GAHCHO KUÉ PROJECT

ENVIRONMENTAL IMPACT STATEMENT

SECTION 9

KEY LINE OF INQUIRY: DOWNSTREAM WATER EFFECTS

December 2010 **09-1365-1004**

TABLE OF CONTENTS

SECTION **PAGE**

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

9 KEY LINE OF INQUIRY: DOWNSTREAM WATER EFFECTS

9.1 INTRODUCTION

9.1.1 Context

This section of the Environmental Impact Statement (EIS) for the Gahcho Kué Project (Project) consists solely of the key line of inquiry on downstream water effects. In the *Terms of Reference for the Gahcho Kué Environmental Impact Statement* (Terms of Reference) issued on October 5, 2007, the Gahcho Kué Panel (2007) defined this topic as a key line of inquiry based on the following concerns:

> *"The release of large quantities of water during the dewatering of Kennady Lake may have effects on downstream creeks and lakes. Large short-term increases in water flow will be followed by a substantial decrease over a longer period of time as the tertiary pit and lake are re-filling. In addition to fluctuations in lake water volume, Aboriginal communities are concerned about possible water contamination, their experience with older mines being mainly negative."*

The potential effects of the proposed Project on the aquatic environment are spread among three key lines of inquiry presented in EIS Sections 8, 9, and 10 of the EIS, as required by the Terms of Reference. The geographic extent of effects is divided into Kennady Lake (Section 8) and the streams and lakes downstream of Kennady Lake (Section 9). The temporal extent is spread across all three key lines of inquiry. The effects of the construction, operations, and closure phases are addressed in detail in Sections 8 and 9. Section 10 provides a comprehensive summary of the long-term effects on both Kennady Lake and downstream lakes and streams during closure and reclamation, and during post-closure. Although each section can be understood on its own (i.e., it is stand-alone), a holistic understanding of the effect of the Project on aquatic resources is provided by the three key lines of inquiry together.

The Key Line of Inquiry: Downstream Water Effects includes a detailed analysis of the changes to waterbodies located downstream of Kennady Lake as far downstream as effects from the Project are expected to be discernable. Potential cumulative effects are addressed from Kennady Lake downstream to Great Slave Lake.

This key line of inquiry overlaps substantially with the Subject of Note: Impacts on Great Slave Lake presented in Section 11.2 of the EIS. Other subjects of note address topics that may slightly overlap with this key line of inquiry. Where there is overlap between this key line of inquiry and another key line of inquiry or subject of note, information will be provided in both locations. Nevertheless, the key line of inquiry on downstream water effects will contain the primary substantive analysis of the effect of the Project on the streams and lakes downstream of Kennady Lake, including effects on aquatic life.

9.1.2 Purpose and Scope

The purpose of the Key Line of Inquiry: Downstream Water Effects is to meet the Terms of Reference for the EIS issued by the Gahcho Kué Panel. A table of concordance for this key line of inquiry and the Terms of Reference is provided in Table 9.1-1. The entire Terms of Reference document is included in Appendix 1.I and the complete table of concordance for the EIS is in Appendix 1.II of Section 1, Introduction of the EIS.

Effects are included for the construction (i.e., dewatering of Kennady Lake), operation, and closure and reclamation phases. These include, but are not limited to, direct effects on water quality and quantity, riparian vegetation, fish abundance and quality, and wildlife and human health.

9.1.3 Study Areas

9.1.3.1 General Location

The Project is situated at Kennady Lake, north of the East Arm of Great Slave Lake in the Northwest Territories (NWT), at Longitude 63° 26’ North and Latitude 109° 12’ West. The Project site is about 140 kilometres (km) northeast of the nearest community, Łutselk’e, and 280 km northeast of Yellowknife (Figure 9.1-1).

Kennady Lake is a small headwater lake within the Lockhart River system that discharges to the north, via a series of small lakes, into Kirk Lake and then into Aylmer Lake. Aylmer Lake is located on the mainstem of the Lockhart River, about midway along its length. The Lockhart River system drains into the East Arm of Great Slave Lake (Figure 9.1-1).

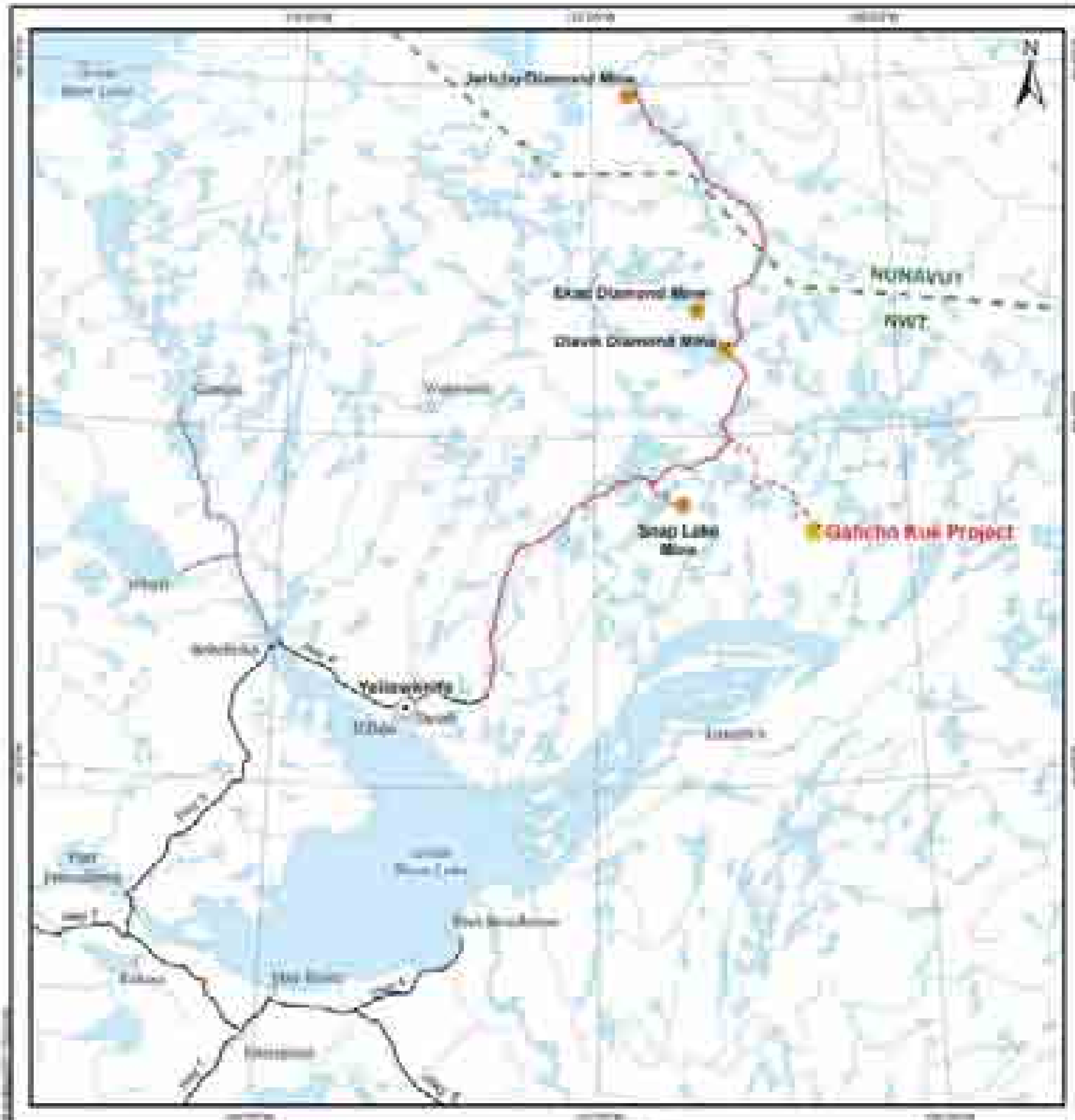
Table 9.1-1 Terms of Reference Pertaining to Downstream Water Effects

Terms of Reference Requirements		Applicable EIS Sub-section
Section	**Description**	
3.1.3 Physical Environment: Water Quality and Quantity	Describe all water bodies, watercourses and major drainage areas and watersheds potentially affected by the proposed development	9.3.2
	Describe existing water quality for each water body identified for use in the proposed development, and those immediately downstream	9.3, Annex I, Addendum II
	Describe existing groundwater resources in the Project area, including quality and quantity, flow patterns, recharge and discharge areas, and interactions with surface water	9.3
	Identify relevant federal, provincial, or territorial guidelines, criteria, or legislation	9.8
3.1.3 Existing Environment: Fish and Aquatic Life Forms	Describe fish-bearing waterbodies and watercourses that may be affected by the proposed development	9.3
	Describe potentially affected fish species and local populations, and for each describe:	
	- seasonal and life cycle movements;	9.3.5
	- habitat requirements for each life stage;	9.3.5
	- local and regional abundance, distribution, use of habitat; and	9.3.5
	- known sensitive habitat areas, species or life stage/activity (e.g., spawning, hatching, feeding)	9.3.5, 9.10
	Describe key species used for traditional harvesting activities and any ecotourism activities.	9.5.1.3
	Describe any known issues currently affecting fish and aquatic life forms in the proposed development (e.g., contamination of food sources, parasites, disease).	9.3.5
4.1.3 Key Lines of Inquiry: Downstream Water Effects	General requirements pertaining to downstream water effects include:	
	Specific requirements pertaining to downstream water effects include:	
	- describe the physical effects of increased flows and changes to water quality on downstream water bodies	9.7
	- provide an analysis of the geographic extent of any downstream effects and a water balance for all affected water bodies	9.7
	- provide a detailed assessment of impacts on aquatic life that considers timing and levels of increased flows and changes to downstream water quality relative to sensitive life stages of fish	9.7
	- provide a detailed assessment of the potential biological impacts of changes, such as effects on riparian habitat and wildlife such as semi-aquatic fur-bearers and waterfowl that use riparian habitat	9.8, 9.9, 9.10, 9.11

Table 9.1-1 Terms of Reference Pertaining to Downstream Water Effects (continued)

Terms of Reference Requirements		Applicable EIS Sub-section
Section	**Description**	
7 (Table 7-3) Water Issues	Remaining issues pertaining to surface water and watershed include:	
	- downstream effects of large water releases;	9.7, 9.8, 9.9, 9.10
	- reduced water flows as lake level is restored;	9.7.3, 9.7.4
	- ice quality on Kennady Lake and surrounding lakes;	9.3.2.2.2
	- cumulative effects on Hoarfrost and Lockhart rivers and Great Slave Lake; and	9.12, 11.2
	- extent of downstream effects	9.7, 9.8, 9.9, 9.10
	Remaining issues pertaining to surface water use and management include:	
	- water diversion effects; and	9.7, 9.10
	- alterations to natural drainage	9.7, 9.10
	Remaining issues pertaining to public concern include:	
	- implications of water quality on human health; and	9.8, 9.11
	- public notification of flooding events	3
3.2.7 Follow-up Programs	The EIS must include a description of any follow up programs, contingency plans, or adaptive management programs the developer proposes to employ before, during, and after the proposed development, for the purpose of recognizing and managing unpredicted problems. The EIS must explain how the developer proposes to verify impact predictions. The impact statement must also describe what alternative measures will be used in cases were a proposed mitigation measure does not produce the anticipated result.	9.13.4, 9.14, 9.15, ,
	The EIS must provide a review of relevant research, monitoring and follow up activities since the first diamond mine was permitted in the Slave Geological Province to the extent that the relevant information is publicly available. This review must focus on the verification of impact predictions and the effectiveness of mitigation measures proposed in previous diamond mine environmental impact assessments. In particular the developer must make every reasonable effort to verify and evaluate the effectiveness of any proposed mitigation measures that have been used, or are similar to those used at other diamond mining projects in the Mackenzie Valley.	9.2, 9.3.1, 9.6.2.1.2

Source: Terms of Reference for the Gahcho Kué Environmental Impact Statement (Gahcho Kué Panel 2007).



LEGEND

- Gahcho Kué Project
- Existing Mine
- Territorial Capital
- Populated Place
- Highway
- Existing Winter Road
- Tibbitt-to-Contwoyto Winter Road
- Winter Access Road
- Watercourse
- Waterbody
- Territorial/Provincial Boundary

NOTES
Base data source: The Atlas of Canada

GAHCHO KUÉ PROJECT

Location of the Gahcho Kué Project

PROJECTION: Canadian Lambert Conf. Conic	DATUM: NAD83		
SCALE 1:3,000,000			
FILE NO: B-Heritage-001-GIS			DATE: September 20, 2010
JOB NO: 09-1365-1004	REVISION NO: 8		**Figure 9.1-1**
OFFICE: GOLD-CAL	DRAWN: CW	CHECK: JB	

9.1.3.2 Study Area Boundaries

To assess the potential effects of the Project on downstream water effects, it is necessary to define appropriate spatial boundaries. The study area for this key line of inquiry was identified in the Terms of Reference as follows:

> *"The geographical scope of this Key Line of Inquiry includes all water bodies (and associated riparian areas) downstream of Kennady Lake up to Great Slave Lake."*

Baseline studies were completed before the Terms of Reference were issued; the boundaries for most of the baseline field work were based on two concepts:

- watersheds; and
- expected extent of the Project-related effects.

The baseline boundaries were set so that all the expected direct and indirect effects of the Project would lie within the Local Study Area (LSA) boundary. The LSA in the baseline studies extended from Kennady Lake watershed to the outlet of Kirk Lake, and included all the watersheds that could potentially be affected between these points.

The downstream extent of the LSA was based on the downstream limit of effects resulting from anticipated changes in lake levels, stream flows, or water quality (e.g., trace metals) during construction, operations, and closure. Effects were expected to be negligible beyond Kirk Lake, which would make the outflow at Kirk Lake a key node of analysis. Therefore, the baseline LSA was extended to the outflow of Kirk Lake. From the results of baseline studies, this delineation of the LSA would also encompass movement patterns of fish populations in Kennady Lake, as well as lakes and streams in its upstream and downstream watershed.

The study area identified by the Gahcho Kué Panel (2007) forms the lower part of the baseline LSA (i.e., the part below the Kennady Lake watershed). Therefore, a new LSA has been defined that is specific to the Key Line of Inquiry: Downstream Water Effects. The LSA for this key line of inquiry was selected to assess the immediate direct, and indirect, effects of the Project on downstream lakes and streams, and associated aquatic and semi-aquatic life.

Baseline survey intensity varied within each spatial boundary depending on the anticipated magnitude of the effect. The most intense effort was directed at waterbodies that would be directly affected by the Project in the baseline LSA;

existing government information summarized in the baseline was used to characterize the Lockhart River beyond Kirk Lake.

The Key Line of Inquiry: Downstream Water Effects was completed within the following spatial boundaries:

- downstream water effects Regional Study Area (RSA); and
- downstream water effects LSA.

9.1.3.3 Downstream Local Study Area

The downstream LSA (Figure 9.1-2) extends from the outlet of Kennady Lake at Area 8 (Stream K5) downstream to the outlet of Kirk Lake, and includes all the associated watersheds. The Kennady Lake watershed was assessed in the Key Line of Inquiry: Water Quality and Fish in Kennady Lake (Section 8).

The proposed Project is expected to directly affect the L and M watersheds located downstream, and north of the Kennady Lake outlet. The Project will also affect the watershed immediately adjacent to the west and north of Kennady Lake (the N watershed) during construction and operations by lowering the level of Kennady Lake (pumping to Lake N11), during operations by the diversion of the A, B, D and E watersheds (i.e., sub-watersheds in the Kennady Lake watershed), and during closure, as water will be pumped from Lake N11 to Kennady Lake to supplement natural refilling. The drainage from the adjacent N watershed joins the natural drainage from Kennady Lake at Lake 410. The combined drainage then flows out of Lake 410 through the P watershed to Kirk Lake, and then to Aylmer Lake.

9.1.3.4 Regional Study Area

The RSA for the Key Line of Inquiry: Downstream Water Effects was selected to encompass the entire Lockhart River watershed to its outlet into Great Slave Lake. The RSA was selected to capture any effect that may extend beyond the LSA, and could potentially interact with other existing or proposed development projects to cumulatively affect hydrology, water quality, fisheries, and other aquatic resources.

The RSA for this key line of inquiry (Figure 9.1-3) is unchanged from the baseline RSA used by the surface water disciplines. Clear RSA boundaries are not possible to define for the deep groundwater component of the downstream water effects key line of inquiry.

LEGEND

- Study Area
- Water Effects Boundary
- Boundary
- Intermediate Contour (20m interval)

NOTES
Base data source: National Topographic Base Data (NTDB) 1:250,000 096C

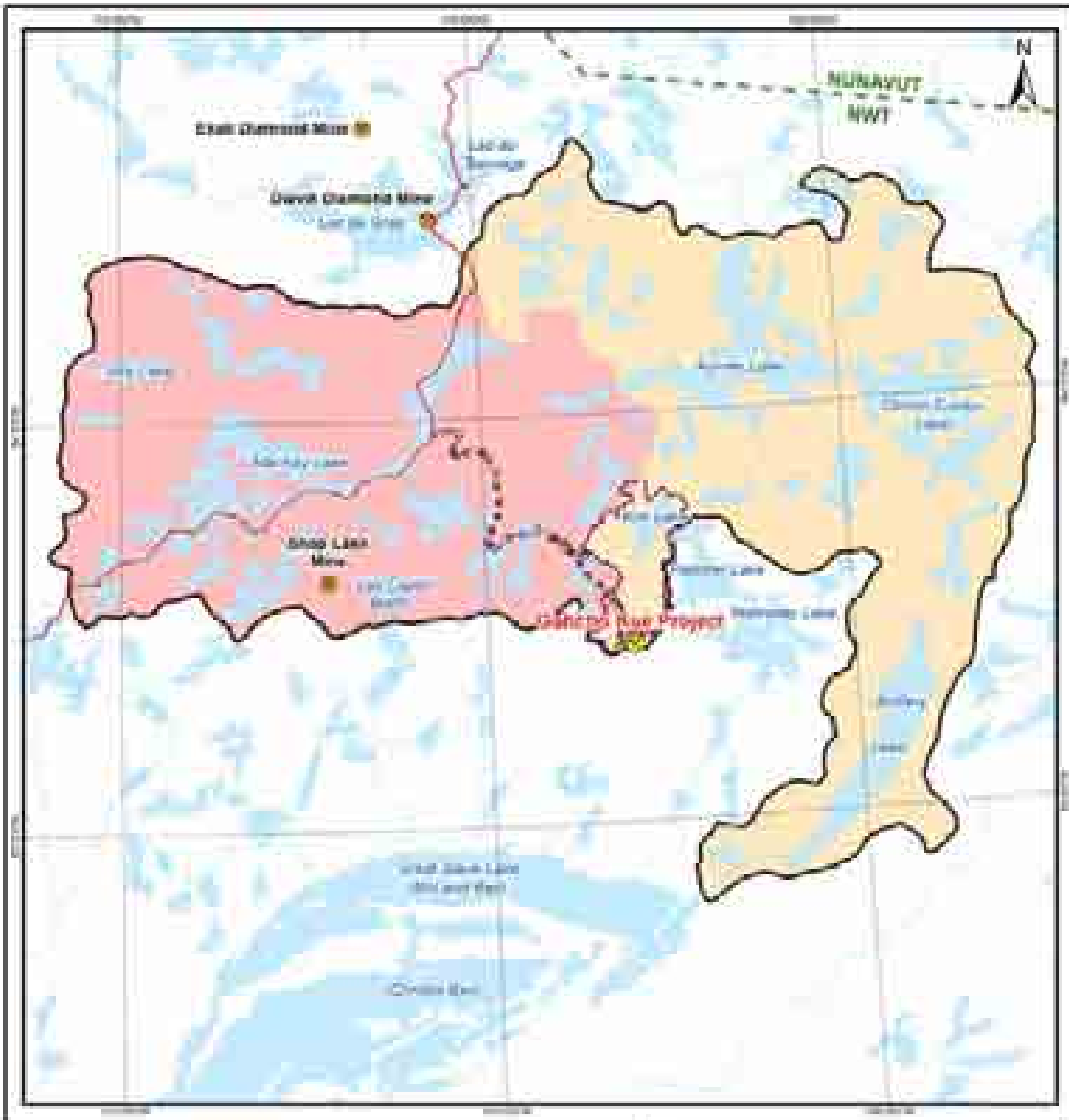
GAHCHO KUE PROJECT

Downstream Water Effects Local Study Area

Kilometres

FILE No: KLOI-09-002-GIS	DATE: December 17, 2010
JOB NO: 09-1365-1004	REVISION NO: 2
OFFICE: GOLD-CAL	DRAWN: SK
CHECK: JF	

Figure 9.1-2



LEGEND

- Gahcho Kue Project
- Existing Mine
- Tibbitt-to-Contwoyto Winter Road
- Baseline Winter Access Road
- Proposed Winter Access Road
- Watercourse
- Waterbody
- Territorial/Provincial Boundary
- Downstream Watershed Boundary
- Lower Lockhart River Watershed
- Upper Lockhart River Watershed
- Regional Study Area

NOTES
Base data source: The Atlas of Canada

GAHCHO KUÉ PROJECT

Downstream Water Effects Regional Study Area

PROJECTION: Canadian Lambert Conf. Conic	DATUM: NAD83	
FILE No: KLOI-09-001-GIS		DATE: December 17, 2010
JOB NO: 09-1365-1004	REVISION NO: 2	
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF

Figure 9.1-3

9.1.4 Content

This key line of inquiry consists of details of the impact analysis and assessment related to downstream water effects. The key headings of this section are arranged according to the sequence of steps in the assessment. The disciplines relevant to this key line of inquiry are presented in a logical order with progressively longer pathways between the original sources and the receptors. The following briefly describes the content under each heading of this key line of inquiry:

- **Existing Environment** summarizes relevant baseline information for all waterbodies and associated riparian areas downstream of Kennady Lake to Great Slave Lake, beginning with the general environmental setting in which the Project occurs, which includes a summary of baseline methods and results for specific disciplines, including hydrogeology, surface water quantity, surface water quality, aquatic habitat, lower trophic levels, fish, and wildlife and human use (Section 9.3).
- **Water Management Plan Summary** presents a conceptual plan for water management during Project construction and operations, with emphasis on aspects relevant to downstream water effects (Section 9.4).
- **Assessment Approach** provides details on specific aspects of the assessment approach (described in Section 6) that are particularly relevant to the assessment of effects to downstream waters (Section 9.5).
- **Pathway Analysis** identifies all potential pathways by which the Project could affect downstream waterbodies, and provides a screening level assessment of each pathway after applying environmental design features and mitigation that reduce or eliminate Project-related effects (Section 9.6).
- **Effects to Water Quantity** explains the scientific methods that were used to predict the changes to surface water quantity in downstream waterbodies; and presents the results of the analysis of effects to downstream surface water quantity as a result of the Project (Section 9.7).
- **Effects to Surface Water Quality** explains the scientific methods that were used to predict the changes to surface water quality in downstream waterbodies; and presents the results of the analysis of effects to downstream surface water quality as a result of the Project (Section 9.8).
- **Effects to Aquatic Health** explains the scientific methods that were used to assess effects to the health of aquatic life (aquatic health) in

downstream waterbodies; and presents the results of the analysis of downstream effects to aquatic health as a result of the Project (Section 9.9).

- **Effects to Fish and Fish Habitat** explains the scientific methods that were used to predict the changes to fish and fish habitat in downstream waterbodies; and presents the results of the analysis of downstream effects to fish and fish habitat as a result of the Project (Section 9.10).
- **Related Effects to Wildlife and Human Health** explains the scientific methods that were used to predict the changes to wildlife and human health in downstream waterbodies, and presents the results of the analysis of effects to wildlife and human health that flow from effects to downstream waterbodies as a result of the Project (Section 9.11).
- **Residual Effects Summary** summarizes the effects to downstream waterbodies that are predicted to remain after all measures (e.g., environmental design features and mitigation) to eliminate potential pathways or reduce associated negative effects have been incorporated into the Project design (Section 9.12).
- **Residual Impact Classification** describes methods used to classify residual effects, and summarizes the classification results (Section 9.13).
- **Uncertainty** discusses sources of uncertainty surrounding the predictions of downstream water effects and how this uncertainty is addressed by the Project (Section 9.14).
- **Monitoring and Follow-up** describes proposed monitoring programs, contingency plans, and/or adaptive management strategies related to downstream water effects (Section 9.15).
- **References** list all documents and other material used in the preparation of this section (Section 9.16).
- **Glossary, Acronyms, and Units** explains the meaning of scientific, technical, or other uncommon terms used in this section. In addition, acronyms and abbreviated units are defined (Section 9.17).

9.2 SUMMARY

Background

The proposed Project is a diamond mine situated at Kennady Lake in the Northwest Territories (NWT) about 280 kilometres (km) northeast of Yellowknife. Kennady Lake is a small headwater lake within the Lockhart River system that drains northward about 70 km, via a series of small lakes, into Kirk Lake and then into Aylmer Lake. Aylmer Lake is located on the mainstream of the Lockhart River, about midway along its length. The Lockhart River system drains into the East Arm of Great Slave Lake. Downstream water effects were identified in the *Terms of Reference for the Gahcho Kué Environmental Impact Statement* as a key line of inquiry because of concerns related to effects of changes in flows and water quality to downstream lakes and streams resulting from Kennady Lake dewatering, during mining operations, and after reconnection.

The downstream Local Study Area (LSA) extends from the outlet of Kennady Lake at Area 8 (Stream K5), downstream to the outlet of Kirk Lake, and includes all of the associated watersheds. The proposed Project is expected to directly affect the L and M watersheds located downstream, and north, of Stream K5. The Project will also affect the watershed immediately adjacent to the west and north of Kennady Lake (the N watershed) during construction and operations by pumping water to Lake N11 as a component of dewatering Kennady Lake; during operations by the diversion of the A, B, D, and E watersheds (i.e., sub-watersheds in the Kennady Lake watershed) and pumped discharge on an as-needed basis from the Water Management Pond (WMP); and during closure, as water will be pumped from Lake N11 to Kennady Lake to supplement natural refilling. The drainage from the adjacent N watershed joins the natural drainage from Kennady Lake at Lake 410. The combined drainage then flows out of Lake 410 through the P watershed to Kirk Lake, and then to Aylmer Lake.

Existing Environment

Components of the existing environment that are relevant to this key line of inquiry include surface water quantity, surface water quality, physical aquatic habitat, lower trophic levels, and fish. Where available, historical baseline data in streams and lakes in the LSA downstream of Kennady Lake were reviewed and summarized; multi-year, seasonal baseline sampling was conducted to supplement existing information.

Water Management Plan

A Water Management Plan has been developed for the Project. This plan was designed to minimize the impact of the Project on the aquatic ecosystem of

Kennady Lake and downstream environments during the construction, operations, and closure phases.

The most significant water-related activities that will take place during the Project will be the dewatering of Areas 2 through 7 of Kennady Lake, and the subsequent re-filling of the lake upon completion of mining. These activities will have a substantial bearing on the downstream waterbodies. During operations, activities that will affect aquatic environments downstream of the Project include the diversion of flows from the A, B, D, and E watersheds to the N watershed, the pumped discharge from the WMP, and the reduction of inflows to Area 8. During closure, the key activities that will affect aquatic environments downstream of the Project include the restoration of the natural drainage system in the Kennady Lake watershed, with the exception of watershed A. Once Kennady Lake (Areas 3 to 7) is refilled and water quality meets specific criteria, Dyke A will be breached allowing Kennady Lake to discharge natural flows through Area 8.

Assessment Approach

The pathway analysis identified and screened the linkages between Project components or activities and the potential effects to receptors within the aquatic environment. Pathways were determined to be primary, secondary (minor), or as having no linkage using scientific and traditional knowledge, logic, and experience with similar developments and environmental design features and mitigation. All primary pathways were carried forward in the assessment for detailed effects analysis.

The selection of Valued Components (VCs) specific to this key line of inquiry resulted from issues scoping sessions for the Project with community members, federal and territorial regulators, and other stakeholders. For this key line of inquiry, water quality and fish were identified as VCs, with the following being identified as the assessment endpoints:

- Suitability of Water Quality to Support a Viable Aquatic Ecosystem
- Abundance and Persistence of Desired Population(s) of Lake Trout
- Abundance and Persistence of Desired Population(s) of Northern Pike
- Abundance and Persistence of Desired Population(s) of Arctic Grayling

Water Quantity

Dewatering: During construction, the dewatering of Kennady Lake will result in discharges to Area 8 and Lake N11. Discharges to Area 8 and Lake N11 will be limited to prevent downstream erosion or geomorphological changes. Pumping will be timed to begin after the peak of the spring freshet, such that peak flows will not be increased.

Peak daily discharges at the Area 8 outlet (Stream K5) will be slightly reduced, with low flows increasing substantially as dewatering discharges are sustained through the open-water season. A similar trend also occurs with water levels in downstream lakes, although the magnitude of change in water level is relatively small. Effects on downstream waterbodies and streams will be progressively reduced with increased distance from the Project as more undisturbed areas contribute to runoff, which acts to attenuate the magnitude of change.

Dewatering discharges to Lake N11 are expected to increase flows at the Lake N11 and Lake N1 outlets. Peak daily discharges for the Lake N11 and N1 outlets will be approximately equal to baseline conditions, with low flows increasing substantially as dewatering discharges are sustained through the open-water season. A similar trend also occurs with water levels in lakes N11 and N1, although the magnitude of change in water level is relatively small.

Lake 410 and downstream waterbodies will be affected by the dewatering discharges to Area 8 and Lake N11. The peak daily discharges for the Lake 410 outlet will be approximately equal to baseline conditions, with low flows increasing substantially as dewatering discharges are sustained through the open-water season. Water levels in Lake 410 will follow a similar trend during peak and low flow periods, although the magnitude of change in water level is relatively small. The peak daily discharges for the Kirk Lake outlet are expected to increase marginally and low flows will also increase, but to a lesser extent than at upstream locations. Water levels in Kirk Lake are expected to increase slightly, although the magnitude of change in water level is relatively small.

No adverse effects on the stability of the shorelines of downstream lakes are anticipated during the dewatering phase, as limiting discharges to a 2-year flood water level will mean that the downstream lakes have the capacity to accommodate the planned discharge rates.

Operations: After construction dewatering has been completed, Kennady Lake will retain a volume of water in Areas 3 and 5 that will constitute the WMP for the remaining period of operation. Pumped water from the WMP pond directly to Lake N11 will occur as required through operations. Pumping will be managed such that peak flows will remain similar to baseline, and low flow augmentation will not extend throughout the open-water period. Seasonal low flows return to near baseline conditions by mid-summer and remain for the duration of the open-water period.

To reduce the amount of runoff from the upstream watersheds to Kennady Lake throughout the operation period, four upper tributary watersheds will be diverted to the adjacent N watershed. The diversion of the A and B watersheds will result in small increases in peak flows and low flows at the Lake N6 outlet. Water levels in Lake N6 are also expected to increase a small amount. The diversion of the D and E watersheds will result in moderate increases in peak flows and low flows at the Lake N17 outlet. Water levels in Lake N17 are also expected to increase a small amount. Increases in flows at the Lake N6 and Lake N17 outlets due to operational diversions will be mitigated to prevent erosion. Changes to the flow regime in downstream channels are not expected to cause adverse impacts on channel or bank stability or erosion, as flow increases will be limited.

Dyke A will isolate Kennady Lake Areas 2 to 7 from Area 8, reducing the upstream drainage area at the Area 8 outlet (Stream K5). This will substantially reduce peak daily discharges and low flows through Stream K5 because of the reduction in upstream storage and drainage area. Effects on downstream waterbodies will be progressively reduced as additional undisturbed watersheds contribute to runoff.

Lake 410 receives inflow from both the N watershed and the M watershed. Reduced flows downstream of Area 8 through the M watershed are offset by increased flows in the N watershed such that the water levels and outlet discharge at Lake 410 are similar to baseline conditions. At Kirk Lake, changes in water level and outlet discharges during operations will be negligible.

Closure: During refilling, the flow and water level regime in the Stream K5 channel and downstream to the Lake M1 outlet will be the same as during operations. The diversion of water from Lake N11 to refill Kennady Lake will result in a small reduction of monthly mean flows at the Lake N11 and Lake N1 outlets. Similarly, small changes in water levels of Lake N11 and N1 will also occur. A reduction in the monthly mean flows at the Lake 410 and Kirk Lake outlets will also be expected due to the combined effects of abstraction for lake refilling and the removal of upstream drainage areas, although the change is small. No effects on outlet channel or bank stability during operations are expected, because flows will be reduced or subject to only small increases.

Post-Closure: Watersheds downstream of Kennady Lake return to near baseline conditions, but will be affected by the post-closure hydrological regime of the Kennady Lake watershed, which includes a small increase in mean annual water yield and a slight increase in flood peak discharges. The effects of these changes to downstream watersheds will be progressively reduced with increased distance downstream from Kennady Lake as more watershed areas contribute to runoff, which acts to attenuate the magnitude of change. The post-closure hydrological regimes of the N11 and upstream watersheds is expected to be almost identical to the baseline conditions, with the post-closure hydrological regime of the N1 watershed affected to a negligible extent by the permanent diversion of the A watershed.

Water Quality

As a result of the Project, water quality in the downstream waters was predicted to change in waterbodies downstream of Kennady Lake, through the Interlakes (i.e., the L and M watersheds) to Lake 410. Additionally, water quality in the N watershed, from Lake N11 through to Lake 410 was predicted to change. The modelling nodes used in this assessment included Lake N11, the Interlakes and Lake 410.

Lake N11: During dewatering of Areas 3 and 5 of Kennady Lake to Lake N11, changes to total suspended solids (TSS) levels will be negligible, as water to be initially pumped will be surface waters. TSS levels in the WMP will be at, or similar, to background concentrations. After dewatering, any continued pumped discharge during operations from the WMP to Lake N11 will not be a source of TSS to Lake N11. At closure, active pumping from Lake N11 to Areas 3 and 5 to augment lake refilling will not be a source of additional TSS in Lake N11.

During the operations phase, concentrations of TDS and major ions in Lake N11 are projected to increase as a result of pumped discharge from the WMP. During the closure period, total dissolved solids (TDS) concentrations are predicted to return to background levels when pumping from the WMP ceases. During construction and operation, and in the early years of closure, concentrations of TDS and all major ions are predicted to increase above background conditions, but remain below concentrations that would affect aquatic health.

All modelled forms of nitrogen are predicted to increase in Lake N11 due to inputs from blasting residue in the pumped discharge from the WMP to Lake N11. Nitrate and ammonia concentrations are predicted to remain below guidelines and return to background conditions within the first few years of the closure period. Concentrations of phosphorus are also predicted to increase. However, De Beers is currently evaluating a variety of environmental design features and mitigation measures to limit phosphorus loading to the environment. The effectiveness of these environmental design features and mitigation measures is uncertain and requires further analysis. Accordingly, the amount of phosphorus that may be released into the environment is uncertain at this time. As a result, potential effects related to phosphorus have not been presented and will not be available until such time as additional analysis is completed. This analysis will be provided to the Panel in 2011.

During operations, pumped discharge of the WMP to Lake N11 will result in increased metals concentrations in Lake N11. Of the 23 trace metals that were modelled for this assessment:

- 17 metals are predicted to increase in concentration during the operations phase, and they will follow the same temporal patterns as for TDS and major ions. These include antimony, arsenic, barium, boron, chromium, iron, manganese, molybdenum, nickel, lead, selenium, silver, strontium, thallium, uranium, vanadium, and zinc. Metals that are influenced more by groundwater inflows are predicted to have maximum peaks early in the operational phase (e.g., chromium). Metals that are more strongly influenced by geochemical loading sources (i.e., from PK and mine rock sources) are predicted to have the highest peaks near the end of the operational phase (e.g., strontium). Only chromium is predicted to exceed guidelines in Years 2 and 4. Within the first few of closure, metals concentrations are expected to return to background concentrations.
- Six of the 23 modelled metals are predicted to have slight increases in concentration (i.e., less than 20 percent [%] from background) due to pumped discharge from the WMP. These metals include aluminum, beryllium, cadmium, cobalt, copper, and mercury. Of these metals, only cadmium is predicted to exceed guidelines, and these exceedances are observed in background conditions.

The Interlakes (L and M Watersheds): 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 (as outlined in Section 8.8), although some attenuation is expected due to increased dilution with distance downstream.

Lake 410: During dewatering of Area 7 of Kennady Lake to Area 8, changes to TSS levels will be negligible in Area 8, and therefore through the Interlakes to Lake 410, as water to be initially pumped will be surface waters. As the water level in Area 7 is drawn down and water quality does not meet discharge criteria, pumping to Area 8 will cease so that there is no additional source of TSS to Area 8 and downstream waters. Contributions of TSS from the N watershed to Lake 410 will be negligible.

Concentrations of TDS and major ions in Lake 410 are projected to increase during the operations phase due to relative contribution of pumped discharge from the WMP to Lake N11. Temporal patterns of concentrations in Lake 410 are similar to those in Lake N11, except that concentrations are lower in Lake 410 due to dilution from the majority of the Lake 410 watershed, and are offset by 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, TDS concentrations will increase slightly in Lake 410. Patterns of concentrations in Lake 410 will be similar to those predicted for Area 8, except that these will also be lower due to dilution and offset due to travel time. Concentrations of TDS and major ions are predicted to remain elevated above background levels for the long-term; however, the loading of TDS to Kennady Lake is expected to decrease with the establishment of permafrost through the fine PK material. TDS and all major ions are predicted to remain above background conditions but below levels that would affect aquatic health.

Concentrations of all modelled forms of nitrogen are predicted to increase in Lake 410, with operations concentrations higher than closure concentrations. Closure concentrations of nitrogen are predicted to decline to near-background concentrations, because there are no major loading sources of nitrogen. In post-closure, nitrogen concentrations increase several years after the removal of Dyke A and then decline to near background concentrations. Concentrations of nitrate and ammonia are predicted to remain below guidelines throughout the life of the Project and beyond.

Concentrations of phosphorus are also predicted to increase in Lake 410 throughout operations and several years into post-closure, after Dyke A is removed. However, De Beers is currently evaluating a variety of environmental design features and mitigation measures to limit phosphorus loading to the environment. The effectiveness of these environmental design features and mitigation measures is uncertain and requires further analysis. Accordingly, the amount of phosphorus that may be released into the environment is uncertain at this time. As a result, potential effects related to phosphorus have not been presented and will not be available until such time as additional analysis is completed. This analysis will be provided to the Panel in 2011.

Of the 23 modelled trace metals:

- 12 are predicted to have small increases in concentration (i.e., maximum concentrations less than twice as high as baseline) in Lake 410 associated with operations discharge to Lake N11 and in the early post-closure period with the removal of Dyke A. These metals are aluminum, barium, beryllium, cadmium, cobalt, copper, iron, lead, manganese, mercury, nickel, and zinc. These metals are predicted to return to near-background conditions in the long-term.
- Three metals (chromium, selenium, and thallium) 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 have similar trends to TDS and the major ions.

- Eight metals are predicted to increase and reach long-term steady state concentrations more than double baseline concentrations. These metals include antimony, arsenic, boron, molybdenum, silver, strontium, uranium, and vanadium. Concentrations of these metals are predicted to increase after closure, and reach steady state conditions in Lake 410 within about 40 years. As these geochemical sources are the primary contributors of these metals, the majority of total concentrations will be in the dissolved form.

Cadmium is the only metal predicted to exceed guidelines in Lake 410, and the guideline exceedance is due to naturally elevated background concentrations.

Aquatic Health

Changes in water quality in Lake N11 and Lake 410 are predicted in constructions, operations, and closure of the Project. The potential effect of these changes on aquatic health was evaluated considering both direct waterborne exposure and accumulation within fish tissues. For direct waterborne exposure, predicted maximum concentrations for all substances of potential concern were lower than the corresponding CEB. Predicted fish tissue concentrations were below tissue-based toxicological benchmarks for the substances considered in the assessment.

With respect to the interlakes, the 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 previously noted, water quality in the interlakes is predicted to be similar to that in Area 8, although parameters concentrations will gradually decline with distance downstream due to dilution. Consequently, the conclusions and recommendations put forward for Area 8 apply to the interlakes as well.

Based on the above, changes to concentrations of all substances considered in this assessment are predicted to result in negligible effects to aquatic health in waterbodies downstream of Kennady Lake.

Effects to Fish and Fish Habitat

Dewatering: Dewatering of Kennady Lake will result in augmented flows in the N watershed, and in the L and M watersheds downstream of Kennady Lake during the open-water period. Most of the pumping will occur after the peak of the spring freshet has occurred, and peak discharges will remain similar to baseline conditions. No changes to fish habitat due to changes in channel morphology are predicted. As a result of mitigation, the risk of flushing or stranding fish during the start-up and shut-down of pumping is considered to be negligible.

From the evaluation of spring (June) discharges and average June water velocities in Stream N11 and N1 during dewatering, the effect of dewatering on spawning Arctic grayling in Streams N11 and N1 is expected to be negligible. Higher summer discharges are expected to have a minor effect on any young-of-the-year (YOY) Arctic grayling rearing in these streams.

From the evaluation of spring (June) discharges and average June water velocities downstream of Kennady Lake during dewatering, Arctic grayling are likely to continue spawning successfully, and as a result, the effect of dewatering on spawning Arctic grayling in streams downstream of Kennady Lake is expected to be negligible. Given the small increases in average water velocities during dewatering, and the availability of suitable low velocity habitat for small YOY Arctic grayling, the effect of dewatering on Arctic grayling YOY in streams downstream of Kennady Lake is expected to be negligible. The density and species composition of benthic invertebrate communities and invertebrate drift are not expected to change as a result of higher summer flows in streams in the L, M, and N watersheds downstream of Kennady Lake. Dewatering is not expected to result in an increase in barriers to fish migration and may improve accessibility for some species.

Small increases in lake water levels and lake areas are predicted compared to baseline conditions in the N watershed. Water levels in the L and M lakes downstream of Kennady Lake and Lake 410 will remain near spring freshet levels longer into the summer and early fall compared to baseline conditions, which may benefit fish in these lakes during summer through increased littoral area and summer rearing habitat. Lake levels will return to baseline conditions before winter, and therefore, no changes to overwintering habitat are expected.

Operations: Flows in the N watershed during operations are similar to the dewatering phase of the project for June and July. During operations, flows return to conditions similar to baseline in August and for the remainder of the open-water season. No changes are predicted to channel morphology. As a result of mitigation on ramp-up and ramp-down rates, effects to fish and fish habitat in the N watershed are considered to be negligible as a result of the pumped discharge from the WMP to Lake N11 during operations. Improved fish movements can be expected in the N watershed during operations. As the projected mean current velocities in N watershed streams are within the expected range of natural variation, they are therefore not predicted to influence benthic invertebrate communities or invertebrate drift.

Flow reductions in the L and M watersheds during operations will result in a reduction of available habitat. The change from baseline generally declines moving downstream, with the largest changes found in Streams K5 and L3. During operations, flows in June are substantially reduced in streams between Kennady Lake and Lake 410. The increase in frequency of barriers preventing spring spawning migrations of Arctic grayling is likely to have a negative impact on Arctic grayling populations between Area 8 and Lake 410. The projected decreases in mean current velocity relative to baseline are small, and therefore, are not expected to alter benthic invertebrate communities or invertebrate drift. Predicted changes in wetted width and water depth are not expected to alter benthic community composition and drift density; however, the amount of invertebrate biomass and total drift are expected to be reduced in proportion to the reduction in stream width and flow.

Water levels and lake areas in the N watershed are expected to increase compared to baseline, but decrease compared to dewatering. As the changes in water level and lake area are small and within natural variability, no effects on fish and fish habitat are expected. Water levels and lake areas in lakes between Kennady Lake and Lake 410 are generally expected to decrease during operations compared to baseline conditions. However, as the changes in water levels are small, the effects on fish habitat or benthic invertebrate communities in these lakes are expected to be minor. In Lake 410, the predicted changes are small and within natural variability; no effects on fish and fish habitat would be expected to occur.

The above statements are put forward without consideration of potential nutrient-related effects. Once the additional nutrient-related analysis is complete, they will be updated, if and as required.

Closure: The flow regime in the N watershed will return to near baseline conditions during closure, with small seasonal reductions in flow due to pumping to Area 3 to augment the refilling of Kennady Lake. At the outlet of Lake N1, flows will return effectively to baseline conditions. Effects on lower trophic communities will cease and communities are expected to return to those characteristic of baseline conditions.

Flows downstream of Kennady Lake to Lake 410 during closure will remain reduced, with the same flow regime from operations continuing through the refilling phase; the same conclusions for fish habitat availability, fish habitat suitability, changes to fish migrations, and changes to lower trophic communities from operations apply.

Small decreases in lake water levels and lake areas are predicted in Lake N11 and Lake N1, but as the changes are small compared to baseline conditions, they are unlikely to have a substantive effect on fish habitat or benthic invertebrate communities in these lakes. The lake levels, and associated effects on fish and fish habitat, in the L and M lakes are the same as for operations.

Post-closure: Flows return to near baseline conditions throughout the N, L, and M watersheds and the effects to fish habitat are considered to be negligible. Benthic invertebrates are expected to quickly re-colonize the re-wetted stream areas. Water levels and lake areas in lakes between Kennady Lake and Lake 410 are expected to slightly decrease, but as the changes are small compared to baseline, effects to fish and fish habitat would be negligible.

Reconnection of Area 8 to the remainder of Kennady Lake may result in increased nutrient concentrations in the L and M watershed, along the flow-path to Lake 410. However, De Beers is currently evaluating a variety of environmental design features and mitigation measures to limit phosphorus loading to the environment. The effectiveness of these environmental design features and mitigation measures is uncertain and requires further analysis. Accordingly, the amount of phosphorus that may be released into the environment is uncertain at this time. As a result, potential effects related to phosphorus have not been presented and will not be available until such time as additional analysis is completed. This analysis will be provided to the Panel in 2011.

The Project is expected to have negligible effects on aquatic health in waterbodies downstream of Kennady Lake (i.e., Lake N11 and Lake 410) from changes in chemical constituents of water quality; therefore, no effects to fish populations or communities are expected to occur from changes in aquatic health.

Residual Impact Classification

The classification was carried out on residual impacts (i.e., impacts with environmental design features and mitigation considered). Residual impacts were classified for two time periods: from the initiation of the Project to 100 years later; and future conditions after 100 years from Project initiation. Projected impacts were then evaluated to determine if they were environmentally significant.

The projected impacts of the Project on the suitability of water downstream of Kennady Lake to support a viable and self-sustaining aquatic ecosystem are considered to be not environmentally significant for both time periods. Water quality is predicted to change, but is expected to result in negligible effects to aquatic health. However, this classification of impacts and those outlined below do not account for potential changes in nutrient levels and are subject to re-evaluation once further predictive modelling of nutrient concentrations and the associated effects assessment are complete.

The projected impacts on the abundance and persistence of Arctic grayling, lake trout, and northern pike are considered to be not environmentally significant for both time periods. During the first time period, reduced flows and lake levels that occur downstream of Area 8 during operations and closure may affect habitat availability, suitability, and movement of the VCs between Area 8 and Lake 410. For Arctic grayling, this has the potential to affect the population size by restricting spawning migrations and reducing the area available for spawning; for lake trout and northern pike, this is not expected to result in population level changes. In the second time period, flows return to near baseline conditions and the population and distribution of Arctic grayling are also expected to return to baseline conditions. All three species are expected to continue to persist in the watershed downstream of Kennady Lake during construction, operations, closure, and post-closure.

9.3 EXISTING ENVIRONMENT

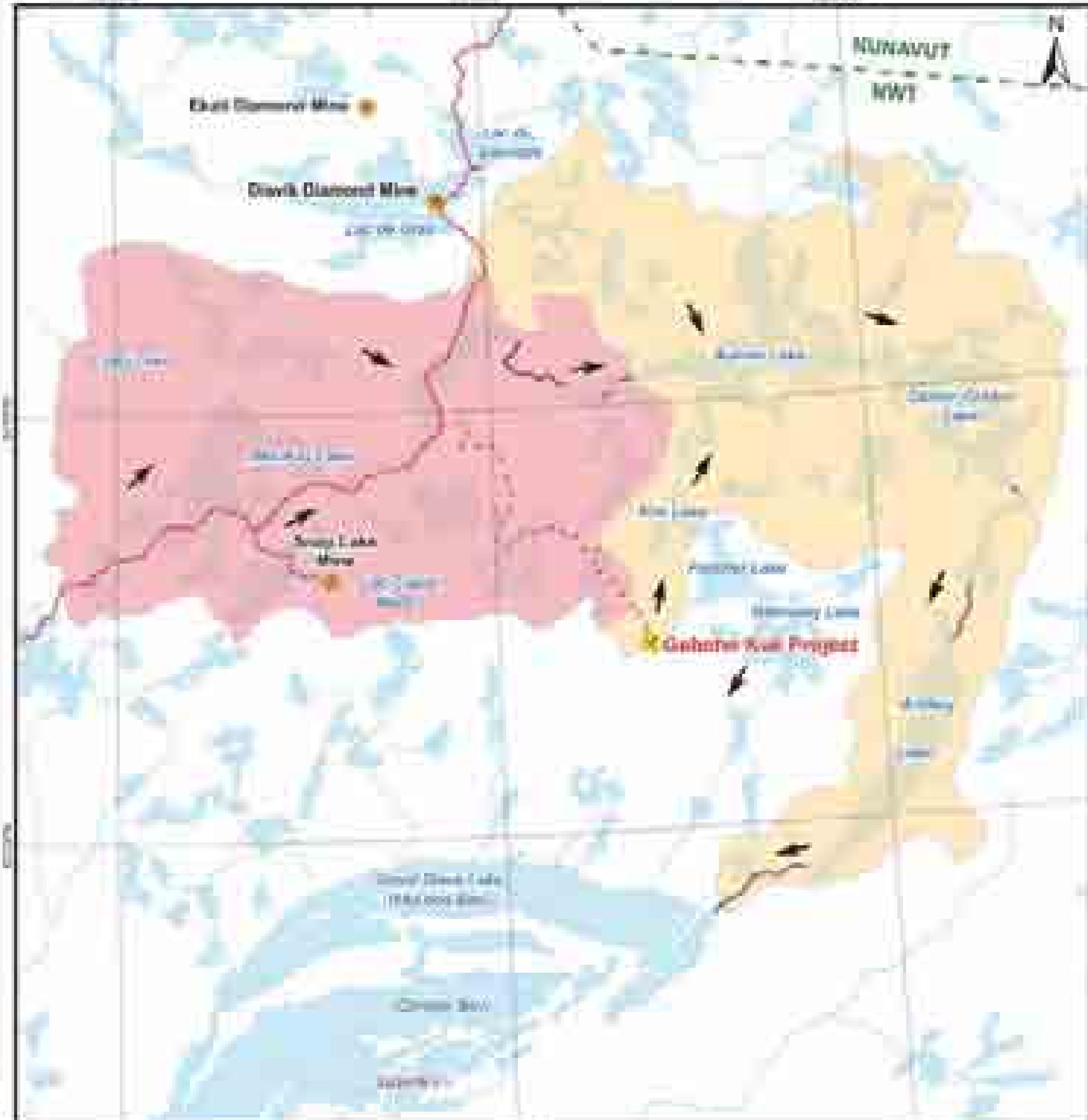
The following section provides a brief description of the existing environment downstream of the Kennady Lake watershed. Components of the existing conditions discussed herein include surface water quantity, surface water quality, physical aquatic habitat, lower trophic levels, and fish. The focus of the descriptions below is on results for each component, although methods are briefly discussed. For more details on methods or results, supplementary information regarding the existing environment downstream of the Kennady Lake watershed is provided in the following annexes of this environmental impact statement (EIS):

- Annex H (Climate and Hydrology Baseline);
- Annex I (Water Quality Baseline); and
- Annex J (Fisheries and Aquatic Resources Baseline).

9.3.1 General Setting

The Gahcho Kué Project (Project) is located within the Kennady Lake watershed at Kennady Lake (63° 26’ N; 109° 12’ W), a small headwater lake of the Lockhart River watershed in the Northwest Territories (NWT). Kennady Lake is about 140 kilometres (km) northeast of the nearest community Łutselk’e on the eastern arm of Great Slave Lake, and about 280 km northeast of Yellowknife (Figure 9.1-1). Kennady Lake is 84 km east of the Snap Lake Mine, the only other active mine in the Lockhart River watershed. The Diavik and Ekati diamond mines are located in the Coppermine River watershed, approximately 127 km and 158 km northeast of Kennady Lake, respectively. The Project site is located at an elevation of approximately 420 metres (m) above sea level.

Kennady Lake drains north for approximately 70 km through Kirk Lake and into Aylmer Lake. Aylmer Lake is located on the mainstem of the Lockhart River, approximately halfway between the Kennady lake watershed and Great Slave Lake. The Lockhart River then drains southeast from Aylmer Lake through Clinton Colden and Artillery lakes into the East Arm of Great Slave Lake. The Kennady Lake watershed (37 square kilometres [km^2]) comprises approximately 0.14 percent (%) of the 27,500 km^2 Lockhart River watershed. Regional drainage at the Project is shown in Figure 9.3-1.



LEGEND

- Gahcho Kué Project
- Existing Mine
- Tibbitt-to-Contwoyto Winter Road
- Winter Access Road
- Existing Winter Road
- Watercourse
- Waterbody
- Lockhart River
- Territorial/Provincial Boundary
- Drainage Direction
- Lower Lockhart River Watershed
- Upper Lockhart River Watershed

NOTES
Base data source: The Atlas of Canada

GAHCHO KUÉ PROJECT

Regional Drainage

FILE NO	B-Hydro-011-GIS
DATE	October 21, 2010
JOB NO	09-1365-1004
REVISION NO	4
OFFICE	GOLD-CAL
DRAWN	JH
CHECK	NS

Figure 9.3-1

The area downstream of the Kennady Lake watershed is located in the sub-Arctic tundra, north of the treeline, and near the southern limit of continuous permafrost. Topography downstream of the Kennady Lake watershed is characterized by low relief with occasional rocky ridges. Muskeg is the dominant vegetation, but willow shrubs exist in riparian areas and black spruce are found in valley depressions where wind exposure is reduced.

The Project is accessed in the winter by a 120 km long winter road, the Winter Access Road, which extends from the Tibbitt-to-Contwoyto Winter Road at MacKay Lake to Kennady Lake. The Winter Access Road to Kennady Lake crosses Reid, Munn, Margaret and Murdock lakes as well as a large number of smaller lakes and streams. The Winter Access Road typically operates for less than 70 days each year between November and March. The Project can also be accessed by air in winter, and by float plane in summer.

9.3.2 Surface Water Quantity

This section describes the hydrological conditions downstream of the Kennady Lake watershed.

For additional baseline details, including a summary of regional background climate conditions, the reader is referred to EIS Annex H (Climate and Hydrology Baseline) and Addendum HH (Additional Climate and Hydrology Baseline Information).

9.3.2.1 Methods

The description of hydrology focuses on characterizing the streamflow at lake outlets downstream of the Kennady Lake watershed. Hydrometric data, stream geomorphology data, and ice and winter flow information was collected for baseline reporting. The baseline report examined local and regional data to develop estimates for the following:

- long-term mean values of discharge and annual water yield;
- ranges of natural variability;
- dry and wet year values;
- peak discharges; and
- low flows.

Due to the paucity of long-term regional hydrometric stations, the unreliability of applying regional data to small, local watersheds with variable storage and lake outlet geometry, and the short periods of record for hydrometric stations at the project, a water balance model was developed to derive long-term mean characteristics and variability for key waterbodies.

9.3.2.2 Results

The local drainage network from Kennady Lake to the downstream limit of the Local Study Area (LSA) at the outlet of Kirk Lake is shown in Figure 9.3-2. The general characteristics of component watersheds are summarized in Table 9.3-1. The drainage direction from Kennady Lake is northward, and passes through the L watershed, M watershed, Lake 410, P watershed, and finally Kirk Lake. The drainage from Kirk Lake passes through the Q watershed before entering Aylmer Lake. N watershed is adjacent to the Kennady Lake watershed, and also drains to Lake 410. Watersheds within the LSA have lake surface fractions of up to 30%, and the hydrology of these watersheds is dominated by lake storage and evaporation.

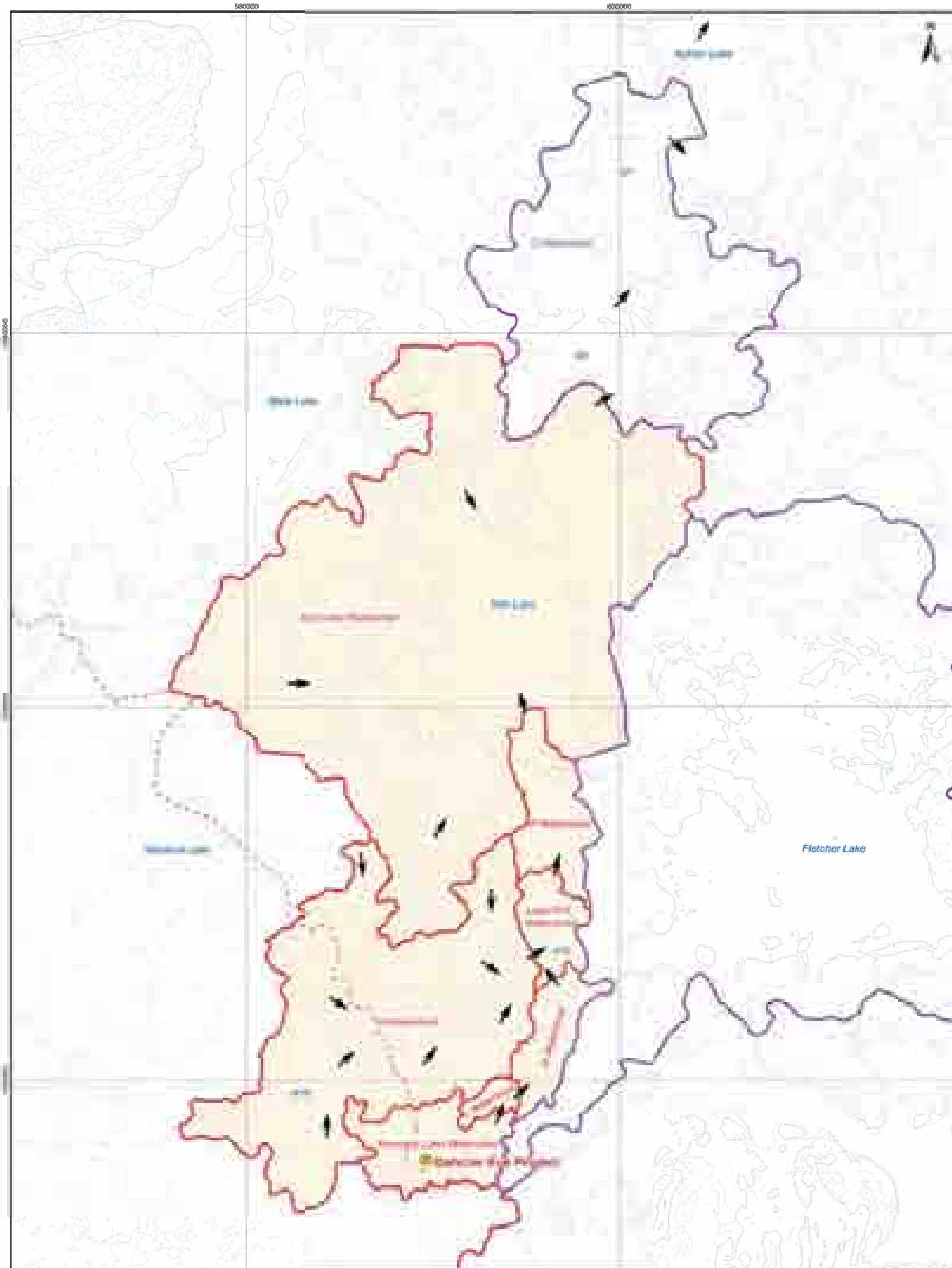
Table 9.3-1 Local Study Area Watershed Area Summary

Watershed or Sub-watershed	Land Surface Area (km^2)	Lake Surface Area (km^2)	Total Area (km^2)	Lake Surface Fraction
L	25.2	12.3	37.5	0.329
M	40.7	16.0	56.7	0.282
N2	12.2	3.64	15.8	0.230
N	129	53.9	183	0.295
Lake 410	179	76.7	256	0.300
P	203	81.9	284	0.288
Kirk Lake	527	212	739	0.286
Q	670	267	937	0.285

km^2 = square kilometres.

9.3.2.2.1 Stream Geomorphology

Lakes comprise greater than 25% of the landscape within the LSA and are typically connected by short outlet channels that are steep relative to overall land slopes. Channels are typically only slightly entrenched, have high bankfull width-to-depth ratios (greater than 12) and moderate sinuosity (S) (greater than 1.2). Most lake outlet channels in the LSA could be described as C1 or C2 channels by the Rosgen Level II classification system (Rosgen 1994), though some have side channels and very high width-to-depth ratios, and could be classified as D1 or D2 channels.



NOTES
Base data source: National Topographic Base Data (NTDB) 1:250,000

GAHCHO KUÉ PROJECT

Local Study Area Watersheds

Kilometres

FILE No: B_Hydro-013-GIS			DATE: October 21, 2010
JOB NO: 09-1365-1004	REVISION NO: 3		**Figure 9.3-2**
OFFICE: GOLD-CAL	DRAWN: JH	CHECK: NS	

The beds of larger channels are typically armoured with unerodible bedrock or boulder layers. Channels may include flat and steep reaches as governed by the local topography and bedrock outcrops. Channel banks typically consist of vegetated mats of organic material up to 300 millimetres (mm) thick, below which are found organics and fine soils within a matrix of boulders similar to the bed materials. Mid-channel islands were observed to also consist of a veneer of vegetated organic material resting on a boulder substrate.

Erosion resistance of channel banks is also likely enhanced by frozen conditions during spring snowmelt peak discharges, as has been observed in other northern areas (Scott 1978). However, during unfrozen conditions after spring runoff, these banks may be sensitive to changes in flow regime. The Lake N11 outlet channel is an exception to this observation, where channel banks are naturally armoured with boulders, bedrock, and till.

Channels at the outlets of small, headwater lakes may be poorly defined and flow through organic substrates, mostly without the cobble and boulder bed typical of the medium to larger channels described for the other watersheds. For instance, the Lake N13 outlet has no defined channel, with discharge appearing to flow through a vegetated mat along numerous flow paths, with occasional pools of open water. Although there may be some cobble and boulder substrate present along the channel, the bed and banks are largely composed of easily erodible organics and fine-grained soils, which could be sensitive to changes in flow regime.

A summary of lake outlet channel characteristics in the LSA downstream of Kennady Lake is shown in Table 9.3-2.

Table 9.3-2 Lake Outlet Channel Data Downstream of Kennady Lake

Outlet Channel	Watershed Area (km^2)	Length (m)	Elevation Drop (m)	Slope	Channel Type
L3	32.7	463	1.360	0.003	well-defined with boulder bed, shallow and wide, with sub- and side channels present
L2	36.3	300	1.640	0.005	
L1b	37.2	85	0.655	0.008	
L1a	37.5	346	4.408	0.013	
M4	45.1	305	0.916	0.003	
M3	52.6	216	0.297	0.001	
M2	54.2	211	0.555	0.003	
M1	56.7	237	0.283	0.001	
Total/Mean	**56.7**	**2163**	**10.114**	**0.005**	–
N13	0.25	141	2.260	0.016	poorly defined
N12	3.89	481	4.160	0.009	poorly defined
N14	0.98	500	2.051	0.004	well-defined, bed and banks of organics and fine-grained soil

Table 9.3-2 Lake Outlet Channel Data Downstream of Kennady Lake (continued)

Outlet Channel	Watershed Area (km^2)	Length (m)	Elevation Drop (m)	Slope	Channel Type
N17	18.8	348	0.255	0.001	well-defined
N16	52.9	276	no data	no data	well-defined
N15	53.7	382	no data	no data	well-defined
N18	1.63	538	8.1	0.015	some well-defined channel but much flow through boulder garden and subsurface
N11	115	174	4.5	0.026	well-defined; banks armoured and bedrock bed control
Total/Mean	**115**	**-[(a)]**	**-**	**-**	**-**
Lake 410	256	193	1.615	0.008	wide with numerous small islands
Total/Mean	**256**	**193**	**1.615**	**0.008**	**-**
P8b	266	300	1.000	0.003	wide with numerous small islands
P8a	266	121	1.897	0.016	
P7		96	1.991	0.021	
P6b	275	200	0.535	0.003	
P6a	275	712	4.610	0.006	
P5	279	575	1.708	0.003	
P4	280	233	2.936	0.013	
P3 west (via P2)	284	1200	7.649	0.006	wide with numerous small islands; 80% of flow
P3 east (via P1)	284	1700	7.649	0.004	wide with numerous small islands; 20% of flow
Total/Mean (excl. P3 east)	284	**3630**	**23.941**	**0.007**	–
Kirk Lake	739	900	3	0.003	pool and riffle with stable boulder bed and banks

[(a)] Total not calculated, as the streams are not contiguous.

km^2 = square kilometres; m = metres; % = percent; – = not applicable.

9.3.2.2.2 Ice and Winter Flows

Winter Conditions

Data and observations of ice conditions and winter flows in the LSA are summarized in Table 9.3-3. Only limited field data collection was performed, because Project effects on winter flows are expected to be small. Data are not available for the ice thickness of most lakes surveyed in 2004 and 2005, except for Lake N1, which had 1.7 m of ice in 2004, and Lake N1 and Lake N2, both which had approximately 1.8 m ice cover in 2005. Ice surface and water levels for lakes downstream of the Kennady Lake watershed typically had no data available. However, Lake N1 had an ice surface level approximately 15 centimetres (cm) higher than the water levels, indicating a floating ice cover with some snow load.

All lake outlets that were examined, except for Lake N11 and Lake N1, were consistently observed to be completely frozen, with no measurable flow during the winter. This appears to be the typical winter condition for all lakes downstream of the Kennady Lake watershed, and also for all smaller lakes downstream to Kirk Lake. Both Lake N1, and its major tributary Lake N11, appear to have a combination of discharge volume and outlet characteristics that allows flow to be sustained over the winter. Lake N11 appears to be the lake farthest upstream within the local drainage network that flows through the winter, as evidenced by the absence of winter inflows from the upstream Lake N16.

Winter flows from Lake N1 into Lake 410 were observed to disappear under the Lake 410 ice cover rather than flowing onto the ice surface, indicating that surface icing (aufeis formation) did not occur. Most winter outflows from Lake N1 appear to be stored in Lake 410.

Table 9.3-3 Lake Ice and Winter Water Levels and Outlet Flow Conditions in the LSA, 2004 and 2005

Lake	Date	Ice Thickness (m)	Ice Level (m)[a]	Water Level (m)[a]	Outlet Condition
L1	May 2004	no data	8.384	ice to bottom	frozen, no flow
	April 2005	(>1.1)	no data	ice to bottom	frozen, no flow
M4, M3, M2	May 2004	no data	no data	no data	frozen, no flow
M2	January 2005	no data	no data	no data	aerial observation showed no open water
M1	May 2004	(>1.2)	no data	ice to bottom	frozen, no flow
	January 2005	no data	no data	no data	aerial observation showed no open water
N16	April 2005	no data	no data	no data	frozen, no flow
N7, N6, N5, N4, N3, N2	May 2004	no data	no data	no data	frozen, no flow
N6	April 2005	(>1.2)	no data	ice to bottom	frozen, no flow
N2	April 2005	1.86	no data	8.479	frozen, no flow
N11	April 2005	no data	no data	no data	aerial observation showed open water at the outlet and also collapsed and cracked ice cover at two locations at narrows in Lake N11
N1	May 2004	1.72	8.153	8.013	some open water, flow
	January 2005	no data	no data	no data	some open water, flow
	April 2005	1.80	no data	8.014	some open water, flow
P Lakes	May 2004	no data	no data	no data	aerial observation showed no open water
P3	January 2005	no data	no data	no data	aerial observation showed no open water

[a] Local datum.

m = metres; > = greater than.

Spring Melt Conditions

During the first week or two of the runoff period, regular observations of water levels and discharge measurements were made at intervals of one to two days. Notable dates relating to the start of runoff for the monitoring stations for 2004 and 2005 are presented in Table 9.3-4.

Table 9.3-4 Runoff Start-up Dates in the LSA, 2004 and 2005

Location	Year	Start of Runoff	First Discharge Measurement	Runoff Peak
Lake L1a	2004	June 1	June 3	June 12
	2005	June 3	June 5	June 11
Lake N2	2004	June 10	June 11	June 12
	2005	June 6	June 8	June 8
Lake N1	2004	continuous	June 2	June 21
	2005	continuous	June 4	June 21
Lake N6	2005	June 5	June 4	June 9
Lake N16	2005	June 5	June 6	June 22
Kirk Lake	2005	continuous	June 3	July 11

Freeze-up Conditions

On the basis of the observed winter conditions, observed start and end of season lake levels, the likely influence of watershed area, upstream lakes, and typical regional temperatures, the following estimates were made for freeze-up of the outlets:

- Lakes L1a, N2, and N6 typically discharge to about the end of October;
- Lake N16 and Lake 410 typically discharge to the end of December;
- all lakes in the P watershed discharge to the end of December; and
- Lake N11, N1, and Kirk Lake typically discharge through the winter.

9.3.2.2.3 Mean Water Balance

A mean annual water balance for a typical watershed in the Kennady Lake area was developed based on the mean values of the various parameters, on a hydrological year basis. The example of Lake L1 is presented in Table 9.3-5 to provide a basic characterization for mean conditions.

The total evaporative loss from lake and land surfaces (lake evaporation and land evapotranspiration) equals 138.6 mm or 50% of the net pre-snowmelt precipitation input. When combined with sublimation of snow (51.9 mm), the total loss equals 190.5 mm or 57% of the total precipitation.

The surface runoff amount represents 43% of the total precipitation, or 50% of the net precipitation, which is the precipitation remaining after the snow sublimation loss is deducted.

Table 9.3-5 Representative Watershed (Lake L1) Mean Annual Water Balance for Natural Conditions

Component	Magnitude (mm)	Comment
Total precipitation	331.6	mean annual value
Rainfall	162.0	mean annual value
Snowfall as SWE	169.6	mean annual value
Spring SWE	117.7	mean annual value, accounting for 30% loss due to sublimation (51.9 mm)
Net precipitation input	279.7	rainfall + spring SWE
Surface runoff (at Lake L1 outlet)	141.1	mean annual value
Lake evaporation at 285 mm	93.8[a]	32.9% of Watershed L is lake surface
Evapotranspiration at 66.8 mm	44.8[b]	67.1% of Watershed L is land surface
Net watershed output	279.7	surface runoff + lake evaporation + evapotranspiration

[a] Total evaporation loss from lake surfaces = (285 mm) x (0.329) = 93.8 mm.

[b] Total evapotranspiration loss from land surfaces = (66.8 mm) x (0.671) = 44.8 mm.

SWE = snow water equivalent; mm = millimetres; % = percent.

9.3.2.2.4 Lake Outlet Flow Regimes

Frequency analysis of the hydrology model results (floods and droughts) for lake outflows of interest at lakes downstream of the Project site were carried out for use in fisheries and water quality baseline reports and to provide a basis for environmental impact assessment and engineering design. The following parameters were examined:

- maximum, mean, and minimum daily outflow volumes for each calendar month;
- annual 7-day and 14-day mean flood discharges; and
- annual 30-day, 60-day, and 90-day low flow discharges for the period of July, August, and September.

Results are presented for selected lakes (i.e., L1, N18, N11, N1, Lake 410, and Kirk Lake). Results for additional lakes, and for maximum and minimum daily outflow volumes, are presented in Annex H and Addendum HH.

Lake L1

Results for Lake L1 are presented in Table 9.3-6 (mean daily outflow volumes) and Table 9.3-7 (long duration floods and low flow discharges).

Table 9.3-6 Derived Mean Daily Outflow at Lake L1

Condition	Return Period (years)	Monthly Mean Outflow (m^3/d)					
		May	June	July	August	September	October
Wet	100	31,500	130,000	111,000	67,700	85,000	20,600
	50	19,700	122,000	102,000	60,900	67,400	16,700
	20	10,500	112,000	90,500	52,200	49,900	12,200
	10	6,380	102,000	81,400	45,700	38,900	9,240
	5	3,370	90,600	70,300	38,400	28,300	6,650
Median	2	998	67,800	52,300	28,100	16,400	3,630
Dry	5	0	47,200	36,700	20,200	10,300	2,090
	10	0	35,700	29,300	17,100	8,310	1,620
	20	0	26,800	23,900	14,900	7,210	1,330
	50	0	16,500	18,100	12,700	6,250	1,100
	100	0	10,700	14,200	11,300	5,750	976

m^3/d = cubic metres per day.

Table 9.3-7 Derived Representative Discharges at Lake L1

Condition	Return Period (years)	Peak Daily Q (m^3/s)	7-Day Avg. Peak Q (m^3/d)	14-Day Avg. Peak Q (m^3/d)	30-Day (July to September) Low Flow Q (m^3/d)	60-Day (July to September) Low Flow Q (m^3/d)	90-Day (July to September) Low Flow Q (m^3/d)
Wet	100	2.62	214,000	189,000	57,000	63,400	76,800
	50	2.54	208,000	184,000	48,400	55,600	69,300
	20	2.40	197,000	174,000	38,300	45,900	59,500
	10	2.25	185,000	164,000	31,300	38,900	51,900
	5	2.05	168,000	150,000	24,700	32,000	44,100
Median	2	1.59	131,000	119,000	16,100	22,400	32,500
Dry	5	1.12	93,300	85,600	9,990	15,500	23,500
	10	0.86	71,700	66,800	7,980	13,000	19,900
	20	0.63	53,500	50,800	6,870	11,500	17,700
	50	0.39	33,200	32,800	6,090	10,400	15,800
	100	0.23	20,000	21,000	5,770	9,970	15,000

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Lake N18

Results for Lake N18 are presented in Table 9.3-8 (mean daily outflow volumes) and Table 9.3-9 (long duration floods and low flow discharges).

Table 9.3-8 Derived Mean Daily Outflow at Lake N18

Condition	Return Period (years)	Monthly Mean Outflow (m^3/d)					
		May	June	July	August	September	October
Wet	100	5,020	8,440	4,240	3,380	5,600	255
	50	3,290	7,940	3,810	2,920	4,020	207
	20	1,820	7,190	3,230	2,330	2,430	148
	10	1,110	6,550	2,780	1,900	1,560	107
	5	623	5,800	2,290	1,480	902	68
Median	2	184	4,420	1,530	896	308	18
Dry	5	0	3,130	951	519	95	0
	10	0	2,490	704	378	45	0
	20	0	1,970	524	283	20	0
	50	0	1,400	344	196	3	0
	100	0	1,040	237	147	0	0

m^3/d = cubic metres per day.

Table 9.3-9 Derived Representative Discharges at Lake N18

Condition	Return Period (years)	Peak Daily Q (m^3/s)	7-Day Avg. Peak Q (m^3/d)	14-Day Avg. Peak Q (m^3/d)	30-Day (July to September) Low Flow Q (m^3/d)	60-Day (July to September) Low Flow Q (m^3/d)	90-Day (July to September) Low Flow Q (m^3/d)
Wet	100	0.20	15,000	12,900	3,210	3,100	2,890
	50	0.19	14,200	12,100	2,410	2,570	2,570
	20	0.17	12,900	11,100	1,570	1,930	2,140
	10	0.16	11,900	10,100	1,070	1,500	1,820
	5	0.14	10,600	9,070	665	1,110	1,490
Median	2	0.11	8,390	7,130	259	620	990
Dry	5	0.09	6,300	5,330	89	351	636
	10	0.07	5,260	4,450	44	263	493
	20	0.06	4,430	3,750	19	208	393
	50	0.05	3,530	2,980	1	160	296
	100	0.04	2,950	2,490	0	136	239

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day; - = not applicable.

Lake N11

Results for Lake N11 are presented in Table 9.3-10 (mean daily outflow volumes) and Table 9.3-11 (long duration floods and low flow discharges).

Table 9.3-10 Derived Mean Daily Outflow at Lake N11

Condition	Return Period (years)	Monthly Mean Outflow (m^3/d)					
		May	June	July	August	September	October
Wet	100	236,000	443,000	293,000	221,000	258,000	50,700
	50	149,000	425,000	270,000	197,000	206,000	43,300
	20	79,600	392,000	239,000	168,000	155,000	34,400
	10	48,900	359,000	215,000	147,000	123,000	28,200
	5	25,900	327,000	186,000	124,000	91,800	22,300
Median	2	7,610	257,000	141,000	91,400	56,800	14,700
Dry	5	0	191,000	101,000	68,100	39,100	10,300
	10	0	155,000	83,600	58,800	33,300	8,740
	20	0	126,000	70,200	52,600	30,100	7,750
	50	0	92,800	56,300	46,400	27,400	6,870
	100	0	71,900	46,900	42,600	25,900	6,400

m^3/d = cubic metres per day.

Table 9.3-11 Derived Representative Discharges at Lake N11

Condition	Return Period (years)	Peak Daily Q (m^3/s)	7-Day Avg. Peak Q (m^3/d)	14-Day Avg. Peak Q (m^3/d)	30-Day (July to September) Low Flow Q (m^3/d)	60-Day (July to September) Low Flow Q (m^3/d)	90-Day (July to September) Low Flow Q (m^3/d)
Wet	100	9.77	747,000	630,000	179,000	198,000	215,000
	50	9.38	718,000	608,000	154,000	175,000	196,000
	20	8.78	672,000	572,000	124,000	146,000	171,000
	10	8.22	630,000	538,000	102,000	125,000	152,000
	5	7.50	576,000	495,000	82,000	104,000	131,000
Median	2	6.00	464,000	404,000	55,500	75,000	98,700
Dry	5	4.32	339,000	300,000	39,500	55,700	74,400
	10	3.36	269,000	240,000	33,900	48,500	64,200
	20	2.53	208,000	188,000	30,200	43,600	56,800
	50	1.54	135,000	125,000	27,000	39,100	49,600
	100	0.85	85,300	81,700	25,200	36,500	45,200

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Lake N1

Results for Lake N1 are presented in Table 9.3-12 (mean daily outflow volumes) and Table 9.3-13 (long duration floods and low flow discharges).

Table 9.3-12 Derived Mean Daily Outflow at Lake N1

Condition	Return Period (years)	Monthly Mean Outflow (m^3/d)					
		May	June	July	August	September	October
Wet	100	444,000	737,000	470,000	370,000	398,000	84,100
	50	284,000	704,000	436,000	333,000	333,000	72,300
	20	153,000	654,000	387,000	285,000	256,000	57,800
	10	91,000	609,000	348,000	248,000	204,000	47,600
	5	49,700	554,000	303,000	211,000	157,000	37,900
Median	2	13,900	444,000	229,000	156,000	99,000	25,100
Dry	5	0	331,000	166,000	117,000	67,100	17,300
	10	0	270,000	138,000	102,000	56,600	14,600
	20	0	219,000	116,000	91,400	50,100	12,800
	50	0	161,000	93,400	81,200	44,500	11,200
	100	0	121,000	79,300	75,400	41,600	10,300

m^3/d = cubic metres per day.

Table 9.3-13 Derived Representative Discharges at Lake N1

Condition	Return Period (years)	Peak Daily Q (m^3/s)	7-Day Avg. Peak Q (m^3/d)	14-Day Avg. Peak Q (m^3/d)	30-Day (July to September) Low Flow Q (m^3/d)	60-Day (July to September) Low Flow Q (m^3/d)	90-Day (July to September) Low Flow Q (m^3/d)
Wet	100	25.90	1,250,000	1,050,000	285,000	333,000	353,000
	50	24.20	1,210,000	1,010,000	249,000	295,000	323,000
	20	21.90	1,140,000	960,000	204,000	247,000	283,000
	10	19.90	1,080,000	910,000	171,000	212,000	251,000
	5	17.60	997,000	845,000	139,000	177,000	218,000
Median	2	13.50	827,000	704,000	95,600	128,000	166,000
Dry	5	9.94	636,000	539,000	67,600	95,900	126,000
	10	8.22	527,000	441,000	57,200	83,800	109,000
	20	6.87	432,000	354,000	50,300	75,600	96,500
	50	5.43	320,000	249,000	44,000	68,000	84,400
	100	4.51	242,000	174,000	40,500	63,800	77,100

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Lake 410

Results for Lake 410 are presented in Table 9.3-14 (mean daily outflow volumes) and Table 9.3-15 (long duration floods and low flow discharges).

Table 9.3-14 Derived Mean Daily Outflow at Lake 410

Condition	Return Period (years)	Monthly Mean Outflow (m^3/d)					
		May	June	July	August	September	October
Wet	100	402,000	934,000	678,000	475,000	587,000	135,000
	50	248,000	891,000	633,000	432,000	477,000	114,000
	20	128,000	823,000	569,000	374,000	355,000	88,500
	10	73,800	759,000	514,000	329,000	278,000	70,700
	5	39,000	681,000	452,000	282,000	211,000	54,000
Median	2	10,300	537,000	344,000	210,000	135,000	32,700
Dry	5	0	399,000	249,000	155,000	91,000	20,300
	10	0	329,000	203,000	132,000	73,900	16,000
	20	0	275,000	168,000	116,000	63,200	13,300
	50	0	222,000	130,000	99,700	54,200	10,900
	100	0	190,000	106,000	90,100	49,800	9,660

m^3/d = cubic metres per day.

Table 9.3-15 Derived Representative Discharges at Lake 410

Condition	Return Period (years)	Peak Daily Q (m^3/s)	7-Day Avg. Peak Q (m^3/d)	14-Day Avg. Peak Q (m^3/d)	30-Day (July to September) Low Flow Q (m^3/d)	60-Day (July to September) Low Flow Q (m^3/d)	90-Day (July to September) Low Flow Q (m^3/d)
Wet	100	20.00	1,420,000	1,240,000	404,000	443,000	491,000
	50	19.10	1,380,000	1,200,000	351,000	395,000	451,000
	20	17.70	1,300,000	1,140,000	285,000	333,000	398,000
	10	16.50	1,230,000	1,080,000	237,000	287,000	355,000
	5	14.90	1,140,000	1,000,000	191,000	240,000	308,000
Median	2	11.90	942,000	837,000	128,000	173,000	234,000
Dry	5	8.78	713,000	640,000	88,700	126,000	175,000
	10	7.11	580,000	523,000	74,200	108,000	150,000
	20	5.71	462,000	418,000	64,600	96,000	131,000
	50	4.11	319,000	290,000	55,800	84,200	112,000
	100	3.03	219,000	200,000	50,900	77,500	100,000

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Kirk Lake

Results for Kirk Lake are presented in Table 9.3-16 (mean daily outflow volumes) and Table 9.3-17 (long duration floods and low flow discharges).

Table 9.3-16 Derived Monthly Mean Outflow at Kirk Lake

Condition	Return Period (years)	Monthly Mean Outflow (m^3/d)					
		May	June	July	August	September	October
Wet	100	641,000	1,850,000	1,730,000	1,250,000	1,370,000	420,000
	50	410,000	1,740,000	1,650,000	1,150,000	1,120,000	337,000
	20	220,000	1,590,000	1,530,000	1,020,000	852,000	246,000
	10	131,000	1,450,000	1,420,000	916,000	676,000	188,000
	5	72,000	1,290,000	1,290,000	796,000	520,000	137,000
Median	2	20,400	995,000	1,020,000	596,000	332,000	75,700
Dry	5	0	708,000	752,000	427,000	208,000	37,700
	10	0	562,000	607,000	349,000	161,000	24,500
	20	0	443,000	486,000	290,000	130,000	16,100
	50	0	312,000	348,000	229,000	101,000	8,710
	100	0	226,000	255,000	191,000	85,200	4,760

m^3/d = cubic metres per day.

Table 9.3-17 Derived Representative Discharges at Kirk Lake

Condition	Return Period (years)	Peak Daily Q (m^3/s)	7-Day Avg. Peak Q (m^3/d)	14-Day Avg. Peak Q (m^3/d)	30-Day (July to September) Low Flow Q (m^3/d)	60-Day (July to September) Low Flow Q (m^3/d)	90-Day (July to September) Low Flow Q (m^3/d)
Wet	100	25.50	2,160,000	2,100,000	1,050,000	1,140,000	1,290,000
	50	24.70	2,100,000	2,040,000	925,000	1,030,000	1,210,000
	20	23.40	1,990,000	1,940,000	759,000	887,000	1,080,000
	10	22.10	1,890,000	1,850,000	636,000	774,000	981,000
	5	20.50	1,760,000	1,720,000	512,000	654,000	864,000
Median	2	17.10	1,460,000	1,440,000	333,000	467,000	660,000
Dry	5	13.00	1,110,000	1,090,000	211,000	323,000	480,000
	10	10.60	902,000	884,000	163,000	262,000	395,000
	20	8.44	714,000	694,000	131,000	218,000	328,000
	50	5.83	485,000	459,000	99,700	174,000	258,000
	100	3.98	321,000	290,000	82,100	148,000	213,000

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Lockhart River

A frequency analysis was performed on data from the Water Survey of Canada hydrometric station on the Lockhart River at the Outlet of Artillery Lake (Station 07RD001). This examined annual flood and low flow discharges (mean daily flows) and annual water yields. The results of this analysis are presented in Table 9.3-18.

Table 9.3-18 Frequency Analysis Results for Lockhart River Hydrometric Station

Condition	Return Period (years)	Annual Flood (m^3/s)	Annual Low Flow (m^3/s)	Annual Water Yield (mm)
Wet	100	301	-	217
	50	282	-	209
	20	254	-	196
	10	232	-	185
	5	208	-	172
Median	2	168	78.0	146
Dry	5	-	64.9	122
	10	-	57.9	108
	20	-	52.0	97.3
	50	-	45.3	84.9
	100	-	40.7	76.6

m^3/s = cubic metres per second; mm = millimetre; - = not applicable.

9.3.3 Surface Water and Sediment Quality

The following section provides an overview of the baseline surface water quality and sediment quality for streams and lakes downstream of the Kennady Lake watershed. The baseline setting is defined from published work by others and several seasons of investigations by several consultants and consulting teams. For additional information regarding surface water quality, the reader is referred to Annex I (Water Quality Baseline) and Addendum II (Additional Water Quality Baseline Information).

9.3.3.1 Methods

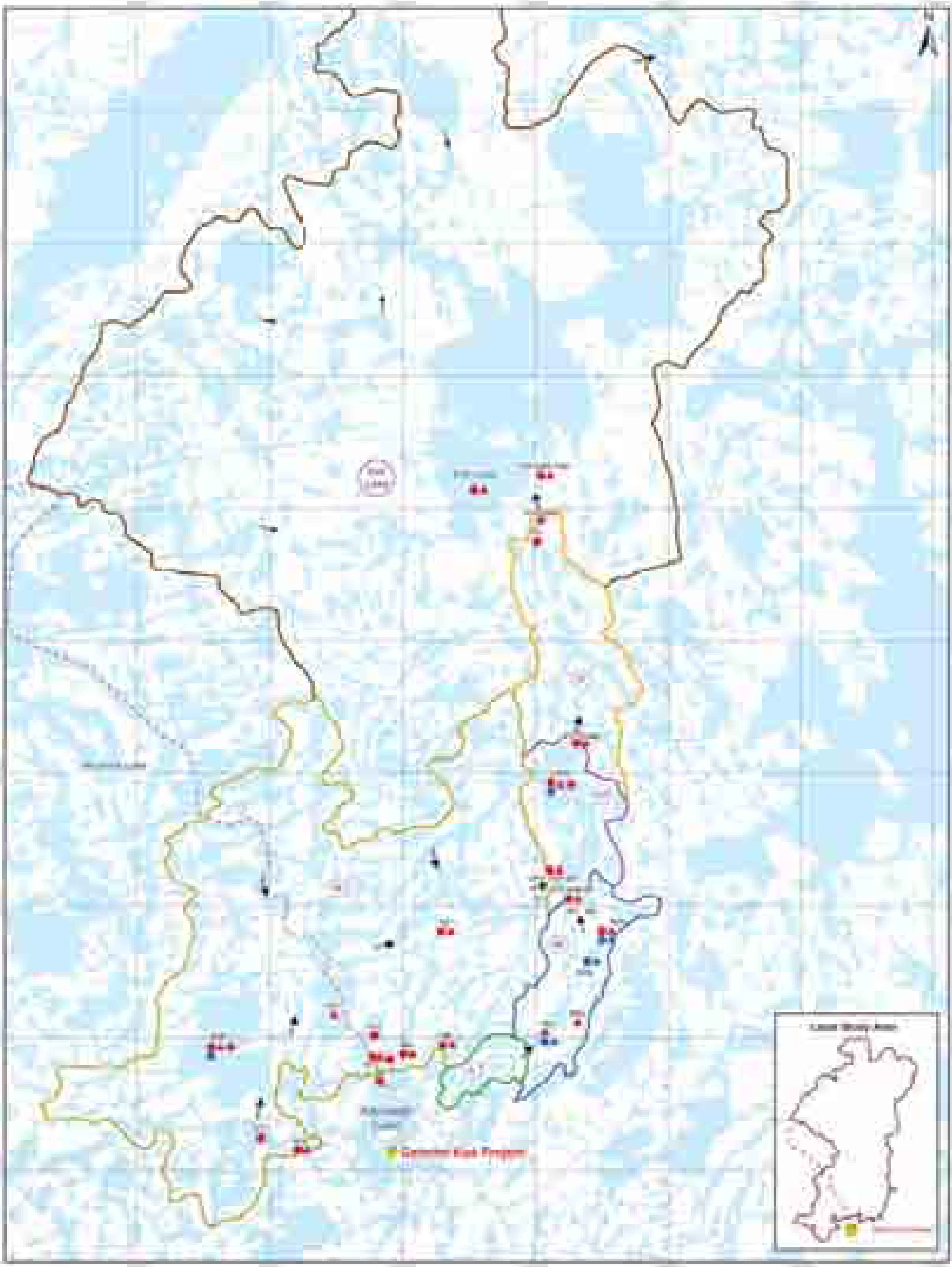
9.3.3.1.1 Location and Timing of Sampling

The baseline sampling programs involved the collection of water and sediment samples from waterbodies downstream of Kennady Lake to the inlet basin of Kirk Lake. Several baseline field programs have been conducted in areas downstream of the Kennady Lake watershed since 1998. The location and timing for each sampled stream and lake is denoted for each water or sediment sample collected. These are represented in Figure 9.3-3 using different symbols:

- in-situ (field) measurements are denoted with a circle;
- grab water samples and water samples collected as part of a vertical field profile are denoted with a triangle; and
- grab sediment samples are denoted with a diamond.

The colour of the symbol denotes sampling during under-ice (blue) and open water (red) conditions.

All data from the baseline study reports were classified as in-situ (spot or profile measurements), grab samples, or vertical profile samples. Summary statistics for water and sediment quality, including the median, minimum, and maximum values, as well as the range of sample sizes, were prepared for each chemical constituent analyzed and are presented in tabular format. Water quality summaries were prepared for both under-ice and open water conditions.



LEGEND

Water Column Profile Samples

Sampling

SampleType

Water Column Profile Samples

NOTES

Base data source: National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Surface Water Quality Sampling Locations in Streams and Lakes Downstream of Kennady Lake to Kirk Lake Outlet

E-SWQ-004-GIS			December 17, 2010
JOB NO. 09-1365-1004	REVISION NO. 1		**Figure 9.3-3**
OFFICE GOLD-CAL	DRAWN CW	CHECK JF	

All data were summarized into the following three categories, based on the proportion of values below their respective method detection limits (MDLs), and analyzed separately:

- data series where values below the MDL consisted of approximately one-third to one-quarter (or less) of the data series;
- data series where values below the MDL ranged from approximately one-third to two-thirds of the data series; and
- data series where values below the MDL comprised approximately two-thirds to three-quarters (or more) of the data series.

When the data series occurred in the first category, all values below the MDL were assigned a value of one-half of the most sensitive MDL, and descriptive statistics (e.g., minimum, median, and maximum) were calculated. By using a value of half of the most sensitive MDL in this case, a representative statistical analysis of the natural conditions could be accomplished.

For data in the second category, descriptive statistics were calculated on values at or above the MDL only. If a value of half the most sensitive MDL was used in this case, the data series may have become skewed.

For the data series in the final category, only minimum and maximum values were provided. By using a value of half the most sensitive MDL in this case, descriptive statistics may have provided a median below the most sensitive MDL.

Minimum and maximum detection limits were presented in addition to the statistical descriptors of the data range for each parameter to assist in understanding the statistical descriptors presented. The baseline data represents data collected over more than 10 years. Improvements or changes in analytical methods and procedures over the period of baseline data collection have resulted in inconsistent detection limits within the data. Generally, lower detection limits have been associated with more recent baseline field programs.

All results for the water sampling programs were compared to both the most recent Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQG) for the protection of aquatic life (CCME 1999a, with updates to 2010) and Health Canada Guidelines for Canadian Drinking Water Quality Guidelines (CDWQG) (Health Canada 2008). The results of the sediment sampling programs were compared to the CCME Interim Sediment Quality Guidelines (ISQG) for the protection of aquatic life (CCME 1999b, with updates to 2002).

The CWQG and ISQG are intended to protect aquatic life, including the most sensitive species, for the long-term (CCME 1999a, CCME 1999b). They are based on toxicity tests of the effects on sensitive aquatic species and tend to be conservative in nature.

9.3.3.2 Results

9.3.3.2.1 The Interlakes - Lakes Immediately Downstream of Kennady Lake

Physical Limnology and Vertical Structure

Under-ice Conditions

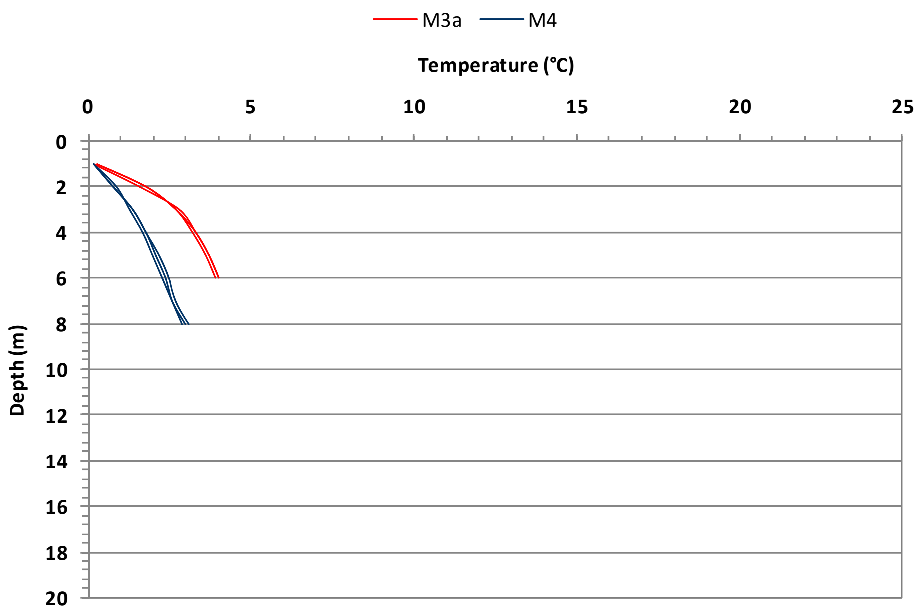
During under-ice conditions, Lakes M3 and M4 exhibited inverse thermal gradients. Cooler waters approaching 0 degrees Celsius (°C) occurred immediately below the ice, with temperatures gradually increasing with depth to a maximum temperature around 4°C (Figure 9.3-4a). The maximum temperatures occurred generally at near-bottom depths.

Concentrations of dissolved oxygen (DO) ranged from 14 to 21 milligrams per litre (mg/L) in the upper 2 m of the water column near the ice-water interface and decreased with depth to less than the lower CWQG for cold water aquatic life (i.e., 6.5 mg/L for other life stages) (Figure 9.3-4b). Water column DO trends in Lakes M3 and M4 were similar to DO profiles measured in Kennady Lake under-ice conditions. However, DO concentrations did not reach the under-ice anoxic conditions measured in the deeper waters of Kennady Lake.

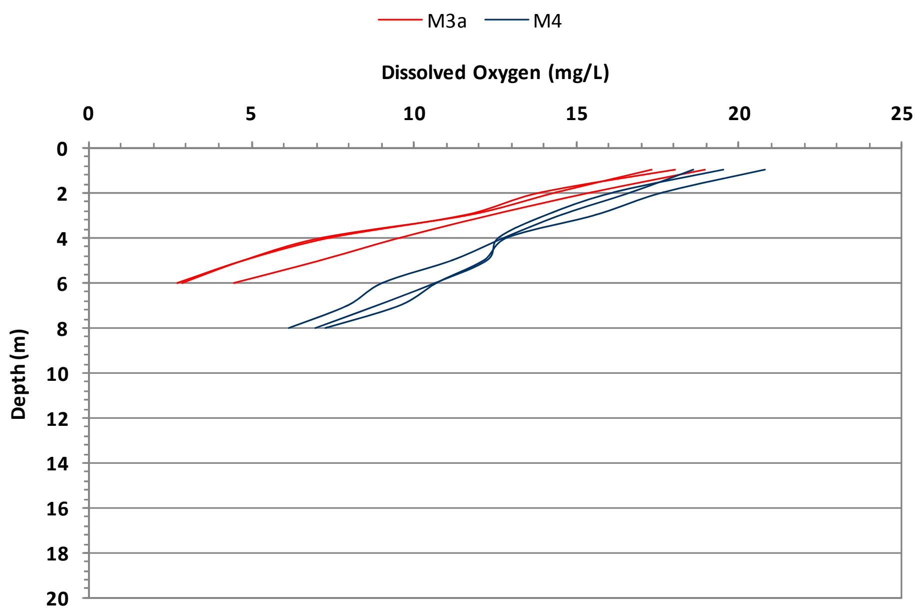
Field measurements of conductivity and pH were not collected during under-ice conditions from lakes in the L and M watersheds. Laboratory measurements of conductivity and pH for water samples collected from these lakes during under-ice conditions had conductivity values that ranged between 9 to 24 microSiemens per centimetre (μS/cm) and pH values that ranged between 6.1 to 6.6 pH units (Table 9.3-19). Some pH readings were below the acceptable CWQG and CDWQG ranges.

Figure 9.3-4 Physico-chemical Water Quality Profile Data for Water Temperature and Dissolved Oxygen for the Interlakes during Under-ice Conditions (1998 to 2010)

a) Water Temperature



b) Dissolved Oxygen



m = metre, °C = degrees Celsius.

Individual field results not presented in field profile figures.

Table 9.3-19 Water Quality Data Summary for the Interlakes Downstream of Kennady Lake, 1998 to 2010

Parameter Name	Unit	Method Detection Limit			Under-ice Conditions (1998-2004)										Open Water Conditions (1996-2010)									
											Guidelines										Guidelines			
											Aquatic Life-Chronic (a)		Human Health-Chronic (b)								Aquatic Life-Chronic (a)		Human Health-Chronic (b)	
		Min	Max	Number of MDL	n	Min	Med	Max	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count	n	Min	Med	Max	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count
Field Measured																								
pH	pH units	-	-	0	0	-	-	-	0	-	6.5-8.5	0	5.0-9.0	0	48	**6.2**[(c)]	**6.4**[(c)]	8.3	0	0	6.5-8.5	28	5.0-9.0	0
Temperature	°C	-	-	0	54	0.2	2.2	4	0	0	-	0	-	0	85	10	13	18	0	0	-	0	-	0
Conductivity	µS/cm	-	-	0	0	-	-	-	0	-	-	0	-	0	85	10	13	14	0	0	-	0	-	0
Dissolved Oxygen	mg/L	-	-	0	54	**2.7**[(c)]	12	21	0	0	6.5	9	-	0	71	**0.7**[(c)]	9.3	12	0	0	6.5	1	-	0
Conventional Parameters																								
Colour	TCU	-	-	0	0	-	-	-	0	-	-	0	-	0	3	10	20	30	0	0	-	0	-	0
Conductivity	µS/cm	-	-	0	14	9	21	24	0	0	-	0	-	0	7	13	16	25	0	0	-	0	-	0
Dissolved Organic Carbon	mg/L	-	-	0	0	-	-	-	0		-	0	-	0	5	4	4	6	0	0	-	0	-	0
Hardness	mg/L	6	6	1	14	3.3	7	9	0	0	-	0	-	0	8	0.5	3.8	7	3	37.5	-	0	-	0
pH	pH units	-	-	0	14	**6.1**[(c)]	6.4	6.6	0	0	6.5-8.5	7	5.0-9.0	0	7	**6.1**[(c)]	6.6	6.8	0	0	6.5-8.5	3	5.0-9.0	0
Total Alkalinity	mg/L	5	5	1	14	2	8	8	0	0	-	0	-	0	10	2.5	7.5	30	2	20	-	0	-	0
Total Dissolved Solids	mg/L	10	10	1	2	22	-	39	0	0	-	0	-	0	8	24	26	35	3	37.5	-	0	-	0
Total Organic Carbon	mg/L	-	-	0	12	5	6	6.6	0	0	-	0	-	0	5	3	4.1	6	0	0	-	0	-	0
Total Suspended Solids	mg/L	1	3	3	14	<1	-	<3	14	100	-	0	-	0	5	<3	-	3	3	60	-	0	-	0
Major Ions																								
Bicarbonate	mg/L	5	5	1	12	9	10	10	0	0	-	0	-	0	10	2.5	9.4	36	2	20	-	0	-	0
Calcium	mg/L	-	-	0	14	0.73	1.7	2.1	0	0	-	0	-	0	7	1	1	1.9	0	0	-	0	-	0
Carbonate	mg/L	-	5	3	12	<5	-	<5	12	100	-	0	-	0	10	<0.5	-	<5	10	100	-	0	-	0
Chloride	mg/L	0.5	1	2	14	<0.5	-	1	11	78.6	230	0	-	0	10	0.2	0.6	1	6	60	230	0	-	0
Magnesium	mg/L	-	-	0	14	0.35	0.7	0.9	0	0	-	0	-	0	7	0.34	0.5	0.62	0	0	-	0	-	0
Potassium	mg/L	-	-	0	14	0.44	0.6	0.8	0	0	-	0	-	0	7	0.35	0.41	0.5	0	0	-	0	-	0
Sodium	mg/L	1	1	1	14	0.41	1.1	1.3	0	0	-	0	-	0	7	0.5	0.57	3	2	28.6	-	0	-	0
Sulphate	mg/L	1	1	1	14	0.5	1.3	1.4	1	7.1	-	0	-	0	10	<1	1.1	1.3	4	40	-	0	-	0
Sulphide	µg/L	2	2	1	0	-	-	-	0	-	5.6	0	-	0	2	<2	-	<2	2	100	2.3	0	-	0
Nutrients																								
Nitrate + Nitrite	mg N/L	0.003	0.006	2	12	0.02	0.037	0.14	5	41.7	2.93	0	10	0	4	<0.003	-	<0.006	4	100	2.93	0	10	0
Nitrogen-Ammonia	mg N/L	0.05	0.1	2	14	0.009	0.018	0.1	0	0	5	0	-	0	8	<0.05	-	<0.1	8	100	26	0	-	0
Nitrogen-Kjeldahl	mg N/L	0.2	0.2	1	0	-	-	-	0	-	-	0	-	0	3	<0.2	-	<0.2	3	100	-	0	-	0
Phosphorus, total	mg/L	0.02	0.3	4	2	<0.3	-	<0.3	2	100	0.05	0	-	0	9	<0.02	-	0.005	7	77.8	-	0	-	0
Phosphorus, dissolved	mg/L	0.005	0.3	2	2	<0.3	-	<0.3	2	100	-	0	-	0	5	0.003	-	0.003	3	60	-	0	-	0
General Organics																								
Total Phenolics	µg/L	2	2	1	0	-	-	-	0	-	5	0	-	0	2	<2	-	<2	2	100	5	0	-	0
Total Recoverable Hydrocarbons	mg/L	0.1	2	2	0	-	-	-	0	-	-	0	-	0	5	<0.1	-	<2	5	100	-	0	-	0
Total Metals[(e)]																								
Aluminum	µg/L	20	20	1	14	20	26	83	0	0	100	0	100	0	11	15	18	**170**[(c, H)]	6	54.5	100	2	100	2
Antimony	µg/L	0.02	1	5	14	0.025	0.09	0.48	2	14.3	-	0	5.5	0	11	<0.02	-	<1	11	100	-	0	5.5	0
Arsenic	µg/L	0.4	1	2	14	0.08	0.13	0.18	0	0	5	0	10	0	11	<0.4	-	0.15	8	72.7	5	0	10	0
Barium	µg/L	5	5	1	14	2.2	2.9	3.9	0	0	-	0	1000	0	11	1.6	2.5	6.7	3	27.3	-	0	1000	0
Beryllium	µg/L	0.01	1	4	14	<0.2	-	<0.5	14	100	-	0	4	0	11	<0.01	-	<1	11	100	-	0	4	0
Boron	µg/L	8	20	3	14	2	2	3	0	0	-	0	5000	0	11	<8	-	2	10	90.9	-	0	5000	0
Cadmium	µg/L	0.002	0.2	4	14	<0.05	-	<0.05	14	100	0.0034	0	5	0	13	<0.002	-	**0.017**[(c)]	11	84.6	0.002	2	5	0
Chromium	µg/L	0.06	5	6	14	0.08	0.095	0.1	8	57.1	1	0	50	0	11	<0.1	-	<5	11	100	1	0	50	0
Cobalt	µg/L	0.1	0.5	2	14	<0.1	-	0.8	10	71.4	-	0	-	0	11	0.025	0.11	0.3	7	63.6	-	0	-	0
Copper	µg/L	5	5	1	14	0.8	1	**48**[(c)]	0	0	2	2	1300	0	11	0.5	0.63	**4**[(c)]	6	54.5	2	1	1300	0
Iron	µg/L	50	50	1	14	18	46	260	0	0	300	0	300	0	9	25	74	184	1	11.1	300	0	300	0
Lead	µg/L	0.05	0.5	3	14	<0.05	-	0.1	13	92.9	1	0	10	0	11	<0.05	-	0.037	9	81.8	1	0	10	0
Lithium	µg/L	0.1	20	3	14	0.05	1	1.3	4	28.6	-	0	-	0	6	1	1.1	1.1	3	50	-	0	-	0
Manganese	µg/L	-	-	0	14	1.1	6.1	31	0	0	-	0	50	0	9	2	2.8	5	0	0	-	0	50	0
Mercury	µg/L	0.0006	500	6	14	<0.01	-	<0.02	14	100	0.026	0	1	0	10	<0.0006	-	0.008	8	80	0.026	0	1	0
Molybdenum	µg/L	0.05	5	4	14	<0.05	-	<0.06	14	100	73	0	-	0	11	<0.05	-	0.2	9	81.8	73	0	-	0
Nickel	µg/L	0.6	8	2	14	0.22	0.5	1.4	0	0	25	0	340	0	11	0.2	0.51	2.1	5	45.5	25	0	340	0

Table 9.3-19 Water Quality Data Summary for the Interlakes Downstream of Kennady Lake, 1998 to 2010 (continued)

Parameter Name	Unit	Method Detection Limit			Under-ice Conditions (1998-2004)										Open Water Conditions (1996-2010)									
											Guidelines										Guidelines			
											Aquatic Life-Chronic [a]		Human Health-Chronic [b]								Aquatic Life-Chronic [a]		Human Health-Chronic [b]	
		Min	Max	Number of MDL	n	Min	Med	Max	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count	n	Min	Med	Max	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count
Selenium	µg/L	0.04	10	5	14	<0.1	-	<1	14	100	1	0	10	0	11	<0.04	-	<10	11	100	1	0	10	0
Silver	µg/L	0.01	0.4	4	14	<0.01	-	<0.1	14	100	0.1	0	-	0	13	<0.01	-	0.0028	9	69.2	0.1	0	-	0
Strontium	µg/L	-	-	0	14	4.4	8.8	11	0	0	-	0	-	0	8	5	6.4	12	0	0	-	0	-	0
Sulphur	µg/L	10000	10000	1	0	-	-	-	0	-	-	0	-	0	5	400	400	500	2	40	-	0	-	0
Thallium	µg/L	0.002	0.1	3	2	<0.05	-	<0.05	2	100	0.8	0	0.13	0	11	<0.002	-	<0.1	11	100	0.8	0	0.13	0
Titanium	µg/L	0.5	10	3	2	<10	-	<10	2	100	-	0	-	0	8	3	3	3	5	62.5	-	0	-	0
Uranium	µg/L	0.05	0.1	2	14	<0.05	-	0.06	12	85.7	-	0	-	0	10	<0.05	-	0.013	8	80	-	0	-	0
Vanadium	µg/L	0.05	5	5	14	<0.05	-	<1	14	100	-	0	-	0	11	<0.1	-	0.6	8	72.7	-	0	-	0
Zinc	µg/L	0.8	2	3	14	0.8	1.7	3	5	35.7	30	0	5100	0	11	0.5	4	30	3	27.3	30	0	5100	0
Dissolved Metals[e]																								
Aluminum	µg/L	-	-	0	14	17	24	71	0	0	-	0	-	0	5	12	13	28	0	0	-	0	-	0
Antimony	µg/L	0.05	0.1	2	14	0.025	0.09	0.32	2	14.3	-	0	-	0	5	0.03	-	0.03	3	60	-	0	-	0
Arsenic	µg/L	0.1	0.1	1	14	0.09	0.15	0.29	0	0	-	0	-	0	5	0.13	0.13	0.2	2	40	-	0	-	0
Barium	µg/L	3	3	1	14	2.2	2.8	3.9	0	0	-	0	-	0	5	2.2	-	2.2	3	60	-	0	-	0
Beryllium	µg/L	0.01	0.5	4	14	<0.2	-	<0.5	14	100	-	0	-	0	5	<0.01	-	<0.1	5	100	-	0	-	0
Boron	µg/L	4	20	2	14	1	2	3	0	0	-	0	-	0	5	<4	-	<20	5	100	-	0	-	0
Cadmium	µg/L	0.005	0.05	2	14	<0.05	-	<0.05	14	100	-	0	-	0	5	<0.005	-	<0.05	5	100	-	0	-	0
Chromium	µg/L	0.06	0.5	4	14	0.07	0.12	0.15	6	42.9	-	0	-	0	5	<0.1	-	<0.4	5	100	-	0	-	0
Cobalt	µg/L	0.05	0.1	2	14	<0.1	-	0.7	11	78.6	-	0	-	0	5	0.31	-	0.31	3	60	-	0	-	0
Copper	µg/L	2	2	1	14	0.8	1.1	39	0	0	-	0	-	0	5	0.86	-	0.86	3	60	-	0	-	0
Iron	µg/L	-	-	0	14	15	36	200	0	0	-	0	-	0	5	20	39	99	0	0	-	0	-	0
Lead	µg/L	0.05	0.05	1	14	<0.05	-	<0.05	14	100	-	0	-	0	5	0.038	0.038	0.52	2	40	-	0	-	0
Lithium	µg/L	0.1	1	2	14	0.05	1	1.3	4	28.6	-	0	-	0	2	1	-	1	0	0	-	0	-	0
Manganese	µg/L	-	-	0	14	0.4	5.7	27	0	0	-	0	-	0	5	1.2	1.3	3.7	0	0	-	0	-	0
Mercury	µg/L	0.01	1	3	14	<0.01	-	<0.02	14	100	-	0	-	0	5	0.007	-	0.007	3	60	-	0	-	0
Molybdenum	µg/L	0.05	0.3	3	14	<0.05	-	<0.06	14	100	-	0	-	0	5	<0.05	-	<0.3	5	100	-	0	-	0
Nickel	µg/L	-	-	0	14	0.18	0.58	1.3	0	0	-	0	-	0	5	0.2	0.4	0.42	0	0	-	0	-	0
Selenium	µg/L	0.04	2	3	14	<0.1	-	0.1	13	92.9	-	0	-	0	5	<0.04	-	<2	5	100	-	0	-	0
Silver	µg/L	0.005	0.1	4	14	<0.01	-	<0.1	14	100	-	0	-	0	5	<0.005	-	5	4	80	-	0	-	0
Strontium	µg/L	-	-	0	14	4.3	9	11	0	0	-	0	-	0	2	6.2	-	6.2	0	0	-	0	-	0
Sulphur	µg/L	10000	10000	1	0	-	-	-	0	-	-	0	-	0	2	<10000	-	<10000	2	100	-	0	-	0
Thallium	µg/L	0.002	0.05	3	2	<0.05	-	<0.05	2	100	-	0	-	0	5	<0.002	-	<0.02	5	100	-	0	-	0
Titanium	µg/L	0.5	10	2	2	<10	-	<10	2	100	-	0	-	0	2	<0.5	-	<0.5	2	100	-	0	-	0
Uranium	µg/L	0.05	0.05	1	14	<0.05	-	0.05	12	85.7	-	0	-	0	5	0.012	-	0.012	3	60	-	0	-	0
Vanadium	µg/L	0.05	1	4	14	<0.05	-	0.15	13	92.9	-	0	-	0	5	<0.2	-	<0.5	5	100	-	0	-	0
Zinc	µg/L	0.8	2	2	14	0.4	2	7.4	1	7.1	-	0	-	0	5	0.9	0.9	3	2	40	-	0	-	0

Note: Presented guidelines were calculated using median values for data when applicable.
Individual guidelines were calculated for each sample, to determine the number of results above guidelines when applicable.
Bold values indicate a guideline exceedance.

(a) Canadian Environmental Quality Guidelines (CCME 1999a, with updates to 2010). Winnipeg, MB.
(b) The human health guideline is based on the CCME drinking water guideline, Health Canada (2008).
(C) Concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
(H) Concentration higher than the relevant human health guideline or beyond the recommended pH range.
(e) Some maximum dissolved metals concentrations are higher than the maximum total metal concentration in the statistical summary.

NA = not applicable, "-" = not available; °C = degrees Celsius, µS/cm = microSiemens per centimetre, mg/L = milligrams per litre, mg-N/L = milligrams nitrogen per litre, µg/L = micrograms per litre, TCU = True colour units; % = percent, n = number of samples, < = less than; min = minimum; med = median; max = maximum; MDL = method detection limits

Open Water Conditions

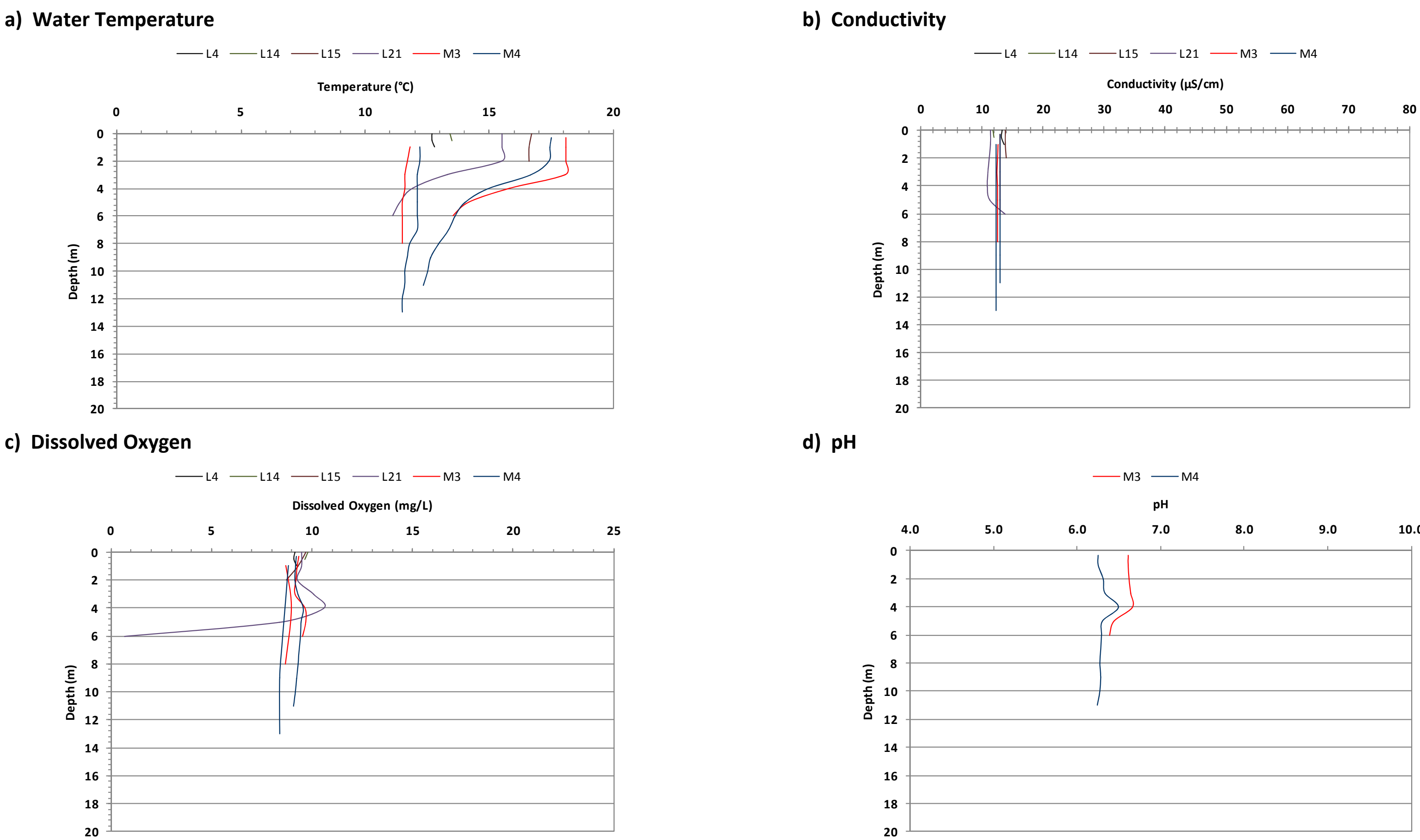
Water column profile measurements for temperature were collected in August of 2002 and 2005 from Lakes L4, L14, L15, L21, M3, and M4 (Figure 9.3-5a). The lakes had near surface temperatures ranging from 13 to 18°C. The lakes exhibited well mixed conditions, by temperature-related, density-driven overturn in spring and fall, as well as wind-driven circulation during summer months in some of the shallow lakes. Stratified conditions, with seasonal thermoclines (steep temperature gradients), were observed between depths of 2 and 6 m in Lakes M3, M4, and L21 (Figure 9.3-5a).

Vertical conductivity profile measurements through the water column during open water conditions were low, ranging between 11 and 14 µS/cm in the L and M lakes (Figure 9.3-5b). Despite the occurrence of a pronounced seasonal thermocline, little variability in conductivity was evident throughout the water column indicating that total dissolved solids (TDS) were equally distributed throughout the lakes.

With the exception of one lake, vertical DO concentrations through the water column in open water conditions in the L and M lakes ranged between 8.5 and 9.8 mg/L, and were generally uniform with depth (Figure 9.3-5c). The DO concentrations measured during most sampling events were above the lowest acceptable dissolved oxygen concentration for the protection of cold water aquatic life (i.e., other life stages [6.5 mg/L]) in the CWQG. The exception was Lake L21 measured in August, where DO decreased rapidly below the thermocline at 2 m to near anoxia at the bottom of the water column (i.e., 6 m).

Open water pH measurements through the water column in the M lakes ranged between 6.2 and 6.6 (Figure 9.3-5d). Some of the pH values measured were below the acceptable pH range of the CWQG (6.5 to 8.5) (Figure 9.3-5d). Field water column profile data for pH were not collected for the L lakes.

Figure 9.3-5 Physico-chemical Field Data for the Interlakes (L and M Lakes) during Open Water Conditions Open Water Interlakes Field Data (1998 to 2010)



m = metre; °C = degrees Celsius; µS/cm = microSiemens per centimetre; mg/L = milligrams per litre.
Individual field results not presented in field profile figures.

Water Quality

Since the small lakes in the interlakes watershed (i.e., L and M watersheds) contribute to the loading of substances to downstream lakes, the water quality similarities and differences are discussed for all surveyed lakes. The available data for all lakes in the L and M watershed are presented in Table 9.3-19.

The water in the interlakes (the L and M lakes watersheds) is soft, having a median hardness of 7 mg/L during under-ice conditions and 3.8 mg/L during open water conditions (Table 9.3-19). The median alkalinity during both under-ice and open water conditions, which is also 8 and 7.5 mg/L, respectively, is also low and an indication of the low buffering capacity of water in these lakes.

The concentrations of TDS were low during under-ice and open water conditions, with values ranging between 22 and 39 mg/L, indicating a small amount of dissolved substances in the water (Table 9.3-19). Bicarbonate was the dominant ion measured during both seasonal sampling conditions, whereas sulphate and chloride were at or below the detection limit during most sampling events. Calcium was the major cation measured in the L and M lakes.

Water in the L and M lakes is very clear and contains very little suspended particulate matter. Total suspended solids (TSS) were not detected during under-ice conditions (Table 9.3-19), and were at, or below, detection limits during open water conditions (i.e., 60% of samples were below detection limits; Table 9.3-19).

The concentrations of inorganic nitrogen compounds, such as ammonia, nitrate, and nitrite, generally were below detection during open water conditions (Table 9.3-19). Total Kjeldahl nitrogen (TKN) was measured below detection limits during ice-covered and open water conditions. Most total phosphorus (TP) concentrations were at, or below, detection during under-ice and open water conditions; due to the limited number of samples and the number of results below detection, a median TP concentration could not be calculated. The measured concentrations of nitrogen and phosphorus nutrients indicate that the L and M lakes can be classed as oligotrophic.

Levels of total organic carbon (TOC) and dissolved organic carbon (DOC) were low (3 to 6 mg/L) during both open water and under-ice conditions (Table 9.3-19). Colour was measured in open water conditions at levels above the CDWQG of 15 true colour units (TCU). Phenol and petroleum hydrocarbons were not detected.

The concentrations of total and dissolved metals were low, with several metals near or below detection limits (e.g., cadmium, lead, mercury, molybdenum, selenium, and thallium) (Table 9.3-19). More variability was observed during open water conditions; however, median concentrations for most metals were similar during both under-ice and open water conditions. Exceedances of applicable guidelines were observed for total aluminum, cadmium, and copper. The median concentrations of dissolved metals were similar to the total fraction.

Sediment Quality

Baseline sediment quality for the Interlakes is limited to sediment samples collected from Lake M3 and Lake M4 in July 2010.

Sediment from the M lakes was mainly composed of sand, with some silt and clay (Table 9.3-20). The total carbon (TC) content ranged from 11 to 14% of the sediment composition, with TOC comprising the majority of the sediment carbon (i.e., 10% to 13%). Inorganic carbon constituted less than 0.9%.

Available phosphorus concentrations in the sediment samples were low, ranging from 5 to 9 micrograms per gram (µg/g) dry weight (Table 9.3-20). Total sediment phosphorus and sediment nitrogen concentrations were not available for the Interlakes.

Total petroleum hydrocarbon (TPH) compounds were not detected in the sediment samples collected from Lakes M3 and M4.

Concentrations of metals in the sediment were generally within the applicable aquatic life guidelines (CCME 1999b) (Table 9.3-20); however, arsenic, chromium, cadmium, copper and zinc exceeded the interim sediment quality guidelines (ISQG) in one or both M lakes.

Table 9.3-20 Sediment Quality Data Summary for Lakes in the M Watershed, in 2010

Parameter	Unit	Method Detection Limit		Lake M3	Lake M4	ISQG
		Minimum	Maximum			
Particle Size and Carbon Content						
Sand	%	2	2	64	51	-
Silt	%	2	2	26	36	-
Clay	%	2	2	10	13	-
Total Inorganic Carbon	%	0.02	0.02	0.89	0.6	-
Total Organic Carbon	%	0.02	0.2	13	10	-
Total Carbon	%	0.02	0.2	14	11	-
Nutrients and Organics						
Available Phosphorus	µg/g	1	2	5	9	-
Total Petroleum Hydrocarbons	µg/g	500	600	<600	<500	-
Total Metals						
Arsenic	µg/g	1	1	**10**	**7**	5.9
Barium	µg/g	10	10	84	100	-
Cadmium	µg/g	0.1	0.1	0.5	**1**	0.6

Table 9.3-20 Sediment Quality Data Summary for Lakes in the M Watershed (continued)

Parameter	Unit	Method Detection Limit		Lake M3	Lake M4	ISQG
		Minimum	Maximum			
Chromium	µg/g	1	1	**42**	**60**	37.3
Cobalt	µg/g	1	1	29	18	-
Copper	µg/g	5	5	**62**	**85**	35.7
Lead	µg/g	1	1	7	7	35
Mercury	µg/g	0.05	0.05	0.13	0.08	0.17
Molybdenum	µg/g	0.4	0.4	4.6	6.4	-
Nickel	µg/g	1	1	39	45	-
Potassium	µg/g	2	4	82	50	-
Selenium	µg/g	0.5	0.5	0.9	1.5	-
Thallium	µg/g	0.3	0.3	<0.3	<0.3	-
Vanadium	µg/g	1	1	48	65	-
Zinc	µg/g	10	10	**130**	**150**	123

Note: **Bolded** numbers identify values above guidelines.
ISQG = Interim Sediment Quality Guideline (CCME 1999b, with updates to 2002).% = percent; µg/g = micrograms per gram, dry weight;-= not applicable.

9.3.3.2.2 Lakes in the N Watershed

Physical Limnology and Vertical Structure

Vertical profile physico-chemical data were collected from Lake N16 during both open water and ice-covered conditions in 2004, 2005, and 2010. In-situ spot measurements for physico-chemical data were collected from several other lakes in the N watershed, but were limited to open water conditions.

Under-ice Conditions

A vertical temperature profile measured for Lake N16 in 2004 showed that the lake was inversely stratified in winter conditions (Figure 9.3-6). The temperature increased from 1°C at the ice-water interface to 2°C at depths of 6 m and greater.

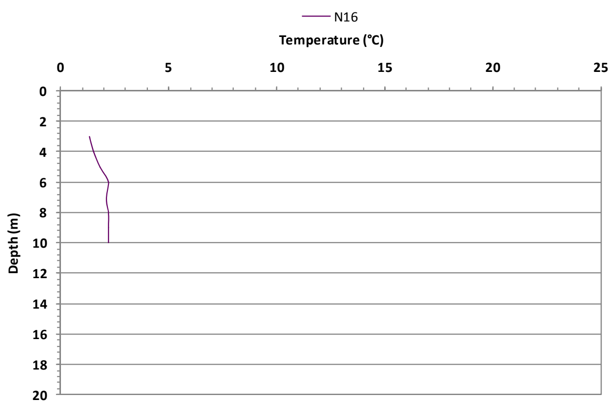
The vertical conductivity profile measurements were low, ranging from 8 µS/cm at the ice-water interface to 11 µS/cm at a depth of 10 m (Figure 9.3-6). The little variability through the water column indicated that the TDS was generally equally distributed through the water column.

The concentration of DO through the water column varied only slightly between the ice-water interface to 8 m depth, below which the DO rapidly reduced to anoxic levels (Figure 9.3-6). Above 6 m, the DO concentrations were below the lowest acceptable guideline for early life stages of cold water fish (9.5 mg/L) but above the guidelines for other life (6.5 mg/L). Low DO concentrations during under-ice conditions are a common feature of northern lakes, and have been routinely measured in other lakes within the study area.

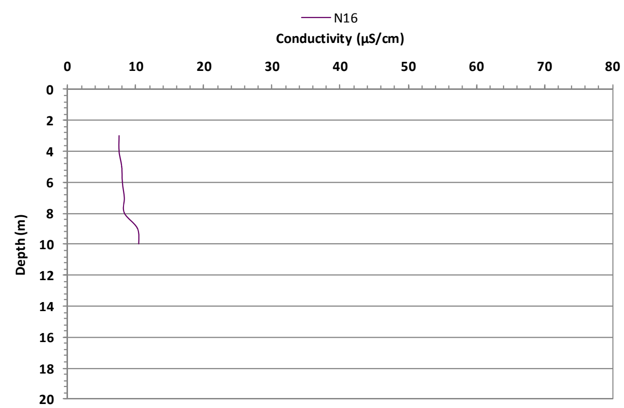
Vertical pH profile measurements and in-situ spot pH measurements were not collected during under-ice conditions from lakes in the N watershed.

Figure 9.3-6 Physico-chemical Field Data for Lakes in the N Watershed during Under-ice Conditions (2004)

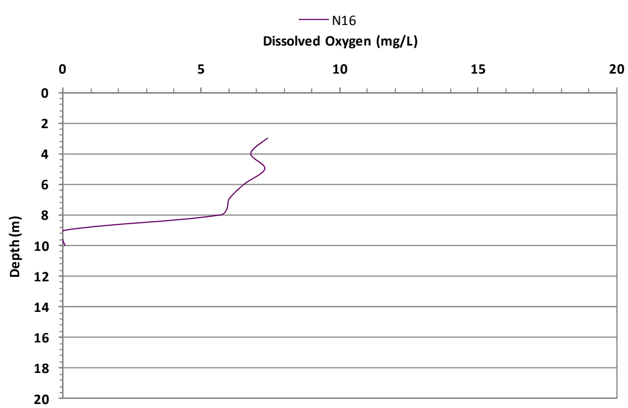
a) Water Temperature



b) Conductivity



c) Dissolved Oxygen



m = metre; °C = degrees Celsius; µS/cm = microSiemens per centimetre; mg/L = milligrams per litre.

Open Water Conditions

Vertical physico-chemical profile measurements were collected from Lake N16 in August 2004 and July 2010 (Figure 9.3-7). In-situ field measurements were collected from Lakes N2, N6a, and N7.

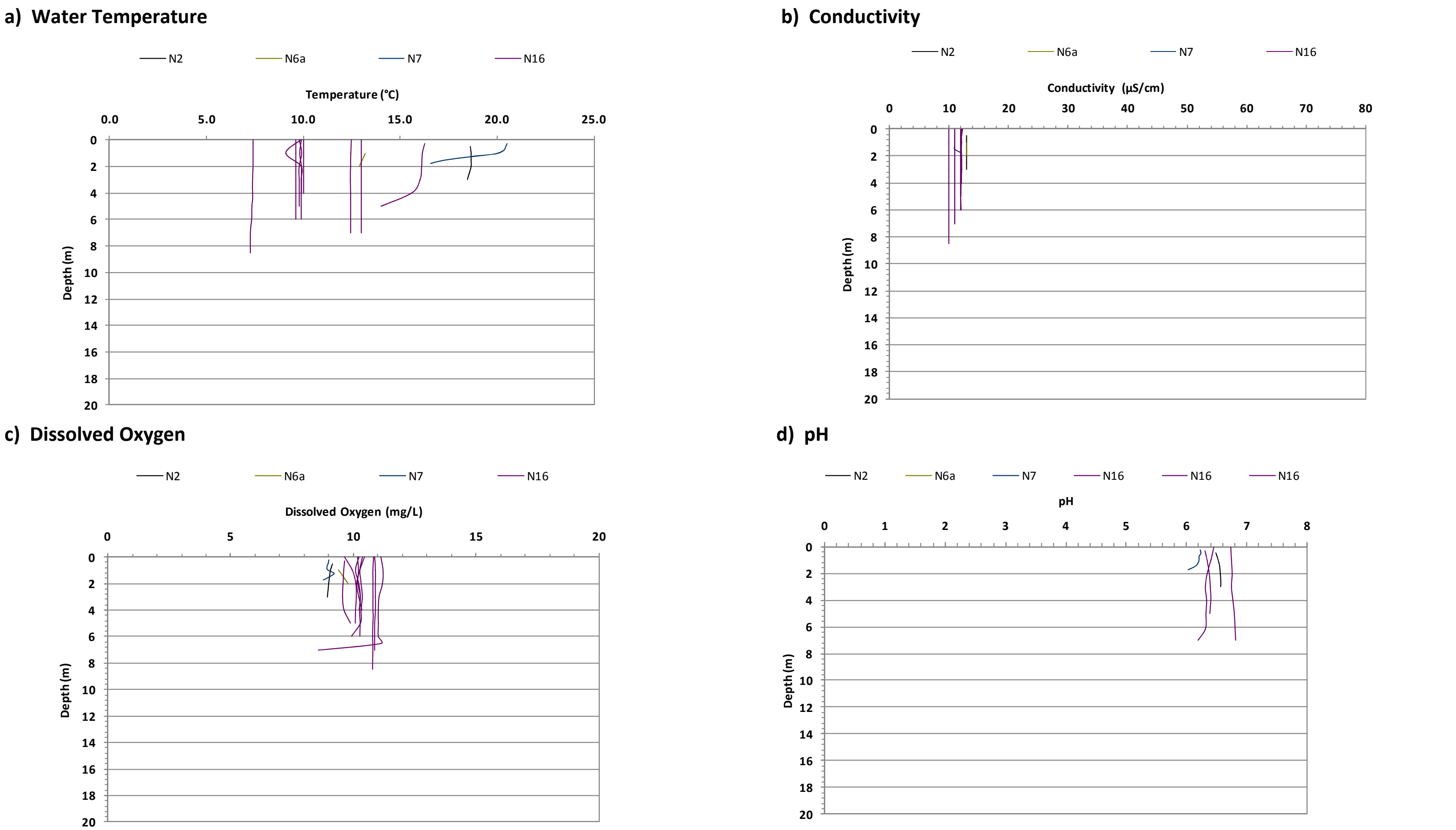
Vertical temperature profiles from Lake N16 indicated that the lake was well-mixed, with near surface temperatures that ranged from approximately 7 to 16°C. Near surface temperatures measured in other lakes in the N watershed varied between 19 and 21°C at the time of measurement. Seasonal thermoclines (steep temperature gradients) were measured in Lake N16 and Lake N7 in July 2010, just below the water surface (Figure 9.3-7a). The temperature gradients were between 2 and 4°C per metre.

Measured conductivity during open water conditions was very low, ranging between 10 and 12 μS/cm (Figure 9.3-7b). There was very little variability throughout the water column indicating that total dissolved solids (TDS) were equally distributed and that the lake was well mixed during open water conditions.

Dissolved oxygen concentrations were generally homogenous throughout the water column of Lake N16, concentrations ranging from 9 and 11 mg/L (Figure 9.3-7c). The DO concentrations in the surface waters of other lakes in the N watershed varied between 9 and 9.5 mg/L. The DO concentrations measured during most sampling events were above the CWQG for DO concentrations applicable to the protection of early life stages (9.5 mg/L) and other life stages (6.5 mg/L) of cold water aquatic life.

Vertical profiles of pH in Lake N16 showed only small variability throughout the water column. The values for Lake N16 were below the acceptable CWQG and CDWQG range, as were some in-situ measurements collected from other lakes in the watershed, which ranged between 6.0 and 6.8 pH units. Some of the lakes were slightly more acidic than Kennady Lake.

Figure 9.3-7 Physico-chemical Field Data for Lakes in the N Watershed during Open Water Conditions (1998 to 2010)



m = metre; °C = degrees Celsius; µS/cm = microSiemens per centimetre; mg/L = milligrams per litre.
Individual field results not presented in field profile figures.

Water Quality

The lakes within the N lakes watershed contribute to the loading of substances from the N watershed to Lake 410. The water quality data from samples collected from each of the N lakes surveyed are discussed for all surveyed lakes grouped together. The available data for the sample lakes in the N lakes watershed are presented in Table 9.3-21.

Baseline water quality information for lakes in the N lakes watershed was limited to samples collected during open water conditions. Lakes included in baseline surveys between 1995 and 2010 were Lakes N2, N6a, N7, N9, N11, N13, N14, and N16 (Figure 9.3-3).

The water in the N lakes is soft, having a median hardness of 4 mg/L during open water conditions (Table 9.3-21). The median total alkalinity during open water ice conditions is also 4 mg/L, indicating a low buffering capacity of water in these lakes.

The concentrations of TDS were low, but variable among the lakes during open water (5 to 52 mg/L), with a median concentration of 16 mg/L (Table 9.3-21). Bicarbonate was the dominant anion in most lakes and the major contributor to TDS. Sulphate and chloride were observed within the range recorded for the Kennady Lake watershed. Calcium and sodium were the major cations.

Concentrations of TSS were generally measured below detection limits in the N lakes during open water conditions (Table 9.3-21). Approximately 61% of open water samples were measured below detection. The highest measurement of TSS was 10 mg/L.

Low levels of nutrients were measured in samples collected from the N lakes (Table 9.3-21). Most concentrations of nitrate+nitrite were measured at, or below, detection during open water conditions (i.e., 9 of 10 samples below the detection limit of 0.003 mg/L). Ammonia concentrations were more variable, ranging from below detection to 0.22 mg N/L, with 71% of the samples measured below detection. Two of the five total Kjeldahl nitrogen (TKN) samples were above the detection limit of 0.2 mg N/L during open water conditions (i.e. values above detection were 0.3 and 0.4 mg N/L).

