APPENDIX 1

Review of the Suggested Effluent Quality Criteria for the Snap Lake Diamond Mine

MacDonald Environmental Sciences Limited

Development of Water Quality Objectives for Total Dissolved Solids and Chloride in Snap Lake, Lockhart River, and Associated Receiving Waters

Final Report

Prepared for:

Government of Northwest Territories
4923-52nd Street
PO BOX 1500
Yellowknife, Northwest Territories X1A 2R3

Prepared – *May, 2014* – by:

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MACDONALD
ENVIRONMENTAL SCIENCES LTD.

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List of Acronyms

AANDC	Aboriginal Affairs and Northern Development Canada
BCMOE	British Columbia Ministry of Environment
Ca^{2+}	calcium
CCME	Canadian Council of Ministers of the Environment
CEB	chronic effects benchmark
CERC	Columbia Environmental Research Center
Cl^{-}	chloride
COPCs	chemicals of potential concern
DBCI	De Beers Canada Inc.
EC_x	effective concentration to x% of the population
EQC	effluent quality criteria
HC_5	5th percentile hazard concentration
HCO_{3-}	bicarbonate
IC_x	inhibition concentration to x% of the population
K^{+}	potassium
LC_x	lethal concentration to x% of the population
LOEC	lowest observed effect concentration
LSA	local study area
MATC	maximum acceptable toxicant concentration
Mg^{2+}	magnesium
MVLWB	Mackenzie Valley Land and Water Board
Na^{+}	sodium
NOEC	no observed effect concentration
NWT	Northwest Territories
RSA	regional study area
SC	specific conductivity
SO_{42-}	sulphate
SSD	species sensitivity distribution
SSWQO	site-specific water quality objective
TDS	total dissolved solids
UCL	upper confidence limit
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WER	water-effect ratio
WQC	water quality criteria
WQG	water quality guideline
WQO	water quality objective

1.0 Introduction

De Beers Canada Inc. (DBCI) owns and operates the Snap Lake Mine, which is located approximately 220 km northeast of Yellowknife, Northwest Territories. The mine is located about 30 km south of MacKay Lake and 100 km south of Lac de Gras, were the Ekati and Diavik diamond mines are located.

The Mackenzie Valley Land and Water Board (MVLWB) issued a Type "A" water licence to DBCI (i.e., MV2001L2-0002) to facilitate construction and operation of the Snap Lake Mine during the period April, 2004 to April, 2012. In April 2012, MVLWB issued DBCI water licence MV2011L2-0004 to facilitate operation of the mine. Recently, however, it has become apparent that the mine will not be able to meet the effluent quality criteria (EQC) for certain variables and/or the whole-lake water quality objective (WQO) for total dissolved solids (TDS; which is a measure of the concentration of major anions and major cations in water) in Snap Lake. For this reason, DBCI has made an application to the MVLWB to amend its existing water licence for the Snap Lake Mine. This report is intended to provide the MVLWB with supplemental input relevant for making an informed decision on the application from the proponent.

1.1 Proposed Amendments to Water Licence MV2011L2-0004

In its application for a water licence amendment, DBCI requested changes in the EQC for at least six chemicals of potential concern (COPCs), including chloride, fluoride, ammonia, sulphate, nitrite, and nitrate. In addition, DBCI proposed to raise the WQO for TDS above the limit that was set during the original environmental assessment of the Snap Lake project (i.e., 350 mg/L, as a whole-lake average). More specifically, DBCI proposed the following EQC for these COPCs in effluent (DBCI 2013a):

- Chloride: Maximum daily limit - 607 mg/L; Average monthly limit - 378 mg/L; Existing EQC are 320 mg/L and 160 mg/L);
- Fluoride - Maximum daily limit - 3.73 mg/L; Average monthly limit - 2.43 mg/L; Existing EQC are 0.30 mg/L and 0.15 mg/L);
- Nitrate - Maximum daily limit - 32 mg/L; Average monthly limit - 14 mg/L; Existing EQC are 8.0 mg/L and 4.0 mg/L, after January 1, 2015);

- Nitrite - Maximum daily limit - 3.0 mg/L; Average monthly limit - 1.4 mg/L; Existing EQC are 1.0 mg/L and 0.5 mg/L);
- Sulphate - Maximum daily limit - 640 mg/L; Average monthly limit - 427 mg/L; Existing EQC are 150 mg/L and 75 mg/L); and,
- TDS - Maximum daily limit - 1,003 mg/L; Average monthly limit - 684 mg/L; There are currently no EQC for TDS).

For TDS, DBCI proposed that the water licence limit of 350 mg/L, which applies as a whole-lake average for Snap Lake, be removed and that the above EQC for TDS apply at the end-of-pipe. To support the development of the recommended EQC, DBCI conducted reviews of the scientific literature and site-specific toxicity testing to derive chronic effects benchmarks (CEBs; functionally equivalent to WQOs) for selected COPCs. More specifically, DBCI proposed the following CEBs for two nutrients, three major ions, and TDS for Snap Lake (DBCI 2013a):

- Chloride - 388 mg/L;
- Fluoride - 2.46 mg/L;
- Nitrate - 16.4 mg-N/L;
- Nitrite - 0.06 mg/L;
- Sulphate - 429 mg/L; and
- TDS - 684 mg/L.

These proposed changes to the EQC for effluent from the Snap Lake Mine represent a substantial departure from the EQC that were established in water licence MV2011L2-0004. Incorporation of such EQC into a water licence for the Snap Lake Mine will result in further degradation of water quality conditions in Snap Lake and alter water quality conditions in downstream areas within the Lockhart River basin. As such changes in water quality conditions can adversely affect uses of these receiving waters, it is essential to conduct a critical evaluation of DBCIs requested EQC amendments and the WQOs (i.e., CEBs) for Snap Lake upon which the EQC are based.

1.2 Background on Major Ions and Nutrients at the Snap Lake Mine

According to DBCI (2013a), water quality in Snap Lake is changing over time, predominantly due to discharges of effluent from the Snap Lake Mine. The concentrations of major ions and TDS have increased in Snap Lake in response to discharges of mine effluent resulting from liberation of deep groundwater during mining activities. Elevated nutrient concentrations in Snap Lake have resulted from discharges of mine effluent that contain high levels of nitrogen due to the use of an emulsion-type explosive as a blasting agent.

Total dissolved solids comprises the major ions found in freshwater systems in the dissolved form. These exist as cations (i.e., positively charged ions) and anions (i.e., negatively charged ions). The primary ions in freshwater environments include bicarbonate (HCO_3^-), calcium (Ca^{2+}), chloride (Cl^-), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), and sulphate (SO_{42-}). While these ions are essential elements for aquatic organisms, adverse effects to aquatic life and other water uses can occur at elevated levels. Other ions, including nitrate, nitrite, and ammonia, can also have adverse effects by causing direct toxicity to aquatic organisms at elevated levels in the freshwater environment. In addition, release of these ions (i.e., nutrients) also represents a water quality concern when concentrations reach levels that result in eutrophication of receiving waters (i.e., higher than normal algal growth and primary productivity).

All of the substances for which DBCI is seeking amended EQC can adversely affect beneficial water uses in receiving waters. The beneficial uses of the waters of Snap Lake and/or downstream waters can be adversely affected when:

- The concentrations of major ions or nutrients change from background conditions;
- The concentrations of major ions or nutrients exceed toxicity thresholds for sensitive species; and/or,
- The concentrations of major ions occur in unusual proportions (i.e., a condition known as ion imbalance; Goodfellow *et al.* 2000).

For this reason, it is important to collect data on the levels of major ions in receiving waters under baseline conditions. It is also important to compile data on the toxicity of the various major ions to facilitate evaluations of toxicity to fish and other aquatic organisms associated with exposure to individual major ions or mixtures of major ions (i.e., TDS) in surface water. Together, these types of data provide the information needed to derive and recommend site-specific WQOs (SSWQOs) for substances of interest.

1.3 Purpose of Report

This report was prepared to provide an independent evaluation of the EQC that DBCI has recommended for discharges of effluent from the Snap Lake Mine and the WQOs upon which the recommended EQC are based. This evaluation was conducted by compiling data and information on:

- Beneficial water uses in the Lockhart River watershed;
- Baseline water quality conditions in Snap Lake and elsewhere in the Lockhart River watershed;
- Classification of waters within the Lockhart River watershed;
- Existing water quality guidelines, criteria, and standards; and,
- Procedures for deriving SSWQOs.

These data and information were used to recommend WQOs for Snap Lake and the waters of the Lockhart River watershed. The resultant WQOs were then compared to the CEBs that were developed by DBCI to determine if the recommended EQC are likely to protect and conserve beneficial water uses in Snap Lake and elsewhere in the Lockhart River watershed. It is anticipated that the MVLWB will consider this information during the establishment of EQC for the Snap Lake mine.

2.0 Study Area

Snap Lake is situated in the Lockhart River watershed in the Northwest Territories (NWT). Waters from Snap Lake flow into the Lockhart River, which ultimately drains into Great Slave Lake. The Snap Lake watershed encompasses an area of approximately 67 km^2. The lake serves as a source, via groundwater, to nearby lakes including North Lake and Northeast Lake. As such, the Snap Lake Watershed, North Lake, and Northeast Lake comprise the local study area (LSA).

The Lockhart River flows from its headwaters near Snap Lake through a series of Lakes including Lac Capot Blanc, MacKay Lake, Aylmer Lake, Clinton Colder Lake, and Artillery Lake, before ultimately draining into Great Slave Lake. The Lockhart River watershed encompasses an area of approximately 27,237 km^2 and comprises the regional study area (RSA).

The LSA and RSA contain additional water bodies that are either directly affected by discharges into Snap Lake or are within the Lockhart River watershed downstream of Snap Lake. North Lake and Northeast Lake are situated north of Snap Lake and are hydrologically connected to Snap Lake (i.e., via transfer of groundwater from Snap Lake). Based on a hydrogeological study conducted in 2001 (DBCI 2002), it was found that the movement of groundwater from Snap Lake to North Lake and to Northeast Lake was substantial. Hence, water quality conditions in these water bodies can be directly affected by effluent discharges to Snap Lake. Accordingly, these two waterbodies were added to the LSA. Waters draining directly from Snap Lake to the Lockhart River have the potential to alter water quality conditions and adversely affect aquatic life in downstream water bodies, including the Lockhart River, MacKay Lake, Lac Capot Blanc, Aylmer Lake, Clinton Colder Lake, Artillery Lake, and Great Slave Lake.

Culturally significant areas in the Lockhart River watershed include the Old Lady of the Falls (Tsanku Theda), situated in the East Arm of Great Slave Lake.

3.0 Water Uses

The Lockhart River watershed supports a variety of beneficial water uses. Accordingly, water management decisions that have the potential to influence water quality conditions need to ensure that effluent discharges from the Snap Lake Mine do not compromise beneficial uses in Snap Lake or elsewhere in the Lockhart River watershed. The water uses that need to be protected in these areas include:

- Fish and Aquatic Life;
- Drinking Water;

- Wildlife Watering (i.e., drinking water for birds and mammals);
- Recreation and Aesthetics; and,
- Spiritual, Cultural, and Ceremonial Water Uses.

4.0 Baseline Water Quality Conditions

Baseline monitoring of water quality conditions is required to document pre-existing environmental conditions in the vicinity of development projects to facilitate determination of actual project effects through comparisons of conditions before and after development. The principal objectives of baseline water quality monitoring programs are to generate the data and information needed to:

- Determine ambient surface water quality conditions before they are altered by the development;
- Evaluate the need for SSWQOs (i.e., WQOs are needed at sites where the concentrations of one or more COPCs exceed Canadian Council of Ministers of the Environment [CCME] water quality guidelines [WQGs] under baseline conditions);
- Support the development of SSWQOs (i.e., using the background concentration approach; CCME 2003);
- Develop predictions of future water quality conditions and associated effects of beneficial water uses; and,
- Evaluate the effects of the development on water quality conditions and associated beneficial water uses (BCMOE 2012).

Prior to development of the Snap Lake Mine, a substantial quantity of data were collected to evaluate baseline water quality conditions in Snap Lake and in associated downstream areas of the Lockhart River. The available baseline water quality data for these areas were summarized to document baseline conditions in the vicinity of the Snap Lake Mine.

4.1 Baseline Water Quality Conditions in Snap Lake

Baseline water quality data were collected between 1993 and 2001 in Snap Lake to support the Environmental Assessment of the Snap Lake diamond project (DBCI 2002). In addition, a single sample was collected in 1993 as part of a larger sampling effort to provide information on baseline conditions in the Lockhart River watershed (Puznicki 1996). During this period, water samples were collected from seven stations in Snap Lake (Figure 1). Each sample was analyzed to measure the concentrations of conventional parameters, major ions, dissolved metals, and total metals. In total, 34 samples were collected in Snap Lake (a summary of the samples is presented in Table 1). Generally, samples were collected from multiple depths when a conductivity gradient was observed. Under these conditions, samples were collected below the surface, at a mid-depth of the water column, and at 1 m above the sediment-water interface. A summary of the concentrations of the major ions and TDS is presented in Table 2 (the baseline data that were collected during the baseline sampling programs are presented in Appendix 1).

Under baseline conditions, the concentrations of TDS in Snap Lake ranged from <10 to 70 mg/L, with 50% of the samples having concentrations below 15 mg/L. The mean concentration of TDS in Snap Lake was 17.1 mg/L. A comparison of TDS concentrations under ice-covered conditions (November through April, n = 16) and under open-water conditions (May through October, n = 18) showed that mean TDS concentrations were significantly higher during the open-water period (22.3 mg/L; vs. 11.4 mg/L under ice-covered conditions) when data from all stations and depths were pooled ($t_{0.05(2),32} = 2.29$, $p = 0.0324$). Based on the data collected during these sampling efforts, sulphate and bicarbonate were the predominant TDS constituents (accounting for approximately 64% of TDS). Under baseline conditions, calcium accounted for approximately 8% of TDS, while the other anions and cations (i.e., magnesium, sodium, potassium, chloride, and fluoride) each accounted for less than 5% of the TDS and cumulatively accounted for approximately 12% of the TDS. The concentrations of other ions, including carbonate, were below detection limits in all of the samples that were collected (Table 2).

4.2 Baseline Water Quality Conditions in the Lockhart River

Baseline water quality data for the Lockhart River watershed have been collected as part of Aboriginal Affairs and Northern Development Canada (AANDC) sampling programs designed to characterize baseline conditions prior to development. Samples were collected in the Lockhart River watershed between 1993 and 1994 (Puznicki 1996). In addition, samples were collected in the Lockhart River watershed in 1999 (unpublished data collected by AANDC; DBCI 2002). As part of the long-term monitoring program conducted by Environment Canada, water quality samples have been collected in the Lockhart River at the outlet of Artillery Lake since 1969. Data collected in all of the monitoring programs conducted between 1969 and 2000 were compiled by DBCI (2002) to support the characterization of baseline conditions within the RSA (Figure 2). A summary of the samples collected to support the characterization of baseline conditions in the Lockhart River is provided in Table 3. A summary of the concentrations of the major ions and TDS concentrations is presented in Table 4 (the baseline data generated from these sampling programs are presented in Appendix 2).

To facilitate the characterization of baseline conditions in the Lockhart River, water quality data collected from stations along the mainstem were grouped into areas of interest (Table 4). The concentration of TDS was measured in a total of 58 samples collected between 1993 and 2000 from a total of 10 stations. The concentrations of TDS in the entire Lockhart River ranged between <10 and 53 mg/L. The mean concentration of TDS in the Lockhart River during that period was 17.8 mg/L. A comparison of TDS concentrations from the entire dataset under ice-covered conditions (November through April, n = 16) and open-water conditions (May through October, n = 18) showed no significant difference in TDS concentrations measured during the two time periods (i.e., a mean of 17.5 mg/L of TDS was calculated for open-water conditions, while a mean of 18.1 mg/L was calculated for ice-covered conditions) when the data from all stations and depths were pooled ($t_{0.05(2),56} = 0.253$, $p = 0.801$).

Based on the data collected on all 58 samples from the Lockhart River, alkalinity (bicarbonate and carbonate) and sulphate were the predominant major ions that contributed to TDS (approximately 42%). Calcium and magnesium accounted for approximately 11% of the TDS each, on average. The other anions and cations that were measured (i.e., sodium, potassium, chloride, nitrate, and fluoride) each accounted for less than 3% of the measured TDS.

4.3 Baseline Water Quality Conditions in the Associated Waterbodies of the Lockhart River Watershed

The waterbodies that are associated with Snap Lake and the Lockhart River include a number of lakes that are hydrologically connected to the waterbodies of interest, either through surface water or groundwater. Work that was completed to support the Environmental Assessment Report (DBCI 2002) concluded that North Lake and Northeast Lake were recharged directly by Snap Lake through groundwater transfer, while Downstream Lake is directly connected to Snap Lake. Other associated waterbodies in the study area include MacKay Lake, Aylmer Lake, Clinton Colder Lake, and Artillery Lake (Figure 2).

Limited baseline data have been collected from the additional waterbodies that are associated with Snap Lake (Table 5). In total, 17 samples have been collected from North Lake (n = 6), the North Shore Lakes (n = 7), and Downstream Lake (n = 4); the baseline data that were collected during the baseline sampling programs are presented in Appendix 3). Under baseline conditions, the concentration of TDS in North Lake under ice-covered conditions averaged 16.8 mg/L, and ranged between 13.0 and 22.0 mg/L (Table 6). In North Lake, sulphate and bicarbonate were the primary constituents contributing to TDS concentrations. Similar to Snap Lake, these two ions, on average, accounted for approximately 78% of TDS. Calcium and magnesium, together, accounted for approximately 19% of the TDS, while the other anions and cations each accounted for less than 5% of TDS. Chloride concentrations represented up to 0.6% of the TDS.

Data collected from the North Shore Lakes showed that the mean concentration of TDS under baseline conditions ranged from 10 to 41 mg/L. The mean concentration of TDS in these lakes was 23.1 mg/L (Table 6) when all data were pooled (i.e., ice-covered and open water; $t_{0.05(2),5} = 0.600$, $p = 0.592$). Sulphate and bicarbonate made up the majority of the TDS measured in these samples (approximately 59%), while calcium and magnesium accounted for approximately 13% of the TDS. The other anions and cations (i.e., sodium, potassium, chloride, nitrate, and fluoride) each accounted for less than 3% of the TDS.

In Downstream Lake, concentrations of TDS under ice-covered and open-water conditions were not significantly different under baseline conditions ($t_{0.05(2),2} = 0.25$, $p = 0.844$). Collectively, the samples collected throughout the year showed a range of TDS from 12 to 20 mg/L. The mean concentration of TDS in Downstream Lake was 15.5 mg/L (Table 6). Bicarbonate was the predominant component of TDS in the samples that were collected (representing approximately 42% of the TDS), while calcium and sulphate accounted for approximately 9.5% and 9.4%, respectively. The other anions and cations (i.e., sodium, magnesium, potassium, chloride, nitrate, and fluoride) each accounted for less than 5% of the TDS.

A total of 18 samples were collected from MacKay Lake (n = 5), Aylmer Lake (n = 10), and Clinton Colder Lake (n = 3) under baseline conditions. The concentration of TDS in MacKay Lake under ice-covered and open-water conditions ranged from 16 to 24 mg/L, while the mean concentration was 18.8 mg/L (Table 6). There was no significant difference in concentrations between the ice-covered and open-water periods ($t_{0.05(2),3} = 1.6$, $p = 0.239$). Of the constituents that were measured, sulphate and bicarbonate (i.e., alkalinity) were the predominant ions comprising TDS, together making up approximately 36% of the TDS. Calcium accounted for 6.4% of the TDS, while the other anions and cations measured (i.e., magnesium, potassium, sodium, chloride, and nitrate) each accounted for less than 3% of the TDS.

The concentrations of TDS in Aylmer Lake ranged from <10 to 31 mg/L under baseline conditions. During this period, the TDS concentrations averaged 18.1 mg/L. No significant difference in TDS concentrations during the ice-covered and open-water periods was observed ($t_{0.05(2),8} = 2.16$, $p = 0.107$). The relative composition of the TDS was similar for Aylmer Lake and MacKay Lake under baseline conditions. Sulphate and bicarbonate (i.e., alkalinity) together accounted for approximately 34.6% of the TDS, while the other anions and cations (i.e., calcium, magnesium, potassium, sodium, chloride, and nitrate) each accounted for less than 5% of TDS.

In Clinton Colder Lake, samples were collected under ice-covered conditions only. Based on the data collected from the lake, the mean concentration of TDS under baseline conditions was 35 mg/L, ranging from 31 to 42 mg/L. Not enough information was available from Clinton Colder Lake to generate robust estimates of the relative composition of TDS under baseline conditions.

5.0 Classification of Waters in the Study Area

The NWT is characterized by an abundance of fresh water of exceptional quality, including a diversity of streams, rivers, and lakes. Managing these diverse water bodies represents a daunting challenge because each of these systems has unique characteristics that must be considered in decisions related to water resources management. Key factors that could affect the sensitivity and importance of the water body include:

- Uniqueness or special significance of the water body (e.g., area or waterbody of unique spiritual, cultural, or traditional importance, critical drinking water source);
- Various physical factors that influence the environmental sensitivity of the water body (e.g., size of water body, presence of ice-rich permafrost, dominant substrate type, other permitted discharges, variability of flow or depth, trophic status, water hardness and alkalinity, dissolved organic carbon levels, and metal levels);
- Various ecological factors that influence the ecological significance of the water body (e.g., presence of fish, occurrence of fish spawning habitat, use by aquatic-dependent wildlife, use by seasonally-resident birds, presence of open-water areas in winter, and presence of species at risk); and,
- Various social and cultural factors that influence the importance of the water body to people (e.g., cultural or historical importance, pristine nature of water body, subsistence use, commercial use, recreational use, use as drinking water source).

5.1 Classification of Waters Located within the Lockhart River Watershed

Available data and information on the study area were compiled and reviewed to support a preliminary classification of these waters. While the results of such a preliminary evaluation should be reviewed by the Aboriginal organizations with an interest in the study area, the available information on the historical and current water quality conditions for waterbodies in the Lockhart River watershed and on the cultural importance of areas of the Lockhart River (i.e., Old Lady of the Falls) indicate that the following classifications should be adopted in the near-term:

- **Snap Lake (Snap Lake and hydrologically connected waterbodies):**

Under current conditions, water quality conditions are being affected by permitted discharges of effluent from the Snap Lake mine. In addition, other uses of water are limited in Snap Lake and hydrologically connected waterbodies, in part due to the presence of the mine on the lake. Accordingly, these waters should be classified as having normal sensitivity to releases of contaminants from anthropogenic sources.

- **Lockhart River downstream of Snap Lake (Lockhart River from the outlet of Snap Lake to MacKay Lake):**

  The portion of the Upper Lockhart River between the outlet of Snap Lake and MacKay Lake provides high quality habitat for aquatic life and aquatic-dependent wildlife. In addition, this portion of the Lockhart River is capable of supporting a variety of other beneficial water uses (e.g., drinking water, recreation and aesthetics, etc.). However, due to the hydrological connectivity and proximity to Snap Lake water quality conditions within this portion of the Lockhart River have been altered. To prevent further alteration of water quality conditions and to protect beneficial water uses in downstream areas, this portion of the Lockhart River should be afforded enhanced use-protection.

- **Upper Lockhart River (Lockhart River from MacKay Lake to the inlet of Aylmer Lake):**

  The portion of the Lockhart River between MacKay Lake and the Inlet of Artillery Lake provides high quality habitat for aquatic life and aquatic-dependent wildlife. In addition, this portion of the Lockhart River is capable of supporting a variety of other beneficial water uses (i.e., drinking water, recreation and aesthetics, etc.). This reach of the Lockhart River is used extensively by Aboriginal peoples practicing traditional lifestyles, emphasizing the cultural importance of this area. In addition, downstream waters (i.e., in the vicinity of the Old Lady of the Falls) have been identified as having special cultural and spiritual significance to Aboriginal peoples. Therefore, water quality conditions in this portion of the Lockhart River should not change from background conditions.

- **Central Lockhart River (Lockhart River from Aylmer Lake to the boundary of the Lower Lockhart River Work Unit):**

  The portion of the Lockhart River from Aylmer Lake to the boundary of the Lower Lockhart River Work Unit provides high quality habitat for aquatic life and aquatic-dependent wildlife. In addition, this portion of the Lockhart River is capable of supporting a variety of other beneficial water uses (i.e., drinking water, recreation and aesthetics, etc.). This reach of the Lockhart River is used extensively by Aboriginal peoples practicing traditional lifestyles, emphasizing the cultural importance of this area. In addition, downstream waters (i.e., in the vicinity of the Old Lady of the Falls) have been identified as having special cultural and spiritual significance to Aboriginal peoples. Therefore, water quality conditions in this portion of the Lockhart River should not change from background conditions.

- **Lower Lockhart River (Lockhart River from the boundary of the Central Lockhart River Work Unit to Artillery Lake and including Artillery Lake):**

  The portion of the Lockhart River from the boundary of the Central Lockhart River Work Unit to Artillery Lake and Artillery Lake provides high quality habitat for aquatic life and aquatic-dependent wildlife. In addition, this portion of the Lockhart River is capable of supporting a variety of other beneficial water uses (i.e., drinking water, recreation and aesthetics, etc.). This reach of the Lockhart River is used extensively by Aboriginal peoples practicing traditional lifestyles, emphasizing the cultural importance of this area. In addition, downstream waters (i.e., in the vicinity of the Old Lady of the Falls) have been identified as having special cultural and spiritual significance to Aboriginal peoples. Therefore, water quality conditions in this portion of the Lockhart River should not change from background conditions.

- **Lockhart River in the vicinity of the Old Lady of the Falls (i.e., from the inlet of Artillery Lake to Great Slave Lake):**

  The Old Lady of the Falls (Tsanku Theda) and the Lockhart River (Desnethche) have been identified as the fundamental core of the Lutsel

K'e Denesoline cultural identity (Nitah 2009). As one of the most culturally and spiritually important water bodies in the NWT, existing water quality conditions must be maintained at all times to protect these waters of special significance.

