SECTION 8.0 – SURFACE WATER QUALITY
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8.0 SURFACE WATER QUALITY

8.1 Introduction

The baseline presents a description of existing surface water quality based upon historical data and data obtained specifically for the project from watercourses and waterbodies within and around the project area. Potential impacts of the proposed project that could affect water quality are assessed.

8.2 Study Area

The boundaries of the aquatic local study area (ALSA) and the aquatic regional study area (ARSA) for the project are shown in Figure 8.2-1.

The ALSA includes the Sunday Creek watershed, which is the largest stream located within the ALSA. Two unnamed streams, which are tributaries of Christina Lake, and several small waterbodies also exist within the project area (Figure 8.2-2).

The ARSA includes the Christina Lake watershed and a portion of the Jackfish River catchment between the outlet of Christina Lake and the mouth at the Christina River.

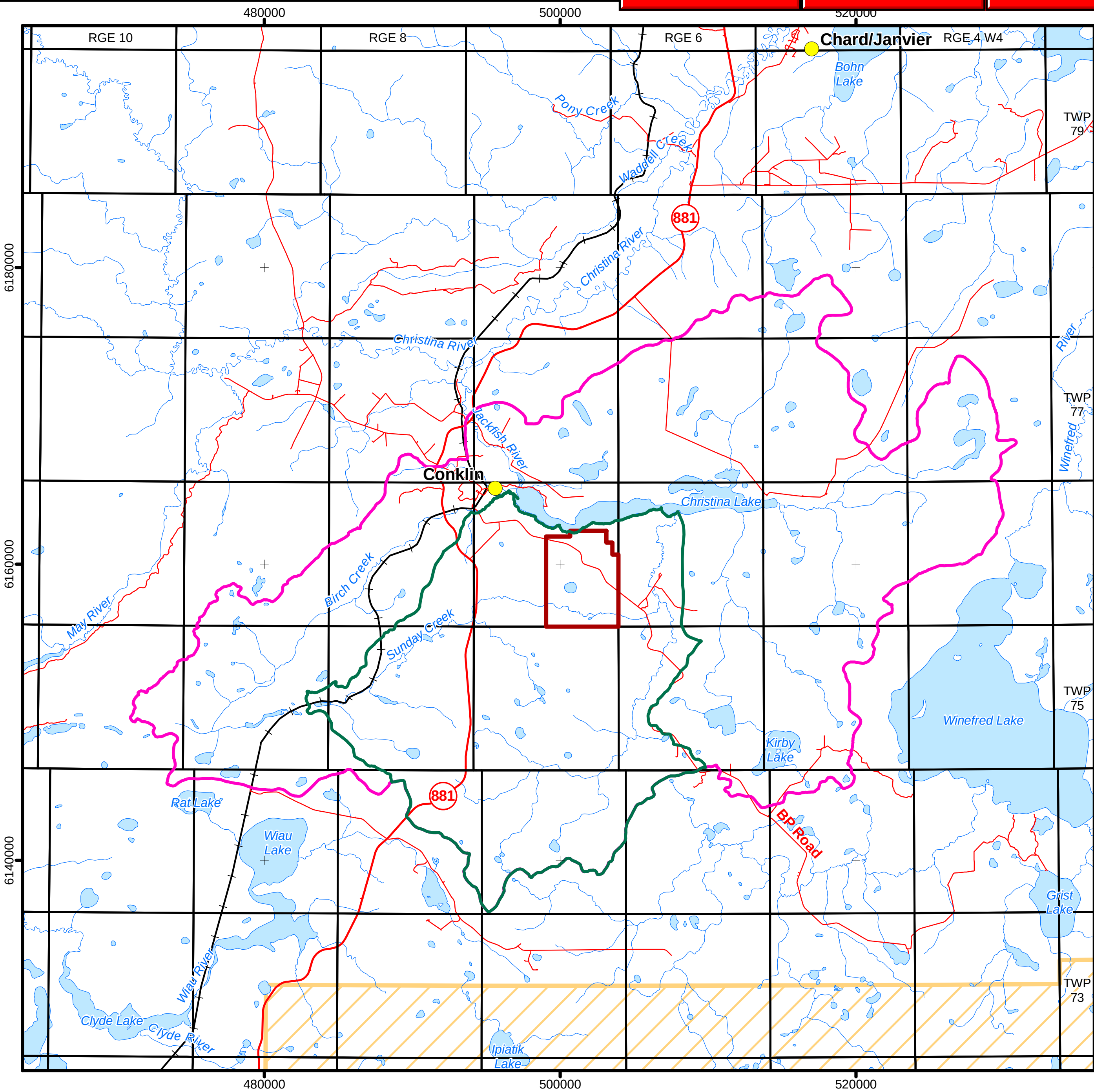
The air quality regional study area (AQRSA) was used to evaluate the acid sensitivity of lakes.

8.3 Issues and Assessment Criteria

Construction and operation of the project has the potential to affect the quality of waterbodies within the project area. The assessment considered what activities might cause physical or chemical changes that were ecologically relevant. Key issues related to the project have been identified. These issues are identified through public and regulatory consultation, professional experience and issues related to other similar developments in the oil sands area.

The project could potentially affect the surface water quality within the study area in the following ways:

- changes in runoff characteristics, stream flow and erosion potential as a result of land disturbance during construction and operation of the project;
- withdrawal of groundwater for operational and utility water supply;
- wastewater releases into nearby waterbodies during operations;
- accidental spills of liquids that could reach surface waterbodies or groundwater infiltration; and
- changes in streams and lakes acidity in the region as a result of acidifying air emissions.



Legend

- Aquatics Regional Study Area
- Aquatics Local Study Area
- Project Area
- Cold Lake Air Weapons Range
- Open Water
- Watercourse

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Aquatics Local and Regional Study Areas

DATE: December 2009	**Figure 8.2-1**
PROJECT: CE03745/410	Fig08.02-01 Aquatic Study Areas 09-11-15
ANALYST: TM; QA/QC: KW JH DR	DRAWN BY: AMEC
PROJECTION/DATUM: UTM Zone 12 NAD83	PREPARED BY: AMEC

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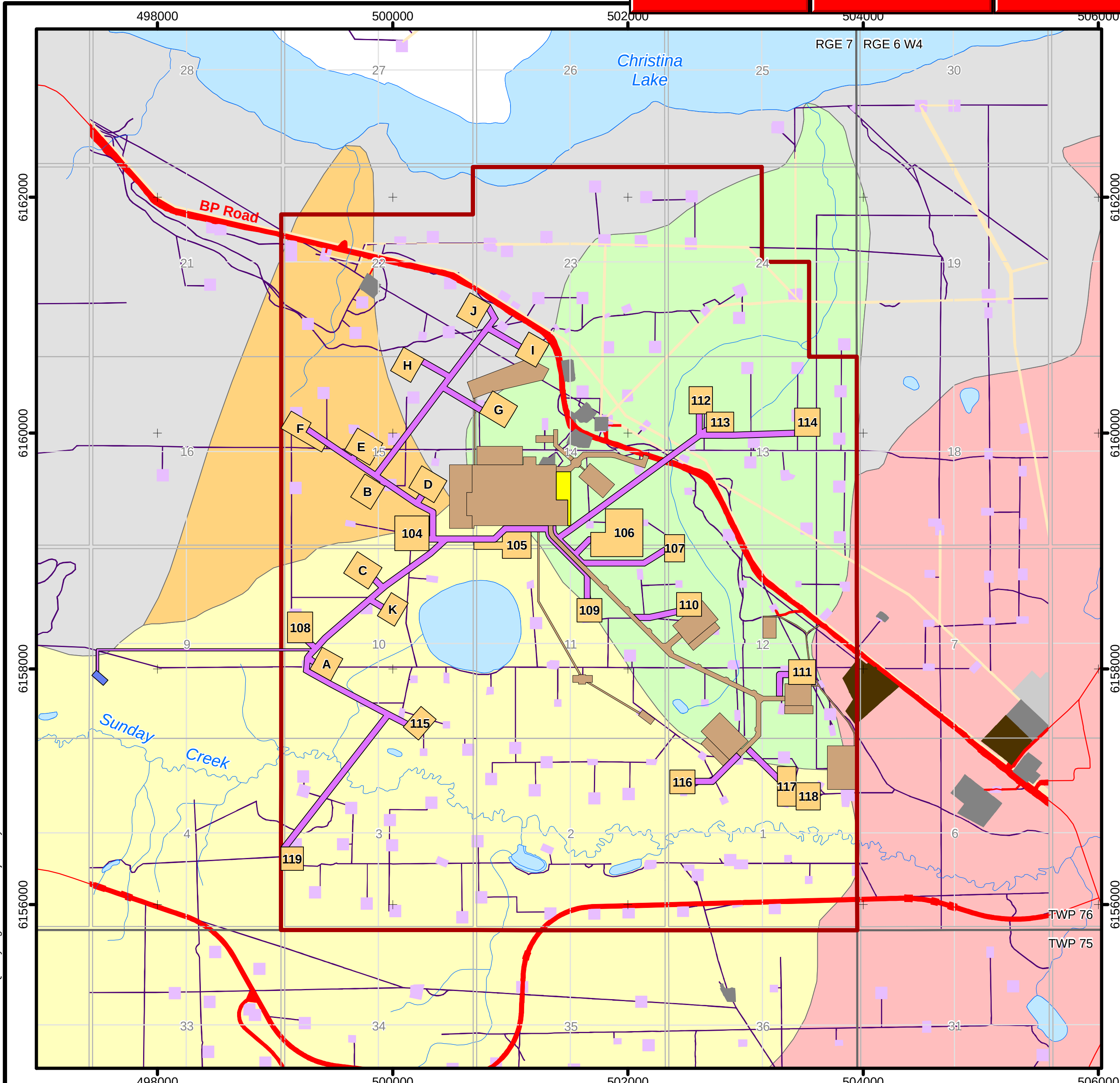

