Table 9.8-4 Predicted Water Quality in Lake N11 for the Construction and Operations, and Closure Phases

Regulated Parameter	Units	Water Quality Guidelines [a]	Baseline WQ [b]	Predicted Values / Concentrations
				Maximum during all Project Phases [b]
Conventional				
pH	pH units	6.5 - 9.0	**6.4**	**6.4** [c]
Total Dissolved Solids	mg/L	-	16	46
Total Suspended Solids	mg/L	-	1.3	1.3 [d]
Hardness [e]	mg/L as $CaCO_3$	-	4.5	25
Major Ions				
Calcium	mg/L	-	1.1	7.5
Chloride	mg/L	-	0.49	16
Magnesium	mg/L	-	0.43	1.5
Potassium	mg/L	-	0.39	0.95
Sodium	mg/L	-	0.78	4.1
Sulphate	mg/L	-	0.88	3.9
Nitrogen - Nutrients				
Ammonia	mg/L as N	23 [e]	0.019	1.7
Nitrate	mg/L as N	2.9	0.019	1.6
Total Nitrogen	mg/L as N	-	0.12	3.4
Total Metals				
Aluminum	mg/L	0.1 [f]	0.019	0.026
Antimony	mg/L	-	0.000062	0.00053
Arsenic	mg/L	0.005	0.00012	0.00041
Barium	mg/L	-	0.0027	0.017
Beryllium	mg/L	-	0.000064	0.000072
Boron	mg/L	1.5	0.0017	0.023
Cadmium	mg/L	0.000002 [g]	**0.000019**	**0.000022**
Chromium	mg/L	0.001	0.00016	**0.0016**
Cobalt	mg/L	-	0.00019	0.00023
Copper	mg/L	0.002 [g]	0.0013	0.0015
Iron	mg/L	0.3	0.059	0.13
Lead	mg/L	0.001 [g]	0.000061	0.00012
Manganese	mg/L	-	0.0057	0.019
Mercury	mg/L	0.000026	0.0000051	0.0000079
Molybdenum	mg/L	0.073	0.00003	0.00073
Nickel	mg/L	0.025 [g]	0.00047	0.00096
Selenium	mg/L	0.001	0.000032	0.00021
Silver	mg/L	0.0001	0.0000081	0.000022
Strontium	mg/L	-	0.0069	0.015
Thallium	mg/L	0.0008	0.000014	0.000072
Uranium	mg/L	-	0.000016	0.00033
Vanadium	mg/L	-	0.000094	0.00078
Zinc	mg/L	0.03	0.0024	0.0038
Dissolved Metals				
Aluminum	mg/L	0.1 [f]	0.017	0.02
Antimony	mg/L	-	0.000053	0.00051
Arsenic	mg/L	0.005	0.0001	0.00039
Barium	mg/L	-	0.002	0.016
Beryllium	mg/L	-	0.000064	0.000072

Table 9.8-4 Predicted Water Quality in Lake N11 for the Construction and Operations, and Closure Phases (continued)

Regulated Parameter	Units	Water Quality Guidelines [a]	Baseline WQ [b]	Predicted Values / Concentrations
				Maximum during all Project Phases [b]
Boron	mg/L	1.5	0.0017	0.023
Cadmium	mg/L	0.000002 [g]	**0.000019**	**0.000021**
Chromium	mg/L	0.001	0.00016	**0.0015**
Cobalt	mg/L	-	0.00019	0.00022
Copper	mg/L	0.002 [g]	0.00099	0.00115
Iron	mg/L	0.3	0.045	0.101
Lead	mg/L	0.001 [g]	0.000027	0.000088
Manganese	mg/L	-	0.004	0.017
Mercury	mg/L	0.000026	0.0000051	0.0000075
Molybdenum	mg/L	0.073	0.000014	0.00072
Nickel	mg/L	0.025 [g]	0.00039	0.00057
Selenium	mg/L	0.001	0.000032	0.00021
Silver	mg/L	0.0001	0.0000025	0.000018
Strontium	mg/L	-	0.0069	0.015
Thallium	mg/L	0.0008	0.0000012	0.00006
Uranium	mg/L	-	0.000011	0.00032
Vanadium	mg/L	-	0.000039	0.00068
Zinc	mg/L	0.03	0.0024	0.0038

a) Chronic Aquatic Health Guidelines from Canadian Environmental Quality Guidelines, Update 7.0 (CCME 2007).
b) Bold font indicates concentration exceeds guideline.
c) Assumed no change in pH based on geochemical characteristics and acidification assessment of local waterbodies.
d) Theoretical hardness calculated based on observed calcium and magnesium concentrations.
e) Dependent on pH and temperature (assumed 15°C, to give most conservative guideline).
f) Dependent on pH.
g) Dependent on hardness.
WQ = water quality; mg/L = milligrams per litre; mg/L as $CaCO_3$ = milligrams per litre as calcium carbonate; mg/L as N = milligrams per litre as nitrogen

Table 9.8-5 Projected Phosphorus Concentrations in Lake N11 for Construction and Operations, and Closure Phases with Supplemental Mitigation Strategies

Regulated Parameter	Units	Water Quality Guidelines	Baseline WQ	Predicted Values / Concentrations
				Maximum during all Project Phases
Phosphorus - Nutrients				
Dissolved Phosphorus	mg/L	-	0.005	0.007
Total Phosphorus	mg/L	-	0.005	0.009

WQ = water quality; mg/L = milligrams per litre

Total Dissolved Solids and Major Ions

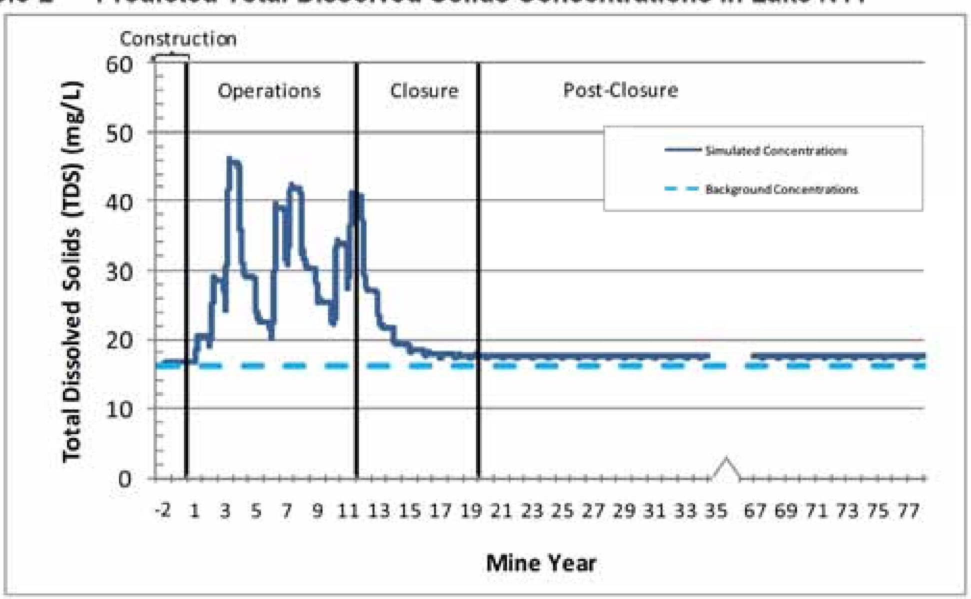
Concentrations of TDS and major ions in Lake N11 are projected to increase during the operations phase due to the input of water pumped from the WMP. All major ions follow a similar trend, as shown in Figure 9.8-2 for TDS. Project TDS concentrations show characteristic peaks each year that correspond with pumping during the open water season.

During the first five years of pumping, concentrations in Lake N11 are driven primarily by the high volume of water being pumped. In subsequent years, pumping volumes are anticipated to decrease, but concentrations in the WMP are anticipated to increase due to inputs from process water and mine pit seepage. The result to Lake N11 is a fluctuation in water chemistry, with three distinct peaks in Year 3, Year 7 and Year 11.

During closure, concentrations are predicted to return to background levels when pumping from the WMP ceases.

There are no Canadian Council of Ministers of the Environment (CCME) guidelines for TDS or any of the major ions. To put the predicted concentrations into context, TDS and all major ions are predicted to increase above background conditions, but remain below concentrations that would affect aquatic health (Section 9.9).

Figure 9.8-2 Predicted Total Dissolved Solids Concentrations in Lake N11



mg/L = milligrams per litre

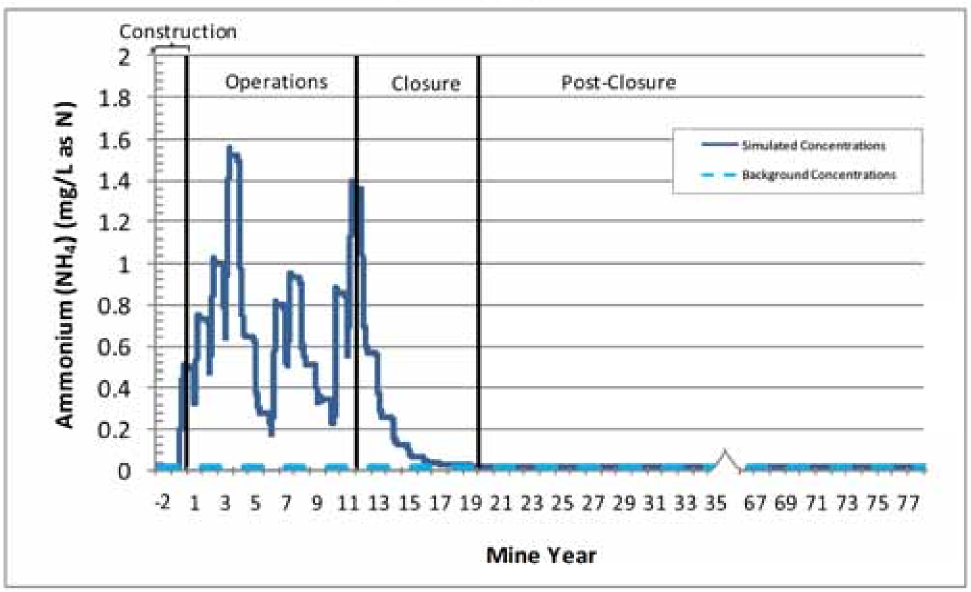
Nutrients

Nitrogen

Concentrations of all modelled forms of nitrogen are predicted to increase in Lake N11 due to inputs from blasting residue to the WMP and ultimate discharge to Lake N11.

Concentrations are predicted to remain below guidelines for nitrate and ammonia (Figure 9.8-3) and return to background conditions within the first few years of closure (Table 9.8-4). Total nitrogen, for which there is no CCME guideline, is predicted to follow a similar pattern, as it is predominantly comprised of nitrate and ammonia.

Figure 9.8-3 Predicted Ammonium (as Nitrogen) Concentrations in Lake N11



mg/L as N = milligrams per litre as nitrogen

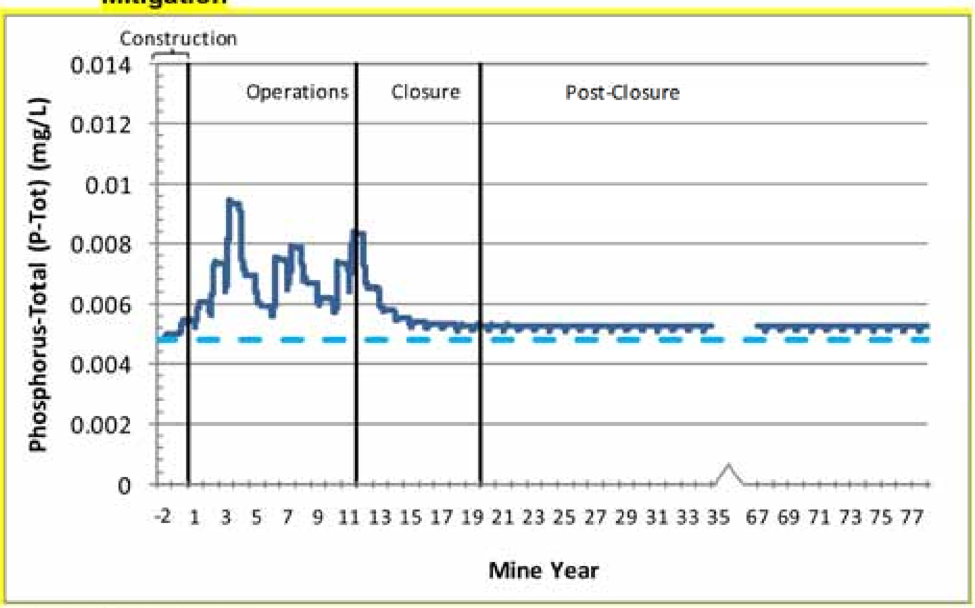
Phosphorus

Phosphorus plays an important role in aquatic systems primarily because of its importance in biological metabolism. In contrast to the availability of other nutrients to biota, such as carbon and nitrogen, phosphorus is generally the least abundant. This lack of natural availability commonly leads to phosphorus limitation in lakes, which affects biological productivity. Most natural lakes are considered phosphorus limited or co-limiting with nitrogen.