The preliminary classification used here provides a basis for classifying waters based on their potential to be adversely affected by anthropogenic developments and, hence, describes the level of protection that needs to be afforded these waters. As such, this classification system establishes narrative WQOs that should apply to each water body in the Lockhart River basin (Figure 3; Table 7). Such narrative WQOs should guide the development of numerical WQOs for COPCs in each of the reaches of the Lockhart River basin.

6.0 Toxicity of Major Ions to Fish and Aquatic Life

Data and information on the toxicity of individual major ions and mixtures of major ions (i.e., TDS) are relevant to the development of numerical WQOs for receiving waters in the Lockhart River watershed. For this reason, a review of the literature on the toxicity of chloride and TDS was conducted to provide a scientific basis for evaluating the chronic effects benchmarks that were proposed by DBCI for Snap Lake. The results of this review are presented in the following sections of this document.

6.1 Toxicity of Chloride to Aquatic Organisms

Chloride is an essential element to aquatic organisms in the maintenance of physiological functions. However, elevated or fluctuating concentrations of chloride can result in adverse effects to aquatic life. Specifically, exposure to elevated levels of chloride in water can disrupt osmoregulation in aquatic organisms, leading to impaired survival, growth, and/or reproduction (Nagpal *et al.* 2003). The bioaccumulation potential of chloride is low because excess chloride is actively excreted from animal tissues to achieve osmoregulatory balance. Several factors such as dissolved oxygen concentration, temperature, exposure duration and the presence of other contaminants influence the toxicity of chloride. Only a few studies have evaluated the influence of confounding variables on chloride (Nagpal *et al.* 2003). However, some studies reviewed by Evans and Frick (2001) measured the effects of physical variables on tolerance to TDS. Aquatic organisms are more tolerant of chloride in water in which oxygen concentrations are close to saturation. While some studies suggest that organisms are more tolerant to chloride at lower temperatures, other studies have shown that the reverse is true. Zooplankton and benthic invertebrates appear to be relatively more sensitive to sodium chloride concentrations than fish. As well, within a given taxonomic category (e.g., benthic invertebrates or fish), there is significant inter-species variation in salinity tolerances (Nagpal *et al.* 2003).

To support the review of the CEBs proposed by DBCI and to develop recommended WQOs for chloride, information on studies conducted to evaluate the effects of chloride toxicity were compiled from the following sources:

- Scientific Criteria Document for the Development of Canadian Water Quality Guidelines for the Protection of Aquatic Life - Chloride Ion (CCME 2011);
- Unpublished data provided by the United States Geological Survey Columbia Environmental Research Center (USGS CERC); and,
- Other primary literature.

6.1.1 Acute Toxicity of Chloride

Fish generally have a high tolerance for chloride exposure. From the compiled literature, 96-h LC_{50} values ranged from 2,123 mg/L Cl^- for <24-h old fathead minnow (*Pimephales promelas*) at a nominal hardness of 39.2 mg $CaCO_3$/L (USEPA 1991) to 13,012 mg/L Cl^- for American eel (*Anguilla rostrata*; black eel stage) at a nominal hardness of 40 - 48 mg $CaCO_3$/L (Hinton and Eversole 1979). However, in a 24-h toxicity test with striped bass (*Morone saxatilis*), an LC_{50} of 854 mg/L Cl^- was observed (hardness unknown; Grizzle and Mauldin 1995). Few studies have been conducted to evaluate the toxicity of chloride to salmonids, but of the studies compiled, 96-h LC_{50} values ranged from 6,030 mg/L Cl^- (hardness of 40 mg $CaCO_3$/L; Elphick *et al.* 2011) to 12,363 mg/L Cl^- (hardness of 284 mg $CaCO_3$/L; Vosyliene *et al.* 2006); both of these tests were conducted with juvenile rainbow trout (*Oncorhynchus mykiss*). Amphibians appear to be more sensitive to chloride than fish. The spotted salamander (*Ambystoma maculatum*) was most sensitive to chloride, with a 96-h LC_{50} value of 1,178 mg/L Cl^- at a nominal hardness of 33 mg $CaCO_3$/L (Collins and Russell 2009). The most tolerant amphibian to chloride was the bullfrog

(*Rana catesbeiana*), with a 96-h LC_{50} value of 5,846 mg/L Cl^- at a nominal hardness of 300 mg $CaCO_3$/L (ENVIRON International Corporation 2009). In addition, a test conducted with the American toad (*Bufo americanus*) at a nominal hardness of 33 mg $CaCO_3$/L resulted in a 96-h LC_{50} value of 3,926 mg/L Cl^- (Collins and Russell 2009), indicating that some amphibians are fairly tolerant of chloride.

In general, invertebrates are more sensitive to chloride exposure during short-term exposures than fish or amphibians. Mussel glochidia appear to be the most sensitive, with the lowest LC_{50} value of all species studied (i.e., a 24-h LC_{50} of 113 mg/L Cl^- at a nominal hardness of 95 - 115 mg $CaCO_3$/L) reported for wavy-rayed lampmussel (*Lampsilis fasciola*) glochidia (Gillis 2011). However, the tolerance of glochidia to chloride does vary, with the highest 24-h LC_{50} being 2,008 mg/L Cl^- for Eastern creekshell mussel (*Villosa delumbis*) glochidia in tests conducted at a nominal hardness of 170-192 mg $CaCO_3$/L (Bringolf *et al.* 2007). Cladocerans are also sensitive to chloride; tests conducted with *Ceriodaphnia dubia* reported lower 48-h LC_{50} values than *Daphnia magna*. These LC_{50} values ranged from 447 mg/L Cl^- for *C. dubia* at a nominal hardness of 39.2 mg $CaCO_3$/L (Hoke *et al.* 1992) to > 2,669 mg/L Cl^- for *D. magna* at a nominal hardness of 169.5 mg $CaCO_3$/L (Seymour *et al.* 1997). Other authors reported similar values for chloride. For example, Khangarot and Ray (1989) reported a 48-h LC_{50} value of 621 mg/L Cl^- for *D. magna* at a nominal hardness of 240 mg $CaCO_3$/L. The aquatic life stages of insects tended to be more tolerant to chloride exposure. Mayfly 48-h LC_{50} values ranged from 2,875 mg/L Cl^- at a nominal hardness of 178 mg $CaCO_3$/L (*Baetis tricaudatus*; Lowell *et al.* 1995) to 4,671 mg/L Cl^- at a nominal hardness of 160 - 180 mg $CaCO_3$/L (*Hexagenia* spp.; Wang and Ingersoll 2010). In addition, Echols *et al.* (2010) found a 96-h LC_{50} value of 1,891 mg/L Cl^- for the mayfly *Isonychia bicolor* (hardness unknown). For midges, acute LC_{50} toxicity values ranged from a 96-h LC_{50} value of 3,761 mg/L Cl^- for *Chironomus dilutus* to a 48-h LC_{50} value of 6,912 mg/L Cl^- for *Chironomus riparius*, both at a nominal hardness of 160 - 180 mg $CaCO_3$/L (Wang and Ingersoll 2010). Amphipods appear to have an intermediate tolerance to chloride between cladocerans and aquatic insects. For *Hyalella azteca*, 96-h LC_{50} values ranged from 1,382 mg/L Cl^- at a nominal hardness of 76 mg $CaCO_3$/L (Elphick *et al.* 2011) to 3,947 mg/L Cl^- at a nominal hardness of 102.5 mg $CaCO_3$/L (Lasier *et al.* 1997). The 48-h LC_{50} values for *H. azteca* ranged from 2,253 mg/L Cl^- (hardness of 100 mg $CaCO_3$/L; USGS Unpublished data) to 3,700 mg/L Cl^- (hardness of 160-180 mg $CaCO_3$/L; Wang and Ingersoll 2010). The copepod *Cyclops abyssorum prealpinus* had the greatest tolerance to chloride of all invertebrates tested in the compiled studies, with a 48-h LC_{50} value of 12,385 mg/L Cl^- at a nominal hardness of 33 mg $CaCO_3$/L (Baudouin and Scoppa 1974). A point to note is that Baudouin and Scoppa (1974) presented the results as mg/L Ca^{2+} and CCME (2011) converted them to mg/L Cl^- because the test had been performed with $CaCl_2$. The second largest acute LC_{50} value for invertebrates was a 96-h LC_{50} value of 7,886 mg/L Cl^- for the worm *Tubifex tubifex* at a nominal hardness of 160-180 mg $CaCO_3$/L (Wang and Ingersoll 2010).

6.1.2 Chronic Toxicity of Chloride

Algae tend to be relatively tolerant of chloride toxicity. A three to six day EC_{49} value for growth of 3,014 mg/L Cl^- was reported by Reynoso *et al.* (1982) for the alga *Chlamydomonas reinhardtii*. The largest effect concentration from algae cited in CCME (2011) for the derivation of the long-term WQG was a maximum acceptable toxicant concentration (MATC) for growth of 6,824 mg/L Cl^- for *Chlorella emersonii* (Setter *et al.* 1982). Plants appear to be more sensitive to chloride than algae, with compiled effect values ranging from a 96-h MATC for frond production in duckweed (*Lemna minor*) of 1,171 mg/L Cl^- at a nominal hardness of 39 mg $CaCO_3$/L (Taraldsen and Norberg-King 1990) to a 32-d EC_{50} for population growth of Eurasian milfoil (*Myriophyllum spicatum*) of 4,965 mg/L Cl^- (hardness unknown; Stanley 1974).

Based on the effect values at the high end of the spectrum, the second most tolerant receptor group is amphibians, with northern leopard frog (*Rana pipiens*) eggs having a 108-d MATC for survival of 3,431 mg/L Cl^- and an LC_{50} of 2,265 mg/L Cl^- at a nominal hardness of 80 - 100 mg $CaCO_3$/L (Doe 2010). A 4-d and a 7-d test with northern leopard frog eggs each resulted in an LC_{50} of 3,397 mg/L Cl^- at a nominal hardness of 80 - 100 mg $CaCO_3$/L (Doe 2010). However, there was 100% mortality of African clawed frog tadpoles in a treatment of 4,853 mg/L Cl^- in a 7-d test at a nominal hardness of 110 - 120 mg $CaCO_3$/L (Beak International Inc. 1999). In addition, green frog (*Rana clamitans*) and common frog (*Rana temporaria*) tadpoles were much more sensitive to chloride exposure than northern leopard frog eggs, with chronic effect values ranging from a 7-d LC_{50} value of 246 mg/L Cl^- (Dougherty and Smith 2006) to a 42-d lowest observed effect concentration (LOEC) of 910 mg/L Cl^- for mean swimming speed in reconstituted soft water (Denoel *et al.* 2010). Denoel *et al.* (2010) also found a 56-d LC_{10} value of 292 mg/L Cl^- for total distance moved in common frog tadpoles, showing that the observed result varies by length of test and the endpoint measured.

Fish exhibit a wide scope of sensitivity to chloride, with rainbow trout and fathead minnow (the most-tested species) having a similar range of effect values. As cited in CCME (2011), the lowest effect value for a fish was a 33-d survival MATC of 431 mg/L Cl^- for fathead minnow eggs, 6 - 12 hours post-fertilization, at a nominal hardness of 97 mg $CaCO_3$/L. The lowest effect value for rainbow trout was a 7-d EC_{25} for embryo viability of 989 mg/L Cl^- in an embryo-larval test conducted at a hardness of 120 mg $CaCO_3$/L (Beak International Inc. 1999). The highest effect value for a fish was a 7-d survival LOEC of 4,853 mg/L Cl^- for 1 to 7-d old fathead minnow at a nominal hardness of 86 - 94 mg $CaCO_3$/L (Pickering *et al.* 1996). For fathead minnow, 7-d tests started with larvae tended to result in higher effect values than 33- or 34-d tests started with eggs/embryos. The highest effect value for rainbow trout was a 54-d biomass and mortality LOEC of 2,327 mg/L Cl^- in a test that started with dry fertilized gametes at a nominal hardness of 40 - 76 mg $CaCO_3$/L (Rescan Environmental Services Ltd 2007; Elphick *et al.* 2011). From the available data (Appendix 4), it appears that survival is generally a more sensitive endpoint than growth in chronic fish toxicity tests.

Invertebrates appear to be the most sensitive receptor group to chronic chloride toxicity. The lowest effect value cited in CCME (2011) for the derivation of the long-term WQG was a 24-h EC_{10} for survival of 24 mg/L Cl^- for wavy-rayed lampmussel glochidia at a nominal hardness of 170 - 192 mg $CaCO_3$/L (Bringolf *et al.* 2007). The lowest effect value reported by CCME (2011) was a 48-h EC_{10} for survival of 2 mg/L Cl^- for wavy-rayed lampmussel glochidia at a nominal hardness of 170 - 192 mg $CaCO_3$/L (Bringolf *et al.* 2007). Most mollusk effect concentrations were under 1,000 mg/L Cl^-, though Bringolf *et al.* (2007) found a 96-h survival EC_{10} of 1,474 mg/L Cl^- at a nominal hardness of 170 - 192 mg $CaCO_3$/L for the fatmucket mussel (*Lampsilis siliquoidea*), which was considered to be a chronic endpoint by CCME (2011). The one test with a snail suggested *Physa* sp. are more tolerant to chloride, with a 60-d survival no observed effect concentration (NOEC) of 2,000 mg/L Cl^- (hardness unknown; Williams *et al.* 1999). In longer term toxicity tests, the lowest effect value reported for invertebrates was a 7-d IC_{25} for reproduction of 69.1 mg/L Cl^- for the cladoceran *C. dubia* at a nominal hardness of 40 mg $CaCO_3$/L (Rescan Environmental Services Ltd. 2008). Reproduction tended to be the most sensitive endpoint for cladocerans (Birge *et al.* 1985; Cooney *et al.* 1992; Diamond *et al.* 1992; Aragao and Pereira 2003; Harmon *et al.* 2003; Lasier *et al.* 2006; Rescan Environmental Services Ltd. 2008; Lasier and Hardin 2010; Elphick *et al.* 2011). Amphipods appear to have a varying degree of sensitivity to chloride. On one end, Williams *et al.* (1999) reported a 60-d reproduction MATC of 100 mg/L Cl^- (hardness unknown) for

Gammarus pseudopinmaeus while Bartlett (2009) reported a 28-d growth EC_{25} of 421 mg/L Cl^- (hardness unknown) for *H. azteca*. On the other end, Williams *et al.* (1999) reported a 60-d survival NOEC of 2,000 mg/L Cl^- for *G. pseudopinmaeus* (hardness unknown). The most tolerant invertebrates to chronic chloride toxicity were aquatic insects (including chironmids, mayflies, and caddisflies) and oligochaete worms. Effect values ranged from a 28-d LOEC of 366 mg/L Cl^- for reproduction in *L. variegatus* at a nominal hardness of 80-100 mg $CaCO_3$/L (Elphick *et al.* 2011) to a 6-d LC_{80} of 5,999 mg/L Cl^- for the caddisfly *Hydropsyche betteni* (hardness unknown; Kersey 1981). The highest low-effect value was a 7-d LOEC for development and a 14-d LOEC for growth and mortality of 4,246 mg/L Cl^- for the mayfly *Stenonema modestum* (hardness unknown; Diamond *et al.* 1992).

6.2 Toxicity of Total Dissolved Solids to Aquatic Organisms

Major ions (e.g., Ca^{2+}, Mg^{2+}, Na^+, K^+, SO_{42-}, Cl^-, HCO_{3-}) in water can elicit a toxic response to aquatic organisms at elevated levels or in unusual proportions (i.e., ratios); this is known as ion imbalance (Goodfellow *et al.* 2000). The toxicity of TDS is highly dependent on the relative concentrations of the major ions that make up the solution. Some ions or combinations of ions are more toxic than others (Weber-Scannell and Duffy 2007). Using a multiple logistic regression approach, Mount *et al.* (1997) determined the relative ion toxicity based on toxicity tests conducted with *C. dubia*, *D. magna*, and the fathead minnow. Based on the results, Mount *et al.* (1997) reported the relative ion toxicity to be $K^+ > HCO_3 \approx Mg^{2+} > Cl^- > SO_{42-}$. It was reported that the toxicity of Na^+ and Ca^{2+} was not significant, according to the regression analysis (Mount *et al.* 1997). Other studies (Gregory Pyle, University of Lethbridge, personal communication; Stekoll *et al.* 2009) suggest that calcium is more toxic than magnesium. Toxicity of Cl^-, SO_{42-}, and K^+ to *C. dubia* and *D. magna* was reduced in solutions with more than one cation (Mount *et al.* 1997). Therefore, the individual components of TDS must be quantified to facilitate the interpretation of the results generated from toxicity tests.

Few studies conducted to evaluate the toxicity of TDS to aquatic organisms have quantified the TDS mixture. Many of these studies have used TDS mixtures where SO_{42-} and Ca^{2+} were the dominant ions (e.g., Chapman *et al.* 2000; LeBlond and Duffy 2001; Stekoll *et al.* 2009; Brix *et al.* 2010a; Brix *et al.* 2010b; Kunz *et al.* 2013), to emulate the effluents from mines of interest (e.g., Kensington Mine and Red Dog Mine in Alaska). In addition, effluent from a coal mine where the TDS was composed primarily of SO_{42-} and Na^+ prompted toxicity tests with these two ions (Kennedy *et al.* 2005; Kunz *et al.* 2013). Other than the tests conducted during the Phase 1 toxicity testing program (DBCI 2013b), studies conducted with waters of a similar ionic composition to Snap Lake (i.e., about 48% chloride and 21% calcium) could not be found.

6.2.1 Acute Toxicity of Total Dissolved Solids

No acute tests were performed as part of the Snap Lake site-specific toxicity testing (DBCI 2013b). As the majority of TDS in Snap Lake is Cl^- and Ca^{2+}, studies performing toxicity tests with $CaCl_2$ provide useful information. Mount *et al.* (1997) conducted acute toxicity tests with $CaCl_2$. For fathead minnows, the reported 96-h LC_{50} value was 4,630 mg/L $CaCl_2$. For *C. dubia* and *D. magna*, the reported 48-h LC_{50} values were 1,830 mg/L $CaCl_2$ and 2,770 mg/L $CaCl_2$, respectively (Mount *et al.* 1997).

Acute toxicity tests with different mixtures of TDS relative to Snap Lake have been conducted. For example, Brix *et al.* (2010a) ran eight 72-h toxicity tests with Arctic grayling (*Thymallus arcticus*) embryos, with variable results. The EC_{20} value for fertilization success was 202 mg/L TDS in one test and 748 mg/L TDS in another, while in the other six tests the EC_{20} value was greater than the highest concentration tested (921 - 2782 mg/L TDS; Brix *et al.* 2010a). For similar 24-h tests with Dolly Varden (*Salvelinus malma*) embryos, all five tests with acceptable control fertilization resulted in an EC_{20} value for fertilization success greater than the highest concentration tested (1,704 - 1,817 mg/L TDS; Brix *et al.* 2010a). Two other tests had an inverse concentration response relationship, with fertilization success lower in the controls than in the elevated TDS concentrations. The main ion in these TDS mixtures was SO_4^{2-}, followed by Ca^{2+} (Brix *et al.* 2010a). Stekoll *et al.* (2009) also performed toxicity tests with SO_4^{2-} and Ca^{2+}-dominated TDS mixtures. Coho salmon (*Oncorhynchus kisutch*) were exposed to TDS mixtures for 96-h at fertilization, epiboly, eye, hatch, and swim-up stages. For eggs only exposed to TDS during fertilization, there was a significant decrease in the number of eggs fertilized, with an EC_{20} of 510 mg/L and EC_{50} of 1,770 mg/L, but there was not a significant effect on mortality of fertilized eggs after 96-h. For eggs exposed from fertilization to 96-h post-fertilization the EC_{20} for number of eggs fertilized was 560 mg/L TDS for one brood year (EC_{50} = 1,600 mg/L) and 1,300 mg/L TDS for another brood year (EC_{50} = 3,280). Eggs that were exposed to TDS from two minutes post-fertilization to the end of the test did not show significant effects of the TDS exposure. Exposure to elevated TDS for 96-h at the epiboly, eye, hatch, or swim-up life stages did not have a significant effect on mortality (Stekoll *et al.* 2009). Therefore, egg fertilization appears to be the most sensitive time for salmonids to be exposed to elevated TDS concentrations. Other tests comparing the sensitivity of different salmonid species to TDS found a large range of effect values. For fish exposed from fertilization until 96-h post fertilization, coho salmon were the most sensitive (EC_{20} = 45 mg/L), followed by chinook salmon (*Oncorhynchus tshawytscha*; EC_{20} = 85 mg/L), pink salmon (*Oncorhynchus gorbuscha*; EC_{20} = 280 mg/L), chum salmon (*Oncorhynchus keta*; EC_{20} = 500 mg/L), Arctic charr (*Salvelinus alpinus*; EC_{20} = 830 mg/L), and steelhead (*Oncorhynchus mykiss*; EC_{20} = 1100 mg/L; Stekoll *et al.* 2009). Separate tests with coho salmon looking at different ion mixtures found that Ca^{2+} had the largest effect on fertilization success, with an EC_{50} of 102 mg/L. The next most toxic ions were K^+, Mg^{2+}, and then SO_{42-} (Stekoll *et al.* 2009). However, there was a large difference in sensitivity to TDS between brood years of coho salmon in the various tests conducted by Stekoll *et al.* (2009). Coho from brood year 2001 (those used in the specific ion tests) were approximately six to fourteen times more sensitive to TDS than other brood years, when comparing EC_{50} values (Stekoll *et al.* 2009). There is considerable uncertainty in the results reported by Stekoll *et al.* (2009).

Chapman *et al.* (2000) also performed toxicity tests with TDS mixtures composed primarily of SO_{42-} and Ca^{2+}. Tests were conducted with two different TDS mixtures, emulating the effluents of the Red Dog Mine and Kensington Mine, respectively. There were no significant adverse effects at any of the TDS concentrations in 7-d (exposed to synthetic effluent for 4 days) rainbow trout embryo viability tests and 7-d swim-up fry growth and survival tests. The highest TDS concentration for these tests ranged from 1,961 mg/L to 2,080 mg/L (Chapman *et al.* 2000). Kennedy *et al.* (2005) conducted 48-h tests with *C. dubia* in two different TDS mixtures, consisting of SO_{42-}, Na^+, Ca^{2+}, and Mg^{2+} in one test (MS-1), and SO_{42-} and Na^+ in the other (MS-II). Specific conductivity (SC) was used as a surrogate for TDS, and a linear regression was used to estimate the TDS concentration. The calculated 48-h LC_{50} values were 5,483 mg/L TDS and 3,469 mg/L TDS for the MS-I and MS-II solutions, respectively. The authors suggest that the increased hardness of MS-I decreased the toxicity of TDS (Kennedy *et al.* 2005).

6.2.2 Chronic Toxicity of Total Dissolved Solids

Snap Lake site-specific chronic toxicity tests were performed with algae (*Navicula pelliculosa* and *Pseudokirchneriella subcapitata*), invertebrates (*C. dilutus*, *C. dubia*, *D. magna*, and *Brachionus calyciflorus*), and fish (lake trout [*Salvelinus namaycush*] and Arctic grayling; DBCI 2013b). Of these organisms, the growth inhibition IC_{10}, IC_{20}, and IC_{50} for *N. pelliculosa* and *P. subcapitata*, and the LC_{20}, LC_{50}, and growth IC_{20} and IC_{50} for *C. dilutus* and Arctic grayling were greater than the highest TDS concentration tested, ranging from 1,379 to 1,487 mg/L TDS (DBCI 2013b). With dry fertilization, an LC_{20} of 991 mg/L for lake trout in a test that lasted from fertilization to 30-d post swim-up was reported, while all other endpoints measured were > 1,490 mg/L TDS. Wet fertilization of lake trout gametes resulted in all endpoints (i.e., LC_{20}, LC_{50}, growth IC_{20}, and growth IC_{50}) being > 1,484 mg/L TDS (DBCI 2013b). The rotifer *B. calyciflorus* 48-h IC_{10} for intrinsic rate of population increase was 241 mg/L TDS, while the IC_{20} and IC_{50} were both > 1,474 mg/L TDS (DBCI 2013b). The cladocerans were the most sensitive to TDS in the Phase 1 testing. *C. dubia* exhibited a 7-d IC_{10} and IC_{20} for reproduction of 560 mg/L and 778 mg/L, respectively, while all survival endpoints were > 1,474 mg/L (DBCI 2013b). *D. magna* exhibited a 21-d LC_{10} of 183 mg/L and an LC_{20} of 663 mg/L. However, there is considerable uncertainty in this endpoint as there was less mortality at the highest TDS concentrations (i.e., 90% survival at 1000 mg/L and 80% survival at 1500 mg/L). The reproduction IC_{10} was 312 mg/L and the reproduction IC_{20} was 684 mg/L. DBCI (2013b) did not consider the LC_{10} or IC_{20} to be technically defensible endpoints because of the lower survival at intermediate TDS concentrations. The LC_{50} and reproduction IC_{50} were both > 1,474 mg/L (DBCI 2013b).

As the cladocerans were most sensitive to TDS, DBCI (2013b) conducted toxicity tests during Phase 2 of the program to determine if certain ions were more toxic than others. The test was run four times, each with varying TDS mixtures made up primarily of one salt: $CaCl_2$, $CaSO_4$, Na_2SO_4, or NaCl. For *C. dubia* reproduction, the relative toxic ranking of the salts from highest to lowest was $CaSO_4$ > $CaCl_2$ > Na_2SO_4 > NaCl. Reproduction IC_{20} values ranged from 428 mg/L for the $CaSO_4$ test to 1,170 mg/L for the NaCl test, while IC_{10} values ranged from 232 mg/L for the Na_2SO_4 test to 1,000 mg/L for the NaCl test. The LC_{20} for *C. dubia* from the $CaSO_4$ test was 1,240 mg/L, while the LC_{20}s from the tests with other salts were all greater than the highest concentration tested. Nonetheless, the LC_{10}s for the tests with $CaSO_4$, $CaCl_2$, and Na_2SO_4 were all bounded values (1,189, 1,516, and 1,554 mg/L, respectively; DBCI 2013b). In contrast, for *D. magna* reproduction the relative ranking of salts from highest to lowest toxicity was NaCl > Na_2SO_4 = $CaCl_2$ > $CaSO_4$. Reproduction IC_{20} values ranged from 493 mg/L for NaCl to 1,235 mg/L for $CaSO_4$, while the IC_{10} values ranged from 388 mg/L for Na_2SO_4 to 470 mg/L for $CaCl_2$ (DBCI 2013b). However, according to DBCI (2013b), the test with NaCl showed high variability in replicate response, adding uncertainty to the results. The LC_{20} values for *D. magna* were 804 mg/L, 1,247 mg/L, > 1,531 mg/L, and > 1,556 mg/L from the Na_2SO_4, $CaCl_2$, $CaSO_4$, and NaCl tests, respectively. The LC_{10} values from the NaCl, $CaSO_4$, Na_2SO_4, and $CaCl_2$ tests were 522 mg/L, 573 mg/L, 678 mg/L, and 726 mg/L, respectively (DBCI 2013b).