Legend

Project Area
Open Water
Watercourse

BlackGold Expansion Project Layout

Temporary Construction Laydown Area
Project ROW
Source Water Well
Well Pad

Baseline Disturbance

BlackGold Initial Project
Borrow Pit
Camp
Cutblock
Industrial/Clearing
Wellsite
ROW
Road
2D Seismic/Trail

Baseline Disturbance

Basin A - Sunday Creek Upstream of Project Area
Basin B - Sunday Creek Downstream of Project Area
Basin C - East Unnamed Creek
Basin D - West Unnamed Creek
Direct Drainage to Christina Lake

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BlackGold Expansion Project

Drainage Basins within the BlackGold Expansion Project

DATE: December 2009	**Figure 8.2-2**
PROJECT: CE03745/310	Fig08.02-02 Project Layout 09-12-15
ANALYST: TM; QA/QC: KW AR DR	DRAWN BY: AMEC
PROJECTION/DATUM: UTM Zone 12 NAD83	PREPARED BY: AMEC

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Effects on surface water quality may then have impacts on other components of the ecosystem in the study area, such as aquatic resources and wildlife habitat.

Assessment criteria used in evaluating effects on surface water quality were based on current provincial and federal water quality guidelines for the protection of aquatic life (AENV 1999, CCME 2007) and drinking water quality guidelines (Health Canada 2008). These guidelines were then used to evaluate and assess impacts on water quality.

8.4 Methods

8.4.1 Review of Existing Information

A review of existing information was conducted including the collection of the following:

- the baseline report for the lease area prepared by Matrix Solutions Inc. (Newmont 2006);
- the North American Oil Corporation Application for Approval of the Kai Kos Desheh Project (NAOSC 2007);
- the Devon Applications for Approval of the Jackfish and Jackfish Phase 2 Projects (Devon 2003, 2006);
- the MEG Energy Application for Approval of the Christina Lake Regional Project, Phase 3 (MEG 2008); and
- the Canadian Natural Resources Application for Approval of the Kirby In-Situ Oil Sands Project (CNRL 2007).

Historical data were collected from the Alberta Environment database (AENV 2009) and the Atlas of Alberta Lakes (Mitchell and Prepas 1990).

8.4.2 Field Survey

A field survey program was developed, and water and sediment samples were collected for laboratory analyses. Standard operating procedures (SOPs) were used to ensure sample quality. The analytical laboratory provided all sampling bottles, jars and the required preservatives. Sample bottles were rinsed three times with site water prior to filling. Bottles were labelled with the site number, date and time of collection, project number and sampler's name. All samples were kept cool until delivered to the laboratory. Chain-of-custody forms were provided with all samples delivered to the lab.

Field blank and field duplicate samples for each survey were taken at one site as part of the QA/QC program. The field blank sample was prepared by sampling reverse osmosis deionized water or organic free water provided by the laboratory. The field blank was used to detect sample contamination during the collection, shipping, and analysis of water samples. The field duplicate sample was taken by filling an extra set of bottles at one site, which was labelled with a different site number, not known by the laboratory. The field duplicate was used to check for laboratory analysis accuracy.

Trip blanks were also used during the field program as part of the QA/QC program, in order to detect contamination during the transport of water samples to the laboratory. Reverse osmosis de-ionized water or organic free water was poured into clean sample bottles and preserved (if necessary) by the laboratory prior to the field program. The trip blanks were labelled and sealed by the laboratory and sent along with the clean sample bottles that were used to collect the baseline samples. The trip blanks were kept sealed for the duration of the field program and returned to the laboratory along with the other samples.

Sites were sampled in fall (September) 2008, and the samples analyzed by the AMEC Laboratory in Edmonton.

Sample parameters included:

- field parameters including temperature, dissolved oxygen (DO), specific conductivity, and pH;
- conventional water chemistry ;
- nutrients;
- total and dissolved metals; and
- polycyclic aromatic hydrocarbons (PAHs).

Sediments were sampled and analyzed for the following parameters:

- texture (sand, silt, clay); and
- polycyclic aromatic hydrocarbons (PAHs).

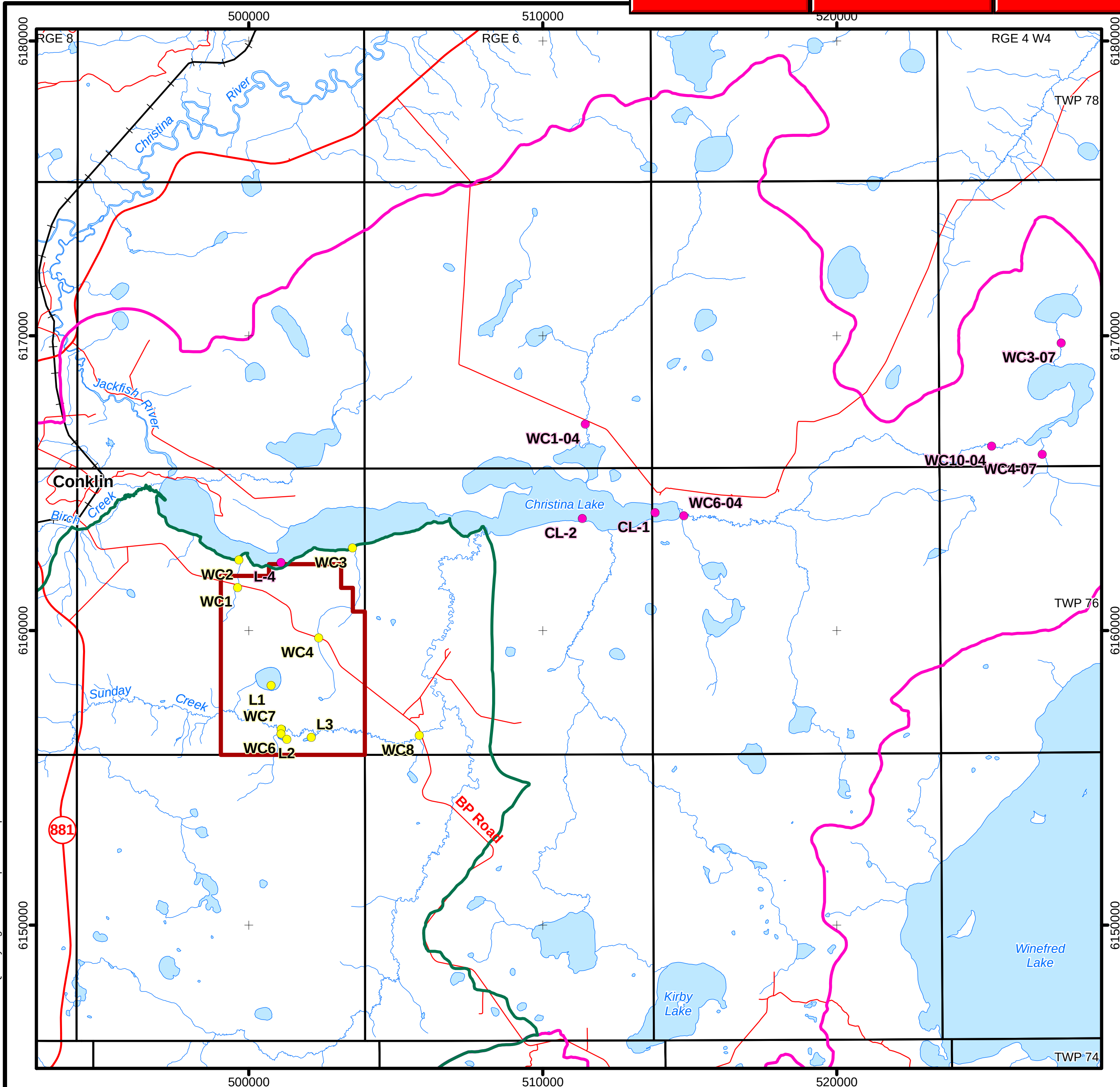
Water quality data were compared to the federal Canadian Environmental Quality Guidelines (CEQG) for the protection of aquatic life (CCME 2007), the provincial Surface Water Quality Guidelines for use in Alberta (ASWQG) (AENV 1999), and the federal Guidelines for Canadian Drinking Water Quality (CDWQG) (Health Canada 2008). Sediment quality parameters were compared to Canadian Council of Ministers of Environment (CCME) interim sediment quality guidelines (ISQG) (CCME 2002).