Concentrations of phosphorus are predicted to increase from a background concentration of 0.005 mg/L in Lake N11, to a peak of 0.009 mg/L during operations as a result of loading from active WMP discharge. Phosphorus levels in the WMP are influenced by runoff and seepage through the mine rock piles, Coarse PK Pile, and the Fine PKC Facility. More specifically, phosphorus is mobilized into seepage flows that come into contact with mine rock, coarse PK, and fine PK material as flows travel through the external structures, with fine PK in saturated conditions being the largest contributing source of phosphorus. Following mine operations, any discharge from the WMP to Lake N11 will cease, and as a result, phosphorus concentrations are projected to return to concentrations consistent with background concentrations during closure (Figure 9.8-4).

The modelled increases in phosphorus in Lake N11 during operations (Figure 9.8-4) were developed assuming mitigation strategies for the Fine PKC Facility within the Kennady Lake watershed that will reduce the overall footprint area of the facility, reduce overall infiltration of water into the facility, and reduce water contact with materials that have the potential to release elevated concentrations of phosphorus in the WMP. These strategies are described further in Section 9.8.2.2

Figure 9.8-4 Predicted Total Phosphorus Concentrations in Lake N11 with Supplemental Mitigation



mg/L = milligrams per litre

The majority of the total phosphorus predicted to be present in Kennady Lake in post-closure is expected to be dissolved phosphorus, because it is likely to largely originate from geochemical reactions that occur within the mine rock piles, Coarse PK Pile, and Fine PKC Facility. As a result, trends of these two parameters are predicted to be similar. There is no current CCME guideline for total or dissolved phosphorus.

Potential Effects of Nutrient Enrichment

Phosphorus is generally a limiting nutrient in freshwater systems, so its concentration can be used to determine trophic status. Based on the total phosphorus concentrations projected for operations, including a peak concentration of 0.009 mg/L, an increase in primary productivity would be expected in Lake N11 during operations. However, the trophic status of Lake N11 would remain oligotrophic (i.e., 0.004 to 0.010 mg/L; Environment Canada 2004; CCME 2004), as it is under baseline conditions.

Trace Metals

Trace metals can be toxic to aquatic life in high concentrations. The toxicity of some metals (e.g., cadmium, copper, lead, nickel, and zinc) can vary with hardness, with increasing hardness levels resulting in a decrease in the potential toxicity of these metals to aquatic life.

There are several potential loading sources of trace metals to the WMP during the operations phase. Geochemical sources include loadings from mine rock and PK drainage, and pit wall exposure. Groundwater inflows from the active pits will contribute metals during the period when groundwater is discharged to the WMP (Sections 8.4.3.5 and 8.8.4.1.1). Increased concentrations in the WMP will result in increased concentrations in Lake N11 when that water is pumped there. In general, the trends predicted for trace metals are similar to those predicted for TDS and major ions, with a few notable differences described below.

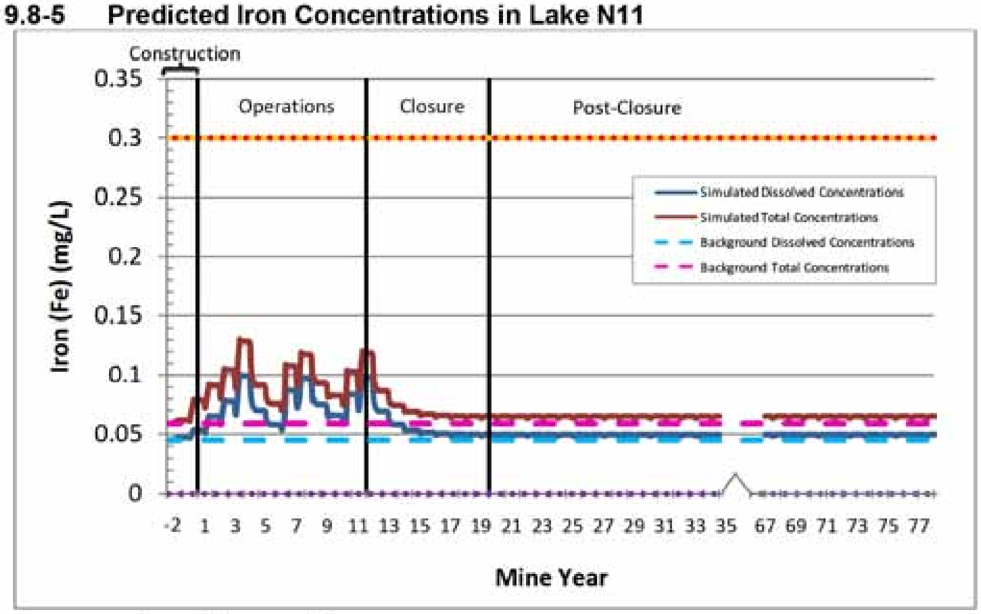
Trace Metals that are Predicted to Follow Similar Trends to TDS

Of the 23 trace metals that were modelled for this assessment, 17 are predicted to increase in concentration during the operations phase and generally follow the same temporal patterns as those for TDS and major ions. All metals not specifically mentioned in subsequent categories follow this trend. A representative time series plot is shown for iron in Figure 9.8-5.

Depending on the primary loading source of these metals to the WMP, the characteristic peaks predicted to occur in Lake N11 may vary somewhat for these 17 metals. Metals that are influenced more by groundwater inflows are predicted to have maximum peaks early in the operational phase, as illustrated by the chromium time series plot (Figure 9.8-6). Metals that are more strongly influenced by geochemical loading sources are predicted to have the highest peaks near the end of the operational phase, as illustrated by the time series plot of strontium (Figure 9.8-7).

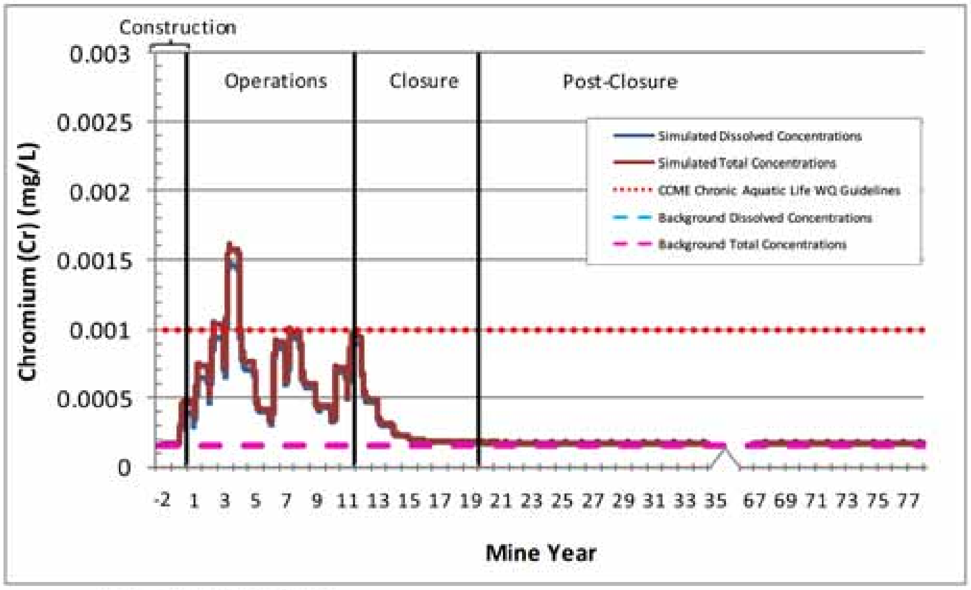
Of these 17 metals, only chromium is predicted to exceed guidelines (Table 9.8-4), and the guideline exceedance is predicted to be limited to the Years 2 and 4. In the case of chromium, it should be noted that the guideline for chromium (VI) was conservatively applied to total and dissolved chromium predictions, although it is anticipated that most chromium will be present as chromium (III). The basis for this assumption is that the dominant sources of chromium to Kennady Lake, which will ultimately be discharged to Lake N11, are groundwater and seepage from fine PK and waste rock, and these are not highly oxidative systems that would generate chromium (VI). Predicted concentrations of total and dissolved chromium are below the CCME guideline of 0.0089 mg/L for chromium (III).

Figure 9.8-5 Predicted Iron Concentrations in Lake N11



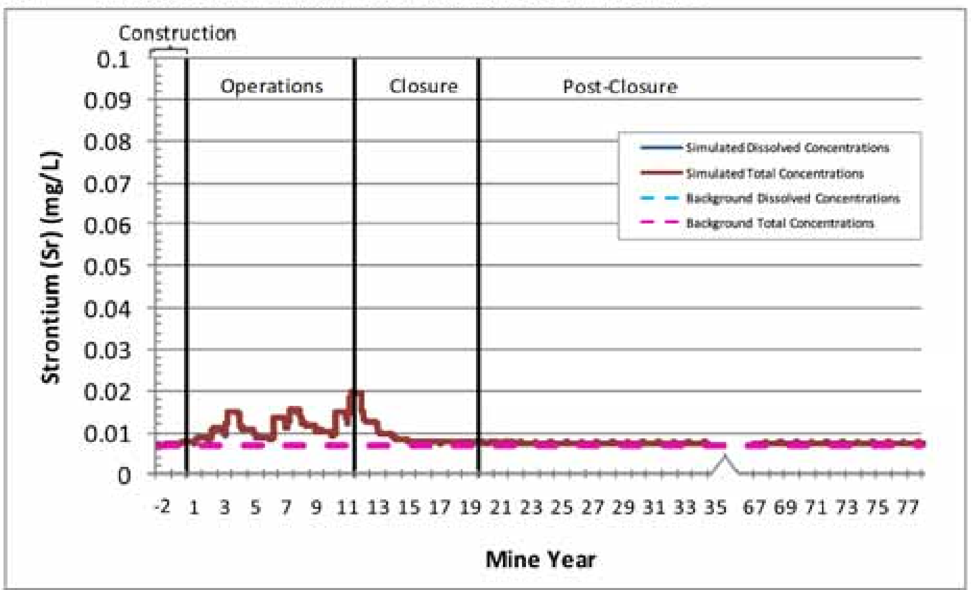
mg/L = milligrams per litre

Figure 9.8-6 Predicted Chromium Concentrations in Lake N11



mg/L = milligrams per litre

Figure 9.8-7 Predicted Strontium Concentrations in Lake N11

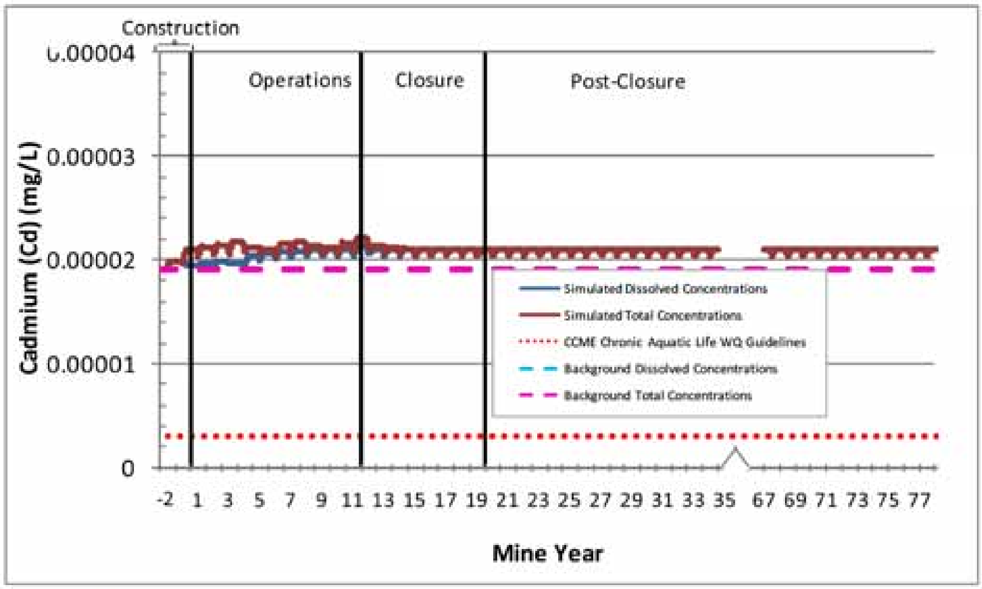


mg/L = milligrams per litre

Trace Metals that are not Predicted to Follow Similar Trends to TDS

Six of the 23 modelled metals are predicted to have slight (i.e., less than 20 percent [%]) increases in concentration due to inputs from the WMP. Aluminum, beryllium, cadmium, cobalt, copper and mercury are predicted to have smaller relative increases in concentration because their relative increases in the WMP are also small during the operational phase. A representative timeseries plot is shown for cadmium in Figure 9.8-8. Of these metals, only cadmium is predicted to exceed guidelines, and these exceedances are observed in background conditions.

