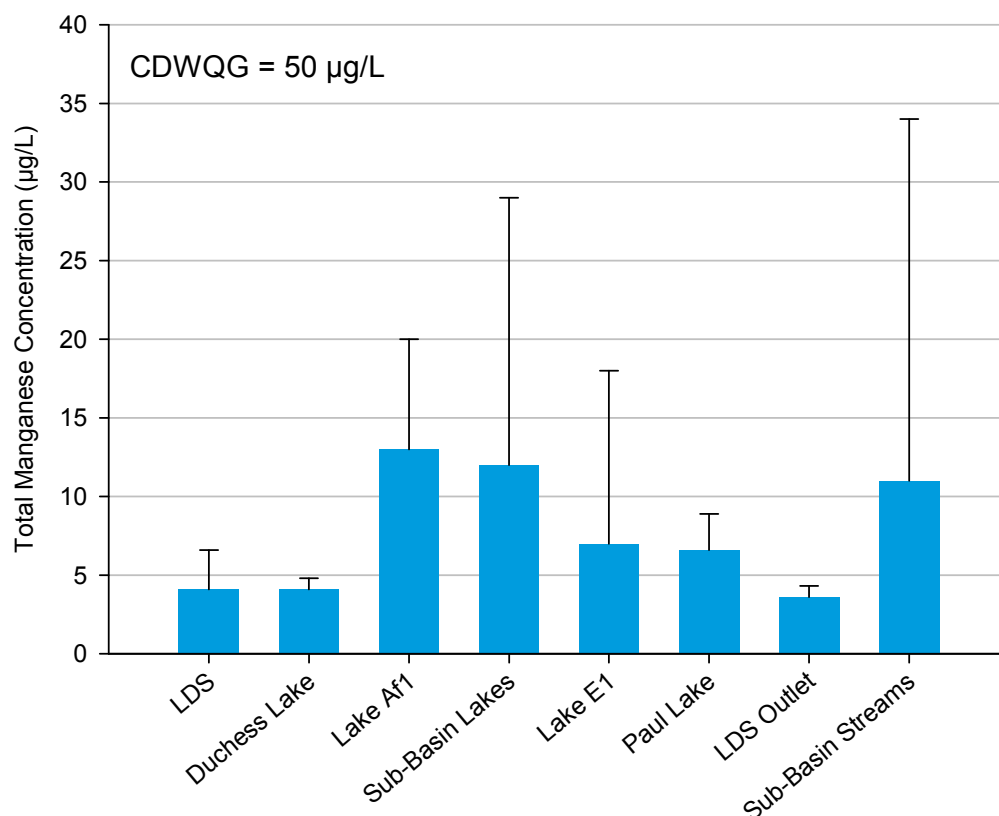
CWQG = Canadian Water Quality Guideline; CDWQG = Canadian Drinking Water Quality Guideline; LDS = Lac du Sauvage; $\mu\text{g/L}$ = micrograms per litre.

Figure 7.1-5 Mean (\pm Standard Deviation) Total Copper Concentrations ($\mu\text{g/L}$) in Water for the Baseline Study Area during the Open-Water Period, 2013



CWQG = Canadian Water Quality Guideline; CDWQG = Canadian Drinking Water Quality Guideline; LDS = Lac du Sauvage; $\mu\text{g/L}$ = micrograms per litre.

Figure 7.1-6 Mean (\pm Standard Deviation) Total Manganese Concentrations ($\mu\text{g/L}$) in Water for the Baseline Study Area during the Open-Water Period, 2013



CDWQG = Canadian Drinking Water Quality Guideline; LDS = Lac du Sauvage; $\mu\text{g/L}$ = micrograms per litre.

7.1.1.7 Other Parameters

The hydrocarbon parameters (benzene, ethylbenzene, toluene, xylene (BTEX), petroleum hydrocarbons F1 ($\text{C}_6\text{-C}_{10}$), F1 ($\text{C}_6\text{-C}_{10}$)-BTEX, and F2 ($\text{C}_{10}\text{-C}_{16}$) were not detected in water samples from the baseline study area during the open-water sampling period.

Total recoverable hydrocarbons were detected at concentrations near the DL in Lac du Sauvage (maximum = 1.2 mg/L; median = less than 1 mg/L), Duchess Lake (maximum = 1.4 mg/L; median = less than 1 mg/L), Lac du Sauvage outlet (median = less than 1.1 mg/L), and the Lac du Sauvage sub-basin streams (maximum = 1 mg/L; median = less than 1 mg/L), but were not detected in the Lac du Sauvage sub-basin lakes, Lake E1, or Paul Lake.

Fecal coliforms were detected near the DL in Duchess Lake (maximum = 1 CFU/100 mL; median = less than 1 CFU/100 mL), the Lac du Sauvage sub-basin lakes (maximum = 1 CFU/100 mL; median = less than 1 CFU/100 mL), Paul Lake (maximum = 5 CFU/100 mL; median = less than 1 CFU/100 mL), the Lac du Sauvage outlet (median = less than 1 CFU/100 mL), and the Lac du Sauvage sub-basin streams (maximum = 12 CFU/100 mL; median = less than 1 mg/L), and were not detected in Lac du Sauvage or Lake E1.

7.1.1.8 *Nutrients and Chlorophyll a in Depth-Integrated Samples*

Depth-integrated samples were collected from Lac du Sauvage, Paul Lake, Duchess Lake and sub-basin Lake E1. Concentrations of TP ranged from 0.0060 to 0.020 mg/L; TN concentrations ranged from 0.194 to 0.568 mg/L; SRSi concentrations ranged from 0.03 to 0.207 mg/L. Total nitrogen concentrations were highest at Duchess Lake (median = 0.377 mg/L) and lowest at Paul Lake (median = 0.24 mg/L). Total phosphorus concentrations were also highest at Duchess Lake (0.021 mg/L), and lowest at Lac du Sauvage (0.008 mg/L). Concentrations of SRSi were highest overall in sub-basin Lake E1 (median = 0.207 mg/L), lowest in Lac du Sauvage (median = 0.04 mg/L), and above the threshold for silica limitation (0.1 mg/L; Reynolds 2006) in Duchess Lake, Lake E1, and Paul Lake.

In the summer sampling at Lac du Sauvage, TP concentrations in the depth-integrated samples were higher and SRSi concentrations were lower than those in the discrete samples (top and mid samples) (Table 7.1-2). In Paul Lake during the summer, TN concentrations in the depth-integrated samples were higher, and TP and SRSi concentrations were similar to those in the discrete samples (top samples). These differences are not unexpected; monitoring conducted at Snap Lake (De Beers 2013) identified higher concentrations of ammonia, nitrate, TKN, and TP in the depth-integrated sample, but similar concentrations of TN, TDP, and orthophosphate between the depth-integrated and mid-depth samples.

Table 7.1-2 Phosphorus, Nitrogen, and Silica in Baseline Study Area Lakes, August 2013

Lake	Parameter	Discrete Samples (median value)	Depth-Integrated Samples (median value)
Lac du Sauvage ^(a)	TP (mg P/L)	0.004	0.008
	SRSi (mg/L)	0.12	0.04
Lake E1 ^(b)	TN (mg N/L)	0.36	0.323
	TP (mg P/L)	0.016	0.015
	SRSi (mg/L)	0.295	0.207
Paul Lake ^(a)	TN (mg N/L)	0.14	0.24
	TP (mg P/L)	0.009	0.01
	SRSi (mg/L)	0.17	0.16

Note: Depth-integrated samples were not collected from Duchess Lake in August 2013.

a) Concentrations are median values of multiple stations within the lake collected in August 2013.

b) Concentrations are results from single samples collected in August 2013.