Table 9.3-21 Water Quality Data Summary for Lakes in the N Watershed, 1998 to 2010

Parameter Name	Unit	Method Detection Limit			Lakes in the N Watershed, 1998-2010									
					n	Minimum	Median	Maximum	Count Below Detection	% Below Detection	Guidelines			
											Aquatic Life-Chronic [a]		Human Health-Chronic [b]	
		Minimum	Maximum	Number of Method Detection Limits							Value	Guideline Exceedance Count	Value	Guideline Exceedance Count
Field measured														
pH	pH units	-	-	0	103	**6.4**[c]	**6.0**[c]	7.1	0	0	6.5-8.5	62	5.0-9.0	0
Temperature	°C	-	-	0	118	1.3	15	21	0	0	-	0	-	0
Specific Conductance	µS/cm	-	-	0	118	7	11	17	0	0	-	0	-	0
Dissolved Oxygen	mg/L	-	-	0	118	**0.06**[c]	9.6	13	0	0	6.5	5	-	0
Conventional Parameters														
Colour	TCU	1	1	1	12	0.5	10	30	3	25	-	0	-	0
Specific Conductance	µS/cm	-	-	0	31	8	12	24	0	0	-	0	-	0
Dissolved Organic Carbon	mg/L	-	-	0	22	2.8	4.8	9	0	0	-	0	-	0
Hardness	mg/L	6	6	1	21	3.9	4	5.3	12	57.1	-	0	-	0
pH	pH units	-	-	0	31	**5.5**[c]	**6.4**[c]	6.8	0	0	6.5-8.5	20	5.0-9.0	0
Total Alkalinity	mg/L	-	-	0	31	2	4	34	0	0	-	0	-	0
Total Dissolved Solids	mg/L	10	10	1	31	5	16	52	7	22.6	-	0	-	0
Total Organic Carbon	mg/L	-	-	0	28	2	4	8	0	0	-	0	-	0
Total Suspended Solids	mg/L	1	3	3	31	1	2	10	19	61.3	-	0	-	0
Major Ions														
Bicarbonate	mg/L	-	-	0	22	2.5	9	42	0	0	-	0	-	0
Calcium	mg/L	-	-	0	31	0.66	0.97	1.5	0	0	-	0	-	0
Carbonate	mg/L	0.5	1	2	22	<0.5	-	<1	22	100	-	0	-	0
Chloride	mg/L	0.1	1	3	31	0.1	0.4	1	17	54.8	230	0	-	0
Magnesium	mg/L	0.5	0.5	1	31	0.25	0.38	0.55	6	19.4	-	0	-	0
Potassium	mg/L	0.5	0.5	1	31	0.24	0.36	0.45	6	19.4	-	0	-	0
Sodium	mg/L	0.5	0.5	1	31	0.25	0.5	2.7	1	3.2	-	0	-	0
Sulphate	mg/L	0.5	1	2	31	0.6	1	1.6	18	58.1	-	0	-	0
Sulphide	µg/L	2	2	1	10	2	3	**4**[c]	5	50	2.3	3	-	0
Nutrients														
Nitrate + Nitrite	mg-N/L	0.003	0.003	1	10	<0.003	-	0.006	9	90	2.93	0	10	0
Nitrogen-Ammonia	mg-N/L	0.005	0.1	3	31	<0.005	-	0.22	22	71	23	0	-	0
Nitrogen-Kjeldahl	mg-N/L	0.2	0.2	1	5	0.3	-	0.4	3	60	-	0	-	0
Phosphorus, total	µg/L	20	300	3	31	5	6.5	**118**[c]	19	61.3	-	2	-	0
Phosphorus, dissolved	mg/L	0.005	0.3	2	31	<0.005	-	0.007	21	67.7	-	0	-	0
General Organics														
Total Phenolics	µg/L	2	2	1	10	<2	-	3	9	90	5	0	-	0
Total Recoverable Hydrocarbons	mg/L	0.1	2	2	22	<0.1	-	24	18	81.8	-	0	-	0
Total Metals[e]														
Aluminum	µg/L	20	20	1	31	6	10	**482**[c, H]	6	19.4	100	1	100	1
Antimony	µg/L	0.02	0.1	3	31	<0.02	-	0.02	29	93.5	-	0	5.5	0
Arsenic	µg/L	0.1	0.4	2	31	0.09	0.13	0.4	20	64.5	5	0	10	1
Barium	µg/L	5	5	1	31	1.6	2.2	7	11	35.5	-	0	1000	0
Beryllium	µg/L	0.01	0.5	2	31	<0.01	-	<0.5	31	100	-	0	4	0
Boron	µg/L	10	20	2	31	<10	-	2	22	71	-	0	5000	0
Cadmium	µg/L	0.002	0.2	4	32	<0.002	-	**0.011**[c]	24	75	0.0021	7	5	0
Calcium	µg/L	1000	1000	1	31	380	940	3730	4	12.9	-	0	-	0

Table 9.3-21 Water Quality Summary for Lakes in the N Watershed, 1995 to 2010 (continued)

Parameter Name	Unit	Method Detection Limit			Lakes in the N Watershed, 1998-2010									
											Guidelines			
											Aquatic Life-Chronic [(a)]		Human Health-Chronic [(b)]	
		Minimum	Maximum	Number of Method Detection Limits	n	Minimum	Median	Maximum	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count
Chromium	µg/L	0.1	0.9	3	31	<0.1	-	**1.2**[(c)]	29	93.5	1	1	50	0
Cobalt	µg/L	0.1	0.1	1	31	0.019	0.037	0.3	17	54.8	-	0	-	0
Copper	µg/L	1	5	2	31	0.4	0.5	**7**[(c)]	9	29	2	2	1300	0
Iron	µg/L	10	50	3	31	18	67	250	11	35.5	300	0	300	0
Lead	µg/L	0.05	0.1	2	31	0.008	0.04	1	15	48.4	1	0	10	0
Lithium	µg/L	1	1	1	19	0.5	0.9	0.9	9	47.4	-	0	-	0
Magnesium	µg/L	500	500	1	31	310	391	620	11	35.5	-	0	-	0
Manganese	µg/L	3	3	1	31	1	3.6	26	1	3.2	-	0	50	0
Mercury	µg/L	0.0006	500	5	32	<0.0006	-	0.01	23	71.9	0.026	0	1	0
Molybdenum	µg/L	0.05	0.5	2	31	<0.05	-	0.06	30	96.8	73	0	-	0
Nickel	µg/L	0.6	0.6	1	31	0.15	0.3	1.3	8	25.8	25	0	340	0
Potassium	µg/L	500	500	1	31	300	370	460	12	38.7	-	0	-	0
Selenium	µg/L	0.04	10	4	31	<0.04	-	<10	31	100	1	0	10	0
Silver	µg/L	0.005	0.2	2	32	0.0005	0.0095	0.01	13	40.6	0.1	0	-	0
Sodium	µg/L	500	2000	2	31	360	420	620	12	38.7	-	0	-	0
Strontium	µg/L	-	-	0	19	4.3	6.1	8.2	0	0	-	0	-	0
Sulphur	µg/L	10000	10000	1	10	<10000	-	<10000	10	100	-	0	-	0
Thallium	µg/L	0.002	0.05	2	31	<0.002	-	0.05	22	71	0.8	0	0.13	0
Titanium	µg/L	0.5	0.5	1	19	10	10	10	10	52.6	-	0	-	0
Uranium	µg/L	0.05	0.05	1	31	0.003	0.01	0.08	11	35.5	-	0	-	0
Vanadium	µg/L	0.1	1	3	31	<0.1	-	1.4	24	77.4	-	0	-	0
Zinc	µg/L	1	2	2	31	0.6	2	14	11	35.5	30	0	5100	0
Dissolved Metals[(e)]														
Aluminum	µg/L	10	10	1	31	2.9	9.5	57	1	3.2	-	0	-	0
Antimony	µg/L	0.02	0.1	3	31	<0.02	-	0.09	22	71	-	0	-	0
Arsenic	µg/L	0.1	0.1	1	31	0.07	0.1	0.3	15	48.4	-	0	-	0
Barium	µg/L	3	3	1	31	1.5	2.1	3.7	12	38.7	-	0	-	0
Beryllium	µg/L	0.01	0.5	3	31	<0.01	-	0.1	28	90.3	-	0	-	0
Boron	µg/L	4	20	2	31	<4	-	2	22	71	-	0	-	0
Cadmium	µg/L	0.005	0.05	2	31	<0.005	-	0.13	29	93.5	-	0	-	0
Chromium	µg/L	0.1	0.4	2	31	<0.1	-	0.5	22	71	-	0	-	0
Cobalt	µg/L	0.05	0.1	2	31	0.025	0.1	1.6	9	29	-	0	-	0
Copper	µg/L	1	2	2	31	0.36	0.6	0.97	12	38.7	-	0	-	0
Iron	µg/L	1	30	3	31	0.5	20	1080	9	29	-	0	-	0
Lead	µg/L	0.005	0.05	2	31	<0.005	-	0.08	21	67.7	-	0	-	0
Lithium	µg/L	1	1	1	19	0.8	0.9	1.3	9	47.4	-	0	-	0
Manganese	µg/L	0.5	2	3	31	0.22	1.7	22	3	9.7	-	0	-	0
Mercury	µg/L	0.01	1	3	31	<0.01	-	0.009	21	67.7	-	0	-	0
Molybdenum	µg/L	0.05	0.3	2	31	<0.05	-	0.06	30	96.8	-	0	-	0
Nickel	µg/L	-	-	0	31	0.17	0.29	1.1	0	0	-	0	-	0
Selenium	µg/L	0.04	2	4	31	<0.04	-	<2	31	100	-	0	-	0
Silver	µg/L	0.005	0.05	3	31	<0.005	-	<0.05	31	100	-	0	-	0
Strontium	µg/L	-	-	0	19	4.1	6.1	8	0	0	-	0	-	0

Table 9.3-21 Water Quality Summary for Lakes in the N Watershed, 1995 to 2010 (continued)

Parameter Name	Unit	Method Detection Limit			Lakes in the N Watershed, 1998-2010						Guidelines			
											Aquatic Life-Chronic (a)		Human Health-Chronic (b)	
		Minimum	Maximum	Number of Method Detection Limits	n	Minimum	Median	Maximum	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count
Sulphur	µg/L	10000	10000	1	10	<10000	-	<10000	10	100	-	0	-	0
Thallium	µg/L	0.002	0.05	3	31	<0.002	-	0.003	28	90.3	-	0	-	0
Titanium	µg/L	0.5	10	2	19	<0.5	-	<10	19	100	-	0	-	0
Uranium	µg/L	0.01	0.05	2	31	0.004	0.01	0.025	18	58.1	-	0	-	0
Vanadium	µg/L	0.2	1	3	31	<0.2	-	<1	31	100	-	0	-	0
Zinc	µg/L	2	2	1	30	0.8	2	11	2	6.7	-	0	-	0

Note: Presented guidelines were calculated using median values for data when applicable.
Individual guidelines were calculated for each sample, to determine the number of results above guidelines when applicable.
Bold values indicate a guideline exceedance.
(a) Canadian Environmental Quality Guidelines (CCME 1999a, with updates to 2010). Winnipeg, MB.
(b) The human health guideline is based on the CCME drinking water guideline, Health Canada (2008).
(c) Concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
(H) Concentration higher than the relevant human health guideline or beyond the recommended pH range.
(e) Some maximum dissolved metals concentrations are higher than the maximum total metal concentration in the statistical summary.

NA = not applicable, "-" = not available; °C = degrees Celsius, µS/cm = microSiemens per centimetre, mg/L = milligrams per litre, mg-N/L = milligrams nitrogen per litre, µg/L = micrograms per litre; TCU = True colour units; % = percent, n = number of samples, < = less than.

Total phosphorus concentrations were variable, with 61% measured below the detection limit. The maximum concentration was 0.012 mg/L. Dissolved phosphorus concentrations were near, or below, detection. The measured concentrations of nitrogen and phosphorus nutrients indicated that the lakes in the N watershed, like lakes in the Kennady Lake watershed, were typically oligotrophic.

Levels of TOC and DOC (< 10 mg/L) were low during open water conditions (Table 9.3-21). Colour was measured at levels up to twice the CDWQG of 15 TCU (Table 9.3-21). Phenol and petroleum hydrocarbons were detected on few occasions (Table 9.3-21).

The concentrations of total and dissolved metals were typically low during open water conditions, with a range of metals near or below detection limits (e.g., cadmium, molybdenum, selenium and thallium) (Table 9.3-21). Exceedances of applicable guidelines were observed for total aluminum, cadmium, chromium, and copper. The median concentrations of many of the dissolved metals were similar to the total fraction.

Sediment Quality

Sediments collected from lakes within the N lakes watershed for sediment quality analyses were mainly composed of sand, with some silt and clay (Table 9.3-22). The total carbon (TC) content ranged from 0.4 to 18% of the sediment composition, with TOC comprising the majority of the sediment carbon (i.e., 0.4% to 17%). Inorganic carbon constituted less than 1.7%.

Total phosphorus was the dominant nutrient bound to the sediment, although the observed concentrations were variable (ranging from 458 to 997 µg/g dry weight) (Table 9.3-22). In comparison, available phosphorus concentrations ranged from 9 to 27 µg/g dry weight. Nitrate concentrations were low (maximum of 0.9 µg/g dry weight).

The TPH content in sediment from the N lakes was variable, ranging from 63 to 117 µg/g dry weight, with two values reporting below a higher detection limit (i.e., <600 µg/g) (Table 9.3-22). Hydrocarbons found in the sediment may be from natural sources, such as by-products associated with the decomposition of organic matter.

The predominant metals in the sediment included aluminum and iron (Table 9.3-22). Concentrations of metals in the sediment were generally within the applicable aquatic life guidelines; however, chromium, copper, and zinc concentrations were measured above the ISQG; the median copper concentrations was above the ISQG.

Table 9.3-22 Sediment Quality Data Summary for Lakes in the N Watershed

Parameter	Unit	Method Detection Limit		N Watershed							Guideline
		Min	Max	n	Min	Med	Max	Number Below Detection	% Below Detection	No. of Times a Guideline is Exceeded	ISQG
Texture and Carbon Content											
Sand	%	1	2	4	71	76.5	93	0	0	0	-
Silt	%	1	2	4	6	20	24	0	0	0	-
Clay	%	1	2	4	<1	3.5	5	1	25	0	-
Calcium Carbonate	%	0.005	0.005	2	0.114	0.14	0.167	0	0	0	-
Inorganic Carbon, Total	%	0.01	0.02	5	<0.01	0.94	1.69	1	20	0	-
Organic Carbon, Total	%	0.01	0.2	6	0.39	4.23	17	0	0	0	-
Carbon, Total	%	0.01	0.2	6	0.39	3.49	18	0	0	0	-
Nutrients and Organics											
Nitrate, Available	µg/g	0.5	0.5	2	<0.5	0.9	0.9	1	50	0	-
Phosphorus, Available	µg/g	1	1	4	9	17	27	0	0	0	-
Phosphorus, Total	µg/g	5	5	2	458	728	997	0	0	0	-
Total Petroleum Hydrocarbons	µg/g	8	600	4	63	90	<600	2	50	0	-
Total Metals											
Aluminum	µg/g	5	5	2	10900	11050	11200	0	0	0	-
Arsenic	µg/g	0.5	1	5	<0.5	2	3.2	1	20	0	5.9
Barium	µg/g	1	10	5	18	68	74	0	0	0	-
Cadmium	µg/g	0.1	0.2	5	0.3	0.3	0.4	2	40	0	0.6
Chromium	µg/g	0.5	1	5	7	27.2	**82**	0	0	2	37.3
Cobalt	µg/g	0.5	1	5	3	8	9.4	0	0	0	-
Copper	µg/g	0.1	5	5	7	**40**	**53.2**	0	0	3	35.7
Iron	µg/g	5	5	2	18100	21000	23900	0	0	0	-
Lead	µg/g	0.5	1	5	2	2.5	6	0	0	0	35
Manganese	µg/g	0.5	0.5	2	174	196	217	0	0	0	-
Mercury	µg/g	0.05	0.5	5	<0.05	-	<0.5	5	100	0	0.17
Molybdenum	µg/g	0.4	0.5	5	<0.4	2	3.1	1	20	0	-
Nickel	µg/g	0.5	1	5	7	32.8	50	0	0	0	-
Selenium	µg/g	0.5	0.5	5	<0.5	-	0.7	4	80	0	-
Sodium	µg/g	1	1	2	113	120	127	0	0	0	-
Thallium	µg/g	0.3	0.5	5	<0.3	-	<0.5	5	100	0	-
Vanadium	µg/g	0.2	1	5	7	23	31	0	0	0	-
Zinc	µg/g	0.5	10	5	11	61	**167**	0	0	1	123

Source: Canadian Environmental Quality Guidelines (CCME 1999b [with updates to 2002). Winnipeg, MB.

Note: **Bolded** numbers indicate where a guideline is exceeded.

ISQG = Interim Sediment Quality Guidelines (CCME 1999b); CCME = Canadian Council of Ministers of the Environment; min = minimum; med = median; max = maximum; % = percent; µg/g = micrograms per gram (dry weight basis);-= not applicable; min = minimum; med = medium; max = maximum

9.3.3.2.3 Lake 410 and Kirk Lake

Physical Limnology and Vertical Structure

Under-ice Conditions

A single vertical profile was measured during under-ice conditions for Lake 410 in May 2004, beginning at a depth of 3 m and ranging down to 6 m (Figure 9.3-8a). The profile had an inverse thermal gradient, with temperatures increasing from near 0°C near the ice-water interface to 3°C near the bottom of the lake.

The measured conductivity profile indicated low TDS concentrations, ranging between 15 and 17 µS/cm (Figure 9.3-8b).

The vertical DO profile had a concentration of 11 mg/L at the ice-water interface, which rapidly declined with increasing depth to anoxia near the bottom of the lake (i.e., 6 m) (Figure 9.3-8c). The DO concentrations near the water surface were greater than the upper range of acceptable concentrations for cold-water aquatic life in the CWQG (9.5 mg/L), whereas concentrations below 4 m were below the lowest acceptable concentration (6.5 mg/L). This profile pattern is commonly observed during under-ice conditions due to the ice cover and lack of wind-generated mixing in the waterbody.

Measurements of pH were not collected during under-ice conditions from Lake 410.

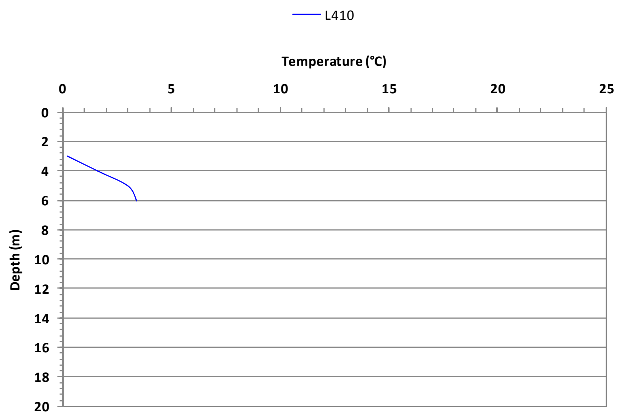
Open Water Conditions

Vertical physico-chemical data profiles were measured in Lake 410 and Kirk Lake in early August 2005, September 2007, and July 2010. Temperature profiles were variable (ranging from 6°C to 19°C) over the open water period, but typically isothermal (Figure 9.3-9a). Water column temperatures measured in Lake 410 and Kirk Lake in August 2005 were similar in both lakes, ranging between 13°C and 14°C. The mid-September temperature profile measured in Lake 410 indicated the lake was well mixed and at a temperature of about 6°C. July 2010 profiles were warmer than the other water column measurements, ranging in temperature from 17°C to 19°C.

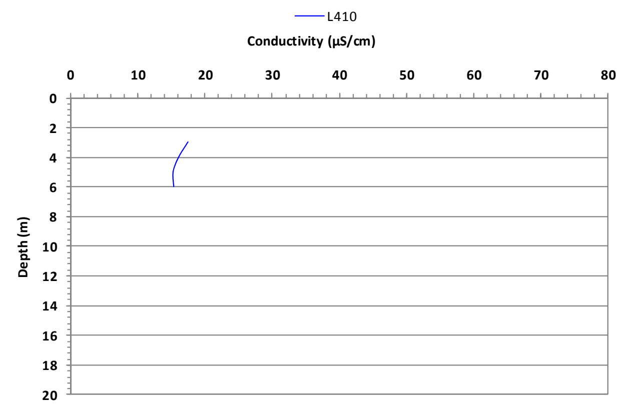
Measured conductivity profiles in Lake 410 and Kirk Lake during open water conditions ranged between 5 and 12 µS/cm (Figure 9.3-9b). There was very little variability in conductivity throughout the water column, indicating that the low TDS concentrations were equally distributed throughout the lakes, and that the lakes were well mixed during open water conditions.

Figure 9.3-8 Physico-chemical Field Data for Lake 410 during Under-ice Conditions (May 2004)

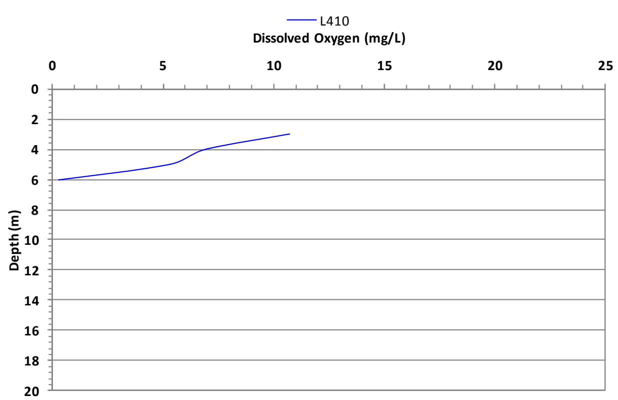
a) Water Temperature



b) Conductivity



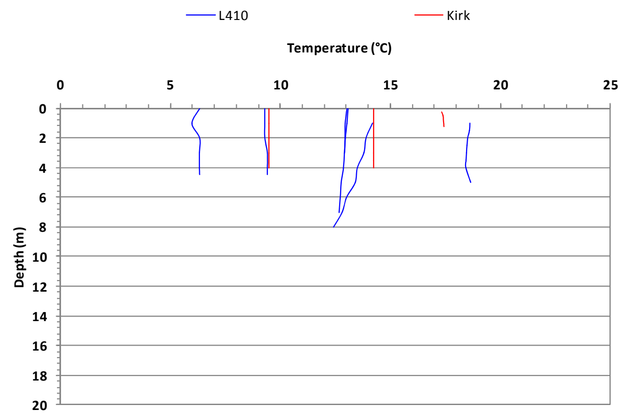
c) Dissolved Oxygen



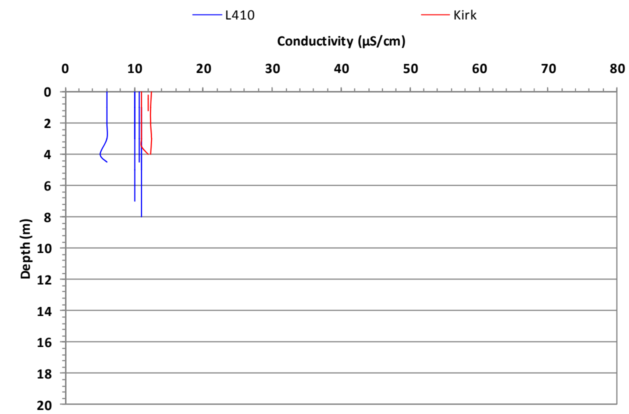
m = metre; °C = degrees Celsius; µS/cm = micro Siemens per centimetre; mg/L = milligrams per litre.
Individual field results not presented in field profile figures.

Figure 9.3-9 Physico-chemical Field Data for Lake 410 and Kirk Lake during Open Water Conditions (2005 to 2010)

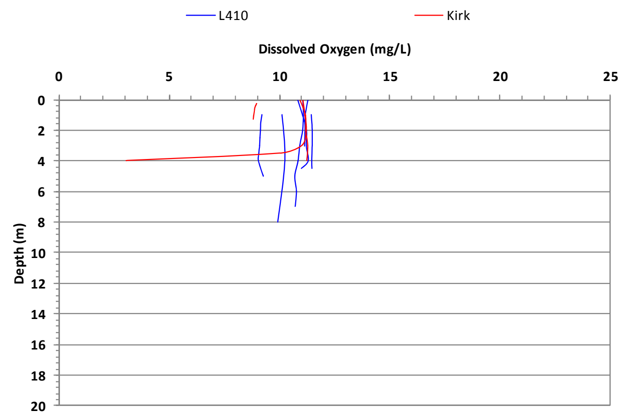
a) Water Temperature



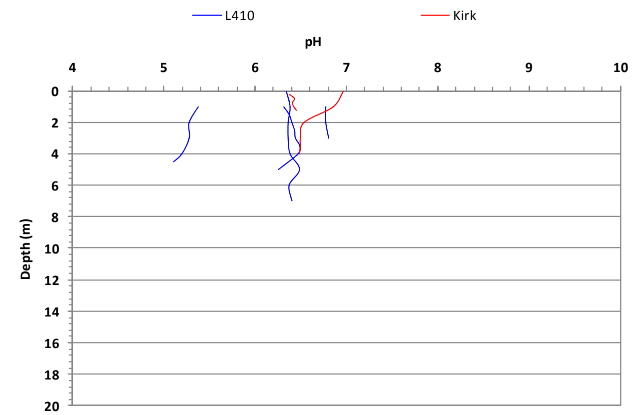
b) Conductivity



c) Dissolved Oxygen



d) pH



m = metre; °C = degrees Celsius; µS/cm = microSiemens per centimetre; mg/L = milligrams per litre.
Individual field results not presented in field profile figures.

Vertical DO concentrations in Lake 410 and Kirk Lake had only slight variability between the surface and the near bottom of these lakes, indicating that the lakes were typically well mixed during open water conditions. With the exception of one sampling event, dissolved oxygen concentrations ranged between 9 and 11 mg/L, and were generally greater than the upper range of acceptable concentrations for cold-water aquatic life in the CWQG (9.5 mg/L). A distinct oxycline (Figure 9.3-9c) was evident in Kirk Lake on August 2, 2005, below which the DO concentration dropped to 3.0 mg/L near the lake bottom.

Vertical profiles of pH (Figure 9.3-9d) in Lake 410 and Kirk Lake were slightly acidic to neutral, with little variance observed through the water column profile. The pH profile measurements were typically within the acceptable CWQG and CDWQG ranges; however, pH measured in Lake 410 in September 2004 were below the lower range of acceptable pH (i.e., pH 6.5).

Water Quality

Hardness and alkalinity were low in Lake 410 and Kirk Lake (Table 9.3-24), with several hardness measurements below the detection limit. These hardness and alkalinity results indicate that water in most of the lakes in the Kennady Lake watershed is soft and has a low buffering capacity.

The concentrations of TDS were low in the downstream lakes, ranging from <10 to 26 mg/L, indicating a very small amount of dissolved substances in the water (Table 9.3-24). For both lakes, bicarbonate was the dominant ion measured, with calcium being the next highest. Other ions were measured just above, at, or below, detection.

Both lakes were clear and contained very little suspended particulate matter, with most TSS concentrations measured at detection limits (Table 9.3-24). The highest concentration of TSS (3 mg/L) was measured in Lake 410.

Low levels of nutrients were measured in samples collected from Lake 410 and Kirk Lake (Table 9.3-24). Concentrations of nitrate+nitrite, ammonia and Kjeldahl nitrogen were measured below detection in all samples. Total phosphorus concentrations were variable, with 50% measured below the detection limit in Lake 410; however, the maximum concentration measured in Lake 410 was 0.071 mg/L, and in Kirk Lake it was 0.052 mg/L. Dissolved phosphorus concentrations were at, or below, detection. Based on the summary data for measured concentrations of nitrogen and phosphorus nutrients, the trophic status of Lake 410 and Kirk Lake is oligotrophic; however, the data are subject to poor detection limits and anomalously high values to provide a confident baseline concentration.

Levels of TOC and DOC in Lake 410 and Kirk Lake were low (3 to 6 mg/L) (Table 9.3-24). Colour was measured in Lake 410 at levels up to 20 TCU, which is above the CDWQG of 15 TCU (Table 9.3-24). Phenol was not detected, (Table 9.3-24). Total Recoverable Hydrocarbons were detected at levels up to 0.3 mg/L, although most (87.7%) were below detection limits.

The concentrations of total and dissolved metals were typically very low, with a range of metals near or below detection limits (e.g., beryllium, boron, chromium, molybdenum, selenium and thallium) (Table 9.3-21). No exceedances of applicable guidelines were observed for total metals measured in Lake 410 or Kirk Lake. The median concentrations of dissolved metals were similar to the total fraction.

Sediment Quality

Baseline sediment data for Kirk Lake consisted of two samples collected in 1999 and 2005. Two samples were collected from Lake 410 in 2004 and 2010. As sediment quality data were very limited from these lakes, the sediment data from both lakes were combined for the summary assessment.

Sediment samples collected from Lake 410 and Kirk Lake for sediment quality analyses were mainly composed of sand, with some silt and clay (Table 9.3-25). The total carbon (TC) content ranged from 4 to 19.5% of the sediment composition, with TOC comprising the majority of the sediment carbon (i.e., 0.7% to 18%) in most of the samples. Inorganic carbon constituted less than 3%.

Total phosphorus concentrations in the sediment ranged from 642 to 839 µg/g dry weight. In comparison, available phosphorus concentrations ranged from 23 to 60.7 µg/g dry weight (Table 9.3-25). Nitrate concentrations were below the detection limit of 0.5 µg/g dry weight.

The TPH content in the lake sediments was variable, ranging from below detection (i.e., <8 µg/g) to 3,030 µg/g dry weight (Table 9.3-25).

The predominant metals in the sediment included aluminum and iron (Table 9.3-25). Concentrations of metals in the sediment were generally within the applicable aquatic life guidelines; however, chromium and copper were measured above the ISQG in all samples.

Table 9.3-24 Water Quality Data Summary for Lake 410 and Kirk Lake (2004 to 2010)

Parameter Name	Unit	Method Detection Limit			Lake 410 Summary (2004-2010)										Kirk Lake Results (2005 and 2010)						
											Guidelines							Guidelines			
											Aquatic Life-Chronic [a]		Human Health-Chronic [b]		Kirk Lake	Kirk Lake	Kirk Lake Inlet	Aquatic Life-Chronic		Human Health-Chronic	
		Min	Max	No. of MDL	n	Min	Med	Max	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count	02-Aug-05	18-Jul-10	02-Aug-05	Value	No. of Times Guideline is Exceeded	Value	No. of Times Guideline is Exceeded
Field measured																					
pH	pH units	-	-	0	34	**5.2[c]**	**6.4[c]**	8	0	0	6.5-8.5	25	5.0-9.0	0	**6.49[C]**	**6.41[C]**	**6.44[C]**	6.5-8.5	3	5.0-9.0	0
Temperature	°C	-	-	0	46	0.2	13	19	0	0	-	0	-	0	14.26	17.42	10.86	-	0	-	0
Specific Conductance	µS/cm	-	-	0	46	8	11	17	0	0	-	0	-	0	11	12	10	-	0	-	0
Dissolved Oxygen	mg/L	-	-	0	41	**0.27[c]**	11	16	0	0	6.5	3	-	0	11.02	8.87	11.58	6.5	0	-	0
Conventional Parameters																					
Colour	TCU	1	1	1	10	0.5	5	20	2	20	-	0	-	0	5	-	5	-	0	-	0
Specific Conductance	µS/cm	-	-	0	14	11	13	18	0	0	-	0	-	0	14	12	12	-	0	-	0
Dissolved Organic Carbon	mg/L	-	-	0	14	3	4	6	0	0	-	0	-	0	5	3.8	6	-	0	-	0
Hardness	mg/L	6	6	1	13	<6	-	1.2	10	76.9	-	0	-	0	<6	-	<6	-	0	-	0
pH	pH units	-	-	0	15	**5.4[c]**	6.6	6.8	0	0	6.5-8.5	7	5.0-9.0	0	**5.62[C]**	**6.46[C]**	**5.41[C]**	6.5-8.5	3	5.0-9.0	0
Total Alkalinity	mg/L	-	-	0	14	1.9	10	27	0	0	-	0	-	0	14	3.9	17	-	0	-	0
Total Dissolved Solids	mg/L	10	10	1	14	10	12	26	5	35.7	-	0	-	0	<10	<10	<10	-	0	-	0
Total Organic Carbon	mg/L	-	-	0	14	3	4	6	0	0	-	0	-	0	5	4	4	-	0	-	0
Total Suspended Solids	mg/L	2	2	1	14	1	1	3	9	64.3	-	0	-	0	<2	1	<2	-	0	-	0
Major Ions																					
Bicarbonate	mg/L	-	-	0	14	2.3	12	32	0	0	-	0	-	0	17	4.8	21	-	0	-	0
Calcium	mg/L	-	-	0	14	0.77	0.9	1.3	0	0	-	0	-	0	0.9	0.8	0.9	-	0	-	0
Carbonate	mg/L	0.5	1	2	14	<0.5	-	<1	14	100	-	0	-	0	<1	<0.5	<1	-	0	-	0
Chloride	mg/L	1	1	1	14	0.3	0.45	1	3	21.4	230	0	-	0	0.4	1	0.3	230	0	-	0
Magnesium	mg/L	0.5	0.5	1	14	0.36	0.48	0.62	5	35.7	-	0	-	0	<0.5	0.5	<0.5	-	0	-	0
Potassium	mg/L	0.5	0.5	1	14	0.33	0.37	0.41	5	35.7	-	0	-	0	<0.5	0.4	<0.5	-	0	-	0
Sodium	mg/L	0.5	0.5	1	14	0.25	0.6	2.2	1	7.1	-	0	-	0	0.7	0.6	0.6	-	0	-	0
Sulphate	mg/L	1	1	1	14	0.5	0.7	1.5	4	28.6	-	0	-	0	0.9	<1	<0.5	-	0	-	0
Sulphide	µg/L	2	2	1	4	2	-	**3[c]**	2	50	2.3	1	-	0	-	**3[C]**	-	2.3	1	-	0
Nutrients																					
Nitrate + Nitrite	mg-N/L	0.003	0.003	1	4	<0.003	-	<0.003	4	100	2.93	0	10	0		<0.003		2.93	0	10	0
Nitrogen-Ammonia	mg-N/L	0.05	0.1	2	14	<0.05	-	<0.1	14	100	26	0	-	0	<0.1	<0.05	<0.1	22	0	-	0
Nitrogen-Kjeldahl	mg-N/L	0.2	0.2	1	5	<0.2	-	<0.2	5	100	-	0	-	0	-	-	-	-	0	-	0
Phosphorus, total	µg/L	20	50	2	14	4	7	**71[c]**	7	50	50	3	-	0	<50	3	**52[C]**	-	0	-	0
Phosphorus, dissolved	mg/L	0.005	0.005	1	14	<0.005	-	0.005	10	71.4	-	0	-	0	<0.005	0.002	<0.005	-	0	-	0
General Organics																					
Total Phenolics	µg/L	0.002	2	2	4	<2	-	<2	4	100	5	0	-	0	-	<0.002	-	5	0	-	0
Total Recoverable Hydrocarbons	mg/L	0.1	2	2	14	<0.1	-	0.3	12	85.7	-	0	-	0	<0.1	<2	<0.1	-	0	-	0
Total Metals[e]																					
Aluminum	µg/L	20	20	1	14	6	13	55	2	14.3	100	0	100	0	23	16.6	23	100	0	100	0
Antimony	µg/L	0.02	0.1	2	14	<0.02	-	0.5	12	85.7	-	0	5.5	0	0.6	<0.02	<0.1	-	0	5.5	0
Arsenic	µg/L	0.4	0.4	1	14	<0.4	-	0.12	10	71.4	5	0	10	0	0.8	0.11	<0.4	5	0	10	0
Barium	µg/L	5	5	1	14	<5	-	2	10	71.4	-	0	1000	0	<5	2.01	<5	-	0	1000	0
Beryllium	µg/L	0.01	0.5	2	14	<0.01	-	<0.5	14	100	-	0	4	0	<0.5	<0.01	<0.5	-	0	4	0
Boron	µg/L	10	20	2	14	<10	-	<20	14	100	-	0	5000	0	<10	<20	<10	-	0	5000	0
Cadmium	µg/L	0.002	0.2	2	14	<0.002	-	0.0033	13	92.9	0.054	0	5	0	<0.2	0.008	<0.2	0.054	0	5	0
Chromium	µg/L	0.1	0.9	2	14	<0.1	-	<0.9	14	100	1	0	50	0	0.9	<0.1	<0.9	1	0	50	0
Cobalt	µg/L	0.1	0.1	1	14	0.026	0.038	0.1	9	64.3	-	0	-	0	<0.1	0.037	<0.1	-	0	-	0
Copper	µg/L	1	5	2	14	0.45	0.56	1.8	9	64.3	2	0	1300	0	1.5	0.78	<1	3	0	1300	0
Iron	µg/L	10	50	2	14	30	50	186	6	42.9	300	0	300	0	<10	61	70	300	0	300	0
Lead	µg/L	0.1	0.1	1	14	0.006	0.018	0.7	8	57.1	1	0	10	0	0.4	0.034	<0.1	4	0	10	0
Lithium	µg/L	-	-	0	4	0.8	0.95	1.1	0	0	-	0	-	0	-	1.2	-	-	0	-	0
Manganese	µg/L	1	1	1	14	0.5	3	8.6	4	28.6	-	0	50	0	<1	3.41	3	-	0	50	0
Mercury	µg/L	0.0006	500	4	14	<0.0006	-	0.006	11	78.6	0.026	0	1	0	<0.1	0.007	<0.1	0.026	0	1	0
Molybdenum	µg/L	0.05	0.5	2	14	<0.05	-	<0.5	14	100	73	0	-	0	<0.5	<0.05	<0.5	73	0	-	0
Nickel	µg/L	0.6	0.6	1	14	0.17	0.44	2	7	50	25	0	340	0	2.5	0.5	<0.6	110	0	340	0
Selenium	µg/L	0.04	10	3	14	<0.04	-	<10	14	100	1	0	10	0	<0.8	<0.04	<0.8	1	0	10	0

Table 9.3-24 Water Quality Summary for Lake 410, 2004 to 2010 (continued)

Parameter Name	Unit	Method Detection Limit			Lake 410 Summary (2004-2010)						Guidelines				Kirk Lake Results (2005 and 2010)			Guidelines			
											Aquatic Life-Chronic [a]		Human Health-Chronic [b]		Kirk Lake	Kirk Lake	Kirk Lake Inlet	Aquatic Life-Chronic		Human Health-Chronic	
		Min	Max	No. of MDL	n	Min	Med	Max	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count	02-Aug-05	18-Jul-10	02-Aug-05	Value	No. of Times Guideline is Exceeded	Value	No. of Times Guideline is Exceeded
Silver	µg/L	0.2	0.2	1	14	<0.2	-	0.0056	10	71.4	0.1	0	-	0	<0.2	0.005	<0.2	0.1	0	-	0
Strontium	µg/L	-	-	0	4	5.2	5.4	6	0	0	-	0	-	0	0	5.53	0	-	0	-	0
Sulphur	µg/L	10,000	10,000	1	4	<10,000	-	<10,000	4	100	-	0	-	0	0	<10,000	0	-	0	-	0
Thallium	µg/L	0.002	0.05	2	14	<0.002	-	<0.05	14	100	0.8	0	0.13	0	<0.05	0.002	<0.05	0.8	0	0.13	0
Titanium	µg/L	0.5	0.5	1	4	<0.5	-	<0.5	4	100	-	0	-	0	0	<0.5	0	-	0	-	0
Uranium	µg/L	0.05	0.05	1	14	<0.05	-	0.013	10	71.4	-	0	-	0	<0.05	0.015	<0.05	-	0	-	0
Vanadium	µg/L	0.1	0.2	2	14	0.1	0.2	0.3	6	42.9	-	0	-	0	0.3	<0.2	0.3	-	0	-	0
Zinc	µg/L	2	2	1	14	0.5	0.8	24	7	50	30	0	5100	0	17	1.3	<2	30	0	5100	0
Dissolved Metals[e]																					
Aluminum	µg/L	10	10	1	14	5	10	16	2	14.3	-	0	-	0	14	12	18	-	0	-	0
Antimony	µg/L	0.1	0.1	1	14	<0.1	-	0.09	10	71.4	-	0	-	0	<0.1	0.1	<0.1	-	0	-	0
Arsenic	µg/L	0.1	0.1	1	14	0.07	0.1	0.2	7	50	-	0	-	0	0.1	1.5	<0.1	-	0	-	0
Barium	µg/L	3	3	1	14	<3	-	2	10	71.4	-	0	-	0	<3	1.9	<3	-	0	-	0
Beryllium	µg/L	0.01	0.1	2	14	0.1	0.1	0.1	9	64.3	-	0	-	0	<0.1	<0.05	0.1	-	0	-	0
Boron	µg/L	4	300	3	14	<4	-	<20	14	100	-	0	-	0	<4	<300	<4	-	0	-	0
Cadmium	µg/L	0.005	0.05	2	14	0.11	0.11	0.12	9	64.3	-	0	-	0	<0.05	<0.03	0.12	-	0	-	0
Chromium	µg/L	0.1	0.5	3	14	<0.1	-	<0.4	14	100	-	0	-	0	<0.4	<0.5	<0.4	-	0	-	0
Cobalt	µg/L	0.05	0.05	1	14	0.09	0.1	0.84	5	35.7	-	0	-	0	<0.05	3.68	0.11	-	0	-	0
Copper	µg/L	1	2	2	14	0.46	0.52	1.4	9	64.3	-	0	-	0	1.4	0.8	<1	-	0	-	0
Iron	µg/L	20	20	1	14	9	26	80	4	28.6	-	0	-	0	50	21	140	-	0	-	0
Lead	µg/L	0.05	0.05	1	14	<0.05	-	0.05	10	71.4	-	0	-	0	<0.05	0.03	<0.05	-	0	-	0
Lithium	µg/L	3	3	1	4	0.7	0.85	1	0	0	-	0	-	0	0	<3	0	-	0	-	0
Manganese	µg/L	2	2	1	14	0.9	2	16	3	21.4	-	0	-	0	<2	7.6	4	-	0	-	0
Mercury	µg/L	0.1	1	2	14	<0.1	-	0.007	10	71.4	-	0	-	0	<0.1	<0.002	<0.1	-	0	-	0
Molybdenum	µg/L	0.05	0.3	2	14	<0.05	-	<0.3	14	100	-	0	-	0	<0.3	<0.3	<0.3	-	0	-	0
Nickel	µg/L	-	-	0	14	0.1	0.3	1.2	0	0	-	0	-	0	2.1	0.9	0.4	-	0	-	0
Selenium	µg/L	0.04	2	3	14	<0.04	-	<2	14	100	-	0	-	0	<0.4	<0.2	<0.4	-	0	-	0
Silver	µg/L	0.005	0.05	2	14	<0.005	-	<0.05	14	100	-	0	-	0	<0.05	<0.03	<0.05	-	0	-	0
Strontium	µg/L	-	-	0	4	5.3	5.5	6.1	0	0	-	0	-	0	0	5.7	0	-	0	-	0
Sulphur	µg/L	10,000	10,000	1	4	<10,000	-	<10,000	4	100	-	0	-	0	0	1,860,000	0	-	0	-	0
Thallium	µg/L	0.002	0.02	2	14	<0.002	-	<0.02	14	100	-	0	-	0	0.03	<0.01	<0.02	-	0	-	0
Titanium	µg/L	0.5	0.5	1	4	<0.5	-	<0.5	4	100	-	0	-	0	0	<3	0	-	0	-	0
Uranium	µg/L	0.05	0.05	1	14	<0.05	-	0.012	10	71.4	-	0	-	0	<0.05	0.01	<0.05	-	0	-	0
Vanadium	µg/L	0.2	0.5	2	14	<0.2	-	<0.5	14	100	-	0	-	0	<0.5	<1	<0.5	-	0	-	0
Zinc	µg/L	2	2	1	14	0.6	2	3	5	35.7	-	0	-	0	20	1.3	<2	-	0	-	0

Note: Presented guidelines were calculated using median values for data when applicable.
Individual guidelines were calculated for each sample, to determine the number of results above guidelines when applicable.
Bold values indicate a guideline exceedance.

(a) Canadian Environmental Quality Guidelines (CCME 1999a, with updates to 2010). Winnipeg, MB.
(b) The human health guideline is based on the CCME drinking water guideline, Health Canada (2008).
(c) Concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
(H) Concentration higher than the relevant human health guideline or beyond the recommended pH range.
(e) Some maximum dissolved metals concentrations are higher than the maximum total metal concentration in the statistical summary.

NA = not applicable, "-" = not available; °C = degrees Celsius, µS/cm = microSiemens per centimetre, mg/L = milligrams per litre, mg-N/L = milligrams nitrogen per litre, µg/L = micrograms per litre, .TCU = true colour units; % = percent, n = number of samples, < = less than; min = minimum; med = median; max = maximum.

Table 9.3-25 Sediment Quality Data Summary for Lake 410 and Kirk Lake (1999, 2004, 2005, and 2010)

Parameter	Unit	Method Detection Limit		Lake 410 and Kirk Lake							Guideline
		Min	Max	n	Min	Med	Max	No. Below Detection	% Below Detection	No. of Times a Guideline is Exceeded	ISQG
Texture and Carbon Content											
Sand	%	1	2	2	61	67	73	0	0	0	-
Silt	%	1	2	2	24	29.5	35	0	0	0	-
Clay	%	1	2	2	3	3.5	4	0	0	0	-
Calcium Carbonate	%	0.005	0.005	2	0.2	0.28	0.37	0	0	0	-
Inorganic Carbon, Total	%	0.01	0.02	3	1.6	2.3	3	0	0	0	-
Organic Carbon, Total	%	0.01	0.2	4	0.7	15.1	18	0	0	0	-
Carbon, Total	%	0.01	0.2	3	4	19.5	20	0	0	0	-
Nutrients and Organics											
Nitrate, Available	µg/g	0.5	0.5	1	<0.5	-	<0.5	1	100	0	-
Phosphorus, Available	µg/g	1	1	2	23	41.9	60.7	0	0	0	-
Phosphorus, Total	µg/g	5	5	2	642	741	839	0	0	0	-
Total Petroleum Hydrocarbons	µg/g	8	800	3	<8	583	3030	1	33	0	-
Total Metals											
Aluminum	µg/g	5	5	3	10,300	10,500	15,000	0	0	0	-
Arsenic	µg/g	0.5	1	4	1.4	2.5	4.2	0	0	0	5.9
Barium	µg/g	1	10	4	63	76	101	0	0	0	-
Cadmium	µg/g	0.1	0.2	4	<0.1	0.25	0.3	1	25	0	0.6
Chromium	µg/g	0.5	1	4	22.3	35.7	**79**	0	0	1	37.3
Cobalt	µg/g	0.5	1	4	7	8.75	17.4	0	0	0	-
Copper	µg/g	0.1	5	4	29.3	35.5	**59.4**	0	0	2	35.7
Iron	µg/g	5	5	3	15,400	16,400	26,300	0	0	0	-
Lead	µg/g	0.5	1	4	2	3.95	18.3	0	0	0	35
Manganese	µg/g	0.5	0.5	3	167	171	209	0	0	0	-
Mercury	µg/g	0.05	0.5	4	<0.05	-	<0.5	4	100	0	0.17
Molybdenum	µg/g	0.4	0.5	4	0.9	1.2	3.2	0	0	0	-
Nickel	µg/g	0.5	1	4	27	35.1	50	0	0	0	-
Selenium	µg/g	0.5	0.5	4	<0.5	0.65	20	1	25	0	-
Thallium	µg/g	0.3	0.5	4	<0.3	-	<0.5	4	100	0	-
Vanadium	µg/g	0.2	1	4	23	28.8	34.4	0	0	0	-
Zinc	µg/g	0.5	10	4	50	69.5	76.5	0	0	0	123

Source: Canadian Environmental Quality Guidelines (CCME 1999b [with updates to 2002]). Winnipeg, MB.

Note: **Bolded** numbers indicate where a guideline is exceeded.

ISQG = Interim Sediment Quality Guidelines (CCME 1999b); CCME = Canadian Council of Ministers of the Environment; min = minimum; med = median; max = maximum; % = percent; µg/g = micrograms per gram (dry weight basis);-= not applicable.

9.3.4 Lower Trophic Levels

The following section describes baseline limnology and lower trophic information collected downstream of the Kennady Lake watershed.

For additional information regarding limnology and lower trophic levels, the reader is referred to the limnology and lower trophic level sections of EIS Annex J (Fisheries and Aquatic Resources Baseline) and Addendum JJ (Additional Fisheries and Aquatic Resources Information).

9.3.4.1 Methods

Studies of limnology and lower trophic communities in the Kennady Lake area were initiated in 1996, and continued through 2007. Data collected for lower trophic levels include the following:

- Phytoplankton and zooplankton communities were sampled in Lake N16, Lake 410, and Kirk Lake.
- Benthic invertebrate communities sampled in Lake N16, Lake 410, Kirk Lake, and small streams downstream of Kennady Lake.
- Invertebrate drift was measured in two streams downstream of Kennady Lake.
- Sediment samples were collected from Lake N16, Lake 410, and Kirk Lake for toxicity analysis.

9.3.4.2 Results

9.3.4.2.1 Plankton Communities

Phytoplankton communities in Lake N16, Lake 410, and Kirk Lake consist of representatives of six major taxonomic groups: cyanobacteria (blue-green algae); Chlorophyta (green algae); Chrysophyta (golden algae); Cryptophyta (biflagellates with chloroplasts); Bacillariophyceae (diatoms); and Pyrrophyta (dinoflagellates). This phytoplankton taxonomic composition is consistent with the observed communities in Kennady Lake.

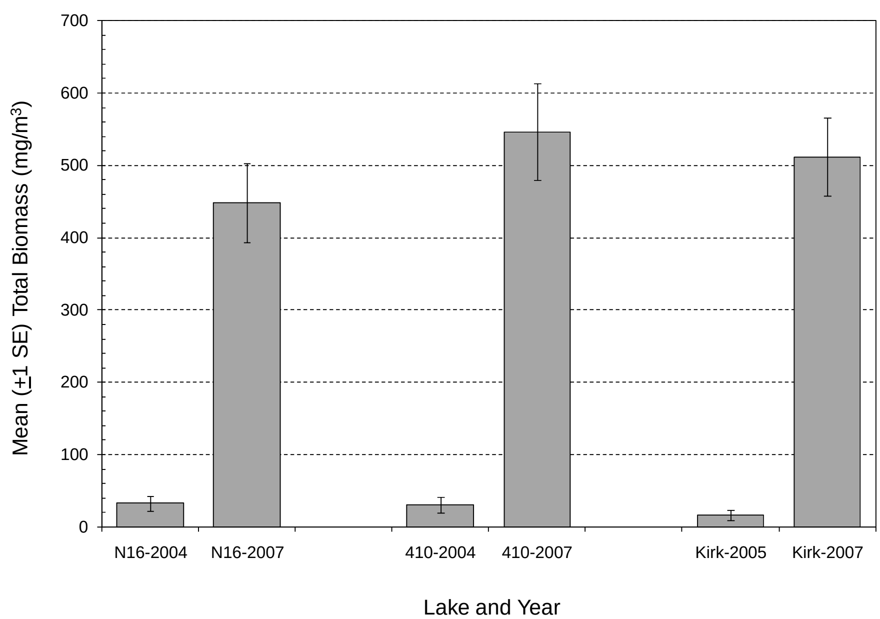
Total phytoplankton biomass varied little among the three lakes within studies, but was considerably lower in 2004 and 2005 than in 2007 (Figure 9.3-10).

Cyanobacteria were consistently the most abundant taxonomic group in all lakes in 2004 and 2005, whereas Chrysophyta were dominant in 2007 (Figure 9.3-11). Relative abundances of other groups were similar between years.

Cyanobacteria accounted for only a small proportion of the total phytoplankton biomass in 2004 and 2005, and for about a third of the total biomass in 2007 (Figure 9.3-12). Chrysophyta typically dominated the phytoplankton biomass in 2004 and 2005; co-dominance by two groups (Chrysophyta and cyanobacteria) or three groups (Chrysophyta, cyanobacteria, and Chlorophyta) was observed in 2007 (Figure 9.3-12). The observed dominance pattern is indicative of oligotrophic to oligo-mesotrophic conditions.

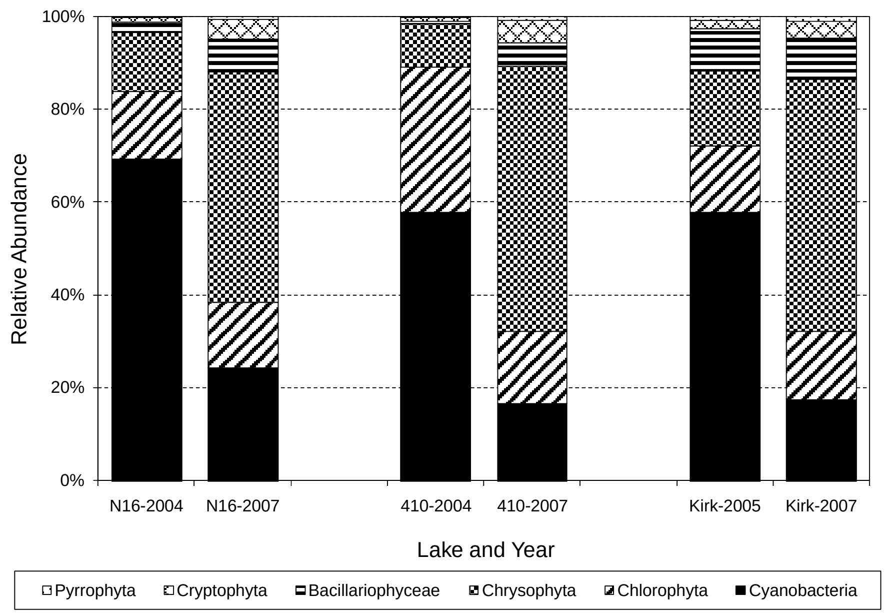
There was little variation in chlorophyll *a* concentration among the three lakes. Concentrations (about 1.0 micrograms per litre [µg/L]) were within a range characteristic of oligotrophic lakes and were consistent with lakes of similar trophic status in the Slave Geological Province, lakes between southern Yukon Territory and the Tuktoyaktuk Peninsula, Northwest Territories (NWT), and lakes between Yellowknife and Contwoyto Lake, NWT (Pienitz et al. 1997a, b).

Figure 9.3-10 Total Phytoplankton Biomass in Lakes Downstream of Kennady Lake, 2004, 2005, and 2007



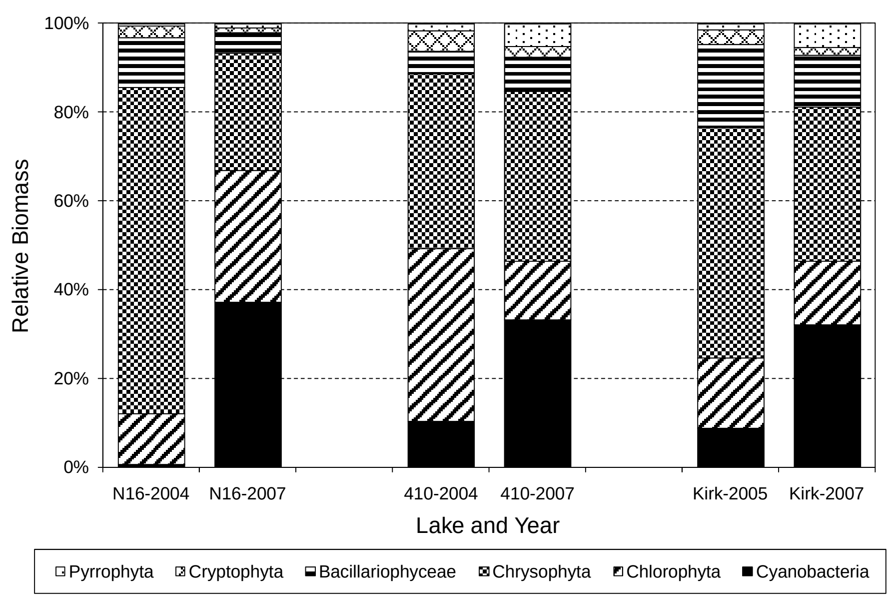
Note: + = plus or minus; SE = standard error; mg/m^3 = milligrams per cubic metre.

Figure 9.3-11 Relative Abundances of Major Phytoplankton Taxa in Lakes Downstream of Kennady Lake, 2004, 2005, and 2007



Note: % = percent.

Figure 9.3-12 Relative Biomass of Major Phytoplankton Taxa in Lakes Downstream of Kennady Lake, 2004, 2005, and 2007



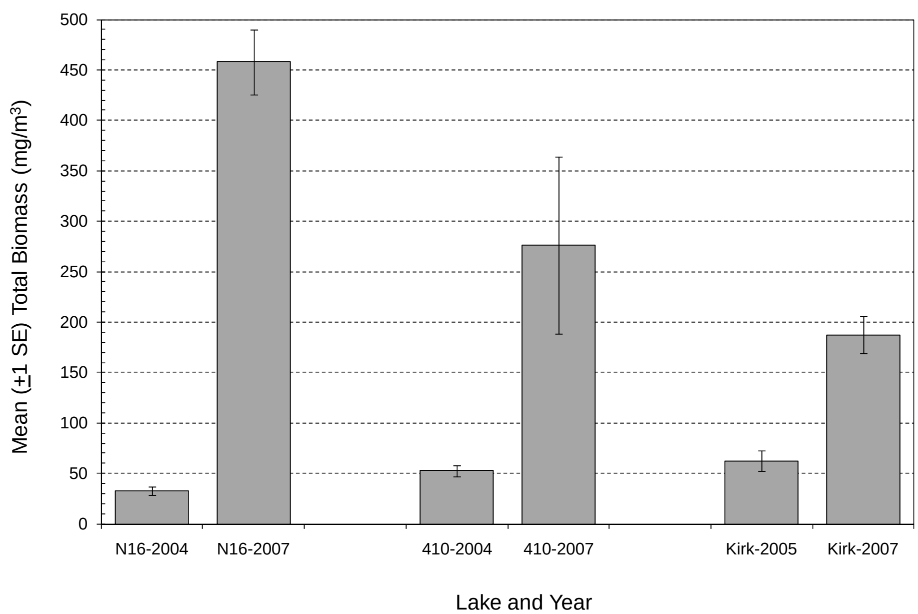
Note: % = percent.

The zooplankton communities of Lake N16, Lake 410, and Kirk Lake consisted of representatives of four major taxonomic groups: Rotifera, Cladocera, Calanoida (calanoid copepods), and Cyclopoida (cyclopoid copepods).

Total zooplankton biomass increased in a downstream direction from Lake N16 to Kirk Lake in 2004/2005, and showed the opposite spatial trend in 2007 (Figure 9.3-13). Total zooplankton biomass was considerably lower in 2004 and 2005 than in 2007. Total abundance of Rotifera was determined, but biomass was not measured in 2004 and 2005. Rotifer biomass contributed very little to total biomass in 2007.

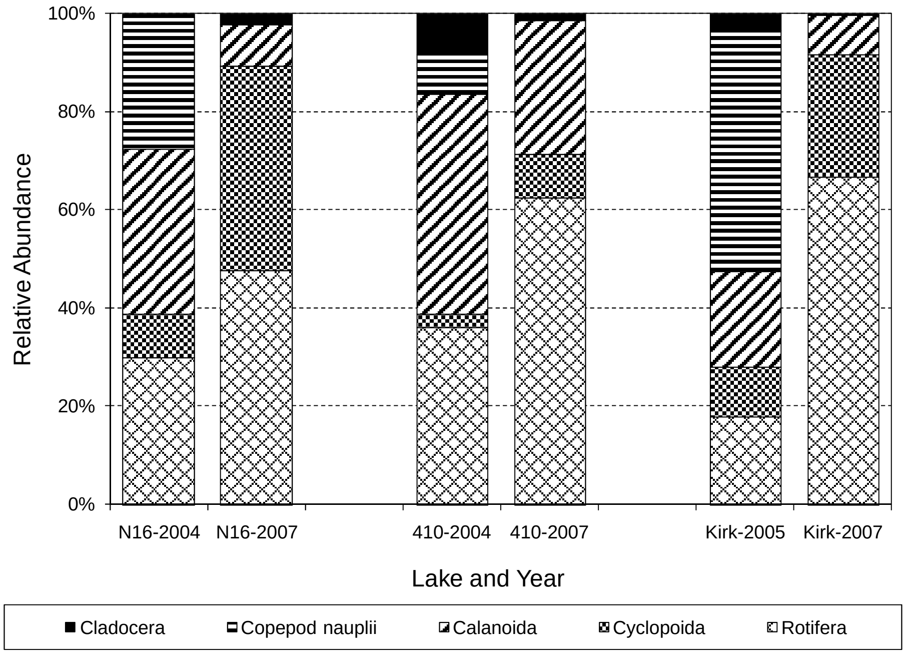
The relative abundances of major taxonomic groups were variable among lakes, with one of rotifers, cyclopoid copepods, calanoid copepods, or copepod nauplii dominating the community (Figure 9.3-14). The relative abundance of Cladocera was consistently low in all three lakes, in both years. Relative biomass (Figure 9.3-15) was more similar among lakes and years than density. Calanoid copepods generally dominated the zooplankton communities in all three lakes, in both years. Despite their low abundance, cladocerans accounted for about 10 to 50% of total biomass.

Figure 9.3-13 Total Zooplankton Biomass in Lakes Downstream of Kennady Lake, 2004, 2005, and 2007



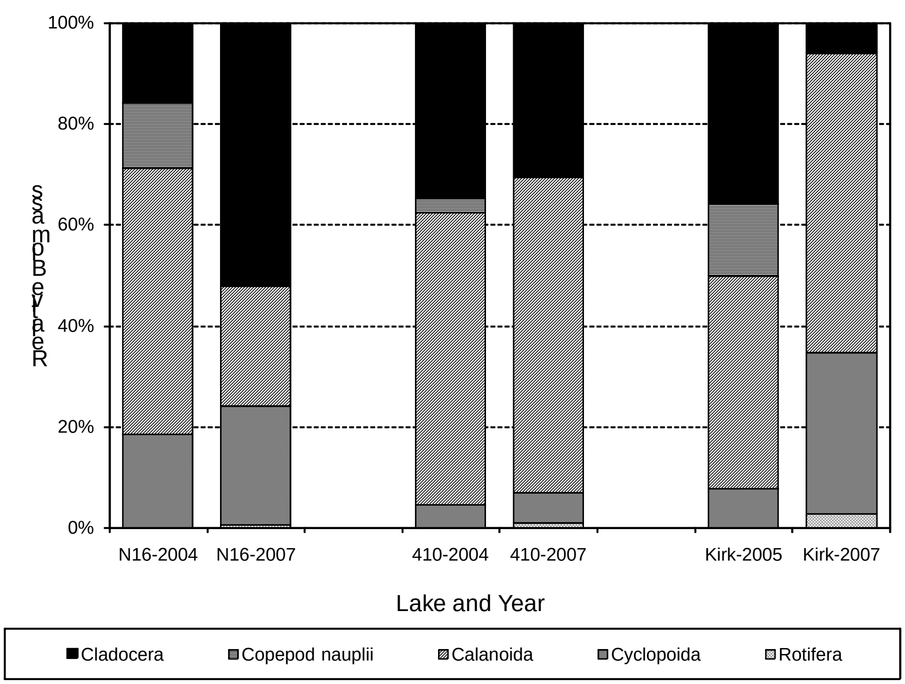
Note: ± = plus or minus; SE = standard error; mg/m³ = milligrams per cubic metre.

Figure 9.3-14 Relative Abundance of Major Zooplankton Taxa in Lakes Downstream of Kennady Lake, 2004, 2005, and 2007



Note: % = percent.

Figure 9.3-15 Relative Biomass of Major Zooplankton Taxa in Lakes Downstream of Kennady Lake, 2004, 2005 and 2007



Note: % = percent.

9.3.4.2.2 Benthic Invertebrate Community

Lakes

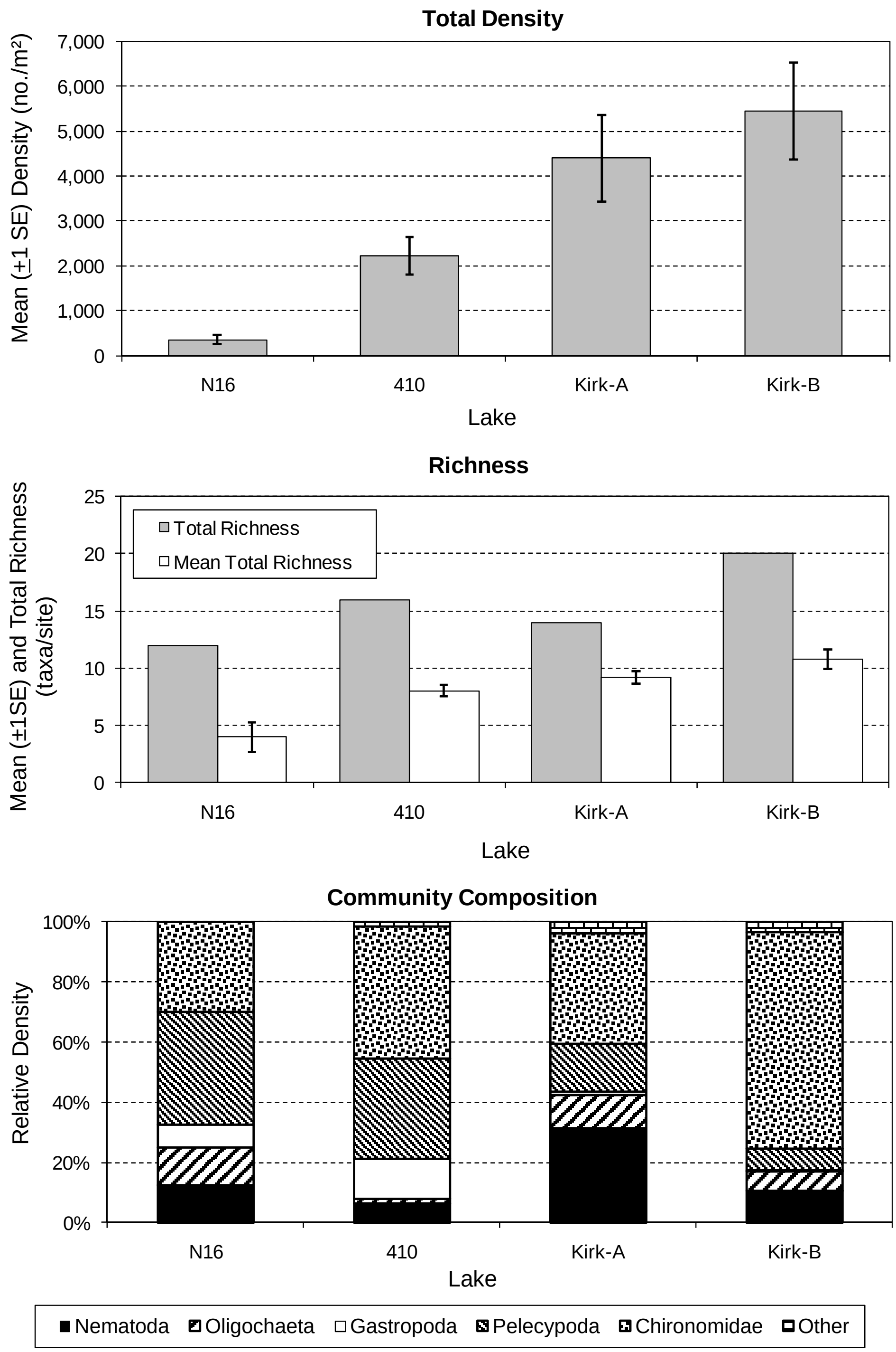
The benthic invertebrate community of Lake N16 in August (deep site) and September (shallow site) 2004 was characterized by low density (less than 1,000 organisms/m^2) and total richness of about 10 taxa (Figures 9.3-16 and 9.3-17). The 2007 data collected at four shallow sites revealed a greater degree of variability in both total density and richness (Figure 9.3-18). Midges (Chironomidae) were the dominant invertebrate group at the shallow sites in September 2004 and 2007, whereas fingernail clams (Pelecypoda: Sphaeriidae) were dominant at the deep site sampled in August 2004. Other common groups in Lake N16 included roundworms (Nematoda), aquatic worms (Oligochaeta), and snails (Gastropoda).

The benthic invertebrate community of Lake 410 at shallow sites sampled in August and September 2004 was more abundant and diverse than those at deeper sites in Lake N16 (Figure 9.3-16 and 9.3-17). This result was expected, because shallow sites usually support more abundant and diverse benthic communities. Midges and fingernail clams were co-dominant in this lake. Other common taxa included roundworms, aquatic worms, and snails.

Benthic communities of the two shallow sites (A and B) sampled in Kirk Lake in August 2005 had higher densities and similar richness compared to shallow sites sampled in Lake 410 in August 2004 (Figure 9.3-16). The benthic community of Kirk Lake was dominated by midges; roundworms, fingernail clams, and aquatic worms were also common.

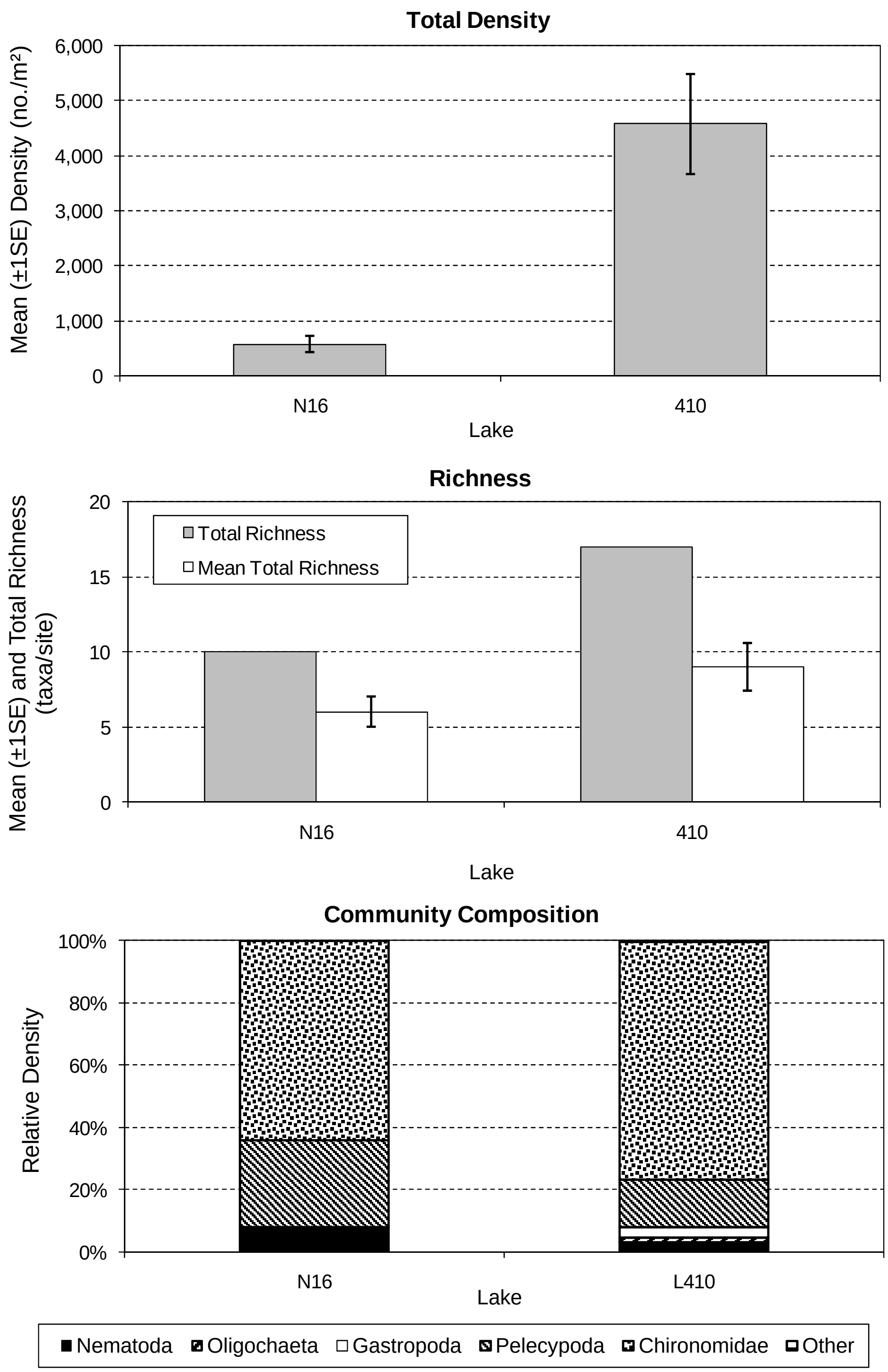
In summary, the benthic invertebrate communities of lakes downstream of Kennady Lake were characterized by low to moderate density and richness. The dominant taxa were similar among lakes and sites within lakes, and consisted of midges or fingernail clams. Roundworms, aquatic worms, and snails were also common in these lakes.

Figure 9.3-16 Total Abundance, Richness, and Community Composition of Benthic Invertebrates in Lakes Downstream of Kennady Lake, August 2004 and 2005



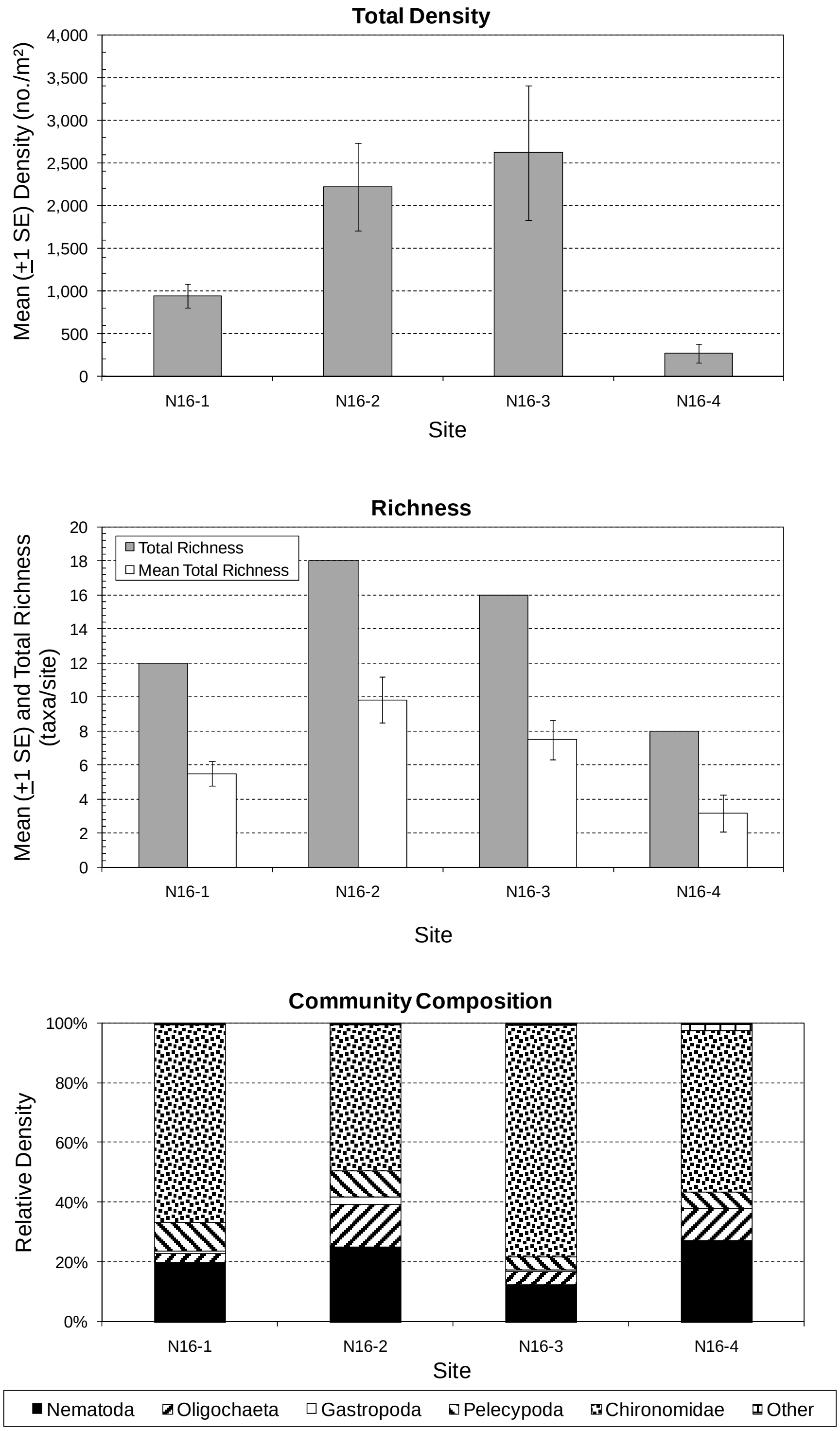
Note: Lakes N16 and 410 were sampled in August 2004, and Kirk Lake was sampled in August 2005; n=5.
± = plus or minus; SE = standard error; no/m² = number of organisms per square metre; % = percent.

Figure 9.3-17 Total Abundance, Richness, and Community Composition of Benthic Invertebrates in Lakes Downstream of Kennady Lake, September 2004



Note: n=5; ± = plus or minus; SE = standard error; no/m² = number of organisms per square metre; % = percent.

Figure 9.3-18 Total Abundance, Richness, and Community Composition of Benthic Invertebrates in Lake N16, Fall 2007



Note: n = 5; ± = plus or minus; SE = standard error; no/m² = number of organisms per square metre; % = percent.

Streams

Stream benthic communities sampled in summer 2005 in the N watershed and downstream of Kennady Lake were characterized by low to moderate density and richness (Table 9.3-27). Common benthic invertebrates in these streams included hydras (Hydrozoa), mites, and larvae of midges (Chironomidae) and blackflies. Stream sites sampled downstream of Kennady Lake in fall 2007 were characterized by low density and moderate richness (Figure 9.3-19). In 2007, the stream benthic community was dominated by midges. Caddisflies (Trichoptera) were also common. The “other taxa” group, which included hydras, snails, true bugs (Hemiptera), beetles (Coleoptera), and other true flies (other Diptera), accounted for up to about 20% of the benthic invertebrate community at various stream sites in 2007.

The benthic component of stream drift samples collected in summer 2005 in streams N3 and L3 was dominated by hydras (Hydrozoa); mites (Acari) and midges were occasionally common (Figure 9.3-20). Mean drift density was low (i.e., less than 50 organisms/100 m^3) near the water surface in both streams. Near-bottom drift density was slightly higher in Stream L3 and substantially higher in Stream N3, where it was about 1,000 organisms/100 m^3. Richness of drifting invertebrates showed a similar pattern as drift density, with a maximum value in Stream N3 near the bottom. Invertebrate drift also included a planktonic component, dominated by water fleas, which originated from lakes drained by the sampled streams.

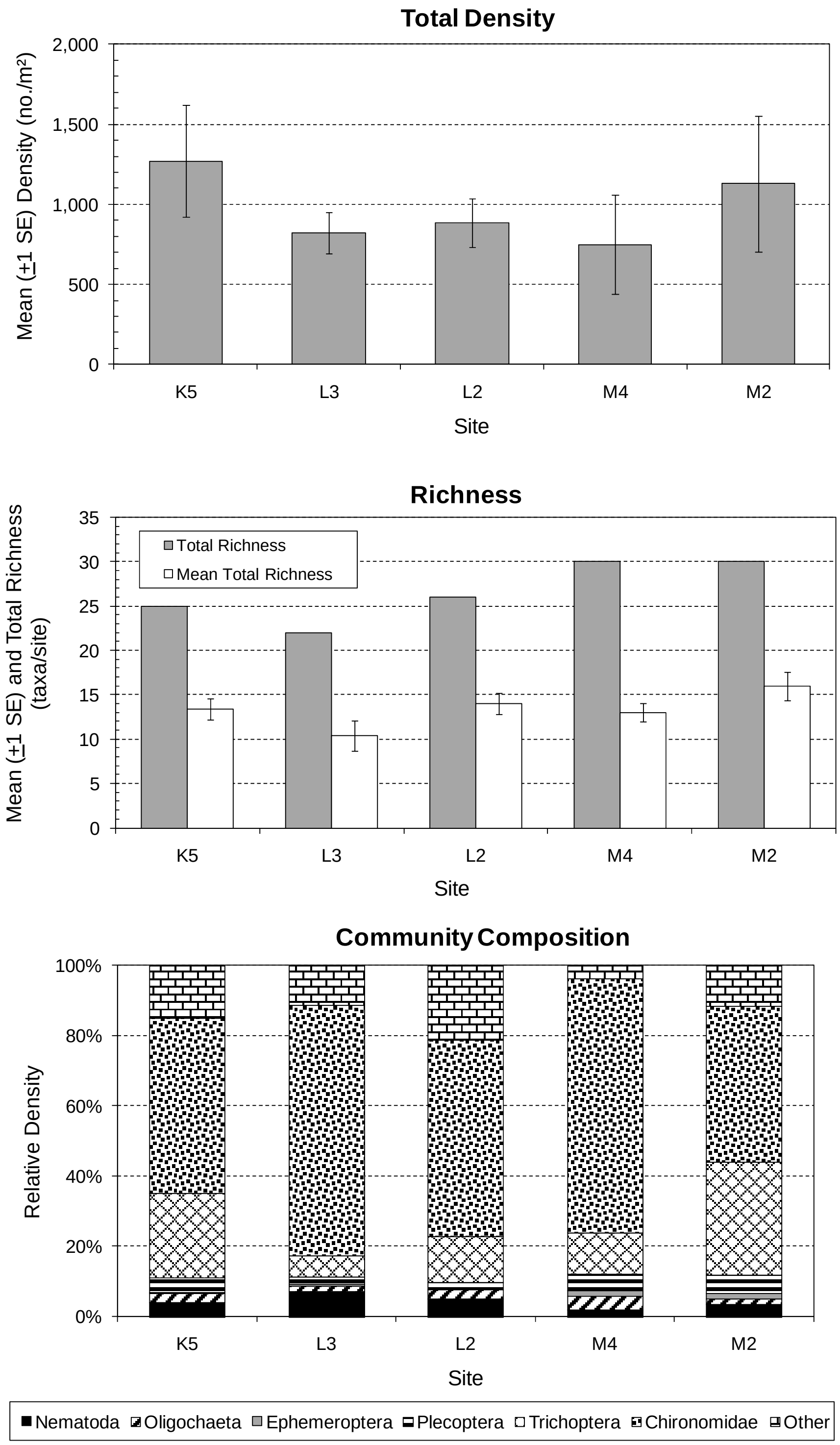
Table 9.3-27 Summary of Stream Benthic Invertebrate Data Collected in 2005

Stream	Total Density (number/m^2)	Richness (no. taxa)
N6	433	14
N5	467	7
N4	6,299	19
N3	578	7
N2	1,589	14
L3	8,710	11
L2	1,989	9
L1b	3,366	13
L1a	8,655	12
P4	1,222	11
K5 (Kennady Lake outlet stream)	2,122	11
KO (Kirk Lake outlet stream)	3,055	9
Mean ±1 SE	**3,207 ± 874**	**11 ± 1**

Note: Total density and richness values are presented for individual samples, because a single sample was collected in each stream.

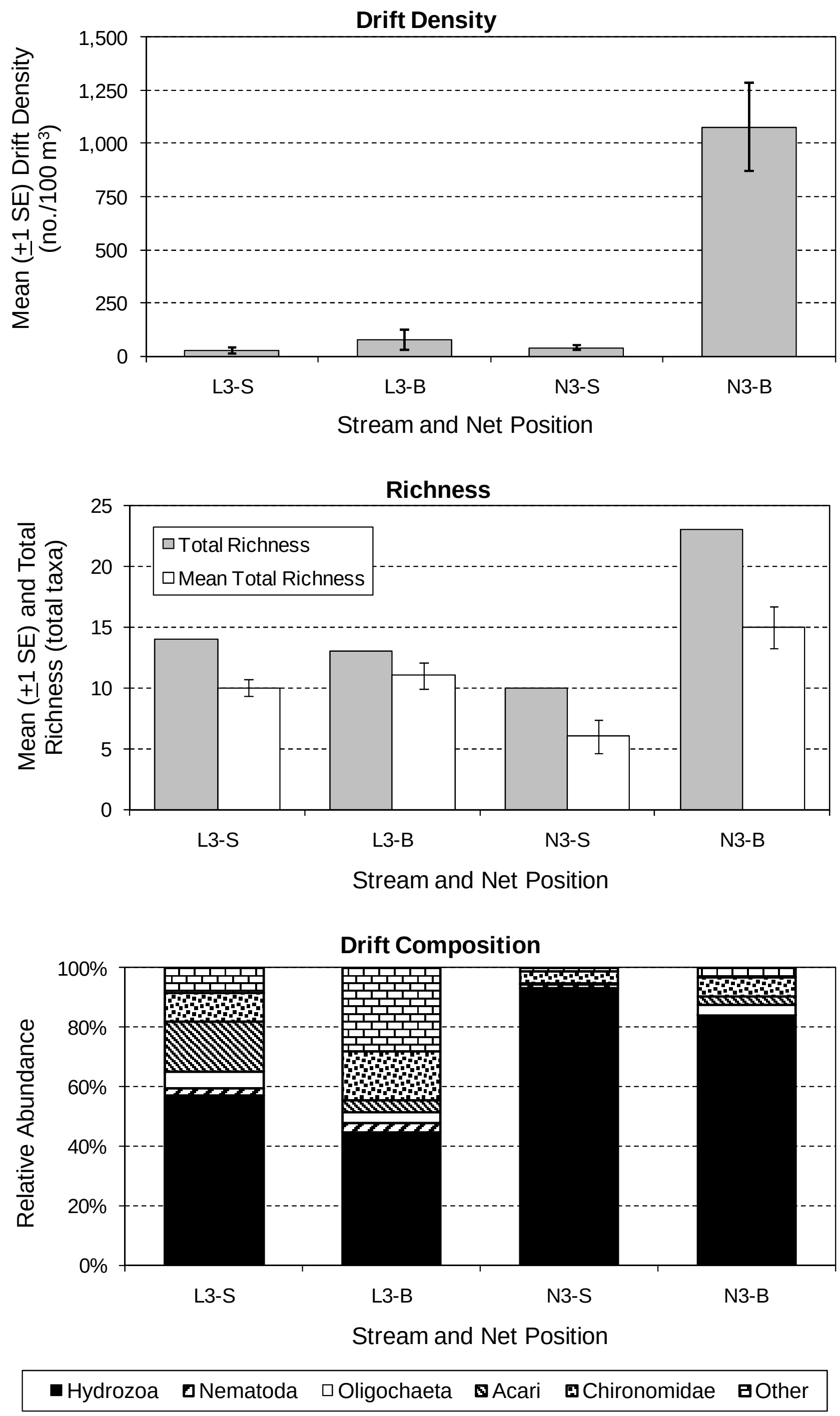
number/m^2 = number per square metre; no. taxa = number of taxa; SE = standard error.

Figure 9.3-19 Total Abundance, Richness, and Community Composition of Benthic Invertebrates in Streams Downstream of Kennady Lake, Fall 2007



Note: n = 5; ± = plus or minus; SE = standard error; no/m² = number of organisms per square metre; % = percent.

Figure 9.3-20 Density, Richness, and Community Composition of Drifting Benthic Invertebrates in Streams L3 and N3, Summer 2005



Note: Net position: S = immediately below water surface; B = near the bottom; n=4.
± = plus or minus; SE = standard error; no./100 m^3 = number of organisms per 100 cubic metres; % = percent.

9.3.4.2.3 Sediment Toxicity

In 2005, *Hyalella azteca* survival and growth, and *Chironomus tentans* survival in sediments collected from Kirk Lake and Lake N16 were not significantly different from the laboratory controls. *Chironomus tentans* growth in the Kirk Lake sample was also not significantly different from the laboratory control; however, growth in Lake N16 sample was significantly lower than in the laboratory control but not significantly different than in the Kirk Lake sample.

These results indicate that bottom sediments in Lake 410, Lake N16 and Kirk Lake are generally non-toxic to aquatic life. Of the eight survival and growth tests run in 2004 and 2005 combined, results were found to be significantly different from the laboratory controls for only one *Chironomus* test (growth) in 2005.

9.3.5 Fish

The following section describes the fish and fish habitat baseline information collected downstream of the Kennady Lake watershed and the adjacent 'N' watershed from 1996 to 2010. For additional information regarding fish and fish habitat, the reader is referred to Annex J and Addendum JJ.

9.3.5.1 Methods

Aquatics studies in the Kennady Lake area were initiated in 1996, and continued through 2010.

The following data were collected from fisheries studies conducted between 1996 and 2010:

- Habitat information was collected for 32 small lakes. These included 18 lakes downstream of the Kennady Lake watershed, and 15 lakes in the N watershed. Small lake habitat sampling locations are shown in Figure 9.3-21.
- Limnological surveys were conducted in selected lakes in the N watershed and downstream of Kennady Lake. Limnology sampling locations are shown in Figure 9.3-22a.
- Stream habitat assessments were conducted in 21 streams in the N watershed and 26 streams downstream of the Kennady Lake watershed. Stream habitat sampling locations are shown in Figure 9.3-23.

- Aquatic habitat along the existing Winter Access Road route was assessed by helicopter.
- Gill-netting surveys were conducted to characterize the large-bodied fish community in Lake N16, Lake 410, and Kirk Lake
- Minnow traps and/or shoreline electrofishing were used to characterize the littoral fish community in Lake N16, Lake 410, and Kirk Lake
- Fish counting fences were installed to assess spring spawning migrations in five streams downstream of the Kennady Lake watershed and four streams in the N watershed.
- Lake habitat assessments were conducted in 17 small lakes downstream of the Kennady Lake watershed and 14 small lakes in the N watershed, as well as in Lake 410.
- Fish sampling was conducted to assess the fish-bearing status of 16 small lakes downstream of the Kennady Lake watershed and 13 small lakes in the N watershed. Small lake fish sampling locations are shown in Figure 9.3-24.
- Stream utilization surveys were conducted in 18 streams downstream of the Kennady Lake watershed and in 14 streams in the N watershed. Stream fish sampling locations are shown in Figure 9.3-25.
- Radio telemetry was used to monitor movements of fish within Kennady Lake and between Kennady Lake and downstream lakes.
- Fish tissue burdens were assessed by collecting muscle and liver samples for metals analysis from lake trout in Lake N16, Lake 410, and Kirk Lake.

LEGEND

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Fish Habitat Sampling Locations in Small Lakes in the N Watershed and Downstream of Kennady Lake, 2009 to 2010

Kilometres

FILE No:			DATE:
E-Fish-131-GIS			December 17, 2010
JOB NO: 09-1365-1004	REVISION NO: 1		**Figure 9.3-21**
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF	

Watershed Boundary

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Limnological Sampling Locations in the N Watershed and Downstream of Kennedy Lake, 2002 to 2010

Kilometres

FILE No: E-Fish-133-GIS	DATE: December 17, 2010
JOB NO: 09-1365-1004	REVISION NO: 1
OFFICE: GOLD-CAL	DRAWN: SK / CHECK: JF

Figure 9.3-22

LEGEND

GAHCHO KUÉ PROJECT

Stream Fish Habitat Sampling Locations in the N Watershed and Downstream of Kennady Lake, 2000 to 2010

Kilometres

FILE No: E-Fish-132-GIS		DATE: December 17, 2010
JOB NO: 09-1365-1004	REVISION NO: 1	**Figure 9.3-23**
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000
Habitat Surveys Conducted in 1999, 2000, 2004, 2005 and/or 2010

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Lake Fish Sampling Locations in the N Watershed and Downstream of Kennedy Lake, 2004 to 2010

Kilometres

FILE No: E-Fish-134-GIS	DATE: December 17, 2010
JOB NO: 09-1365-1004	REVISION NO: 1
OFFICE: GOLD-CAL	DRAWN: SK
CHECK: JF	

Figure 9.3-24

LEGEND

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Stream Fish Sampling Locations in the N Watershed and Downstream of Kennedy Lake, 2005 to 2010

Kilometres

FILE No. E-Fish-135-GIS	DATE December 17, 2010
JOB NO. 09-1365-1004	REVISION NO. 1
OFFICE GOLD-CAL	DRAWN SK
CHECK JF	

Figure 9.3-25

9.3.5.2 Results

9.3.5.2.1 Aquatic Habitat

Lakes

A summary of lake area, depth, and dominant nearshore habitat type for each small lake sampled is presented in Table 9.3-28.

For the most part, lakes in the L watershed are small (less than 13 hectares [ha]), shallow (less than 4 m), with silt covered boulders in the nearshore areas. Lake L18 was larger, but still considered a relatively small lake, with a surface area of 14.2 ha and a maximum depth of 5.5 m. Lakes in the M watershed farther downstream are larger (11 to 91 ha) and generally deeper (up to 13 m). Lakes less than 3 m deep are unlikely to provide overwintering habitat for fish because the annual ice depth is typically 2 m thick and each of the lakes between Kennady Lake and Lake 410 become isolated once ice freezes solid to the bottom of streams.

Lake 410 is a 579 ha lake, located approximately 12 km downstream of Kennady Lake. Lake 410 receives inflow from two sources: from Kennady Lake and the L and M watersheds, and from the much larger N watershed. For its size, Lake 410 is shallow, having a mean depth of approximately 4 m. The deepest spot in Lake 410 is in the narrows between its northern and southern basins where water is up to 9 m deep. Large boulders are common throughout the lake, even in offshore areas, and silt covered boulders dominate the shoreline substrates.

Lakes in the adjacent N watershed range in size and depth (Table 9.3-28). A series of small lakes drain from the northern edge of Kennady Lake to Lake N11 (i.e., Lake N7 to Lake N2). Lake N5 in this series is deep (12.8 m) in comparison to the other lakes sampled in the N watershed. Only the northeast basin of Lake N17 was surveyed; the basin had a surface area of 91.5 ha and a maximum depth of 10.5 m (Table 9.3-28).

Most of the lakes surveyed were shallow depressions in the tundra, characterized by low gradient shorelines dominated by fines and boulder substrates. Aquatic vegetation, when present, was typically restricted to shorelines and inlet/outlets of streams. At depths greater than 2 m, lake bottom substrate was generally fines/organics and absent of aquatic vegetation.

Table 9.3-28 Summary of Habitat Characteristics for Small Lakes and Lake 410 in the Downstream Watersheds and Adjacent N Watershed.

Lake Identifier	Lake Area (ha)	Maximum Depth (m)	Dominant Shallow Habitat[(a)]
Downstream of Kennady Lake			
L1a	3.6	1.2	10LI
L1b	5.4	1.8	10LI
L1c	0.5	-	1LI
L2	12.6	3.4	10LI
L3	4.4	1.0	10LI
L4	2.4	1.3	-
L13	3.3	1.3	8LI
L14	3.6	0.6	-
L15	6.1	2.5	-
L18	14.2	5.5	1LI
L19	2.1	2.0	1LI
L20	0.2	0.5	8LI
L21	6.6	7.3	10LI
M1	11.0	1.9	1LI
M2	32.1	5.7	10LI
M3	91.0	7.5	10LI
M4	80.6	13.0	10LI
410	579.0	9.1	10LI
Adjacent N watershed			
N2	27.1	5.5	10LI
N3	12.2	5.5	10LI
N4	3.1	2.8	10LI
N5	52.4	12.8	10LI
N6a	77.2	4.0	10LI
N6b	4.2	-	10LI
N7	5.6	2.5	2LI
N12	100.8	5.8	-
N13	3.6	1.8	1LI
N14	21.5	2.8	10LI
N14a	3.2	3.5	10LI
N14b	2.0	0.7	8LI
N17[(b)]	91.5	10.5	10LI
N18	51.3	4.1	-

(a) Habitat Quality as described:

1 = Boulder/cobble-substrates generally clean due to wave action and ice scour; on average 60% boulders, 40% cobbles; interstitial spaces generally clean.

2 = Boulder-substrates 80% or greater boulder; remainder cobble, gravel, or fine sediments.

8 = Fines/organics-substrates predominantly fines, organics, or sand.

10= Boulder/fines-highly embedded boulders overlain with layer of fine sediments; substrates greater than 40% boulder.

L = Low gradient (<10°).

I = 0 to 2 m depth.

(b) Of the northeast basin surveyed, not the entire lake.

ha =hectare; m = metre;-= not available.

Due to typical winter ice depths of 2 m in the region, many of the lakes were not considered suitable for overwintering, as the maximum depths observed were less than 2 m. Lakes with maximum depths between 3 and 5 m may provide some pockets of overwintering habitat at their deepest locations, but likely have oxygen depletion in mid to late winter. Based on depth, Lakes L18, L21, M2, M3, M4, 410, N2, N3, N5, and the northeast basin of Lake N17 likely provide suitable overwintering habitat for fish.

Streams

Kennady Lake is naturally drained at the eastern end of Area 8 through a series of streams and small lakes. Streams downstream of Kennady Lake to Lake 410 typically have a low gradient (less than 1%), are shallow (less than 50 cm deep), and are comprised of braided channels with low (less than 0.5 m) banks and large angular boulders (Table 9.3-29). Gravel substrates are rare but do exist in small patches in some streams. In spring, water typically flows over stream banks and floods extensive areas of riparian tundra. In summer and fall when flows are lowest, water is generally confined to one main channel and, in most areas, is limited to flows between and under boulders.

Eight streams between Kennady Lake and Lake 410 have high quality spawning habitat for Arctic grayling (Table 9.3-29). Riffle habitat with various sized cobble and gravel substrates exists in most of these streams in spring, although most of the available habitat is characterized by large boulder substrate. Arctic grayling prefer to spawn in riffles with water velocities less than 1.5 metres per second (m/s) and typically at velocities ranging between 0.3 to 0.8 and substrates ranging from pea-sized gravel (1 cm diameter) to large cobble (20 cm diameter) (Scott and Crossman 1973; Hubert et al. 1985; Evans et al. 2002; Stewart et al. 2007).

In general, water depth and flow is insufficient in most of the streams in the L watershed in summer to provide fish passage for large-bodied adult fish, such as Arctic grayling and northern pike. The passage of fish is possible in streams of the M watershed because they are larger and deeper; however, passage in these streams is likely restricted in summer due to low flows. Stream L11 contained dry sections of channel at the time of the survey and was thus considered ephemeral. Streams L13, L14, L15, and L18 contained flow at the time of the survey and thus were classified as permanent in Table 9.3-29; however, poorly defined banks indicate these streams may also dry up under some low flow conditions. These five streams surveyed did not provide fish passage for large-bodied adult fish between lakes at the time of the survey. Barriers to fish passage included boulder gardens with interstitial flow or very low water levels, which are seasonal barriers to large fish but would not necessarily deter small-bodied YOY or forage fish species.

Table 9.3-29 Summary of Fish Habitat Quality in Streams between Kennady Lake and Kirk Lake

Stream	Gradient (%)	Flow Duration	Overall Habitat Quality Rating[a]	Spawning Habitat Quality[b]		Fish Passage			Comments
				ARGR	NRPK	Spring	Summer	Fall	
L1a	1.3	perm	H	H	L	yes	no	no	sheet flow over bedrock by summer
L1b	0.8	perm	H	H	N	yes	yes	no	interstitial flow by fall
L1c	0.5	perm	M	H	N	yes	no	no	
L2	0.5	perm	M	H	L	yes	yes	yes	
L3	0.3	perm	H	H	L	yes	no	no	
L11	0.8	ephem	L-M	N	L	-	no[c]	-	
L13	0.5	perm	M	N	L	-	no[c]	-	
L14	0.6	perm	M	N-L	L	-	no[c]	-	
L15	0.8	perm	M	N-L	L	-	no[c]	-	
L18	1.5	perm	L-M	N-L	N-L	-	no[c]	-	
M1	0.1	perm	H	H	H	yes	yes	yes	
M2	0.3	perm	H	H	M	yes	yes	yes	
M3a [d]	0.1	perm	H	M	M	yes	yes	yes	
M3b [d]	0.0	perm	H	N	H	yes	yes	yes	lake narrowing
M4	0.3	perm	H	H	M	yes	yes	no	interstitial flow by fall
410	0.8	perm	L	M	N	yes	yes[b]	yes[b]	wide (>100 m), boulder strewn, multi-braided outlet
P1	-	perm	M	M	M	yes	yes[b]	yes[b]	abundant flooded riparian vegetation
P2	-	perm	H	H	L	yes	yes[b]	yes[b]	
P3[e]	0.6	perm	H	H	N	yes	yes[b]	yes[b]	
P4	1.3	perm	H	H	N	yes	yes[b]	yes[b]	
P5	0.3	perm	H	H	N	yes	yes[b]	yes[b]	
P6	0.6	perm	H	H	N	yes	yes[b]	yes[b]	
P7	2.1	perm	-	-	-	yes	yes[b]	yes[b]	steep gradient with high velocities (>1.5 m/s) in spring
P8	1.6	perm	-	-	-	yes	yes[b]	yes[b]	steep gradient with high velocities (>1.5 m/s) in spring
Kirk	0.3	perm	H	H	N	yes	yes	yes	constricted between bedrock outcrops

(a) Habitat Quality Ratings: H = High; M = Moderate; L = Low; N = Nil.
(b) Inferred from size of stream, upstream watershed area, and characteristics of stream in spring.
(c) For large-bodied adult fish at the time of the survey.
(d) Streams M3a and M3b were surveyed as two separate channels and are indicated as M3 in Figure 9.3-12.
(e) P3 stream into P2

ARGR = Arctic grayling; NRPK = northern pike; perm = permanent; ephem = ephemeral; % = percent; m = metre; m/s = metres per second;-= not available.

Streams downstream of Lake 410 are substantially wider (about 50 m wide) and deeper (greater than 1 m) than streams between Kennady Lake and Lake 410. This is because Lake 410 has two inlets and receives approximately 80% of its inflow from the adjacent N watershed. The streams are generally low gradient, with the exception of Streams P4, P7, and P8, with substrates consisting almost exclusively large angular boulders. Spawning habitat is available for Arctic grayling in all of these streams, whereas northern pike likely use flooded riparian tundra where available in spring. All of the streams are large enough to provide fish passage throughout the open-water season.

A summary of habitat quality of select streams in the adjacent N watershed is provided in Table 9.3-30. Streams north of Kennady Lake (N9 to N2) drain a series of small headwater lakes into Lake N1 downstream, which also receives the drainage from watersheds (N18 to N11) to the west and northwest side of Kennady Lake. Typical of headwater streams in the LSA, these streams generally have a low gradient and consist of multiple braided channels with large angular boulders and cobble substrates. Many of these streams have moderate to high quality spawning habitat available for Arctic grayling.

Table 9.3-30 Summary of Fish Habitat Quality in N Watershed Streams

Stream	Gradient (%)	Flow Duration	Overall Habitat Quality Rating[a]	Spawning Habitat Quality[b]		Fish Passage			Comments
				ARGR	NRPK	Spring	Summer	Fall	
N1	1.6	perm	M	M	N	yes	yes	yes	large riffle with pocket pools; angular boulders
N2	1.2	perm	H	H	M	yes	no	no	flow constricted over bedrock face at low flow
N3	0.3	perm	M	M	N	yes	yes	yes	
N4	2.2	perm	M	M	N	yes	no	no	boulder and bedrock constrictions at low flow
N5	0.3	perm	H	M	H	yes	no	no	boulder barrier at low flow
N6a (R ch)	2.5	perm	N	N	N	no	no	no	boulder barrier at low flow
N6a (L ch)	2.5	perm	M	M	N	yes	no	no	boulder barriers at low flow
N6b	0.0	perm	M	N	H	yes	yes	yes	lake narrowing
N7	1.2	ephem	N	N	N	no	no	no	
N9	-	perm	M	M	M	yes	yes	yes	run with fine substrates transitional to boulder riffle before draining into Lake N6
N10	-	perm	M	M	L	yes	yes	yes	incised channel in the tundra with fine substrates
N11	2.6	perm	H	H	N	yes	yes[b]	yes[b]	large bedrock constricted cascade
N12	0.9	perm	L	L	L	yes	no	no	boulder barrier at inlet
N13	1.6	none	N	N	N	no	no	no	perched lake, no outlet
N14	0.4	perm	L	L	M	yes	no	no	upstream passage restricted at mouth by plunge pool
N14a	0.0	ephem	L	N	L	-	no[c]	-	
N14b	N/A	ephem	N	N	N	-	no[c]	-	dry at time of survey, with no defined bed or banks
N15	-	perm	H	H	N	yes	yes	yes	
N16	-	perm	H	H	L	yes	yes	yes	
N17	0.1	perm	H	H	M	yes	yes	yes	boulder and bedrock constrictions at low flow
N18	1.5	perm	M	M	L	yes	-	-	multi-braided channel through willows

(a) Habitat Quality Ratings: H = High; M = Moderate; L = Low; N = Nil.
(b) Inferred from size of stream, upstream watershed area, and characteristics of stream in spring.
(c) For large-bodied adult fish at the time of the survey.
ARGR = Arctic grayling; NRPK = northern pike; Perm = Permanent; Ephem = Ephemeral; % = percent; m = metre; L ch = left channel; R ch = right channel;-= not available.

Streams N9, N10, and N11 are permanent streams that provide moderate to high habitat quality and passage for fish (Table 9.3-30). Stream N12 is a small, low gradient stream incised within a narrow, low-banked single channel. Habitat is almost entirely comprised of runs with embedded boulders and cobbles, although silt bottomed pools with aquatic vegetation are present. Stream N12 drains a small, shallow (less than 1 m deep) boulder-strewn pond between Lake N12 and Lake N11 and is impassable by large-bodied fish in summer.

Stream N13 is an incised channel in the tundra that extends approximately 25 m downslope from Lake N13 before abruptly disappearing into the tundra. Lake N13, therefore, is a perched lake and any runoff to Lake N12 must flow under or through the tundra in spring.

Stream N14a and Stream N14b were either entirely dry or contained dry sections of channel at the time of the survey and, thus, were considered ephemeral.

Stream N18 drains a large headwater lake into Lake N12. This stream is typical of headwater streams in the LSA; it is a moderate gradient, multi-channel stream with boulder substrates, and areas of gravel and smaller cobbles.

Stream N1 drains the entire N watershed into Lake 410 and is a wide (greater than 100 m), steep stream, with boulder-riffle habitat and high water velocities throughout the spring, summer, and fall. Stream N1 provides high water velocities in the spring and a large area for potential Arctic grayling spawning. Its actual use as a spawning site may be tempered, however, by the paucity of gravel substrates. Stream N1 remains open during winter (see also Annex H).

Winter Road

Thirty-three portages were identified along the existing Gahcho Kué Project Winter Access Road route (Table 9.3-31), of which seven portages are located in the N watershed. Aquatic habitats at portage locations included lake shorelines where the road accessed a lake, as well as stream crossings.

In general, lake shoreline habitats along the 33 portages of the existing Gahcho Kué Project Winter Access Road had shallow gradients and could be classified into three categories: boulder, wetland, and vegetated shorelines. Boulder shorelines were the most common type observed and had variable widths of exposed boulder/cobble substrates separating the wetted margin of the lake from the open tundra vegetation. Wetland shorelines were typically characterized by fine organic sediments with inundated terrestrial or emergent aquatic vegetation. Gradient was lower at wetland shorelines than at boulder shorelines. Vegetated shorelines were the least common lake shoreline type and consisted of tundra vegetation growing to the wetted edge.

Table 9.3-31 Summary of Aquatic Habitats Assessed along the Existing Gahcho Kué Project Winter Access Road, 2004

Portage summary	total number of portages	33
	total lake shorelines	66
	small ponds along portages	6
	total shorelines along Winter Access Road route	72
Lake and pond shorelines	boulder shorelines	29
	wetland shorelines	27
	vegetated shorelines	15
	total shorelines assessed	71
Stream crossings	portages with stream crossings	10
	portages where route parallels stream	10

9.3.5.2.2 Large-bodied Fish Community

Relative abundance and catch-per-unit-effort for fish captured gillnetting in Lake N16 in the summers of 1996 and 1999 and in Lake 410 in summer of 2005 are provided in Table 9.3-32.

Table 9.3-32 Species Composition, Relative Abundance, and Average Catch-per-Unit-Effort of Fish Captured in Lake N16 and Lake 410 during Summer Gillnetting Surveys in 1996, 1999, and 2005

Species	Lake N16						Lake 410		
	1996			1999			2005		
	No. of Fish	% of Catch	CPUE	No. of Fish	% of Catch	CPUE	No. of Fish	% of Catch	CPUE
Lake chub	38	25.9	1.2	2	2.7	0.2	0	0.0	0.0
Lake trout	29	19.7	1.0	25	34.2	2.7	52	43.7	5.7
Round whitefish	65	44.2	2.1	13	17.8	1.4	43	36.1	4.8
Cisco	5	3.4	0.2	30	41.1	3.3	24	20.2	2.11
White sucker[(a)]	0	0.0	0.0	3	4.1	0.3	0	0.0	0.0
Longnose sucker[(a)]	10	6.8	0.3	0	0.0	0.0	0	0.0	0.0
Total	**147**	**100.0**	**4.8**	**73**	**100.0**	**7.9**	**119**	**100.0**	**12.6**

(a) Of sucker species, only longnose sucker was captured in Lake N16 in 1996 and only white sucker in 1999. This is the only reported instance of white sucker in the watershed upstream of Kirk Lake and, therefore, may potentially be a misidentification.

CPUE = catch-per-unit-effort measured as number of fish/100 m^2/12 hours; No. = number; % = percent; m^2 = square metre

Round whitefish and lake trout are the most abundant large-bodied fish species in Lake N16 and Lake 410. Lake trout are the most abundant predator. This is similar to the fish community structure in Kennady Lake.

Lake N16 contains fish species not found in Kennady Lake. These include cisco, which comprised over 40% of the total catch in Lake N16 in summer 1999, and longnose sucker and possibly white sucker, although the white sucker may have been mis-identified.

Cisco also were captured in Lake 410, where it was the third most abundant species. Cisco also were present in Lake M4 (less than 5 km downstream of Kennady Lake) in 1996, comprising 71% of the total catch. It is unclear why cisco are absent from Kennady Lake but found in relatively large numbers in Lake N16 and in lakes in close proximity downstream. Cisco are pelagic planktivores, requiring protected rocky bays for rearing areas, and substrates ranging from sand to boulders in 1 to 5 m of water for spawning (Richardson et al. 2001). Kennady Lake appears to provide this habitat; therefore, it is likely that cisco are excluded from Kennady Lake due to some other habitat (e.g., lake size and/or depth, absence of shoals) or ecological constraint (e.g., competition or predation from other species).

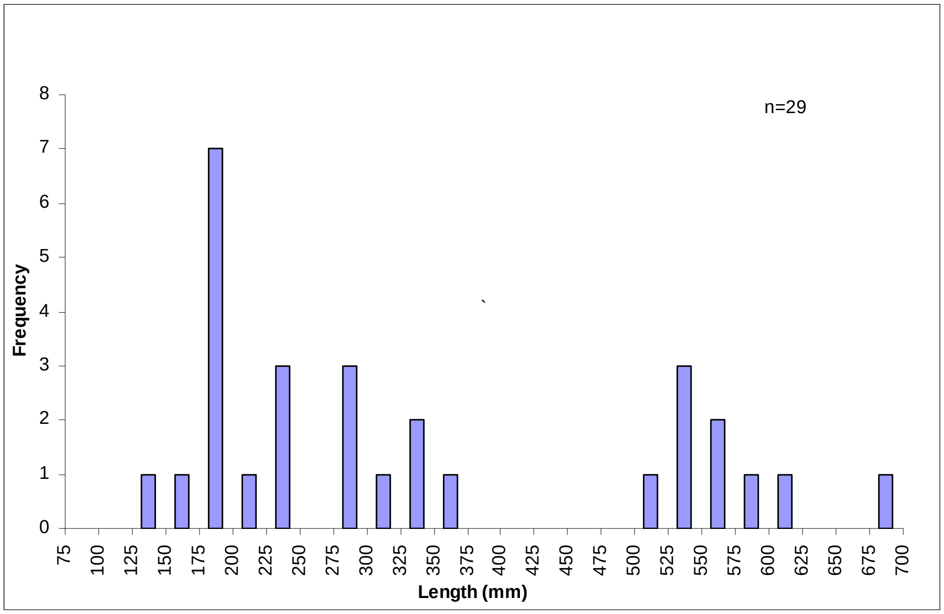
Northern pike were not captured in Lake N16, or anywhere else in the N watershed, but populations exist in Kennady Lake and in Lake 410. Similarly, Arctic grayling were not captured in Lake N16 or Lake 410, but populations exist in Kennady Lake. Arctic grayling are known to use the Lake N16 inlet and outlet streams for spawning in spring (EBA and Jacques Whitford 2001); therefore, Lake N16 likely supports an Arctic grayling population even though they were not represented in lake catches.

Lake Trout in Lake N16

Lake trout captured in Lake N16 in summer 1996 ranged in length from 143 to 677 mm, with a modal length class of 175 to 200 mm (Figure 9.3-26). Most lake trout captured in Lake N16 in summer 1996 were small fish less than 300 mm in length. Lake trout captured in summer 1999 ranged in length from 140 to 620 mm (Figure 9.3-27), with the majority (80%) of lake trout captured in 1999 being greater than 300 mm in length.

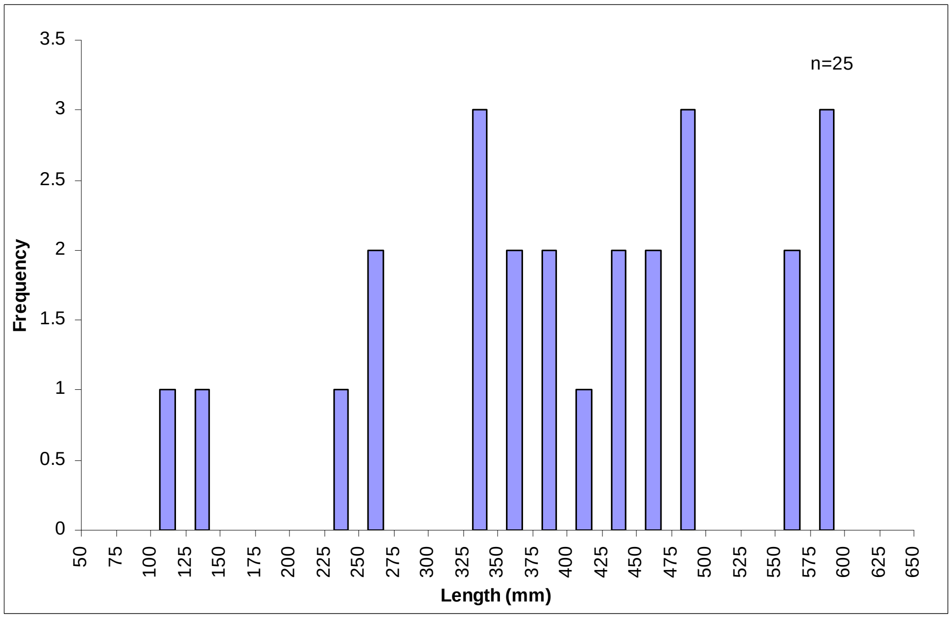
Mean length-at-age and weight-at-age for lake trout captured in Lake N16 in 1996, 1999, and 2004 are presented in Table 9.3-33. Lake trout ranged in age between 3 and 28 years old. Growth rates of lake trout in Lake N16 appear similar to Kennady Lake.

Figure 9.3-26 Length-frequency Distribution for Lake Trout Gillnetted in Lake N16, Summer 1996



n = number of fish; mm = millimetres.

Figure 9.3-27 Length-frequency Distribution for Lake Trout Gillnetted in Lake N16, Summer 1999



n = number of fish; mm = millimetres.

Table 9.3-33 Mean Length-at-Age and Weight-at-Age for Lake Trout in Lake N16, 1996, 1999, and 2004

Age	Length (mm)				Weight (g)			
	n	Mean	Min	Max	n	Mean	Min	Max
3+	1	172	-	-	1	48	-	-
4+								
5+								
6+								
7+								
8+								
9+	2	407	384	430	3	675	450	900
10+	2	414	343	485	2	1,098	945	1,250
11+	1	468	-	-	1	850	-	-
12+	4	518	506	544	6	1,221	1,025	1,575
13+	2	573	519	626	3	1,625	1,175	2,200
14+								
15+	1	542	-	-	3	1,423	1,160	1,700
16+	1	607	-	-	2	2,038	1,875	2,200
17+	4	550	510	582	5	1,848	1,550	2,390
18+	3	580	528	620	3	2,210	1,590	2,600
19+	1	558	-	-	2	1,920	915	2,925
20+	1	677	-	-	1	2,975	-	-
21+								
22+								
23+	1	754	-	-	1	4,500	-	-
24+	2	584	515	653	2	1,768	1,360	2,175
25+	3	604	561	649	3	2,230	1,750	2,650
26+								
27+	1	543	-	-	1	1,300	-	-
28+	1	658	-	-	2	2,468	2,025	2,910

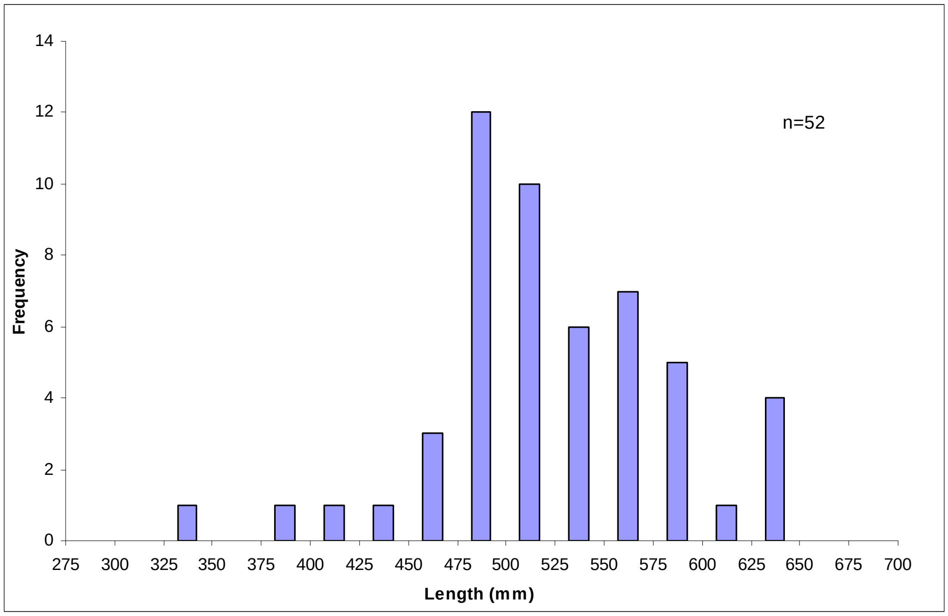
Note: 1996 (n=10); 1999 (n=5); 2004 (n=26). Differences in length and weight sample sizes (n) due to unrecorded lengths.

n = number of fish; mm = millimetre; g = grams; Min = minimum; Max = maximum; blank cells indicate that fish of the age indicated were not captured;-= not applicable.

Lake Trout in Lake 410

Lake trout captured in Lake 410 in 2005 ranged from 328 to 638 mm in length with a modal length class of 475 to 500 mm (Figure 9.3-28). The majority (92%) of lake trout captured in Lake 410 were greater than 450 mm in length. Length-at-age and weight-at-age for lake trout captured in Lake 410 in 2004 are provided in Table 9.3-34. Lake trout ranged in age between 5 and 16 years old. Growth rates in Lake 410 were similar to those in Kennady Lake and Lake N16.

Figure 9.3-28 Length-frequency Distribution for Lake Trout Gillnetted in Lake 410, Summer 2005



n = number of fish; mm = millimetre.

Table 9.3-34 Mean Length-at-Age and Weight-at-Age for Lake Trout Gillnetted in Lake 410, 2004

Age	Length (mm)				Weight (g)			
	n	Mean	Minimum	Maximum	n	Mean	Minimum	Maximum
5+	1	391	-	-	1	825	-	-
6+	1	386	-	-	1	600	-	-
7+	0				0			
8+	0				0			
9+	2	514	486	541	2	1,363	1,225	1,500
10+	4	438	399	455	4	1,063	775	1,200
11+	2	516	516	516	2	1,438	1,425	1,450
12+	2	508	505	510	2	1,663	1,600	1,725
13+	2	521	498	543	2	1,438	1,325	1,550
14+	2	560	531	589	2	1,988	1,775	2,200
15+	5	608	517	735	7	2,174	1,210	3,750
16+	3	580	543	605	3	1,933	1,425	2,275

n = number of fish; mm = millimetre; g = grams; blank cells indicate that fish of the age indicated were not captured;-= not applicable.

Kirk Lake

Kirk Lake is located approximately 25 km downstream of Kennady Lake and is the downstream-most reference lake for the Project. Kirk Lake has a surface area of 6,418 ha and a watershed area of 739 km^2. All water in the study area drains into the southern basin of Kirk Lake.

Gillnetting was conducted in Kirk Lake in summer 2005 to collect lake trout for analysis of muscle tissue burdens. The total catch of 95 fish included 51 lake whitefish (*Coregonus clupeaformis*), 37 lake trout, three northern pike, two round whitefish, and two cisco. Among all lakes sampled in the study area, lake whitefish were captured only in Kirk Lake. Species captured in Kirk Lake outlet stream included Arctic grayling, slimy sculpin, and ninespine stickleback, suggesting that these species are also likely present in the lake,

9.3.5.2.3 Littoral Fish Community

Minnow traps used to sample the littoral fish communities of Lake N16 in 1999 were ineffective in comparison to backpack shoreline electrofishing used in 2005 (Table 9.3-35). Lake chub was the most common species captured in Lake N16 in 2005, followed by slimy sculpin and ninespine stickleback. Juvenile burbot, juvenile northern pike, lake chub, and slimy sculpin were captured in nearshore areas of Lake 410. In general, densities of fish in Lake N16 and Lake 410 were low, similar to the low densities observed in Kennady Lake. Shoreline electrofishing of Lake 410 and Kirk Lake was conducted in 2007 to collect fish for metals analysis; one slimy sculpin and one northern pike were captured.

Table 9.3-35 Summary of Fish Captured, by Gear Type, in Littoral Areas of Lake N16, Lake 410, and Kirk Lake in 1999, 2005, and 2007

Lake	Year	Effort Type	Effort[a]	Catch					Total
				BURB	LKCH	NRPK	SLSC	NNST	
Lake N16	1999	minnow traps[b]	49.7	0	0	0	0	0	0
	2005	backpack electrofishing	400	0	10	0	3	1	14
Lake 410	2005	backpack electrofishing	800	2	3	3	3	0	11
	2007	backpack electrofishing	200	0	0	0	1	0	1
Kirk Lake	2007	backpack electrofishing	250	0	0	1	0	0	1

(a) Effort for minnow traps reported in trap-hours and effort for backpack electrofishing reported in metres of shoreline shocked.

(b) Includes only fish captured in traps and not fish observed along the shoreline.

BURB = burbot; LKCH = lake chub; NRPK = northern pike; SLSC = slimy sculpin; NNST = ninespine stickleback.

9.3.5.2.4 *Spring Spawning Runs*

A summary of the fish captured (by number, species and direction) in spring fish fences set in streams downstream of Kennady Lake and in the adjacent N watershed in 2000, 2004, and 2005 is presented in Tables 9.3-36, 9.3-37, and 9.3-38, respectively.

Arctic grayling were the most abundant fish captured in the two traps set downstream of Kennady Lake in spring 2000 (at sites K5 and L2). Most Arctic grayling captured at these two locations were ripe adults. Arctic grayling was also the most abundant species captured in the outlet of Lake N16 in spring 2000. Lake trout was the most abundant species captured moving upstream into stream N17 (tributary of Lake N16) in spring 2000. Lake trout are fall spawners and the upstream movement of these fish into Stream N17 in spring was most likely to feed on spawning Arctic grayling and/or their newly laid eggs. Longnose sucker were also captured in the inlet and outlet streams of Lake N16, presumably using these streams for spawning.

Table 9.3-36 Numbers of Fish Captured in Fish Fences Set Downstream of Kennady Lake and in Lake N16 inlet (N17) and Outlet (N16) Streams, Spring 2000

Species	Downstream of Kennady Lake		Lake N16 Streams	
	L2[b]	K5[b]	N17[a]	N16[b]
Arctic grayling	60	53	1	27
Burbot	1	0	0	0
Lake trout	1	12	20	12
Northern pike	1	0	0	0
Lake chub	0	1	0	5
Slimy sculpin	0	0	0	1
Longnose sucker	0	1	6	16
Total	**63**	**67**	**27**	**61**

[a] Set to capture fish moving upstream.
[b] Set to capture fish moving downstream.

Similar to 2000, most Arctic grayling were captured moving out of Kennady Lake to stream habitat downstream in the spring of 2004. A large number of Arctic grayling were also captured moving upstream into Stream L1a from Lake M4 (Table 9.3-37). Similar to the downstream migrants from Kennady Lake, most of these fish were spawning adults.

Table 9.3-37 Numbers of Fish Captured, by Species and Direction of Movement, in Fish Fences Set Downstream of Kennady Lake, Spring 2004

Species	Downstream of Kennady Lake				Total
	K5[a]		L1a [b]		
	U/S	D/S	U/S	D/S	
Arctic grayling	1	48	37	0	86
Lake trout	0	7	0	0	7
Northern pike	7	6	5	0	18
Round whitefish	0	1	0	0	1
Slimy sculpin	0	1	0	0	1
Grand Total	**8**	**63**	**42**	**0**	**113**

(a) Downstream count includes one Arctic grayling located in the wing of the fish fence.
(b) Upstream from Lake M4
U/S = Set to capture fish moving upstream; D/S = Set to capture fish moving downstream.

Small numbers of Arctic grayling were captured in fish fences and hoopnets set in Streams M1 and M4 downstream of Kennady Lake in the spring of 2005 (Table 9.3-38). In comparison, larger numbers of Arctic grayling were captured moving in streams N3 and N12 in the adjacent N watershed. Longnose sucker, another spring-spawning species, were also captured in Stream N3.

Table 9.3-38 Number of Fish Captured by Species and Direction of Movement in Fish Fences and Hoopnets Set in Streams Downstream of Kennady Lake and in the Adjacent N Watershed, Spring 2005

Species	Downstream of Kennady Lake				Adjacent N Watershed				Total
	M1		M4		N3		N12		
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	
Arctic grayling	5	3	2	2	1	25	16	1	**55**
Burbot	0	0	0	0	0	0	1	1	**2**
Lake chub	0	0	0	0	0	0	10	1	**11**
Lake trout	1	1	1	0	0	4	0	0	**7**
Longnose sucker	0	0	0	0	10	3	0	0	**13**
Northern pike	4	1	7	2	0	0	0	0	**14**
Round whitefish	1	0	0	0	0	0	0	0	**1**
Total	**11**	**5**	**10**	**4**	**11**	**32**	**27**	**3**	**103**

U/S = Set to capture fish moving upstream; D/S = Set to capture fish moving downstream;

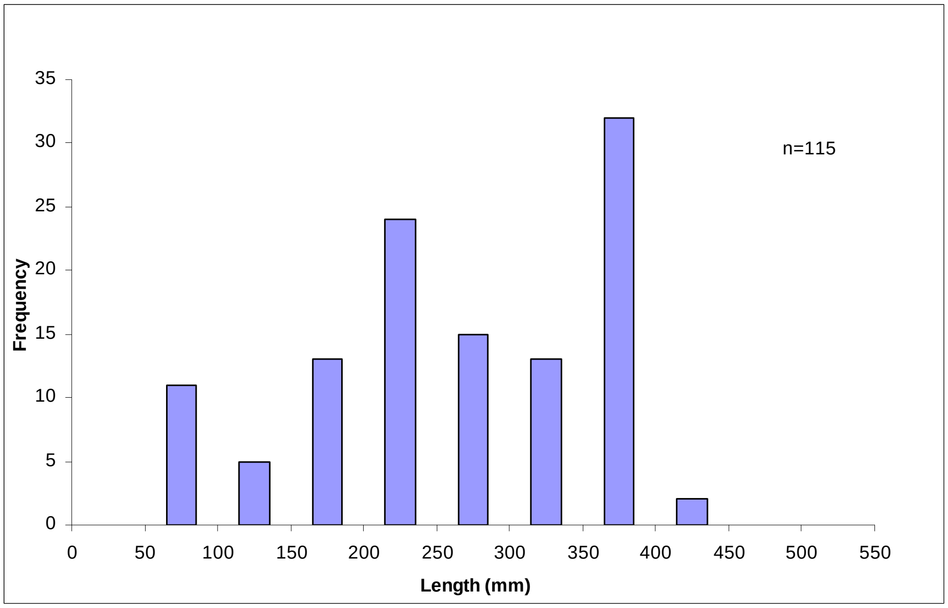
Arctic grayling in Kennady Lake and adjoining areas exhibit an adfluvial life history. Adults and juveniles reside in the lake for most of the year. In spring, adult Arctic grayling migrate into streams soon after ice break-up to spawn. Adults move back into the lake soon after spawning. Eggs hatch in June and young-of-the-year rear in natal streams for the summer, moving downstream (e.g., Lake N12) or upstream (e.g., Lake N3) to overwintering habitat in lakes by late August.

The notable downstream migration of mature Arctic grayling from Kennady Lake in both 2000 and 2004 suggests strongly that the streams immediately downstream of Kennady Lake provide important spawning habitat for Arctic grayling in Kennady Lake. Streams K5, L3, L2, and L1a have high quality spawning habitat for Arctic grayling due to the presence of gravel riffles in spring. Like most streams in the LSA, substrates within these streams are primarily angular boulders but gravel and smaller cobble substrates do exist in small patches. These are also the streams where the largest numbers of young-of-the-year Arctic grayling have been found in summer.

Stream habitat between Kennady Lake and Lake M4 also appears to be important spawning habitat for the Arctic grayling in Lake M4, as large numbers of mature Arctic grayling were captured moving upstream from Lake M4 (at Stream L1a) in spring 2004. The low numbers of Arctic grayling captured moving upstream in streams M1 and M4 in spring 2005 suggest that the habitat between Kennady Lake and Lake M4 is used primarily by local Arctic grayling populations, and not by Arctic grayling from farther downstream.

Arctic grayling moving into tributaries of Kennady Lake and downstream of Kennady Lake in spring 2004 ranged in length between 86 and 410 mm, but most (75%) were greater than 200 mm (Figure 9.3-29). The mean length of Arctic grayling was 266 mm, the mean weight was 324 grams (g), and the mean condition factor was 1.14. Although aging data are limited, most Arctic grayling greater than 200 mm are three years of age or older and most Arctic grayling greater than 350 mm are six years old or older (Table 9.3-39). Based on the length frequency distribution, this suggests that Arctic grayling in Kennady Lake begin spawning at three or four years of age, but the majority of spawning fish are likely six years or older. Similar age structure of spawning Arctic grayling occurs in Great Slave Lake (Scott and Crossman 1973). Arctic grayling in Chena River in Alaska reach first maturity at five years of age (Clark 1992).

Figure 9.3-29 Length-frequency Distribution for Arctic Grayling Captured Moving into Kennady Lake Tributaries and Downstream of Kennady Lake in Spring 2004



Note: Data include 31 fish captured in tributaries of sub-watersheds A, B, and D of Kennady Lake, 45 fish from Stream K5, and 39 fish from Stream L1a

n = number; mm = millimetre.

Table 9.3-39 Length-at-Age and Weight-at-Age for Arctic Grayling Captured Downstream of Kennady Lake (Streams L1a and K5) in Spring 2004

Age	Fork Length (mm)			Weight (g)		
	N	Mean	Range	N	Mean	Range
3+	5	207.4	197-221	5	116.0	90-200
4+	4	253.5	250-258	4	191.3	175-200
5+	2	211.5	201-222	1	126.6	-
6+	4	376.3	362-391	4	592.5	500-700
7+	1	253.0	-	1	172.5	-
8+	1	393.0	-	1	880.0	-

N =number/count; mm = millimetre; g = gram;-= not applicable.

9.3.5.2.5 Small Lakes Surveys

A summary of fish species captured in all lakes sampled downstream of Kennady Lake and in the adjacent N watershed is provided in Table 9.3-40.

Table 9.3-40 Summary of Fish Species Captured in Small Lakes Downstream of Kennady Lake and in the Adjacent N Watershed, 1996 to 2010

Lake	Fish Species Captured
Downstream of Kennady Lake	
L1a	ARGR, SLSC
L1b	NRPK
L2	ARGR, NRPK
L3	NRPK
L13	-
L14	-
L15	-
L18	ARGR, BURB, LKTR,
L19	-
L20	-
L21	ARGR
M1	BURB, NRPK, RNWH
M2	CISC, LKTR, NRPK, SLSC
M3	BURB, LKTR, NRPK, RNWH
M4	ARGR, CISC, LKCH, LKTR, NNST, RNWH, SLSC
Lakes in the Adjacent N Watershed	
N2	ARGR, LKCH, LKTR, NNST RNWH, SLSC,
N3	ARGR, BURB, LKCH, RNWH
N4	ARGR, LKCH
N5	ARGR, LKCH, LKTR, NNST, RNWH, SLSC
N6	ARGR, BURB, LKTR, NNST, RNWH
N7	-
N12	ARGR, LKTR, LNSC
N13	-
N14	ARGR, LKCH, LKTR, LNSC, NNST, SLSC
N14a	LKCH, LNSC, SLSC
N14b	-
N17	BURB, LKCH, LKTR, SLSC
N18	ARGR, LKTR

ARGR = Arctic grayling; BURB = burbot; LKCH = lake chub; CISC = cisco; LKTR = lake trout;
LNSC = longnose sucker; NNST = ninespine stickleback; RNWH = round whitefish;
NRPK = northern pike; SLSC = slimy sculpin;-= no fish captured.

Lake trout, cisco, round whitefish, and Arctic grayling were common large-bodied fish species captured in gillnets set in small lakes between Kennady Lake and Lake 410 (Table 9.3-41). The first three species were captured primarily in the M watershed lakes, whereas Arctic grayling were captured mainly in the L watershed lakes, The largest catches of Arctic grayling were recorded in Lake L21, located in the upper part of the L watershed, indicating that Lake L21 is connected to lakes downstream of Kennady Lake in spring in some or all years. Cisco were captured only in Lake M2 and Lake M4. Other species captured infrequently in gill nets set in small lakes downstream of Kennady Lake included northern pike and lake chub.

Juvenile stages of Arctic grayling, northern pike, and burbot were the most abundant fish species captured in shoreline areas of lakes downstream of Kennady Lake (Table 9.3-41). Juvenile northern pike were typically captured in areas where emergent sedges were present. Juvenile burbot were captured along the shorelines of lakes L18, M1, and M3. Other species captured in shoreline areas were slimy sculpin and ninespine stickleback.

Arctic grayling were the most common large-bodied species captured in small lakes of the N watershed, primarily in lakes N14 and N18 (Table 9.3-41). Longnose sucker were present in lakes N12, N14 and N14a. The presence of longnose sucker in these lakes, in addition to the documented longnose sucker spawning runs in the outlet and inlet streams of Lake N16 in 2000 and in stream N3 in 2005, suggests that longnose sucker are found throughout the N watershed. As mentioned previously, Kennady Lake and the lakes in the L and M basins downstream of Kennady Lake do not appear to support populations of longnose sucker; however, one longnose sucker was captured moving downstream in the fish fence located at the outlet of Kennady Lake in 2000.

Lake chub were the most abundant and widely found small-bodied fish species in lakes of the N watershed. Juvenile burbot were found along the shoreline of lakes N3, N6, and N17, whereas juvenile Arctic grayling were captured in lakes N3 and N14. Other species captured infrequently along the shoreline areas of small lakes in the N watershed were slimy sculpin, longnose sucker, and ninespine stickleback.

Fish were not captured in Lake N13. Lake N13 is a small lake perched on the watershed divide with no outlet channel and fish from Lake N12 cannot access Lake N13 even during freshet flows.

Table 9.3-41 Number of Fish Captured, by Gear Type, in Small Lakes Downstream of Kennady Lake and in the Adjacent N Watershed, 1996 to 2010

Lake	Gillnetting							Shoreline Electrofishing and Minnow Trapping							Total
	ARGR	CISC	LKCH	LKTR	LNSC	NRPK	RNWH	ARGR	BURB	LKCH	LNSC	NNST	NRPK	SLSC	
Downstream of Kennady Lake															
L1a	0	0	0	0	0	0	0	7	0	0	0	0	0	1	**8**
L1b	0	0	0	0	0	0	0	0	0	0	0	0	3	0	**3**
L2	1	0	0	0	0	2	0	0	0	0	0	0	1	0	**4**
L3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	**1**
L4	-	-	-	-	-	-	-	0	0	0	0	0	0	0	**0**
L13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
L14	-	-	-	-	-	-	-	0	0	0	0	0	0	0	**0**
L15	-	-	-	-	-	-	-	0	0	0	0	0	0	0	**0**
L18	3	0	0	1	0	0	0	0	1	0	0	0	0	0	**5**
L19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
L20	-	-	-	-	-	-	-	0	0	0	0	0	0	0	**0**
L21	19	0	0	0	0	0	0	0	0	0	0	0	0	0	**19**
M1	0	0	0	0	0	0	6	0	1	0	0	0	1	0	**8**
M2	0	2	0	1	0	0	0	0	0	0	0	0	3	3	**9**
M3	0	0	0	4	0	0	1	0	1	0	0	0	1	0	**7**
M4	2	75	2	41	0	0	12	0	0	0	0	1	0	1	**134**
Lakes in the Adjacent N Watershed															
N2	3	0	0	6	0	0	13	0	0	8	0	1	0	1	**32**
N3	3	0	0	0	0	0	4	2	1	9	0	0	0	0	**19**
N4	1	0	0	0	0	0	0	0	0	29	0	0	0	0	**30**
N5	1	0	0	2	0	0	1	0	0	6	0	1	0	2	**13**
N6	5	0	0	8	0	0	8	0	2	0	0	2	0	0	**25**
N7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
N12	4	0	0	5	4	0	0	-	-	-	-	-	-	-	**13**
N13	0	0	0	0	0	0	0	-	-	-	-	-	-	-	**0**
N14	17	0	0	2	3	0	0	1	0	3	2	1	0	1	**30**
N14a	0	0	0	0	5	0	0	0	0	67	0	0	0	2	**74**
N14b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
N17	0	0	2	0	0	0	0	0	1	4	0	0	0	2	**9**
N18	14	3	0	0	0	0	0	-	-	-	-	-	-	-	**17**

ARGR = Arctic grayling; LKTR = lake trout; CISC = cisco; RNWH = round whitefish; LNSC = longnose sucker; BURB = burbot; NRPK = northern pike; LKCH = lake chub; SLSC = slimy sculpin; NNST = ninespine stickleback;-= not sampled.

9.3.5.2.6 Stream Sampling

An overall summary of fish species captured in streams sampled downstream of Kennady Lake and in the adjacent N watershed is presented in Table 9.3-42.

Table 9.3-42 Fish Species Captured in Streams Downstream of Kennady Lake and in the Adjacent N Watershed, 1996 to 2010

Stream	Fish Species Captured
Downstream of Kennady Lake	
K5	ARGR, BURB, LKCH, LKTR, LNSC, NRPK, RNWH, SLSC
L1a	ARGR, BURB, LKCH, NRPK, SLSC
L1b	ARGR, BURB, SLSC
L1c	SLSC
L2	ARGR, BURB, LKTR, NNST, NRPK, SLSC
L3	ARGR, BURB, NRPK
L11	-
L13	BURB
L14	RNWH
L15	RNWH
L18	RNWH, SLSC
M1	ARGR, BURB, LKCH, LKTR, NRPK, RNWH, SLSC
M2	BURB, LKCH, NNST, NRPK, SLSC
M3	ARGR, BURB, NRPK, SLSC
M4	ARGR, BURB, LKTR, NRPK, SLSC
P4	ARGR, BURB
410	BURB, LKCH, SLSC
Kirk	ARGR, NNST, SLSC
Adjacent 'N' Watershed	
N1	BURB, LKCH, SLSC
N2	ARGR, BURB, LKCH, LNSC, NNST, SLSC
N3	ARGR, BURB, LKCH, LKTR, LNSC, SLSC
N4	ARGR, BURB, LKCH, NNST, SLSC
N5	ARGR, BURB, LKCH, NNST, SLSC
N6	ARGR, BURB, LKCH, NNST, SLSC
N9	BURB, LKCH, SLSC
N11	BURB, LKCH, NNST, SLSC
N12	ARGR, BURB, LKCH, NNST, SLSC
N14	ARGR
N14a	SLSC
N16	ARGR, BURB, LKCH, LKTR, LNSC, SLSC
N17	ARGR, BURB, LKCH, LKTR, LNSC, NNST, SLSC
N18	ARGR, BURB, LKCH, LKTR, SLSC

ARGR = Arctic grayling; LKTR = lake trout; NRPK = northern pike; BURB = burbot; SLSC = slimy sculpin; LKCH = lake chub; NNST = ninespine stickleback; LNSC = longnose sucker; RNWH = round whitefish.