Figure 9.8-8 Predicted Cadmium Concentrations in Lake N11



mg/L = milligrams per litre

The potential health effects of all trace metals on aquatic life are assessed in Section 9.9.

9.8.2.2 Effect of Project Activities on Water Quality in Interlakes during the Closure Phase

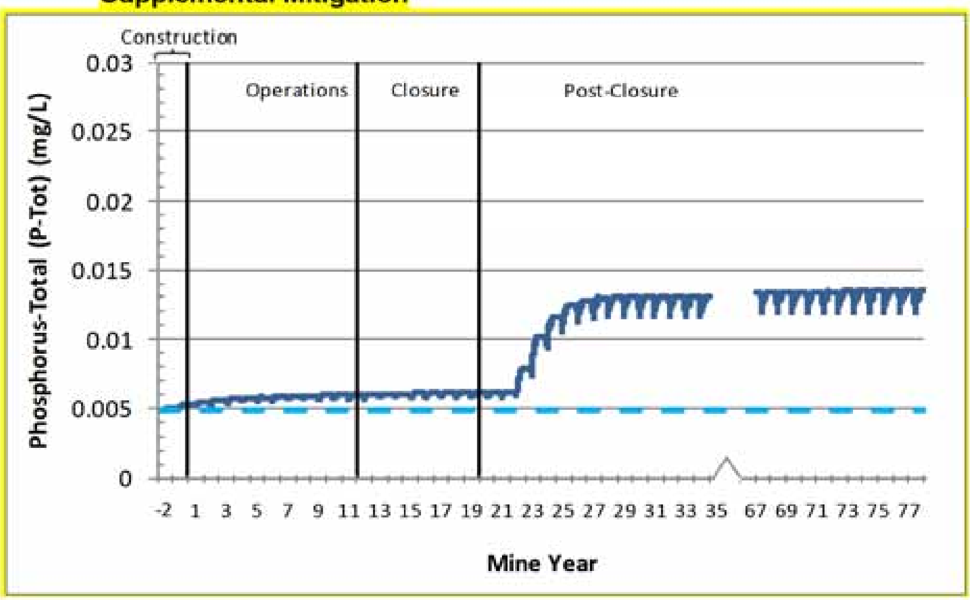
Water quality in the interlakes (the chain of lakes within the L and M watersheds) will be similar to that described for Area 8 in Section 8.8.4.1.2. Project activities that could potentially affect water quality in Area 8 will have a similar, though attenuated, effect on water quality in the interlakes, because Area 8 forms the upstream source of water flowing through this system. As water moves downstream, effects will be progressively attenuated by dilution from the sub-watersheds.

Water quality in Area 8 was assessed in Section 8.8.4.1.2, and aquatic health in Area 8 was assessed in Section 8.9.3.2. The assessment of water quality (Section 8.8) and aquatic health (Section 8.9) in Area 8 concluded that Project activities were predicted to result in negligible effects to water quality and aquatic health, with the possible exception of phosphorus. Therefore, the assessment of water quality in the interlakes has excluded all parameters, with the exception of phosphorus.

Phosphorus

As described in Sections 8.8.4.1, there is potential for phosphorus to increase over the long-term in Kennady Lake and Area 8 during the closure phase. These concentrations are anticipated to extend downstream, but decline with distance as inflows from the L and M watersheds dilute the concentrations originating from the Kennady Lake watershed. Average long-term steady state phosphorus concentrations for lakes along the main flow path in the L and M watersheds are projected to be 0.015 and 0.013 mg/L, respectively. Based on the trophic classification listed in Environment Canada (2004) and CCME (2004), these lakes are likely to be mesotrophic in the long-term.

Figure 9.8-9 Predicted Total Phosphorus Concentrations in the M Lakes Watershed with Supplemental Mitigation



mg/L = milligrams per litre

Concentrations of phosphorus are projected to increase in Kennady Lake during operations due to loading to the WMP from process water, runoff and seepage inputs from Project facilities, and groundwater inputs. Concentrations are then projected to decrease during closure due to the refilling of Kennady Lake, and then gradually increase to steady state concentrations after closure. The long-term phosphorus increases result from seepage through the mine rock piles, Coarse PK Pile, and the Fine PKC Facility, which eventually flows to Kennady Lake. More specifically, phosphorus is mobilized into seepage flows that come into contact with mine rock, coarse PK, and fine PK material as flows travel through the external structures, with fine PK in saturated conditions being the largest contributing source of phosphorus.

The majority of the total phosphorus that will be sourced from seepage through the mine rock and PK storage facilities is predicted to be dissolved phosphorus, because it is likely to largely originate from geochemical reactions that occur within the mine rock piles and Coarse PK Pile, and Fine PKC Facility. As a result, trends of these two parameters are predicted to be similar. There is no current CCME guideline for total or dissolved phosphorus.

The modelled phosphorus projections for Kennady Lake and downstream waters to Lake 410 were developed assuming contact of seepage flows with materials located in the mine rock piles, the Coarse PK Pile, and the Fine PKC Facility, including supplemental mitigation associated with the fine PK deposit in the Fine PKC Facility. Source terms for these materials in the water quality model were based on ranked statistical measurements in the geochemical testing of mine rock and coarse PK, and fine PK completed in support of the EIS (refer to Appendix 8.I, Attachment 8.I.3). As described in Section 9.8.1.1.1, water quality modelling did not include the aggradation of permafrost through the mine rock piles, the Coarse PK Pile, and the Fine PKC Facility.

Without supplemental mitigation (i.e., mitigation as described below), water quality modelling has shown that the concentration of total phosphorus in the L and M watersheds during post-closure could increase to approximately 0.024 mg/L in lakes within the L watershed and 0.020 mg/L in lakes within the the M watershed. Baseline concentrations of total phosphorus are substantially lower, with a concentration range of <0.001 to 0.010 mg/L. This nutrient enrichment would increase the productivity of the watersheds by two trophic levels from oligotrophic to meso-eutrophic. Nutrient enrichment effects would extend further downstream beyond Kennady Lake.

Three mitigation strategies are being considered for the Fine PKC Facility, since fine PK is the largest source of phosphorus to the lake. These strategies include:

- reducing the overall footprint area of fine PK in the facility;
- reducing the potential for overall infiltration of water into the facility; and
- reducing seepage contact with materials with the potential to release elevated concentrations of phosphorus.

De Beers is committed to incorporating additional mitigation to achieve a long-term maximum steady state total phosphorus concentration of 0.018 mg/L in

Kennady Lake. Pre-screening of the strategies listed above is underway and, where available, key information from this analysis, including the required reduction in flows through the fine PK needed to achieve the target phosphorus concentration, has been incorporated into the water quality modelling for Kennady Lake and downstream waters.

Prior to construction of the facility, and throughout operations, additional geochemical testing will be completed to obtain additional information about the potential for fine PK and other site materials to be a source of total phosphorus to Kennady Lake and downstream waters.

As discussed in Section 8.8.4.1, a change in trophic status based on the projected long-term phosphorus concentrations will lead to increased primary productivity, with some implications regarding water column oxygen dynamics. Increased oxygen demand in the interlakes along the main flow path is predicted as a result of the projected phosphorus concentrations. For the lakes with depths greater than 6 m that have overwintering habitat for fish (i.e., Lakes M3 and M4), dissolved oxygen concentrations will remain sufficient to support aquatic life. As the small lakes in the L watershed and M watershed, upstream of Lake M3, are currently subject to low under-ice dissolved oxygen levels with nil or limited overwintering habitat for fish, potential increases in winter oxygen depletion due to nutrient enrichment would not be expected to change the overwintering capability or suitability of these small lakes (Section 9.10.4.3.2).

9.8.2.3 Effect of Project Activities on Water Quality in Lake 410 during Construction, Operations and Closure Phases

Lake 410 is the receptor of loads from Kennady Lake during all phases of the project. During construction and operations, water discharged to Lake N11 (Section 9.8.2.1) will flow to Lake 410 via the N watershed. During closure and post-closure, water released from the refilled Kennady Lake (Section 8.8.4.1) will flow into Lake L 410 via the L and M watersheds (the Interlakes). Therefore, the changes in water quality will be similar in scope but smaller in magnitude than those described for Lake N11 and the interlakes.

Predicted concentrations in Lake 410 are listed in Table 9.8-6. Results for phosphorus, which include supplemental mitigation strategies, are provided in Table 9.8-7. The concentrations listed in these tables are the maximum concentrations over the modelled timeframe, so they represent the maximum of all phases of the project, including long-term concentrations.

A discussion of the water quality modelling results is provided below, which includes time series plots for selected water quality parameters. Time series plots for each water quality parameter listed in Tables 9.8-6 and 9.8-7 are provided in Appendix 9.I.

Table 9.8-6 also includes a comparison to the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME 2007) for reference; however, the assessment of effects of changes in water quality to aquatic life is presented in Section 9.9, and a summary of the assessment of potential effects to human and wildlife health is presented in Section 9.11.

Within each assessment, the water quality modelling results have been grouped into three categories:

- total dissolved solids (TDS) and major ions;
- nutrients; and
- trace metals.

Table 9.8-6 Predicted Water Quality in Lake 410 for Construction and Operation, and Closure Phases

Regulated Parameter	Units	Water Quality Guidelines [(a)]	Baseline WQ[(b)]	Predicted Values / Concentrations
				Maximum during All Project Phases [(b)]
Conventional				
pH	pH units	6.5 - 9.0	**6.4**	**6.4** [(c)]
Total Dissolved Solids	mg/L	-	16	29
Total Suspended Solids	mg/L	-	1.3	1.3 [(d)]
Hardness [(e)]	mg/L as $CaCO_3$	-	4.5	13
Major Ions				
Calcium	mg/L	-	1.1	3.5
Chloride	mg/L	-	0.49	6.0
Magnesium	mg/L	-	0.43	0.92
Potassium	mg/L	-	0.39	1.1
Sodium	mg/L	-	0.78	2.2
Sulphate	mg/L	-	0.88	3.7
Nitrogen - Nutrients				
Ammonia	mg/L as N	23 [(f)]	0.019	0.62
Nitrate	mg/L as N	2.9	0.019	0.61
Total Nitrogen	mg/L as N	-	0.12	1.4
Total Metals				
Aluminum	mg/L	0.1[(g)]	0.019	0.026
Antimony	mg/L	-	0.000062	0.00031
Arsenic	mg/L	0.005	0.00012	0.00043
Barium	mg/L	-	0.0027	0.027
Beryllium	mg/L	-	0.000064	0.000079
Boron	mg/L	1.5	0.0017	0.077
Cadmium	mg/L	0.000002 [(h)]	**0.000019**	**0.000024**
Chromium	mg/L	0.001	0.00016	0.0007
Cobalt	mg/L	-	0.00019	0.00023

Table 9.8-5 Predicted Water Quality in Lake 410 for Construction and Operation, and Closure Phases (continued)