TP = total phosphorus; SRSi = soluble reactive silica; TN = total nitrogen; mg/L = milligrams per litre; mg P/L = milligrams phosphorus per litre; mg N/L = milligrams nitrogen per litre.

Median chlorophyll *a* concentrations varied by lake and sampling event. The lowest concentrations were observed in Lac du Sauvage, whereas the highest concentrations were observed in Lake Af1 (Table 7.1-3). In general, peak chlorophyll *a* concentrations occurred in the fall in Lac du Sauvage, Duchess Lake, and Paul Lake, and in the summer in Lake Af1. Seasonality in chlorophyll *a* concentrations could not be determined in Lake E1 or any of the other sub-basin lakes (i.e., Lakes C1, D3 [Counts Lake], G2, and H1) because samples were not collected in the late spring. However, chlorophyll *a* concentrations in these waterbodies in the summer and fall were comparable to concentrations observed in Duchess Lake and Paul Lake.

Table 7.1-3 Summary of Median Chlorophyll *a* Concentrations in Lakes in the Baseline Study Area, 2013

Lake	Late Spring (µg/L)	Summer (µg/L)	Fall (µg/L)
Lac du Sauvage	1.65	0.96	3.11
Duchess Lake	2.92	3.07	5.17
Lake Af1	9.49	13.45	8.95
Sub-Basin Lakes	—	2.49	4.88
Lake E1	—	4.25 ^(a)	3.58
Paul Lake	2.94	1.75	4.75

Note: Concentrations are median values of multiple stations within the lake, with the exception of the sub-basin lakes, which are medians of multiple lakes, and Lake Af1, which only had one station.

a) = only one station was sampled in the summer.

µg/L = micrograms per litre; — = not sampled.

7.1.1.9 Trophic Status Classification

The trophic status of each lake was classified based on the TSI calculations for discrete and depth-integrated water samples using Secchi depth, TP, and chlorophyll *a* concentration data from the open-water sampling events in 2013, and the classification scheme of Carlson (1977). Lac du Sauvage and Lac du Sauvage sub-basin Lake D3 (Counts Lake) were classified as oligotrophic lakes. Lac du Sauvage sub-basin Lakes C1, G2, and H1, and Paul Lake were classified as oligotrophic to mesotrophic lakes, and Duchess Lake, Lake Af1, and Lake E1 were classified as mesotrophic lakes. The variable trophic status of these lakes could be due to local watershed influences, biological uptake variability, or sampling effort intensity.

Based on average or median TP concentrations measured during the open-water sampling events in 2013 and CCME (2004)'s classification scheme for Canadian lakes and streams, the Lac du Sauvage outlet and other streams in the Lac du Sauvage basin (Streams C1, D1, E2, F1, G1, I1, J1, K1, and L1) were classified as oligotrophic.

7.1.2 Sediment Quality

Sediment samples were collected from each lake and stream monitoring station once during the open-water sampling period in 2013.

7.1.2.1 Physical Parameters

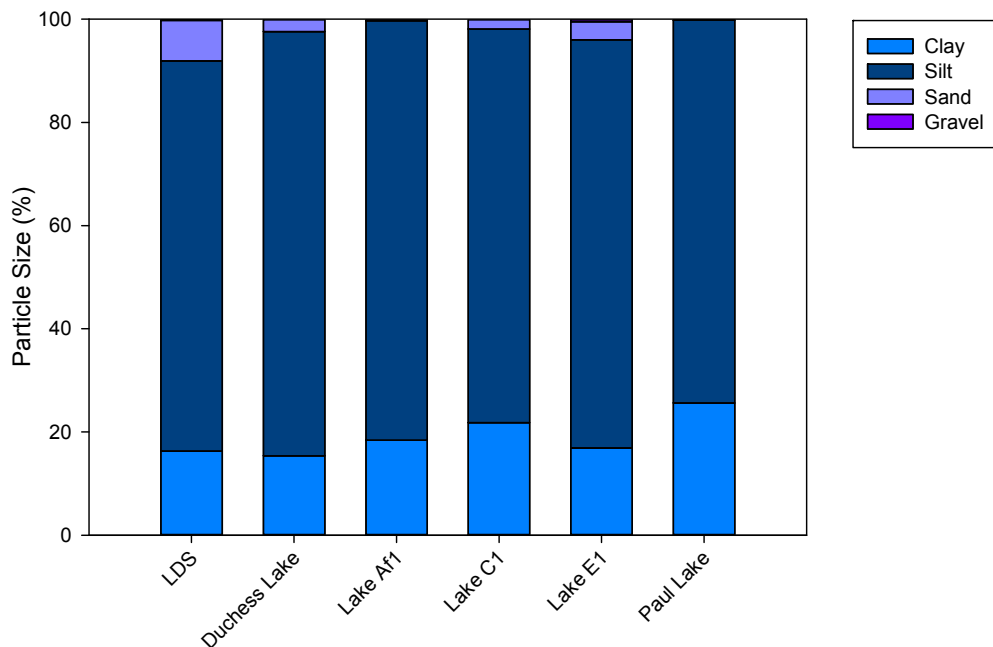
The surface bed sediment of lakes in the baseline study area was dominated by silt and clay; stream sediment was more variable (Figures 7.1-7 and 7.1-8). The dominant sediment particle size for Lac du Sauvage, Duchess Lake, Lake Af1, Lake C1, Lake E1, and Paul Lake, as based on laboratory particle size analysis of sediments samples, was silt (mean silt composition = 76%, 82%, 81%, 76%, 79%, and 74%, respectively) (Figure 7.1-7).

Clay comprised the second most abundant component of the sediment in Lac du Sauvage, Duchess Lake, Lake Af1, Lake C1, Lake E1, and Paul Lake stations (mean clay composition = 16%, 15%, 18%, 22%, 17%, and 26% respectively). Detailed substrate mapping was also conducted in the study lakes (Fish and Fish Habitat Baseline Report, Annex XIV).

Based on detailed substrate analyses in the lakes, coarse substrates dominated in the shallow depths (0 to 2 m water depth), coarse substrates and fines co-dominated in the intermediate depths (2 to 6 m), and fines dominated in areas deeper than 6 m (Annex XIV).

In contrast, stream sediment ranged from very coarse material in the Lac du Sauvage outlet and Stream G1, which were dominated by sand (i.e., 58% and 50%, respectively) and gravel (i.e., 33% and 45% respectively), to fine sediment in Stream E2 dominated by silt (mean = 77%; Figure 7.1-8).