8.5 Existing Conditions

The development of the project has the potential to impact watercourses and waterbodies within the project lease and surrounding areas (Figure 8.5-1), including:

- two small unnamed creeks, which drain into Christina Lake;
- a portion of Sunday Creek; and
- three unnamed tributaries and waterbodies, which feed into Sunday Creek.

Christina Lake and Birch Creek are included in the ARSA and will also be discussed. A total of 193 lakes in the AQRSA were assessed for acid sensitivity.



Legend

- Aquatics Regional Study Area
- Aquatics Local Study Area
- Project Area
- Open Water
- Watercourse
- Aquatics Regional Study Area Sampling Site
- Aquatics Local Study Area Sampling Site

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Aquatics Sampling Sites

DATE: December 2009	**Figure 8.5-1**
PROJECT: CE03745/410	Fig08.05-01 Aquatic Sample Sites 09-11-15
ANALYST: TM; QA/QC: KW JH DR	DRAWN BY: AMEC
PROJECTION/DATUM: UTM Zone 12 NAD83	PREPARED BY: AMEC

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8.5.1 Local Study Area

8.5.1.1 Unnamed Sunday Creek Tributaries

Several unnamed tributary watercourses and waterbodies connected to Sunday Creek have been sampled and include:

- Lake L1;
- Unnamed Sunday Creek Tributary (watercourse site WC6 and lake L2); and
- Lake L3.

Lake Site L1

Site L1 is on an unnamed lake within the Sunday Creek watershed. Vegetation around the edges of the lake consists of black spruce, muskeg, and grasses. The outlet is located on the southwest end of the lake. The lake is relatively uniform in depth with a recorded maximum of 1.3 m. Site L1 was sampled during all four seasons in 2005 and 2006 and in the fall of 2008. Water quality data for this site is in Appendix D, Table D.1, and sediment data in Table D.2.

The pH of the lake was slightly acidic (range: 5.9 to 7.3) and was below the CEQG (range: 6.5 to 9.0) and the CDWQG (range: 6.5 to 8.0). The DO concentrations ranged from 0.8 to 13.1 mg/L, with the lowest concentrations occurring during winter. Concentrations were below the CEQG twice during the sampling period, in winter and in spring. Total dissolved solids (TDS) concentrations ranged from 42 to 148 mg/L. Total suspended solids (TSS) concentrations were low, ranging from 1 to 7 mg/L. Calcium and bicarbonate were the dominant ions in the lake. Calcium concentrations ranged from 11 to 37 mg/L while bicarbonate concentrations ranged from 51 to 175 mg/L.

Nutrient levels in the lake were generally low, except for total Kjeldahl nitrogen (TKN). Concentrations of 1.14 mg/L and 2.18 mg/L, which exceeded the ASWQG of 1 mg/L were found on two occasions. Nitrate concentrations were below detection limits. Total phosphorus concentrations vary seasonally, from 0.011 mg/L in the spring to 0.044 mg/L in the winter.

Samples collected for PAH analysis showed that pyrene, benz[a]anthracene, and benzo[a]pyrene were all at detectable levels in the winter samples. Benz[a]anthracene were found just above the CEQG level of 0.018 µg/L in the winter sample with a concentration of 0.02 µg/L. Concentrations of PAHs in all other seasons were below the analytical limits of detection.

Generally, samples analyzed for total metals were below detection limits, with some exceptions. Cadmium exceeded the CEQG of 0.02 µg/L once, in the summer sampling period, with a concentration of 0.05 µg/L. Selenium exceeded the CEQG of 1 µg/L in the fall with a concentration of 1.4 µg/L. Silver concentrations exceeded the CEQG of 0.1 µg/L twice, in both the spring (0.2 µg/L) and summer (0.9 µg/L).

Sediment samples from this site were comprised of sand (88%), silt (8%) and clay (4%). Total petroleum hydrocarbon parameters were below detection limits except for F1-BTEX (25 µg/g) and the F3 hydrocarbon fraction (156 µg/g).

Watercourse Site WC6

Site WC6 is located on an unnamed Sunday Creek tributary, which is located in the south of the lease area. The watercourse drains waterbody L2 to Sunday Creek. The watercourse was sampled in three seasons (spring, summer and fall) in 2005 (Appendix D, Table D.3).

The pH of this watercourse is neutral. Conductivity ranges from 100 to 242 µS/cm. This watercourse is well oxygenated, with DO ranging from 9.1 to 15.7 mg/L, and concentrations that are never below the CEQG or the ASWQG.

TDS range from 149 to 246 mg/L while TSS range from 2 to 4 mg/L. Hardness ranges from 76 to 130 mg/L.

Nutrient concentrations were low in this watercourse, with nitrate and nitrite concentrations often below detection limits. Ammonia concentrations were measured at a maximum of 0.04 mg/L while TKN concentrations ranged from 0.3 to 0.6 mg/L. Total phosphorus concentrations were measured at a maximum of 0.02 mg/L.

PAH concentrations were never above analytical detection limits in this watercourse.

Total metals concentrations in this watercourse were often below detection limits. Guideline exceedances were noted only for silver and iron. Silver concentrations of 0.3 and 1.0 µg/L, respectively, exceeded the CEQG of 0.1 µg/L. A fall iron concentration of 350 µg/L exceeded the CEQG and CDWQG of 300 µg/L.

Lake Site L2

Site L2 is located on a small lake that drains north-westward via an unnamed tributary to Sunday Creek. A large beaver dam obstructs the lake outlet, creating lake depths of 3 to 3.8 m. The lake was sampled in the summer and fall of 2005 (Appendix D, Table D.4).

Dissolved oxygen concentrations in the lake ranged from 6.1 to 11.9 mg/L, with the summer concentration of 6.1 mg/L being below the CEQG of 6.5 mg/L. The pH of the lake was neutral, having been measured at 7.0 in both seasons. TDS ranged from 121 to 130 mg/L, while TSS ranged from 2 to 3 mg/L. Hardness was measured at 120 mg/L in the summer and 130 mg/L in the fall.

Nutrient concentrations were low in the lake. Nitrite concentrations were below detection limits in both seasons, while nitrate concentrations were either below, or at detection limits (method detection limit [MDL] = 0.003 mg/L for both parameters). Ammonia concentrations ranged from 0.01 to 0.02 mg/L, while TKN concentrations ranged from 0.54 to 0.65 mg/L. Total phosphorus concentrations ranged from 0.008 to 0.012 mg/L.

All PAH concentrations were below analytical detection limits.

Total metals concentrations were often above detection limits but rarely exceeded guidelines. A fall arsenic concentration of 5.8 µg/L exceeded the CEQG of 5 µg/L. A summer cadmium concentration of 0.06 µg/L exceeded the CEQG of 0.02 µg/L. A silver concentration of 1 µg/L exceeded the CEQG of 0.01 µg/L.

Lake Site L3

Site L3 is located on a small unnamed lake located in the south portion of the lease area and connects via a short outlet channel to Sunday Creek. Vegetation along the edge of the lake consists of coniferous forest, muskeg, and grasses. Water depth ranges from 0.3 to 2 m. This site was sampled in all four seasons in 2005/2006 (Appendix D, Table D.5).

The lake was well oxygenated, except in winter when concentrations were measured at 0.8 mg/L. This value was below the CEQG of 6.5 mg/L. The pH of the lake was neutral and ranged from 6.7 to 7.2. TDS increased through the seasons from spring to winter and ranged from 79 to 275 mg/L. TSS varied through the seasons, and ranged from 3 to 37 mg/L with the highest concentrations measured in the summer.

Nutrient concentrations were higher at this site than at other sites in the ALSA. Nitrate concentrations were always above detection limits and ranged from 0.003 to 0.006 mg/L. Nitrite concentrations were always below detection limits. Ammonia concentrations ranged from 0.01 to 1.84 mg/L. TKN concentrations ranged from 0.51 to 2.77 mg/L with the fall and winter concentrations, of 1.06 and 2.77 mg/L, respectively, being above the ASWQG of 1 mg/L. Total phosphorus concentrations were above the ASWQG of 0.05 mg/L in every season except spring, and ranged from 0.016 to 1 mg/L.

PAH concentrations were below analytical detection limits in all seasons.

Total metals concentrations were often below detection limits. However, a few guideline exceedances were noted. The summer cadmium concentration of 0.06 µg/L was above the CEQG of 0.02 µg/L. The spring and winter mercury concentrations of 0.0021 µg/L were above the CEQG of 0.004 µg/L and the ASWQG of 0.002 µg/L. Silver concentrations in spring and summer of 0.4 and 0.9 µg/L, respectively, were above the CEQG of 0.1 µg/L.

8.5.1.2 Christina Lake Tributaries

Sunday Creek and Birch Creek

Sunday Creek flows along the south boundary of the lease area and then flows northeast of the lease area, before discharging to Christina Lake. Two sites were sampled on Sunday Creek; WC7 was sampled in all four seasons of 2005 and 2006, and WC8 was sampled in all four seasons of 2005 and 2006, as well as during the fall of 2008 (Appendix D, Table D.6 and Table D.2).