Regulated Parameter	Units	Water Quality Guidelines [a]	Baseline WQ[b]	Predicted Values / Concentrations
				Maximum during All Project Phases [b]
Copper	mg/L	0.002 [h]	0.0013	0.0016
Iron	mg/L	0.3	0.059	0.09
Lead	mg/L	0.001[h]	0.000061	0.00009
Manganese	mg/L	-	0.0057	0.011
Mercury	mg/L	0.000026	0.0000051	0.0000067
Molybdenum	mg/L	0.073	0.00003	0.0016
Nickel	mg/L	0.025 [h]	0.00047	0.00084
Selenium	mg/L	0.001	0.000032	0.000099
Silver	mg/L	0.0001	0.0000081	0.000017
Strontium	mg/L	-	0.0069	0.03
Thallium	mg/L	0.0008	0.000014	0.000036
Uranium	mg/L	-	0.000016	0.00019
Vanadium	mg/L	-	0.000094	0.00047
Zinc	mg/L	0.03	0.0024	0.0034
Dissolved Metals				
Aluminum	mg/L	0.1[g]	0.017	0.021
Antimony	mg/L	-	0.000053	0.0003
Arsenic	mg/L	0.005	0.0001	0.00041
Barium	mg/L	-	0.002	0.026
Beryllium	mg/L	-	0.000064	0.000079
Boron	mg/L	1.5	0.0017	0.077
Cadmium	mg/L	0.000002 [h]	**0.000019**	**0.000023**
Chromium	mg/L	0.001	0.00016	0.00065
Cobalt	mg/L	-	0.00019	0.00023
Copper	mg/L	0.002 [h]	0.00099	0.00121
Iron	mg/L	0.3	0.045	0.069
Lead	mg/L	0.001[h]	0.000027	0.000056
Manganese	mg/L	-	0.004	0.009
Mercury	mg/L	0.000026	0.0000051	0.0000065
Molybdenum	mg/L	0.073	0.000014	0.0016
Nickel	mg/L	0.025 [h]	0.00039	0.00058
Selenium	mg/L	0.001	0.000032	0.000099
Silver	mg/L	0.0001	0.0000025	0.000012
Strontium	mg/L	-	0.0069	0.031
Thallium	mg/L	0.0008	0.0000012	0.000023
Uranium	mg/L	-	0.000011	0.00019
Vanadium	mg/L	-	0.000039	0.00038
Zinc	mg/L	0.03	0.0024	0.0034

a) Chronic Aquatic Health Guidelines from Canadian Environmental Quality Guidelines, Update 7.0 (CCME 2007).

b) Bold font indicates concentration exceeds guideline (below guideline in the case of pH).

c) Assumed no change in pH based on geochemical characteristics and acidification assessment of local waterbodies.

d) Assumed negligible increase in total suspended solids based on mitigation practices (Section 8.4).

e) Theoretical hardness calculated based on background calcium and magnesium concentrations.

f) Dependent on pH and temperature (assumed 15°C, to give most conservative guideline).

g) Dependent on pH.

h) Dependent on hardness.

WQ = water quality; mg/L = milligrams per litre; mg/L as $CaCO_3$ = milligrams per litre as calcium carbonate; mg/L as N = milligrams per litre as nitrogen.

Table 9.8-7 Projected Phosphorus Concentrations in Lake 410 for Construction and Operations, and Closure Phases with Supplemental Mitigation Strategies

Regulated Parameter	Units	Water Quality Guidelines	Baseline WQ	Predicted Values / Concentrations
				Maximum during all Project Phases
Phosphorus - Nutrients				
Dissolved Phosphorus	mg/L	-	0.005	0.005
Total Phosphorus	mg/L	-	0.005	0.007

WQ = water quality; mg/L = milligrams per litre.

Total Dissolved Solids and Major Ions

Concentrations of TDS and major ions in Lake 410 are projected to increase during the operational phase due to input of water pumped from the WMP to Lake N11 (Section 9.8.2.1). Temporal patterns of concentrations in Lake 410 are similar to those in Lake N11, with the following exceptions:

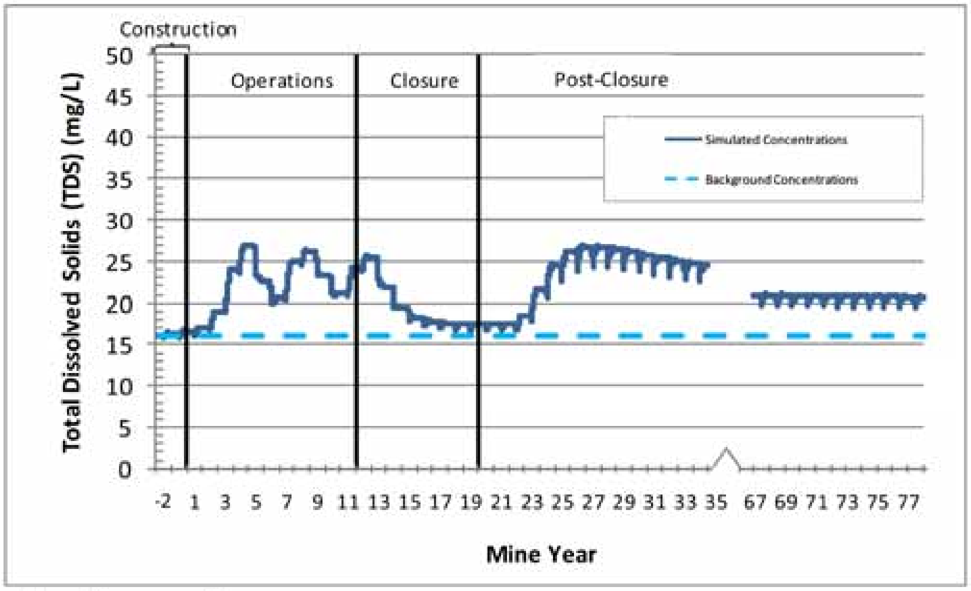
- concentrations are lower in Lake 410 due to dilution from the majority of the Lake 410 watershed, which will be unaffected by mining activities; and
- the characteristic peaks in Lake N11 show up one to two years later in Lake 410, reflecting travel time.

During the closure phase, concentrations in Lake 410 are predicted to return to near background conditions during the refilling period, at which time no water will be released from Kennady Lake. In post-closure, when water is released to Area 8, concentrations will increase slightly in Lake 410. In the post-closure phase, patterns of concentrations in Lake 410 will be similar to those predicted for Area 8 (Section 8.8.4.1), except that these will also be lower due to dilution and offset due to travel time.

In Lake 410, most major ions follow a similar trend, shown in Figure 9.8-10 for TDS, reaching similar peak concentrations in the operational and closure phases. Ions such as potassium and sulphate, which are driven more by geochemical loadings, are predicted to follow similar trends but remain higher in post-closure than in the operational phase (Figure 9.8-11 for potassium).

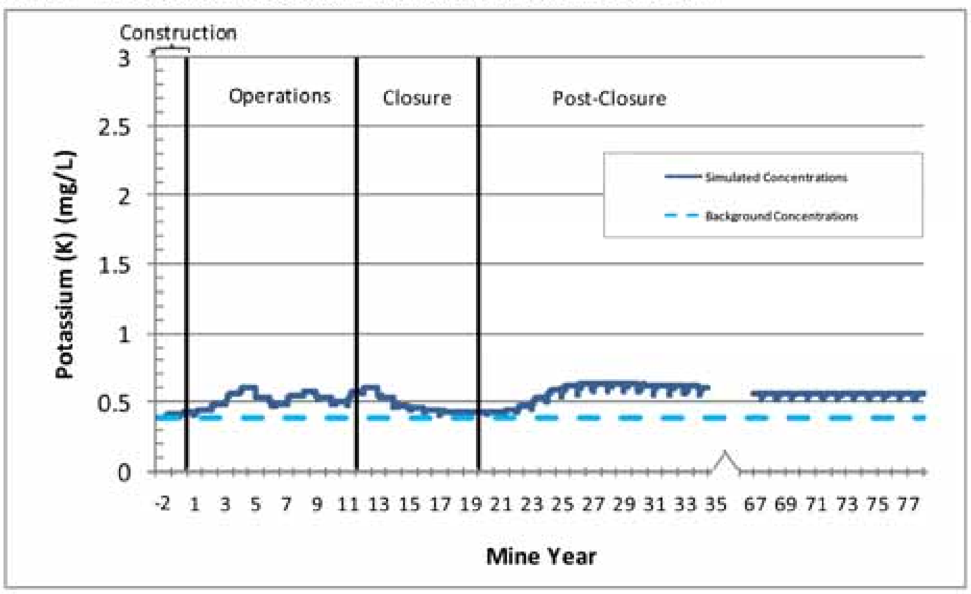
There are no CCME guidelines for TDS or any of the major ions. To put the predicted concentrations into context, TDS and all major ions are predicted to increase above background conditions, but remain below concentrations that would affect aquatic health (Section 9.9).

Figure 9.8-10 Predicted Total Dissolved Solids Concentrations in Lake 410



mg/L = milligrams per litre

Figure 9.8-11 Predicted Potassium Concentrations in Lake 410



mg/L = milligrams per litre

Nutrients

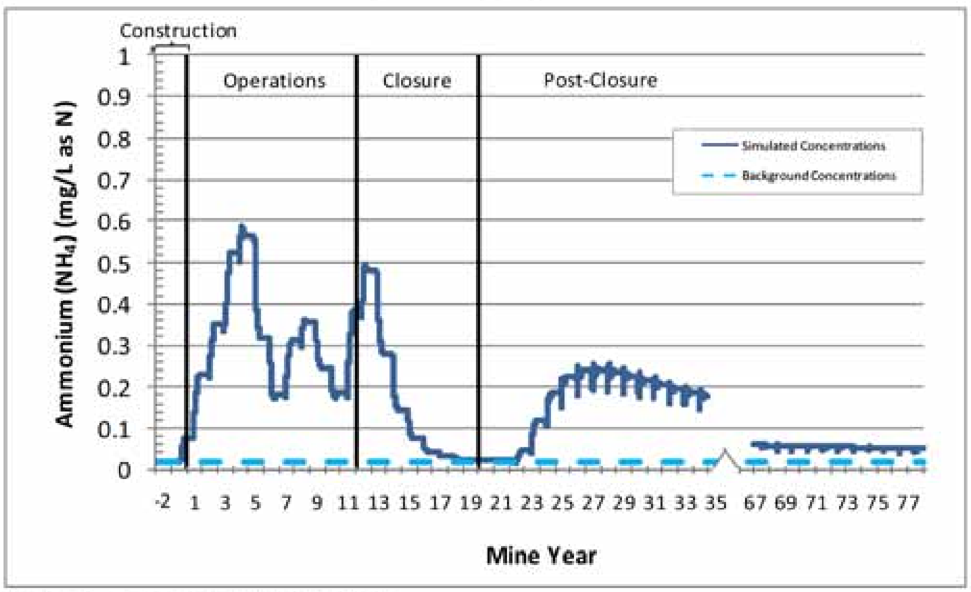
Nitrogen

Concentrations of all modelled forms of nitrogen are predicted to increase in Lake 410 due to inputs from blasting residue and ultimate discharge through either Lake N11 or Area 8. The temporal patterns of nitrogen concentrations in

Lake 410 are similar to those for TDS, except that operational concentrations are higher than closure concentrations. A representative time series plot is shown for ammonia in Figure 9.8-12. Closure concentrations of nitrogen are predicted to decline to near-background concentrations, because there are no major loading sources of nitrogen once pumping from the WMP to Lake N11 ceases and Areas 3 through 7 still remains isolated from Area 8. However, in post-closure, after Dyke A is removed, nitrogen concentrations are projected to peak several years after the reconnection of Kennady Lake to downstream waters and then gradually decline to a steady state after blasting residue has been flushed from the system.

Concentrations are predicted to remain below guidelines for nitrate and ammonia (Table 9.8-6). Total nitrogen, for which there is no CCME guideline, is predicted to follow a similar pattern as ammonia (Figure 9.8-12), as it is predominantly comprised of nitrate and ammonia.