Chapman *et al.* (2000) performed 10-d *C. dilutus* toxicity tests with TDS mixtures composed primarily of sulphate and calcium. In the test with synthetic Red Dog Mine effluent there was no effect on survival at the highest concentration tested (2,089 mg/L TDS), but growth (dry weight) was reduced by about 45% (LOEC = 2,089 mg/L TDS). In contrast, the synthetic Kensington Mine effluent had no effect on chironomid growth, but the authors reported a LOEC of 1,750 mg/L TDS for survival (Chapman *et al.* 2000). Stekoll *et al.* (2009) also performed toxicity tests with sulphate and calcium-dominated TDS mixtures to mimic the Red Dog Mine effluent. Coho salmon were exposed to the mock effluent from fertilization to swim-up. There was a significant decrease in fertilization success and an increase in mortality to post-hatch with increasing TDS. In addition, the time to 50% hatch in the two highest TDS concentrations (1,250 and 2,500 mg/L TDS) was significantly less than in the control. Furthermore, exposure to 500 to 2,500 mg/L TDS resulted in significantly decreased length and weight of swim-up larvae compared to control, though this difference was gone two months later (Stekoll *et al.* 2009). In a second test, exposure to mock effluent at different time periods (e.g., fertilization to two minutes post-fertilization, two minutes post-fertilization to swim-up) was tested to see when the salmon were most sensitive to TDS. Eggs exposed to 2,500 mg/L TDS during fertilization had significantly higher pre-hatch mortality than controls, whereas those exposed two minutes or 24-h after fertilization did not. However, fish exposed to 2,500 mg/L TDS from 24-h after fertilization until swim-up had significantly higher post-hatch mortality than controls (Stekoll *et al.* 2009).

Kennedy *et al.* (2005) conducted 7-d tests with *C. dubia* in two different TDS mixtures, consisting of SO_{42-}, Na^+, Ca^{2+}, and Mg^{2+} in one test (MS-1), and SO_{42-} and Na^+ in the other (MS-II). Specific conductivity (SC) was used as a surrogate for TDS, and a linear regression was used to estimate the TDS concentration. The calculated IC_{25} value for reproduction for these tests was 2,371 mg/L for MS-I and 966 mg/L for

MS-II. The authors suggest that the increased hardness of MS-I decreased the toxicity. Survival was less sensitive than reproduction to TDS toxicity (Kennedy *et al.* 2005).

Kunz *et al.* (2013) conducted chronic toxicity tests with three different TDS mixtures that were representative of three sites impacted by coal mining: Winding Shoals, Boardtree, and Upper Dempsey. All three mixtures were prepared with SO_{42-} as the dominant ion. The next two most prevalent ions in the Winding Shoals solution were Mg^{2+} and then Ca^{2+}, while Boardtree had similar concentrations of Mg^{2+} and Ca^{2+}. Sodium was the second most abundant ion in the Upper Dempsey solution (Kunz *et al.* 2013). The concentration of TDS in the 100% solution was 1,405 mg/L for Winding Shoals, 2,125 mg/L for Boardtree, and 1,110 mg/L for Upper Dempsey. For 7-d tests with *C. dubia*, the only defined effect on survival was with the Upper Dempsey solution, with a LOEC of 100% TDS solution. For *C. dubia* reproduction, both Boardtree and Upper Dempsey had a LOEC of 100% TDS solution. For the fatmucket mussel, 28-d exposures resulted in a LOEC for survival of 10% TDS solution for all three mixtures. However, growth (length) was not affected. Survival of the amphipod *H. azteca* was not affected by any of the TDS mixtures at the highest concentration tested in 28-d exposures. Nevertheless, there was a reported LOEC for reproduction of 33% of the Winding Shoals solution and in the undiluted Boardtree and Upper Dempsey solutions. The mayfly *Centroptilum triangulifer* responded to all three mixtures differently in approximately 35-d exposures. The Winding Shoals solution resulted in a LOEC of 33% solution for both survival and biomass. The LOEC was 50% of the Boardtree solution for survival and biomass and > 100% of the Upper Dempsey solution for survival and biomass (Kunz *et al.* 2013). These results show that different species have different levels of sensitivity to TDS. In addition, the four species tested were affected differently by the different ionic compositions of the three solutions. The mussel and amphipod were negatively affected by all three test waters. However, the Upper Dempsey solution was toxic to the cladoceran but not the mayfly, while the Winding Shoals and Boardtree solutions were toxic to the mayfly. Therefore, the relative ion composition plays an important role in the toxicity of the mixture (Kunz *et al.* 2013).

7.0 Compilation of Canadian Water Quality Guidelines and Other Water Quality Benchmarks

Water quality guidelines and other water quality benchmarks provide useful tools for evaluating water quality conditions. In addition, numerical WQGs can provide a basis for establishing SSWQOs. In this review, a hierarchical approach was selected for compiling WQGs that may be relevant for establishing WQOs that would be protective of beneficial water uses in Snap Lake and elsewhere in the Lockhart River basin. This hierarchical approach involved compiling Canadian WQGs, WQGs from provincial agencies, and water quality benchmarks from other sources. The results of this review of the WQGs literature is provided in the following sections of this report.

7.1 Background Information of Canadian Water quality Guidelines

The Canadian WQGs are nationally endorsed, science-based goals for the quality of aquatic ecosystems. The guiding principles and procedures for deriving such WQGs have been documented in a series of national scientific protocols (CCME 1999). The three guiding principles that are fundamental to the development and implementation of Canadian WQGs include:

- WQGs embody a national goal for environmental quality of non-observable adverse effects on aquatic ecosystems over the long term;
- WQGs are developed for the major uses of aquatic resources in Canada; and,
- WQGs are generic recommendations that are based on the most current scientific information (i.e., they do not consider site-specific or management factors that may influence their implementation).

All of the national protocols include minimum requirements for the quality and quantity of toxicological data to ensure the guidelines derived are protective of the designated uses of aquatic ecosystems. Importantly, the use of national protocols ensures consistency, transparency, and scientific defensibility in the guidelines development process (CCME 1999). The Canadian WQGs have a number of functional uses in various environmental assessment and management programs. The recommended applications of the Canadian WQGs include (CCME 1999):

- National benchmarks to assess potential or actual impairment of socially-relevant water uses;
- Scientific basis for the development of SSWQOs and water quality standards;
- Indicators for state-of-the-environment reporting;
- Science-based performance indicators for regional, national, or international management strategies for toxic substances;
- Interim management objectives for persistent, bioaccumulative, and toxic substances to track progress toward virtual elimination;
- Indicators of ecotoxicologically-relevant concentrations of persistent, bioaccumulative, and toxic substances for the purpose of improving analytical detection and quantification capabilities;
- Tools for developing licences and/or permits for point source effluent discharges;
- Tools to evaluate the effectiveness of point source controls;
- Scientific basis for environmental regulations;
- Scientific benchmarks or targets in the assessment and remediation of contaminated sites; and,
- Science-based assessments and tools for consideration in the development of Canada-wide standards under the Canada-wide Accord on Environmental Harmonization.

Although the Canadian WQGs are broadly used within Canada and elsewhere to assess and manage water quality conditions, they should not be regarded as blanket values for national environmental quality (CCME 1999). Variations in environmental conditions (e.g., site-specific background levels of naturally-occurring substances, levels of the water quality variables that influence the toxicity of priority substances, sensitivity ranges of resident species) across the country have the potential to influence the applicability of the Canadian WQGs. Therefore, it may be necessary to establish SSWQOs or water quality standards that account for such variations in environmental conditions. Except of the development of Canada-wide standards, all of the aforementioned uses of the Canadian WQGs also apply to SSWQOs.

Adoption of existing water quality standards, WQGs, or water quality criteria (WQC) represents one of procedures that have been established for establishing use-protection based WQOs (CCME 2003). While numerical water quality standards have not been established for the majority of water bodies in the NWT, the narrative standards that have been articulated under the water classification system provide a basis for evaluating the relevance of numerical WQGs for potential adoption as WQOs. For this reason, a review of the literature was conducted to identify candidate WQGs for use in establishing WQOs for Snap Lake and the Upper Lockhart River. Table 8 provides a summary of the WQGs that were compiled for TDS and selected major ions. Since chloride is expected to be the dominant ion in TDS in Snap Lake, the following section focuses on WQGs for chloride and TDS.

7.2 Existing Water Quality Guidelines and Other Benchmarks

The water quality guidelines that were compiled from a variety of sources for TDS and selected major ions are presented in Table 8. The following sections of this document briefly describe the existing WQGs for TDS and chloride, a major component of the TDS in Snap Lake.

7.2.1 CCME Water Quality Guidelines

The CCME is the national body that promulgates water quality guidelines for the protection of aquatic life. The CCME WQGs for short-term and long-term exposure to chloride is 640 mg Cl^-/L and 120 mg Cl^-/L, respectively (CCME 2014). CCME currently has no guideline for TDS for the protection of aquatic life.

The CCME has also established WQGs for chloride and TDS for the protection of agricultural water uses. The CCME WQG for chloride for irrigation ranges from 100 mg Cl^-/L to 900 mg Cl^-/L, depending on the type of crop being irrigated. The CCME WQG for TDS for irrigation varies from 500 mg/L to 3500 mg/L, depending on the type of crop being irrigated. The CCME WQG for TDS for livestock watering is 3000 mg/L (CCME 2014).

Health Canada establishes drinking water guidelines (end-of-tap) for microbiological, chemical, and radiological contaminants, as well as physical characteristics such as taste and odour. The Health Canada WQG for chloride is 250 mg Cl^-/L, which is based on taste and corrosion potential in the distribution system. Health Canada's WQG for TDS is 500 mg/L, which is based on taste and the potential for scaling in the distribution system and water pipes, water heaters, boilers, and appliances (Health Canada 2014).

7.2.2 British Columbia Water Quality Guidelines

The British Columbia Ministry of Environment (BCMOE) promulgates guidelines to support the management of water resources in BC, which include approved and working WQG (BCMOE 2014). BCMOE (2014) has approved WQGs for chloride for the protection of aquatic life, including a WQG for short-term exposure (600 mg Cl^-/L) and a WQG for long-term exposure (150 mg Cl^-/L). BCMOE does not currently have any WQGs for TDS for protecting aquatic life.

BCMOE also has working WQGs for a number of other water uses. Working WQGs for chloride have been established for irrigation (100 mg Cl^-/L), livestock (600 mg Cl^-/L), and wildlife (600 mg Cl^-/L). Working WQGs for TDS have been established for irrigation (500 mg/L to 3500 mg/L, depending on the type of plant being irrigated), livestock (1000 mg/L for sensitive species and 3000 mg/L for other species), and industrial uses (process dependent; ranges from 0.5 mg/L for boilers to 35000 mg/L for cooling; Nagpal *et al.* 2006). In addition, BCMOE has established WQGs for drinking water (end-of-tap), including a WQG of 250 mg Cl^-/L for chloride (BCMOE 2014). BCMOE currently has no guideline for TDS for drinking water.

7.2.3 United States Environmental Protection Agency Water Quality Criteria

The United States Environmental Protection Agency (USEPA) recommends acute (i.e., short-term) and chronic (i.e., long-term) national WQC for the protection of aquatic life. These ambient WQC are typically used by the states and tribes to establish water quality standards. The WQC for short-term and long-term exposure to chloride are 860 mg Cl-/L and 230 mg Cl-/L, respectively (USEPA 2014). USEPA does not currently have any WQC for TDS for the protection of aquatic life. USEPA has also established standards for drinking water, some of which are secondary guidelines that regulate contaminants associated with aesthetic effects. Secondary Drinking Water Regulations include standards for chloride and TDS, set at 250 mg Cl-/L and 500 mg/L, respectively (USEPA 2012).

7.2.4 Other Water Quality Guidelines

The State of Alaska recommends water quality standards and criteria for a variety of designated uses. The WQC for chloride for the protection of aquatic life is 860 mg Cl-/L for short-term exposure and 230 mg Cl-/L for long-term exposure. However, these criteria apply to dissolved chloride when associated with sodium, and may not be adequately protective when the chloride is associated with potassium, calcium, or magnesium (ADEC 2008). For TDS, Alaska has a short-term water quality standard for the protection of aquatic life of 1000 mg/L, and states that "a concentration of TDS may not be present in the water if that concentration causes or reasonably could be expected to cause an adverse effect to aquatic life" (ADEC 2012).

The State of Alaska also has WQG for the protection of agricultural water uses. For TDS, a WQG of 1000 mg/L is specified irrigation and livestock (ADEC 2012); no WQGs are specified for chloride for agricultural water uses. WQGs for drinking water are 250 mg Cl-/L for chloride and 500 mg/L for TDS (ADEC 2012).

8.0 Approaches to the Development of Water Quality Objectives

In Canada, WQOs are defined as narrative statements or numerical concentrations of specific substances that are recommended to support and maintain the designated uses of a specific receiving water system (e.g., the Fraser River). The development of WQOs represents one component of an integrated process for implementing ecosystem-based natural resource management in Canada (see MacDonald 1994 for more information). The other elements of the process involve implementation of a regional basin assessment, consultation with stakeholder groups, and collection and interpretation of additional information on the ecosystem.

8.1 Federal Policy on the Development of Water Quality Objectives

Water quality objectives form a cornerstone of the Federal Water Policy (Minister of Environment 1987). In addition, the need for WQOs is explicitly recognized in the Canadian Environmental Protection Act [Section 8(1)]. To guide federal government staff, Environment Canada and Fisheries and Oceans Canada jointly developed a policy statement on the use and application of WQOs. In addition, the policy statement outlines the federal approach for reviewing WQOs that are derived by other agencies.

In the federal policy, WQOs are defined as numerical concentrations or narrative statements that have been established to support and protect the designated uses of water at a specified site (CCREM 1987). Such objectives are based on the best scientific information available. When insufficient information exists, provisional WQOs are applied until the data required to develop scientifically-defensible objectives are available. Provisional WQOs are deliberately conservative and implemented with due caution.

Water quality objectives are developed to conserve and protect the designated water uses of the waterbody under consideration. The designated water uses recognized in the federal policy include:

- Raw water for drinking water supply;
- Recreation and aesthetics;
- Freshwater, estuarine, and marine fish;
- Migratory birds and other aquatic life;
- Agriculture (including irrigation and livestock watering); and,
- Industrial water supplies.

While provincial and territorial jurisdictions frequently recognize waste assimilation as a valid water use, a non-degradation policy has been adopted by the federal government. This policy states that all reasonable and preventative measures should be taken to maintain existing conditions when they are better than the conditions specified by the WQGs. Hence, the existing conditions should be adopted as the objectives for waters of superior quality. For waters with impaired quality, the objectives may be used as a basis for improving water quality.

The federal policy identifies a number of applications for the WQOs. For example, evaluation of attainment with the objectives provides a useful means of predicting and assessing whether effluent quality standards (which are based on best available or practicable technology) provide adequate protection for designated water uses. However, the objectives cannot be used to derive allowable effluent contaminant concentrations if they would result in relaxation of effluent treatment requirements such that legislated effluent standards (e.g., Metal Mining Liquid Effluent Regulations) are no longer met. The objectives also provide a basis for identifying emerging water quality problems resulting from multiple point and diffuse sources and for determining the need to address such problems when they arise.

The federal policy recognizes that the management and control of certain toxic substances cannot be achieved using WQOs. For many toxic and/or bioaccumulative substances, it is not feasible to develop objectives due to the lack of aquatic toxicity data. Additionally, it may be necessary to establish objectives at levels below current analytical limits of quantification for substances that exhibit high acute toxicity or bioaccumulation potential. In these cases, more information will be needed to prescribe appropriate objectives.

8.2 Procedures for Deriving Water Quality Objectives in Canada

The CCME (2003) developed two strategies for deriving SSWQOs for application in Canada. These strategies have also been adopted for use throughout Canada (CCME 2003). The two strategies include:

- The non-degradation strategy; and,
- The use-protection strategy.

The non-degradation strategy is applied to those waters in which it is desirable to maintain or restore superior water quality conditions. The use-protection strategy is applied when some degradation of water quality conditions is considered to be tolerable, provided that the designated uses of the water body are maintained (MacDonald 1997; CCME 2003). The recent revision of the BCMOE guidance document (BCMOE 2013) has affirmed these two strategies as the foundations for deriving SSWQOs.

8.2.1 Non-Degradation Strategy

The non-degradation strategy is used to establish SSWQOs that are representative of baseline water quality conditions (i.e., using the background concentration procedure). The background concentration procedure provides a basis for deriving numerical

SSWQOs that can be applied to maintain water quality at, or restore water quality to, pre-development conditions. For this procedure, natural background concentrations of COPCs are measured and the resultant data are used to characterize acceptable water quality conditions for the area (MacDonald 1997; CCME 2003; BCMOE 2013). Natural background concentrations are those concentrations that have not been significantly altered by local land-use or water-use activities (although water quality conditions may be altered somewhat by regional or global activities). Whenever possible, water quality data collected prior to development are used to determine background conditions within the watershed. When such data are not available, water quality data collected at stations located upstream of land-use or water-use activities within the watershed or at appropriately-selected reference sites, must be used to establish background conditions (CCME 2003; BCMOE 2013).

Using the background concentration procedure, numerical SSWQOs can be established in a number of ways. However, all of these methods are based on first establishing background water quality conditions within the waterbody under consideration and then defining SSWQOs that reflect the temporal variability in background water quality conditions based on daily, seasonal, and/or annual variability (e.g., freshet). Based on the exhibited variability in many waterbodies, it is desirable to determine background conditions for relevant time periods (e.g., monthly, seasonal, or by flow period) and/or relevant forms of the COPC (e.g., total vs. dissolved metals). Typically, SSWQOs derived using this approach are established at the upper limit of background (e.g., 95th percentile concentration) or some increment over background conditions (e.g., 10% above the upper limit of background concentrations; MacDonald 1997; CCME 2003).

8.3.2 Use-Protection Strategy

The use-protection strategy provides a consistent scientific basis for establishing SSWQOs that can be used to accommodate multiple water uses of aquatic ecosystems. Using this strategy, ambient SSWQOs can be derived using three approaches (MacDonald 1997; CCME 2003; BCMOE 2013), including:

- Direct adoption of generic WQGs;
- Derivation of site-adapted WQOs (e.g., using the recalculation or water-effect ratio [WER] procedures); and,

- Development of *de novo* WQOs (e.g., using the resident species procedure).

8.3.2.1 Adoption of Generic Water Quality Guidelines

At many sites, the Canadian WQGs can be adopted directly as the WQO. Typically, such WQGs are adjusted to account for site-specific water quality conditions (i.e., background conditions), such as temperature, pH, or water hardness. Once the WQGs for each water use have been compiled or calculated, the WQG for the most sensitive water use is adopted as the SSWQO for the substance under consideration (MacDonald 1997; CCME 2003).

8.3.2.2 Derivation of Site-Adapted Water Quality Objectives

The recalculation procedure provides another relevant method for deriving site-adapted WQOs. The recalculation procedure is used in circumstances when the species represented in the toxicological data set used to derive the WQG are not present and are not expected to occur at the site (e.g., not within historical range, natural barriers to access). This procedure accounts for any differences in sensitivity between species present at the site and those used to derive the generic WQG. With the recalculation procedure, species that are not (now or historically) present at the site or nearby waters are eliminated from the toxicological data set that was used to calculate the generic WQG. Then, a site-adapted WQO is calculated using the guidance for deriving WQGs provided by the CCME. During implementation of the recalculation procedure, practitioners must follow the rules for evaluating the applicability of toxicity data to the site under consideration. These rules explicitly recognize the inherent limitations of the available toxicity data and are intended to ensure that data on the toxicity of a COPC to a species that is related to one that occurs or ought to occur at the site is not eliminated from the data set used to recalculate the WQGs (i.e., if fingernail clams exist at a site, then all of the toxicity data on freshwater bivalve molluscs must be retained in the data set used to recalculate the WQGs). If the minimum data requirements for deriving the site-adapted WQO are not met, additional toxicity testing on resident species in laboratory water is recommended (MacDonald 1997; CCME 2003; BCMOE 2013).

The second option for deriving site-adapted WQOs is the WER procedure. This procedure provides a robust method for modifying generic WQGs to account for unique characteristics at the site. The premise of the WER procedure is that site-specific physical and/or chemical characteristics of water can affect the bioavailability and, hence, toxicity of environmental contaminants (MacDonald 1997; CCME 2003; BCMOE 2013). For example, increased water hardness is known to decrease the acute toxicity of certain metals (e.g., cadmium, copper, lead, nickel, and zinc) to fish (CCREM 1987; Nagpal 1999). Similarly, the toxicity of ammonia to fish is affected by pH and temperature (MacDonald *et al.* 1987). These factors are accounted for in the derivation of generic WQGs and, hence, are not appropriate for evaluation using the WER procedure. However, there are also other factors (e.g., dissolved organic carbon, suspended particulate matter) at a site that could affect the bioavailability of the COPC under investigation. These factors are typically not accounted for in the derivation of the generic WQGs. The WER procedure provides a science-based method for accounting for such factors, thereby deriving WQOs that are more site-specific (MacDonald 1997; CCME 2003; BCMOE 2013).

To develop a WER, acute and/or short-term chronic toxicity tests are conducted with a minimum of two indicator and/or resident species (consisting of one fish and one invertebrate species), using both site water and laboratory water. Indicator species are nonresident species that are known to be acceptable surrogates for resident species (MacDonald 1997; CCME 2003; BCMOE 2013). Rainbow trout, fathead minnow, the water flea *C. dubia*, and the alga, *P. subcapitata*, are commonly used as indicator species because they are widely available, easy to culture, and consistently provide reliable results (Willingham 1988; MacDonald *et al.* 1989). In addition, these species are representative of those that are frequently present in waters within northern Canada (MacDonald 1997). The results of these toxicity tests are used to calculate the ratio of the toxicity of the COPC in site water to its toxicity in laboratory water. The geometric mean of the ratios from the two tests is calculated to determine the WER (MacDonald 1997; BCMOE 2013). The WER is then applied to the generic WQG to convert it to a site-adapted WQO (USEPA 1994). For example, if a COPC is half as toxic in site water as it is in laboratory water, the generic WQG would be multiplied by a WER of 2.0 to obtain the site-adapted WQO (CCME 2003; BCMOE 2013).

8.3.2.3 Development of **de novo** *Water Quality Objectives*

The final approach for calculating WQOs is the resident species procedure. The resident species procedure takes into account the sensitivity of species at the site and the influence of site-specific water quality characteristics (MacDonald 1997; CCME

2003; BCMOE 2013). To apply this procedure, toxicity tests are conducted with species that are resident at the site, using water from the site that represent background conditions (i.e., upstream from non-point and point discharge sources). Data must be generated in a manner that is consistent with the guidance provided by CCME (2003). Although the resident species procedure generates robust SSWQOs, the time and resources needed to conduct the required bioassays are often substantial (MacDonald 1997; CCME 2003; BCMOE 2013).

9.0 Derivation of Water Quality Objectives for Major Ions

Based on the results of the water classification process, it is apparent that several different procedures need to be applied to derive numerical WQOs for the waterbodies located within the Lockhart River basin, as follows:

- **Snap Lake:** Water quality conditions in Snap Lake have already been impaired by releases of effluent from the Snap Lake mine. Therefore, it is likely that a use-protection approach represents the most viable alternative for accommodating multiple interests, including continuing mining activities and protecting beneficial water uses.

- **Lockhart River downstream of Snap Lake:** The upper reach of the Lockhart River represents a transitional water body that has already been affected by discharges from the Snap Lake mine. While it may be no longer possible to meet WQOs established using background concentration procedure, this reach of the Lockhart River basin should still be afforded enhanced protection. For this reason, WQOs should be established at levels between those calculated using the use-protection procedure and the background concentration procedure (i.e., using the enhanced use-protection procedure).

- **Remaining Reaches of the Lockhart River Basin:** The use-protection approach is not appropriate for the middle and lower reaches of the Lockhart River, where protection of baseline water quality conditions has been identified as a high priority by Aboriginal organizations and the Government of the NWT. For this reason, the background concentration procedure is the most appropriate for deriving numerical WQOs for these reaches of the watershed.

The following sections of this document present data and information relevant to the establishment of WQOs for Snap Lake, the Lockhart River downstream of Snap Lake, and the remaining reaches of the Lockhart River Basin.

9.1 Derivation of Numerical Water Quality Objectives for Snap Lake

DBCI (2013b) has proposed numerical WQOs for chloride and TDS for use in Snap Lake (Table 9). As water quality conditions in Snap Lake have already been impaired by releases of effluent from the Snap Lake mine, a use-protection approach was employed to derive WQOs that are purported to be protective of water uses. Based on guidance provided by CCME (2003) to derive SSWQOs, the following methods could be used:

- Direct adoption of generic WQGs;
- Derivation of site-adapted WQOs (e.g., using the recalculation or WER procedures); or,
- Development of *de novo* WQOs (e.g., using the resident species procedure).

In cases where generic WQGS do not exist for a substance of interest, generic WQGs may be developed for use as WQOs. These WQGs must be derived using the guidance provided by CCME (2007). In the CCME (2007) guidance, two approaches are described for developing numerical WQGs that apply to short-term and long-term durations. The approaches for deriving guidelines include:

- Type A: Species sensitivity distribution (SSD) approach; and,
- Type B: Lowest endpoint derivation approach.