In summer sampling, Arctic grayling were typically the most abundant fish found in streams downstream of Kennady Lake and in the N watershed, often comprising over 80% of the total catch. Juvenile burbot, slimy sculpin, lake chub, and ninespine stickleback were also found in streams of both watersheds in summer, but in substantially lower numbers. In contrast, juvenile northern pike were common in streams downstream of Kennady Lake, but were not captured in the N watershed. Other species captured infrequently in summer sampling included lake trout in Stream N18, longnose sucker in Streams N2 and N17, and round whitefish in Streams L14, L15, and L18.

In fall sampling, the majority of fish captured in the 29 streams surveyed were slimy sculpin, comprising 77% of the total catch of 305 fish. Other commonly caught fish included Arctic grayling, burbot, lake chub and ninespine stickleback. Northern pike, lake trout, and longnose sucker were not captured or observed in the streams during fall sampling period.

Young-of-the-Year Arctic Grayling Stream Utilization

Young-of-the-year Arctic grayling were captured in streams immediately downstream of Kennady Lake in summer, i.e., between Kennady Lake and Lake 410. Much lower densities were observed farther downstream in streams M1, M2, M3, and M4. While some of the difference in densities between streams may be due to lower catch efficiencies in the larger, deeper streams of the M watershed, these data, and the paucity of adult Arctic grayling in fish fences in streams M1 and M4 in spring of 2005, suggest that more Arctic grayling spawning occurs in streams upstream of Lake M4 (i.e., streams K5, L3, L2, L1b, L1a) than in streams downstream of Lake M4 (i.e., streams M4, M3, M2, and M1). Sampling results indicate that each of the streams between Kennady Lake and Lake M4 provide spawning and rearing habitat for Arctic grayling in most years.

On average, highest number of young-of-year Arctic grayling were captured in the summer 2005 in the streams between lakes N6 and N1 immediately north of Kennady Lake compared to any other area within the LSA. Juvenile Arctic grayling were captured in several streams throughout both the N watershed and downstream of Kennady Lake.

In fall 2005 and 2007, the majority of Arctic grayling captured were juveniles and very few young-of-the-year Arctic grayling were captured. This indicated that young-of-the-year Arctic grayling moved out of natal streams by the end of August. This is similar timing to that observed in streams near the Ekati Diamond Mine (Jones et al. 2003a).

9.3.5.2.7 Fish Movements

Arctic Grayling

In the radio telemetry study, only one previously tagged Arctic grayling was recaptured in a different location from where it was tagged. This fish was originally tagged in stream L1a in spring 2004, which was recaptured in stream M1. In the one year since its original capture, this fish moved downstream through all four lakes of the M watershed. All other marked fish released in Kennady Lake were recaptured in Kennady Lake and none were found downstream of Area 8.

With the exception of one fish that died in Lake L2, all five Arctic grayling tagged moving downstream out of Kennady Lake returned to Kennady Lake between June 24 (immediately following fish fence removal) and July 2. One of the two Arctic grayling radio-tagged in stream L1a in 2004 moved as far upstream as stream L3. The second tagged Arctic grayling remained in stream L1a. Both fish returned downstream after fish fences were removed in spring; one moved as far downstream as Lake 410 (9.5 km downstream). This migration suggests that at least some proportion of the Arctic grayling population in Lake M4 move upstream to use spawning habitat in stream L3.

Although some populations of Arctic grayling are known to make extensive migration (up to 320 km) from overwintering areas to spawning grounds (Evans et al., 2002), Arctic grayling in Kennady Lake and in lakes downstream rarely move more than 2 km to spawning habitat in spring.

Lake Trout

Evidence from radio telemetry supports the mark/recapture and spring fish fence data that suggest lake trout undertake directed spring migrations to feed on accumulations of spawning Arctic grayling at the Kennady Lake outlet. In spring 2005, 8 of 24 radio-tagged lake trout at large had moved into Area 8 near the outlet of Kennady Lake or into the series of small lakes and streams farther downstream. These fish likely moved back into Kennady Lake after the peak of Arctic grayling spawning. Tracking conducted in 2004 showed that three of the four lake trout tagged at the Kennady Lake outlet moved back upstream into Kennady Lake soon after fish fences were removed in spring.

9.3.5.2.8 Fish Tissue Burdens

The metal concentrations in the muscle tissue of lake trout from Kirk Lake and Lake 410 are summarized in Table 9.3-43. Concentrations of aluminum, antimony, arsenic, barium, beryllium, cadmium, cobalt, lead, molybdenum, silver, thallium, and tin were below analytical detection limits in 75% or more of the fish that were analyzed and are not presented here for this reason. Mean and maximum chromium and mercury concentrations in lake trout muscle tissue from both lakes and mean and maximum vanadium concentrations in fish from Lake 410 exceeded the risk-based screening criteria for human consumption (Table 9.3-43).

Chromium was detected in almost all lake trout muscle samples from Kirk Lake and Lake 410. Chromium concentrations reported above the detection limits ranged from 0.05 to 0.21 mg/kg wet weight (ww) and were generally higher than the risk-based criterion of 0.063 mg/kg ww.

Total mercury was detected in all of the lake trout muscle samples from both lakes. Concentrations ranged from 0.13 to 1.2 mg/kg ww, which were all higher than the risk-based criterion of 0.028 mg/kg ww for methyl mercury. No analysis of methyl mercury was undertaken, but it is generally accepted that total mercury levels in fish muscle are reliable indicators of methyl mercury, as methyl mercury can contribute to at least 90% of the total methyl mercury concentration values in fish tissue (Rai et al. 2002; Lasorsa and Allen-Gil 1995). Methyl mercury is the form of mercury that poses a public health risk in fish and shellfish tissue due to its tendency to bioaccumulate (US EPA 1997). The detected concentrations of total mercury in muscle tissue of lake trout show that baseline concentrations currently exceed the risk-based criterion for human consumption. It should be noted, however, that lake trout, which are a long-lived top predator in the lakes, typically bio-accumulate mercury concentrations to similar or higher levels in most northern systems where they occur.

Vanadium was also detected in most lake trout muscle samples from Kirk Lake and all samples from Lake 410. Vanadium concentrations reported above the detection limit of 0.006 mg/kg ww ranged from 0.011 to 0.016 mg/kg ww in lake trout muscle from Kirk Lake. Concentrations were somewhat higher in Lake 410 fish, ranging from 0.008 to 0.037 mg/kg ww. About half of the muscle tissues from Lake 410 had vanadium concentrations that were higher than the risk-based criteria of 0.019 mg/kg ww.

Table 9.3-43 Overall Mean and Maximum Metal Concentrations (mg/kg wet weight) in Lake Trout Muscle Tissue Samples Collected from Kirk Lake and Lake 410 between 2004 and 2007

Parameter	Kirk Lake		Lake 410		Risk-based criteria(c)
	Mean(a)	Maximum(b)	Mean(a)	Maximum(b)	
Chromium	**0.072**	**0.11**	**0.13**	**0.21**	0.063(d)
Copper	0.67	1.9	0.50	1.7	11
Iron	7.5	23	2.7	4.0	190
Manganese	0.060	0.17	0.074	0.12	38
Mercury	**0.60**	**1.2**	**0.30**	**0.77**	0.028(e)
Nickel	0.059	0.18	0.12	0.49	5.4
Selenium	0.26	0.39	0.24	0.34	1.4
Strontium	0.39	1.3	0.21	0.93	162
Titanium	0.26	1.1	0.36	1.2	nc
Vanadium	0.0087	0.016	**0.022**	**0.037**	0.019
Zinc	3.9	7.9	3.1	4.3	82

Note: Shaded values equal or exceed the US EPA risk-based criteria.
Metal concentrations are presented as mg/kg wet weight.
(a) Detection limits were used to calculate mean metal concentrations for individuals with metal concentrations below detection limit.
(b) When indicated by a less than sign (<), the maximum concentration was reported at below the sample-specific detection limit.
(c) Risk-based criteria for fish consumption were based on a 70 kg individual consuming 54 g of fish per day over a 70-year period (US EPA 2010). The US EPA screening values were adjusted to a carcinogenic risk of 1E-5 and a hazard quotient of 0.2 for non-carcinogens (carcinogens were multiplied by 10 and non-carcinogens were multiplied by 0.2). When criteria were available for both carcinogenic and non-carcinogenic exposure scenarios, the lowest value was used.
(d) Criterion is for hexavalent chromium.
(e) Criterion is for methyl mercury.
US EPA = United States Environmental Protection Agency; nc = no criterion; mg/kg = milligram per kilogram.

9.3.5.2.9 Comparison to Other Large Lakes

Lake N16

Lake N16 is a headwater lake of the Lockhart River located approximately 4 km northwest of Kennady Lake in the N watershed. Lake N16 drains to Lake 410 via Lakes N15, N11, and N1.

Lake N16 has shoreline habitat that is similar to Kennady Lake. Boulder/cobble substrates dominate most shoreline areas and clean substrates are generally found down to the 4 m depth contour.

Similar to Kennady Lake, Lake N16 is almost entirely mixed in summer. During the winter, dissolved oxygen concentrations below 8 m approach 0 mg/L.

Similar to Kennady Lake, round whitefish are the most abundant species in Lake N16, lake trout are the most abundant predator and lake chub are the most abundant forage fish. Northern pike and Arctic grayling have not been captured in Lake N16, although Arctic grayling were recorded in the inlet and outlet streams.

Cisco are also present in Lake N16 but not in Kennady Lake. Kennady Lake appears to provide suitable habitat for cisco (e.g., protected rocky bays for rearing areas, and substrates ranging from sand to boulders in 1 m to 5 m of water for spawning) so their absence is likely due to some other habitat (e.g., lake size and/or depth, absence of shoals) or ecological constraint (e.g., competition or predation from other species). Lake N16 is also known to support populations of longnose sucker and possibly white sucker. While only small numbers of longnose sucker have been captured in summer, spawning migrations of this species have been recorded moving into Lake N16 outlet and inlet streams in spring. Neither sucker species is found in Kennady Lake, nor in the watersheds L and M farther downstream, although one longnose sucker was reported moving downstream in a fish fence in the outlet of Kennady Lake in spring 2000, suggesting that a small, yet unrecorded, population of longnose sucker may be present in the Kennady Lake.

Lake 410

Lake 410 is approximately 10 km downstream of Kennady Lake. Lake 410 has two major inflows and receives approximately 20% of its water from the Kennady Lake watershed and 80% of its water from the larger N watershed. Lake 410 has a surface area of 579 ha and is comprised of two main basins. The larger northern basin is separated from the southern basin by a narrow channel. This channel is the deepest part of the lake, with a maximum depth of approximately 9 m. In comparison to Kennady Lake and Lake N16, Lake 410 is shallow with a mean depth of approximately 4 m. Nearshore areas of Lake 410 are dominated by boulder/cobble substrates. Sheltered bays with silt and fine organic substrates are common although aquatic vegetation in these bays remains sparse.

Fish species composition in Lake 410 is dominated by round whitefish, lake trout, and cisco. Northern pike, burbot, lake chub, slimy sculpin, and ninespine stickleback also are present in Lake 410. Arctic grayling and sucker species were not captured in Lake 410. As reported for Kennady Lake and Lake N16, the total catch-per-unit-effort in littoral areas of Lake 410 was low.

Kirk Lake

Kirk Lake is located approximately 25 km downstream of Kennady Lake and is the most downstream reference lake for the Project. Kirk Lake has a surface area of 6,418 ha and a watershed area of 739 km^2. All water in the LSA drains into the southern basin of Kirk Lake.

Limnology, water, sediment, plankton, and benthic invertebrate sampling was conducted only in the southern basin of Kirk Lake, which may not be representative of the entire lake. The rationale for sampling only in the southern basin, was to collect baseline information from lower trophic communities in the area where the potential effects on changes in water quality due to the Project would be most likely to occur. The southern basin of Kirk Lake has a relatively consistent depth (3.5 m), with a sand/silt substrate lakebed composition. Shoreline habitat is predominantly boulder/cobble substrates, but sandy beaches exist.

Gillnetting was conducted in Kirk Lake in summer 2005 to collect lake trout for analysis of muscle tissue burdens. The catch was dominated by lake whitefish and lake trout, with smaller numbers of northern pike, round whitefish, and cisco also captured. Species captured in Kirk Lake outlet stream included Arctic grayling, slimy sculpin, and ninespine stickleback, suggesting that these species are also likely present in the lake, Lake whitefish are not present in Kennady Lake, Lake N16, or Lake 410.

Lockhart River Watershed

In the Lockhart River watershed, 14 fish species are known to be present (Table 9.3-44). In addition to the eight species that have been recorded in Kennady Lake (round whitefish, lake trout, northern pike, Arctic grayling, lake chub, burbot, slimy sculpin, ninespine stickleback), these species include cisco, lake whitefish, longnose sucker, white sucker, Arctic lamprey, and least cisco (Annex J). Lake trout, Arctic grayling, and round whitefish are the most widely distributed species in the watershed.

None of these fish species are identified as extirpated, endangered, threatened or special concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), or federally listed as a species-at-risk under the federal *Species at Risk Act* (SARA). Arctic grayling are listed as “sensitive” in the Northwest Territories (NWT) due to the increasing pressures of resource development and climate change (GNWT 2006). All other species are considered to be secure at the regional level.

Table 9.3-44 Known Fish Presence in the Lockhart River Watershed

Species	Artillery Lake	Aylmer Lake	Clinton-Colden Lake	Courageous Lake	Jolly Lake	Lac Capot Blanc	Lockhart River	MacKay Lake	Snap Lake
Arctic lamprey	X						X		
Burbot				X		X	X		X
Arctic grayling		X	X	X	X		X	X	X
Lake chub									X
Cisco			X				X		
Lake trout	X	X	X	X	X	X	X	X	X
Lake whitefish					X		X	X	
Least cisco				X					
Longnose sucker				X	X	X	X		X
Ninespine stickleback				X			X		
Northern pike							X		
Round whitefish			X	X		X	X		X
Slimy sculpin							X		X
White sucker							X		

Note: X = species is present; blank cell = species is absent.

9.4 WATER MANAGEMENT PLAN SUMMARY

9.4.1 Introduction

The following section provides a summary of the Water Management Plan that has been developed for the Gahcho Kué Project (Project). This plan was designed to minimize the impact of the Project on the aquatic ecosystem of Kennady Lake and downstream environments. The Water Management Plan summary presented herein focuses on elements that affect downstream waterbodies. The main elements include:

- Project activities during construction, operations, and closure that will affect downstream waterbodies;
- Project infrastructure that may lead to water quality effects in downstream waterbodies; and
- a summary of the water balance for Kennady Lake for the operations and closure phases of the Project as it relates to the downstream environment.

9.4.2 Overview

The Project will be located at Kennady Lake, a small headwater lake of the Lockhart River watershed in the Northwest Territories (NWT).

The most significant water-related activities that will take place during the operation of the Project will be the dewatering of Areas 2 through 7 of Kennady Lake and Lake A1, and the subsequent re-filling of the lake. These activities will have a substantial bearing on the downstream waterbodies.

The dewatering process will begin during the first year of construction (Year -2) and will take place during the open water season. To facilitate the dewatering process, natural drainage from the upper portion of the watershed will be diverted to the adjacent N watershed by the establishment of several earth-filled dykes. Area 8 will be separated from the rest of Kennady Lake by the construction of a water-retaining dyke (Dyke A). The construction phase of the Water Management Plan is described in Section 9.4.3.

During operations, water will continue to be pumped on an as-needed basis from Areas 3 and 5 of Kennady Lake (the Water Management Pond [WMP]) to Lake N11. The operations phase of the Water Management Plan is described in Section 9.4.4.

At closure, the temporary diversion dykes will be removed from the D and E watersheds and breached in the B watershed to allow watershed flows to return to Kennady Lake. Augmented flows from Lake N11 will be pumped to Area 3 to supplement the re-filling of Kennady Lake. The closure phase of the Water Management Plan as it pertains to the downstream environment is discussed in Section 9.4.5.

Infrastructure relevant to downstream water management during these stages of the Project will include:

- a direct pipeline between Area 3 and Lake N11 for direct discharge during dewatering and during refilling, and between Area 7 and Area 8 for direct discharge during dewatering; and
- dykes to temporarily divert water from the upper B, D and E watersheds of Kennady Lake to the adjacent N lakes watershed; and
- a permanent dyke between the Fine Processed Kimberlite Containment (PKC) Facility and Lake A3 to permanently divert water to the adjacent N watershed.

The Water Management Plan is discussed in terms of the following time periods:

- Construction phase (initial dewatering) – Years -2 to -1. Kennady Lake is drawn down to increase available capacity and facilitate dyke construction; water is discharged to Lake N11 and Area 8.
- Operational phase – Years 1 to 11. Water is diverted from mine pits and lake areas to the WMP (Areas 3 and 5); water is discharged from the WMP to Lake N11.
- Closure phase – Years 12 to 20. Water is transferred from the WMP to Tuzo Pit and Kennady Lake is refilled from natural drainage and water pumped from Lake N11.
- Post-closure (i.e., beyond closure) – Year 21 onwards. Kennady Lake receives only natural drainage and releases water to Area 8.

A summary of the annual inflows to and outflows from the water management system during the construction, operations, and closure phases of the Project is presented in Section 9.4.6. Additional flows from the water management system into and out of the downstream environment are listed in Table 9.4-1.

Table 9.4-1 Summary of Gains and Losses in Flows to Downstream Watersheds due to Project Activities

Gains in Flows to the Downstream Waterbodies	Losses in Flows to Downstream Waterbodies
Water pumped to Area 8 and Lake N11 during the dewatering of Kennady Lake	water pumped from Lake N11 during the refilling of Kennady Lake
Diverted flows from upper portions of B, D, and E watersheds located on the west side of Kennady Lake during construction and operations	reduction of flows through the Area 8 outlet during operations and closure (i.e., the refilling of Kennady Lake)
Diverted flows from a portion of upper Kennady Lake watershed A during construction, operations, closure, and post-closure	

9.4.3 Construction

During construction, the key water management activities related to downstream waters will be the diversion of upper Kennady Lake watersheds (i.e., watersheds A, B, D, and E) to the adjacent N watershed, the construction of a dyke (Dyke A) that separates the most downstream basin of Kennady Lake (Area 8) from Area 7, and the commencement of dewatering of Kennady Lake.

9.4.3.1 Diversion of A, B, D, and E Watersheds

To supplement the dewatering process, natural drainage from the upper (i.e., upstream) portions of the Kennady Lake watershed will be diverted to an adjacent watershed by the establishment of several earth-filled dykes. Area 8 will be separated from the rest of Kennady Lake by the construction of a water retaining dyke (Dyke A). The close-circuiting of Kennady Lake (Areas 2 to 7) will reduce natural inflows to Area 8; only the H, I, J, and Ke watersheds will continue to flow into Area 8 during operations and closure.

To facilitate the dewatering of Kennady Lake and reduce surface inflows to Kennady Lake, a portion of the upper Kennady Lake watershed will be isolated (A watershed) or diverted (B, D, and E watersheds), so that the runoff from these upper watersheds is directed away from Kennady Lake. The diversion of watersheds B, D, and E will rely on temporary, earth-filled dykes that will be placed across the outlets of the B, D and E watersheds. Water levels in Lakes D2, D3, and E1 will be raised to facilitate flow to Lake N14. The surface water diversions from Kennady Lake are illustrated in Figure 9.4-1.

The establishment of the Fine PKC Facility in the A watershed will result in the isolation of Lake A3 from Lakes A1 and A2 through the construction of a permanent saddle dam (Dyke C) between Area 1 and Lake A3 to the north (Figure 9.4-1). Dyke C will raise the level of Lake A3 to a point where the Lake A3 outlet will be permanently diverted into Lake N9.

The diversion system will rely on natural flow paths and constructed ditches (as required), and saddle dams that will be constructed across the outlet of Lake A3 and the outlets of the B, D, and E watersheds. Runoff from Lakes B1, D2, D3, and E1 will be diverted to lakes in the N watershed, which will supplement the water yield of the N watershed. Figure 9.4-1 shows the re-aligned Kennady Lake watershed after the diversion of the A, B, D, and E watersheds.

9.4.3.2 Construction of Dyke A

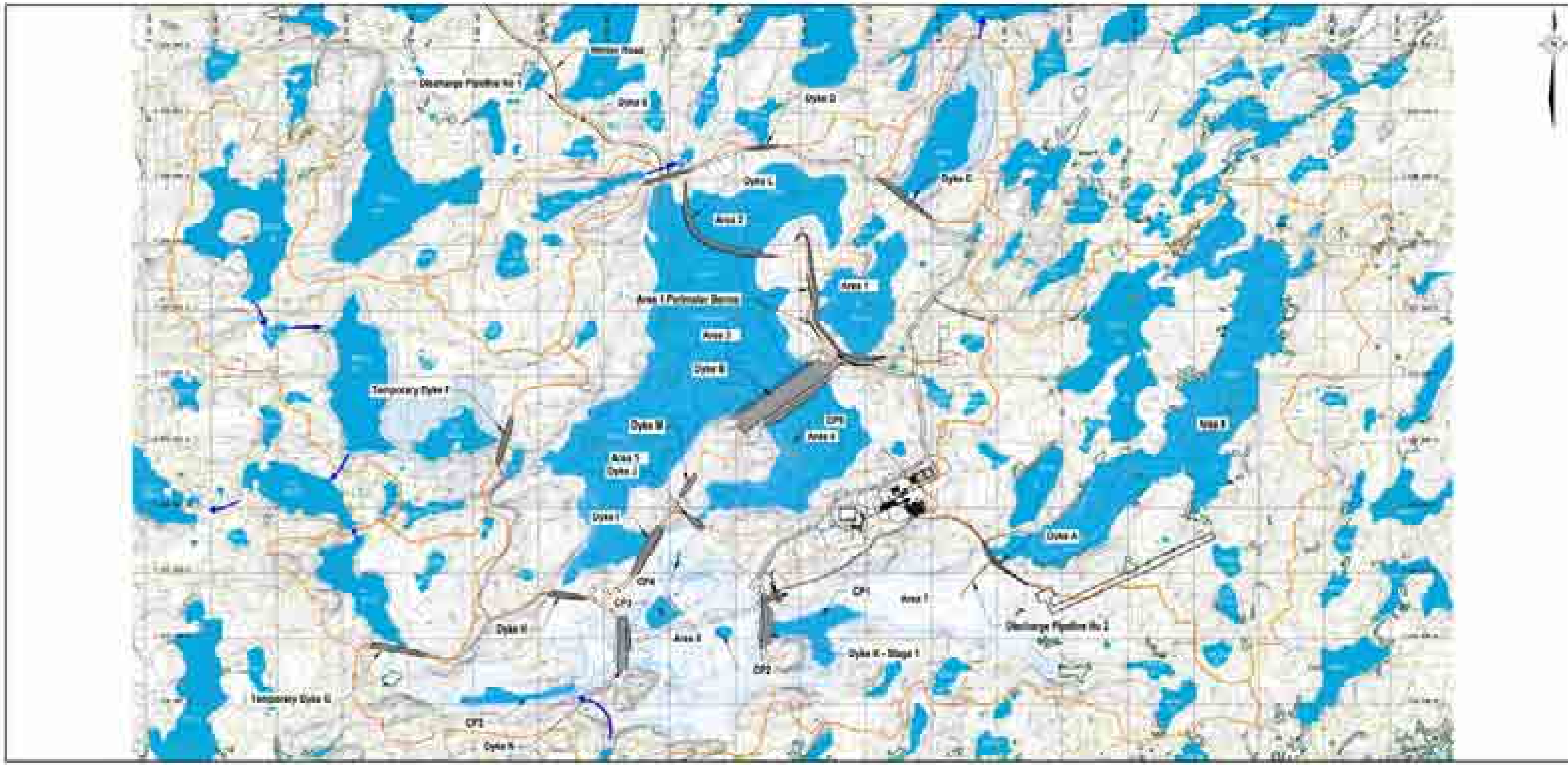
A key activity during the first summer of construction will be the construction of Dyke A at the narrows separating Areas 7 and 8. The dyke will be constructed in two stages. First, a temporary structure will be placed in the narrows between Areas 7 and 8. The dewatering process will then commence and continue until the water depth is approximately 2 metres (m), at which time a permanent structure will be constructed to separate Area 8 from the rest of Kennady Lake (i.e., Areas 2 through 7).

9.4.3.3 Dewatering of Kennady Lake

Dewatering of Kennady Lake is expected to begin in construction and will continue throughout the operations period. Dewatering will entail pumping water from Kennady Lake to provide access to the open pits. The water will be pumped to Lake N11, which is located approximately 2 kilometres (km) northwest of Kennady Lake, and to Area 8. To retain water in the appropriate Kennady Lake areas and to manage potentially large recharge volumes, several dykes will be constructed.

The object of the dewatering program is to initially drain Areas 6 and 7 of Kennady Lake, to later drain Areas 2 and 4, and to decrease the amount of water in Areas 3 and 5 to approximately 800,000 cubic metres (m^3). The water level of Kennady Lake must be lowered during the open water season, because lake waters can only be pumped out when the surface of the lake receiving the water is not frozen. The dewatering of Areas 3 and 5 will begin at the start of construction to allow the complete draining of Areas 6 and 7 into Areas 3 and 5, allowing early access to the lake bed and underlying kimberlite pipes.

The initial draw down of Kennady Lake will be achieved via direct pumped discharge. It is expected that the first two to three metres of the water column can be released to the environment before suspension of lake bed sediment will result in total suspended solids level that are too high to discharge. Water quality will be monitored, and when it is determined that water quality parameters, such as turbidity or TSS, are approaching criteria specified in regulatory permits, discharge will cease.



LEGEND

Existing Ground Contours 5m Index - 1m Intermediate

Bathymetry Contours 5m Index - 1m Intermediate

CP Collection Pond

Winter Road

Marsh Area

Scrub

Subwatershed Boundary

Drainage Flow Direction

Discharge Pipeline

Lake / Pond

Flooded Area

NOTES

Base data source: EBA Figure 4.2 - Stage 1 - Initial Lake Dewatering (June-July, 2013)

GAHCHO KUE PROJECT

Water Management Areas Showing Dykes, Diversions, and Pipelines

SON-09-001-CAD	December 3, 2010
JOB No: 09-1365-1004	REVISION No: 0
OFFICE: GOLD - SAS	DRAWN: TAH; CHECK: JF

Figure 9.4-1

Discharge flow rates to the N watershed and Area 8 will be restricted to 1-in-2-year flood levels at the Lake N1 and Area 8 outlet (Stream K5) to reduce the potential to exceed natural rates of erosion in the outlet channel. Although the discharge to the N watershed will be directed to Lake N11, the Lake N11 outlet is well armoured so discharges will be allowed to exceed the 1-in-2-year flood conditions (see Section 9.7.3.1.3). However, the discharge flow rate to Lake N11 will be limited to ensure that the water levels do not exceed the 1-in-2-year flood water level at the Lake N1 outlet. The projected initial pumping rates are a maximum of 114,000 cubic metres per day (m^3/d) to Area 8 and 500,000 m^3/d to Lake N11. No discharge will occur if snowmelt and rainfall runoff cause water levels to exceed the 1-in-2-year flood water level in Area 8 or Lake N1.

The potential for erosion of lake-bottom sediments in Area 8 and Lake N11 will be reduced during dewatering pumping with the use of diffusers on the discharge pipe outlets. These diffusers will be placed close to the lake surface at the discharge points in Area 8 and Lake N11 to increase the distance between the outfall and the bottom sediments. The discharge point will also be located in relatively deep sections of the receiving waters. Although some sediment may be mobilized despite these measures, the extent of any effect is likely to occur primarily in the initial stages of discharge and be limited to the zone of turbulence immediately adjacent to the diffuser. Sediment resuspension is likely to quickly diminish after sediments in the zone of turbulence are mobilized in the initial stages of discharge and become re-deposited farther away from the outfall.

9.4.4 Operations

During operations, activities that will affect aquatic environments downstream of the Project include the continued diversion of flows from the A, B, D, and E watersheds, the continued dewatering of Areas 3 and 5, and the reduction of inflows to Area 8.

During operations, Project activities associated with the Water Management Plan will be designed to discharge site water to downstream waterbodies only when specific water quality criteria are met. During operations, water for use in the processing plant will be sourced from the WMP and recycled to the greatest extent possible. After the Fine PKC Facility has been closed, the groundwater flowing into the open pits will be the primary source of make-up water for the processing facility.

9.4.5 Closure

During closure, the key activities that will affect aquatic environments downstream of the Project include the restoration of the natural drainage system in the Kennady Lake watershed, with the exception of watershed A. Water will be pumped from Lake N11 to supplement the refilling of Kennady Lake, and once Kennady Lake (Areas 3 to 7) is refilled and water quality meets specific criteria, Dyke A will be breached and Kennady Lake will be reconnected to Area 8.

9.4.5.1 Refilling of Kennady Lake

At the end of operations, the temporary diversion dykes constructed at the outlets of the B, D, and E watersheds will be breached or removed to allow the upper portions of watersheds along the west side of Kennady Lake to resume their flow into Kennady Lake. Natural runoff from these upper watersheds and supplemental pumping from Lake N11 will be used to refill Kennady Lake. It is expected to take approximately eight years to fill the lake to the original water levels. With the removal of the temporary dykes, flows from these watersheds will no longer be diverted to the adjacent N watershed.

Supplemental water will be pumped from Lake N11 to Area 3 during the early high-water season. Pumping will typically begin in June and end in July, although it may extend into August. In wet years, flow forecasts, based on snow pack conditions and seasonal precipitation trends, will be used to estimate annual water yields from Lake N11. Planned pumping rates will be set accordingly to ensure that the total annual outflow from Lake N11 does not drop below the one-in-five-year dry condition. During the pumping season, pumping rates will be adjusted as required to meet this objective. In years where the Lake N11 outflow is forecast to naturally fall below the one-in-five-year dry condition, no pumping will occur.

The total annual diversion from Lake N11 will be in the order of 3.7 million cubic metres per year (Mm^3/y), which represents no more than 20 percent (%) of the normal annual flow to Lake N11. The 20% cut-off will be used to ensure that sufficient water remains in Lake N11 to support downstream aquatic systems in the N watershed. The value of 3.7 Mm^3/y represents the difference between the flow reporting to Lake N11 under median/normal flow conditions, and that which occurs under one-in-five-year dry conditions. Based on a six-week pumping period, the average daily pumping rate will be 88,100 m^3/d. It is anticipated that more water will be withdrawn during wetter years (i.e., up to a maximum of 175,200 m^3/d). In drier years, less water will be withdrawn. At no time will the diversion result in an outflow from Lake N11 below that which occurs under a one-in-five-year dry condition.

Once Areas 3 through 7 are refilled to the same elevation as Area 8, and the water quality within the refilled lake is acceptable, the in-lake portion of Dyke A will be removed, and the refilling of Kennady Lake and its reconnection with the downstream watersheds will be completed.

9.4.6 Water Balance pertaining to Downstream Waterbodies

A water balance model has been developed that provides a prediction of monthly inflows and outflows to the downstream environment for each year of the Project. Table 9.4-2 shows a summary of the outflows from Area 8, the inflows to and outflows from Lake N11, and the resultant outflows from Lake N1 during the construction, operations, and closure phases of the Project, including post-closure after Kennady Lake has been reconnected to Area 8. The table was compiled using data for the 1-in-2 wet year freshet (median values).

The outflow from Area 8 will experience the greatest changes in flow rates over the Project life. During the dewatering phase, flows will double. The downstream annual flow rate at the outlet will exceed a 1-in-100-year high flow condition. The total annual outflow from Area 8 during operations and closure will decrease to 25% of the existing outflow under baseline conditions. The annual water yield downstream will be less than a 1-in-100-year dry condition. Flow from Area 8 will be slightly higher than baseline conditions after closure. The total annual post-closure outflow from Area 8 will be 6% higher than existing baseline outflow (i.e., between median and 1-in-5-year wet flow conditions). A flow mitigation plan is being developed to mitigate any fish habitat losses due to reduced flows. The specifics of the mitigation plan have not been developed, but would focus on providing suitable spawning and rearing habitat for Arctic grayling (*Thymallus arcticus*).

Table 9.4-2 Annual Flow Rates at the Lake N1, N11, and Area 8 Outlets

Phase	Outlet	Proportional Annual Flow (m^3/y)	Total Annual Flow (m^3/y)
Existing Condition			
Total outflow from Lake N1	N1		31,500,000
Total outflow from Lake N11	N11		18,600,000
Total outflow from Area 8	Area 8		4,760,000
Construction – (Year -2 to -1)			
Total Outflow from Lake N1	N1		44,500,000
Total outflow from Lake N11	N11		31,500,000
Dewatering to Lake N11		12,800,000	
Runoff to Lake N11 (including runoff from upstream watersheds plus A, B, D, and E diversions)		18,700,000[a]	
Total outflow from Area 8	Area 8		9,750,000
Dewatering to Area 8		8,550,000	
Runoff to Area 8		1,200,000	
Operations (Year 1 to Year 11)			
Total outflow from Lake N1	N1		37,200,000
Total outflow from Lake N11	N11		23,900,000
Dewatering to Lake N11		4,300,000	
Runoff to Lake N11 (including runoff from upstream watersheds plus A, B, D, and E diversions)		19,600,000[a]	
Total outflow from Area 8			1,200,000
Closure (Year 12 to Year 19)			
Total outflow from Lake N1	N1		29,100,000
Total outflow from Lake N11	N11		16,000,000
Total outflow from Area 8	Area 8		1,200,000
Post-closure (Year 20+)			
Total outflow from Lake N1	N1		31,600,000
Total outflow from Lake N11	N11		18,700,000
Total outflow from Area 8	Area 8		5,050,000

(a) This outflow from the Lake N11 outlet includes the additional inflow from the diversion of the A, B, D, and E watersheds to the N watershed.

m^3/y = cubic metres per year.

9.5 ASSESSMENT APPROACH

The assessment approach for this key line of inquiry follows the overall approach described in Section 6 of the environmental impact statement (EIS). The assessment approach described herein (Section 9.5) provides details on specific aspects of the approach that are particularly relevant to the assessment of the effects of the Gahcho Kué Project (Project) on surface waters downstream of Kennady Lake.

This key line of inquiry is closely linked to Section 8, Key Line of Inquiry: Water Quality and Fish in Kennady Lake, which provides the results of the assessment of effects on water quality and fish in Kennady Lake and its watershed. Downstream effects on surface waters are the direct result of changes in water quantity (hydrology) and water quality in the Kennady Lake watershed. Thus the major Project-related factors influencing downstream surface waters include flow changes from dewatering and refilling of part of Kennady Lake, diversions around the lake during operations and water quality in Area 8, all of which have been discussed in Section 8. This key line of inquiry focuses on the quantity and quality of outflows from the Kennady Lake watershed, using the results of the assessment presented in Section 8 as the starting point.

9.5.1 Pathway Analysis

The pathway analysis for this key line of inquiry is provided in Section 9.6. The potential pathways reflect potential linkages between the Project and the physical and biological properties of surface waters downstream of Kennady Lake. The pathway analysis identifies and screens the linkages between Project components or activities (e.g., Kennady Lake dewatering) and the potential effects to receptors within the environment (e.g., Arctic grayling [*Thymallus arcticus*]). Pathways were screened for activities during the construction, operations, and closure phases.

Pathway analysis is a screening step that uses largely qualitative information to distinguish valid pathways from no linkage and secondary pathways. The pathway analysis examines all potential pathways relevant to this key line of inquiry, and environmental design features and mitigation integrated into the Project that remove the pathway or limit the effects along a primary or secondary (minor) pathway (e.g., setting limits on minimum and maximum flows during the dewatering of Kennady Lake). Environmental design features and mitigation include the Project design and environmental best practices, management policies and procedures, and social programs. Primary pathways are those that continue to exist after environmental design features and mitigation have been applied (i.e., those that are expected to lead to residual effects after mitigation).

Secondary and no linkage pathways are described in Section 9.6 and an explanation provided detailing why they have been characterized as such. No linkage pathways are removed by environmental design features and mitigation, so that the Project results in no detectable environmental change and residual effects to a valued component (VC) relative to baseline or guideline values. Secondary pathways could result in a minor environmental change, but would have a negligible residual effect on a VC relative to baseline or guideline values. No linkage and secondary pathways do not appreciably contribute to environmental effects analysis and consideration of their effects ends in Section 9.6; this allows the assessment to focus on primary pathways.

All primary pathways are carried forward in the assessment for detailed effects analysis.

9.5.1.1 Valued Components

A VC is a component of the environment that people consider to be ecologically, culturally, socially, or economically important. Valued components occur at different levels, and levels may be determined naturally (e.g., ecological importance of a top predator) or through the importance placed on them by people.

In this EIS, VCs can be found at the beginning, middle, or end of pathways. Downstream of Kennady Lake, VCs can be found at the bottom, middle, or top trophic level of food chains. For example, in sub-Arctic streams, changes to water quality (particularly, increased nutrient concentrations) represent initial pathways to changes in benthic algal productivity, which influence other lower trophic level (e.g., benthic invertebrates), forage fish, and, ultimately, large-bodied fish, that represent the highest trophic level.

The selection of VCs specific to this key line of inquiry resulted from issues scoping sessions for the Project with community members, federal and territorial regulators, and other stakeholders. The *Terms of Reference for the Gahcho Kué Environmental Impact Statement* (Terms of Reference) (Gahcho Kué Panel 2007) provides a list of important biophysical components that were identified in the issues contained in the Gahcho Kué Report of Environmental Assessment (MVEIRB 2006). The Terms of Reference also define different levels of importance attributed to the biophysical components. For this key line of inquiry, the water quality and fish were identified as being the most important components, that is, VCs (Gahcho Kué Panel 2007). Key biophysical components identified as contributing to, or comprising an important feature of, these VCs are discussed in the following section.

9.5.1.2 Water Quality

Within this EIS, water quality has both an important ecological and a human health value. It can provide a basis for evaluating aquatic ecosystems to determine whether water quality during each phase of the Project meets acceptable levels for the protection of aquatic life. Water quality can also be compared to drinking water standards and used in a risk assessment to assess effects on human health. Since changes to water quality may ultimately affect fish, wildlife, and human health, the selection of water quality as a VC is appropriate. The societal goals that make water quality a VC are the protection of both drinking water and aquatic life.

The natural water quality of a lake or stream is the product of the physical (e.g., climate and resulting water inputs), chemical (e.g., weathering of bedrock, interaction with groundwater), and biological (e.g., algal growth) processes in the watershed and within the waterbody. It can be directly measured by the physico-chemical and chemical analysis of water column samples.

The key biophysical components within the Kennady Lake area that influence water quality include the following:

- permafrost and groundwater quality and quantity ;
- water levels and flow patterns (i.e., hydrology);
- water chemistry; and
- sediment quality.

The potential of the Project to have both direct and indirect effects on the water quality downstream of Kennady Lake is high. Changes in environmental components tend to occur sequentially (e.g., highly saline, deep groundwater, if not managed appropriately, could cause an increase in total dissolved solids [TDS] in surface water leading to water quality that might affect fish health). Understanding the resulting pathways to fish in this example would require an analysis of the measurement endpoints associated with hydrogeology, hydrology, water quality, and aquatic health.

The potential for pathways within each environmental component listed above to contribute to effects to water quality is discussed in the following sections.

Permafrost and Groundwater

Permafrost and groundwater are important features of the Kennady Lake area, and were identified in the technical issues scoping for water issues in Kennady Lake (MVEIRB 2006). Both were identified as key biophysical components for assessing the effects of the project on water quality in Kennady Lake and its watershed, and were assessed in Subject of Note: Permafrost, Groundwater, and Hydrogeology (Section 11.6). Potential effects to water quality in Kennady Lake and its watershed from changes in permafrost and groundwater were evaluated in Key Line of Inquiry: Water Quality and Fish in Kennady Lake (Section 8).

Because mining and related infrastructure will be located in the Kennady Lake watershed, any direct effects on water quality and fish habitat from changes in permafrost and groundwater will occur within the Kennady Lake watershed. The potential for effects from these changes downstream of Kennady Lake will be limited to indirect effects through changes in hydrology (Section 9.7) or water quality (Section 9.8). Therefore, an assessment of pathways specifically related to permafrost and groundwater is not provided in this key line of inquiry. Rather, indirect effects from changes in permafrost and groundwater are assessed through evaluation of downstream effects resulting from altered hydrology and water quality.

Hydrology

Hydrology focuses on surface water levels, flows, and channel bank stability. Because downstream effects of Kennady Lake dewatering and refilling were identified during the technical issues scoping (MVEIRB 2006), hydrology is considered a key biophysical component. Hydrology provides a measurement endpoint to pathways between the Project and potential effects to water quality and fish. The Project, through the diversion of the upper watersheds of Kennady Lake, and the dewatering and refilling of Kennady Lake, will affect the hydrology in downstream watercourses and waterbodies in terms of water quantity and seasonal patterns of flow. Changes to hydrology may result in effects to fish habitat through changes to water level, flow rates, and the stability of stream channels. Erosion and resuspension of sediment may affect water quality (e.g., increased nutrients, metals, and total suspended solids [TSS]). Each of these potential pathways is considered in the EIS, and discussed in more detail in Section 9.7.

Sediment Quality

Sediment quality is an important feature of the Kennady Lake watershed, and chemical changes in sediment were identified in the technical issues scoping for fish issues; therefore, sediment quality is considered a key biophysical component. It also provides a measurement endpoint to pathways to water quality and fish through the potential for exchange between the bed sediment, aquatic habitat and overlying water column. Additionally, alterations to the lake bed or stream bed from Project activities can lead to increased sediment deposition, which can smother aquatic habitat, or to the deposition of metals and nutrients, which can affect water chemistry and aquatic health. Changes in sediment quality, therefore, have the potential to affect fish, and ultimately people who may eat the fish or use the overlying water as a source of drinking water.

Water Chemistry

Water chemistry is a principal component of water quality, which was identified as an issue related to fish during the technical issues scoping (MVEIRB 2006). It comprises the chemical constituents that characterize the waterbody and reflects the geomorphology and condition of the watershed. Water chemistry is highly responsive to changes in watershed runoff and input sources, and can provide an indication of the productivity of the waterbody. Changes in water chemistry in Kennady Lake as discussed in Key Line of Inquiry: Water Quality and Fish in Kennady Lake (Section 8) has the potential to affect water quality in downstream lakes. Changes in water chemistry in downstream waters may result in effects to lower trophic organisms (e.g., plankton and benthic invertebrates), and ultimately fish and people.

9.5.1.2.1 Value of Water Quality

The societal goals that make water quality a VC are the protection of both drinking water and aquatic life from effects of possible water contamination from the Project. Within this EIS, water quality has both an ecological and a human health value. It can provide a basis for evaluating aquatic ecosystems to determine whether water quality during the Project phases meets acceptable levels for the protection of aquatic life. Water quality can also be compared to drinking water standards and used in a risk assessment to assess effects on human health. Since water quality may ultimately affect fish, wildlife, and human health, the selection of water quality as a valued component is appropriate.

9.5.1.3 Fish

9.5.1.3.1 Importance of Fish

Fish are traditionally important to Aboriginal communities and are also valued by non-traditional land users. Fish also provide a direct link between potential effects to water quality and human health.

The potential for the Project to affect the abundance, behaviour, and health of fish downstream of Kennady Lake is high. Therefore, selecting fish as a VC component is appropriate. Any changes in measurement endpoints, such as fish abundance, behaviour, and health, may ultimately affect humans.

The VC represented by fish includes individual fish species, because interactions between each Project activity and the unique habitat requirements and life history characteristics of fish can be fully assessed only at the species level.

The productivity of key fish species (e.g., Arctic grayling) is linked directly and indirectly to physical habitat, hydrology (e.g., water levels in lakes and flow velocities in streams), water chemistry (e.g., nutrients, dissolved oxygen conditions), lower trophic levels, which provide the base of the food web, and forage fish. As described for water quality, a pathway may include several VCs that lead to fish, which are the VCs.

9.5.1.3.2 Fish Habitat

Fish habitat is not a VC for this assessment because it is the fish that are ultimately valued by people rather than the habitat that supports them. Fish habitat is represented by the streams and lakes downstream of Kennady Lake for this key line of inquiry. While these streams and lakes undoubtedly have value to people, it is their ability to produce fish that is most valued. Fish habitat is, therefore, a key biophysical component that contributes to fish species selected as VCs. Changes to fish habitat is a measurement endpoint that is used to determine Project-related effects to fish species.

Effects of Project activities on fish habitat are included in the impact assessment. The federal *Fisheries Act* defines fish habitat as, “spawning grounds and nursery, rearing, food supply, and migration areas on which fish depend directly or indirectly to carry out their life processes”. By this definition, fish habitat is the integration of physical, chemical, and biological parameters that combine to create the space, food, competitors, predators, and abiotic features that determine the growth and survival of individual fish and, ultimately, the productivity of the population. Because fish habitat is required to produce fish, Project activities that affect fish habitat will ultimately affect fish. Similarly, measures taken to reduce effects to fish habitat will reduce effects to fish.

9.5.1.4 Fish Species Selected as Valued Components

Fish species that are characterized as being important to people have been selected from the list of fish species present in order to focus the assessment. At least 14 fish species are known to exist downstream of Kennady Lake and could be considered as VCs (Table 9.5-1). The following criteria were used to select highly valued fish species from the list of fish species present:

- traditional importance to Aboriginal communities (i.e., subsistence, cultural, and spiritual values);
- economic importance to traditional and non-traditional land users (e.g., commercial sport fisheries, sport fisheries);
- species listed federally as extirpated, endangered, or threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and/or regionally by the Government of the Northwest Territories (GNWT 2006) as “sensitive” or “may be at risk”
- relatively high abundance in streams and lakes downstream of Kennady Lake;
- unique life history characteristics or habitat requirements;
- distribution in comparison to the anticipated downstream extent of potential effects; and
- important ecological niche in streams and lakes downstream of Kennady Lake (e.g., top predator).

There is no commercial fishery within the Regional Study Area (RSA) as defined in the Fisheries and Aquatic Resources Baseline (Annex J) (i.e., the Lockhart River watershed). As a result, the importance of a fish species to commercial fishing was not included in the VC selection criteria.

There are no federally listed fish species in the Local Study Area (LSA) or RSA downstream of Kennady Lake. Arctic grayling are listed as “sensitive” in the Northwest Territories (NWT) due to the increasing pressures of resource development and climate change (GNWT 2006). There are no other “sensitive” or “may be at risk” species in the LSA or RSA.

Based on the above criteria and the analysis in Table 9.5-1, lake trout (*Salvelinus namaycush*), Arctic grayling, and northern pike (*Esox lucius*) were selected as highly valued fish species for this key line of inquiry. The rationale for selecting each of these species as a VC is described in the following sections, as well as reasons for not selecting other species.

Table 9.5-1 Valued Component Evaluation for Fish Species Downstream of Kennady Lake

Species	Importance to Aboriginal Communities[a]	Importance to Non-traditional Land Users[b]	Known Abundance Downstream of Kennady Lake	Known Downstream Distribution in Relation to Kennady Lake	Ecological Niche	Valued Component	Rationale
Lake trout	subsistence use and as dog food	popular sport-fish in NWT	most abundant predator in lakes	found in most lakes immediately and far downstream	piscivore; top-predator in sub-Arctic tundra lakes	yes	most abundant top predator in sub-Arctic tundra lakes; valued by local Aboriginal communities and sport anglers in the NWT
Arctic grayling	subsistence use	popular sport-fish in NWT	relatively abundant large-bodied fish species	found in most lakes immediately and far downstream	invertivore; adfluvial life history	yes	important to local Aboriginal communities and sport anglers in the NWT; adfluvial life history suitable for assessing effects to streams; listed as "sensitive" in the NWT
Round whitefish	subsistence use	none	most abundant large-bodied fish in sub-Arctic tundra lakes	found in most lakes immediately and far downstream	invertivore; principal prey species for lake trout	no	most abundant large-bodied fish in Kennady Lake but not an important sport fish in the NWT and is less valued than lake whitefish as a food source by local Aboriginal communities due to its smaller size
Lake whitefish	subsistence use and as dog food	secondary sport-fish in NWT	abundant in larger lakes	Kirk Lake and larger lakes farther downstream	invertivore	No	important to local Aboriginal communities and sport anglers in the NWT but found only as far upstream as Kirk Lake
Lake cisco	none	none	less abundant than round whitefish	Lake M4, Lake 410, Lake N16 and larger lakes downstream	invertivore	No	not an important sport fish in the NWT and less valued by local Aboriginal communities than lake whitefish
Least cisco	none	none	unknown	Courageous Lake only	invertivore	No	not an important sport fish in the NWT and less valued by local Aboriginal communities than lake whitefish
Northern pike	subsistence use	popular sport-fish in NWT	populations limited by paucity of aquatic vegetation in sub-Arctic lakes	found in most lakes immediately and far downstream	piscivore; secondary top-predator to lake trout; dependent on aquatic vegetation	yes	important sport fish in the NWT and valued by local Aboriginal communities; dependence on aquatic vegetation suitable for assessing effects to nearshore habitat
Burbot (moria)	subsistence use	none	found in low numbers	found in most lakes immediately and far downstream	omnivore	no	marginally important sport fish and subsistence fish for Aboriginal communities; population sizes smaller than lake trout

Table 9.5-1 Valued Component Evaluation for Fish Species Downstream of Kennady Lake (continued)

Species	Importance to Aboriginal Communities[(a)]	Importance to Non-traditional Land Users[(b)]	Known Abundance Downstream of Kennady Lake	Known Downstream Distribution in Relation to Kennady Lake	Ecological Niche	Valued Component	Rationale
Longnose sucker	subsistence use	none	most abundant sucker species	N watershed	invertivore	no	large-bodied species valued by Aboriginal communities but not by sport anglers in the NWT; found in relatively small numbers in comparison to other fish species present
White sucker	none	none	less abundant than longnose sucker	N watershed	invertivore	no	large-bodied species not valued by Aboriginal communities or by sport anglers in the NWT
Lake chub	none	none	most abundant small-bodied forage fish	found in most lakes immediately and far downstream	invertivore	no	forage fish species not valued by Aboriginal communities or by sport anglers in the NWT
Slimy sculpin	none	none	more abundant in streams than in lakes	found in most lakes immediately and far downstream	invertivore	no	forage fish species found principally in streams but not valued by Aboriginal communities or by sport anglers in the NWT
Ninespine stickleback	none	none	populations limited by paucity of aquatic vegetation in sub-Arctic lakes	found in most lakes immediately and far downstream	invertivore; dependent on aquatic vegetation or organics for spawning	no	forage fish species not valued by Aboriginal communities or by sport anglers in the NWT
Arctic lamprey	none	none	unknown	Artillery Lake and Lockhart River in RSA	parasitic on large-bodied fish species	no	fish species not valued by Aboriginal communities or by sport anglers in the NWT; known to exist in RSA downstream of Aylmer Lake only

(a) Traditional Knowledge and Traditional Land Use Baseline (Annex M).

(b) Non-traditional Land Use and Resource Use Baseline (Annex N).

NWT = Northwest Territories; RSA = Regional Study Area.

9.5.1.3.3 Lake Trout

Lake trout was selected as a valued fish species for this assessment principally because:

- it is the most abundant top predator in lakes downstream of Kennady Lake;
- it is an important species to local Aboriginal communities and non-traditional land users; and
- the potential for the Project to affect lake habitats upon which lake trout depend is high.

Lake trout is one of the most highly valued fish species for food by Aboriginal peoples who have fished in the Lockhart River watershed (Annex M, Traditional Knowledge and Traditional Land Use Baseline). Along with Arctic grayling and northern pike, lake trout is one of a prized fish species in the NWT for resident and non-resident sport anglers (Annex N, Non-traditional Land Use and Resources Use Baseline).

Lake trout completes all of its life history in lakes, and is therefore a suitable species for assessing the potential effects of the Project on lake habitat downstream of Kennady Lake. Lake trout use nearshore areas for spawning and rearing and deeper, offshore areas for foraging and overwintering. Alteration of lake levels can affect downstream lake trout populations by reducing the amount of suitable spawning and nursery habitat. Changes in forage fish populations due to changes in stream flows and lake levels will also affect lake trout because they are the top-predators.

Lake trout are also suitable for assessing potential effects of water quality changes. Because of their position at the top of the food chain, any changes in lower trophic organisms or fish will ultimately have an effect on lake trout. Lake trout are also appropriate for assessing potential effects of metals or other contaminants that have the potential to bioaccumulate (e.g., mercury).

9.5.1.3.4 Arctic Grayling

Arctic grayling was selected as a valued fish species for this assessment principally because of its importance to local Aboriginal communities and to the Northwest Territories (NWT) sport fishery, and because its unique life history makes it suitable for assessing the potential effects of the Project on streams. In the Barrenlands, Arctic grayling have an adfluvial life history and is the only species that uses stream habitat exclusively for spawning and rearing. Arctic grayling are known to use streams immediately downstream of Kennady Lake for spawning and rearing and populations of Arctic grayling exist in most, if not all, lakes downstream of Kennady Lake and in the adjacent N watershed, which are expected to be affected by the Project.

The Project has the potential to alter the physical and hydrological characteristics of streams downstream of Kennady Lake. Therefore, potential effects to streams will have a direct effect on Arctic grayling recruitment and the sustainability of downstream populations during and after the Project.

9.5.1.3.5 Northern Pike

Northern pike was selected as a valued fish species for this assessment because of its importance to local Aboriginal communities as a food source, its importance to the NWT sport fishery, and its dependence on aquatic macrophytes for spawning, rearing, and foraging. Aquatic macrophytes are scarce downstream of Kennady Lake and restricted to tributary mouths and isolated nearshore areas where fine sediments accumulate. As a result, the northern pike populations in lakes downstream of Kennady Lake are small and are restricted to areas where aquatic macrophytes exist. These areas include some of the small lakes immediately downstream of Kennady Lake.

The Project has the potential to affect water levels in the downstream lakes during construction, operation and closure. Water level fluctuations may increase or decrease the abundance of aquatic vegetation in these lakes, and alter their distribution, depending on whether lake levels rise or fall. Any change in the aquatic macrophyte community, positive or negative, will ultimately affect northern pike. These effects would not be identified or would be inadequately assessed using lake trout alone. For this reason, northern pike are included as a VC in this assessment.

9.5.1.3.6 Other Fish Species

There are at least 11 other fish species that could have been selected as VCs for this assessment. These include round whitefish (*Prosopium cylindraceum*), lake whitefish (*Coregonus* sp.), lake cisco (*Coregonus artedii*), least cisco (*Coregonus sardinella*), burbot (moria; *Lota lota*), lake chub (*Couesius plumbeus*), longnose sucker (*Catostomus catostomus*), white sucker (*Catostomus commersoni*), slimy sculpin (*Cottus cognatus*), ninespine stickleback (*Pungitius pungitius*), and Arctic lamprey (*Lampetra japonica*). Each of these species did not meet at least one of the criteria listed above and, therefore, were not selected as a VC (Table 9.5-1).

Round whitefish is the most abundant large-bodied fish species in lakes downstream of Kennady Lake and is the primary prey species for lake trout and northern pike. However, round whitefish was not selected because it is less valued by Aboriginal communities and sport fishermen than lake trout. Round whitefish uses very similar nearshore habitat as lake trout for spawning and rearing; therefore, potential effects to round whitefish from alteration of lake habitats are likely to be identified, assessed, and mitigated by using lake trout as the VC.

Even though they are as important to local Aboriginal communities as lake trout, lake whitefish was not selected as a VC because this species is known to exist only as far upstream as Kirk Lake. Kirk Lake is approximately 24 kilometres (km) downstream from Kennady Lake and the Kennady Lake watershed comprises less than 5 percent (%) of the Kirk Lake watershed. The potential for the Project to affect fish in Kirk Lake is expected to be negligible because of the attenuating effect of runoff from its large upstream watershed and the numerous lakes between Kennady Lake and Kirk Lake. Lake whitefish are not known to make extensive migrations and it is unlikely that any lake whitefish would move upstream from Kirk Lake to lakes or streams potentially affected by the Project. As a result, the selection of lake whitefish as a VC was considered unwarranted.

Burbot and longnose sucker have also been identified as species used by local Aboriginal communities for subsistence use or as dog food. Neither species was selected as a VC because they are not important sport fish, are found in relatively low numbers in comparison to other fish species present, do not have any unique life history, habitat requirements, or ecological niche not already addressed by other fish species selected as VCs, and are not federally or regionally listed.

Slimy sculpin is the only other stream-dwelling fish species besides Arctic grayling, downstream of Kennady Lake. Slimy sculpin was not selected as a VC fish species because it has little value to traditional and non-traditional land users and because it has very similar habitat requirements to Arctic grayling. Inclusion of Arctic grayling is likely to provide sufficient indication of potential effects to stream habitat to slimy sculpin.

9.5.1.4 Assessment Endpoints and Measurement Endpoints

Assessment endpoints are the ultimate properties of VCs that should be protected or developed for use by future human generations. They are general statements about what is being protected (e.g., persistence of water quality to support a thriving aquatic ecosystem).

Measurement endpoints are defined as quantifiable (i.e., measurable) expressions of the environment that influence the assessment endpoints. For example, for water quality, the assessment endpoint is the suitability of water quality to support a viable aquatic ecosystem, and the relevant endpoints included projected concentrations of nutrients (e.g., nitrogen and phosphorus), ionic constituents (e.g., dissolved salts, such as calcium and chloride) and metals (e.g., copper and iron) in downstream lakes over time. These measurement endpoints will be compared to applicable environmental guidelines and standards to assess the effect of the Project on water quality (the assessment endpoint).

The difference between measurement and assessment endpoints may appear subtle, but is important to the assessment approach used in the EIS. Effects analyses and residual impact classification are completed on assessment endpoints. Assessment endpoints are phrased as effects statements (e.g., effects of Project activities on water quality, effects of dewatering activities on fish and fish habitat), and then analyzed using quantitative and qualitative methods, based on measurement endpoints. The overall significance of Project impacts on VCs is predicted by linking residual changes in measurement endpoints to impacts on the associated assessment endpoint.

Assessment endpoints and measurement endpoints for this key line of inquiry are provided in Table 9.5-2. Permafrost and groundwater are specifically assessed in the Subject of Note: Permafrost, Groundwater, and Hydrogeology (Section 11.6).

Although wildlife and human health are also VCs that are briefly discussed in this key line of inquiry, potential effects to wildlife and human health have not been classified in this section of the EIS. Classification of potential effects to wildlife and human health requires the consideration of all pathways by which effects to wildlife and human health can occur. These pathways include the inhalation of air and the consumption of terrestrial-based foods, the quality of which may potentially be affected by the Project. These pathways are not the subject of this key line of inquiry and are not discussed herein. As such, a summary of potential effects to wildlife and human health has been provided in this section of the EIS (i.e., Section 9.11), but a classification of the potential effects has not.

Table 9.5-2 Assessment Endpoints and Measurement Endpoints for Valued Components Identified for Water Quality and Fish in Kennady Lake

Valued Components	Principal Components	Assessment Endpoints	Measurement Endpoints
Water Quality Fish (lake trout, Arctic grayling and northern pike)	• Permafrost and Groundwater • Surface Water Quantity • Sediment Quality • Aquatic Health • Fish Habitat	• Suitability of Water Quality to Support a Viable Aquatic Ecosystem • Abundance and Persistence of Desired Population(s) of Lake Trout • Abundance and Persistence of Desired Population(s) of Northern Pike • Abundance and Persistence of Desired Population(s) of Arctic Grayling	• permafrost depth and distribution, location and size of taliks near waterbodies and watercourses • groundwater level and flow rate, groundwater quantity and quality • surface topography, drainage boundaries, and waterbodies (e.g., streams, lakes, and drainages), stream flow rates, and spatial and temporal distribution of surface water, shoreline and channel morphology • physical characteristics of water (e.g., pH, conductivity, turbidity), concentrations of major ions, nutrients, total and dissolved metals and trace organic compounds in water • physical and chemical properties of sediment • physical aquatic habitat characteristics, habitat quantity and quality • plankton community structure and composition • benthic invertebrate community structure and composition • fish habitat availability and use • fish numbers, movement and behaviour, fish survival and reproduction, fish reproductive condition and health • access to fish and wildlife • human health

9.5.2 Spatial and Temporal Boundaries

The Terms of Reference (Gahcho Kué Panel 2007) identify the importance of spatial scale when analyzing and predicting the effects from the Project on VCs. It also emphasizes that the spatial scope of the study must be appropriate for the potential impact being assessed. For example, as lake trout spend all of their life history within a lake environment, individuals within populations of lake trout in Kennady Lake or any of the fish-bearing lakes within its watershed can be affected by the Project. For this species, the spatial boundary for the assessment of effects for this key line of inquiry was defined by the range of the population, which conforms to the requirements of the Terms of Reference (Gahcho Kué Panel 2007).

The approach used to determine the temporal scales of effects from natural and human-related disturbances on VCs is similar to the approach used to define spatial boundaries. In the EIS, the temporal boundaries are linked to the construction, operation, and closure phases of the Project, and beyond closure (i.e., the post-closure period).

The duration of some changes from the Project, such as potential changes to air quality, will likely end when mining operations end at closure. In contrast, effects to fish will likely continue beyond the closure phase, because it will take some time for the fish community to re-establish itself in Kennady Lake after refilling and restoration of water quality. Thus, the temporal boundary for a VC is defined as the amount of time between the start and end of a relevant Project activity or stressor (which is related to development phases), plus the duration required for the effect to be reversed.

After removal of the stressor, reversibility incorporates the likelihood and time required for a VC or system to return to a state that is similar to the state of systems of the same type that are not affected by the Project. For effects that are reversible, the EIS provides an estimate of the duration or time required to reverse the effects on the VC or system. Some effects may be reversible soon after the removal of the stressor, such as effects to water flows in Lake N11 after cessation of the pumped discharge for the refilling of Kennady Lake.

Other effects may require a longer duration before changes are reversed. For example, after Kennady Lake has been refilled and water quality permits the breaching of dyke A to reconnect Areas 2 to 7 and Area 8, it may take a few years for the lower trophic community structure within Kennady Lake to return to an ecological state that will allow fish to successfully return to the lake, as discussed in Section 8.11.

Examples of irreversible effects include permanent loss of lake habitat. Although some permanent loss of lake habitat will occur in the Kennady Lake watershed, none is expected to occur downstream of Kennady Lake.

9.5.3 Effects Analysis

In the EIS, the effects analysis considers all primary pathways that likely result in measurable environmental changes and residual effects to VCs (i.e., after implementing environmental design features and mitigation). Thus, the analysis is based on residual Project-specific (incremental) effects that are predicted to be primary in the pathway analysis. Residual effects to VCs are analyzed using measurement endpoints and expressed as effects statements (e.g., Effects of Project activities to water quality in downstream waters, and effects of closure activities to fish and fish habitat in streams and lakes downstream of Kennady Lake). Effects statements may have more than one primary pathway that link a Project activity with a change in the environment and an effect on a VC. For example, the pathways for effects to fish and fish habitat include alteration of local flows and drainage areas, and water quality.

A detailed description of the spatial and temporal boundaries, and methods used to analyze residual effects from the Project is provided for each VC. The analyses are quantitative, where possible, and include data from field studies, scientific literature, government publications, effects monitoring reports, and personal communications. To limit the degree of technical information in the main text, specific details on modelling and statistical techniques, assumptions, analyses, and data sources are provided in appendices. Available traditional knowledge and community information are incorporated into the analysis and results, where appropriate. Due to the amount and type of data available, some analyses are qualitative and include professional judgment or experienced opinion.

The effects to water quality and fish downstream of Kennady Lake are assessed during construction, operations, and closure. The assessment requires the synthesis of information generated by each of the assessment components for which there are valid pathways: hydrology, water quality, aquatic health, fish and fish habitat, and related effects to wildlife and human use. The detailed description of the methods used to analyze the effects from the Project on the VCs for each component is provided in Sections 9.7 to 9.11.

Assessment components focusing on the physical and chemical environment (e.g., hydrology and water quality) use baseline information and known processes in the sub-Arctic environment in combination with the Project design to develop mathematical models to predict conditions during construction, operation, and closure. Models are calibrated to baseline data and source input values, and scenarios are created representing periods during mine construction and operations when the greatest effects are expected to occur (e.g., highest or lowest flows, highest emissions). Model predictions are developed for locations (i.e., nodes) chosen to represent areas of concern regarding biological communities, such as stream reaches used by fish during spawning or migrations, or input points to downstream waterbodies.

Results of models simulating physical changes are either used directly by the biological components (e.g., flow data by fish and fish habitat) to predict potential effects based on known habitat relationships of individual VCs (e.g., swimming ability of a fish species in relation to predicted current velocity), or are used as part of the input data to additional modelling. Water quality modelling incorporates physical processes (e.g., hydrology model results), mine-related water inputs and their estimated flow rates and chemistry (e.g., geochemistry fluxes from mine rock and PK material to porewater, groundwater flow to open pits), baseline water quality, and natural physico-chemical processes to predict surface water quality at key locations in the downstream watersheds. Model predictions are made on a monthly basis for periods of greatest concern (e.g., lowest stream flows combined with highest effluent flows during construction) and are restricted to a relatively average climate conditions (i.e., 1:2 year wet [median] conditions).

Water quality model results, in combination with model results for physical conditions (e.g., changes in water levels and flows), are used by the fish and fish habitat component to predict direct effects to highly valued fish species, or indirect effects through changes in biological components of fish habitat (e.g., lower trophic communities, including plankton and benthic invertebrates). In addition to direct effects from changes in physical habitat (e.g., stream flows), direct effects due to changes in water chemistry (e.g., potential toxic effects from changes in concentrations of metals or ammonia) are also evaluated. Indirect effects through lower trophic communities consider potential direct effects (i.e., toxicity) and effects on productivity through nutrient enrichment from discharges of treated sewage and mine water.

Following the effects analysis, a summary of residual effects is provided in Section 9.12. Where possible, every effort is made to express the expected changes quantitatively or numerically. For example, the magnitude (intensity) of the effect may be expressed in absolute or percentage values above baseline (existing) conditions or a guideline value. The geographic extent of effects is expressed in area (hectares [ha]) or distance (km) from the Project. The expected duration would be expressed in years. In addition, the direction, likelihood, and frequency of effects may also be described, where applicable.

The technical information is then explained using non-technical descriptions. The quantitative description of effects is interpreted for a broader audience. For example, the appearance of a stream experiencing a one-in-two-year flood would be described, for example, in terms of flow rate and water level.

Expressions such as “short-term” duration or “moderate” magnitude are not used in the summary of residual effects. These expressions are reserved for the classification of impacts, where definitions of these expressions are provided. The classification follows the summary of residual effects in this key line of inquiry.

9.5.4 Cumulative Effects

The local study area (LSA) was defined by the watersheds of the lakes and streams that may be directly affected by the proposed Project, and includes Kennady Lake downstream to Kirk Lake. Existing and planned projects in the NWT are located outside of the LSA (i.e., Kennady Lake watershed or in downstream areas potentially affected by the Project). As such, there is no opportunity for the releases of those projects to interact with those of the Project within the Kennady Lake watershed downstream to Kirk Lake. Consequently, there is no potential for cumulative effects to fish or water quality downstream of Kennady Lake.

9.5.5 Residual Impact Classification

To assess the environmental significance of the projected changes to the hydrology, water quality, and aquatic communities downstream of Kennady Lake resulting from the Project, a residual impact classification system was applied to the VC considered in this key line of inquiry. First, each residual impact was rated for a series of criteria (Section 9.5.5.1), based on the results of the effects analysis. Second, the criteria ratings were combined to classify environmental consequence (Section 9.5.5.2), which represents the overall impact of the Project on the assessment endpoint. In the final step, the projected impacts were evaluated to determine if they were of environmental significance (Section 9.5.5.3).

9.5.5.1 Criteria

The classification of residual impacts for this key line of inquiry is provided in Section 9.13. The purpose of the residual impact classification is to describe the residual effects from the Project on the highly valued components using a scale of common words (rather than numbers and units). The classification of impacts is based on the following criteria specified in the Terms of Reference:

- direction;
- magnitude;
- geographic extent;
- duration;
- reversibility;
- frequency;
- likelihood; and
- ecological context.

These criteria are defined and explained in Section 6 of this EIS, with more specific details on the scale of each criteria provided in Section 9.13. The definitions for these scales are ecologically or logically based on the characteristics of the VC in question and the associated assessment endpoint, although the use of professional judgment is inevitable in some cases.

9.5.6 Significance

The evaluation of significance for biophysical VCs considers the entire set of primary pathways that influence a particular assessment endpoint, but significance is not explicitly assigned to each pathway. Rather, the relative contribution of each pathway is used to determine the significance of the Project on assessment endpoints, which represents a weight of evidence approach.

Environmental significance is used to identify predicted impacts that have sufficient magnitude, duration, and geographic extent to cause fundamental changes to a VC. Significance is determined by the risk to desired water quality and the persistence of fish populations (i.e., population level effects) within aquatic ecosystems. It is difficult to provide generalized definitions for environmental significance that are universally applicable to each assessment endpoint. Consequently, specific definitions are provided for each assessment endpoint.

Some of the key factors considered in the determination of environmental significance include:

- results from the residual impact classification of primary pathways are used to evaluate the significance of impacts from the Project on the assessment endpoint of VCs.
- magnitude, geographic extent, and duration (which includes reversibility) of the impact are the principal criteria, with frequency and likelihood as modifiers.
- professional judgment, experienced opinion, and ecological principles, such as resilience, are used to predict the duration and associated reversibility of impacts.

The following is an example of definitions for assessing the significance of impacts on the aquatic VCs, and the associated continued opportunity for traditional and non-traditional use of the VCs.

Not significant – impacts are measurable but are not likely to decrease resilience and increase the risk to the persistence of specific fish populations.

Significant – impacts are measurable and likely to decrease resilience and increase the risk to the persistence of specific fish populations. A number of high magnitude and irreversible impacts at the population level would be significant.

These lower and upper bounds on the determination of significance are relatively straightforward to apply. It is the area between these bounds where ecological principles and professional judgment are applied to determine significance.

9.5.7 Uncertainty

Most assessments of effects embody some degree of uncertainty. Section 9.14 includes a discussion of the key sources of uncertainty for each component (e.g., hydrology, water quality). It describes how uncertainty has been addressed to increase the level of confidence that potential effects have not been under-estimated. Confidence in effects analyses can be related to many elements, including the following:

- adequacy of baseline data for understanding existing conditions and future changes unrelated to the Project (e.g., climate change);
- model inputs (e.g., change in chemical concentrations in water over time and space);
- degree to which the models used in the assessment accurately describe the key processes that dominate the functioning of the systems being modelled;

- understanding of Project-related impacts on complex ecosystems that contain interactions across different scales of time and space (e.g., how and why the Project will influence surface hydrology); and
- knowledge of the effectiveness of the environmental design features and mitigation for reducing or removing impacts (e.g., environmental performance of the mine rock management area).

9.5.8 Monitoring and Follow-up

For this key line of inquiry, the monitoring and follow-up is provided in Section 9.15. In this section, monitoring programs will be proposed to deal with the uncertainties associated with the impact predictions and environmental design features and mitigation. In general, monitoring will be used to test (verify) impact predictions and determine the effectiveness of environmental design features and mitigation. To meet the Terms of Reference, the monitoring programs that may be applied during the development of the Project will be distinguished among the following:

- **Compliance inspection**: monitoring the activities, procedures, and programs undertaken to confirm the implementation of approved design standards, mitigation, and conditions of approval and company commitments.
- **Environmental effects monitoring**: monitoring to track conditions or issues during the development lifespan, and subsequent adaptation of Project management.
- **Follow-up**: programs designed to verify the accuracy of impact predictions, to reduce uncertainty, and to determine the effectiveness of mitigation.

These programs will form part of the environmental management system (EMS) for the Project. If monitoring or follow-up detects effects beyond those predicted or the need for improved or modified design features, then adaptive management strategies will be developed and implemented, as required.

9.6 PATHWAY ANALYSIS

9.6.1 Methods

Pathway analysis identifies and assesses the issues and linkages between components or activities associated with the Gahcho Kué Project (Project), and the correspondent potential residual effects on water quality and fish downstream of Kennady Lake. Pathway analysis is a three-step process for identifying and validating linkages between Project activities and environmental effects that are assessed in Sections 9.7 to 9.10. Potential pathways through which the Project could influence water quality and fish downstream of Kennady Lake were identified from a number of sources including:

- potential pathways identified in the *Terms of Reference for the Gahcho Kué Environmental Impact Statement* (Terms of Reference) (Gahcho Kué Panel 2007) and the Report of Environmental Assessment (MVEIRB 2006);
- a review of the Project Description and scoping of potential effects by the environmental assessment and Project engineering teams for the Project; and
- consideration of potential effects identified for the other diamond mines in the Northwest Territories (NWT) and Nunavut.

The first part of the analysis is to produce a list of all potential effects pathways for the Project. This step is followed by a summary of environmental design features and mitigation that can be incorporated into the Project to remove the pathway or limit (mitigate) the effects to water quality and fish downstream of Kennady Lake. Environmental design features include Project designs and environmental best practices, and management policies and procedures. Environmental design features and mitigation practices were developed through an iterative process with the Project design and environmental assessment teams.

Knowledge of the ecological system and environmental design features and mitigation is then applied to each of the pathways to determine the expected amount of Project-related changes to the environment and the associated residual effects (i.e., after mitigation) on water quality and fish downstream of Kennady Lake. For an effect to occur there has to be a source (Project component or activity) and a primary connection (pathway) to water quality and fish downstream of Kennady Lake.

Project activity → change in environment → effect on a valued component (VC)

Pathway analysis is a screening step that is used to determine the existence and magnitude of linkages from the initial list of potential effects pathways for the Project. This screening step is largely a qualitative assessment, and is intended to focus the effects analysis on pathways that require a more comprehensive assessment of effects on water quality and fish downstream of Kennady Lake. Pathways are determined to be primary, secondary (minor), or as having no linkage using scientific and traditional knowledge, logic, and experience with similar developments and environmental design features. Each potential pathway is assessed and described as follows:

- no linkage – pathway is removed by environmental design features and mitigation so that the Project results in no detectable environmental change and residual effects to a VC relative to baseline or guideline values;
- secondary – pathway could result in a measurable and minor environmental change, but would have a negligible residual effect on a VC relative to baseline or guideline values (e.g., an increase in a water quality parameter that is small compared to the range of baseline values and is well within the water quality guideline for that parameter); or
- primary – pathway is likely to result in a measurable environmental change that could contribute to residual effects on a VC relative to baseline or guideline values.

Primary pathways require further effects analysis and impact classification to determine the environmental significance from the Project on the suitability of water quality to support a viable aquatic ecosystem, persistence of desired population(s) of key fish species, continued opportunity for traditional and non-traditional use of water and fish and the protection of human health. Pathways with no linkage to water quality and fish downstream of Kennady Lake or that are considered minor are not analyzed further or classified in Sections 9.7 to 9.11 because environmental design features and mitigation will remove the pathway (no linkage) or residual effects to water quality and fish downstream of Kennady Lake can be determined to be negligible through a simple qualitative evaluation of the pathway (secondary). Pathways determined to have no linkage to water quality and fish downstream of Kennady Lake or those that are considered secondary are not predicted to result in environmentally significant effects to water quality, fish, continued opportunity for traditional and non-traditional use of water and fish, and protection of wildlife and human health. All primary pathways are assessed in Sections 9.7 to 9.10.

The section is organized by Project phase. The pathways for construction and operations are described in Section 9.6.2.1, and the pathways for closure are described in Section 9.6.2.3.

9.6.2 Results

Pathways potentially leading to effects on water quality and fish downstream of Kennady Lake include direct and indirect effects. These changes may ultimately affect the suitability of water quality to support a viable aquatic ecosystem, persistence of desired population(s) of key fish species, continued opportunity for traditional and non-traditional use of water and fish and the protection of human health. Evaluation of effects on water quality and fish downstream of Kennady Lake also considers changes to hydrology, and air quality, and during the construction and operations, and closure phases of the Project, as well as effects remaining after closure. Table 9.6-1 and Table 9.6-4 (found in Section 9.6.2.3) summarize the environmental design features and mitigation that were incorporated into the Project to eliminate or reduce effects to water quality, fish, and fish habitat downstream of Kennady Lake during construction, operations, and closure.

Potential pathways are based primarily on public concerns identified during the Mackenzie Valley Environmental Impact Review Board (MVEIRB) scoping process (MVEIRB 2006), some may not represent actual pathways. The issues are screened and considered for inclusion as pathways for that could lead to effects. Some issues may not represent actual pathways, and in other instances, the preliminary screening and/or analysis may show that potential effects considered during issues scoping are so small that they are not relevant. Other concerns may be screened out through the incorporation of environmental design features and mitigation during the development of the Project, which address these issues by reducing or eliminating potential effects. Other potential pathways may be primary pathways and are included in the effects analysis. The following sections discuss the potential pathways relevant to water quality and fish in Kennady Lake downstream of Kennady Lake.

No pathways were identified for permafrost and hydrogeology. Mining and related infrastructure will be located in the Kennady Lake watershed; therefore, any direct effects on water quality and fish habitat from changes in permafrost and groundwater will occur within the Kennady Lake watershed and have been addressed in Section 8. The potential for effects from these changes downstream of Kennady Lake will be limited to indirect effects through changes in hydrology or water quality.

9.6.2.1 Potential Pathways during Construction and Operations

Potential pathways through which the Project could affect water quality and fish downstream of Kennady Lake during construction and operations were developed based on the pathway analysis for effects on water quality and fish in Kennady Lake (Section 8) as well as the Terms of Reference (Gahcho Kué Panel 2007), and the Report of Environmental Assessment (MVEIRB 2006).

Table 9.6-1 summarizes the potential direct and indirect effects of the Project on the suitability of water quality to support a viable aquatic ecosystem, persistence of desired population(s) of key fish species, continued opportunity for traditional and non-traditional use of water and fish and the protection of human health during construction and operations.

Table 9.6-1 Potential Pathways for Effects to Water Quality and Fish Downstream of Kennady Lake During Construction and Operations

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Project development in the Kennady Lake watershed (e.g., dykes)	• reduction in watershed areas may change flows, water levels, and channel/bank stability in downstream waterbodies, and affect water quality and fish habitat and fish	• compact layout of the surface facilities within the Kennady Lake watershed will limit the area that is disturbed by construction and operation	Primary
Diversion of upper Kennady Lake watersheds to the N lakes watershed	• alteration of watershed flow paths may change flows, water levels, and channel/bank stability in downstream waterbodies, and affect water quality, fish habitat and fish	• areas to be flooded by raising water levels of Lakes A3, D1, D2, and E1 will be surveyed and where necessary, will be prepared to reduce the release of organic material upon flooding • shoreline areas susceptible to extensive erosion will be armoured by cobbles and boulders to reduce erosion and associated resuspension of fine sediments	Primary
	• changes in flow paths from diversions may increase shoreline erosion, re-suspension of sediments and sedimentation in downstream waterbodies, and affect water quality, fish habitat and fish		Primary
	• changes in flow paths may change water quality in the receiving N lakes (i.e., suspended sediments, major ions, metals, and nutrients concentrations), and affect aquatic health and fish		Secondary
Dewatering of Kennady Lake to downstream waterbodies	• erosion of lake-bottom sediments in Lake N11 and Area 8 from pumped discharge may change water quality and fish habitat in downstream waterbodies, and affect fish habitat and fish	• pumped discharge to Lake N11 and Area 8 will be directed through properly designed outfalls/diffusers to prevent erosion	No Linkage
	• dewatering of Kennady Lake to Lake N11 and Area 8 may change flows, water levels, and channel/bank stability in downstream waterbodies, and affect water quality, fish habitat and fish	• pumped discharge to Lake N11 and Area 8 will only occur while water quality discharge criteria are met • discharge from Area 7 to Area 8 is proposed to cease after Year 2, when water levels in Area 7 drop to a level that turbidity levels exceed discharge criteria • pumped discharge will be directed to the lake environment in Lake N11 and Area 8, and not directly to outlets, to attenuate flow changes	Primary

Table 9.6-1 Potential Pathways for Effects to Water Quality and Fish Downstream of Kennady Lake During Construction and Operations (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Dewatering of Kennady Lake to downstream waterbodies (continued)	• dewatering of Kennady Lake to Lake N11 may change water quality (i.e., suspended sediments, major ions, metals, and nutrients concentrations) in downstream waterbodies, and affect aquatic health, and fish habitat and fish	• dewatering activities will be monitored so that the lake surface remains at a level that limits sediments becoming suspended due to wave action. • lake dewatering discharge will be sampled regularly to monitor for compliance with discharge criteria, and any water not meeting the criteria will be stored within the controlled Water Management Pond • pumped discharge flow rates to Lake N11 and Area 8 will be limited to 1-in-2 year flood levels except at outlets where there is sufficient protection, to eliminate erosion concerns. • pumped discharge from Kennady Lake and Area 8 will be sourced from the surface of the lakes	Primary
Use of Area 8 as the potable water supply and additional fire suppression capacity	• impingement and entrainment of fish in intake pumps during dewatering may cause injury and mortality to fish, and affect downstream fish populations	• appropriate sized fish screens following DFO guidelines will be used on the pump intakes to limit fish becoming entrained • covering the intake under rock fill will provide a secondary screen • pumping rates will conform with DFO guideline for intake velocities	Secondary
Pit development in the Kennady Lake watershed	• alteration of groundwater regime with pit development may change surface water levels and water quantity in downstream lakes, and affect fish habitat	• none	Secondary
Construction and Operations Winter Access Road and Tibbitt-to-Contwoyto Winter Road	• deposition of dust and metals from fugitive dust sources (i.e., particulate matter [PM], and total suspended particulates [TSP]) may change water quality and sediment quality in downstream waterbodies, and affect aquatic health, fish habitat, and fish	• regular watering of the exposed lake bottoms, roads, airstrip, and laydown areas will facilitate dust suppression • the compact layout of the surface facilities will limit the area disturbed at construction and reduce traffic around the site • heavy equipment and mine vehicles will undergo regular maintenance of engines, maintain emission guidelines for internal combustion engines and use low-sulphur diesel fuel	Secondary
	• air emission and deposition of sulphur dioxide [SO_2], nitrogen oxides [NO_X], may change water quality in downstream waterbodies, and affect aquatic health and fish		Secondary

Table 9.6-1 Potential Pathways for Effects to Water Quality and Fish Downstream of Kennady Lake During Construction and Operations (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Construction and Operations Winter Access Road and Tibbitt-to-Contwoyto Winter Road (continued)	• increased under-ice noise and vibrations from traffic on the winter road may affect fish	• none	Secondary
	• spills along the ice-road (e.g., petroleum products, reagents, wash-down) may change surface water quality and sediment quality in downstream waterbodies, and affect aquatic health, fish habitat, and fish	• petroleum products will only be handled by Mine personnel who have received appropriate training • an emergency and spill contingency plan will be developed • haulage trucks will be maintained to operational standards and will carry standard emergency clean-up kits	Secondary

PM = particulate matter; TSP = total suspended particulates; SO_2 = sulphur dioxide; NO_x = nitrogen oxides; DFO = Fisheries and Oceans Canada

9.6.2.1.1 Pathways with No Linkage

Erosion of lake-bottom sediments in Lake N11 and Area 8 from pumped discharge may change water quality and fish habitat in downstream waterbodies, and affect fish

The potential for erosion of lake-bottom sediments in Lake N11 and Area 8 will be minimized during the pumped discharge from Kennady Lake. Constructed channel outfalls or diffusers will be used to reduce the erosive energy of water pumped out of Areas 3 and 7 during dewatering. Outfalls will be constructed to diffuse the velocity of the pumped discharge. Diffusers, if required, will be placed as close to the surface as possible over deep regions of Lake N11 and Area 8 to increase the distance between the outfall and the bottom sediments. Although some sediment may be mobilized despite these measures, the extent of this effect is likely to occur primarily in the initial stages of discharge and be limited to the zone of turbulence immediately adjacent to the diffuser. Sediment resuspension is likely to quickly diminish after sediments in the zone of turbulence are mobilized and become re-deposited farther away from the outfall.

As a result, discharge of water from Kennady Lake to Lake N11 and Area 8 during dewatering is not expected to result in measurable changes to the lake bed in either lake. Consequently, this pathway was determined to have no linkage to effects to water and sediment quality, fish habitat and fish.

Discharge of Kennady Lake to Lake N11 and Area 8 may change the seasonal water temperature regime in downstream waterbodies, and affect fish habitat and fish

Discharge of Kennady Lake water to Lake N11 and Area 8 during dewatering will not alter stream temperatures in lakes within the N or L watersheds because pumped discharge from the surface of Kennady Lake is expected to be similar to the receiving lakes. Kennady Lake is generally well-mixed and only becomes thermally stratified in the deepest portions of the lake in late summer the majority of the lake is completely mixed and isothermal throughout the open water season. These physical characteristics are consistent with Lake N11 and Area 8.

It is anticipated that the upper 2 to 3 metres (m) of water will be removed from Kennady Lake during the initial dewatering phase, with the extent of pumped discharge from Area 3 to Lake N11 during operations occurring as required. Pumped discharge to Area 8 will only occur during construction to reduce the water level in Area 7.

As a result, discharge of water from Kennady Lake to Lake N11 and Area 8 during dewatering is not expected to result in measurable changes to surface water temperatures in Lake N11 of lakes in the L watershed. Consequently, this pathway was determined to have no linkage to effects to water and sediment quality, fish habitat and fish.

9.6.2.1.2 Secondary Pathways

Changes in flow paths may change water quality and fish habitat in the receiving N lakes (i.e., suspended sediments, major ions, metals, and nutrients concentrations), and affect aquatic health and fish

The change in flow paths from the raised and diverted lakes in the A, B, D, and E watersheds of Kennady Lake to lakes in the N watershed may lead to potential changes to water quality and fish habitat within the receiving lakes of the N watershed. Flows from the diverted lakes to the N lakes will not be immediate; the time required to fill the lakes is predicted to take between one year (i.e., Lakes B1 and E1) and eleven years (i.e., Lake A3 is predicted to fill in the final year of operations); Lakes D2 and D3 will take three years to fill.

Flows from the raised lakes to the N watershed will occur over natural drainage courses based on topographic lows between the lakes or require construction of diversion channels to connect the lakes. Natural drainage courses will be surveyed, and if required, armoured to limit potential for erosion, and to provide fish passage and spawning habitat between the re-aligned lakes. Where channel construction is required, channel design considering flow mitigation and fish habitat will be referenced from other northern mining experiences (e.g., Ekati Diamond Mine [Jones et al. 2003a]).

Channel armouring and diversion channel construction will be timed to occur prior the water levels of the lakes reaching a height in which flows commence to the N lakes watershed. Physical disturbance along the natural flow paths associated with construction or stabilizing works will be minimized to reduce the potential for erosion and resulting elevated suspended sediment concentrations once flows eventuate. Construction activities will be avoided during the spring freshet when the potential for erosion is highest.

Changes in water quality in the raised A3, D2 and D3, and E1 lakes due to the flooding of riparian habitat around the lakes are expected to be minor relative to background conditions. These changes are anticipated to be temporary and may be associated with elevated nutrients and metals concentrations from the flooding of organic material (e.g., vegetation). Where necessary, preparation of the areas to be flooded, armouring of lake margins that may be prone to erosional processes, and on-going monitoring will be conducted.

The diversion of the A, B, D, and E watersheds are not expected to change migration patterns of fish in the N watershed, such that populations of fish are negatively affected. During baseline sampling, northern pike have not been captured in lakes and streams in the N watershed, although they are present in Kennady Lake and downstream to Lake 410; therefore, it appears that northern pike are absent from the N watershed, or are present in extremely low numbers. As a result of the diversions, it will be possible for northern pike from Kennady Lake to move into the upper part of the N watershed, where suitable spawning and rearing habitat exists in shallow bays of downstream lakes. It should be noted, however, that the lower part of the N watershed is already well connected to Lake 410 (i.e., Lake N16 is about 15 km upstream from Lake 410) and northern pike have not taken advantage of this connection to disperse into the N watershed. Although habitat conditions in the Kennady and N watersheds are generally similar, differences in the abundance and distribution of aquatic vegetation may have contributed to the apparent difference in northern pike use of the two watersheds. As such, the probability of northern pike dispersing into the N watershed via the proposed diversion channel in the upper part of the N watershed (i.e., from D and E watersheds to Lake N14) is expected to be low, and no substantial changes to the resident fish communities in the N watershed are anticipated.

As a result of the mitigation associated with the diversion of the upper Kennady Lake watershed lakes to the receiving N lakes, changes to water and sediment quality and fish habitat in the N lakes is expected to be minor. Residual effects to fish in the receiving lakes in the N watershed are predicted to be negligible.

Impingement and entrainment of fish in potable water intake pumps in Area 8 may cause injury and mortality to fish and affect downstream fish populations

The freshwater intake and pumphouse will be located on the northwestern shore of Area 8. The intake will consist of vertical filtration wells fitted with vertical turbine pumps that supply water on demand. The intake will be connected to the pumphouse with piping buried under a rock-filled embankment (Section 3).

The installation of fish screens on the intake and a buried intake under rock fill is anticipated to reduce fish mortality resulting from impingement or entrainment. The overlaid embankment will act as a secondary filtration screen, which will prevent fish from becoming entrained. Any mortality of small species and young life stages from impingement or entrainment would be limited to a localized area and will have a negligible influence on downstream fish populations. Therefore, residual effects to fish from the pumping of potable water from Area 8 are predicted to be negligible.

Alteration of groundwater regime with pit development may change surface water levels and water quantity in downstream lakes, and affect fish habitat

Dewatering of the Kennady Lake bed and mine pits will induce groundwater to flow toward the open pits from all directions. The reduced groundwater pressures in the deep groundwater flow system will cause a small volume of water to flow from Lakes X4 and X6 toward the pit. Lakes X4 and X6 are located outside of the Kennady Lake watershed, but are the most hydraulically connected to groundwater below Kennady Lake due to their elevation and proximity. Changes in groundwater discharges to other lakes within the LSA that are hydraulically connected to the deep groundwater through fully penetrating taliks are predicted to be less than those in these two lakes due to their smaller size. The maximum reduction lake volume for Lakes X4 and X6 through groundwater flows due to dewatering and pit development is predicted to be in the order of 100 cubic metres per day (m^3/d). The net precipitation to the lake surfaces of X4 and X6 Lakes only, not including the rest of the catchment, is in the order of 2,400 m^3/d. Climatic inputs to the area therefore vastly overwhelm the magnitude of this change to lake volume.

Altered groundwater flows are anticipated in large lakes within the LSA surrounding the pit development in the Kennady Lake watershed, but measureable changes to water quantity and water levels in these lakes are expected to be minor. Therefore, changes to fish habitat will be small. This pathway was determined to have negligible residual effects to fish.

Deposition of dust and metals from fugitive dust sources may change water quality and sediment quality in downstream waterbodies, and affect aquatic health, fish habitat, and fish

Analysis of metals deposition in waterbodies in, and adjacent to, the Kennady Lake watershed from air emissions concluded that the incremental changes in metals concentrations were limited to lakes within 2 kilometres (km) of the Project boundary (Section 8.8.3; Section 11.4 Subject of Note: Air Quality). Deposition rates of dust and metals to watersheds beyond 2 km from the Kennady Lake watershed are markedly reduced, which will result in minor changes to water and sediment quality in the adjacent lakes. Consequently, residual effects to fish are expected to be negligible.

Air emission and deposition of sulphur dioxide [SO_2] and nitrogen oxides [NO_X] may change water quality in downstream waterbodies, and affect aquatic health and fish

Analysis of acidifying air emission deposition in waterbodies in, and adjacent to, the Kennady Lake watershed from air emissions concluded that the critical loads in the downstream waterbodies were sufficient to buffer any potential effects from SO_2 and NO_X deposition (Section 8.8.3; Section 11.4 Subject of Note: Air Quality). Consequently, acidifying changes to water quality as a result of the deposition of SO_X and NO_X are not expected to result in acidic lake conditions, and therefore residual effects to fish in these downstream waterbodies are expected to be negligible.

Increased under-ice noise and vibrations from traffic on the winter road may affect fish

Trucks travelling on winter roads can cause increased noise levels on lakes. The level at which fish can detect sounds depends on the background noise (Stewart 2001). Fish have been documented to show an avoidance reaction to vessels when the radiated noise levels exceed their threshold of hearing by 30 decibels (dB) or more (ICES 1995). Many factors, including the presence of predators or prey, seasonal or daily variations in physiology, and spawning or migratory activities can make them more or less sensitive to unfamiliar sounds (Schwartz 1985; ICES 1995). Mann et al. (2009) found that anthropogenic (man-made) noise (e.g., helicopters, ice-road traffic) raised ambient sound levels by approximately 30 dB; however, this was within the range of natural ambient noise in the lake. Most of the anthropogenic sounds measured were considered to be only detectable by fish species with specialized hearing adaptations, such as lake chub (*Couesius plumbeus*) and suckers (*Catostomidae*) (Mann et al. 2007; Mann et al. 2009).

The low level of truck traffic noise on winter roads on frozen lakes will have a negligible effect on fish because the noise will be intermittent and sound propagation is limited under ice in shallow water. Fish will also have the ability to move away from the noise; any movements would be expected to within their normal daily or day-to-day range. Traffic activity on the winter road is anticipated to cause under-ice noise and vibrations that will be localized and temporary. As such, disturbances from vehicle activity on the winter road are expected to have negligible residual effects on fish.

Spills along the ice-road (e.g., petroleum products, reagents, wash-down) may change water and sediment quality in the downstream waterbodies, and affect aquatic health, fish habitat and fish

Spills along the ice road can adversely affect surface water quality and fish and fish habitat. Spills are usually localized, and will be quickly reported and managed. Mitigation identified in the Emergency Response and Spill Contingency Plan (Section 3, Appendix 3.I, Attachment 3.I.1) for haulage traffic along the ice-road (e.g., spill kits, specialized containers for transport) will be in place to limit the frequency and extent of any spills that result from trucks. Spill response kits will be carried by each haulage truck to address minor fuel and chemical spillage.

Drivers will be trained by their employer in the transportation of dangerous goods, and domestic and recyclable waste dangerous goods will be transported in appropriate storage containers. Storage containers used for haulage of hazardous substances and waste dangerous goods will meet regulatory requirements and will be designed to protect the environment and workers from exposure.

The implementation of emergency response and contingency plans, environmental design features and monitoring programs would minimize any potential effects to water quality and fish habitat. Therefore, this pathway was determined to have negligible residual effects to fish....

9.6.2.2 Primary Pathways for Effects from Construction and Operations

The remaining pathways for water quality and fish downstream of Kennady Lake and its watershed are classified as primary (listed below) and are carried forward as effects statements (Table 9.6-3) to be assessed in the effects analysis sections (Sections 9.7 to 9.11). Potential effects related to permafrost and hydrogeology were determined to possess no linkage or be secondary pathways. Therefore, no pathways related to these disciplines will be carried forward in this key line of inquiry. However, further assessment of Project effects to permafrost, hydrogeology and groundwater is included in the Subject of Note: Permafrost, Groundwater, and Hydrogeology (Section 11.6).

9.6.2.3 Potential Pathways during Closure

Pathways for effects to water quality and fish in downstream waters during closure include direct impacts to fish and fish habitat (e.g., alteration of flows during the refilling of Kennady Lake in the N lakes watershed and downstream of Area 8), and indirect effects to fish through changes in water quality (e.g., change in concentrations of metals or nutrients in lakes downstream of Area 8 when Dyke A is breached) (Table 9.6-4). The effects of the Project on fish populations downstream of Kennady Lake after Areas 3 to 7 are reconnected to Area 8 are addressed in this section.

Potential pathways through which the Project could affect water quality and fish downstream of Kennady Lake during closure were developed based on the pathway analysis for effects on water quality and fish in Kennady Lake (Section 8), as well as the *Terms of Reference for the Gahcho Kué Environmental Impact Statement* (Gahcho Kué Panel 2007) and the Gahcho Kué Report of Environmental Assessment (MVEIRB 2006). An overview of major pathways is provided below in Table 9.6-4 and detailed lists of pathways are provided in Section 9.6.2.4.

Table 9.6-3 Effects Statements for Water Quality and Fish during Construction and Operations

Discipline	Project Activity	Pathway	Effects Statement
Hydrology	Project development in the Kennady Lake watershed (e.g., dykes)	reduction in watershed areas of Kennady Lake may change flows, water levels, and channel/bank stability in streams and lakes in downstream watersheds	Effects of Project infrastructure in Kennady Lake watershed to flows, water levels and channel/bank stability in streams and lakes in downstream waters
	Diversion of upper Kennady Lake watersheds to the N lakes watershed	alteration of watershed flow paths may change flows, water levels, and channel/bank stability in streams and lakes in downstream watersheds	Effects of watershed diversions in watersheds A, B, D, and E to flows, water levels and channel/bank stability in streams and lakes in the N lakes watershed
		changes in flow paths from diversions may increase shoreline erosion, re-suspension of sediments and sedimentation in downstream waterbodies	
	Dewatering of Kennady Lake to downstream waterbodies	dewatering of Kennady Lake to Lake N11 and Area 8 may change flows, water levels, and channel/bank stability in downstream waterbodies	Effects of dewatering Kennady Lake to flows, water levels and channel/bank stability in downstream waters
Water Quality	Dewatering of Kennady Lake to downstream waterbodies	dewatering of Kennady Lake to Lake N11 may change water quality (i.e., suspended sediments, major ions, metals, and nutrients concentrations) in downstream waterbodies	Effects of dewatering Kennady Lake to Lake N11 to water quality in downstream waters
Aquatic Health	Dewatering of Kennady Lake to downstream waterbodies	dewatering of Kennady Lake to Lake N11 may change aquatic health in downstream waterbodies	Effects of dewatering Kennady Lake to Lake N11 to aquatic health in downstream waters
Fish and Fish Habitat	Dewatering of Kennady Lake to downstream waterbodies	dewatering of Kennady Lake to Lake N11 and Area 8 may result in changes to flows, alteration of water levels and lake areas, channel/shoreline erosion, and changes to lower trophic levels, fish habitat and behaviour in downstream waterbodies	Effects of Project construction and operations activities to fish and fish habitat in streams and lakes of the N lakes watershed and downstream of Kennady Lake
		water management during operations may result in changes to flows, alteration of water levels and lake areas, channel/shoreline erosion, and changes to lower trophic levels, fish habitat and behavior in downstream waterbodies	
		changes to nutrient levels in N watershed may result in changes to lower trophic communities and fish and fish habitat in downstream waterbodies	

Table 9.6-4 Potential Pathways for Downstream Effects to Water Quality and Fish during Closure

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
Removal and reclamation of Project infrastructure	• removal of project infrastructure (e.g., roads, airstrip, dykes, buildings) may change flows, water levels, and channel/bank stability in downstream waterbodies, and affect water quality, fish habitat and fish	• to the extent possible, all disturbed areas will be reclaimed and the surface stabilized • surfaces will be re-graded and, as appropriate, till or mine rock will be used as a cover layer to prevent dusting and water erosion, and stabilizing, as required, against thermokarst from freeze-thaw processes within the active layer • drainage patterns will be re-established as close to pre-operational conditions as possible, with drainage ditches contoured or backfilled as appropriate to remove any hazards to wildlife	No Linkage
	• seepage from mine rock and PK storage repositories, and the open Tuzo Pit may change water quality in Kennady Lake, and affect water quality in downstream waterbodies, aquatic health, and fish habitat and fish		Primary
	• reclaimed project area may result in long-term changes to hydrology, water quality, aquatic health and fish in downstream waters	• closure and reclamation plan for the site, including removal of all buildings and infrastructure, realigning diverted upper watersheds B, D , and E, grading storage mine rock and PK storage repositories to manage drainage, using mine rock and till (overburden) to cover disturbed lands and storage repositories	Primary
Removal of diversions in B, D, and E watersheds	• realignment of flow paths in the B, D, and E watersheds may change flows, water levels, and channel/bank stability in streams and lakes in the N lakes watershed, and affect water quality, fish habitat and fish	• the realignment of the B, D and E watersheds will return the watershed flows to their pre-development condition • the diverted lakes, once the dykes are removed, will flow through existing channels to Kennady Lake	No Linkage
	• changes to fish behaviour and migration in N watershed	• streams from the diverted lakes, once the dykes are removed, will flow through existing channels to Kennady Lake	Primary
Permanent diversion in the A watershed	• Continuing and permanent diversion of Lake A3 to the N watershed may change flows, water levels, and channel/bank stability in streams and lakes in the N lakes watershed, and affect water quality, fish habitat and fish	• The permanent diversion channel will be sized and designed with rock armour to limit erosion to natural rates	Primary
Refilling of Kennady Lake	• pumping from Lake N11 for refilling Areas 3 to 7 may change flows, water levels, and channel/bank stability in streams and lakes in the N watershed, and affect water quality, fish habitat and fish	• the volume of water that will be withdrawn from Lake N11 will be limited based on annual flows to avoid creating effects to fish and fish habitat downstream due to changes in lake levels or stream flows	Primary

Table 9.6-4 Potential Pathways for Downstream Effects to Water Quality and Fish during Closure (continued)

Project Component/Activity	Effects Pathways	Environmental Design Features and Mitigation	Pathway Assessment
	• impingement and entrainment of fish in intake pumps in Lake N11 may cause injury and mortality to fish, and affect fish populations	• the water intake in Lake N11 will be designed and located within a rock structure to avoid the need for screens • pumping rates will conform with DFO guideline for intake velocities	Secondary
	• continued isolation of Area 8 during refilling and recovery period may change flows, water levels, and channel/bank stability in streams and lakes downstream of Kennady Lake, and affect water quality, fish habitat and fish	• none	Primary
Breaching and Removal of Dyke A to reconnect Kennady Lake with downstream watersheds	• alteration of flows may change water levels, and channel/bank stability in streams and lakes in streams and lakes downstream of Area 8 after reconnection with Kennady Lake, and affect fish habitat and fish	• none	Primary
	• reconnection of Kennady Lake with Area 8 may increase shoreline erosion, re-suspension of sediments and sedimentation in downstream waterbodies	• silt curtains will be placed upstream and downstream of the construction area to control the release of suspended sediments	No Linkage
	• reconnection of Kennady Lake with Area 8 may change the water quality of downstream waterbodies, and affect aquatic health and fish	• Dyke A will not be removed from between Area 7 and 8 unless the water quality of Areas 3 through 7 of Kennady Lake meets specific criteria	Primary

PK = processed kimberlite

9.6.2.3.1 No Linkage Pathways

Removal of project infrastructure (e.g., roads, airstrip, dykes, buildings) may change flows, water levels, and channel/bank stability in downstream waterbodies, and affect water quality, fish habitat and fish

Project surface infrastructure in watersheds downstream of Kennady Lake will be decommissioned during closure, including breaching of dykes and restoration of pre-existing flow patterns (including removing culverts and restoring open channels at road crossings. Restoration of baseline flows and water levels to natural or reconstructed channels is not expected to affect channel/bank stability in downstream waterbodies. Consequently, this pathway was determined to have no linkage to effects to water quality and fish.

Realignment of flow paths in the B, D, and E watersheds may change flows, water levels, and channel/bank stability in streams and lakes in the N lakes watershed and affect water quality, fish habitat and fish

Decommissioning of temporary diversions from Lake B1 to Lake N8, from Lakes D2 and D3 to Lake N14, and from Lake E1 to Lake N14, will restore flow and water level regimes in those lakes and downstream waterbodies to baseline. This reduction in flow is not expected to have any effect on channel/bank stability in downstream waterbodies. Consequently, this pathway was determined to have no linkage to effects to water and sediment quality, fish habitat and fish.

Reconnection of Kennady Lake with Area 8 may increase shoreline erosion, re-suspension of sediments and sedimentation in downstream waterbodies and affect fish habitat and fish

When Kennady Lake and Area 8 are reconnected, water levels in Area 8 will increase slightly from the operations and closure period, i.e., an annual average water level increase of approximately 0.08 m. This predicted water level in the post-closure phase is approximately 0.03 m below baseline conditions, due to changes in Kennady Lake and the A sub-watershed. This minor change in water level is within the natural variability of the Area 8.

During the removal of Dyke A, suspended sediment concentrations in Area 8 and the refilled areas of Kennady Lake will be minimized by the use of silt curtains. Using appropriate design criteria, silt curtains would be installed upstream and downstream of the dyke before breaching Dyke A, and would be maintained until the entire dyke is removed and habitat underneath the dyke has been replaced. With this environmental design feature in place, sediment re-suspension and sedimentation in Areas 7 and 8 are anticipated to result in minor changes to water quality and fish habitat, which will be localized and temporary.

Changes to water level and resuspension of sediments associated with the reconnection of Kennady Lake to Area 8 are not expected to be measureable in lakes within the L watershed downstream of the outlet of Area 8 (i.e., Stream K5). As such, residual effects to fish in waters downstream of Area 8 will be negligible.

9.6.2.3.2 Secondary Pathways

Impingement and entrainment of fish in intake pumps in Lake N11 may cause injury and mortality to fish

During the pumping of water from Lake N11 to Kennady Lake, to augment natural refilling, it is expected that some fish could become impinged or entrained in the intake pump. The intake pumps used for providing supplemental water for refilling Kennady Lake will be appropriately screened to meet federal requirements to prevent fish entrainment or impingement (DFO 1995). The appropriate screen mesh size will be determined in consultation with DFO for the planned pumping rates to prevent fish from entering the pump during dewatering. This includes the determination of a maximum approach velocity for water at the screen surface to prevent fish from being entrained or impinged on the screen. The intake screen mesh size and dimensions will be influenced by the species found within Lake N11, as well as the swimming abilities of these species and the likely age classes of fish present at the water withdrawal location. Fish species captured in Lake N11 include burbot (*Lota lota*), lake chub (*Couesius plumbeus*), ninespine stickleback (*Pungitius pungitius*) and slimy sculpin (*Cottus cognatus*). The screens will also be regularly maintained throughout the pumping period.

The screening and maintenance of intake pumps is expected to reduce fish mortality in Lake N11 resulting from impingement or entrainment. Furthermore, the mortality of small fish species and young life stages are anticipated to be limited to a localized area. Therefore, residual effects to fish from the pumping from Lake N11 are predicted to be negligible.

9.6.2.4 Primary Pathways for Effects from Closure

The remaining pathways for downstream water effects during closure are classified as primary and are carried forward as effects statements in (Table 9.6-5) to be assessed in the impact analysis sections (Sections 9.7 to 9.11).

Table 9.6-5 Effects Statements for Water Quality and Fish during Closure

Discipline	Project Activity	Pathway	Effects Statement
Hydrology	Refilling of Kennady Lake	pumping from Lake N11 for refilling Areas 3 to 7 may change flows, water levels, and channel/bank stability in streams and lakes in the N watershed	Effects of pumping supplemental flows from Lake N11 to Kennady Lake during refilling to flows, water levels, and channel/bank stability in streams and lakes in the N watershed
	Permanent diversion of the A watershed	changes in watershed areas and flow paths, resulting in alteration of flows, water levels and channel/bank stability in downstream waterbodies (Lakes N9, N6, N2) during and after closure	Effects of watershed diversions in watershed A to flows, water levels and channel/bank stability in streams and lakes in the N lakes watershed
	Removal and reclamation of Project infrastructure	Reclaimed project area may result in long-term changes to hydrology to downstream watersheds	Effects of the Project to long-term hydrology downstream of Area 8
	Breaching and Removal of Dyke A to reconnect Kennady Lake with downstream watersheds	reconnection of Kennady Lake with Area 8 may increase shoreline erosion, re-suspension of sediments and sedimentation in downstream waterbodies	
Water Quality	Removal and reclamation of Project infrastructure	seepage from mine rock and PK storage repositories, and the open Tuzo pit may change water quality in Kennady Lake, and affect water quality in downstream waterbodies	Effects of Project activities to water quality in downstream waters
		Reclaimed project area may result in long-term changes to water quality in downstream watersheds	
	Breaching and Removal of Dyke A to reconnect Kennady Lake with downstream watersheds	reconnection of Kennady Lake with Area 8 may change the water quality of downstream waterbodies	
Aquatic Health	Removal and reclamation of Project infrastructure	seepage from mine rock and PK storage repositories, and the open Tuzo pit may change water quality in Kennady Lake, and affect water quality in downstream waterbodies, aquatic health, and fish and fish habitat	Effects of Project activities to aquatic health in downstream waters
		reclaimed project area may result in long-term changes to aquatic health in downstream watersheds	
	Breaching and Removal of Dyke A to reconnect Kennady Lake with downstream watersheds	reconnection of Kennady Lake with Area 8 may change the aquatic health of downstream waterbodies	

Table 9.6-5Effects Statements for Water Quality and Fish during Closure (continued)

Discipline	Project Activity	Pathway	Effects Statement
Fish	Removal of diversions in B, D, and E watersheds	removal of diversions may result in changes to flows, alteration of water levels and lake areas, channel/shoreline erosion, and changes to lower trophic levels, fish habitat, fish behaviour and migration in the N watershed	Effects of Project closure and post-closure activities to fish and fish habitat in streams and lakes of the N lakes watershed and downstream of Kennady Lake
	Breaching and Removal of Dyke A to reconnect Kennady Lake with downstream watersheds	water management during closure and post-closure may result in changes to flows, alteration of water levels and lake areas, channel/shoreline erosion, and changes to lower trophic levels, fish habitat, fish behavior and migration in downstream waterbodies	
		changes to water quality (e.g., nutrient levels) may result in changes to lower trophic communities and fish and fish habitat in downstream waterbodies	
		changes to aquatic health may affect fish populations and abundance	

9.7 EFFECTS TO WATER QUANTITY

The pathway analysis presented in Section 9.6 considered potential effects to hydrology in the lakes and streams downstream of the Kennady Lake watershed. A summary of the valid pathways by which changes to water quantity could occur in the downstream waterbodies during construction and operation is presented in Table 9.7-1, and during closure in Table 9.7-2.

Section 9.7.1 provides an overview of the methodology used to develop the hydrology predictions in the lakes and streams downstream of the Kennady Lake watershed during construction and operation, followed by a discussion of the results of the effects analysis in Section 9.7.3.

Section 9.7.2 provides an overview of the methodology used to develop the hydrology predictions in the downstream waterbodies during closure, followed by discussion of effects analysis results in Section 9.7.4.

Table 9.7-1 Valid Pathways for Effects to Water Quantity in Kennady Lake Watershed during Construction and Operation

Project Activity	Pathway	Effects Statement	Effects Addressed
Dewatering of Kennady Lake to downstream waterbodies	dewatering of Kennady Lake to Lake N11 and Area 8 may change flows, water levels, and channel/bank stability in downstream waterbodies	Effects of dewatering Kennady Lake to flows, water levels and channel/bank stability in downstream waters	Section 9.7.3.1
Diversion of upper Kennady Lake watershed to the N lakes watershed	alteration of watershed flow paths may change flows, water levels, and channel/bank stability in streams and lakes in downstream watersheds	Effects of watershed diversions in watersheds A, B, D, and E to flows, water levels and channel/bank stability in streams and lakes in the N lakes watershed	Section 9.7.3.2
	changes in flow paths from diversions may increase shoreline erosion, re-suspension of sediments and sedimentation in downstream waterbodies		
Project development in the Kennady Lake watershed (i.e., Kennady Lake closed-circuiting)	reduction in watershed areas of Kennady Lake may change flows, water levels, and channel/bank stability in streams and lakes in downstream watersheds	Effects of Project infrastructure in Kennady Lake watershed to flows, water levels and channel/bank stability in streams and lakes in downstream waters	Section 9.7.3.3

Table 9.7-2 Valid Pathways for Effects to Water Quantity in Kennady Lake Watershed during Closure

Project Activity	Pathway	Effects Statement	Effects Addressed
Refilling of Kennady Lake	pumping from Lake N11 for refilling Areas 3 to 7 may change flows, water levels, and channel/bank stability in streams and lakes in the N watershed	Effects of pumping supplemental flows from Lake N11 to Kennady Lake during refilling to flows, water levels, and channel/bank stability in streams and lakes in the N watershed	Section 9.7.4.1
Permanent Diversion in the A watershed	changes in watershed areas and flow paths, resulting in alteration of flows, water levels and channel/bank stability in downstream waterbodies (Lakes N9, N6, N2) during and after closure	Effects of watershed diversions in watershed A to flows, water levels and channel/bank stability in streams and lakes in the N lakes watershed	Section 9.7.4.2
Removal and reclamation of Project infrastructure, including breaching and removal of Dyke A to reconnect Kennady lake with downstream watersheds	reclaimed project may result in long-term changes to hydrology to downstream watersheds reconnection of Kennady Lake with Area 8 may increase shoreline erosion, resuspension of sediments and sedimentation in downstream waterbodies	Effects of the Project to long-term hydrology downstream of Area 8	Section 9.7.4.3

9.7.1 Effects Analysis Methods – Construction and Operation

9.7.1.1 Water Balance Model

The baseline water balance model described in Annex H, Climate and Hydrology Baseline, was modified to represent changes to Kennady Lake and downstream watersheds. The model was set up using GoldSim™ software on a daily time step for the period of 1950 to 2005. This time period was selected to allow for the use of the long term climate data derived for the site. The Kennady Lake watershed was divided into sub-watersheds including Kennady Lake, its tributaries and land area adjacent the lake. Downstream and adjacent watersheds L, M, N, Lake 410, P and Kirk Lake were also divided into sub-watersheds.

The water balance for each sub-watershed considered rainfall and snowmelt runoff, inflow from upstream watersheds, changes in lake storage, lake evaporation, and discharge to downstream watersheds. The model incorporated runoff coefficients from land surfaces, lake outlet stage-discharge rating curves, and degree-day models for snowmelt and spring ice melt in outlet channels. These parameters were used to calibrate the model using site-specific data collected in 2004 and 2005.

The baseline water balance model described in Annex H was modified to model the effects on Kennady Lake during construction and operations. The following changes were made to the water balance model:

- Areas 2, 3, 4, 5, 6, and 7 were isolated from Area 8 of Kennady Lake, due to the presence of Dyke A during construction and operations;
- runoff from the A watershed, upstream of the Lake A3 outlet, was permanently diverted out of the Kennady Lake watershed due to the presence of Dyke C during Operations;
- the A watershed, in Area 1 downstream of the Lake A3 outlet, was treated as land area due to the establishment of the Fine PKC Facility during Operations;
- runoff from the B watershed was diverted out of the Kennady Lake watershed due to the presence of temporary Dyke E during Operations;
- runoff from the D watershed, upstream of the Lake D2 outlet, was diverted out of the Kennady Lake watershed due to the presence of temporary Dyke F during Operations; and
- runoff from the E watershed, upstream of the Lake E1 outlet, was diverted out of the Kennady Lake watershed due to the presence of temporary Dyke G during Operations.

During construction, dewatering will discharge approximately half the volume in Areas 2, 3, 4, 5, 6, and 7 of Kennady Lake to Lake N11, and to Area 8 of Kennady Lake. Dewatering discharges to Area 8 will be managed to prevent downstream erosion or geomorphological changes. The Dewatering model was set up such that:

- pumping began on June 1 of each year;
- the pumping rate was limited to ensure that the total of natural and diverted discharge will not exceed the 2-year (median) maximum daily flow rate at Area 8 (135,000 cubic metres per day [m^3/d]) and will not exceed 500,000 m^3/d at the Lake N11 outlet, and that no pumping occurred when natural flows exceeded that rate;

- water was pumped from Kennady Lake Areas 2, 3, 4, 5, 6, and 7 until half the initial volume remains (about 17.6 million cubic metres [Mm^3]); and
- runoff from Kennady Lake Areas 2, 3, 4, 5, 6, and 7 and their tributaries was accounted for in the model.

During Operations, Areas 2, 3, 4, 5, 6, and 7 of Kennady Lake will continue to be separated from Area 8, and the volume remaining in Kennady Lake will be kept constant by pumping any excess capacity in the Water Management Pond (WMP, Areas 3 and 5) to Lake N11, subject to the same discharge limits. Inflows to Area 8 will be limited to natural runoff from its adjacent watersheds (i.e., Ke, H, I and J watersheds).

Also during operations, several Kennady Lake tributaries will be diverted to the N watershed, and these diversions are considered in the water balance model. Lake A3 will be diverted to Lake N9, Lake B1 will be diverted to Lake N8, and lakes D2, D3 and E1 will be diverted to Lake N14.

9.7.1.2 Analysis

The time series of flows for representative conditions were subject to frequency analysis at key nodes, including the outlets of lakes N14, N17, N16, N11, N9, N6, N2, N1, L1, M1, 410, and Kirk Lake to determine median flows and those for 10- and 100-year wet and dry conditions. Values were calculated for monthly mean daily discharge volumes, as well as representative flows including 1-, 7-, and 14-day peak flows and 30-, 60-, and 90-day low flows. Corresponding water levels, presented as stages above the zero flow level, were also calculated. These simulated discharges and water levels are presented in figures and tables.

The frequency analysis used to characterize discharge and water level regimes was based on 56 years of data and was used to estimate values up to the 100-year return period. In general, this avoids the danger of extrapolating characteristics of a short data set to estimate extreme events. However, in some instances, estimates of extreme wet values are influenced by the presence of zero-discharge months in dry years, or by the effects of water management activities that have a greater influence on dry year flows.

Changes to lakes may affect the quantity, rate and timing of discharge to downstream watersheds. It must be noted that percent changes to discharge may produce different changes to water level from lake to lake, because each lake's water level regime depends on both discharge and the stage-discharge rating curve at the lake outlet.

Effects on channel and bank stability were evaluated qualitatively, except for the Lake N11 outlet, where the sum of natural and diverted flows may exceed the 2-year flood discharge. At this outlet, a detailed site survey was done to identify bed and bank materials and a flow model was constructed to derive flow depths and velocities at cross-sections on intervals of 10 metres (m). These were compared against rock sizing criteria for bank protection to evaluate erosion resistance.

9.7.2 Effects Analysis Methods – Closure and Post-closure

9.7.2.1 Water Balance Model

The baseline water balance model described in Annex H, Climate and Hydrology Baseline, was modified to represent changes to the Kennady Lake and downstream watersheds during closure and refilling. The model was set up using GoldSim™ software on a daily time step for the period of 1950 to 2005. This time period was selected to allow use of the long term climate data derived for the site. The Kennady Lake watershed was divided into sub-watersheds including Kennady Lake, its tributaries and land area adjacent the lake. Downstream and adjacent watersheds L, M, N, Lake 410, P and Kirk Lake were also divided into sub-watersheds.

The water balance for each sub-watershed considered rainfall and snowmelt runoff, inflow from upstream watersheds, changes in lake storage, lake evaporation, and discharge to downstream watersheds. The model incorporated runoff coefficients from land surfaces, lake outlet stage-discharge rating curves and degree-day models for snowmelt and spring ice melt in outlet channels. These parameters were used to calibrate the model using site-specific data collected in 2004 and 2005.

To model the effects on Kennady Lake and downstream watersheds at closure, the following changes were made to the water balance model:

- Areas 2, 3, 4, 5, 6, and 7 were isolated from Area 8 of Kennady Lake; and
- operational diversions of watersheds B, D and E were removed and their runoff to Areas 3 to 7 of Kennady Lake was restored.

The refilling scenario that was modeled involved refilling Kennady Lake with runoff from the reconnected Kennady Lake watershed with supplemental diversion from Lake N11 to Area 3 to reduce the refill time.

The refilling approach involved diverting water from Lake N11 to refill Kennady Lake, while leaving enough flow to prevent adverse downstream effects in the N watershed (i.e., Lake N11). The diversion criterion was to allow flow to be diverted for refilling while maintaining a minimum Lake N11 discharge equal to the 5-year dry flow condition (refer to Section 9.7.4). The model was set up as follows:

- diversion occurred within a 6-week period centred in June and July;
- if the annual flow from Lake N11 was greater than the 5-year dry flow, the difference in volume was diverted over the 6-week period; and
- if the annual flow was less than the 5-year dry flow, no water was diverted.

During Closure, operational diversions of Lakes B1, D2, D3 and E1 will be decommissioned and removed, and only the Lake A3 diversion to the N9 watershed will be remain as a permanent feature of the landscape.

9.7.2.2 Monte Carlo Simulation

The water balance model was used in conjunction with a Monte Carlo simulation to develop probability-based estimates of the refill times for each of the two scenarios. Output from the water balance model was used to develop probability distributions that generate inflows into the Monte Carlo simulation. These outputs included annual water yield from Lake N11 and the Areas 3 to 7 of Kennady Lake. Refilling was modelled in stages that considered pit and lake refilling.

Annual water yields at Kennady Lake and Lake N11 were arranged statistically in bins, showing that each data set was normally distributed (normal distribution using a mean and a standard deviation). Statistical parameters were approximated in Microsoft Excel. The normal distributions both fit the data well and were available for use with the GoldSim software used for the water balance model.

The Monte Carlo simulation was performed for the Base Case scenario as well as for the No Pumping scenario. Inflows to the model were set up as probability distributions of annual volumes, which were sampled each year to obtain annual values. The entire system was simulated 2,500 times (realizations), generating multiple numbers of refilling times and allowing probabilities to be assigned.

The Monte Carlo simulation for the Base Case scenario sampled the water yield distributions for the natural Kennady Lake watershed, the dry pit and lake areas, and the Lake N11 discharge distribution each year. The Monte Carlo simulation for the No Pumping scenario considered only runoff from the natural Kennady Lake watershed, as well as dry pit and lake areas.

9.7.2.3 Analysis

The analysis approach for closure is identical to that described in Section 9.7.1.2.

9.7.3 Effects Analysis Results – Construction and Operation

9.7.3.1 Effect of Dewatering Kennady Lake Areas 2 to 7 to Flows, Water Levels, and Channel/Bank Stability in Downstream Waters

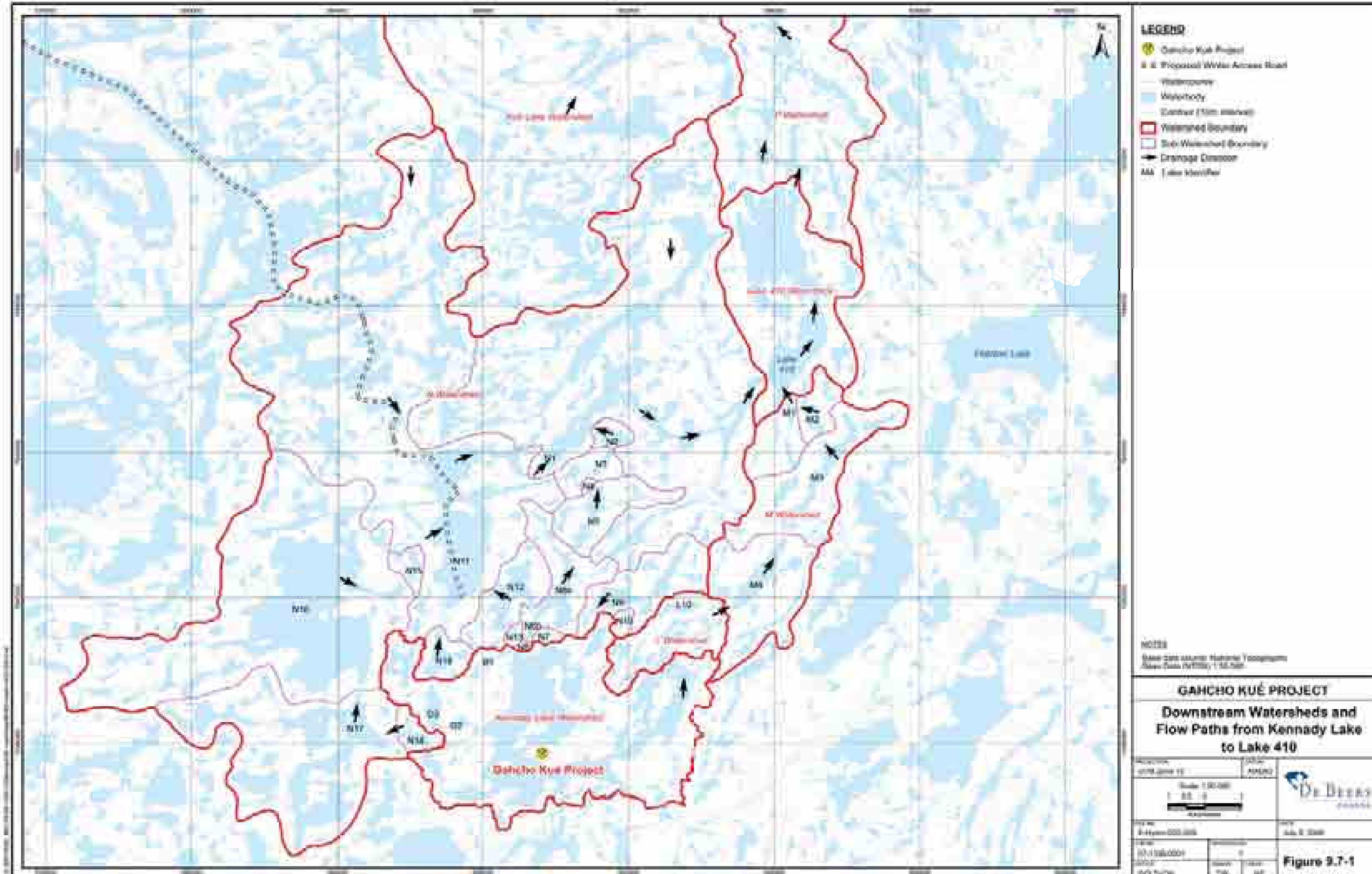
9.7.3.1.1 Project Activities

The effects of dewatering Kennady Lake Areas 2 to 7 on Kennady Lake Area 8 were described in Section 8.7. Dewatering will affect these basins and downstream waterbodies, including lakes L3, L2, L1, M4, M3, M2 and M1.

During dewatering (direct discharge), untreated water will be pumped from Kennady Lake Area 3 to Lake N11. This will affect downstream waterbodies, including lakes N11 and N1.

Lakes N1 and M1 flow into Lake 410, so the effects of each dewatering discharge will be combined at Lake 410 and downstream waterbodies, including mainstem lakes within the P watershed, Kirk Lake, and watersheds further downstream. The downstream watersheds and flow paths from Kennady Lake to Lake 410 are shown in Figure 9.7-1, and the downstream watersheds and flow paths from Lake 410 to Kirk Lake are shown in Figure 9.7-2.

The operational diversions of the A, B, D and E watersheds into watershed N are discussed further in Section 9.7.3.3. The effects of these diversions are included in modelling of effects on Lake N11 and downstream watersheds.


LEGEND
Gahcho Kué Project
Proposed Winter Access Road
Watercourse
Waterbody
Contour (10m interval)
Watershed Boundary
Sub Watershed Boundary
Drainage Direction
Lake Identifier
Hoarfrost Lake
Lake 410
M1
M2
M3
M4
N1
N2
N6
N11
N12
N14
N16
N17
N18
L10
D2
D7
B1
Kennady Lake Watershed
Gahcho Kué Project
NOTES
GAHCHO KUÉ PROJECT
Downstream Watersheds and Flow Paths from Kennady Lake to Lake 410
Figure 9.7-1

LEGEND

- Watercourse
- Waterbody
- Contour (10m interval)
- Watershed Boundary
- Sub-Watershed Boundary
- Drainage Direction
- P3 Lake Identifier

NOTES

Base data source: National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Downstream Watersheds and Flow Paths from Lake 410 to Kirk Lake

Kilometres

FILE No: E-Hydro-006-GIS		DATE: July 10, 2008
JOB NO: 07-1336-0001	REVISION NO: 0	**Figure 9.7-2**
OFFICE: GOLD-CAL	DRAWN: CW / CHECK: NS	

9.7.3.1.2 Environmental Design Features and Mitigation

With the exception of Lake N11 and its outlet channel, dewatering discharges will be limited to ensure that pumping will not increase discharges above the baseline 2-year flood levels in downstream lakes and channels. These levels were selected to minimize the potential for bed and bank erosion and minimize effects to fish and fish habitat. With this environmental design feature, effects to channel/bank stability will be a minor pathway that will not contribute to effects to fish and fish habitat for all channels, except for the outlet channel from Lake N11. Effects to channel/bank stability in the outlet channel from Lake N11 is a valid pathway that is assessed herein. Effects to fish and fish habitat are assessed in Section 9.10.

Runoff forecasting based on snowcourse surveys and short-term rainfall forecasts will be undertaken to ensure that the cumulative effect of runoff and dewatering discharges does not exceed discharge targets.

9.7.3.1.3 Effects Analysis

Kennady Lake (Area 8) Outlet (Stream K5) to Lake M1 Outlet

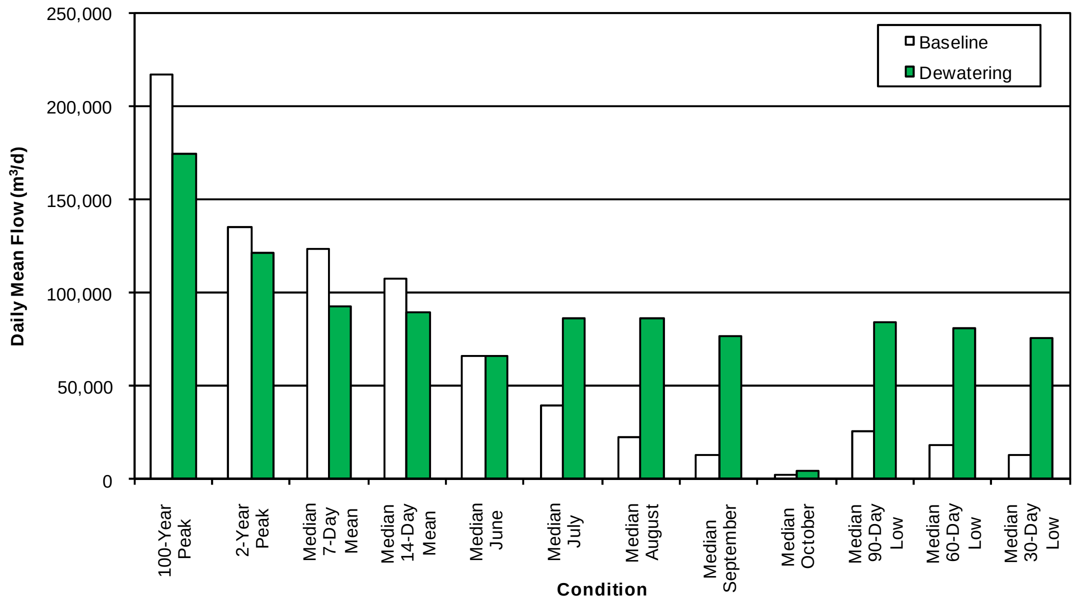
Dyke A will prevent water from flowing between Kennady Lake Areas 2 to 7 and Area 8 during dewatering and operation. Area 8 will be preserved as a free-draining waterbody throughout this period, though its hydrological regime will be changed.

During dewatering, discharges to Area 8 will be limited to ensure that 2-year flood conditions are not exceeded within the basin or its outlet channel. This diversion will occur after construction of Dyke A, meaning that natural runoff from Areas 2 to 7 will not contribute to flow at the Area 8 outlet during this period.

Discharges will be limited to a maximum of the baseline 2-year flood discharge of 135,000 m^3/d (1.56 cubic metres per second [m^3/s]) at the Area 8 outlet (Stream K5). A volume of approximately 8.6 (Mm^3) will be diverted, following the spring runoff peak. In accord with the mine water balance, the flow diversion was modeled over an extended period of several months, meaning that modeled discharges at the Area 8 outlet are typically on the order of 90,000 m^3/d or less for median conditions.

The water balance model for the Gahcho Kué Project (Project) examined all downstream waterbodies between the Area 8 outlet channel and the Lake M1 outlet channel. Project effects on the Area 8 outlet during dewatering are summarized in Figure 9.7-3 and Tables 9.7-3 to 9.7-4. Project effects on Lake L1 during dewatering are summarized in Figures 9.7-4 to 9.7-5 and Tables 9.7-5 to 9.7-8. Project effects on Lake M1 during dewatering are summarized in Figures 9.7-6 to 9.7-7 and Tables 9.7-9 to 9.7-12.

Figure 9.7-3 Comparison of Effects on Area 8 Outlet Discharges – Dewatering



m^3/d = cubic metres per day.

Table 9.7-3 Monthly Mean Discharges at the Area 8 Outlet – Dewatering

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	121,000	86,500	59,600	68,600	13,500
		dewatering	91,500	92,800	93,300	90,800	18,400
	10	baseline	97,600	61,900	38,100	29,200	6,640
		dewatering	83,800	89,600	89,700	88,100	10,200
Median	2	baseline	65,900	39,300	22,800	13,200	3,070
		dewatering	65,700	86,600	86,500	77,200	4,680
Dry	10	baseline	36,900	23,100	13,900	6,880	1,430
		dewatering	41,000	85,500	85,400	57,300	1,880
	100	baseline	12,900	12,000	9,420	4,910	878
		dewatering	6,470	84,900	84,800	43,800	1,270

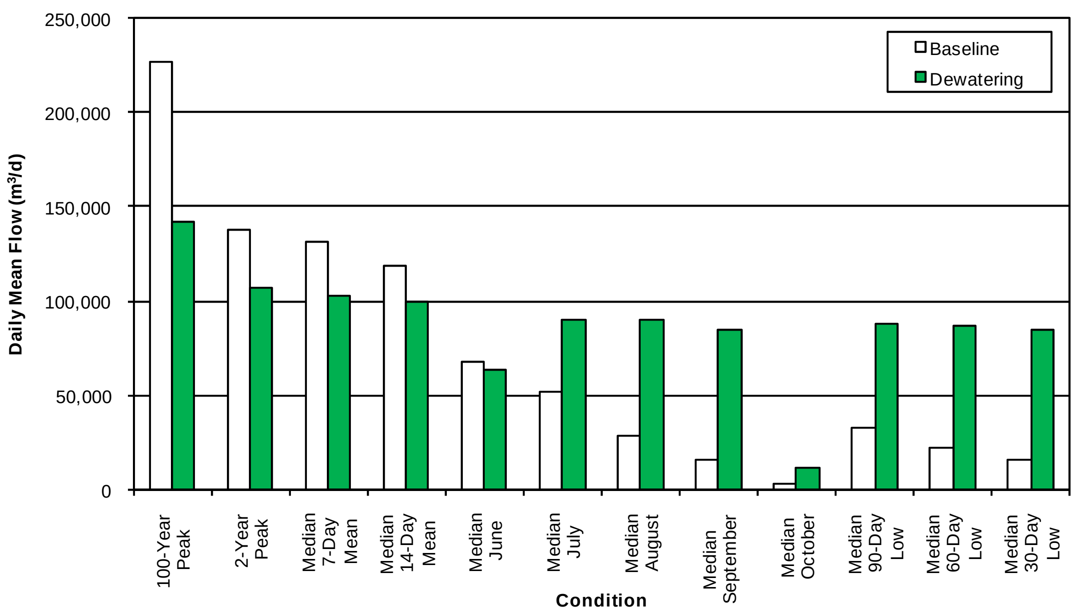
m^3/d = cubic metres per day.

Table 9.7-4 Derived Representative Discharges at the Area 8 Outlet – Dewatering

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	2.51	192,000	167,000	48,900	52,500	59,000
		dewatering	2.02	103,000	96,900	91,800	90,100	89,200
	10	baseline	2.14	166,000	145,000	26,200	32,300	41,000
		dewatering	1.68	97,600	93,100	88,100	87,500	87,700
Median	2	baseline	1.56	123,000	108,000	12,800	18,300	26,000
		dewatering	1.41	92,600	89,900	76,100	81,400	83,800
Dry	10	baseline	0.80	65,100	60,000	6,560	10,900	16,100
		dewatering	1.24	89,400	88,000	56,700	71,800	77,500
	100	baseline	0.15	14,900	17,300	5,000	9,340	13,200
		dewatering	1.16	88,100	87,200	42,300	64,000	72,200

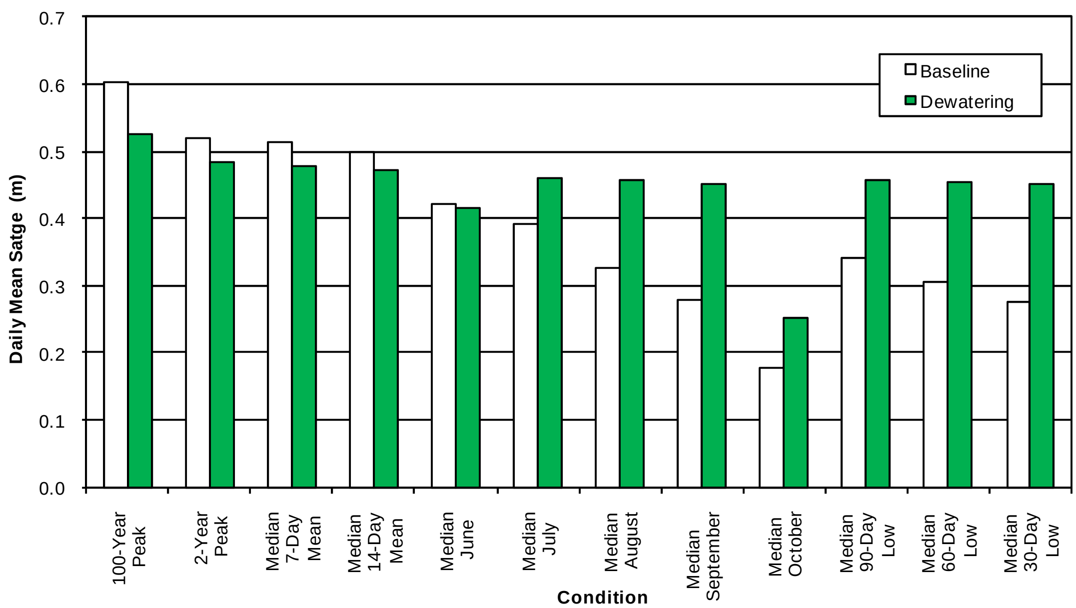
Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Figure 9.7-4 Comparison of Effects on Lake L1 Outlet Discharges – Dewatering



m^3/d = cubic metres per day.

Figure 9.7-5 Comparison of Effects on Lake L1 Stages – Dewatering



m = metres.

Table 9.7-5 Monthly Mean Discharges at the Lake L1 Outlet – Dewatering

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	130,000	111,000	67,700	85,000	20,600
		dewatering	94,200	102,000	98,900	98,400	50,800
	10	baseline	102,000	81,400	45,700	38,900	9,240
		dewatering	82,700	95,700	93,700	93,400	29,100
Median	2	baseline	67,800	52,300	28,100	16,400	3,630
		dewatering	64,100	90,600	89,600	84,900	11,700
Dry	10	baseline	35,700	29,300	17,100	8,310	1,620
		dewatering	39,000	87,100	86,900	72,500	3,720
	100	baseline	10,700	14,200	11,300	5,750	976
		dewatering	12,100	85,100	85,500	58,500	1,520

m^3/d = cubic metres per day.