Figure 9.8-12 Predicted Ammonium (as Nitrogen) Concentrations in Lake 410

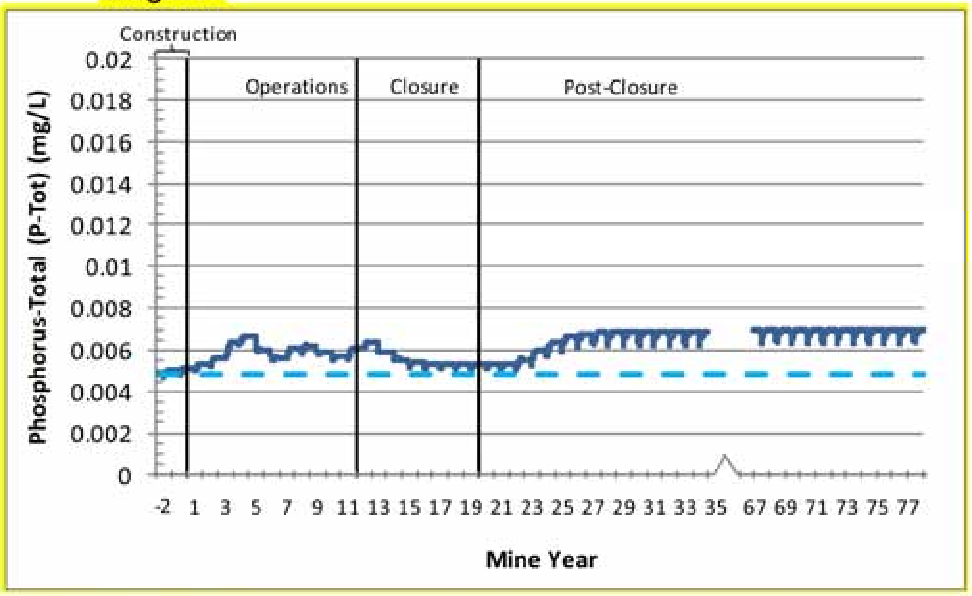


mg/L as N = milligrams per litre as nitrogen

Phosphorus

Concentrations of phosphorus are projected to increase in Lake 401 from a background concentration of 0.005 mg/L to a peak of 0.007 mg/L (Figure 9.8-13). The phosphorus increase in Lake 410 during operations and several years into closure will be associated with pumped discharge from the WMP to Lake N11. Increases several years into post-closure will follow the removal of Dyke A and the reconnection of Kennady Lake to the downstream lakes. The increase represents a relatively small change in phosphorus concentrations, considering that some of the predicted change is due to conservative assumptions in the modelling approach.

Figure 9.8-13 Predicted Total Phosphorus Concentrations in Lake 410 with Supplemental Mitigation



mg/L = milligrams per litre

The modelled phosphorus increases in Lake 410 during operations and closure (Table 9.8-7 and Figure 9.8-13) were developed assuming mitigation strategies for the Fine PKC Facility described in Section 9.8.2.2.

Potential Effects of Nutrient Enrichment

Phosphorus is generally a limiting nutrient in freshwater systems, so its concentration can be used to determine trophic status. Based on peak phosphorus concentrations of 0.007 mg/L projected for operations and post-closure, a slight increase in primary productivity would be expected in Lake 410. However, the trophic status of Lake N11 would remain oligotrophic (i.e., 0.004 to 0.010 mg/L; Environment Canada 2004; CCME 2004), as it is under baseline conditions.

Trace Metals

Concentrations of trace metals are predicted to generally follow the same trends as TDS, increasing during the operational phase due to discharges to Lake N11, declining during the closure phase, then increasing in post-closure when Kennady Lake is reconnected to Area 8. The predicted behavior of metals in Lake 410 can be further classified into those that demonstrate little change, those that increase and return to near-background conditions and those that increase in the long-term.

Trace Metals with Little or No Increase in Predicted Concentrations

Of the 23 modelled metals, 12 are predicted to have small increases in concentration (i.e., maximum concentrations less than twice as high as baseline) in Lake 410. These metals are aluminum, barium, beryllium, cadmium, cobalt, copper, iron, lead, manganese, mercury, nickel and zinc. These metals are generally predicted to return to near-background conditions in the long-term. A representative timeseries plot is shown in Figure 9.8-14 for zinc. Cadmium is the only metal predicted to exceed guidelines in Lake 410, and the guideline exceedance is due to baseline concentrations.

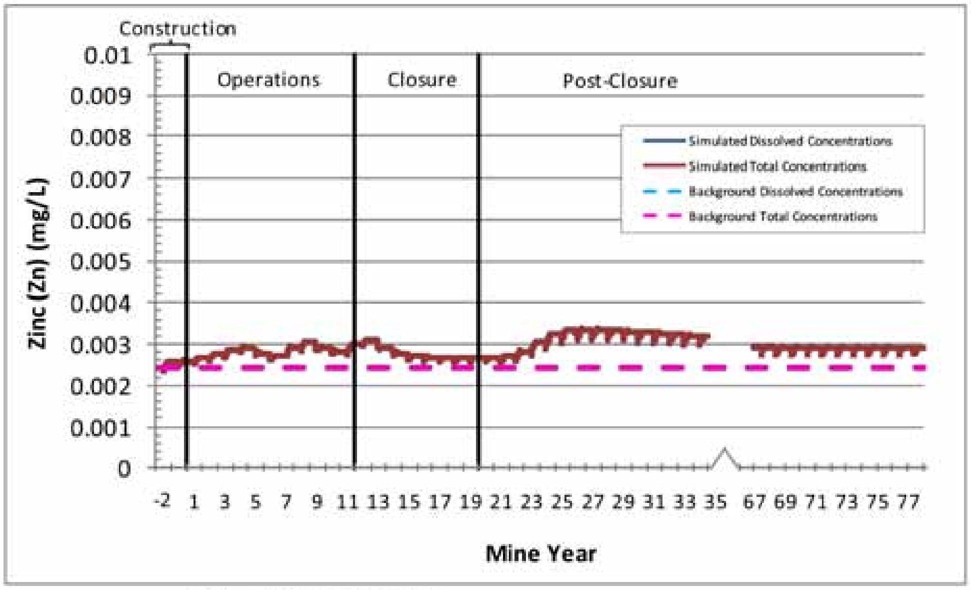
Trace Metals that are Predicted to Follow Similar Trends to TDS

Three metals are predicted to increase well above baseline conditions during the operational and closure phases, but return to near-background conditions in the long-term. These metals are predicted to behave similar to TDS and the major ions. These metals are chromium, selenium and thallium. A representative timeseries plot is shown in Figure 9.8-15 for chromium.

Trace Metals that are Predicted to Increase in the Long-term

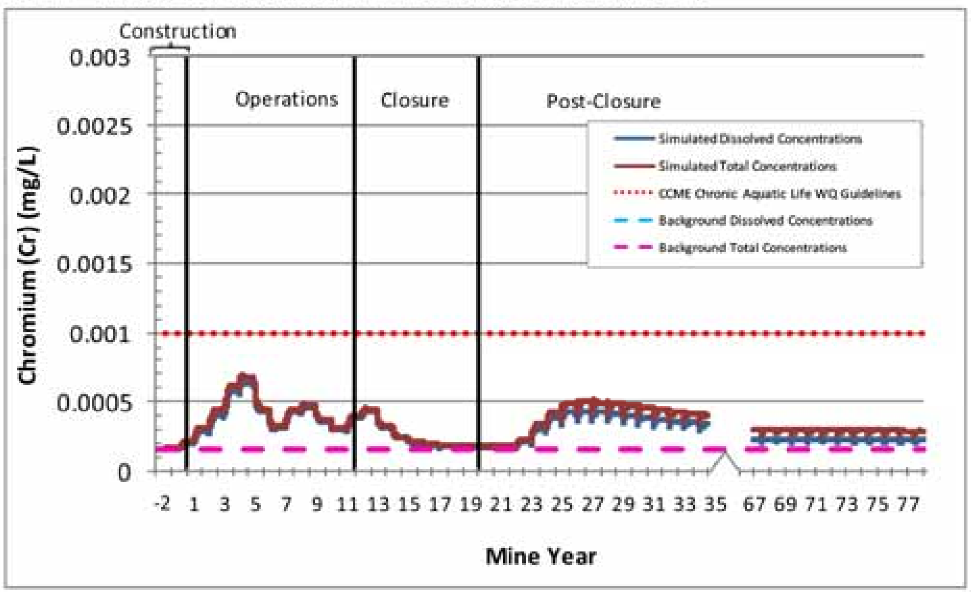
Eight metals are predicted to increase and reach long-term steady state concentrations more than double baseline concentrations. These metals are antimony, arsenic, boron, molybdenum, silver, strontium, uranium and vanadium. None of these metals are predicted to exceed guidelines at any time. A representative timeseries plot is shown in Figure 9.8-16 for molybdenum.

Figure 9.8-14 Predicted Zinc Concentrations in Lake 410



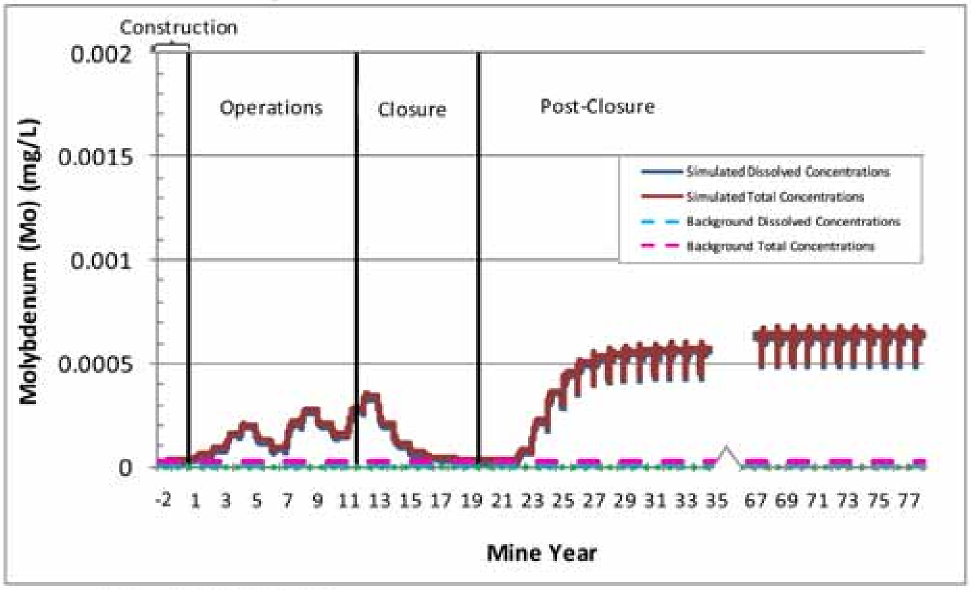
mg/L = milligrams per litre

Figure 9.8-15 Predicted Chromium Concentrations in Lake 410



mg/L = milligrams per litre

Figure 9.8-16 Predicted Molybdenum Concentrations in Lake 410



mg/L = milligrams per litre

The potential health effects of all trace metals on aquatic life are assessed in Section 9.9.

9.9 EFFECTS TO AQUATIC HEALTH

9.9.1 Introduction

This section assesses the potential for effects to the health of aquatic life (referred to herein as aquatic health) in waterbodies downstream of Kennady Lake resulting from the modelled changes in water quality that were presented in Section 9.8. A summary of the valid pathways by which changes to aquatic health could occur during construction and operation is presented in Table 9.9-1 and a summary of those during closure is presented in Table 9.9-2.

Table 9.9-1 Valid Pathways and Effects Statements for Effects to Aquatic Health during Construction and Operation

Project Component	Pathway	Effects Statement	Effects Addressed
Dewatering of Kennady Lake to downstream waterbodies	dewatering of Kennady Lake to Lake N11 may change water quality and thus affect aquatic health in downstream waterbodies	effects of project activities to aquatic health in downstream waters	Section 9.9.3.1

Table 9.9-2 Valid Pathways and Effects Statements for Effects to Aquatic Health during Closure

Project Component	Pathway	Effects Statement	Effects Addressed
Removal and reclamation of Project infrastructure	seepage from mine rock and processed kimberlite (PK) storage repositories, and the open Tuzo Pit may change water quality and thus affect aquatic health in downstream waterbodies	effects of project activities to aquatic health in downstream waters	Section 9.9.3.1
	reclaimed project area may result in long-term changes to water quality and thus affect aquatic health in downstream watersheds		

Based on the primary pathway, two scenarios were assessed:

- Water quality in Lake N11 during construction, operation, and closure. This scenario summarizes the maximum concentrations of substances in Lake N11 after Kennady Lake is dewatered during construction, during mine operations when mine-affected water from the Water Management Pond (WMP) is discharged to Lake N11, and during closure when water is withdrawn from Lake N11 to refill Kennady Lake.

- Water quality in Lake 410 during construction, operations, and closure. This scenario summarizes the overall effect to Lake 410 as a result of project activities (expressed as maximum concentrations of substances).

A similar assessment for the interlakes was not explicitly undertaken, because, as discussed in Section 9.8, water quality in the interlakes (the chain of lakes within the L and M watersheds) is predicted to be similar to that in Area 8, although parameters concentrations will gradually decline with distance downstream due to dilution. Results of the aquatic health assessment completed for Area 8 concluded that Project activities were predicted to result in negligible effects to aquatic health, with follow-up monitoring being recommended to confirm these results (see Section 8.9). As such, the conclusions and recommendations put forward for Area 8 apply to the interlakes as well, negating the need for a separate, explicitly aquatic health analysis of conditions in the interlakes.