Birch Creek flows in a northeasterly direction, outside the western boundary of the lease. The creek discharges into the western side of Christina Lake. Sunday Creek and Birch Creek have similar hydrogeological characteristics (Devon 2006). Thus, it can be inferred that water quality characteristics between the two creeks under natural conditions are similar. Since Birch Creek was not sampled, Sunday Creek will be used as an analogue for Birch Creek.

Sunday Creek was well oxygenated. DO concentrations ranged from 7.3 to 15.1 mg/L. The pH at this site was neutral (median = 7.4) except for the winter sample which was acidic (5.3) and below the CEQG and CDWQG ranges. Hardness increased through the seasons from 69 mg/L in the spring to 180 mg/L in the winter. TDS ranged from 75 to 206 mg/L and also increased from spring to winter. TSS concentrations were low, ranging from below the detection limit of 2 mg/L to 12 mg/L. The highest TSS concentrations were measured in the spring. Calcium and bicarbonate were the major ions at this site. Calcium concentrations ranged from 17.9 to 50.2 mg/L and bicarbonate concentrations ranged from 91 to 258 mg/L.

Nutrient concentrations were generally low, and a few guideline exceedances were noted in winter. A winter nitrite concentration of 0.18 mg/L exceeded the CEQG of 0.06 mg/L. Total phosphorus ranged from 0.008 to 0.11 mg/L. The winter sample of 0.11 mg/L was above the ASWQG of 0.05 mg/L. Ammonia concentrations ranged from below detection limit (0.01 mg/L) to 0.26 mg/L, while TKN ranged from 0.3 to 0.7 mg/L.

PAH analysis showed that concentrations for all parameters were below detection limits.

The concentrations of total metals in samples from Sunday Creek were often below detection limits. A few guideline exceedances were noted. The summer sample of cadmium (0.05 µg/L) was above the CEQG (0.03 µg/L). Iron concentrations exceeded the CEQG and CDWQG of 300 µg/L with a median concentration of 400 µg/L. Manganese concentrations exceeded drinking water guidelines in the winter (190 µg/L). As with other sites in the Sunday Creek watershed, silver concentrations were often above the CEQG of 0.1 µg/L (median 0.5 µg/L).

Sediment samples taken at site WC8 were mostly sand (96%), with minor amounts of silt (1%) and clay (3%). All petroleum hydrocarbon parameters were below detection limits.

West Unnamed Creek (Christina Lake Tributary 1)

West Unnamed Creek, an unnamed tributary of Christina Lake that flows north through the lease and drains into Christina Lake, was sampled in two locations. WC1 was sampled in all four seasons of 2005 and 2006, and in fall 2008. WC2 was sampled only in fall of 2005 (Appendix D, Table D.7 and Table D.2).

The pH of this watercourse was close to neutral, and ranged from 6.9 to 7.7. Conductivity ranged from 52 µS/cm in the spring to 476 µS/cm in the winter. The watercourse was well oxygenated, with DO concentrations that ranged from 10.4 to 12.8 mg/L.

TDS concentrations ranged from 29 mg/L in the spring to 251 mg/L in the winter. Hardness followed the same pattern as TDS, with spring concentrations of 29 mg/L and winter concentrations of 230 mg/L. TSS concentrations ranged from a low of 1 mg/L in the winter to 21 mg/L in the fall of 2005.

Nutrient concentrations were generally low in this watercourse, with nitrite concentrations always found to be below detection limits, and nitrate concentrations were measured at a maximum of 0.012 mg/L. Ammonia concentrations ranged from below detection limits (0.01 mg/L) to 0.03 mg/L. Total Kjeldahl nitrogen concentrations ranged from 0.3 to 0.6 mg/L, while total phosphorus concentrations ranged from below detection limits (0.02 mg/L) to 0.03 mg/L.

PAH concentrations were generally below analytical detection limits, except for phenanthrene, which was measured at 0.05 mg/L in spring, summer, fall and winter of 2005 at WC1. Concentrations were below detection limits at WC2.

Total metal concentrations were generally low in this water course, and were often below detection limits. Occasional guideline exceedances were noted for cadmium, iron, manganese, silver and zinc.

Sediments samples taken from site WC1 were comprised almost entirely of sand (99%). None of the petroleum hydrocarbon parameters were above analytical detection limits in sediment at this site.

East Unnamed Creek (Christina Lake Tributary 2)

East Unnamed Creek, the other sampled unnamed Christina Lake tributary, flows northward through the eastern portion of the lease and drains into Christina Lake. This watercourse was sampled at one site, WC4, in all four seasons in 2005 and 2006, and once in the fall of 2008 (Appendix D, Table D.8 and Table D.2).

The pH at this site was slightly acidic to neutral (ranged from 6.3 to 7.2) and in the fall (2005) it was below the CDWQG (6.5 to 8.5) and the CEQG (6.5 to 9.0). DO concentrations tended to be low at this site and ranged from 0.3 to 7.9 mg/L. The lowest levels were measured in the winter. Summer, fall (2005) and winter concentrations were below the CEQG of 6.5 mg/L.

Hardness increased seasonally, from 38 mg/L in the spring to 200 mg/L in the winter. TDS concentrations followed the same pattern, and ranged from 39 mg/L in the spring to 221 mg/L in the winter. TSS concentrations were variable and ranged from below the detection limit of 2 mg/L in the fall of 2008 to 20 mg/L in the winter (2006). Calcium and bicarbonate were the dominant ions. Calcium concentrations ranged from 9.5 to 53 mg/L and bicarbonate concentrations ranged from 46 to 276 mg/L. Ion concentrations increased through the seasons from spring to winter.

Nutrient concentrations were generally low in this watercourse, although some guideline exceedances occurred in winter. Nitrate concentrations were below detection limits in all samples, while nitrite concentrations were below detection limits in the majority of samples. Ammonia concentrations ranged from 0.04 to 1.43 mg/L. TKN concentrations ranged from 0.43 mg/L in the spring to 3.0 mg/L in the winter, with the winter sample being above the ASWQG of 1 mg/L. Total phosphorus concentrations, which ranged from below the detection limit of 0.02 mg/L to 1.2 mg/L, were also above the ASWQG of 0.05 mg/L in the winter.

Analysis for PAHs showed that concentrations of all parameters were below analytical detection limits.

Most of the samples that were analyzed for total metals were below detection limits. However a few guideline exceedances were noted. Arsenic levels were above the CEQG of 5 µg/L in the winter with a concentration of 5.2 µg/L. Cadmium levels were above the CEQG of 0.02 µg/L once with a concentration of 0.06 µg/L. Iron concentrations were above the CDWQG and the CEQG (300 µg/L) in all seasons but spring (range: 170 to 700 µg/L), while manganese concentrations were above the CDWQG (50 µg/L) in all samples (range: 60 to 890 µg/L). Silver concentrations were above the CEQG of 0.1 µg/L twice, in spring (0.4 µg/L) and summer (1.0 µg/L).

Sediment samples from this site indicated that sand was the dominant substrate type (48%) with equal parts of silt and clay also being present (26% for both). The F1-BTEX and F3 fractions of total petroleum hydrocarbons were the only hydrocarbon parameters that were above detection limits with concentrations of 49 and 977 µg/g, respectively.

8.5.2 Aquatic Regional Study Area

The ARSA includes Christina Lake and its watershed. Several sites were sampled on Christina Lake, as well as on unnamed watercourses in the Christina Lake watershed. Data for unnamed waterbodies in the Christina Lake watershed are discussed in the following section on the acid sensitivity of lakes.

8.5.2.1 Christina Lake

Christina Lake is a long, narrow waterbody located to the north of the lease boundary. Much of its drainage basin lies to the south of the lake and much of this part of the basin is drained by Sunday and Birch Creeks. The lake is drained by the Jackfish River, which is located on the western edge of the lake. The Jackfish River then drains to the Christina River.

The lake has three deep basins with maximum depths of 33 m, 26 m and 24 m (Mitchell and Prepas 1990). The lake also has two shallower basins, one with a depth of 12.2 m, and one with a depth of 1.5 m (Mitchell and Prepas 1990). Available water quality data for Christina Lake is in Appendix D, Tables D.9 and D.10.

Because of its depth, the lake becomes strongly thermally stratified in the summer (Figure 8.5-2). Dissolved oxygen declines steadily with depth (Figure 8.5-3).

The lake was well buffered and the dominant ions were bicarbonate and calcium. Hardness ranged from 82 to 114 mg/L. TSS was variable in the lake, and ranged from 1 to 124 mg/L. TDS ranged from 173 to 230 mg/L.

Nutrient concentrations were low in Christina Lake. Nitrate concentrations were generally above detection limits, but were always below guideline values. Nitrite and ammonia concentrations were rarely above detection limits. TKN concentrations ranged between 0.4 and 0.6 mg/L, while total phosphorus concentrations ranged between 0.003 and 0.02 mg/L.

PAH concentrations were not observed above analytical detection limits in Christina Lake over the period of observations.

Total metals concentrations were generally low in the lake, and were often below detection limits. A few guideline exceedances were noted. A cadmium concentration of 0.05 µg/L exceeded the CEQG of 0.02 µg/L. A mercury concentration of 0.0023 µg/L exceeded the CEQG of 0.004 µg/L. Two silver concentrations of 0.3 and 0.6 µg/L exceeded the CEQG of 0.1 µg/L.