Table 9.7-6 Derived Representative Discharges at the Lake L1 Outlet – Dewatering

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	2.62	214,000	189,000	57,000	63,400	76,800
		dewatering	1.64	129,000	120,000	92,500	95,800	97,100
	10	baseline	2.25	185,000	164,000	31,300	38,900	51,900
		dewatering	1.42	115,000	109,000	90,100	92,200	93,200
Median	2	baseline	1.59	131,000	119,000	16,100	22,400	32,500
		dewatering	1.24	103,000	99,300	84,500	87,000	88,500
Dry	10	baseline	0.86	71,700	66,800	7,980	13,000	19,900
		dewatering	1.12	94,700	92,700	73,600	80,700	84,000
	100	baseline	0.23	20,000	21,000	5,770	9,970	15,000
		dewatering	1.06	89,600	88,900	57,600	74,500	80,400

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-7 Monthly Mean Stages at Lake L1 – Dewatering

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.512	0.488	0.422	0.451	0.297
		dewatering	0.465	0.476	0.472	0.471	0.388
	10	baseline	0.476	0.446	0.376	0.358	0.235
		dewatering	0.448	0.468	0.465	0.464	0.329
Median	2	baseline	0.422	0.391	0.326	0.278	0.178
		dewatering	0.415	0.460	0.459	0.451	0.252
Dry	10	baseline	0.350	0.330	0.281	0.227	0.140
		dewatering	0.359	0.455	0.454	0.431	0.179
	100	baseline	0.245	0.266	0.249	0.204	0.121
		dewatering	0.254	0.452	0.452	0.404	0.138

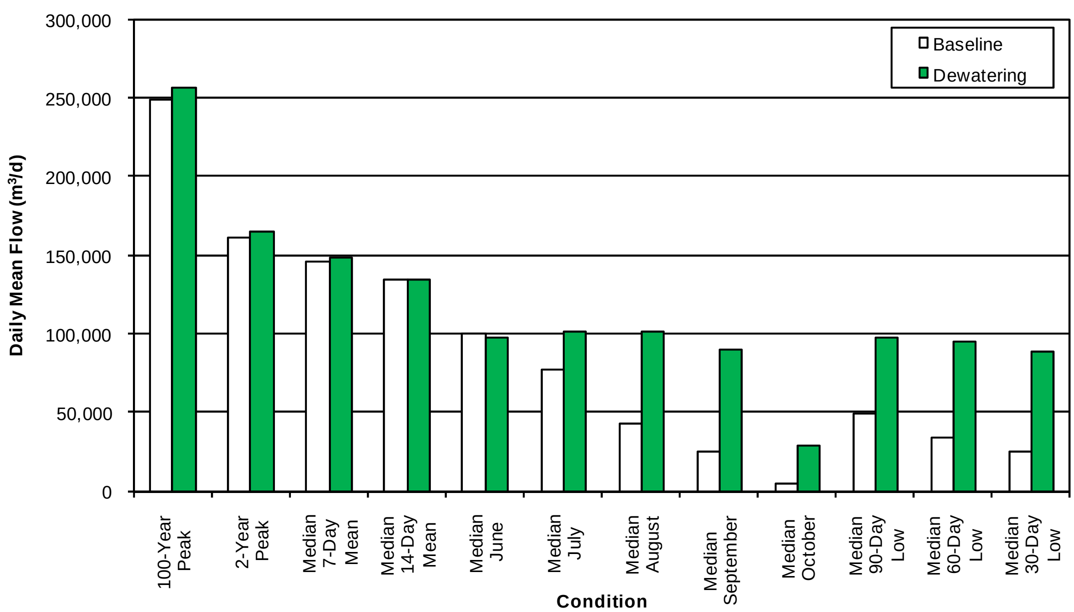
m =metre.

Table 9.7-8 Derived Representative Stages at Lake L1 – Dewatering

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.603	0.593	0.571	0.401	0.414	0.438
		dewatering	0.525	0.511	0.500	0.463	0.468	0.470
	10	baseline	0.576	0.568	0.548	0.336	0.358	0.390
		dewatering	0.503	0.494	0.486	0.459	0.462	0.464
Median	2	baseline	0.520	0.513	0.499	0.276	0.305	0.340
		dewatering	0.483	0.478	0.473	0.451	0.455	0.457
Dry	10	baseline	0.433	0.429	0.420	0.225	0.259	0.294
		dewatering	0.469	0.466	0.463	0.433	0.445	0.450
	100	baseline	0.292	0.295	0.299	0.204	0.240	0.271
		dewatering	0.462	0.459	0.457	0.403	0.434	0.444

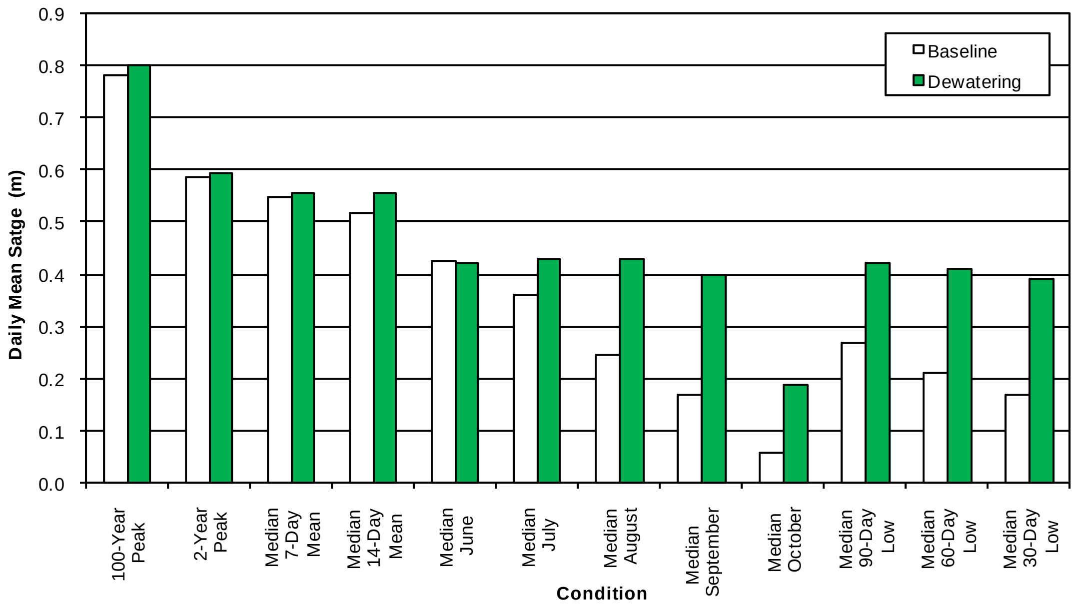
m = metre.

Figure 9.7-6 Comparison of Effects on Lake M1 Outlet Discharges – Dewatering



m^3/d = cubic metres per day.

Figure 9.7-7 Comparison of Effects on Lake M1 Stages – Dewatering



m = metres.

Table 9.7-9 Monthly Mean Discharges at the Lake M1 Outlet – Dewatering

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	178,000	152,000	102,000	116,000	29,300
		dewatering	149,000	140,000	135,000	143,000	46,400
	10	baseline	142,000	116,000	69,100	56,400	13,500
		dewatering	126,000	118,000	116,000	109,000	41,100
Median	2	baseline	100,000	77,600	43,200	25,100	5,140
		dewatering	97,700	101,000	101,000	90,400	28,900
Dry	10	baseline	61,000	43,900	27,300	12,900	1,880
		dewatering	69,600	91,200	91,400	82,600	15,300
	100	baseline	30,800	19,800	19,100	8,800	762
		dewatering	46,800	86,000	86,600	79,700	8,280

m^3/d = cubic metres per day.

Table 9.7-10 Derived Representative Discharges at the Lake M1 Outlet – Dewatering

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	2.88	220,000	205,000	84,900	92,300	105,000
		dewatering	2.97	215,000	200,000	115,000	127,000	131,000
	10	baseline	2.45	189,000	176,000	48,200	58,500	75,700
		dewatering	2.40	181,000	166,000	98,900	107,000	111,000
Median	2	baseline	1.87	146,000	134,000	24,700	34,400	49,700
		dewatering	1.91	148,000	135,000	88,100	94,900	97,900
Dry	10	baseline	1.26	96,400	85,100	13,200	21,300	31,200
		dewatering	1.57	122,000	113,000	82,400	88,900	91,900
	100	baseline	0.73	50,300	38,600	8,380	15,200	20,200
		dewatering	1.37	104,000	99,300	79,900	86,400	89,400

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-11 Monthly Mean Stages at Lake M1 – Dewatering

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.626	0.563	0.432	0.470	0.188
		dewatering	0.556	0.533	0.520	0.541	0.255
	10	baseline	0.538	0.470	0.333	0.291	0.112
		dewatering	0.497	0.476	0.470	0.451	0.235
Median	2	baseline	0.426	0.360	0.243	0.170	0.059
		dewatering	0.419	0.429	0.429	0.398	0.186
Dry	10	baseline	0.306	0.246	0.179	0.109	0.030
		dewatering	0.335	0.401	0.401	0.375	0.122
	100	baseline	0.194	0.145	0.141	0.084	0.016
		dewatering	0.257	0.385	0.387	0.366	0.081

m = metre.

Table 9.7-12 Derived Representative Stages at Lake M1 – Dewatering

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.782	0.721	0.687	0.382	0.404	0.440
		dewatering	0.798	0.710	0.676	0.468	0.500	0.510
	10	baseline	0.702	0.651	0.621	0.262	0.298	0.354
		dewatering	0.693	0.633	0.597	0.423	0.446	0.457
Median	2	baseline	0.587	0.548	0.518	0.168	0.209	0.267
		dewatering	0.595	0.553	0.520	0.392	0.411	0.420
Dry	10	baseline	0.451	0.416	0.383	0.110	0.152	0.196
		dewatering	0.522	0.486	0.462	0.374	0.394	0.403
	100	baseline	0.314	0.269	0.226	0.082	0.121	0.147
		dewatering	0.477	0.437	0.424	0.367	0.386	0.395

m = metre; m^3/d = cubic metres per day.

Summary of Effects on Flows, Water Levels and Channel/Bank Stability

Kennady Lake Area 8 Outlet Flows: The water balance results for Area 8 show that during dewatering, post-freshet monthly mean flows will increase due to pumping to Area 8. However, because of closed-circuiting of Kennady Lake Areas 2 to 7, the 2-year flood discharge during dewatering will decrease by approximately 10 percent (%) below the baseline value, and the 100-year flood discharge will decrease by approximately 20%. Pumping will cause low flows to increase by 200% to 500%.

Kennady Lake Area 8 Water Levels: Project effects on Area 8 water levels were addressed in Section 8.7.

Kennady Lake Area 8 Outlet Channel/Bank Stability: No effects on Area 8 Outlet channel or bank stability are expected during dewatering, because flood magnitudes will not exceed baseline values.

Lake L1 Outlet Flows: The water balance results for Lake L1 show that during dewatering, post-freshet monthly mean flows will increase due to pumping to Area 8. However, because of closed-circuiting of Kennady Lake Areas 2 to 7, the 2-year flood discharge during dewatering will decrease by approximately 22% above the baseline value, and the 100-year flood discharge will decrease by approximately 37%. Pumping will cause low flows to increase by 170% to 425%.

Lake L1 Water Levels: Lake L1 flood water levels are also expected to decrease during dewatering. The 2-year flood level is expected to decrease by approximately 0.037 m, the 100-year flood level by 0.078 m, while monthly mean stages decrease by 0.007 metres (m) (June) and increase by 0.069 m (July), 0.133 m (August), 0.173 m (September) and 0.074 m (October), under median conditions.

Lake L1 and Outlet Channel/Bank Stability: No effects on Lake L1 and Outlet channel or bank stability are expected during dewatering, because flood magnitudes will not exceed baseline values.

Lake M1 Outlet Flows: The water balance results for Lake M1 show that during dewatering, post-freshet monthly mean flows will increase due to pumping to Area 8. Because of the relative timing of dewatering discharges arriving at Lake M1, the 2-year flood discharge during dewatering will increase by approximately 2% above the baseline value, and the 100-year flood discharge will decrease by approximately 3%. Pumping will cause low flows to increase by 100% to 260%.

Lake M1 Water Levels: Lake M1 flood water levels are expected to increase slightly during dewatering. The 2-year flood level is expected to increase by approximately 0.008 m, the 100-year flood level by 0.016 m, while monthly mean stages decrease by 0.007 m (June) and increase by 0.069 m (July), 0.186 m (August), 0.228 m (September) and 0.127 m (October), under median conditions.

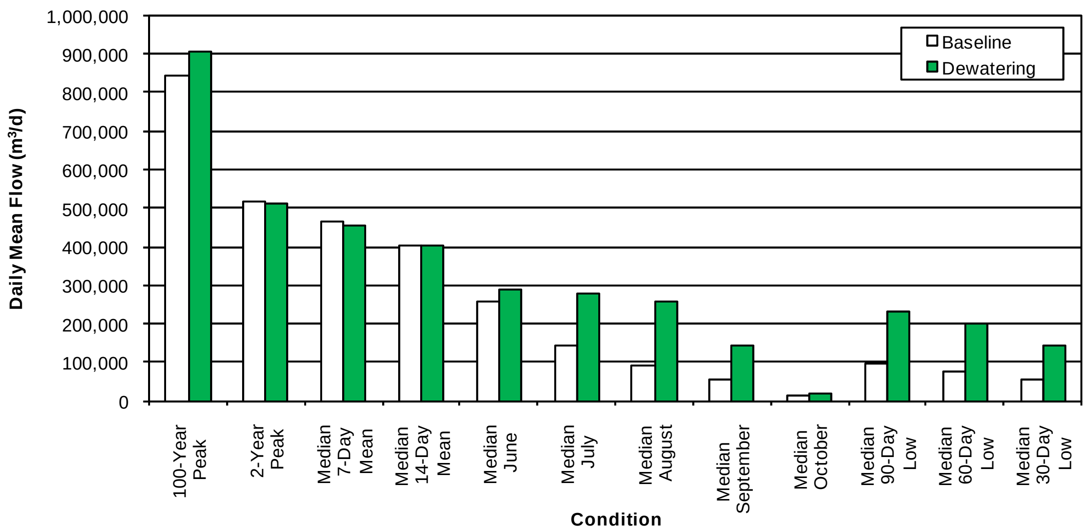
Lake M1 and Outlet Channel/Bank Stability: No effects on Lake M1 and Outlet channel or bank stability are expected during dewatering, because flood magnitudes will not exceed baseline values.

Lake N11 to Lake N1 Outlet

During dewatering, discharges to Lake N11 will be limited to ensure that 2-year flood conditions at Lake N1 and its outlet channel are held similar to baseline. Discharges will be limited to a maximum of 500,000 m^3/d (5.79 m^3/s), as compared to the baseline 2-year flood discharge of 1,166,000 m^3/d (13.50 m^3/s) at the Lake N1 outlet. No direct discharge will occur if snowmelt or rainfall runoff cause water levels to significantly exceed the 2-year flood water level in Lake N1. A volume of approximately 12.8 Mm^3 will be diverted, following the spring runoff peak. In accord with the mine water balance, the flow diversion was modeled over an extended period of several months, meaning that modeled discharges at the Lake N1 outlet are typically on the order of 300,000 m^3/d or less for median conditions.

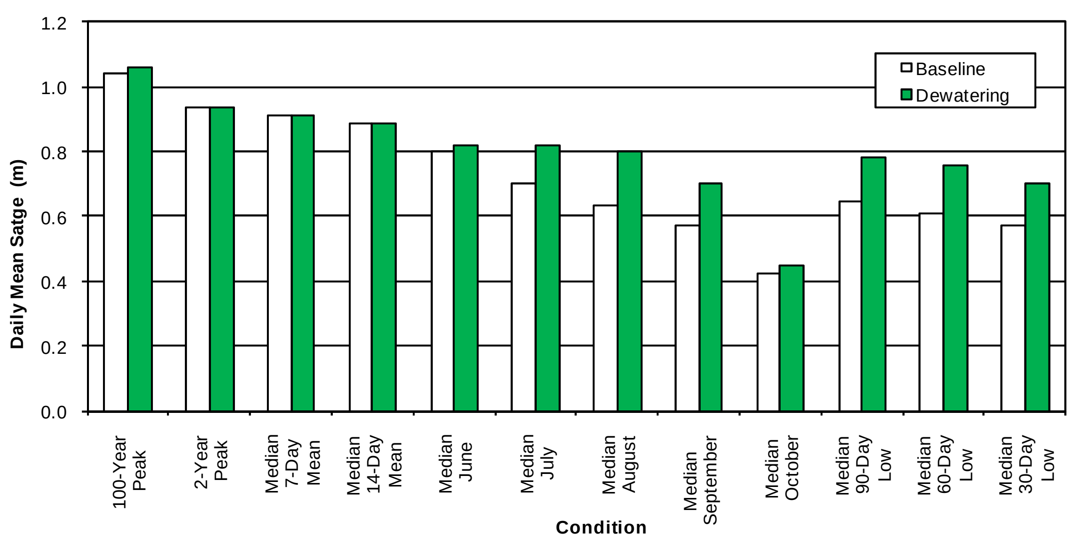
The water balance model for the Project examined all downstream waterbodies between Lake N11 and the Lake N1 outlet channel. Project effects on Lake N11 during dewatering are summarized in Figures 9.7-8 to 9.7-9 and Tables 9.7-13 to 9.7-16. Project effects on Lake N1 during dewatering are summarized in Figures 9.7-10 to 9.7-11 and Tables 9.7-17 to 9.7-20.

Figure 9.7-8 Comparison of Effects on Lake N11 Outlet Discharges – Dewatering



m^3/d = cubic metres per day.

Figure 9.7-9 Comparison of Effects on Lake N11 Stages – Dewatering



m = metres.

Table 9.7-13 Monthly Mean Discharges at the Lake N11 Outlet – Dewatering

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	443,000	293,000	221,000	258,000	50,700
		dewatering	478,000	373,000	332,000	370,000	62,900
	10	baseline	359,000	215,000	147,000	123,000	28,200
		dewatering	389,000	324,000	294,000	247,000	35,100
Median	2	baseline	257,000	141,000	91,400	56,800	14,700
		dewatering	288,000	280,000	256,000	142,000	18,600
Dry	10	baseline	155,000	83,600	58,800	33,300	8,740
		dewatering	196,000	248,000	226,000	71,700	11,200
	100	baseline	71,900	46,900	42,600	25,900	6,400
		dewatering	126,000	230,000	207,000	32,400	8,380

m^3/d = cubic metres per day.

Table 9.7-14 Derived Representative Discharges at the Lake N11 Outlet – Dewatering

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	9.8	747,000	630,000	179,000	198,000	215,000
		dewatering	10.5	805,000	676,000	326,000	331,000	343,000
	10	baseline	8.22	630,000	538,000	102,000	125,000	152,000
		dewatering	8.27	634,000	543,000	239,000	264,000	284,000
Median	2	baseline	6.00	464,000	404,000	55,500	75,000	98,700
		dewatering	5.92	457,000	405,000	143,000	200,000	229,000
Dry	10	baseline	3.36	269,000	240,000	33,900	48,500	64,200
		dewatering	4.12	321,000	296,000	73,500	152,000	189,000
	100	baseline	0.85	85,300	81,700	25,200	36,500	45,200
		dewatering	3.19	250,000	238,000	43,600	128,000	167,000

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-15 Monthly Mean Stages at Lake N11 – Dewatering

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.903	0.824	0.774	0.801	0.558
		dewatering	0.919	0.869	0.847	0.868	0.585
	10	baseline	0.862	0.769	0.707	0.680	0.490
		dewatering	0.878	0.843	0.825	0.793	0.514
Median	2	baseline	0.800	0.700	0.636	0.572	0.424
		dewatering	0.821	0.816	0.800	0.702	0.447
Dry	10	baseline	0.715	0.624	0.577	0.508	0.378
		dewatering	0.754	0.794	0.778	0.603	0.399
	100	baseline	0.603	0.548	0.537	0.481	0.352
		dewatering	0.683	0.781	0.763	0.505	0.374

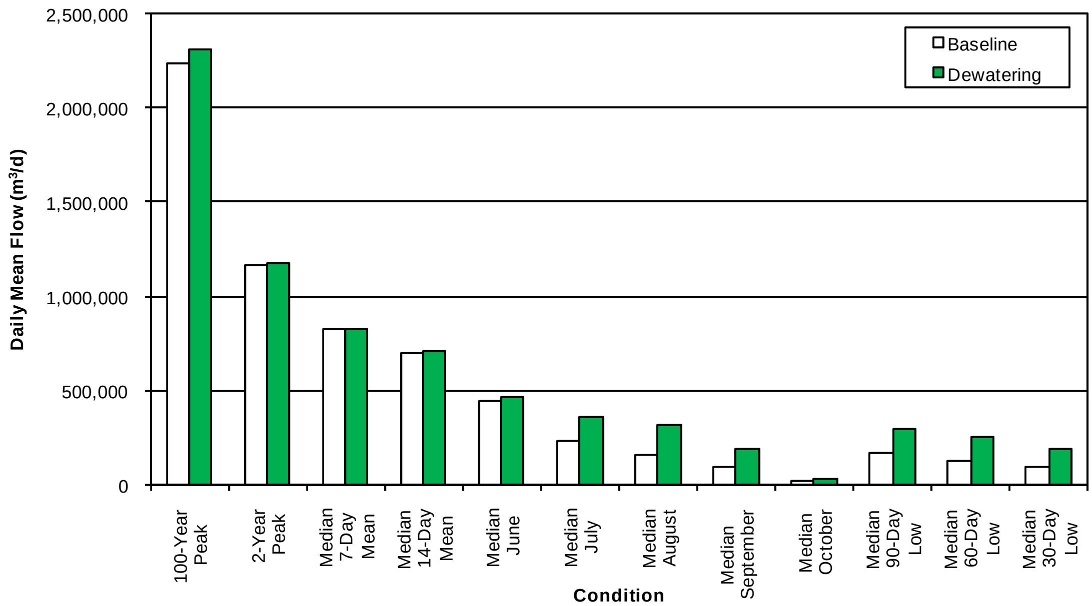
m = metre.

Table 9.7-16 Derived Representative Stages at Lake N11 – Dewatering

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	1.043	1.015	0.977	0.739	0.755	0.769
		dewatering	1.059	1.032	0.992	0.844	0.847	0.853
	10	baseline	1.003	0.977	0.943	0.652	0.682	0.712
		dewatering	1.005	0.978	0.945	0.788	0.805	0.818
Median	2	baseline	0.935	0.913	0.885	0.569	0.609	0.647
		dewatering	0.933	0.910	0.886	0.703	0.757	0.780
Dry	10	baseline	0.822	0.809	0.788	0.510	0.553	0.588
		dewatering	0.861	0.841	0.826	0.606	0.712	0.748
	100	baseline	0.606	0.626	0.620	0.478	0.519	0.544
		dewatering	0.813	0.796	0.787	0.540	0.686	0.727

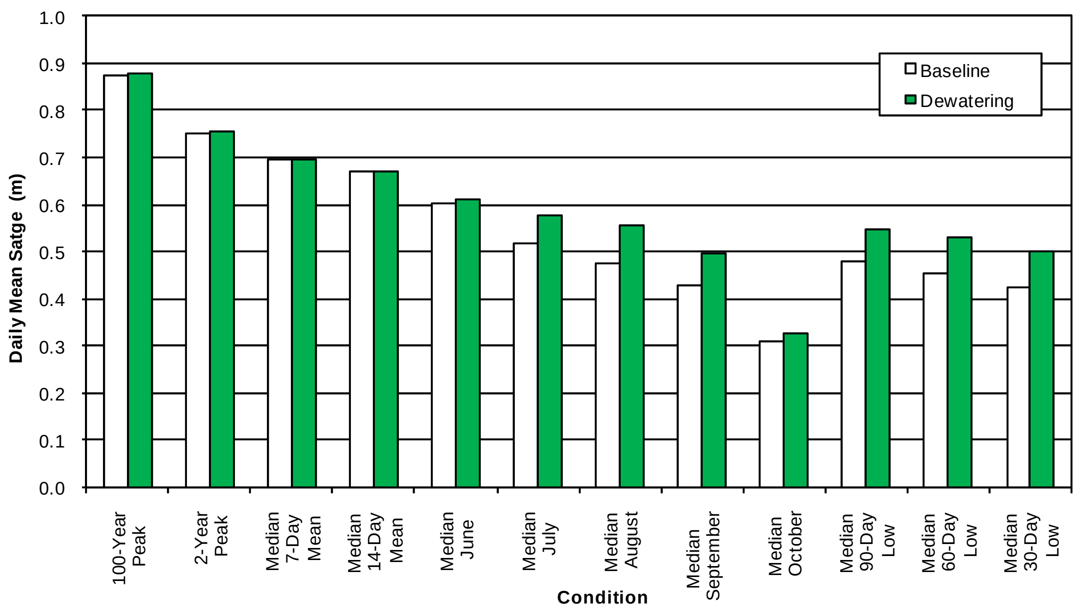
m = metre.

Figure 9.7-10 Comparison of Effects on Lake N1 Outlet Discharges – Dewatering



m^3/d = cubic metres per day.

Figure 9.7-11 Comparison of Effects on Lake N1 Stages – Dewatering



m = metres.

Table 9.7-17 Monthly Mean Discharges at the Lake N1 Outlet – Dewatering

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	737,000	470,000	370,000	398,000	84,100
		dewatering	764,000	550,000	499,000	490,000	99,600
	10	baseline	609,000	348,000	248,000	204,000	47,600
		dewatering	632,000	453,000	396,000	326,000	57,400
Median	2	baseline	444,000	229,000	156,000	99,000	25,100
		dewatering	471,000	364,000	317,000	194,000	30,900
Dry	10	baseline	270,000	138,000	102,000	56,600	14,600
		dewatering	312,000	297,000	272,000	111,000	18,400
	100	baseline	121,000	79,300	75,400	41,600	10,300
		dewatering	184,000	256,000	249,000	66,700	13,300

m^3/d = cubic metres per day.

Table 9.7-18 Derived Representative Discharges at the Lake N1 Outlet – Dewatering

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	25.9	1,250,000	1,050,000	285,000	333,000	353,000
		dewatering	26.7	1,280,000	1,070,000	417,000	462,000	482,000
	10	baseline	19.9	1,080,000	910,000	171,000	212,000	251,000
		dewatering	19.9	1,080,000	914,000	304,000	351,000	384,000
Median	2	baseline	13.5	827,000	704,000	95,600	128,000	166,000
		dewatering	13.6	826,000	705,000	195,000	257,000	296,000
Dry	10	baseline	8.2	527,000	441,000	57,200	83,800	109,000
		dewatering	8.8	561,000	473,000	112,000	195,000	235,000
	100	baseline	4.5	242,000	174,000	40,500	63,800	77,100
		dewatering	5.8	335,000	264,000	59,400	161,000	199,000

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-19 Monthly Mean Stages at Lake N1 – Dewatering

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.677	0.610	0.577	0.587	0.411
		dewatering	0.682	0.633	0.619	0.616	0.427
	10	baseline	0.648	0.569	0.527	0.504	0.360
		dewatering	0.653	0.605	0.587	0.561	0.376
Median	2	baseline	0.602	0.517	0.473	0.426	0.311
		dewatering	0.610	0.575	0.557	0.498	0.326
Dry	10	baseline	0.537	0.460	0.429	0.375	0.274
		dewatering	0.555	0.549	0.538	0.438	0.289
	100	baseline	0.446	0.405	0.400	0.349	0.253
		dewatering	0.492	0.531	0.527	0.389	0.269

m = metre.

Table 9.7-20 Derived Representative Stages at Lake N1 – Dewatering

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.874	0.764	0.734	0.544	0.564	0.571
		dewatering	0.880	0.768	0.737	0.594	0.608	0.614
	10	baseline	0.822	0.739	0.710	0.483	0.508	0.528
		dewatering	0.822	0.739	0.711	0.552	0.571	0.582
Median	2	baseline	0.752	0.695	0.670	0.423	0.452	0.480
		dewatering	0.753	0.695	0.670	0.498	0.531	0.549
Dry	10	baseline	0.671	0.626	0.601	0.376	0.410	0.436
		dewatering	0.682	0.636	0.611	0.439	0.498	0.520
	100	baseline	0.584	0.524	0.485	0.347	0.385	0.403
		dewatering	0.620	0.564	0.534	0.379	0.477	0.501

m = metre.

Summary of Effects on Flows, Water Levels and Channel/Bank Stability

Lake N11 Outlet Flows: The water balance results for Lake N11 show that during dewatering, monthly mean flows will increase due to pumping to Lake N11. The 2-year flood discharge during dewatering will be approximately equal to the baseline value, and the 100-year flood discharge will increase by approximately 7%. Low flows will also increase by 132% to 167%.

Lake N11 Water Levels: Lake N11 water levels are also expected to increase during dewatering. The 2-year flood level is expected to decrease by approximately 0.002 m, the 100-year flood level by 0.016 m, and monthly mean stages by 0.021 m (June), 0.116 m (July), 0.164 m (August), 0.130 m (September) and 0.023 m (October), under median conditions.

Lake N11 and Outlet Channel/Bank Stability: No effects on Lake N11 and Outlet channel or bank stability are expected during dewatering, because increases in flood magnitude are small relative to the existing flood regime. Additional information on the Lake N11 Outlet follows this summary.

Lake N1 Outlet Flows: The water balance results for Lake N1 show that during dewatering, monthly mean flows will increase due to pumping to Lake N11. The 2-year flood discharge during dewatering will increase by approximately 1% above the baseline value, and the 100-year flood discharge will increase by approximately 3%. Low flows will also increase by 78% to 104%.

Lake N1 Water Levels: Lake N1 water levels are also expected to increase during dewatering. The 2-year flood level is expected to increase by approximately 0.001 m, the 100-year flood level by 0.006 m, and monthly mean stages by 0.008 m (June), 0.058 m (July), 0.084 m (August), 0.072 m (September) and 0.015 m (October), under median conditions.

Lake N1 and Outlet Channel/Bank Stability: No effects on Lake N1 and Outlet channel or bank stability are expected during dewatering, because increases in flood magnitude are small relative to the existing flood regime.

Additional comment on the Lake N11 Outlet channel: The project description indicates that dewatering discharges to Lake N11 will be limited to 500,000 m^3/d and a prior dewatering plan considered this magnitude of discharge. For that reason, a detailed analysis of hydraulic characteristics and erosion potential at the Lake N11 outlet was performed. The current dewatering plan involves dewatering a reduced quantity of water at a lower rate, such that dewatering discharges to Lake N11 will typically be on the order of 300,000 m^3/d and occur after the freshet peak.

Surveys of the Lake N11 outlet channel indicate that it is naturally armoured with boulders and bedrock and any effects of the higher flows to scour of finer sediment fractions from interstitial areas between boulder and cobble substrates would be temporary and limited. A summary of the flow area, velocity and water surface elevation of each cross-section of the Lake N11 outlet channel during dewatering, is provided in Table 9.7-21 for 2, 10 and 100-year flood conditions.

The locations of these cross-sections are shown superimposed on an oblique aerial photo mosaic in Figure 9.7-12.

A conservative estimate of rock size required to resist local, depth-averaged flow velocities, as presented by TAC (2001), indicates that nominal rock diameters of 0.26 m, 0.54 m, 0.94 m and 1.48 m would be required for stability at flow velocities of 3 metres per second (m/s), 4 m/s, 5 m/s and 6 m/s, respectively. The largest mean channel velocities anticipated for the Lake N11 outflow channel are 1.9 m/s (2-year flood) and 2.3 m/s (100-year flood) at cross-section 6. Applying a conservative factor of 1.5 yields local, depth-averaged flow velocities of approximately 3 m/s (2-year flood) and 3.5 m/s (100-year flood). This indicates that boulders of diameter 0.26 m (2-year flood) and 0.40 m (100-year flood) would be stable at this section.

An evaluation of erosion potential at each section of the Lake N11 outlet is provided in Table 9.7-22. Based on this analysis, no erosion due to dewatering is expected in the outlet channel from Lake N11 outlet (i.e., stream N11).

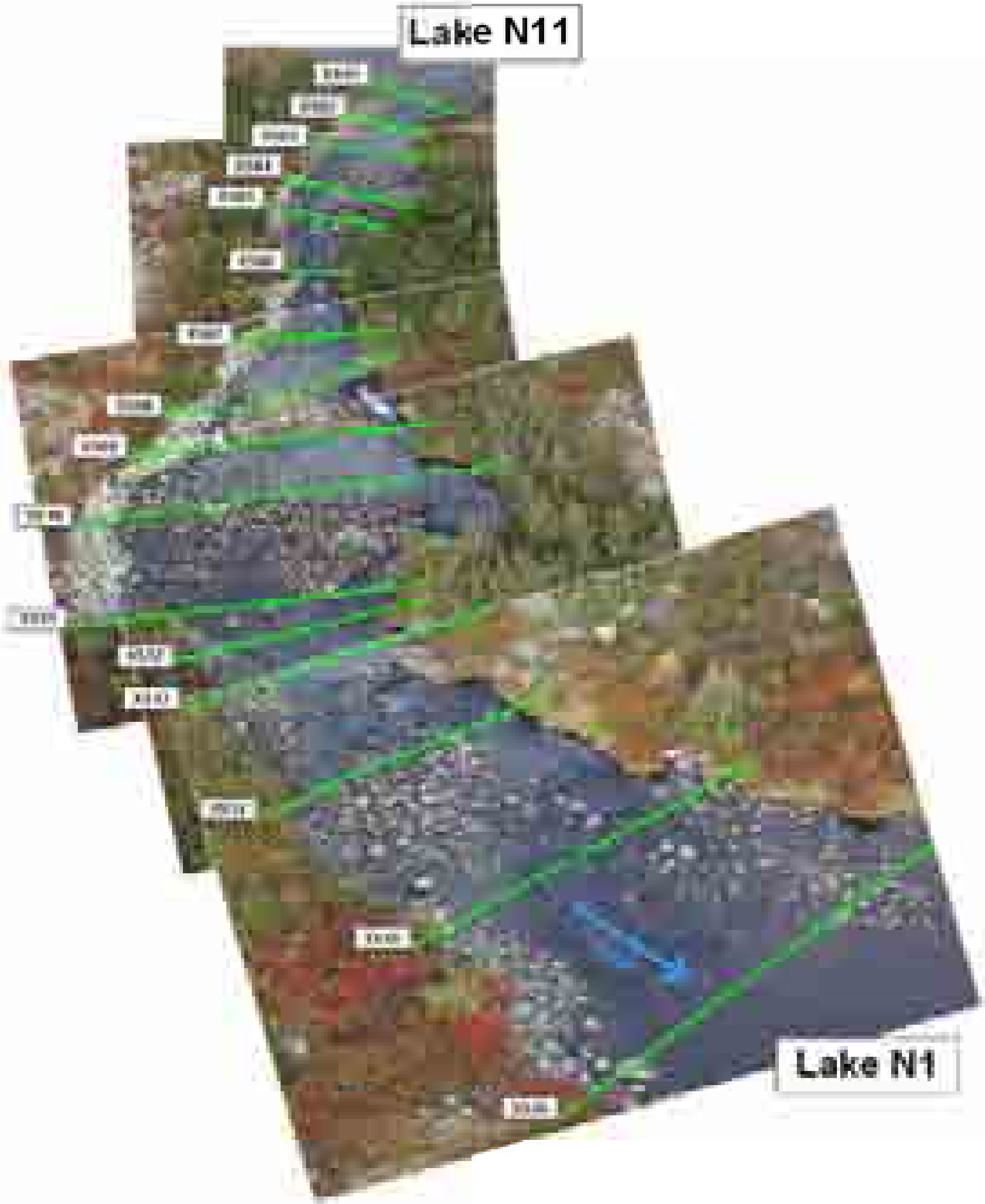
Table 9.7-21 Derived Changes to Discharge, Velocity, Flow Area and Water Surface Elevation at the Lake N11 Outlet during Dewatering

Section	Quantity	2-year Flood Discharge		10-year Flood Discharge		100-year Flood Discharge	
		Baseline	Dewatering	Baseline	Dewatering	Baseline	Dewatering
	Discharge (m^3/s)	6.00	5.92	8.22	8.27	9.77	10.5
XS1	flow area (m^2)	17.87	17.74	21.27	21.34	23.29	24.16
	velocity (m/s)	0.34	0.34	0.39	0.39	0.43	0.44
	max depth (m)	1.02	1.02	1.13	1.14	1.2	1.23
XS2	flow area (m^2)	9.52	9.46	11.30	11.34	12.42	12.9
	velocity (m/s)	0.65	0.64	0.76	0.76	0.82	0.85
	max depth (m)	1.11	1.11	1.22	1.22	1.28	1.31
XS3	flow area (m^2)	3.68	3.64	4.65	4.67	5.25	5.55
	velocity (m/s)	1.67	1.66	1.82	1.82	1.91	1.95
	max depth (m)	0.44	0.44	0.51	0.51	0.55	0.57
XS4	flow area (m^2)	15.52	15.39	18.98	19.06	21.26	22.30
	velocity (m/s)	0.41	0.40	0.46	0.46	0.49	0.50
	max depth (m)	0.92	0.92	1.06	1.06	1.14	1.18
XS5	flow area (m^2)	10.60	10.51	13.03	13.08	14.59	15.29
	velocity (m/s)	0.61	0.61	0.69	0.69	0.74	0.76
	max depth (m)	1.13	1.12	1.25	1.26	1.34	1.37

Table 9.7-21 Derived Changes to Discharge, Velocity, Flow Area and Water Surface Elevation at the Lake N11 Outlet during Dewatering (continued)

Section	Quantity	2-year Flood Discharge		10-year Flood Discharge		100-year Flood Discharge	
		Baseline	Dewatering	Baseline	Dewatering	Baseline	Dewatering
	Discharge (m^3/s)	6.00	5.92	8.22	8.27	9.77	10.5
XS6	flow area (m^2)	3.14	3.1	3.88	3.89	4.35	4.57
	velocity (m/s)	1.91	1.91	2.12	2.12	2.24	2.30
	max depth (m)	0.94	0.94	1.03	1.03	1.08	1.11
XS7	flow area (m^2)	6.68	6.67	8.44	8.47	9.31	9.67
	velocity (m/s)	0.95	0.94	1.03	1.04	1.12	1.16
	max depth (m)	0.93	0.93	1.05	1.05	1.10	1.12
XS8	flow area (m^2)	3.26	3.09	4.52	4.54	5.39	5.68
	velocity (m/s)	1.84	1.91	1.82	1.82	1.81	1.85
	max depth (m)	0.71	0.69	0.82	0.82	0.88	0.90
XS9	flow area (m^2)	8.46	8.42	9.70	9.73	10.54	10.92
	velocity (m/s)	0.71	0.70	0.85	0.85	0.93	0.96
	max depth (m)	0.87	0.87	0.94	0.95	0.99	1.01
XS10	flow area (m^2)	4.73	4.68	5.85	5.88	6.41	6.74
	velocity (m/s)	1.27	1.26	1.40	1.41	1.53	1.56
	max depth (m)	0.46	0.46	0.50	0.50	0.52	0.53
XS11	flow area (m^2)	7.40	7.33	9.38	9.42	10.62	11.17
	velocity (m/s)	0.81	0.81	0.88	0.88	0.92	0.94
	max depth (m)	0.79	0.79	0.89	0.90	0.96	0.98
XS12	flow area (m^2)	7.15	7.1	8.42	8.44	9.21	9.56
	velocity (m/s)	0.84	0.83	0.98	0.98	1.07	1.11
	max depth (m)	0.91	0.91	1.00	1.01	1.06	1.09
XS13	flow area (m^2)	3.94	3.90	4.94	4.96	5.65	6.00
	velocity (m/s)	1.53	1.53	1.69	1.69	1.76	1.78
	max depth (m)	0.60	0.60	0.67	0.67	0.72	0.75
XS14	flow area (m^2)	6.11	6.06	7.32	7.35	8.14	8.56
	velocity (m/s)	0.98	0.98	1.13	1.13	1.21	1.23
	max depth (m)	0.80	0.80	0.87	0.87	0.92	0.94
XS15	flow area (m^2)	3.89	3.85	4.84	4.87	5.48	5.75
	velocity (m/s)	1.54	1.54	1.70	1.70	1.78	1.82
	max depth (m)	0.50	0.50	0.55	0.56	0.59	0.61
XS16	flow area (m^2)	12.47	12.42	12.96	12.98	13.31	13.48
	velocity (m/s)	0.48	0.48	0.63	0.64	0.73	0.78
	max depth (m)	0.87	0.87	0.89	0.89	0.91	0.92

m/s = metres per second; m^3/s = cubic metres per second; m^2 = square metres; m = metres.



GAHCHO KUÉ PROJECT

Aerial Photo Mosaic of the Lake N11 Outlet Channel to Lake N1 Showing the Cross-Section Survey Transects Used to Describe the Channel Morphology

PROJECTION: N/A	DATUM: N/A	
Scale: N/A		
FILE No: E-Hydro-011-GIS		DATE: December 17, 2010
JOB NO: 09-1365-1004	REVISION NO: 0	**Figure 9.7-12**
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF

Table 9.7-22 Evaluation of Erosion Potential in the Lake N11 Outlet Channel during Dewatering

Section	Quantity	2-year Discharge		10-year Discharge		100-year Discharge	
		Natural	Dewatering	Natural	Dewatering	Natural	Dewatering
	Discharge (m^3/s)	**6.00**	**5.92**	**8.22**	**8.27**	**9.77**	**10.5**
XS1	velocity (m/s)	0.34	0.34	0.39	0.39	0.43	0.44
	materials	boulders with vegetation in low velocity areas of sediment deposition					
	evaluation	transition zone from Lake N11 with low velocities, low erosion potential					
XS2	velocity (m/s)	0.65	0.64	0.76	0.76	0.82	0.85
	materials	boulders embedded in LDB high bank, large boulders at RDB					
	evaluation	low velocities, low erosion potential					
XS3	velocity (m/s)	1.67	1.66	1.82	1.82	1.91	1.95
	materials	boulders embedded in LDB bank, large boulders at RDB					
	evaluation	lake outlet sill; mean flow velocity increased by up to 20%, boulder armour adequate					
XS4	velocity (m/s)	0.41	0.40	0.46	0.46	0.49	0.50
	materials	boulders embedded in LDB bank, large boulders at RDB					
	evaluation	low velocities because channel increases in width, low erosion potential					
XS5	velocity (m/s)	0.61	0.61	0.69	0.69	0.74	0.76
	materials	large boulders at LDB and RDB					
	evaluation	low velocities, low erosion potential					
XS6	velocity (m/s)	1.91	1.91	2.12	2.12	2.24	2.30
	materials	natural rock boulders, D_{50} approximately 600 mm					
	evaluation	constriction causes highest velocities, but still well below stability threshold					
XS7	velocity (m/s)	0.95	0.94	1.03	1.04	1.12	1.16
	materials	large boulders at LDB and RDB					
	evaluation	low velocities, low erosion potential					
XS8	velocity (m/s)	1.84	1.91	1.82	1.82	1.81	1.85
	materials	bedrock control in bed and banks					
	evaluation	this section is resistant to erosion, and insensitive to increase in velocity and discharge					
XS9	velocity (m/s)	0.71	0.70	0.85	0.85	0.93	0.96
	materials	bedrock at LDB, large boulders at RDB					
	evaluation	immediately below bedrock control. Low erosion potential					
XS10	velocity (m/s)	1.27	1.26	1.40	1.41	1.53	1.56
	materials	bedrock in LDB, large boulders at RDB					
	evaluation	this section is insensitive to increase in velocity and discharge					

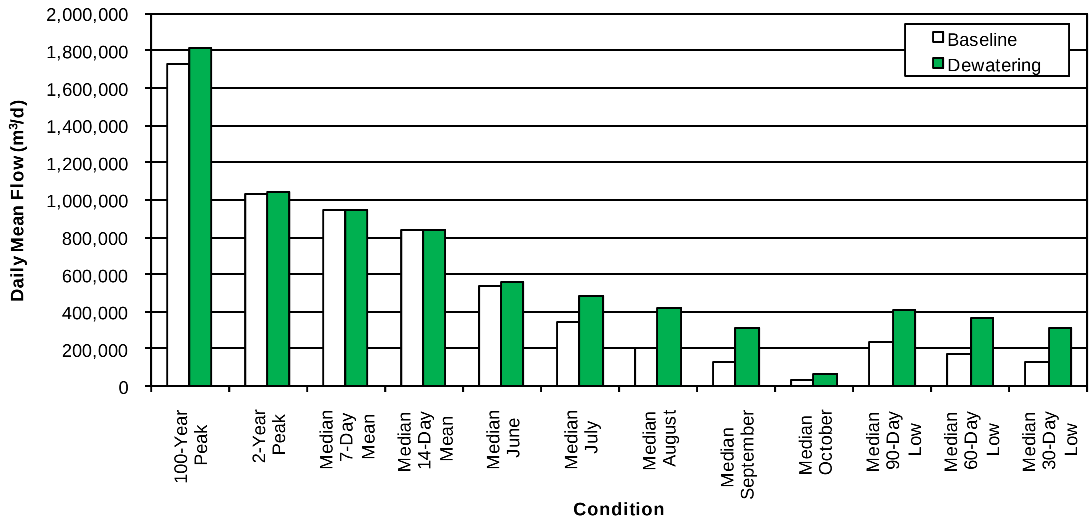
Section	Quantity	2-year Discharge		10-year Discharge		100-year Discharge	
		Natural	Dewatering	Natural	Dewatering	Natural	Dewatering
	Discharge (m^3/s)	**6.00**	**5.92**	**8.22**	**8.27**	**9.77**	**10.5**
XS11	velocity (m/s)	0.81	0.81	0.88	0.88	0.92	0.94
	materials	bedrock in LDB, large boulders at RDB					
	evaluation	this section is insensitive to increase in velocity and discharge					
XS12	velocity (m/s)	0.84	0.83	0.98	0.98	1.07	1.11
	materials	bedrock in LDB, large boulders at RDB					
	evaluation	this section is insensitive to increase in velocity and discharge					
XS13	velocity (m/s)	1.53	1.53	1.69	1.69	1.76	1.78
	materials	bedrock at LDB, large boulders at RDB					
	evaluation	constriction causes relatively high velocities, but still well below stability threshold					
XS14	velocity (m/s)	0.98	0.98	1.13	1.13	1.21	1.23
	materials	boulders embedded in bank on LDB, large boulders at RDB					
	evaluation	this section is insensitive to increase in velocity and discharge					
XS15	velocity (m/s)	1.54	1.54	1.70	1.70	1.78	1.82
	materials	large boulders at LDB and RDB					
	evaluation	this section is insensitive to increase in velocity and discharge					
XS16	velocity (m/s)	0.48	0.48	0.63	0.64	0.73	0.78
	materials	large boulders at LDB and RDB					
	evaluation	transition zone to Lake N1 with low velocities, low erosion potential					

m^3/s =cubic metres per second; m/s = metres per second; RDB – right descending bank; LDB – left descending bank.

Lake 410 to Kirk Lake Outlet

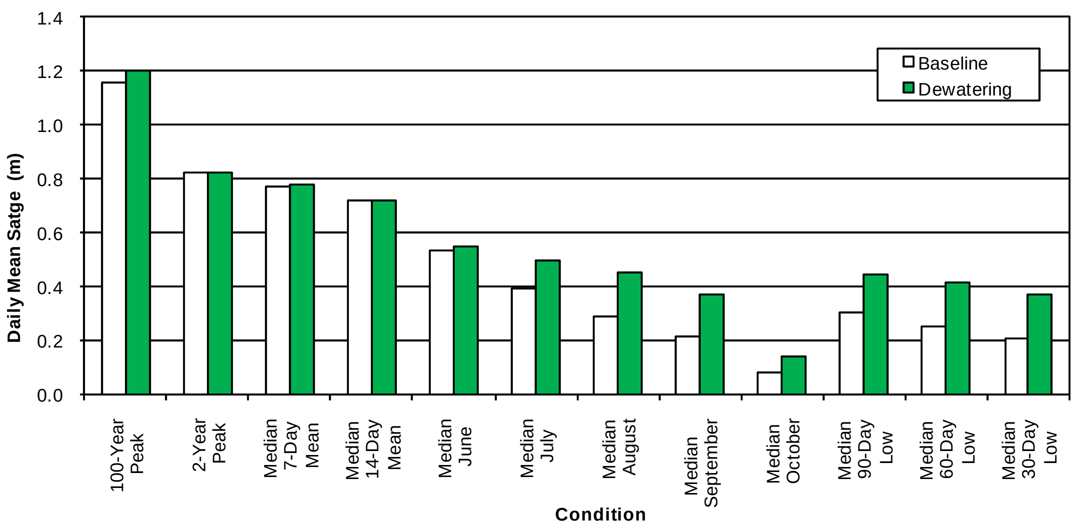
Lake N1 and Lake M1 flow into Lake 410, which then drains through watershed P through to Kirk Lake. The water balance model for the Project examined all downstream waterbodies between Lake 410 and Kirk Lake. Project effects on Lake 410 during dewatering are summarized in Figures 9.7-13 to 9.7-14 and Tables 9.7-23 to 9.7-26. Project effects on Kirk Lake during dewatering are summarized in Figures 9.7-15 to 9.7-16 and Tables 9.7-27 to 9.7-30.

Figure 9.7-13 Comparison of Effects on Lake 410 Outlet Discharges – Dewatering



m^3/d = cubic metres per day.

Figure 9.7-14 Comparison of Effects on Lake 410 Stages – Dewatering



m = metres.

Table 9.7-23 Monthly Mean Discharges at the Lake 410 Outlet – Dewatering

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	934,000	678,000	475,000	587,000	135,000
		dewatering	929,000	732,000	640,000	656,000	178,000
	10	baseline	759,000	514,000	329,000	278,000	70,700
		dewatering	762,000	603,000	518,000	460,000	114,000
Median	2	baseline	537,000	344,000	210,000	135,000	32,700
		dewatering	564,000	482,000	423,000	308,000	69,900
Dry	10	baseline	329,000	203,000	132,000	73,900	16,000
		dewatering	374,000	392,000	365,000	217,000	46,400
	100	baseline	190,000	106,000	90,100	49,800	9,660
		dewatering	225,000	337,000	336,000	170,000	35,700

m^3/d = cubic metres per day.

Table 9.7-24 Derived Representative Discharges at the Lake 410 Outlet – Dewatering

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	20.00	1,420,000	1,240,000	404,000	443,000	491,000
		dewatering	21.00	1,480,000	1,290,000	546,000	601,000	630,000
	10	baseline	16.50	1,230,000	1,080,000	237,000	287,000	355,000
		dewatering	16.70	1,240,000	1,090,000	426,000	472,000	513,000
Median	2	baseline	11.90	942,000	837,000	128,000	173,000	234,000
		dewatering	12.00	949,000	843,000	309,000	366,000	409,000
Dry	10	baseline	7.11	580,000	523,000	74,200	108,000	150,000
		dewatering	8.08	652,000	588,000	220,000	298,000	338,000
	100	baseline	3.03	219,000	200,000	50,900	77,500	100,000
		dewatering	5.27	407,000	375,000	162,000	260,000	296,000

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-25 Monthly Mean Stages at Lake 410 – Dewatering

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.769	0.621	0.490	0.564	0.212
		dewatering	0.766	0.653	0.597	0.607	0.255
	10	baseline	0.669	0.516	0.383	0.343	0.138
		dewatering	0.671	0.574	0.519	0.479	0.189
Median	2	baseline	0.531	0.395	0.284	0.212	0.082
		dewatering	0.549	0.495	0.453	0.367	0.136
Dry	10	baseline	0.383	0.278	0.209	0.142	0.051
		dewatering	0.418	0.431	0.411	0.290	0.104
	100	baseline	0.266	0.180	0.162	0.109	0.036
		dewatering	0.298	0.390	0.389	0.247	0.087

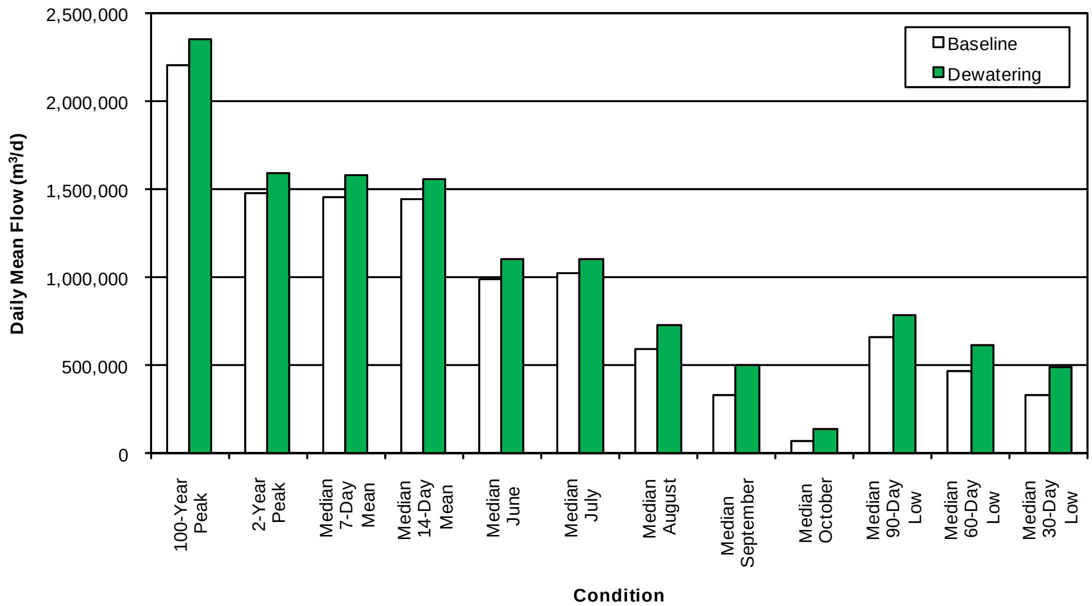
m =metre.

Table 9.7-26 Derived Representative Stages at Lake 410 – Dewatering

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	1.158	1.016	0.928	0.440	0.467	0.501
		dewatering	1.197	1.045	0.953	0.537	0.573	0.591
	10	baseline	1.019	0.923	0.847	0.308	0.350	0.403
		dewatering	1.027	0.928	0.852	0.455	0.488	0.515
Median	2	baseline	0.819	0.773	0.714	0.204	0.250	0.305
		dewatering	0.824	0.777	0.718	0.368	0.412	0.443
Dry	10	baseline	0.581	0.559	0.522	0.142	0.182	0.227
		dewatering	0.633	0.605	0.565	0.293	0.359	0.390
	100	baseline	0.329	0.292	0.275	0.110	0.146	0.173
		dewatering	0.476	0.442	0.418	0.239	0.328	0.357

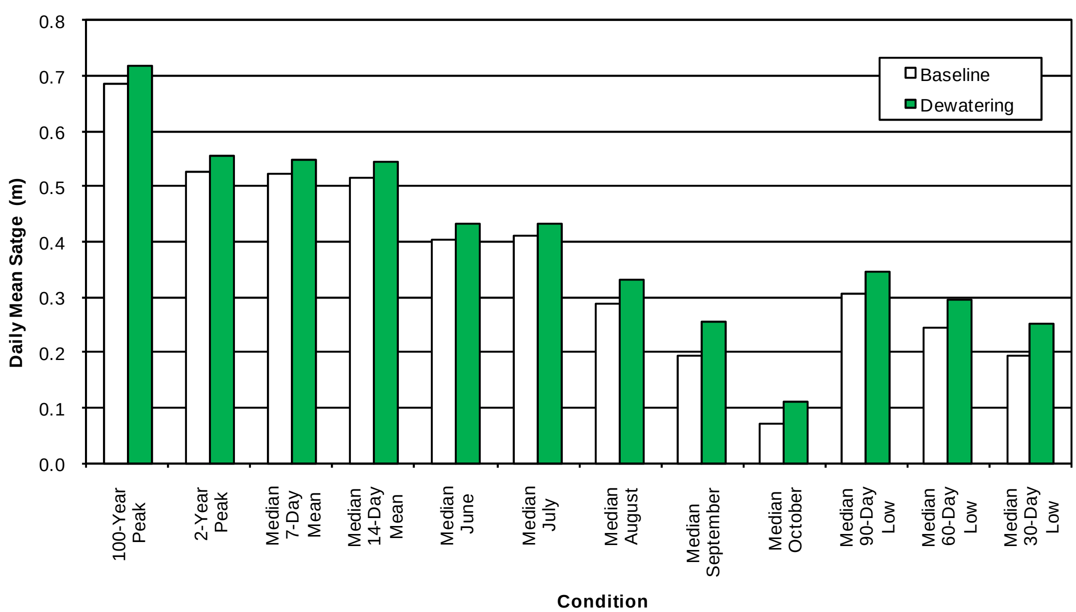
m =metre.

Figure 9.7-15 Comparison of Effects on Kirk Lake Outlet Discharges – Dewatering



m^3/d = cubic metres per day.

Figure 9.7-16 Comparison of Effects on Kirk Lake Stages – Dewatering



m = metres.

Table 9.7-27 Monthly Mean Discharges at the Kirk Lake Outlet – Dewatering

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	1,850,000	1,730,000	1,250,000	1,370,000	420,000
		dewatering	1,960,000	1,830,000	1,360,000	1,410,000	454,000
	10	baseline	1,450,000	1,420,000	916,000	676,000	188,000
		dewatering	1,570,000	1,500,000	1,040,000	860,000	266,000
Median	2	baseline	995,000	1,020,000	596,000	332,000	75,700
		dewatering	1,110,000	1,100,000	734,000	500,000	142,000
Dry	10	baseline	562,000	607,000	349,000	161,000	24,500
		dewatering	681,000	710,000	508,000	321,000	79,600
	100	baseline	226,000	255,000	191,000	85,200	4,760
		dewatering	345,000	391,000	366,000	244,000	52,600

m^3/d = cubic metres per day.

Table 9.7-28 Derived Representative Discharges at the Kirk Lake Outlet – Dewatering

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	25.50	2,160,000	2,100,000	1,050,000	1,140,000	1,290,000
		dewatering	27.30	2,360,000	2,260,000	1,200,000	1,260,000	1,410,000
	10	baseline	22.10	1,890,000	1,850,000	636,000	774,000	981,000
		dewatering	23.70	2,030,000	1,980,000	795,000	916,000	1,100,000
Median	2	baseline	17.10	1,460,000	1,440,000	333,000	467,000	660,000
		dewatering	18.50	1,580,000	1,560,000	494,000	619,000	789,000
Dry	10	baseline	10.60	902,000	884,000	163,000	262,000	395,000
		dewatering	12.30	1,060,000	1,030,000	323,000	422,000	540,000
	100	baseline	3.98	321,000	290,000	82,100	148,000	213,000
		dewatering	6.28	576,000	497,000	239,000	311,000	374,000

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-29 Monthly Mean Stages at Kirk Lake – Dewatering

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.610	0.584	0.470	0.500	0.227
		dewatering	0.634	0.606	0.497	0.509	0.239
	10	baseline	0.519	0.512	0.382	0.312	0.133
		dewatering	0.547	0.531	0.416	0.366	0.168
Median	2	baseline	0.404	0.410	0.287	0.194	0.072
		dewatering	0.434	0.432	0.330	0.255	0.110
Dry	10	baseline	0.276	0.290	0.201	0.120	0.034
		dewatering	0.314	0.322	0.258	0.190	0.075
	100	baseline	0.150	0.163	0.134	0.078	0.011
		dewatering	0.199	0.217	0.207	0.158	0.057

m = metre.

Table 9.7-30 Derived Representative Stages at Kirk Lake – Dewatering

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.686	0.677	0.664	0.418	0.442	0.480
		dewatering	0.718	0.718	0.698	0.457	0.473	0.509
	10	baseline	0.623	0.619	0.610	0.300	0.342	0.400
		dewatering	0.653	0.649	0.639	0.348	0.382	0.432
Median	2	baseline	0.525	0.521	0.517	0.195	0.244	0.307
		dewatering	0.554	0.550	0.545	0.253	0.294	0.346
Dry	10	baseline	0.382	0.378	0.373	0.121	0.166	0.218
		dewatering	0.422	0.421	0.413	0.191	0.228	0.269
	100	baseline	0.199	0.190	0.177	0.077	0.113	0.144
		dewatering	0.269	0.280	0.254	0.156	0.186	0.210

m = metre.

Summary of Effects on Flows, Water Levels and Channel/Bank Stability

Lake 410 Outlet Flows: The water balance results for Lake 410 show that during dewatering, monthly mean flows will increase due to pumping to Lake N11 and Kennady Lake Area 8. The 2-year flood discharge during dewatering will increase by approximately 1% above the baseline value, and the 100-year flood discharge will increase by approximately 5%. Low flows will also increase by 75% to 141%.

Lake 410 Water Levels: Lake 410 water levels are also expected to increase during dewatering. The 2-year flood level is expected to increase by approximately 0.005 m, the 100-year flood level by 0.039 m, and monthly mean stages by 0.018 m (June), 0.100 m (July), 0.169 m (August), 0.155 m (September) and 0.054 m (October), under median conditions.

Lake 410 and Outlet Channel/Bank Stability: No effects on Lake 410 and Outlet channel or bank stability are expected during dewatering, because increases in flood magnitude are small relative to the existing flood regime.

Kirk Lake Outlet Flows: The water balance results for Kirk Lake show that during dewatering, monthly mean flows will increase due to pumping to Lake N11 and Kennady Lake Area 8. The 2-year flood discharge during dewatering will increase by approximately 8% above the baseline value, and the 100-year flood discharge will increase by approximately 7%. This apparent inconsistency with flow increases with Lake 410 is because the Kirk Lake natural flood peak typically occurs in July, later than upstream lakes which tend to peak in June. Therefore, while dewatering discharges to Lake N11 occur after the Lake N11 outlet flood peak and only cause slight increases in the flood peaks at the Lake N1 and Lake 410 outlets, the sustained post-peak flows cause an incremental increase in flood discharge at the later-peaking Kirk Lake outlet. Low flows will also increase by 20% to 48%.

Kirk Lake Water Levels: Kirk Lake water levels are also expected to increase during dewatering. The 2-year flood level is expected to increase by approximately 0.029 m, the 100-year flood level by 0.032 m, and monthly mean stages by 0.030 m (June), 0.022 m (July), 0.043 m (August), 0.061 m (September) and 0.038 m (October), under median conditions.

Kirk Lake and Outlet Channel/Bank Stability: No effects on Kirk Lake and Outlet channel or bank stability are expected during dewatering, because increases in flood magnitude are small relative to the existing flood regime.

9.7.3.2 Effect of Diversion in Watersheds A, B, D, and E to Flows, Water Levels and Channel/Bank Stability in Streams and Lakes in the N lakes Watershed

9.7.3.2.1 Project Activities

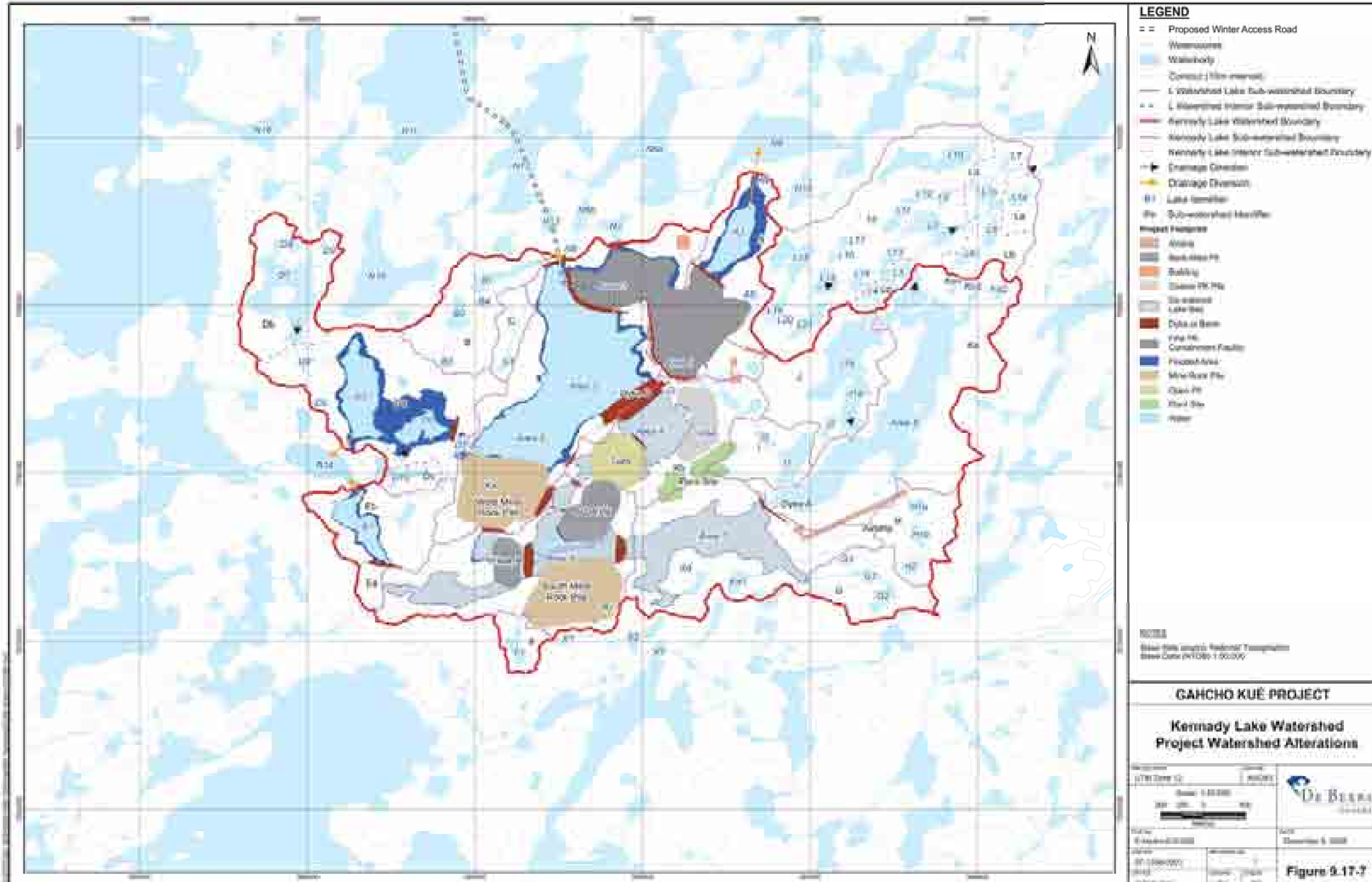
To reduce the amount of runoff into the dewatered Kennady Lake Areas 2 to 7, and the amount of water that must be managed by the mine water management system, four tributary watersheds will be diverted to the adjacent N watershed during operations. These diversions will remain in place until the start of Kennady Lake refilling. The location and layout of these diversions are shown in Figure 9.7-17.

The A watershed above the Lake A3 outlet will be diverted to Lake N9 by constructing a diversion dyke (Dyke C) at the Lake A3 outlet and constructing a diversion channel or pipeline to Lake N9. The ultimate water level of the diverted lake will also inundate Lake A4. This will be a permanent diversion.

The B watershed above the Lake B1 outlet will be diverted to Lake N13 by constructing a diversion dyke (Dyke E) at the Lake B1 outlet and constructing a diversion channel or pipeline from Lake B1 to Lake N13. The dyke will be breached in Year 11 to restore drainage from the B watershed to Kennady Lake.

The D watershed above the Lake D2 outlet will be diverted to Lake N14 by constructing a diversion dyke (Dyke F) at the Lake D2 outlet and constructing a diversion channel or pipeline to Lake N14. The ultimate water level of the diverted lake will also inundate Lake D3. This will be a temporary diversion that is removed during mine closure.

The E watershed above the Lake E1 outlet will be diverted to Lake N14 by constructing a diversion dyke (Dyke G) at the Lake E1 outlet and constructing a diversion channel or pipeline to Lake N14. This will be a temporary diversion that is removed during mine closure.



LEGEND
Proposed Winter Access Road
N
South Mine Rock Pile
GAHCHO KUÉ PROJECT
Kennady Lake Watershed
Project Watershed Alterations
Figure 9.17-7

9.7.3.2.2 Environmental Design Features

Diversion of the A, B, D and E watersheds into the N watershed will reduce the amount of runoff from undisturbed areas that must be managed by the mine water system. At diversion outlets, a channel or pipeline will be constructed to convey flows. A diversion outlet structure will be designed to approximate the natural hydrograph to the extent possible during operations, to manage the water level regime of the diverted lake. Diversion channels or pipeline foundations will be designed and constructed to prevent erosion and sedimentation and to incorporate lessons learned at the Ekati Diamond Mine (Jones et al. 2003a; see also Sections 9.6.1.1 and 9.10.3.7).

9.7.3.2.3 Effects Analysis

Effects of the Project activities on Kennady Lake tributary A, B, D and E watersheds were described in EIS Section 8.7. Diverted water from the A watershed will be conveyed to Lake N9, and from there will be combined with natural flow to Lake N6, N5, N4, N3 and N2 before reaching Lake N11. Diverted water from the B watershed will be conveyed to Lake N8, and from there will be combined with natural flow to Lake N6, N5, N4, N3 and N2 before reaching Lake N11. Diverted water from the D and E watersheds will be conveyed to Lake N14, and from there will be combined with natural flow to Lake N17, N16 and N15 before reaching Lake N11.

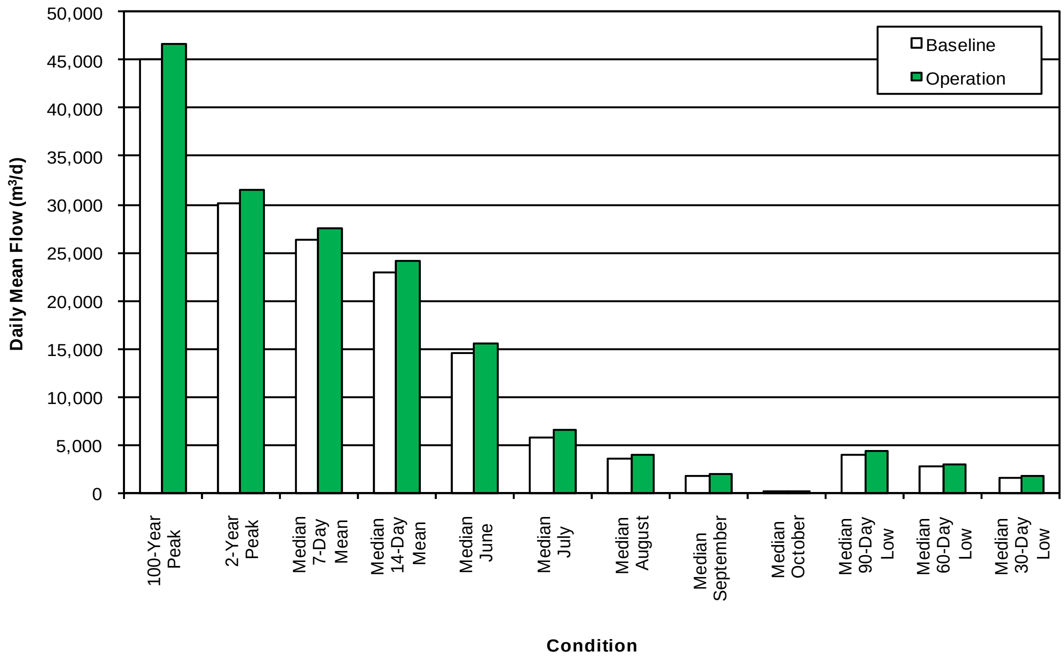
Effects of the Project on Lake N11 and Lake N1 due to the combined diversions are presented in this section. Downstream effects from Lake 410 to Kirk Lake were included in the assessment presented in Section 9.7.3.1.

Lake N8 and Lake N9 to Lake N1 Inflow (A Watershed and B Diversions)

The water balance model for the Project examined this receiving watershed by modeling the flow diverted from the A watershed into Lake N9, a tributary of Lake N6. Lake N8 was not modeled due to its small size and low storage/flow attenuation capacity, but was lumped, along with Lake N6b, as part of the entire Lake N6 watershed. Below Lake N6, Lake N5, Lake N3 (including Lake N4, lumped for the same reasons) and Lake N2 were modelled.

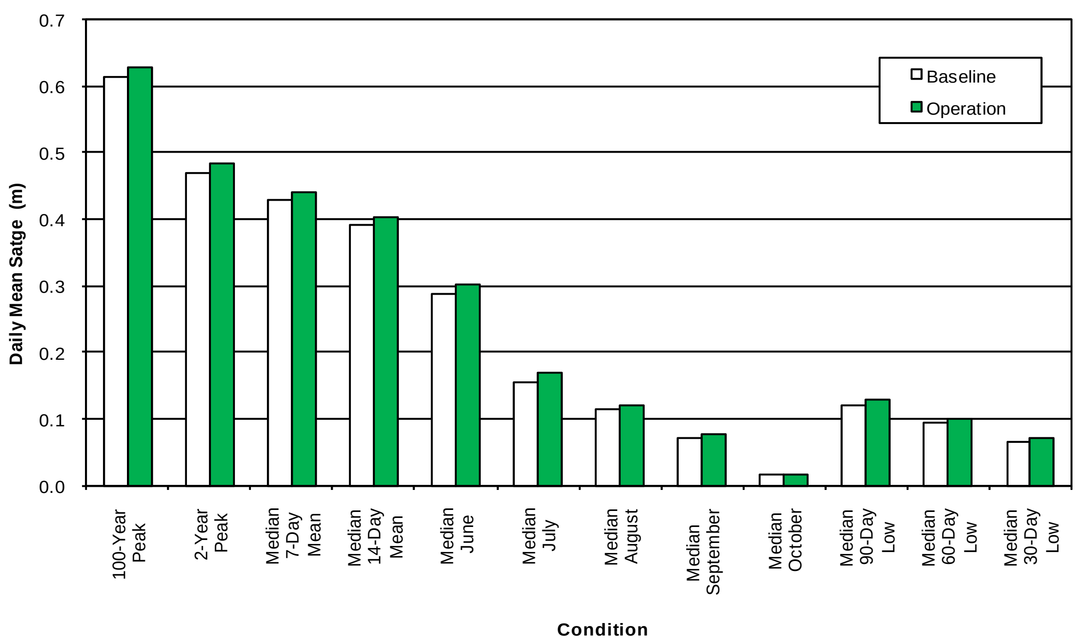
Project effects on Lake N9, which receives the A watershed diversion, are presented in Figures 9.7-18 to 9.7-19 and Tables 9.7-31 to 9.7-34, Project effects on Lake N6, where the two diversions meet, are presented in Figures 9.7-20 to 9.7-21 and Tables 9.7-35 to 9.7-38, and Project effects on Lake N2, upstream of its confluence with Lake N1, are presented in Figures 9.7-22 to 9.7-23 and Tables 9.7-39 to 9.7-42.

Figure 9.7-18 Comparison of Effects on Lake N9 Outlet Discharges – Operation



m^3/d = cubic metres per day.

Figure 9.7-19 Comparison of Effects on Lake N9 Stages – Operation



m = metres.

Table 9.7-31 Monthly Mean Discharges at the Lake N9 Outlet – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	22,600	13,900	10,700	12,000	1,340
		operation	24,800	15,800	12,300	13,500	1,570
	10	baseline	19,300	9,540	6,580	5,280	677
		operation	20,900	11,000	7,390	5,800	767
Median	2	baseline	14,500	5,670	3,580	1,810	195
		operation	15,500	6,580	3,970	1,970	215
Dry	10	baseline	8,690	2,960	1,920	507	0
		operation	9,260	3,420	2,150	570	0
	100	baseline	3,010	1,370	1,120	73	0
		operation	3,390	1,510	1,310	118	0

m^3/d = cubic metres per day.

Table 9.7-32 Derived Representative Discharges at the Lake N9 Outlet – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	0.52	38,100	32,300	7,810	9,920	9,650
		operation	0.54	40,300	34,600	8,980	11,300	11,000
	10	baseline	0.45	33,400	28,800	3,980	5,390	6,440
		operation	0.47	35,300	30,600	4,490	6,050	7,340
Median	2	baseline	0.35	26,300	22,900	1,610	2,670	3,860
		operation	0.36	27,500	24,100	1,800	2,950	4,360
Dry	10	baseline	0.23	17,100	14,800	506	1,440	2,230
		operation	0.23	17,700	15,300	576	1,590	2,490
	100	baseline	0.11	7,830	5,810	58	951	1,370
		operation	0.10	7,590	5,860	97	1,060	1,500

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-33 Monthly Mean Stages at Lake N9 – Operation

Conditions	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.387	0.280	0.235	0.254	0.059
		operation	0.412	0.305	0.258	0.275	0.065
	10	baseline	0.348	0.218	0.170	0.147	0.037
		operation	0.367	0.240	0.184	0.156	0.041
Median	2	baseline	0.288	0.154	0.113	0.072	0.016
		operation	0.301	0.170	0.121	0.076	0.017
Dry	10	baseline	0.205	0.100	0.075	0.031	-
		operation	0.214	0.110	0.081	0.033	-
	100	baseline	0.101	0.060	0.052	0.008	-
		operation	0.109	0.064	0.058	0.012	-

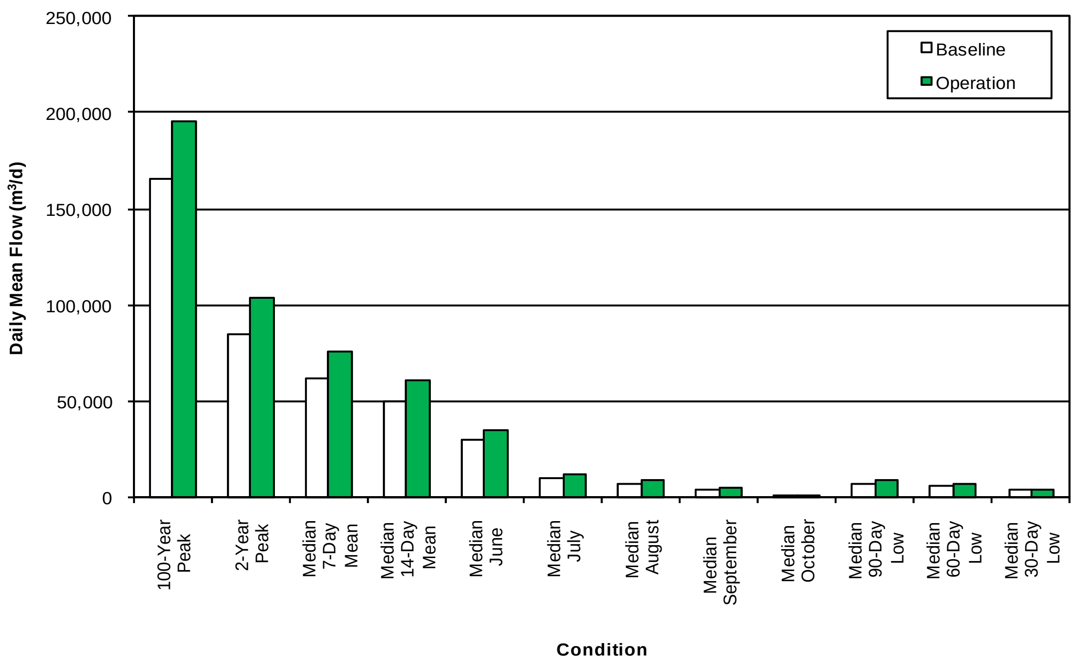
m = metre.

Table 9.7-34 Derived Representative Stages at Lake N9 – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.613	0.548	0.491	0.191	0.224	0.220
		operation	0.628	0.569	0.514	0.209	0.244	0.240
	10	baseline	0.557	0.502	0.455	0.122	0.149	0.168
		operation	0.572	0.521	0.474	0.132	0.161	0.183
Median	2	baseline	0.469	0.428	0.391	0.067	0.093	0.119
		operation	0.483	0.441	0.404	0.072	0.100	0.129
Dry	10	baseline	0.352	0.321	0.292	0.031	0.062	0.083
		operation	0.358	0.329	0.298	0.034	0.066	0.089
	100	baseline	0.217	0.191	0.157	0.007	0.047	0.060
		operation	0.207	0.187	0.157	0.010	0.050	0.063

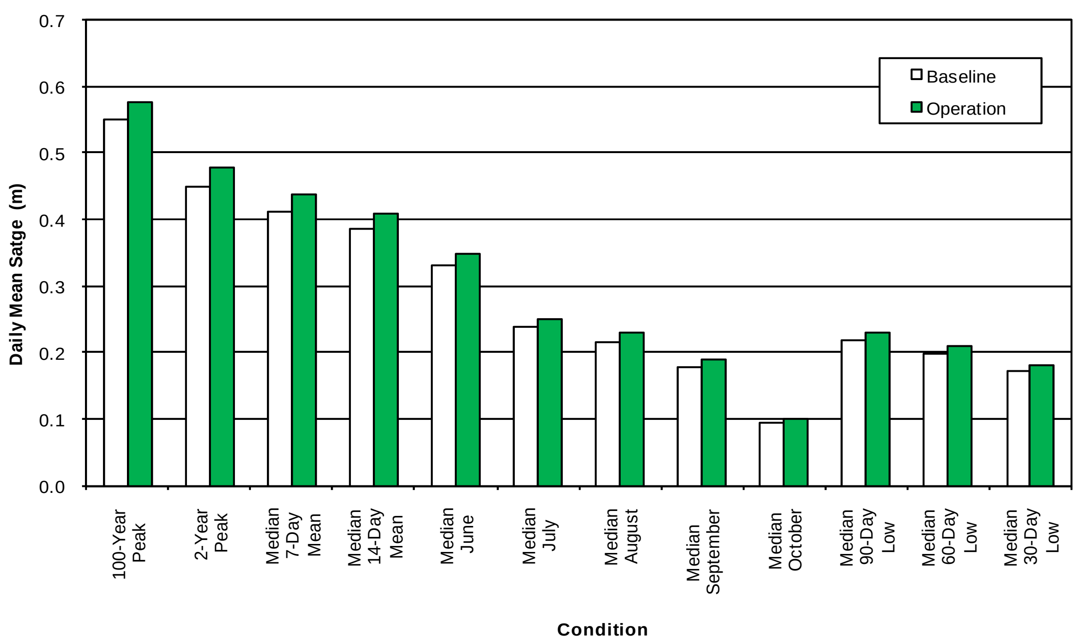
m = metre.

Figure 9.7-20 Comparison of Effects on Lake N6 Outlet Discharges – Operation



m^3/d = cubic metres per day.

Figure 9.7-21 Comparison of Effects on Lake N6 Stages – Operation



m = metres.

Table 9.7-35 Monthly Mean Discharges at the Lake N6 Outlet – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	44,300	25,100	22,200	22,200	3,600
		operation	53,000	29,900	27,100	26,500	4,220
	10	baseline	38,800	16,700	13,100	9,900	1,430
		operation	46,500	20,000	16,000	11,900	1,670
Median	2	baseline	29,400	9,740	6,980	3,650	431
		operation	35,100	11,600	8,530	4,390	505
Dry	10	baseline	15,800	5,140	3,860	1,330	102
		operation	18,300	6,020	4,740	1,580	121
	100	baseline	329	2,590	2,500	576	5
		operation	0	2,910	3,080	656	9

m^3/d = cubic metres per day.

Table 9.7-36 Derived Representative Discharges at the Lake N6 Outlet – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	1.91	91,800	70,600	13,400	19,300	18,200
		operation	2.26	113,000	86,000	15,900	23,200	22,000
	10	baseline	1.44	79,600	63,000	7,180	10,400	11,900
		operation	1.74	97,400	76,600	8,550	12,500	14,400
Median	2	baseline	0.98	61,800	50,000	3,220	5,240	7,140
		operation	1.20	75,700	60,800	3,860	6,380	8,570
Dry	10	baseline	0.60	40,400	31,500	1,330	3,040	4,290
		operation	0.75	50,300	38,500	1,580	3,730	5,170
	100	baseline	0.35	19,700	10,500	547	2,220	2,840
		operation	0.44	26,300	13,500	622	2,740	3,470

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-37 Monthly Mean Stages at Lake N6 – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.373	0.315	0.304	0.304	0.178
		operation	0.393	0.332	0.322	0.320	0.186
	10	baseline	0.358	0.279	0.260	0.239	0.135
		operation	0.378	0.295	0.276	0.253	0.142
Median	2	baseline	0.330	0.238	0.216	0.178	0.095
		operation	0.348	0.251	0.229	0.188	0.100
Dry	10	baseline	0.275	0.197	0.181	0.132	0.062
		operation	0.287	0.207	0.193	0.139	0.065
	100	baseline	0.088	0.161	0.160	0.103	0.025
		operation	-	0.167	0.170	0.108	0.030

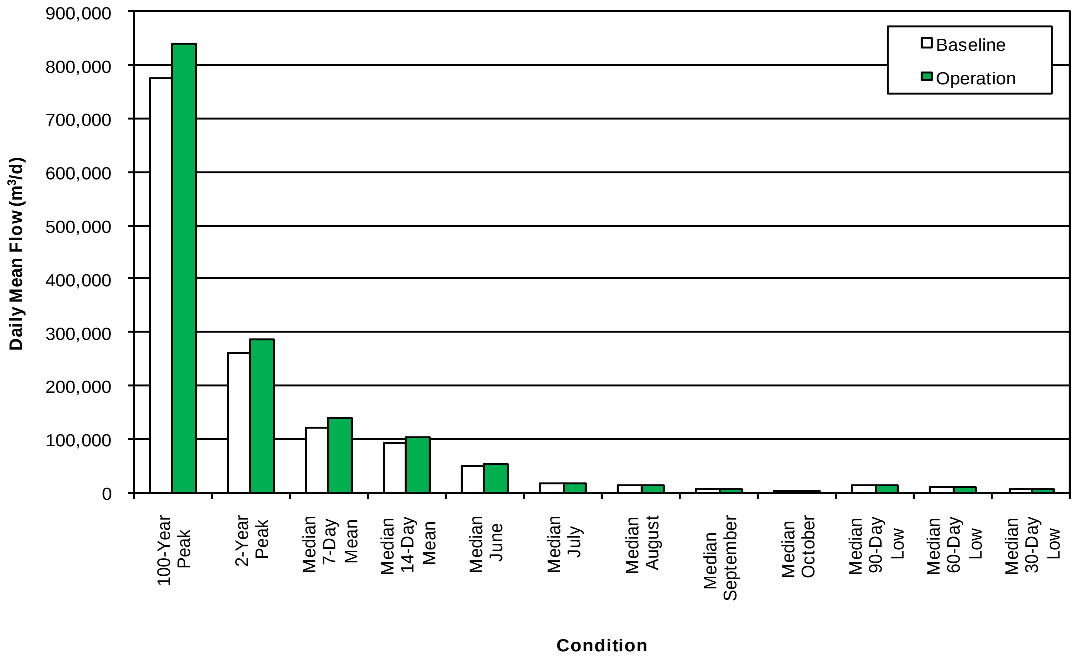
m = metre.

Table 9.7-38 Derived Representative Stages at Lake N6 – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.549	0.462	0.427	0.262	0.292	0.287
		operation	0.577	0.491	0.453	0.275	0.308	0.303
	10	baseline	0.505	0.443	0.413	0.218	0.243	0.253
		operation	0.534	0.470	0.438	0.229	0.256	0.267
Median	2	baseline	0.450	0.411	0.386	0.172	0.198	0.217
		operation	0.479	0.436	0.409	0.181	0.210	0.229
Dry	10	baseline	0.391	0.363	0.337	0.132	0.169	0.187
		operation	0.417	0.387	0.357	0.139	0.180	0.198
	100	baseline	0.334	0.293	0.244	0.102	0.154	0.166
		operation	0.355	0.319	0.262	0.106	0.164	0.176

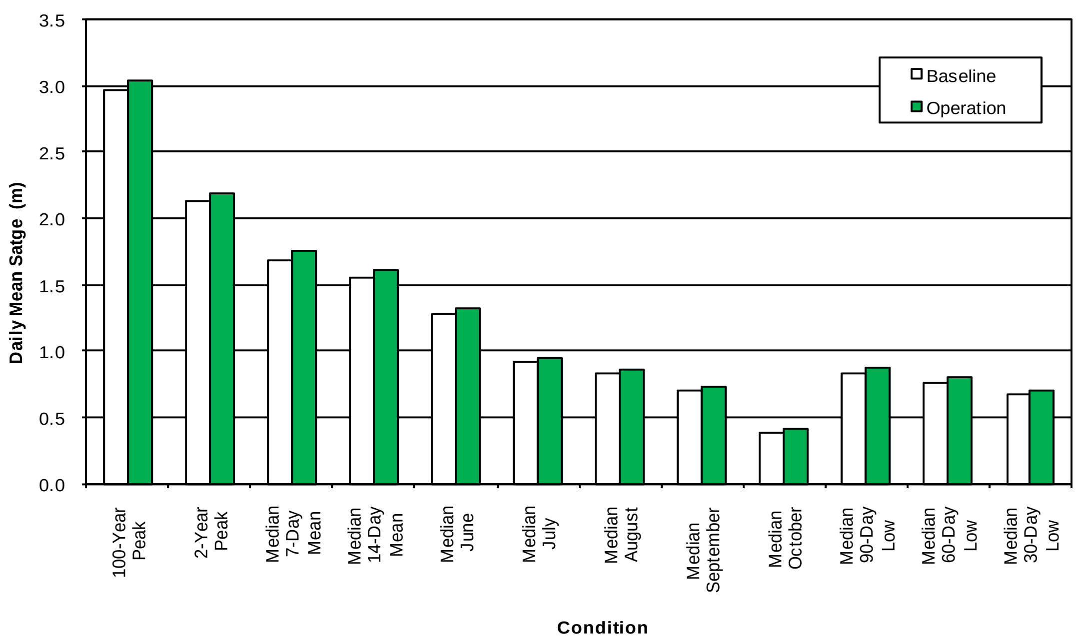
m = metre.

Figure 9.7-22 Comparison of Effects on Lake N2 Outlet Discharges – Operation



m^3/d = cubic metres per day.

Figure 9.7-23 Comparison of Effects on Lake N2 Stages – Operation



m = metres.

Table 9.7-39 Monthly Mean Discharges at the Lake N2 Outlet – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	74,000	40,000	33,500	36,300	6,640
		operation	82,800	44,500	38,100	41,000	7,360
	10	baseline	63,800	27,200	20,700	17,000	2,840
		operation	71,500	30,400	23,600	19,300	3,230
Median	2	baseline	47,900	16,200	11,600	6,710	964
		operation	53,700	18,100	13,300	7,710	1,120
Dry	10	baseline	27,100	8,800	6,590	2,710	282
		operation	30,200	9,790	7,550	3,160	332
	100	baseline	5,550	4,580	4,230	1,330	63
		operation	5,630	4,990	4,850	1,580	70

m^3/d = cubic metres per day.

Table 9.7-40 Derived Representative Discharges at the Lake N2 Outlet – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	8.96	159,000	123,000	22,300	30,700	29,400
		operation	9.74	180,000	138,000	25,300	34,500	33,300
	10	baseline	5.62	146,000	112,000	12,400	17,100	19,700
		operation	6.13	165,000	126,000	14,000	19,400	22,200
Median	2	baseline	3.03	121,000	91,700	5,890	8,960	12,000
		operation	3.33	138,000	103,000	6,720	10,300	13,600
Dry	10	baseline	1.49	81,300	60,200	2,680	5,350	7,360
		operation	1.65	92,800	68,000	3,110	6,160	8,350
	100	baseline	0.70	30,400	21,800	1,310	3,950	4,960
		operation	0.78	35,200	25,500	1,570	4,550	5,640

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-41 Monthly Mean Stages at Lake N2 – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	1.454	1.206	1.143	1.171	0.700
		operation	1.504	1.246	1.189	1.215	0.722
	10	baseline	1.390	1.073	0.988	0.931	0.541
		operation	1.439	1.110	1.028	0.967	0.563
Median	2	baseline	1.274	0.917	0.829	0.702	0.390
		operation	1.319	0.949	0.864	0.732	0.408
Dry	10	baseline	1.072	0.762	0.698	0.534	0.269
		operation	1.108	0.787	0.728	0.559	0.282
	100	baseline	0.663	0.625	0.611	0.430	0.171
		operation	0.666	0.642	0.636	0.453	0.176

m = metre.

Table 9.7-42 Derived Representative Stages at Lake N2 – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.372	2.962	1.833	1.696	1.011	1.113
		operation	0.372	3.037	1.903	1.756	1.050	1.154
	10	baseline	0.322	2.571	1.786	1.648	0.846	0.932
		operation	0.321	2.640	1.854	1.708	0.878	0.969
Median	2	baseline	0.257	2.132	1.687	1.551	0.675	0.767
		operation	0.257	2.194	1.756	1.607	0.703	0.800
Dry	10	baseline	0.189	1.719	1.496	1.366	0.532	0.656
		operation	0.189	1.773	1.557	1.417	0.556	0.684
	100	baseline	0.124	1.367	1.110	1.004	0.428	0.598
		operation	0.124	1.414	1.161	1.053	0.452	0.624

m = metre.

Summary of Effects on Flows, Water Levels and Channel/Bank Stability

Conveyance from Lake A3 to Lake N9 was discussed in Section 8.7. Because this will be a permanent diversion, an engineered channel will be constructed at this location.

Conveyance from Lake B1 to Lake N8 was also discussed in Section 8.7. This temporary diversion will comprise an engineered channel or pipeline, to prevent erosion by flowing water. Because Lake N8 is small, it provides little storage or flow attenuation, and diverted flows in the Lake N8 outlet channel to Lake N6 will greatly exceed baseline values, particularly during spring freshet. Alternatives for flow conveyance from Lake N8 to Lake N6 include improving the existing outlet channel to ensure that it is resistant to erosion, or constructing a parallel engineered channel or pipeline to handle excess discharge. Any of these will allow flows and water levels to be managed to prevent adverse effects on Lake N8 and Outlet channel and bank stability.

Note that these values represent changes that will occur after Lake A3 fills to its spill elevation, which would take 11 years under median conditions. Changes to Lake N6 and downstream waterbodies due to the Lake B1 diversion only, which would occur in the first year of operation, would be lower.

Lake N9 Outlet Flows: The water balance results for Lake N9 show that during operation, monthly mean flows will increase in proportion to the additional flow from the diverted A watershed. The 2-year flood discharge during operation will increase by approximately 3% above the baseline value, and the 100-year flood discharge will increase by approximately 4%. Low flows will also increase by 10% to 13%.

Lake N9 Water Levels: Lake N9 water levels are also expected to increase during operation. The 2-year flood level is expected to increase by approximately 0.014 m, the 100-year flood level by 0.015 m, and monthly mean stages by 0.013 m (June), 0.016 m (July), 0.008 m (August), 0.004 m (September) and 0.001 m (October), under median conditions.

Lake N9 and Outlet Channel/Bank Stability: No effects on Lake N9 and Outlet channel or bank stability are expected during operation, because increases in flood magnitude are small relative to the existing flood regime.

Lake N6 Outlet Flows: The water balance results for Lake N6 show that during operation, monthly mean flows will increase in proportion to the additional flow from the diverted A and B watersheds. The 2-year flood discharge during operation will increase by approximately 22% above the baseline value, and the 100-year flood discharge will increase by approximately 18%. Low flows will also increase by 20% to 22%.

Lake N6 Water Levels: Lake N6 water levels are also expected to increase during operation. The 2-year flood level is expected to increase by approximately 0.029 m, the 100-year flood level by 0.028 m, and monthly mean stages by 0.018 m (June), 0.013 m (July), 0.013 m (August), 0.010 m (September) and 0.005 m (October), under median conditions.

Lake N6 and Outlet Channel/Bank Stability: No effects on Lake N6 and Outlet channel or bank stability are expected during operation, because increases in flood magnitude are small relative to the existing flood regime.

Lake N2 Outlet Flows: The water balance results for Lake N2 show that during operation, monthly mean flows will increase in proportion to the additional flow from the diverted A and B watersheds. The 2-year flood discharge during operation will increase by approximately 10% above the baseline value, and the 100-year flood discharge will increase by approximately 9%. Low flows will also increase by 13% to 15%.

Lake N2 Water Levels: Lake N2 water levels are also expected to increase during operation. The 2-year flood level is expected to increase by approximately 0.062 m, the 100-year flood level by 0.075 m, and monthly mean stages by 0.045 m (June), 0.032 m (July), 0.035 m (August), 0.030 m (September) and 0.018 m (October), under median conditions.

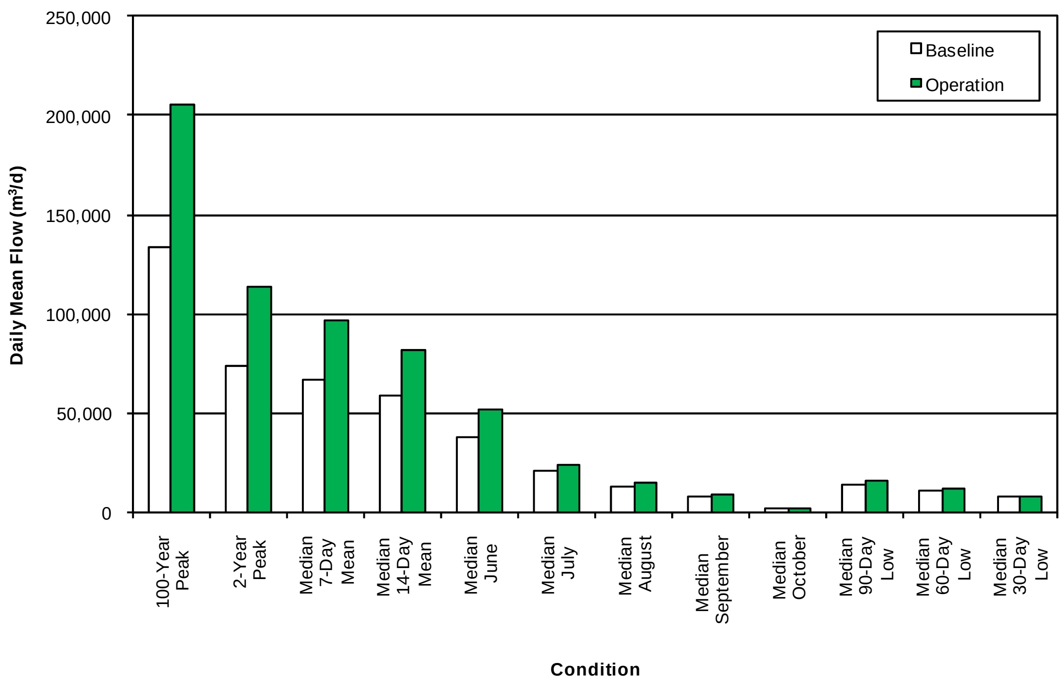
Lake N2 and Outlet Channel/Bank Stability: No effects on Lake N2 and outlet channel or bank stability are expected during operation, because increases in flood magnitude are small relative to the existing flood regime.

Lake N14 to Lake N11 Inflow (Watershed D and E Diversions)

The water balance model for the Project examined this receiving watershed by modeling the flow diverted from the D and E watersheds into Lake N17, with Lake N14 being lumped into the N17 watershed due to its small size and low storage/flow attenuation capacity. Lake N16, located below Lake N17, was modeled, and Lake N15 was not, due to its small size and low storage.

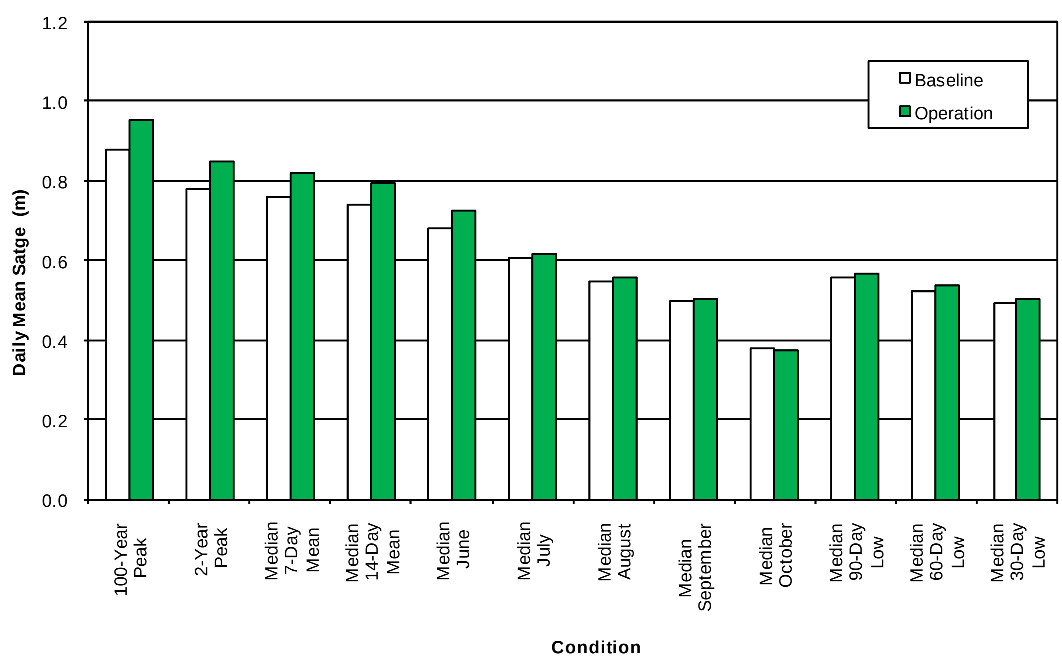
Project effects on Lake N17 are presented in Figures 9.7-24 to 9.7-25 and Tables 9.7-43 to 9.7-46, and Project effects on Lake N16 are presented in Figures 9.7-26 to 9.7-27 and Tables 9.7-47 to 9.7-50.

Figure 9.7-24 Comparison of Effects on Lake N17 Outlet Discharges – Operation



m^3/d = cubic metres per day.

Figure 9.7-25 Comparison of Effects on Lake N17 Stages – Operation



m = metres.

Table 9.7-43 Monthly Mean Discharges at the Lake N17 Outlet – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	66,800	44,200	31,800	36,800	7,720
		operation	88,000	52,900	39,600	47,800	8,340
	10	baseline	54,000	32,400	20,900	17,300	4,100
		operation	72,300	37,300	24,700	20,400	4,210
Median	2	baseline	38,000	21,100	12,800	7,830	2,040
		operation	51,500	23,400	14,200	8,220	1,910
Dry	10	baseline	21,800	12,400	8,050	4,500	1,160
		operation	29,000	13,500	8,550	4,370	963
	100	baseline	8,350	6,980	5,720	3,460	835
		operation	9,180	7,620	5,920	3,270	620

m^3/d = cubic metres per day.

Table 9.7-44 Derived Representative Discharges at the Lake N17 Outlet – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	1.55	115,000	95,800	26,300	30,300	35,000
		operation	2.38	168,000	133,000	30,800	36,500	42,200
	10	baseline	1.28	96,700	82,100	14,300	17,800	22,400
		operation	1.98	141,000	115,000	16,000	20,600	25,700
Median	2	baseline	0.85	66,500	58,300	7,690	10,300	13,900
		operation	1.32	96,900	81,900	8,130	11,400	15,400
Dry	10	baseline	0.42	34,700	32,300	4,340	6,590	9,200
		operation	0.64	50,400	45,200	4,160	6,940	9,990
	100	baseline	0.09	8,900	10,300	3,530	5,780	7,880
		operation	0.10	12,800	13,500	3,240	6,090	8,680

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-45 Monthly Mean Stages at Lake N17 – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.762	0.702	0.657	0.677	0.495
		operation	0.806	0.728	0.687	0.713	0.503
	10	baseline	0.731	0.660	0.604	0.582	0.436
		operation	0.775	0.679	0.625	0.601	0.439
Median	2	baseline	0.681	0.606	0.548	0.497	0.379
		operation	0.724	0.618	0.559	0.501	0.375
Dry	10	baseline	0.609	0.544	0.499	0.445	0.339
		operation	0.645	0.554	0.505	0.442	0.327
	100	baseline	0.503	0.485	0.466	0.422	0.317
		operation	0.513	0.494	0.470	0.417	0.299

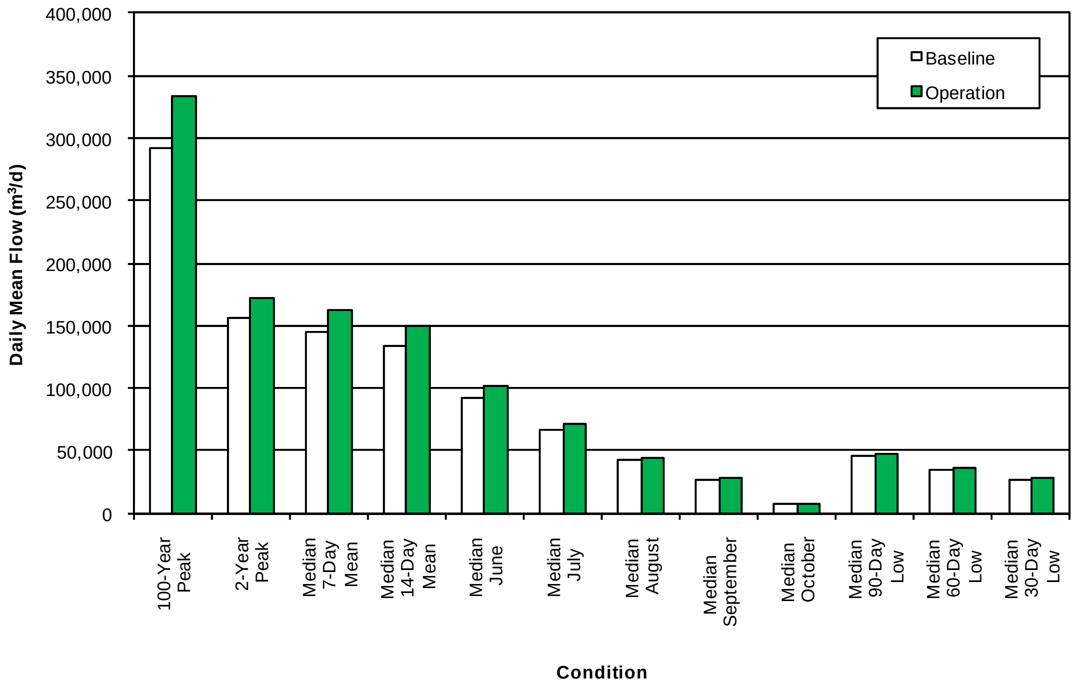
m = metre.

Table 9.7-46 Derived Representative Stages at Lake N17 – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.876	0.850	0.819	0.633	0.651	0.670
		operation	0.955	0.917	0.875	0.653	0.676	0.696
	10	baseline	0.843	0.821	0.795	0.560	0.585	0.613
		operation	0.920	0.885	0.850	0.573	0.603	0.630
Median	2	baseline	0.778	0.762	0.742	0.495	0.525	0.557
		operation	0.849	0.821	0.794	0.500	0.535	0.569
Dry	10	baseline	0.675	0.669	0.659	0.441	0.480	0.513
		operation	0.735	0.721	0.705	0.438	0.485	0.521
	100	baseline	0.491	0.510	0.525	0.423	0.467	0.497
		operation	0.510	0.548	0.554	0.416	0.472	0.507

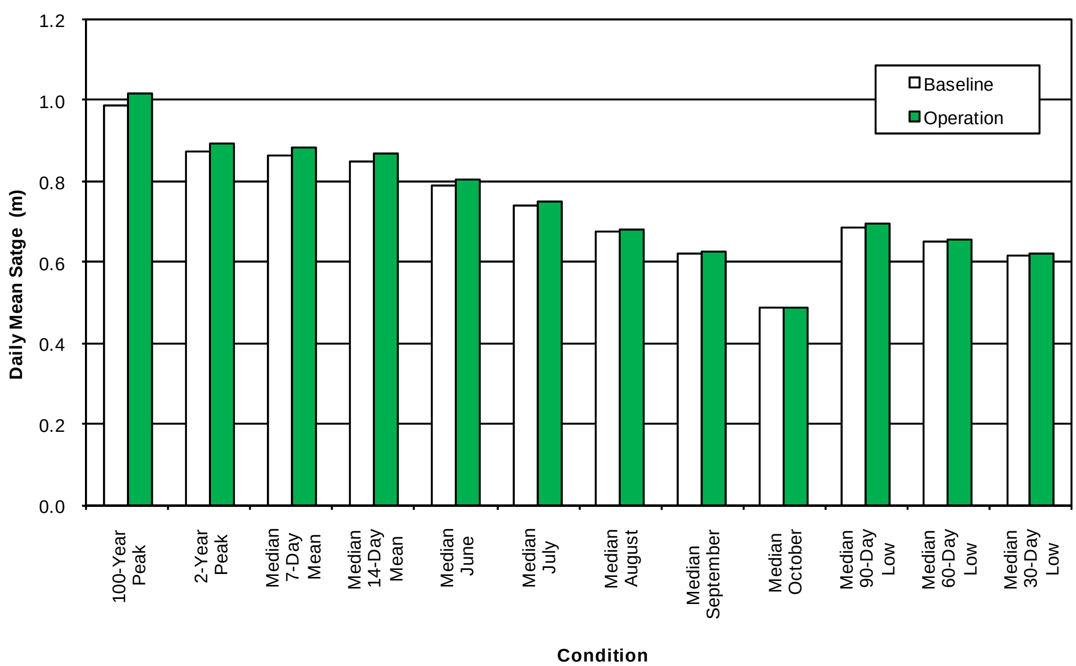
m = metre.

Figure 9.7-26 Comparison of Effects on Lake N16 Outlet Discharges – Operation



m^3/d = cubic metres per day.

Figure 9.7-27 Comparison of Effects on Lake N16 Stages – Operation



m = metres.

Table 9.7-47 Monthly Mean Discharges at the Lake N16 Outlet – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	171,000	127,000	92,300	93,600	23,800
		operation	190,000	138,000	98,700	101,000	25,400
	10	baseline	134,000	97,800	64,700	51,400	14,100
		operation	149,000	105,000	68,500	54,400	14,700
Median	2	baseline	91,900	66,900	42,400	27,300	7,910
		operation	102,000	71,600	44,300	28,300	8,140
Dry	10	baseline	53,200	40,900	28,200	17,000	4,960
		operation	57,800	43,400	29,300	17,500	5,060
	100	baseline	23,900	22,600	20,500	13,200	3,740
		operation	24,600	23,900	21,300	13,600	3,820

m^3/d = cubic metres per day.

Table 9.7-48 Derived Representative Discharges at the Lake N16 Outlet – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	3.37	257,000	228,000	79,300	89,800	100,000
		operation	3.86	295,000	258,000	84,700	96,100	108,000
	10	baseline	2.71	212,000	190,000	45,800	55,800	69,400
		operation	3.07	242,000	215,000	48,200	58,800	73,900
Median	2	baseline	1.80	145,000	133,000	26,700	34,500	45,500
		operation	2.00	163,000	149,000	27,700	36,000	48,000
Dry	10	baseline	0.94	78,200	74,600	16,700	23,300	30,500
		operation	1.00	84,500	81,300	17,200	24,200	32,100
	100	baseline	0.31	26,400	29,000	14,300	20,700	25,500
		operation	0.30	25,100	28,500	14,600	21,400	26,900

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-49 Monthly Mean Stages at Lake N16 – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.891	0.840	0.789	0.791	0.604
		operation	0.910	0.854	0.799	0.803	0.612
	10	baseline	0.849	0.798	0.736	0.703	0.545
		operation	0.867	0.809	0.744	0.711	0.549
Median	2	baseline	0.788	0.740	0.677	0.621	0.486
		operation	0.805	0.750	0.683	0.625	0.489
Dry	10	baseline	0.708	0.672	0.624	0.565	0.443
		operation	0.719	0.680	0.629	0.568	0.445
	100	baseline	0.604	0.598	0.586	0.538	0.419
		operation	0.608	0.604	0.591	0.541	0.421

m = metre.

Table 9.7-50 Derived Representative Stages at Lake N16 – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.989	0.965	0.943	0.766	0.785	0.801
		operation	1.016	0.992	0.966	0.776	0.795	0.814
	10	baseline	0.948	0.929	0.910	0.687	0.714	0.746
		operation	0.971	0.954	0.932	0.694	0.722	0.755
Median	2	baseline	0.874	0.862	0.848	0.618	0.650	0.686
		operation	0.893	0.883	0.867	0.622	0.655	0.694
Dry	10	baseline	0.769	0.764	0.757	0.563	0.601	0.634
		operation	0.779	0.775	0.769	0.566	0.606	0.641
	100	baseline	0.619	0.616	0.628	0.546	0.588	0.612
		operation	0.612	0.610	0.626	0.548	0.591	0.619

m = metre.

Summary of Effects on Flows, Water Levels and Channel/Bank Stability

Conveyance from Lake D2/D3 and Lake E1 to Lake N14 was discussed in Section 8.7. These temporary diversion flows will be conveyed by engineered channel or pipeline to manage flows and water levels and prevent any adverse effects on diversion channel and bank stability.

Because the existing Lake N14 watershed is small relative to the upstream diverted area, diverted flows will greatly exceed baseline values, particularly during spring freshet. Alternatives for flow conveyance from Lake N14 to Lake N17 include improving the existing outlet channel to ensure that it is resistant to erosion, or constructing a parallel engineered channel or pipeline to handle excess discharge. Any of these will allow flows and water levels to be managed to prevent adverse effects on Lake N14 and Outlet channel and bank stability.

Note that these values presented here represent changes that will occur after Lake D2/D3 fills to its spill elevation, which will take 3 years under median conditions. Changes due to only the Lake E1 diversion, which would occur in the first year of operation, would be lower.

Lake N17 Outlet Flows: The water balance results for Lake N17 show that during operation, monthly mean flows will increase in proportion to the additional flow from the diverted D and E watersheds. The 2-year flood discharge during operation will increase by approximately 54% above the baseline value, and the 100-year flood discharge will increase by approximately 55%. Low flows will also increase by 6% to 11%.

Lake N17 Water Levels: Lake N17 water levels are also expected to increase during operation. The 2-year flood level is expected to increase by approximately 0.071 m, the 100-year flood level by 0.079 m, and monthly mean stages by 0.043 m (June), 0.012 m (July), 0.011 m (August), 0.004 m (September) and -0.004 m (October), under median conditions.

Lake N17 and Outlet Channel/Bank Stability: No effects on Lake N17 and Outlet channel or bank stability are expected during operation, because increases in flood magnitude are small relative to the existing flood regime. Water level increases of 50 to 80 mm are unlikely to affect lake shorelines, but increased flood magnitudes are large enough to warrant more intensive monitoring on this lake outlet channel. It is expected that bouldery substrates, along with frozen bank conditions during spring freshet, will prevent any adverse effects to the outlet channel.

Lake N16 Outlet Flows: The water balance results for Lake N16 show that during operation, monthly mean flows will increase in proportion to the additional flow from the diverted D and E watersheds. The 2-year flood discharge during operation will increase by approximately 11% above the baseline value, and the 100-year flood discharge will increase by approximately 15%. Low flows will also increase by 4% to 5%.

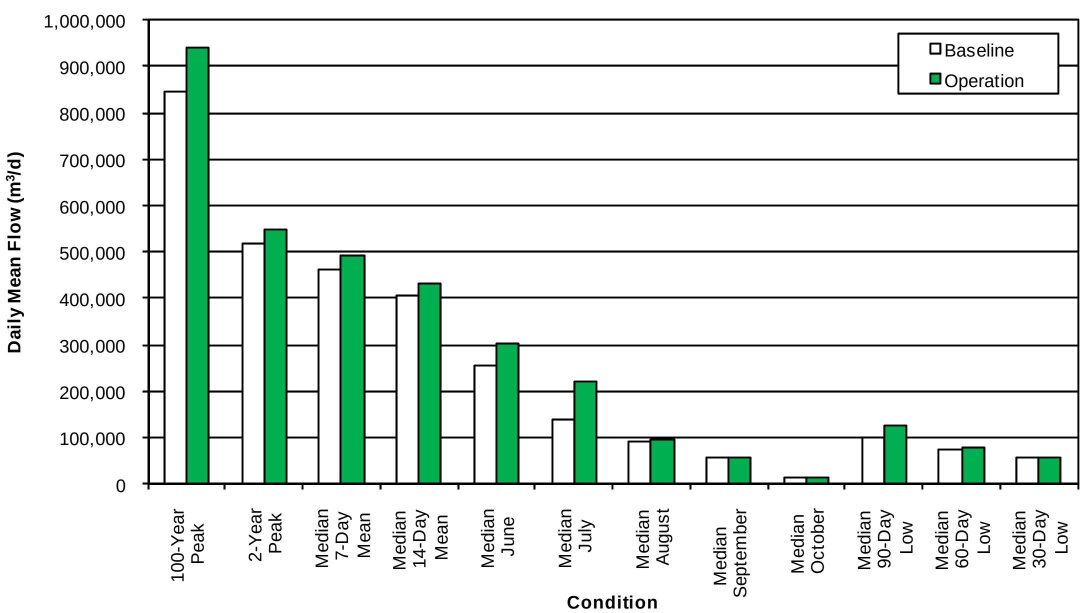
Lake N16 Water Levels: Lake N16 water levels are also expected to increase during operation. The 2-year flood level is expected to increase by approximately 0.019 m, the 100-year flood level by 0.027 m, and monthly mean stages by 0.017 m (June), 0.010 m (July), 0.006 m (August), 0.004 m (September) and 0.003 m (October), under median conditions.

Lake N16 and Outlet Channel/Bank Stability: No effects on Lake N16 and Outlet channel or bank stability are expected during operation, because increases in flood magnitude are small relative to the existing flood regime.

Lake N11 to Lake N1 (Combined Diversion)

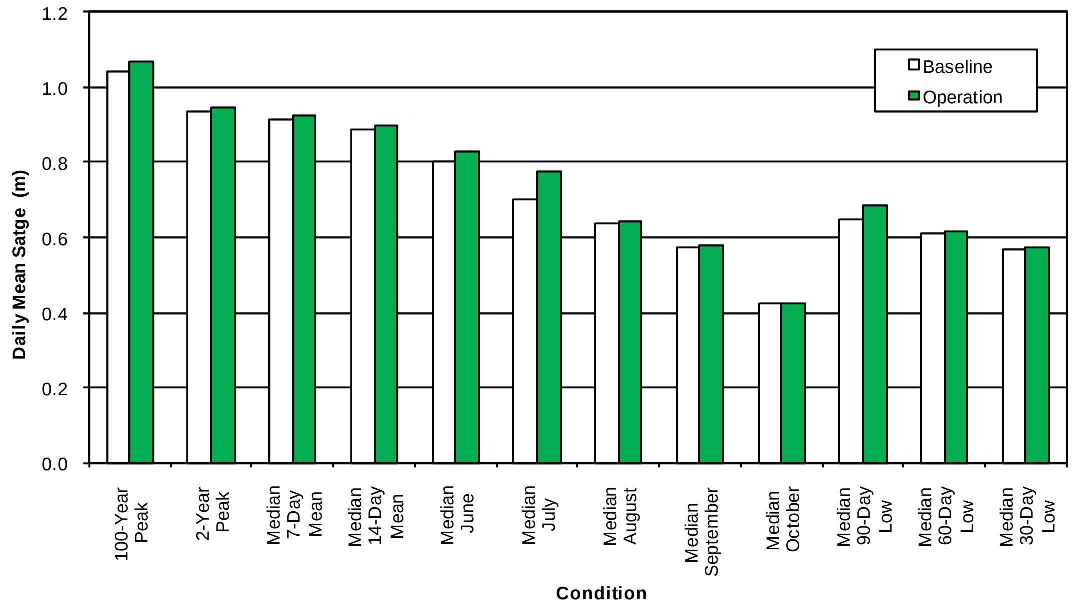
The water balance model for the Project examined flows and water levels at Lake N11 and Lake N1. Project effects on Lake N11 are presented in Figures 9.7-28 to 9.7-29 and Tables 9.7-69 to 9.7-72, and Project effects on Lake N1 are presented in Figures 9.7-30 to 9.7-31 and Tables 9.7-73 to 9.7-76.

Figure 9.7-28 Comparison of Effects on Lake N11 Outlet Discharges – Operation



m^3/d = cubic metres per day.

Figure 9.7-29 Comparison of Effects on Lake N11 Stages – Operation



m = metres.

Table 9.7-51 Monthly Mean Discharges at the Lake N11 Outlet – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	443,000	293,000	221,000	258,000	50,700
		operation	508,000	388,000	243,000	267,000	53,300
	10	baseline	359,000	215,000	147,000	123,000	28,200
		operation	413,000	311,000	158,000	127,000	29,200
Median	2	baseline	257,000	141,000	91,400	56,800	14,700
		operation	304,000	221,000	96,600	58,700	15,100
Dry	10	baseline	155,000	83,600	58,800	33,300	8,740
		operation	202,000	132,000	62,200	34,400	8,880
	100	baseline	71,900	46,900	42,600	25,900	6,400
		operation	123,000	62,600	45,700	26,700	6,510

m^3/d = cubic metres per day.

Table 9.7-52 Derived Representative Discharges at the Lake N11 Outlet – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	9.77	747,000	630,000	179,000	198,000	215,000
		operation	10.90	838,000	702,000	196,000	222,000	259,000
	10	baseline	8.22	630,000	538,000	102,000	125,000	152,000
		operation	8.86	680,000	580,000	109,000	135,000	189,000
Median	2	baseline	6.00	464,000	404,000	55,500	75,000	98,700
		operation	6.37	493,000	433,000	57,900	78,800	127,000
Dry	10	baseline	3.36	269,000	240,000	33,900	48,500	64,200
		operation	3.87	311,000	288,000	34,900	50,700	83,000
	100	baseline	0.85	85,300	81,700	25,200	36,500	45,200
		operation	1.82	167,000	172,000	25,900	38,600	57,000

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-53 Monthly Mean Stages at Lake N11 – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.903	0.824	0.774	0.801	0.558
		operation	0.931	0.877	0.791	0.807	0.564
	10	baseline	0.862	0.769	0.707	0.680	0.490
		operation	0.889	0.835	0.718	0.684	0.494
Median	2	baseline	0.800	0.700	0.636	0.572	0.424
		operation	0.831	0.774	0.644	0.577	0.426
Dry	10	baseline	0.715	0.624	0.577	0.508	0.378
		operation	0.759	0.690	0.584	0.512	0.379
	100	baseline	0.603	0.548	0.537	0.481	0.352
		operation	0.680	0.585	0.545	0.484	0.354

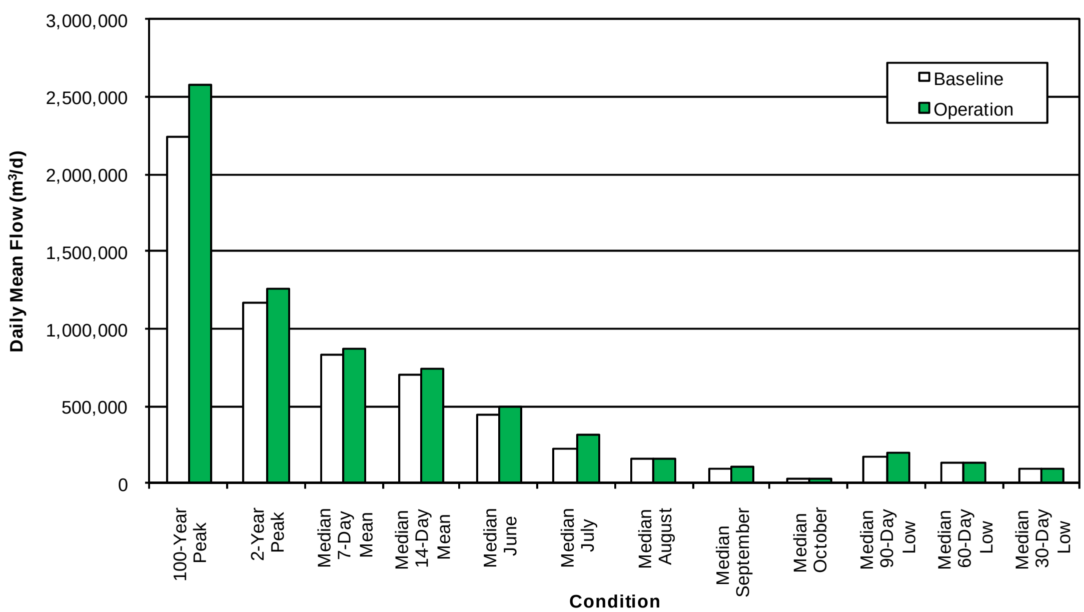
m = metre.

Table 9.7-54 Derived Representative Stages at Lake N11 – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	1.043	1.015	0.977	0.739	0.755	0.769
		operation	1.068	1.041	1.001	0.754	0.775	0.802
	10	baseline	1.003	0.977	0.943	0.652	0.682	0.712
		operation	1.020	0.994	0.959	0.662	0.694	0.748
Median	2	baseline	0.935	0.913	0.885	0.569	0.609	0.647
		operation	0.948	0.925	0.899	0.575	0.616	0.684
Dry	10	baseline	0.822	0.809	0.788	0.510	0.553	0.588
		operation	0.849	0.835	0.821	0.514	0.558	0.623
	100	baseline	0.606	0.626	0.620	0.478	0.519	0.544
		operation	0.718	0.727	0.732	0.481	0.525	0.573

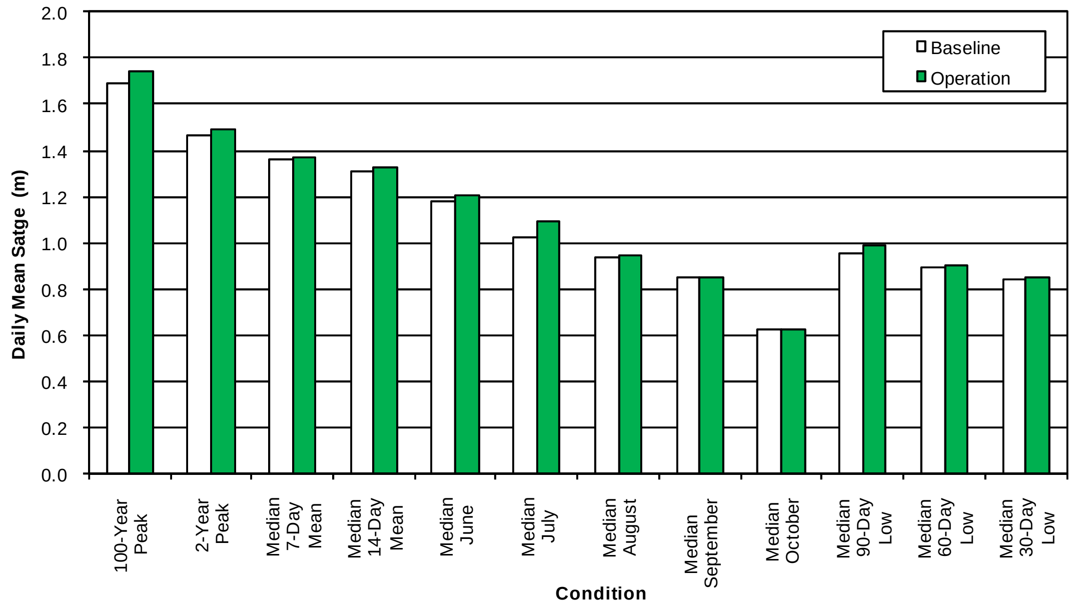
m = metre.

Figure 9.7-30 Comparison of Effects on Lake N1 Outlet Discharges – Operation



m^3/d = cubic metres per day.

Figure 9.7-31 Comparison of Effects on Lake N1 Stages – Operation



m = metres.

Table 9.7-55 Monthly Mean Discharges at the Lake N1 Outlet – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	737,000	470,000	370,000	398,000	84,100
		operation	801,000	569,000	401,000	418,000	87,900
	10	baseline	609,000	348,000	248,000	204,000	47,600
		operation	660,000	448,000	265,000	213,000	49,300
Median	2	baseline	444,000	229,000	156,000	99,000	25,100
		operation	489,000	315,000	164,000	102,000	25,700
Dry	10	baseline	270,000	138,000	102,000	56,600	14,600
		operation	319,000	197,000	107,000	58,300	14,900
	100	baseline	121,000	79,300	75,400	41,600	10,300
		operation	183,000	111,000	79,700	43,000	10,500

m^3/d = cubic metres per day.

Table 9.7-56 Derived Representative Discharges at the Lake N1 Outlet – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	25.90	1,250,000	1,050,000	285,000	333,000	353,000
		operation	29.80	1,350,000	1,110,000	312,000	368,000	404,000
	10	baseline	19.90	1,080,000	910,000	171,000	212,000	251,000
		operation	22.10	1,150,000	962,000	183,000	227,000	293,000
Median	2	baseline	13.50	827,000	704,000	95,600	128,000	166,000
		operation	14.60	872,000	740,000	100,000	134,000	197,000
Dry	10	baseline	8.22	527,000	441,000	57,200	83,800	109,000
		operation	8.68	557,000	472,000	59,100	87,500	132,000
	100	baseline	4.51	242,000	174,000	40,500	63,800	77,100
		operation	4.84	270,000	211,000	41,600	67,200	95,000

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-57 Monthly Mean Stages at Lake N1 – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	1.323	1.197	1.135	1.154	0.817
		operation	1.348	1.249	1.156	1.166	0.825
	10	baseline	1.268	1.120	1.039	0.995	0.720
		operation	1.291	1.185	1.054	1.004	0.725
Median	2	baseline	1.182	1.020	0.937	0.847	0.624
		operation	1.208	1.095	0.947	0.853	0.628
Dry	10	baseline	1.058	0.912	0.853	0.748	0.553
		operation	1.098	0.987	0.862	0.753	0.556
	100	baseline	0.886	0.806	0.797	0.698	0.512
		operation	0.971	0.869	0.807	0.704	0.514

m = metre.

Table 9.7-58 Derived Representative Stages at Lake N1 – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	1.693	1.488	1.431	1.071	1.109	1.123
		operation	1.747	1.514	1.449	1.093	1.134	1.158
	10	baseline	1.597	1.440	1.387	0.956	1.003	1.041
		operation	1.635	1.461	1.404	0.971	1.018	1.078
Median	2	baseline	1.465	1.357	1.310	0.840	0.897	0.950
		operation	1.491	1.373	1.324	0.849	0.906	0.987
Dry	10	baseline	1.312	1.228	1.180	0.750	0.816	0.865
		operation	1.328	1.243	1.198	0.755	0.824	0.903
	100	baseline	1.148	1.033	0.960	0.694	0.768	0.801
		operation	1.167	1.058	1.002	0.698	0.777	0.839

m = metre.

Summary of Effects on Flows, Water Levels and Channel/Bank Stability

Lake N11 Outlet Flows: The water balance results for Lake N11 show that during operations, monthly mean flows will increase due to the upstream diversion of the D and E watersheds. The peak daily discharges will increase by 6% (2-year flood) and 12% (100-year flood). Low flows will increase by up to 29% because of the increased upstream storage and flow area.

Lake N11 Water Levels: Lake N11 water levels are also expected to increase during operation. The 2-year flood level is expected to increase by approximately 0.013 m, the 100-year flood level by 0.025 m, and monthly mean stages by 0.031 m (June), 0.074 m (July), 0.008 m (August), 0.005 m (September) and 0.002 m (October), under median conditions.

Lake N11 and Outlet Channel/Bank Stability: No effects on Lake N11 and Outlet channel or bank stability are expected during operation, because increases in flood magnitude are small relative to the existing flood regime, and the channel is naturally well armoured.

Lake N1 Outlet Flows: The water balance results for Lake N1 show that during operations, monthly mean flows will increase due to the upstream diversion of the A, B, D and E watersheds. The peak daily discharges will increase by 8% (2-year flood) and 15% (100-year flood). Low flows will increase by up to 19% because of the increased upstream storage and flow area.

Lake N1 Water Levels: Lake N1 water levels are also expected to increase during operation. The 2-year flood level is expected to increase by approximately 0.026 m, the 100-year flood level by 0.054 m, and monthly mean stages by 0.026 m (June), 0.075 m (July), 0.010 m (August), 0.006 m (September) and 0.004 m (October), under median conditions.

Lake N1 and Outlet Channel/Bank Stability: No effects on Lake N1 and Outlet channel or bank stability are expected during operation, because increases in flood magnitude are small relative to the existing flood regime, and the channel is naturally well armoured.

9.7.3.3 Effect of Project Infrastructure in Kennady Lake Watershed to Flows, Water Levels, and Channel/Bank Stability in Streams and Lakes in Downstream Waters

9.7.3.3.1 Project Activities

Effects of the Project activities on the water balance of Kennady Lake Area 8 during operation were described in EIS Section 8.7. Water management activities that affect the water balance of Area 8 during operation (i.e., after Dyke A is constructed and dewatering is complete) include:

- Dewatered Areas 2 to 7 will be isolated from Area 8 of Kennady Lake.
- A reduction of inflow to dewatered Areas 2 to 7 will result from diversion of the A, B, D and E watersheds.

The effects of these activities on the water balance and water levels in Area 8 were assessed in Section 8.7 (Effects to Water Quality and Fish in Kennady Lake; Effects to Water Quantity). The effects of changes in the discharge from Area 8 on flows, water levels and channel/bank stability in the Area 8 outlet channel and downstream waterbodies is assessed herein. The assessment below includes mainstem lakes within the L and M watersheds, Lake 410, mainstem lakes within the P watershed, Kirk Lake and watersheds further downstream. The downstream watersheds and flow paths from Kennady Lake to Lake 410 (Figure 9.7-1), and the downstream watersheds and flow paths from Lake 410 to Kirk Lake (Figure 9.7-2).

The operational diversion of the A, B, D and E watersheds into watershed N is discussed further in Section 9.7.3.3. The effects of these diversions are included in modelling of effects on Lake 410 and downstream watersheds.

9.7.3.3.2 Environmental Design Features and Mitigation

During operation, all contact water, including Project site contact water and inflows to the dewatered lake bed will be collected in the WMP (Areas 3 and 5). In general, this will reduce flows in Kennady Lake Area 8 during spring runoff, due to closed-circuiting of Areas 2 to 7. The relative magnitude of these effects on each waterbody will diminish with downstream distance.

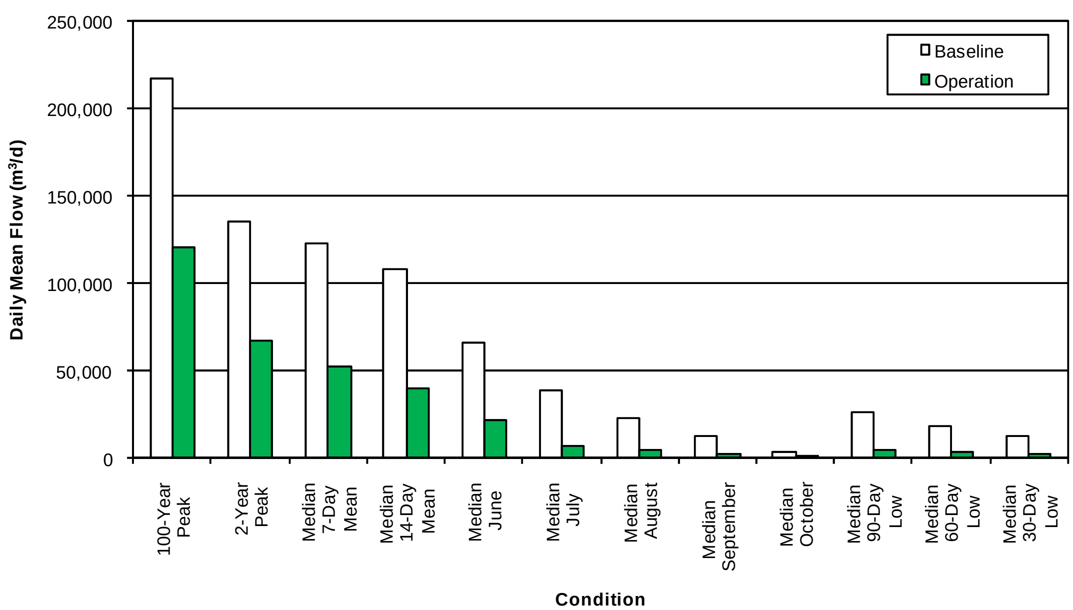
9.7.3.3.3 Effects Analysis

Kennady Lake (Area 8) Outlet (Stream K5) to Lake M1 Outlet

Dyke A will prevent water from flowing from Area 8 into Areas 2 to 7 during dewatering and operation. Area 8 will be preserved as a free-draining waterbody throughout this period, though its hydrological regime will be changed.

The water balance model for the Project examined all downstream waterbodies between the Kennady Lake Area 8 outlet channel and the Lake M1 outlet channel. Project effects on the Area 8 outlet channel during dewatering are summarized in Figure 9.7-32 and Tables 9.7-59 to 9.7-60. Project effects on Lake L1 during dewatering are summarized in Figure 9.7-33 to 9.7-34 and Tables 9.7-61 to 9.7-64. Project effects on Lake M1 during dewatering are summarized in Figures 9.7-35 to 9.7-36 and Tables 9.7-65 to 9.7-68.

Figure 9.7-32 Comparison of Effects on Area 8 Outlet Discharges – Operation



m^3/d = cubic metres per day.

Table 9.7-59 Monthly Mean Discharges at the Area 8 Outlet – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	121,000	86,500	59,600	68,600	13,500
		operation	35,500	19,600	14,700	16,900	2,030
	10	baseline	97,600	61,900	38,100	29,200	6,640
		operation	30,700	12,000	8,680	6,620	967
Median	2	baseline	65,900	39,300	22,800	13,200	3,070
		operation	21,900	6,670	4,580	2,460	371
Dry	10	baseline	36,900	23,100	13,900	6,880	1,430
		operation	12,000	3,570	2,310	892	91
	100	baseline	12,900	12,000	9,420	4,910	878
		operation	2,380	1,880	1,390	496	18

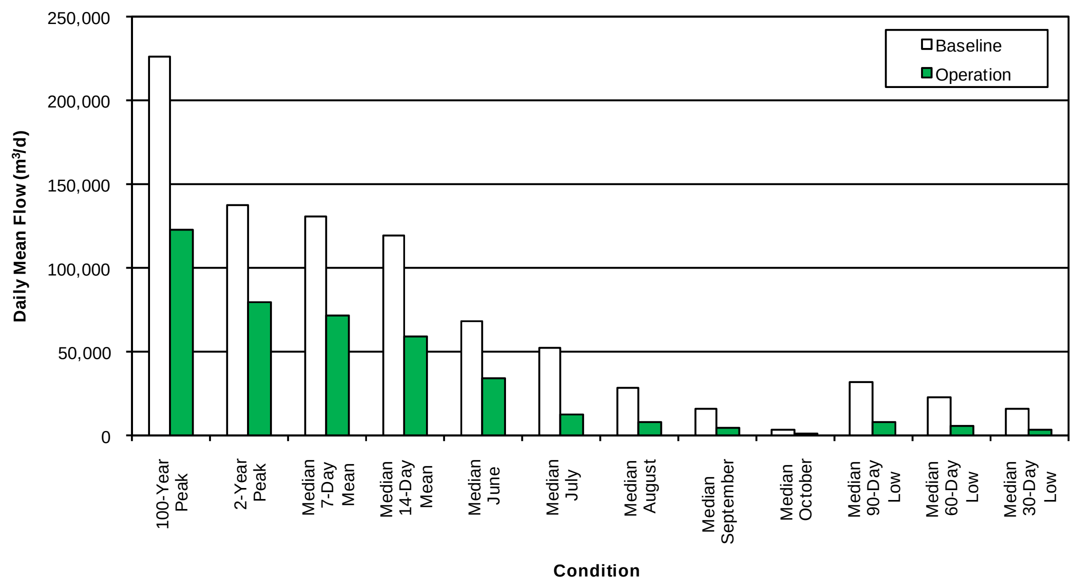
m^3/d = cubic metres per day.