9.9.2 Methods

9.9.2.1 Effect of Project Activities on Aquatic Health Downstream of Kennady Lake

Predicted changes to water quality could affect aquatic health through two exposure pathways:

- direct exposure to substances in the water column; and,
- indirect effects related to possible accumulation of substances within fish tissue via uptake from both water and diet.

Both mechanisms were evaluated as part of the aquatic health assessment. Potential effects related to direct exposure were evaluated based on modelled water quality in Lake N11 and Lake 410 during construction, operation, and closure (Section 9.9.2.1.1). Predicted water concentrations were compared with chronic effects benchmarks (CEBs) to evaluate the potential for aquatic health effects due to direct waterborne exposure. The analysis of indirect effects to fish tissue quality was conducted by using measured baseline water quality, modelled water quality, and measured fish tissue concentrations to predict tissue concentrations of chemicals within aquatic organisms (Section 9.9.2.2.2). Predicted tissue concentrations were compared with toxicological benchmarks to evaluate the potential for aquatic health effects related to tissue concentrations. The methods used for both evaluations are outlined in more detail below.

9.9.2.1.1 *Direct Waterborne Exposure*

Changes to water quality in Lake N11 and Lake 410 during construction, operation, and closure were predicted using a dynamic water quality model following the methods described in Section 9.8.2 and Appendix 9.I. The resulting modelled water quality results were passed through a screening procedure to identify substances of potential concern (SOPCs), which are substances for which the modelled concentrations were higher than those observed under baseline conditions and that were also higher than relevant and applicable water quality guidelines for the protection of aquatic life. To assess whether the SOPCs have the potential to affect aquatic health under the evaluated scenarios, modelled concentrations of these substances were compared to CEBs, which were derived from a review of available toxicological literature.

The screening procedure used to identify an SOPC was a three-step process. The first step (Step 1) in the process involved assessing which of the modelled parameters had the potential to detrimentally affect aquatic health and which parameters could be excluded from further consideration for one of the following reasons:

- the parameter in question has been shown to have limited potential to affect aquatic health (i.e., innocuous substances);
- potential effects related to the parameter in question are assessed elsewhere in the environmental impact statement (EIS); and/or
- the parameter in question is a component of another parameter, which is a more suitable focus point for the analysis.

Parameters excluded during the first step of the screening process consisted of:

- sodium, based on work by Mount et al. (1997), which indicates that this substance has low toxicity to aquatic life;
- phosphorus and nitrogen compounds as nutrients, because potential effects related to increased nutrient levels are assessed in Section 9.10.2 (however, nitrate and ammonia were screened for toxicity effects using water quality guidelines for the protection of aquatic life);
- calcium, chloride, magnesium, sulphate, and potassium, because they are individual ions for which Canadian protection of aquatic life guidelines have not yet been established and they are components of

total dissolved solids (TDS), another modelled parameter included in the assessment; and,

- the dissolved form of metals, metalloids and non-metals[1], because they are a component of the corresponding total metal concentrations and total metal measurements are a more conservative basis for assessment than dissolved metals measurements.

The remaining substances, which included total metals, total suspended solids (TSS), and TDS, were subjected to a screening process, which involved comparing predicted maximum concentrations with:

- baseline water quality concentrations (Step 2); and,
- Canadian water quality guidelines for the protection of aquatic life (CCME 1999a) (Step 3).

Step 2 recognized that existing concentrations may also exceed water quality guidelines. If the predicted concentration was less than or within 10 percent (%) of the long-term average concentration under baseline conditions, then the parameter was excluded from the assessment, because no incremental impact on aquatic health would be expected. A difference of less than or equal to 10% was not considered to be a change that would represent a potential effect to water quality, because:

- analytical uncertainty can be as high as, or higher than, 10%, depending on the individual parameter in question;
- a difference of less than 10% is unlikely to be statistically significant; for example, with a sample size of less than 200, the 95% confidence interval of the mean of a normally distributed variable with a typical coefficient of variation of 0.6 will be greater than 10%; and
- effects to aquatic organisms are unlikely to be detectable for a change in a substance concentration of less than 10%.

Step 3 involved a comparison to water quality guidelines to determine whether substances with guidelines have the potential to affect aquatic health. For SOPCs with guidelines that were dependent on pH (i.e., aluminum) or hardness (i.e., cadmium, copper, lead, nickel), the predicted pH or hardness associated with those SOPC concentrations were used in the screening. For chromium, which has a guideline that is dependent on speciation, the most conservative

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

guideline was used (i.e., hexavalent chromium) although it is assumed that most of the chromium will be present as trivalent chromium (see Section 8.8.4.1.1).

Water quality guidelines represent levels that, if met in any surface water, will provide a high level of protection to aquatic life. In this assessment, the *Canadian Water Quality Guidelines for the Protection of Aquatic Life* were used; these conservative guidelines are intended to "protect all forms of aquatic life and all aspects of the aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term" (CCME 1999a). That is, exceedance of a water quality guideline indicates the possibility of adverse effects, but not necessarily a likelihood. At this stage in the screening process, parameters without guidelines were identified as SOPCs, with the exception of those specifically excluded above.

For each SOPC, predicted concentrations were compared to CEBs. The CEBs were developed using species sensitivity distributions (SSDs) whenever sufficient toxicity data were available. In the absence of sufficient data, CEBs were defined using the lowest chronic toxicity test value available for species relevant to the Gahcho Kué Project (Project) area. The toxicity database excluded non-resident species, which improved the relevance of the CEBs to the receiving environment of Kennady Lake and the downstream lakes.

The CEBs represent substance concentrations above which changes to aquatic health could occur on the scale of individual organisms. The benchmarks are less conservative (i.e., more realistic) than water quality guidelines, but retain a level of conservatism for the evaluation of population-level effects, which would require concentrations to be higher than the CEBs described herein. Consequently, the CEBs are considered to be conservative thresholds by which potential effects to aquatic health can be assessed. Further detail as to the methods used to derive the CEBs is provided in Appendix 8.IV.

9.9.2.1.2 *Indirect Exposure - Changes to Fish Tissue Quality*

In addition to assessing potential effects to aquatic health due to direct waterborne exposure, potential effects due to changes in fish tissue quality were assessed. Potential changes to fish tissue concentrations in Lake N11 and Lake 410 were estimated by multiplying predicted maximum concentrations in water by parameter-specific bioaccumulation factors (BAFs). Only those parameters for which toxicological benchmarks could be defined were considered. These parameters, hereafter called substances of interest (SOI), were:

- aluminum
- antimony
- arsenic
- cadmium
- chromium
- copper
- lead
- mercury
- nickel
- selenium
- silver
- vanadium
- zinc

Site-specific BAFs for each SOI were derived for each lake and fish species using water quality concentrations and fish tissue concentrations measured during the baseline sampling programs. The lake- and species-specific BAFs were calculated using the following formula:

$$BAF_{(lake,\ species)} = C_{Fish} \div C_{Water}$$

where:

$BAF_{(lake,\ species)}$ = bioaccumulation factor for a specific lake and fish species

C_{Fish} = concentration of substance "x" in fish (milligrams per kilogram wet weight [mg/kg wet wt])

C_{Water} = concentration of substance "x" in water (mg/L).

The term C_{Water} was set to the median concentration observed in the water quality samples collected from the lake being considered. Given that water quality in the study lakes was similar among years, all available baseline water quality data were pooled and overall median water concentrations were calculated. The term C_{Fish} was similarly set to the median concentration observed in fish muscle tissue samples collected from either Kennady Lake, Lake N16, Kirk Lake, or Lake 410. All non-detectable tissue concentration results were set to the corresponding detection limit, which resulted in conservative multiplication factors.

Bioaccumulation factors were derived based on concentrations of substances measured in muscle tissue of lake trout and round whitefish. Only whole-body concentration data were available for slimy sculpin, and these were not included in BAF derivation based on the following rationale:

- The primary concern in terms of potential effects on fish health is large-bodied fish such as lake trout and round whitefish. These species are abundant in the lakes downstream of Kennady Lake, form a key component of the lake ecosystem, and are fished for consumption. Slimy sculpin are small-bodied, benthic feeding fish that are not abundant in the study lakes and are not fished. During the baseline sampling program in 2007, sculpin had to be collected from the outlet creeks of the lakes to obtain sufficient sample for tissue analysis.
- Analysis of whole body samples of sculpin unavoidably leads to the inclusion of gut contents in the analysis, and this can give unreliable measurements of the actual concentrations of substances in the tissues of the sculpin. Sculpin are benthic feeding fish that have a relatively high potential to ingest sediment with their prey. Thus, by including gut contents, whole body measurements can result in artificially inflated measurements of metals that are abundant in mineral sediments (e.g., aluminum), due to the inclusion of prey and incidentally-ingested sediment in the gut in the analysis.

The whole-body sculpin tissue concentrations of several metals, including aluminum and several other substances abundant in mineral sediments, were substantially higher than concentrations measured in lake trout and round whitefish (Annex J, Fisheries and Aquatic Resources Baseline). The concentrations measured in sculpin whole body analyses are therefore considered most likely to be artefactual (i.e., reflecting the inclusion of sediment and prey in the gut), and not an accurate representation of the accumulation of these substances in fish tissue. Inclusion of the sculpin whole body concentration data in the BAF analysis would result in unrealistic estimates of tissue concentrations in fish. Therefore, the sculpin data were excluded and the BAF analysis was based on lake trout and round whitefish.

The lake- and species-specific BAFs were categorized by level of reliability based on the frequency of detections in the water and tissue data. The BAFs calculated from water and tissue concentrations with high detection frequencies were considered the most reliable BAFs, and therefore were selected preferentially over less reliable BAFs. The reliability criteria were:

- If both water and tissue concentrations were frequently detected, then the resulting BAF was considered to be the most reliable;

- If water was detected frequently, but tissue was not, then the resulting BAF was considered to be less reliable, but still an acceptable upper-bound estimate (i.e., likely a conservative over-estimate) for the purposes of this assessment;
- If water was infrequently detected, and tissue was frequently detected, then the resulting BAF was considered less reliable and a potentially lower-bound estimate for the purposes of this assessment; and
- If both water and tissue were infrequently detected, then the resulting BAF was considered to be unreliable and was not used in this assessment.

The BAFs for each SOI used in the indirect exposure assessment are summarized in Table 9.9-3.

Table 9.9-3 Selected Bioaccumulation Factors for the Indirect Exposure Assessment

Substance of Interest	Selected Bioaccumulation Factor	Reliability Category
Aluminum	278	less reliable; upper-bound estimate
Antimony	2729	less reliable; upper-bound estimate
Arsenic	417	less reliable; upper-bound estimate
Cadmium	237	less reliable; lower-bound estimate
Chromium	78	most reliable
Copper	839	most reliable
Lead	80	less reliable; upper-bound estimate
Mercury	9450	less reliable; lower-bound estimate
Nickel	232	most reliable
Selenium	3000	less reliable; lower-bound estimate
Silver	2000	less reliable; upper-bound estimate
Vanadium	95	most reliable
Zinc	379	most reliable

Predicted fish tissue metal concentrations were compared to toxicological benchmarks that have been shown in laboratory studies to be associated with sublethal effects in fish. Jarvinen and Ankley (1999) provide a database linking effects on aquatic organisms and concentrations of inorganic and organic chemicals in various fish tissues. Both acute and chronic effect-endpoints for a range of species and trophic levels are provided in the database. Occasionally, only lethal endpoints were available. A summary of the Jarvinen and Ankley (1999) endpoints that were relevant to the current assessment is provided in Table 9.9-4.