Sediment samples collected in Christina Lake in the fall of 2007 were comprised mainly of sand (84%) (Appendix D, Table D.11). All total metal concentrations were below the CCME interim sediment quality guidelines. Total recoverable hydrocarbons were below detection limits.

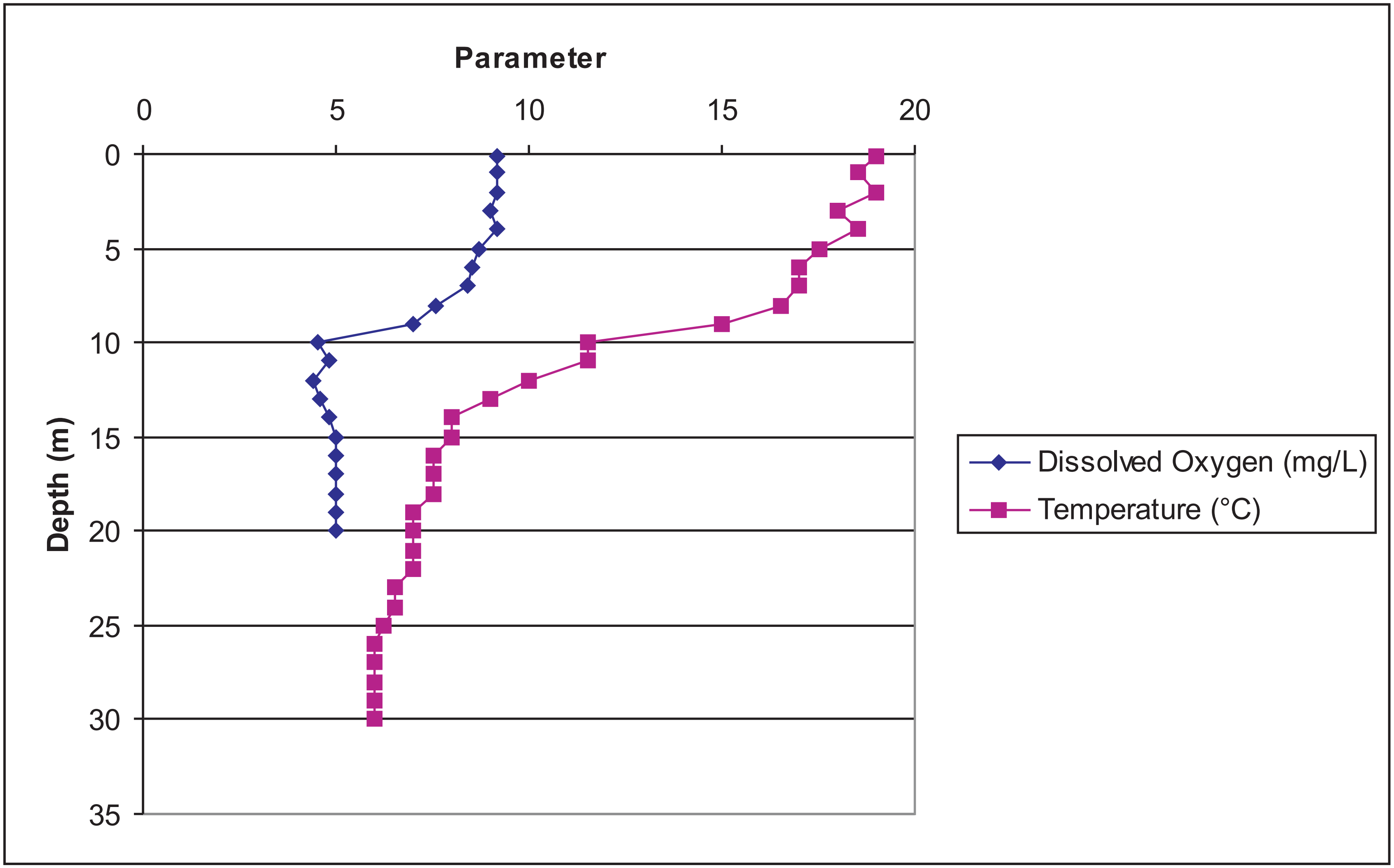
8.5.2.2 Unnamed Watercourses of the Christina Lake Watershed

Five unnamed watercourses were sampled in the ARSA in 2004 and 2007 (Appendix D, Tables D.11 and Table D.10).

Watercourses in the ARSA were generally well oxygenated. Dissolved oxygen concentrations were below the CEQG of 6.5 mg/L in two of the watercourses in summer with concentrations of 3.4 and 5.8 mg/L. The pH of these watercourses was neutral to slightly acidic (ranged from 6.6 to 7.6) and conductivity ranged from 75 to 242 µS/cm.

TSS concentrations were generally low ranging from below the detection limit of 3 mg/L to 12 mg/L, except for a single spring concentration of 54 mg/L at site WC3-07. TDS ranges from 55 to 301 mg/L. Calcium and bicarbonate are the dominant ions.

Nutrient concentrations were low, although some guideline exceedances were noted. Several spring and summer total phosphorus concentrations exceeded the Alberta chronic water quality guideline of 0.05 mg/L. Concentrations ranged from 0.01 to 0.18 mg/L. A summer TKN concentration of 2.1 mg/L exceeded the Alberta chronic water quality guideline of 1 mg/L



Source: AENV (1983)

Korea National Oil Corporation BlackGold Expansion Project	Dissolved Oxygen and Temperature Depth Profiles Christina Lake 29 August 1983	DATE: December 2009 PROJECT: CE03745/330 ANALYST: KW QA/QC: KW ST DR	Fig08.05-02 Depth 1983 09-11-30 DRAWN BY: AMEC PREPARED BY: AMEC

Figure 8.5-2

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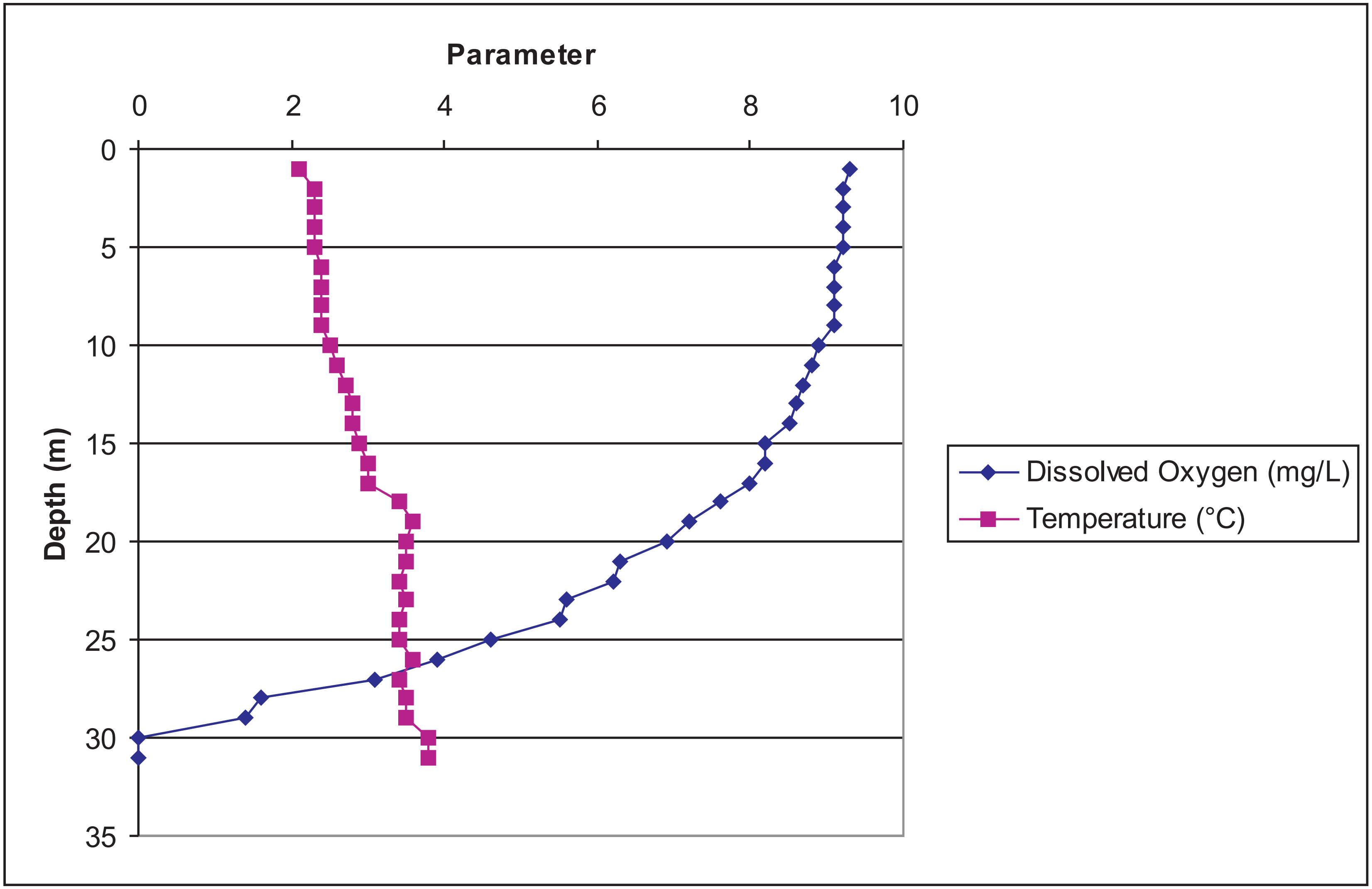