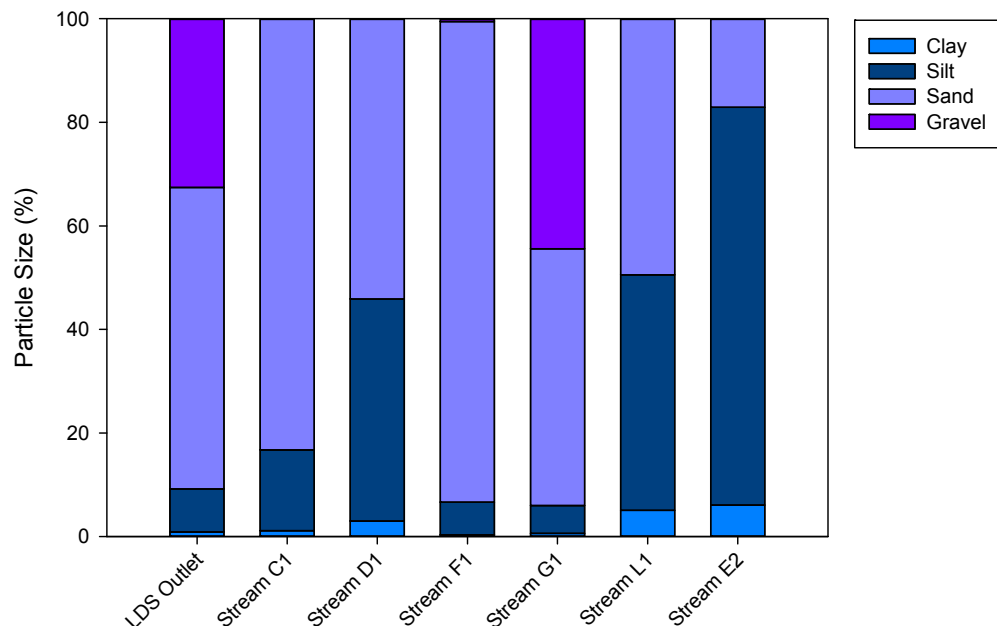
Figure 7.1-7 Mean Particle Size Distribution in Lakes for the Jay Baseline Study Area during the Open-Water Period, 2013



Note: based on laboratory particle size analysis.

LDS = Lac du Sauvage; % = percent.

Figure 7.1-8 Mean Particle Size Distribution in Streams for the Jay Baseline Study Area during the Open-Water Period, 2013



Note: based on laboratory particle size analysis.

LDS = Lac du Sauvage; % = percent.

7.1.2.2 Nutrients

Across the baseline study area, TKN concentrations in lake sediments ranged from 0.08% to 0.36% (median = 0.15%), TP concentrations ranged from 511 to 1,850 mg/kg dw (median = 1,010 mg/kg dw), and TOC concentrations ranged from less than 0.8% to 3.7% (median = 1.2%). Streams in the baseline study area had TKN concentrations ranging from less than 0.02% to 0.36% (median = 0.14%), TP concentrations ranging from 321 to 695 mg/kg dw (median = 499 mg/kg dw), and TOC concentrations ranging from 0.16% to 6.5% (median = 2.9%).

Median concentrations varied among lakes for TKN and TOC, but were similar for TP. Concentrations of TKN were highest overall in Lake E1 (median = 0.35%) and Lake C1 (median = 0.32%), and lowest in Duchess Lake (median = 0.13%) and Lac du Sauvage (median = 0.14%). Total phosphorus concentrations were relatively similar among the lakes. Median concentrations were highest in Paul Lake (median = 1,150 mg/kg dw), Lac du Sauvage (median = 1,020 mg/kg dw), Lake Af1 (median = 1,010 mg/kg dw), and Lake C1 (median = 947 mg/kg dw).

Median concentrations were lowest in Duchess Lake (median = 882 mg/kg dw) and Lake E1 (median = 863 mg/kg dw). Similar to TKN, TOC concentrations were highest overall in Lake C1 (5.8%) and Lake E1 (median = 3.5%), and lowest in Lac du Sauvage and Duchess Lake (medians = 1.2%). The median TOC concentration in Lake Af1 was 2.1% and 2.4% in Paul Lake.

Stream sediment nutrient concentrations in the baseline study area were variable for TKN and TOC compared to TP. Concentrations of TKN and TOC were highest in Stream D1 and Stream L1 (TKN = 0.25% and 0.33%, respectively; TOC = 6.3% and 6.2%, respectively), and lowest in the Lac du Sauvage outlet, Stream F1, and Stream G1 (TKN = less than 0.02% to 0.029%; TOC less than 0.1% to 0.22%).

Concentration of TKN was 0.13% in Stream C1 and 0.16% (median of four stations) in Stream E2; TOC concentrations were 2.2% and 2.9%, respectively. Concentrations of TP were more similar among streams, ranging from 321 to 499 mg/kg dw with the exception of Stream G1 (less than 50 mg/kg dw).

7.1.2.3 Metals

Arsenic and chromium concentrations in sediment from the lakes and streams in the baseline study area were often above SQGs, with copper concentrations periodically above SQGs. Mercury concentrations in sediments were below their SQG.

Mean arsenic concentrations were above the ISQG (i.e., 5.9 mg/kg dw) in all lakes, but below the ISQG in the Lac du Sauvage outlet (Station Ab-S1) and the sub-basin streams. Concentrations were above the PEL (i.e., 17 mg/kg dw) in Lac du Sauvage, Duchess Lake, and Paul Lake. The highest overall arsenic concentrations were observed in Lac du Sauvage sediments (Figure 7.1-9).

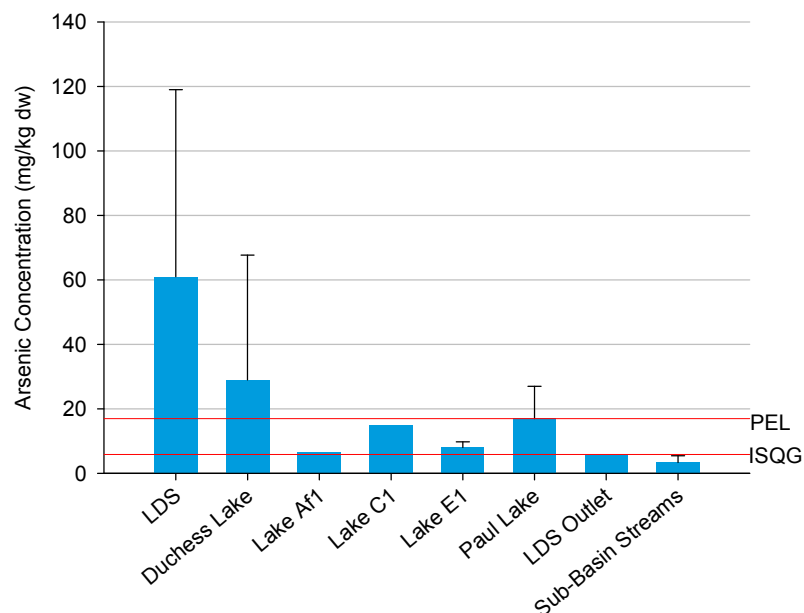
Concentrations of arsenic were above the ISQG in: 13 of the 14 stations in Lac du Sauvage (93% of samples); 3 of 4 stations in Duchess Lake (80% of samples); all stations in Paul Lake and Lake E1; the single samples from Lake Af1 and Lake C1; and, in one stream sample (D-S1). Concentrations of arsenic were above the PEL in 11 of the 14 stations in Lac du Sauvage (79% of samples) and 1 of 4 stations in Duchess Lake (20% of samples).

Mean chromium concentrations were above the ISQG (i.e., 37.3 mg/kg dw) in all lakes and the Lac du Sauvage outlet (Station Ab-S1). The highest concentrations were observed in Paul Lake (median = 74 mg/kg dw); the lowest concentrations were observed in the Lac du Sauvage sub-basin streams (median = 34 mg/kg dw) (Figure 7.1-10).

Chromium concentrations were above the ISQG in all samples in Lac du Sauvage, Duchess Lake, Lake Af1, Lake C1, Lake E1, Paul Lake, and the Lac du Sauvage outlet. In the sub-basin streams, concentrations were below ISQG with the exception of the sample from Stream G1 (the concentration of 96 mg/kg dw was above the PEL [i.e., 90 mg/kg dw]), and one of the four samples from Stream E2 (42 mg/kg dw).