Table 9.9-4 Fish Tissue Effects Concentrations

Substance of Interest	Effects Concentration (mg/kg wet weight)	Endpoint	Tissue	Fish, Age/Size
Aluminum	20	survival – reduced	whole body	Atlantic salmon, alevin
	<8	growth – no effect		
	1.15	survival – no effect	muscle	rainbow trout, 171 g
Antimony	9.0	survival – reduced 50%	whole body	rainbow trout, fingerling
	5.0	survival – no effect		
Arsenic	11.2	survival – reduced	carcass	rainbow trout, juvenile
	6.1	survival, growth – no effect		
	3.1	growth – reduced		
Cadmium	2.8	survival, growth – no effect	muscle	rainbow trout, adult
	0.6	reproduction – reduced	muscle	
	0.4	reproduction – no effect	muscle	
Chromium	0.58	survival – no effect	muscle	rainbow trout, 150 to 200 g
Copper	3.4	survival, growth, reproduction – no effect	muscle	brook trout, embryo, adult, juvenile
	0.5	survival – no effect	muscle	rainbow trout, 138 g
Lead	4.0	survival – no effect	carcass	rainbow trout, under-yearlings
	2.5 to 5.1	growth – no effect	whole body	brook trout, embryo – juvenile
Mercury	5.8	survival – no effect growth – reduced	muscle	chum salmon, fry, juvenile
	5.0	growth, survival – no effect	whole body	rainbow trout, juvenile
	0.8	growth – no effect	whole body	fathead minnow, adult
Nickel	118.1	survival – reduced 50%	white muscle	carp, 15 g
	58.0	survival – no effect	white muscle	freshwater carp, 15 g
	0.82	survival – no effect	muscle	rainbow trout, 150 to 200 g
Silver	0.06	survival, growth – no effect	whole body	bluegill, young-of-the-year
	0.003	survival, growth – no effect	carcass	largemouth bass, young-of-the-year
Vanadium	5.33	survival – no effect	carcass	rainbow trout, juvenile
	0.41	growth – reduced		
	0.02	growth – no effect		
Zinc	60	survival, growth – no effect	whole body	Atlantic salmon, juvenile
	4.5	survival, growth – no effect	whole body	brook trout, embryo-larvae

Source: Jarvinen and Ankley (1999).

mg/kg = milligrams per kilogram; < = less than; g = gram; % = percent.

Benchmarks were selected from the Jarvinen and Ankley (1999) database to represent levels beyond which detrimental effects (e.g., reduced growth or reproductive success) may occur. However, for some SOIs, available information was limited to no observed effect concentrations (NOECs). The parameters for which only NOECs were available were arsenic, chromium, copper, lead, mercury, nickel, silver, and zinc. The tissue-based NOECs are similar to most water-based no-effect thresholds in that concentrations less than a NOEC are not considered likely to lead to detrimental effects, whereas the opposite is not necessarily true (i.e., concentrations in excess of NOECs will not necessarily result in detrimental effects). This resulted in benchmarks that were overly conservative estimates of effects thresholds, and predicted fish tissue concentrations were interpreted with this limitation in mind.

Although the Jarvinen and Ankley (1999) database includes information for selenium, the selenium threshold used herein originates from the United States Environmental Protection Agency (US EPA 2004), which represents a more up-to-date assessment of potential effects of selenium on fish health. The threshold derived from the US EPA (2004) data was evaluated by a review of more recent selenium toxicity studies with coldwater fish (Holm et al. 2005, Muscatello et al. 2006, Rudolph et al. 2008, McDonald et al. 2010) and was determined to be an appropriately protective benchmark for fish species that occur in the study area.

9.9.3 Results

9.9.3.1 Effect of Project Activities on Aquatic Health Downstream of Kennady Lake

9.9.3.1.1 Direct Waterborne Exposure

Based on the three-step screening process described in Section 9.9.2.2.1, 11 SOPCs were identified in Lake N11 during construction, operation, and closure (Table 9.9-5):

- TDS
- antimony
- barium
- beryllium
- cadmium
- chromium
- cobalt
- manganese
- strontium
- uranium
- vanadium

Based on the three-step screening process described in Section 8.9.2.2.1, ten SOPCs were identified in Lake 410 during construction, operation, and closure (Table 9.9-6):

- TDS
- antimony
- barium
- beryllium
- cadmium
- cobalt
- manganese
- strontium
- uranium
- vanadium

A summary of the SOPCs identified at each assessment point is presented in Table 9.9-7.

Table 9.9-5 Initial Screening Results for Lake N11 during Construction, Operation, and Closure

Parameter	Background Concentrations (Long-term Average) (mg/L)	CCME Freshwater Aquatic Life Guideline (mg/L)[a]	Predicted Maximum Concentration (mg/L)	Screening		Retained as Substance of Potential Concern?
				Higher than Predicted Background + 10%?	Higher than CCME Guideline?	
Conventional Parameters						
Total Dissolved Solids	16	-	46	yes	-	**yes**
Total Suspended Solids	<2[b]	5[c]	1.0	no	no	no
Nutrients						
Ammonia as Nitrogen	0.019	4.5[d]	1.7	yes	no	no
Nitrate as Nitrogen	<0.007[b]	2.9	1.6	yes	no	no
Total Metals						
Aluminum	0.019	0.1[e]	0.026	yes	no	no
Antimony	0.000062	-	0.00053	yes	-	**yes**
Arsenic	0.00012	0.005	0.00041	yes	no	no
Barium	0.0027	-	0.017	yes	-	**yes**
Beryllium	0.000064	-	0.000072	yes	-	**yes**
Boron	0.0017	1.5	0.023	yes	no	no
Cadmium	0.000019	0.000010[f]	0.000022	yes	yes	**yes**
Chromium	0.00016	0.001[g]	0.0016	yes	yes	**yes**
Cobalt	0.00019	-	0.00023	yes	-	**yes**
Copper	0.0013	0.002[f]	0.0015	yes	no	no
Iron	0.059	0.3	0.13	yes	no	no
Lead	0.000061	0.001[f]	0.00012	yes	no	no
Manganese	0.0057	-	0.019	yes	-	**yes**
Mercury	0.0000051	0.000026	0.0000079	yes	no	no
Molybdenum	0.00003	0.073	0.00073	yes	no	no
Nickel	0.00047	0.025[f]	0.00096	yes	no	no
Selenium	0.000032	0.001	0.00021	yes	no	no
Silver	0.0000081	0.0001	0.000022	yes	no	no
Strontium	0.0069	-	0.015	yes	-	**yes**
Thallium	0.000014	0.0008	0.000072	yes	no	no
Uranium	0.000016	-	0.00033	yes	-	**yes**
Vanadium	0.000094	-	0.00078	yes	-	**yes**
Zinc	0.0024	0.03	0.0038	yes	no	no

(a) From CCME (1999a).
(b) Median detection limit.
(c) Guideline is dependent on background concentration: predicted concentration must not be more than 5 mg/L higher than the background concentration.
(d) Guideline is dependent on temperature and pH. The value is based on pH = 7.0, temperature = 18°C.
(e) Aluminum guideline is dependent on pH; guideline shown is for pH ≥6.5, which corresponds to expected conditions in Kennady Lake.
(f) Guideline is hardness dependant; value shown based on a maximum predicted hardness of 25 mg/L as calcium carbonate ($CaCO_3$).
(g) Guideline is for hexavalent chromium (CrVI), because it is more stringent than the trivalent chromium (CrIII) guideline of 0.0089 mg/L.

mg/L = milligrams per litre; % = percent; < = less than; - = no guideline available or predicted concentration was less than the observed maximum background.

Table 9.9-6 Initial Screening Results for Lake 410 during Construction, Operation, and Closure

Parameter	Background Concentrations (Long-term Average) (mg/L)	CCME Freshwater Aquatic Life Guideline (mg/L)[a]	Predicted Maximum Concentration (mg/L)	Screening		Retained as Substance of Potential Concern?
				Higher than Predicted Background + 10%?	Higher than CCME Guideline?	
Conventional Parameters						
Total Dissolved Solids	16	-	29	yes	-	**yes**
Total Suspended Solids	<2[b]	5[c]	1.0	no	no	no
Nutrients						
Ammonia as Nitrogen	0.019	4.5[d]	0.62	yes	no	no
Nitrate as Nitrogen	<0.007[b]	2.9	0.61	yes	no	no
Total Metals						
Aluminum	0.019	0.1[e]	0.026	yes	no	no
Antimony	0.000062	-	0.00031	yes	-	**yes**
Arsenic	0.00012	0.005	0.00043	yes	no	no
Barium	0.0027	-	0.027	yes	-	**yes**
Beryllium	0.000064	-	0.000079	yes	-	**yes**
Boron	0.0017	1.5	0.077	yes	no	no
Cadmium	0.000019	0.0000056[f]	0.000024	yes	yes	**yes**
Chromium	0.00016	0.001[g]	0.00070	yes	no	no
Cobalt	0.00019	-	0.00023	yes	-	**yes**
Copper	0.0013	0.002[f]	0.0016	yes	no	no
Iron	0.059	0.3	0.092	yes	no	no
Lead	0.000061	0.001[f]	0.000091	yes	no	no
Manganese	0.0057	-	0.011	yes	-	**yes**
Mercury	0.0000051	0.000026	0.0000067	yes	no	no
Molybdenum	0.00003	0.073	0.0016	yes	no	no
Nickel	0.00047	0.025[f]	0.00084	yes	no	no
Selenium	0.000032	0.001	0.000099	yes	no	no
Silver	0.0000081	0.0001	0.000017	yes	no	no
Strontium	0.0069	-	0.030	yes	-	**yes**
Thallium	0.000014	0.0008	0.000036	yes	no	no
Uranium	0.000016	-	0.00019	yes	-	**yes**
Vanadium	0.000094	-	0.00047	yes	-	**yes**
Zinc	0.0024	0.03	0.0034	yes	no	no

(a) From CCME (1999a).

(b) Median detection limit.

(c) Guideline is dependent on background concentration; predicted concentration must not be more than 5 mg/L higher than the background concentration.

(d) Guideline is dependent on temperature and pH. The value is based on pH = 7.0, temperature = 18°C.

(e) Aluminum guideline is dependent on pH; guideline shown is for pH ≥6.5, which corresponds to expected conditions in Kennady Lake.

(f) Guideline is hardness dependant; value shown based on a maximum predicted hardness of 13 mg/L as calcium carbonate ($CaCO_3$).

(g) Guideline is for hexavalent chromium (CrVI), because it is more stringent than the trivalent chromium (CrIII) guideline of 0.0089 mg/L.

mg/L = milligrams per litre; % = percent; < = less than; - = no guideline available or predicted concentration was less than the observed maximum background.

Table 9.9-7 Summary of Substances of Potential Concern Identified in Lake N11 and Lake 410 during Modelled Scenarios

Parameter[a]	Lake N11	Lake 410
	Construction, Operation, and Closure	Construction, Operation, and Closure
Conventional Parameters		
Total Dissolved Solids	√	√
Total Suspended Solids		
Nutrients		
Ammonia		
Nitrate		
Total Metals		
Aluminum		
Antimony	√	√
Arsenic		
Barium	√	√
Beryllium	√	√
Boron		
Cadmium	√	√
Chromium	√	
Cobalt	√	√
Copper		
Iron		
Lead		
Manganese	√	√
Mercury		
Molybdenum		
Nickel		
Selenium		
Silver		
Strontium	√	√
Thallium		
Uranium	√	√
Vanadium	√	√
Zinc		

(a) Checkmark (√) indicates that the substance in question was identified as a substance of potential concern.

For the direct waterborne exposure assessment, CEBs were derived for the SOPCs. For TDS, the CEB took the form of a range of concentrations, which were derived based on a review of the applicable literature. For the remaining SOPCs, single point benchmarks were identified, following the approach outlined in Appendix 8.IV. The predicted water concentrations summarized in Tables 9.9-5 and 9.9-6 were compared to the CEBs to conservatively evaluate the potential for adverse effects to aquatic health. The results of these comparisons are discussed below, beginning with TDS.

Total Dissolved Solids

Total dissolved solids was identified as an SOPC in Lake N11 and Lake 410 because of a projected increase in TDS concentrations over those that currently occur. The largest predicted increase occurs in Lake N11 during construction and operation, when TDS levels are predicted to increase from an existing maximum concentration of about 16 mg/L to a peak of 46 mg/L (Table 9.9-4). Water quality in Lake 410 during construction, operation, and closure will have a maximum concentration of 29 mg/L.

Total dissolved solids concentration (TDS) is a measurement of inorganic salts (e.g., sodium, potassium, calcium, magnesium, chloride, sulphate, and bicarbonate), organic matter, and other dissolved materials in water (Weber-Scannell and Duffy 2007). Toxicity can be caused by an increase in salinity, changes in ionic composition of the waters, or through toxicity of individual ions (Weber-Scannell and Duffy 2007). Sensitivity to TDS varies by species and is dependent on both the absolute concentration of all of the major ions contained in solution (effectively the absolute TDS concentration) as well as their relative abundance. In general, Mount et al. (1997) found that relative ion toxicity to freshwater species was potassium > bicarbonate = magnesium > chloride > sulphate, whereas calcium and sodium did not cause significant toxicity. However, ratios of particular TDS constituents, such as the ratio of calcium to sodium, may affect toxicity (Goodfellow et al. 2000). Species sensitivity may also vary with life stage; for example, fish embryos appear to be more sensitive if exposed before fertilization as opposed to after fertilization (Weber-Scannell and Duffy 2007). There is a very wide range of TDS and major ion concentrations in natural waterbodies. As a result of the significant variations in sensitivity of aquatic organisms and large range of concentrations in natural waterbodies, water quality guidelines have not been established in Canada for TDS or most major ions.