Table 9.7-60 Derived Representative Discharges at the Area 8 Outlet – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	2.51	192,000	167,000	48,900	52,500	59,000
		operation	1.39	85,200	61,000	10,500	14,100	13,300
	10	baseline	2.14	166,000	145,000	26,200	32,300	41,000
		operation	1.11	71,700	52,600	5,070	7,200	8,450
Median	2	baseline	1.56	123,000	108,000	12,800	18,300	26,000
		operation	0.78	52,900	39,900	2,100	3,390	4,830
Dry	10	baseline	0.80	65,100	60,000	6,560	10,900	16,100
		operation	0.46	31,100	23,700	900	1,820	2,720
	100	baseline	0.15	14,900	17,300	5,000	9,340	13,200
		operation	0.21	10,800	7,400	473	1,260	1,680

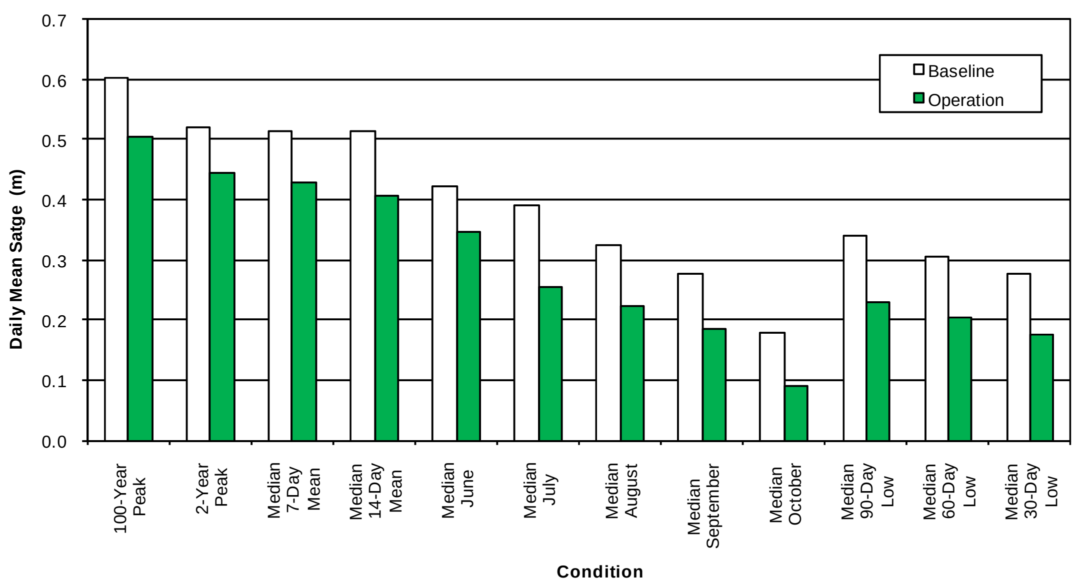
Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Figure 9.7-33 Comparison of Effects on Lake L1 Outlet Discharges – Operation



m^3/d = cubic metres per day.

Figure 9.7-34 Comparison of Effects on Lake L1 Stages – Operation



m = metres.

Table 9.7-61 Monthly Mean Discharges at the Lake L1 Outlet – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	130,000	111,000	67,700	85,000	20,600
		operation	57,000	36,100	23,600	31,300	8,690
	10	baseline	102,000	81,400	45,700	38,900	9,240
		operation	47,200	22,700	14,400	12,800	2,140
Median	2	baseline	67,800	52,300	28,100	16,400	3,630
		operation	34,300	12,300	7,690	4,190	376
Dry	10	baseline	35,700	29,300	17,100	8,310	1,620
		operation	20,500	6,140	3,940	1,310	57
	100	baseline	10,700	14,200	11,300	5,750	976
		operation	8,500	2,980	2,130	448	4

m^3/d = cubic metres per day.

Table 9.7-62 Derived Representative Discharges at the Lake L1 Outlet – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	2.62	214,000	189,000	57,000	63,400	76,800
		operation	1.42	112,000	89,500	17,000	23,300	23,000
	10	baseline	2.25	185,000	164,000	31,300	38,900	51,900
		operation	1.23	96,200	77,900	8,570	12,100	14,800
Median	2	baseline	1.59	131,000	119,000	16,100	22,400	32,500
		operation	0.93	72,200	59,700	3,540	5,780	8,520
Dry	10	baseline	0.86	71,700	66,800	7,980	13,000	19,900
		operation	0.54	42,100	35,500	1,300	3,100	4,770
	100	baseline	0.23	20,000	21,000	5,770	9,970	15,000
		operation	0.13	12,000	10,200	427	2,120	2,860

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-63 Monthly Mean Stages at Lake L1 – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.512	0.488	0.422	0.451	0.297
		operation	0.401	0.351	0.309	0.336	0.230
	10	baseline	0.476	0.446	0.376	0.358	0.235
		operation	0.380	0.306	0.267	0.258	0.152
Median	2	baseline	0.422	0.391	0.326	0.278	0.178
		operation	0.345	0.255	0.222	0.186	0.091
Dry	10	baseline	0.350	0.330	0.281	0.227	0.140
		operation	0.297	0.208	0.182	0.132	0.052
	100	baseline	0.245	0.266	0.249	0.204	0.121
		operation	0.229	0.168	0.152	0.096	0.023

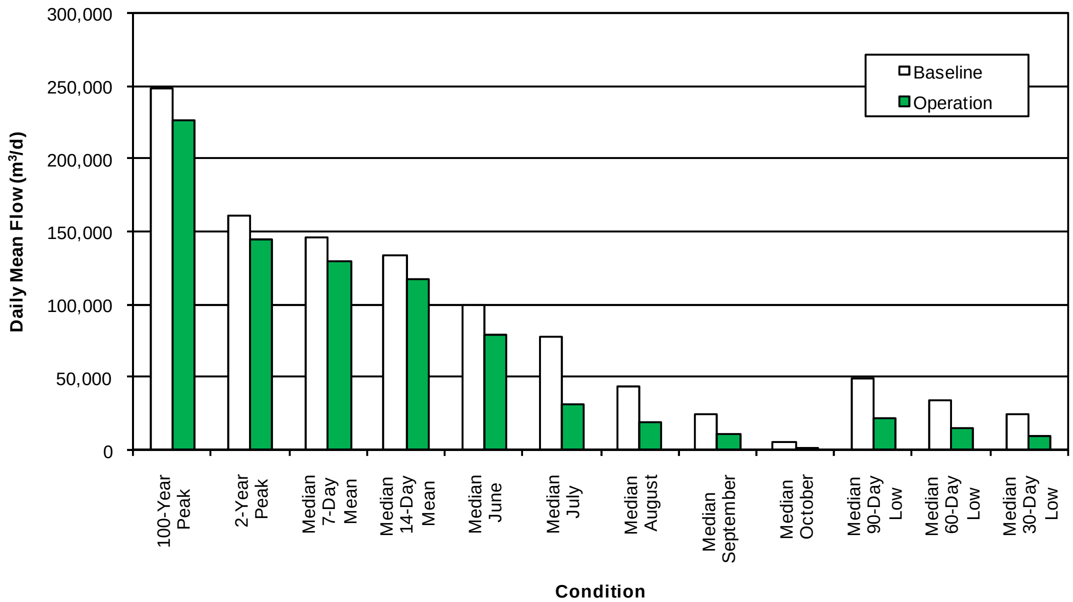
m = metre.

Table 9.7-64 Derived Representative Stages at Lake L1 – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.603	0.593	0.571	0.401	0.414	0.438
		operation	0.503	0.490	0.458	0.281	0.308	0.307
	10	baseline	0.576	0.568	0.548	0.336	0.358	0.390
		operation	0.482	0.468	0.440	0.229	0.254	0.270
Median	2	baseline	0.520	0.513	0.499	0.276	0.305	0.340
		operation	0.443	0.430	0.407	0.177	0.204	0.229
Dry	10	baseline	0.433	0.429	0.420	0.225	0.259	0.294
		operation	0.377	0.367	0.349	0.132	0.170	0.193
	100	baseline	0.292	0.295	0.299	0.204	0.240	0.271
		operation	0.250	0.253	0.242	0.095	0.152	0.166

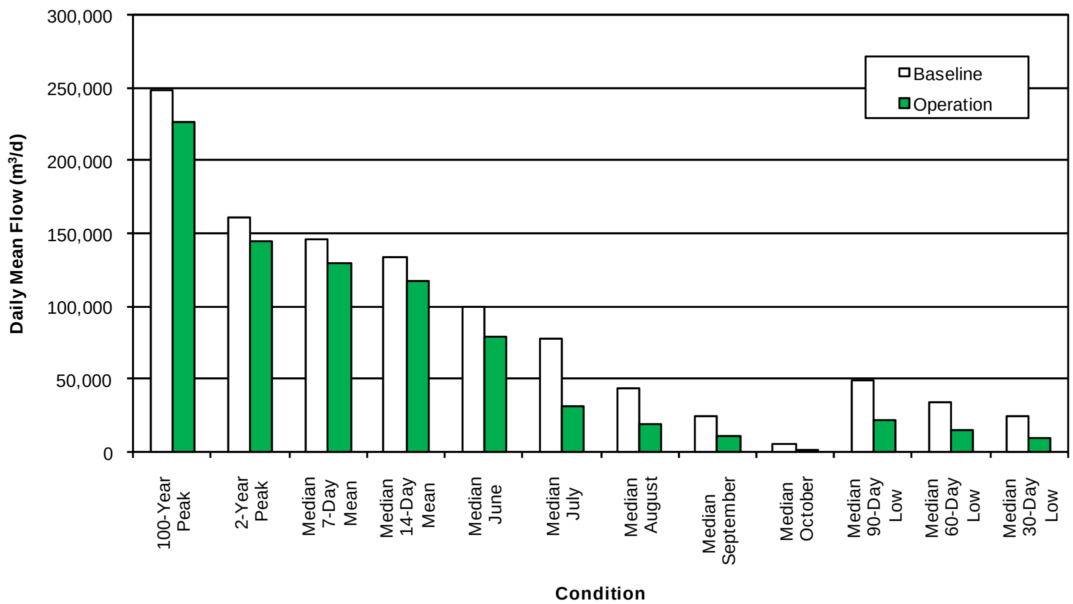
m = metre.

Figure 9.7-35 Comparison of Effects on Lake M1 Outlet Discharges – Operation



m^3/d = cubic metres per day.

Figure 9.7-36 Comparison of Effects on Lake M1 Stages – Operation



m = metres.

Table 9.7-65 Monthly Mean Discharges at the Lake M1 Outlet – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	178,000	152,000	102,000	116,000	29,300
		operation	126,000	83,900	57,800	70,300	8,410
	10	baseline	142,000	116,000	69,100	56,400	13,500
		operation	106,000	55,600	35,800	30,500	4,450
Median	2	baseline	100,000	77,600	43,200	25,100	5,140
		operation	78,800	31,900	19,600	11,000	1,500
Dry	10	baseline	61,000	43,900	27,300	12,900	1,880
		operation	48,000	16,300	10,600	3,890	0
	100	baseline	30,800	19,800	19,100	8,800	762
		operation	20,100	7,750	6,180	1,640	0

m^3/d = cubic metres per day.

Table 9.7-66 Derived Representative Discharges at the Lake M1 Outlet – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	2.88	220,000	205,000	84,900	92,300	105,000
		operation	2.62	187,000	169,000	44,200	57,600	54,800
	10	baseline	2.45	189,000	176,000	48,200	58,500	75,700
		operation	2.22	165,000	149,000	22,400	30,200	36,400
Median	2	baseline	1.87	146,000	134,000	24,700	34,400	49,700
		operation	1.68	130,000	117,000	9,470	14,800	21,800
Dry	10	baseline	1.26	96,400	85,100	13,200	21,300	31,200
		operation	1.09	83,500	73,600	3,790	8,480	12,800
	100	baseline	0.73	50,300	38,600	8,380	15,200	20,200
		operation	0.56	34,300	28,300	1,600	6,170	8,000

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-67 Monthly Mean Stages at Lake M1 – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.626	0.563	0.432	0.470	0.188
		operation	0.497	0.379	0.296	0.337	0.082
	10	baseline	0.538	0.470	0.333	0.291	0.112
		operation	0.443	0.288	0.215	0.193	0.053
Median	2	baseline	0.426	0.360	0.243	0.170	0.059
		operation	0.363	0.199	0.144	0.098	0.026
Dry	10	baseline	0.306	0.246	0.179	0.109	0.030
		operation	0.261	0.127	0.095	0.049	-
	100	baseline	0.194	0.145	0.141	0.084	0.016
		operation	0.146	0.077	0.067	0.027	-

m = metre.

Table 9.7-68 Derived Representative Stages at Lake M1 – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.782	0.721	0.687	0.382	0.404	0.440
		operation	0.734	0.647	0.604	0.247	0.295	0.285
	10	baseline	0.702	0.651	0.621	0.262	0.298	0.354
		operation	0.658	0.595	0.556	0.157	0.192	0.217
Median	2	baseline	0.587	0.548	0.518	0.168	0.209	0.267
		operation	0.546	0.507	0.473	0.089	0.119	0.154
Dry	10	baseline	0.451	0.416	0.383	0.110	0.152	0.196
		operation	0.409	0.378	0.347	0.048	0.082	0.108
	100	baseline	0.314	0.269	0.226	0.082	0.121	0.147
		operation	0.263	0.209	0.184	0.027	0.067	0.079

m = metre.

Summary of Effects on Flows, Water Levels and Channel/Bank Stability

Area 8 Outlet Flows: The water balance results for Area 8 show that during operations, monthly mean flows will decrease due to the upstream closed-circuiting. The peak daily discharges will decrease by 50% (2-year flood) and 45% (100-year flood). Low flows will decrease by up to 84% because of the reduction of upstream storage and flow area. A flow mitigation plan is being developed to mitigate any fish habitat losses due to reduced flows. The specifics of the mitigation plan have not been developed, but would focus on providing suitable spawning and rearing habitat for Arctic grayling (*Thymallus arcticus*).

Area 8 Outlet Channel/Bank Stability: No effects on Area 8 outlet channel or bank stability are expected, because flows and water levels will decrease during operation.

Lake L1 Outlet Flows: The water balance results for Lake L1 show that during operations, monthly mean flows will decrease due to the upstream closed-circuiting. The peak daily discharges will decrease by 42% (2-year flood) and 46% (100-year flood). Low flows will decrease by up to 78% because of the reduction of upstream storage and flow area. A flow mitigation plan is being developed to mitigate any fish habitat losses due to reduced flows. The specifics of the mitigation plan have not been developed, but would focus on providing suitable spawning and rearing habitat for Arctic grayling (*Thymallus arcticus*).

Lake L1 Water Levels: Lake L1 water levels are also expected to decrease during operation. The 2-year flood level is expected to decrease by approximately 0.077 m, and monthly mean stages are expected to decrease by 0.077 m (June), 0.136 m (July), 0.104 m (August), 0.092 m (September) and 0.087 m (October), under median conditions.

Lake L1 and Outlet Channel/Bank Stability: No effects on Lake L1 and outlet channel or bank stability are expected, because flows and water levels will decrease during operation.

Lake M1 Outlet Flows: The water balance results for Lake M1 show that during operations, monthly mean flows will decrease due to the upstream closed-circuiting. The peak daily discharges will decrease by 10% (2-year flood) and 9% (100-year flood). Low flows will decrease by up to 62% because of the reduction of upstream storage and flow area. A flow mitigation plan is being developed to mitigate any fish habitat losses due to reduced flows. The specifics of the mitigation plan have not been developed, but would focus on providing suitable spawning and rearing habitat for Arctic grayling (*Thymallus arcticus*).

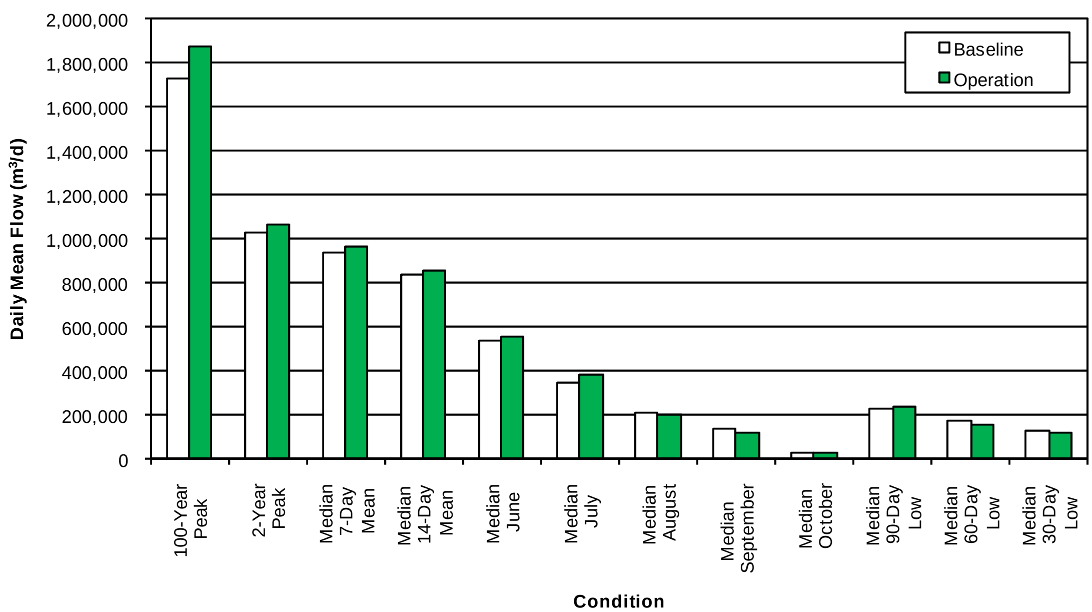
Lake M1 Water Levels: Lake M1 water levels are also expected to decrease during operation. The 2-year flood level is expected to decrease by approximately 0.041 m, and monthly mean stages are expected to decrease by 0.063 m (June), 0.161 m (July), 0.099 m (August), 0.072 m (September) and 0.033 m (October), under median conditions.

Lake M1 and Outlet Channel/Bank Stability: No effects on Lake M1 and outlet channel or bank stability are expected, because flows and water levels will decrease during operation.

Lake 410 to Kirk Lake Outlet

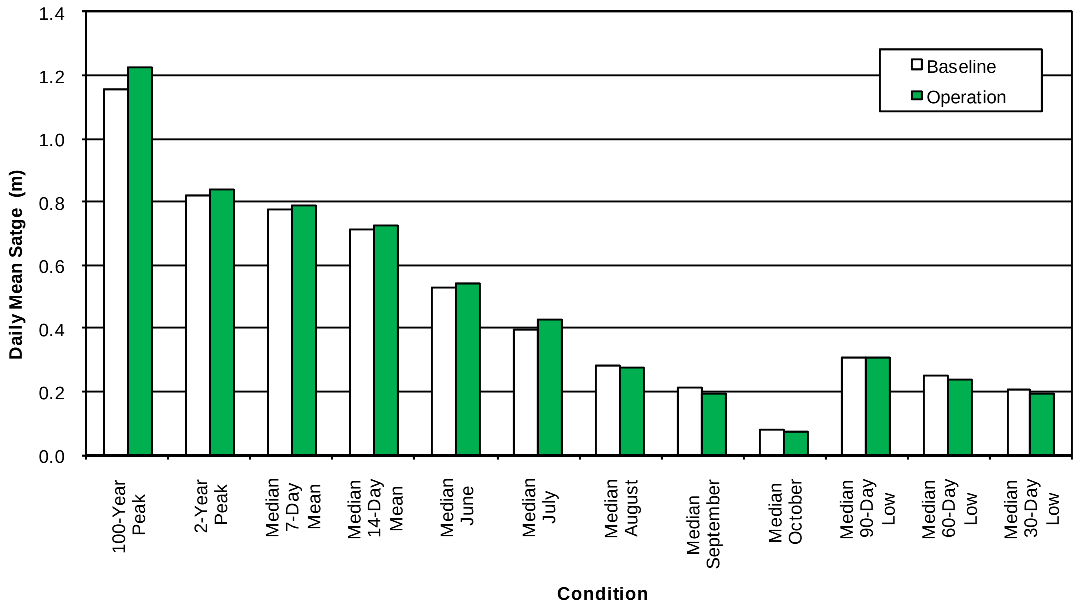
Lake M1 flows into Lake 410, which also receives inflow from Lake N1. Lake 410 then drains through watershed P to Kirk Lake. The water balance model for the Project examined all downstream waterbodies between Lake 410 and Kirk Lake. Project effects on Lake 410 during dewatering are summarized in Figures 9.7-37 to 9.7-38 and Tables 9.7-69 to 9.7-72. Project effects on Kirk Lake during dewatering are summarized in Figures 9.7-39 to 9.7-40 and Tables 9.7-73 to 9.7-76.

Figure 9.7-37 Comparison of Effects on Lake 410 Outlet Discharges – Operation



m^3/d = cubic metres per day.

Figure 9.7-38 Comparison of Effects on Lake 410 Stages – Operation



m = metres.

Table 9.7-69 Monthly Mean Discharges at the Lake 410 Outlet – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	934,000	678,000	475,000	587,000	135,000
		operation	935,000	710,000	467,000	534,000	123,000
	10	baseline	759,000	514,000	329,000	278,000	70,700
		operation	762,000	553,000	317,000	264,000	63,400
Median	2	baseline	537,000	344,000	210,000	135,000	32,700
		operation	555,000	388,000	198,000	121,000	28,900
Dry	10	baseline	329,000	203,000	132,000	73,900	16,000
		operation	353,000	248,000	123,000	65,400	14,000
	100	baseline	190,000	106,000	90,100	49,800	9,660
		operation	193,000	149,000	82,800	46,100	8,420

m^3/d = cubic metres per day.

Table 9.7-70 Derived Representative Discharges at the Lake 410 Outlet – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	20.00	1,420,000	1,240,000	404,000	443,000	491,000
		operation	21.70	1,490,000	1,280,000	388,000	441,000	495,000
	10	baseline	16.50	1,230,000	1,080,000	237,000	287,000	355,000
		operation	17.40	1,280,000	1,110,000	224,000	276,000	358,000
Median	2	baseline	11.90	942,000	837,000	128,000	173,000	234,000
		operation	12.30	966,000	859,000	118,000	161,000	240,000
Dry	10	baseline	7.11	580,000	523,000	74,200	108,000	150,000
		operation	7.33	596,000	539,000	66,300	100,000	159,000
	100	baseline	3.03	219,000	200,000	50,900	77,500	100,000
		operation	3.44	241,000	218,000	44,500	72,300	113,000

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day

Table 9.7-71 Monthly Mean Stages at Lake 410 – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.769	0.621	0.490	0.564	0.212
		operation	0.769	0.640	0.484	0.529	0.199
	10	baseline	0.669	0.516	0.383	0.343	0.138
		operation	0.671	0.542	0.374	0.331	0.128
Median	2	baseline	0.531	0.395	0.284	0.212	0.082
		operation	0.543	0.428	0.273	0.197	0.076
Dry	10	baseline	0.383	0.278	0.209	0.142	0.051
		operation	0.402	0.318	0.199	0.131	0.047
	100	baseline	0.266	0.180	0.162	0.109	0.036
		operation	0.269	0.226	0.153	0.103	0.033

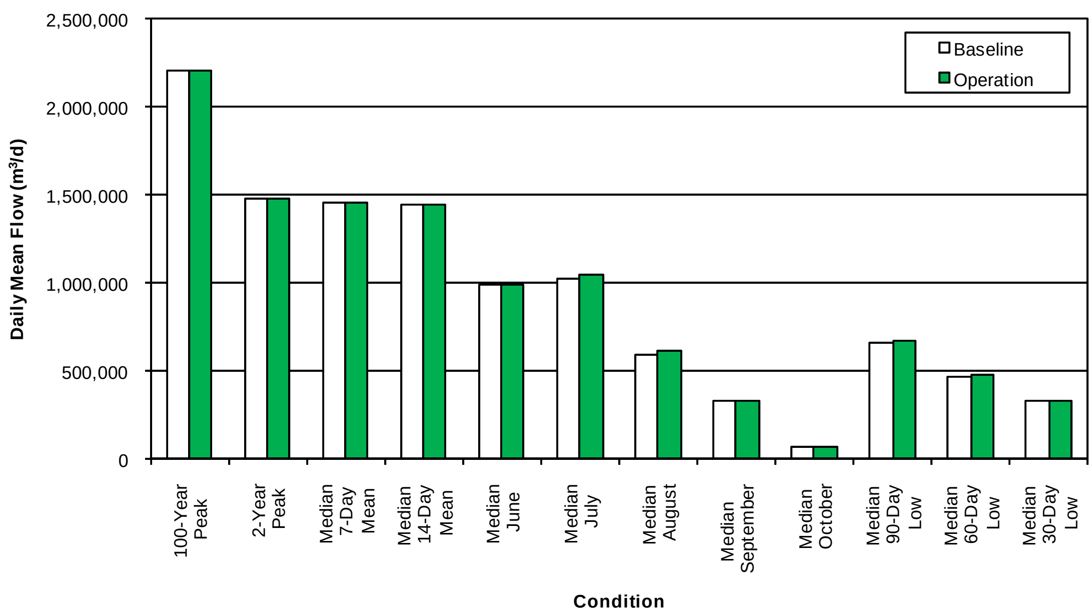
m = metre.

Table 9.7-72 Derived Representative Stages at Lake 410 – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	1.158	1.016	0.928	0.440	0.467	0.501
		operation	1.223	1.049	0.948	0.428	0.466	0.503
	10	baseline	1.019	0.923	0.847	0.308	0.350	0.403
		operation	1.056	0.948	0.862	0.297	0.341	0.406
Median	2	baseline	0.819	0.773	0.714	0.204	0.250	0.305
		operation	0.838	0.786	0.727	0.194	0.238	0.311
Dry	10	baseline	0.581	0.559	0.522	0.142	0.182	0.227
		operation	0.593	0.570	0.533	0.132	0.173	0.236
	100	baseline	0.329	0.292	0.275	0.110	0.146	0.173
		operation	0.358	0.312	0.291	0.101	0.140	0.188

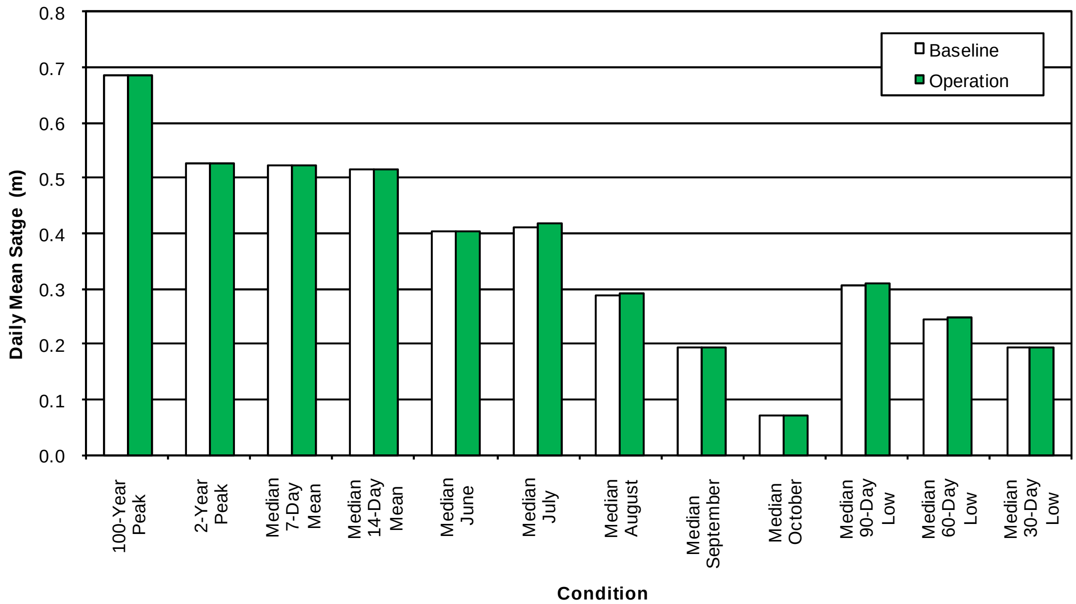
m = metre.

Figure 9.7-39 Comparison of Effects on Kirk Lake Outlet Discharges – Operation



m^3/d = cubic metres per day.

Figure 9.7-40 Comparison of Effects on Kirk Lake Stages – Operation



m = metres.

Table 9.7-73 Monthly Mean Discharges at the Kirk Lake Outlet – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	1,850,000	1,730,000	1,250,000	1,370,000	420,000
		operation	1,840,000	1,750,000	1,270,000	1,220,000	390,000
	10	baseline	1,450,000	1,420,000	916,000	676,000	188,000
		operation	1,450,000	1,440,000	937,000	683,000	190,000
Median	2	baseline	995,000	1,020,000	596,000	332,000	75,700
		operation	993,000	1,050,000	615,000	335,000	73,900
Dry	10	baseline	562,000	607,000	349,000	161,000	24,500
		operation	560,000	637,000	368,000	164,000	24,100
	100	baseline	226,000	255,000	191,000	85,200	4,760
		operation	224,000	292,000	210,000	90,900	5,370

m^3/d = cubic metres per day.

Table 9.7-74 Derived Representative Discharges at the Kirk Lake Outlet – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	25.50	2,160,000	2,100,000	1,050,000	1,140,000	1,290,000
		operation	25.50	2,170,000	2,110,000	1,070,000	1,150,000	1,300,000
	10	baseline	22.10	1,890,000	1,850,000	636,000	774,000	981,000
		operation	22.20	1,890,000	1,850,000	638,000	784,000	992,000
Median	2	baseline	17.10	1,460,000	1,440,000	333,000	467,000	660,000
		operation	17.10	1,460,000	1,440,000	333,000	476,000	674,000
Dry	10	baseline	10.60	902,000	884,000	163,000	262,000	395,000
		operation	10.60	906,000	889,000	166,000	274,000	413,000
	100	baseline	3.98	321,000	290,000	82,100	148,000	213,000
		operation	4.14	335,000	303,000	88,200	161,000	235,000

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-75 Monthly Mean Stages at Kirk Lake – Operation

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.610	0.584	0.470	0.500	0.227
		operation	0.608	0.588	0.475	0.463	0.216
	10	baseline	0.519	0.512	0.382	0.312	0.133
		operation	0.519	0.517	0.388	0.314	0.134
Median	2	baseline	0.404	0.410	0.287	0.194	0.072
		operation	0.403	0.418	0.293	0.195	0.071
Dry	10	baseline	0.276	0.290	0.201	0.120	0.034
		operation	0.275	0.300	0.208	0.121	0.034
	100	baseline	0.150	0.163	0.134	0.078	0.011
		operation	0.149	0.178	0.143	0.082	0.012

m = metre.

Table 9.7-76 Derived Representative Stages at Kirk Lake – Operation

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.686	0.677	0.664	0.418	0.442	0.480
		operation	0.686	0.679	0.666	0.424	0.445	0.483
	10	baseline	0.623	0.619	0.610	0.300	0.342	0.400
		operation	0.625	0.619	0.610	0.300	0.344	0.403
Median	2	baseline	0.525	0.521	0.517	0.195	0.244	0.307
		operation	0.525	0.521	0.517	0.195	0.247	0.311
Dry	10	baseline	0.382	0.378	0.373	0.121	0.166	0.218
		operation	0.382	0.379	0.375	0.122	0.171	0.225
	100	baseline	0.199	0.190	0.177	0.077	0.113	0.144
		operation	0.204	0.195	0.183	0.080	0.120	0.154

m = metre.

Summary of Effects on Flows, Water Levels and Channel/Bank Stability

Lake 410 Outlet Flows: The water balance results for Lake 410 show that during operations, monthly mean flows will increase slightly in the early open water season and decrease slightly in the late open water season, due to the upstream closed-circuiting and diversions. The peak daily discharges will increase by 3% (2-year flood) and 9% (100-year flood). Low flows will decrease by up to 8% because of the reduction of upstream storage and flow area.

Lake 410 Water Levels: Lake 410 water levels are also expected to decrease during operation. The 2-year flood level is expected to increase by approximately 0.019 m, and monthly mean stages are expected to increase by 0.012 m (June) and 0.033 m (July), and decrease by 0.011 m (August), 0.015 m (September) and 0.006 m (October), under median conditions.

Lake 410 and Outlet Channel/Bank Stability: No effects on Lake 410 and Outlet channel or bank stability are expected during operation, because flow and water level increases will be small.

The water balance results for Kirk Lake show that during operations, changes to floods and mean flows will be negligible, as will corresponding changes to water levels. No adverse effects on downstream channel/bank stability are anticipated.

9.7.4 Effects Analysis Results – Closure

9.7.4.1 Effect of Pumping Supplemental Flows from Lake N11 to Kennady Lake during Refilling to Flows, Water Levels, and Channel/Bank Stability in Streams and Lakes in the N Watershed

9.7.4.1.1 Activity Description

To expedite the refilling of Kennady Lake Areas 2 to 7, water will be pumped from Lake N11. Pumping will typically begin in June and end in July, although it may extend into August. The conceptual layout of the refilling system is shown in Figure 9.7-41. In wet years, flow forecasts, based on snow pack conditions and seasonal precipitation trends, will be used to estimate annual water yields from Lake N11. Planned pumping rates will be set accordingly to ensure that the total annual discharge from Lake N11 does not drop below the 1-in-5 year dry condition. During the pumping season, pumping rates will be adjusted as required to meet this objective. In years where the Lake N11 discharge is forecast to naturally fall below the 5-year dry condition, no pumping will occur.

The total annual average diversion from Lake N11 will be on the order of 3.7 million cubic metres per year (Mm^3/y), which represents no more than 20% of the normal annual flow to Lake N1. The 20% cut-off will be used to ensure that sufficient water remains in Lake N11 to support downstream aquatic systems in the N watershed. The value of 3.7 Mm^3/y represents the difference between the flow reporting to Lake N11 under median/normal flow conditions, and that which occurs under 1-in-5 year dry conditions. Based on a six-week pumping period, the average pumping rate will be in the order of 88,100 m^3/d. It is anticipated that more water will be withdrawn during wet years, i.e., up to a maximum of 175,200 m^3/d. In drier years, less water will be withdrawn. At no time will the diversion cause discharge from Lake N11 to drop below that which occurs under a 1-in-5 year dry condition.

During closure, the permanent diversion of Lake A3 to Lake N9, as described in Section 9.7.3.2.1, will continue.

GAHCHO KUÉ PROJECT

Conceptual Layout of Kennady Lake Refilling Pipeline System

Figure 9.7-41

9.7.4.1.2 *Environmental Design Features and Mitigation*

Pumping water from Lake N11 to reduce the time required to refill Kennady Lake will be done to accelerate the recovery of the aquatic ecosystem in Kennady Lake. Pumping rates will be managed to minimize effects in Lake N11 and downstream waterbodies.

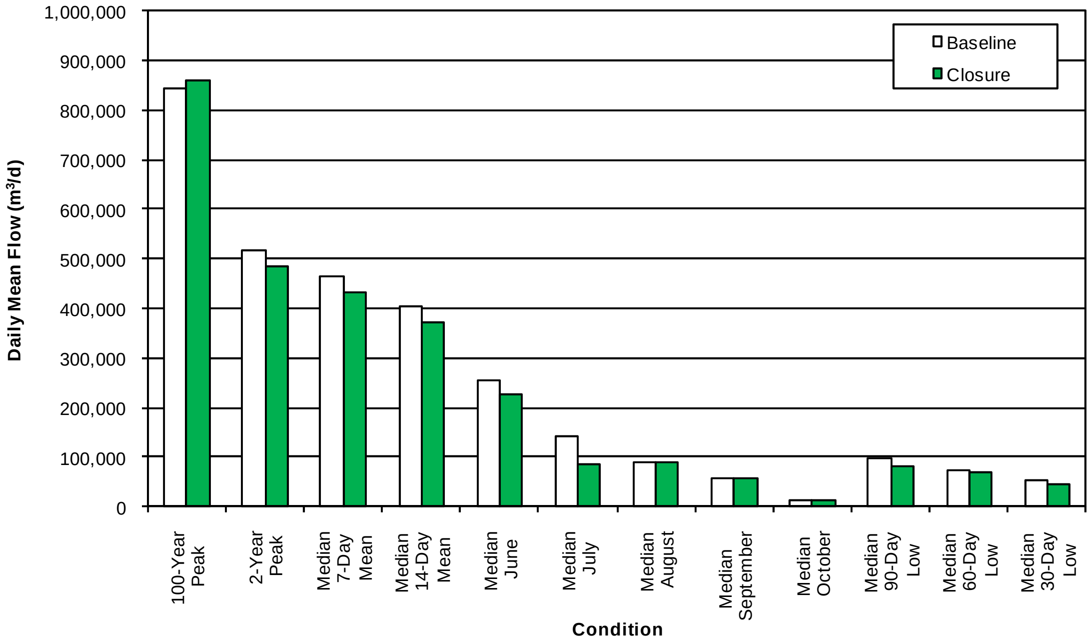
9.7.4.1.3 *Effects and Mitigation*

Lake N11 to Lake N1 Outlet

Effects to Lake N11 and downstream waterbodies to the Lake N1 outlet are due to the abstraction of flow for Kennady Lake refilling. Pumping will be limited to mitigate downstream effects of the water pumped from Lake N11. Additional effects to the N1 outlet will occur due to the permanent diversion of Lake A3. The operational diversions of the B, D and E watersheds will be removed so that their flow has been rerouted back to Kennady Lake.

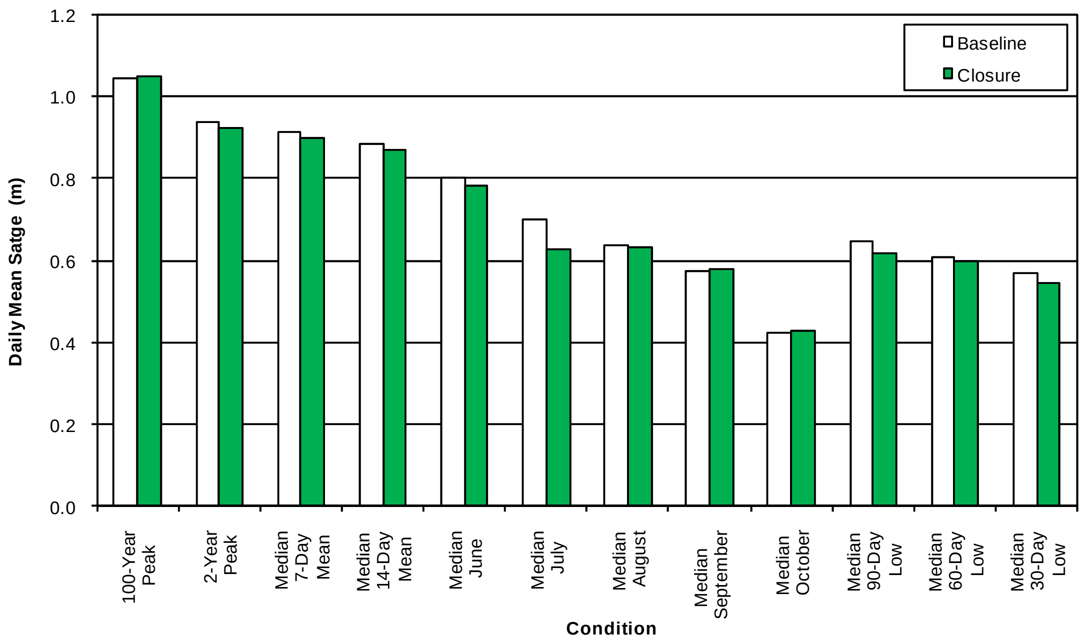
The water balance model for the Project examined all downstream waterbodies between Lake N11 and the Lake N1 outlet channel. Project effects on Lake N11 and outlet during refilling are shown in Figures 9.7-42 and 9.7-43 and summarized in Tables 9.7-77 to 9.7-80. Project effects on Lake N1 during refilling are shown in Figures 9.7-44 and 9.7-45 and summarized in Tables 9.7-81 to 9.7-84.

Figure 9.7-42 Comparison of Effects on Lake N11 Outlet Discharges – Closure



m^3/d = cubic metres per day.

Figure 9.7-43 Comparison of Effects on Lake N11 Stages – Closure



m = metres

Table 9.7-77 Monthly Mean Discharges at the Lake N11 Outlet – Closure

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			June	July	August	September	October
Wet	100	baseline	443,000	293,000	221,000	258,000	50,700
		closure	395,000	201,000	221,000	268,000	53,600
	10	baseline	359,000	215,000	147,000	123,000	28,200
		closure	320,000	144,000	146,000	127,000	29,300
Median	2	baseline	257,000	141,000	91,400	56,800	14,700
		closure	228,000	85,100	88,800	58,600	15,100
Dry	10	baseline	155,000	83,600	58,800	33,300	8,740
		closure	138,000	37,400	54,400	34,300	8,890
	100	baseline	71,900	46,900	42,600	25,900	6,400
		closure	65,000	5,180	36,800	26,700	6,520

m^3/d = cubic metres per day.

Table 9.7-78 Representative Discharges at the Basin N11 Outlet – Closure

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	9.77	747,000	630,000	179,000	198,000	215,000
		closure	9.93	751,000	600,000	106,000	145,000	175,000
	10	baseline	8.22	630,000	538,000	102,000	125,000	152,000
		closure	7.96	607,000	501,000	75,000	106,000	122,000
Median	2	baseline	6.00	464,000	404,000	55,500	75,000	98,700
		closure	5.62	434,000	373,000	46,200	69,700	80,500
Dry	10	baseline	3.36	269,000	240,000	33,900	48,500	64,200
		closure	3.38	266,000	237,000	25,100	42,800	54,700
	100	baseline	0.85	85,300	81,700	25,200	36,500	45,200
		closure	1.61	132,000	119,000	12,100	26,300	41,200

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-79 Monthly Mean Stages at the Lake N11 Outlet – Closure

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			June	July	August	September	October
Wet	100	baseline	0.903	0.824	0.774	0.801	0.558
		closure	0.881	0.758	0.774	0.808	0.565
	10	baseline	0.862	0.769	0.707	0.680	0.490
		closure	0.840	0.704	0.706	0.684	0.494
Median	2	baseline	0.800	0.700	0.636	0.572	0.424
		closure	0.779	0.626	0.632	0.576	0.426
Dry	10	baseline	0.715	0.624	0.577	0.508	0.378
		closure	0.697	0.522	0.567	0.512	0.379
	100	baseline	0.603	0.548	0.537	0.481	0.352
		closure	0.590	0.336	0.520	0.484	0.354

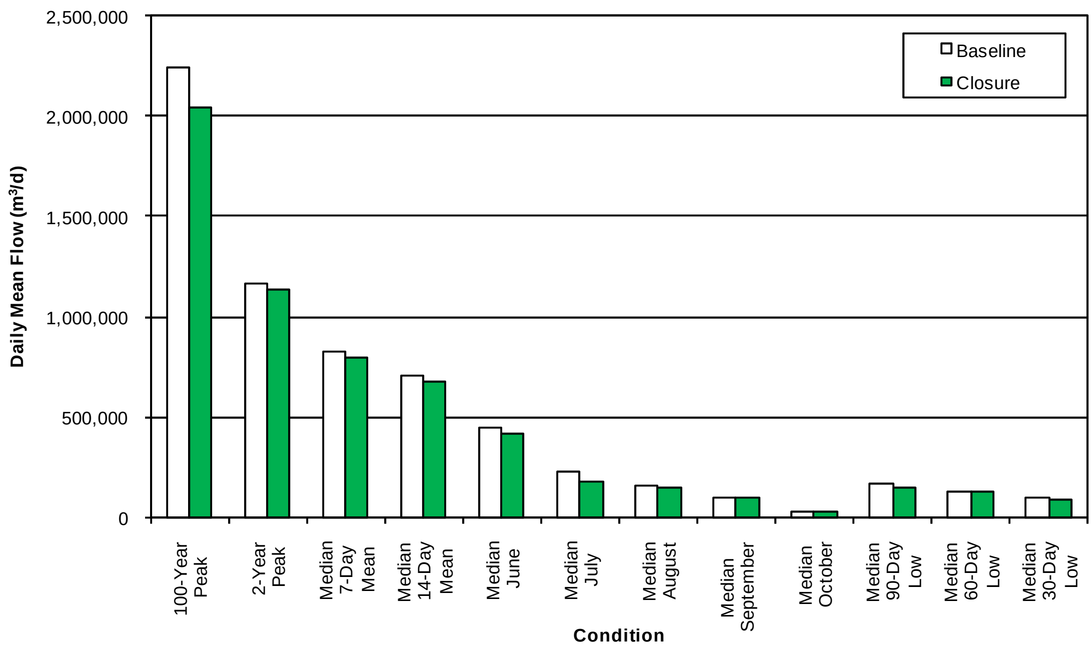
m = metre.

Table 9.7-80 Representative Stages at the Basin N11 Outlet – Closure

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	1.043	1.015	0.977	0.739	0.755	0.769
		closure	1.046	1.016	0.966	0.657	0.705	0.735
	10	baseline	1.003	0.977	0.943	0.652	0.682	0.712
		closure	0.996	0.969	0.928	0.609	0.657	0.678
Median	2	baseline	0.935	0.913	0.885	0.569	0.609	0.647
		closure	0.922	0.899	0.869	0.547	0.599	0.618
Dry	10	baseline	0.822	0.809	0.788	0.510	0.553	0.588
		closure	0.823	0.807	0.786	0.477	0.537	0.568
	100	baseline	0.606	0.626	0.620	0.478	0.519	0.544
		closure	0.698	0.690	0.675	0.406	0.482	0.533

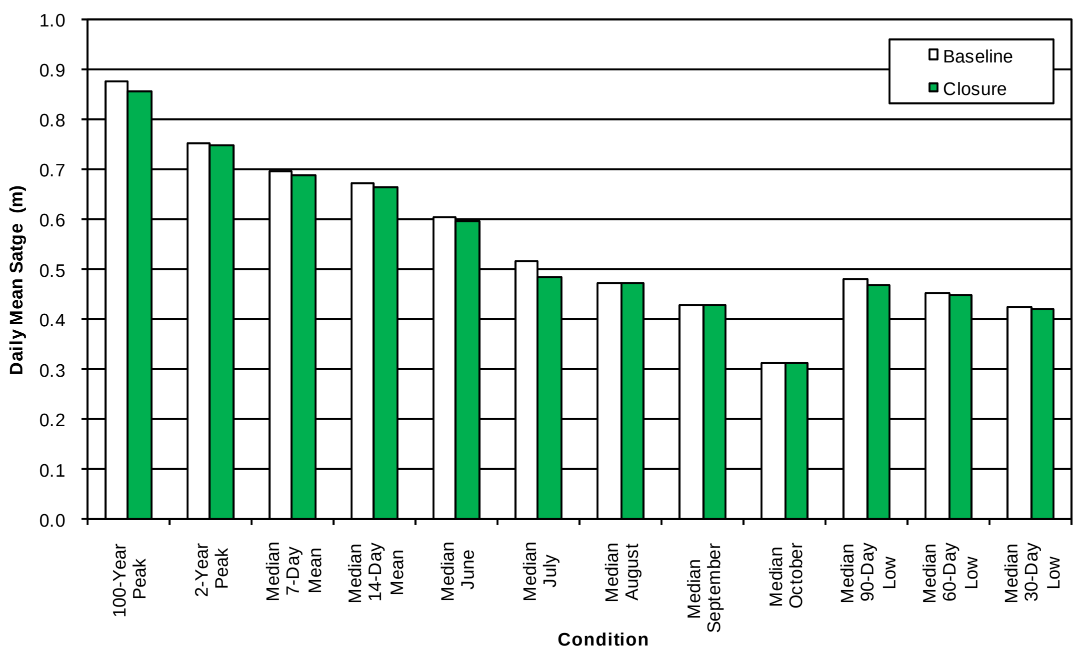
m = metre.

Figure 9.7-44 Comparison of Effects on Lake N1 Outlet Discharges – Closure



m^3/d = cubic metres per day.

Figure 9.7-45 Comparison of Effects on Lake N1 Stages – Closure



m = metres.

Table 9.7-81 Monthly Mean Discharges at the Lake N1 Outlet – Closure

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			June	July	August	September	October
Wet	100	baseline	737,000	470,000	370,000	398,000	84,100
		closure	691,000	375,000	375,000	415,000	87,700
	10	baseline	609,000	348,000	248,000	204,000	47,600
		closure	570,000	265,000	247,000	211,000	49,200
Median	2	baseline	444,000	229,000	156,000	99,000	25,100
		closure	417,000	172,000	151,000	101,000	25,600
Dry	10	baseline	270,000	138,000	102,000	56,600	14,600
		closure	259,000	110,000	97,300	57,800	14,800
	100	baseline	121,000	79,300	75,400	41,600	10,300
		closure	127,000	75,100	70,900	42,700	10,500

m^3/d = cubic metres per day.

Table 9.7-82 Representative Discharges at the Lake N1 Outlet – Closure

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	25.90	1,250,000	1,050,000	285,000	333,000	353,000
		closure	23.60	1,250,000	1,020,000	229,000	294,000	305,000
	10	baseline	19.90	1,080,000	910,000	171,000	212,000	251,000
		closure	18.60	1,050,000	878,000	149,000	195,000	219,000
Median	2	baseline	13.50	827,000	704,000	95,600	128,000	166,000
		closure	13.10	797,000	676,000	90,800	124,000	148,000
Dry	10	baseline	8.22	527,000	441,000	57,200	83,800	109,000
		closure	8.27	527,000	443,000	57,700	83,600	102,000
	100	baseline	4.51	242,000	174,000	40,500	63,800	77,100
		closure	4.74	294,000	226,000	41,800	64,500	77,500

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-83 Monthly Mean Stages at the Lake N1 Outlet – Closure

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			June	July	August	September	October
Wet	100	baseline	0.677	0.610	0.577	0.587	0.411
		closure	0.667	0.579	0.579	0.593	0.415
	10	baseline	0.648	0.569	0.527	0.504	0.360
		closure	0.638	0.535	0.526	0.507	0.363
Median	2	baseline	0.602	0.517	0.473	0.426	0.311
		closure	0.594	0.484	0.470	0.428	0.312
Dry	10	baseline	0.537	0.460	0.429	0.375	0.274
		closure	0.532	0.437	0.425	0.377	0.275
	100	baseline	0.446	0.405	0.400	0.349	0.253
		closure	0.451	0.400	0.395	0.351	0.254

m = metre.

Table 9.7-84 Representative Stages at the Basin N1 Outlet – Closure

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.874	0.764	0.734	0.544	0.564	0.571
		closure	0.855	0.764	0.729	0.517	0.548	0.552
	10	baseline	0.822	0.739	0.710	0.483	0.508	0.528
		closure	0.810	0.734	0.705	0.468	0.498	0.512
Median	2	baseline	0.752	0.695	0.670	0.423	0.452	0.480
		closure	0.747	0.689	0.663	0.418	0.449	0.468
Dry	10	baseline	0.671	0.626	0.601	0.376	0.410	0.436
		closure	0.672	0.626	0.602	0.377	0.410	0.429
	100	baseline	0.584	0.524	0.485	0.347	0.385	0.403
		closure	0.591	0.548	0.516	0.350	0.386	0.403

m = metre.

Summary of Effects on Flows, Water Levels and Channel/Bank Stability

Lake N11 Outlet Flows: The water balance results for Lake N11 show that during closure, monthly mean flows will decrease in proportion to the flow diverted to refill Kennady Lake. The 2-year flood discharge during operation will decrease by approximately 6% above the baseline value, and the 100-year flood discharge will be approximately equal to baseline. Low flows will also decrease by 7% to 18%.

Lake N11 Water Levels: Lake N11 water levels are also expected to decrease during closure. The 2-year flood level is expected to decrease by approximately 0.013 m, the 100-year flood level remain approximately the same as for baseline, and monthly mean stages to decrease by 0.021 m (June), 0.074 m (July), 0.004 m (August), under median conditions, with smaller increases in September and October.

Lake N11 and Outlet Channel/Bank Stability: No effects on Lake N11 and outlet channel or bank stability are expected during closure, because flood discharges and water levels will be equal to or reduced from baseline.

Lake N1 Outlet Flows: The water balance results for Lake N1 show that during closure, monthly mean flows will decrease in proportion to the flow diverted to refill Kennady Lake. The 2-year flood discharge during closure will decrease by approximately 3% below the baseline value, and the 100-year flood discharge will decrease by approximately 9%. Low flows will also increase by 3% to 11%.

Lake N1 Water Levels: Lake N1 water levels are also expected to decrease during closure. The 2-year flood level is expected to decrease by approximately 0.005 m, the 100-year flood level by 0.019 m, and monthly mean stages by 0.008 m (June), 0.033 m (July), 0.003 m (August), under median conditions, with smaller increases in September and October.

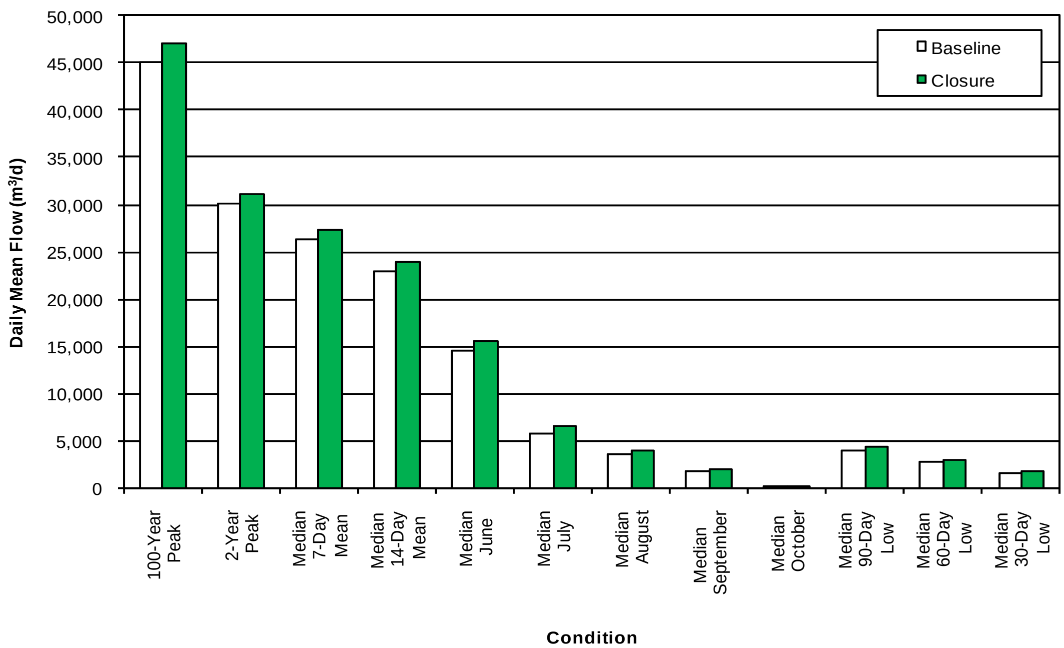
Lake N1 and Outlet Channel/Bank Stability: No effects on Lake N1 and Outlet channel or bank stability are expected during closure, because flood discharges and water levels will be equal to or reduced from baseline.

Lake N9 to Lake N1 Inflow (Watershed A Diversion)

The water balance model for the Project examined this receiving watershed by modeling the flow diverted from Watershed A into Lake N9, a tributary of Lake N6. Below Lake N6, Lake N5, Lake N3 (including Lake N4, lumped for the same reasons) and Lake N2 were modeled.

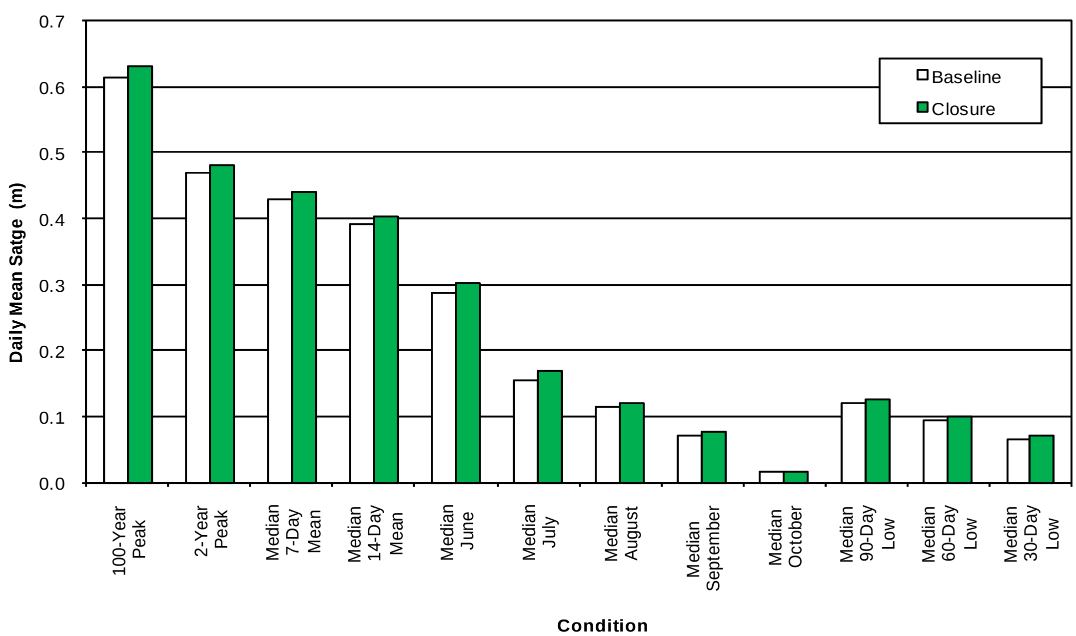
Project effects on Lake N9, which receives the A watershed diversion, are presented in Figures 9.7-46 to 9.7-47 and Tables 9.7-85 to 9.7-88, Project effects on Lake N6 are presented in Figures 9.7-48 to 9.7-49 and Tables 9.7-89 to 9.7-92, and Project effects on Lake N2, upstream of its confluence with Lake N1, are presented in Figures 9.7-50 to 9.7-51 and Tables 9.7-93 to 9.7-96.

Figure 9.7-46 Comparison of Effects on Lake N9 Outlet Discharges – Closure



m^3/d = cubic metres per day.

Figure 9.7-47 Comparison of Effects on Lake N9 Stages – Closure



m = metres.

Table 9.7-85 Monthly Mean Discharges at the Lake N9 Outlet – Closure

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	22,600	13,900	10,700	12,000	1,340
		closure	24,800	15,800	12,300	13,500	1,570
	10	baseline	19,300	9,540	6,580	5,280	677
		closure	20,900	11,000	7,390	5,800	767
Median	2	baseline	14,500	5,670	3,580	1,810	195
		closure	15,500	6,580	3,970	1,970	215
Dry	10	baseline	8,690	2,960	1,920	507	0
		closure	9,260	3,420	2,150	570	0
	100	baseline	3,010	1,370	1,120	73	0
		closure	3,390	1,520	1,310	118	0

m^3/d = cubic metres per day.

Table 9.7-86 Derived Representative Discharges at the Lake N9 Outlet – Closure

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	0.52	38,100	32,300	7,810	9,920	9,650
		closure	0.55	40,600	35,000	8,980	11,300	12,000
	10	baseline	0.45	33,400	28,800	3,980	5,390	6,440
		closure	0.48	35,900	31,200	4,490	6,050	7,350
Median	2	baseline	0.35	26,300	22,900	1,610	2,670	3,860
		closure	0.36	27,300	23,900	1,800	2,950	4,260
Dry	10	baseline	0.23	17,100	14,800	506	1,440	2,230
		closure	0.23	17,600	15,300	576	1,590	2,540
	100	baseline	0.11	7,830	5,810	58	951	1,370
		closure	0.11	8,340	6,930	97	1,060	2,080

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-87 Monthly Mean Stages at Lake N9 – Closure

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.387	0.280	0.235	0.254	0.059
		closure	0.412	0.305	0.258	0.275	0.065
	10	baseline	0.348	0.218	0.170	0.147	0.037
		closure	0.367	0.240	0.184	0.156	0.041
Median	2	baseline	0.288	0.154	0.113	0.072	0.016
		closure	0.301	0.170	0.121	0.076	0.017
Dry	10	baseline	0.205	0.100	0.075	0.031	-
		closure	0.214	0.110	0.081	0.033	-
	100	baseline	0.101	0.060	0.052	0.008	-
		closure	0.109	0.064	0.058	0.012	-

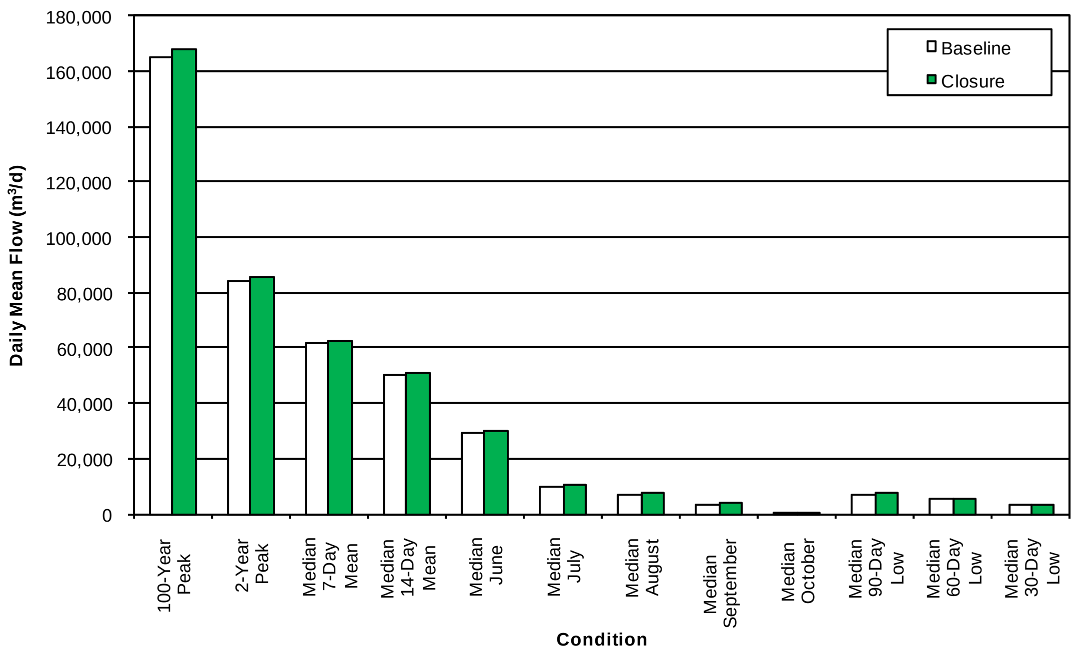
m = metre.

Table 9.7-88 Derived Representative Stages at Lake N9 – Closure

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.613	0.548	0.491	0.191	0.224	0.220
		closure	0.632	0.572	0.518	0.209	0.244	0.254
	10	baseline	0.557	0.502	0.455	0.122	0.149	0.168
		closure	0.579	0.527	0.480	0.132	0.161	0.183
Median	2	baseline	0.469	0.428	0.391	0.067	0.093	0.119
		closure	0.480	0.439	0.402	0.072	0.100	0.127
Dry	10	baseline	0.352	0.321	0.292	0.031	0.062	0.083
		closure	0.357	0.328	0.298	0.034	0.066	0.090
	100	baseline	0.217	0.191	0.157	0.007	0.047	0.060
		closure	0.221	0.199	0.176	0.010	0.050	0.079

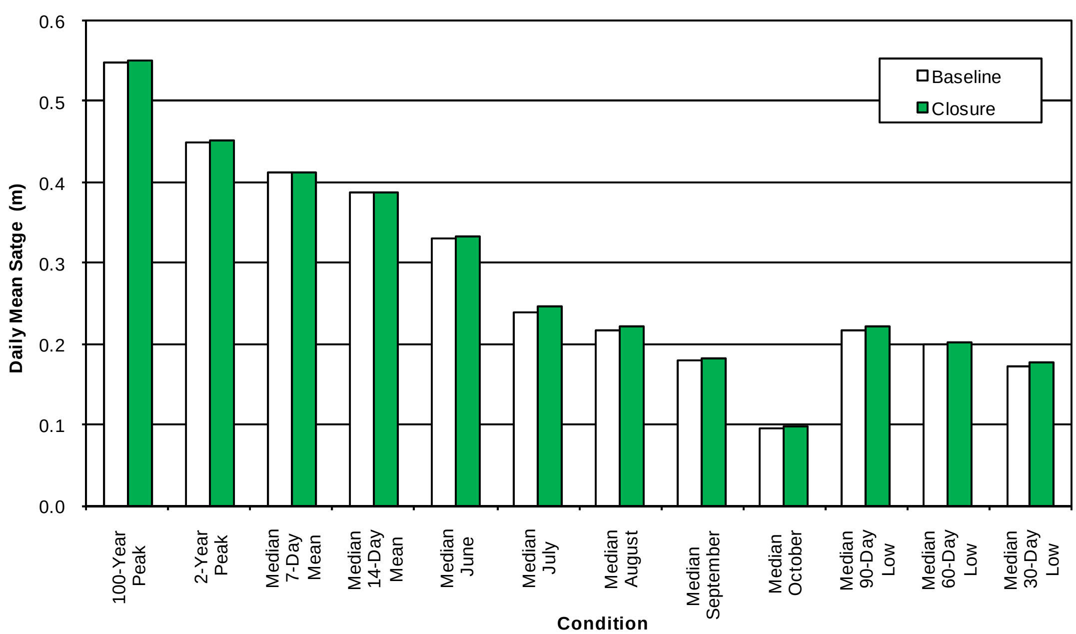
m = metre.

Figure 9.7-48 Comparison of Effects on Lake N6 Outlet Discharges – Closure



m^3/d = cubic metres per day.

Figure 9.7-49 Comparison of Effects on Lake N6 Stages – Closure



m = metres.

Table 9.7-89 Monthly Mean Discharges at the Lake N6 Outlet – Closure

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	44,300	25,100	22,200	22,200	3,600
		closure	46,200	26,900	23,900	23,500	3,830
	10	baseline	38,800	16,700	13,100	9,900	1,430
		closure	40,200	18,200	14,000	10,500	1,520
Median	2	baseline	29,400	9,740	6,980	3,650	431
		closure	30,300	10,700	7,480	3,870	465
Dry	10	baseline	15,800	5,140	3,860	1,330	102
		closure	16,500	5,680	4,200	1,440	112
	100	baseline	329	2,590	2,500	576	5
		closure	1,320	2,810	2,780	644	8

m^3/d = cubic metres per day.

Table 9.7-90 Derived Representative Discharges at the Lake N6 Outlet – Closure

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	1.91	91,800	70,600	13,400	19,300	18,200
		closure	1.94	92,700	72,000	14,600	20,700	19,500
	10	baseline	1.44	79,600	63,000	7,180	10,400	11,900
		closure	1.46	80,500	64,100	7,790	11,100	12,900
Median	2	baseline	0.98	61,800	50,000	3,220	5,240	7,140
		closure	0.99	62,600	50,900	3,490	5,630	7,730
Dry	10	baseline	0.60	40,400	31,500	1,330	3,040	4,290
		closure	0.61	40,900	31,900	1,440	3,280	4,630
	100	baseline	0.35	19,700	10,500	547	2,220	2,840
		closure	0.36	19,800	10,700	601	2,400	3,040

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-91 Monthly Mean Stages at Lake N6 – Closure

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	0.373	0.315	0.304	0.304	0.178
		closure	0.377	0.322	0.311	0.309	0.181
	10	baseline	0.358	0.279	0.260	0.239	0.135
		closure	0.362	0.287	0.265	0.244	0.138
Median	2	baseline	0.330	0.238	0.216	0.178	0.095
		closure	0.333	0.245	0.220	0.181	0.097
Dry	10	baseline	0.275	0.197	0.181	0.132	0.062
		closure	0.278	0.203	0.186	0.136	0.064
	100	baseline	0.088	0.161	0.160	0.103	0.025
		closure	0.132	0.165	0.165	0.107	0.029

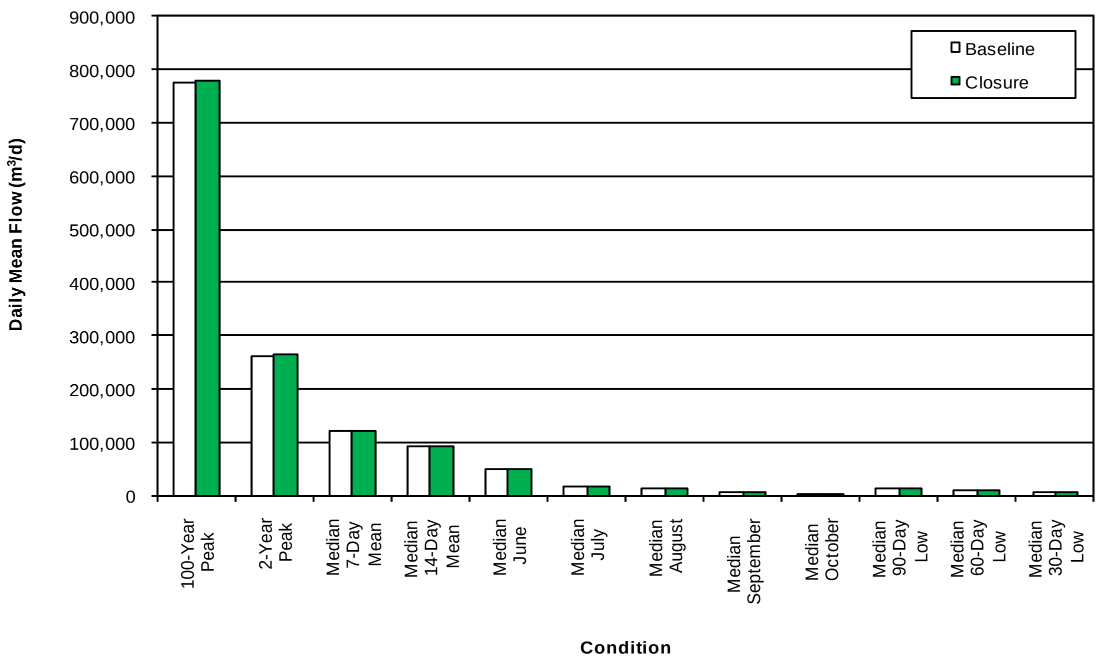
m = metre.

Table 9.7-92 Derived Representative Stages at Lake N6 – Closure

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.549	0.462	0.427	0.262	0.292	0.287
		closure	0.552	0.463	0.430	0.269	0.298	0.292
	10	baseline	0.505	0.443	0.413	0.218	0.243	0.253
		closure	0.507	0.444	0.415	0.223	0.248	0.259
Median	2	baseline	0.450	0.411	0.386	0.172	0.198	0.217
		closure	0.452	0.413	0.388	0.176	0.203	0.223
Dry	10	baseline	0.391	0.363	0.337	0.132	0.169	0.187
		closure	0.392	0.364	0.338	0.136	0.173	0.191
	100	baseline	0.334	0.293	0.244	0.102	0.154	0.166
		closure	0.334	0.294	0.245	0.105	0.158	0.169

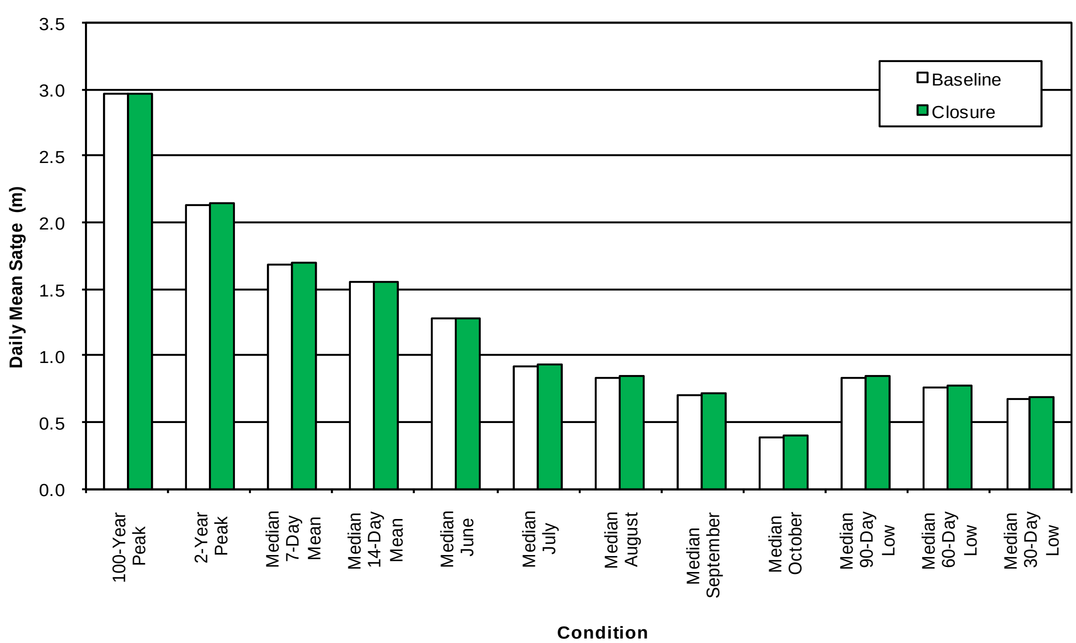
m = metre.

Figure 9.7-50 Comparison of Effects on Lake N2 Outlet Discharges – Closure



m^3/d = cubic metres per day.

Figure 9.7-51 Comparison of Effects on Lake N2 Stages – Closure



m = metres.

Table 9.7-93 Monthly Mean Discharges at the Lake N2 Outlet – Closure

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	74,000	40,000	33,500	36,300	6,640
		closure	75,700	41,800	35,200	37,600	6,890
	10	baseline	63,800	27,200	20,700	17,000	2,840
		closure	65,000	28,700	21,800	17,600	2,990
Median	2	baseline	47,900	16,200	11,600	6,710	964
		closure	48,600	17,300	12,300	7,040	1,030
Dry	10	baseline	27,100	8,800	6,590	2,710	282
		closure	27,700	9,430	7,070	2,880	304
	100	baseline	5,550	4,580	4,230	1,330	63
		closure	6,350	4,860	4,630	1,440	69

m^3/d = cubic metres per day.

Table 9.7-94 Derived Representative Discharges at the Lake N2 Outlet – Closure

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	8.96	159,000	123,000	22,300	30,700	29,400
		closure	9.00	160,000	124,000	23,600	32,000	30,900
	10	baseline	5.62	146,000	112,000	12,400	17,100	19,700
		closure	5.67	147,000	113,000	13,100	17,900	20,700
Median	2	baseline	3.03	121,000	91,700	5,890	8,960	12,000
		closure	3.07	122,000	92,600	6,270	9,490	12,700
Dry	10	baseline	1.49	81,300	60,200	2,680	5,350	7,360
		closure	1.51	82,000	60,800	2,870	5,690	7,800
	100	baseline	0.70	30,400	21,800	1,310	3,950	4,960
		closure	0.71	30,900	22,300	1,410	4,200	5,240

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-95 Monthly Mean Stages at Lake N2 – Closure

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			Jun	Jul	Aug	Sep	Oct
Wet	100	baseline	1.454	1.206	1.143	1.171	0.700
		closure	1.464	1.223	1.161	1.184	0.708
	10	baseline	1.390	1.073	0.988	0.931	0.541
		closure	1.398	1.091	1.004	0.941	0.550
Median	2	baseline	1.274	0.917	0.829	0.702	0.390
		closure	1.280	0.936	0.844	0.713	0.398
Dry	10	baseline	1.072	0.762	0.698	0.534	0.269
		closure	1.079	0.779	0.713	0.543	0.275
	100	baseline	0.663	0.625	0.611	0.430	0.171
		closure	0.691	0.637	0.628	0.440	0.176

m = metre.

Table 9.7-96 Derived Representative Stages at Lake N2 – Closure

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	2.962	1.833	1.696	1.011	1.113	1.099
		closure	2.966	1.836	1.700	1.028	1.128	1.116
	10	baseline	2.571	1.786	1.648	0.846	0.932	0.973
		closure	2.578	1.790	1.653	0.860	0.945	0.988
Median	2	baseline	2.132	1.687	1.551	0.675	0.767	0.838
		closure	2.141	1.692	1.556	0.688	0.780	0.852
Dry	10	baseline	1.719	1.496	1.366	0.532	0.656	0.722
		closure	1.726	1.500	1.370	0.543	0.668	0.735
	100	baseline	1.367	1.110	1.004	0.428	0.598	0.641
		closure	1.372	1.116	1.011	0.438	0.609	0.652

m = metre.

Summary of Effects on Flows, Water Levels and Channel/Bank Stability

Lake N9 Outlet Flows: The water balance results for Lake N9 show that during closure, monthly mean flows will increase in proportion to the additional flow from the diverted A watershed. The 2-year flood discharge during closure will increase by approximately 3% above the baseline value, and the 100-year flood discharge will increase by approximately 6%. Low flows will also increase by 10% to 12%.

Lake N9 Water Levels: Lake N9 water levels are also expected to increase during closure. The 2-year flood level is expected to increase by approximately 0.011 m, the 100-year flood level by 0.019 m, and monthly mean stages by 0.013 m (June), 0.016 m (July), 0.008 m (August), 0.004 m (September) and 0.001 m (October), under median conditions.

Lake N9 and Outlet Channel/Bank Stability: No effects on Lake N9 and outlet channel or bank stability are expected during closure, because increases in flood magnitude are small relative to the existing flood regime.

Lake N6 Outlet Flows: The water balance results for Lake N6 show that during closure, monthly mean flows will increase in proportion to the additional flow from the diverted A watershed. The 2-year flood discharge during closure will increase by approximately 1% above the baseline value, and the 100-year flood discharge will increase by approximately 2%. Low flows will also increase by 7% to 8%.

Lake N6 Water Levels: Lake N6 water levels are also expected to increase during closure. The 2-year flood level is expected to increase by approximately 0.002 m, the 100-year flood level by 0.003 m, and monthly mean stages by 0.003 m (June), 0.007 m (July), 0.004 m (August), 0.003 m (September) and 0.002 m (October), under median conditions.

Lake N6 and Outlet Channel/Bank Stability: No effects on Lake N6 and outlet channel or bank stability are expected during closure, because increases in flood magnitude are small relative to the existing flood regime.

Lake N2 Outlet Flows: The water balance results for Lake N2 show that during closure, monthly mean flows will increase in proportion to the additional flow from the diverted A watershed. The 2-year flood discharge during closure will increase by approximately 1% above the baseline value, and the 100-year flood discharge by less than 1%. Low flows will also increase by 6%.

Lake N2 Water Levels: Lake N2 water levels are also expected to increase during closure. The 2-year flood level is expected to increase by approximately 0.009 m, the 100-year flood level by 0.004 m, and monthly mean stages by 0.006 m (June), 0.019 m (July), 0.015 m (August), 0.011 m (September) and 0.008 m (October), under median conditions.

Lake N2 and Outlet Channel/Bank Stability: No effects on Lake N2 and outlet channel or bank stability are expected during closure, because increases in flood magnitude are small relative to the existing flood regime.

Kennady Lake Area 8 Outlet to Lake M1 Outlet

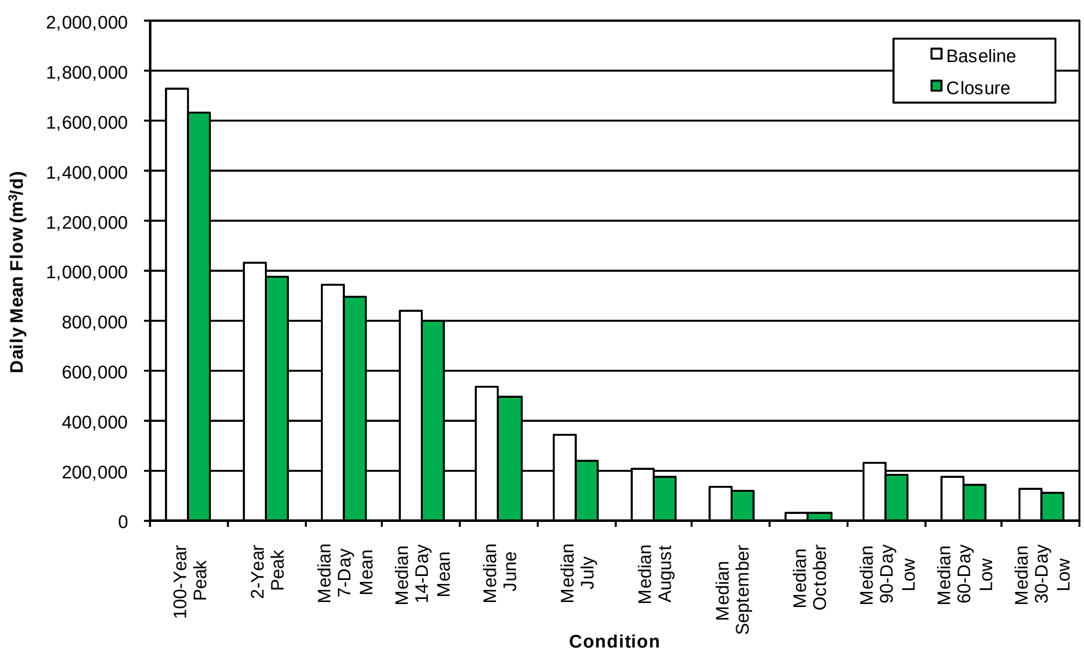
Effects of the Project on the reach from the Area 8 outlet to the Lake M1 outlet during closure are identical to the effects during operation, as presented in Section 9.7.3.3.

Lake 410 to Kirk Lake Outlet

Effects on the reach from Lake 410 to the Kirk Lake outlet during closure are due to the abstraction of flow from Lake N11 for Kennady Lake refilling and the removal of flow from 77% of the natural drainage area (Areas 2 to 7) during the refilling period of Kennady Lake.

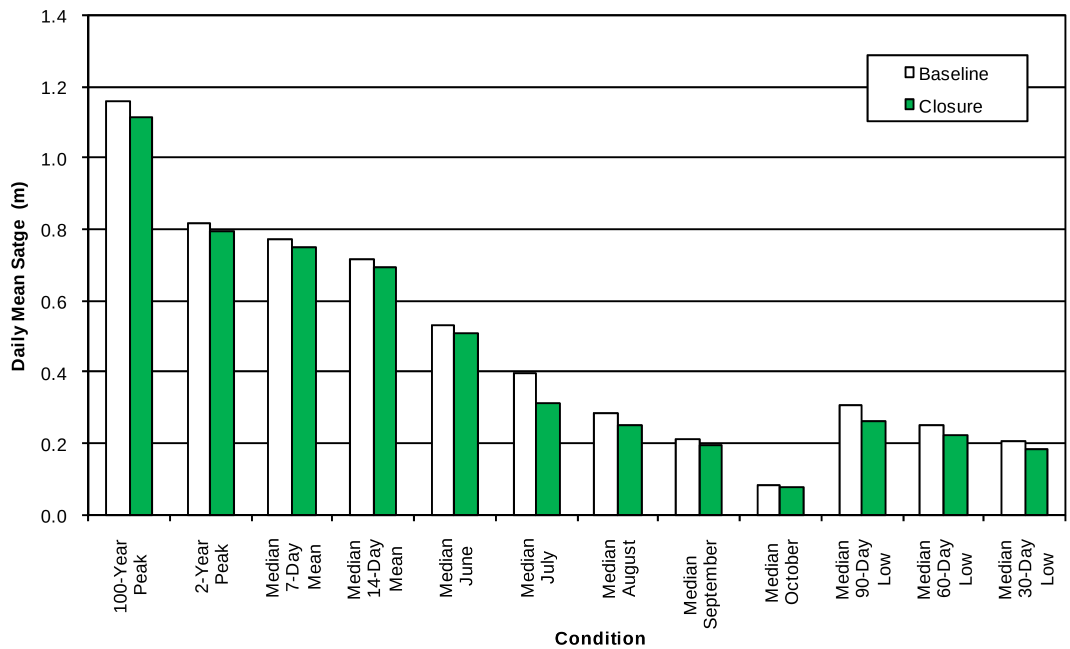
The water balance model for the Project examined all downstream waterbodies between Lake 410 and the Kirk Lake outlet channel. Project effects on Lake 410 and outlet during refilling are shown in Figures 9.7-52 and 9.7-53, and summarized in Tables 9.7-97 to 9.7-100. Project effects on Kirk Lake during refilling are shown in Figures 9.7-54 and 9.7-55, and summarized in Tables 9.7-101 to 9.7-104.

Figure 9.7-52 Comparison of Effects on Lake 410 Outlet Discharges – Closure



m^3/d = cubic metres per day.

Figure 9.7-53 Comparison of Effects on Lake 410 Stages – Closure



m = metres.

Table 9.7-97 Monthly Mean Discharges at the Lake 410 Outlet – Closure

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			June	July	August	September	October
Wet	100	baseline	934,000	678,000	475,000	587,000	135,000
		closure	852,000	518,000	427,000	531,000	123,000
	10	baseline	759,000	514,000	329,000	278,000	70,700
		closure	691,000	371,000	283,000	262,000	63,200
Median	2	baseline	537,000	344,000	210,000	135,000	32,700
		closure	499,000	240,000	172,000	120,000	28,800
Dry	10	baseline	329,000	203,000	132,000	73,900	16,000
		closure	313,000	148,000	105,000	64,600	13,900
	100	baseline	190,000	106,000	90,100	49,800	9,660
		closure	164,000	94,600	71,200	45,700	8,400

m^3/d = cubic metres per day.

Table 9.7-98 Representative Discharges at the Lake 410 Outlet – Closure

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	20.00	1,420,000	1,240,000	404,000	443,000	491,000
		closure	18.90	1,400,000	1,190,000	298,000	364,000	388,000
	10	baseline	16.50	1,230,000	1,080,000	237,000	287,000	355,000
		closure	15.60	1,190,000	1,030,000	187,000	237,000	277,000
Median	2	baseline	11.90	942,000	837,000	128,000	173,000	234,000
		closure	11.30	897,000	796,000	108,000	144,000	184,000
Dry	10	baseline	7.11	580,000	523,000	74,200	108,000	150,000
		closure	7.00	572,000	515,000	64,600	92,700	122,000
	100	baseline	3.03	219,000	200,000	50,900	77,500	100,000
		closure	3.37	276,000	246,000	44,600	68,100	87,900

Q =discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-99 Monthly Mean Stages at the Lake 410 Outlet – Closure

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			June	July	August	September	October
Wet	100	baseline	0.769	0.621	0.490	0.564	0.212
		closure	0.723	0.519	0.456	0.527	0.199
	10	baseline	0.669	0.516	0.383	0.343	0.138
		closure	0.629	0.415	0.347	0.329	0.128
Median	2	baseline	0.531	0.395	0.284	0.212	0.082
		closure	0.506	0.311	0.249	0.196	0.076
Dry	10	baseline	0.383	0.278	0.209	0.142	0.051
		closure	0.371	0.225	0.179	0.130	0.047
	100	baseline	0.266	0.180	0.162	0.109	0.036
		closure	0.241	0.167	0.138	0.103	0.033

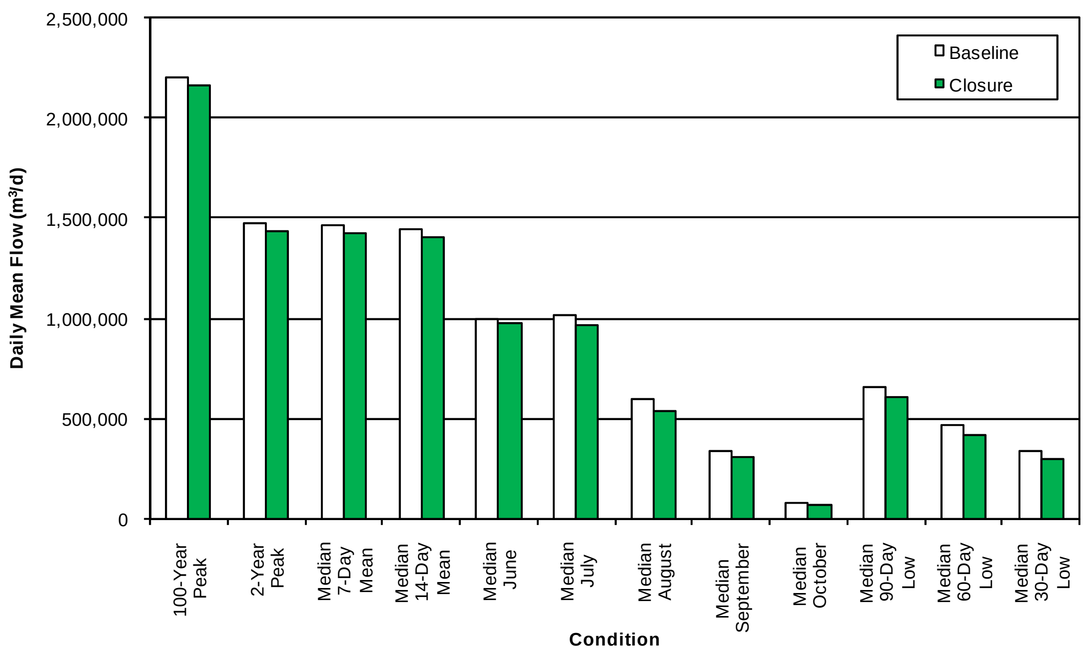
m = metre.

Table 9.7-100 Representative Stages at the Lake 410 Outlet – Closure

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	1.158	1.016	0.928	0.440	0.467	0.501
		closure	1.115	1.007	0.903	0.359	0.410	0.428
	10	baseline	1.019	0.923	0.847	0.308	0.350	0.403
		closure	0.982	0.903	0.820	0.263	0.308	0.342
Median	2	baseline	0.819	0.773	0.714	0.204	0.250	0.305
		closure	0.792	0.748	0.691	0.182	0.221	0.260
Dry	10	baseline	0.581	0.559	0.522	0.142	0.182	0.227
		closure	0.575	0.554	0.517	0.130	0.165	0.198
	100	baseline	0.329	0.292	0.275	0.110	0.146	0.173
		closure	0.353	0.341	0.316	0.101	0.134	0.159

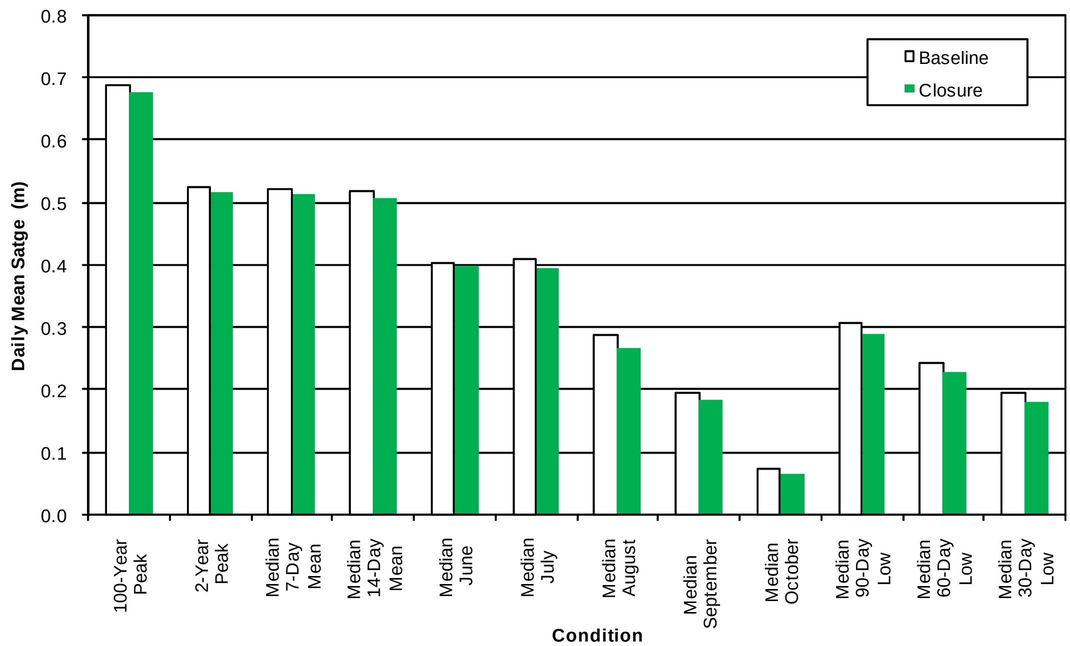
m = metre.

Figure 9.7-54 Comparison of Effects on Kirk Lake Outlet Discharges – Closure



m^3/d = cubic metres per day.

Figure 9.7-55 Comparison of Effects on Kirk Lake Stages – Closure



m = metres.

Table 9.7-101 Monthly Mean Discharges at the Kirk Lake Outlet – Closure

Condition	Return Period (years)	Snapshot	Monthly Mean Discharge (m^3/d)				
			June	July	August	September	October
Wet	100	baseline	1,850,000	1,730,000	1,250,000	1,370,000	420,000
		closure	1,820,000	1,600,000	1,110,000	1,140,000	382,000
	10	baseline	1,450,000	1,420,000	916,000	676,000	188,000
		closure	1,430,000	1,330,000	812,000	632,000	180,000
Median	2	baseline	995,000	1,020,000	596,000	332,000	75,700
		closure	975,000	964,000	533,000	304,000	66,800
Dry	10	baseline	562,000	607,000	349,000	161,000	24,500
		closure	546,000	582,000	321,000	144,000	20,200
	100	baseline	226,000	255,000	191,000	85,200	4,760
		closure	216,000	254,000	188,000	77,200	3,290

m^3/d = cubic metres per day.

Table 9.7-102 Representative Discharges at the Kirk Lake Outlet – Closure

Condition	Return Period (years)	Snapshot	Peak Daily Q (m^3/s)	7-Day Mean Peak Q (m^3/d)	14-Day Mean Peak Q (m^3/d)	30-Day Low Flow Q (m^3/d)	60-Day Low Flow Q (m^3/d)	90-Day Low Flow Q (m^3/d)
Wet	100	baseline	25.50	2,160,000	2,100,000	1,050,000	1,140,000	1,290,000
		closure	25.00	2,130,000	2,070,000	950,000	1,020,000	1,170,000
	10	baseline	22.10	1,890,000	1,850,000	636,000	774,000	981,000
		closure	21.70	1,850,000	1,810,000	573,000	693,000	894,000
Median	2	baseline	17.10	1,460,000	1,440,000	333,000	467,000	660,000
		closure	16.60	1,420,000	1,400,000	299,000	420,000	608,000
Dry	10	baseline	10.60	902,000	884,000	163,000	262,000	395,000
		closure	10.40	886,000	868,000	147,000	240,000	373,000
	100	baseline	3.98	321,000	290,000	82,100	148,000	213,000
		closure	4.24	343,000	310,000	74,400	140,000	213,000

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day.

Table 9.7-103 Monthly Mean Stages at the Kirk Lake Outlet – Closure

Condition	Return Period (years)	Snapshot	Monthly Mean Stage (m)				
			June	July	August	September	October
Wet	100	baseline	0.610	0.584	0.470	0.500	0.227
		closure	0.604	0.554	0.434	0.442	0.213
	10	baseline	0.519	0.512	0.382	0.312	0.133
		closure	0.514	0.490	0.353	0.298	0.129
Median	2	baseline	0.404	0.410	0.287	0.194	0.072
		closure	0.398	0.395	0.266	0.183	0.067
Dry	10	baseline	0.276	0.290	0.201	0.120	0.034
		closure	0.271	0.282	0.190	0.111	0.030
	100	baseline	0.150	0.163	0.134	0.078	0.011
		closure	0.146	0.162	0.133	0.073	0.009

m = metre.

Table 9.7-104 Representative Stages at the Kirk Lake Outlet – Closure

Condition	Return Period (years)	Snapshot	Peak Daily Stage (m)	7-Day Mean Peak Stage (m)	14-Day Mean Peak Stage (m)	30-Day Low Flow Stage (m)	60-Day Low Flow Stage (m)	90-Day Low Flow Stage (m)
Wet	100	baseline	0.686	0.677	0.664	0.418	0.442	0.480
		closure	0.677	0.671	0.658	0.391	0.410	0.450
	10	baseline	0.623	0.619	0.610	0.300	0.342	0.400
		closure	0.616	0.610	0.602	0.279	0.317	0.376
Median	2	baseline	0.525	0.521	0.517	0.195	0.244	0.307
		closure	0.515	0.512	0.507	0.181	0.227	0.291
Dry	10	baseline	0.382	0.378	0.373	0.121	0.166	0.218
		closure	0.377	0.374	0.369	0.113	0.156	0.210
	100	baseline	0.199	0.190	0.177	0.077	0.113	0.144
		closure	0.207	0.198	0.186	0.072	0.109	0.144

m = metre.

Summary of Effects on Flows, Water Levels and Channel/Bank Stability

Lake 410 Outlet Flows: The water balance results for Lake 410 show that during closure, monthly mean flows will decrease, as withdrawals from Lake N11 for Kennady Lake refilling combined with the continued closed-circuiting of Kennady Lake upstream of Area 8, are greater than increased inflow to Lake N1 due to the Lake A3 diversion. The 2-year flood discharge during closure will decrease by approximately 5% from the baseline value, and the 100-year flood discharge will decrease by approximately 6%. Low flows will also decrease by 16% to 21%.

Lake 410 Water Levels: Lake 410 water levels are also expected to decrease during closure. The 2-year flood level is expected to decrease by approximately 0.027 m, the 100-year flood level by 0.043 m, and monthly mean stages by 0.025 m (June), 0.084 m (July), 0.035 m (August), 0.016 m (September) and 0.006 m (October), under median conditions.

Lake 410 and Outlet Channel/Bank Stability: No effects on Lake 410 and Outlet channel or bank stability are expected during operation, because flood discharges and water levels will be reduced from baseline.

Kirk Lake Outlet Flows: The water balance results for Kirk Lake show that during closure, monthly mean flows will decrease, as withdrawals from Lake N11 for Kennady Lake refilling combined with the continued closed-circuiting of Kennady Lake upstream of Area 8, are greater than increased inflow to Lake N1 due to the Lake A3 diversion. The 2-year flood discharge during closure will decrease by approximately 3% from the baseline value, and the 100-year flood discharge will decrease by approximately 2%. Low flows will also decrease by 8% to 10%.

Kirk Lake Water Levels: Kirk Lake water levels are also expected to decrease during closure. The 2-year flood level is expected to decrease by approximately 0.010 m, the 100-year flood level by 0.009 m, and monthly mean stages by 0.006 m (June), 0.015 m (July), 0.021 m (August), 0.011 m (September) and 0.005 m (October), under median conditions.

Kirk Lake and Outlet Channel/Bank Stability: No effects on Kirk Lake and Outlet channel or bank stability are expected during operation, because flood discharges and water levels will be reduced from baseline.

9.7.4.2 Effect of Permanent Diversion in the A Watershed

The effects of the permanent diversion of Lake A3 to Lake N9 during and beyond closure will be identical to those presented in Section 9.7.4.1.3 for downstream lakes N9, N6 and N2. Because effects on Lake N2 are negligible, effects on further downstream lakes are not presented.

9.7.4.3 Effects of the Project to Long-Term Hydrology Downstream of Area 8

Changes to the post closure hydrological regime of the Kennady Lake watershed were discussed in Section 8.7.4.4. Expected changes are minor and include a 3.8% increase in mean annual water yield and a slight increase in flood peak discharges. Because the changes are so small, effects to watersheds downstream of Kennady Lake will be proportionately small at Lake L1 and diminish with distance downstream.

The post-closure hydrological regimes of the N11 and upstream watersheds will be identical to the baseline regimes. The post-closure regimes of the N2 and upstream watersheds will be as discussed in Section 9.7.4.2, with negligible changes due to the permanent diversion of Lake A3 into Lake N9. Changes to the post-closure regime of the N1 watershed will similarly be negligible.

9.8 EFFECTS TO SURFACE WATER QUALITY

The pathway analysis presented in Section 9.6 considered potential effects to water quality downstream of Kennady Lake and in Lake N11. The implementation of the Gahcho Kué Project (Project) environmental design features and mitigation reduced the number of potential effects that were carried forward to the detailed effect analysis. A summary of the primary pathways by which changes to downstream water quality could occur during construction and operation is presented in Table 9.8-1.

Table 9.8-1 Valid Pathways and Effect Statements for Effects to Water Quality Downstream of Kennady Lake – 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 (i.e., suspended sediments, major ions, metals, and nutrients concentrations) in downstream waterbodies	Effects of dewatering Kennady Lake to Lake N11 to water quality in downstream waters	Section 9.8.2.1

A summary of the primary pathways by which changes to downstream water quality could occur during closure is presented in Table 9.8-2.

Table 9.8-2 Valid Pathways and Effect Statements for Effects to Water Quality Downstream of Kennady Lake – Closure

Project Component	Pathway	Effects Statement	Effects Addressed
Removal and reclamation of Project infrastructure	seepage from mine rock and processed kimberlite storage repositories, and the open Tuzo Pit may change water quality in Kennady Lake, and affect water quality in downstream waterbodies	Effects of Project activities to water quality in downstream waters	Section 9.8.2.2 and 9.8.2.3
	reclaimed project area may result in long-term changes to water quality in downstream watersheds		
Breaching and Removal of Dyke A to reconnect Kennady Lake with downstream watersheds	reconnection of Kennady Lake with Area 8 may change the water quality of downstream waterbodies		

Section 9.8.1 provides an overview of the methodology used to analyze the effects to water quality downstream of Kennady Lake during construction operations, and closure. The discussion of analysis results for construction and operation, and closure is provided in Section 9.8.2.

During the mine operation phase of the Project there will be discharges from the Water Management Pond (WMP) to Lake N11. Details regarding water management during all phases of the project are included in Section 9.4. From the N watershed, water drains into Lake 410. The effect to water quality in this system during the construction and operation phases is assessed by downstream mass balance modelling using GoldSim™.

During the initial dewatering in the construction phase, there will be discharges from Area 7 to Area 8. This water will continue to flow through the downstream lake system. This discharge will be comprised of natural, background waters, so there is no primary pathway for effects to water quality during this period. During the closure phase, the refilled Kennady Lake will be reconnected to Area 8, and mine-affected waters will flow through Area 8 (see Section 8.8) and continue through to the downstream lake system. The downstream lake system consists of a number of small and medium interconnected lakes (Figure 9.8-1), which includes lakes in the L watershed, and a chain of lakes in the M watershed. The lakes modelled in the L and M watershed are referred to as the Interlakes system. From the M watershed, water drains into Lake 410. The effect to water quality in this system at during the closure phase is assessed by downstream mass balance modelling using GoldSim™.

The assessment of potential effects of water releases from the WMP and the refilled Kennady Lake to the water quality in the downstream lake systems will include a comparison of modelled water quality results to background natural levels and applicable guidelines for water quality constituents.

GAHCHO KUÉ PROJECT

Watershed Boundaries and Lakes Downstream of Kennady Lake

LEGEND

- Gahcho Kué Project
- Winter Access Road
- Watercourse
- Waterbody
- Flow Direction

Watershed Boundary

- Watershed L
- Watershed M
- Watershed N
- Lake 410 Watershed
- Watershed P
- Kirk Lake Watershed
- Watershed Identifier

PROJECTION: UTM Zone 12		DATUM: NAD83	
Scale 1:250,000			
FILE No: KLOI-09-005-GIS		DATE: December 17, 2010	
JOB NO: 09-1365-1004	REVISION NO: 2		
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF	Figure 9.8-1

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

Another potential source of effects to the downstream lakes is atmospheric deposition of Project emissions, such as dust and metals, as well as effects from acidifying emissions. These effects are associated with the transport of Project emissions through the airshed and their deposition onto watersheds and/or waterbodies. The level of effects depends on the distance from emission sources as well as downstream transport through lakes and streams. The effects analysis within Kennady Lake watershed (Section 8.8.3) shows that measurable effects from dust and metal depositions onto lakes water quality are projected to occur within the immediate vicinity to the Project (i.e., within 2 kilometres [km] of the Project); however, these effects are anticipated to be primarily limited to the freshet period when accumulated winter deposition to the watershed is transported through the lakes with the snow melt at a time that peak total suspended sediments (TSS) and metals concentrations naturally occur for short peak flow periods. Therefore, it is expected that there will be negligible effects to water quality from dust or metals deposition outside of the Kennady Lake watershed, and as a result this assessment was not carried through to the downstream lakes system.

Potential acidification analysis outside of the Kennady Lake watershed, including the Lockhart River and Hoarfrost River watersheds, is also expected to be a No Linkage pathway (Section 9.6). The effects analysis within Kennady Lake watershed (Section 8.8.3) shows that non-measurable effects from potentially acidifying deposition onto lakes are projected within the Kennady Lake watershed.

Effects of changes in water quality on the health of aquatic life in Area 8 during closure and post-closure was assessed in Section 8.9.3.1, considering fish tissue accumulation, and direct exposure. During all phases of the Project, including closure and post-closure periods, predicted changes to water quality in Area 8 were projected to result in negligible effects to fish tissue quality and, by association, aquatic health, because fish tissue concentrations were projected to be below toxicological benchmarks for all parameters considered in the assessment. Predicted peak concentrations for all substances of potential concern (SOPCs) resulting from direct exposure during closure and post-closure phases were lower than the corresponding chronic effects benchmark (CEB). Potential effects to fish tissue quality and aquatic health for Lake 410 during closure and post-closure are assessed in Section 9.9.

9.8.1 Effects Analysis Methods

9.8.1.1 Effect of Water Releases on Water Quality in Downstream Waterbodies – Construction, Operations and Closure Phases

9.8.1.1.1 Introduction

Water quality and quantity in Kennady Lake will vary over time as the Project proceeds through the construction and operations, and closure phases. As water from the WMP is discharged to Lake N11, water quality in Lake N11 and downstream waterbodies may be affected by loading inputs from this discharge. Following the refilling of Kennady Lake and reconnection to Area 8, mine-affected water will flow through Area 8 and continue downstream through the interlakes watersheds and into Lake 410.

During the construction and operations phases, water quality within Kennady Lake was modelled throughout these phases to determine the quality of water that would be discharged to Lake N11, and to determine the quality of water in Kennady Lake when it becomes reconnected to Area 8. Details of this modelling are provided in Appendix 8.I and Section 8.8.2.1.1. The water quality parameter concentration time series plots predicted by the Kennady Lake model were used as inputs to the downstream water quality model, which includes Area 8, the L, M and N watersheds and Lake 410. Inputs from the Kennady Lake model included a discharge to Lake N11 during the construction and operational phase and an outflow to Area 8 during post-closure. The downstream water quality model, developed in GoldSim™, is detailed briefly below and fully described in Appendix 8.I.

The hydrology model (see Section 9.7.1) formed the basis of the downstream water quality model. Within each watershed, water quality profiles were assigned as baseline or background chemistry. Throughout the construction, operations, and closure phases of the project, the downstream watershed was assumed to behave according to baseline conditions, with the following exceptions, which are included in the model:

- inflow to Kennady Lake from its immediate watershed will be diverted to the N watershed;
- water will be discharged from the WMP to Lake N11 during the construction and operations phases;
- water will be drawn from Lake N11 to refill Kennady Lake during the closure phase;

- the flow path from Area 7 to Area 8 will be disconnected during the operations and closure phases; and
- the flow path from Area 7 to Area 8 will be reconnected after Kennady Lake has refilled (i.e., the post-closure period).

The water quality model predicted concentrations for a range of water quality parameters at all downstream nodes during the construction, operations and closure phases. The model assumed fully mixed conditions within each waterbody at each daily timestep.

A median climate scenario (i.e., 1-in-2 year wet climate condition) was used to assess likely changes in water quality in the downstream watersheds. This scenario represents a relatively average climate condition.

9.8.1.1.2 Data Sources

Background water quality data in the L, M and N watersheds and Lake 410 were collected between 1995 and 2010. The data were collected by various consultants during open water and under-ice conditions (Section 9.3). For the purposes of the downstream lakes water quality assessment, data collected from the sources presented in Table 9.8-3 were used.

Table 9.8-3 Water Quality Studies Used in the Assessment of Kennady Lake, 1995 to 2010

Report Author(s)	Publication Date	Report Title
JWEL	July 1998	Water Quality Assessment of Kennady Lake, 1998 Final Report. Project No. BCV50016. Submitted to Monopros Limited, Yellowknife, NWT (Jacques Whitford 1998)
JWEL	October 14, 1999	Results of Water Sampling Program for Kennady Lake July 1999 Survey. Project No. 50091. Submitted to Monopros Limited, Yellowknife, NWT (Jacques Whitford 1999)
EBA & JWEL	2001	Gahcho Kué (Kennady Lake) Environmental Baseline Investigations (2000) Submitted to De Beers Canada Exploration Ltd., Yellowknife, NWT (EBA and Jacques Whitford 2001)
JWEL	April 29, 2002	Data Compilation (1995-2001) and Trends Analysis Gahcho Kué (Kennady Lake). Project No. ABC50310. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2002)
JWEL	June 4, 2003	Gahcho Kué (Kennady Lake) Limnological Survey of Potentially Affected Bodies of Water (2002). Project No. NTY71008. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2003)
JWEL	January 20, 2004	Baseline Limnology Program (2003) Gahcho Kué (Kennady Lake). Project No. NTY71037. Submitted to De Beers Canada Exploration Inc., Yellowknife, NWT (Jacques Whitford 2004)
EBA	2004	Faraday Lake Winter 2003 Water Quality Sampling Program. Submitted to DeBeers Canada Exploration Inc., Yellowknife, NWT (EBA 2004a)
EBA	2004	Kelvin Lake Winter 2003 Water Quality Sampling Program. Submitted to DeBeers Canada Exploration Inc., Yellowknife, NWT (EBA 2004b)
AMEC	2004-2005	Unpublished water chemistry and field data collected in Kennady Lake and surrounding watersheds (AMEC 2004 and 2005)
Section 9.3	2010	Additional baseline data collected in support of this application

JWEL = Jacques Whitford Environment Ltd.; EBA = EBA Environmental Consultants Ltd.; AMEC = AMEC Earth & Environmental.

9.8.2 Effects Analysis Results

9.8.2.1 Effect of Project Activities on Water Quality in Lake N11 during Construction and Operations, and Closure Phases

During the construction and operations phases of the project, Kennady Lake will be segmented by dykes into separate areas to allow for the creation of a WMP and to allow dewatering in the areas with active mine pits (Section 8.4). Initially, clean water will be withdrawn from the lake to increase the water storage capacity during mining operations. This water will be pumped from the WMP to Lake N11 and from Area 7 to Area 8. Throughout the operations phase, water will continue to be discharged from the WMP to Lake N11.

Because the WMP will receive runoff and direct discharge from mine-related sources, discharge of this water to Lake N11 may potentially affect water quality in Lake N11 and downstream waterbodies. Therefore, water quality was assessed in Lake N11, which represents the node of maximum potential impact in the N watershed, and in Lake 410 (see Section 9.8), which represents far-field effects.

Maximum concentrations of each of the water quality parameters in Lake N11 during all phases are presented in Table 9.8-4. Maximum concentrations for all parameters are attained either early in the operations phase, when discharges to Lake N11 are highest, or at the end of the operations phase, when concentrations in the WMP are highest.

Concentrations of parameters in Lake N11 were predicted to return to background levels during the closure or post-closure phases within five years after discharges to Lake N11 cease.

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 Table 9.8-4 are provided in Appendix 9.I.

Table 9.8-4 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 9.8-4 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 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
Nutrients				
Ammonia	mg/L as N	23[(f)]	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
Dissolved Phosphorus	mg/L	-	n/a	n/a
Total Phosphorus	mg/L	-	n/a	n/a
Dissolved Metals				
Aluminum	mg/L	0.1[(g)]	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
Boron	mg/L	1.5	0.0017	0.023
Cadmium	mg/L	0.000002[(h)]	**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[(h)]	0.00099	0.00115
Iron	mg/L	0.3	0.045	0.101
Lead	mg/L	0.001[(h)]	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[(h)]	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
Total Metals				
Aluminum	mg/L	0.1 [g]	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

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 Concentrations
				Maximum during all Project Phases[b]
Cadmium	mg/L	0.000002[h]	**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[h]	0.0013	0.0015
Iron	mg/L	0.3	0.059	0.13
Lead	mg/L	0.001[h]	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[h]	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

(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 (see Section 8.4).
(e) Theoretical hardness calculated based on background calcium and magnesium concentrations.
(f) Dependent on pH and temperature (assumed 15ºC, 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; n/a = these values are currently subject to further analysis and are not being reported at this time; they will be provided later in a supplemental filing

Total Dissolved Solids and Major Ions

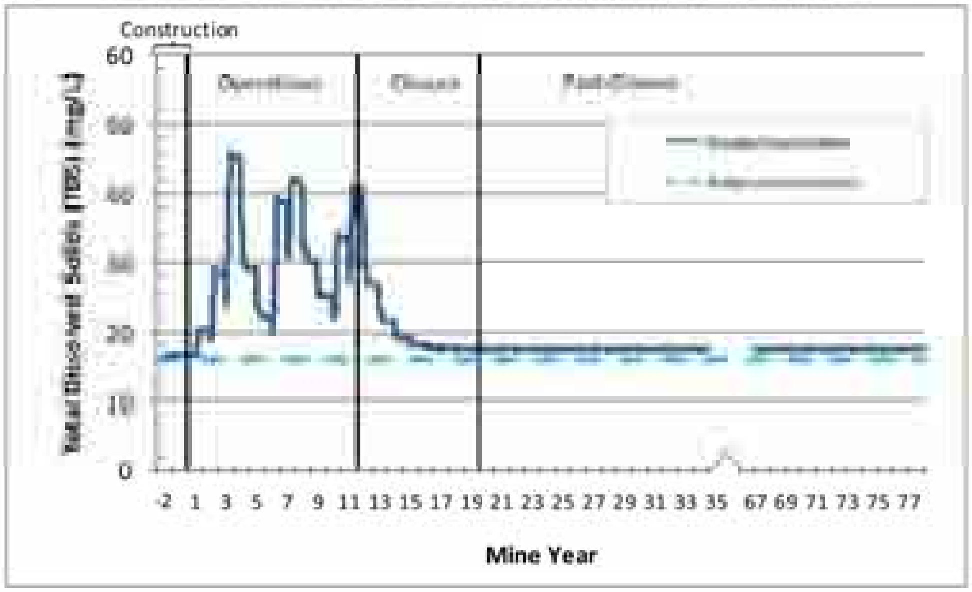
Concentrations of TDS and major ions in Lake N11 are projected to increase during the operations phase due to the input of water pumped from the WMP. All major ions follow a similar trend, as shown in Figure 9.8-2 for TDS. Project TDS concentrations show characteristic peaks each year that correspond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

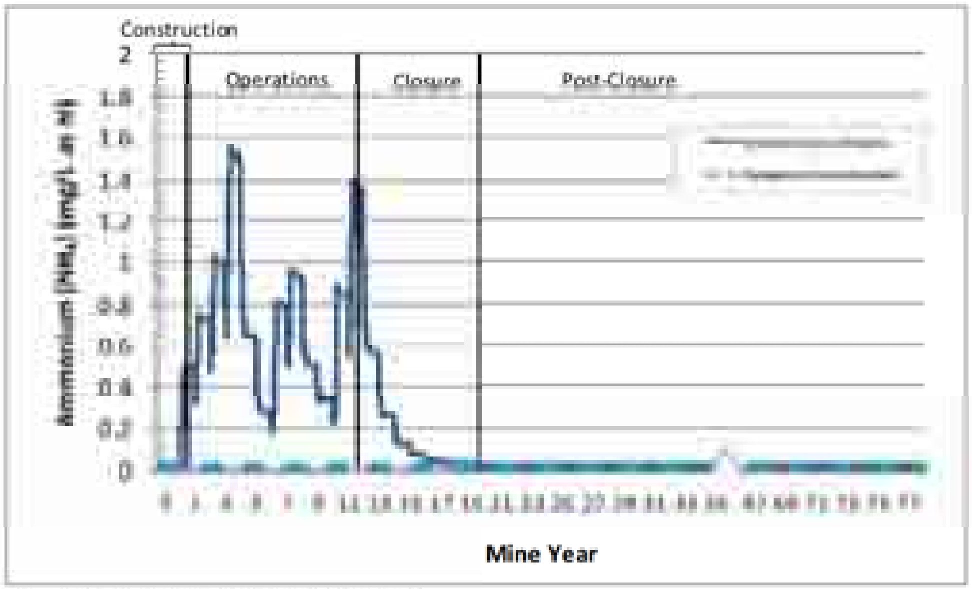
Nutrients

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 (Table 9.8-4) and return to background conditions within the first few years of the closure period (Figure 9.8-3). 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 Ammonia 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 in Lake N11 as a result of loading from the WMP. Phosphorus levels in the WMP itself are influenced runoff waters that pick up phosphorus from the mine rock, coarse PK and fine PK as they travel through the external structures, with the fine PK being the largest source of phosphorus. De Beers is currently evaluating a variety of environmental design features and mitigation measures to limit phosphorous loading to the environment. These environmental design features and mitigation measures include, for example:

- Promotion of permafrost development in the Fine PKC Facility.
- Use of low permeability cover material to limit infiltration into key areas, such as the Fine PKC Facility.

The effectiveness of these environmental design features and mitigation measures is uncertain and requires further analysis. Accordingly, the amount of phosphorus that may be released into the environment is uncertain at this time. As a result, potential effects related to phosphorus have not been presented and will not be available until such time as additional analysis is completed. This analysis will be provided to the Panel in 2011.

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.

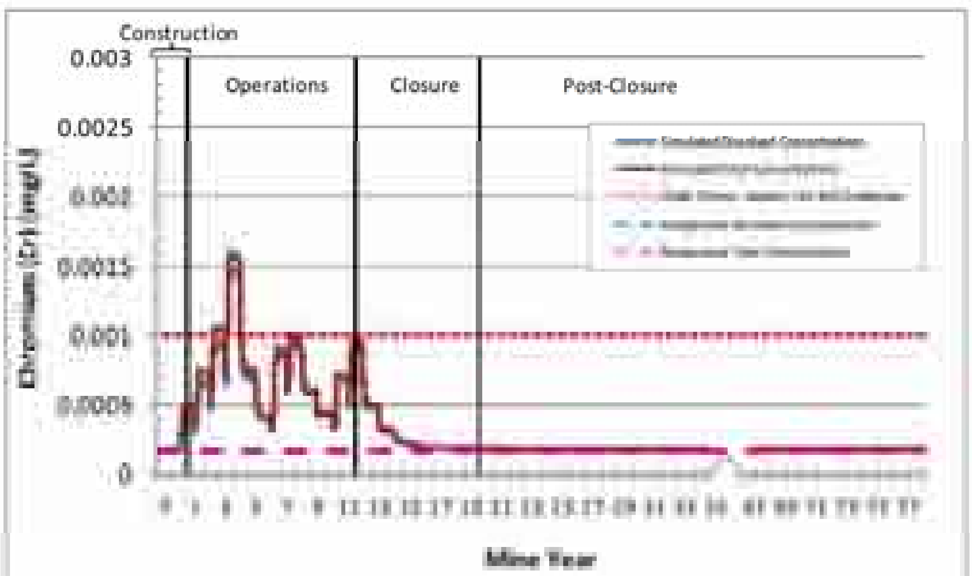
Depending on the primary loading source of these metals to the WMP, the characteristic peaks predicted to occur in Lake N11 may vary somewhat for these 17 metals. Metals that are influenced more by groundwater inflows are predicted to have maximum peaks early in the operational phase, as illustrated 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

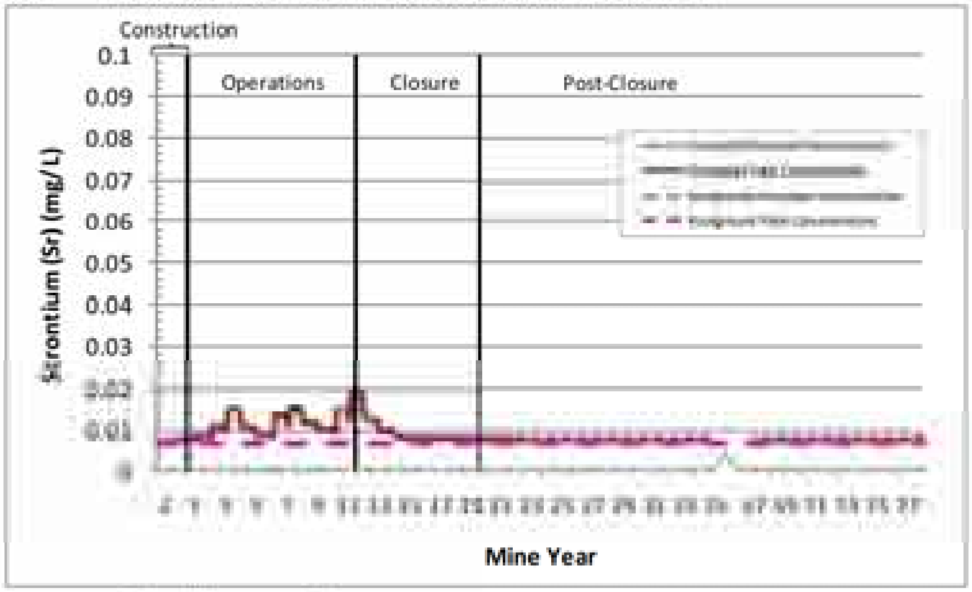
mg/L = milligrams per litre

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

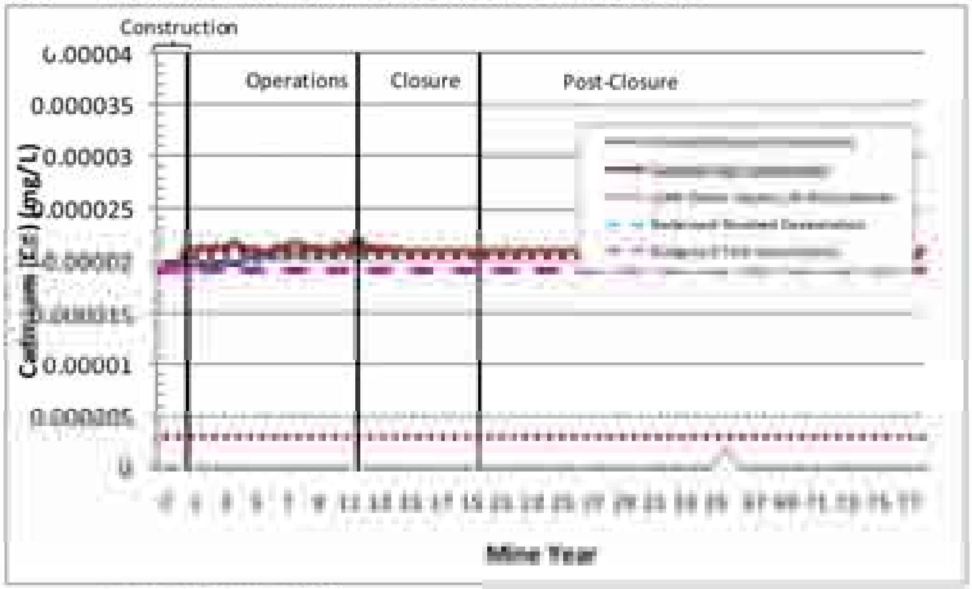


mg/L = milligrams per litre

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. Follow-up monitoring was, however, recommended to confirm the results of the aquatic health assessment. These conclusions and recommendations would apply to the interlakes as well.

Post-closure model results suggest that there is a potential for phosphorus levels to increase in Kennady Lake, relative to pre-project conditions, as a result of runoff from the reclaimed mine site. The runoff waters pick up phosphorus from the mine rock, coarse PK and fine PK as they travel through the external structures, with the fine PK being the largest source of phosphorus. The projected increase could lead to a similar increase in phosphorus levels in the L and M watersheds. However, the modelling analysis was completed assuming free and complete contact between the runoff waters and the materials contained in the mine rock piles, the Coarse PK Pile and the Fine PKC Facility.

De Beers is currently evaluating a variety of environmental design features and mitigation measures to limit contact between site runoff waters and the fine PK located within the Fine PKC Facility and other potential sources. The effectiveness of these environmental design features and mitigation measures is uncertain and requires further analysis. Accordingly, the amount of phosphorus that may be released into the environment is uncertain at this time. As a result, potential effects related to phosphorus have not been presented and will not be available until such time as additional analysis is completed. This analysis will be provided to the Panel in 2011.

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

Lake 410 is the ultimate 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 9.8-5. The concentrations listed in this table are the maximum concentrations over the modelled timeframe, so they represent the maximum of all phases of the project, including long-term concentrations.

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

Regulated Parameter	Units	Water Quality Guidelines[(a)]	Baseline WQ[(b)]	Predicted 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
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
Dissolved Phosphorus	mg/L	-	n/a	n/a
Total Phosphorus	mg/L	-	n/a	n/a
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
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
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

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 Concentrations
				Maximum during All Project Phases[b]
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

(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 15ºC, 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; n/a = these values are currently subject to further analysis and are not being reported at this time; they will be provided later in a supplemental filing

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 Table 9.8-5 are provided in Appendix 9.I.

Table 9.8-5 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.

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:

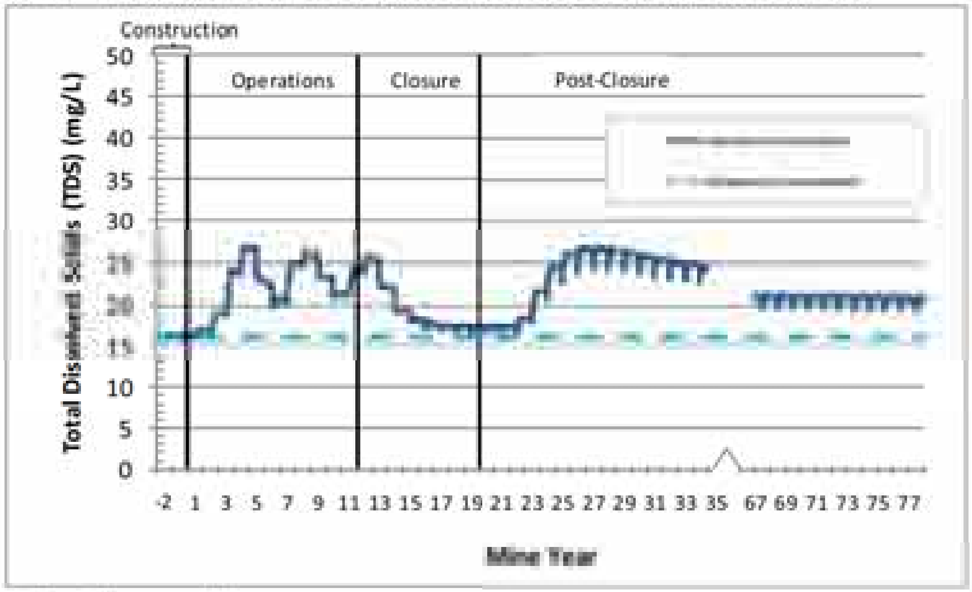
- concentrations are lower in Lake 410 due to dilution from the majority of the Lake 410 watershed, which will be unaffected by mining activities; and
- the characteristic peaks in Lake N11 show up one to two years later in Lake 410, reflecting travel time.

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 the post-closure period, 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 9.8-11 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 the post-closure period than in the operational phase (Figure 9.8-12 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 9.8-11 Predicted Total Dissolved Solids Concentrations in Lake 410



mg/L = milligrams per litre

Figure 9.8-12 Predicted Potassium Concentrations in Lake 410

mg/L = milligrams per litre

Nutrients

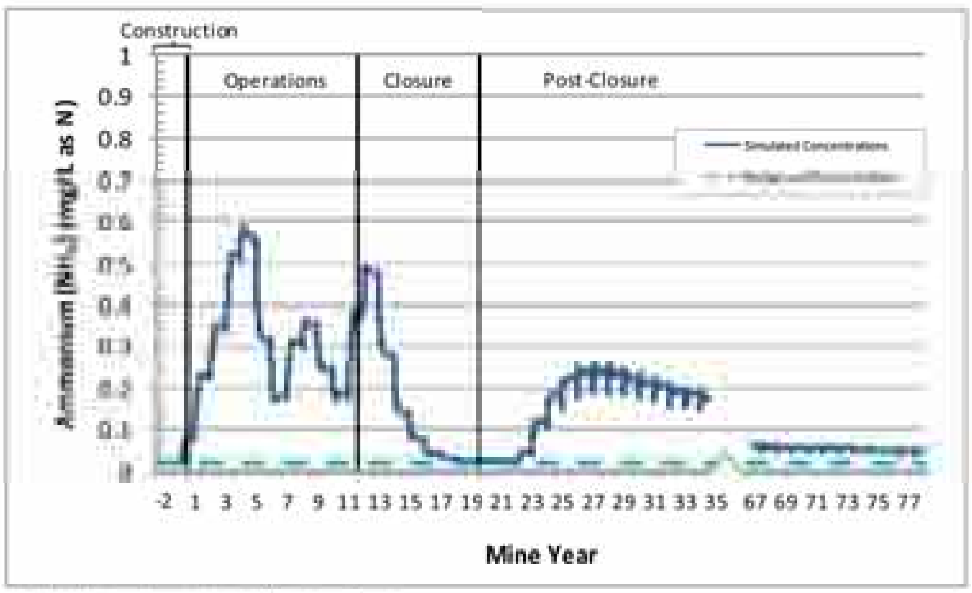
Nitrogen

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 9.8-13. 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 the post-closure period, 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 9.8-5). Total nitrogen, for which there is no CCME guideline, is predicted to follow a similar pattern as ammonia, as it is predominantly comprised of nitrate and ammonia.

Figure 9.8-13 Predicted Ammonia Concentrations in Lake 410



mg/L as N = milligrams per litre as nitrogen

Phosphorus

Concentrations of phosphorus are predicted to increase in Lake 410 at the end of operations and several years into post-closure, after dyke A is removed. With the cessation of pumped discharge from the WMP to Lake N11, phosphorus concentrations are predicted to return to background concentrations. Increases in phosphorus in Lake 410 occur as a result of the geochemical phosphorus loadings to the WMP from runoff contact with the Fine PKC Facility and mine rock piles.

As previously noted, De Beers is currently evaluating a variety of environmental design features and mitigation measures to limit contact between site runoff waters and the fine PK located within the Fine PKC Facility and other potential sources. The effectiveness of these environmental design features and mitigation measures is uncertain and requires further analysis. Accordingly, the amount of phosphorus that may be released into the environment is uncertain at this time. As a result, potential effects related to phosphorus have not been presented and will not be available until such time as additional analysis is completed. This analysis will be provided to the Panel in 2011.

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, twelve 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 9.8-15 for zinc. Cadmium is the only metal predicted to exceed guidelines in Lake 410, and the guideline exceedance is due to baseline concentrations.

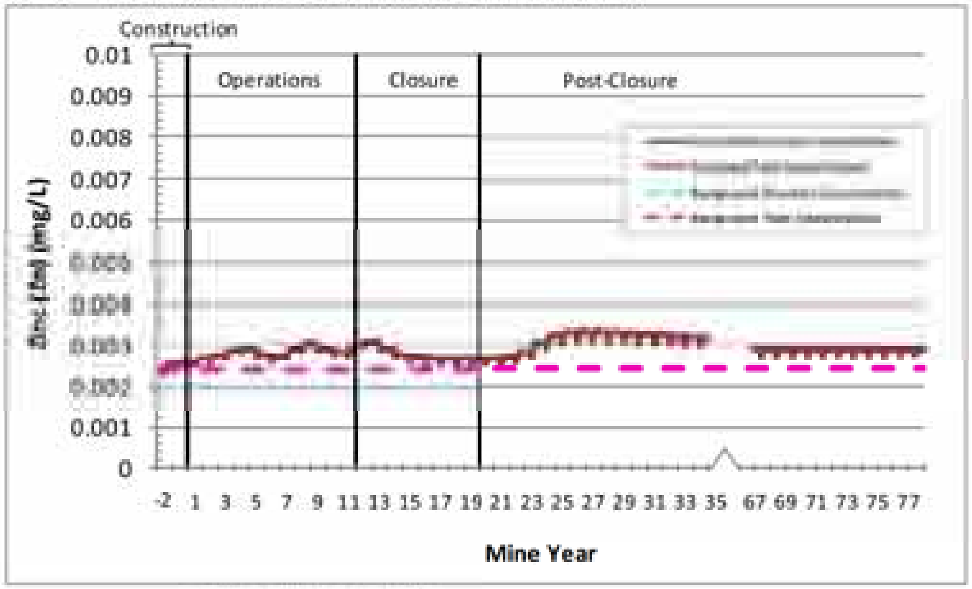
Trace Metals that are Predicted to Follow Similar Trends to TDS

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 9.8-16 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 9.8-17 for molybdenum.

Figure 9.8-15 Predicted Zinc Concentrations in Lake 410



mg/L = milligrams per litre

Figure 9.8-16 Predicted Chromium Concentrations in Lake 410

mg/L = milligrams per litre

Figure 9.8-17 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: Higher than Predicted Background + 10%?	Screening: Higher than CCME Guideline?	Retained as Substance of Potential Concern?
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.

9.10 EFFECTS TO FISH AND FISH HABITAT

Construction, operations, and closure of the Gahcho Kué Project (Project) will result in the potential for effects to fish and fish habitat downstream of Kennady Lake as a result of changes to the quantity and quality of water released from the Kennady Lake watershed. A summary of the valid pathways by which potential changes to fish and fish habitat downstream of Kennady Lake could occur are presented in Table 9.10-1 for construction and operation, and in Table 9.10-2 for closure and post-closure.

Table 9.10-1 Valid Pathways and Effect Statements for Effects to Fish and Fish Habitat Downstream of Kennady Lake – Construction and Operation

<table>
<tr><th>Project Activity</th><th>Pathway</th><th>Effects Statement</th></tr>
<tr><td>Dewatering of Kennady Lake</td><td>dewatering of Kennady Lake to Lake N11 and Area 8 may result in changes to flows, alteration of water levels and lake areas, channel/shoreline erosion, and changes to lower trophic levels, fish habitat and behaviour in downstream waterbodies</td><td rowspan="3">Effects of Project construction and operations activities to fish and fish habitat in streams and lakes of the N lakes watershed and downstream of Kennady Lake</td></tr>
<tr><td rowspan="2">Operational water management</td><td>water management during operations may result in changes to flows, alteration of water levels and lake areas, channel/shoreline erosion, and changes to lower trophic levels, fish habitat, and fish behaviour in downstream waterbodies</td></tr>
<tr><td>changes to nutrient levels in the N watershed may result in changes to lower trophic communities and fish and fish habitat in downstream waterbodies</td></tr>
</table>

Table 9.10-2 Valid Pathways and Effect Statements for Effects to Fish and Fish Habitat Downstream of Kennady Lake – Closure and Post-Closure

<table>
<tr><th>Project Activity</th><th>Pathway</th><th>Effects Statement</th></tr>
<tr><td>Removal of diversions in B, D, and E watersheds</td><td>removal of diversions may result in changes to flows, alteration of water levels and lake areas, channel/shoreline erosion, and changes to lower trophic levels, fish habitat, and fish behaviour in the N watershed</td><td rowspan="4">Effects of Project closure and post-closure activities to fish and fish habitat in streams and lakes of the N lakes watershed and downstream of Kennady Lake</td></tr>
<tr><td rowspan="3">Breaching and Removal of Dyke A to reconnect Kennady Lake with downstream watersheds</td><td>water management during closure and post-closure may result in changes to flows, alteration of water levels and lake areas, channel/shoreline erosion, and changes to lower trophic levels, fish habitat, and fish behaviour in downstream waterbodies</td></tr>
<tr><td>changes to nutrient levels may result in changes to lower trophic communities and fish and fish habitat in downstream waterbodies</td></tr>
<tr><td>changes to aquatic health may affect fish populations and abundance</td></tr>
</table>

Sections 9.10.1 and 9.10.2 provide an overview of the methods used to analyze the effects to fish and fish habitat downstream of Kennady Lake during construction and operation, and closure and post-closure, respectively. Results of the analysis are provided in Section 9.10.3 for construction and operations, and in Section 9.10.4 for closure. Pathways related to aquatic health are addressed in Section 9.9 (Effects to Aquatic Health); only the conclusions of the Aquatic Health assessment are presented herein in Section 9.10.4.4.

The assessment was completed under a scenario of no additional flow augmentation downstream of Area 8 to mitigate for reduced flows during operations and closure. If the results of the assessment conclude that negative impacts will result that would require habitat compensation, then a pumping plan would be developed to mitigate any habitat losses due to reduced flows. The specifics of the mitigation plan have not been developed, but would focus on providing suitable spawning and rearing habitat for Arctic grayling (*Thymallus arcticus*).

9.10.1 Effects Analysis Methods – Construction and Operations

9.10.1.1 Effects of Changes to the Flow Regime in Streams Downstream of Kennady Lake on Fish and Fish Habitat

9.10.1.1.1 Changes to Fish Habitat Availability

Changes to habitat availability downstream of Kennady Lake and in the N watershed may result from changes in the flow regime. An initial screening of potential change to fish habitat was conducted through a visual examination of flow duration curves comparing each project phase to pre-development conditions. The natural flow regime, as represented by the timing, magnitude, duration, and frequency of flow events, is considered to be a key factor in determining the function of the aquatic ecosystem (Poff et al. 1997, 2003; Richter et al. 1997; Bunn and Arthington 2002; Annear et al. 2004). Flow duration curves provide a visual indication on changes to key components of the flow regime. Although no single accepted standard is available for defining the extent to which an altered flow regime can be considered protective of the aquatic environment, a number of jurisdictions in Canada, including British Columbia (Hatfield et al. 2004) and Alberta (Clipperton et al. 2003) have adopted approaches that define flow regimes as a proportion of the natural flow regime (Locke et al. 2009). As an initial conservative screening criterion, project phases that result in a change in the flow regime greater than 15 percent (%) from the pre-development flow regime were assessed in further detail. The downstream extent of effects was determined to be when the project flow regime is within 15% of the pre-development flow as determined through comparison of flow duration curves and key flow statistics.

During project phases where the flow regime differs substantively from the pre-development flow regime, changes in habitat availability were assessed semi-quantitatively by comparison of the change in wetted width at streams with available transect data downstream of Kennady Lake. Effective loss of available habitat may also result during dewatering at the start-up by flushing fish downstream out of their preferred habitat location or during the shut-down stage by stranding fish. The potential for fish to become flushed or stranded during start-up and shut-down of dewatering was evaluated qualitatively, based on the pumping plan presented in Section 9.7. Changes to habitat availability can also result due to changes in channel form resulting from channel erosion and alteration of the riparian habitat. Conclusions from the hydrology assessment, with consideration of the environmental design features in place to mitigate channel changes, were used to determine the potential for channel alterations to affect fish habitat.