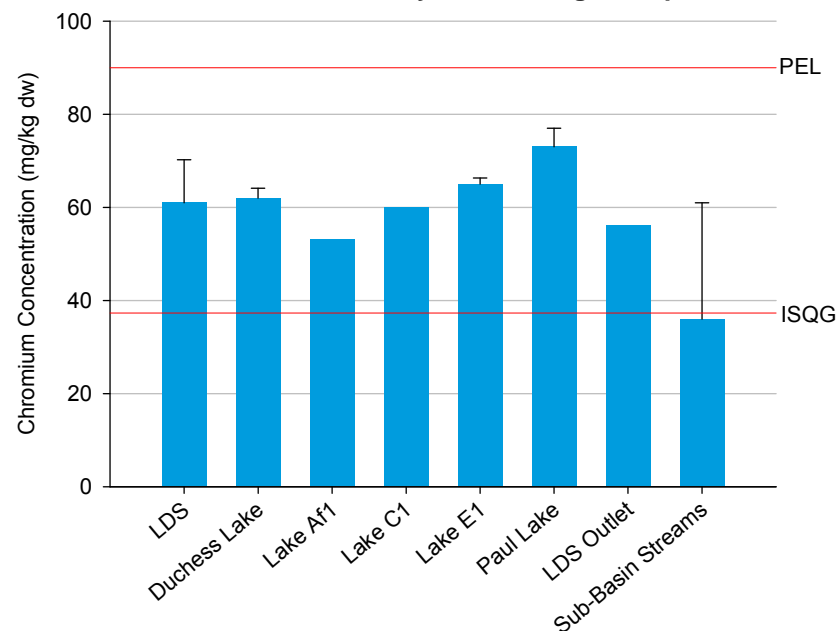
Mean copper concentrations were below the ISQG (i.e., 35.7 mg/kg dw) in most lakes and streams, with the exception of Lake C1 (Figure 7.1-11). Concentrations at lake stations were noticeably higher than the stream stations (Figure 7.1-11); copper concentrations in stream sediments were below SQGs. Concentrations of copper were above the ISQG in one of 14 stations in Lac du Sauvage (7% of samples), in the single sample from Lake C1, and in three of five stations in Paul Lake (60% of samples).

Figure 7.1-9 Mean (\pm Standard Deviation) Arsenic Concentrations (mg/kg dw) in Sediment for the Baseline Study Area during the Open-Water Period, 2013



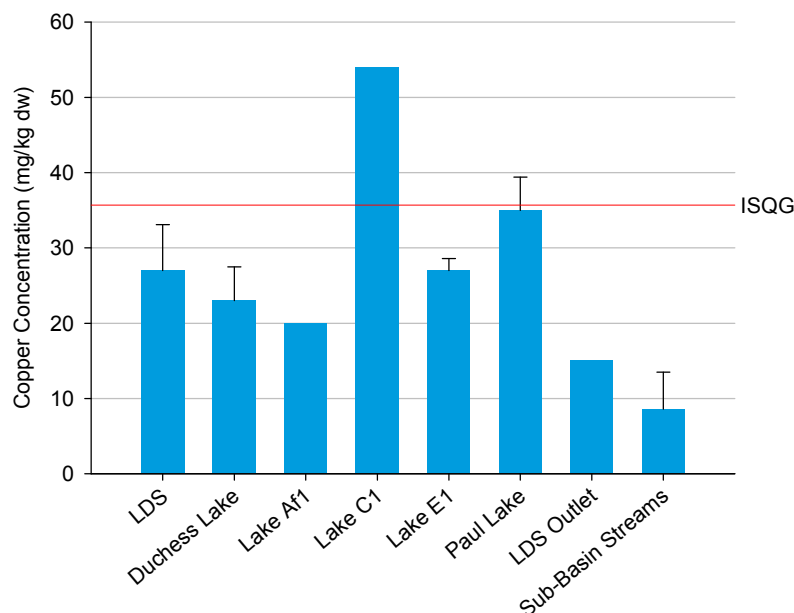
LDS = Lac du Sauvage; mg/kg dw = milligram per kilogram dry weight; ISQG = Interim Sediment Quality Guideline.

Figure 7.1-10 Mean (\pm Standard Deviation) Chromium Concentrations (mg/kg dw) in Sediment for the Baseline Study Area during the Open-Water Period, 2013



LDS = Lac du Sauvage; mg/kg dw = milligram per kilogram dry weight; PEL = probable effects level; ISQG = Interim Sediment Quality Guideline.

Figure 7.1-11 Mean (\pm Standard Deviation) Copper Concentrations (mg/kg dw) in Sediment for the Baseline Study Area during the Open-Water Period, 2013



LDS = Lac du Sauvage; mg/kg dw = milligram per kilogram dry weight; PEL = probable effects level; ISQG = Interim Sediment Quality Guideline.

7.1.3 Deep and Shallow Sites

Concentrations of detected water and sediment quality parameters were generally similar between deep and shallow stations. Water and sediment quality were relatively homogenous between deep and shallow stations across the baseline study area. This finding suggests that water and sediment quality from deep stations can be used to characterize baseline quality in the baseline study area.

7.2 Overview of Historical Data and 2013 Data

Water quality in lakes and streams of the baseline study area during the open-water season of 2013 was typical of that found in Arctic and sub-Arctic freshwater systems. Water quality in the lakes and streams can be characterized as follows:

- clear, with mean Secchi depths ranging from 2 to 9 m, and vertical light attenuation coefficients (K_d) that ranged between 0.38 and 0.83;
- thermally stratified in summer, but not in late spring or summer;
- well oxygenated at surface in streams and at depth in most lakes with certain exceptions; dissolved oxygen concentrations were sufficient to support aquatic life (i.e., not below the CWQG of 6.5 mg/L), with the exception of deeper in the water column in Lake Af1 and Lake E1 in summer;
- slightly acidic (laboratory-measured pH values, used as a surrogate because field-measured pH data were unreliable, were near or below the lower CWQG of pH 6.5);

- low in alkalinity (i.e., lakes were highly sensitive to acid inputs as per the lake acid sensitivity scale of Saffran and Trew [1996], and streams were sensitive as per the stream acid sensitivity scale of Boward et al. [1999]);
- low in hardness (i.e., lakes and streams had very soft water as per the scale of water hardness of McNeely et al. [1979]);
- low in nutrients, with mean TSI values (based on Secchi depth, TP, and chlorophyll *a* concentrations) within the range for oligotrophic to mesotrophic lakes and oligotrophic streams (as per the classification scheme in Carlson 1977);
- low in metals concentrations (except for a single sample from L-S1), which were either not detected or below the CWQG, with the exception of aluminum concentrations, which were generally above the pH-dependent CWQG of 5 µg/L (Tables 7.1-4 and 7.1-5); and,
- no obvious spatial or temporal trends in the open-water samples.

Sediment quality in the lakes and streams can be characterized as follows:

- consistent silty-clay composition in lakes, but variable sediment composition in streams (ranging from very coarse material dominated by sand and gravel to fine sediments dominated by silt);
- variable in nitrogen, organic carbon, and phosphorus content between locations; and,
- arsenic and chromium concentrations above SQGs, and copper occasionally above SQGs (Tables 7.1-4 and 7.1-5).

Detailed summaries by lake and stream are provided in Table 7.1-4 (lakes) and Table 7.1-5 (streams).