Background TDS in the lakes is a mixture of calcium, chloride, magnesium, potassium, sodium, and sulphate, with calcium being slightly more abundant than the other ions. During construction, operation, and closure, the ionic composition of the waters in Lake N11 and Lake 410 will be dominated by chloride, followed by calcium.

Toxicity data on the effects of TDS on freshwater species indicate that aquatic life in Lake N11 and Lake 410 will be largely unaffected by the projected increase in salinity. Beadle (1969), as cited in Bierhuizen and Prepas (1985), noted that freshwater species tend to be routinely found in waters with TDS levels of less than 1,000 mg/L, whereas they start to disappear when TDS levels exceed 3,000 mg/L (Hammer et al. 1975).

Adverse effects to fish are not expected at the predicted TDS concentrations in Lake N11 and Lake 410. Optimal habitat for northern pike (*Esox lucius*), one of the fish species present in the study area, includes TDS concentrations in the range of 80 to 800 mg/L (US FWS 1982). Northern pike and other freshwater fish species can be found in environments with higher TDS concentrations. For example, Buffalo Lake, which is located near Stettler, Alberta, has a moderate salinity (i.e., TDS concentrations around 1,500 mg/L) and contains northern pike, along with white suckers (*Catostomus commersonii*) and burbot (*Lota lota*) (University of Alberta 2008).

Most of the laboratory studies with fish embryos and swim-up fry have been conducted with TDS mixtures dominated by calcium and sulphate (e.g., Chapman et al. 2000, Stekoll et al. 2003, Brix et al. 2010). There were no adverse effects on early life stages of rainbow trout (*Oncorhynchus mykiss*) after seven days exposure to 2,000 mg/L TDS (Chapman et al. 2000). Brix et al. (2010) found no significant effects of elevated TDS on fertilization success and reported a 72-h EC20 of >2,782 mg/L for Arctic grayling (*Thymallus arcticus*) and a 24-h EC20 of >1,817 mg/L for Dolly Varden (*Salvelinus malma*). However, embryo water absorption was affected in 14-h exposures, with LOECs of 1,402 mg/L for Arctic grayling and 964 mg/L for Dolly Varden. Stekoll et al. (2003) found that salmonid embryos were most sensitive to TDS when exposed during fertilization: the 24-h LOECs ranged from 250 to 1,875 mg/L. Brannock et al. (2002) found that calcium chloride and sodium sulphate had the most detrimental effect on fertilization rates in king salmon (*Oncorhynchus tshawytscha*) and pink salmon (*Oncorhynchus gorbuscha*). As predicted closure concentrations in Lake N11 and Lake 410 are below these levels, negligible effects to fish health are expected.

Potential effects to pelagic invertebrates also are not expected to occur. Most of the TDS toxicity data are from studies with cladocerans, such as *Ceriodaphnia dubia*, and *Daphnia magna*, because these species are common laboratory test organisms. Predicted ion concentrations and TDS levels are lower than toxic thresholds identified by Cowgill and Milazzo (1990) for these species (i.e., 1,200 mg/L sodium chloride [NaCl]). Predicted concentrations are also lower than the 48-h LC50s reported by Mount et al. (1997) for *Ceriodaphnia dubia* for solutions containing a mixture of ions, including sodium, sulphate, bicarbonate, calcium, chloride and magnesium (i.e., 1,510 to greater than 5,700 mg/L). Although neither of these cladocerans may be present in the study area, they are recognized as being among the most sensitive invertebrates for a wide range of substances. For example, *Daphnia magna* and *Ceriodaphnia dubia* are more sensitive to calcium chloride than copepods (Baudouin and Scoppa 1974). As the predicted TDS and major ion concentrations in Kennady Lake and Area 8 are expected to be below the levels associated with effects in the literature, negligible effects to pelagic invertebrates are expected.

Toxicity data specific to benthic invertebrates indicate that benthic invertebrate populations in Lake N11 and Lake 410 will be largely unaffected by the projected increase in salinity. Chapman et al. (2000) reported a 10-d LOEC of 1,750 mg/L for survival of *Chironomus tentans* exposed to synthetic TDS mixtures (TDS consisted mainly of calcium sulphate). Hynes (1990) described no effects on the benthic invertebrate community of a lake in northern Saskatchewan receiving treated uranium mill effluent where TDS levels increased from 76 to 2,700 mg/L. The major ions primarily responsible for this increase were calcium, sodium, chloride, and sulphate. No statistically significant decreases in abundance or species diversity were observed in the affected lake relative to reference conditions. Based on the above, predicted changes to major ion levels and TDS concentrations in Lake N11 and Lake 410 are expected to have a negligible effect on aquatic health.

Remaining Parameters

In addition to TDS, 10 other SOPCs were identified in one or more of the assessment scenarios for direct waterborne exposure:

- antimony
- barium
- beryllium
- cadmium
- chromium
- cobalt
- manganese
- strontium
- uranium
- vanadium

During closure, maximum concentrations of all SOPCs are predicted to remain below the CEB identified for each substance, as shown in Table 9.9-8. As a result, the predicted increases in the concentrations of these ten substances are expected to have a negligible effect on aquatic health in Lake N11 and Lake 410 under the assessed conditions.

Table 9.9-8 Comparison of Maximum Concentrations to Chronic Effects Benchmarks for Selected Substances of Potential Concern

Substance of Potential Concern	Chronic Effect Benchmark (mg/L) [(a)]	Lake N11		Lake 410
		Maximum Concentration during Construction, Operation, and Closure (mg/L)		Maximum Concentration during Construction, Operation, and Closure (mg/L)
Antimony	0.157	0.00053		0.00031
Barium	5.8	0.017		0.027
Beryllium	0.0053	0.000072		0.000079
Cadmium	0.000088 [(b)]	0.000022		0.000024
Chromium	0.0083 [(c)]	0.0016		- [(d)]
Cobalt	0.0093	0.00023		0.00023
Manganese	1.455	0.019		0.011
Strontium	0.049	0.015		0.030
Uranium	0.015	0.00033		0.00019
Vanadium	0.0338	0.00078		0.00047

(a) Developed as outlined in Appendix 8.IV.

(b) The CEB for cadmium varies with hardness; the reported value is based on a hardness of 11 mg/L, which is the lowest predicted hardness of the three scenarios presented in this table.

(c) The CEB for chromium varies with speciation; the CEB for chromium (VI) is 0.0083 mg/L whereas the CEB for chromium (III) is 0.089 mg/L. Although it is anticipated that most chromium will be present as chromium (III) (Section 8.8.4.1.1), the more conservative CEB was used in the current assessment.

(d) - = parameter was not identified as a substance of potential concern (SOPC) at the scenario indicated.

mg/L = milligrams per litre.

9.9.3.1.2 Indirect Exposure - Changes to Fish Tissue Quality

Predicted fish tissue concentrations in Lake N11 and Lake 410 are below toxicological benchmarks for all parameters considered in the assessment (Tables 9.9-9 and 9.9-10). As a result, changes to water quality in waterbodies downstream of Kennady Lake are predicted to result in negligible effects to aquatic health.

Table 9.9-9 Predicted Metal Concentrations in Fish Tissues in Lake N11 during Construction, Operation, and Closure

Metal	Predicted Maximum Concentration (mg/L)	Bioaccumulation Factor	Estimated Fish Tissue Concentrations (mg/kg ww) [(a)]	Toxicological Benchmark (mg/kg ww)[(b)]
Aluminum	0.019	278	7.2	20
Antimony	0.000062	2729	1.4	9
Arsenic	0.00012	417	0.17	3.1
Cadmium	0.000019	237	0.0052	0.6
Chromium	0.00016	78	0.13	0.58
Copper	0.0013	839	1.3	3.4
Lead	0.000061	80	0.010	4.0
Mercury	0.0000051	9450	0.074 [(c)]	0.8
Nickel	0.00047	232	0.22	0.82
Selenium	0.000032	3000	0.63	2.58
Silver	0.0000081	2000	0.045	0.06
Vanadium	0.000094	95	0.075	0.41
Zinc	0.0024	379	1.4	60

(a) **Bolded** estimated fish tissue concentrations are greater than corresponding toxicological benchmark.

(b) Benchmarks originate from Jarvinen and Ankley (1999), with the exception of selenium; the selenium benchmark is based on data contained in US EPA (2004) expressed as wet weight assuming a moisture content of 76%.

(c) Mercury concentration in tissue increases with fish size. The largest lake trout captured during the baseline (789 mm) had mercury concentration in muscle tissue that was about three times higher than the median concentration. A predicted tissue concentration that is three times higher than that reported here would not exceed the toxicological benchmark, indicating that there is negligible risk of the predicted mercury water concentrations even to the largest fish.

mg/L = milligrams per litre; mg/kg ww = milligrams per kilogram wet weight.

Table 9.9-10 Predicted Metal Concentrations in Fish Tissues in Lake 410 during Construction, Operation, and Closure

Metal	Predicted Concentration (mg/L)	Bioaccumulation Factor	Estimated Fish Tissue Concentrations (mg/kg ww) [(a)]	Toxicological Benchmark (mg/kg ww) [(b)]
Aluminum	0.019	278	7.4	20
Antimony	0.000062	2729	0.85	9
Arsenic	0.00012	417	0.18	3.1
Cadmium	0.000019	237	0.0056	0.6
Chromium	0.00016	78	0.054	0.58
Copper	0.0013	839	1.3	3.4
Lead	0.000061	80	0.0072	4.0
Mercury	0.0000051	9450	0.063 [(c)]	0.8
Nickel	0.00047	232	0.19	0.82
Selenium	0.000032	3000	0.30	2.58
Silver	0.0000081	2000	0.034	0.06
Vanadium	0.000094	95	0.045	0.41
Zinc	0.0024	379	1.3	60

(a) **Bolded** estimated fish tissue concentrations are greater than corresponding toxicological benchmark.

(b) Benchmarks originate from Jarvinen and Ankley (1999), with the exception of selenium; the selenium benchmark is based on data contained in US EPA (2004) expressed as wet weight assuming a moisture content of 76%.

(c) Mercury concentrations in tissue increases with fish size. The largest lake trout captured during the baseline (789 mm) had mercury concentration in muscle tissue that was about three times higher than the median concentration. A predicted tissue concentration that is three times higher than that reported here would not exceed the toxicological benchmark, indicating that there is negligible risk of the predicted mercury water concentrations even to the largest fish.

mg/L = milligrams per litre; mg/kg ww = milligrams per kilogram wet weight; < = less than.

9.9.4 Sources of Uncertainty

Key sources of uncertainty in this aquatic health assessment were the data used to estimate exposure and effects.

The predicted water concentrations are a source of uncertainty in this aquatic health assessment and Section 9.8 outlines the assumptions used in the water quality modelling. To address this uncertainty, maximum predicted water concentrations were used as conservative estimates of the exposure concentrations for aquatic life in the lakes downstream of Kennady Lake.

The predicted tissue concentrations are a source of uncertainty in this aquatic health assessment. The predicted tissue concentrations were derived from predicted water concentrations and BAFs derived using baseline conditions. To address this uncertainty, maximum predicted water concentrations and the highest BAF for each SOI was used to calculate tissue concentrations, which provided a conservative estimate of predicted tissue concentrations.

A source of uncertainty in the effects assessment was that the potential for the predicted water concentrations to cause adverse effects on aquatic life in lakes downstream of Kennady Lake could not be assessed with site-specific toxicity data. There are no toxicity data for populations of aquatic life in the downstream lakes and toxicity data from the scientific literature were used as surrogates. In general, these toxicity data were based on studies with laboratory organisms tested under optimal culture conditions. Therefore, the use of literature-based data is a conservative approach to address this source of uncertainty. In the direct waterborne assessment, either the estimated hazard concentration above which 5% of the species would be affected or the lowest chronic toxicity value was used as the CEB. In the fish tissue quality assessment, the lowest tissue concentration related to an effect from waterborne exposure was used to assess effects. Finally, individual-level effects were used to judge the potential of effects on populations. These approaches provided conservatism to the effects assessment.