Source: AENV (1986)

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Korea National Oil Corporation

BlackGold Expansion Project

Dissolved Oxygen and Temperature Depth Profiles
Christina Lake
19 March 1986

DATE: December 2009		Fig08.05-03 Depth 1986 09-11-30	**Figure 8.5-3**
PROJECT: CE03745/330		DRAWN BY: AMEC	
ANALYST: KW	QA/QC: KW ST DR	PREPARED BY: AMEC	

Total metals concentrations were often below detection limits in watercourses in the ARSA, although a few guideline exceedances were noted. Two aluminum concentrations of 100 and 110 µg/L were at or near the CEQG of 100 µg/L. Iron concentrations were often above the CEQG and CDWQG of 300 µg/L and ranged from 70 to 980 µg/L. Manganese concentrations exceeded the CDWQG (50 µg/L) four times and ranged from 5 to 180 µg/L. A single silver concentration of 0.12 µg/L exceeded the CEQG of 0.1 µg/L in spring and a zinc concentration of 250 µg/L exceeded the CEQG of 30 µg/L in summer.

Sediments in the watercourses were composed primarily of sand and clay particles. Metal concentrations in all sediments were below the CCME interim sediment quality guidelines.

8.5.3 Acid Sensitivity of Lakes

Acid sensitivity for 193 waterbodies present in the AQRSA (Figure 8.5-4) were assessed using the classification system presented in Saffran and Trew (1996). Classification of acid sensitivity were based on alkalinity and calcium cations and rated on a scale where "high" indicates an increased acidification potential due to relatively low concentrations, and "least" refers to the potentially higher buffering capacity of a given waterbody due to the presence of a high concentration of these parameters (Table 8.5-1).

Table 8.5-1: Acid Sensitivity Ratings Based on Saffran and Trew (1996)

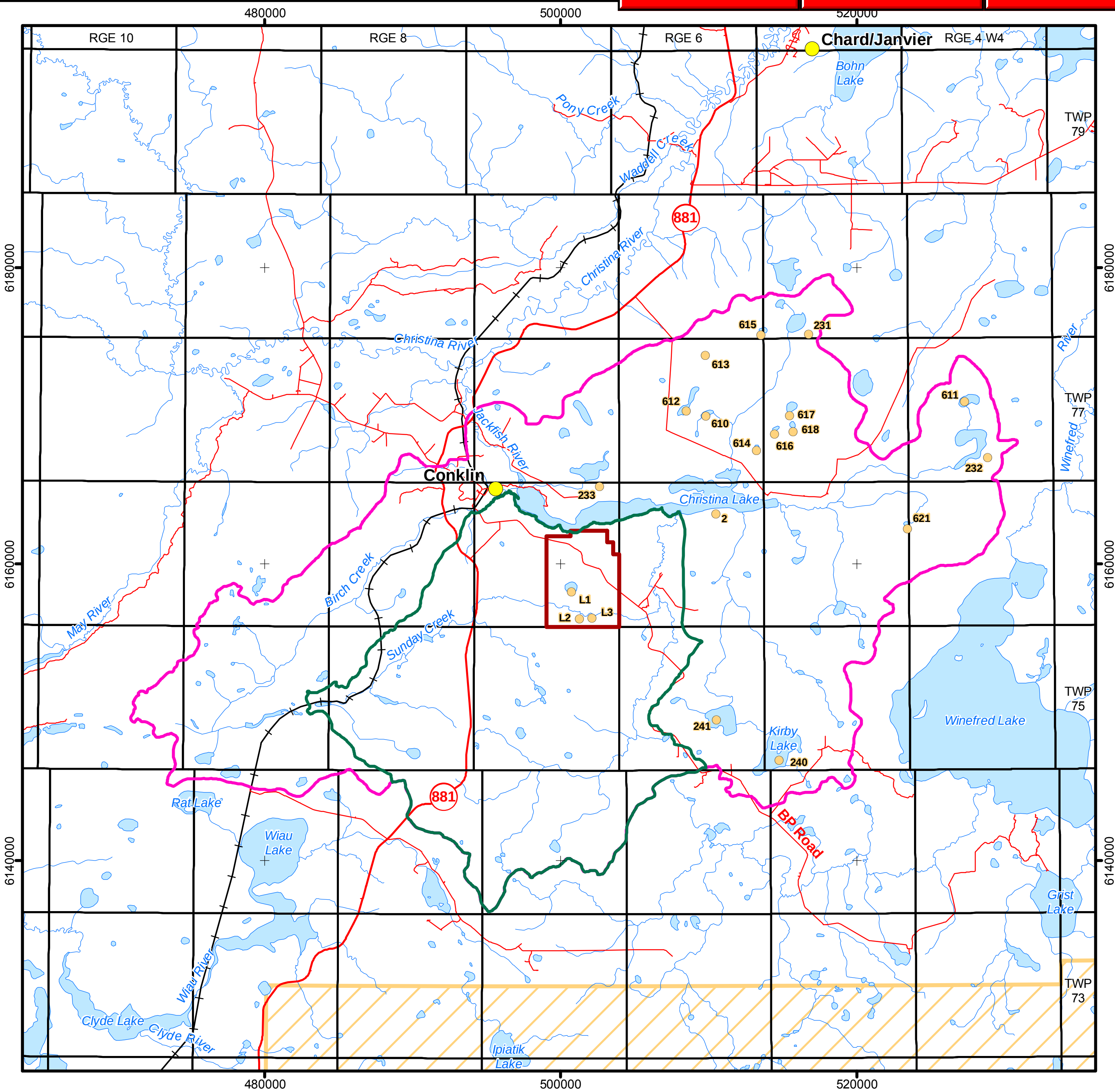
Parameter	Unit	High	Moderate	Low	Least
Alkalinity	mg/L	0-10	11-20	21-40	>40
pH	pH Unit	0-6.5	6.6-7.0	7.1-7.5	>7.5
Calcium	mg/L	0-4	5-8	9-25	>25

The pH was rated similarly, where a "high" acid sensitivity rank was attributed when the pH value was relatively low; a high pH value was attributed a "least" sensitive rank.

The lake database used was developed by Saffran and Trew (1996), and extended by the addition of data presented in recent environmental impact assessments (EIAs) and consultant reports (MEG 2008, Devon 2003, LICA 2007) (Appendix D, Table D.11).

Sensitivity ratings of "least" for alkalinity were measured in 128 lakes (66%), indicated a high buffering capacity to acid inputs. "Low" sensitivity ratings were attributed to 34 lakes (18%), while "moderate" sensitivity ratings were attributed to 11 lakes (6%). Twenty lakes (10%) were identified as having a low buffering capacity to acid inputs, with an attributed acid sensitivity rating of "high". However, these lakes had acid sensitivity parameter levels at the upper boundary of the high range so they were more likely in the moderate to high range.

Sensitivity ratings of "least" for pH were measured in 125 lakes (65%). "Low" sensitivity ratings were attributed to 37 lakes (19%) and "Moderate" sensitivity ratings were attributed to 13 lakes (7%). Eighteen lakes (9%) were identified as having a "high" sensitivity rating for pH.



Legend

- Aquatics Regional Study Area
- Aquatics Local Study Area
- Project Area
- Cold Lake Air Weapons Range
- Open Water
- Watercourse
- Surveyed Lake

5 2.5 0 5 10
Kilometres
1:400,000

N

Korea National Oil Corporation

BlackGold Expansion Project

Surveyed Lakes Acid Sensitivity

DATE: March 2010	**Figure 8.5-4**
PROJECT: CE03745/410	Fig08.05-04 Lake Acid 10-03-25
ANALYST: TM; QA/QC: KW JH DR	DRAWN BY: AMEC
PROJECTION/DATUM: UTM Zone 12 NAD83	PREPARED BY: AMEC

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Sensitivity ratings of "least" for calcium were measured in 43 lakes (22%). "Low" sensitivity ratings were attributed to 106 lakes (55%). "Moderate" sensitivity ratings for calcium were attributed to 21 lakes (11%) while 23 lakes (12%) were identified as having a "high" acid sensitivity rating.

The majority of lakes in the AQRSA fall within the "Least" sensitive to acidifying emissions category, indicating they are well buffered against acidifying emissions. Many lakes also fall within the "Low" category, while fewer lakes fall within the "Moderate" and "High" categories.

8.5.4 Summary of Guideline Exceedances in ASLA

Baseline water quality data for the project area suggested that waterbodies were generally well buffered against the effects of acidifying emissions, and few guideline exceedances were noted (Table 8.5-2). The concentrations of some total metal parameters exceeded guidelines relatively frequently (i.e., silver). Dissolved metals were present in lower concentrations in the dissolved form, and not bioavailable.