Table 7.1-4 Summary of Water and Sediment Quality in Lakes of the Baseline Study Area during the Open-Water Period, 2013

Area	Basin ID	Station ID	Water Quality Parameters Above Guidelines or Outside the Guideline Range ^(a)	Sediment Quality Parameters Above Guidelines ^(b)	Sensitivity to Acid Deposition ^(c)	Water Hardness ^(d)	Trophic State ^(e)
Lac du Sauvage	Aa	Aa-1	pH, aluminum	chromium	highly sensitive	very soft	oligotrophic
		Aa-2	pH, aluminum	<u>arsenic</u> , chromium			
	Ab	Ab-1	pH, aluminum	<u>arsenic</u> , chromium			
		Ab-2	pH, aluminum	arsenic, chromium			
	Ac	Ac-1	pH, aluminum	<u>arsenic</u> , chromium			
		Ac-2	pH, aluminum	<u>arsenic</u> , chromium			
		Ac-4	pH, aluminum	<u>arsenic</u> , chromium, copper			
		Ac-5	pH, aluminum	<u>arsenic</u> , chromium			
		Ac-7	pH, aluminum	<u>arsenic</u> , chromium			
		Ac-8	pH, aluminum	<u>arsenic</u> , chromium			
	Ad	Ad-1	pH, aluminum	<u>arsenic</u> , chromium			
		Ad-2	pH, aluminum	arsenic, chromium			
	Ae	Ae-1	pH, aluminum	<u>arsenic</u> , chromium			
		Ae-2	pH, aluminum	<u>arsenic</u> , chromium			
Duchess Lake	Af	Af-1	pH, aluminum	chromium	highly sensitive	very soft	mesotrophic
		Af-2	pH, aluminum	<u>arsenic</u> , chromium			
		Af-4	pH, aluminum	arsenic, chromium			
		Af-7	pH, aluminum	arsenic, chromium			
Lake Af1	Af	Af-10	pH, aluminum, dissolved oxygen (near lake bottom in summer)	arsenic, chromium	highly sensitive	very soft	mesotrophic

Table 7.1-4 Summary of Water and Sediment Quality in Lakes of the Baseline Study Area during the Open-Water Period, 2013

Area	Basin ID	Station ID	Water Quality Parameters Above Guidelines or Outside the Guideline Range ^(a)	Sediment Quality Parameters Above Guidelines ^(b)	Sensitivity to Acid Deposition ^(c)	Water Hardness ^(d)	Trophic State ^(e)
Lac du Sauvage Sub-Basin Lakes	C	C-L1	None	<u>arsenic, chromium, copper</u>	highly sensitive	very soft	oligotrophic to mesotrophic
	D	D-L3	None	n/a			oligotrophic
	G	G-L2	pH, aluminum	n/a			oligotrophic to mesotrophic
	H	H-L1	None	n/a			oligotrophic to mesotrophic
Lake E1	E	E-L1-1	pH, aluminum, iron, dissolved oxygen (near lake bottom in summer)	arsenic, chromium	highly sensitive	very soft	mesotrophic
		E-L1-2	pH, aluminum	arsenic, chromium			
Paul Lake	Lac de Gras	PL-1	pH	<u>arsenic, chromium, copper</u>	highly sensitive	very soft	oligotrophic to mesotrophic
		PL-2	pH, aluminum	arsenic, chromium,			
		PL-3	pH, aluminum	<u>arsenic, chromium, copper</u>			
		PL-4	pH, aluminum	arsenic, chromium, copper			
		PL-5	None	arsenic, chromium			

a) Parameters above Canadian Water Quality Guideline (CWQG) or Canadian Drinking Water Quality Guidelines (CDWQG).

b) Parameters above Interim Sediment Quality Guidelines (ISQGs); underlined parameters were above their PEL.

c) Classifications are based on the lake acid sensitivity scale (Saffran and Trew 1996).

d) Classifications are based on the qualitative scale of water hardness (McNeely et al. 1979).

e) Trophic status is based on calculated trophic state index (TSI) values for discrete and depth-integrated samples and classification scheme of Carlson (1977).

n/a = no samples were collected; none = no parameters were above guidelines; ID = identification; PEL = probable effects level.

Table 7.1-5 Summary of Water and Sediment Quality in Streams of the Baseline Study Area during the Open-Water Period, 2013

Area	Basin	Station ID	Water Quality Parameters Exceeding Guidelines ^(a)	Sediment Quality Parameters Exceeding Guidelines ^(b)	Sensitivity to Acid Deposition ^(c)	Water Hardness ^(d)	Trophic State ^(e)
Lac du Sauvage Outlet	A	Ab-S1	pH, aluminum	chromium	sensitive	very soft	oligotrophic
Lac du Sauvage Sub-Basin Streams	C	C-S1	pH	none	sensitive	very soft	oligotrophic
	D	D-S1	pH, aluminum	arsenic			oligotrophic
	F	F-S1	pH, aluminum	none			oligotrophic
	G	G-S1	pH, aluminum	<u>chromium</u>			oligotrophic
	L	L-S1	pH, aluminum, chromium, copper, iron, manganese	none			oligotrophic to mesotrophic
	E	E-S2	pH, aluminum	chromium	n/a	n/a	oligotrophic
		E-S2-3	n/a	none			n/a
		E-S2-4	n/a	none			n/a
		E-S2-5	n/a	none			n/a

a) Parameters above Canadian Water Quality Guideline (CWQG) or Canadian Drinking Water Quality Guidelines (CDWQG).

b) Parameters above Interim Sediment Quality Guidelines (ISQGs); underlined parameters were above their PEL.

c) Classifications are based on the stream acid sensitivity scale (Boward et al. 1999).

d) Classifications are based on the qualitative scale of water hardness (McNeely et al. 1979).

e) Trophic status is based on total phosphorus concentrations and CCME (2004)'s trophic classification of Canadian lakes and streams.

n/a = no samples were collected; none = no parameters were above guidelines; ID = identification; PEL = probable effects level.

The 2013 study characterized lakes and streams in the baseline study area as being relatively clear, well oxygenated (except at depth in two lakes: Lake Af1 and Lake E1), very soft in hardness, highly sensitive (lakes) or sensitive (streams) to acid inputs (i.e., low alkalinity), and with waters containing low concentrations of major ions, nutrients, and metals (Table 7.1-4).

Lake sediments were typically fine (silty-clay) whereas stream sediments were more variable; arsenic, chromium, and occasionally copper concentrations in sediments were higher than SQGs. The results of the 2013 study are similar to those found in other baseline and monitoring programs in the baseline study area: the Ekati AEMP (Rescan 2012a; ERM Rescan 2013); Jay Pipe 2006 aquatic baseline study (Rescan 2007); and, the Diavik AEMP (Golder 2014).