The Type A (i.e., SSD) approach should be employed when minimum data requirements are met relative to toxicity of the substance of interest to aquatic organisms. The minimum data requirements stated in the CCME (2007) guidance for the derivation of an SSD for long-term exposures includes:

- Three toxicity tests on fish species, with at least one salmonid and one non-salmonid species;
- Three aquatic or semi-aquatic invertebrate species, with at least one planktonic crustacean; and,
- At least one vascular plant or algal species.

Consistent with the guiding principles of the water quality guidelines (e.g., protection of all forms of aquatic life, including the most sensitive life stage of the most sensitive species over the long term), the Type A guideline is derived using no-effect concentrations (i.e., EC_{10} values) for the species used in the SSD. Other less preferred endpoints (e.g., MATC or LOEC values) may be incorporated into the SSD to fulfill the minimum data requirements. The SSD approach is a regression-based method for estimating the 5th percentile of the SSD by fitting a series of models to define the cumulative density function of the compiled data and selecting the most appropriate model by evaluating the goodness of fit (CCME 2007). The resultant 5th percentile of the cumulative density function is termed the HC_5 (hazard concentration). The value represents a point estimate above which 5% of the species would exhibit an effect response of greater than 10%.

The Type B approach should be employed when insufficient data are available to derive a guideline using the Type A (i.e., SSD) approach. The Type B approach is further divided into two methods (i.e., Type B1 and Type B2) depending on the quantity and quality of the available data. The minimum data requirements for deriving a Type B1 guideline are the same as for the Type A approach, while the Type B2 minimum data requirements includes:

- Two fish species, one salmonid and one non-salmonid; and,
- Two aquatic or semi-aquatic invertebrate species, with at least one planktonic crustacean.

The lowest endpoint derivation (i.e., Type B) method utilizes low-effect values (e.g., $EC_{15\text{-}25}$, LOEC, MATC) from the data compiled from the toxicity literature. The guideline is derived using the lowest effect value (considering all effects) for the most sensitive species in the compiled data set. To calculate the WQG, the lowest effect values is divided by a safety factor of 10 for Type B1 and Type B2 guidelines.

9.1.1 Water Quality Objective for Chloride

The WQO proposed by DBCI (2013b) for chloride is based on the WQO developed by Elphick *et al.* (2011) for the EKATI diamond mine in NWT. The WQO was developed by compiling literature-based information on the toxicity of chloride to aquatic species and data resulting from a toxicity testing program conducted by Elphick *et al.* (2011). The data used to generate the generic WQG are presented in Table 10 and Appendix 5. At the time of development of the EKATI WQO, no national (i.e. CCME) guideline existed for chloride, so the study was designed augment toxicity data from the literature to facilitate derivation of a generic WQG. Subsequent to the study conducted by Elphick *et al.* (2011), CCME promulgated short-term and long-term water quality guidelines for chloride in freshwater environments (CCME 2011).

While Elphick *et al.* (2011) compiled sufficient information to meet the minimum data requirements outlined in the guidance developed by CCME (2007), the toxicological data that were compiled were not consistent with those required support derivation of a WQG using the SSD approach (i.e., the use of EC_{10} values). For example, the 48-h IC_{25} for *B. calyciflorus* reproduction of 3,074 mg/L of chloride was used by Elphick *et al.* (2011), while the CCME (2013) relied on the IC_{10} (the preferred endpoint) for *B. calyciflorus* from the same study of 1,474 mg/L chloride. In addition, CCME included additional information on sensitive species including the wavy-rayed lampmussel (*L. fasciola*), the Northern riffleshell mussel (*Epioblasma torulosa rangiana*), the Fingernail clam (*Musculium securis*), and the water flea, *Daphnia ambigua*. The estimated no-effect values used in the derivation of the CCME water quality guideline for these species ranged from 24 to 259 mg/L of chloride. No rationale was provided in Elphick *et al.* for excluding these data in the generation of the proposed WQO. Based on information compiled by DBCI (2002), mollusks are present in Snap Lake and the Lockhart River watershed (Table 10) and, therefore, should be included in the toxicological data set used to derive WQOs based on the use-protection approach.

Elphick *et al.* (2011) proposed that water hardness be included as a toxicity modifying factor for chloride. That is, Elphick *et al.* (2011) stated that as water hardness increases (to a threshold of 160 mg $CaCO_3$/L) the toxicity of chloride is ameliorated. In the paper, the authors designed and conducted a toxicity study using *C. dubia* run at increasing water hardness (from 10 to 320 mg $CaCO_3$/L). The results of the study are plotted in Figure 4. While it appears that the toxicity of chloride is ameliorated with increasing hardness, it is apparent that the toxicity modifying effect is not consistent across endpoints (i.e., survival versus reproduction) or effect values (i.e., IC_{25} versus LC_{50}; Figure 4). That is, the magnitude of effect (i.e., the slope of the regression) is significantly different between the survival and reproduction endpoints ($F_{(1, 12)} = 8.37, p = 0.005$). Based on these results, there is considerable uncertainty in the relationship between the toxicity of chloride and the effect of hardness. Furthermore, the results of the study indicate that chloride toxicity increases when hardness increase from 160 to 320 mg $CaCO_3$/L. These data suggest that TDS concentration (i.e., including hardness) is likely contributing to the toxicity observed in the treatment. While CCME does provide limited guidance on the incorporation of toxicity modifying factors into WQG derivation (CCME 2007), CCME did not include hardness as a modifying factor in the promulgated WQG for chloride (CCME 2011). More specifically, CCME (2011) states that insufficient information on the effects of water hardness on chloride toxicity is available in the scientific literature to support inclusion of water hardness as a toxicity modifying factor for the chloride WQGs.

The WQO proposed by DBCI (2013b) for use in Snap Lake is not protective of sensitive species to the toxic effects of chloride. Low-effect concentrations (i.e., $EC_{15\text{-}25}$, LOEC, MATC) from studies that were compiled for deriving the CCME guideline for chloride are plotted in Figure 5. The proposed WQO (DBCI 2013b) does not protect against effects to both aquatic invertebrates and fish (Figure 5). Specifically, using the results of toxicity tests presented in CCME (2011), toxic effects to mollusks (e.g., fingernail clams) were observed well below the proposed WQO values (DBCI 2013b). Based on information provided in DBCI (2002; Table 11), these clam species are present in the study area. For sensitive crustacean species, the available toxicity data indicate that chloride concentrations at the proposed WQO (DBCI 2013b) could result in adverse effects greater than 25% (Figure 5).

Recommended Water Quality Objectives for Chloride: Water quality conditions in Snap Lake have already been impaired by releases of effluent from the Snap Lake mine. Hence, it is reasonable to apply the a use-protection approach to derive WQOs. Based on the information compiled on water quality guidelines for chloride, drinking water (short-term) and aquatic life (long-term; Table 8) are the most sensitive water uses. Based on the guidance provided in CCME (2003), the promulgated water quality guidelines developed for use in Canada should be adopted as the WQOs for Snap Lake. While other methods such as the recalculation method or the resident species approach could be employed to derive SSWQOs, it is unlikely that the resultant WQOs would be higher than the current WQG becuase the species that define the lower end of the SSD (i.e., mollusks and cladocerans) are present in Snap Lake and the Lockhart River. Therefore, it is recommended that a short-term WQO of 250 mg/L chloride and a long-term WQO of 120 mg/L chloride be established for Snap Lake.

9.1.2 Water Quality Objectives for Total Dissolved Solids

The WQO for TDS proposed by DBCI (2013b) was derived using the results of a toxicity testing program designed to emulate site-specific water quality conditions in Snap Lake (Table 12; Appendix 6). Specifically, test waters were created with relative ion concentrations that are consistent with current and expected major ion ratios in Snap Lake. This is an important step in the development of SSWQOs for Snap Lake, because the toxicity of TDS is highly dependent on the ions present in the water and should result in data that are appropriate for deriving a WQO for TDS. However, the approach employed to derive the WQO is not consistent with guidance provided by CCME (2003) for deriving WQOs. Rather, DBCI (2003) compiled sufficient data on the toxicity of TDS to support application of the CCME (2007) Type B2 approach to WQG development. However, DBCI (2013b) failed to apply the mandatory safety factor (of 10) to the lowest-effect level in the toxicological data set. This is inconsistent with the guidance provided by CCME. Further, DBCI (2013b) stated that insufficient information was generated in the site-specific toxicity testing program to support the derivation of a WQG using the Type A approach. While this is correct, the SSD approach can be applied by bringing in information from the scientific literature on the toxic effects of TDS to aquatic organisms (specifically salmonid fish) to fulfill the minimum data requirements. Such augmentation of the toxicity data with additional information from the literature is consistent with CCME (2007) methods. In addtion, DBCI (2013b) asserts that unbounded point estimates should not be used in the derivation of an SSD. However, CCME guidance does not state that unbounded estimates should be excluded from the SSD. In fact, these estimates are simply no-effect levels and are clearly identified as being appropriate for use in the development of a WQG.

The WQO proposed by DBCI (2013b) does not result in a protective value for aquatic life in Snap Lake. For example, the 10% effect concentrations (i.e., EC/IC_{10}) reported from the Phase 1 results range between 183 and >1487. Bounded results (i.e., point estimates) of these no-effect concentrations for the most sensitive species include:

- 183 mg/L TDS for *D. magna* survival;
- 241 mg/L TDS for the rotifer, *B. calyciflorus*, intrinsic rate of population increase;
- 312 mg/L TDS for *D. magna* reproduction; and,
- 560 mg/L TDS for *C. dubia* reproduction.

Therefore, the proposed benchmark of 684 mg/L TDS is likely to result in adverse effects to sensitive aquatic species, causing roughly 20% reductions in the sruvival, growth, or reproduction of sensitive species.

Recommended Water Quality Objectives for TDS: Water Quality Objectives for TDS in Snap Lake should be established by deriving a *de novo* water quality guideline using the guidance provided by CCME (2007). The results of the Phase I toxicity testing program presented in DBCI (2013b) and the compiled literature on the effects of TDS on aquatic organisms provide appropriate information to derive a WQO for Snap Lake. As insufficient information to generate a WQG using the Phase 1 toxicity test results alone (i.e., only two fish species were tested) was available, the primary literature was reviewed to identify additional information for inclusion in the SSD. It is important to consider the relative ion composition of the TDS in the information compiled. While no information on the toxicity of TDS at the appropriate ion composition was available, the literature compiled for the review of the toxicity of chloride (chloride makes up approximately 48% of the TDS in Snap Lake) was evaluated to identify an appropriate no-effect concentration for non-salmonid fish. Because this toxicity test was conducted using sodium chloride (rather than calcium chloride), the resultant effect level is likely substantially higher than would be the case had calcium chloride been used as the toxicant (Mount *et al.* 1997). The combined Phase 1 and literature-based no-effects data used in the generation of the SSD includes:

- Alga, *N. pelliculosa* (NOEC; >1487 mg/L TDS);
- Alga, *P. subcapitata* (NOEC; >1474 mg/L TDS);
- Lake trout (LC_{20}; 991 mg/L TDS);
- Arctic grayling (NOEC; >1414 mg/L TDS);

- Fathead minnow (MATC survival; 431 mg/L TDS; Birge *et al.* 1985);
- Midge, *C. dilutus* (NOEC; > 1379 mg/L TDS);
- Water flea, *C. dubia* (IC_{10} reproduction; 560 mg/L TDS);
- Water flea, *D. magna* (LC_{20}; 663 mg/L TDS); and,
- Rotifer, *B. calyciflorus* (IC_{10} intrinsic rate of population increase; 241 mg/L TDS).

The SSD was generated using SSD Master Version 3.0 (CCME May 2013). Four cumulative density function models were generated for the data set, with the resultant HC_5s ranging from 194 mg/L TDS (using the Extreme Value model) to 328 mg/L TDS (using the Gumbel model). After review of the resultant curves, the Extreme Value model (HC_5 of 194 mg/L TDS) best fit the data at the lower end of the curve. While the LC_{10} value for *D. magna* could be used to generate the SSD, there is considerable uncertainty in this value. Incorporation of this value into the SSD would result in a HC_5 of 160 mg/L TDS.

Water quality conditions in Snap Lake have already been impaired by releases of effluent from the Snap Lake mine. Therefore, it is reasonable to apply the use-protection approach for deriving WQOs for Snap Lake. Based on the information compiled on water quality guidelines for TDS, drinking water is the most sensitive water use during short-term exposure, while aquatic life is the most sensitive water use under long-term exposure. In accordance with CCME (2003), the drinking water WQG should be adopted as the short-term WQO for Snap Lake (i.e., 500 mg/L TDS). In addition, it is recommended that the HC_5 of 194 mg/L TDS for the protection of aquatic life should be established as the long-term WQO for Snap Lake (Table 13).

9.2 Derivation of Numerical Water Quality Objectives for the Lockhart River Downstream of Snap Lake (Outlet of Snap Lake to Inlet of MacKay Lake)

No WQOs have been proposed for the Lockhart River downstream of Snap Lake by DBCI. However, the Lockhart River provides high quality habitat for aquatic life and aquatic-dependent wildlife. In addition, this portion of the Lockhart River (from Snap lake to MacKay Lake) is capable of supporting a variety of other beneficial water uses (i.e., drinking water, recreation and aesthetics, etc.). However, due to the hydrological connectivity and proximity to Snap Lake, water quality conditions within this portion of the Lockhart River have been altered by effluent discharges from the Snap Lake mine. To prevent further alteration of water quality conditions and to protect beneficial water uses in downstream areas, this portion of the Lockhart River should be afforded enhanced use-protection. Thus, WQOs should be developed using the enhanced use-protection approach.

The enhanced use-protection procedure derives a WQO that is half-way between the WQO (or WQG) that is based on the most sensitive designated use and the background concentration. The WQO can be derived using the following equation:

$$WQO_{\text{Enhanced Use-protection}} = (WQO_{\text{Use-protection}} + C_{\text{Background}}) / 2$$

9.2.1 Water Quality Objectives for Chloride

The upper reach of the Lockhart River represents a transitional water body that has already been affected by discharges from the Snap Lake mine. While it may be no longer possible to meet WQOs established using the background concentration procedure, this reach of the Lockhart River basin should still be afforded enhanced protection. For this reason, WQOs should be established at levels between those calculated using the use-protection procedure and the background concentration procedure (i.e., using the enhanced use-protection procedure).

Limited baseline water quality data are available on the Lockhart River immediately downstream of Snap Lake. One sample collected during baseline characterization at Station 37 in 1993 was used to characterize background conditions. The concentration of chloride in this sample was 0.99 mg/L chloride. While the information on chloride concentrations in this portion of the Lockhart River is limited, it is within the expected range of chloride concentrations (Tables 2, 4,and 6) in the Lockhart River watershed under baseline conditions and provides an estimate of background concentrations in this area of interest.

Based on the limitations of the background concentrations, the value of 0.99 mg/L chloride was used to calculate both the short-term and long-term WQOs for the Lockhart River downstream of Snap Lake. Using the short-term WQO recommended for Snap Lake of 250 mg/L for the protection of drinking water, it is recommended that a short-term WQO of 125 mg/L chloride be established for the Lockhart River downstream of Snap Lake (i.e., Lockhart River from the outlet of Snap Lake to MacKay Lake). Using the long-term WQO recommended for Snap Lake of 120 mg/L for the protection of aquatic life, it is recommended that a long-term WQO of 60 mg/L chloride be established for the Lockhart River downstream of Snap Lake (i.e., Lockhart River from the outlet of Snap Lake to MacKay Lake; Table 13).

9.2.2 Water Quality Objectives for Total Dissolved Solids

The upper reach of the Lockhart River represents a transitional water body that has already been affected by discharges from the Snap Lake mine. While it may be no longer possible to meet WQOs established using the background concentration procedure, this reach of the Lockhart River basin should still be afforded enhanced protection. For this reason, WQOs should be established at levels between those calculated using the use-protection procedure and the background concentration procedure (i.e., using the enhanced use-protection procedure).

Limited baseline water quality data were available on the Lockhart River immediately downstream of Snap Lake. One sample collected during baseline characterization at Station 37 in 1993 was used to characterize background conditions. The concentration of TDS in this sample was 17 mg/L TDS. While the information on TDS concentrations in this portion of the Lockhart River is limited, it is within the expected range of TDS concentrations (Tables 2, 4, and 6) in the Lockhart River watershed under baseline conditions and provides an estimate of background concentrations in this area of interest.

Based on the limitations of the background concentrations, the value of 17 mg/L TDS was used to calculate both the short-term and long-term WQOs for use in the Lockhart River downstream of Snap Lake. Using the short-term WQO recommended for Snap Lake of 500 mg/L TDS for the protection of drinking water, it is recommended that a short-term WQO of 259 mg/L TDS be established for the Lockhart River downstream of Snap Lake (i.e., Lockhart River from the outlet of Snap Lake to MacKay Lake). Using the long-term WQO recommended for Snap Lake of 194 mg/L for the protection of aquatic life, it is recommended that a long-term WQO of 106 mg/L TDS be established for the Lockhart River downstream of Snap Lake (i.e., Lockhart River from the outlet of Snap Lake to MacKay Lake; Table 13).

9.3 Derivation of Numerical Water Quality Objectives for the Remaining Reaches of the Lockhart River Basin

No WQOs have been proposed by DBCI for the Lockhart River from MacKay Lake to the Great Slave Lake. However, the Lockhart River provides high quality habitat for aquatic life and aquatic-dependent wildlife. In addition, this portion of the Lockhart River is capable of supporting a variety of other beneficial water uses (i.e., drinking water, recreation and aesthetics, etc.). These reaches of the Lockhart River is used extensively by Aboriginal peoples practicing traditional lifestyles, emphasizing the cultural importance of this area. Therefore, WQOs for these waters (.e., MacKay Lake to Artillery Lake) should be derived using the non-degradation (i.e., background concentration) procedure (CCME 2003). In addition, the Old Lady of the Falls (Tsanku Theda) and the Lockhart River (Desnethche) have been identified as the fundamental core of the Lutsel K'e Denesoline cultural identity (Nitah 2009). As one of the most culturally and spiritually important water bodies in the NWT, existing water quality conditions must be maintained at all times to protect these water of special significance. Therefore, it is important that WQOs be developed for these portions of the Lockhart River using the non-degradation approach.

Derivation of WQOs using the background concentration procedure necessitates the characterization the levels of the substances of interest under background conditions. Derivation of numerical WQOs using the background-concentration procedure requires estimation of both the central tendency and upper limit of background concentrations of each of the substances of interest. The estimate of central tendency of the background concentrations is used to establish a long-term (typically 30-day average) SSWQO, while the upper limit of background conditions is used to establish the short-term (i.e., maximum) SSWQO for a water quality variable. As such, water quality conditions for each of the identified COPCs should be characterized by determining the central tendency, calculated as the 95% upper confidence limit (UCL) of the mean (or the arithmetic mean if fewer than 10 measurements are available), and upper limit of natural conditions, calculated as the 95^{th} percentile of concentrations.

9.3.1 Water Quality Objectives for Chloride

The use-protection approach is not appropriate for these reaches of the Lockhart River (i.e., from MacKay Lake to Great Slave Lake), where protection of baseline water quality conditions has been identified as a high priority by Aboriginal organizations and the Government of the NWT. For this reason, the background concentration procedure is the most appropriate for deriving numerical WQOs for chloride for these reaches of the watershed.

The short-term and long-term WQOs derived for the Lockhart River are provided in Table 13. The WQOs have been developed for each of the waterbodies in each area of interest (i.e., Upper Lockhart River, Central Lockhart River, Lower Lockhart River, and the Lower Lockhart River in the vicinity of Old Lady of the Falls) using the baseline chloride data that were collected in that are of interest. The recommended short-term WQOs for chloride range from 0.290 to 0.794 mg/L chloride in the Lockhart River and associated waterbodies, while the long-term WQOs range from 0.186 to 0.556 mg/L chloride. It is recommended that the WQOs listed in Table 13 be established for the Lockhart River.

9.3.2 Water Quality Objectives for Total Dissolved Solids

The use-protection approach is not appropriate for these reaches of the Lockhart River (i.e., Lockhart River from MacKay Lake to Great Slave Lake), where protection of baseline water quality conditions has been identified as a high priority by Aboriginal organizations and the Government of the NWT. For this reason, the background concentration procedure is the most appropriate for deriving numerical WQOs for TDS for these reaches of the watershed.

The short-term and long-term WQOs derived for the Lockhart River are provided in Table 13. The WQOs have been developed for each of the waterbodies within each area of interest (i.e., Upper Lockhart River, Central Lockhart River, Lower Lockhart River, and the Lower Lockhart River in the vicinity of Old Lady of the Falls). The recommended short-term WQOs for TDS range from 22.2 to 41 mg/L TDS in the Lockhart River and associated waterbodies, while the long-term WQOs range from 18.7 to 35 mg/L TDS. It is recommended that the WQOs listed in Table 13 be established for the Lockhart River.

10.0 Aquatic Effects Monitoring Program

Compliance monitoring represents an essential element of any effective water quality management system. In the NWT, two types of monitoring programs are typically conducted to evaluate compliance with EQC and WQOs. First, surveillance network monitoring is conducted by proponents to demonstrate that requirements identified in their water licence, including EQC, have been met. This monitoring typically involves collection of samples within various project-related structures and at the final point of control. Such samples are typically subjected to chemical analysis and the results are compared to the EQC. In addition, acute toxicity testing is typically conducted to confirm that the effluent is not acutely toxic to aquatic organisms.

In addition to surveillance network monitoring, aquatic effects monitoring is conducted to evaluate compliance with WQOs and to assess the effects of the project on the aquatic ecosystem. Such monitoring typically involves collection of environmental samples at various locations within the areas of interest (i.e., upstream of effluent discharges, edge of the initial dilution zone, and downstream areas). Such samples are usually subjected to chemical analysis and the resultant data are compared to the WQOs that have been established. This monitoring to assess compliance with WQOs is an important part of the overall WQOs process and is necessary to guide management decisions (BCMOE 2013). Monthly sampling, as well as a minimum of two 5-in-30 day sampling events (i.e., 5 samples collected at six-day intervals over a 30 day period) should be conducted at compliance points within each of the areas of interest in Snap Lake and the Lockhart River. The 5-in-30 day sampling events should be conducted during the periods of time with which the maximum variability in water quality conditions is expected (i.e., in periods of high or low flow in streams, or with mixing in lakes). Compliance with the recommended WQOs should be evaluated as follows:

- Short-term WQOs should be compared to any of the five weekly samples collected within a 30-d period; and,
- Long-term WQOs should be compared to results of any monthly grab sample, mean of five samples collected within 30-d, or annual mean.

It is recommended that the Surveillance Network Program and Aquatic Effects Monitoring Program that are currently being conducted in the vicinity of the Snap Lake mine site be reviewed and evaluated to assure consistency with the recommended WQOs that are established. In addition, there may be a need for expanded biological monitoring of receiving water bodies to ensure that the WQOs are protective of designated water uses and do not adversely affect aquatic ecosystems.

The expanded biological monitoring program should include a surface-water toxicity testing program conducted quarterly using site water from Snap Lake and the Lockhart River with the following toxicity tests:

- Early life-stage tests using rainbow trout embryos (Endpoints: survival and growth);
- 7-day toxicity test using the fathead minnow (Endpoints: survival and growth);
- 7-day toxicity test using the water fleas, *C. dubia* (Endpoints: survival and reproduction); and,
- 72-hour toxicity test using the green alga, *P. subcapitata* (Endpoint: cell yield).

11.0 Summary and Conclusions

DBCI (2013b) has proposed numerical WQOs for chloride and TDS for use in Snap Lake. These WQOs were reviwed and evaluated to determine if they were derived using appropriate procedures and if they would provide an adequate level of protection for beneficial water uses. The results of that review showed that the WQOs for chloride and TDS were not derived using the procedures that have been established by CCME (CCME 2003, Appendix 7; CCME 2007, Appendix 8). In addition, the WQOs proposed by DBCI would not be protective of beneficial water uses. Accordingly, recommended WQOs were derived to assist the MVLWB in establishing WQOs for Snap Lake and downstream waters (Section 9).

In Snap Lake, water quality conditions are currently being affected by permitted discharges of effluent from the Snap Lake mine. Other uses of water may be somewhat restricted in Snap Lake, in part due to the presence of the mine on the lake. Accordingly, these waters should be classified as having normal sensitivity to releases of contaminants from anthropogenic sources and WQOs should be developed using the use-protection approach. The Lockhart River downstream of Snap Lake (Lockhart

River from the outlet of Snap Lake to MacKay Lake) provides high quality habitat for aquatic life and aquatic-dependent wildlife. In addition, this portion of the Lockhart River is capable of supporting a variety of other beneficial water uses (e.g., drinking water, recreation and aesthetics, etc.). However, due to the hydrological connectivity and proximity to Snap Lake water quality conditions within this portion of the Lockhart River have been altered by discharges of effluent from the Snap Lake mine. To prevent further alteration of water quality conditions and to protect beneficial water uses in downstream areas, WQOs should be developed using an enhanced use-protection approach. The remainder of the Lockhart River watershed also provides high quality habitat for aquatic life and aquatic-dependent wildlife In addition, these reaches of the Lockhart River are capable of supporting a variety of other beneficial water uses (i.e., drinking water, recreation and aesthetics, etc.). These reaches of the Lockhart River are used extensively by Aboriginal peoples practicing traditional lifestyles, emphasizing the cultural importance of this area. In addition, certain downstream waters (i.e., in the vicinity of the Old Lady of the Falls) have been identified having special cultural and spiritual significance to Aboriginal peoples. Water quality objectives should be developed for these reaches of the Lockhart River using the non-degradation approach (i.e., background concentration procedure).

Recommended WQOs (Table 13) have been developed for use in Snap Lake based on the use-protection approach. For chloride, it is recommended that the drinking water guideline be adopted as the short-term WQO (i.e., 250 mg/L chloride) and that the long-term WQG for the protection of aquatic life (i.e., 120 mg/L chloride) be adopted as the long-term WQO for Snap Lake (CCME 2011). In addition, it is recommended that the short-term CCME WQG for TDS (drinking water) be established as the short-term WQO for Snap Lake (i.e., 500 mg/L TDS), while the long-term WQO derived using the CCME Guidance (Type A approach) described in section 9.1.2 be established as the long-term TDS WQO in Snap Lake (i.e., 194 mg/L TDS). Water quality objectives for the various reaches of the Lockhart River are recommended in Table 13. These WQOs were developed using the enhanced use-protection and non-degradation approaches depending on the reach of the river that was considered.