8.6 Potential Impacts and Mitigative Measures

8.6.1 Impact of Subsurface Operations

Water will be extracted from deep aquifers for the operations phase of the project. Groundwater withdrawals are not predicted to impact surface water.

8.6.2 Impact from Changes in Runoff

The following maximum changes in flow due to the project were identified in Volume 2 (Section 7.0) and are summarized below:

- the total annual runoff increased in many of the basins in the ALSA. No impact on annual runoff is predicted to occur for Birch Creek and only low impact is predicted to occur for Sunday Creek and areas of direct drainage. Both East and West unnamed creeks are predicted to experience moderate increases to the annual runoff;
- moderate increases at East Unnamed Creek and West Unnamed Creek are also predicted for the 1:10 year flood event, as well as the 1:100 year flood event. Low increases in both flood events are predicted for Sunday Creek and areas of direct drainage; and
- the effect on low flow volume is predicted to be near zero in Basins C and D.

Water quality parameters, such as conductivity, can be used as a 'dilution indicator'. If stream discharge decreases, then the stream conductivity will increase. Conversely, if stream discharge increases, then the stream conductivity will decrease. Table 8.6-1 shows the projected medians in TDS and major ions expected for Sunday Creek, West Unnamed Creek and East Unnamed Creek.

Table 8.5-2: Water Quality Guideline Exceedances at Baseline (ALSA)

Parameter	Units	Guidelines				n	No. of Exceedances	% of Exceedances
		Aquatic Life			Drinking Water			
		CCME (2006)	AENV (1999)		Health Canada (2007)			
			Acute	Chronic				
pH	pH units	6.5 to 9.0	6.5 to 8.5[b1]	–	6.5 to 8.5[d1]	33	4	12
Dissolved Oxygen	mg/L	6.5 or 9.5[a1]	5.0	6.5[c1]	–	39	7	18
Nitrite	mg/L	0.06	–	–	3.2[d3]	41	1	2
Total Kjeldahl Nitrogen	mg/L	–	–	1	–	37	5	14
Total Phosphorus	mg/L	–	–	0.05	–	42	5	12
Benz[a]anthracene	µg/L	0.018	–	–	–	35	1	3
Arsenic	µg/L	5	–	–	10[d2]	40	2	5
Cadmium	µg/L	0.02[a2]	–	–	5[d2]	41	6	15
Iron	µg/L	300	–	–	≤300[d1]	43	14	33
Manganese	µg/L	–	–	–	≤0.05[d1]	41	12	29
Mercury	µg/L	0.004[a3]	0.002[b2]	0.001[c2]	1[d2]	40	3	8
Selenium	µg/L	1	–	–	10[d2]	40	3	8
Silver	µg/L	0.1	–	–	–	39	17	44
Zinc	µg/L	30	–	–	≤5 000[d1]	41	1	2

Canadian Environmental Quality Guidelines (CEQG) (CCME 2007)

a1 = Guideline is based on temperature preferences of biota. In this case, the cold water biota guidelines for both early life and other life stages are shown.

a2 = Cadmium guideline = 10[0.86 [log(hardness)] - 3.2].

a3 = Guideline for methyl-mercury provided. The guideline for total inorganic mercury is 0.1 µg/L.

Alberta Acute Water Quality Guidelines (AAWQG) (AENV 1999)

b1 = The pH is to be in the range of 6.5 to 8.5 but not altered by more than 0.5 pH units from background values.

b2 = Guideline for methymercury provided. The total mercury guideline is 0.013 µg/L.

Alberta Chronic Water Quality Guidelines (ACWQG) (AENV 1999)

c1 = Seven day mean. The chronic guidelines should be increased to 8.3 mg/L from mid May to the end of June to protect the emergence of mayfly species into adults; it should be increased to 9.5 mg/L for those areas and times where embryonic and larval stages develop within gravel beds (some salmonids).

c2 = Guideline for methymercury provided. The total mercury guideline is 0.005 µg/L.

Guideline for Canadian Drinking Water Quality (CDWQG) (Health Canada 2008)

d1 = Aesthetic objective.

d2 = Maximum allowable concentration (MAC).

d3 = Equivalent to 10 mg/L as nitrate-nitrogen. Where nitrate and nitrite are determined separately, levels of nitrite should not exceed 3.2 mg/L.

Table 8.6-1: Projected Parameter Medians in Stream TDS and Major Ions

Watercourse	% Flow Increase	Projected Parameter Medians (mg/L)					
		TDS	Hardness	Calcium	Sodium	Bicarbonate	Chloride
Sunday Creek	0.47	134	134	33	5	163	1
W. Unnamed Creek	5.1	49	51	12	1.4	60	1
E. Unnamed Creek	5.9	65	67	17	1.2	78	1

All projected median values are within the range of maximum and minimum values for Sunday Creek, East Unnamed Creek and West Unnamed Creek (Appendix D). As discharge is expected to increase for Sunday Creek, East Unnamed Creek and West Unnamed Creek, TDS and major ion levels are expected to remain within or below the natural variation. No impacts to discharge are predicted for Birch Creek. TDS are not expected to change. Negligible impact is predicted in the ALSA in terms of impacts to runoff.

The natural variations for Christina Lake, as well as the various unnamed tributaries assessed as part of the ARSA, are presented in Appendix D. Similar variations in TDS and major ions exist between Christina Lake and the tributaries found within the ARSA.

No additional impacts outside the ALSA are anticipated for the ARSA. Runoff impacts on a regional scale are predicted to be negligible.

8.6.3 Effects of Construction Activities on Local Waterbodies

The construction of roads, pads, pipelines and water crossings has the potential to directly impact the water quality of local waterbodies. Potential impacts include the introduction of sediments into streams. During construction, appropriate technologies and best management practices will be used to minimize erosion and sediment loadings to streams. These include:

- the selection of pipeline and road routes will be based on minimizing area disturbance by maximizing the use of existing corridors, minimizing habitat disruption, minimizing watercourse crossings and balancing costs versus mitigation;
- the use of common corridors for both pipelines and roads;
- the minimization of site disturbance by using existing disturbed/cleared sites for the project facilities wherever possible;
- a 100 m buffer zone applied to waterbodies;
- the design and installation of pipeline and road crossings will be in accordance with AENV's *Codes of Practice for Pipelines and Telecommunications Line Crossing a Water Body* (2003a) and *Code of Practice for Watercourse Crossings* (2003b) under the *Water Act*. The pipeline crossings will be aboveground. Water quality will be monitored during construction of watercourse crossings;
- the use of appropriate sediment control techniques, such as silt fences, during construction of roads, drainage ditches and pipelines to minimize sediment runoff;

- the use of appropriate stabilization techniques during soil stockpiling to minimize deposition from wind and water erosion (see Volume 1, Section 3.0 Conservation and Reclamation Plan); and
- all drilling waste will be disposed of in accordance with ERCB Directive 58: *Oilfield Waste Management Requirements for the Upstream Petroleum Industry* and Directive 50: *Drilling Waste Management*.

With these mitigation measures in place, impacts due to construction activities are predicted to be negligible.

8.6.4 Effects of Runoff from the Well Pads on Surface Water

During plant operations, runoff from the well pads could directly affect surface waters by introducing sediments. Mitigation measures will include:

- all well pads will be surrounded by ditches. The spill contingency plan, as described in Volume 1, Section 2.6, will be implemented as necessary. Contaminated runoff will be taken to the CPF for recycling.

As a result of the implementation of the above-mentioned measures, the residual effects of runoff from the well pads on the water quality of the receiving waterbodies are predicted to be negligible.

8.6.5 Effects of Runoff from the Roads and Utility Corridors on Local Waterbodies

Runoff to surface waters from roads and utility corridors can potentially affect surface water quality by introducing sediments into local waterbodies. Standard mitigation measures and proper road maintenance will be employed to control road runoff. These include:

- constructing and vegetating roadside ditches to collect and contain local road runoff; and
- installing bridges, culverts and/or rock drains at drainage lows, wetlands and watercourse crossings.

The type of pipeline or road crossings will be selected during detailed design and based on applicable practice. The project will include the temporary alteration of surface runoff through the incorporation of surface runoff impoundments. The ditches will be designed to ensure that the natural drainage patterns are maintained and to avoid ponding of water along roads. No impact is predicted from the runoff from roads and utility corridors. The effects of runoff from roads and utility corridors on the surface water quality of the local waterbodies are considered negligible.

8.6.6 Effects of Acid Deposition on Waterbodies of the ALSA and ARSA

8.6.6.1 Assessment Method

The assessment method involved calculations of critical loads of acidity for lakes in the Air Quality Regional Study Area (AQRSA) (Volume 4, Section 4.0). Critical loads were then compared to potential acid inputs (PAI) at each of the lakes for the baseline, impact and cumulative effects scenarios (Figure 8.5-4). The PAI values for the derived scenarios were obtained from air quality modeling results (Volume 4, Section 4.0) and determined for the coordinates of each lake. If the PAI value was greater than the calculated critical load, there was potential for acidification of the lake at the current rates of deposition. If the critical load was not exceeded, the buffering capacity was sufficient to protect the lake from acidification.