8 REFERENCES

- AENV (Alberta Environment). 2006. Aquatic Ecosystems Field Sampling Protocols. Prepared by Alberta Environment, March 2006.
- Boward D, Kayzak P, Stranko S, Hurd M, Prochaska A. 1999. From the Mountains to the Sea: the State of Maryland's Freshwater Streams. Maryland Department of Natural Resources.
- Carlson RE. 1977. A trophic state index for lakes. *Limnol Oceanogr* 22: 361-369.
- CCME (Canadian Council of Ministers of the Environment). 1999, with updates to 2014. Canadian Environmental Quality Guidelines. Winnipeg, MB, Canada.
- CCME. 2001. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Introduction. Updated. Canadian Environmental Quality Guidelines, 1999. Winnipeg, MB, Canada.
- CCME. 2002. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Total Particulate Matter. In Canadian Environmental Quality Guidelines, 1999. Winnipeg, MB, Canada.
- CCME. 2004. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems. Canadian Environmental Quality Guidelines, 2004. Winnipeg, MB, Canada.
- DDMI (Diavik Diamond Mines Inc.). 2001. Diavik Diamond Mine 2000 Aquatic Effects Monitoring Program, Technical Report, March 2001.
- DDMI. 2007. Diavik Diamond Mine Aquatic Effects Monitoring Program, AEMP Design Document, Version 1.0.
- DDMI. 2008. Diavik Diamond Mine Aquatic Effects Monitoring Program 2007 Annual Report. Submitted to Wek'èezhìi Land and Water Board. Yellowknife, NWT, Canada.
- DDMI. 2009. Diavik Diamond Mine Aquatic Effects Monitoring Program 2008 Annual Report. Submitted to Wek'èezhìi Land and Water Board. Yellowknife, NWT, Canada.
- DDMI. 2010. Diavik Diamond Mine Aquatic Effects Monitoring Program 2009 Annual Report. Submitted to Wek'èezhìi Land and Water Board. Yellowknife, NWT, Canada.
- DDMI. 2011. Diavik Diamond Mine Aquatic Effects Monitoring Program 2010 Annual Report. Submitted to Wek'èezhìi Land and Water Board. Yellowknife, NWT, Canada.
- DDMI. 2013. Diavik Diamond Mine Aquatic Effects Monitoring Program 2012 Annual Report. Submitted to Wek'èezhìi Land and Water Board. Yellowknife, NWT, Canada.
- De Beers (De Beers Canada Inc.). 2013. 2012 Annual Report in Support of the Aquatic Effects Monitoring Program for the Snap Lake Mine. Water License (MV2001L2-0002). Submitted to the Mackenzie Valley Land and Water Board. Yellowknife, NWT, Canada.

- Dodds WK, Whiles MR. 2010. Freshwater Ecology: Concepts and Environmental Applications of Limnology. Academic Press, San Diego, CA, USA.
- Dodds WK, Jones JR, Welch EB. 1998. Suggested classification of stream trophic state: distribution of temperate stream types by chlorophyll, total nitrogen and phosphorus. J Water Res 32: 1455-1462.
- EIFAC (European Inland Fisheries Advisory Commission). 1964. Water Quality Criteria for European Freshwater Fish: Report on Finely Divided Solids and Inland Fisheries. Prepared by EIFAC Working Party on Water Quality. EIFAC Technical Paper No. 1.
- Elphick JRF, Bergh KD, Bailey HC. 2011. Chronic toxicity of chloride to freshwater species: effects of hardness and implications for water quality guidelines. Environ Toxicol Chem 30: 230-246.
- Environment Canada. 2004. Canadian Guidance Framework for the Management of Phosphorus in Freshwater Systems. Scientific Supporting Document. National Guidelines and Standards Office, Water Policy and Coordination Directorate, Ottawa, ON, Canada.
- ERM Rescan (ERM Rescan Environmental Services Ltd.). 2013. Ekati Diamond Mine 2012 Aquatic Effects Monitoring Program Annual Report. Prepared for BHP Billiton Canada Inc. Yellowknife, NWT, Canada.
- Franklin DJ, Airs RL, Fernandes M, Bell TG, Bongaerts RJ, Berges JA, Malin G. 2012. Identification of senescence and death in *Emiliana huxleyi* and *Thalassiosira pseudonana*: cell staining, chlorophyll alterations, and dimethylsulfoniopropionate (DMSP) metabolism. Limnol Oceanogr 57:305-317.
- Golder (Golder Associates Ltd.). 1997. Baseflow Study of Flow Circulation in Lac de Gras. Environmental Baseline Program. Prepared for Diavik Diamond Mines Inc. Yellowknife, NWT, Canada.
- Golder. 2011. Diavik Diamond Mine Inc., 2007 to 2010 AEMP Summary Report. Prepared for Diavik Diamond Mines Inc. Yellowknife, NWT, Canada.
- Golder. 2012. SD 7-1 Aquatics Baseline Synthesis Report, 1994 to 2009, Meliadine Gold Project, Nunavut. Prepared for Agnico-Eagles Mine Limited for the Meliadine Gold Project. Calgary, AB, Canada.
- Golder. 2014. Aquatic Effects Monitoring Program Study Design Version 3.4. Submitted to Diavik Diamond Mines Inc. Yellowknife, NWT, Canada.
- Health Canada. 2012. Summary of Guidelines for Canadian Drinking Water Quality (CDWQ) Prepared by the Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial-Territorial Committee on Environmental and Occupational Health.
- Kirk JTO. 1994. Light and Photosynthesis in Aquatic Ecosystems. 2nd Ed. Cambridge University Press. Cambridge, UK.

- Koenings JP, Edmundson JA. 1991. Secchi disk and photometer estimates of light regimes in Alaskan lakes: effects of yellow color and turbidity. *Limnol Oceanogr* 36: 91-105.
- Lyons WB, Finlay JC. 2008. Biogeochemical Processes in High-Latitude Lakes and Rivers. In Vincent WF, Laybourne-Parry J (eds), *Polar Lakes and Rivers: Limnology of Arctic and Antarctic Aquatic Ecosystems*. Oxford University Press Inc., New York, USA.
- McNeely RN, Neimanis VP, Dwyer L. 1979. *Water Quality Sourcebook – A Guide to Water Quality Parameters*. Inland Waters Directorate, Water Quality Branch, Minister of Supply and Services Canada.
- Medeiros AS, Biastoch RG, Luszczek EE, Wang XA, Muir DCG, Quinlan R. 2012. Patterns in the limnology of lakes and ponds across multiple local and regional environmental gradients in the eastern Canadian Arctic. *Inland Waters*. 2:59-76.
- Newcombe CP, Jensen JOT. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. *N Am J Fish Manage* 16:693-727.
- Newcombe CP, MacDonald DD. 1991. Effects of suspended sediments on aquatic ecosystems. *N Am J Fish Manage* 11: 72-82.
- Peramaki L, Stone M. 2005. Fluxes of As, Cu, Hg and Pb in Lake Sediments in the Coppermine River Basin: Implications for Planning and Management of Northern Aquatic Ecosystems. 15th International Northern Research Basins Symposium and Workshop. August 29– September 2, 2005.
- Pienitz R, Smol JP, Lean DRS. 1997. Physical and chemical limnology of 24 lakes located between Yellowknife and Contwoyto Lake, Northwest Territories (Canada). *Can. J. Fish Aquat. Sci.* 54:347-358.
- Pieters R, Lawrence GA. 2009. Effect of salt exclusion from lake ice on seasonal circulation. *Limnol Oceanogr* 54: 401-412.
- Rescan (Rescan Environmental Services Ltd.). 2007. Ekati Diamond Mine 2006 Jay Pipe Aquatic Baseline. Prepared for BHP Billiton Canada Inc. Yellowknife, NWT, Canada.
- Rescan. 2011. Ekati Diamond Mine: 2010 Aquatic Effects Monitoring Program Annual Report. Prepared for BHP Billiton Canada Inc. Yellowknife, NWT, Canada.
- Rescan. 2012a. Ekati Diamond Mine 2011 Aquatic Effects Monitoring Program Annual Report. Prepared for BHP Billiton Canada Inc. Yellowknife, NWT, Canada.
- Rescan. 2012b. Ekati Diamond Mine: Site-Specific Water Quality Objective for Potassium. Prepared for BHP Billiton Canada Inc. Yellowknife, NWT, Canada.
- Rescan. 2012c. Ekati Diamond Mine: Site-specific Water Quality Objective for Sulphate. Prepared for BHP Billiton Canada Inc. Yellowknife, NWT, Canada.