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Tables

Table 1. Summary of water quality samples collected to support the characterization of baseline conditions in Snap Lake (1993-2001).

Station / Sample Date	Depth (m)[1]	Number of Samples	Analytes Measured				
			Conventionals	Nutrients	Major Ions	Dissolved Metals	Total Metals
WQ1							
1998-02-02	NA	1	x	x	x	x	x
1998-07-20	NA	2	x	x	x	x	x
1999-03-24	2	1	x	x	x	x	x
1999-03-24	16	1	x	x	x	x	x
1999-08-12	Integrated	1	x	x	x	x	x
2001-03-16	NA	1	x	x	x	x	x
2001-07-22	3	1	x	x	x	x	x
WQ2							
1998-02-02	NA	1	x	x	x	x	x
1998-07-20	NA	1	x	x	x	x	x
1999-03-24	2	1	x	x	x	x	x
1999-03-24	6.5	1	x	x	x	x	x
1999-08-12	Integrated	1	x	x	x	x	x
2001-07-22	3	1	x	x	x	x	x
WQ3							
1998-02-02	NA	1	x	x	x	x	x
1998-07-20	NA	1	x	x	x	x	x
1999-03-24	2	1	x	x	x	x	x
1999-08-12	Integrated	1	x	x	x	x	x
2001-03-16	NA	1	x	x	x	x	x
2001-07-22	3	1	x	x	x	x	x
WQ4							
1999-03-24	3	1	x	x	x	x	x
1999-08-12	Integrated	1	x	x	x	x	x
2001-07-22	3	1	x	x	x	x	x
WQ6							
1999-03-24	2	1	x	x	x	x	x
1999-03-24	6	1	x	x	x	x	x
1999-08-12	Integrated	1	x	x	x	x	x
2001-07-22	3	1	x		x	x	
WQ7							
1998-07-20	NA	1	x	x	x	x	x
1999-03-24	2	1	x	x	x	x	x
1999-03-24	7	1	x	x	x	x	x
1999-08-12	Integrated	1	x	x	x	x	x
2001-03-16	NA	1	x	x	x	x	x
2001-07-22	3	1	x	x	x	x	x
29							
1993-07-21	NA	1	x	x	x		x

[1] Integrated samples were collected from multiple depths. NA = depth information not available.

Table 2. Summary statistics of major ions and total dissolved solids in water quality samples collected to support the characterization of baseline conditions in Snap Lake (1993-2001).

Major Ion	Lake Cover[1]	Period of Record	n	Non-Detect Samples (%)	Mean	Standard Deviation	95% UCL	Minimum	Maximum	Percentile						
										5th	10th	25th	50th	75th	90th	95th
Alkalinity (mg/L)	Ice	1998-2001	16	0	7.06	1.34	7.78	5	10	5.75	6	6	7	7.25	9	9.25
	Open	1993-2001	18	0	5.01	1.55	5.78	2.2	8	3.73	4	4	4.5	6	7.3	8
	Total	1993-2001	34	0	5.98	1.77	6.59	2.2	10	4	4	4.25	6	7	8	9
Bicarbonate (mg CO_3/L)	Ice	1999-2001	13	0	7.32	2.38	8.75	5.2	12	5.38	5.52	5.7	6.6	7.3	11	11.4
	Open	2001-2001	6	0	8.67	1.21	9.94	7	10	7.25	7.5	8	8.5	9.75	10	10
	Total	1999-2001	19	0	7.74	2.15	8.78	5.2	12	5.47	5.58	5.8	7	9.5	11	11.1
Calcium (mg/L)	Ice	1998-2001	16	0	1.65	0.314	1.82	1.33	2.43	1.34	1.35	1.44	1.54	1.77	2.08	2.2
	Open	1993-2001	18	0	1.15	0.165	1.24	0.93	1.42	0.93	0.944	1	1.17	1.27	1.35	1.39
	Total	1993-2001	34	0	1.39	0.349	1.51	0.93	2.43	0.943	0.979	1.15	1.34	1.52	1.8	2.06
Carbonate (mg/L)	Ice	2001-2001	3	100	2.5	0	2.5	<5	<5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	Open	2001-2001	6	100	2.5	0	2.5	<5	<5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	Total	2001-2001	9	100	2.5	0	2.5	<5	<5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Chloride (mg/L)	Ice	1998-2001	16	62.5	0.309	0.253	0.444	<0.2	<1	0.1	0.1	0.1	0.2	0.5	0.665	0.742
	Open	1993-2001	18	61.1	0.351	0.203	0.452	<0.2	<1	0.1	0.1	0.125	0.4	0.5	0.53	0.618
	Total	1993-2001	34	61.8	0.331	0.225	0.41	<0.2	<1	0.1	0.1	0.1	0.25	0.5	0.607	0.72
Fluoride (mg/L)	Ice	2001-2001	3	0	0.06	0	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
	Open	1999-2001	12	50	0.033	0.00783	0.0375	0.04	<0.05	0.025	0.025	0.025	0.033	0.04	0.04	0.04
	Total	1999-2001	15	40	0.038	0.0133	0.0454	0.04	0.06	0.025	0.025	0.025	0.04	0.04	0.06	0.06
Hardness (mg/L)	Ice	1998-2001	14	0	6.72	2.29	8.04	0.04	10	3.91	6	6	7	7	9	9.35
	Open	1993-2001	18	0	5	0.767	5.38	4	6	4	4	4.25	5	5.75	6	6
	Total	1993-2001	32	0	5.75	1.81	6.4	0.04	10	4	4	5	6	7	7	9
Magnesium (mg/L)	Ice	1998-2001	16	0	0.759	0.115	0.821	0.61	1.01	0.61	0.625	0.682	0.75	0.802	0.91	0.958
	Open	1993-2001	18	0	0.55	0.0397	0.57	0.48	0.62	0.488	0.497	0.51	0.57	0.577	0.58	0.586
	Total	1993-2001	34	0	0.649	0.134	0.695	0.48	1.01	0.496	0.5	0.57	0.595	0.73	0.825	0.901

Table 2. Summary statistics of major ions and total dissolved solids in water quality samples collected to support the characterization of baseline conditions in Snap Lake (1993-2001).

Major Ion	Lake Cover[1]	Period of Record	n	Non-Detect Samples (%)	Mean	Standard Deviation	95% UCL	Minimum	Maximum	Percentile						
										5th	10th	25th	50th	75th	90th	95th
Nitrate-N (mg/L)	Ice	1999-2001	13	61.5	0.013	0.0141	0.0217	<0.006	0.041	0.0036	0.004	0.004	0.004	0.02	0.0362	0.0392
	Open	1993-2001	18	88.9	0.004	0.00191	0.00534	<0.006	0.01	0.003	0.003	0.004	0.004	0.004	0.0055	0.0092
	Total	1993-2001	31	77.4	0.008	0.01	0.0117	<0.006	0.041	0.003	0.003	0.004	0.004	0.004	0.02	0.0335
Potassium (mg/L)	Ice	1998-2001	16	0	0.584	0.115	0.646	0.44	0.78	0.455	0.47	0.49	0.55	0.673	0.755	0.772
	Open	1993-2001	18	0	0.384	0.0454	0.407	0.3	0.46	0.317	0.327	0.342	0.4	0.42	0.423	0.434
	Total	1993-2001	34	0	0.479	0.132	0.525	0.3	0.78	0.326	0.333	0.4	0.435	0.535	0.677	0.75
Sodium (mg/L)	Ice	1998-2001	16	0	0.689	0.175	0.783	0.5	1	0.515	0.525	0.565	0.615	0.78	0.97	1
	Open	1993-2001	18	0	0.498	0.0675	0.531	0.44	0.6	0.44	0.44	0.45	0.46	0.575	0.6	0.6
	Total	1993-2001	34	0	0.588	0.161	0.644	0.44	1	0.44	0.443	0.46	0.56	0.608	0.852	0.961
Sulphate (mg/L)	Ice	1998-2001	16	56.2	4.54	8.53	9.09	1.98	36	1.5	1.5	1.5	1.5	3.06	6	13.5
	Open	1993-2001	18	38.9	1.96	0.829	2.37	1.31	4	1.34	1.36	1.5	1.5	2.7	3	3.15
	Total	1993-2001	34	47.1	3.17	5.93	5.24	1.31	36	1.36	1.42	1.5	1.5	2.94	4	6
Total Dissolved Solids (mg/L)	Ice	1998-2001	16	43.8	11.4	6.5	14.8	<10	25	5	5	5	12.5	15.2	18.5	21.2
	Open	1993-2001	18	27.8	22.3	19	31.7	<10	70	5	5	7	18	27.2	46	61.5
	Total	1993-2001	34	35.3	17.1	15.4	22.5	<10	70	5	5	5	15	18.8	37	47

n = number of samples; UCL = upper confidence limit of the mean.

[1] Ice: November to April; Open: May to October.

Table 3. Summary of water quality samples collected to support the characterization of baseline conditions in the entire Lockhart River (1969-2000).

Station / Sample Date[1]	Depth (m)	Number of Samples	Analytes Measured				
			Conventionals	Nutrients	Major Ions	Dissolved Metals	Total Metals
37							
1993-07-21	NA	1	x	x	x		x
11							
1993-07-25	NA	1	x	x	x		x
23							
1999-08-06	2	1	x	x	x		x
24							
1993-07-24	NA	1	x	x	x		x
1999-03-08	2	1	x	x	x		x
1999-03-08	5	1	x	x	x		x
26							
1999-03-10	2	1	x	x	x		x
1999-03-10	5	1	x	x	x		x
1999-03-10	9	1	x	x	x		x
1999-08-06	2	2	x	x	x		x
1999-08-06	5	2	x	x	x		x
1999-08-06	9	3	x	x	x		x
3							
1999-03-10	3	2	x	x	x		x
52							
1999-03-10	2	2	x	x	x		x
1999-03-10	5	3	x	x	x		x
1999-03-10	10	2	x	x	x		x
OA1							
1969-06-12	NA	1	x	x	x	x	
1969-07-18	NA	1	x	x	x	x	
1970-07-16	NA	1	x	x	x	x	
1970-10-06	NA	1	x	x	x	x	
1971-08-13	NA	1	x	x	x	x	
1972-06-26	NA	1	x	x	x	x	
1972-09-20	NA	1	x	x	x	x	
1972-12-08	NA	1	x	x	x	x	
1973-02-02	NA	1	x	x	x		
1973-05-31	NA	1	x	x	x	x	
1974-10-11	NA	1	x	x	x		
1975-07-11	NA	1	x	x	x		
1976-04-21	NA	1	x	x	x		
1976-07-22	NA	1	x	x	x		
1976-09-30	NA	1	x	x	x		

Table 3. Summary of water quality samples collected to support the characterization of baseline conditions in the entire Lockhart River (1969-2000).

Station / Sample Date[1]	Depth (m)	Number of Samples	Analytes Measured				
			Conventionals	Nutrients	Major Ions	Dissolved Metals	Total Metals
OA1 (cont.)							
1977-04-04	NA	1	x	x	x		
1977-05-25	NA	1	x	x	x		
1977-08-18	NA	1	x	x	x		
1977-09-29	NA	1	x	x	x		
1978-09-05	NA	1	x	x	x	x	
1979-06-27	NA	1	x	x	x	x	x
1979-08-08	NA	1	x	x	x	x	
1979-11-20	NA	1	x	x	x	x	x
1980-02-04	NA	1	x	x	x	x	x
1980-05-08	NA	1	x	x	x	x	x
1980-06-19	NA	1	x	x	x	x	x
1980-07-30	NA	1	x	x	x	x	x
1980-09-16	NA	1	x	x	x	x	x
1981-06-24	NA	1	x	x	x	x	x
1981-07-22	NA	1	x	x	x	x	x
1983-06-10	NA	1	x	x	x	x	x
1983-07-11	NA	1	x	x	x	x	x
1983-08-24	NA	1	x	x	x	x	x
1983-11-24	NA	1	x	x	x		x
1984-03-21	NA	1	x	x	x	x	x
1984-07-05	NA	1	x	x	x	x	x
1984-09-26	NA	1	x	x	x	x	x
1985-01-16	NA	1	x	x	x	x	x
1985-03-11	NA	1	x	x	x	x	x
1985-05-22	NA	1	x	x	x	x	x
1985-06-25	NA	1	x	x	x	x	x
1985-08-13	NA	1	x	x	x	x	x
1985-12-18	NA	1	x	x	x	x	x
1986-01-29	NA	1	x	x	x	x	x
1986-05-14	NA	1	x	x	x	x	x
1986-07-09	NA	1	x	x	x	x	x
1986-08-13	NA	1	x	x	x	x	x
1987-02-12	NA	1	x	x	x	x	x
1987-05-20	NA	1	x	x	x	x	x
1987-07-07	NA	1	x	x	x	x	x
1987-09-23	NA	1	x	x	x	x	x
1988-01-15	NA	1	x	x	x	x	x
1988-05-12	NA	1	x	x	x	x	x
1988-07-28	NA	1	x	x	x	x	x
1988-09-07	NA	1	x	x	x	x	x
1989-03-02	NA	1	x	x	x	x	x
1989-06-07	NA	1	x	x	x	x	x
1989-08-30	NA	1	x	x	x	x	x
1990-02-11	NA	1	x	x	x	x	x

Table 3. Summary of water quality samples collected to support the characterization of baseline conditions in the entire Lockhart River (1969-2000).

Station / Sample Date[1]	Depth (m)	Number of Samples	Analytes Measured				
			Conventionals	Nutrients	Major Ions	Dissolved Metals	Total Metals
OA1 (cont.)							
1990-05-14	NA	1	x	x	x	x	x
1990-07-19	NA	1	x	x	x	x	x
1990-09-05	NA	1	x	x	x	x	x
1991-01-30	NA	1	x	x	x	x	x
1991-07-29	NA	1	x	x	x	x	x
1991-08-28	NA	3	x	x	x	x	x
1992-02-11	NA	1	x	x	x	x	x
1992-05-04	NA	1	x	x	x	x	x
1992-10-08	NA	1	x	x	x	x	x
1993-03-04	NA	3	x	x	x	x	x
1993-07-13	NA	1	x	x	x	x	x
1993-08-21	NA	1	x	x		x	x
1994-01-21	NA	3	x	x	x	x	x
1994-05-17	NA	1	x	x	x	x	x
1994-06-06	NA	1	x	x	x	x	x
1994-08-26	NA	3	x	x	x	x	x
1994-11-15	NA	1	x	x	x	x	x
1995-01-31	NA	1	x	x	x	x	x
1995-05-05	NA	1	x	x	x	x	x
1995-06-09	NA	1	x	x	x	x	x
1995-09-19	NA	3	x	x	x	x	x
1995-11-27	NA	1	x	x	x	x	x
1996-02-03	NA	1	x	x	x	x	x
1996-06-18	NA	1	x	x	x	x	x
1996-09-16	NA	3	x	x		x	x
1997-08-28	NA	1	x	x	x		x
1998-02-10	NA	1	x	x	x	x	x
1998-08-29	NA	1	x	x	x	x	x
1999-02-04	NA	1	x	x	x	x	x
1999-06-13	NA	1	x	x	x	x	x
2000-01-17	NA	1	x	x	x	x	x
2000-04-10	NA	1	x	x	x	x	x
2000-06-17	NA	1	x	x	x	x	x
2000-08-23	NA	3	x	x	x	x	x
43							
1993-07-22	NA	1	x	x	x		x
19							
1999-03-17	0	2	x	x	x		x

NA = depth information not available.

[1] Stations listed in order descending downstream.

Table 4. Summary statistics of major ions and total dissolved solids in water quality samples collected to support the characterization of baseline conditions in the Lockhart River (1969-2000).

Major Ion	Period of Record	n	Non-Detect Samples (%)	Mean	Standard Deviation	95% UCL	Minimum	Maximum	Percentile						
									5th	10th	25th	50th	75th	90th	95th
Lockhart River downstream of Snap Lake [1]															
Alkalinity (mg/L)	1993-1993	1	0	2.2	NA	NA	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Bicarbonate (mg CO_3/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Calcium (mg/L)	1993-1993	1	0	1.2	NA	NA	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Carbonate (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloride (mg/L)	1993-1993	1	0	0.99	NA	NA	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
Fluoride (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hardness (mg/L)	1993-1993	1	0	5	NA	NA	5	5	5	5	5	5	5	5	5
Magnesium (mg/L)	1993-1993	1	0	0.4	NA	NA	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Nitrate-N (mg/L)	1993-1993	1	100	0.004	NA	NA	<0.008	<0.008	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Potassium (mg/L)	1993-1993	1	0	0.5	NA	NA	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sodium (mg/L)	1993-1993	1	0	0.5	NA	NA	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sulphate (mg/L)	1993-1993	1	100	1.5	NA	NA	<3	<3	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Total Dissolved Solids (mg/L)	1993-1993	1	0	17	NA	NA	17	17	17	17	17	17	17	17	17
Upper Lockhart River [2]															
Alkalinity (mg/L)	1993-1999	17	0	5.42	3.4	7.17	2.4	17.8	2.48	3.4	4	4.6	5.7	6.34	8.68
Bicarbonate (mg CO_3/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Calcium (mg/L)	1993-1999	17	0	1.26	0.255	1.39	1.03	1.89	1.04	1.05	1.05	1.13	1.49	1.52	1.6
Carbonate (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloride (mg/L)	1993-1999	17	52.9	0.18	0.103	0.233	<0.2	0.39	0.1	0.1	0.1	0.1	0.2	0.328	0.374
Fluoride (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hardness (mg/L)	1993-1999	10	0	4.67	0.187	4.81	4.39	5	4.39	4.4	4.61	4.67	4.78	4.85	4.92
Magnesium (mg/L)	1993-1999	17	0	0.565	0.116	0.624	0.4	0.74	0.4	0.418	0.5	0.53	0.65	0.74	0.74
Nitrate-N (mg/L)	1993-1999	17	58.8	0.0104	0.0105	0.0157	<0.008	0.037	0.004	0.004	0.004	0.004	0.012	0.0246	0.0338
Potassium (mg/L)	1993-1999	17	0	0.492	0.085	0.536	0.4	0.63	0.416	0.42	0.43	0.44	0.56	0.63	0.63
Sodium (mg/L)	1993-1999	17	0	0.549	0.083	0.592	0.48	0.7	0.48	0.48	0.49	0.5	0.62	0.68	0.684
Sulphate (mg/L)	1993-1999	17	82.4	1.94	1.04	2.48	<3	5	1.5	1.5	1.5	1.5	1.5	3.4	4.2
Total Dissolved Solids (mg/L)	1993-1999	16	6.2	15.9	5.24	18.7	<10	26	8.75	10.5	12.8	15	19.2	21	22.2

Table 4. Summary statistics of major ions and total dissolved solids in water quality samples collected to support the characterization of baseline conditions in the Lockhart River (1969-2000).

Major Ion	Period of Record	n	Non-Detect Samples (%)	Mean	Standard Deviation	95% UCL	Minimum	Maximum	Percentile						
									5th	10th	25th	50th	75th	90th	95th
Central Lockhart River [3]															
Alkalinity (mg/L)	1993-1999	17	0	5.42	3.4	7.17	2.4	17.8	2.48	3.4	4	4.6	5.7	6.34	8.68
Bicarbonate (mg CO_3/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Calcium (mg/L)	1993-1999	17	0	1.26	0.255	1.39	1.03	1.89	1.04	1.05	1.05	1.13	1.49	1.52	1.6
Carbonate (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloride (mg/L)	1993-1999	17	52.9	0.18	0.103	0.233	<0.2	0.39	0.1	0.1	0.1	0.1	0.2	0.328	0.374
Fluoride (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hardness (mg/L)	1993-1999	10	0	4.67	0.187	4.81	4.39	5	4.39	4.4	4.61	4.67	4.78	4.85	4.92
Magnesium (mg/L)	1993-1999	17	0	0.565	0.116	0.624	0.4	0.74	0.4	0.418	0.5	0.53	0.65	0.74	0.74
Nitrate-N (mg/L)	1993-1999	17	58.8	0.0104	0.0105	0.0157	<0.008	0.037	0.004	0.004	0.004	0.004	0.012	0.0246	0.0338
Potassium (mg/L)	1993-1999	17	0	0.492	0.085	0.536	0.4	0.63	0.416	0.42	0.43	0.44	0.56	0.63	0.63
Sodium (mg/L)	1993-1999	17	0	0.549	0.083	0.592	0.48	0.7	0.48	0.48	0.49	0.5	0.62	0.68	0.684
Sulphate (mg/L)	1993-1999	17	82.4	1.94	1.04	2.48	<3	5	1.5	1.5	1.5	1.5	1.5	3.4	4.2
Total Dissolved Solids (mg/L)	1993-1999	16	6.2	15.9	5.24	18.7	<10	26	8.75	10.5	12.8	15	19.2	21	22.2
Lower Lockhart River [4]															
Alkalinity (mg/L)	1999-1999	7	0	3.94	0.127	4.06	3.7	4.1	3.76	3.82	3.9	4	4	4.04	4.07
Bicarbonate (mg CO_3/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Calcium (mg/L)	1999-1999	7	0	1.03	0.0291	1.06	1	1.07	1	1.01	1.01	1.02	1.04	1.07	1.07
Carbonate (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloride (mg/L)	1999-1999	7	57.1	0.186	0.121	0.298	<0.2	0.4	0.1	0.1	0.1	0.1	0.25	0.34	0.37
Fluoride (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hardness (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Magnesium (mg/L)	1999-1999	7	0	0.536	0.00535	0.541	0.53	0.54	0.53	0.53	0.53	0.54	0.54	0.54	0.54
Nitrate-N (mg/L)	1999-1999	7	0	0.0123	0.00309	0.0151	0.01	0.018	0.01	0.01	0.01	0.011	0.0135	0.0162	0.0171
Potassium (mg/L)	1999-1999	7	0	0.46	0.00816	0.468	0.45	0.47	0.45	0.45	0.455	0.46	0.465	0.47	0.47
Sodium (mg/L)	1999-1999	7	0	0.491	0.0069	0.498	0.48	0.5	0.483	0.486	0.49	0.49	0.495	0.5	0.5
Sulphate (mg/L)	1999-1999	7	85.7	2.57	2.83	5.19	<3	9	1.5	1.5	1.5	1.5	1.5	4.5	6.75
Total Dissolved Solids (mg/L)	1999-1999	7	0	24.4	6.19	30.2	18	34	18.3	18.6	20.5	23	27.5	32.8	33.4

Table 4. Summary statistics of major ions and total dissolved solids in water quality samples collected to support the characterization of baseline conditions in the Lockhart River (1969-2000).

Major Ion	Period of Record	n	Non-Detect Samples (%)	Mean	Standard Deviation	95% UCL	Minimum	Maximum	Percentile						
									5th	10th	25th	50th	75th	90th	95th
Lower Lockhart River in the vicinity of Old Lady of the Falls [5]															
Alkalinity (mg/L)	1969-2000	105	4.8	4.98	2.86	5.53	<0.1	30.5	3.08	3.8	4.2	4.6	5.3	6.06	6.46
Bicarbonate (mg CO_3/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Calcium (mg/L)	1969-2000	102	1	1.58	1.13	1.8	0.6	8.2	1	1.1	1.2	1.3	1.5	1.9	3.65
Carbonate (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloride (mg/L)	1969-2000	105	2.9	0.489	0.35	0.556	<0.1	3.6	0.2	0.3	0.4	0.43	0.5	0.7	0.794
Fluoride (mg/L)	1969-2000	97	24.7	0.0287	0.0117	0.0311	<0.01	<0.1	0.01	0.02	0.02	0.025	0.03	0.04	0.05
Hardness (mg/L)	1969-1993	20	0	9.22	7.94	12.9	2.2	34	4.67	4.89	5.3	5.95	9.68	13.9	28.6
Magnesium (mg/L)	1978-2000	84	0	0.663	0.36	0.741	0.4	3.8	0.5	0.537	0.58	0.6	0.662	0.761	0.8
Nitrate-N (mg/L)	1969-2000	101	17.8	0.0278	0.0985	0.0473	<0.001	1	0.004	0.005	0.01	0.016	0.023	0.037	0.045
Potassium (mg/L)	1969-2000	103	1	0.442	0.145	0.47	<0.1	1.5	0.3	0.37	0.4	0.41	0.475	0.508	0.58
Sodium (mg/L)	1969-2000	104	1	0.533	0.277	0.587	<0.1	3	0.4	0.4	0.46	0.5	0.55	0.6	0.717
Sulphate (mg/L)	1969-2000	103	10.7	1.53	1.09	1.74	<0.2	9	0.5	0.62	1.05	1.4	1.65	2	2.83
Total Dissolved Solids (mg/L)	1993-2000	34	17.6	17.3	10.3	20.9	<10	53	5	5	10.2	15.5	23.2	29.7	30.7

n = number of samples; ND = no data; UCL = upper confidence limit of the mean.

[1] Background conditions calculated using the water quality data from station 37.

[2] Background conditions calculated using the water quality data from stations 11, 23, 24, 26, and 3.

[3] Background conditions calculated using the water quality data from stations 11, 23, 24, 26, and 3 as no samples were collected in this area during background characterization.

[4] Background conditions calculated using the water quality data from station 52.

[5] Background conditions calculated using the water quality data from stations 19, 43, and OA1.

Table 5. Summary of water quality samples collected to support the characterization of baseline conditions of associated waterbodies in the Lockhart River watershed (1993-2001).