Critical Loads

A critical load for each lake in AQRSA was calculated using the Henriksen steady state water chemistry ratio (Henriksen *et al.* 1992).

$$CL = ([BC]^*_o - [ANC_{lim}]) * Q$$

where:

CL critical loading level of acidity [KeqH$^+$/ha/yr];

$[BC]^*_o$ original non-marine base cation concentration in the lake [μeq/L];

[ANC] critical value for the acid neutralizing capacity in the water for an indicator organism [μeq/L];

Q mean annual runoff [L/ha/yr].

Calculations were completed based on actual water quality observations.

The median critical load value for each lake was calculated using base cations (calcium, magnesium, potassium and sodium) from compiled historical data. Appendix D, Table D.12 presents the median values for base cations, as well as pH, specific conductivity and TDS. Median concentrations were used rather than average concentrations as the median is less influenced by outliers in the data series. When base cation concentrations were below the detection limit, a concentration equivalent to one half of the parameter's detection limit was used.

The ANC_{lim} value represents a dose-response relationship between a water quality variable and an aquatic indicator organism. ANC_{lim} is a function of the acid-base chemistry within a waterbody; and represents the lowest neutralizing flux that will not result in negative consequence to the aquatic indicator organism (Sullivan 2000; Henriksen *et al.* 2002). An ANC_{lim} value of 75 μeq/L was chosen to be consistent with the *Acid Deposition Management Framework for the Oil Sands Region of North-Eastern Alberta* (CEMA 2004). This value was uniformly applied to all waterbodies considered in the assessment.

The mean annual runoff was calculated by averaging the runoff measured in Sunday Creek, Unnamed Creek and Birch Creek, and presented in unit discharge values (L/ha/yr).

Deposition of Acidifying Substances

The rate of deposition, expressed as PAI (keq/ha/yr), for each of the surveyed lakes was modeled using CALPUFF (as described in Volume 4, Section 4.0 Air Quality). Deposition was calculated for the Baseline and Application cases (Appendix D, Table D.13).

The calculated critical loads of lakes were evaluated against a seasonal deposition pattern. Since winter (under-ice) conditions effectively prevent direct acid deposition to lakes for about seven months of the year, deposition of acidic substances accumulates on the snow and ice. During spring snow and ice melt, substances accumulated over the winter are released to the lakes. Because the ground is still frozen during this period and plants do not assimilate nitrate (NO_3^-), it is assumed that the entire quantity of accumulated acidic substances enter the receiving lakes.

During open water conditions, it is assumed that all sulphate (SO_4^{2-}) deposited will ultimately enter a receiving waterbody but that nitrogen will be taken up by vegetation, thus reducing its acidification effects. Several ranges have been suggested for nitrogen adsorption in the Athabasca oil sands region and similar ecosystems; including 8 to 24 kg N/ha/yr for 100 years (CEMA 2005), 9 kg/ha/yr (Sullivan 2000) and 10 to 20 kg N/ha/yr (Laxton *et al.* 2010). A value of 8 kg N/ha/yr was adopted as the most conservative estimate; thus NO_3^- deposition over 8 kg N/ha/yr was included in the total deposition calculation for open water conditions.

8.6.6.2 Baseline and Application Assessment

Waterbodies within the ALSA and ARSA were classified for sensitivity using the Saffran and Trew (1996) ratings. The acid sensitivity analysis (Appendix D, Table D.12) indicated that 77% to 84% of alkalinity, calcium and pH measurements yielded results in the least to low categories for sensitivity.

Nitrogen deposition is predicted to be less than 8 kg N/ha/yr for all waterbodies included in the deposition assessment (Appendix D, Table D.13). Thus, contribution of NO_3^- deposition is considered during the winter months only. Table 8.6-2 presents the comparison between critical loads and calculated deposition for the Baseline and Application cases.

Table 8.6-2: Critical Loads and Depositions Comparison for Baseline and Application Effects (keq/ha/yr)

Waterbody ID	Critical Load	Baseline	Project	Relative Project Effects on Critical Loads
		Critical Load minus Deposition	Critical Load minus Deposition	
ALSA				
L1	1.002	0.889	0.866	3%
L2	2.775	2.657	2.645	0%
L3	2.848	2.726	2.716	0%
ARSA				
2	2.219	2.087	2.083	0%
231	0.665	0.529	0.526	1%
232	0.973	0.850	0.848	0%
233	1.239	1.138	1.134	0%
240	2.696	2.598	2.595	0%
241	2.320	2.198	2.194	0%
610	0.748	0.629	0.625	1%
611	0.873	0.746	0.744	0%
612	0.955	0.836	0.831	1%
613	0.819	0.696	0.693	0%
614	1.714	1.575	1.571	0%
615	0.596	0.473	0.470	1%
616	1.575	1.440	1.437	0%
617	0.814	0.661	0.658	0%
618	1.485	1.327	1.324	0%
621	2.146	2.008	2.005	0%

Total deposition is predicted to be lower than the lake critical loads in the ALSA and ARSA. The project contributed a 0.01 N keq/ha/yr increase to waterbodies with depositions greater than the critical load, compared to the Baseline case. Therefore, the potential for lake acidification due to project operations is predicted to be negligible.

8.7 Cumulative Effects Assessment

The project contribution to acid deposition is negligible, thus, the exceedances of critical loads identified in the Planned Development Case indicate that emissions from other operations are the major contributors. Detailed calculations are presented in Appendix D, Table D.14. Table 8.7-1 presents a summary of the cumulative effect analysis of critical loads and deposition for the ALSA and ARSA.

Table 8.7-1: Critical Loads and Depositions Comparison for Baseline and Planned Development Cases (keq/ha/yr)

Waterbody ID	Domain	Critical Load	Baseline	Planned Development	Relative Planned Development Case Projects Effects on Critical Loads
			Critical Load minus Deposition	Critical Load minus Deposition	
ALSA					
L1	LSA	1.002	0.889	0.843	5%
L2	LSA	2.775	2.657	2.623	1%
L3	LSA	2.848	2.726	2.694	1%
ARSA					
2	RSA	2.219	2.087	2.060	1%
231	RSA	0.665	0.529	0.479	9%
232	RSA	0.973	0.850	0.803	5%
233	RSA	1.239	1.138	1.107	3%
240	RSA	2.696	2.598	2.577	1%
241	RSA	2.320	2.198	2.176	1%
610	RSA	0.748	0.629	0.586	7%
611	RSA	0.873	0.746	0.704	6%
612	RSA	0.955	0.836	0.790	5%
613	RSA	0.819	0.696	0.622	11%
614	RSA	1.714	1.575	1.536	3%
615	RSA	0.596	0.473	0.421	11%
616	RSA	1.575	1.440	1.399	3%
617	RSA	0.814	0.661	0.615	7%
618	RSA	1.485	1.327	1.282	3%
621	RSA	2.146	2.008	1.963	2%

8.8 Monitoring

Surface water quality monitoring will be developed to ensure the following:

- mitigation measures are effective in reducing or eliminating the potential impacts of the project;
- any required remedial measures are identified and incorporated into the operational plan; and
- water quality of discharge waters is consistent with natural variations.

Specific aspects of the monitoring program will include:

- water quality observation/testing in ditches at well pads, from which a discharge to the ambient waterbodies is anticipated;
- water quality observation in the streams during road crossings and pipeline installation;

- background water quality monitoring will be conducted in the waterbodies where discharge of water from ditches at well pads can occur; and
- seasonal monitoring of streams in the project area to ensure the surface water quality leaving the area satisfies the applicable guidelines and to track potential trends in the water quality over time.

The surface water quality monitoring program will be coordinated with the hydrological and aquatics monitoring networks to ensure that the suite of data available will be comprehensive enough to support water management plan.

8.9 Summary

Potential impacts included: changes in runoff during operations; surface runoff and sedimentation from construction activities; surface runoff from well pads, roads and utility corridors during operations; and acid emissions on lakes. With the exception of impacts from changes in runoff, all other activities are predicted to have no or negligible impacts on water quality (Table 8.9-1). Impacts from changes in runoff are expected to fall within the range of natural variability, therefore the overall impact rating is low. Overall, the effects of the project on surface water quality are predicted to be low and localized in extent (Table 8.9-1).

Table 8.9-1: Summary of Impact Assessment

Resource or Indicator Assessed	Magnitude	Direction	Geographic Extent	Duration	Frequency	Reversible	Confidence	Overall Impact Rating
Impact from subsurface operations	No impact	n/a	n/a	n/a	n/a	Yes	High	No impact
Impact from changes in runoff	Negligible	Positive & Neutral	Local	Long-term	Continuous	Yes	High	Low
Surface runoff and sedimentation from construction activities	Negligible	Negative	Local	Short-term	Infrequent	Yes	High	Negligible
Surface runoff from well pads during operations	Negligible	Negative	Local	Long-term	Seasonal	Yes	High	Negligible
Surface runoff from roads and utility corridors during operations	Negligible	Negative	Local	Long-term	Seasonal	Yes	High	Negligible
Effects from acid emissions on lakes	Low	Negative	Local	Long-term	Continuous	Yes	High	Negligible

Note:
n/a – not applicable.

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