- Rescan. 2012d. Ekati Diamond Mine: Site-Specific Water Quality Objective for Nitrate, 2012. Prepared for BHP Billiton Canada Inc. Yellowknife, NWT, Canada.
- Rescan. 2012e. Ekati Diamond Mine: Site Specific Water Quality Objective for Molybdenum, 2011. Prepared for BHP Billiton Canada Inc. Yellowknife, NWT, Canada.
- Rescan. 2012f. Ekati Diamond Mine: Site-specific Water Quality Objective for Vanadium. Prepared for BHP Billiton Canada Inc. Yellowknife, NWT, Canada.
- Reynolds CS. 2006. Ecology of Phytoplankton. 1st Edition. Cambridge University Press, Cambridge, UK.
- Robertson MJ, Scruton DA, Gregory RS, Clake KD. 2006. Effect of suspended sediment on freshwater fish and fish habitat. Canadian Technical report on Fisheries and Aquatic Sciences 2644. Fisheries and Oceans Canada. St. John's, NL, Canada.
- Rühland K, Smol JP. 1998. Limnological characteristics of 70 lakes spanning Arctic treeline from Coronation Gulf to Great Slave Lake in the central Northwest Territories, Canada. *Internat. Rev. Hydrobiol.* 83(3):183-203.
- Saffran KA, Trew DO. 1996. Sensitivity of Alberta lakes to Acidifying Deposition: An Update of Maps with Emphasis on 109 Northern Lakes. Water Management Division. Alberta Environmental Protection. W9603.
- Schindler DW. 1974. Eutrophication and recovery in experimental lakes: implications for lake management. *Science* 184: 897-899.
- Vincent WF, Hobbie JE, Laybourne-Parry J. 2008. Introduction to the limnology of high-latitude lake and river ecosystems. In Vincent WF, Laybourne-Perry J (eds), *Polar Lakes and Rivers: Limnology of Arctic and Antarctic Aquatic Ecosystems*. Oxford University Press, New York, NY, USA.
- Vollenweider RA. 1970, *Scientific Fundamentals of the Eutrophication of Lakes and Flowing Waters, with Particular Reference to Nitrogen and Phosphorus as Factors in Eutrophication*. OECD, Paris. Tech. Rpt. DA 5/SCI/68.27. 250 pp.
- Vollenweider RA, Kerekes J. 1982. *Eutrophication of Waters. Monitoring Assessment and Control*. Organization for Economic Cooperation and Development (OECD). Paris, France.
- Wetzel RG. 2001. *Limnology: Lake and River Ecosystems*. 3rd Ed. Academic Press, San Diego, CA, USA.
- Wek'èezhìi Land and Water Board. 2014. Water Licence for Dominion Diamond Ekati Corporation. Water Licence #W2012L2-0001 (Amendment to incorporate Ekati Lynx Project). Wekweètì, NWT, Canada.
- Wilson WE, Moore JE. 1998, Benzene, toluene, ethylbenzene, xylene. In Wilson WE, Moore JE (eds), *Glossary of Hydrology*. American Geological Institute, Alexandria, VA, USA, 20pp.
- Wilson A, Fox D, Poole G, Bujold R. 2011. Linking incineration to dioxins and furans in lakebed sediments (or the case of the missing water license condition). *Integrated Environmental Assessment and Management* 7:302-304.

9 GLOSSARY

Term	Definition
Alkalinity	A measurement (expressed in milligrams per litre of calcium carbonate) of the capacity of water to neutralize acids. The concentration is measured based on the presence of naturally available bicarbonate, carbonate, and hydroxide ions.
Anion	A negatively charged ion.
Anthropogenic	The influence of human activities on nature.
Aquatic Effects Monitoring Program	A monitoring program designed to evaluate the effect of mining activities and mitigation on the aquatic environment.
Baseline	A base for measurement or comparison.
Baseline study area	The area (spatial, temporal, or both) used to collect baseline information.
Basin	A large area that is lower in elevation than surrounding areas and contains water. Basins are separated by land or shallow channels.
Bathymetry	Measurements defining depth, area, and volume of a lake.
Bedrock	Continuous solid rock exposed at the surface of the Earth or overlain by a layer of loose material such as that deposited by glaciers, water, or wind.
Bicarbonate	A negatively charged ion or anion (HCO_3^-) that forms carbonic acid salts that increase the buffering capacity of water.
Canadian Water Quality Guideline (CWQG) for the Protection of Aquatic Life	Guidelines established by the Canadian Council of Ministers of the Environment and used to evaluate the potential effects of the concentration of different water quality parameters upon aquatic life (i.e., fish, aquatic plants [macrophytes], and benthic invertebrates).
Cation	A positively charged ion.
Catchment area	See drainage basin area.
Chlorophyll a	A photosynthetic pigment found in plants responsible for the conversion of inorganic carbon and water into organic carbon. The concentration of chlorophyll a is an indicator of algal concentration.
Composite sample	A sample taken by combining several fractions of water from different depths within the water column of a lake into a common vessel that is used to collect the water sample destined for the laboratory. A composite sample can also be obtained as a combination of samples taken from different parts of a waterbody laterally.
Conductivity	A measure of the ability of water to carry an electrical current. This measurement is directly related to the amount of positively (cations) and negatively (anions) charged ions in the water and can be correlated with the concentration of total dissolved solids.
Discrete samples	Samples taken at single locations using a single collection device.
Dissolved organic carbon	All organic carbon that results from the decomposition of organic matter (such as sugars and acids) that leaches from soils and becomes dissolved within the water. High dissolved organic carbon concentrations change the water colour from clear to "tea-coloured".
Dissolved oxygen (DO)	The amount of free oxygen dissolved in water, usually expressed in milligrams per litre (mg/L), parts per million (ppm), or percent of saturation (%). Adequate concentrations of dissolved oxygen are necessary for fish and other aquatic organisms.
Drainage area	Total area of a watershed, including land and water surfaces.
Drainage basin	An area of land where surface water converges to a single point at a lower elevation.
Duplicate field sample	A second sample collected at the same time and from the same location, repeating the same collection procedure as the original sample. The sample is used to detect variability at a site and verify the field sampling method.
Duplicate laboratory sample	Also referred to as a Split Sample. A water sample that is split into two discrete samples by the analytical laboratory and tested separately. The results of these samples assess the reproducibility of the laboratory results (i.e., laboratory method and analyses).
Ekman dredge	A sampling apparatus used to collect a discrete sample of sediment.