Waterbody / Station[1]	Sample Date	Depth (m)[2]	Number of Samples	Analytes Measured				
				Conventionals	Nutrients	Major Ions	Dissolved Metals	Total Metals
Associated Waterbodies - Snap Lake								
North Lake								
WQR10	1999-03-24	NA	2	x	x	x	x	x
WQR11	1999-03-24	NA	2	x	x	x	x	x
WQR12	1999-03-24	NA	2	x	x	x	x	x
North Shore Lakes								
NL1	1999-03-24	2.5	1	x	x	x	x	x
NL1	1999-08-12	Int	1	x	x	x	x	x
NL2	1999-03-24	2.2	1	x	x	x	x	x
NL2	1999-08-12	Int	1	x	x	x	x	x
NL3	1999-03-24	4	1	x	x	x	x	x
NL3	1999-08-12	Int	1	x	x	x	x	x
NL4	1999-08-12	Int	1	x	x	x	x	x
Downstream Lake								
WQ5	1999-03-24	2.3	2	x	x	x	x	x
WQ5	1999-08-12	Int	1	x	x	x	x	x
WQ5	2001-07-11	NA	1	x	x	x	x	x
Associated Waterbodies - Lockhart River								
MacKay Lake								
49	1993-07-20	NA	1	x	x	x		x
25	1993-07-20	NA	1	x	x	x		x
22	1999-03-11	2	1	x	x	x		x
22	1999-03-11	5	1	x	x	x		x
22	1999-03-11	9	1	x	x	x		x
Aylmer Lake								
7	1993-07-25	NA	1	x	x	x		x
4	1999-03-10	2	1	x	x	x		x
4	1999-03-10	5	1	x	x	x		x
4	1999-03-10	9	1	x	x	x		x
4	1999-08-06	2	3	x	x	x		x
18	1994-07-12	NA	1	x	x	x		x
5	1993-07-25	NA	1	x	x	x		x
6	1993-07-25	NA	1	x	x	x		x
Clinton Colder Lake								
53	1999-03-10	2	2	x	x	x		x
53	1999-03-10	5	1	x	x	x		x

[1] Stations listed in order descending downstream.

[2] Int = Integrated; samples were collected from multiple depths. NA = depth information not available.

Table 6. Summary statistics of major ions and total dissolved solids in water quality samples collected to support the characterization of baseline conditions of associated waterbodies in the Lockhart River watershed (1993-2001).

Waterbody / Major Ion	Lake Cover[1]	Period of Record	n	Non-Detect Samples (%)	Mean	Standard Deviation	95% UCL	Minimum	Maximum	Percentile						
										5th	10th	25th	50th	75th	90th	95th
Associated Waterbodies - Snap Lake																
North Lake																
Alkalinity (mg/L)	Ice	1999-1999	6	0	8.5	0.548	9.07	8	9	8	8	8	8.5	9	9	9
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	6	0	8.5	0.548	9.07	8	9	8	8	8	8.5	9	9	9
Bicarbonate (mg CO_3/L)	Ice	1999-1999	6	0	8.33	0.802	9.17	7.5	9.3	7.5	7.5	7.62	8.25	9.02	9.25	9.28
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	6	0	8.33	0.802	9.17	7.5	9.3	7.5	7.5	7.62	8.25	9.02	9.25	9.28
Calcium (mg/L)	Ice	1999-1999	6	0	2.24	0.257	2.51	1.96	2.54	1.97	1.98	2.03	2.19	2.47	2.54	2.54
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	6	0	2.24	0.257	2.51	1.96	2.54	1.97	1.98	2.03	2.19	2.47	2.54	2.54
Carbonate (mg/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloride (mg/L)	Ice	1999-1999	6	100	0.1	0	0.1	<0.2	<0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	6	100	0.1	0	0.1	<0.2	<0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Fluoride (mg/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hardness (mg/L)	Ice	1999-1999	6	0	9.83	0.983	10.9	9	11	9	9	9	9.5	10.8	11	11
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	6	0	9.83	0.983	10.9	9	11	9	9	9	9.5	10.8	11	11
Magnesium (mg/L)	Ice	1999-1999	6	0	0.997	0.101	1.1	0.88	1.15	0.885	0.89	0.918	1	1.05	1.1	1.12
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	6	0	0.997	0.101	1.1	0.88	1.15	0.885	0.89	0.918	1	1.05	1.1	1.12

Table 6. Summary statistics of major ions and total dissolved solids in water quality samples collected to support the characterization of baseline conditions of associated waterbodies in the Lockhart River watershed (1993-2001).

Waterbody / Major Ion	Lake Cover[1]	Period of Record	n	Non-Detect Samples (%)	Mean	Standard Deviation	95% UCL	Minimum	Maximum	Percentile 5th	10th	25th	50th	75th	90th	95th
North Lake (cont.)																
Nitrate-N (mg/L)	Ice	1999-1999	6	66.7	0.006	0.00335	0.00951	<0.008	0.012	0.004	0.004	0.004	0.004	0.007	0.01	0.011
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	6	66.7	0.006	0.00335	0.00951	<0.008	0.012	0.004	0.004	0.004	0.004	0.007	0.01	0.011
Potassium (mg/L)	Ice	1999-1999	6	0	0.812	0.0911	0.907	0.71	0.95	0.712	0.715	0.74	0.81	0.857	0.91	0.93
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	6	0	0.812	0.0911	0.907	0.71	0.95	0.712	0.715	0.74	0.81	0.857	0.91	0.93
Sodium (mg/L)	Ice	1999-1999	6	0	0.715	0.0766	0.795	0.63	0.83	0.633	0.635	0.655	0.71	0.758	0.8	0.815
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	6	0	0.715	0.0766	0.795	0.63	0.83	0.633	0.635	0.655	0.71	0.758	0.8	0.815
Sulphate (mg/L)	Ice	1999-1999	6	16.7	4.75	4.14	9.1	<3	13	1.88	2.25	3	3.5	4	8.5	10.8
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	6	16.7	4.75	4.14	9.1	<3	13	1.88	2.25	3	3.5	4	8.5	10.8
Total Dissolved Solids (mg/L)	Ice	1999-1999	6	0	16.8	3.25	20.2	13	22	13.5	14	15	16	18.5	20.5	21.2
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	6	0	16.8	3.25	20.2	13	22	13.5	14	15	16	18.5	20.5	21.2
North Shore Lakes																
Alkalinity (mg/L)	Ice	1999-1999	3	0	9.67	2.31	15.4	7	11	7.4	7.8	9	11	11	11	11
	Open	1999-1999	4	0	4.75	0.5	5.55	4	5	4.15	4.3	4.75	5	5	5	5
	Total	1999-1999	7	0	6.86	2.97	9.6	4	11	4.3	4.6	5	5	9	11	11
Bicarbonate (mg CO_3/L)	Ice	1999-1999	3	0	9.6	2.44	15.7	6.8	11.3	7.19	7.58	8.75	10.7	11	11.2	11.2
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	3	0	9.6	2.44	15.7	6.8	11.3	7.19	7.58	8.75	10.7	11	11.2	11.2
Calcium (mg/L)	Ice	1999-1999	3	0	2.7	1.08	5.39	1.5	3.6	1.65	1.8	2.25	3	3.3	3.48	3.54
	Open	1999-1999	4	0	1.32	0.386	1.94	1.1	1.9	1.1	1.1	1.1	1.15	1.38	1.69	1.79
	Total	1999-1999	7	0	1.91	1	2.84	1.1	3.6	1.1	1.1	1.15	1.5	2.45	3.24	3.42

Table 6. Summary statistics of major ions and total dissolved solids in water quality samples collected to support the characterization of baseline conditions of associated waterbodies in the Lockhart River watershed (1993-2001).

Waterbody / Major Ion	Lake Cover[1]	Period of Record	n	Non-Detect Samples (%)	Mean	Standard Deviation	95% UCL	Minimum	Maximum	Percentile						
										5th	10th	25th	50th	75th	90th	95th
North Shore Lakes (cont.)																
Carbonate (mg/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloride (mg/L)	Ice	1999-1999	3	66.7	0.133	0.0577	0.277	<0.2	<0.2	0.1	0.1	0.1	0.1	0.15	0.18	0.19
	Open	1999-1999	4	75	0.125	0.05	0.205	<0.2	0.2	0.1	0.1	0.1	0.1	0.125	0.17	0.185
	Total	1999-1999	7	71.4	0.129	0.0488	0.174	<0.2	<0.2	0.1	0.1	0.1	0.1	0.15	0.2	0.2
Fluoride (mg/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	1999-1999	4	0	0.085	0.03	0.133	0.04	0.1	0.049	0.058	0.085	0.1	0.1	0.1	0.1
	Total	1999-1999	4	0	0.085	0.03	0.133	0.04	0.1	0.049	0.058	0.085	0.1	0.1	0.1	0.1
Hardness (mg/L)	Ice	1999-1999	3	0	13.3	5.69	27.5	7	18	7.8	8.6	11	15	16.5	17.4	17.7
	Open	1999-1999	4	0	7	2.16	10.4	5	10	5.15	5.3	5.75	6.5	7.75	9.1	9.55
	Total	1999-1999	7	0	9.71	4.96	14.3	5	18	5.3	5.6	6.5	7	12.5	16.2	17.1
Magnesium (mg/L)	Ice	1999-1999	3	0	1.57	0.808	3.57	0.7	2.3	0.8	0.9	1.2	1.7	2	2.18	2.24
	Open	1999-1999	4	0	0.8	0.294	1.27	0.5	1.2	0.53	0.56	0.65	0.75	0.9	1.08	1.14
	Total	1999-1999	7	0	1.13	0.655	1.73	0.5	2.3	0.56	0.62	0.7	0.8	1.45	1.94	2.12
Nitrate-N (mg/L)	Ice	1999-1999	3	0	0.02	0.006	0.0349	0.014	0.026	0.0146	0.0152	0.017	0.02	0.023	0.0248	0.0254
	Open	1999-1999	4	100	0.004	0	0.004	<0.008	<0.008	0.004	0.004	0.004	0.004	0.004	0.004	0.004
	Total	1999-1999	7	57.1	0.011	0.00923	0.0194	<0.008	0.026	0.004	0.004	0.004	0.004	0.017	0.0224	0.0242
Potassium (mg/L)	Ice	1999-1999	3	0	0.9	0.458	2.04	0.4	1.3	0.46	0.52	0.7	1	1.15	1.24	1.27
	Open	1999-1999	4	0	0.5	0.216	0.844	0.3	0.8	0.315	0.33	0.375	0.45	0.575	0.71	0.755
	Total	1999-1999	7	0	0.671	0.373	1.02	0.3	1.3	0.33	0.36	0.4	0.5	0.9	1.12	1.21
Sodium (mg/L)	Ice	1999-1999	3	0	0.9	0.173	1.33	0.7	1	0.73	0.76	0.85	1	1	1	1
	Open	1999-1999	4	0	0.5	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Total	1999-1999	7	0	0.671	0.236	0.89	0.5	1	0.5	0.5	0.5	0.5	0.85	1	1

Table 6. Summary statistics of major ions and total dissolved solids in water quality samples collected to support the characterization of baseline conditions of associated waterbodies in the Lockhart River watershed (1993-2001).

Waterbody / Major Ion	Lake Cover[1]	Period of Record	n	Non-Detect Samples (%)	Mean	Standard Deviation	95% UCL	Minimum	Maximum	Percentile 5th	10th	25th	50th	75th	90th	95th
North Shore Lakes (cont.)																
Sulphate (mg/L)	Ice	1999-1999	3	0	5.33	2.52	11.6	3	8	3.2	3.4	4	5	6.5	7.4	7.7
	Open	1999-1999	4	0	3	0	3	3	3	3	3	3	3	3	3	3
	Total	1999-1999	7	0	4	1.91	5.77	3	8	3	3	3	3	4	6.2	7.1
Total Dissolved Solids (mg/L)	Ice	1999-1999	3	0	26.3	14.5	62.4	12	41	13.4	14.8	19	26	33.5	38	39.5
	Open	1999-1999	4	0	20.8	8.1	33.6	10	27	11.3	12.7	16.8	23	27	27	27
	Total	1999-1999	7	0	23.1	10.6	32.9	10	41	10.6	11.2	15.5	26	27	32.6	36.8
Downstream Lake																
Alkalinity (mg/L)	Ice	1999-1999	2	0	6.1	0.141	7.37	6	6.2	6.01	6.02	6.05	6.1	6.15	6.18	6.19
	Open	1999-2001	2	0	5	1.41	17.7	4	6	4.1	4.2	4.5	5	5.5	5.8	5.9
	Total	1999-2001	4	0	5.55	1.04	7.2	4	6.2	4.3	4.6	5.5	6	6.05	6.14	6.17
Bicarbonate (mg CO_3/L)	Ice	1999-1999	2	0	6.25	0.0707	6.89	6.2	6.3	6.2	6.21	6.22	6.25	6.28	6.29	6.3
	Open	2001-2001	1	0	7	NA	NA	7	7	7	7	7	7	7	7	7
	Total	1999-2001	3	0	6.5	0.436	7.58	6.2	7	6.21	6.22	6.25	6.3	6.65	6.86	6.93
Calcium (mg/L)	Ice	1999-1999	2	0	1.6	0	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
	Open	1999-2001	2	0	1.36	0.0849	2.12	1.3	1.42	1.31	1.31	1.33	1.36	1.39	1.41	1.41
	Total	1999-2001	4	0	1.48	0.147	1.71	1.3	1.6	1.32	1.34	1.39	1.51	1.6	1.6	1.6
Carbonate (mg/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloride (mg/L)	Ice	1999-1999	2	0	0.2	0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Open	1999-2001	2	50	0.65	0.212	2.56	0.8	<1	0.515	0.53	0.575	0.65	0.725	0.77	0.785
	Total	1999-2001	4	25	0.425	0.287	0.882	0.2	<1	0.2	0.2	0.2	0.35	0.575	0.71	0.755
Fluoride (mg/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	1999-2001	2	0	0.055	0.00707	0.119	0.05	0.06	0.0505	0.051	0.053	0.055	0.058	0.059	0.0595
	Total	1999-2001	2	0	0.055	0.00707	0.119	0.05	0.06	0.0505	0.051	0.053	0.055	0.058	0.059	0.0595

Table 6. Summary statistics of major ions and total dissolved solids in water quality samples collected to support the characterization of baseline conditions of associated waterbodies in the Lockhart River watershed (1993-2001).

Waterbody / Major Ion	Lake Cover[1]	Period of Record	n	Non-Detect Samples (%)	Mean	Standard Deviation	95% UCL	Minimum	Maximum	Percentile						
										5th	10th	25th	50th	75th	90th	95th
Downstream Lake (cont.)																
Hardness (mg/L)	Ice	1999-1999	2	0	7	0	7	7	7	7	7	7	7	7	7	7
	Open	1999-2001	2	0	5.5	0.707	11.9	5	6	5.05	5.1	5.25	5.5	5.75	5.9	5.95
	Total	1999-2001	4	0	6.25	0.957	7.77	5	7	5.15	5.3	5.75	6.5	7	7	7
Magnesium (mg/L)	Ice	1999-1999	2	0	0.72	0.0141	0.847	0.71	0.73	0.711	0.712	0.715	0.72	0.725	0.728	0.729
	Open	1999-2001	2	0	0.5	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Total	1999-2001	4	0	0.61	0.127	0.813	0.5	0.73	0.5	0.5	0.5	0.605	0.715	0.724	0.727
Nitrate-N (mg/L)	Ice	1999-1999	2	0	0.025	0.0141	0.152	0.015	0.035	0.016	0.017	0.02	0.025	0.03	0.033	0.034
	Open	1999-2001	2	50	0.035	0.0431	0.422	<0.008	0.065	0.0071	0.0101	0.019	0.035	0.05	0.0589	0.062
	Total	1999-2001	4	25	0.03	0.0268	0.0724	<0.008	0.065	0.0057	0.0073	0.012	0.025	0.043	0.056	0.0605
Potassium (mg/L)	Ice	1999-1999	2	0	0.535	0.00707	0.599	0.53	0.54	0.53	0.531	0.532	0.535	0.538	0.539	0.54
	Open	1999-2001	2	0	0.335	0.0495	0.78	0.3	0.37	0.304	0.307	0.318	0.335	0.352	0.363	0.366
	Total	1999-2001	4	0	0.435	0.119	0.624	0.3	0.54	0.31	0.321	0.352	0.45	0.532	0.537	0.539
Sodium (mg/L)	Ice	1999-1999	2	0	0.67	0	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
	Open	1999-2001	2	0	0.73	0.24	2.89	0.56	0.9	0.577	0.594	0.645	0.73	0.815	0.866	0.883
	Total	1999-2001	4	0	0.7	0.143	0.928	0.56	0.9	0.576	0.593	0.643	0.67	0.728	0.831	0.865
Sulphate (mg/L)	Ice	1999-1999	2	100	1.5	0	1.5	<3	<3	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Open	1999-2001	2	50	1.43	0.099	2.32	1.36	<3	1.37	1.37	1.4	1.43	1.46	1.49	1.49
	Total	1999-2001	4	75	1.46	0.07	1.58	1.36	<3	1.38	1.4	1.46	1.5	1.5	1.5	1.5
Total Dissolved Solids (mg/L)	Ice	1999-1999	2	0	15	0	15	15	15	15	15	15	15	15	15	15
	Open	1999-2001	2	0	16	5.66	66.8	12	20	12.4	12.8	14	16	18	19.2	19.6
	Total	1999-2001	4	0	15.5	3.32	20.8	12	20	12.4	12.9	14.2	15	16.2	18.5	19.2

Table 6. Summary statistics of major ions and total dissolved solids in water quality samples collected to support the characterization of baseline conditions of associated waterbodies in the Lockhart River watershed (1993-2001).

Waterbody / Major Ion	Lake Cover[1]	Period of Record	n	Non-Detect Samples (%)	Mean	Standard Deviation	95% UCL	Minimum	Maximum	Percentile 5th	10th	25th	50th	75th	90th	95th
Associated Waterbodies - Lockhart River																
MacKay Lake																
Alkalinity (mg/L)	Ice	1999-1999	3	0	4.73	0.153	5.11	4.6	4.9	4.61	4.62	4.65	4.7	4.8	4.86	4.88
	Open	1993-1993	2	0	3.15	0.354	6.33	2.9	3.4	2.92	2.95	3.02	3.15	3.28	3.35	3.38
	Total	1993-1999	5	0	4.1	0.892	5.21	2.9	4.9	3	3.1	3.4	4.6	4.7	4.82	4.86
Bicarbonate (mg CO_3/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Calcium (mg/L)	Ice	1999-1999	3	0	1.2	0.0351	1.28	1.16	1.23	1.16	1.17	1.18	1.2	1.21	1.22	1.23
	Open	1993-1993	2	0	1.2	0.141	2.47	1.1	1.3	1.11	1.12	1.15	1.2	1.25	1.28	1.29
	Total	1993-1999	5	0	1.2	0.075	1.29	1.1	1.3	1.11	1.12	1.16	1.2	1.23	1.27	1.29
Carbonate (mg/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloride (mg/L)	Ice	1999-1999	3	66.7	0.233	0.231	0.807	<0.2	0.5	0.1	0.1	0.1	0.1	0.3	0.42	0.46
	Open	1993-1993	2	0	0.735	0.0212	0.926	0.72	0.75	0.722	0.723	0.728	0.735	0.742	0.747	0.748
	Total	1993-1999	5	40	0.434	0.32	0.831	<0.2	0.75	0.1	0.1	0.1	0.5	0.72	0.738	0.744
Fluoride (mg/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hardness (mg/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	1993-1993	2	0	5.5	0.707	11.9	5	6	5.05	5.1	5.25	5.5	5.75	5.9	5.95
	Total	1993-1993	2	0	5.5	0.707	11.9	5	6	5.05	5.1	5.25	5.5	5.75	5.9	5.95
Magnesium (mg/L)	Ice	1999-1999	3	0	0.52	0.02	0.57	0.5	0.54	0.502	0.504	0.51	0.52	0.53	0.536	0.538
	Open	1993-1993	2	0	0.55	0.0707	1.19	0.5	0.6	0.505	0.51	0.525	0.55	0.575	0.59	0.595
	Total	1993-1999	5	0	0.532	0.0415	0.583	0.5	0.6	0.5	0.5	0.5	0.52	0.54	0.576	0.588

Table 6. Summary statistics of major ions and total dissolved solids in water quality samples collected to support the characterization of baseline conditions of associated waterbodies in the Lockhart River watershed (1993-2001).

Waterbody / Major Ion	Lake Cover[1]	Period of Record	n	Non-Detect Samples (%)	Mean	Standard Deviation	95% UCL	Minimum	Maximum	Percentile 5th	10th	25th	50th	75th	90th	95th
MacKay Lake (cont.)																
Nitrate-N (mg/L)	Ice	1999-1999	3	0	0.009	0.000577	0.0108	0.009	0.01	0.009	0.009	0.009	0.009	0.01	0.0098	0.0099
	Open	1993-1993	2	100	0.004	0	0.004	<0.008	<0.008	0.004	0.004	0.004	0.004	0.004	0.004	0.004
	Total	1993-1999	5	40	0.007	0.00295	0.0109	<0.008	0.01	0.004	0.004	0.004	0.009	0.009	0.0096	0.0098
Potassium (mg/L)	Ice	1999-1999	3	0	0.443	0.0115	0.472	0.43	0.45	0.432	0.434	0.44	0.45	0.45	0.45	0.45
	Open	1993-1993	2	0	0.5	0.141	1.77	0.4	0.6	0.41	0.42	0.45	0.5	0.55	0.58	0.59
	Total	1993-1999	5	0	0.466	0.0777	0.562	0.4	0.6	0.406	0.412	0.43	0.45	0.45	0.54	0.57
Sodium (mg/L)	Ice	1999-1999	3	0	0.553	0.0153	0.591	0.54	0.57	0.541	0.542	0.545	0.55	0.56	0.566	0.568
	Open	1993-1993	2	0	0.3	0	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Total	1993-1999	5	0	0.452	0.139	0.625	0.3	0.57	0.3	0.3	0.3	0.54	0.55	0.562	0.566
Sulphate (mg/L)	Ice	1999-1999	3	33.3	3.5	1.8	7.98	<3	5	1.75	2	2.75	4	4.5	4.8	4.9
	Open	1993-1993	2	100	1.5	0	1.5	<3	<3	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Total	1993-1999	5	60	2.7	1.68	4.79	<3	5	1.5	1.5	1.5	1.5	4	4.6	4.8
Total Dissolved Solids (mg/L)	Ice	1999-1999	3	0	20.3	4.04	30.4	16	24	16.5	17	18.5	21	22.5	23.4	23.7
	Open	1993-1993	2	0	16.5	0.707	22.9	16	17	16	16.1	16.2	16.5	16.8	16.9	17
	Total	1993-1999	5	0	18.8	3.56	23.2	16	24	16	16	16	17	21	22.8	23.4
Aylmer Lake																
Alkalinity (mg/L)	Ice	1999-1999	3	0	4.3	0.2	4.8	4.1	4.5	4.12	4.14	4.2	4.3	4.4	4.46	4.48
	Open	1993-1999	7	0	3.61	3.15	6.53	0.4	10.2	0.82	1.24	1.9	3.5	3.7	6.3	8.25
	Total	1993-1999	10	0	3.82	2.6	5.68	0.4	10.2	1.03	1.66	2.38	3.7	4.25	5.07	7.63
Bicarbonate (mg CO_3/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Calcium (mg/L)	Ice	1999-1999	3	0	1.06	0.0702	1.24	0.99	1.13	0.998	1.01	1.03	1.07	1.1	1.12	1.12
	Open	1993-1999	7	0	0.809	0.143	0.941	0.5	0.92	0.59	0.68	0.8	0.87	0.885	0.902	0.911
	Total	1993-1999	10	0	0.885	0.173	1.01	0.5	1.13	0.635	0.77	0.818	0.885	0.972	1.08	1.1

Table 6. Summary statistics of major ions and total dissolved solids in water quality samples collected to support the characterization of baseline conditions of associated waterbodies in the Lockhart River watershed (1993-2001).

Waterbody / Major Ion	Lake Cover[1]	Period of Record	n	Non-Detect Samples (%)	Mean	Standard Deviation	95% UCL	Minimum	Maximum	Percentile						
										5th	10th	25th	50th	75th	90th	95th
Aylmer Lake (cont.)																
Carbonate (mg/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloride (mg/L)	Ice	1999-1999	3	100	0.1	0	0.1	<0.2	<0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Open	1993-1999	7	42.9	0.291	0.199	0.476	<0.2	0.62	0.1	0.1	0.1	0.37	0.375	0.476	0.548
	Total	1993-1999	10	60	0.234	0.187	0.368	<0.2	0.62	0.1	0.1	0.1	0.1	0.37	0.404	0.512
Fluoride (mg/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hardness (mg/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	1993-1999	7	0	3.86	0.546	4.37	2.9	4.44	3.11	3.32	3.6	3.9	4.3	4.36	4.4
	Total	1993-1999	7	0	3.86	0.546	4.37	2.9	4.44	3.11	3.32	3.6	3.9	4.3	4.36	4.4
Magnesium (mg/L)	Ice	1999-1999	3	0	0.577	0.0306	0.653	0.55	0.61	0.552	0.554	0.56	0.57	0.59	0.602	0.606
	Open	1993-1999	7	0	0.45	0.0624	0.508	0.4	0.52	0.4	0.4	0.4	0.4	0.515	0.52	0.52
	Total	1993-1999	10	0	0.488	0.0809	0.546	0.4	0.61	0.4	0.4	0.4	0.515	0.542	0.574	0.592
Nitrate-N (mg/L)	Ice	1999-1999	3	0	0.015	0.00306	0.0223	0.012	0.018	0.0122	0.0124	0.013	0.014	0.016	0.0172	0.0176
	Open	1993-1999	7	85.7	0.01	0.0151	0.0237	<0.008	0.044	0.004	0.004	0.004	0.004	0.004	0.02	0.032
	Total	1993-1999	10	60	0.011	0.0127	0.0203	<0.008	0.044	0.004	0.004	0.004	0.004	0.014	0.0206	0.0323
Potassium (mg/L)	Ice	1999-1999	3	0	0.51	0.03	0.585	0.48	0.54	0.483	0.486	0.495	0.51	0.525	0.534	0.537
	Open	1993-1999	7	0	0.419	0.0234	0.44	0.4	0.45	0.4	0.4	0.4	0.4	0.44	0.444	0.447
	Total	1993-1999	10	0	0.446	0.0502	0.482	0.4	0.54	0.4	0.4	0.4	0.44	0.472	0.513	0.526
Sodium (mg/L)	Ice	1999-1999	3	0	0.55	0.0346	0.636	0.51	0.57	0.516	0.522	0.54	0.57	0.57	0.57	0.57
	Open	1993-1999	7	0	0.407	0.0652	0.467	0.3	0.47	0.315	0.33	0.375	0.4	0.465	0.47	0.47
	Total	1993-1999	10	0	0.45	0.0887	0.513	0.3	0.57	0.322	0.345	0.4	0.465	0.5	0.57	0.57

Table 6. Summary statistics of major ions and total dissolved solids in water quality samples collected to support the characterization of baseline conditions of associated waterbodies in the Lockhart River watershed (1993-2001).