9.10.1.1.2 Changes to Fish Habitat Suitability

Changes in the flow regime can result in changes to the depth and velocity conditions in the stream, which in turn can affect the suitability of the habitat available for fish. Both flow augmentation and flow reductions are predicted at different stages of the Project, and both may alter the suitability of the habitat available. Changes in habitat suitability for fish were assessed using Arctic grayling as the primary assessment endpoint, as it is the most abundant of the highly valued stream-dwelling fish species found downstream of Kennady Lake (Section 9.3.5.2.6).

Slimy sculpin (*Cottus cognatus*), the only other common stream-dwelling species found downstream of Kennady Lake, was not specifically assessed as it is not identified as a valued component (VC). However, the habitat requirements of slimy sculpin overlap the habitat requirements of Arctic grayling, and are likely less sensitive to changes in depth and velocity, as slimy sculpin remain largely associated with cover within the stream substrate. Therefore, the conclusions made for Arctic grayling are considered suitable to represent the overall suitability of stream habitat with changes to the flow regime.

Potential effects of changes to the flow regime on Arctic grayling spawning and young-of-year (YOY) rearing in streams were assessed either qualitatively or semi-quantitatively by the following:

- comparing average water depths and velocities modelled for June discharges to water depth and velocities preferred by adult Arctic grayling for spawning and egg incubation available in the published literature (Hubert et al. 1985; Evans et al. 2002; Stewart et al. 2007);
- comparing average water depths and velocities modelled for July and August to water depths and velocities based on habitat preferences for YOY Arctic grayling rearing available in the published literature (Hubert et al. 1985; Jones and Tonn 2004; Stewart et al. 2007) and on published swimming performance criteria (Deegan et al. 2005); and
- qualitatively assessing the anticipated change in available refugia within microhabitat conditions available for adult and YOY Arctic grayling based on field measurements of the relative availability of depth, velocity, and substrate conditions at a range of discharges.

Arctic grayling have been found to spawn in areas with water velocity less than 1.5 metres per second (m/s), with a preference for velocities in the range of 0.3 m/s to 0.8 m/s (Stewart et al. 2007). This range is slightly different from Hubert et al. (1985), which identified a maximum suitable velocity of 1.2 m/s and also identified that a velocity less than 0.15 m/s had no suitability. For the purpose of the assessment, velocities that fall below 0.15 m/s will be considered to have reduced suitability, but will still be considered as suitable spawning habitat. Spawning depths are usually shallow (less than 1.0 metres [m]), and can be as shallow as a few centimetres of depth (Stewart et al. 2007). Increased depth is not considered a limiting factor to Arctic grayling spawning habitat selection.

Arctic grayling YOY have been found to occupy areas with average water velocities of less than 0.8 m/s, in depths ranging from 0.05 m to 0.5 m (Stewart et al. 2007). Within this range, they show a preference for slow (range of 0.0 m/s to 0.25 m/s), shallow (range of 0.06 m to 0.3 m) habitats. Average velocity is likely not a good measure of microhabitat conditions used by YOY, as YOY will seek out velocity shelter from the substrate. Jones and Tonn (2004) found small YOY select shallow, slow areas with depths less than 0.3 m and velocities less than 0.1 m/s, while larger YOY select slightly deeper and faster areas with depths less than 1.0 m and velocities less than 0.3 m/s. A qualitative assessment on the availability of suitable cover from large substrate (i.e., boulders and cobble), which are not anticipated to change due to the altered flow regimes, was also considered as part of the assessment.

Survival of Arctic grayling in their first year of life is, in part, dependent on their ability to grow and acquire enough energy reserves in natal streams before their first winter (Deegan et al. 1997), and growth of YOY Arctic grayling has been found to be negatively correlated to discharge (Deegan et al. 1998). YOY Arctic grayling are approximately 15 millimetres (mm) in length at swim-up in early July (Jones et al. 2003a). Fish of this size are poor swimmers and have a sustained swimming speed of 0.15 m/s (Table 9.10-3). YOY Arctic grayling become better swimmers (Deegan et al. 2005; Table 9.10-3) and also become increasingly territorial as they grow (Jones et al. 2003a,b; O'Brien et al. 2001).

Table 9.10-3 Swimming Performance of Young-of-Year Arctic Grayling

Length	Time Period	Swimming Speed (m/s)	
		Prolonged[(a)]	Sustained[(b)]
15 mm[(c)]	Early July[(c)]	0.20	0.15
30 mm[(d)]	Early August[(d)]	0.40 to 0.50	0.15 to 0.25
65 mm[(c)]	Late August[(c)]	0.60 to 0.65	0.15 to 0.25

Notes: Table adapted from Deegan et al. (2005).

(a) Maintainable up to 200 minutes.

(b) Cruising speed, which can be maintained indefinitely.

(c) Jones et al. (2003a);

(d) Jones et al. (2003a) and Annex J, Fisheries and Aquatic Resources Baseline (unpublished data).

m/s = metres per second; mm = millimetres.

The preferences for depth and velocity identified above are in reference to the microhabitat conditions that fish directly experience when selecting suitable habitat, i.e., the depth and velocity conditions in the immediate vicinity of where a fish is located. Most of the results available to conduct the assessment on fish habitat reference average conditions across the entire channel, and not microhabitat conditions. The average conditions will provide a semi-quantitative index of overall suitability, with the assumption that there will be a distribution of depths and velocities above and below the channel average throughout the stream. Some field measurements of microhabitat distribution are available from 2005 (Appendix 9.II) to put the average conditions in the appropriate context, but are not available for all of the modeled discharge conditions. Average water velocities and depths in each stream between Kennady Lake and Lake 410 were estimated from hydraulic relationships developed for each stream (Annex H, Climate and Hydrology Baseline) and from discharges for each stream projected during each phase of the Project.

9.10.1.1.3 Changes to Fish Migrations

There is a potential that the altered downstream flow regime may create barriers to seasonal feeding migrations and spawning migrations. Potential barriers within the N watershed were assessed semi-quantitatively based on predicted changes in depth and velocity conditions at a series of likely barrier locations (e.g., boulder cascades) and on the timing and swimming ability of species that are known to migrate through the N watershed.

Potential barriers to Arctic grayling spawning migration of the eight streams between Kennady Lake and Lake 410 were assessed semi-quantitatively based on visual field assessments. Visual assessments of each stream were conducted in the spring, summer, and fall of 2004 and 2005 to identify if any potential barriers to migration were present at the time of the assessment. Results were correlated to daily discharges at the Kennady Lake outlet (Stream K5) to determine the upper and lower discharges between which barriers form in any or all of these streams.

9.10.1.1.4 Changes to Lower Trophic Levels

Potential changes in abundance, biomass, and species composition of the benthic community during the Kennady Lake dewatering period and mine operations were qualitatively assessed based on the anticipated changes in water velocity, water depth and wetted width, and the known habitat preferences of different benthic invertebrate groups from the published literature. Changes in the species composition and density of invertebrate drift due to changes in flows were assessed qualitatively based on the expected changes in water velocity and known effects of flow changes on invertebrate drift patterns (Brittain and Eikeland 1988; Svendsen et al. 2004).

9.10.1.2 Effects of Changes in Water Levels in Lakes Downstream of Kennady Lake to Fish and Fish Habitat

9.10.1.2.1 Changes to Fish Habitat

The quantification of changes to water levels and lake areas resulting from dewatering during construction and water management during operations is based on the data and results presented in Section 9.7, Effects to Water Quantity. The predicted changes in water depth were based on the hydrology model (Section 9.7) using mean monthly results for a median year runoff return period. The estimated change in lake circumference each month was calculated from the change in water depth (assuming a 5% shoreline slope) using Geographic Information System (GIS). Baseline lake areas were based on a single snap-shot 1:4,000 digital mapping layer; monthly baseline lake areas were not available. Monthly changes in lake area as a result of the Project were compared to these “representative” lake areas.

The effects on fish and fish habitat were assessed qualitatively, taking into the account the fish species present, their habitat use, and life history requirements.

Habitat use was based on results of baseline investigations and from the published literature. Effects on bank/shoreline stability were evaluated qualitatively, taking into account the effects identified in the Section 9.7, Effects to Water Quantity.

9.10.1.2.2 Changes to Lower Trophic Levels

Effects on lower trophic levels were assessed qualitatively, based on the anticipated changes in lake water levels and lake areas, and responses of invertebrates and plankton to similar changes, as described in the published literature.

9.10.1.3 Effects of Increased Nutrients on Fish and Fish Habitat

As discussed in the water quality assessment (Section 9.8), model results suggest that phosphorus concentrations in downstream systems may increase during the operation and post-closure periods. The predicted increases result from runoff waters within the Kennady Lake watershed coming into contact with the mine rock piles, Coarse PK Pile and the Fine PKC Facility. These waters then flow to downstream systems either through the WMP to Lake N11 during operations or through the refilled Kennady Lake once it is reconnected to Area 8 in the post-closure phase of the Project.

De Beers is currently evaluating a variety of environmental design features and mitigation measures to limit contact between site runoff waters and the fine PK located within the Fine PKC Facility and other potential sources. These environmental design features and mitigation measures include, for example:

- Promotion of permafrost development in the Fine PKC Facility
- Use of low permeability cover material to limit infiltration into key areas, such as the Fine PKC Facility.

The effectiveness of these environmental design features and mitigation measures is uncertain and requires further analysis. Accordingly, the amount of phosphorus that may be released into the environment is uncertain at this time. As a result, potential effects related to phosphorus have not been presented and will not be available until such time as additional analysis is completed. This analysis will be provided to the Panel in 2011.

When available, the analysis of potential effects related to predicted changes in nutrient levels will consider the following components of fish and fish habitat:

- lower trophic communities, including phytoplankton and benthic invertebrates;
- physical habitat, including the availability of spawning habitat and dissolved oxygen levels;
- fish abundance; and
- fish community structure.

9.10.2 Effects Analysis Methods – Closure and Post-Closure

9.10.2.1 Effects of Changes to the Flow Regime in Streams Downstream of Kennady Lake on Fish and Fish Habitat

Changes to fish habitat availability, fish habitat suitability, fish migrations and lower trophic levels due to alteration of the flow regime during closure were assessed using the same approach as described for the construction and operations assessment (Section 9.10.1).

9.10.2.2 Effects of Changes in Water Levels in Lakes Downstream of Kennady Lake to Fish and Fish Habitat

Effects to fish and fish habitat due to changes to water levels and lake areas during closure were assessed using the same approach as described for the construction and operations assessment (Section 9.10.1).

9.10.2.3 Effects of Increased Nutrients on Fish and Fish Habitat

As outlined in Section 9.10.1.3, the amount of phosphorus that may be released into the environment is uncertain at this time. As a result, potential effects related to phosphorus have not been presented and will not be available until such time as additional analysis is completed. This analysis will be provided to the Panel in 2011.

9.10.2.4 Effects of Changes in Aquatic Health on Fish and Fish Habitat

Fish populations and abundance can be affected by changes in water quality if they result in changes in aquatic health (i.e., fish and invertebrate health). Potential effects to aquatic health were evaluated in Section 9.9, Effects to Aquatic Health through 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. Potential effects related to direct exposure were evaluated based on modelled water quality in Lake N11 and Lake 410 during closure and post-closure (Section 9.9.2.1.1).

The results of the aquatic health assessment were then used to describe and assess changes that relate to fish and fish habitat (i.e., fish populations and communities). A discussion of the methods, models, and assumptions used in the Water Quality and Aquatic Health assessments can be found in Sections 9.8 and 9.9.

9.10.2.5 Long-term Effects to Fish and Fish Habitat Downstream of Kennady Lake

Long-term effects on fish and fish habitat were assessed qualitatively, based on the assessments of post-closure hydrology and water quality, and the spatial extent and magnitude of downstream effects to fish and fish habitat during mine operations. Factors influencing the recovery of fish populations to physical and chemical stressors were considered when assessing the long-term effects on fish populations downstream of Kennady Lake.

9.10.3 Effects Analysis Results – Construction and Operations

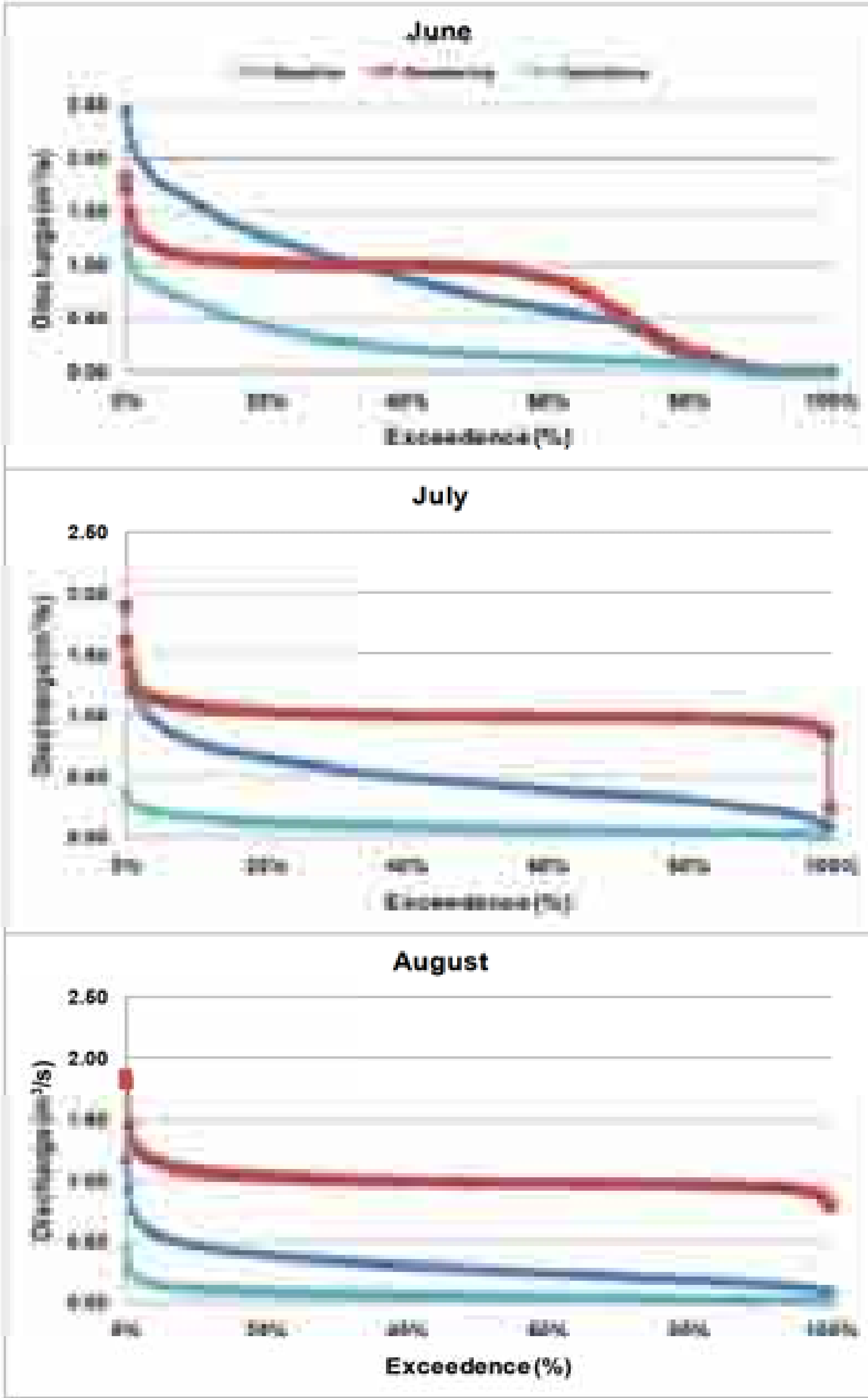
9.10.3.1 Effects of Changes to the Flow Regime in Streams Downstream of Kennady Lake on Fish and Fish Habitat

The flow regime in the N watershed and downstream of Kennady Lake to Lake 410 will be altered during construction and operations due to Project activities. The magnitude of the change is greater than the 15% threshold identified in Section 9.10.1, during at least a portion of the year. During construction, dewatering activities result in flow augmentation at all sites, and during operations, flow augmentation continues in the N watershed due to watershed diversions and continued pumping, whereas flow reductions occur downstream of Kennady Lake. A representative sample of monthly flow duration curves for June, July and August are presented for downstream locations within each watershed in Figures 9.10-1 to 9.10-8.

Downstream Extent of Effects

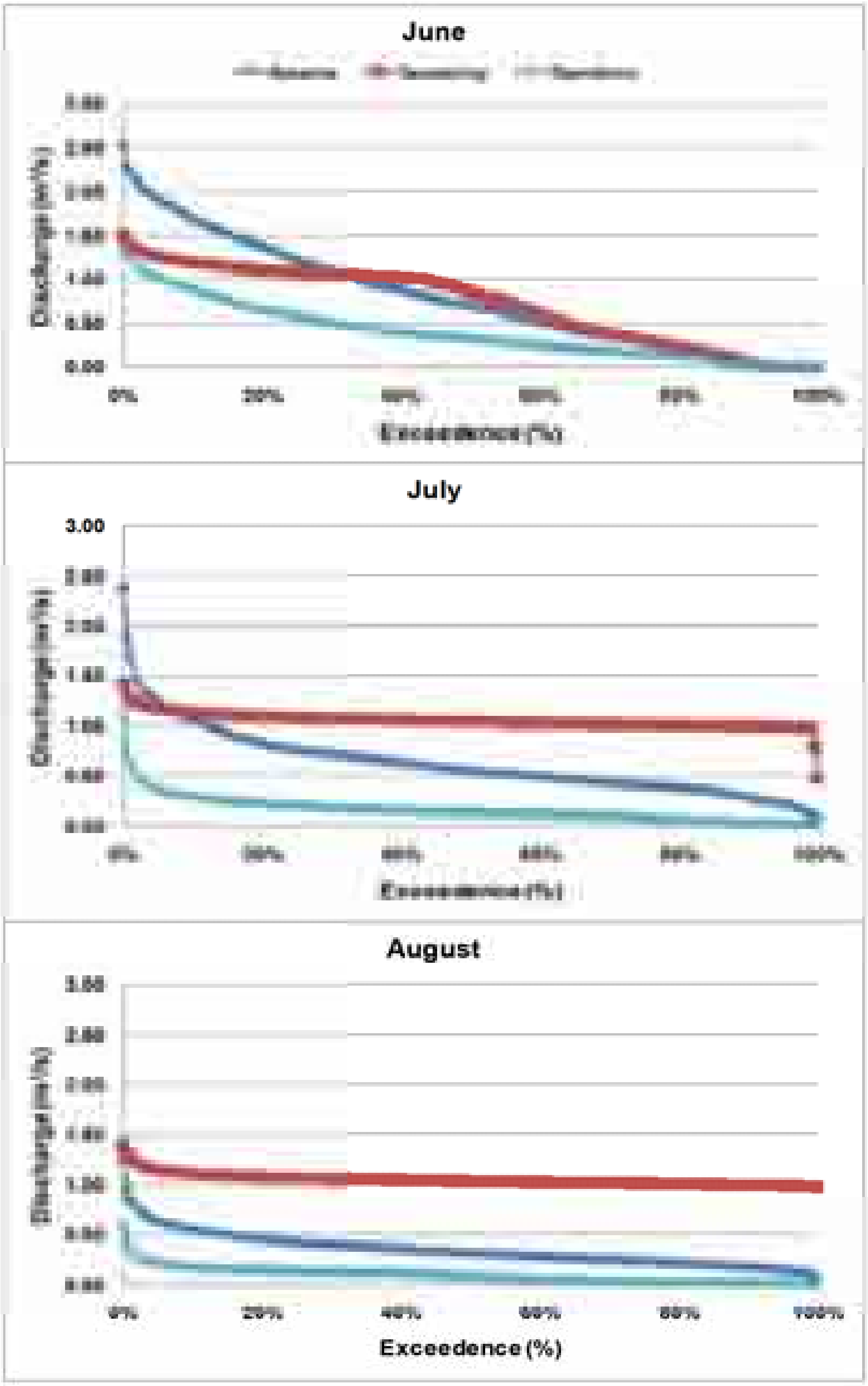
Changes to seasonal flow beyond a 15% change from baseline are predicted in the N, L and M watersheds during both construction and operations. At the Lake 410 outlet, peak flows are similar to baseline conditions during construction; however flow augmentation remains evident between July and September. During operations, flows at the outlet of Lake 410 return to conditions similar to baseline and were not assessed further.

Figure 9.10-1 Flow Duration Curves for June, July, and August at the Outlet of Kennady Lake under Baseline, Construction, and Operations



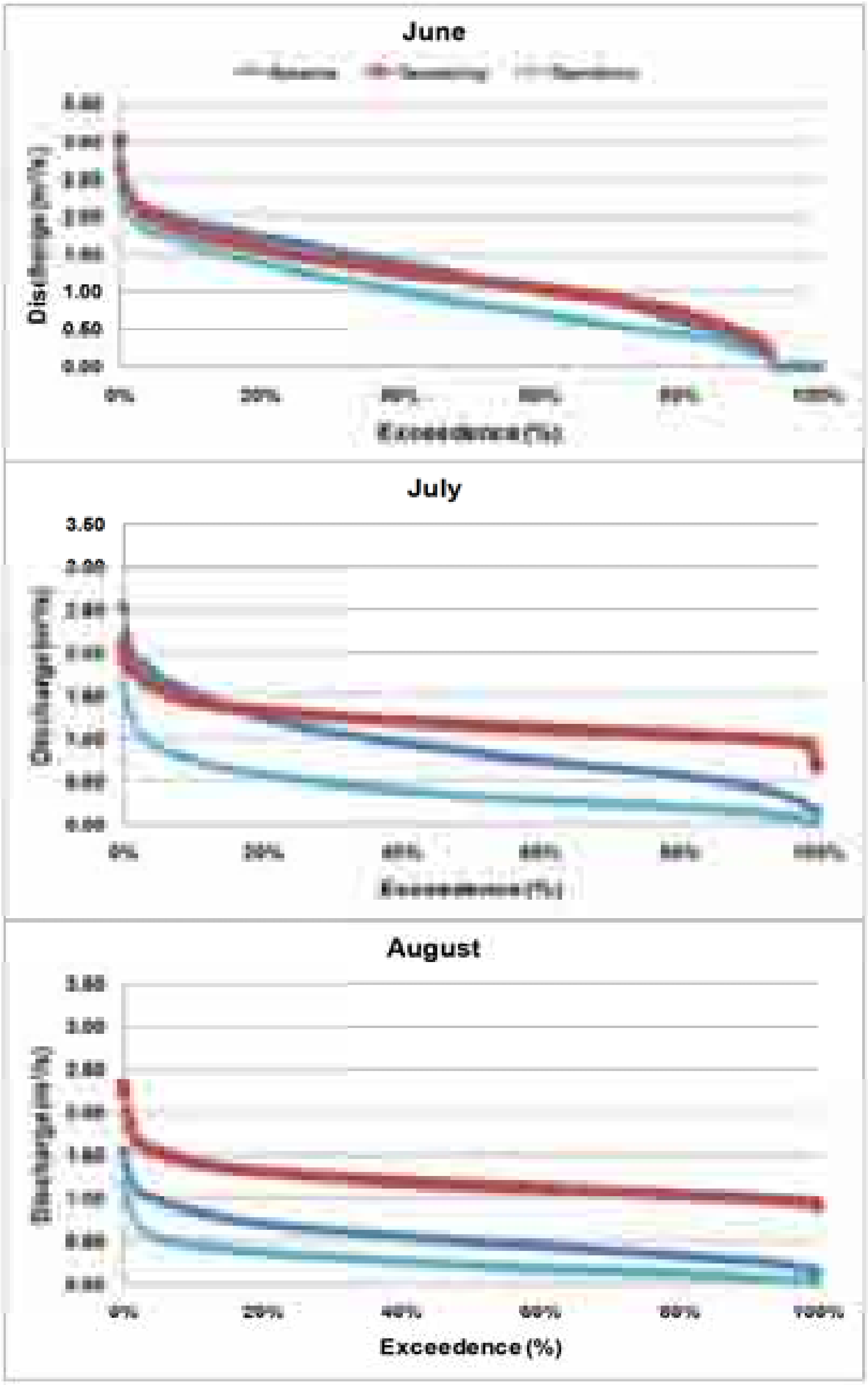
m^3/s = cubic metres per second; % = percent

Figure 9.10-2 Flow Duration Curves for June, July, and August at the Outlet of Lake L1a under Baseline, Construction, and Operations



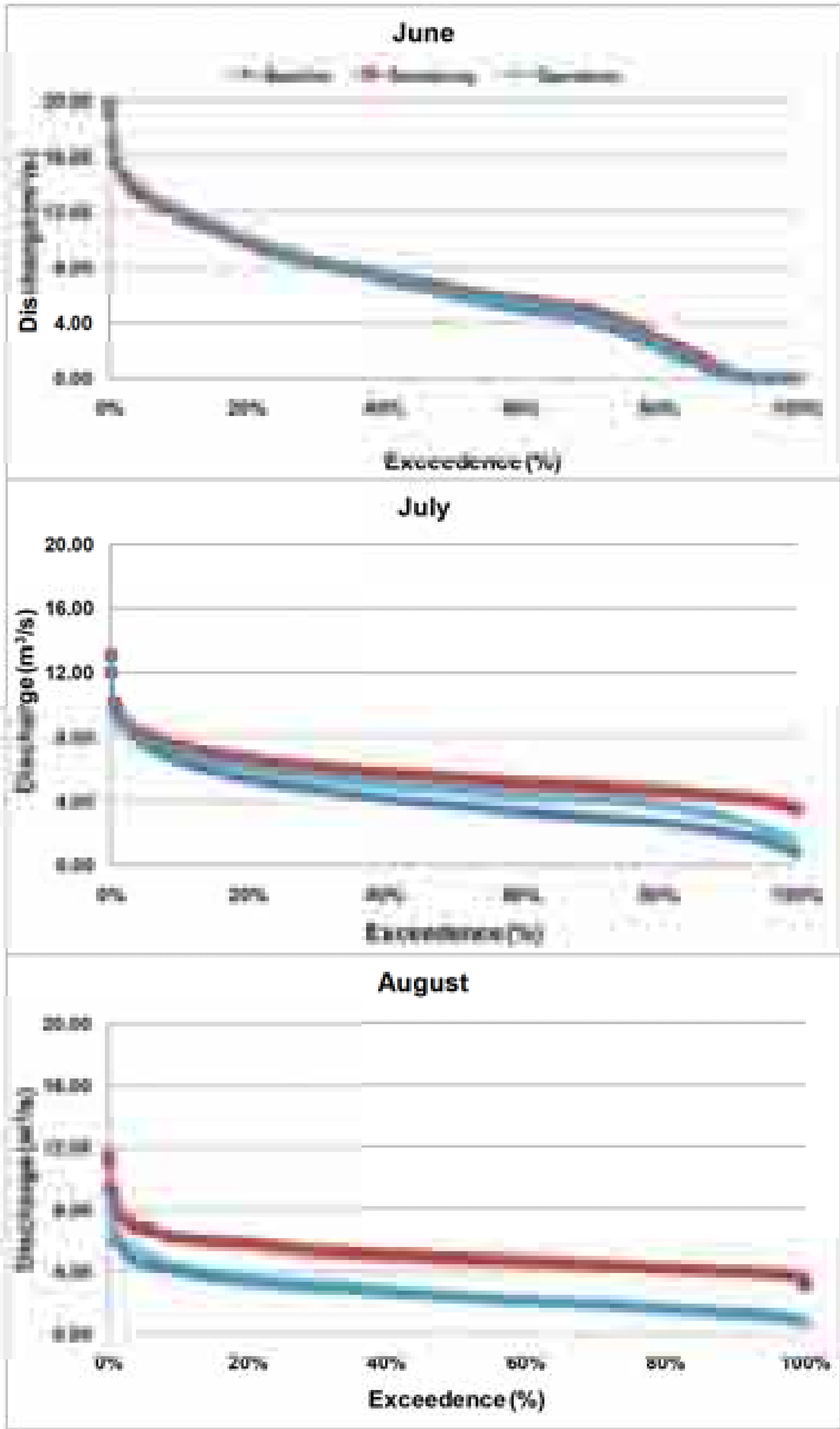
m^3/s = cubic metres per second; % = percent

Figure 9.10-3 Flow Duration Curves for June, July, and August at the Outlet of Lake M1 under Baseline, Construction, and Operations



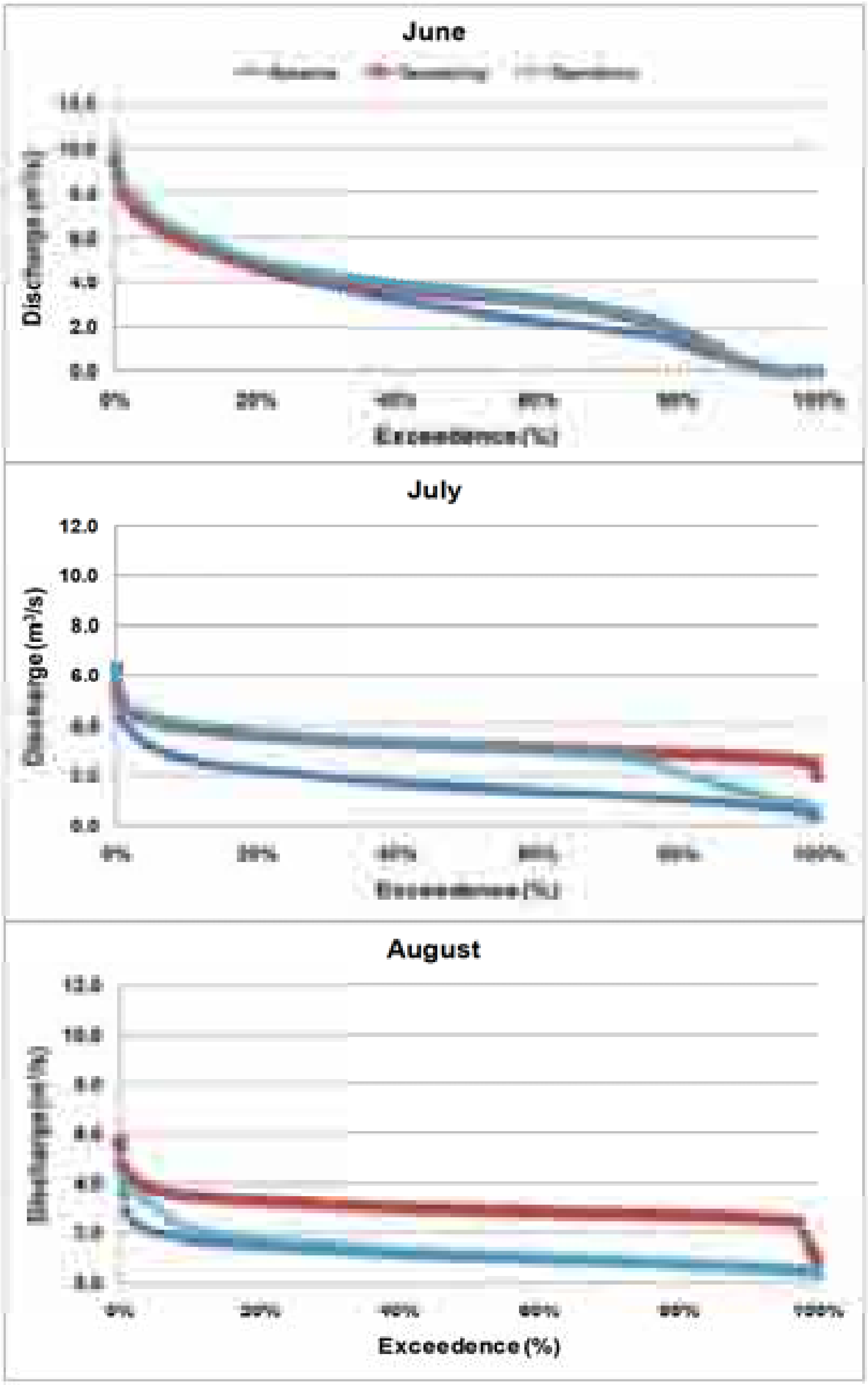
m^3/s = cubic metres per second; % = percent

Figure 9.10-4 Flow Duration Curves for June, July, and August at the Outlet of Lake 410 under Baseline, Construction, and Operations



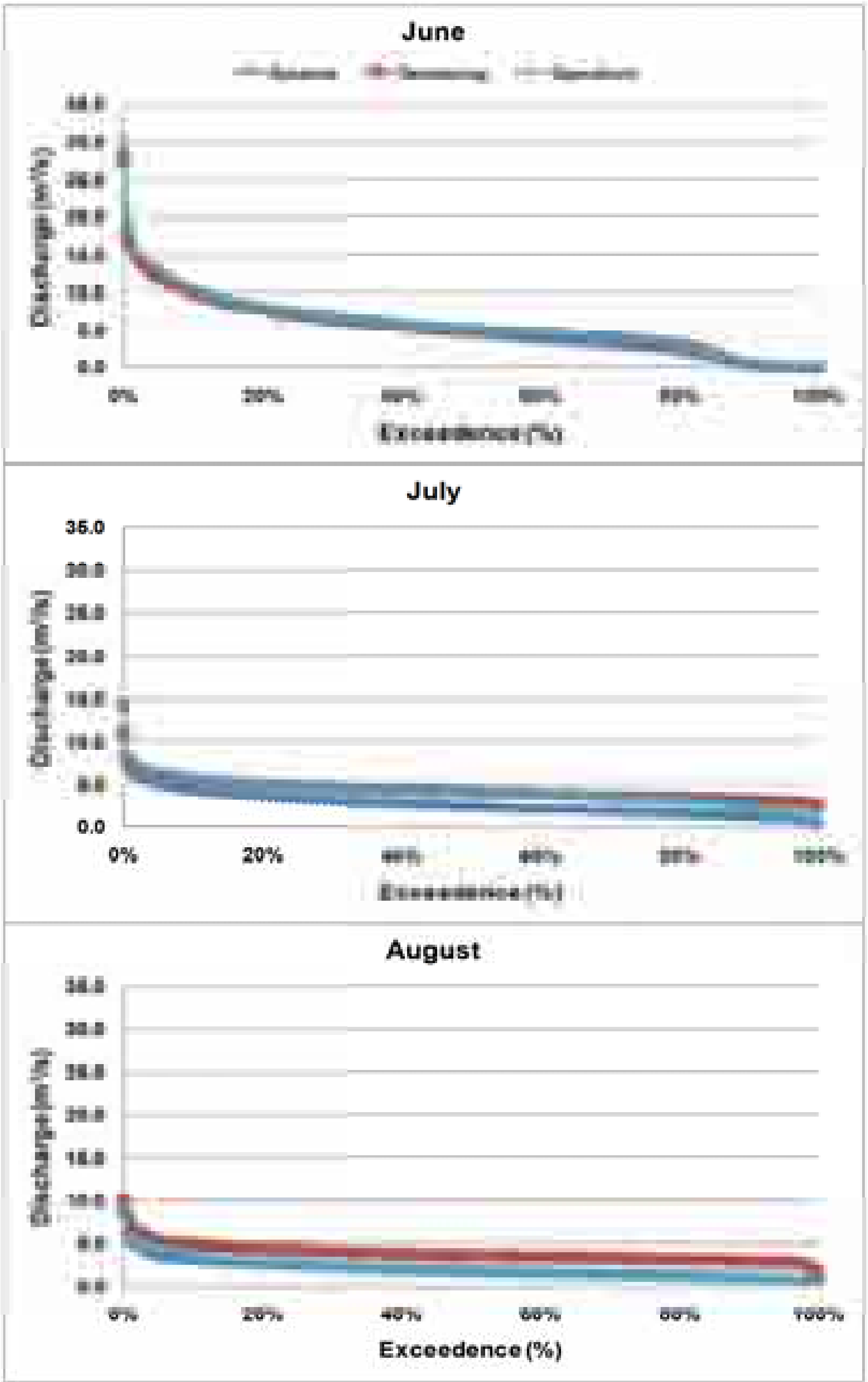
m^3/s = cubic metres per second; % = percent

Figure 9.10-5 Flow Duration Curves for June, July, and August at the Outlet of Lake N11 under Baseline, Construction, and Operations



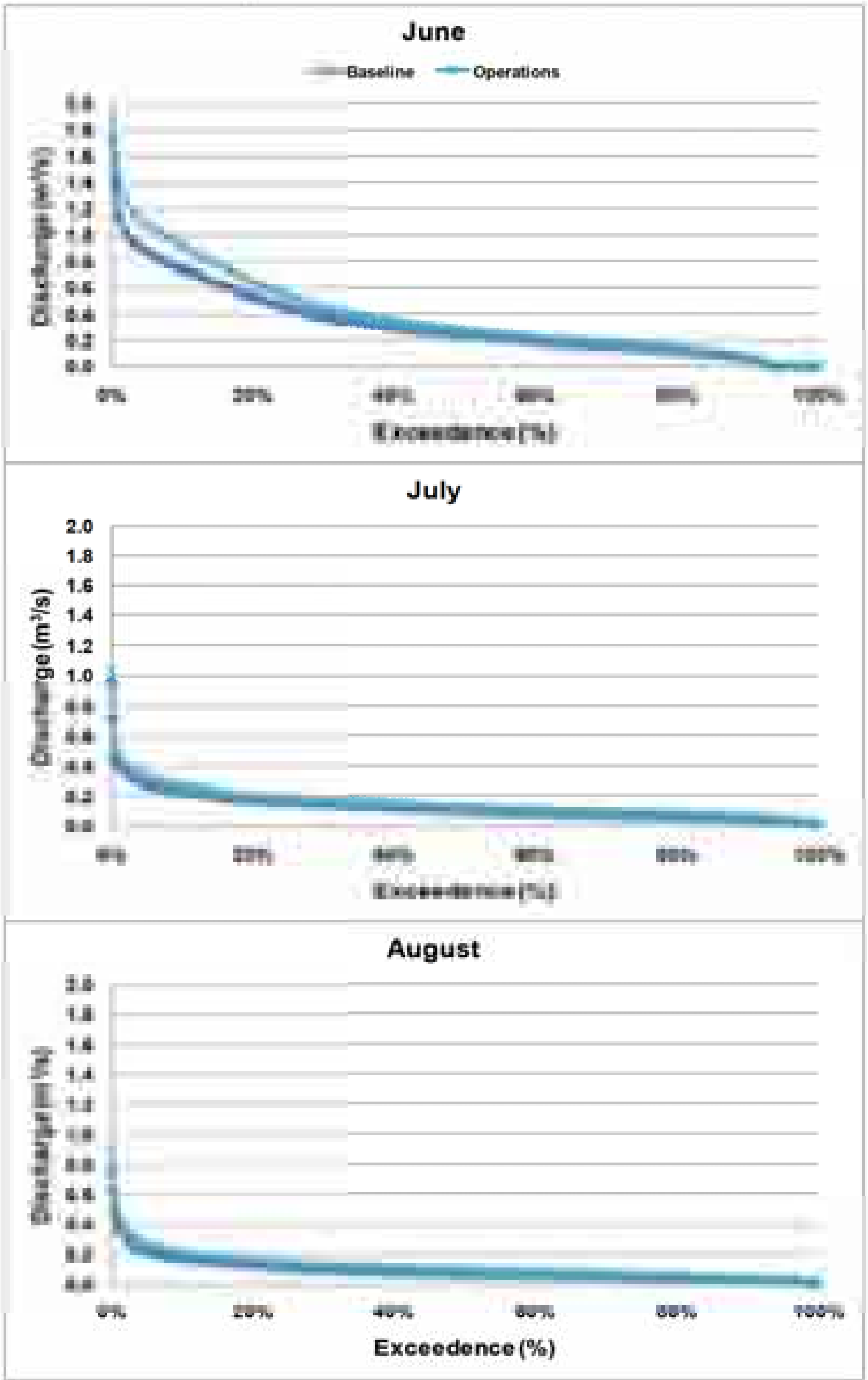
m³/s = cubic metres per second; % = percent

Figure 9.10-6 Flow Duration Curves for June, July, and August at the Outlet of Lake N1 under Baseline, Construction, and Operations



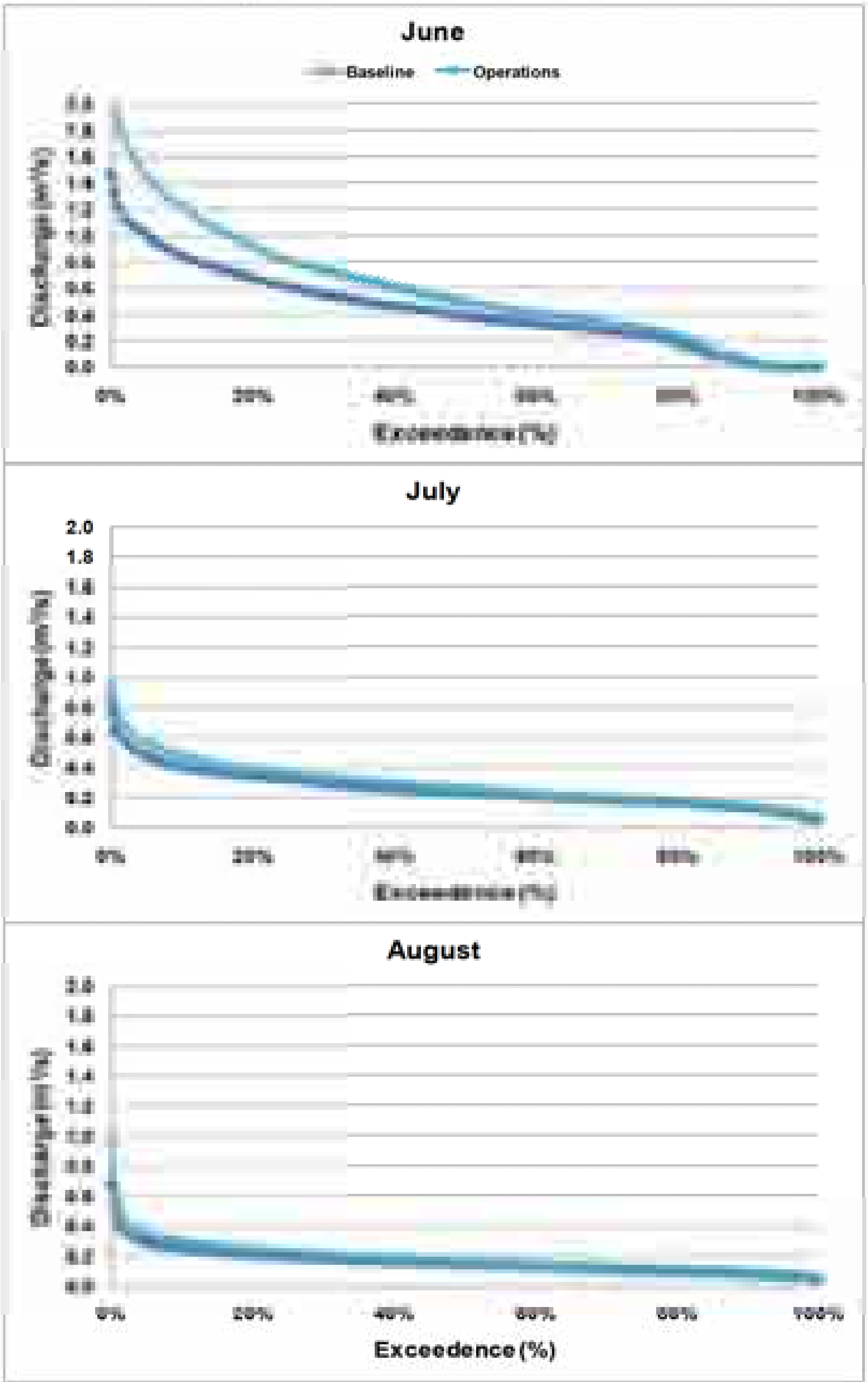
m^3/s = cubic metres per second; % = percent

Figure 9.10-7 Flow Duration Curves for June, July, and August at the Outlet of Lake N6 under Baseline and Operations



m^3/s = cubic metres per second; % = percent

Figure 9.10-8 Flow Duration Curves for June, July, and August at the Outlet of Lake N17 under Baseline and Operations



m^3/s = cubic metres per second; % = percent

9.10.3.1.1 Changes to Fish Habitat Availability - Construction

During the construction phase, dewatering of Kennady Lake will result in augmented flows in the N, L and M watersheds during the summer months. Augmented flows will result in an increase in the wetted area of each stream, and the area of potential available habitat would also increase and, therefore, is not considered a negative project effect. Increased peak flows can, however, result in an increase in channel erosion, and as a result, could alter the channel morphology and fish habitat area available. The start-up and shut-down of pumping can also result in the flushing or stranding of fish, respectively.

N Watershed

Dewatering of Kennady Lake will result in higher sustained flows between Lake N11 and Lake N1 during the summer months (Section 9.7.3.1.3). Flows will be managed such that the discharge at the outlet of Lake N1 during dewatering will approximate the 2-year flood discharge. To achieve this objective, most of the pumping for dewatering will occur after the peak of the spring freshet has occurred, and as a result, peak discharges will remain similar to baseline conditions. Based on the proposed environmental design features, no changes to fish habitat due to changes in the channel morphology are predicted.

Pumping will begin as the peak flows in the spring begin to recede, and as a result, there will not be a drastic change in flow condition during pumping start-up (i.e., ramping up from a low baseflow to a peak flow will not occur) that would result in a sudden change in habitat conditions that could flush fish downstream. In addition to the timing mitigation used for pumping, all of the pumping will be discharged into lakes within the N watershed, which will act to further attenuate any sudden changes in stream discharge downstream of Lake N11 and minimize flushing potential. Similarly, when pumping is stopped at the end of each season, lake levels will recede gradually, attenuating sudden and rapid declines in stream discharge. By fall, Arctic grayling YOY are capable swimmers and are beginning to move to overwintering habitat in adjacent lakes. It is anticipated that the gradual decline in flow at the end of pumping each season will trigger a response for fish to move out of declining habitat areas and into their overwintering habitats. As a result of environmental design features considered in the pumping plan and the natural attenuation of rapid changes in stream discharge provided by the lakes in the watershed, the risk of flushing or stranding fish during the start-up and shut-down of pumping will be negligible.

L and M Watersheds

The drainage system downstream of Kennady Lake from its outlet at Area 8 to Lake 410 consists of a sequence of lakes with relatively short connecting channels. The sequence consists of the following eight lakes in the L and M watersheds (Addendum HH, Additional Climate and Hydrology Baseline Information):

(Area 8)→Lake L3→Lake L2→Lake L1b→Lake L1a→
Lake M4→Lake M3→Lake M2→Lake M1→ (Lake 410)

Dewatering of Kennady Lake will result in higher sustained flows during the summer months. Discharge directed downstream of Area 8 will be restricted to the 2-year flood level and no changes to channel morphology are predicted. As a result, this was considered a minor pathway and no changes to fish habitat due to changes in the channel morphology are predicted (Section 9.7.3.1.2).

The same environmental design features and natural lake attenuation during the start-up and shut-down of pumping activities as described for the N watershed would also apply to the streams downstream of Kennady Lake. Water will be directed to Area 8 during dewatering, providing the initial attenuation of flow for Stream K5, and each subsequent downstream lake providing additional attenuation of flow. As a result of environmental design features considered in the pumping plan and the natural attenuation of rapid changes in stream discharge provided by the lakes in the watershed, the risk of flushing or stranding fish during the start-up and shut-down of pumping will be negligible.

9.10.3.1.2 Changes to Fish Habitat Suitability - Construction

Augmented flows during dewatering may alter the suitability of habitat that is available to fish during the open-water season, primarily through changes to the depth and velocity characteristics within the streams. The natural hydrograph in the N watershed and downstream of Kennady Lake typically includes a spring freshet that peaks in June, gradually receding over July to a summer baseflow by the beginning of August. Therefore, although the total volume of water pumped downstream will be restricted, discharges in streams in the N watershed and downstream of Kennady Lake will not recede over the summer and instead, high spring discharges will be sustained from June to October.

High flows are necessary in the spring to allow for adult Arctic grayling to move from their overwintering habitat in lakes into adjacent streams to spawn. Since augmented flows will be managed to remain similar to 2-year flood flows within all of the streams in the N watershed and downstream of Kennady Lake, changes to habitat suitability for migration and spawning are not predicted during dewatering as the habitat available would be within the range of naturally occurring conditions (Figures 9.10-1 through 9.10-6).

Although spring flows are predicted to be similar to baseline conditions, higher sustained flows in summer have the potential to negatively affect Arctic grayling, particularly YOY fish that use the streams to feed prior to moving to the lakes to overwinter. Clark (1992) found that annual recruitment of Arctic grayling in the Chena River, Alaska, was negatively correlated to spring discharge (i.e., poor year-classes coincided with years of high average flow and strong year-classes coincided with years of low average flow). While the mechanisms for the influence of stream flows on recruitment were largely unknown, it is possible that high stream flows disrupted the bottom sediments, dislodged eggs, or flushed newly hatched larvae downstream into areas of low food abundance (Clark 1992). Although spring flows are not predicted to increase, the augmented flows during July and August (Figures 9.10-1 through 9.10-6) fall largely outside the range of naturally occurring flows during this time of the year and would potentially result in conditions for which YOY Arctic grayling are not naturally adapted.

An increase in channel velocity may result from augmented flows, causing either flushing of YOY Arctic grayling downstream, or potentially reducing their growth and fitness while maintaining their position in the stream channel during their first growing season. To avoid being flushed downstream, small YOY Arctic grayling use marginal habitats along the banks with water velocities typically less than 0.05 m/s (Jones et al. 2003a; Jones and Tonn 2004).

N Watershed

Arctic Grayling Spawning

Spring (June) discharges in Stream N11 will remain similar to baseline conditions, and as a result, the average channel velocities during dewatering are very similar to baseline conditions. In some instances, an increase in flow does not result in an increase in average velocity since the channel becomes wider and slightly deeper at the higher flows without resulting in a substantial change in average velocity. A more detailed description of the modelling results is provided in Section 9.7.

Average June water velocities in Stream N11 typically fall within or slightly above the optimal range of 0.3 m/s to 0.8 m/s under natural conditions, but well below the upper limit of 1.5 m/s for Arctic grayling spawning (Stewart et al. 2007). Average June water velocities in Stream N11 during dewatering will be similar to baseline in wet years, but substantively higher in dry years, but still within the range of preferred water velocities for Arctic grayling spawning (Table 9.10-4). As a result, the effect of dewatering on spawning Arctic grayling in Stream N11 is expected to be negligible.

Table 9.10-4 Comparison of Average June Water Velocities in Streams N1 and N11 between Baseline and Kennady Lake Dewatering Phase

Condition	Return Period	Average Velocity (m/s)			
		Stream N1		Stream N11	
		Baseline	Dewatering	Baseline	Dewatering
Wet	100	0.86	0.87	0.93	0.96
	50	0.84	0.84	0.91	0.93
	20	0.81	0.81	0.88	0.89
	10	0.78	0.78	0.85	0.85
	5	0.74	0.74	0.80	0.80
Median	2	0.66	0.66	0.71	0.70
Dry	5	0.57	0.57	0.57	0.59
	10	0.51	0.52	0.48	0.53
	20	0.46	0.47	0.40	0.48
	50	0.38	0.41	0.26	0.41
	100	0.31	0.35	0.12	0.37

m/s = metres per second.

June discharge in Stream N1 during dewatering will be similar to baseline conditions. This is because the volume of water diverted will be restricted during dewatering so that the total discharge at Stream N1 does not exceed the maximum daily discharge in a 1:2 year return period flood. Average June water velocities in Stream N1 typically fall within or slightly above the optimal range under natural conditions. Average June water velocities in Stream N1 during dewatering will be similar to baseline in wet years and only marginally higher in dry years but still well within the range of preferred water velocities for Arctic grayling spawning (Table 9.10-4). As a result, the effect of dewatering on spawning Arctic grayling in Stream N1 is expected to be negligible.

Arctic Grayling Rearing

Spring discharge levels will be sustained in Streams N11 and N1 over the duration of the summer months during dewatering. These higher summer discharges have the potential to affect any YOY Arctic grayling rearing in these streams in July and August, which is the primary growth season prior to downstream movements to overwintering habitats in adjacent lakes. Arctic grayling YOY have a preference for velocities less than 0.25 m/s, with an upper suitability limit of 0.8 m/s (Stewart et al. 2007). The sustained swimming speed of small YOY Arctic grayling that would be present in July is 0.15 m/s, and 0.25 m/s for larger YOY that would be present in August (Deegan et al. 2005).

Higher summer discharges in Streams N11 and N1 are expected to have a minor effect on any YOY Arctic grayling rearing in these streams. Few YOY Arctic grayling have been captured in Stream N1 and none have been captured in Stream N11. The paucity of YOY Arctic grayling may be partially due to high average summer water velocities above those preferred by YOY Arctic grayling under natural conditions, particularly in July when Arctic grayling are emerging and have relatively poorer swimming ability. The distribution of velocities found from microhabitat field measurements during the spring of 2005 found very little slow water habitat (i.e., less than 0.1 m/s) in Streams N1 and N11, representing approximately 6% of the available habitat at each site (Appendix 9.II). Velocity shelter would likely be available along the stream margins associated with large boulders, which are abundant at each site, but likely not widespread throughout the channel.

It would appear that Streams N1 and N11 provide marginal rearing habitat under baseline conditions. The higher summer discharges in Streams N11 and N1 from dewatering would result in an increase in average velocity, particularly during dry years; however the average velocity remains below the upper velocity limit of 0.8 m/s and largely within the natural range of variability (Table 9.10-5). Based on the low availability of suitable low velocity habitat under baseline conditions, it is expected that most of the suitable habitat under the dewatering condition would be associated with velocity refugia behind boulders along the stream margins, similar to baseline conditions. The availability of this microhabitat in both Stream N1 and Stream N11 will be unchanged during dewatering, and therefore the effect of dewatering on Arctic grayling YOY is considered negligible.

Table 9.10-5 Comparison of Average July Water Velocities in Streams N1 and N11 between Baseline and Kennady Lake Dewatering Phase

Condition	Return Period	Average Velocity (m/s)			
		Stream N1		Stream N11	
		Baseline	Dewatering	Baseline	Dewatering
Wet	100	0.59	0.64	0.67	0.72
	50	0.57	0.62	0.64	0.70
	20	0.54	0.59	0.59	0.66
	10	0.52	0.56	0.55	0.63
	5	0.49	0.54	0.50	0.60
Median	2	0.43	0.49	0.42	0.55
Dry	5	0.38	0.45	0.35	0.52
	10	0.35	0.43	0.31	0.50
	20	0.33	0.42	0.28	0.49
	50	0.30	0.41	0.24	0.48
	100	0.29	0.40	0.22	0.47

m/s = metres per second

L and M Watersheds

Arctic grayling Spawning

Spring (June) discharge downstream of Kennady Lake during dewatering will be similar to the natural spring freshet. As a result, the predicted average water velocities under all hydrologic conditions are predicted to be similar, with slight increases during dry periods (Table 9.10-6). Almost all of the average velocities at each site, under both baseline and dewatering conditions, are lower than the preferred range for spawning (0.3 m/s to 0.8 m/s), but are within the range considered as suitable spawning habitat (Stewart et al. 2007). Arctic grayling in these downstream lakes are likely to continue spawning successfully in streams downstream of Kennady Lake during dewatering, and as a result, the effect of dewatering on spawning Arctic grayling in streams downstream of Kennady Lake is expected to be negligible.

Table 9.10-6 Comparison of Average June Water Velocities in Streams in the L and M Watersheds between Baseline and Kennady Lake Dewatering Phase

Stream	Phase	Average Velocity (m/s) by Return Period for June						
		1:100 Wet	1:50 Wet	1:10 Wet	1:2 Median	1:10 Dry	1:50 Dry	1:100 Dry
K5	Baseline	0.23	0.23	0.22	0.20	0.21	0.19	0.18
	Dewatering	0.22	0.21	0.20	0.19	0.18	0.18	0.18
L3	Baseline	0.19	0.18	0.18	0.16	0.13	0.12	0.16
	Dewatering	0.16	0.16	0.15	0.14	0.14	0.14	0.14
L2	Baseline	0.25	0.25	0.24	0.22	0.21	0.18	0.17
	Dewatering	0.22	0.22	0.23	0.22	0.21	0.21	0.21
L1	Baseline	0.20	0.20	0.19	0.18	0.14	0.13	0.13
	Dewatering	0.18	0.18	0.17	0.16	0.15	0.15	0.15
M4	Baseline	0.15	0.15	0.14	0.13	0.11	0.10	0.10
	Dewatering	0.14	0.14	0.13	0.12	0.12	0.12	0.11
M3	Baseline	0.13	0.13	0.12	0.11	0.09	0.08	0.08
	Dewatering	0.13	0.13	0.12	0.11	0.10	0.09	0.09
M2	Baseline	0.33	0.32	0.31	0.29	0.28	0.27	0.27
	Dewatering	0.33	0.32	0.30	0.30	0.29	0.29	0.28
M1	Baseline	0.23	0.22	0.21	0.20	0.19	0.20	0.19
	Dewatering	0.23	0.23	0.22	0.20	0.19	0.19	0.19

m/s = metres per second.

Arctic grayling Rearing

Young-of-the-year (YOY) Arctic grayling have been documented to rear in the streams between Kennady Lake and Lake 410 during the summer months before moving upstream or downstream to overwintering habitat in lakes. Average water velocities at all sites except Stream M2 fall within the optimal range for Arctic grayling YOY (0.0 m/s to 0.25 m/s), with Stream M2 just slightly higher than the upper bound of the optimal range (Table 9.10-7). Increases in average water velocities in July are relatively small during dewatering in comparison to average water velocities that occur under baseline conditions. This is due largely to the geometry and morphology of streams downstream of Kennady Lake. Streams downstream of Kennady Lake have low banks, shallow gradients, and large angular boulder substrates. As a result, increases in discharge result in large increases to wetted width as water spills across the floodplain, with small changes in depth and velocity. Although the average water velocities in July are at, and slightly above, the prolonged swimming ability of small YOY (0.15 m/s), the availability of slow (i.e., less than 0.1 m/s) microhabitat areas are abundant, representing more than 50% of the available habitat even during the spring freshet (Figure 9.10-9).

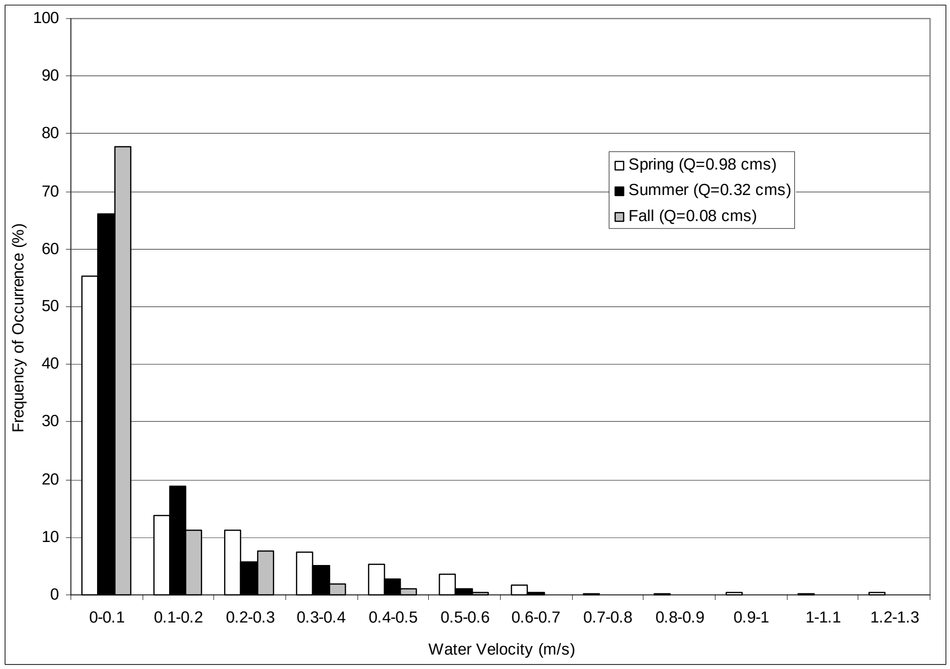
Large boulder substrates dominate the channel and bank substrates in these streams, representing almost 50% of the area (Figure 9.10-10). The large boulders provide an abundance of velocity refugia for small YOY Arctic grayling, similar to what currently exists under baseline flow conditions. Young-of-the-year fish are most susceptible to downstream displacement when smallest (Harvey 1987). To avoid adverse flows, small YOY Arctic grayling use marginal habitats along the banks with water velocities below 0.05 m/s (Jones et al. 2003a; Jones and Tonn 2004).

Table 9.10-7 Comparison of Average July Water Velocities in Streams in the L and M Watersheds between Baseline and Kennady Lake Dewatering Phase

Stream	Phase	Average Velocity (m/s) by Return Period for July						
		1:100 Wet	1:50 Wet	1:10 Wet	1:2 Median	1:10 Dry	1:50 Dry	1:100 Dry
K5	Baseline	0.20	0.19	0.18	0.21	0.20	0.18	0.18
	Dewatering	0.21	0.21	0.20	0.18	0.18	0.18	0.18
L3	Baseline	0.16	0.16	0.15	0.12	0.16	0.16	0.16
	Dewatering	0.16	0.15	0.15	0.14	0.14	0.14	0.14
L2	Baseline	0.23	0.22	0.22	0.21	0.19	0.16	0.16
	Dewatering	0.21	0.23	0.22	0.21	0.21	0.21	0.21
L1	Baseline	0.19	0.19	0.18	0.15	0.12	0.13	0.12
	Dewatering	0.17	0.17	0.16	0.16	0.15	0.15	0.15
M4	Baseline	0.15	0.14	0.14	0.12	0.11	0.10	0.10
	Dewatering	0.14	0.13	0.13	0.12	0.12	0.12	0.12
M3	Baseline	0.13	0.12	0.11	0.10	0.08	0.07	0.07
	Dewatering	0.12	0.12	0.11	0.10	0.10	0.10	0.09
M2	Baseline	0.32	0.31	0.29	0.29	0.28	0.26	0.26
	Dewatering	0.30	0.30	0.30	0.29	0.29	0.29	0.29
M1	Baseline	0.22	0.22	0.20	0.19	0.19	0.18	0.18
	Dewatering	0.21	0.21	0.20	0.19	0.19	0.19	0.19

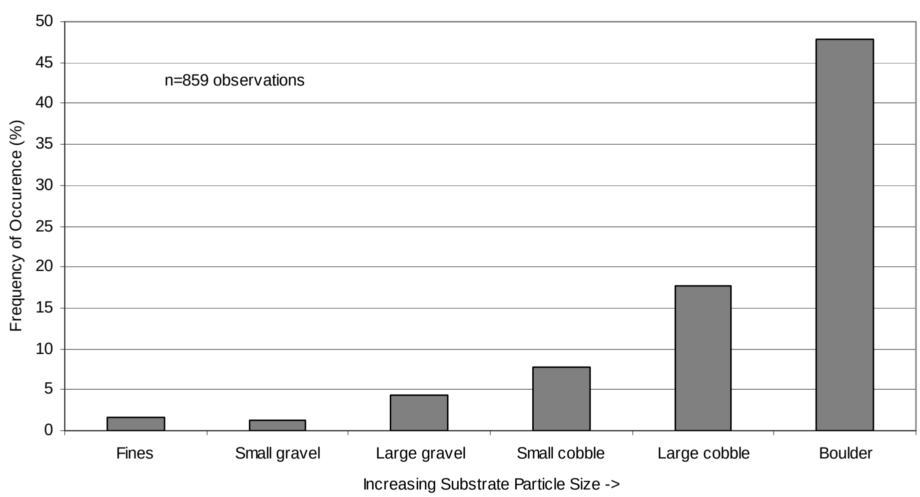
m/s = metres per second.

Figure 9.10-9 Frequency Distribution of Water Velocities Measured in Streams K5 to M1 between Kennady Lake and Lake 410 in Spring, Summer, and Fall 2005



cms = cubic metres per second; m/s = metres per second, % = percent.

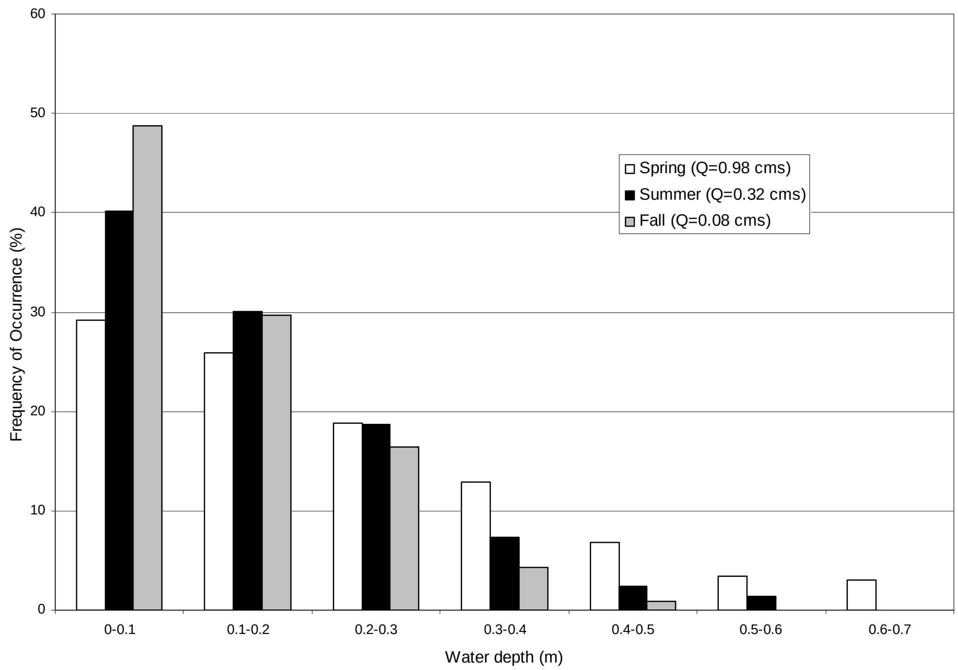
Figure 9.10-10 Substrate Size Frequency Distribution in Streams between Kennady Lake and Lake 410



% = percent.

Arctic grayling also tend to prefer shallow water, with a depth preference of less than 0.3 m (Stewart et al. 2007). Even during the spring freshet, the distribution of shallow water habitat in the streams downstream of Kennady Lake still represents about 75% of the available habitat (Figure 9.10-11). An increase in stream depth during Kennady Lake dewatering in July and August is not expected to result in any change in habitat suitability for Arctic grayling YOY.

Figure 9.10-11 Frequency Distribution of Water Depths Available in Streams between Kennady Lake and Lake 410 in Spring, Summer, and Late Summer 2005



cms = cubic metres per second; % = percent; m = metres.

The discharge in August under dewatering is very similar to the dewatering flow regime in July, and as a result, the average velocities in August are almost identical to the velocities in July (Table 9.10-8). By August, the larger YOY move to deeper faster habitats and use velocity refugia associated with pools or created by boulders along the thalweg, and they feed opportunistically on drifting organisms (Jones et al. 2003b). Given that Arctic grayling become better swimmers by August due to their increase in size, the effects of flow augmentation are expected to be less in August compared to July, when they would be most sensitive to flow augmentation. Given the small increases in average water velocities during dewatering and given the availability of suitable low velocity habitat for small YOY Arctic grayling behind boulders and along stream margins is expected to remain abundant, the effect of dewatering on Arctic grayling YOY in streams downstream of Kennady Lake is expected to be negligible.

Table 9.10-8 Comparison of Average August Water Velocities in Streams in the L and M Watersheds between Baseline and Operations

Stream	Phase	Average Velocity (m/s) by Return Period for August						
		1:100 Wet	1:50 Wet	1:10 Wet	1:2 Median	1:10 Dry	1:50 Dry	1:100 Dry
K5	Baseline	0.18	0.18	0.22	0.19	0.17	0.16	0.16
	Dewatering	0.22	0.21	0.20	0.19	0.18	0.18	0.18
L3	Baseline	0.14	0.14	0.13	0.14	0.16	0.16	0.15
	Dewatering	0.16	0.16	0.15	0.15	0.14	0.14	0.14
L2	Baseline	0.22	0.21	0.20	0.18	0.16	0.15	0.14
	Dewatering	0.21	0.22	0.22	0.21	0.21	0.21	0.21
L1	Baseline	0.16	0.15	0.14	0.13	0.12	0.12	0.12
	Dewatering	0.17	0.17	0.16	0.16	0.15	0.15	0.15
M4	Baseline	0.13	0.12	0.11	0.10	0.10	0.09	0.09
	Dewatering	0.14	0.14	0.13	0.12	0.12	0.12	0.12
M3	Baseline	0.11	0.10	0.09	0.08	0.07	0.06	0.06
	Dewatering	0.12	0.12	0.11	0.10	0.10	0.09	0.09
M2	Baseline	0.30	0.30	0.28	0.27	0.26	0.25	0.24
	Dewatering	0.31	0.30	0.29	0.29	0.29	0.29	0.29
M1	Baseline	0.20	0.19	0.19	0.20	0.18	0.17	0.17
	Dewatering	0.22	0.21	0.20	0.19	0.19	0.19	0.19

m/s = metres per second.

9.10.3.1.3 Changes to Fish Migrations - Construction

N Watershed

Stream N11 includes a series of large (greater than 1 m) boulder/bedrock cascades in the middle of its length. In an average year, it is anticipated that these cascades are passable by fish moving upstream only during the spring freshet when water levels are high enough to reduce the vertical drop necessary for fish to pass upstream. By mid-July, these cascades become impassable to most fish moving upstream as flows recede and vertical barriers form (i.e., a barrier to fish passage is more likely to occur due to vertical drops during low flows than due to high water velocities during high flows).

Higher summer flows may increase the window of opportunity for fish to pass upstream from Lake N1 to Lake N11. Sustaining flows in Stream N11 near the natural 1:2 year discharge during the summer is likely to lengthen the duration these cascades are passable to fish and thereby increase the opportunity for fish to pass upstream from Lake N1 to Lake N11.

The fish most likely to take advantage of this opportunity are adults of large-bodied species that migrate into streams for some part of their life history and have high enough burst swimming speed capacities to pass through the cascade features. Arctic grayling, longnose sucker (*Catostomus catostomus*), and lake trout have all been captured moving upstream and downstream through streams in the N watershed during the spring (Section 9.3.5.2.4). It could be expected that these species would potentially expand the duration of their movements between lakes in the N watershed to throughout the summer.

L and M Watersheds

Barriers in streams between Kennady Lake and Lake 410 appear to form as a result of low flows creating unsuitable depths for fish movements, rather than due to high flows creating velocity barriers. Spring stream flows during Kennady Lake dewatering are also predicted to be similar to baseline conditions, with increased flows during dry periods when barriers would tend to form naturally. As a result, dewatering will not result in an increase in barriers to fish migration in the L and M watersheds and is likely to improve accessibility for spawning during dry years.

9.10.3.1.4 Changes to Lower Trophic Levels - Construction

Invertebrate drift is influenced by a large number of factors, including current velocity, substrate type, photoperiod, water quality, benthic density, presence of predators, life-cycle stage, and others (Resh and Rosenberg 1984; Brittain and Eikeland 1988; Svendsen et al. 2004). Stream discharge and associated changes in water velocity are two of the most important physical factors influencing invertebrate drift (Brittain and Eikeland 1988; Svendsen et al. 2004). An increase in discharge generally leads to increased drift, especially during or after sudden changes in flows. Increased drift may result from the scouring effect of higher water velocity, or possibly other factors.

Although summer flows will increase during dewatering of Areas 2 through 7 of Kennady Lake, the density and species composition of benthic invertebrate communities and invertebrate drift are not expected to change as a result of higher summer flows in Stream K5, and streams in the L, M, and N watersheds downstream of Kennady Lake for the following reasons:

- Pumping activities during dewatering will be timed to start as the peak flows in the spring begin to recede and all of the pumping will be discharged into lakes, which will act to attenuate any sudden changes in downstream discharge, and as a result, there will not be a drastic change in flow condition during pumping start-up that might initiate additional scour.
- Projected changes in mean current velocity are small (i.e., less than or equal to 0.03 m/s in Stream K5 and streams in the L and M watersheds, and typically less than 0.2 m/s in N watershed streams; Tables 9.10-6, though 9.10-8), because it is expected that stream wetted width will

increase to accommodate the increased flows. These changes are within the expected range of natural variation in the affected streams.

- Low velocity microhabitat will continue to be abundant even at the higher summer discharges during the dewatering process.
- Other factors typically found to affect invertebrate drift are unlikely to change to an extent that would negatively influence drift.

9.10.3.1.5 Changes to Fish Habitat Availability – Operations

During operations, flows continue to be diverted to the N watershed, resulting in continued augmented summer flows, although to a lesser extent than during dewatering. Additional flow augmentation occurs due to the diversion of watersheds A, B, D and E. The diversion of the A and B watersheds results in augmented flows through a series of lakes draining to N1, with the largest change in flows occurring at the outlet of Lake N6. The diversion of the D and E watersheds results in flow augmentation through a series of lakes draining to N11, with the largest change in flows occurring at the outlet of Lake N17.

Flows in the L and M watershed become substantially reduced during operations, as the Kennady Lake watershed is isolated and diverted north through the N watershed. The reduction in flow will result in a loss of wetted area within the streams of the L and M watersheds and a direct loss in available habitat area.

N Watershed

Flows in the N watershed between the Lake N11 outlet and the Lake N1 outlet during operations are similar to the dewatering phase of the project for June and July due to diversions of the A, B, D, and E watersheds directed to the N watershed. During operations, flows return to conditions similar to baseline in August and for the remainder of the open-water season as the contribution to summer flow from the diverted watersheds is small. As a result, the conclusions made for the dewatering phase for Stream N11 and Stream N1 hold true for the operations phase as well, with no changes predicted to channel morphology and an increase to wetted area during the spring. Flow augmentation into Lake N6 results in only slight increases in outlet flows above the baseline peak flows (Section 9.7.3.2.3), and changes to the channel due to erosion are not predicted. Larger increases in peak flows are predicted at the outlet of Lake N17 (Section 9.7.3.2.3); however, mitigation measures will be put in place, if required, to prevent channel erosion.

As the primary pathway for flow augmentation during operations is through the diversion of the A, B, D and E watersheds, the ramp-up and ramp-down rate will follow a pattern similar to the natural hydrograph during the spring freshet. When pumping from the WMP to Lake N11 does occur, similar mitigations on ramp-up and ramp-down rates as applied during dewatering would be used to minimize the risk of flushing fish downstream or stranding fish. As a result, effects to fish and fish habitat in the N watershed are considered to be negligible during operations.

L and M Watersheds

Flow reductions in the L and M watersheds during operations will result in a reduction of the area of available habitat (Table 9.10-9). Changes in the wetted width of the channel from baseline to operations vary by stream, but can be as much as 86% reduction from baseline. Reduction in wetted width is observed at both high and low flows and during all seasons at most sites. The change from baseline generally declines moving downstream, with the largest changes found in Streams K5 and L3.

Table 9.10-9 Comparison of Average July Wetted Widths in Streams in the L and M Watersheds between Baseline and Operations

Stream	Phase	Wetted Width (m) by Return Period for July						
		1:100 Wet	1:50 Wet	1:10 Wet	1:2 Median	1:10 Dry	1:50 Dry	1:100 Dry
K5	Baseline	40.37	39.98	36.52	18.41	11.85	10.67	9.03
	Operations	11.79	11.50	9.37	6.18	5.67	5.27	5.12
L3	Baseline	50.93	49.99	47.33	37.86	29.30	8.67	7.65
	Operations	30.23	25.01	8.22	5.38	4.61	4.49	4.49
L2	Baseline	37.19	36.60	26.61	18.91	13.74	11.93	11.79
	Operations	16.95	16.08	13.31	11.38	9.81	9.06	8.63
L1	Baseline	56.29	54.81	49.14	43.91	36.45	21.25	20.60
	Operations	45.17	43.96	39.54	19.90	11.55	9.63	9.02
M4	Baseline	67.35	65.14	57.11	50.27	35.81	28.35	26.82
	Operations	53.76	51.88	45.19	29.09	18.98	14.51	14.12
M3	Baseline	51.75	51.08	49.98	47.04	43.93	39.79	37.98
	Operations	48.68	47.60	45.64	42.24	34.38	24.28	22.24
M2	Baseline	42.69	42.45	40.45	27.37	17.01	12.75	11.91
	Operations	33.69	29.19	23.87	15.88	10.05	7.86	7.60
M1	Baseline	59.77	59.07	56.77	46.83	27.41	20.08	19.90
	Operations	53.96	50.77	41.72	21.66	18.13	16.36	16.05

m = metres.

9.10.3.1.6 Changes to Fish Habitat Suitability – Operations

N Watershed

Flows in the N watershed during operations are similar to the dewatering phase of the Project for June and July. During operations, flows return to conditions similar to baseline in August and for the remainder of the open-water season. Minimal changes to the suitability of habitat conditions were predicted for the dewatering case. Since the peak flows in June and July for operations are essentially the same as for dewatering, these conclusions would not change. Flows return to near baseline levels in August for the remainder of the open-water season and no measurable change in the suitability of fish habitat relative to baseline conditions is predicted.

Average June water velocities in Stream N6 during dewatering will be similar to baseline under all flow conditions and within the range of natural variability (Table 9.10-10). Average velocities under both operations and baseline fall just below the lower boundary of preferred water velocity (0.3 m/s) for Arctic grayling spawning, but would still provide useable spawning conditions. As a result, the effect of dewatering on spawning Arctic grayling in Stream N6 is expected to be negligible. Flows return to near-baseline during July and August and no effects to Arctic grayling rearing are predicted.

Average June water velocities in Stream N17 during dewatering will be similar to baseline under all flow conditions and within the range of natural variability (Table 9.10-10). Average velocities under both operations and baseline fall just below the lower boundary of preferred water velocity (0.3 m/s) for Arctic grayling spawning, but would still provide useable spawning conditions. As a result, the effect of dewatering on spawning Arctic grayling in Stream N6 is expected to be negligible. Flows return to near-baseline during July and August and no effects to Arctic grayling rearing are predicted.

Table 9.10-10 Comparison of Average June Water Velocities in Streams N6 and N17 between Baseline and Operations

Condition	Return Period	Average Velocity (m/s)			
		Stream N6		Stream N17	
		Baseline	Operations	Baseline	Operations
Wet	100	0.22	0.23	0.27	0.29
	50	0.22	0.23	0.27	0.28
	20	0.21	0.22	0.27	0.28
	10	0.20	0.21	0.26	0.27
	5	0.20	0.21	0.25	0.27
Median	2	0.18	0.19	0.23	0.26
Dry	5	0.17	0.18	0.21	0.23
	10	0.16	0.17	0.22	0.21
	20	0.14	0.15	0.24	0.22
	50	0.12	0.13	0.18	0.16
	100	0.10	0.09	-	-

m/s = metres per second; "-" = no value.

L and M Watersheds

Changes in the ability for fish to migrate into the streams is discussed in the next section; however, assuming fish are able to move into the stream, changes in the suitability of the remaining available habitat can result due to the reduction in flow. As discussed in the dewatering section, the depth and velocity of streams in the L and M watersheds are largely insensitive to changes in discharge, both from augmentation and reductions in flow. Depth is a bit more sensitive to flow reductions, although the depths under operations remain within the range necessary for spawning (Table 9.10-11) and for YOY rearing (Table 9.10-12) except under dry conditions in Stream K5 where depth is likely a limiting factor in the availability of suitable habitat.

The average velocity in the channels remains almost unchanged from baseline for median flow conditions, with small reduction occurring at both wet and dry periods (Tables 9.10-13 and 9.10-14). In some instances, a decrease in flow can result in an increase in average velocity since the channel becomes narrower and shallower at the lower flows, resulting in an increase in average velocity. A more detailed description of the modelling results is provided in Section 9.7. The magnitude of loss of habitat due to a change in the suitability of habitat is likely small compared to the loss of available habitat due to reduction in wetted width of the channels.

Table 9.10-11 Comparison of Maximum Water Depths in June in Streams in the L and M Watersheds between Baseline and Operations

Stream	Phase	Maximum Depth (m) by Return Period for June						
		1:100 Wet	1:50 Wet	1:10 Wet	1:2 Median	1:10 Dry	1:50 Dry	1:100 Dry
K5	Baseline	0.64	0.64	0.62	0.57	0.44	0.33	0.31
	Operations	0.56	0.55	0.53	0.45	0.32	0.23	0.20
L3	Baseline	0.78	0.78	0.76	0.72	0.63	0.56	0.46
	Operations	0.69	0.68	0.67	0.63	0.52	0.39	0.33
L2	Baseline	0.78	0.78	0.76	0.70	0.56	0.45	0.43
	Operations	0.66	0.66	0.64	0.58	0.48	0.41	0.38
L1	Baseline	0.69	0.69	0.67	0.63	0.55	0.48	0.46
	Operations	0.61	0.60	0.59	0.56	0.51	0.45	0.43
M4	Baseline	0.68	0.67	0.65	0.59	0.50	0.43	0.42
	Operations	0.60	0.59	0.57	0.53	0.46	0.41	0.39
M3	Baseline	0.80	0.79	0.76	0.70	0.61	0.55	0.53
	Operations	0.76	0.75	0.73	0.67	0.59	0.53	0.51
M2	Baseline	0.70	0.70	0.68	0.64	0.57	0.50	0.49
	Operations	0.68	0.68	0.66	0.61	0.54	0.48	0.46
M1	Baseline	0.66	0.65	0.64	0.60	0.53	0.46	0.44
	Operations	0.65	0.64	0.62	0.58	0.51	0.43	0.42

m = metres.

Table 9.10-12 Comparison of Maximum Water Depths in August in Streams in the L and M Watersheds between Baseline and Operations

Stream	Phase	Maximum Depth (m) by Return Period for August						
		1:100 Wet	1:50 Wet	1:10 Wet	1:2 Median	1:10 Dry	1:50 Dry	1:100 Dry
K5	Baseline	0.52	0.51	0.40	0.33	0.27	0.24	0.23
	Operations	0.35	0.33	0.26	0.17	0.13	0.11	0.11
L3	Baseline	0.67	0.66	0.62	0.53	0.41	0.37	0.35
	Operations	0.57	0.50	0.39	0.28	0.23	0.21	0.21
L2	Baseline	0.63	0.61	0.54	0.45	0.40	0.38	0.37
	Operations	0.49	0.47	0.41	0.34	0.30	0.27	0.27
L1	Baseline	0.59	0.58	0.54	0.49	0.44	0.42	0.41
	Operations	0.49	0.48	0.44	0.40	0.35	0.32	0.31
M4	Baseline	0.57	0.55	0.51	0.44	0.38	0.36	0.36
	Operations	0.48	0.47	0.41	0.34	0.28	0.25	0.24
M3	Baseline	0.68	0.66	0.60	0.54	0.48	0.46	0.45
	Operations	0.61	0.59	0.53	0.45	0.38	0.35	0.34
M2	Baseline	0.62	0.61	0.56	0.49	0.44	0.42	0.41
	Operations	0.57	0.55	0.49	0.41	0.35	0.33	0.33
M1	Baseline	0.59	0.58	0.54	0.46	0.42	0.40	0.40
	Operations	0.54	0.52	0.47	0.41	0.36	0.35	0.34

m = metres.

Table 9.10-13 Comparison of Average Water Velocities in June in Streams in the L and M Watersheds between Baseline and Operations

Stream	Phase	Average Velocity (m/s) by Return Period for June						
		1:100 Wet	1:50 Wet	1:10 Wet	1:2 Median	1:10 Dry	1:50 Dry	1:100 Dry
K5	Baseline	0.23	0.23	0.22	0.20	0.21	0.19	0.18
	Operations	0.19	0.19	0.18	0.21	0.19	0.16	0.16
L3	Baseline	0.19	0.18	0.18	0.16	0.13	0.12	0.16
	Operations	0.15	0.14	0.14	0.13	0.14	0.16	0.15
L2	Baseline	0.25	0.25	0.24	0.22	0.21	0.18	0.17
	Operations	0.22	0.22	0.22	0.21	0.19	0.16	0.15
L1	Baseline	0.20	0.20	0.19	0.18	0.14	0.13	0.13
	Operations	0.17	0.17	0.16	0.15	0.13	0.13	0.12
M4	Baseline	0.15	0.15	0.14	0.13	0.11	0.10	0.10
	Operations	0.13	0.13	0.13	0.12	0.11	0.10	0.10
M3	Baseline	0.13	0.13	0.12	0.11	0.09	0.08	0.08
	Operations	0.12	0.12	0.12	0.11	0.09	0.08	0.07
M2	Baseline	0.33	0.32	0.31	0.29	0.28	0.27	0.27
	Operations	0.31	0.31	0.29	0.30	0.28	0.27	0.26
M1	Baseline	0.23	0.22	0.21	0.20	0.19	0.20	0.19
	Operations	0.22	0.22	0.21	0.20	0.18	0.19	0.18

m = metres.

Table 9.10-14 Comparison of Average Water Velocities in August in Streams in the L and M Watersheds between Baseline and Operations

Stream	Phase	Average Velocity (m/s) by Return Period for August						
		1:100 Wet	1:50 Wet	1:10 Wet	1:2 Median	1:10 Dry	1:50 Dry	1:100 Dry
K5	Baseline	0.18	0.18	0.22	0.19	0.17	0.16	0.16
	Operations	0.20	0.19	0.17	0.14	0.11	0.10	0.10
L3	Baseline	0.14	0.14	0.13	0.14	0.16	0.16	0.15
	Operations	0.12	0.15	0.16	0.13	0.10	0.09	0.09
L2	Baseline	0.22	0.21	0.20	0.18	0.16	0.15	0.14
	Operations	0.19	0.19	0.16	0.13	0.11	0.11	0.11
L1	Baseline	0.16	0.15	0.14	0.13	0.12	0.12	0.12
	Operations	0.13	0.13	0.12	0.11	0.11	0.11	0.11
M4	Baseline	0.13	0.12	0.11	0.10	0.10	0.09	0.09
	Operations	0.11	0.11	0.10	0.09	0.08	0.07	0.07
M3	Baseline	0.11	0.10	0.09	0.08	0.07	0.06	0.06
	Operations	0.09	0.09	0.08	0.06	0.06	0.05	0.05
M2	Baseline	0.30	0.30	0.28	0.27	0.26	0.25	0.24
	Operations	0.29	0.28	0.27	0.24	0.21	0.20	0.19
M1	Baseline	0.20	0.19	0.19	0.20	0.18	0.17	0.17
	Operations	0.19	0.19	0.20	0.18	0.16	0.15	0.15

m = metres.

9.10.3.1.7 Changes to Fish Migrations – Operations

N Watershed

Stream N11 includes a series of large (greater than 1 m) boulder/bedrock cascades in the middle of its length. In an average year, it is anticipated that these cascades are passable by fish only during the spring freshet when water levels are high enough to reduce the vertical drop necessary for fish to pass upstream. By mid-July, these cascades become impassable to most fish as flows recede and vertical barriers form (i.e., a barrier to fish passage is more likely to occur due to vertical drops during low flows than due to high water velocities during high flows). As with the dewatering case, flows will be augmented during June and July, when most migrations would occur. As a result, improved fish movements can be expected in the N watershed during operations. No changes to fish movements are predicted for Stream N6 and N17 as average velocities remain similar to baseline and the period of augmented flows that differ substantially from baseline only occurs during June.

L and M Watersheds

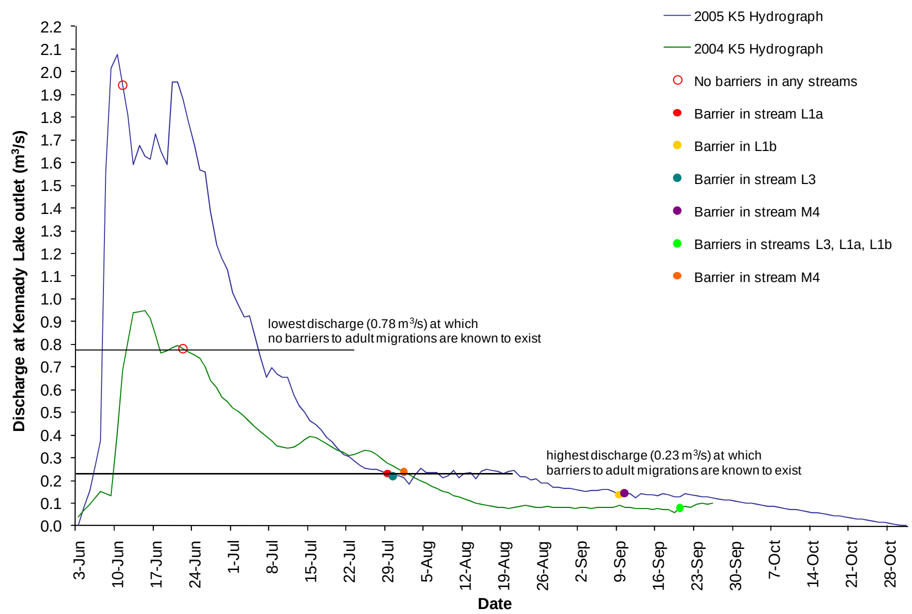
Barriers in streams between Kennady Lake and Lake 410 appear to form as a result of low flows creating unsuitable depths for fish movements, rather than due to high flows creating velocity barriers. Results of barrier surveys conducted in 2004 and 2005 indicated that a barrier to adult Arctic grayling movement exists at Stream L1a, Stream L3, and Stream M4 when the discharge at the outlet of

Kennady Lake is at 0.23 cubic metres per second (m^3/s) (Figure 9.10-12). An additional barrier forms in Stream L1b at 0.14 m^3/s. At a discharge of 0.78 m^3/s, no apparent barriers to adult Arctic grayling movement exist in any of the nine streams between Kennady Lake and Lake 410. The exact discharge when barriers persist is not known, but occurs somewhere between 0.23 m^3/s (confirmed barriers at three locations) and 0.78 m^3/s (confirmed no barriers at all locations).

Barriers in Streams L1b, L3, and M4 are the result of interstitial flow between boulders. Stream L1a is unique among streams between Kennady Lake and Lake 410 because it includes a steep (greater than 15 degrees), 3 m high, bedrock slope. Upstream fish passage becomes increasingly restricted over this slope as flows recede and water depth becomes limited to sheet flow over the bedrock face. The exact discharge at which low flows make this bedrock face a barrier is not yet known, but it is expected that the barrier in Stream L1a forms at a higher discharge than the barriers in Streams L3 or M4.

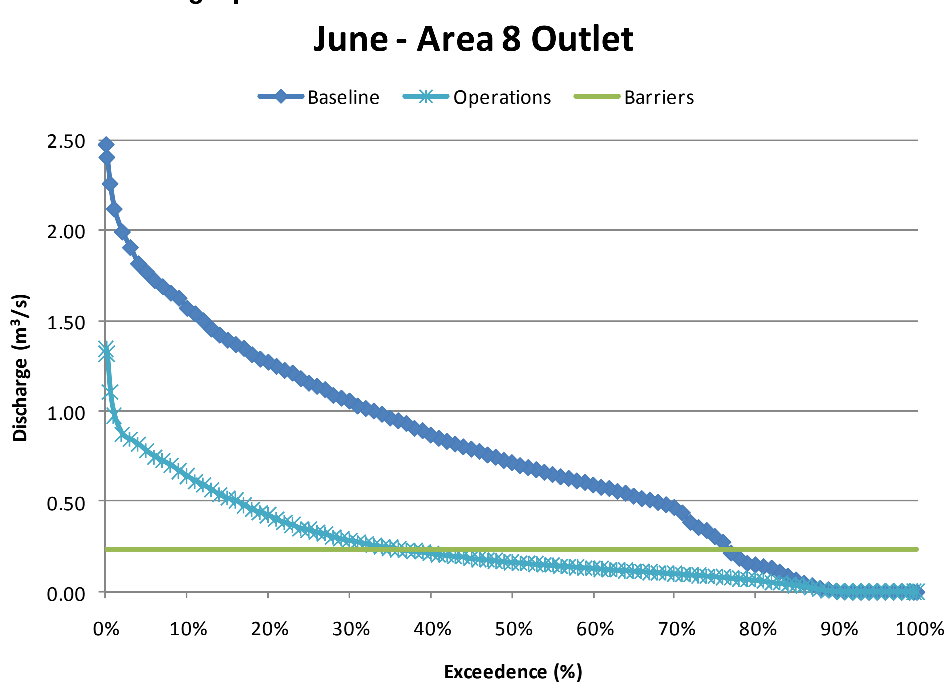
During operations, flows in June are substantially reduced. Under baseline conditions, the barrier to fish migration that is present at a discharge of 0.23 m^3/s would be present about 20% of the time in June, or in other words, would result in a barrier to migration approximately one out of five years. Under operations, the barriers to fish migration would persist about 65% of the time, or result in a barrier to migration approximately two out of three years (Figure 9.10-13). Hubert et al. (1985) identified a habitat suitability variable related to the frequency of access to spawning areas, with annual accessibility receiving a suitability of 1.0 and accessibility once every three years receiving a suitability of approximately 0.3. The increase in frequency of barriers preventing spring spawning migrations of Arctic grayling is likely to have a negative impact on Arctic grayling populations between Area 8 and Lake 410.

Figure 9.10-12 Barrier Formation in Streams between Kennady Lake and Lake 410



m^3/s = cubic metres per second.

Figure 9.10-13 Frequency of Barrier Formation in Streams between Kennady Lake and Lake 410 during Operations



m^3/s = cubic metres per second; % = percent.

9.10.3.1.8 Changes to Lower Trophic Levels – Operations

N Watershed

Streams in the N watershed will receive diverted waters from the A, B, D, and E watersheds during operations, resulting in increased stream flows. The projected mean current velocities in N watershed streams are either similar to those during dewatering (June and July; Tables 9.10-4 and 9.10-5), or lower and similar to baseline velocities. These velocities are within the expected range of natural variation, and are therefore not predicted to influence benthic invertebrate communities or invertebrate drift.

L and M Watersheds

Stream flows in June, July and August will decrease in Stream K5 downstream of Area 8 during operations. The projected decreases in mean current velocity relative to baseline velocities in Stream K5 are very small (i.e., less than or equal to 0.06 m/s; Tables 9.10-12 and 9.10-13), and therefore, not expected to alter benthic invertebrate communities or invertebrate drift. Predicted changes in wetted width and water depth are larger, with maximum reductions in July, when median wetted width and maximum water depth are predicted to be reduced by 66% and 51%, respectively. Although these changes are not expected to alter benthic community composition and drift density, the amount of invertebrate biomass and total drift within this stream are expected to be reduced in proportion to the reduction in stream width and flow, respectively.

Similar or smaller changes in stream flows and current velocities are predicted in L and M watershed streams downstream of Stream K5, which are also not expected to result in changes in benthic invertebrate communities and drift density. Reductions in median wetted width and water depth are predicted to be variable in these streams, with ranges of 10% to 86% and 17% to 46%, respectively. As noted for Stream K5, these reductions are expected to result in proportional decreases in the amount of invertebrate biomass and total drift within these streams.

9.10.3.2 Effects of Changes in Water Levels in Lakes Downstream of Kennady Lake to Fish and Fish Habitat

9.10.3.2.1 Changes to Fish Habitat Availability – Construction

N Watershed

Small increases in lake water levels and lake areas are predicted compared to baseline conditions in the N watershed (i.e., Lake N11 and Lake N1) due to Kennady Lake dewatering (Table 9.10-15). Water will be directly pumped from Kennady Lake to Lake N11, which will then flow to Lake N1 through Stream N11.

During dewatering, discharges to Lake N11 will be limited to ensure that 2-year flood conditions at Lake N1 and its outlet channel are held similar to baseline.

Table 9.10-15 shows the predicted changes in water levels and lake areas in Lake N11 and N1 from June to October. In June, minimal change in water level is predicted compared to baseline conditions, as pumping is restricted to meet the maximum allowed pumping rate, which in June is very close to the average flow. Differences between baseline and dewatering water levels are greater later in the summer, (i.e., August and September) due to lower seasonal flows (Table 9.10-15).

The increases in lake level are projected to be small, i.e., less than 20 centimetres (cm) in Lake N11 and less than 10 cm in Lake N1 (Table 9.10-15). Being farther downstream and with a larger upstream watershed area, the effect of dewatering flows on water levels in Lake N1 is lower than Lake N11. However, as both Lake N11 and N1 are large lakes, the change in water level corresponds to a less than 2% change in surface area. Lake N11 is 538 hectares (ha) with a maximum depth of approximately 10 m, and Lake N1 is 376 ha with a maximum depth of approximately 17 m.

As a result, the increases in water levels during dewatering are unlikely to have a substantive effect on fish habitat or benthic invertebrate communities in these lakes. However, the raised water levels may benefit fish in these lakes during summer through increased littoral area and summer rearing habitat, including small-bodied forage fish (e.g., slimy sculpin, lake chub [*Couesius plumbeus*], and ninespine stickleback [*Pungitius pungitius*]) and large-bodied fish species (e.g., Arctic grayling, burbot [*Lota lota*], and northern pike [*Esox lucius*]). Pumping will stop before streams become frozen in fall to avoid creation of ice jams and to allow lake levels to return to baseline conditions before winter; as a result, no changes to overwintering habitat would be expected. No effects on bank or shoreline stability are expected during dewatering, because increases in flood magnitude are small relative to the existing flood regime (Section 9.7.3.1.3) and the shorelines in both lakes are well armoured by boulder and cobble substrates.

Table 9.10-15 Projected Changes in Water Depth and Lake Area in Lakes in the N Watershed during the Dewatering of Kennady Lake, Compared to Baseline Conditions

Lake	June		July		August		September		October	
	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)
N11	0.02	0.2	0.12	1.3	0.16	1.8	0.13	1.4	0.02	0.3
N1	0.01	0.2	0.06	1.1	0.09	1.6	0.07	1.4	0.02	0.3

Note: Data are presented for median 1:2 year return period flows.
m = metres; % = percent.

L and M Watersheds

Water levels and lake areas in lakes between Kennady Lake and Lake 410 will change as a result of Kennady Lake dewatering (Table 9.10-16). There will be a small decrease in water level and lake areas for the L and M lakes in June compared to baseline conditions. However, these decreases are not expected to affect fish habitat, as they are small (i.e., less than 2 cm change in depth and 1% change in area) and within the natural variability of the lakes.

During summer and fall, water levels and lake areas compared to baseline conditions are predicted to be augmented as a result of dewatering flows (Table 9.10-16). Although pumping starts in June, the dewatering discharge is into Area 8, which attenuates the flow and delays the effect in the downstream watersheds. Water levels will remain at near spring freshet levels longer into the summer and early fall during the dewatering phase compared to baseline conditions. During dewatering, discharges to Area 8 will be limited to ensure that 2-year flood conditions are not exceeded within the basin or its outlet channel (Section 9.7, Effects to Surface Water Quantity).

Downstream of Kennady Lake, greater changes in lake levels and areas are expected in the L lakes than the M lakes, as the L lakes are generally smaller (Table 9.10-17) and located upstream of the M lakes. Being farther downstream and with increasingly larger upstream watershed areas, the effect of dewatering flows on water levels and lake areas in the M lakes will be lower.

Table 9.10-16 Projected Changes in Water Depth and Lake Area in Lakes between Kennady Lake and Lake 410 during the Dewatering of Kennady Lake, Compared to Baseline Conditions

Lake	June		July		August		September		October	
	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)
L3	-0.01	-0.5	0.19	15	0.29	22	0.33	24	0.03	2
L2	-0.01	-0.5	0.17	6	0.28	10	0.32	12	0.04	2
L1	-0.01	-0.4	0.07	4	0.13	7	0.17	9	0.07	4
M4	-0.02	-0.3	0.12	2	0.23	3	0.28	4	0.10	1
M3	-0.01	-0.3	0.09	2	0.20	4	0.24	5	0.12	3
M2	-0.01	-0.2	0.08	1	0.19	3	0.24	4	0.12	2
M1	-0.01	-0.4	0.07	2	0.19	6	0.23	8	0.13	4
410	0.02	0.3	0.10	1	0.17	2	0.15	2	0.05	1

Note: Data are presented for median 1:2 year return period flows.
m = metres; % = percent.

Table 9.10-17 Lake Areas and Maximum Depths in Lakes Downstream of Kennady Lake between Kennady Lake and Lake 410

Lake	Lake Area (ha)	Maximum Depth (m)
L3	4.4	1.0
L2	12.6	3.4
L1b	5.4	1.8
L1a	3.6	1.2
M4	80.6	13.0
M3	91.0	7.5
M2	32.1	5.7
M1	11.0	1.9
410	579	9.1

ha = hectares; m = metres.

Increases in water levels and areas compared to baseline conditions are expected to be greatest in the month of September. The largest changes are in Lakes L3 and L2, which are predicted to have increases in lake depth of 33 cm and 32 cm, respectively (Table 9.10-15). As these lakes are small, shallow lakes (Table 9.10-16), this corresponds to changes in lake area of 24% and 12%, respectively. This is a result of the lakes remaining at near spring freshet levels throughout the open-water period during dewatering, rather than decreasing lake levels through summer and fall from evaporation. For other lakes, the predicted changes in depth are less than 30 cm and lake area less than 10% (Table 9.10-16).

The water level of Lake 410 is projected to be increased 17 cm in August and 15 cm in September during dewatering, as the water levels in the lake do not decrease over summer compared to baseline conditions. Water pumped to both

Area 8 and Lake N11 will converge in Lake 410. As Lake 410 is a large lake (surface area of 579 ha), this relates to only a 2% change in lake area.

The higher water levels over the summer and fall in the L and M lakes downstream of Kennady Lake and Lake 410 during dewatering flows are small in comparison to baseline conditions (i.e., less than 35 cm). However, the higher water levels compared to baseline may benefit fish in these lakes during summer through increased littoral area and summer rearing habitat; species that may benefit include both small-bodied forage fish (e.g., slimy sculpin, lake chub, and ninespine stickleback) and large-bodied fish species (e.g., Arctic grayling, burbot, and northern pike). Pumping will stop before streams become frozen in fall to avoid creation of ice jams and to allow lake levels to return to baseline conditions before winter; as a result, no changes to overwintering habitat would be expected.

No effects to fish and fish habitat would be expected from shoreline erosion in these lakes from the increased water levels compared to baseline conditions. As per Section 9.7, no effects on bank or shoreline stability are expected during dewatering (i.e., Lake L1 and Lake M1), because flood magnitudes will not exceed baseline values. Boulder and cobble constitute most of the shoreline substrates in the lakes downstream of Kennady Lake to Lake 410.

9.10.3.2.2 Changes to Fish Habitat Availability – Operations

N Watershed – Operations

During operations, the A, B, D, and E watersheds will be diverted away from Kennady Lake to the N watershed. Pumping from the WMP will also be directed to Lake N11 during operations. As a result of the combined diversions, water levels and lake areas in Lake N17 and Lake N6 are expected to increase compared to baseline (Table 9.10-18). The diversions combined with the pumping from the WMP will result in water level increases in Lakes N11 and N1; however, this represents a small decrease compared to the augmented lake levels in Lakes N11 and N1 predicted during the Kennady Lake dewatering phase.

For Lake N11 and Lake N1, the largest change compared to baseline is in July (i.e., Lake N11 increases by 7 cm and Lake N1 increases by 4 cm), as spring water levels take longer to attenuate than under baseline conditions and due to the timing of pumping from the WMP; this corresponds to a less than 1% change in lake area. For Lake N17 and Lake N6, the largest change occurs during June, corresponding to spring runoff, which results in a less than 1% change in lake area.

For other months, the predicted increases are less, or zero (Table 9.10-18). As the changes in water level and lake area are small and within natural variability, no effects on fish and fish habitat are expected. No effects on bank or shoreline stability are expected during operations, because increases in flood magnitude are small relative to the existing flood regime (Section 9.7.3.2.3) and the shorelines in both lakes are well armoured by boulder and cobble substrates.

Table 9.10-18 Projected Changes in Water Depth and Lake Area in Lakes in the N Watershed during Operations, Compared to Baseline Conditions

Lake	June		July		August		September		October	
	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)
N11	0.03	0.33	0.07	0.80	0.01	0.09	0.00	0.05	0.00	0.03
N1	0.01	0.26	0.04	0.75	0.01	0.11	0.00	0.06	0.00	0.03
N6	0.02	0.37	0.01	0.26	0.01	0.27	0.01	0.21	0.01	0.09
N17	0.04	0.62	0.01	0.18	0.01	0.17	0.00	0.07	0.00	0.00

Note: Data are presented for median 1:2 year return period flows.
m = metres; % = percent.

L and M Watersheds – Operations

As a result of water management during operations, water levels and lake areas in lakes between Kennady Lake and Lake 410 are generally expected to decrease compared to baseline (Table 9.10-19). Similar to Section 9.10.3.2.1, greater changes are predicted in lake levels and areas in the L lakes than the M lakes, as the L lakes are generally smaller (Table 9.10-17) and located upstream of the M lakes. Decreased water levels and lake areas have the potential to affect fish habitat through reductions in littoral spawning and rearing habitat, overwintering habitat availability, as well as benthic invertebrate communities in the lakes.

For the L lakes, the largest changes are predicted to occur in Lake L3 in June and July, with decreases in lake depth of 21 and 22 cm, respectively. As Lake L3 is a small (4.4 ha), shallow lake (1.0 m maximum depth), this corresponds to a 15% and 16% change in lake area. The reductions in depth are attenuated throughout the summer, with smaller changes predicted for August through October. For the M lakes, the largest change is predicted to occur in Lake M3 in June, with a decrease in lake depth of 19 cm, which results in a 3% change in lake area. The lake water levels during winter are reflective of water levels at freeze up (i.e., around the end of October). Although there will be a reduction in water levels under the ice, it is predicted to be less than a 10 cm change from baseline conditions.

As the decreases in water levels in the L and M lakes downstream of Kennady Lake during operations are small (i.e., less than 25 cm), the effects on fish habitat or benthic invertebrate communities in these lakes would be expected to be minor. No effects on bank or shoreline stability are expected, because flows and water levels will decrease during operations (Section 9.7.3.3.3). Boulder and cobble constitute most of the shoreline substrates in the lakes downstream of Kennady Lake to Lake 410.

For Lake 410, there is a slight increase in water levels in June (1 cm) and July (3 cm), as a result of the augmented flows in the N watershed. For August through October a small decrease is predicted (1 cm). As the predicted changes are small and within natural variability, no effects on fish and fish habitat would be expected to occur in Lake 410 as a result of changes in lake levels.

Table 9.10-19 Projected Changes in Water Depth and Lake Area in Lakes between Kennady Lake and Lake 410 during Operations, Compared to Baseline Conditions

Lake	June		July		August		September		October	
	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)
L3	-0.21	-15.3	-0.22	-16	-0.14	-10	-0.10	-8	-0.04	-3
L2	-0.17	-6.4	-0.21	-8	-0.13	-5	-0.09	-3	-0.04	-2
L1	-0.08	-4.0	-0.14	-7	-0.10	-5	-0.09	-5	-0.09	-4
M4	-0.11	-1.5	-0.19	-3	-0.11	-2	-0.08	-1	-0.04	-1
M3	-0.08	-1.8	-0.17	-4	-0.10	-2	-0.08	-2	-0.03	-1
M2	-0.08	-1.3	-0.17	-3	-0.10	-2	-0.07	-1	-0.03	-1
M1	-0.07	-2.3	-0.16	-5	-0.10	-3	-0.07	-2	-0.03	-1
410	0.01	0.2	0.03	0.5	-0.01	-0.2	-0.01	0	-0.01	0

Note: Data are presented for median 1:2 year return period flows.
m = metres; % = percent.

9.10.3.3 Effects of Increased Nutrients on Fish and Fish Habitat in N Watershed

As previously stated, the analysis of potential effects related to nutrients will be submitted following the completion of additional analysis, which is expected to be completed in 2011.

9.10.4 Effects Analysis Results – Closure and Post-Closure

9.10.4.1 Effects of Changes to the Flow Regime in Streams Downstream of Kennady Lake on Fish and Fish Habitat

A representative sample of monthly flow duration curves for June, July, and August are presented for downstream locations within each watershed for closure and post-closure in Figures 9.10-14 to 9.10-19.

Closure

The flow regime in the N watershed will return to near baseline conditions during closure, with small seasonal reductions in flow due to pumping activities during the refilling of Kennady Lake. The flow reductions at the outlet of N11 are small, typically less than a 10% reduction from baseline flows, and the general flow timing and magnitude is similar to baseline conditions. At the outlet of Lake N1, flows return effectively to baseline conditions.

During closure, flows downstream of Kennady Lake to Lake 410 will be reduced from the refilling of Kennady Lake, with the same flow regime from operations continuing through the refilling phase. The magnitude of the change is greater than the 15% threshold identified in Section 9.10.1, during at least a portion of the year, and additional analysis was conducted to assess the effects of the closure flow regime on fish habitat.

Post-Closure

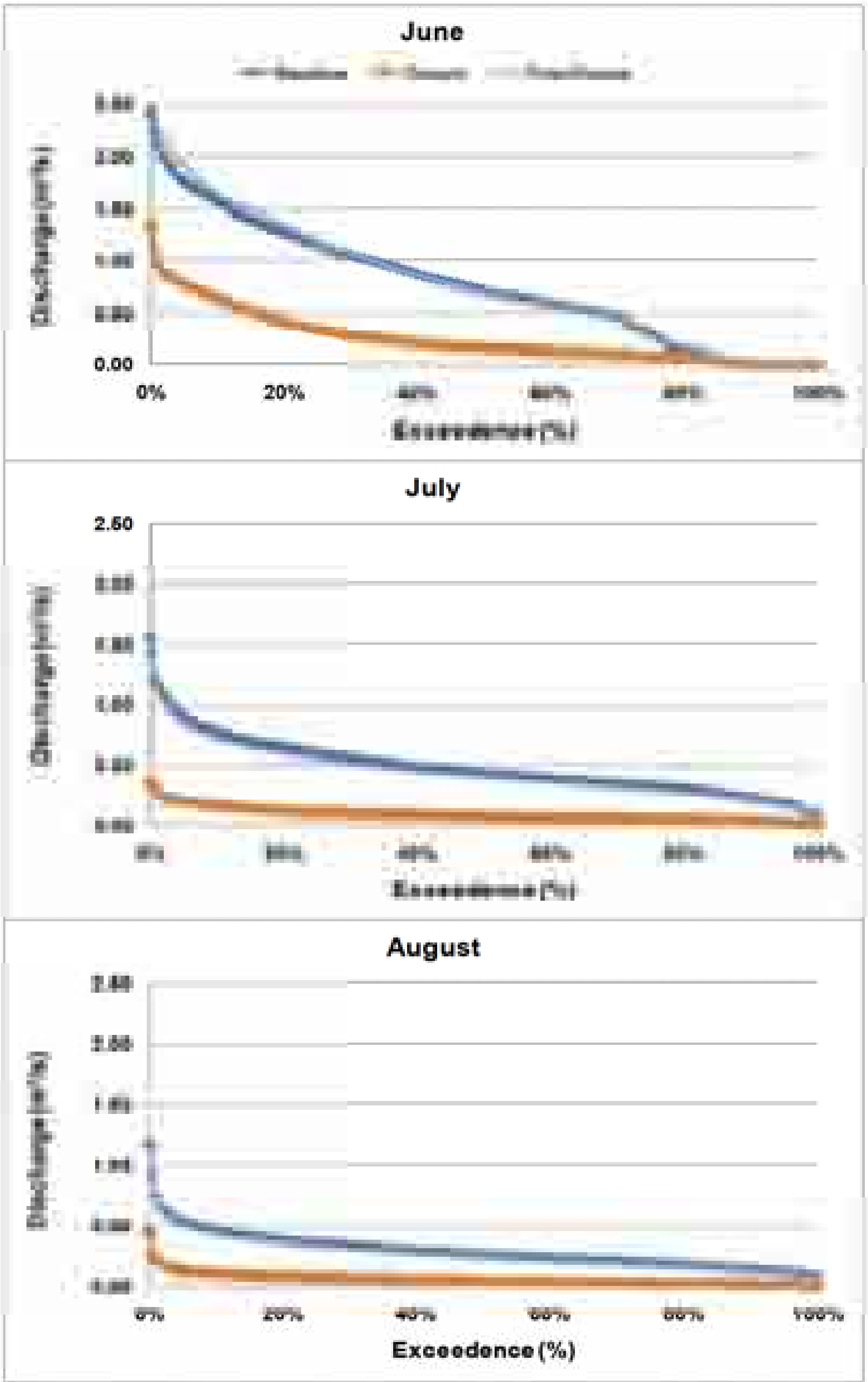
At post-closure, flows return to near baseline conditions throughout the N, L and M watersheds. As a result, additional assessment of flow changes in the N, L and M watersheds during closure and post-closure was not required, and the effects to fish habitat are considered to be negligible.

Downstream Extent of Effects

Within the N watershed, changes to the flow regime are not predicted to extend downstream of Lake N11 during closure. Flow reductions persist at closure in the L and M watersheds, but return to near baseline conditions at the outlet of Lake 410. Flows downstream of Lake 410 are near baseline conditions for most of the open-water period during closure, with a slightly larger flow reduction in June, but still close to baseline conditions and within the range of natural variability (Figure 9.10-17). Therefore, the downstream extent of the assessment for closure will be restricted to the L and M watersheds.

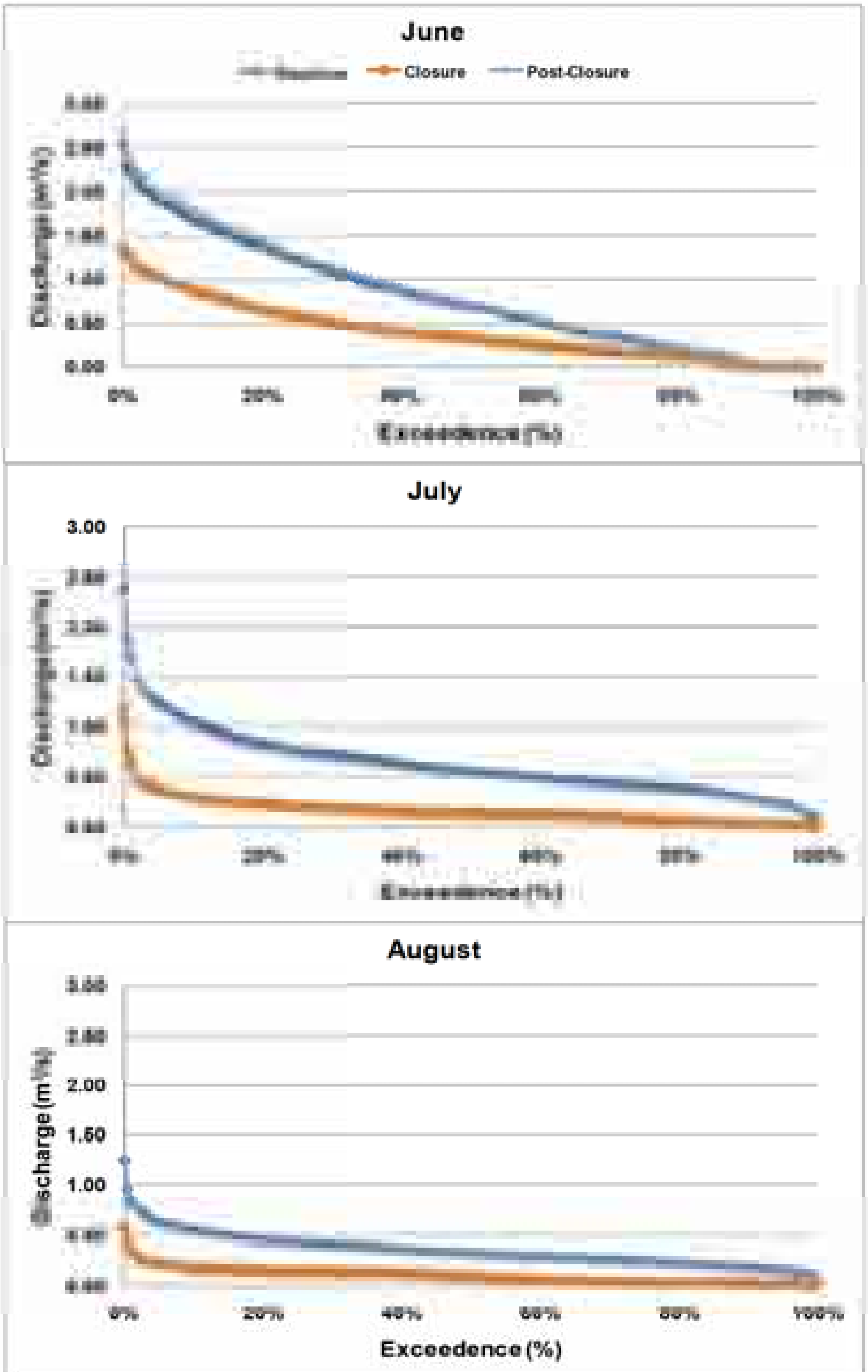
Flows are near baseline conditions at all points downstream of Kennady Lake at post-closure, however predicted increases in nutrient concentrations would be evident downstream to Lake 410, and therefore the downstream extent of the post-closure assessment is Lake 410.

Figure 9.10-14 Flow Duration Curves for June, July, and August at the Outlet of Kennady Lake under Baseline, Closure, and Post-Closure



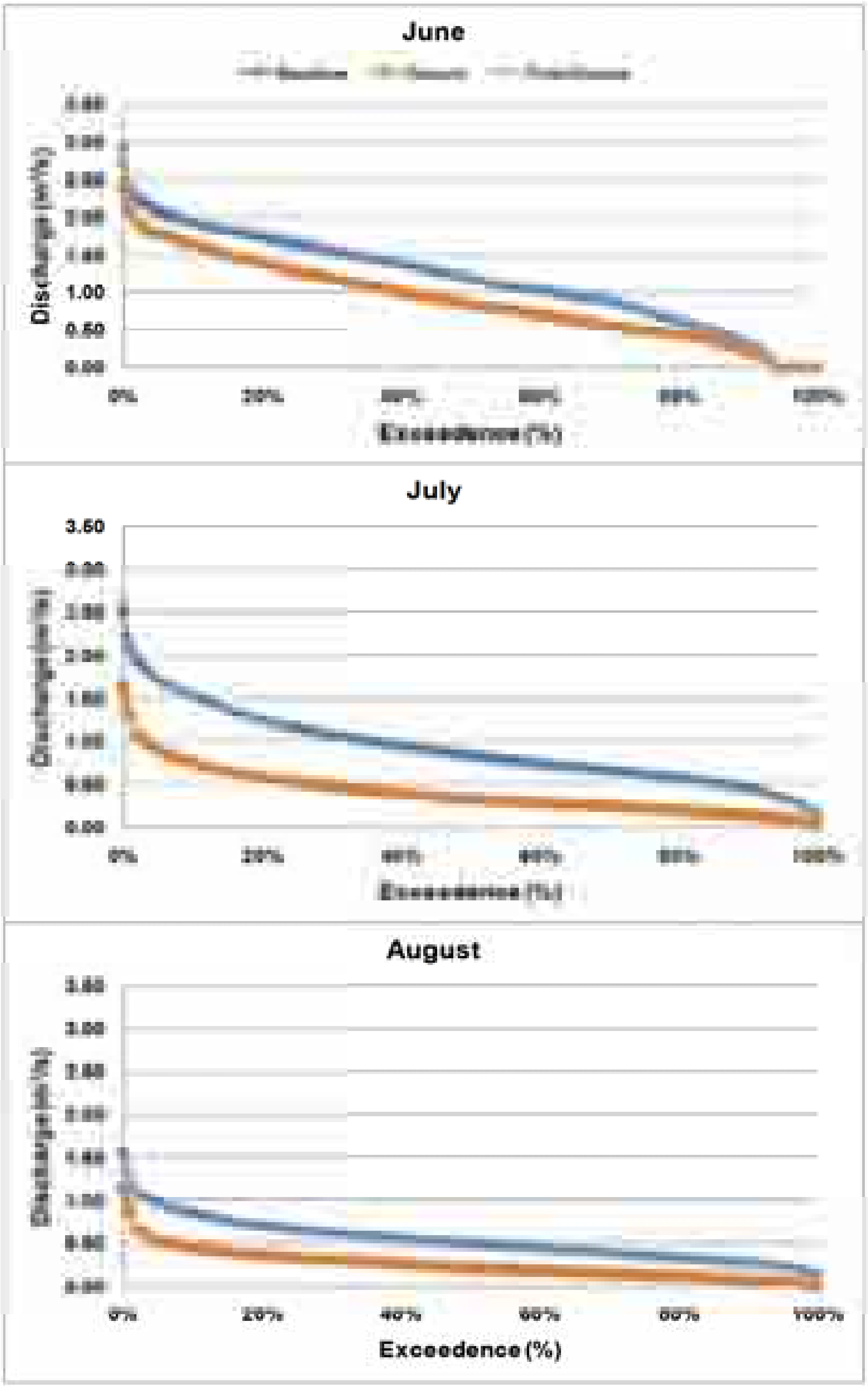
m^3/s = cubic metres per second; % = percent

Figure 9.10-15 Flow Duration Curves for June, July, and August at the Outlet of Lake L1a under Baseline, Closure, and Post-Closure



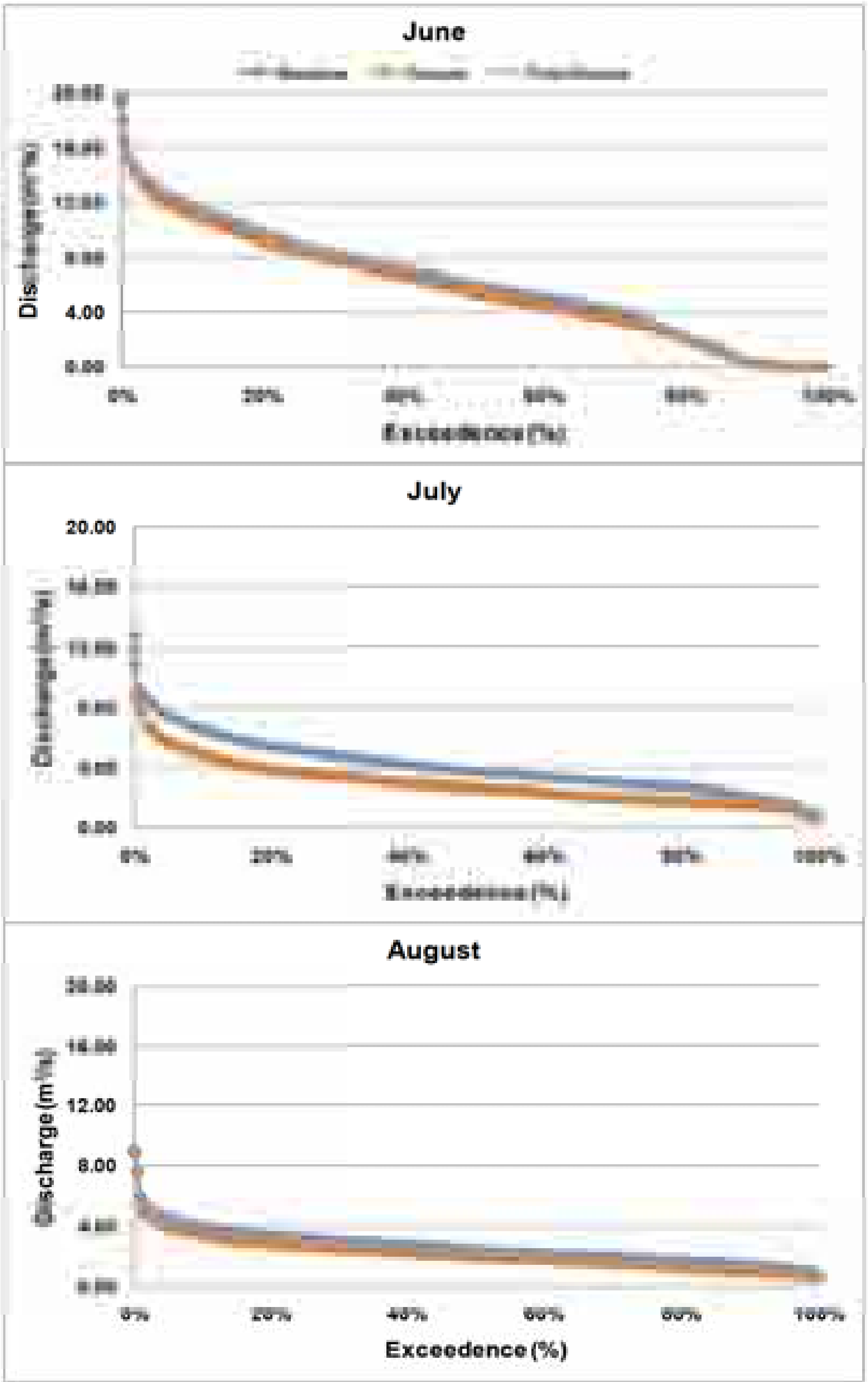
m³/s = cubic metres per second; % = percent

Figure 9.10-16 Flow Duration Curves for June, July, and August at the Outlet of Lake M1 under Baseline, Closure, and Post-Closure



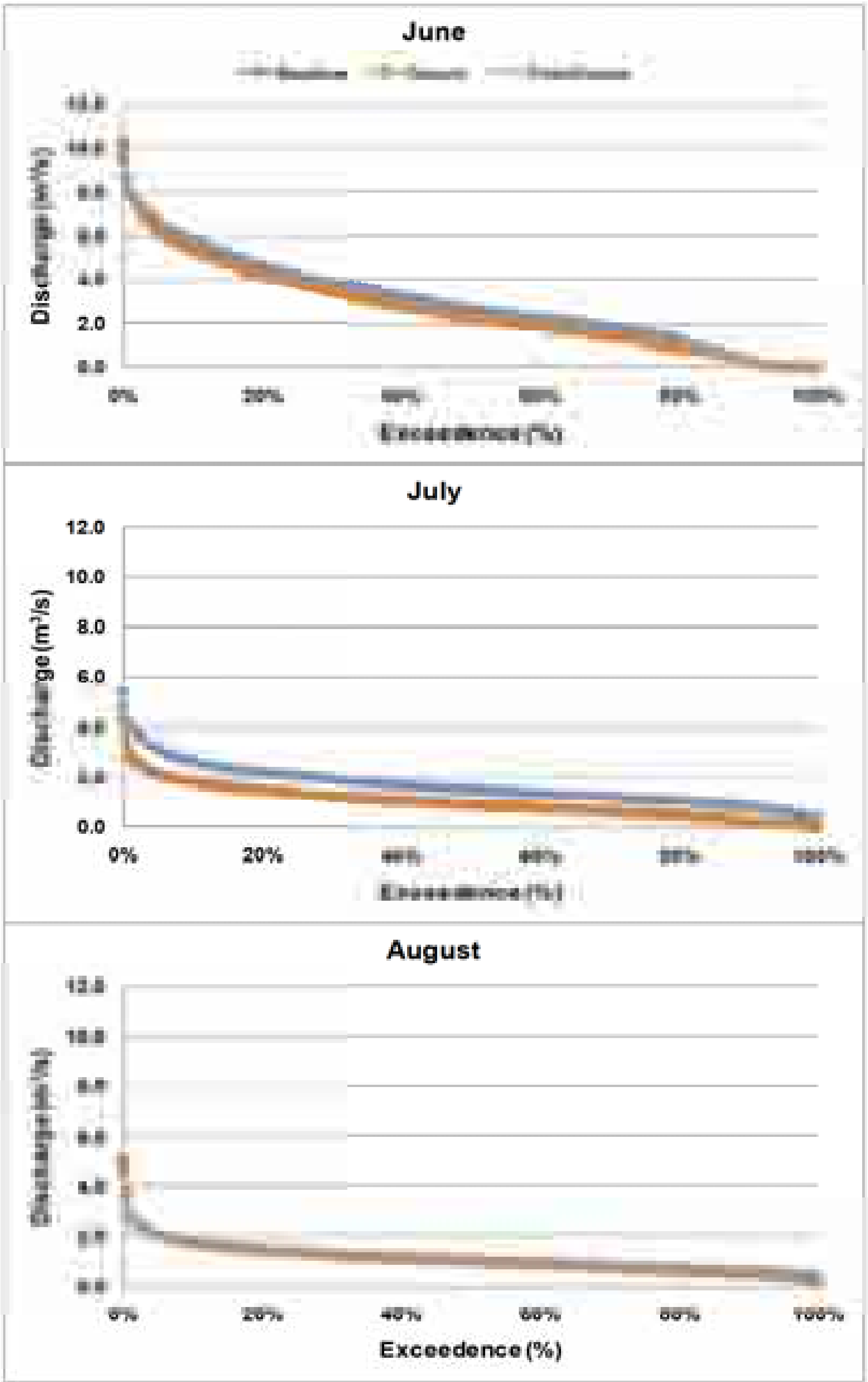
m^3/s = cubic metres per second; % = percent

Figure 9.10-17 Flow Duration Curves for June, July, and August at the Outlet of Lake 410 under Baseline, Closure, and Post-Closure



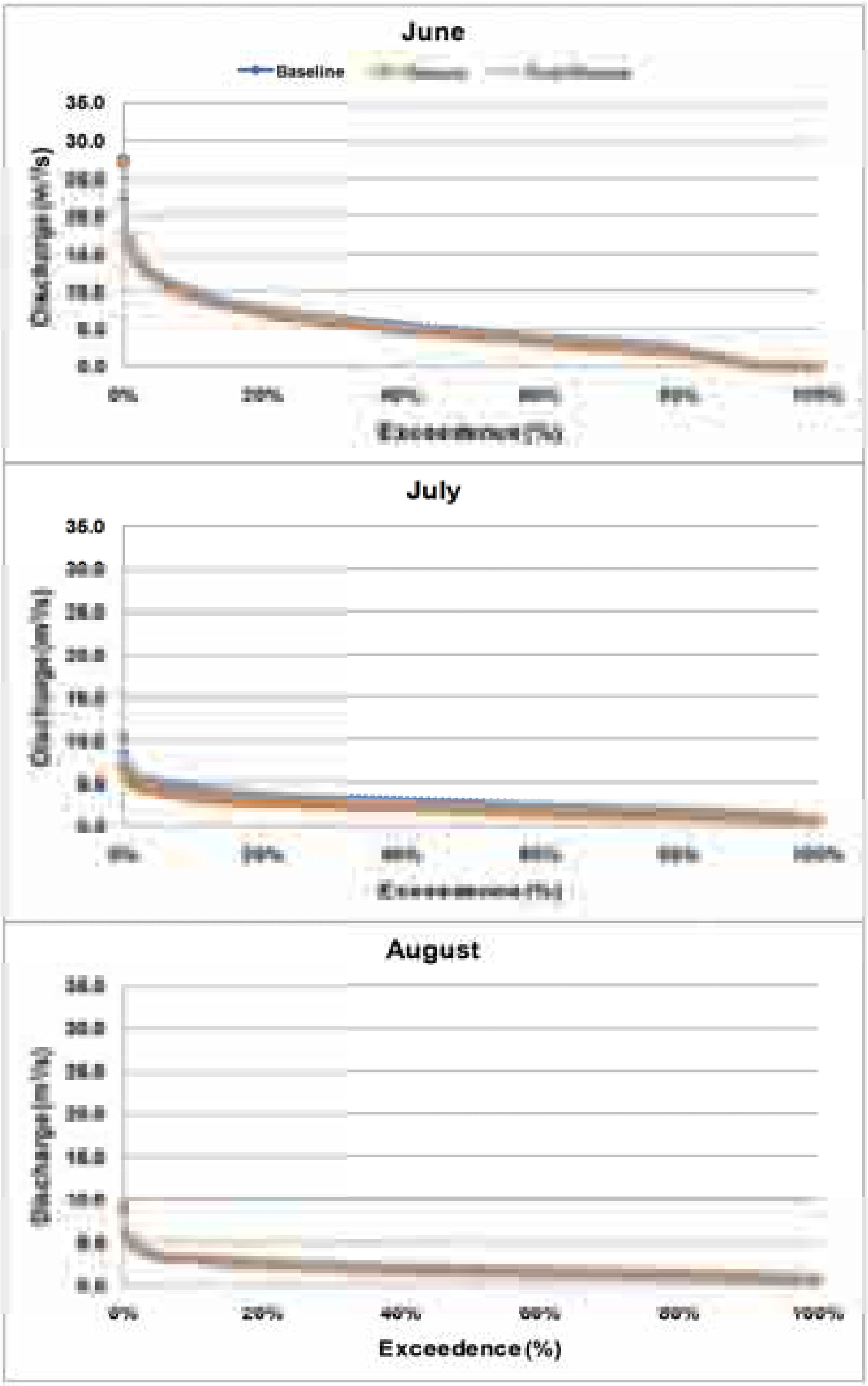
m³/s = cubic metres per second; % = percent

Figure 9.10-18 Flow Duration Curves for June, July, and August at the Outlet of Lake N11 under Baseline, Closure, and Post-Closure



m^3/s = cubic metres per second; % = percent

Figure 9.10-19 Flow Duration Curves for June, July, and August at the Outlet of Lake N1 under Baseline, Closure, and Post-Closure



m^3/s = cubic metres per second; % = percent

9.10.4.1.1 Changes to Fish Habitat

L and M Watersheds – Closure

The closure flow regime for the L and M watersheds is the same as assessed for project operations for fish habitat availability (Section 9.10.3.1.5), fish habitat suitability (Section 9.10.3.1.6) and changes to fish migrations (Section 9.10.3.1.7). Therefore, the conclusions regarding fish habitat are the same as presented for operations.

9.10.4.1.2 Changes to Lower Trophic Levels

N Watershed – Closure and Post-Closure

At closure, the B, D, and E watersheds will be re-diverted to Kennady Lake, resulting in flows through the N watershed returning to close to baseline levels (Figures 9.10-18 and 9.10-19). As a result, effects on lower trophic communities in the N watershed resulting from diversions and WMP discharges during operations will cease. Lower trophic communities are expected to return to those characteristic of baseline conditions in about five years.

L and M Watersheds – Closure and Post-Closure

During closure, flows in the L and M watersheds will be the same as during operations and the conclusions from operations apply (Section 9.10.3.1.8). At post-closure, Area 8 will be reconnected to the refilled Kennady Lake, resulting in flows downstream of Kennady Lake returning to near baseline levels (Figures 9.10-14 through 9.10-17). Changes in stream flows during operations were not predicted to result in altered communities, but total benthic invertebrate biomass and amount of drift were predicted to be reduced due to reduced bottom area and flow volume, respectively. In addition, some encroachment of vegetation may occur during the period of reduced wetted width.

Return to near-baseline flow conditions in these streams is predicted to result in recolonization of the re-wetted stream areas by benthic invertebrates from upstream areas and the existing stream channel, by drift and movement of invertebrates on stream substrates. Flooded vegetation along the stream margins may provide a source of food to invertebrates in the form of decaying organic material during the first year of re-established flows. Therefore, recolonization is expected to occur quickly, mostly during the first two years of re-established flows.

The above statements are put forward without consideration of potential nutrient-related effects. Once the additional nutrient-related analysis identified in Section 9.10.1.3 is complete, they will be updated, if and as required.

9.10.4.2 Effects of Changes in Water Levels in Lakes Downstream of Kennady Lake to Fish and Fish Habitat

N Watershed

During closure, small decreases in lake water levels and lake areas are predicted in Lake N11 and Lake N1 compared to baseline (Table 9.10-20) due to the abstraction of flow for Kennady Lake refilling.

For Lake N11, the largest change compared to baseline is in July, with a decrease in depth of 7 cm; the corresponding change in lake area is less than 1%. For Lake N1, the largest change is also in July, with a decrease in lake depth of 11 cm, and lake area of 2%. Reductions in other months are smaller.

As the decreases in water levels in Lake N11 and N1 during closure are small compared to baseline (i.e., less than 11 cm), they are unlikely to have a substantive effect on fish habitat or benthic invertebrate communities in these lakes. No effects on Lake N11 and Lake N1 bank or shoreline stability are expected during closure, because flood discharges and water levels will be equal to or reduced from baseline (Section 9.7.4.1.3) and the shorelines in both lakes are well armoured by boulder and cobble substrates.

As described in Section 9.7.4.3, the post-closure hydrological regime of Lake N11 will be identical to baseline; changes to the post-closure regime of Lake N1 and its watershed as a result of the permanent diversion of the A watershed into the N1 watershed, will be negligible.

Table 9.10-20 Projected Changes in Water Depth and Lake Area in Lakes in the N Watershed during Closure, Compared to Baseline Conditions

Lake	June		July		August		September		October	
	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)
N11	-0.02	-0.23	-0.07	-0.81	0.00	-0.04	0.00	-0.04	0.00	-0.03
N1	-0.09	-1.64	-0.11	-2.02	-0.06	-1.10	-0.05	-0.93	-0.03	-0.66

Note: Data are presented for median 1:2 year return period flows.
m = metres; % = percent.

L and M Watersheds

During closure, when Kennady Lake is being refilled and the downstream watershed remains isolated, the lake levels, and associated effects on fish and fish habitat, in the L and M lakes downstream of Kennady Lake are as described for operations above.

During post-closure, when Dyke A is removed and the refilled Kennady Lake is discharging through Stream K5, water levels and lake areas in lakes between Kennady Lake and Lake 410 will show a slight decrease in flows compared to baseline (Table 9.10-21). However, lake levels and areas will increase compared to the operational period, when Kennady Lake is isolated. Although the B, D, and E watersheds will be re-diverted to Kennady Lake at closure, the A watershed diversion will be permanent; as a result, there will be a 7% reduction in the input from the upper Kennady Lake watershed.

Predicted changes in depth compared to baseline are less than 10 cm for all lakes. Lake L3 shows the largest change of 9 cm in June, attenuating through the summer to just a 1 cm decrease compared to baseline by October. Changes in other lakes are less. For Lake 410, the maximum predicted decrease is 2 cm.

As the decreases in water levels in the lakes downstream of Kennady Lake during post-closure are small compared to baseline (i.e., less than 10 cm), and expected to increase compared to operations, negligible effects on fish and fish habitat would be expected to occur in these lakes as a result of changes to lake levels.

Table 9.10-21 Projected Changes in Water Depth and Lake Area in Lakes between Kennady Lake and Lake 410 during Post-Closure Compared to Baseline Conditions

Lake	June		July		August		September		October	
	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)	Change in Depth (m)	Change in Area (%)
L3	-0.09	-6.9	-0.07	-5	-0.04	-3	-0.03	-2	-0.01	-1
L2	-0.08	-2.9	-0.07	-3	-0.04	-2	-0.03	-1	-0.01	-0.5
L1	-0.03	-1.7	-0.04	-2	-0.03	-1	-0.03	-1	-0.02	-1
M4	-0.05	-0.7	-0.07	-1	-0.04	-1	-0.03	-0.4	-0.01	-0.2
M3	-0.04	-0.8	-0.06	-1	-0.03	-1	-0.03	-1	-0.01	-0.3
M2	-0.04	-0.6	-0.06	-1	-0.03	-1	-0.02	-0.4	-0.01	-0.2
M1	-0.03	-1.1	-0.06	-2	-0.03	-1	-0.02	-1	-0.01	-0.4
410	0.00	-0.1	-0.02	-0.9	-0.01	-0.1	-0.01	-0.1	0.00	0.0

Note: Data are presented for median 1:2 year return period flows.
m = metres; % = percent.