Term	Definition
Euphotic zone	The upper layer of a waterbody as defined by light penetration with the upper limit determined by the water surface and the lower limit determined as the depth to which sufficient light for photosynthesis can penetrate (nominally 1% of the surface ambient light, measured as PAR).
Eutrophic	A lake with abundant nutrients, high photosynthetic activity, and low transparency.
Exposure lake	A lake that receives direct discharge from mining operations.
Field blank	A solution of de-ionized water provided by the laboratory that is used to detect sample contamination during the collection, shipping, and analysis of samples.
Grab sediment sample	A single sediment sample collected using an Ekman dredge or other similar sampling apparatus.
Grab water sample	A single discrete water sample that is collected from a waterbody.
Groundwater	That part of the subsurface water that occurs beneath the water table, in soils and geologic formations that are fully saturated.
Guideline for Canadian Drinking Water Quality	Health Canada guidelines used to evaluate the suitability of water for human consumption.
Hardness	A characteristic of water caused by the presence of positively charged ions (cations) such as calcium, magnesium, iron, and manganese. This parameter is measured in mg/L of calcium carbonate.
Headwater	The source and upper reaches of a stream; also, the upper reaches of a reservoir. The water upstream from a structure or point on a stream.
Interim Sediment Quality Guideline	In reference to the Canadian sediment quality guidelines (CCME 2001), the concentration above which adverse effects may occur, and below which they are not expected to occur.
In situ measurement	The on-site measurement of physical water quality parameters in a waterbody.
Lake morphometry	Physical structure of a lake including shoreline and depth.
Lake turnover	An event of complete or nearly complete vertical mixing that occurs in a lake. This happens when water either has equal density through the vertical column or when upper layers of water have a higher density and are heavier. The latter causes upper layers of water to sink, while deeper, less dense water layers rise, causing an equilibrium to form for all water quality parameters for a certain period of time. The effect usually occurs in the spring and fall.
Limnology	The study of open fresh and more rarely saline waterbodies, specifically lakes and ponds (both natural and manmade), including their physical, chemical, and biological properties.
Light attenuation	The decrease in light energy through a water column as a function of reflection, refraction, or scattering, and absorption by water, dissolved compounds, and suspended particles.
Mean	The average of a set of values.
Median	The middle value in a series of values ordered from smallest to largest (the 50 th percentile value).
Mesotrophic	Trophic state classification for lakes characterized by moderate productivity and nutrient inputs (particularly total phosphorus).
Method blank	A laboratory grade, pure water sample that is subjected to all laboratory procedures. This is used to detect possibility of cross-contamination between samples in the laboratory.
Method detection limit	The minimum concentration of a substance that can be measured and reported with 99% confidence.
Morphometry	A set of linear, area, and volumetric parameters of a waterbody or watershed that describe geometric features and provide a background for a hydrologic description of a waterbody or drainage area.
Muskeg	A soil type comprised primarily of organic matter. Also known as bog peat.

Term	Definition
Nitrate + nitrite	The sum of the concentrations of nitrate and nitrite.
Nutrients	Elements or chemicals essential to growth or repair of organic bodies, including carbon, oxygen, nitrogen, phosphorus, and silica.
Oil & grease	The concentration of all hydrocarbons found in water, whether from mineral or petroleum (both artificial and natural) sources.
Oligotrophic lake	Waterbodies that are nutrient-poor.
Open-water conditions	The period of time when the surface of a waterbody is completely free of ice.
Permafrost	Permanently frozen ground (subsoil).
pH	The negative log of the concentration of the hydronium ion. The pH is a measure of the acidity or alkalinity of all materials dissolved in water, expressed on a scale from 0 to 14, where 7 is neutral, values below 7 are acidic, and values over 7 are alkaline.
Photosynthesis	A chemical reaction that occurs in the chloroplasts of algae and plants and involves the conversion of water and carbon dioxide into organic carbon.
Photosynthetically active radiation (PAR)	Bandwidth of light (400 to 700 nanometres [nm]) that is used by algae and plants for photosynthesis.
Physico-chemical	A limnological reference to a group of physical and chemical water quality parameters that are measured in situ, and include dissolved oxygen, pH, specific conductivity, temperature and turbidity.
Plankton	Microscopic aquatic organisms (tiny plants [phytoplankton] and animals [zooplankton]) free-floating and suspended in the water column.
Polycyclic aromatic hydrocarbon (PAH)	A chemical by-product of petroleum-related industry, which also occur naturally.
Probable Effects Level	In reference to the Canadian sediment quality guidelines (CCME 2001), the level above which adverse effects are expected to occur but will not always occur.
Quality assurance / quality control procedures	A review by field personnel and laboratories of the procedures used in the collection, transport, and analysis of samples.
Reference lake	A lake that is reasonably similar in terms of monitored components and features to the exposure lakes, though not necessarily identical, but has no potential to be affected by the mine.
Residence times	Also referred to as lake retention time. This is the amount of time it takes for a parcel of water (or a particle) to enter, circle through, and leave a lake.
Runoff	The flow of water over land, typically resulting from direct precipitation or thaw from snow and ice.
Sampling event	Each grab or composite sample collected is referred to as a sampling event.
Secchi depth	<p>A parameter used to inform the clarity of surface waters, typically in lake environments. The measurement is made with a "Secchi" disk, a black and white disk approximately 20 cm in diameter, which that is lowered into the water column. The Secchi depth is the depth at which the disk is no longer visible. A Secchi depth recording of 2 m indicates that the disk was last visible at 2 m below the surface.</p> <p>High Secchi depth readings indicate clearer water that allows sunlight to penetrate to greater depths. Low readings indicate turbid water, which can reduce the passage of sunlight through the water column. Limited light penetration can be a factor in diminished aquatic plant growth beneath the surface, thus reducing the biological re-aeration at lower depths.</p>
Sediment	Solid material that is transported by, suspended in, or deposited from water. It originates mostly from disintegrated rocks; it also includes chemical and biochemical precipitates and decomposed organic material, such as humus.
Specific conductivity	(See also Conductivity). A conductivity reading normalized to a temperature of 25°C.
Standard deviation	A statistical value that is a measure of the dispersion or variation in a set of numbers, equal to the square root of the arithmetic mean of the squares of the deviations from the arithmetic mean.

Term	Definition
Stratification	The separation of lakes into three layers: well mixed top layer, middle layer (see Thermocline), and a bottom layer. In freshwater lakes, stratification usually occurs as a result of temperature effects that cause changes in water density. Stratification may also affect vertical changes in water quality.
Sub-Basin	A discrete part of a basin, which partially separates land features or a shallow lake bed.
Sub-Watershed	A smaller portion of a watershed containing a drainage area, which is connected to the larger portion by a single channel.
Surface area	The area of, for instance, a lake water surface, excluding islands.
Temporal variability	Seasonal or a variation over time.
Total dissolved solids	The dissolved matter found in water comprised of mineral salts and small amounts of other inorganic and organic substances. Also referred to as TDS.
Total Kjeldahl nitrogen	The sum of organic nitrogen and ammonia concentrations measured in a water sample.
Total organic carbon	A measure of the concentration of organic carbon in water, determined by the oxidation of the organic matter into carbon dioxide (CO ₂). Also referred to as TOC.
Total phosphorus	A measurement of particulate and dissolved phosphorus and phosphate molecules in water.
Total suspended solids	A measurement of the concentration of particulate matter found in water. Also referred to as TSS.
Trip blank	A water sample prepared by the laboratory and shipped to the field sampling location and then subsequently returned to the laboratory unaltered for analysis. These samples are used to detect sample contamination during transport.
Trophic state	The trophic state in lakes and streams is determined from the measured concentrations of nutrients (nitrogen and phosphorus), chlorophyll <i>a</i> , and Secchi depth. It provides an indication of the potential productivity of the lake or stream. The trophic classification or state of the lake or stream ranges from oligotrophic (nutrient-poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile).
Tundra	An area where tree growth is limited due to low temperatures and short growing season, and where permafrost is common.
Turbidity	A measure based on the cloudiness or haziness of a fluid caused by individual particles (total suspended or dissolved solids) that informs the clarity or transparency in water. Sometimes used as a surrogate to TSS because it can be measured in situ.
Under ice conditions	The period of year when the lakes are partially or completely covered with ice.
Waterbody	A body of water, such as a lake or pond, in contrast to a watercourse (see Watercourse).
Watercourse	A flowing body of water, such as a stream or river.
Watershed	The entire catchment area of runoff containing a single outlet.
Wetlands	Wetlands are land where the water table is at, near, or above the surface or which is saturated for a long enough period to promote such features as wet-altered soils and water tolerant vegetation. Wetlands include organic wetlands or "peatlands," and mineral wetlands or mineral soil areas that are influenced by excess water but produce little or no peat.