Waterbody / Major Ion	Lake Cover[1]	Period of Record	n	Non-Detect Samples (%)	Mean	Standard Deviation	95% UCL	Minimum	Maximum	Percentile 5th	10th	25th	50th	75th	90th	95th
Aylmer Lake (cont.)																
Sulphate (mg/L)	Ice	1999-1999	3	66.7	4.67	5.48	18.3	<3	11	1.5	1.5	1.5	1.5	6.25	9.1	10
	Open	1993-1999	7	100	1.5	0	1.5	<3	<3	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Total	1993-1999	10	90	2.45	3	4.6	<3	11	1.5	1.5	1.5	1.5	1.5	2.45	6.72
Total Dissolved Solids (mg/L)	Ice	1999-1999	3	0	26	7.81	45.4	17	31	18.3	19.6	23.5	30	30.5	30.8	30.9
	Open	1993-1999	7	14.3	14.7	6.92	21.1	<10	26	6.5	8	10.5	14	18.5	21.8	23.9
	Total	1993-1999	10	10	18.1	8.67	24.3	<10	31	7.25	9.5	11.8	17.5	24.2	30.1	30.6
Clinton Colder Lake																
Alkalinity (mg/L)	Ice	1999-1999	3	0	4.27	0.0577	4.41	4.2	4.3	4.21	4.22	4.25	4.3	4.3	4.3	4.3
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	3	0	4.27	0.0577	4.41	4.2	4.3	4.21	4.22	4.25	4.3	4.3	4.3	4.3
Bicarbonate (mg CO_3/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Calcium (mg/L)	Ice	1999-1999	3	0	1.07	0.0379	1.17	1.03	1.1	1.04	1.04	1.06	1.09	1.1	1.1	1.1
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	3	0	1.07	0.0379	1.17	1.03	1.1	1.04	1.04	1.06	1.09	1.1	1.1	1.1
Carbonate (mg/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloride (mg/L)	Ice	1999-1999	3	33.3	0.2	0.1	0.448	<0.2	0.3	0.11	0.12	0.15	0.2	0.25	0.28	0.29
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	3	33.3	0.2	0.1	0.448	<0.2	0.3	0.11	0.12	0.15	0.2	0.25	0.28	0.29
Fluoride (mg/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 6. Summary statistics of major ions and total dissolved solids in water quality samples collected to support the characterization of baseline conditions of associated waterbodies in the Lockhart River watershed (1993-2001).

Waterbody / Major Ion	Lake Cover[1]	Period of Record	n	Non-Detect Samples (%)	Mean	Standard Deviation	95% UCL	Minimum	Maximum	Percentile						
										5th	10th	25th	50th	75th	90th	95th
Clinton Colder Lake (cont.)																
Hardness (mg/L)	Ice	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Magnesium (mg/L)	Ice	1999-1999	3	0	0.577	0.0153	0.615	0.56	0.59	0.562	0.564	0.57	0.58	0.585	0.588	0.589
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	3	0	0.577	0.0153	0.615	0.56	0.59	0.562	0.564	0.57	0.58	0.585	0.588	0.589
Nitrate-N (mg/L)	Ice	1999-1999	3	0	0.017	0.00321	0.0253	0.015	0.021	0.0151	0.0152	0.016	0.016	0.019	0.02	0.0205
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	3	0	0.017	0.00321	0.0253	0.015	0.021	0.0151	0.0152	0.016	0.016	0.019	0.02	0.0205
Potassium (mg/L)	Ice	1999-1999	3	0	0.513	0.0115	0.542	0.5	0.52	0.502	0.504	0.51	0.52	0.52	0.52	0.52
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	3	0	0.513	0.0115	0.542	0.5	0.52	0.502	0.504	0.51	0.52	0.52	0.52	0.52
Sodium (mg/L)	Ice	1999-1999	3	0	0.627	0.159	1.02	0.52	0.81	0.523	0.526	0.535	0.55	0.68	0.758	0.784
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	3	0	0.627	0.159	1.02	0.52	0.81	0.523	0.526	0.535	0.55	0.68	0.758	0.784
Sulphate (mg/L)	Ice	1999-1999	3	100	1.5	0	1.5	<3	<3	1.5	1.5	1.5	1.5	1.5	1.5	1.5
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	3	100	1.5	0	1.5	<3	<3	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Total Dissolved Solids (mg/L)	Ice	1999-1999	3	0	35	6.08	50.1	31	42	31.1	31.2	31.5	32	37	40	41
	Open	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total	1999-1999	3	0	35	6.08	50.1	31	42	31.1	31.2	31.5	32	37	40	41

n = number of samples; NA = not applicable; ND = no data; UCL = upper confidence limit of the mean.

[1] Ice: November to April; Open: May to October.

Table 7. Classification of waterbodies in the Lockhart River watershed.

Area of Interest	Description	Classification
Snap Lake	Snap Lake and hydrologically connected waterbodies.	Under current conditions, water quality conditions are being affected by permitted discharges of effluent from the Snap lake mine. Other uses are limited in Snap Lake and hydrologically connected waterbodies, in part due to the presence of the mine on the lake. Accordingly, these waters should be classified as having normal sensitivity to releases of contaminants from anthropogenic sources.
Lockhart River downstream of Snap Lake	Lockhart River from the outlet of Snap Lake to MacKay Lake.	The portion of the Lockhart River between the outlet of Snap Lake and MacKay Lake provides high quality habitat for aquatic life and aquatic-dependent wildlife. In addition, this portion of the Lockhart River is capable of supporting a variety of other beneficial water uses (i.e., drinking water, recreation and aesthetics, etc.). However, due to the hydrological connectivity and proximity to Snap Lake, water quality conditions within this portion of the Lockhart River have been altered. To prevent further alteration of water quality conditions and to protect beneficial water uses in downstream areas, this portion of the Lockhart River should be afforded enhanced use-protection.
Upper Lockhart River	Lockhart River from MacKay Lake to the inlet of Aylmer Lake.	This portion of the Lockhart River from MacKay Lake to the inlet of Aylmer Lake provides high quality habitat for aquatic life and aquatic-dependent wildlife. In addition, this portion of the Lockhart River is capable of supporting a variety of other beneficial water uses (i.e., drinking water, recreation and aesthetics, etc.). This reach of the Lockhart River is used extensively by Aboriginal peoples practicing traditional lifestyles, emphasizing the cultural importance of this area. In addition, downstream waters (i.e., in the vicinity of Old Lady of the Falls) have been identified having special cultural and spiritual significance to Aboriginal peoples. Therefore, water quality conditions in this portion of the Lockhart River should not change from background conditions.
Central Lockhart River	Lockhart River from Aylmer Lake to the boundary of the Lower Lockhart River Work Unit).	This portion of the Lockhart River from Aylmer Lake to the boundary of the Lower Lockhart River Work Unit provides high quality habitat for aquatic life and aquatic-dependent wildlife. In addition, this portion of the Lockhart River is capable of supporting a variety of other beneficial water uses (i.e., drinking water, recreation and aesthetics, etc.). This reach of the Lockhart River is used extensively by Aboriginal peoples practicing traditional lifestyles, emphasizing the cultural importance of this area. In addition, downstream waters (i.e., in the vicinity of Old Lady of the Falls) have been identified having special cultural and spiritual significance to Aboriginal peoples. Therefore, water quality conditions in this portion of the Lockhart River should not change from background conditions.

Table 7. Classification of waterbodies in the Lockhart River watershed.

Area of Interest	Description	Classification
Lower Lockhart River	Lockhart River from the boundary of the Central Lockhart River Work Unit to Artillery Lake (and including Artillery Lake).	This portion of the Lockhart River from the boundary of the Central Lockhart River Work Unit to Artillery Lake and Artillery Lake provides high quality habitat for aquatic life and aquatic-dependent wildlife. In addition, this portion of the Lockhart River is capable of supporting a variety of other beneficial water uses (i.e., drinking water, recreation and aesthetics, etc.). This reach of the Lockhart River is used extensively by Aboriginal peoples practicing traditional lifestyles, emphasizing the cultural importance of this area. In addition, downstream waters (i.e., in the vicinity of Old Lady of the Falls) have been identified having special cultural and spiritual significance to Aboriginal peoples. Therefore, water quality conditions in this portion of the Lockhart River should not change from background conditions.
Lower Lockhart River in the vicinity of Old Lady of the Falls	Lower Lockhart River from the outlet of Artillery Lake to Great Slave Lake.	The Old Lady of the Falls (Tsanku Theda) and the Lockhart River (Desnethche) have been identified as the fundamental core of the Lutsel K'e Denesoline cultural identity (Nitah 2009). As one of the most culturally and spiritually important water bodies in the NWT, existing water quality conditions must be maintained at all times to protect these water of special significance.

Table 8. Summary of water quality guidelines for different designated uses from various jurisdictions.

Substance / Jurisdiction	Designated Use												
	Freshwater Aquatic Life		Drinking Water		Irrigation		Livestock		Wildlife		Industrial		Recreation and Aesthetics (Maximum)
	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	
Calcium (mg/L)													
CCME [1]/ Health Canada [2]	NG	NG	NG	NG	NG	NG	1000	NG	NG	NG	NG	NG	NG
BCMOE [3]	Variable [4]	NG	NG	NG	NG	NG	1000 [5]	NG	NG	NG	NG	NG	NG
USEPA [6]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Pennsylvania [7]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Alaska [8]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Chloride (mg Cl^-/L)													
CCME [1]/ Health Canada [2]	640	120	250 [9]	NG	100 - 900 [10]	NG	NG	NG	NG	NG	NG	NG	NG
BCMOE [3]	600	150	250	NG	100	NG	600	NG	600	NG	NG	NG	NG
USEPA [6]	860	230	250 [11]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Pennsylvania [7]	NG	NG	250	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Alaska [8]	860 [12]	230 [12]	250	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Fluoride (mg total F^-/L)													
CCME [1]/ Health Canada [2]	0.12 [13]	NG	1.5	NG	1	NG	1 - 2 [14]	NG	NG	NG	NG	NG	NG
BCMOE [3]	0.4 [15]	NG	1.5	1.0	2.0	1.0	1.5 - 4 [16]	1.0 - 2 [16]	1.5	1.0	1.5	1.0	NG
USEPA [6]	NG	NG	4 [17]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Pennsylvania [7]	NG	NG	NG	2	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Alaska [8]	NG	NG	4	NG	1	NG	NG	NG	NG	NG	NG	NG	NG

Table 8. Summary of water quality guidelines for different designated uses from various jurisdictions.

Substance / Jurisdiction	Designated Use												
	Freshwater Aquatic Life		Drinking Water		Irrigation		Livestock		Wildlife		Industrial		Recreation and Aesthetics (Maximum)
	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	
Nitrate (mg N/L)													
CCME [1]/ Health Canada [2]	124	2.93	10	NG	NG	NG	100 [18]	NG	NG	NG	NG	NG	NG
BCMOE [3]	32.8	3.0	10 [18]	NG	NG	NG	100	NG	100	NG	NG	NG	10
USEPA [6]	NG	NG	10	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Pennsylvania [7]	NG	NG	10 [18]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Alaska [8]	NG	NG	10	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Potassium (mg KCl/L)													
CCME [1]/ Health Canada [2]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
BCMOE [3]	373 - 432 [19]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
USEPA [6]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Pennsylvania [7]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Alaska [8]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Sodium (mg/L)													
CCME [1]/ Health Canada [2]	NG	NG	200 [9]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
BCMOE [3]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
USEPA [6]	NG	NG	20 - 60 [20]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Pennsylvania [7]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Alaska [8]	NG	NG	NG	NG	60% of TDS [21]	NG	60% of TDS [21]	NG	NG	NG	NG	NG	NG

Table 8. Summary of water quality guidelines for different designated uses from various jurisdictions.

Substance / Jurisdiction	Freshwater Aquatic Life		Drinking Water		Irrigation		Livestock		Wildlife		Industrial		Recreation and Aesthetics (Maximum)
	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	
Sulphate (mg/L)													
CCME [1]/ Health Canada [2]	NG	NG	500 [9]	NG	NG	NG	1000	NG	NG	NG	NG	NG	NG
BCMOE [3]	NG	128 [22]	500	NG	NG	NG	1000	NG	NG	NG	175 - 2700 [23]	NG	NG
USEPA [6]	NG	NG	250 [11]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Pennsylvania [7]	NG	NG	250	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Alaska [8]	NG	NG	250	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Total dissolved solids (mg/L)													
CCME [1]/ Health Canada [2]	NG	NG	500 [9]	NG	500 - 3500 [10]	NG	3000	NG	NG	NG	NG	NG	NG
BCMOE [3]	NG	NG	NG	NG	500 - 3500 [24]	NG	1000/ 3000 [25]	NG	NG	NG	0.5 - 35000 [26]	NG	NG
USEPA [6]	NG	NG	500 [11]	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Pennsylvania [7]	NG	NG	750	500	NG	NG	NG	NG	NG	NG	NG	NG	NG
State of Alaska [8]	1000 [27]	NG	500	NG	1000	NG	1000	NG	NG	NG	NG	NG	NG

Ave = average; BCMOE = British Columbia Ministry of Environment; CCME = Canadian Council of Ministers of the Environment; Max = maximum; NG = no guideline; TDS = total dissolved solids; USEPA = United States Environmental Protection Agency.

[1] CCME (2014), for all designated uses except drinking water.

[2] Health Canada (2014), for drinking water guidelines.

[3] BCMOE (2014) and Nagpal et al. (2006) for Approved WQGs and Working WQGs, respectively.

[4] Working WQG. Minimum value based on sensitivity to acid inputs. Up to 4 mg/L = highly sensitive to acid inputs; 4 to 8 mg/L = moderately sensitive; over 8 mg/L = low sensitivity; refer to alkalinity; the more restrictive of the calcium or alkalinity working WQG applies.

[5] Working WQG. Maximum is less if high levels of other major ions are present.

[6] USEPA (2014) and USEPA (2012) for freshwater aquatic life criteria and drinking water standards, respectively.

[7] Pennsylvania (2014).

[8] ADEC (2008) and ADEC (2012).

Footnotes continued on next page…

Table 8. Summary of water quality guidelines for different designated uses from various jurisdictions.

Substance / Jurisdiction	Designated Use												
	Freshwater Aquatic Life		Drinking Water		Irrigation		Livestock		Wildlife		Industrial		Recreation and Aesthetics (Maximum)
	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	

[9] Based on taste and other physical considerations.

[10] The WQG varies according to the type of plant being irrigated.

[11] Secondary Drinking Water Regulation (non-enforceable guideline regulating contaminants that may cause cosmetic effects or aesthetic effects).

[12] Applies to dissolved chloride when associated with sodium. This criterion may not be adequately protective when the chloride is associated with potassium, calcium, or magnesium.

[13] Interim guideline.

[14] WQG is 1 mg/L when the feed of the animals contains fluoride and 2 mg/L when the feed does not contain fluoride.

[15] If the hardness is 10 mg/L $CaCO_3$ or less then 0.4 mg/L is the maximum value, otherwise use the equation: LC_{50} fluoride = [-51.73 + 92.57 * $\log_{10}$(Hardness)] * 0.01. The lower confidence limit of the mean for hardness in the Lockhart River is 5.25 mg/L.

[16] The WQG varies depending on the type of livestock. Dairy cows, breeding stock (long-lived animals) have the lowest WQG .

[17] This is the Maximum Contaminant Level. The Secondary Drinking Water Regulation for fluoride is 2 mg/L.

[18] Applies to nitrate + nitrite (as Nitrogen).

[19] Working WQG. Based on the threshold for *Daphnia magna* immobilization.

[20] Drinking Water Advisory (non-regulatory concentration of a contaminant in water that is likely to be without adverse effects on health and aesthetics) taste threshold (concentration at which the majority of consumers do not notice an adverse taste in drinking water) is 30 - 60 mg/L. The health-based value is 20 mg/L, for individuals on a 500 mg/day restricted sodium diet.

[21] Sodium percentage (amount of sodium compared to the total of sodium, calcium, magnesium, and potassium on a molar basis) must be less than 60%.

[22] Very soft water (0 - 30 mg/L $CaCO_3$) = 128 mg/L; Soft to moderately soft water (31 - 75 mg/L $CaCO_3$) = 218 mg/L; Moderately soft/hard to hard water (76 - 180 mg/L CaCO3) = 309 mg/L; Very hard water (181 - 250 mg/L CaCO3) = 429 mg/L; For > 250 mg/L CaCO3, need to determine based on site water. The lower confidence limit of the mean for hardness in the Lockhart River is 5.25 mg/L.

[23] Working WQG. Value is process dependent, ranging from 175 mg/L for iron and steel to 2700 mg/L for cooling.

[24] Working WQG. Ranges from 500 to 3500 mg/L, crop and soil dependent.

[25] Working WQG. 1000 mg/L is the maximum for sensitive species and 3000 mg/L is the maximum for other species.

[26] Working WQG. Value is process dependent, ranging from 0.5 mg/L for boilers to 35000 mg/L for cooling.

[27] Water quality standard. A concentration of TDS may not be present in water if that concentration causes or reasonably could be expected to cause an adverse effect to aquatic life.

Table 9. Water Quality Objectives proposed by De Beers for Snap Lake (De Beers 2013).

Parameter	Chronic Effects Benchmark
Total Dissolved Solids	684 mg/L
Chloride (hardness-based)	
Equation	116.6 (ln[hardness]) - 204.1
Hardness = 10 mg/L $CaCO_3$	64.4
Hardness = 50 mg/L $CaCO_3$	252
Hardness = 100 mg/L $CaCO_3$	333
Hardness = 150 mg/L $CaCO_3$	380

Table 10. Summary of the results of toxicity tests conducted to support the development of the proposed chronic SSWQO for chloride for Ekati Mine[1].

Receptor Group / Species	Common Name	Test Duration	Toxicity Test Endpoint	Effect Level	Effect Concentration (mg/L Cl^-)	Reference
Algae and Plants						
Chlamydomonas reinhardtii	Alga	6-d	Growth	EC ~50	3,014	Reynoso *et al.* 1982
Chlorella emersonii	Alga	8-14-d	Growth	MATC	7,000	Setter *et al.* 1982
Lemna minor	Duckweed	96-h	Growth	MATC	1,172	Taraldsen and Norberg-King 1990
Nitzschia linearis	Diatom	5-d	Growth	EC50	1,482	Patrick *et al.* 1968
Fish - Non-salmonid						
Pimephales promelas	Fathead minnow	33-d	Survival	LC10	598	Birge *et al.* 1985 / Elphick *et al.* 2011 [2]
Pimephales promelas	Fathead minnow	32-d	Biomass	IC25	704	Elphick *et al.* 2011
Fish - Salmonid						
Oncorhynchus mykiss	Rainbow trout	56-d	Biomass	IC25	1,174	Elphick *et al.* 2011
Invertebrate - Amphipod						
Hyalella azteca	Amphipod	28-d	Growth	IC25	1,705	Elphick *et al.* 2011
Invertebrate - Aquatic Insect						
Chironomus dilutus	Chironomid	20-d	Growth	IC25	2,316	Elphick *et al.* 2011
Stenonema modestum	Mayfly	14-d	Survival	MATC	3,074	Diamond *et al.* 1992
Invertebrate - Cladoceran						
Ceriodaphnia dubia	Water flea	7-d	Reproduction	IC25	454	Elphick *et al.* 2011
Daphnia magna	Water flea	21-d	Reproduction	IC25	421	Elphick *et al.* 2011
Daphnia pulex	Water flea	21-d	Reproduction	IC10	368	Birge *et al.* 1985 / Elphick *et al.* 2011 [3]
Invertebrate - Planktonic Crustacean						
Brachionus calyciflorus	Rotifer	48-h	Reproduction	IC25	1,505	Elphick *et al.* 2011

Table 10. Summary of the results of toxicity tests conducted to support the development of the proposed chronic SSWQO for chloride for Ekati Mine[1].

Receptor Group / Species	Common Name	Test Duration	Toxicity Test Endpoint	Effect Level	Effect Concentration (mg/L Cl^-)	Reference
Invertebrate - Worm						
Lumbriculus variegatus	Oligochaete	28-d	Reproduction	IC25	825	Elphick *et al.* 2011
Tubifex tubifex	Oligochaete	28-d	Reproduction	IC25	519	Elphick *et al.* 2011

d = days; EC_x = effect concentration to x percent of the population; h = hours; IC_x = inhibition concentration to x percent of the population; LCx = lethal concentration to x percent of the population; MATC = maximum acceptable toxicant concentration; SSWQO = site-specific water quality objective.

[1] Data presented in Table 5 of Elphick *et al.* (2011).

[2] Point estimates were calculated by Elphick *et al.* (2011) using Multiple Linear Estimation (Probit) based on original data provided in Birge *et al.* (1985).

[3] Point estimates were calculated by Elphick *et al.* (2011) using linear interpolation based on original data from Birge *et al.* (1985).

Table 11. List of species known to occur in Snap Lake and nearby lakes.[1]

Receptor Group / Species or Group	Common Name
Fish - Non-salmonid	
Catostomus catostomus	Longnose sucker
Cottus cognatus	Slimy sculpin
Couesius plumbus	Lake chub
Culaea inconstans	Brook stickleback
Lota lota	Burbot
Prosopium cylindraceum	Round whitefish
Fish - Salmonid	
Salvelinus namaycush	Lake trout
Thymallus arcticus	Arctic grayling
Invertebrate - Amphipod	
Amphipoda	Scud
Hyalella azteca	Scud
Invertebrate - Aquatic Insect	
Ephemeroptera	Mayfly
Ephemerellidae	Mayfly
Limnophila	Crane fly
Trichoptera	Caddisfly
Mystacides	Caddisfly
Oecetis	Caddisfly
Chyranda	Caddisfly
Philarctus/Limnephilus	Caddisfly
Molannodes tinctus	Caddisfly
Phryganeidae	Caddisfly
Agrypnia	Caddisfly
Ptilostomis	Caddisfly
Bezza/Palpomyia	Biting midge
Dasyhelea	Biting midge
Chironomidae	Midge
Tanypodinae	Midge
Ablabesmyia	Midge
Procladius	Midge
Orthocladiinae	Midge
Heterotanytarsus	Midge
Psectrocladius	Midge
Zalutschia	Midge
Chironominae	Midge
Chironomini	Midge
Chironomus	Midge
Cladopelma	Midge
Cryptochironomus	Midge
Dicrotendipes	Midge
Endochironomus	Midge
Mircotendipes	Midge
Pagastiella	Midge
Phaenopsectra	Midge
Polypedilum	Midge
Stictochironomus	Midge
Pseudochironomus	Midge

Table 11. List of species known to occur in Snap Lake and nearby lakes.[1]

Receptor Group / Species or Group	Common Name
Invertebrate - Aquatic Insect (cont.)	
Tanytarsini	Midge
Cladotanytarsus	Midge
Corynocera	Midge
Paratanytarsus	Midge
Tanytarsus	Midge
Micropsectra	Midge
Aeshna	Dragonfly
Somatochlora cf. albicincta	Dragonfly
Corixidae	Water boatman
Callicorixa	Water boatman
Agabus	Predaceous diving beetle
Colymbetes	Predaceous diving beetle
Invertebrate - Leech	
Erpobdella punctata	Leech
Invertebrate - Mollusk	
Pelecypoda	Clam
Sphaeriidae	Fingernail clam
Pisidium	Fingernail clam
Gastropoda	Snail
Fossaria	Snail
Stagnicola	Snail
Stagnicola (s.str.) catascopium	Snail
Physa	Snail
Gyraulus	Snail
Valvatidae	Snail
Valvata sincera	Snail
Invertebrate - Planktonic Crustacean	
Harpacticoida	Copepod
Ostracoda	Seed shrimp
Invertebrate - Worm	
Nematoda	Nematode worm
Oligochaeta	Aquatic earthworm
Echytraeidae	Aquatic earthworm
Tubificidae	Aquatic earthworm
Lumbriculidae	Aquatic earthworm
Nais	Aquatic earthworm
Pristenella	Aquatic earthworm
Invertebrate - Other	
Hydracarina	Water mite
Collembola	Springtail

[1] Reported species studied or observed in the study area, De Beers (2002; Appendices IX.10 and IX.11).

Table 12. Summary of the 10% and 20% effect concentrations resulting from toxicity tests conducted to support the development of the proposed chronic SSWQO for total dissolved solids for Snap Lake Mine[1].

Receptor Group / Species	Common Name	Phase 1 Results (mg/L)	Phase 2 Results (mg/L)	Comments[2]
Algae				
Pseudokirchneriella subcapitata	Green alga	IC10 > 1,474	Not tested	Growth in all concentrations exceeded control; no growth reductions.
Navicula pelliculosa	Diatom	IC10 > 1,487	Not tested	
Fish - Salmonid				
Salvelinus namaycush	Lake trout	IC20 > 1,490 LC20 = 991	Not tested	Dry fertilization; minor effect on survival but no concentration response for TDS.
		IC20 > 1,484 LC20 > 1,484	Not tested	Wet fertilization; no concentration-response for TDS.
Thymallus arcticus	Arctic grayling	IC20 > 1,419 LC20 > 1,419	Not tested	Dry fertilization; no concentration-response for TDS.
		IC20 > 1,414 LC20 > 1,414	Not tested	Wet fertilization; no concentration-response for TDS.
Invertebrate - Aquatic Insect				
Chironomus dilutus	Chironomid	IC10 > 1,379 LC10 > 1,379	Not tested	No concentration-response for TDS.
Invertebrate - Planktonic Crustacean				
Brachionus calyciflorus	Rotifer	IC20 >1,474	Not tested	No concentration-response for TDS.
Invertebrate - Cladoceran				
Ceriodaphnia dubia	Water flea	IC10 = 560 IC20 = 778 LC10 > 1,474	NaCl: IC20 > 1,170 NaCl: LC20 > 1,561 Na_2SO_4: IC20 = 758 Na_2SO_4: LC20 >1,554 $CaSO_4$: IC20 = 428 $CaSO_4$: LC20 = 1,240 $CaCl_2$: IC20 = 509 $CaCl_2$: LC20 >1,516	Calcium salts had generally higher toxicity than sodium salts; sodium salts had generally similar toxicity to synthetic lake water tested in Phase 1.