9.10.4.3 Effects of Increased Nutrients on Fish and Fish Habitat

As previously stated, the assessment of potential effects related to nutrients will be submitted following the completion of additional analysis, which is expected to be completed in 2011.

9.10.4.4 Effects from Changes to Aquatic Health on Fish and Fish Habitat Downstream of Kennady Lake

Potential effects to aquatic health in Lake N11 and Lake 410 were evaluated for closure and post-closure in the aquatic health assessment (Section 9.9) based on predicted changes in water quality and sediment quality.

For the direct waterborne exposure assessment, total dissolved solids (TDS) was identified as a substance of potential concern (SOPC) in Lake N11 and Lake 410; however, adverse effects to fish and aquatic invertebrates are not expected at the predicted TDS concentrations in Lake N11 and Lake 410 (Section 9.9.3.1.1). During closure, predicted maximum concentrations of all remaining SOPCs in Lake N11 and Lake 410 are predicted to remain below the chronic effects benchmark identified for each substance. As a result, the predicted increases in the concentrations of these substances are expected to have a negligible effect on aquatic health in Lake N11 and Lake 410 under the assessed conditions (Section 9.9.3.1.1).

For the indirect exposure pathway, predicted fish tissue concentrations in Lake N11 and Lake 410 are projected to be below toxicological benchmarks for all parameters considered in the assessment.

Based on the aquatic health assessment (Section 9.9), predicted changes to concentrations of all substances considered in waterbodies downstream of Kennady Lake (i.e., Lake N11 and Lake 410) are projected to result in negligible effects to fish tissue quality and, by association, aquatic health; as a result, no effects to fish populations or communities would occur from changes in aquatic health.

9.10.4.5 Long-term Effects on Fish and Fish Habitat Downstream of Kennady Lake

In the N watershed, flows and water levels will return to near baseline conditions, as will water quality in the affected lakes. As a result, fish and fish habitat is expected to similarly return to a baseline state over time.

The aquatic ecosystem, including fish populations, downstream of Kennady Lake may differ from its current state. Although flows and water levels between Kennady Lake and Lake 410 will return to near baseline conditions, water quality model results indicate that nutrient levels in downstream systems through to Lake 410 may be higher than under existing conditions. The assessment of potential effects related to nutrients will be submitted following the completion of additional analysis, which is expected to be completed in 2011.

9.11 RELATED EFFECTS TO WILDLIFE AND HUMAN HEALTH

9.11.1 Overview

This section presents a summary of the effects of changes to water quantity, water quality, and fish in downstream waterbodies on wildlife and human health. The summary of residual effects is based on assessments presented in other sections of the environmental impact statement (EIS). The assessment of effects to wildlife for all pathways, including changes in water quantity, water quality, and fish are provided in the following other sections of the EIS:

- Key Line of Inquiry: Caribou (Section 7);
- Subject of Note: Carnivore Mortality (Section 11.10);
- Subject of Note: Other Ungulates (Section 11.11); and
- Subject of Note: Species at Risk and Birds (Section 11.12).

Potential pathways for effects to wildlife associated with changes in water quality, water quantity, and fish in downstream waterbodies include the following:

- effects to wildlife health resulting from changes in water quality and fish tissue quality;
- effects of increased flows during dewatering of Areas 2 to 7 of Kennady Lake on the amount and composition of riparian vegetation and related effects to wildlife habitat; and
- effects of increased flows during dewatering Areas 2 to 7 of Kennady Lake on water bird nest mortality and wildlife mortality.

The only potential pathway for effects to human health relevant to Section 9 is associated with changes in water quality and fish tissue quality.

A summary of the residual effects for each of these pathways is provided below.

9.11.2 Summary of Residual Effects

9.11.2.1 Wildlife Health

9.11.2.1.1 Effects of Changes in Water Quality and Fish Tissue Quality to Wildlife Health

An ecological risk assessment was completed to evaluate the potential for adverse effects to individual animal health associated with exposure to materials released from the Project. The result of the assessment indicated the potential for effects to occur to aquatic-dependant birds (i.e., waterfowl and shorebirds) as a result of boron levels in Kennady Lake. No other impacts were predicted to birds or other wildlife, including caribou, muskoxen and moose.

The ecological risk assessment was completed using water quality predictions that were developed assuming that there was no isolation of the fine PKC material located at the base of the Fine PKC Facility, and that all waters travelling over the facility would come into contact with this material, which is the predominate source of boron to the refilled lake. Processes that would modify the degree of contact between the fine PK and the runoff waters were not considered, including the aggradation of permafrost and/or the application of cover material to limit infiltration. In addition, the water quality predictions used in the risk assessment were developed by setting parameters concentrations in the runoff waters to the maximum concentrations observed in the geochemical investigations completed in support of the EIS. Consequently, the results of the risk assessment correspond to an extreme condition that has a low likelihood of occurring.

De Beers is committed to further study of this potential issue in 2011, and will incorporate mitigative strategies into the Project design to the extent required to maintain boron levels in Kennady Lake below those that may be of environmental concern, including the potential application of less permeable cover material to limit infiltration through the Fine PKC Facility. Given these commitments and the low likelihood of the assessed situation actually occurring, overall potential effects to wildlife were deemed to be not environmentally significant, in both the Kennady Lake watershed and in downstream systems. However, the predictions of environmental significance with respect to water birds are dependent on the execution of further study of the ingestion pathways discussed in Section 11.2 and the commitment that mitigative strategies will be incorporated into the Project design to the extent required to invalidate these pathways.

9.11.2.1.2 Effects of Increased Flows during Dewatering of Areas 2 to 7 of Kennady Lake on the Amount and Composition of Riparian Vegetation and Related Effects to Wildlife Habitat

Environmental design features and mitigation have been included in the Project design to limit erosion, and thereby reduce the potential for loss of vegetation in downstream waterbodies during dewatering of Areas 2 to 7 of Kennady Lake to Lake N11, and to the Interlakes through to Lake 410, during construction and operation. Dewatering discharges to Lake N11 through operations, and to Area 8 during construction, will be limited to the 1-in-2 year flood level during open water conditions, which in most cases, will maintain flow within the existing stream channels. Stream channels downstream of Area 8 are less defined than for the N watershed, so 1-in-2-year flood flows may extend beyond the baseline flow paths. Under this flow condition, the potential for full plant submergence may result in a high-stress environment for some plant species; as flows in the N watershed are expected to remain within existing stream channels, full submergence of riparian vegetation is unlikely. However, stream flows downstream of Area 8 may result in some riparian plant submergence. (Section 11.7). Effects to riparian vegetation will therefore be low in magnitude, localized and are not expected to influence the quantity of riparian vegetation and habitat for wildlife relative to existing conditions. No downstream effects are predicted to soils from flow changes during lake dewatering (Section 11.7; Appendix 11.7.I). Consequently, changes to downstream habitat quantity from stream flooding are anticipated to be negligible.

During the post-closure period, changes to the quality of downstream habitat resulting from the reconnection of Areas 2 through 7 of Kennady Lake with downstream lakes and streams are anticipated to be within the range of variation associated with natural stream flooding events. Although locations downstream of Kennady Lake will be affected by the post-closure hydrological regime of the Kennady Lake watershed, the projected increases in flood peak discharges will be slight and for mean annual water yield, increases will be only 3.8%. Consequently, changes to available habitat downstream from the post-closure flow regime are anticipated to be negligible.

The overall impact from increased flows to riparian habitat will not be environmentally significant for local populations of wildlife.

9.11.2.1.3 Effects of Increased Flows during Dewatering of Areas 2 to 7 of Kennady Lake on Water Bird Nest Mortality and Wildlife Mortality

Changes to downstream habitat quality resulting from the dewatering of Kennady Lake are anticipated to be within the range of variation associated with natural stream flooding events in the watershed. It is assumed that dewatering of Kennady Lake will begin before the spring migration and subsequent selection of suitable nesting sites. Because flood conditions will be in effect at the time of nesting site selection, water bird nest mortality from stream flooding is predicted to be negligible.

Wildlife mortality from stream flooding is not predicted to increase beyond the number of animals drowning under natural conditions. This is expected because flow rates associated with the 1-in-2 year flood flows during dewatering occur regularly under natural conditions, despite the higher flow rates lasting longer during the open water season. Therefore, wildlife would be exposed to similar flow conditions (e.g., on average every two years) within the downstream watersheds. Increased flows will not contribute to an increase in wildlife mortality rates beyond existing baseline conditions. The impact will not be environmentally significant for local populations of wildlife.

9.11.2.2 Human Health

9.11.2.2.1 Effects of Changes in Water Quality and Fish Tissue Quality to Human Health

A human health risk assessment was completed to evaluate how the predicted changes to air and water quality in the Kennady Lake watershed could potentially affect human health. Emission sources considered in the assessment included fugitive dust, air emissions, site runoff and seepage and exposed lakebed sediments. Potential exposure pathways included changes in air, water, soil, vegetation and fish tissue quality.

The results of the assessment indicate that individuals living at the Project site could experience health issues should they consume fish, as predicted changes in metal levels in water could affect fish tissue quality. However, individuals working at the Project site will not be allowed to fish and, therefore, will not consume fish from the Kennady Lake watershed. In addition, individuals do not currently live at the Project site, and it is unlikely that non-workers would do so in the future. This exposure scenario was used to provide a conservative evaluation of potential effects to individuals using the area for traditional purposes, because traditional purposes typically involve a temporary presence on the land near the Project site. The human health assessment was also completed using the conservative water quality predictions described herein, which included the free and complete contact between site runoff waters and the materials contained in the mine rock piles, the Coarse PK Pile and the Fine PKC Facility.

De Beers is currently evaluating a variety of environmental design features and mitigation measures to limit contact between site runoff waters and the fine PK located within the Fine PKC Facility and other potential sources. The effectiveness of these environmental design features and mitigation measures is uncertain and requires further analysis. This analysis is expected to be completed in 2011. Once complete, De Beers will update the human health assessment to reflect the effects of these measures. De Beers is also committed to implementing additional environmental design features and mitigation measures to the extend required to protect human health.

As a result, human health is not expected to be detrimentally affected by Project activities, in the Kennady Lake watershed or in downstream systems. However, this statement is contingent on the results of further study and the implementation of mitigation strategies to the extent required to maintain exposure levels below those that would be of concern.

9.12 RESIDUAL EFFECTS SUMMARY

The potential environmental effects related to the valid pathways identified for downstream water effects are provided below for the following components:

- water quantity;
- water quality;
- aquatic health; and
- fish and fish habitat.

9.12.1 Water Quantity

9.12.1.1 Construction and Operation

9.12.1.1.1 Assessment Approach

Effects on hydrology downstream of the Kennady Lake watershed will vary over time as the Project proceeds through construction and operation. The effects to the hydrology of downstream streams and lakes resulting from construction and operation of the Project were determined by examining changes to the Kennady Lake and downstream watersheds from baseline conditions using a water balance model developed using GoldSim™ software.

The baseline water balance model described in Annex H was modified to model the effects on Kennady Lake during construction and operations. The following changes were made to the water balance model:

- Areas 2, 3, 4, 5, 6, and 7 were isolated from Area 8 of Kennady Lake, due to the presence of Dyke A during construction and operations;
- runoff from the A watershed, upstream of the Lake A3 outlet, was permanently diverted out of the Kennady Lake watershed due to the presence of Dyke C during Operations;
- the A watershed, in Area 1 downstream of the Lake A3 outlet, was treated as land area due to the establishment of the Fine PKC Facility during Operations;
- runoff from the B watershed was diverted out of the Kennady Lake watershed due to the presence of temporary Dyke E during Operations;
- runoff from the D watershed, upstream of the Lake D2 outlet, was diverted out of the Kennady Lake watershed due to the presence of temporary Dyke F during Operations; and

- runoff from the E watershed, upstream of the Lake E1 outlet, was diverted out of the Kennady Lake watershed due to the presence of temporary Dyke G during Operations.

During construction, dewatering will discharge approximately half the volume in Areas 2, 3, 4, 5, 6, and 7 of Kennady Lake to Lake N11, and to Area 8 of Kennady Lake. Dewatering discharges to Area 8 will be managed to prevent downstream erosion or geomorphological changes. The dewatering model was set up such that:

- pumping began on June 1 of each year;
- the pumping rate was limited to ensure that the total of natural and diverted discharge will not exceed the 2-year (median) maximum daily flow rate at Area 8 outlet (Stream K5) (135,000 cubic metres per day [m^3/d]) and will not exceed 500,000 m^3/d at the Lake N11 outlet, and that no pumping occurred when natural flows exceeded that rate;
- water was pumped from Kennady Lake Areas 2, 3, 4, 5, 6, and 7 until half the initial volume remains (about 17.6 million cubic metres [Mm^3]); and
- runoff from Kennady Lake Areas 2, 3, 4, 5, 6, and 7 and their tributaries was accounted for in the model.

During Operations, Areas 2, 3, 4, 5, 6, and 7 of Kennady Lake will continue to be separated from Area 8, and the volume remaining in Kennady Lake will be kept constant by pumping any excess capacity in the Water Management Pond (WMP, Areas 3 and 5) to Lake N11, subject to the same discharge limits. Inflows to Area 8 will be limited to natural runoff from its adjacent watersheds (i.e., Ke, H, I and J watersheds).

Also during operations, several Kennady Lake tributaries will be diverted to the N watershed, and these diversions are considered in the water balance model. Lake A3 will be diverted to Lake N9, Lake B1 will be diverted to Lake N8, and lakes D2, D3, and E1 will be diverted to Lake N14.

9.12.1.1.2 Dewatering Discharges

Dewatering discharges to Area 8 and Lake N11 will be limited to prevent downstream erosion or geomorphological changes. Discharge from the Kennady Lake Area 8 outlet will enter the interlakes system, which constitutes a series of streams and lakes in the L and M watersheds before flowing on to Lake 410 and then Kirk Lake. Pumped discharge to Lake N11, including diverted watershed flow, will flow to Lake N1 before flowing on to Lake 410. No effects to the N watershed above Lake N11 are anticipated during dewatering.

Dyke A will isolate Kennady Lake Areas 2 to 7 from Area 8, reducing the upstream drainage area at the Area 8 outlet. Flow reductions will be offset by pumped dewatering discharges. The net result will be to reduce peak daily discharges at the Area 8 outlet by 10% (2-year flood) and 20% (100-year flood), with low flows increasing by up to 500% as dewatering discharges are sustained through the natural low flow season.

Effects on downstream waterbodies will be progressively reduced as more undisturbed areas contribute to runoff. The water balance results for the Lake L1 outlet show that peak daily discharges will decrease by up to 22% (2-year flood) and 37% (100-year flood), with low flows increasing by up to 425%. Water levels in Lake L1 will decrease by approximately 0.037 m (2-year flood) and mean monthly water levels will decrease by up to 0.007 m (June) and increase by up to 0.173 m (September) under open-water conditions. Because of the timing of the dewatering discharge and the later peak at the downstream Lake M1, the water balance results show that peak daily discharges will increase by up to 2% (2-year flood) and 3% (100-year flood), with low flows increasing by up to 260%. Water levels in Lake M1 will increase by approximately 0.008 m (2-year flood) and mean monthly water levels will decrease by up to 0.007 m (June) and increase by up to 0.228 m (September) under open-water conditions.

Dewatering discharges to Lake N11 will increase flows at the Lake N1 and Lake N11 outlets. The water balance results for the Lake N11 outlet show that peak daily discharges will be approximately equal to baseline, with low flows increasing by up to 167%. Peak water levels in Lake N11 will be approximately equal to baseline and mean monthly water levels will increase by 0.021 m to 0.164 m under open-water conditions. The water balance results for the Lake N1 outlet show that peak daily discharges will be approximately equal to baseline, with low flows increasing by up to 104%. Peak water levels in Lake N1 will be approximately equal to baseline and mean monthly water levels will increase by 0.008 m to 0.084 m under open-water conditions.

Lake 410 and downstream waterbodies will be affected by both the pumped discharges to Area 8 and Lake N11. The water balance results for the Lake 410 outlet show that peak daily discharges will increase by 1% (2-year flood) and 5% (100-year flood), with low flows increasing by up to 141%. Peak water levels in Lake 410 will increase by 0.005 m (2-year flood) and mean monthly water levels are expected to increase by 0.018 m to 0.169 m under open-water conditions. The water balance results for the Kirk Lake outlet show that peak daily discharges will increase by 8% (2-year flood) and 7% (100-year flood), the apparent inconsistency with Lake 410 explained by differences in timing of discharges, with low flows increasing by up to 48%. Peak water levels in Kirk

Lake will increase by 0.029 m (2-year flood) and mean monthly water levels will increase by 0.030 m to 0.061 m under open-water conditions.

No adverse effects on the stability of the shorelines of downstream lakes are anticipated during the dewatering, as limiting discharges to a 2-year flood water level, with the possible exception of Lake N11, will mean that the downstream lakes have the capacity to cope with the planned discharge rates. Natural armour at the Lake N11 outlet will provide protection against erosion at levels anticipated during operation.

9.12.1.1.3 Diversion of Upper Kennady Lake Watersheds

To reduce the amount of runoff from the upstream watersheds to Kennady Lake during dewatering and throughout the operation period, four upper tributary watersheds will be diverted to the adjacent N watershed during operation. These diversions will remain in place until the start of Kennady Lake refilling. The upper A watershed will be diverted to Lake N9 by constructing a saddle dyke at the Lake A3 outlet, and the B watershed will be diverted to Lake N8 by constructing a saddle dyke at the Lake B1 outlet. The D watershed will be diverted to Lake N14 by constructing a saddle dyke at the Lake D2 outlet, and the E watershed will also be diverted to Lake N14 by constructing a saddle dyke at the Lake E1 outlet.

The receiving waterbodies at Lake N9 and Lake N8 both flow into Lake N6, and from there to Lakes N5, N4, N3, N2, and N1. Mitigation at the Lake N8 outlet channel will be required to prevent erosion, so that lake was not modeled. The water balance results for the Lake N9 outlet show that peak daily discharges will increase by 3% (2-year flood) and 4% (100-year flood), with low flows increasing by up to 13%. Peak water levels in Lake N9 will increase by 0.014 m (2-year flood) and mean monthly water levels will increase by up to 0.016 m under open-water conditions. The water balance results for the Lake N6 outlet, which will receive flows from both the A and B watershed diversions, show that peak daily discharges will increase by 22% (2-year flood) and 18% (100-year flood), with low flows increasing by up to 22%. Peak water levels in Lake N6 will increase by 0.029 m (2-year flood) and mean monthly water levels will increase by up to 0.018 m under open-water conditions. The water balance results for the Lake N2 outlet show that peak daily discharges will increase by 10% (2-year flood) and 9% (100-year flood), with low flows increasing by up to 15%. Peak water levels in Lake N2 will increase by 0.062 m (2-year flood) and mean monthly water levels will increase by up to 0.045 m under open-water conditions.

The D and E watershed diversions both flow into Lake N14, and from there to Lakes N17, N16, N15, N11, and N1. Lake N1 is also affected by the A and B watershed diversions. Below Lake N1, Lake 410 and downstream watersheds are influenced by Kennady Lake Area 8 flows and effects are discussed in the next section. Mitigation at the Lake N14 outlet channel will be required to prevent erosion, so that lake was not modeled. The water balance results for the Lake N17 outlet show that peak daily discharges will increase by 54% (2-year flood) and 55% (100-year flood), with low flows increasing by up to 11%. Peak water levels in Lake N17 will increase by 0.071 m (2-year flood) and mean monthly water levels will increase by up to 0.043 m under open-water conditions. The water balance results for the Lake N16 outlet show that peak daily discharges will increase by 11% (2-year flood) and 15% (100-year flood), with low flows increasing by up to 5%. Peak water levels in Lake N16 will increase by 0.019 m (2-year flood) and mean monthly water levels will increase by up to 0.017 m under open-water conditions.

Lake N11 was also modeled as receiving an operational diversion of 3.1 Mm^3, which would be pumped from Kennady Lake in the early years of operation if water quality criteria are met. The water balance results for the Lake N11 outlet show that peak daily discharges will increase by 6% (2-year flood) and 12% (100-year flood), with low flows increasing by up to 29%. Peak water levels in Lake N11 will increase by 0.013 m (2-year flood) and mean monthly water levels will increase by up to 0.074 m under open-water conditions. The water balance results for the Lake N1 outlet show that peak daily discharges will increase by 8% (2-year flood) and 15% (100-year flood), with low flows increasing by up to 19%. Peak water levels in Lake N1 will increase by 0.026 m (2-year flood) and mean monthly water levels will increase by up to 0.075 m under open-water conditions. Increases in flows at the Lake N8 and Lake N14 outlets due to operational diversions will be mitigated to prevent erosion. Changes to the flow regime in downstream channels are not expected to cause adverse impacts on channel or bank stability or erosion, as flow increases will be small relative to the existing flow regime Flow and erosion monitoring (see Section 9.15) is recommended for locations where larger increases in flow rates are expected.

9.12.1.1.4 Operational Discharges

After dewatering has been completed, Kennady Lake will retain a volume of water in Areas 3 and 5 that will constitute the water management pond (WMP) for the remaining period of operation. The WMP will receive and contain all site contact water, which will then be either recycled to the process plant water supply system, or in the early years of operation discharged to Lake N11 if water quality criteria are met.

Dyke A will isolate Kennady Lake Areas 2 to 7 from Area 8, reducing the upstream drainage area at the Area 8 outlet. This will reduce peak daily discharges at the Area 8 outlet by 50% (2-year flood) and 45% (100-year flood), with low flows decreasing by up to 84% because of the reduction in upstream storage and drainage area. Effects on downstream waterbodies will be progressively reduced as more undisturbed areas contribute to runoff. The water balance results for the Lake L1 outlet show that peak daily discharges will decrease by up to 42% (2-year flood) and 46% (100-year flood), with low flows decreasing by up to 78%. Water levels in Lake L1 will decrease by approximately 0.077 m (2-year flood) and by 0.077 m to 0.136 m (mean monthly open-water conditions). The water balance results for the Lake M1 outlet show that peak daily discharges will decrease by up to 10% (2-year flood) and 9% (100-year flood), with low flows decreasing by up to 62%. Water levels in Lake M1 will decrease by approximately 0.041 m (2-year flood) and by 0.033 m to 0.161 m (mean monthly open-water conditions). A flow mitigation plan is being developed to mitigate any fish habitat losses due to reduced flows. The specifics of the mitigation plan have not been developed, but would focus on providing suitable spawning and rearing habitat for Arctic grayling (*Thymallus arcticus*).

Lake M1 flows into Lake 410, which also receives inflow from Lake N1, and then drains through watershed P to Kirk Lake. The inflow from Lake N1 will contribute increased flows due to the diversion of the upper Kennady Lake watersheds, as well as pumped discharges from Kennady Lake in early years when water quality criteria are met. The water balance results for the Lake 410 outlet show that peak daily discharges will decrease by up to 3% (2-year flood) and 9% (100-year flood), with low flows decreasing by up to 8%. Water levels in Lake 410 will increase by approximately 0.019 m (2-year flood) and by up to 0.033 m or decrease by up to 0.015 m (mean monthly open-water conditions). The water balance results for the Kirk Lake outlet show that changes to discharges during operations will be negligible.

No effects on outlet channel or bank stability during operations are expected, because flows will be reduced or subject to only small increases.

9.12.1.2 Closure

9.12.1.2.1 Assessment Approach

The effects to the hydrology of downstream streams and lakes resulting from construction and operation of the Project were determined by examining changes to the Kennady Lake and downstream watersheds from baseline conditions using a water balance model developed using GoldSim™ software.

The baseline water balance model described in Annex H was modified to model the effects on Kennady Lake during closure. The following changes were made to the water balance model:

- Areas 2, 3, 4, 5, 6, and 7 were isolated from Area 8 of Kennady Lake; and
- operational diversions of watersheds B, D, and E were removed and their runoff to Areas 3 to 7 of Kennady Lake was restored.

The refilling scenario that was modeled involved refilling Kennady Lake with runoff from the reconnected Kennady Lake watershed, with supplemental pumped diversion from Lake N11 to Area 3 to reduce the refill time.

The refilling approach involved pumping water from Lake N11 to refill Kennady Lake, while leaving enough flow to prevent adverse downstream effects in the N watershed (i.e., Lake N11). The diversion criterion was to allow flow to be pumped for refilling while maintaining a minimum Lake N11 discharge equal to the 5-year dry flow condition (refer to Section 9.7.4). The model was set up as follows:

- pumping occurred within a 6-week period centred in June and July;
- if the annual flow from Lake N11 was greater than the 5-year dry flow, the difference in volume was pumped over the 6-week period; and
- if the annual flow was less than the 5-year dry flow, no water was pumped.

During Closure, operational diversions of Lakes B1, D2, D3, and E1 will be decommissioned and removed, and only the Lake A3 diversion to the N9 watershed will be remain as a permanent feature of the landscape.

9.12.1.2.2 Temporary Diversions during Refilling

During refilling, the flow and water level regime in the Kennady Lake Area 8 outlet channel and downstream to the Lake M1 outlet will be the same as during operations. The diversion of water from Lake N11 to refill Kennady Lake will result in the reduction of monthly mean flows at the Lake N11 and Lake N1 outlets.

The water balance results for the Lake N11 outlet show that peak daily discharges will decrease by up to 6% (2-year flood) with no change to the 100-year flood, and low flows decreasing by up to 18%. Water levels in Lake N11 will decrease by approximately 0.013 m (2-year flood) and by up to 0.074 m (mean monthly open-water conditions). The water balance results for the Lake N1 outlet show that peak daily discharges will decrease by up to 3% (2-year flood) and 9% (100-year flood), with low flows decreasing by up to 11%. Water levels in Lake

N1 will decrease by approximately 0.005 m (2-year flood) and by up to 0.033 m (mean monthly open-water conditions).

A reduction in the monthly mean flows at the Lake 410 and Kirk Lake outlets will also be expected due to the combined effects of abstraction for lake refilling and the continued presence of Dyke A, preventing outflows from Kennady Lake Areas 2 to 7.

The water balance results for the Lake 410 outlet show that peak daily discharges will decrease by up to 5% (2-year flood) and 6% (100-year flood), with low flows decreasing by up to 21%. Water levels in Lake 410 will decrease by approximately 0.027 m (2-year flood) and by 0.006 m to 0.084 m (mean monthly open-water conditions). The water balance results for the Kirk Lake outlet show that peak daily discharges will decrease by up to 3% (2-year flood) and 2% (100-year flood), with low flows decreasing by up to 10%. Water levels in Kirk Lake will decrease by approximately 0.010 m (2-year flood) and by 0.005 m to 0.021 m (mean monthly open-water conditions).

No effects on outlet channel or bank stability during operations are expected, because flows will be reduced or subject to only small increases.

9.12.1.2.3 Permanent Diversion of the A Watershed

The effects of the permanent diversion of Lake A3 to Lake N9 during and beyond closure will be identical to those expected during operations. Effects on Lake N6 and downstream will be less than those expected during operations, due to the removal of the B watershed diversion.

9.12.1.2.4 Long-Term Hydrology

Watersheds downstream of Kennady Lake will be affected by the post closure hydrological regime of the Kennady Lake watershed, which includes a projected 3.8% increase in mean annual water yield and a slight increase in flood peak discharges. The effects of these changes to downstream watersheds will be approximately proportional, based on the ratio of the downstream watershed area to the Kennady Lake watershed area. The post-closure hydrological regimes of the N11 and upstream watersheds is expected to be identical to the baseline conditions, with the post-closure hydrological regime of the N1 watershed affected to a negligible extent by the permanent diversion of the A watershed.

9.12.2 Water Quality

Water quality in the waterbodies downstream of Kennady Lake will vary over time as the Project proceeds through construction and operation, and closure. Project development in the Kennady Lake watershed will result in changes to water quality in Lake N11, the interlakes system, which constitutes lakes in the L watershed and a chain of lakes in the M watershed, through to Lake 410, over the life of the Project and beyond.

During the construction and operations phase of the Project, there will be discharges from the Areas 3 and 5 (Water Management Pond [WMP]) to Lake N11. From the N watershed, water drains into Lake 410. During the initial dewatering in the construction phase, there will also be pumped discharge from Area 7 to Area 8. This water will continue to flow through the downstream lake system. This discharge will be comprised of natural, background waters, so there is no primary pathway for effects to water quality during this period.

During closure, Kennady Lake will be refilled. Three of the four diverted upper watersheds will be realigned so that they flow back to Kennady Lake, but Areas 3 through 7 will remain close-circuited. Supplemental flows from Lake N11 will be pumped to Kennady Lake to reduce the timeframe for refilling.

At the end of the closure phase, the refilled Kennady Lake will be reconnected to Area 8, and mine-affected waters will flow through Area 8 and continue through to the downstream lake system.

To estimate changes to water quality in Lake N11, the interlakes system and Lake 410, a dynamic, mass-balance water quality model was developed in GoldSim™. For this assessment, 1:2 year (median) wet conditions were assumed, which represents a close to average climate scenario. This scenario was selected for three reasons. First, as a lake-dominated system, water quality is less susceptible to inter-annual fluctuations in precipitation and temperature. Second, the majority of changes in water quality parameter concentration due to the Project are large in terms of relative change compared to baseline conditions (see Section 8.8.4.1), so natural variability would be a relatively small contributor to overall change. Finally, using mean conditions allows for a straightforward assessment of incremental changes due to the Project.

The primary pathway for effects to water quality in downstream waterbodies during construction and operations, and closure include the following Project water releases to Lake N11 and Area 8:

- Construction and operations
  - Dewatering of Kennady Lake to Lake N11 may change water quality in downstream waters.
- Closure (and post-closure)
  - seepage from mine rock and processed kimberlite storage repositories, and the open Tuzo Pit may change water quality in Kennady Lake, and affect water quality in downstream waterbodies
  - reclaimed project area may result in long-term changes to water quality in downstream watersheds
  - reconnection of Kennady Lake with Area 8 may change the water quality of downstream waterbodies

Throughout the construction, operations, and closure phases of the project, the downstream watershed was assumed to behave according to baseline conditions, with the following exceptions, which are included in the model:

- water will be discharged from the WMP to Lake N11 during the construction and operations phases;
- water will be drawn from Lake N11 to refill Kennady Lake during the closure phase;
- the flow path from Area 7 to Area 8 will be disconnected during the operations and closure phases; and
- the flow path from Area 7 to Area 8 will be reconnected after Kennady Lake has refilled (i.e., the post-closure period).

The water quality model predicted concentrations for a range of water quality parameters at all downstream nodes during the construction, operational, and closure phases. The model assumed fully mixed conditions within each waterbody at each daily time step.

The remainder of this section presents a summary of the effects of Project water releases on water quality in Lake N11 and Lake 410 during construction and operation, and closure.

9.12.2.1.1 Lake N11

Total Suspended Solids

During the dewatering and active pumping of water from Areas 3 and 5 in the construction and operations phase, TSS concentrations in Lake N11 will remain consistent with the range of background concentrations for Lake N11. Water to be initially pumped from Kennady Lake to Lake N11 will be surface waters (i.e., approximately the top 2 m), which will possess similar TSS concentrations to Lake N11.

Over the course of operations, water will be transferred from Areas 6 and 7 to the WMP. The waters in Area 6 may possess elevated TSS concentrations due to water levels being close to the lake bed following dewatering to Area 8. Where required, water transferred to the WMP will be treated by in-line flocculation to promote settling of suspended solids to reduce suspended solids, thereby maintaining TSS levels in the WMP at, or similar, to background concentrations. After the initial construction dewatering, pumped discharge during operations from Area 3 to Lake N11 will be required to meet specific water quality criteria, which will include TSS.

At closure, active pumping from Lake N11 to Areas 3 and 5 to supplement refilling will also be subject to specific water quality criteria, which will include TSS.

Total Dissolved Solids and Major Ions

During operations, concentrations of TDS in Lake N11 are projected to increase from 16 milligrams per litre (mg/L) to 46 mg/L due to input of water pumped from Areas 3 and 5 (WMP). During the first five years of pumping, concentrations in Lake N11 will be driven primarily by the volume of water being pumped from the WMP. 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 groundwater inflows. The result to Lake N11 is a fluctuation in water chemistry, with three distinct peaks in Year 3, Year 7, and Year 11. During the closure period, concentrations are predicted to return to background levels when pumping from the WMP ceases.

The major ionic contributors to TDS include major ions, such as calcium and chloride, which is consistent with the major ionic composition in the background water quality.

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.

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 and return to background conditions within the first few years of the closure period. 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.

Phosphorus

Concentrations of phosphorus are predicted to increase Lake N11 during the operation phase of the Project. With the cessation of pumped discharge from Area 3 to Lake N11, phosphorus concentrations are predicted to return to background concentrations. Increases in phosphorus in Lake N11 during dewatering of Kennady Lake and operational active discharge of the WMP from Areas 3 and 5 are due to phosphorus increases in the WMP. The predicted increases in the WMP are driven primarily by the release of phosphorus from the Fine PKC Facility and mine rock piles, with the modelling analysis being completed assuming free and complete contact between the runoff waters and the materials contained in the mine rock piles, the Coarse PK Pile and the Fine PKC Facility.

De Beers is currently evaluating a variety of environmental design features and mitigation measures to limit contact between site runoff waters and the fine PK located within the Fine PKC Facility and other potential sources. These environmental design features and mitigation measures include, for example:

- Promotion of permafrost development in the Fine PKC Facility.
- Use of low permeability cover material to limit infiltration into key areas, such as the Fine PKC Facility.

The effectiveness of these environmental design features and mitigation measures is uncertain and requires further analysis. Accordingly, the amount of phosphorus that may be released into the environment is uncertain at this time. As a result, potential effects related to phosphorus have not been presented and will not be available until such time as additional analysis is completed. This analysis will be provided to the Panel in 2011.

Trace Metals

During operations, active pumping from the WMP to Lake N11 will result in increased metals concentrations in Lake N11. There are several potential loading sources of trace metals to the WMP during the operations phase; these include geochemical loadings from mine rock and PK drainage, and groundwater inflows to the pits that are pumped to the WMP.

Of the 23 trace metals that were modelled for this assessment, 17 are predicted to increase in concentration during the operations phase, and they will generally follow the same temporal patterns as those for TDS and major ions. These include antimony, arsenic, barium, boron, chromium, iron, manganese, molybdenum, nickel, lead, selenium, silver, strontium, thallium, uranium, vanadium, and zinc. Depending on the primary loading source of these metals to the WMP, the characteristic peaks predicted to occur in Lake N11 may vary in time. Metals that are influenced more by groundwater inflows are predicted to have maximum peaks early in the operational phase (e.g., chromium). Metals that are more strongly influenced by geochemical loading sources (PK and mine rock leachate) are predicted to have the highest peaks near the end of the operational phase (e.g., strontium). Only chromium is predicted to exceed guidelines, which is predicted to occur in Years 2 and 4. Within three years of closure, metals concentrations return to background concentrations.

Six of the 23 modelled metals are predicted to have slight increases in concentration (i.e., less than 20% from background) due to pumped discharge from the WMP. These include aluminum, beryllium, cadmium, cobalt, copper, and mercury because their relative increases in the WMP are small during the operational phase. Of these metals, only cadmium is predicted to exceed guidelines, and these exceedances are observed in background conditions.

9.12.2.1.2 The Interlakes (L and M Watersheds)

Water quality in the interlakes (the chain of lakes within the L and M watersheds) will be attenuated from that described for Area 8 (Section 8.8). Project activities that could potentially affect water quality in Area 8 will carry through to the series of lakes within the L and M watersheds, because Area 8 forms one of the upstream sources of water flowing through this system. However, 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.

As noted in Section 8.8, post-closure model results suggest that there is a potential for phosphorus levels to increase in Kennady Lake, relative to pre-project conditions, as a result of runoff from the reclaimed mine site. The runoff waters pick up phosphorus from the mine rock, coarse PK and fine PK as they travel through the external structures, with the fine PK being the largest source of phosphorus. The projected increase could lead to a similar increase in phosphorus levels in the L and M watersheds. However, the modelling analysis was completed assuming free and complete contact between the runoff waters and the materials contained in the mine rock piles, the Coarse PK Pile and the Fine PKC Facility.

De Beers is currently evaluating a variety of environmental design features and mitigation measures to limit contact between site runoff waters and the fine PK located within the Fine PKC Facility and other potential sources. The effectiveness of these environmental design features and mitigation measures is, as previously noted, uncertain and requires further analysis. Accordingly, the amount of phosphorus that may be released into the environment is uncertain at this time. As a result, potential effects related to phosphorus have not been presented and will not be available until such time as additional analysis is completed. This analysis will be provided to the Panel in 2011.

9.12.2.1.3 Lake 410

Lake 410 is the ultimate receptor of loads from Kennady Lake during all phases of the project. During construction and operations, water discharged to Lake N11 will flow to Lake 410 via the N watershed. During closure and post-closure, water released from the refilled Kennady Lake will flow into Lake 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.

Total Suspended Solids

During construction, TSS concentrations in Area 8, and therefore the Interlakes and Lake 410 during the dewatering of Area 7, are expected to remain within the range of background concentrations. Water to be pumped from Area 7 and Area 8 will represent surface waters (i.e., approximately the top 2 m), which will possess typically low TSS concentrations. As the water level in Area 7 is drawn down to where wave action would interact with the fine lake bed sediments, and water quality does not meet discharge criteria, pumping to Area 8 will cease so that there is no additional source of TSS to Area 8 and downstream waters.

Total Dissolved Solids and Major Ions

Concentrations of TDS in Lake 410 are projected to increase from 16 mg/L to 27 mg/L during the operational phase due to input of water pumped from the WMP to Lake N11. 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 the post-closure period, when water is released to Area 8, TDS concentrations will increase slightly in Lake 410 from 16 mg/L to 27 mg/L. In the post-closure period, patterns of concentrations in Lake 410 will be similar to those predicted for Area 8, except that TDS will also be lower due to dilution and offset due to travel time. The long-term steady state TDS concentration will be approximately 27 mg/L. The main constituents of TDS during the two periods include calcium and chloride. This major ion dominance is consistent with the composition in background water quality.

The long-term results presented for the post-closure period reflect a reasonable degree of conservatism. Concentrations of TDS and major ions are predicted to remain elevated above background levels because loading of these constituents from the Fine PKC Facility, leaching from mine rock, and diffusion from PK material in the bottom of Hearne Pit are assumed to continue in the long-term.

Most major ions will follow a similar trend to TDS, reaching 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 the post-closure phase than in the operational phase.

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 remain above background conditions but below levels that would affect aquatic health.

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. Closure concentrations of nitrogen are predicted to decline to near-background concentrations, because there are no major loading sources of nitrogen (i.e., no pumped discharge to Lake N11 and Kennady Lake will still be isolated). In post-closure, nitrogen concentrations increase several years after the removal of dyke A and then decline to near background concentrations after blasting residue has been flushed from the mine rock and PK storage facilities.

Concentrations of nitrate and ammonia are predicted to remain below guidelines. Total nitrogen, for which there is no CCME guideline, is predicted to follow a similar pattern as ammonia, as it is predominantly comprised of nitrate and ammonia.

Phosphorus

Concentrations of phosphorus are predicted to increase in Lake 410 at the end of operations and several years into post-closure, after dyke A is removed. With the cessation of pumped discharge from the WMP to Lake N11, phosphorus concentrations are predicted to return to background concentrations. Increases in phosphorus in Lake 410 occur as a result of the geochemical phosphorus loadings to the WMP from runoff contact with the Fine PKC Facility and mine rock piles.

As previously noted, De Beers is currently evaluating a variety of environmental design features and mitigation measures to limit contact between site runoff waters and the fine PK located within the Fine PKC Facility and other potential sources. The effectiveness of these environmental design features and mitigation measures is uncertain and requires further analysis. Accordingly, the amount of phosphorus that may be released into the environment is uncertain at this time. As a result, potential effects related to phosphorus have not been presented and will not be available until such time as additional analysis is completed. This analysis will be provided to the Panel in 2011.

Trace Metals

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 associated with operations discharge to Lake N11 and in the early post-closure with the removal of dyke A. These metals are aluminum, barium, beryllium, cadmium, cobalt, copper, iron, lead, manganese, mercury, nickel, and zinc. These metals are predicted to return to near-background conditions in the long-term. Cadmium is the only metal predicted to exceed guidelines in Lake

410, and the guideline exceedance is due to naturally elevated background concentrations.

Three metals are predicted to increase between two and five times baseline concentrations during the operations and closure phases, but will not exceed guidelines. Concentrations will return to near-background conditions in the long-term. These metals are predicted to have similar trends to TDS and the major ions. These metals are chromium, selenium, and thallium.

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. Concentrations of these metals will mainly be driven by long-term loadings to Kennady Lake from runoff infiltration and contact with mine rock, coarse PK, and fine PK. Because these storage facilities will be present in the post-closure period, concentrations of these metals are predicted to increase after closure, and reach steady state conditions in Lake 410 within about 40 years. As these geochemical sources are the primary contributors of these metals, the majority of total concentrations will be in the dissolved form. None of these metals are predicted to exceed guidelines at any time.

The modelled predictions of metals that will be sourced primarily from geochemical sources were developed assuming full and free contact of all runoff waters with the materials located in the mine rock piles, Coarse PK Pile, and the Fine PKC Facility. In the case of the Fine PKC Facility, all of the runoff waters traveling over this facility were assumed to come into contact with the fine PK located at the base of the facility, and metals concentrations in Lake 410 in these waters reflect this contact. Processes that would modify the degree of contact between the fine PK and the runoff waters were not considered in the assessment, and would potentially result in lower long-term metals concentrations. These include natural and mitigative processes, such as the aggradation of permafrost and the application of cover (capping) material to limit infiltration (i.e., isolation mechanisms/processes).

9.12.3 Aquatic Health

Changes in water quality in Lake 410 are predicted from the dewatering of Kennady Lake during construction and operation, and from removal and reclamation of Project infrastructure during closure. The potential effect of these changes on aquatic health was evaluated considering both direct waterborne exposure and accumulation within fish tissues.

In regard to direct waterborne exposure, predicted maximum concentrations for all substances of potential concern (SOPCs) were lower than the corresponding chronic effects benchmark (CEB). In addition, predicted fish tissue concentrations were below tissue-based toxicological benchmarks for the substances considered in the assessment. As such, changes to concentrations of all substances considered in this assessment are predicted to result in negligible effects to aquatic health in Lake 410 and waterbodies located downstream of Lake 410.

9.12.4 Fish and Fish Habitat

Construction, operations, and closure of the Project may result in potential effects to fish and fish habitat downstream of Kennady Lake as a result of changes to the quantity and quality of water released from the Kennady Lake watershed.

9.12.4.1 Construction and Operations

9.12.4.1.1 Effects of Changes to the Flow Regime in Streams Downstream of Kennady Lake on Fish and Fish Habitat

As an initial conservative screening criterion, Project phases that result in a change in the flow regime greater than 15% from the pre-development flow regime were assessed in further detail.

The magnitude of the change in the flow regime in the N watershed and downstream of Kennady Lake to Lake 410 is greater than the 15% threshold during at least a portion of the year.

Changes to Fish Habitat Availability – Construction

During the construction phase, dewatering of Kennady Lake will result in augmented flows in the N watershed and in the L and M watersheds downstream of Kennady Lake, during the open-water period. Most of the pumping for dewatering will occur after the peak of the spring freshet has occurred, and peak discharges will remain similar to baseline conditions. No changes to fish habitat due to changes in channel morphology are predicted. As a result of environmental design features considered in the pumping plan and the natural attenuation of rapid changes in stream discharge provided by the lakes in the watershed, the risk of flushing or stranding fish during the start-up and shut-down of pumping will be negligible.

Changes to Fish Habitat Suitability – Construction

Spring (June) discharges in Stream N11 and N1 during dewatering will be similar to baseline conditions. Average June water velocities will be similar to baseline in wet years, higher in dry years, but still within the range of preferred water velocities for Arctic grayling spawning. As a result, the effect of dewatering on spawning Arctic grayling in Streams N11 and N1 is expected to be negligible. Spring discharge levels will be sustained in Streams N11 and N1 over the duration of the summer months during dewatering. Higher summer discharges are expected to have a minor effect on any young-of-the-year (YOY) Arctic grayling rearing in these streams. Suitable microhabitat in both Stream N11 and Stream N1 is expected to be available during dewatering, and therefore, the effect on Arctic grayling YOY is considered negligible.

Spring (June) discharge downstream of Kennady Lake during dewatering will be similar to the natural spring freshet; the predicted average water velocities under all hydrologic conditions are predicted to be similar, with slight increases during dry periods. Arctic grayling are likely to continue spawning successfully, and as a result, the effect of Kennady Lake dewatering on spawning Arctic grayling in streams downstream of Kennady Lake is expected to be negligible. The discharges in July and August under dewatering are similar and average velocities are similar to natural conditions and remain within the range of suitable velocities for the stream dwelling fish species found downstream of Kennady Lake. Given the small increases in average water velocities during dewatering, and given the availability of suitable low velocity habitat for small YOY Arctic grayling behind boulders and along stream margins is expected to remain abundant, the effect of dewatering on Arctic grayling YOY in streams downstream of Kennady Lake is expected to be negligible.

Changes to Fish Migrations – Construction

In the N watershed, higher summer flows may increase the window of opportunity for fish to pass upstream from Lake N1 to Lake N11. Fish species, such as Arctic grayling, longnose sucker, and lake trout, could potentially expand the duration of their movements between lakes in the N watershed to throughout the summer.

In the L and M watersheds, spring stream flows during dewatering are predicted to be similar to baseline conditions, with increased flows during dry periods when barriers would tend to form naturally. As a result, dewatering will not result in an increase in barriers to fish migration in the L and M watersheds and is likely to improve accessibility for spawning during dry years.

Changes to Lower Trophic Levels – Construction

The density and species composition of benthic invertebrate communities and invertebrate drift are not expected to change as a result of higher summer flows in streams in the N watershed or in the L and M watersheds downstream of Kennady Lake. This is due to environmental design features to minimize scour, small projected changes in mean current velocity, and the fact that low velocity microhabitat will continue to be abundant.

Changes to Fish Habitat Availability – Operations

Flows in the N watershed during operations are similar to the dewatering phase of the project for June and July. During operations, flows return to conditions similar to baseline in August and for the remainder of the open-water season. No changes are predicted to channel morphology. As a result of mitigation on ramp-up and ramp-down rates, effects to fish and fish habitat in the N watershed are considered to be negligible during operations.

Flow reductions in the L and M watersheds during operations will result in a reduction of the area of available habitat. Changes in the wetted width of the channel from baseline to operations vary by stream, but can be as much as 86% reduction from baseline. Reduction in wetted width is observed at both high and low flows and during all seasons at most sites. The change from baseline generally declines moving downstream, with the largest changes found in Streams K5 and L3.

Changes to Fish Habitat Suitability – Operations

Flows in the N watershed during operations are similar to the dewatering phase for June and July. During operations, flows return to conditions similar to baseline in August and for the remainder of the open-water season. Minimal changes to the suitability of habitat conditions were predicted for dewatering. Since the peak flows in June and July for operations are essentially the same as for dewatering, these conclusions would not change. Flows return to near baseline levels in August for the remainder of the open-water season and no measurable change in the suitability of fish habitat relative to baseline conditions is predicted.

The average velocity in the channels in the L and M watersheds remains almost unchanged from baseline for median flow conditions, with small reductions occurring at both wet and dry periods. The magnitude of loss of habitat due to a change in the suitability of habitat is likely small compared to the loss of available habitat due to reduction in wetted width of the channels.

Changes to Fish Migrations – Operations

Flows in the N watershed will be augmented during June and July, when most migrations would occur; as a result, improved fish movements can be expected in the N watershed during operations.

During operations, flows in June are substantially reduced in streams between Kennady Lake and Lake 410. The increase in frequency of barriers preventing spring spawning migrations of Arctic grayling is likely to have a negative impact on Arctic grayling populations between Area 8 and Lake 410. A similar but lesser impact is predicted for northern pike, as spring movements will be restricted; however, a majority of the spawning for this species is assumed to occur in the lakes and not in the streams.

Changes to Lower Trophic Levels – Operations

The projected mean current velocities in N watershed streams are either similar to those during dewatering, or lower and similar to baseline velocities. These velocities are within the expected range of natural variation, and therefore not predicted to adversely affect benthic invertebrate communities or invertebrate drift.

Stream flows in June, July, and August will decrease in the L and M watershed downstream of Area 8 during operations. The projected decreases in mean current velocity relative to baseline are small, and therefore, not expected to alter benthic invertebrate communities or invertebrate drift. Predicted changes in wetted width and water depth are not expected to alter benthic community composition and drift density; however, the amount of invertebrate biomass and total drift are expected to be reduced in proportion to the reduction in stream width and flow.

9.12.4.1.2 Effects of Changes in Water Levels in Lakes Downstream of Kennady Lake to Fish and Fish Habitat

Changes to Fish Habitat Availability – Construction

Small increases in lake water levels and lake areas are predicted compared to baseline conditions in the N watershed during the one-year dewatering period. Water levels in the L and M lakes downstream of Kennady Lake and Lake 410 will remain near spring freshet levels longer into the summer and early fall compared to baseline conditions. Raised water levels compared to baseline may benefit fish in these lakes during summer through increased littoral area and summer rearing habitat. Lake levels will return to baseline conditions before winter, and therefore, no changes to overwintering habitat are expected.

Changes to Fish Habitat Availability – Operations

During operations, water levels and lake areas in the N watershed are expected to increase compared to baseline due to pumping from the WMP, but will decrease compared to construction dewatering. As the changes in water level and lake area are small and within natural variability (i.e., lake levels during active pumping would not exceed the 2-year flood elevation), no effects on fish and fish habitat are expected.

Water levels and lake areas in lakes between Kennady Lake and Lake 410 are expected to decrease during operations compared to baseline. However, as the changes in water levels are small, the effects on fish habitat or benthic invertebrate communities in these lakes are expected to be minor. In Lake 410, the predicted changes are small and within natural variability; no effects on fish and fish habitat would be expected to occur.

9.12.4.1.3 Effects of Increased Nutrients on Fish and Fish Habitat

As a result of pumping from the WMP, nutrient concentrations in Lake N11 may be higher during the operation phase of the Project than under pre-development conditions. The assessment of potential effects related to nutrients will be submitted following the completion of additional analysis, which is expected to be completed in 2011.

9.12.4.2 Closure and Post-Closure

9.12.4.2.1 Effects of Changes to the Flow Regime in Streams Downstream of Kennady Lake on Fish and Fish Habitat

The flow regime in the N watershed will return to near baseline conditions during closure, with small seasonal reductions in flow due to pumping for Kennady Lake refilling. The flow reductions at the outlet of N11 are small, with the general flow timing and magnitude similar to baseline conditions. At the outlet of Lake N1, flows return effectively to baseline conditions.

During closure, flows downstream of Kennady Lake to Lake 410 will be similar to flows during operations throughout the refilling phase. The conclusions presented for operations would also apply to the closure period for the streams between Kennady Lake and Lake 410.

At post-closure, flows return to near baseline conditions throughout the N, L and M watersheds. As a result, additional assessment of flow changes in the N, L and M watersheds during closure and port-closure was not required, and the effects to fish habitat are considered to be negligible.

Changes to Fish Habitat

The closure flow regime for the L and M watersheds is the same as assessed for project operations for fish habitat availability, fish habitat suitability, and changes to fish migrations; therefore, the conclusions from operations apply.

Changes to Lower Trophic Levels

At closure, flows in the N watershed will return to close to near baseline levels and effects on lower trophic communities will cease. Lower trophic communities are expected to return to those characteristic of baseline conditions in about five years. Flows in the L and M watersheds will be the same as during operations and the conclusions from operations apply.

At post-closure, flows downstream of Kennady Lake will return to near baseline levels, likely resulting in recolonization of the re-wetted stream areas by benthic invertebrates from upstream areas and the existing stream channel, by drift and movement of invertebrates on stream substrates. Recolonization is expected to occur quickly, mostly during the first two years of re-established flows.

9.12.4.2.2 Effects of Changes in Water Levels in Lakes Downstream of Kennady Lake to Fish and Fish Habitat

During closure, small decreases in lake water levels and lake areas are predicted in Lake N11 and Lake N1 compared to baseline. However, as the changes are small compared to baseline, they are unlikely to have a substantive effect on fish habitat or benthic invertebrate communities in these lakes.

During closure, the lake levels, and associated effects on fish and fish habitat, in the L and M lakes downstream of Kennady Lake are the same as for operations. During post-closure, water levels and lake areas in lakes between Kennady Lake and Lake 410 will show a slight decrease compared to baseline, due to the permanent diversion of the Lake A3 watershed into the N watershed; however, as the changes are small compared to baseline, and flows and lake levels expected to increase compared to operations, effects to fish and fish habitat would be negligible.

9.12.4.2.3 Effects of Increased Nutrients on Fish and Fish Habitat

Water quality model results indicate that nutrient levels in downstream systems through to Lake 410 may be higher during certain phases of the Project than they are under existing conditions. The assessment of potential effects related to nutrients will be submitted following the completion of additional analysis, which is expected to be completed in 2011.

9.12.4.2.4 Effects of Changes in Aquatic Health on Fish and Fish Habitat

Based on the aquatic health assessment (Section 9.12.3), predicted changes to concentrations of all substances considered in waterbodies downstream of Kennady Lake, including Lake N11, are projected to result in negligible effects to fish tissue quality and, by association, aquatic health; as a result, no effects to fish populations or communities would occur from changes in aquatic health.

9.12.4.2.5 Long-term Effects to Fish and Fish Habitat in the N Watershed and Downstream of Kennady Lake

In the N watershed, flows and water levels will return to near baseline conditions, as will water quality in the affected lakes. As a result, fish and fish habitat is expected to similarly return to a baseline state over time.

The aquatic ecosystem, including fish populations, downstream of Kennady Lake may differ from its current state. Although flows and water levels between Kennady Lake and Lake 410 will return to near baseline conditions, water quality model results indicate that nutrient levels in downstream systems through to Lake 410 may be higher than under existing conditions. The assessment of potential effects related to nutrients will be submitted following the completion of additional analysis, which is expected to be completed in 2011.

9.13 RESIDUAL IMPACT CLASSIFICATION

Gahcho Kué Project (Project) activities will result in changes to the hydrology, water quality, and aquatic communities downstream of Kennady Lake. As summarized in Section 9.13, these changes are projected to occur during construction and operation, and closure, which will continue beyond closure. To assess the environmental significance of the projected changes, a residual impact classification system was developed and applied to VCs considered in the key line of inquiry. For this key line of inquiry, the VCs for which potential effects are being classified include water quality and specific fish species (i.e., Arctic grayling, lake trout, and northern pike).

Although wildlife and human health are also VCs that are briefly discussed in this key line of inquiry, potential effects to wildlife and human health have not been classified in this section of the EIS. Classification of potential effects to wildlife and human health requires the consideration of all pathways by which effects to wildlife and human health can occur. These pathways include the inhalation of air and the consumption of terrestrial-based foods, the quality of which may potentially be affected by the Project. These pathways are not the subject of this key line of inquiry and are not discussed herein. As such, a summary of potential effects to wildlife and human health has been provided in this section of the EIS (i.e., Section 9.11), but a classification of the potential effects has not.

In the EIS, the term “effect”, used in the effects analyses and residual effects summary, is regarded as an “impact” in the residual impact classification. Therefore, in the residual impact classification for this section, all residual effects are discussed and classified in terms of impacts to downstream waterbodies.

The residual impact classification focused on VCs, because they represent the components of the aquatic ecosystems in downstream waterbodies that are of greatest interest or concern (as outlined in the Terms of Reference). Projected impacts to VCs also incorporate, or account for, changes to other important key components, such as groundwater quality, groundwater flow, hydrology, fish habitat, and aquatic life occupying lower trophic levels in the ecosystem (e.g., aquatic plants, plankton, zooplankton, benthic invertebrates, forage fish species). Notable changes in water flows, for example, will contribute to changes in water quality, and the quantity and quality of habitat available for Arctic grayling, lake trout, or northern pike. The classification of impacts to water quality and the three valued fish species, therefore, incorporates the classification of impacts to hydrology and key components, according to their influence on the VCs.

The classification was carried out on residual impacts (i.e., impacts with environmental design features and mitigation considered). The environmental design features and mitigation were incorporated in the engineering design or the management plans, and were incorporated in the Project as it evolved (i.e., as the engineers received input from various scientists and traditional knowledge holders, the design evolved).

9.13.1 Methods

The pathways to effects to VCs and assessment endpoints were analyzed in Section 9.6. The pathways that were identified as primary pathways (i.e., likely to result in a measurable environmental change that could contribute to residual effects on a VC relative to baseline or guideline values) were considered and aggregated under their respective biophysical environment (i.e., hydrology, water quality, aquatic health, or fish) in effects statements (e.g., changes to water quality as a result of Project activities during construction and operations). These effects statements set the direction for the residual effects analysis (Sections 9.7 to 9.11), which considered the key Project activities (i.e., diversion of upper Kennady Lake watershed to the N watershed, dewatering of Kennady Lake to downstream waterbodies, operational water management, refilling of Kennady Lake, etc.) during the phases of the Project (i.e., construction and operations, or closure), to determine the extent of the change to the biophysical environment, and ultimately to the VCs.

The objective of each effects analysis was to determine how Project activities would affect an individual measurement endpoint or a given set of measurement endpoints for a given biophysical environment, e.g., changes to habitat availability to Arctic grayling from flow changes during operations, or nutrient concentrations downstream of Kennady Lake during post-closure. The measurement endpoints, in turn, are connected to the broader-scale assessment endpoints, which represent the ultimate properties of the system that are of interest or concern.

The residual impact classification focuses on the assessment endpoints, because these are statements of what is most important to future generations. The four assessment endpoints relevant to the Key Line of Inquiry: Water Quality and Fish Downstream of Kennady Lake, as outlined in Section 9.5, include the following:

- suitability of water quality to support a viable aquatic ecosystem downstream of Kennady Lake;
- persistence and abundance of desired population(s) of Arctic grayling downstream of Kennady Lake;
- persistence and abundance of desired population(s) of lake trout downstream of Kennady Lake; and

- persistence and abundance of desired population(s) of northern pike downstream of Kennady Lake.

The effects analyses (Sections 9.7 to 9.11) and residual effects summary (Section 9.12) presented the incremental changes from the Project on water quality and fish, including the key components of these VCs. Incremental effects represent the Project-specific changes relative to baseline conditions (i.e., 1996 and 2010), through construction and operation of the Project (and into the future, i.e., closure and beyond closure). For this key line of inquiry, the primary focus of Project-specific effects during each Project phase is to lakes and streams downstream of Kennady Lake watershed. Therefore, the spatial boundary of the assessment includes the regional study area for the Project. This approach was also adopted to achieve consistency in the scales used to evaluate geographic extent across the key lines of inquiry that focus on aquatic ecosystems.

Residual impacts to each assessment endpoint were classified based on the results of the effects analyses and their linkage to these endpoints. For example, the results of the water quality and aquatic health completed in Sections 9.8 and 9.9 were used to classify residual impacts to the first assessment endpoint (i.e., suitability of water quality to support a viable aquatic ecosystem). Similarly, the results of the analysis of effects to fish and fish habitat, described in Section 9.10, was used to classify residual impacts to the abundance and persistence of desired population(s) of key fish species .

The residual impact classification describes the residual impacts of the Project on the water quality and fish downstream of Kennady Lake using a scale of common words (rather than numbers and units). The use of common words or criteria is a requirement in the Terms of Reference for the Project. The following criteria are used to describe impacts of the Project on the VCs:

- direction;
- magnitude;
- geographic extent;
- duration;
- reversibility;
- frequency;
- likelihood; and
- ecological context.

Generic definitions for each of the residual impact criteria are provided in Section 6.7.2.

The predicted scales for the impact criteria are also considered in the impact classification. The scales used to assign values (e.g., high, moderate, or low) to each of the classification criteria are outlined in Tables 9.13-1 and 9.13-2. The rating system for magnitude is presented separately in Table 9.13-2, because the scales used to define magnitude are specific to each assessment endpoint, whereas the scales defined for the remaining classification criteria are common across all five assessment endpoints. Direction, duration, reversibility, frequency, likelihood, and ecological context are rated on the highest magnitude impact predicted for each time period. The results from this impact classification are then used to determine environmental significance of impacts from the Project on water quality and fish (Section 9.13.2).

To provide transparency in the EIS, the definitions for these scales were ecologically or logically based on aquatic environments. Although professional judgment is inevitable in some cases, a strong effort was made to classify impacts using scientific principles and supporting evidence. The scale for the residual impact criteria for classifying effects from the Project are specifically defined for water quality and fish, and definitions for each criterion are provided in Table 9.14-1.

With respect to potential cumulative effects, existing and other planned projects in the NWT are located outside of the Kennady Lake and Lake 410 watersheds, so there is no opportunity for the releases of those projects to interact with those of the Project within these watersheds. Consequently, there is no potential for cumulative effects to fish or water quality downstream of Kennady Lake to Lake 410.

9.13.1.1 Classification Time Periods

Due to the overall nature of how the Project will affect downstream waterbodies, residual impacts were classified for two specific time periods. The first period extended from the initiation of the Project to 100 years later. This time frame incorporated the construction and operations, and closure phases of the Project, and the expected recovery period in which the Kennady Lake aquatic ecosystem would be in a stable and productive state (i.e., taking into account the duration of the Project during construction, operations, and closure, and recovery during post-closure). The classification of residual impacts within this period was conservatively based on the most negative impact over the 100-year period, rather than the end of this period, when impacts would reflect recovery.

The second period focused on future conditions after 100 years from Project initiation. Rather than classifying one snapshot in time, the classification in this period focused on the ability of the affected ecosystems to recover to a steady state.

Table 9.13-1 Definitions of Scales for Seven of the Eight Criteria Used in the Residual Impact Classification

Direction	Geographic Extent	Duration	Frequency	Reversibility[(a)]	Likelihood	Ecological Context
Neutral: no measurable change to a VC from existing conditions **Negative:** the Project will result in an adverse effect to a VC **Positive:** the Project will result in a beneficial effect to a VC	**Local:** projected impact is confined to watersheds upstream of the outlet of Lake 410; small scale direct and indirect impacts from the Project **Regional:** projected impact extends beyond Lake 410 to the inlet to Aylmer Lake; the predicted maximum spatial extent of combined direct and indirect impacts from the Project that exceed local scale effects **Beyond Regional:** projected impact extends into Aylmer Lake and beyond; cumulative local and regional impacts from the Project and other developments extend beyond the regional scale	**Short-term:** projected impact is reversible by the end of construction **Medium-term:** projected impact is reversible upon completion of refilling Kennady Lake (i.e., end of closure) **Long-term:** projected impact is reversible some time after the refilling of Kennady Lake is complete (i.e., beyond closure) or not reversible	**Isolated:** projected impact occurs once, with an associated short-term duration (i.e., is confined to a specific discrete period) **Periodic:** projected impact occurs intermittently, but repeatedly over the assessment period **Continuous:** projected impact occurs continually	**Reversible:** projected impact will not result in a permanent change from existing conditions or conditions compared to 'similar'[(a)] environments not influenced by the Project **Not reversible:** projected impact is not reversible (i.e., duration of impact is unknown or permanent)	**Unlikely:** projected impact is likely to occur less than one in 100 years **Possible:** projected impact will have at least one chance of occurring in the next 100 years **Likely:** projected impact will have at least one chance of occurring in the next 10 years **Highly Likely:** Projected impact is very probable (100% chance) within a year	**High:** projected impact relates to a highly valued component of the aquatic ecosystem

(a) "similar" implies a stream or waterbody that is similar in general characteristics and location to that affected by the Project.

Table 9.13-2 Definitions Used to Rate the Magnitude of Projected Residual Impacts

Scale	Assessment Endpoint			
	Suitability of Water Quality to Support a Viable Aquatic Ecosystem	Abundance and Persistence of Desired Population(s) of Key Fish Species		
		Abundance of Lake Trout	Abundance of Arctic Grayling	Abundance of Northern Pike
Negligible	results of the aquatic health and productivity assessments indicate that no measurable change to the overall health of the aquatic ecosystem will occur	no measurable change to the abundance of lake trout, relative to existing conditions	no measurable change to the abundance of Arctic grayling, relative to existing conditions	no measurable change to the abundance of northern pike, relative to existing conditions
Low	results of the aquatic health and productivity assessments indicate that a measurable change to the aquatic community may occur, but no notable changes in community structure or overall health of the system are expected	no measurable change in the abundance of lake trout, but population statistics (such as, age-class structure) may differ from existing conditions	no measurable change in the abundance of Arctic grayling, but population statistics (such as, age-class structure) may differ from existing conditions	no measurable change in the abundance of northern pike, but population statistics (such as, age-class structure) may differ from existing conditions
Moderate	results of the aquatic health and productivity assessments indicate that a measurable change to the aquatic community, including a notable shift in community structure may occur, but no effect to the overall health of the system is expected	projected decrease in abundance of lake trout; however, the species is expected to persist	projected decrease in abundance of Arctic grayling; however, the species is expected to persist	projected decrease in abundance of northern pike; however, the species is expected to persist
High	results of the aquatic health and productivity assessments conclude that the overall health of the aquatic ecosystem could be affected	projected decrease in the abundance of lake trout is sufficient to result in a complete loss of the species in question (i.e., will not persist)	projected decrease in the abundance of Arctic grayling is sufficient to result in a complete loss of the species in question (i.e., will not persist)	projected decrease in the abundance of northern pike is sufficient to result in a complete loss of the species in question (i.e., will not persist)

[a] - = not applicable.

9.13.2 Results

9.13.2.1 Suitability of Water Quality to Support Aquatic Life

In Section 9.8 and 9.9, the effects of the Project on water quality and aquatic health in waterbodies downstream of Kennady Lake resulting from the pathways of diversions, dewatering, operational water management and refilling activities were assessed for construction and operations, and for closure (including post-closure). The residual effects for the effects analysis were summarized in Section 9.12. As noted in Sections 9.8 and 9.12, the potential effects of changes to nutrient levels have not been presented. They are the subject of continuing evaluation and are therefore not included at this time in the classification of potential effects for this assessment endpoint. Once the continued analysis is complete, the classification results outlined herein will be updated as appropriate and required.

Potential effects to aquatic health were evaluated for downstream waterbodies for construction, operations, and closure based on predicted changes in water quality (Section 9.8). For the direct waterborne exposure assessment, total dissolved solids (TDS) and ten other substances of potential concern (SOPC) were identified. With respect to predicted TDS concentrations, adverse effects to fish and aquatic invertebrates are not expected. Maximum concentrations of all SOPCs in Lake N11 and Lake 410 are predicted to remain below the Chronic Effects Benchmark (CEB) identified for each substance. For the indirect exposure pathway, predicted fish tissue concentrations in Lake N11 and Lake 410 are below toxicological benchmarks for all parameters considered in the assessment. As a result, changes to water quality in waterbodies downstream of Kennady Lake are predicted to result in negligible effects to aquatic health.

Based on the above, projected impacts of the Project on the suitability of water downstream of Kennady Lake to support a viable and self-sustaining aquatic ecosystem were rated as negative in direction and negligible in magnitude during both time periods, because negligible effects to aquatic health are projected to occur. However, this classification of impacts does not account for potential changes in nutrient levels and is subject to re-evaluation once further predictive modelling of nutrient concentrations and the associated effects assessment is complete.

9.13.2.2 Residual Impacts to the Abundance and Persistence of Desired Population(s) of Key Fish Species

In Section 9.10, the effects of the Project on fish and fish habitat downstream of Kennady Lake as a result of changes to the quantity and quality of water released from the Kennady Lake watershed were assessed for construction and operations and for closure and post-closure. The residual effects for each assessed pathway were summarized in Section 9.12. As noted in Sections 9.10 and 9.12, the potential effects of changes to nutrient levels in Kennady Lake have not been presented. They are the subject of continuing evaluation and are therefore not included at this time in the classification of potential effects for this assessment endpoint. Once the continued analysis is complete, the classification results outlined herein will be updated as appropriate and required.

The flow regime in the N watershed and downstream of Kennady Lake to Lake 410 will be altered during construction and operations due to Project activities. Alterations to flow regime can cause changes to fish habitat availability, fish habitat suitability, fish migration, and lower trophic levels.

Dewatering of Kennady Lake in construction will result in augmented flows in the N watershed and downstream of Kennady Lake to Lake 410, during the summer months, and extending into October. Small increases in lake water levels and lake areas are also predicted compared to baseline conditions in these watersheds and downstream. Lake levels will remain near spring freshet levels throughout the summer and early fall. Changes to channel morphology or shoreline stability are not expected.

During operations, continued pumped discharge from the WMP to Lake N11 will result in flows in the N watershed that are similar to flows from dewatering during the construction phase of the Project for June and July and return to conditions similar to baseline in August and for the remainder of the open-water season. Small increases in water levels and lake areas in the N watershed are expected compared to baseline. Reductions in flows in the L and M watersheds during operations will result in a reduction of the area of available habitat. Small decreases in water levels and lake areas in lakes between Kennady Lake and Lake 410 are expected during operations compared to baseline.

At closure, the flow regime in the N watershed will return to near baseline conditions, with small seasonal reductions in flow while water is pumped to Kennady Lake during refilling. Small decreases in lake water levels and lake areas are predicted in the N watershed compared to baseline. The same flow regime from operations will continue through the refilling phase downstream of

Kennady Lake to Lake 410. At post-closure, flows return to near baseline conditions throughout the N, L, and M watersheds.

From the pathways assessed in Section 9.10, the classification of projected impacts of the Project on the abundance and persistence of the three valued fish species, namely Arctic grayling, lake trout and, northern pike, is outlined in more detail below. As described above, the projected impacts on the abundance and persistence of the three key fish species were classified over two time periods: from the start of the Project to 100 years later; and after the first 100 years.

9.13.2.2.1 Arctic Grayling

During the first 100 year time period, the projected impacts on the abundance and persistence of Arctic grayling are negative in direction, moderate in magnitude, local in geographic extent, medium-term in duration, periodic in nature, reversible, likely to occur, and high ecological context (Table 9.13-3). During Kennady Lake dewatering, effects on Arctic grayling populations in the N watershed and downstream of Kennady Lake from the Project are generally expected to be negligible (i.e., not expected to result in a measurable change to the abundance of Arctic grayling, relative to existing conditions). Flows resulting from dewatering discharge to Lake N11 and Area 8 will be managed to remain similar to 2-year flood flows, so changes to habitat suitability for migration and spawning of adult Arctic grayling are not predicted; the habitat available is expected to remain within the range of naturally occurring conditions. The risk of flushing or stranding Arctic grayling, including YOY, during the start-up and shut-down of pumping is considered to be negligible, due to the environmental design features (i.e., ramp-up and ramp-down) in the pumping plan and the natural attenuation of rapid changes in stream discharge provided by lakes in the watershed. The higher summer discharges are also expected to have a negligible effect on Arctic grayling YOY rearing in these streams due to the continued availability of suitable low velocity habitat for small YOY Arctic grayling behind boulders and along stream margins. Food availability through benthic drift is not expected to be affected.

There may also be some benefits to Arctic grayling during dewatering, as the higher summer flows may allow Arctic grayling to expand the duration of their movements between lakes in the N watershed to throughout the summer and improve accessibility in the L and M watersheds for spawning during dry years. The slightly raised water levels in lakes may also benefit Arctic grayling in these lakes during summer through increased littoral area and summer rearing habitat.

Table 9.13-3 Residual Impact Classification of Projected Impacts to Water Quality and Fish Downstream of Kennady Lake

Assessment Endpoint	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Likelihood	Ecological Context
Suitability of water in downstream waterbodies to support a viable and self-sustaining aquatic ecosystem								
Construction to 100 years from Project start	negative	negligible	-	-	-	-	-	-
Beyond 100 years from Project start	negative	negligible	-	-	-	-	-	-
Abundance and persistence of Arctic grayling in downstream waterbodies								
Construction to 100 years from Project start	negative	moderate[a]	local	medium-term	periodic	reversible	likely	high
Beyond 100 years from Project start	negative	negligible	-	-	-	-	-	-
Abundance and persistence of lake trout in downstream waterbodies								
Construction to 100 years from Project start	negative	low	local	medium-term	periodic	reversible	likely	high
Beyond 100 years from Project start	negative	negligible	-	-	-	-	-	-
Abundance and persistence of Northern pike in downstream waterbodies								
Construction to 100 years from Project start	negative	low	local	medium-term	periodic	reversible	likely	high
Beyond 100 years from Project start	neutral	negligible	-	-	-	-	-	-

- = not applicable.

[a] based on the highest magnitude effect predicted through to completion of Kennady Lake refilling and assumes no mitigation for downstream flows.

During operations and closure, the effects of the Project on Arctic grayling in the L and M watersheds downstream of Kennady Lake are considered to be moderate (i.e., there may be a decrease in the abundance of Arctic grayling resulting from changes due to the Project). Effects to Arctic grayling from changes in flows in the N watershed are expected to be negligible.

Flow reductions during operations in the L and M watersheds downstream of Kennady Lake will result in a reduction of the area of available habitat at both high and low flows and during all seasons. Flows in June are substantially reduced, which is expected to increase the frequency of barriers preventing spring spawning migrations of Arctic grayling; this is likely to have a negative impact on Arctic grayling populations between Area 8 and Lake 410. The flow reductions also cause decreases in stream depths, which may become a limiting factor in the availability of suitable habitat under dry conditions in Stream K5. The amount of invertebrate biomass and total drift are expected to be reduced in proportion to the reduction in stream width and flow, which may also affect Arctic grayling feeding in streams downstream of Kennady Lake. Lake water levels are also expected to decrease, but as the changes are small, the effects on Arctic grayling in these lakes are expected to be minor.

During the second time period, the projected impacts on the abundance and persistence of Arctic grayling were rated as negative in direction and negligible in magnitude, because the flow regime is expected to return to near baseline conditions and potential effects to aquatic health are expected to be negligible (as outlined in Section 9.13.2.1). However, this classification of impacts does not account for potential changes in nutrient levels and is subject to re-evaluation once further predictive modelling of nutrient concentrations and the associated effects assessment is complete.

9.13.2.2.2 Lake Trout

Projected impacts to the abundance and persistence of lake trout during the first time period are negative in direction, low in magnitude, local in geographic extent, medium-term in duration, periodic, and reversible (Table 9.13-3). Lake trout is primarily a lake species and is the top predator fish species in a number of lakes between Kennady Lake and Lake 410, and in the N watershed. During construction and operations, small changes in lake water levels in the N watershed and in lakes downstream of Kennady Lake are unlikely to affect lake trout populations. The changes in water levels are small (i.e., less than 35 cm) and occur primarily during summer months. Lake trout spawning habitat will not be affected, as no erosion or sedimentation is expected along lake shorelines. Lake trout have been documented to move between lakes in the spring, likely to feed, and the ability for fish to move between the lakes downstream of Kennady

Lake during operations and closure will be reduced due to the reduction in stream flows.

During the second time period, the projected impacts on the abundance and persistence of lake trout were rated as negative in direction and negligible in magnitude, because stream flows and lake water levels are expected to return to near baseline conditions and potential effects to aquatic health are expected to be negligible (as outlined in Section 9.13.2.1). However, this classification of impacts does not account for potential changes in nutrient levels and is subject to re-evaluation once further predictive modelling of nutrient concentrations and the associated effects assessment is complete.

9.13.2.2.3 Northern Pike

During the first 100 year time period, the projected impacts on the abundance and persistence of northern pike were rated as negative in direction, low in magnitude, local in geographic extent, medium-term in duration, periodic and reversible (Table 9.14-3). Northern pike have not been captured during baseline sampling in the upper N watershed, and are therefore absent or found at very low levels of abundance. As a result, the discussion below is focused on the L and M watersheds downstream of Kennady Lake.

Northern pike have been captured in the lakes and streams downstream of Kennady Lake, but at a lower abundance than Arctic grayling; their abundance in the watershed may be limited by the availability of suitable spawning habitat, as spawning habitat for northern pike downstream of Kennady Lake is limited to small patches of aquatic vegetation around the periphery of downstream lakes and in flooded riparian areas of connecting streams. Northern pike have been captured in the streams, likely moving between lakes for feeding or possibly for spawning.

During Kennady Lake dewatering, effects from the Project on northern pike populations downstream of Kennady Lake are expected to be negligible. Due to the environmental design features in the pumping plan (i.e., the timing of start-up coinciding with the decline in the spring freshet and the magnitude limited to the 2-year flood flow) and the natural attenuation of rapid changes in stream discharge provided by lakes in the watershed, the risk of flushing or stranding northern pike during the start-up and shut-down of pumping is considered to be negligible. Changes to habitat suitability for migration and spawning of adult northern pike are not predicted during dewatering, as the habitat available would be within the range of naturally occurring conditions and typically more habitat would be available for a longer duration. Flow changes during dewatering are not expected to prevent northern pike from moving through streams downstream of Kennady Lake, and may improve accessibility in the L and M watersheds for spawning if pumping occurred during a dry year. Slightly higher water levels are expected in lakes downstream of Kennady Lake during summer. The raised water levels may benefit northern pike in these lakes through increased littoral area and summer rearing habitat. Spawning habitat in lakes is unlikely to be affected, as the increases in lake levels occur primarily during summer, with the lakes remain at spring freshet levels later into the open water season.

During operations, the effects of the Project on northern pike are considered to be low. Flow reductions during operations in the L and M watersheds downstream of Kennady Lake will result in a reduction of the area of available habitat for all fish species, including northern pike. Although most of the spawning downstream of Kennady Lake likely occurs in the flooded shorelines of the L and M lakes, the substantial reduction of flows in June may affect northern pike spawning movements between lakes and also reduce the availability of stream spawning habitat. Lake water levels are also expected to decrease, but as the changes are small, the effects on northern pike in these lakes are expected to be minor.

During the second time period, the projected impacts on the abundance and persistence of northern pike were rated as neutral in direction and negligible in magnitude (Table 9.14-3), as the flow regime is expected to return to near baseline conditions and potential effects to aquatic health are expected to be negligible (as outlined in Section 9.13.2.1). However, this classification of impacts does not account for potential changes in nutrient levels and is subject to re-evaluation once further predictive modelling of nutrient concentrations and the associated effects assessment is complete.

9.13.3 Environmental Significance

Ultimately, significance will be determined by the Panel. In the Mackenzie Valley Environmental Impact Review Board (MVEIRB 2006) reference bulletin on interpretation of key terminology, the term “significant” means an impact that is, in the view of the MVEIRB, important to its decision. To determine significance, the MVEIRB (2006) “will use its own values and principles of good EIA. It will use its combined experience and knowledge”. Presumably the determination of significance will be made in a similar manner by the Gahcho Kué Panel. However, the Terms of Reference require that De Beers provide its views on the significance of impacts. To that end, projected impacts were evaluated to determine if they were environmentally significant.

The evaluation of significance for this key line of inquiry considers the entire set of primary pathways that influence a particular assessment endpoint, but does not assign significance to each pathway. The relative contribution of each pathway is used to determine the significance of the Project on assessment endpoints, which represents a weight of evidence approach. For example, a pathway with a high magnitude, large geographic extent, and long-term duration would be given more weight in determining significance than pathways with smaller scale effects. The relative impact from each pathway is discussed; however, pathways that are predicted to have the greatest influences on changes to assessment endpoints would be assumed to contribute to most to the determination of environmental significance.

Environmental significance is used here to identify projected impacts that have sufficient magnitude, duration, and/or geographic extent that they could lead to fundamental changes to the VCs. For example, significance is determined by the risk to the persistence of fish populations within the aquatic ecosystem. The following definitions are used for assessing the significance of effects on the protection of surface water quality for aquatic and terrestrial ecosystems, and human use are as follows.

Not significant – impacts are measureable at the local scale, and may be strong enough to be detectable at the regional scale.

Significant – impacts are measurable at the regional scale and are irreversible. A number of high magnitude and irreversible effects (i.e., pathways) at the regional scale would be significant.

The following definitions are used for assessing the significance of impacts on the persistence of VC fish populations, and the associated continued opportunity for traditional and non-traditional use of these VCs.

Not significant – impacts are measurable at the individual level, and strong enough to be detectable at the population level, but are not likely to decrease resilience and increase the risk to population persistence.

Significant – impacts are measurable at the population level and likely to decrease resilience and increase the risk to population persistence. A high magnitude and irreversible impact at the population level would be significant.

Suitability of water downstream of the Kennady Lake watershed to support a viable and self-sustaining aquatic ecosystem

During the first 100 year time period, the projected impacts of the Project on the suitability of water downstream of the Kennady Lake watershed to support a viable and self-sustaining aquatic ecosystem are considered to be not environmentally significant. During the second time frame, projected impacts are also considered to be not environmentally significant. Water quality is predicted to change; however, changes to water quality in waterbodies downstream of Kennady Lake are predicted to result in negligible effects to aquatic health.

The potential effects of changes to nutrient levels in downstream systems have not been presented. They are the subject of continuing evaluation and are therefore not included at this time in the determination of environmental significance for this assessment endpoint. Once the continued analysis is complete, the significance determination outlined herein will be updated as appropriate and required.

Abundance and persistence of Arctic grayling downstream of the Kennady Lake watershed

The projected impacts on the abundance and persistence of Arctic grayling are considered to be not environmentally significant for both time periods. Reduced flows downstream of Area 8 in the first time period, which will only occur during operations and closure, have the potential to affect the population size of Arctic grayling by restricting spawning migrations and reducing the area available for spawning. A flow mitigation plan is under development to avoid population level impacts to Arctic grayling. In the second time period, flows return to near baseline conditions and the population and distribution of Arctic grayling are also expected to return to baseline conditions.

As previously noted, the potential effects of changes to nutrient levels in downstream systems have not been presented. They are the subject of continuing evaluation and are therefore not included at this time in the determination of environmental significance for this assessment endpoint. Once the continued analysis is complete, the significance determination outlined herein will be updated as appropriate and required.

Abundance and persistence of lake trout downstream of the Kennady Lake watershed

The projected impacts on the abundance and persistence of lake trout are considered to be not environmentally significant for both time periods. During the first time period, reduced flows that occur downstream of Area 8 during operations and closure may restrict the movement of lake trout between Area 8 and Lake 410, but are not expected to result in population level changes as changes to the lake habitats that support lake trout, such as Lake M4, are minimal. A flow mitigation plan is under development which would further reduce the risk of population level changes to lake trout. In the second time period, flows and lake levels return to near baseline conditions.

As previously noted, the potential effects of changes to nutrient levels in downstream systems have not been presented. They are the subject of continuing evaluation and are therefore not included at this time in the determination of environmental significance for this assessment endpoint. Once the continued analysis is complete, the significance determination outlined herein will be updated as appropriate and required.

Abundance and persistence of northern pike downstream of the Kennady Lake watershed

The projected impacts on the abundance and persistence of northern pike are considered to be not environmentally significant for both time periods. During the first time period, reduced flows that occur downstream of Area 8 during operations and closure may restrict the movement of northern pike, but are not expected to result in population level changes as changes to the lake habitats are minimal. A flow mitigation plan is under development which would further reduce the risk of population level changes to northern pike. In the second time period, flows return to near baseline conditions and the population and distribution of northern pike are also expected to return to baseline conditions.

As previously noted, the potential effects of changes to nutrient levels in downstream systems have not been presented. They are the subject of continuing evaluation and are therefore not included at this time in the determination of environmental significance for this assessment endpoint. Once the continued analysis is complete, the significance determination outlined herein will be updated as appropriate and required.

9.13.4 On-going Refinement of the Classification

The Terms of Reference require that De Beers identify all proposed mitigation measures, along with evaluations of confidence levels in the effectiveness of those measures and describe residual effects. In addition, it states that the developer must provide its views on the significance of impacts. Accordingly, De Beers has both qualitatively and quantitatively assessed the potential effects of the Project on the key line of inquiry: Water Quality and Fish Downstream of Kennady Lake. At this time, the analysis of potential nutrient related effects is on-going. De Beers is currently considering a variety of environmental design features and mitigation to reduce or eliminate the potential effects related to nutrients, such as:

- Promotion of permafrost development in the Fine PKC Facility
- Use of low permeability cover material to limit infiltration into key areas, such as the Fine PKC Facility.

The effectiveness of these environmental design features and mitigation is uncertain and requires further analysis. Accordingly, the amount of phosphorus that may be released into the environment is uncertain at this time. As a result, potential effects related to phosphorus have not been presented and will not be available until such time as additional analysis is completed. This analysis will be provided to the Panel in 2011. At that time, De Beers will also provide the Panel with its updated findings with regard to significance, the associated level of confidence, and confirmation of the mitigation measures that De Beers will incorporate into the Project design.

9.14 UNCERTAINTY

Key areas of uncertainty for the assessment of effects to downstream waterbodies include the following:

- the Gahcho Kué Project (Project) site water balance and associated uncertainty in downstream flows;
- quality of water in the WMP discharge and outflow from Area 8 to downstream lakes, Lake N11 and Lake 410;
- time required to refill Kennady Lake; and
- incomplete understanding of ecosystems near the Project.

Each area of uncertainty is discussed in more detail below. The following discussion also includes a description of the approaches used to account for uncertainty in the effects analysis, so that potential effects were not underestimated. Where relevant, the inherent advantages of the design of the Project are also discussed, in terms of how they influence uncertainty in the assessment of effects to water quality and fish in Kennady Lake.

9.14.1 Project Site Water Balance and Hydrology

The site water balance describes the movement of water through the Project site over the life of the Project. The water balance determines how much water will be discharged from the Project site to downstream waterbodies. The site water balance also identifies the sources of water entering and leaving the site.

The site water balance was developed through the use of a water balance model, and there is a high degree of confidence in the hydrological aspects of the project description that are considered in the water balance model. In most cases, the changes to the Kennady Lake watershed that will result from the Project are well-defined and subject to limits arising from environmental design features and mitigation. For example, the volume of Kennady Lake is well-defined, and discharges during dewatering will be managed within specified limits. Similarly, the drainage areas of the diverted A, B, D and E sub-watersheds are well-defined, and discharges to waterbodies downstream of Kennady Lake and to the N watershed will be managed within specified limits.

There is a corresponding high degree of confidence in the meteorological inputs to the water balance model inputs (e.g., temperature, precipitation) for median conditions, due to the quality of the available regional dataset. The length of the available datasets, which span from 46 years for the regional dataset to 2 to

7 years for more site-specific information, results in a lower level of confidence in the prediction of events with longer return periods, such as 1-in-50 or 1-in-100 year events. However, lake dynamics are driven to a greater extent by average or median conditions than by extreme events. As such, confidence levels are highest around those elements of the water balance model of most importance.

Uncertainty in predictions of flows and water levels in downstream waterbodies is higher than for the Kennady Lake watershed, because the model incorporates more assumptions with distance downstream from the project (e.g., lake outlet rating curves), as it would not have been practical to monitor and model each of the dozens of individual lakes in the Kirk Lake watershed. This greater uncertainty is somewhat offset by incorporating baseline data from downstream lakes including Kirk Lake, Lake 410 and Lake N1 in the water balance model calibration and validation.

9.14.2 Water Quality Modelling

Water quality in Lake N11, the Interlakes and Lake 410 during construction and operations, and closure will be dependant on the quality of the influent streams entering the basin / lake. The predictions of water quality in these waterbodies during active discharge from the WMP during operations and after refill was completed using a dynamic, mass-balance model built within GoldSim™, which is widely used in environmental assessment. The GoldSim™ model was specifically used to simulate water quality outcomes in a receiving environment over time with multiple input variables.

The GoldSim™ water quality model was based on the site water balance within Kennady Lake and the hydrological model for the surrounding watersheds, and included inputs of material from the following sources:

- natural runoff within the Project area, the N watershed, and the Lake 410 watershed, which were assigned average baseline water quality;
- water quality of the water management pond (WMP) over operations and closure (as Areas 3 through 7 is refilled), which included:
  - metals and other elements associated with the suspended solids in the WMP;
  - groundwater that will be pumped from open pits into the WMP;
  - contact runoff from Project areas to the WMP, including the input of:
    - mine rock and coarse PK leachate and seepage from the Fine PKC Facility; and

– blasting residue.

Baseline water quality data from the Project area provided the basis for estimation of the quality of natural runoff and inflows from unaffected areas. The prediction of water quality in Lake N11 and Lake 410, including the Interlakes, was based on modelling Project releases to average baseline water quality conditions. Some uncertainty around these predictions results from the use of an average baseline value assigned to each water quality parameter, when the dataset contains a naturally large degree of variability. The modelling was also focused on median climatic conditions. Although these areas of uncertainty exist, the selected approach is appropriate for lake systems, which are more strongly influenced by average conditions, rather than short-term extremes.

The initial water quality of the WMP during operations is an important input to the water quality model used to predict the water quality of Lake N11. Likewise, the water quality of Kennady Lake Areas 3 through 7 during refilling is an important input to the water quality model used to predict Area 8 and downstream water quality through the Interlakes in the post-closure and long-term post-closure periods. Combined, the water quality of the Lake N11 and the Interlakes are required to predict the water quality of Lake 410.

The modelled water quality parameters were also treated as conservative substances; no chemical transformations, biological uptake, degradation, or precipitation were assumed. When deriving means for baseline water quality, individual data that were below reporting limits were replaced with a value equal to half the detection limit.

A comprehensive description of the water quality modelling for downstream waters is described in Appendix 8.I. The uncertainty associated with the Project inputs such as the runoff and seepage inputs from contact with the mine rock and PK material, groundwater inflows, and the open pits that will affect downstream waters is also provided in detail in Section 8.15.3.

In summary, the modelling approach is expected to yield a conservative estimate of the actual average concentrations that have been predicted for downstream waterbodies, with a high level of confidence that actual impacts to water quality are not underestimated.

De Beers is committed to undertake regular monitoring and testing using standard field and laboratory procedures during the Project operation to evaluate water quality of the Lake N11, Area 8 and Lake 410. Where necessary, the water quality input profiles assigned to the loadings will be revised and Project effects will be re-assessed, as appropriate. Where required, adaptive management strategies will be adopted.

9.14.3 Time Required to Refill Kennady Lake

The time required to refill Kennady Lake has been estimated at approximately 8 to 9 years. The length of this period is an important factor for impacts to aquatic ecosystems downstream of Kennady Lake, because flow changes during refilling of the lake can notably affect the spawning habitat of a highly-valued fish species (Arctic grayling) in streams. The estimate of 8 to 9 years to refill Kennady Lake was derived from average flow conditions. If climatic conditions are drier than assumed at the time of refill, then the refill period may take longer, up to 14 years (Section 8.7.4.1). Conversely, if wetter conditions prevail during the refill period, it may be notably shorter, on the order of seven years. Therefore, time required for refilling of Kennady Lake is an important source of uncertainty for the assessment of downstream flows.

A change in the filling time of Kennady Lake may alter the proportion of the different influent waters in the lake. Under drier conditions, the refilled system may contain a higher proportion of water originating from the upper watershed than from Lake N11, because the total withdrawal from Lake N11 will be capped to ensure the maintenance of 1-in-5 dry year flows downstream of Lake N11.

Similarly, under wetter conditions, the proportions of the different influent waters may also vary from those that would occur under the assessed case. However, under both scenarios, the variation that may occur in the relative contribution of the different influent sources is unlikely to result in a change to the conclusions of the effects assessment. The water quality from both watersheds is similar. The time to full recovery would be longer, relative to the start of Project operation, if more than 9 years is required to refill the lake.

9.14.4 Understanding of Ecosystems in the Region of the Project

The main sources of uncertainty in the prediction of impacts to fish and fish habitat include the following:

- incomplete knowledge of the relationship between changes in flow and changes in physical habitat of streams and lakes;
- incomplete knowledge of fish migrations and spawning habitat locations downstream of the Project area and if flow barriers will result in a reduction in spawning success; and

- incomplete knowledge of the flows at which barriers to migration persist, resulting in uncertainty in the flows required as part of the flow mitigation plan (magnitude, frequency and duration) to reduce population level effects on Arctic grayling.

The assessment on changes in wetted area and habitat suitability were based on results from single transects and may not be representative of the habitat available for the entire length of the stream. While reductions in habitat were noted, the same magnitude of change may or may not persist within other habitat types present within the stream.

Although extensive baseline studies were conducted in the local study area, some gaps remain in the understanding of spatial distribution of the fish VCs, and their annual migration patterns, particularly as it relates to movements to spawning habitats. For example, it is uncertain whether the B and D catchments support northern pike populations year-round and it is unclear whether upstream migrations of fish occur through stream N11 in spring. Although Arctic grayling have been captured moving between lakes downstream of Kennady Lake in the spring, presumably to access spawning habitat, the location of critical spawning habitats is unknown. When barriers to movement are present, it is unknown if suitable spawning habitat would still be available to Arctic grayling at points downstream of the barriers, or what the relative success of spawning would be during low flow years.

Although flows have been identified where barriers in stream downstream of Kennady Lake persist, and flows where barriers are not present, there is a fairly large gap in flow between these two known points. The development of a successful flow mitigation plan will need to better understand the flows required to allow for fish migrations and widespread spawning and rearing success. The timing, frequency and duration of flow augmentation must also be better understood when developing the flow mitigation plan.

The sources of uncertainty identified will be addressed during monitoring, as described in the Section 9.15 and through the development of a flow mitigation plan. Most of the uncertainty that remains is around changes to the flow regime downstream of Kennady Lake, and as a result, will only affect a few watercourses in the Project area. Based on the uncertainty identified, the assessment was conservative in evaluating impacts to the fish VC's. However, since the scale of impacts is localized and reversible, the confidence level of the overall assessment of downstream impacts to fish and fish habitat is considered to be moderate to high.

9.15 MONITORING AND FOLLOW-UP

9.15.1 Scope of Potential Monitoring Programs

Pursuant to the assessment approach outlined in the environmental impact statement (EIS) Section 6, three types of monitoring are planned, and they include the following:

- compliance inspection;
- follow-up monitoring; and
- effects monitoring.

Compliance inspection will consist of programs designed to confirm the implementation of approved design standards and the environmental design features described in the EIS.

Follow-up monitoring will consist of programs designed to verify key inputs to the effects analysis, such as the quality of the pumped from the Water Management Pond (WMP; Areas 3 and 5) to Lake N11. Results of follow-up monitoring will be used to reduce the level of uncertainty related to impact predictions.

Effects monitoring will involve programs focused on the receiving environment, with the objectives of verifying the conclusions of the EIS, evaluating the short-term and long-term effects on the physical, chemical and biological components of the aquatic ecosystem of Kennady Lake and Area 8, estimating the spatial extent of effects, and providing the necessary input to adaptive management.

Follow-up monitoring and compliance inspection programs will be focused on the Gahcho Kué Project site, with little to no work occurring beyond the immediate Project area. Effects monitoring programs will encompass a larger area; however, they are unlikely to extend beyond Kirk Lake. Anticipated monitoring activities in the N lakes watershed and downstream of the Kennady Lake watershed are described in this section.

There is no requirement for a cumulative effects monitoring program for aquatics, because the projected impacts of the Project on aquatics do not extend beyond the local study area. They do not, as a result, overlap with other regional projects (e.g., Snap Lake Mine).

9.15.2 Potential Monitoring Activities

9.15.2.1 Compliance Inspection

Compliance inspection by De Beers will verify that Project components are built to approved design standards and that environmental design features described in the EIS are incorporated. As each component of the Project is built, constructed features will be inspected to show that they comply with standard protocols, and that any variance from standard protocols has been completed with regulatory permission (as appropriate). A check list will also be developed to show that agreed-upon environmental design features are constructed as required. Compliance monitoring will extend throughout the life of the Project.

9.15.2.2 Follow-up Monitoring

Only limited follow-up monitoring activities are anticipated in downstream waterbodies. Because this type of monitoring is relevant to verifying key inputs to the effects analysis, follow-up monitoring will be primarily focused on the Project site, as described in Section 8.16. One aspect of follow-up monitoring required in the downstream waterbodies is to define an appropriate mitigation flow regime to augment flows downstream of Kennady Lake during operations and refilling. The key aspects of this monitoring will be to better define an appropriate spring spawning flow for Arctic grayling, including determining the flow at which barriers to fish migration no longer exist, and defining a suitable flow for Arctic grayling rearing.

9.15.2.3 Effects Monitoring

Effects monitoring programs will include a Surveillance Network Program (SNP) that focuses primarily on Project site operations as well as a more broadly focused Aquatic Effects Monitoring Program (AEMP). De Beers will develop the scope of the SNP and AEMP in consultation with regulators and interested parties. It is anticipated, however, that the AEMP will include water flow, water quality and sediment quality components, along with components focused on lower trophic communities (i.e., plankton and benthic invertebrates), fish and fish habitat. Sampling stations in downstream waterbodies will be located in streams and lakes at varying distances downstream of Kennady Lake, likely extending to Kirk Lake, and in potentially affected areas of the N watershed, including a suitable reference lake. Components of the AEMP will be developed according to a common, statistically-based study design incorporating regulatory guidance and current scientific principles related to aquatic monitoring.

The scope of the AEMP is expected to change over the life of the Project. In particular, monitoring in adjacent and downstream watersheds is expected to be reduced when operations cease.

Monitoring and sampling techniques, and analysis procedures, will be consistent with methods used during the baseline survey period to the extent possible. The field and laboratory processes will include the implementation of quality assurance/quality control measures for data acquisition, water and biota sampling, and analysis and reporting.

The assessment of data and information collected during the monitoring programs will be compiled into annual aquatics monitoring reports that will be submitted to the appropriate parties for review. Where necessary and appropriate, the results of other monitoring programs (e.g., groundwater monitoring) will be integrated into the AEMP reports.

9.15.2.3.1 Construction and Operation

Potential monitoring in downstream waterbodies during construction and operation is summarized below:

Hydrology

Monitoring of downstream waterbodies will be required for management of water diversions and verification of hydrological effects during construction, operation, and closure. Parameters that will be monitored include discharges, water levels, and bed and channel erosion at key locations, as well as key meteorological parameters. The monitoring program will incorporate some locations monitored during the baseline program.

Potential channel erosion monitoring includes quantitative and qualitative components. At key locations, permanent channel transect markers will be established prior to dewatering discharges to monitor bed and bank geometry, and monitoring will continue through the dewatering period.

Identical surveys and monitoring will be performed at channels receiving operational diversion flows, prior to operational discharges and on a regular basis until closure.

Hydro-meteorological monitoring is required for runoff forecasting to manage diversions, and for hydrological model verification. Parameters recommended for monitoring include:

- Rainfall monitoring at the Project climate station;
- Pan evaporation at the Project climate station; and
- Annual snowcourse surveys in the LSA.

Monitoring of other meteorological parameters will be performed at the Project climate station to assist in interpretation of hydrological data. These parameters include air temperature and solar radiation.

Water Quality

Water quality parameters, consistent with those monitored during baseline surveys and used as input variables through the modelling process (including field parameters [i.e., pH, conductivity, dissolved oxygen, temperature], physical parameters [e.g., TSS, colour], major ions and TDS, total and dissolved metals, total and dissolved nutrients [e.g., total phosphorus, nitrogen compounds and total organic carbon], selected organic parameters), will be targeted. Sampling points will include streams and lakes at varying distances downstream of Kennady Lake, likely extending to Kirk Lake, and in potentially affected areas of the N watershed, including a suitable reference lake.

Water quality sampling will occur on a seasonal basis (i.e., open water and under-ice conditions) to verify effects predictions related to changes in water quality and potential effects to aquatic health.

Bottom sediment sampling will be undertaken at a subset of the water quality sampling stations where fine sediments accumulate, to evaluate the effects of the Project on sediment quality. Sediment quality parameters will include particle size distribution, total organic carbon, and concentrations of nutrients and metals.

Fish and Fish Habitat

Monitoring will include phytoplankton, zooplankton, benthic invertebrates, and fisheries sampling of selected waterbodies downstream of Kennady Lake and in the N watershed, including a reference lake (i.e., stations monitored during Project operation or a subset of those). The study designs, including frequency of sampling, will be dependent on the trophic level. Potential monitoring program components are summarized below:

- Chlorophyll *a* concentrations in downstream lakes and a reference lake will be monitored through the open water season, in conjunction with plankton monitoring.

- Monitoring phytoplankton and zooplankton communities (e.g., species composition, biomass, community structure) in downstream lakes will be conducted through the open-water season.
- Benthic invertebrate communities will be monitored in downstream lakes and streams (e.g., species composition, community structure, compilation of assessment indices).
- Monitoring spring spawning migrations and summer rearing densities of Arctic grayling will be conducted in streams between Kennady Lake and Lake 410. To evaluate the adequacy of the downstream flow augmentation mitigation measures in place to allow Arctic grayling to successfully spawn and rear and to sustain populations in downstream lakes over the mining period.
- Monitoring movements, presence, and utilization of new channels developed in the N watershed from the A, B, D, and E diversions will be conducted. This program will include spring, summer, and fall sampling periods to document spring spawning migrations, summer rearing success, and fall out-migrations. These surveys will document which, and if, fish species are using the channels, if adequate habitat is present throughout the open water season, and if water levels are sufficient for fish passage.

9.15.2.3.2 Closure and Post-closure

The closure period is associated with the refilling of Kennady Lake and the removal of dyke A. Throughout this period, the accelerated refilling of Kennady Lake will result in the reduction of downstream flows. Monitoring through closure is summarized below.

Hydrology

Flow rates and water levels will be monitored at key locations in streams and lakes downstream of Kennady Lake. Monitoring will occur on a seasonal basis, with particular focus on the biennial flow augmentation to assess that downstream flows during spring meet spawning and rearing habitat requirements of Arctic grayling.

Water Quality

Water quality parameters, consistent with those monitored during Project operation, will be targeted. Likely sampling stations will include a subset of those monitored during construction and operation. Monitoring will be maintained on a seasonal basis (i.e., during open water and under-ice conditions).

Fish and Fish Habitat

Monitoring of phytoplankton, zooplankton, benthic invertebrates, and the fish community in selected streams and lakes downstream of Kennady Lake, the N watershed, and a reference lake will be required during the closure phase.

Monitoring of phytoplankton, zooplankton, benthic invertebrates, and the fish community in selected streams and lakes downstream of Kennady Lake, the N watershed, and a reference lake will also continue during post-closure (i.e., after the refilling of Kennady Lake and reconnection of upper drainages) to monitor changes to fish and fish habitat and confirming the predicted recovery processes and timing.

It is expected that post-closure monitoring will cease once results demonstrate that the aquatic ecosystem in downstream waterbodies has reached a stable state.

9.16 REFERENCES

9.16.1 Literature Cited

AMEC Earth & Environmental, A Division of AMEC Americas Limited (AMEC). 2004. Unpublished water chemistry data collected in Kennady Lake and surrounding watersheds (2004). Calgary, AB.

AMEC. 2005. Unpublished water chemistry data collected in Kennady Lake and surrounding watersheds (2005). Calgary, AB.

Annear, T.C., I. Chisholm, H. Beecher, A. Locke, and 12 other authors. 2004. Instream flows for riverine resource stewardship. Published by the Instream Flow Council, Cheyenne, WY.

Ashley, K. L.S. Thompson, D.C. Lasenby, L. McEachern, K.E. Smokorowski and D. Sebastian. 1997. Restoration of an interior lake ecosystem: the Kootenay Lake fertilization experiment. *Water Quality Research Journal of Canada* 32: 295-323 **cited in** Dillon, P.J., B.J. Clark and H.E. Evans. 2004. The effects of phosphorus and nitrogen on lake trout (*Salvelinus namaycush*) production and habitat. In Boreal Shield Watersheds: Lake Trout Ecosystems in a Changing Environment. Gunn, J.M., R.J. Steedman and R.A. Ryder, (eds). Lewis Publishers. CRC Press. 2004. *pp*. 119-131.

Baudouin, M.F. and P. Scoppa. 1974. Acute Toxicity of Various Metals to Freshwater Zooplankton. *Bulletin of Environmental Contamination and Toxicology.* 12:745-751.

Beadle, L.C. 1969. *Osmotic Regulation and Adaptation of Freshwater Animals to Inland Saline Waters*. Verhandlungen des Internationalen Verein Limnologie 17:421-429. Cited in Bierhuizen, J.F.H. and E.E. Prepas. 1985. *Relationship Between Nutrients, Dominant Ions and Phytoplankton Standing Crop in Prairie Saline Lakes*. Canadian Journal of Fisheries and Aquatic Sciences 42:1588-1594.

Bierhuizen, J.F.H. and E.E. Prepas. 1985. *Relationship Between Nutrients, Dominant Ions and Phytoplankton Standing Crop in Prairie Saline Lakes*. *Canadian Journal of Fisheries and Aquatic Sciences.* 42:1588-1594.

Brannock, P., M.S. Stekoll, B. Failor and I. Wang. 2002. *Salt and Salmon: The Effects of Hard Water Ions on Fertilization*. Aquatic Sciences Meeting of the

American Society of Limnology and Oceanography. Cited in Weber-Scannell P.K. and L.K. Duffy. 2007. *Effects of Total Dissolved Solids on Aquatic Organisms: A Review of Literature and Recommendation for Salmonid Species*. *American Journal of Environmental Sciences.* 3:1-6.

Brittain, J.E. and T.J. Eikeland. 1988. Invertebrate Drift – A Review. *Hydrobiologia.* 166: 77-93.

Brix, K.V., R. Gerdes, N. Curry, A. Kasper, and M. Grosell. 2010. The Effects of Total Dissolved Solids on Egg Fertilization and Water Hardening in Two Salmonids – Arctic Grayling (*Thymallus arcticus*) and Dolly Varden (*Salvelinus malma*). *Aquatic Toxicology.* 97:109-115.

Bunn, S.T., and A.H. Arthington. 2002. Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management.* 30(4):492-507.

CCME (Canadian Council of Ministers of the Environment). 1999a (with updates to 2010). *Canadian Environmental Quality Guidelines*. Canadian Council of Ministers of the Environment. Winnipeg, MB.

CCME. 1999b (with updates to 2002). Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Candian Council of Ministers of the Environment. Winnipeg, MB.

CCME. 2004. Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems. Canadian Council of Ministers of the Environment. Winnipeg, MB.

CCME. 2007. Summary Table, Canadian Environmental Quality Guidelines for the Protection of Aquatic Life (Updated July 2006). Canadian Council of Ministers of the Environment. Winnipeg, MB.

Chapman, P.M., H. Bailey and E. Canaria. 2000. Toxicity of Total Dissolved Solids Associated with Two Mine Effluents to Chironomid Larvae and Early Life Stages of Rainbow Trout. *Environmental Toxicology and Chemistry*. 19:210-214.

Clark, R.A. 1992. Influence of Stream Flows and Stock Size on Recruitment of Arctic Grayling (*Thymallus arcticus*) in the Chena River, Alaska. *Canadian Journal of Fisheries and Aquatic Sciences*. 49:1027-1034.

Clipperton, G. K., C. W. Koning, A. G. H. Locke, J. M. Mahoney, and B. Quazi. 2003. Instream flow needs determinations for the South Saskatchewan River Basin, Alberta, Canada. Calgary: Alberta Environment and Sustainable Resource Development. (Pub No. T/719). 271 pp + appendices.

Colby, P.J., G.R. Spangler, D.A Hurley and A.M. McCombie. 1972. Effects of eutrophication on salmonid communities in oligotrophic lakes. *Journal of the Fisheries Research Board Canada.* 29:975-983.

Cowgill, U.M. and Milazzo, D.P. 1990. The Sensitivity of Two Cladocerans to Water Quality Variables - Salinity and Hardness. *Archiv fur Hydrobiologie.* 120:185-196.

Danylchuk, A.J. and W.M. Tonn. 2003. Natural disturbances and fish: Local and regional influences on winterkill of fathead minnows in boreal lakes. *Transactions of the American Fisheries Society*. 132:289-298.

Deegan, L.A., and B.J. Peterson. 1992. Whole River Fertilization Stimulates Fish Production in an Arctic Tundra River. *Canadian Journal of Fisheries and Aquatic Sciences*. 49:1890-1901.

Deegan, L.A., B.J. Peterson, H. Golder, C.C. McIvor, and M.C. Miller. 1997. Effects of Fish Density and River Fertilization on Algal Standing Stocks, Invertebrate Communities, and Fish Production in an Arctic River. *Canadian Journal of Fisheries and Aquatic Sciences*. Sci. 54:269-283.

Deegan, L.A., H.E. Golden, J. Harrison, and K. Kracko. 2005. Swimming Performance and Metabolism of 0+ year *Thymallus arcticus*. *Journal of Fish Biology*. 67:910-918.

DFO (Department of Fisheries and Oceans). 1995. Freshwater Intake End-of-Pipe Fish Screen Guideline. Communications Directorate, Department of Fisheries and Oceans, Ottawa, ON. 26 p.

Dillon, P.J., B.J. Clark and H.E. Evans. 2004. The effects of phosphorus and nitrogen on lake trout (*Salvelinus namaycush*) production and habitat. In Boreal Shield Watersheds: Lake Trout Ecosystems in a Changing Environment. Gunn, J.M., R.J. Steedman and R.A. Ryder, (eds). Lewis Publishers. CRC Press. 2004. *pp*. 119-131.

EBA (EBA Engineering Consultants Ltd.) and Jacques Whitford Environment Ltd. 2001. Gahcho Kué (Kennady Lake) Environmental Baseline Investigations (2000). Submitted to De Beers Canada Exploration Limited, Yellowknife, NT.

EBA. 2004a. Faraday Lake Winter 2003 Water Quality Sampling Program, Project No. 0701-98-13487.048. Prepared for De Beers Canada Inc. Yellowknife, NWT.

EBA. 2004b. Kelvin Lake Winter 2003 Water Quality Sampling Program. Submitted to DeBeers Canada Exploration Inc., Yellowknife, NWT

Evans, C.L., J.D. Reist, and C.K. Minns. 2002. Life History Characteristics of Freshwater Fishes Occurring in the Northwest Territories and Nunavut, with Major Emphasis on Riverine Habitat Requirements. *Canadian Manuscript Report of Fisheries and Aquatic Sciences.* 2614: xiii + 169 p.

Gahcho Kué Panel. 2007. *Terms of Reference for the Gahcho Kué Environmental Impact Statement*. Mackenzie Valley Environmental Impact Review Board. Yellowknife, N.W.T.

GNWT (Government of the Northwest Territories). 2006. NWT Species 2006-2010: General Status Ranks of Wild Species in the Northwest Territories. Working Group on General Status of NWT Species, Department of Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NWT. 111 p.

Goodfellow, W.L., L.W. Ausley, D.T. Burton, D.L. Denton, P.B. Dorn, D.R. Grothe, M.A. Heber, T.J. Norberg-King, and J.H. Jr. Rodgers. 2000. Major Ion Toxicity in Effluents: A Review with Permitting Recommendations. *Environmental Toxicology and Chemistry.* 19:175-182.

Hammer, U.T., R.C. Haynes, J.M. Haseltine, and S.M. Swanson. 1975. The Saline Lakes of Saskatchewan. *Verhandlungen des Internationalen Verein Limnologie* 19:589-598.

Hanson, J.M. and W.C. Leggett. 1982. Empirical Prediction of Fish Biomass and Yield. *Canadian Journal of Fisheries and Aquatic Sciences*. 39:257-263.

Harvey, B.C. 1987. Susceptibility of Young-of-the-year Fishes to Downstream Displacement by Flooding. *Transactions of the American Fisheries Society*. 116:851-855.

Harvey, C.J., B.J. Peterson, W.B. Bowden, A.E. Hershey, M.C. Miller, L.A. Deegan and J.C. Finlay. (eds.). 1998. Biological Responses to Fertilization of Oksrukuyik Creek, a Tundra Stream. *Journal of the North American Benthological Society*. Vol. 17, No. 2, pp. 190-209. Jun 1998.

Hatfield, T., A. Lewis and D. Ohlson. 2004. Instream flow thresholds as guidelines for reviewing proposed water uses. Consultant's report prepared for the British Columbia Ministry of Sustainable Resource Management and the British Columbia Ministry of Water, Land and Air Protection.

Health Canada. 2008. Guidelines for Canadian Drinking Water Quality Summary Table, Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment, May 2008

Hiltner, A.L. and A.E. Hershey. 1992. Blackfly (Diptera: Simuliidae) Responses to Phosphorus Enrichment of an Arctic Tundra Stream. *Hydrobiologia.* 240:259-265.

Holm, J., V. Palace, P. Siwik, G. Sterling, R. Evans, C. Baron, J. Werner and K. Wautier. 2005. *Developmental Effects of Bioaccumulated Selenium in Eggs and Larvae of Two Salmonid Species*. *Environmental Toxicology and Chemistry.* 24:2373-2381.

Hubert, W.A., R.S. Helzner, L.A. Lee, and P.C. Nelson. 1985. Habitat Suitability Index Models and In-stream Flow Suitability Curves: Arctic grayling riverine populations. US Fish and Wildlife Service, U.S. Dept. Interior, Biol. Rep. 82 (10.110). 48 p.

Hyatt, K.D. and J.G. Stockner. 1985. Responses of sockeye salmon (*Oncorhynchus nerka*) to fertilization of British Columbia coastal lakes. *Canadian Journal of Fisheries and Aquatic Sciences.* 42:320-331.

Hynes, T.P. 1990. *The Impacts of the Cluff Lake Uranium Mine and Mill Effluents on the Aquatic Environment of Northern Saskatchewan*. Master of Science Thesis. University of Saskatchewan, Saskatoon, SK, Canada.

ICES (International Council for the Exploration of the Sea). 1995. Underwater Noise of Research Vessels: Review and Recommendations. Cooperative Research Report No. 209. Copenhagen, Denmark.

Jacques Whitford (Jacques Whitford Environment Limited). 1998. Water Quality Assessment of Kennady Lake, 1998 Final Report, Report BCV50016. Prepared for Monopros Ltd. Yellowknife, NWT.

Jacques Whitford. 1999. Results of Water Sampling Program for Kennady Lake July 1999 Survey, Project 50091. Prepared for Monopros Ltd. Yellowknife, NWT.

Jacques Whitford. 2002. Data Compilation (1995 – 2001) and Trends Analysis, Gahcho Kué (Kennady Lake). Project No. ABC50310. Prepared for De Beers Canada Inc. Yellowknife, NWT.

Jacques Whitford. 2003. Gahcho Kué (Kennady Lake) Limnological Survey of Potentially Affected Bodies of Water (2002) Project# NTY71008. Prepared for De Beers Canada Inc. Yellowknife, NWT.

Jacques Whitford. 2004. Baseline Limnology Program (2003) Gahcho Kué (Kennady Lake), Project No. NTY71037. Prepared for De Beers Canada Inc. Yellowknife, NWT.

Jarvinen A.W. and G.T. Ankley. 1999. Linkage of Effects to Tissue Residues: Development of a comprehensive Database for Aquatic Organisms Exposed to Inorganic and Organic Chemicals. Pensacola FL: Society of Environmental Toxicology and Chemistry (SETAC). 364 pp.

Johannesen, M., A. Lande and S. Rognerud. 1984. Fertilization of 6 small mountain lakes in Telemark, Southern Norway, *International Association of Theoretical and Applied Limnology, Proceedings* 22: 673-678 **cited in** Dillon, P.J., B.J. Clark and H.E. Evans. 2004. The effects of phosphorus and nitrogen on lake trout (*Salvelinus namaycush*) production and habitat. In Boreal Shield Watersheds: Lake Trout Ecosystems in a Changing Environment. Gunn, J.M., R.J. Steedman and R.A. Ryder, (eds). Lewis Publishers. CRC Press. 2004. *pp*. 119-131.

Johnston, N.T., C.J. Perrin, P.A. Slaney and B.R. Ward. 1990. Increased salmonid growth by whole-river fertilization. *Canadian Journal of Fisheries and Aquatic Sciences.* 47:862-872.

Jones, N.E., and W.M. Tonn. 2004. Resource Selection Functions for Age-0 Arctic Grayling (*Thymallus arcticus*) and Their Application to Stream Habitat Compensation. *Canadian Journal of Fisheries and Aquatic Sciences*. 61:1736-1746.

Jones, N.E., W.M. Tonn, and G.J. Scrimgeour. 2003b. Selective Feeding of Age-0 Arctic Grayling in Lake-outlet Streams of the Northwest Territories, Canada. *Environmental Biology of Fishes*. 67:169-178.

Jones, N.E., W.M. Tonn, G.J. Scrimgeour, and C. Katapodis. 2003a. *Productive Capacity of an Artificial Stream in the Canadian Arctic: Assessing the Effectiveness of Fish Habitat Compensation*. *Canadian Journal of Fisheries and Aquatic Sciences*. 60:849-863.

Lasorsa, B. and S. Allen-Gil. 1995. The Methylmercury to Total Mercury Ratio in Selected Marine, Freshwater and Terrestrial Organisms. *Water, Air and Soil Pollution.* 80: 905–913.

LeBrasseur, R.J., C.D. McAllister, W.E. Barraclough, O.D. Kennady, J. Manzer, D. Robinson and K. Stevens. 1978. Enhancement of sockeye salmon (Oncorhynchus nerka) by lake fertilization in Great Central Lake: Summary report. *Journal of the Fisheries Research Board Canada* 35: 1580-1596.

Lienesch, P.W., M.E. McDonald, A.E. Hershey, W.J. O'Brien, and N.D. Bettez. 2005. Effects of a Whole-lake Experimental Fertilization on Lake Trout in a Small Oligotrophic Arctic Lake. *Hydrobiologia*. 548:51-66.

Locke, A., C. Stalnaker, S. Zellmer, K. Williams, H. Beecher, T. Richards, C. Robertson, A. Wald, A. Paul, and T. Annear. 2009. *Integrated approaches to riverine resource stewardship: Case studies, science, law, people, and policy*. Instream Flow Council, Cheyenne, WY. 430 pp.

Mann, D. A., P.A. Cott, B.W. Hanna, and A.N. Popper. 2007. Hearing in Eight Species of Northern Canadian Freshwater Fishes. *Journal of Fish Biolology.* 70:109-120.

Mann, D., P. Cott and B. Horne. 2009. Under-ice Noise Generated from Diamond Exploration on a Canadian Sub-arctic Lake and Potential Impacts on Fishes. *Journal of the Acoustical Society of America*. 126(5): 2215-2222.

McDonald, B.G., A.M.H. deBruyn, J.R.F. Elphick, M. Davies, D. Bustard and P.M. Chapman. 2010. Developmental Toxicity of Selenium to Dolly Varden Char (Salvelinus malma). *Environmental Toxicology and Chemistry.* 29(12):2800-2805.

Mount D.R., D.D. Gulley, J.R. Hockett, T.D. Garrison and J.M. Evans. 1997. Statistical Models to Predict the Toxicity of Major Ions to *Ceriodaphnia dubia, Daphnia magna* and *Pimephales promelas* (Fathead Minnows). *Environmental Toxicology and Chemistry*. 16(10): 2,009-2,019.

Muscatello, J.R., P.M. Bennett, K.T. Himbeault, A.M. Belknap and D.M Janz. 2006. Larval Deformities Associated with Selenium Accumulation in Northern Pike *(Esox lucius)* Exposed to Metal Mining Effluent. *Environmental Science and Technology.* 40:6506-6512.

MVEIRB (Mackenzie Valley Environmental Impact Review Board). 2006. Reasons for Decision and Report of Environmental Assessment for the DeBeers Gahcho Kué Diamond Mine, Kennady Lake, NT. Released June 28, 2006.

O'Brien, W.J., M. Barfield, and K. Sigler. 2001. The Functional Response of Drift-feeding Arctic Grayling: the Effects of Prey Density, Water Velocity, and Location Efficiency. *Canadian Journal of Fisheries and Aquatic Sciences*. 58:1957-1963.

Peterson, B.J., J.E. Hobbie, A.E. Hershey, M.A. Lock, T.E. Ford, J.R. Vestal, V.L. McKinley, M.A. Huller, M.C. Miller, R.M. Ventullo and G.S. Volk. 1985. Transformation of a Tundra River form Heterotrophy to Autotrophy by Addition of Phosphorus. *Science.* 229: 1383-1386.

Peterson, B.J., L. Deegan, J. Helfrich, J.E. Hobbie and M. Hullar. (eds.). 1993. Biological Responses of a Tundra River to Fertilization. *Ecology*, Vol. 74, No. 3, p 653-672.

Pienitz, R., J.P. Smol, and D.R.S. Lean. 1997a. Physical and Chemical Limnology of 59 Lakes Located Between the Southern Yukon and the Tuktoyaktuk Peninsula, Northwest Territories (Canada). *Canadian Journal of Fisheries and Aquatic Sciences*. 54: 330-346.

Pienitz, R., J.P. Smol, and D.R.S. Lean. 1997b. Physical and Chemical Limnology of 24 Lakes Located Between Yellowknife and Contwoyto Lake, Northwest Territories (Canada). *Canadian Journal of Fisheries and Aquatic Sciences*. 54: 347-358.

Plante, C. and J.A. Downing. 1993. Relationship of salmonine production to lake trophic status and temperature. *Canadian Journal of Fisheries and Aquatic Sciences.* 50:1324-1328.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Pretegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. *BioScience.* 47(11):769-784.

Poff N.L., J.D. Allan, M.A. Palmer, D.D. Hart, B.D. Richter, A. H. Arthington, K. H. Rogers, J.L. Meyer, J. A. Stanford. 2003. River flows and water wars? Emerging science for environmental decision-making. Frontiers in Ecology and the Environment 1: 298–306.

Rai, R., W. Maher and F. Kirkowa. 2002. Measurement of Inorganic and Methylmercury in Fish Tissues by Enzymatic Hydrolysis and HPLC-ICP-MS. J. Anal. At. Spectrom., 17 (11): 1560 – 1563.

Resh, V.H. and D.M. Rosenberg (eds.). 1984. The Ecology of Aquatic Insects. Praeger Publishers, New York, 625 pp.

Richardson, E.S., J.D. Reist and C.K. Minns. 2001. Life History Characteristics of Freshwater Fishes Occurring in the Northwest Territories and Nunavut, With Major Emphasis on Lake Habitat Requirements. *Canadian Manuscript Report of Fisheries and Aquatic Sciences* Can. 2569. 149p.

Richter, B.D., J.V. Baumgartner, R. Wigington, and D.P. Braun. 1997. How much water does a river need. *Freshwater Biology.* 37: 231-249.

Rosgen DL (1994) A classification of rivers. *Catena*. 22: 169-199

Rudolph, B.L., I. Andreller and C.K. Kennedy. 2008. Reproductive Success, Early Life Stage Development, and Survival of Westslope Cutthroat Trout (Oncorhynchus clarki lewisi) Exposed to Elevated Selenium in an Area of Active Coal Mining. *Environmental Science and Technology.* 42:3109-3114.

Schwartz, A.L. 1985. The Behaviour of Fishes in their Acoustic Environment. *Environmental Biology of Fishes.* 13(1): 3-15.

Scott, K.M. 1978. Effects of Permafrost on Stream Channel Behavior in Arctic Alaska. United States Geological Survey Professional Paper 1068, 19 p.

Scott, WB. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Fisheries Research Board of Canada, Bulletin 184. 966 p.

Slavik, K., B.J. Peterson, L.A. Deegan, W.B. Bowden, A.E. Hershey, and J.E. Hobbie. 2004. Long-term Responses of the Kuparuk River Ecosystem to Phosphorus Fertilization. *Ecology.* 85:939-954.

Stekoll, M.S., W.W. Smoker, I.A. Wang and B.J. Failor. 2003. Final Report for ASTF Grant #98-012, Project: Salmon as a Bioassay Model of Effects of Total Dissolved Solids. Prepared for the Alaska Science and Technology Foundation. Anchorage, AK, USA.

Stewart, D.B. 2001. Possible Impacts on Overwintering Fish of Trucking Granular Materials over Lake and River Ice in the Mackenzie Delta Area. Prepared by Arctic Biological Consultants, Winnipeg, Manitoba for Fisheries Joint Management Committee. Inuvik, Northwest Territories.

Stewart, D.B., N.J. Mochnacz, J.D. Reist, T.J. Carmichael, and C.D. Sawatzky. 2007. Fish Life History and Habitat Use in the Northwest Territories: Arctic Grayling (*Thymallus arcticus*). *Canadian Manuscript Report of Fisheries and Aquatic Sciences*. 2797.

Stockner, J.G. and K.R.S. Shortreed. 1976. Autotrophic production in Carnation Creek, a coastal rainforest stream on Vancouver Island, British Columbia. *Journal of the Fisheries Research Board Canada.* 33: 1553-1563.

Stockner, J.G. and K.R.S. Shortreed. 1978. Enhancement of autotrophic production by nutrient addition in a coastal rainforest stream on Vancouver Island. *Journal of the Fisheries Research Board Canada.* 35: 28-34.

Svendsen, C.R., T. Quinn and D. Kolbe. 2004. Review of Macroinvertebrate Drift in Lotic Ecosystems. Final report prepared for Wildlife Research Program, Environmental and Safety Division, Seattle, WA. 92 pp.

TAC (Transportation Association of Canada). 2001. Guide to Bridge Hydraulics, 2nd Edition. 181 p.

University of Alberta. 2008. Atlas of Alberta Lakes. Buffalo Lake. http://sunsite.ualberta.ca/Projects/Alberta-Lakes/view/?region=South%20Saskatchewan%20Region&basin=Red%20Deer%20River%20Basin&lake=Buffalo%20Lake&number=99

US EPA (United States Environmental Protection Agency). 1997. Mercury Study Report to Congress. Office of Research and Development, Washington, DC. December, 1997.

US EPA. 2004. *Draft Aquatic Life Water Quality Criteria for Selenium*. EPA-822-D-04-001. Washington, DC, USA.

US EPA. 2010. Regional Screening Level Fish Ingestion Supporting Table. May 2010. Available online: http://www.epa.gov/reg3hwmd/risk/human/index.htm.

US FWS (United States Fish and Wildlife Service). 1982. Habitat Suitability Index Models: Northern Pike. Washington, D.C. 48 p.

Weber-Scannell, P.K. and L.K. Duffy. 2007. Effects of Total Dissolved Solids on Aquatic Organisms: A Review of Literature and Recommendation for Salmonid Species. *American Journal of Environmental Sciences.* 3:1-6.

Wetzel, R.G. 2001. Limnology. Lake and River Ecosystems, Third Edition. Elsevier Science Academic Press. 1006 pp.

9.17 ACRONYMS AND GLOSSARY

9.17.1 Acronyms

AENV RELAD model	Alberta Environment Regional Lagrangian Acid Deposition model
ANC	acid-neutralizing capacity
BAF	bioconcentration factor
BOD	biochemical oxygen demand
CALPUFF model	California Puff model
CCME	Canadian Council of Ministers of the Environment
CDWQG	Canadian Drinking Water Quality Guidelines
CEB	chronic effects benchmarks
CO_2	carbon dioxide
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CWQG	Canadian Water Quality Guidelines
dB	decibel
DFO	Fisheries and Oceans Canada
DLSA	downstream local study area
DO	dissolved oxygen
EIS	environmental impact statement
Ekati	Ekati Diamond Mine
EMS	environmental management system
GIS	geographic information system
ICP/MS	inductively coupled plasma/mass spectrometry
ISQG	Interim Sediment Quality Guidelines
LC_{50}	lethal concentration 50
LDB	left downstream bank
LSA	local study area
MAF	mean annual flow
MDL	method detection limit
MMF	mean monthly flow
NO_3^-	nitrate
NOEC	no observed effect concentration
NO_x	nitrogen oxides
NWT	Northwest Territories
PAI	potential acid input
PK	processed kimberlite
PKC	processed kimberlite containment

PM	particulate matterparticulate matter
Project	Gahcho Kué Project
Q	discharge [**for table data only]**
RDB	right downstream bank
RSA	regional study area
SO_2	sulphur dioxide
SO_4^{2-}	sulphate
SOI	substances of interest
SOPCs	substances of potential concern
SSD	species sensitivity distribution
SSWC model	Steady-State Water Chemistry model
SWE	snow water equivalent
STP	sewage treatment plant
TC	total carbon
TDS	total dissolved solids
Terms of Reference	Terms of Reference for the Gahcho Kué Environmental Impact Statement
TKN	total Kjeldahl nitrogen
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorous
TPH	total petroleum hydrocarbons
TSP	total suspended particulates
TSS	total suspended solids
VC	valued component
WMP	Water Management Pond
WTP	water treatment plant
YOY	young-of-the-year

9.17.2 Units of Measure

#/100m	number per 100 metres
%	percent
μeq/L	microequivalents per litre
μg/g	micrograms per gram
μg/L	micrograms per litre
μS/cm	microSiemens per centimetre
$[BC]_0^*$ (μeq/L)	pre-industrial non-marine base cation concentration
<	less than

>	greater than
≤	less than or equal to
≥	greater than or equal to
°	degree
°C	degree Celsius
CFU/100 mL	colony-forming units per 100 millilitres
cm	centimetre
cms	cubic metres per second
CPUE	catch-per-unit effort
D_{90}	the 90th percentile of grain size such that 90% of the sample (by weight or volume of material) is finer and 10% coarser
dam_3	cubic decametres
El.	elevation
g	gram
g P/L	grams of phosphorus per litre
ha	hectare
keq H^+/ha/y	kiloequivalents of H^+ per hectare per year
keq/ha/y	kiloequivalents per hectare per year
km	kilometre
km^2	square kilometre
L	litre
m	metre
m/s	metres per second
m^2	square metre
m^3	cubic metre
m^3/d	cubic metres per day
m^3/s	cubic metres per second
m^3/y	cubic metres per year
masl	metres above sea level
mg N/L	milligrams of nitrogen per litre
mg P/L	milligrams of phosphorus per litre
mg TSS/L	milligrams of total suspended solids per litre
mg/kg	milligrams per kilogram
mg/kg ww	milligrams per kilogram wet weight
mg/L	milligrams per litre
mg/L as $CaCO_3$	milligrams per litre as calcium carbonate
mg/L NaCl	milligrams per litre sodium chloride
mL	millilitre
mm	millimetres
mm/y	millimetres per year
Mm^3	million cubic metres
Mm^3/y	million cubic metres per year
MPN/100 mL	most probable number per 100 millilitres

n	number
N_{leach}	loss of nitrogen due to leaching from a watershed
NOEC	no observed effect concentrations
NTU	nephelometric turbidity unit
number/m^2	number per square metre
ppb	parts per billion
ppm	parts per million
Q	discharge
TCU	true colour unit
TP	total phosphorus
US EPA	United States Environmental Protection Agency

9.17.3 Glossary

Acid Neutralizing Capacity (ANC)	The equivalent capacity of a solution to neutralize strong acids. Acid Neutralizing Capacity can be calculated as the difference between non-marine base cations and strong anions. This is the principal variable used to quantify the acid-base status of surface waters. Acidification is often quantified by decreases in ANC, and susceptibility of surface waters to acidic deposition impacts is often evaluated on the basis of ANC.
Acidification	The decrease of acid neutralizing capacity in water, or base saturation in soil, caused by natural or anthropogenic processes. Acidification is exhibited as the lowering of pH.
Acute	A stimulus severe enough to rapidly induce an effect; in aquatic toxicity tests, an effect observed in 96 hours or less is typically considered acute. When referring to aquatic toxicology or human health, an acute effect is not always measured in terms of lethality.
Alberta Environment (ANEV)	Provincial ministry that looks after the following: establishes policies, legislation, plans, guidelines and standards for environmental management and protection; allocates resources through approvals, dispositions and licenses, and enforces those decisions; ensure water infrastructure and equipment are maintained and operated effectively; and prevents, reduces and mitigates floods, droughts, emergency spills and other pollution-related incidents.
Alevin	A newly-hatched fish in the larval stage, dependent upon a yolk sac for nutrients while their digestive system develops.
Alkalinity	A measure of water's capacity to neutralize an acid. It indicates the presence of carbonates, bicarbonates and hydroxides, and less significantly, borates, silicates, phosphates and organic substances. Alkalinity is expressed as an equivalent of calcium carbonate. Its composition is affected by pH, mineral composition, temperature and ionic strength. However, alkalinity is normally interpreted as a function of carbonates, bicarbonates and hydroxides. The sum of these three components is called total alkalinity.
Anions	A negatively charged ion.
Anoxia	Little to no dissolved oxygen in the water sample. Waters with less than 2 mg/L of dissolved oxygen experience anoxia.
Anthropogenic	Pertaining to the influence of human activities.
Background	An area not influenced by chemicals released from the site under evaluation.
Base Case	The EIA assessment case that includes existing environmental conditions as well

	as existing and approved projects or activities.
Base Cation	An alkali or alkaline earth metal cation (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}).
Bathymetry	Measurement of the depth of an ocean or large waterbody.
Benthic Invertebrates	Invertebrate organisms living at, in or in association with the bottom (benthic) substrate of lakes, ponds and streams. Examples of benthic invertebrates include some aquatic insect species (such as caddisfly larvae) that spend at least part of their lifestages dwelling on bottom sediments in the waterbody. These organisms play several important roles in the aquatic community. They are involved in the mineralization and recycling of organic matter produced in the water above, or brought in from external sources, and they are important second and third links in the trophic sequence of aquatic communities. Many benthic invertebrates are major food sources for fish.
Biochemical Oxygen Demand (BOD)	An empirical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of wastewaters, effluents and polluted waters.
Bioconcentration	A process where there is a net accumulation of a chemical directly from an exposure medium into an organism.
Bog	Sphagnum or forest peat materials formed in an ombrotrophic environment due to the slightly elevated nature of the bog, which tends to disassociate it from the nutrient-rich groundwater or surrounding mineral soils. Characterized by a level, raised or sloping peat surface with hollows and hummocks. Mineral-poor, acidic and peat-forming wetlands that receives water only from precipitation.
Buffering	The capability of a system to accept acids without the pH changing appreciably. The greater amounts of the conjugate acid-base pair, the more resistant they are to a change in pH.
Cations	A positively charged ion.
Chlorophyll *a*	One of the green pigments in plants. It is a photo-sensitive pigment that is essential for the conversion of inorganic carbon (e.g., carbon dioxide) and water into organic carbon (e.g., sugar). The concentration of chlorophyll a in water is an indicator of algal concentration.
Chronic	The development of adverse effects after extended exposure to a given substance. In chronic toxicity tests, the measurement of a chronic effect can be reduced growth, reduced reproduction or other non-lethal effects, in addition to lethality. Chronic should be considered a relative term depending on the life span of the organism.
Conductivity	A measure of the capacity of water to conduct an electrical current. It is the reciprocal of resistance. This measurement provides an estimate of the total concentration of dissolved ions in the water.
Dissolved Organic Carbon (DOC)	The dissolved portion of organic carbon water; made up of humic substances and partly degraded plant and animal materials.
Dissolved Oxygen (DO)	Measurement of the concentration of dissolved (gaseous) oxygen in the water, usually expressed in milligrams per litre (mg/L).
Electrofishing	A 'live' fish capture technique in which negative (anode) and positive (cathode) electrodes are placed in the water and an electrical current is passed between the electrodes. Fish are attracted (galvano-taxis) to the anode and become stunned (galvano-narcosis) by the current, allowing fish to be collected, measured and released.
Epilimnion	A freshwater zone of relatively warm water in which mixing occurs as a result of wind action and convection currents.
Esker	Long, narrow bodies of sand and gravel deposited by a subglacial stream running between ice walls or in an ice tunnel, left behind after melting of the ice of a

	retreating glacier.
Eutrophic	The nutrient-rich status (amount of nitrogen, phosphorus and potassium) of an ecosystem.
Eutrophication	Excessive growth of algae or other primary producers in a stream, lake or wetlands as a result of large amounts of nutrient ions, especially phosphate or nitrate.
Evaprotranspiration	A measure of the capability of the atmosphere to remove water from a location through the processes of evaporation and water loss from plants (transpiration).
Forage Fish	Small fish that provide food for larger fish (e.g., longnose sucker, fathead minnow).
Glaciofluvial	Sediments or landforms produced by melt waters originating from glaciers or ice sheets. Glaciofluvial deposits commonly contain rounded cobbles arranged in bedded layers.
Glaciolacustrine	Sediments that were deposited in lakes that formed at the edge of glaciers when the glaciers receded. Glaciolacustrine sediments are commonly laminar deposits of fine sand, silt and clay.
Groundwater	That part of the subsurface water that occurs beneath the water table, in soils and geologic formations that are fully saturated.
Hydraulic Gradient	A measure of the force of moving groundwater through soil or rock. It is measured as the rate of change in total head per unit distance of flow in a given direction. Hydraulic gradient is commonly shown as being dimensionless, since its units are metres/metre.
Hydrogeology	The study of the factors that deal with subsurface water (groundwater) and the related geologic aspects of surface water. Groundwater as used here includes all water in the zone of saturation beneath the earth's surface, except water chemically combined in minerals.
Hydrology	The science of waters of the earth, their occurrence, distribution, and circulation; their physical and chemical properties; and their reaction with the environment, including living beings.
Morphology	Morphology or fluvial geomorphology is the term used in the description of closure drainage designs that replicate natural analogues. It describes the process and the structure of natural systems that are to be replicated in constructed drainage channels, including regime relationships for various channel parameters such as width, depth, width/depth ratio, meander wavelength, sinuosity, bed material, gradient and bank slope.
Nitrogen Oxides (NO_X)	A measure of the oxides of nitrogen comprised of nitric oxide (NO) and nitrogen dioxide (NO_2).
Oligotrophic	Trophic state classification for lakes characterized by low productivity and low nutrient inputs (particularly total phosphorus).
Outliers	A data point that falls outside of the statistical distribution defined by the mean and standard deviation.
Peatlands	Areas where there is an accumulation of peat material at least 40 cm thick. These are represented by bog and fen wetlands types.
Pelagic	Inhabiting open water, typically well off the bottom. Sometimes used synonymously with limnetic to describe the open water zone (e.g., large lake environments).
Permafrost	Permanently frozen ground (subsoil). Permafrost areas are divided into more northern areas in which permafrost is continuous, and those more southern areas in which patches of permafrost alternate with unfrozen ground.
pH	The degree of acidity (or alkalinity) of soil or solution. The pH scale is generally presented from 1 (most acidic) to 14 (most alkaline). A difference of one pH unit represents a ten-fold change in hydrogen ion concentration.