Table 12. Summary of the 10% and 20% effect concentrations resulting from toxicity tests conducted to support the development of the proposed chronic SSWQO for total dissolved solids for Snap Lake Mine[1].

Receptor Group / Species	Common Name	Phase 1 Results (mg/L)	Phase 2 Results (mg/L)	Comments[2]
Daphnia magna	Water flea	IC20 = 684 LC20 = 662	NaCl: IC20 = 493 NaCl: LC20 >1,556 Na_2SO_4: IC20 = 766 Na_2SO_4: LC20 = 804 $CaSO_4$: IC20 = 1,235 $CaSO_4$: LC20 >1,531 $CaCl_2$: IC20 = 756 $CaCl_2$: LC20 = 1,247	Each of the four salts had similar toxicity to each other and to synthetic lake water tested in Phase 1; the test with NaCl had high variability, which complicated statistical analyses for that test.

IC_x = inhibition concentration to x percent of the population; LCx = lethal concentration to x percent of the population; MATC = maximum acceptable toxicant concentration; SSWQO = site-specific water quality objective; TDS = total dissolved solids.

[1] Data presented in Table 32 of De Beers (2013).

[2] Comments taken directly from Table 32 in De Beers (2013).

Table 13. **Recommended Water Quality Objectives for application in Snap Lake and the Lockhart River.**

Area of Interest / Waterbody / Substance	Preliminary Short-term WQO	Preliminary Long-term WQO	Background Concentration		Recommended Short-term WQO [1]	Recommended Long-term WQO [2]	Method for Deriving Objective
			95th Percentile	95% UCL			
Snap Lake							
Snap Lake [3]							
Chloride (mg/L)	250 [4]	120 [5]	0.72	0.41	250	120	CCME WQG
Total dissolved solids (mg/L)	500 [4]	NG	47	22.5	500 [4]	194	Short-term WQO: Adopt WQG Long-term WQO: CCME Type A Approach
Lockhart River downstream of Snap Lake							
Lockhart River [6]							
Chloride (mg/L)	250 [4]	120 [5]	0.99	0.99	125	60	Enhanced use-protection approach[7]
Total dissolved solids (mg/L)	500 [4]	NG	17	17	259	106	Enhanced use-protection approach[7]
Upper Lockhart River (Class 1)							
Lockhart River [8]							
Chloride (mg/L)	NA	NA	0.374	0.233	0.374	0.233	Background approach[9]
Total dissolved solids (mg/L)	NA	NA	22.2	18.7	22.2	18.7	Background approach[9]
Mackay Lake [10]							
Chloride (mg/L)	NA	NA	0.744	0.434	0.744	0.434	Background approach[9]
Total dissolved solids (mg/L)	NA	NA	23.4	18.8	23.4	18.8	Background approach[9]
Central Lockhart River							
Lockhart River [11]							
Chloride (mg/L)	NA	NA	0.374	0.233	0.374	0.233	Background approach[9]
Total dissolved solids (mg/L)	NA	NA	22.2	18.7	22.2	18.7	Background approach[9]
Aylmer Lake [12]							
Chloride (mg/L)	NA	NA	0.512	0.368	0.512	0.368	Background approach[9]
Total dissolved solids (mg/L)	NA	NA	30.6	24.3	30.6	24.3	Background approach[9]

Table 13. Recommended Water Quality Objectives for application in Snap Lake and the Lockhart River.

Area of Interest / Waterbody / Substance	Preliminary Short-term WQO	Preliminary Long-term WQO	Background Concentration		Recommended Short-term WQO [1]	Recommended Long-term WQO [2]	Method for Deriving Objective
			95th Percentile	95% UCL			
***Clinton Colder Lake* [13]**							
Chloride (mg/L)	NA	NA	0.29	0.2	0.29	0.2	Background approach[9]
Total dissolved solids (mg/L)	NA	NA	41	35	41	35	Background approach[9]
Lower Lockhart River							
***Lockhart River* [14]**							
Chloride (mg/L)	NA	NA	0.37	0.186	0.37	0.186	Background approach[9]
Total dissolved solids (mg/L)	NA	NA	33.4	24.4	33.4	24.4	Background approach[9]
***Artillery Lake* [15]**							
Chloride (mg/L)	NA	NA	0.37	0.186	0.37	0.186	Background approach[9]
Total dissolved solids (mg/L)	NA	NA	33.4	24.4	33.4	24.4	Background approach[9]
Lower Lockhart River in the vicinity of Old Lady of the Falls							
***Lockhart River* [16]**							
Chloride (mg/L)	NA	NA	0.794	0.556	0.794	0.556	Background approach[9]
Total dissolved solids (mg/L)	NA	NA	30.7	20.9	30.7	20.9	Background approach[9]

CCME = Canadian Council of Ministers of the Environment; NA = not applicable; NG = no guideline; UCL = upper confidence limit of the mean; WQG = water quality guideline; WQO = water quality objective.

[1] Compare to any of the five weekly samples collected within a 30-d period.

[2] Compare to results of any monthly grab sample, mean of five samples collected within 30-d, or annual mean.

[3] Background conditions calculated using the water quality data from stations 29, WQ1, WQ2, WQ3, WQ4, WQ6, and WQ7.

[4] Health Canada drinking water guideline.

[5] CCME WQG for protection of aquatic life.

[6] Background conditions calculated using the water quality data from station 37. Only one sample was collected from this station.

[7] Enhanced use-protection values calculated as (WQO for Snap Lake + [Background]) / 2

[8] Background conditions calculated using the water quality data from stations 11, 23, 24, 26, and 3.

[9] Short-term background concentration is defined as the 95th percentile of all samples, while the long-term background concentration is defined by the mean ($n < 10$) or the 95% upper confidence limit of the mean ($n \geq 10$).

Footnotes continued on next page…

Table 13. Recommended Water Quality Objectives for application in Snap Lake and the Lockhart River.

Area of Interest / Waterbody / Substance	Preliminary Short-term WQO	Preliminary Long-term WQO	Background Concentration		Recommended Short-term WQO [1]	Recommended Long-term WQO [2]	Method for Deriving Objective
			95th Percentile	95% UCL			

[10] Background conditions calculated using the water quality data from stations 22, 25, and 49.

[11] Background conditions calculated using the water quality data from stations 11, 23, 24, 26, and 3 as no samples were collected in this area during background characterization.

[12] Background conditions calculated using the water quality data from stations 4, 5, 6, 7, and 18.

[13] Background conditions calculated using the water quality data from station 53.

[14] Background conditions calculated using the water quality data from station 52.

[15] Background conditions calculated using the water quality data from station 52 as no samples were collected in this lake during background characterization.

[16] Background conditions calculated using the water quality data from stations 19, 43, and OA1.

Figures

Figure 1. Location of the baseline water quality stations in Snap Lake (1988 - 2001).

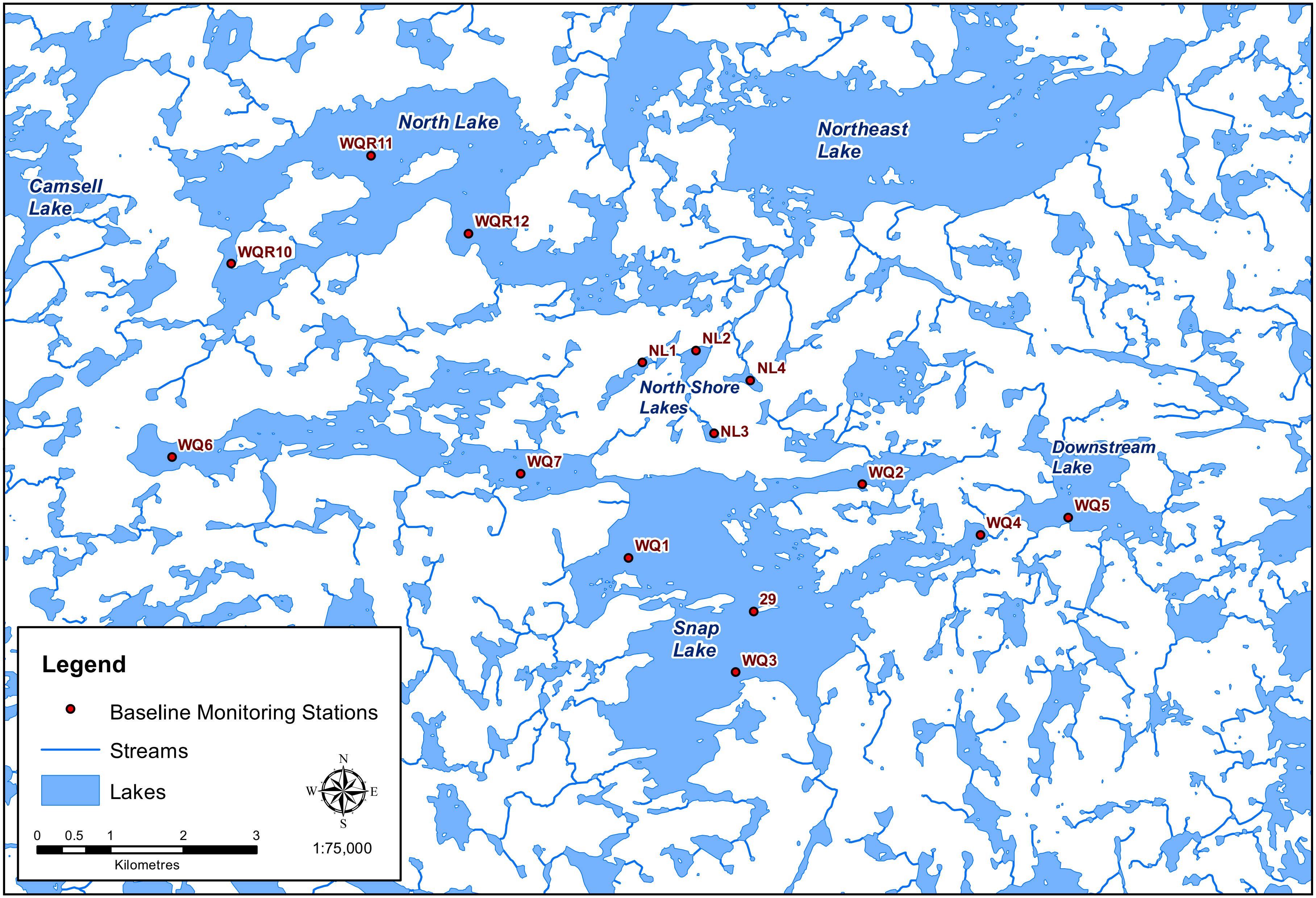


Figure 2. Location of the baseline water quality stations in the Lockhart River watershed (1969 - 2000).

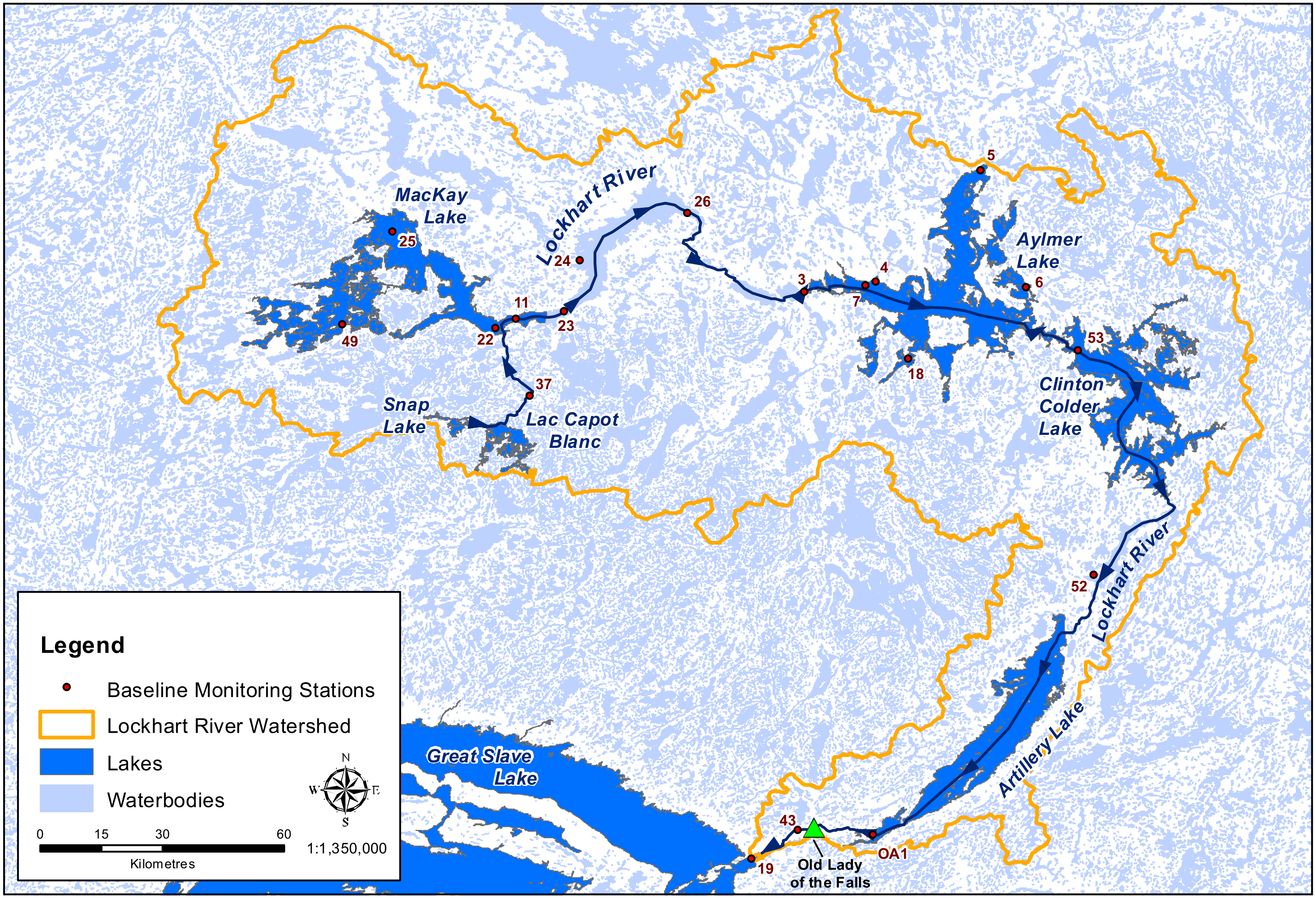


Figure 3. Classification of waters in the study area.

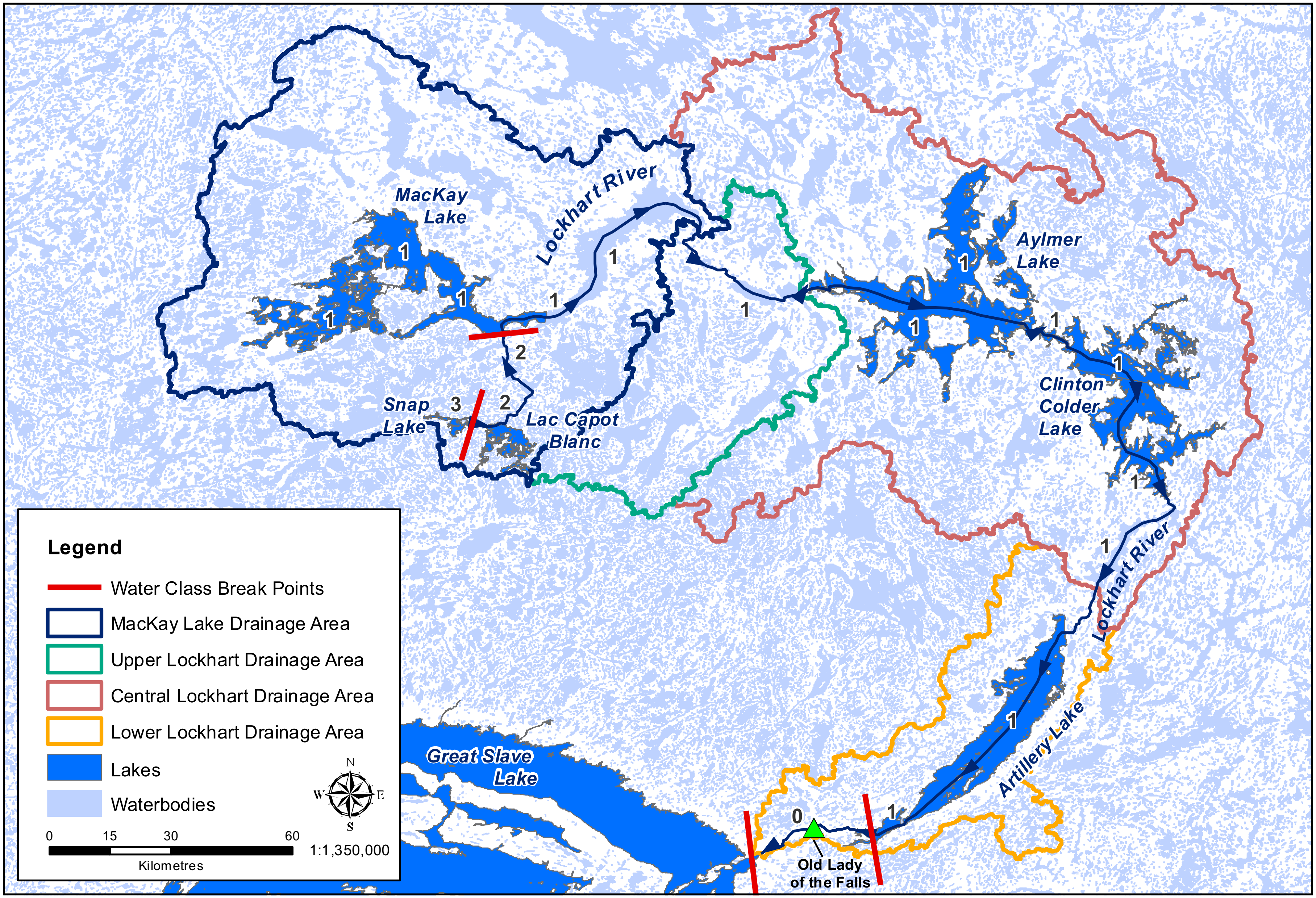


Figure 4. Comparison of the relationship between hardness and toxicity of Chloride to *Ceriodaphnia dubia* (Elphick *et al.* 2011).

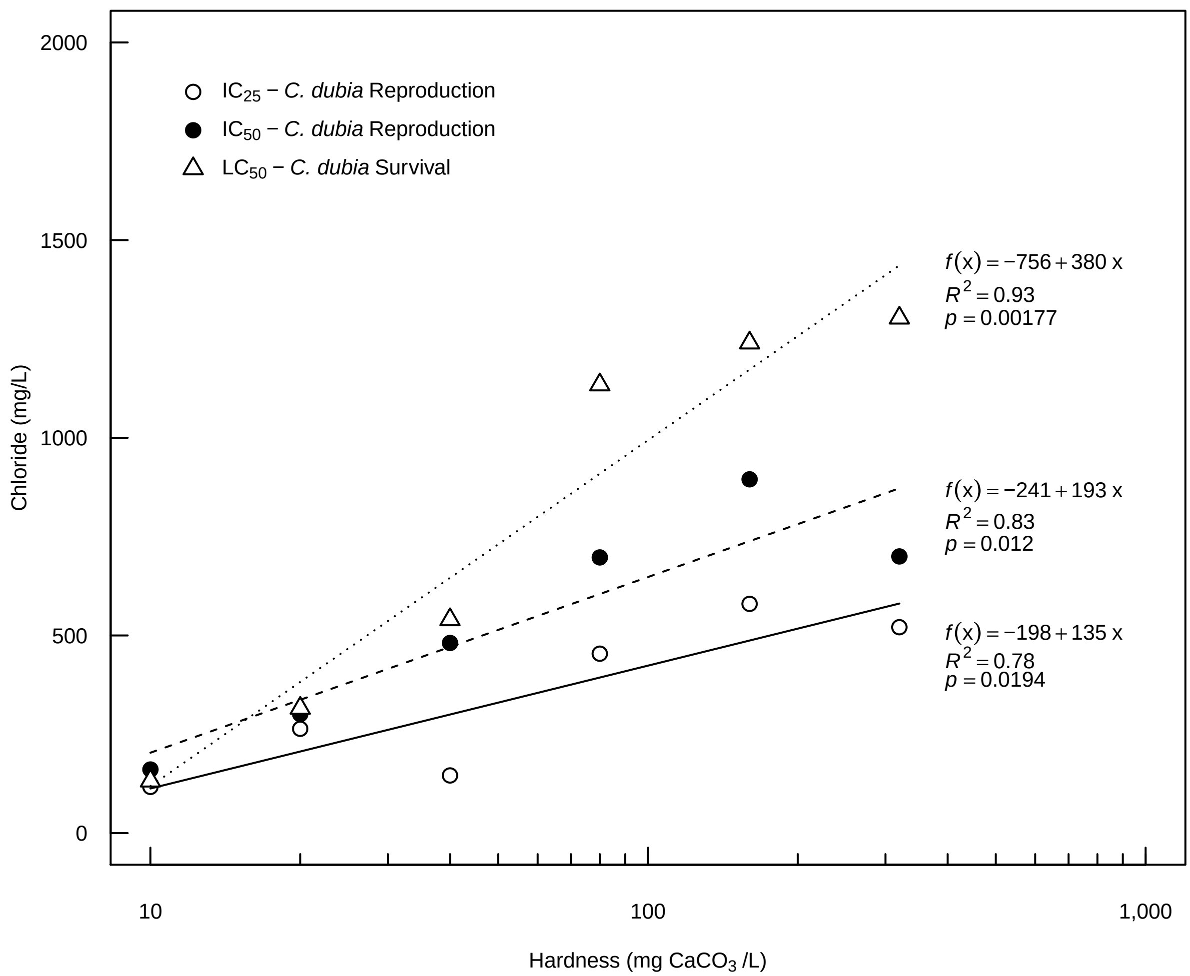
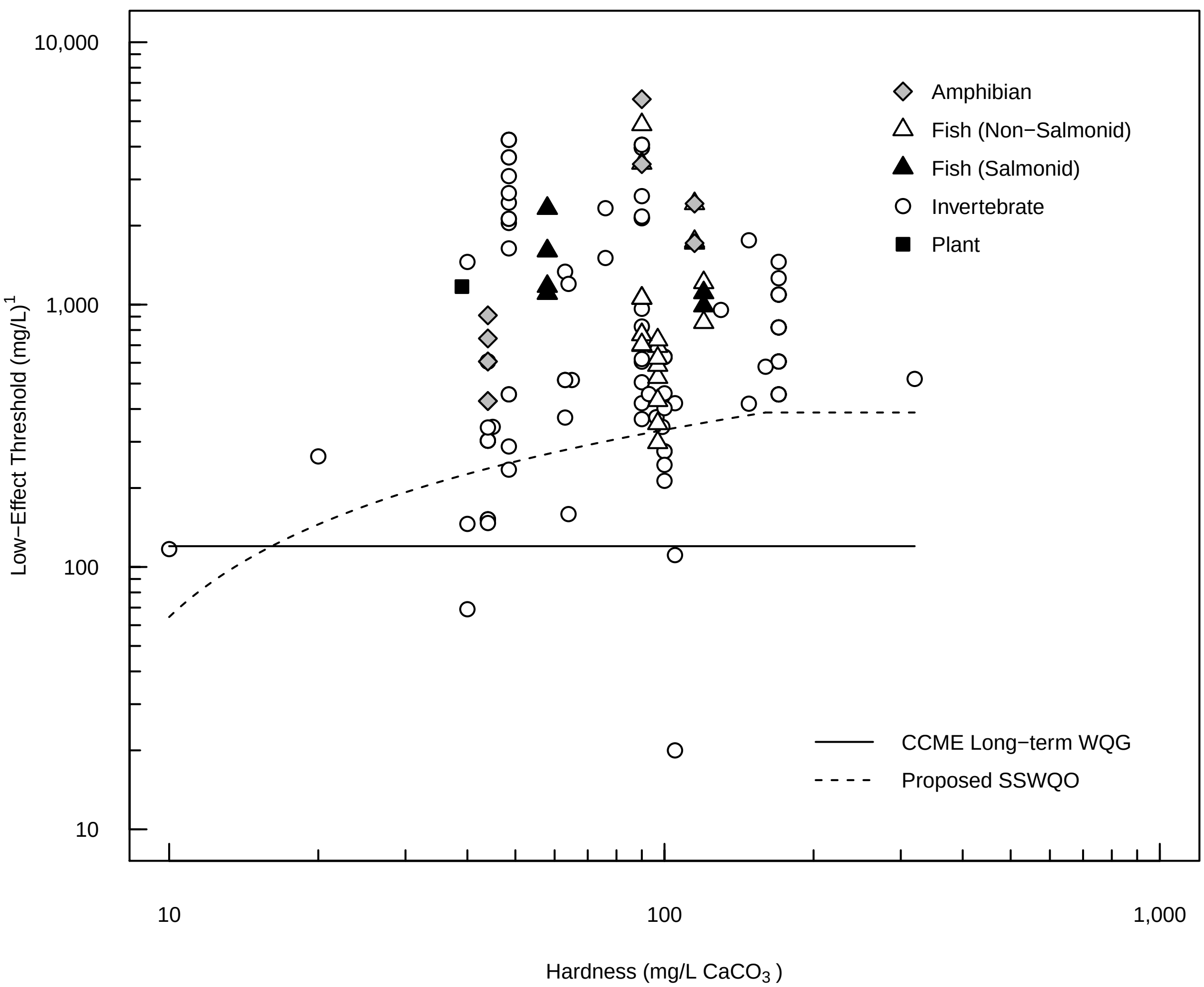


Figure 5. Evaluation of the site−specific Water Quality Objective for chloride proposed for Snap Lake.



1. The $EC_{15–25}$, MATC, and LOEC values from individual toxicity tests are shown.

Figure 6. Species Sensitivity Distribution for TDS using data generated from the Phase 1 toxicity testing program and information compiled from the primary literature.