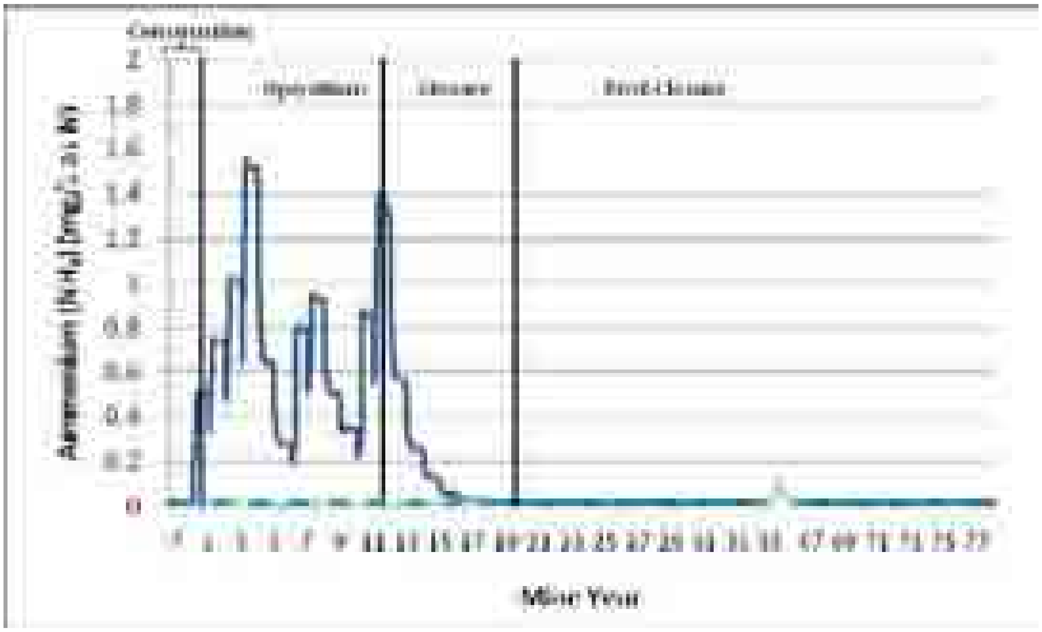
Piezometre	A pipe in the ground in which the elevation of water levels can be measured, or a small diameter observation well.
Polygon	The spatial area delineated on a map to define one feature unit (e.g., one type of ecosite phase).
Potential Acid Input	A composite measure of acidification determined from the relative quantities of deposition from background and industrial emissions of sulphur, nitrogen and base cations.
Riparian	Refers to terrain, vegetation or simply a position next to or associated with a stream, floodplain or standing waterbody.
Runoff	The portion of water from rain and snow that flows over land to streams, ponds or other surface waterbodies. It is the portion of water from precipitation that does not infiltrate into the ground, or evaporate.
Sedge	Any plant of the genus Carex, perennial herbs, often growing in dense tufts in marshy places. They have triangular jointless stems, a spiked inflorescence and long grass-like leaves which are usually rough on the margins and midrib. There are several hundred species.
Sediment	Solid material that is transported by, suspended in, or deposited from water. It originates mostly from disintegrated rocks; it also includes chemical and biochemical precipitates and decomposed organic material, such as humus. The quantity, characteristics and cause of the occurrence of sediment in streams are influenced by environmental factors. Some major factors are degree of slope, length of slope soil characteristics, land usage and quantity and intensity of precipitation.
Solar Radiation	The principal portion of the solar spectrum that spans from approximately 300 nanometres (nm) to 4,000 nm in the electromagnetic spectrum. It is measured in W/m^2, which is radiation energy per second per unit area.
Thermokarst	Pock-marked topography in northern regions caused by the collapse of permafrost features.
Total Dissolved Solids	The total concentration of all dissolved compounds solids found in a water sample. See filterable residue.
Total Organic Carbon	Total organic carbon is composed of both dissolved and particulate forms. Total organic carbon is often calculated as the difference between Total Carbon (TC) and Total Inorganic Carbon (TIC). Total organic carbon has a direct relationship with both biochemical and chemical oxygen demands, and varies with the composition of organic matter present in the water. Organic matter in soils, aquatic vegetation and aquatic organisms are major sources of organic carbon.
Total Suspended Particulate (TSP)	A measure of the total particulate matter suspended in the air. This represents all airborne particles with a mean diameter less than 30 µm (microns) in diameter.
Total Suspended Solids (TSS)	The amount of suspended substances in a water sample. Solids, found in wastewater or in a stream, which can be removed by filtration. The origin of suspended matter may be artificial or anthropogenic wastes or natural sources such as silt.
Toxic	A substance, dose or concentration that is harmful to a living organism.
Trophic	Pertaining to part of a food chain, for example, the primary producers are a trophic level just as tertiary consumers are another trophic level.
Wetlands	Wetlands are land where the water table is at, near or above the surface or which is saturated for a long enough period to promote such features as wet-altered soils and water tolerant vegetation. Wetlands include organic wetlands or “peatlands,” and mineral wetlands or mineral soil areas that are influenced by excess water but produce little or no peat.
Young-of-the-year (fish)	Fish at age 0, within the first year after hatching.

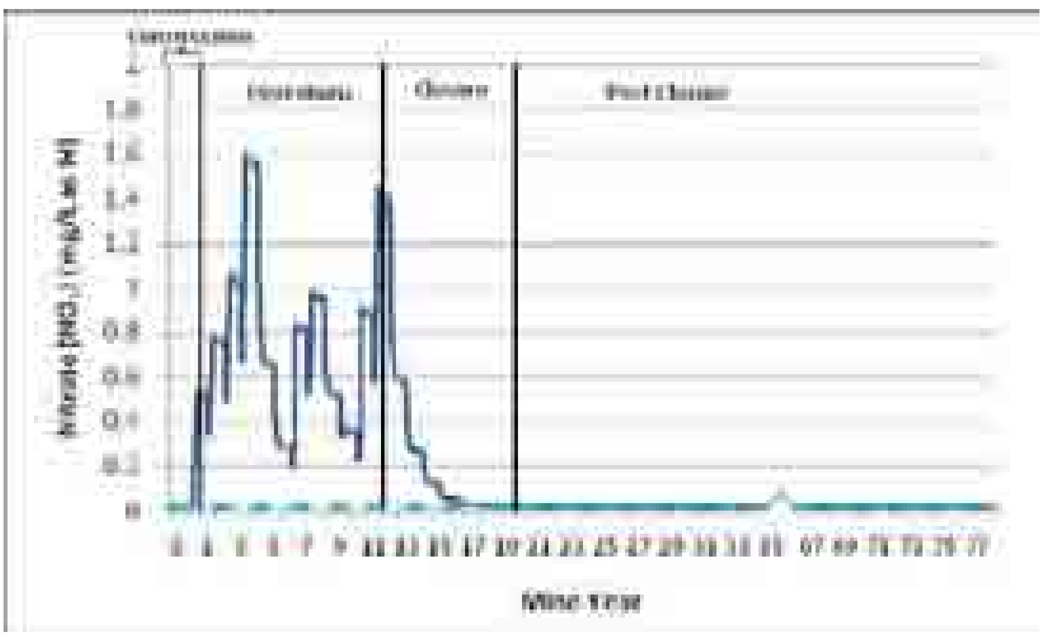
APPENDIX 9.I

TIME SERIES PLOTS

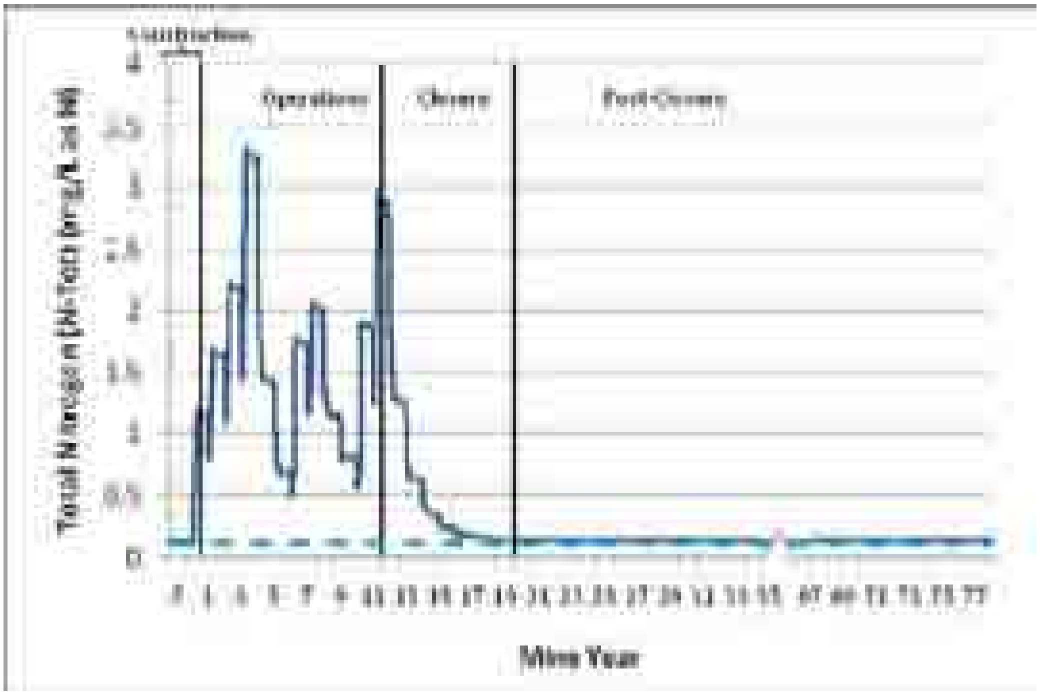
CONSTRUCTION, OPERATIONS, AND CLOSURE AND POST-CLOSURE

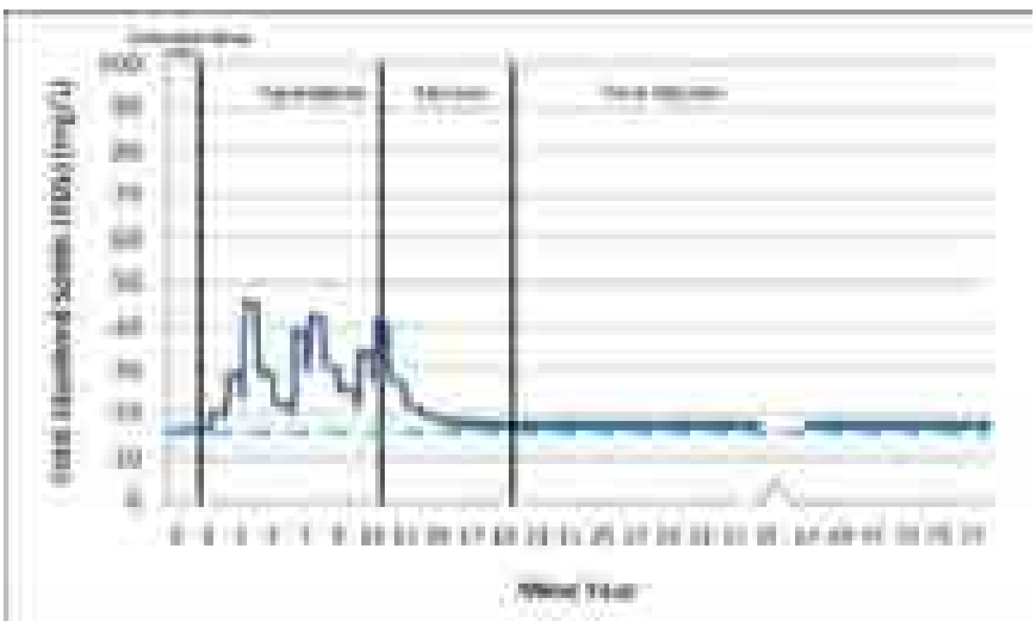
Nutrients and Anions (Lake N11)



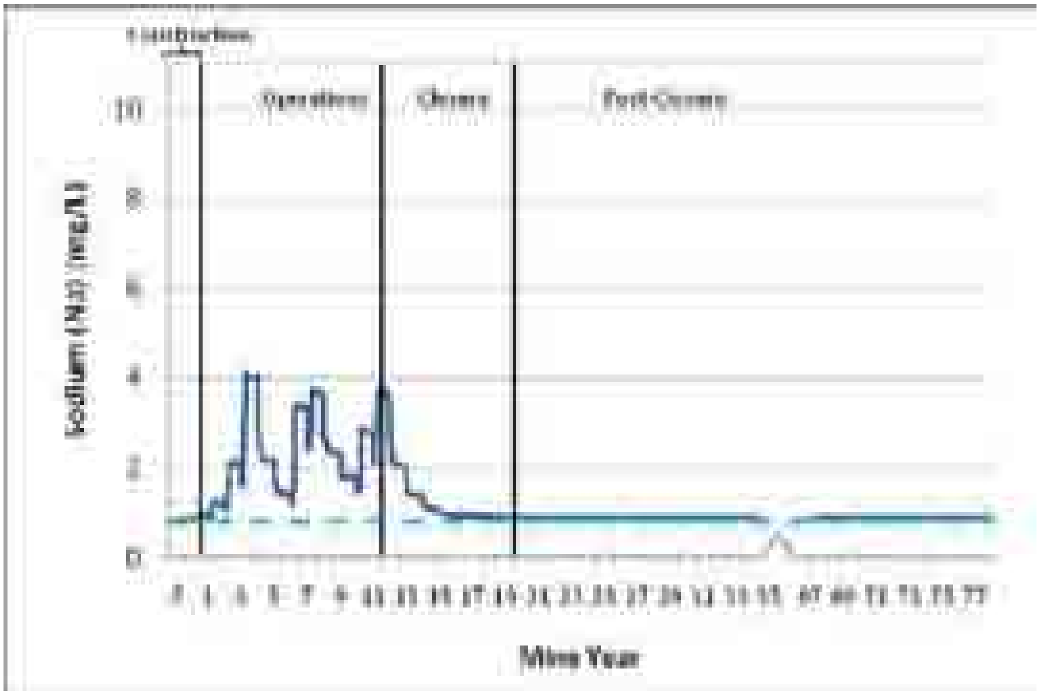


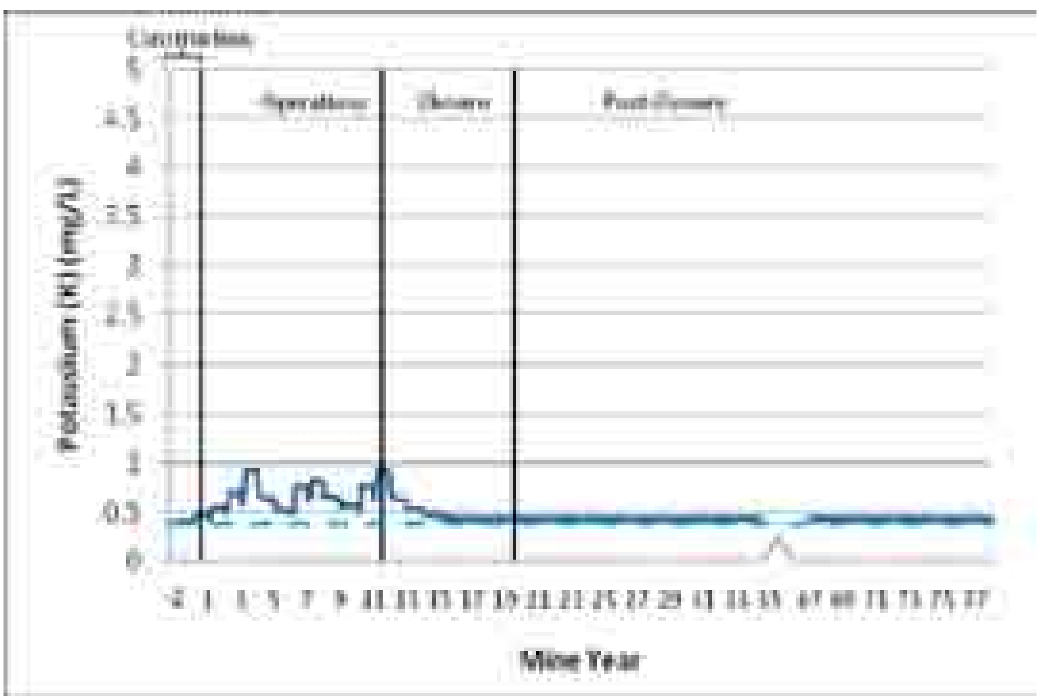
Nutrients and Anions (Lake N11) (continued)

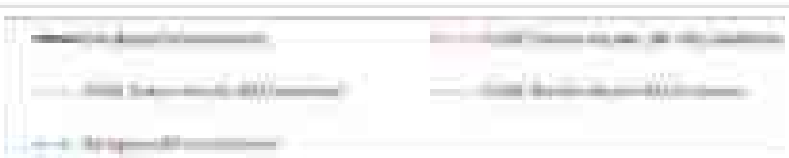




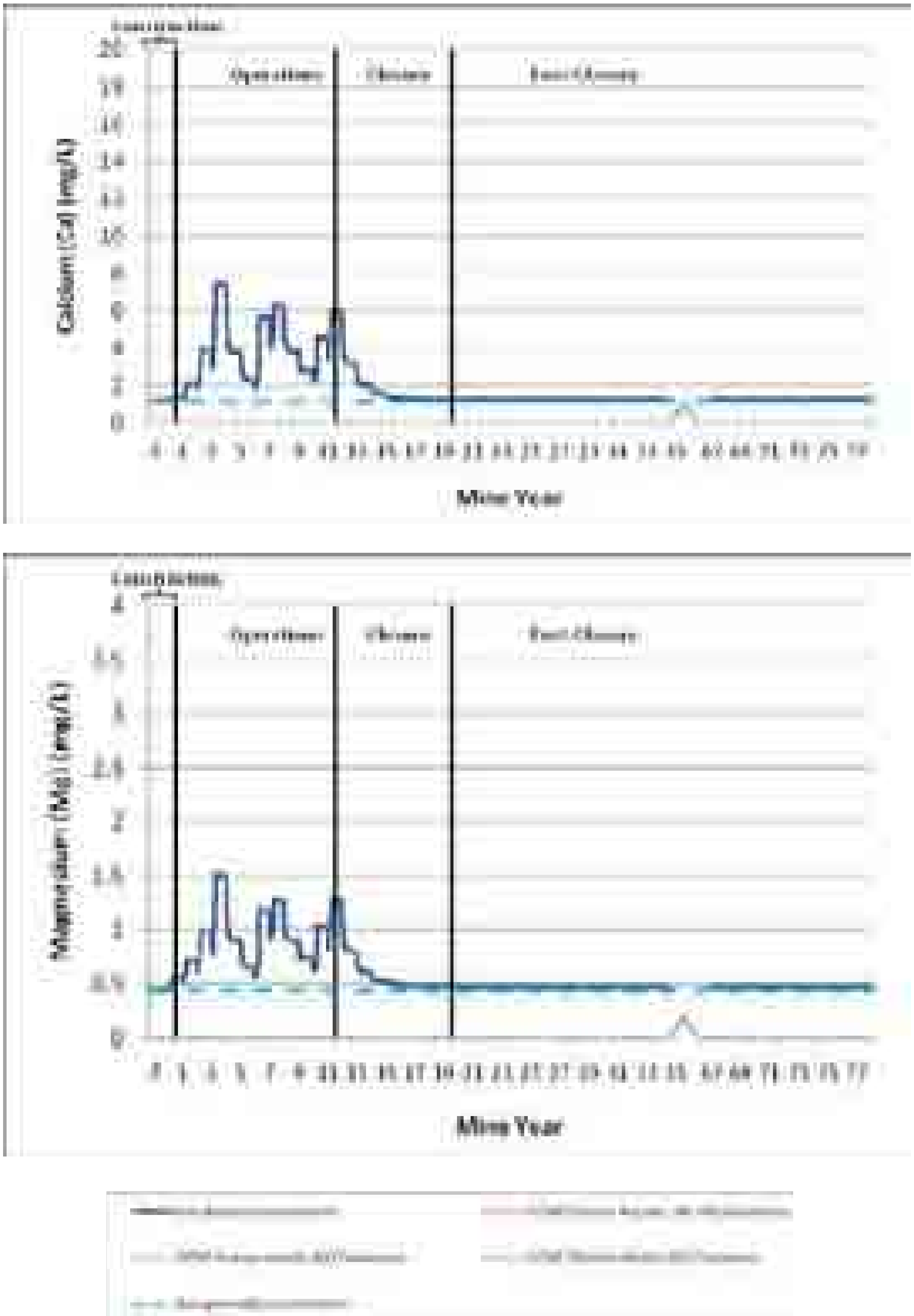
Nutrients and Anions (Lake N11) (continued)



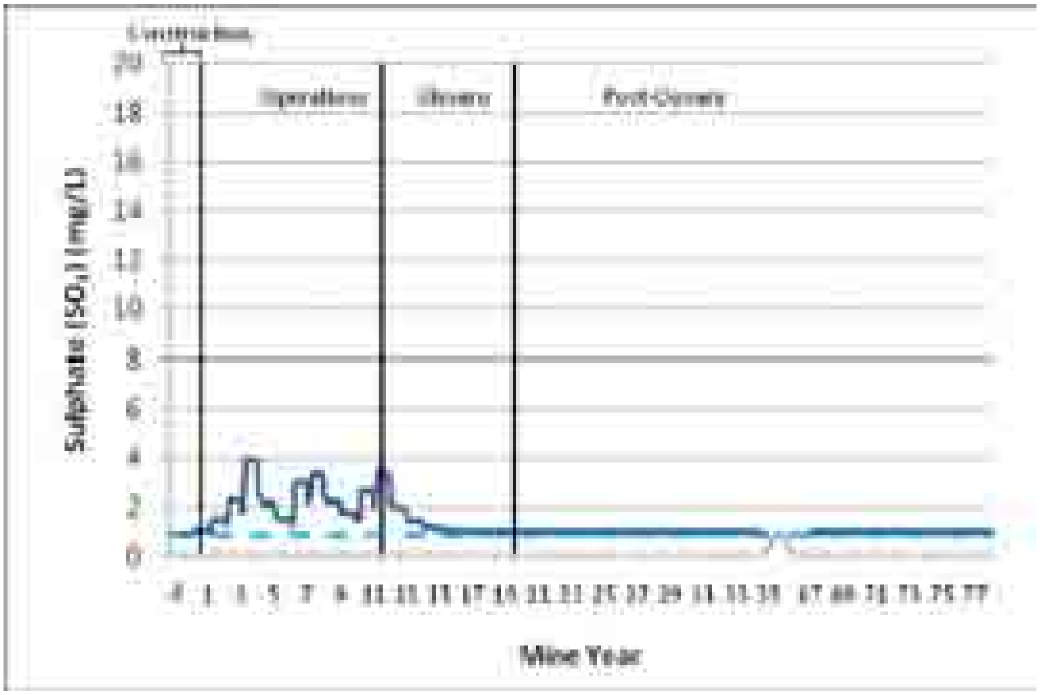


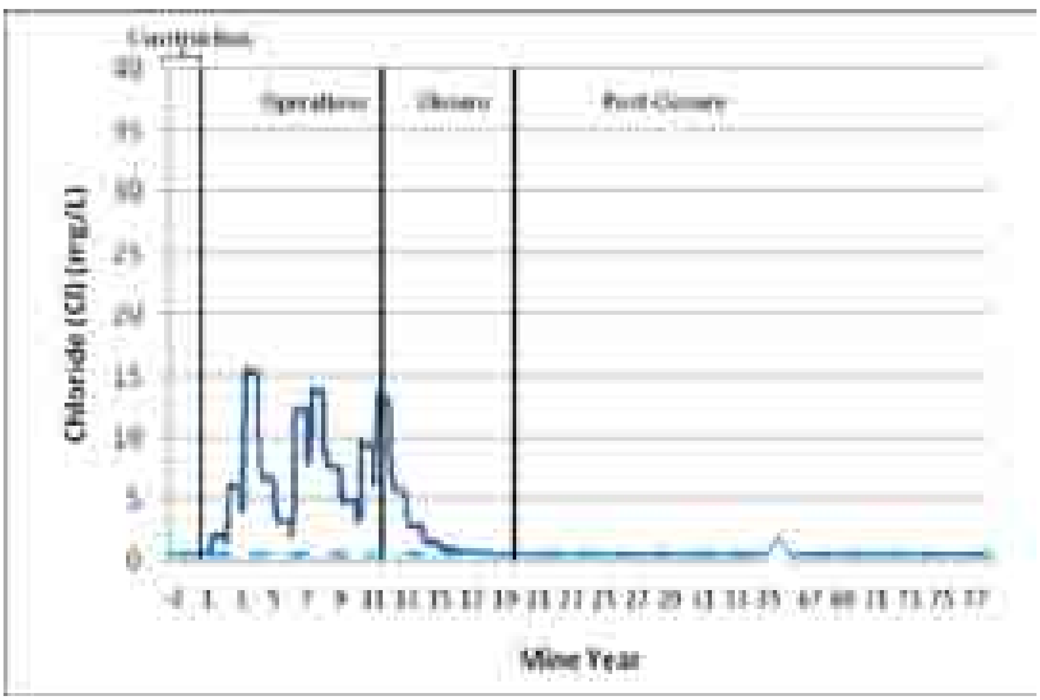


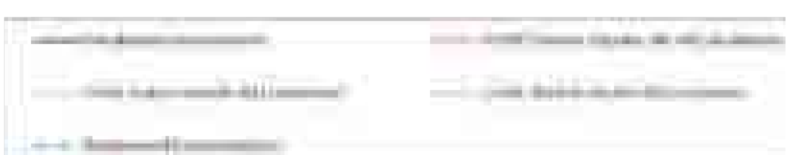
Nutrients and Anions (Lake N11) (continued)



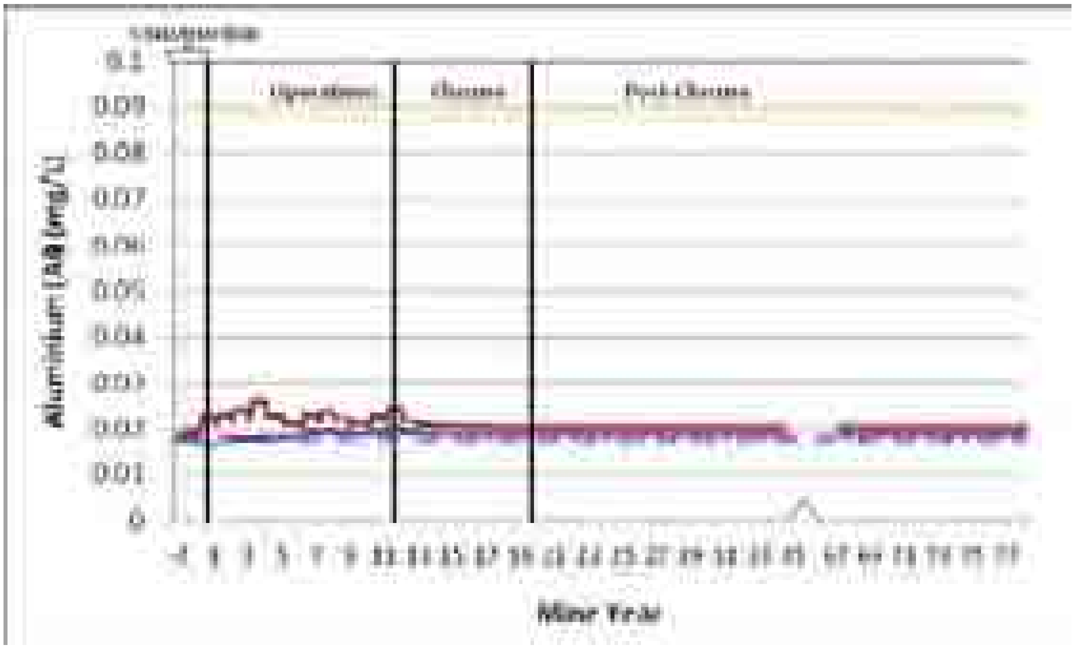
Nutrients and Anions (Lake N11) (continued)

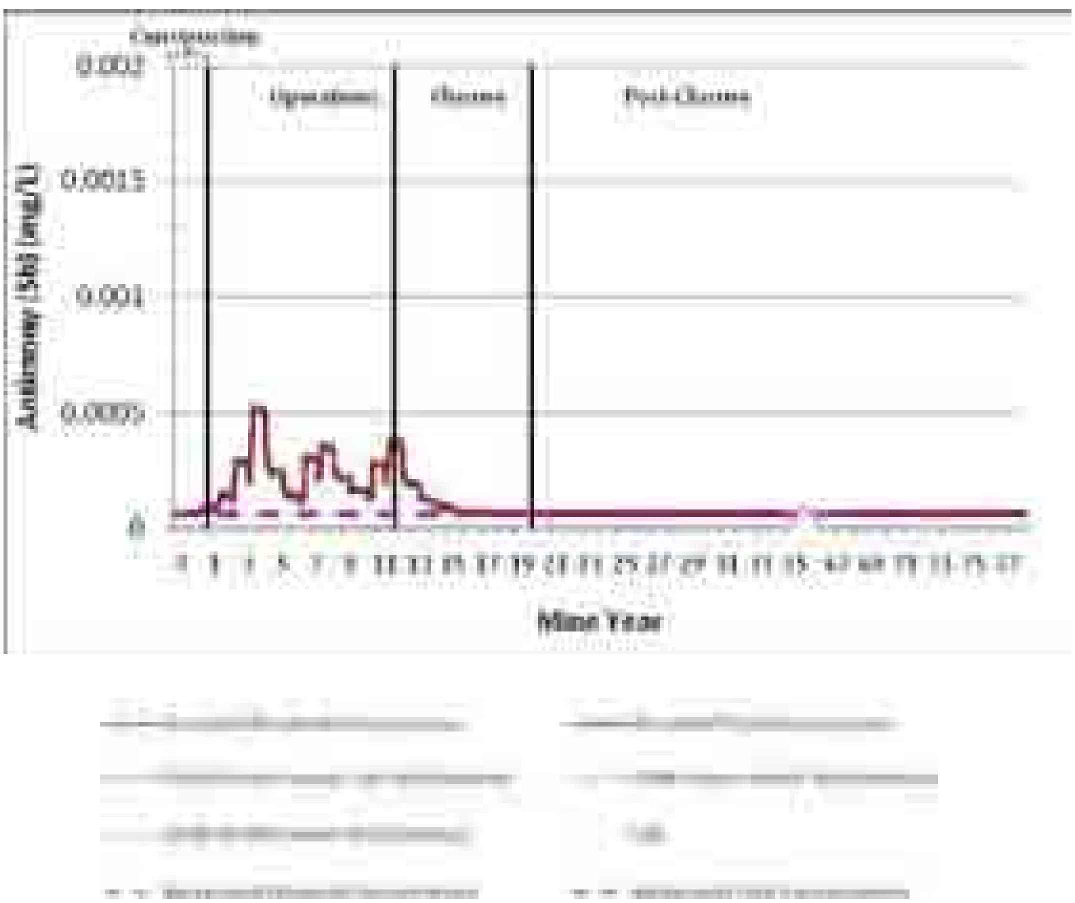




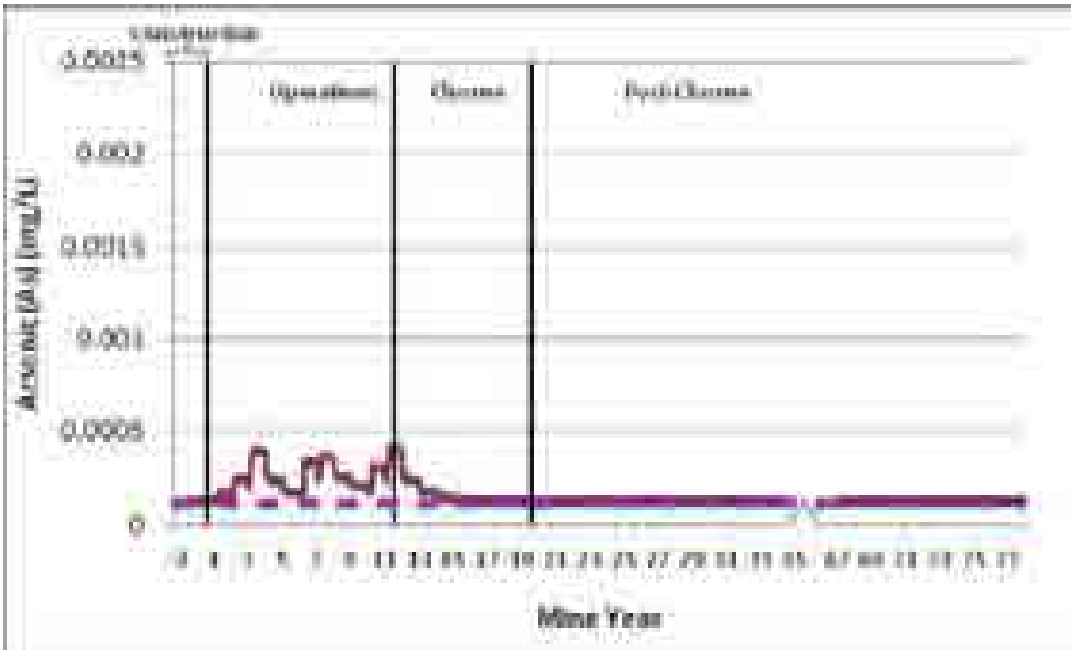


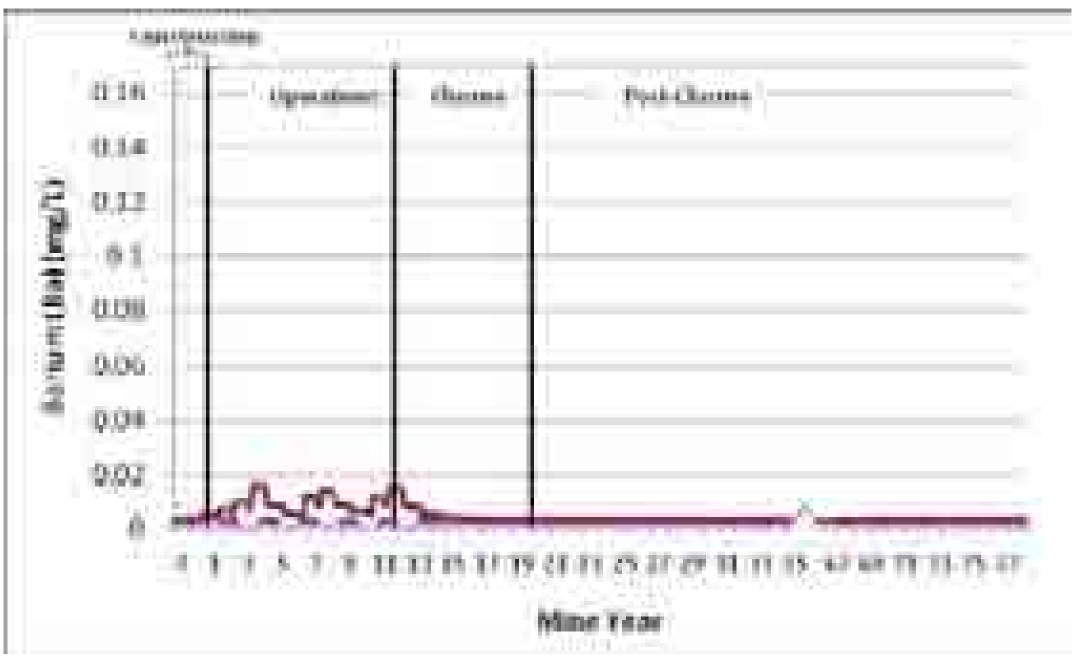
Dissolved and Total Metals (Lake N11)



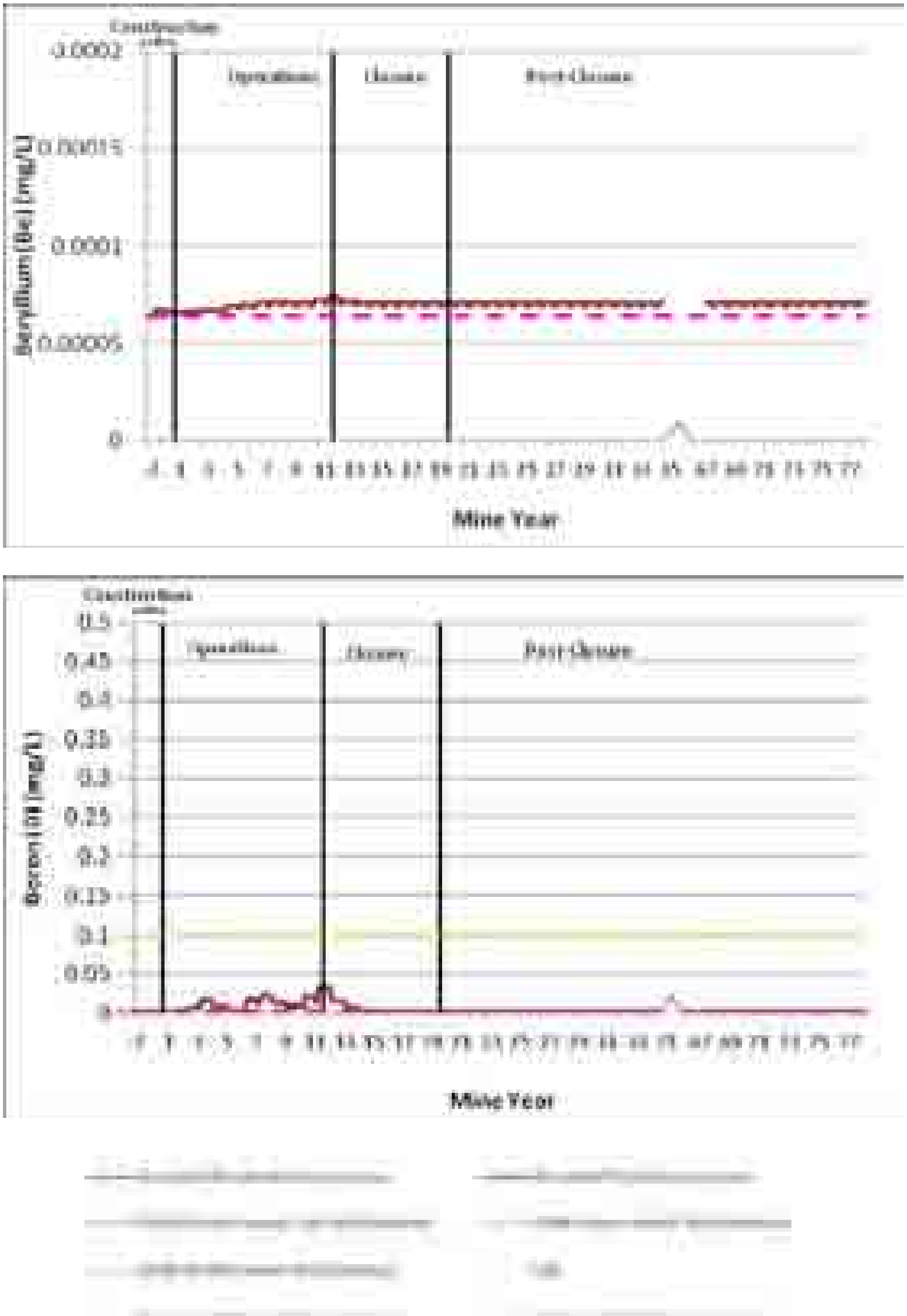


Dissolved and Total Metals (Lake N11) (continued)

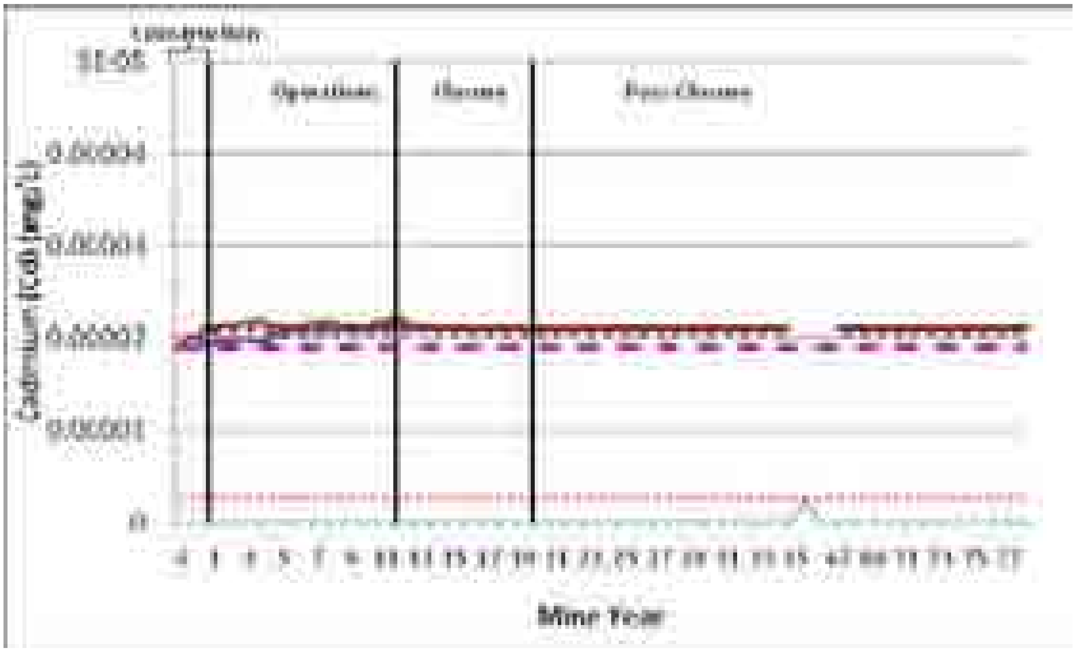


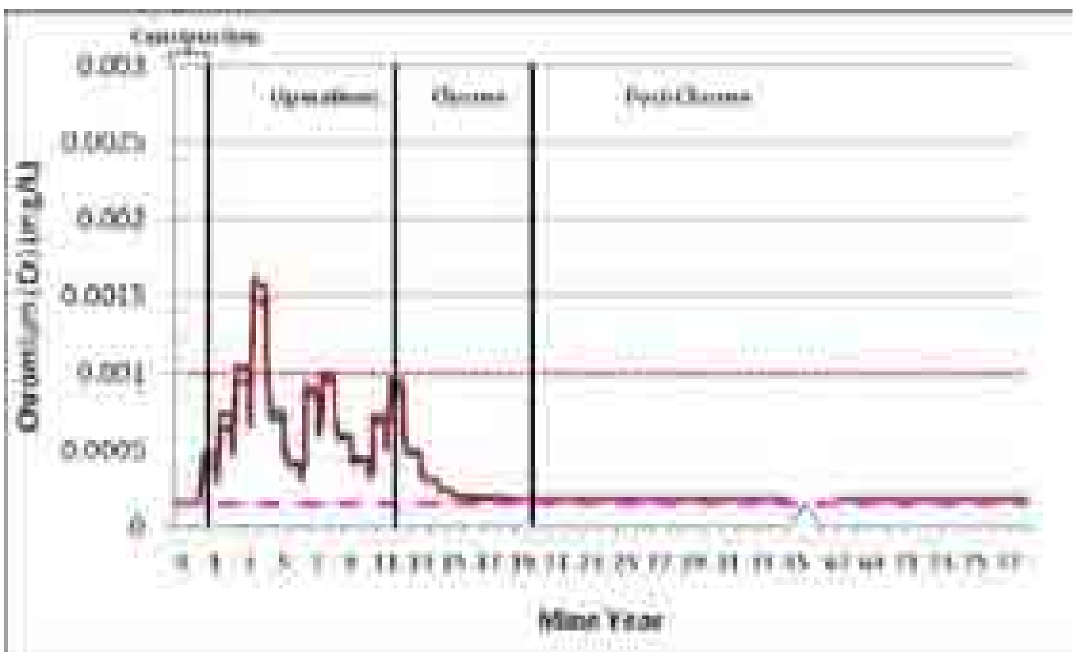


Dissolved and Total Metals (Lake N11) (continued)

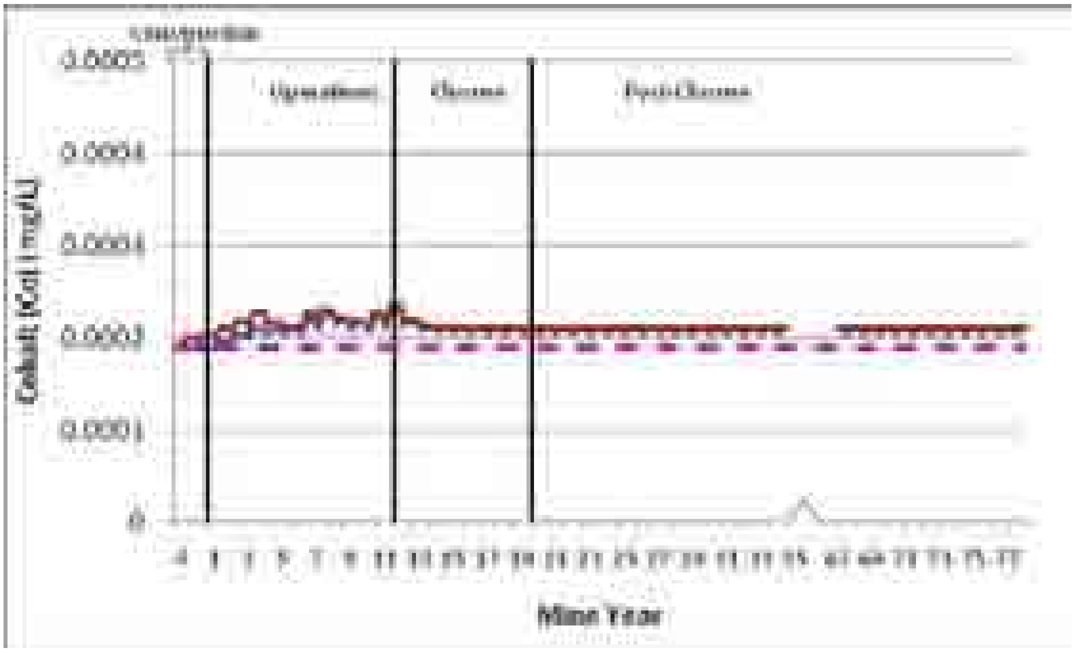


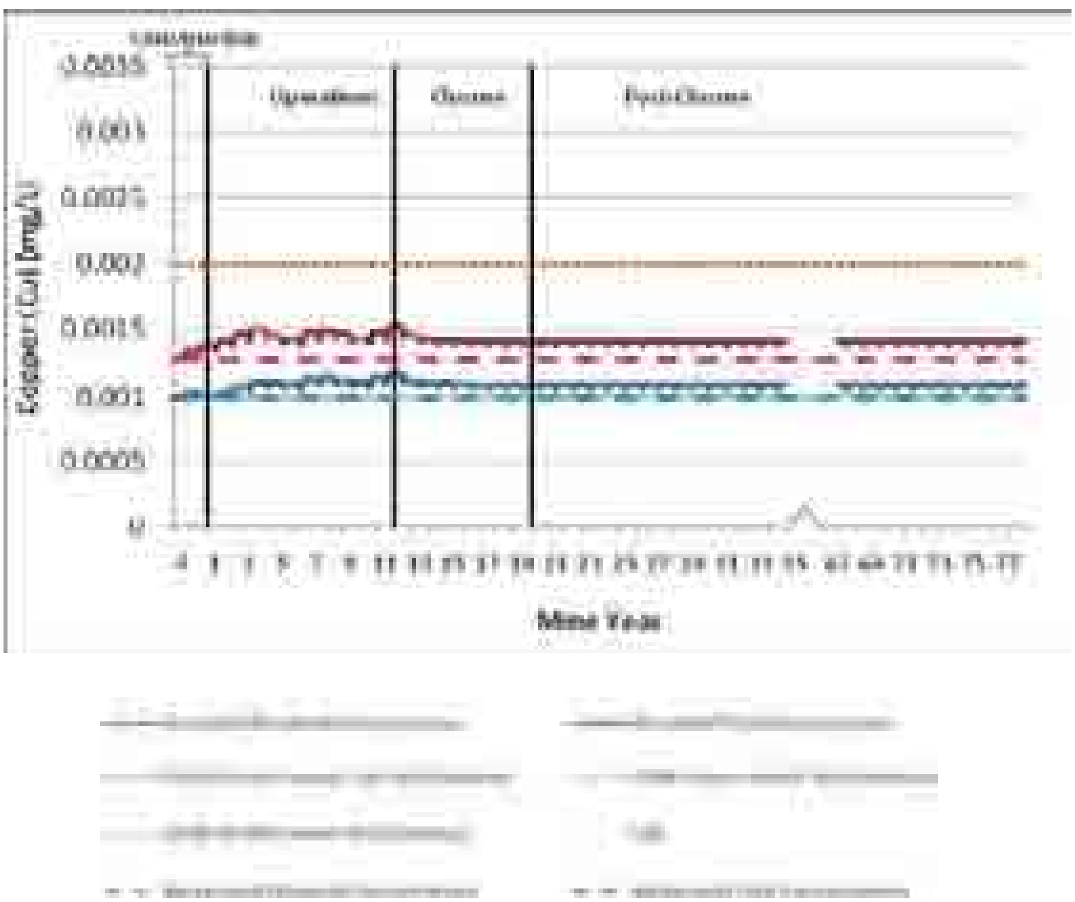
Dissolved and Total Metals (Lake N11) (continued)



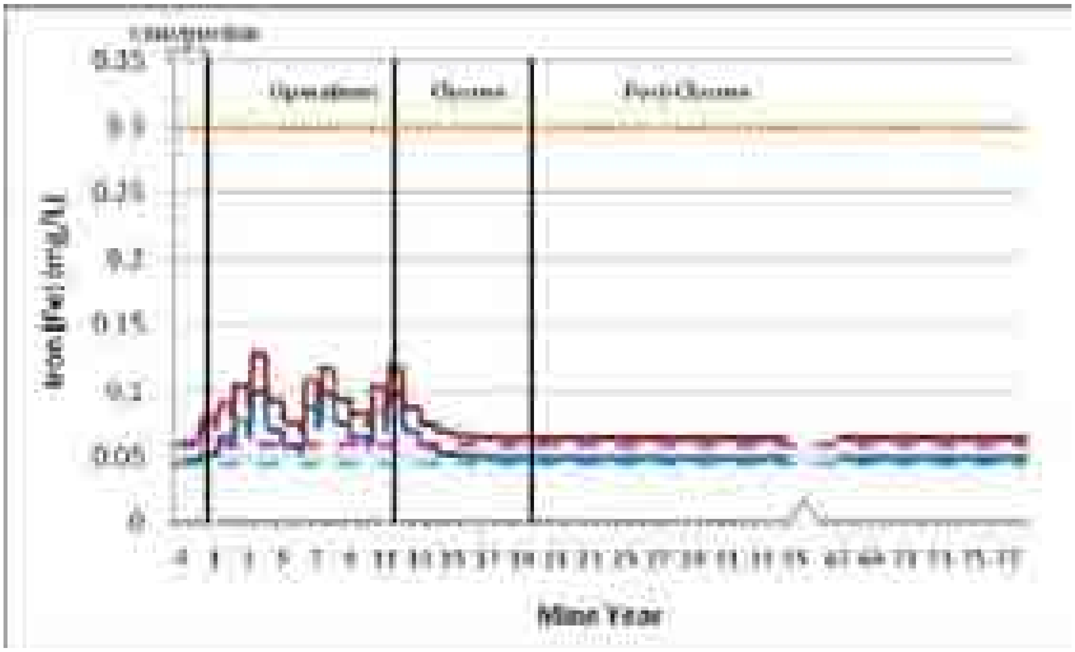


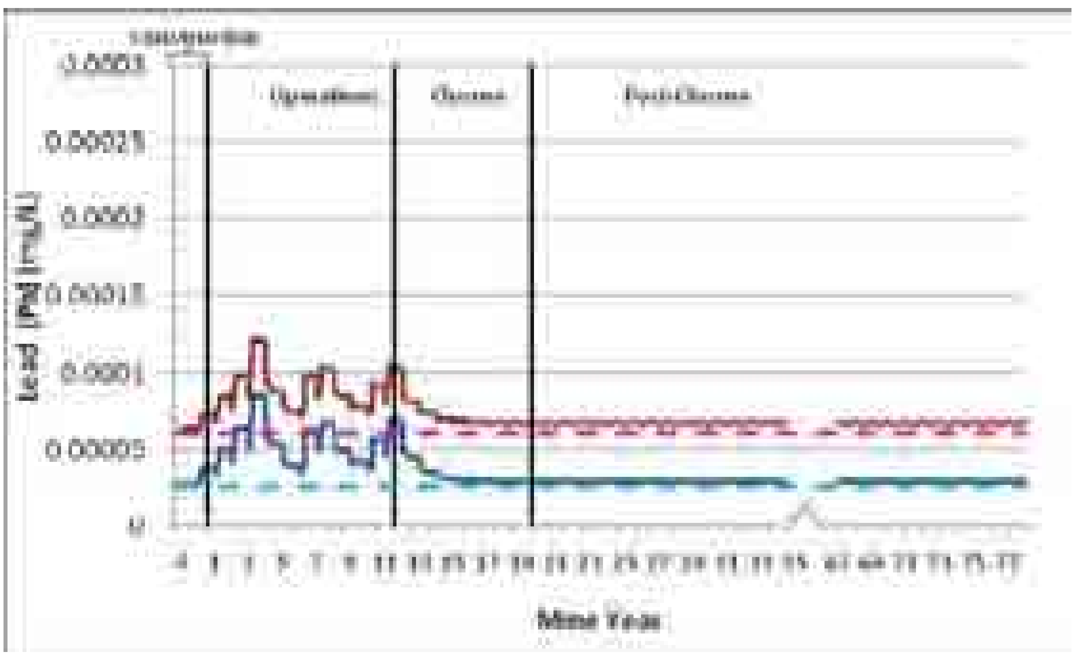
Dissolved and Total Metals (Lake N11) (continued)



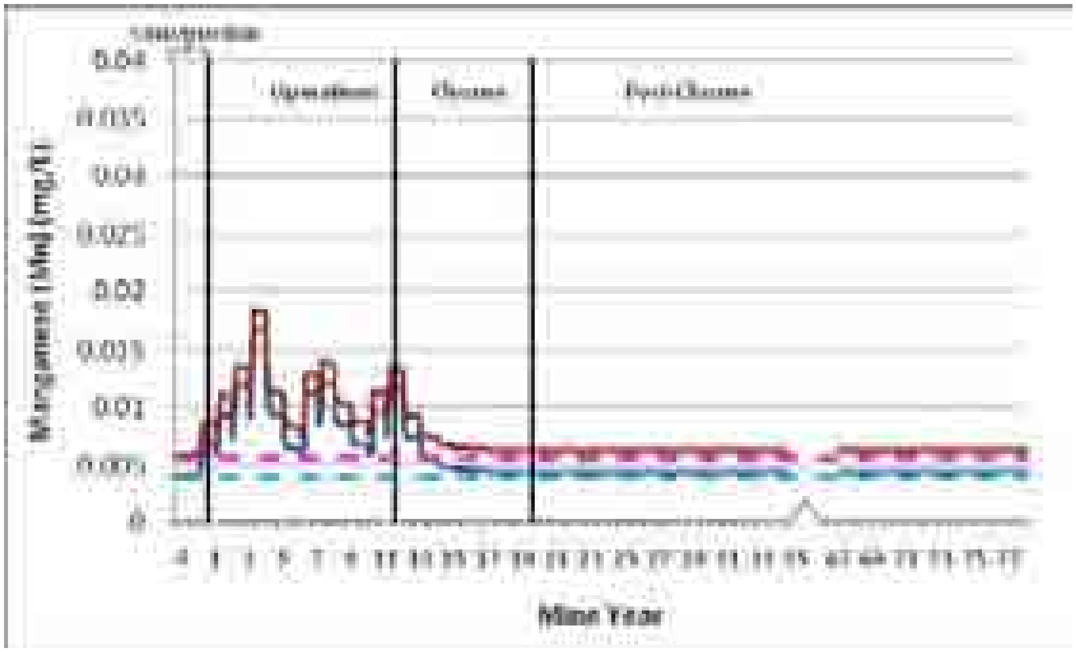


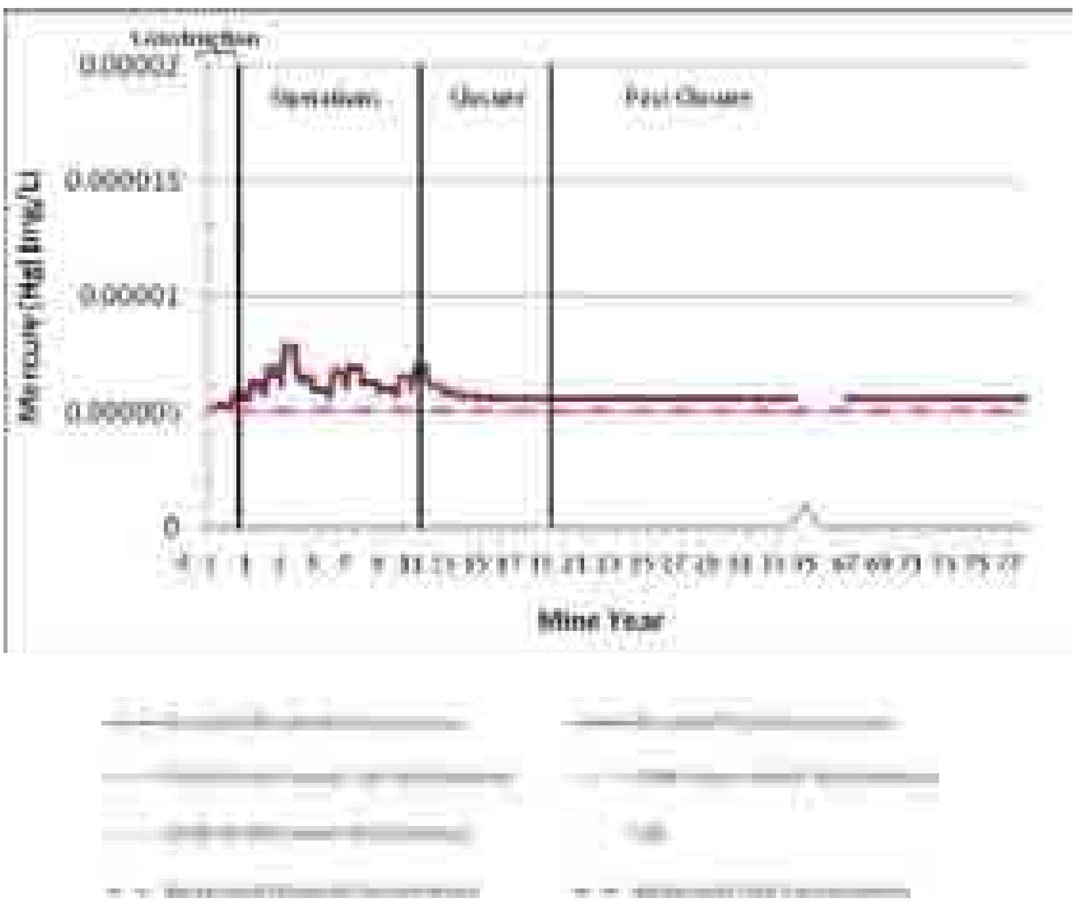
Dissolved and Total Metals (Lake N11) (continued)



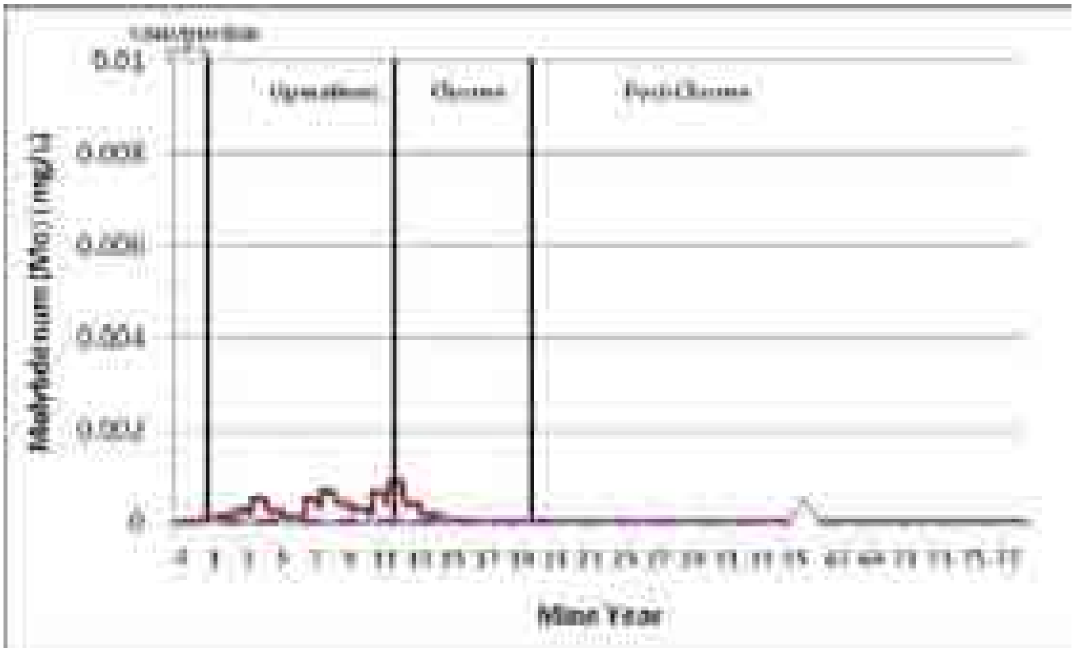


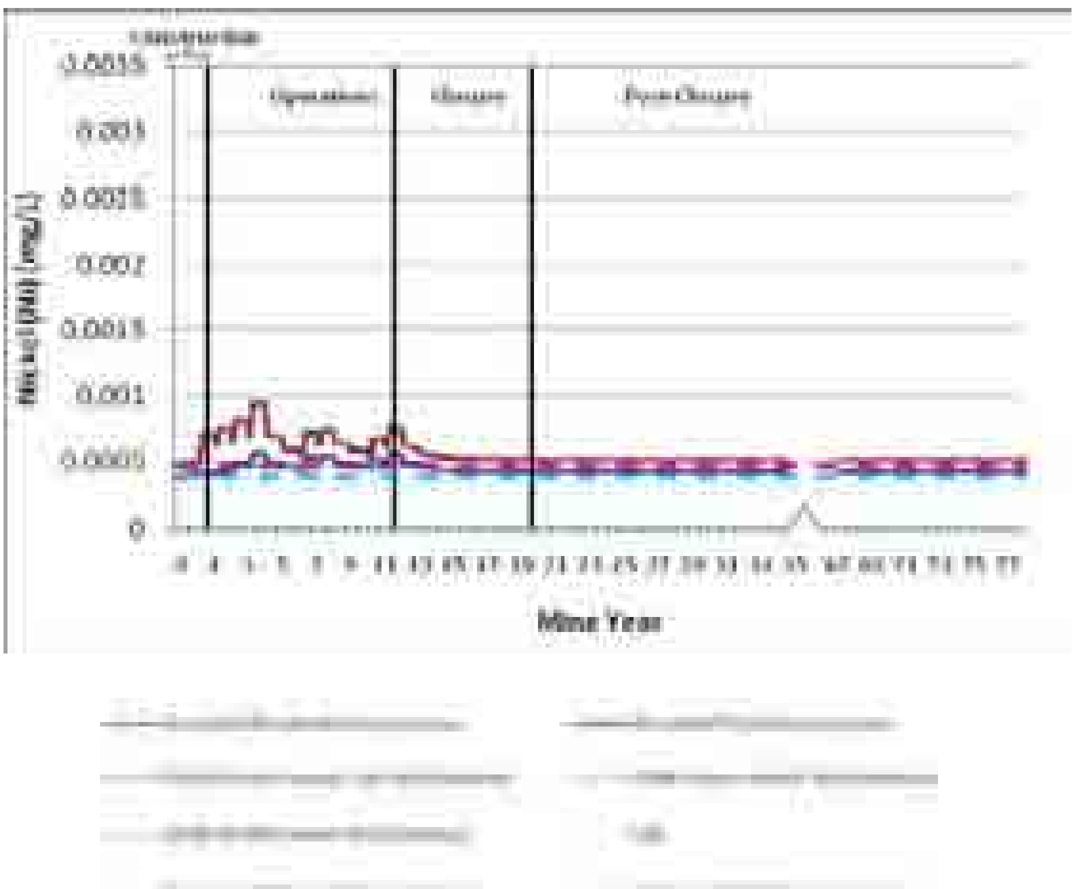
Dissolved and Total Metals (Lake N11) (continued)



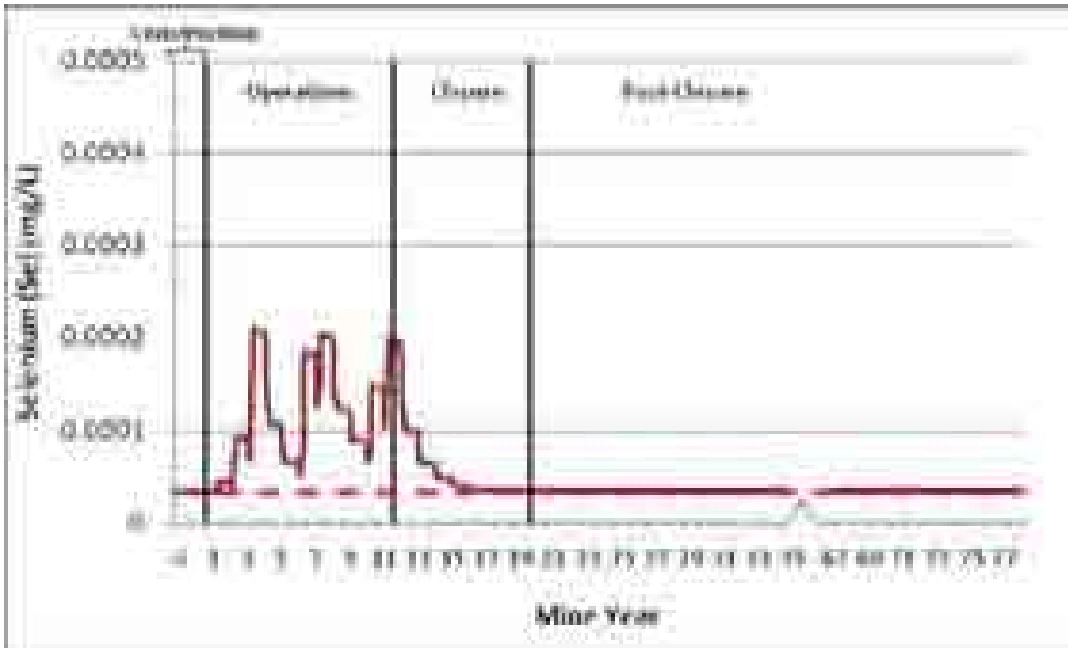


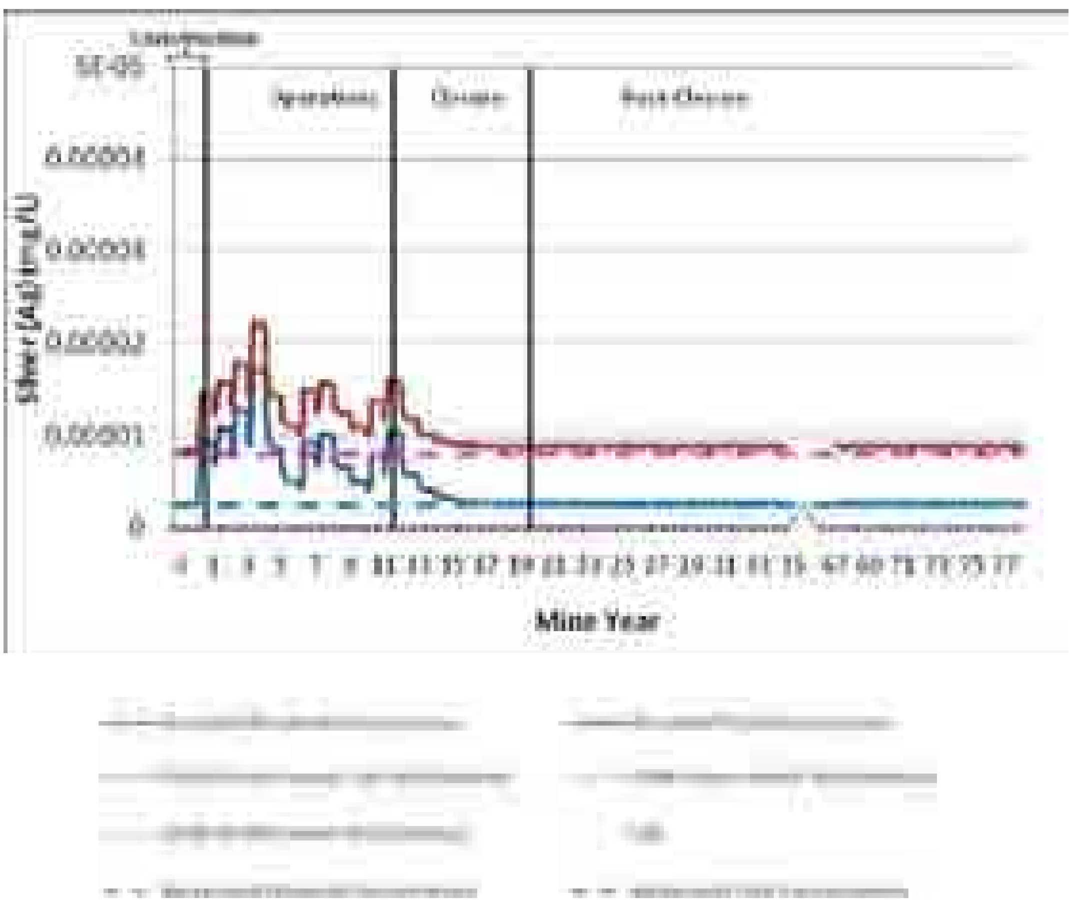
Dissolved and Total Metals (Lake N11) (continued)



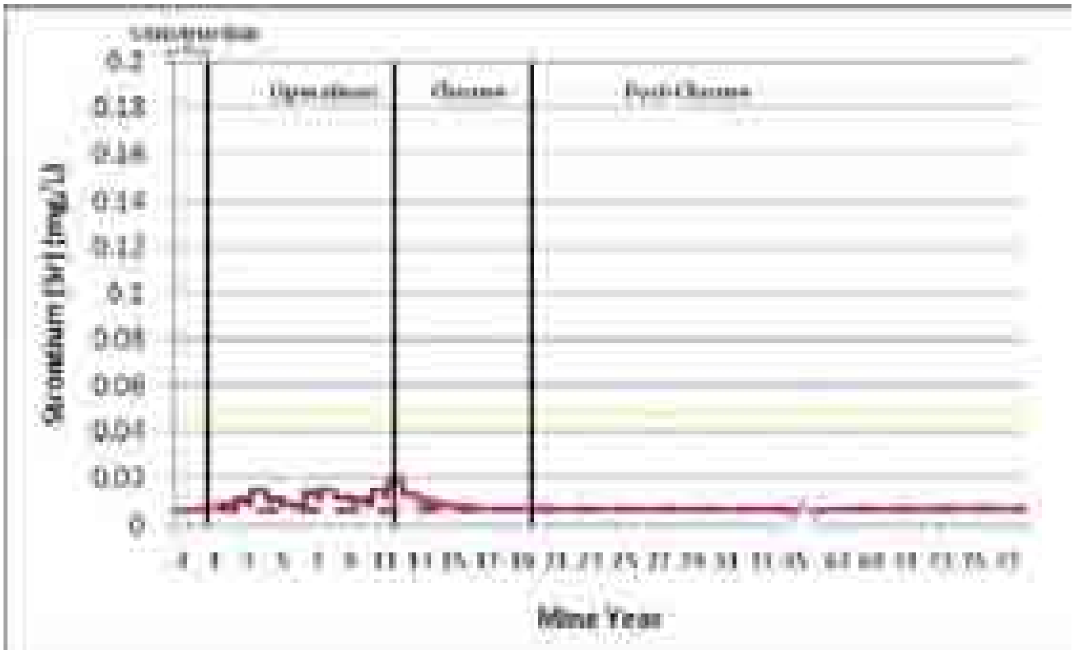


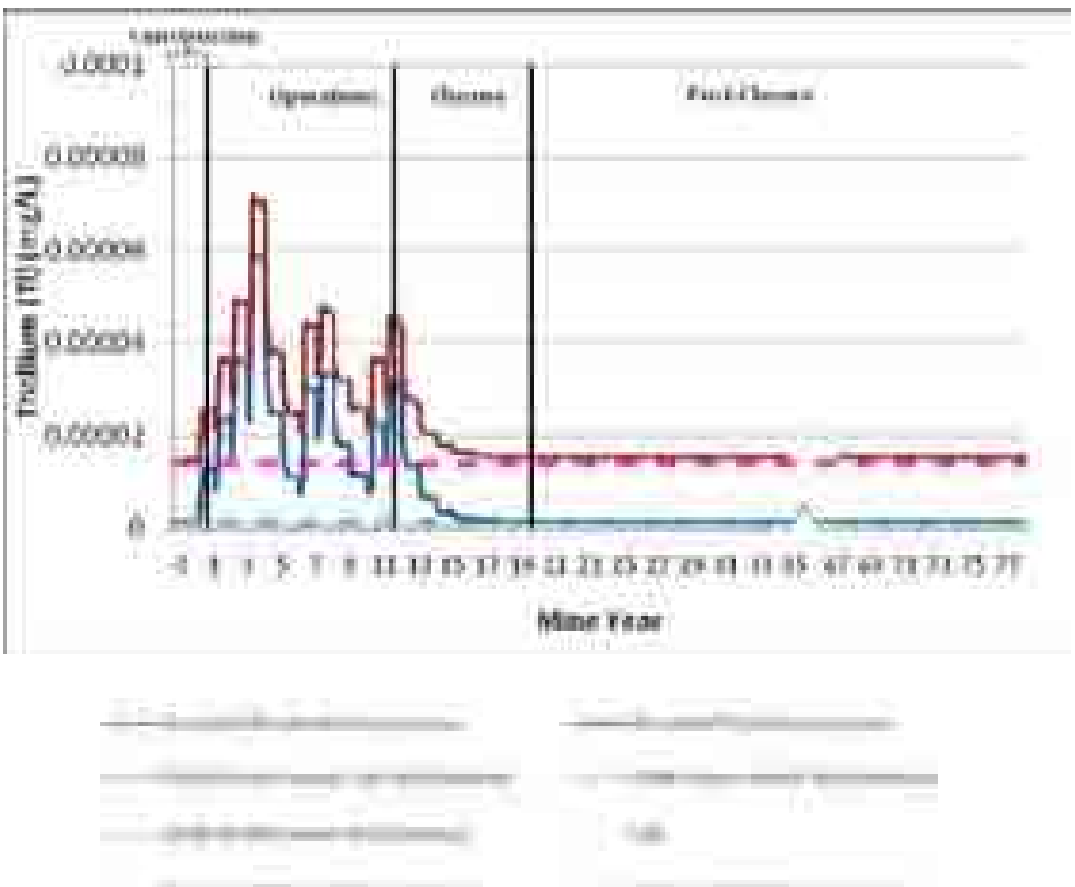
Dissolved and Total Metals (Lake N11) (continued)



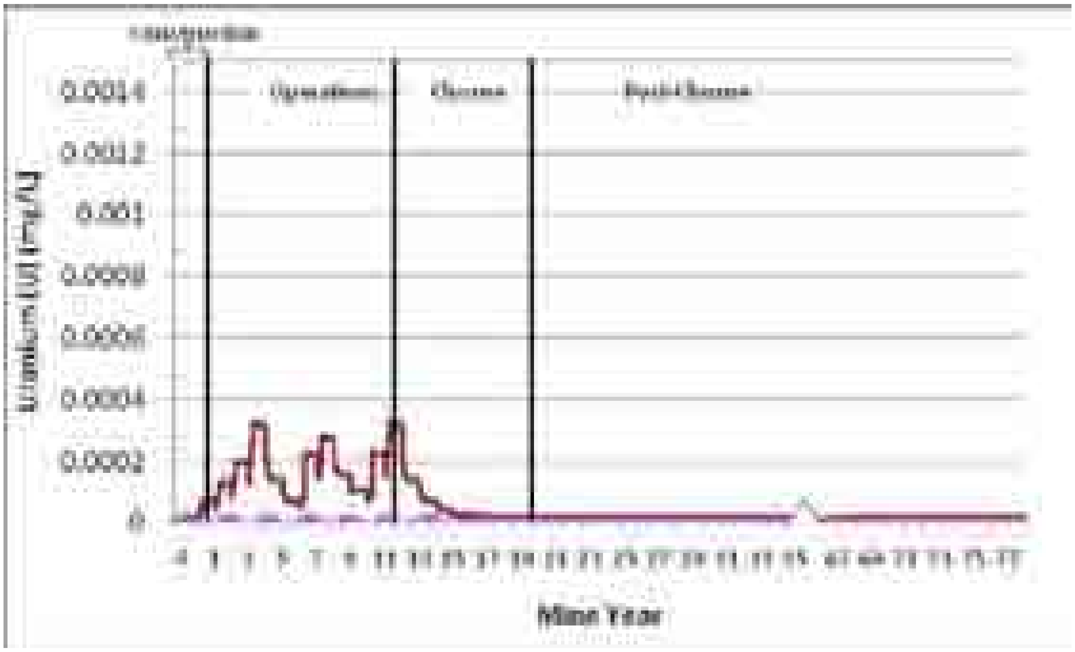


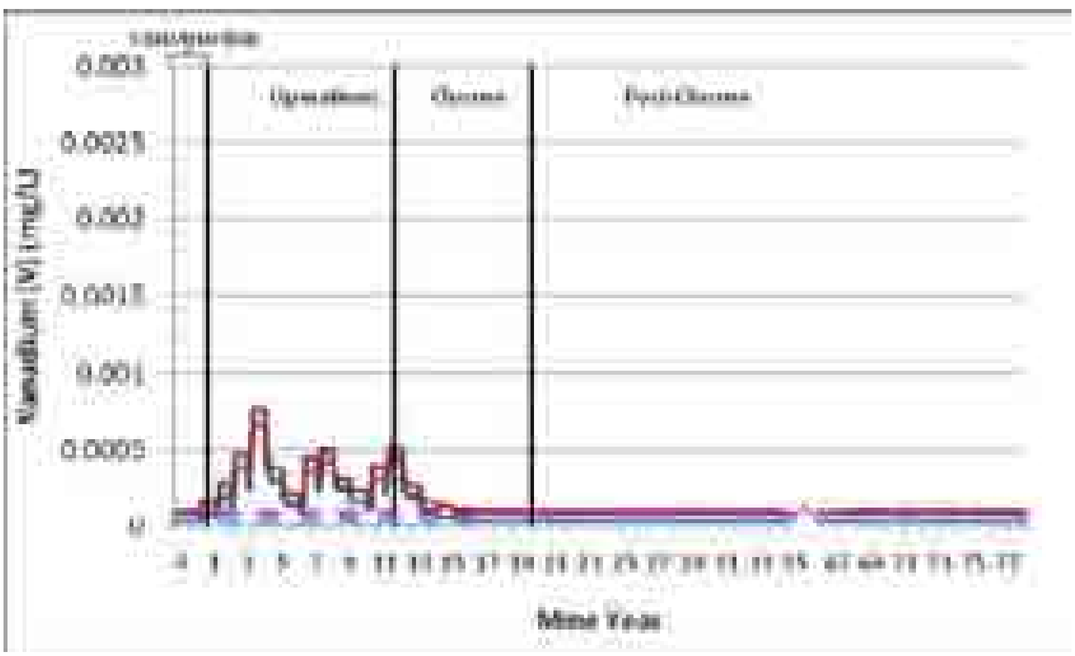
Dissolved and Total Metals (Lake N11) (continued)



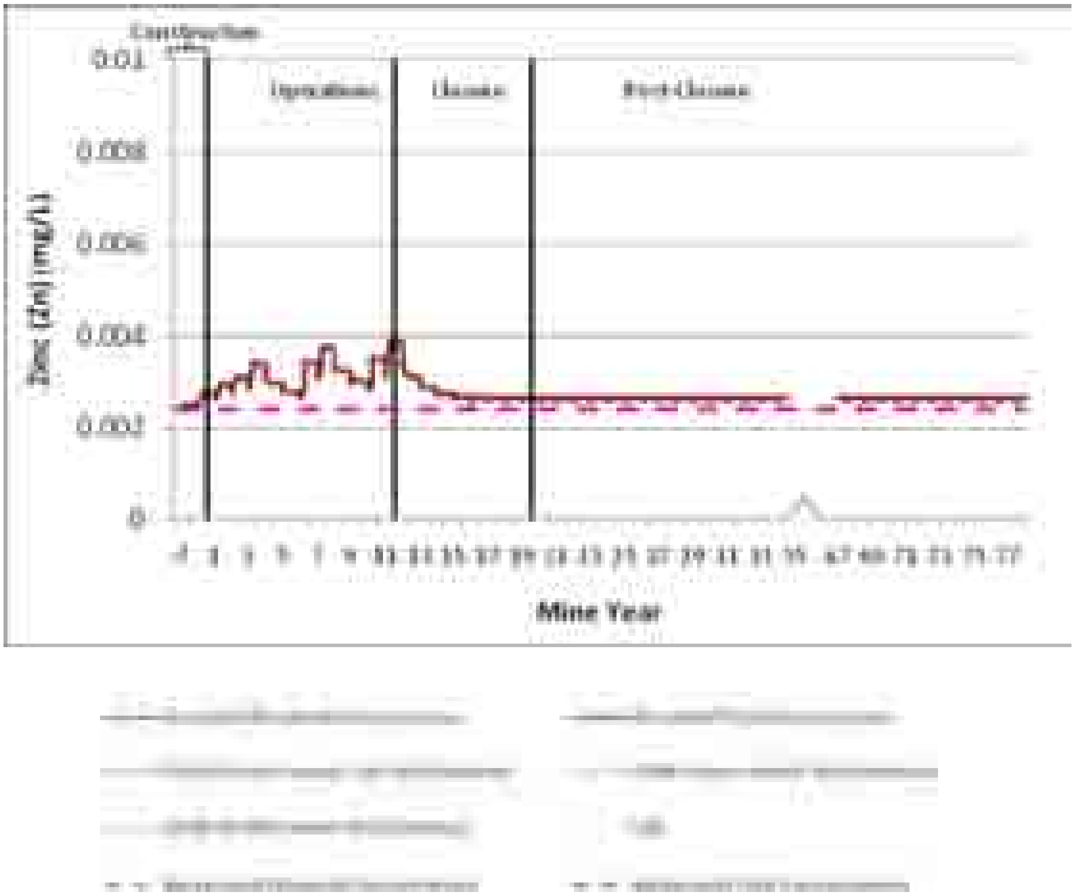


Dissolved and Total Metals (Lake N11) (continued)

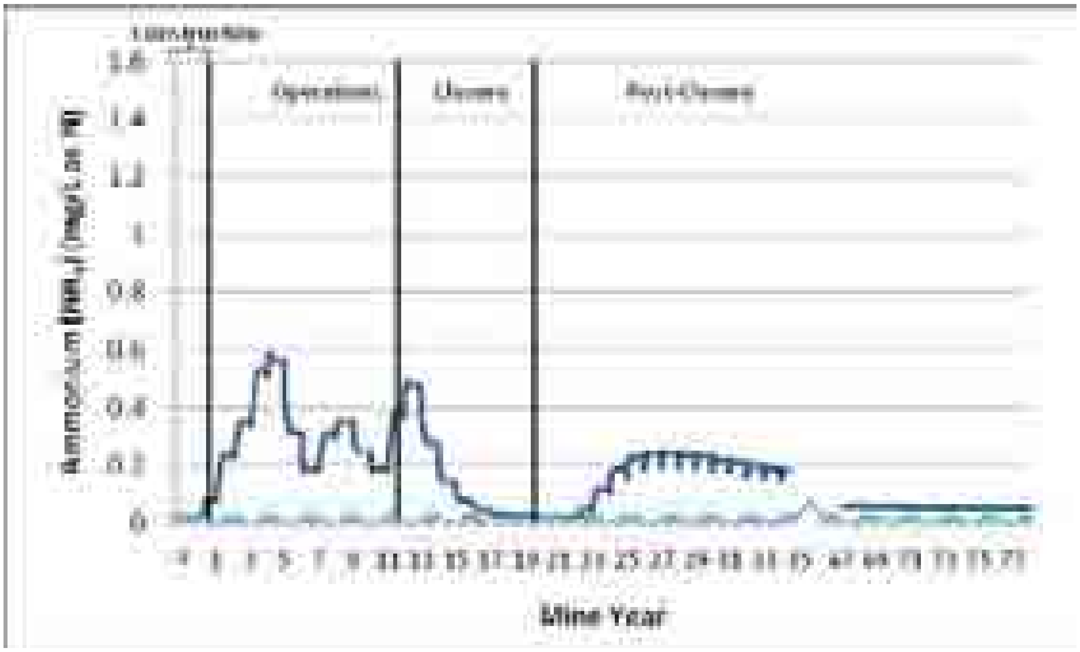


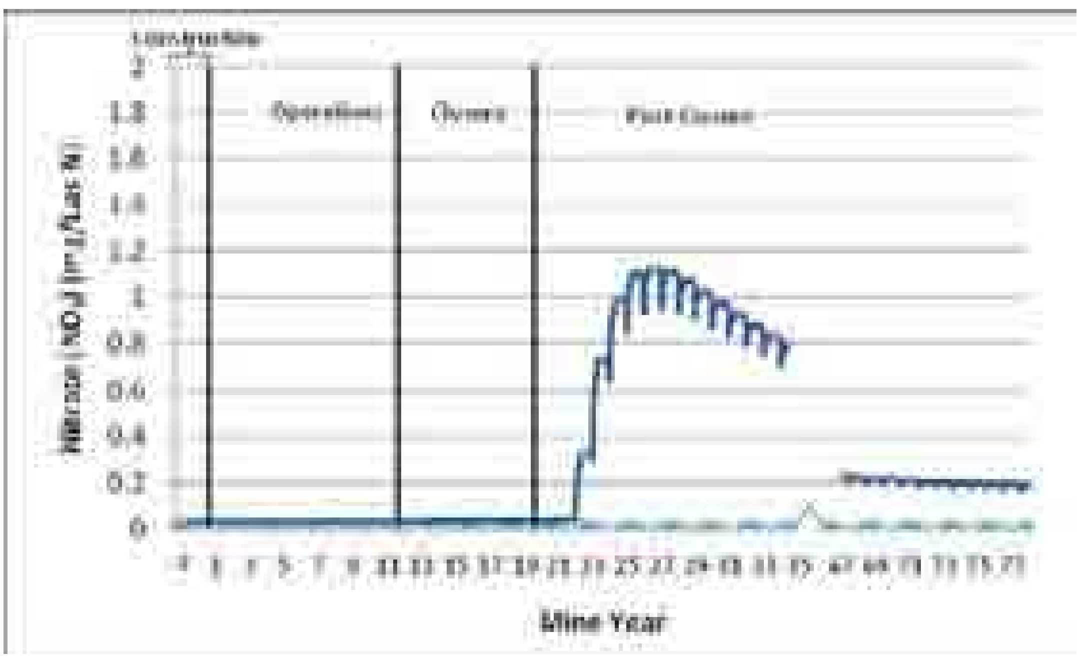


Dissolved and Total Metals (Lake N11) (continued)

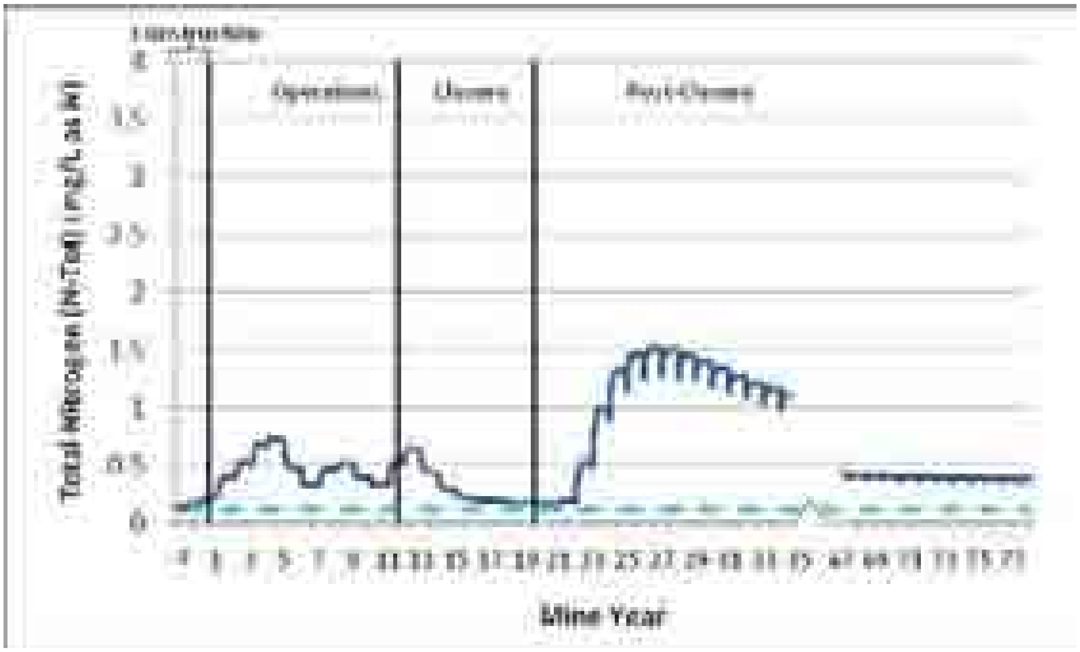


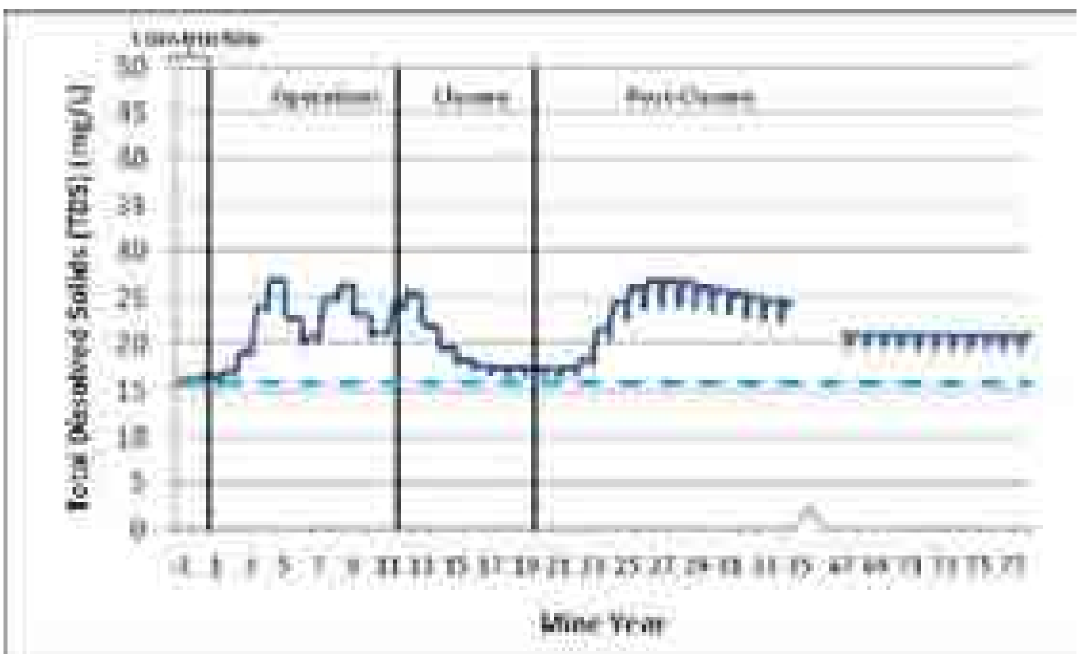
Nutrients and Anions (Lake 410)

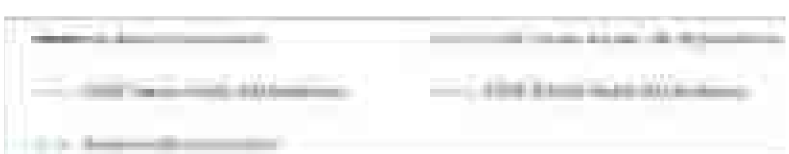




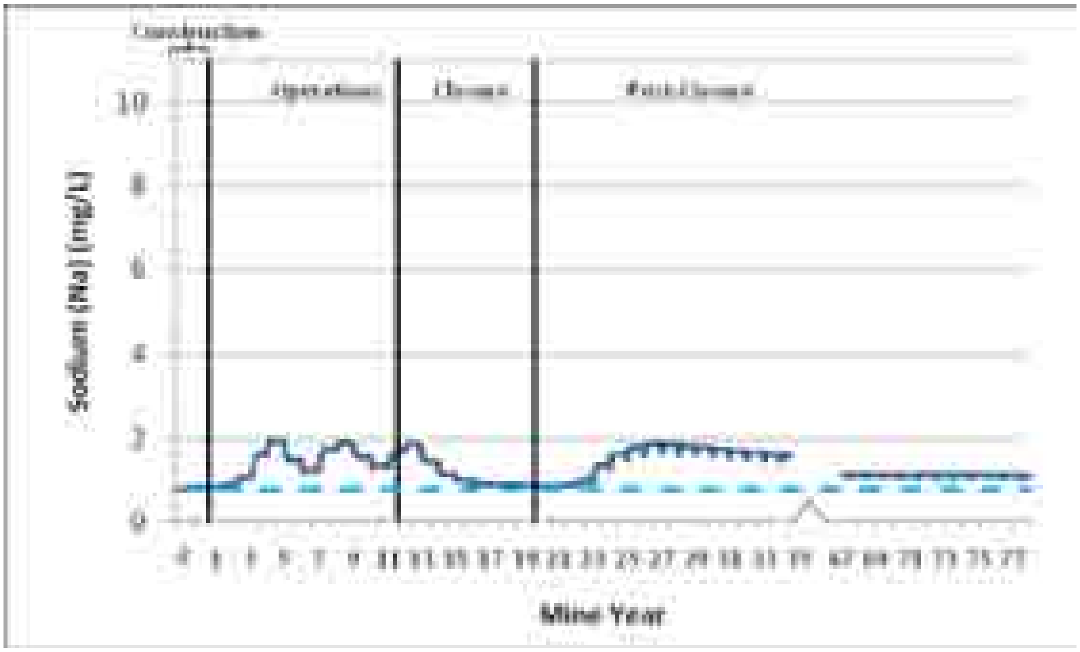
Nutrients and Anions (Lake 410) (continued)

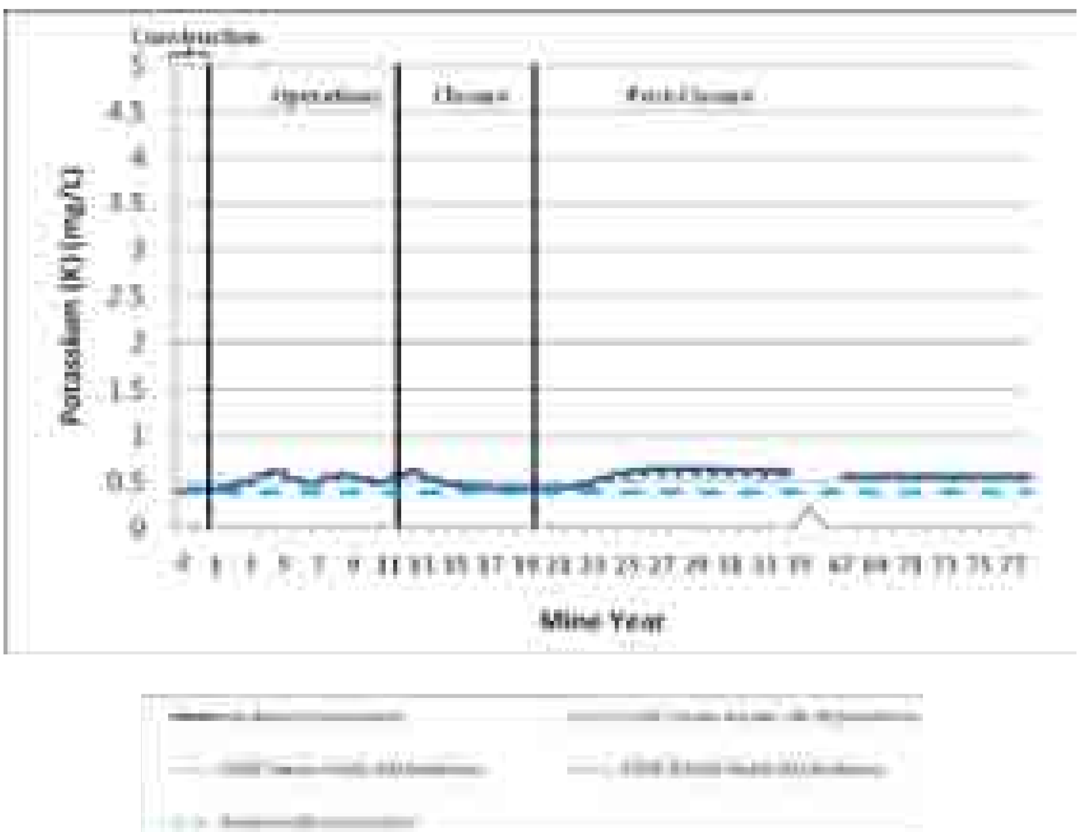




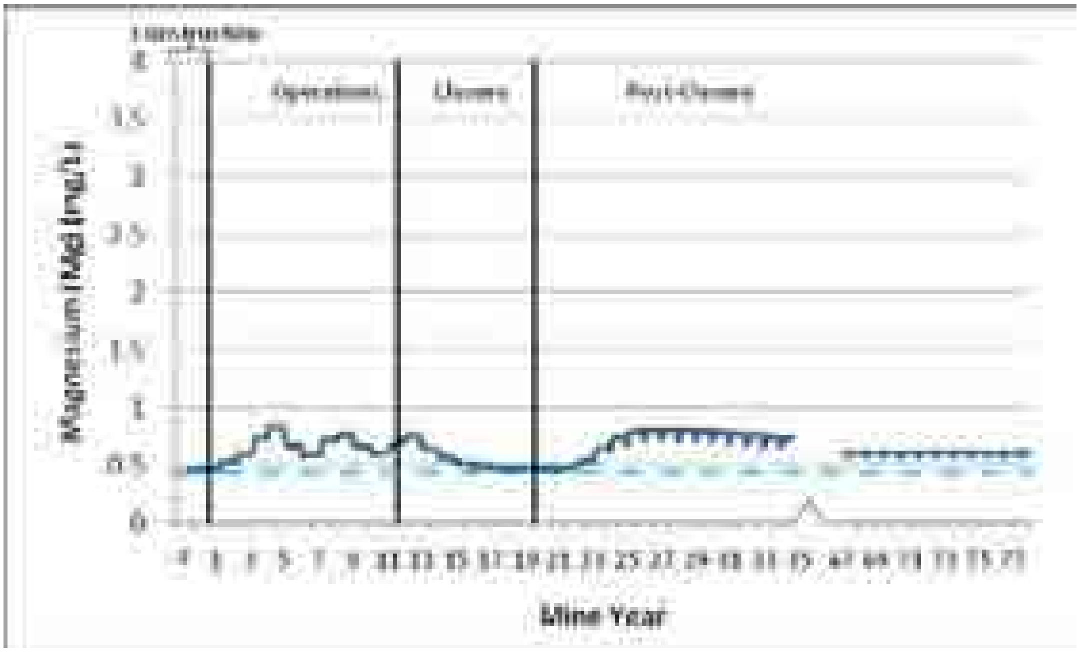


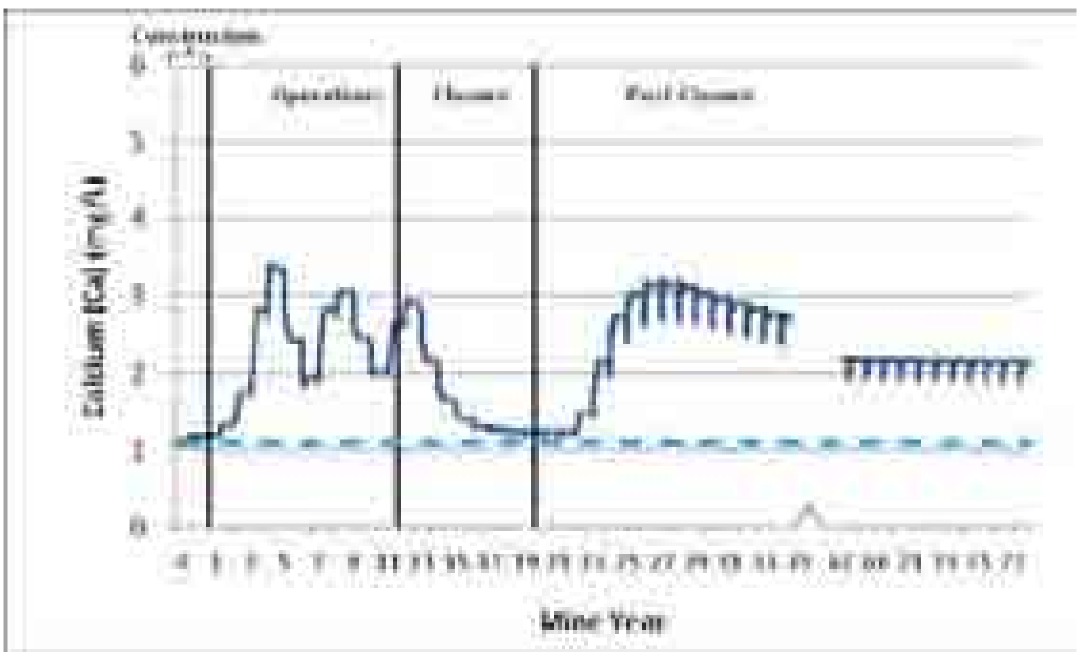
Nutrients and Anions (Lake 410) (continued)



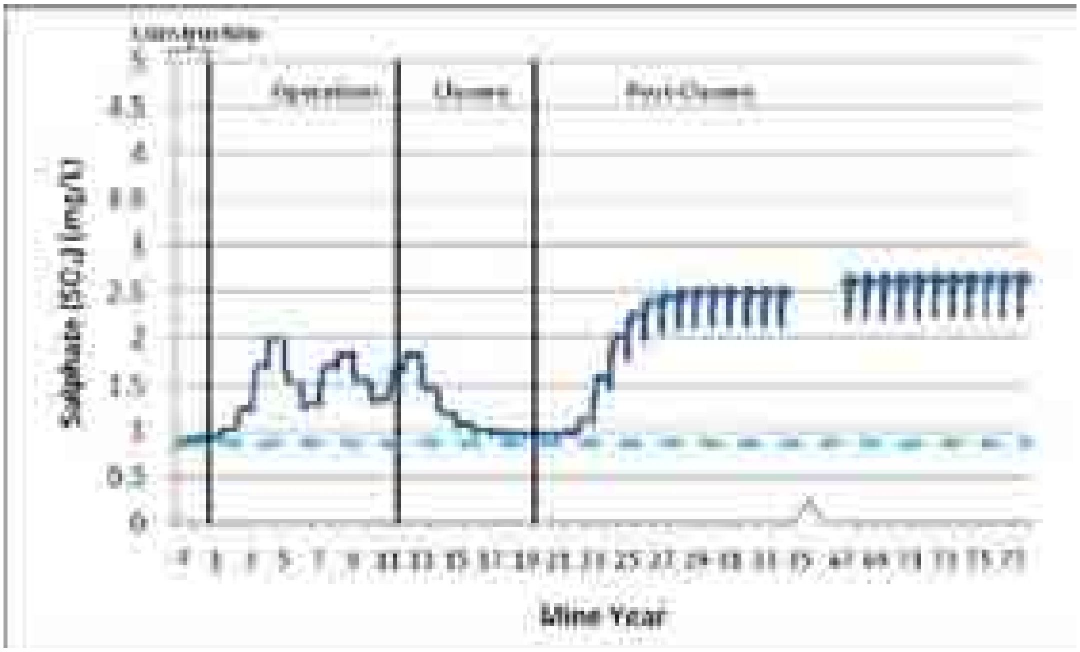


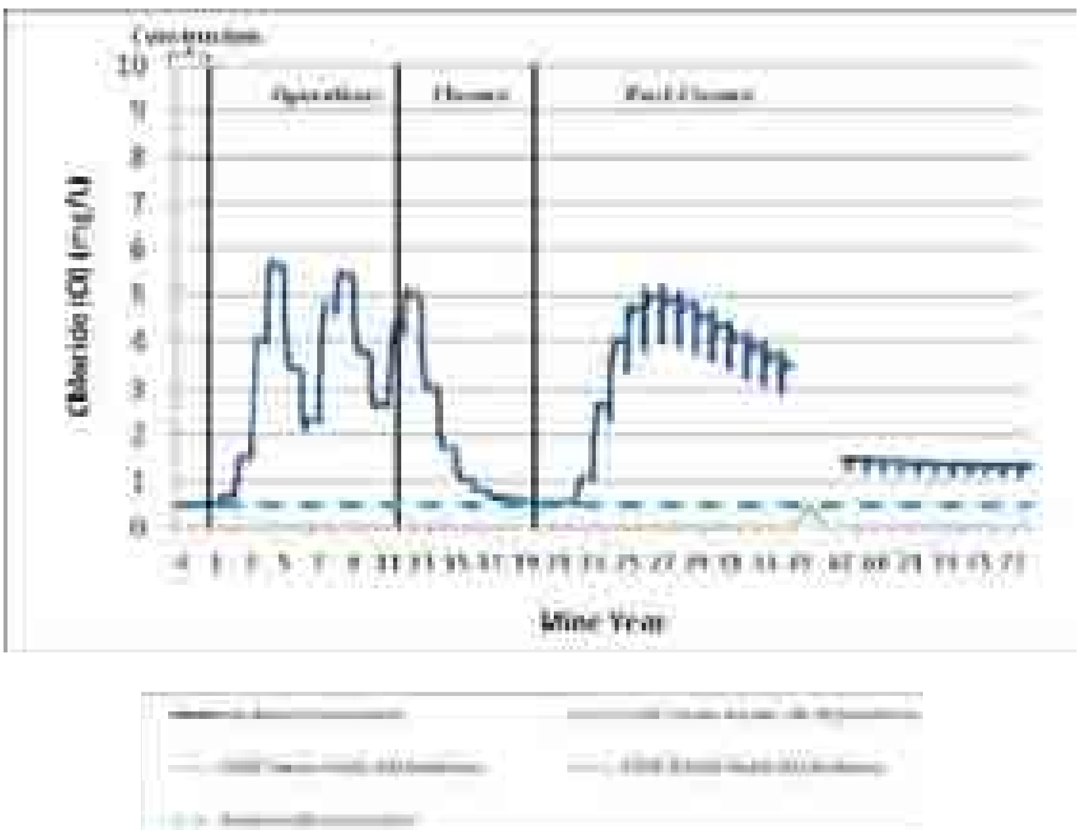
Nutrients and Anions (Lake 410) (continued)



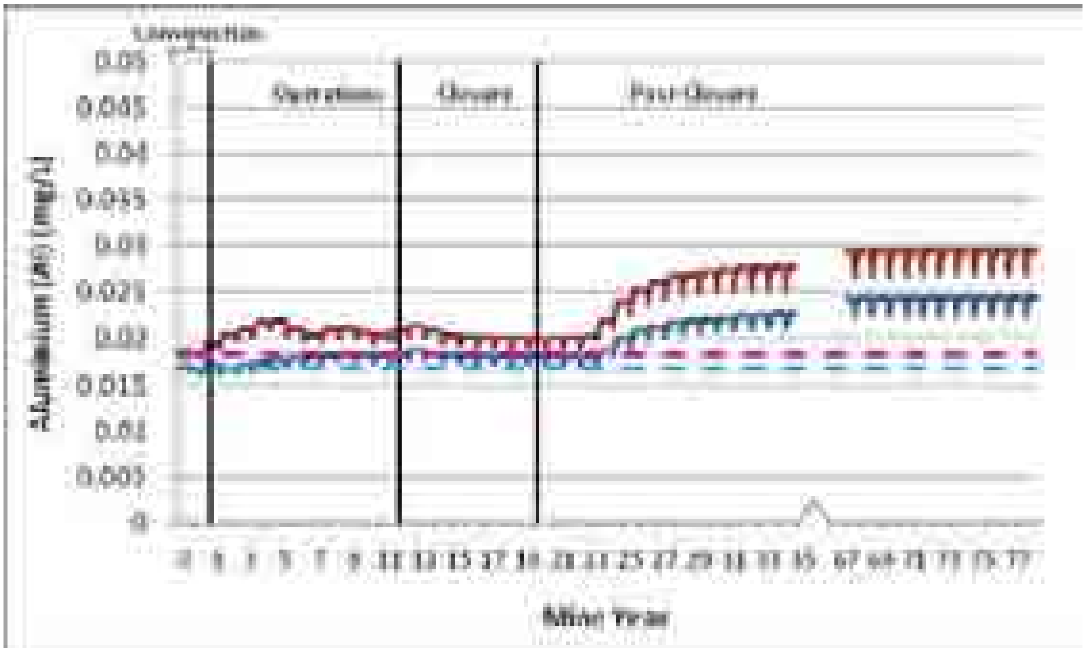


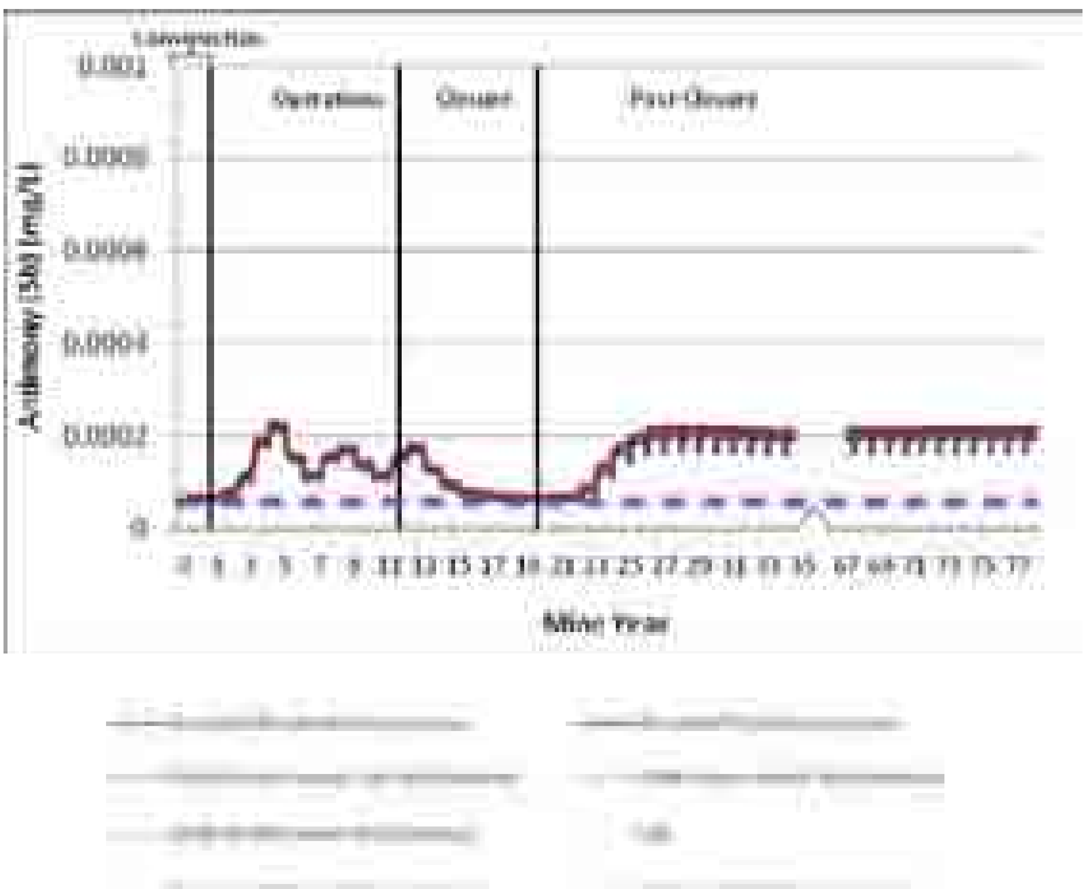
Nutrients and Anions (Lake 410) (continued)



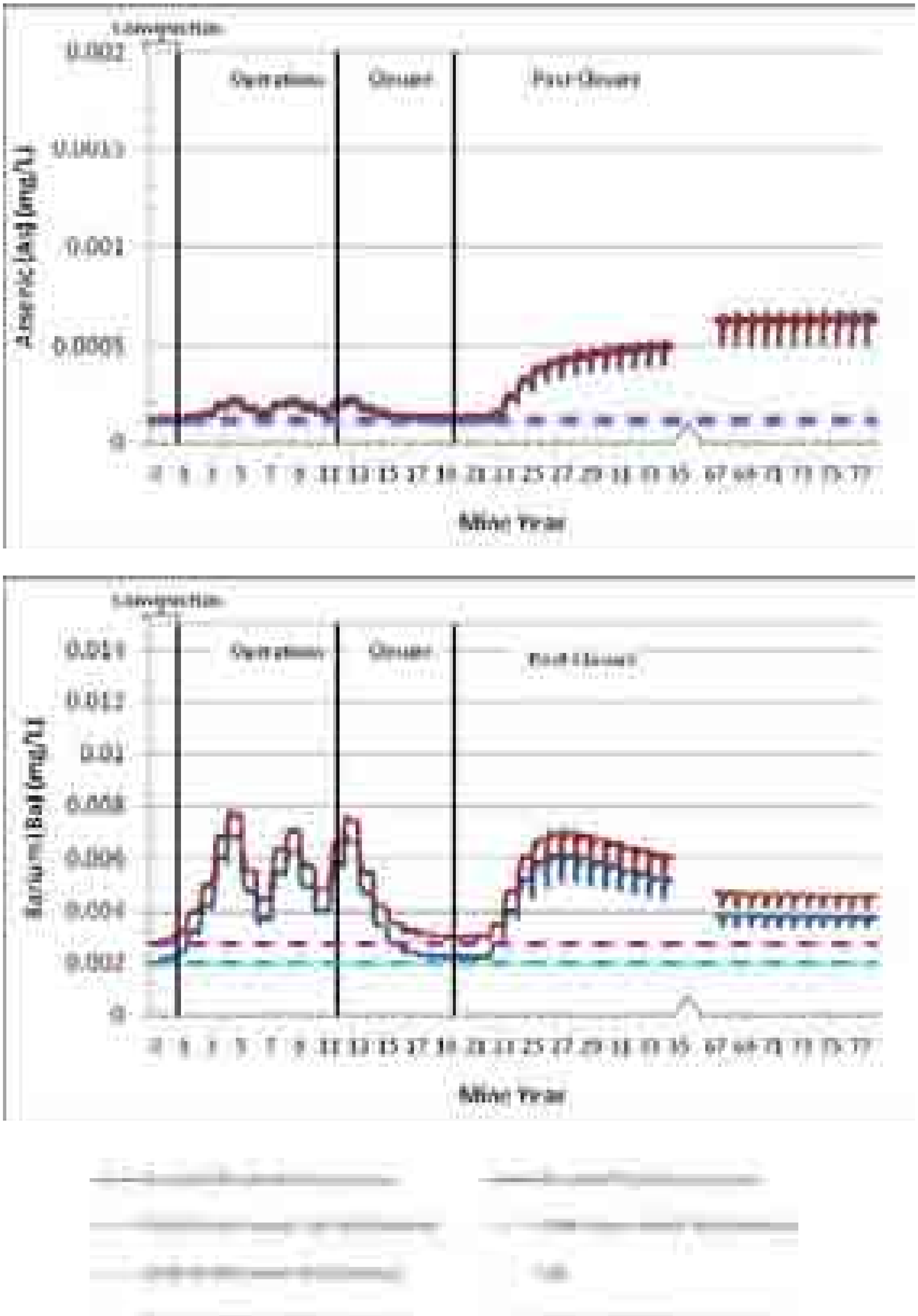


Dissolved and Total Metals (Lake 410)

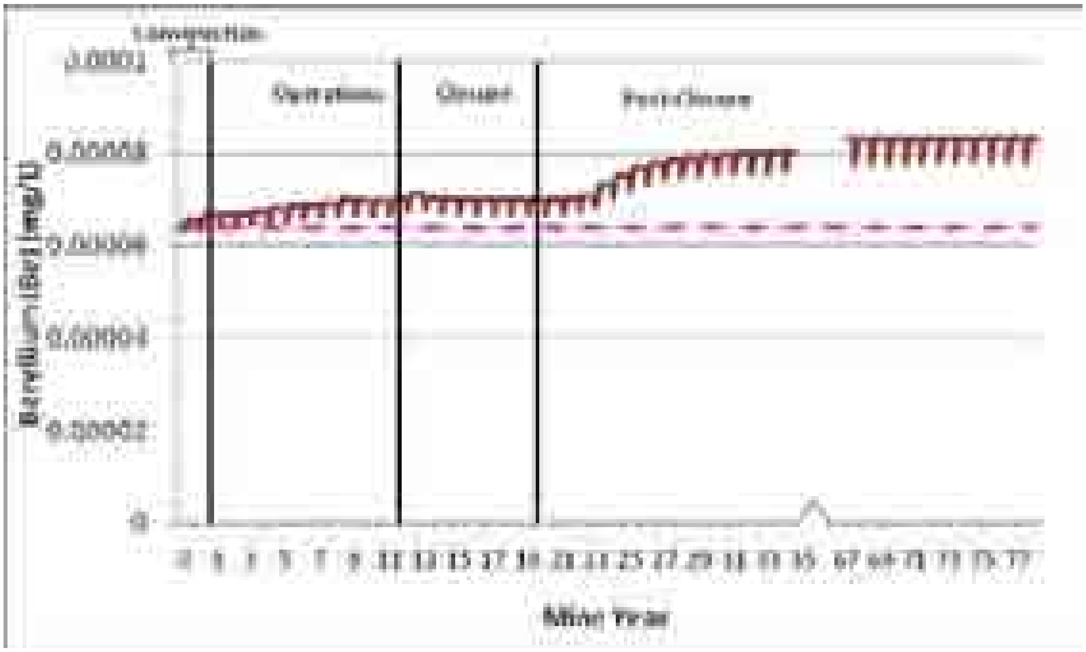


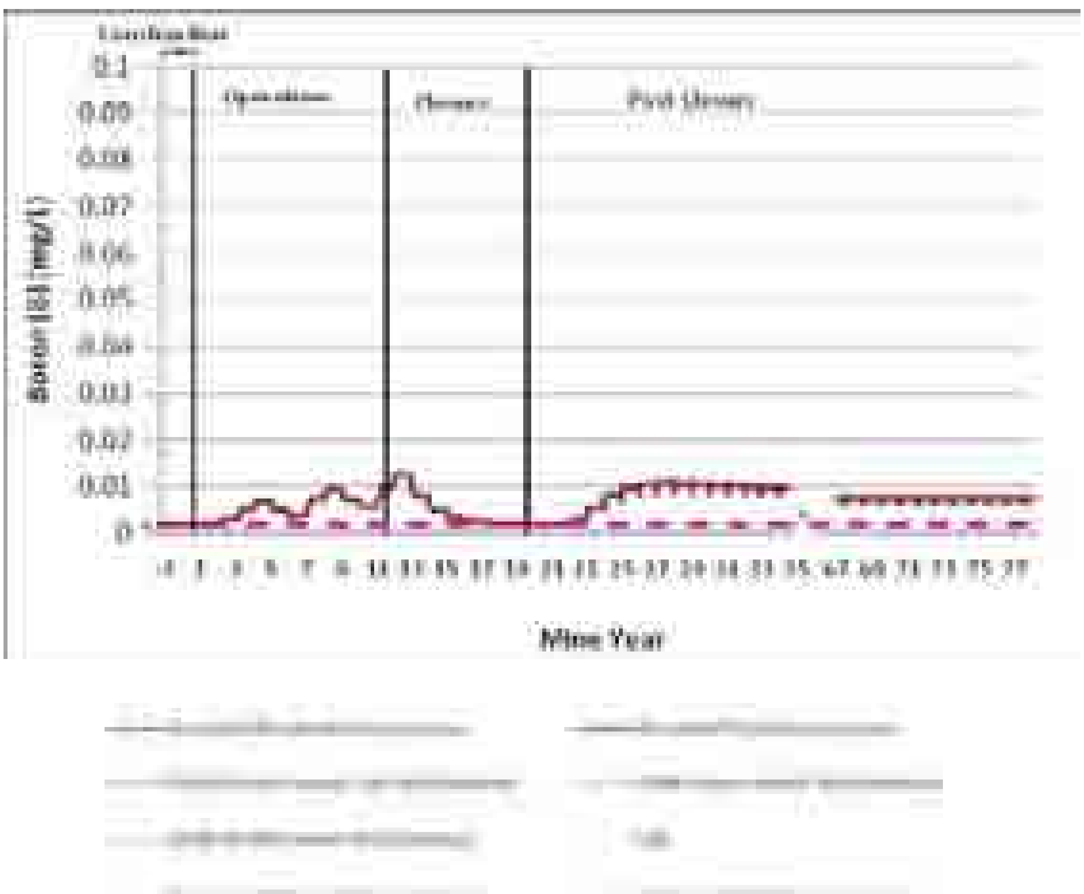


Dissolved and Total Metals (Lake 410) (continued)

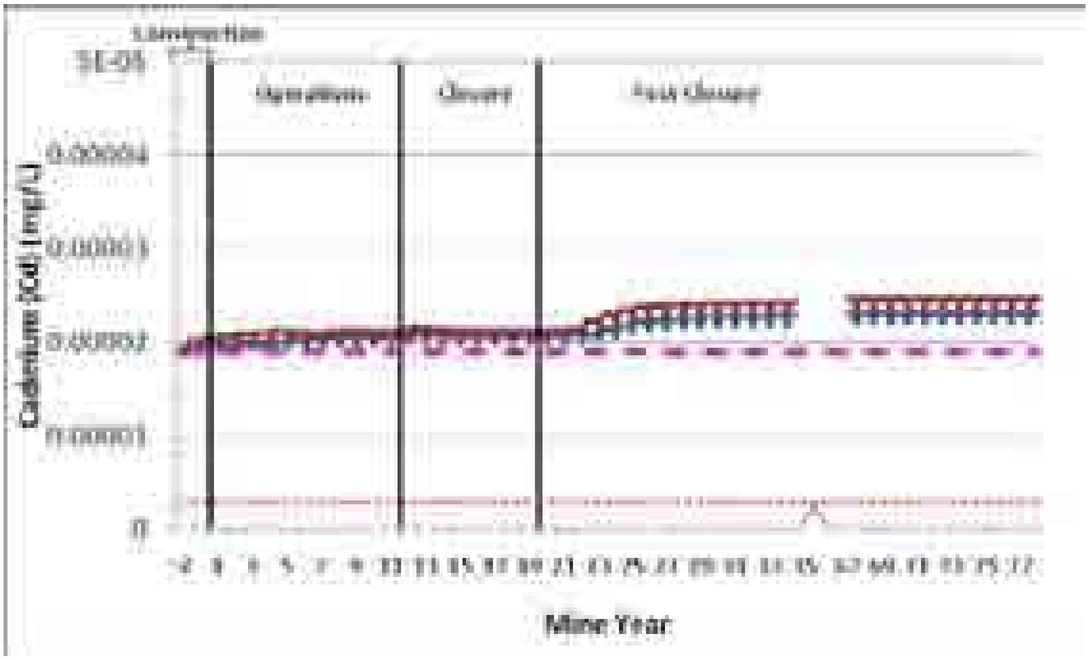


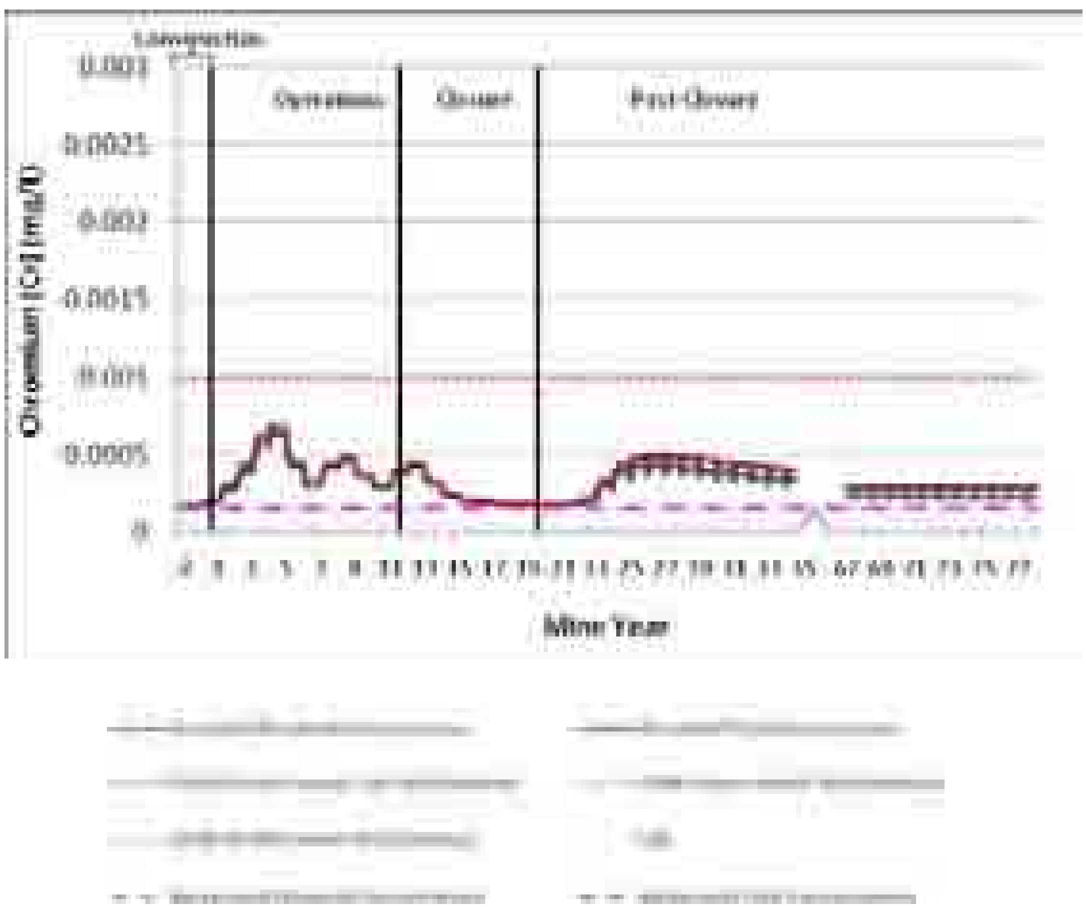
Dissolved and Total Metals (Lake 410) (continued)



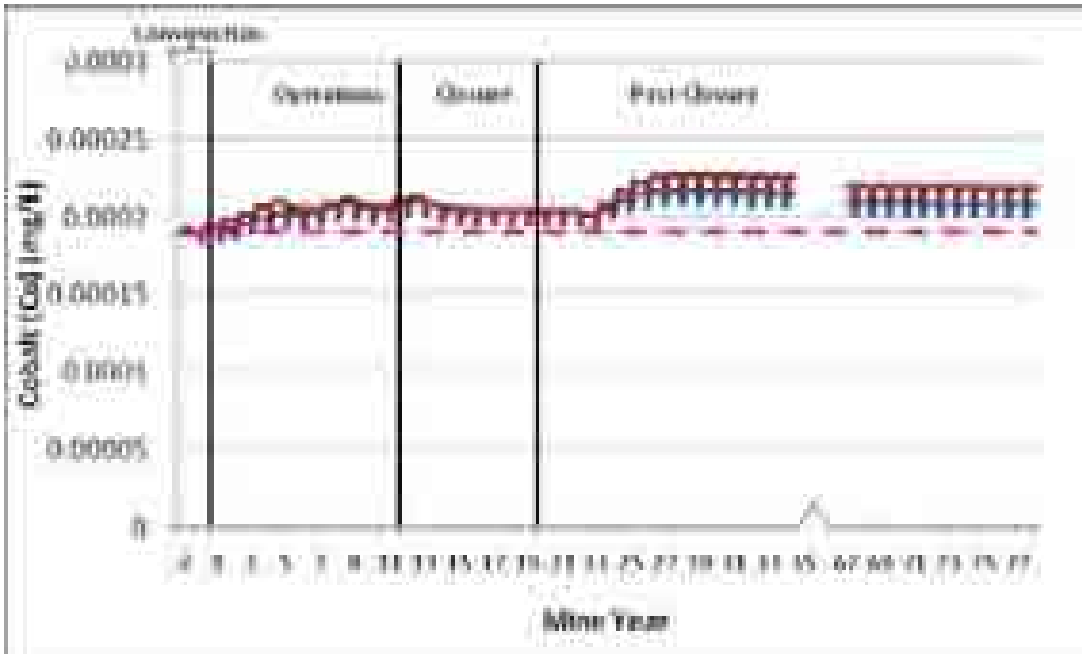


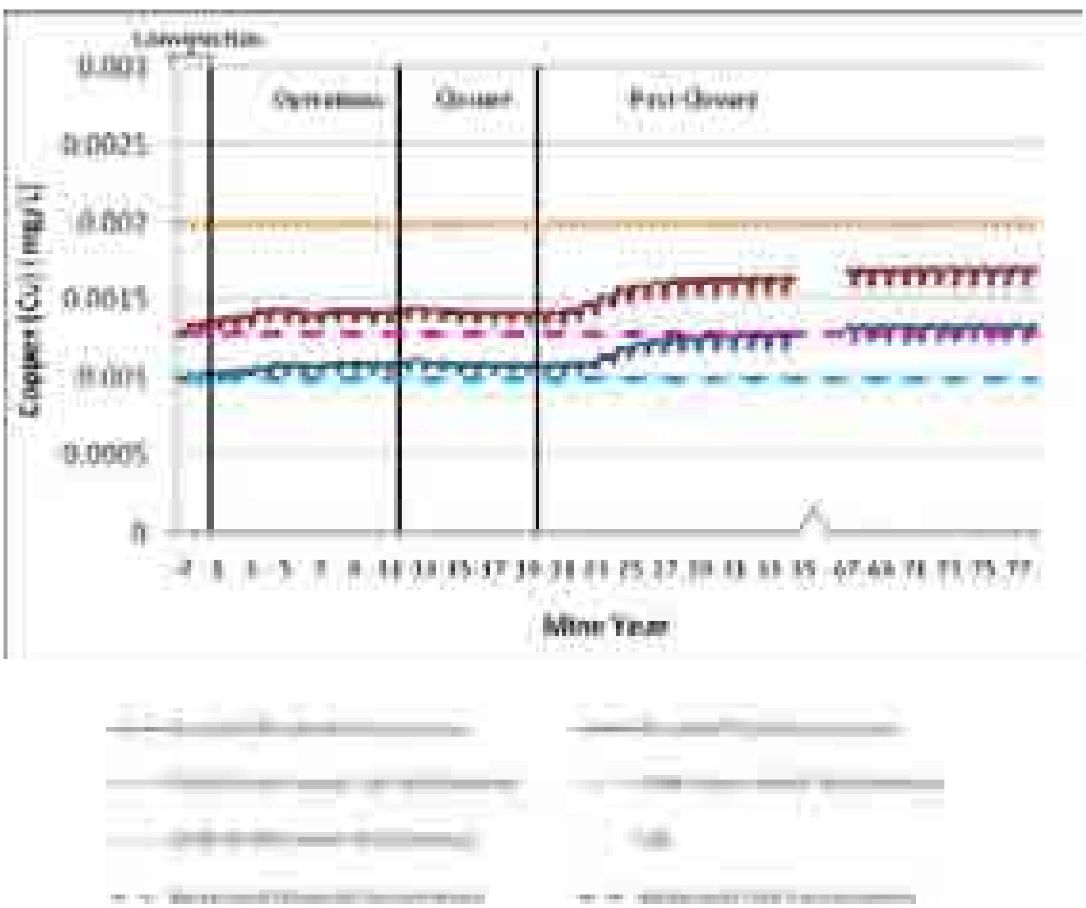
Dissolved and Total Metals (Lake 410) (continued)



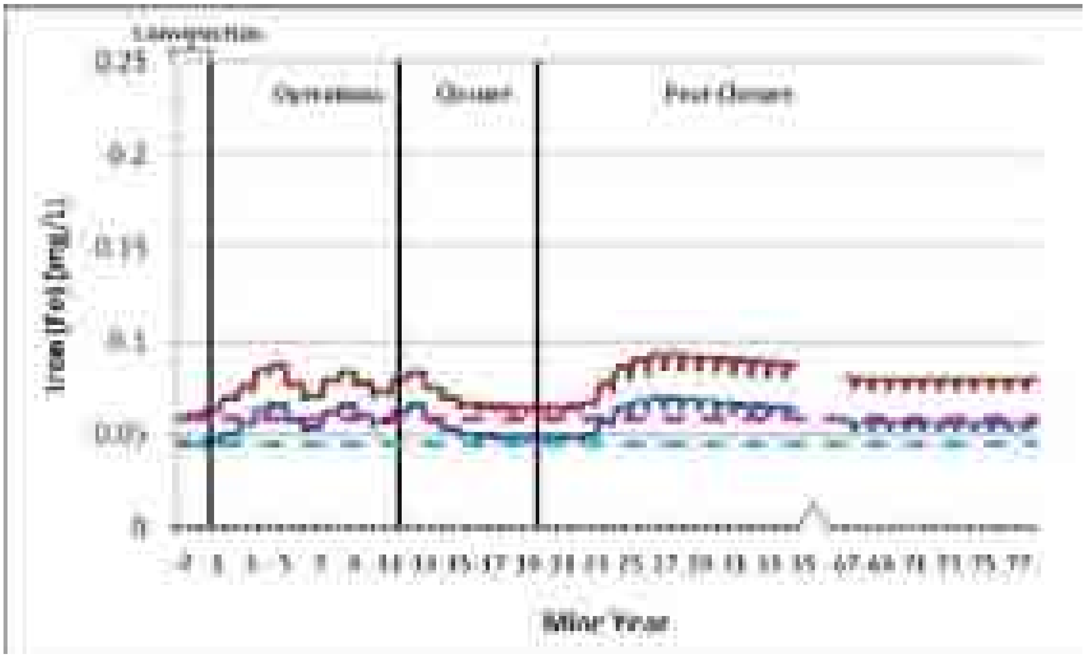


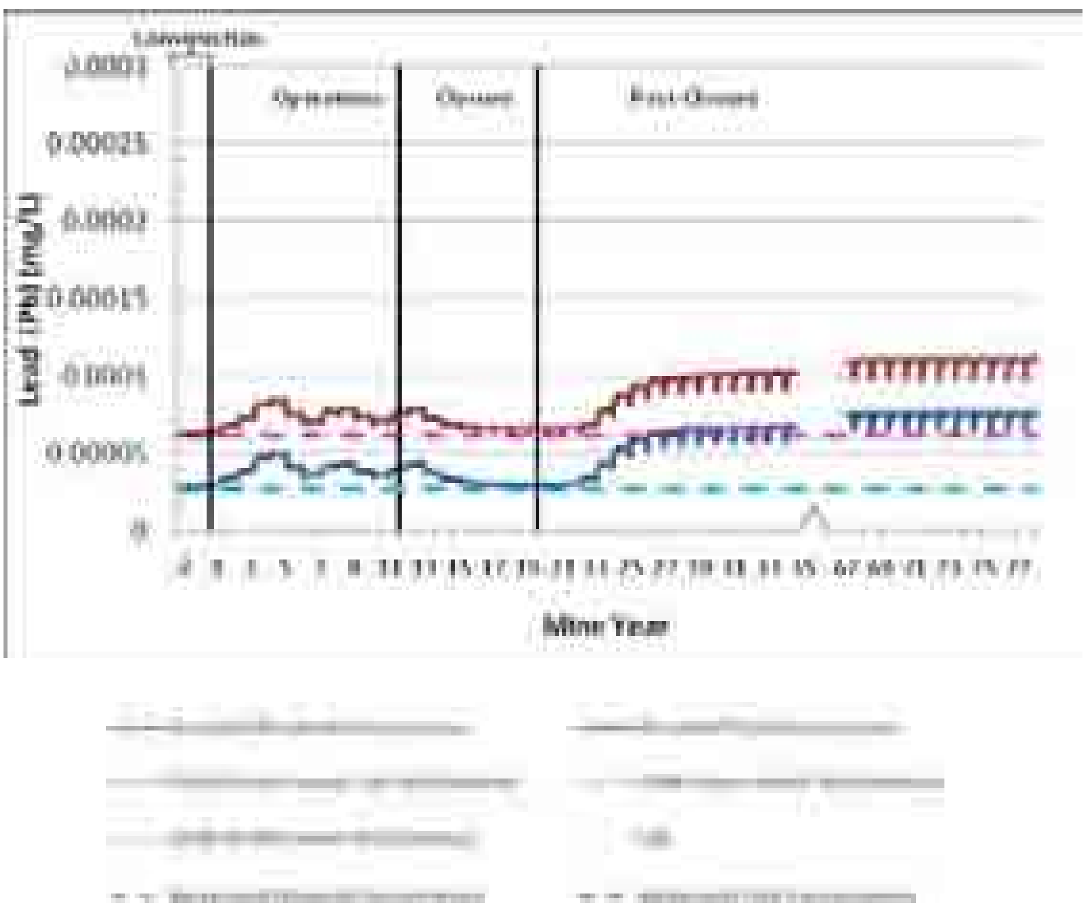
Dissolved and Total Metals (Lake 410) (continued)



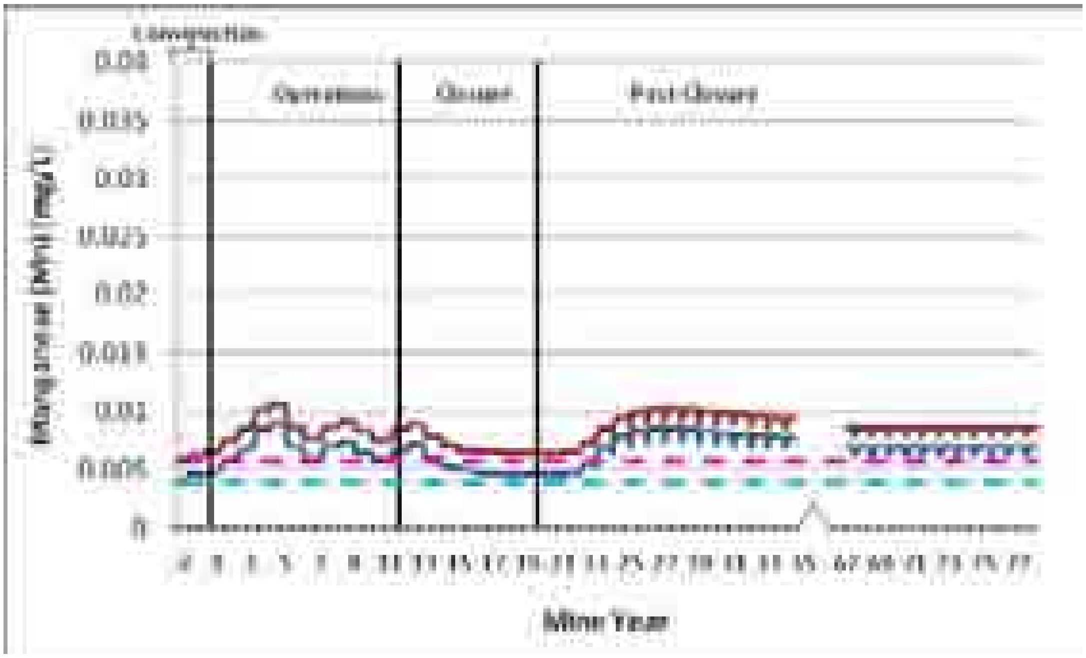


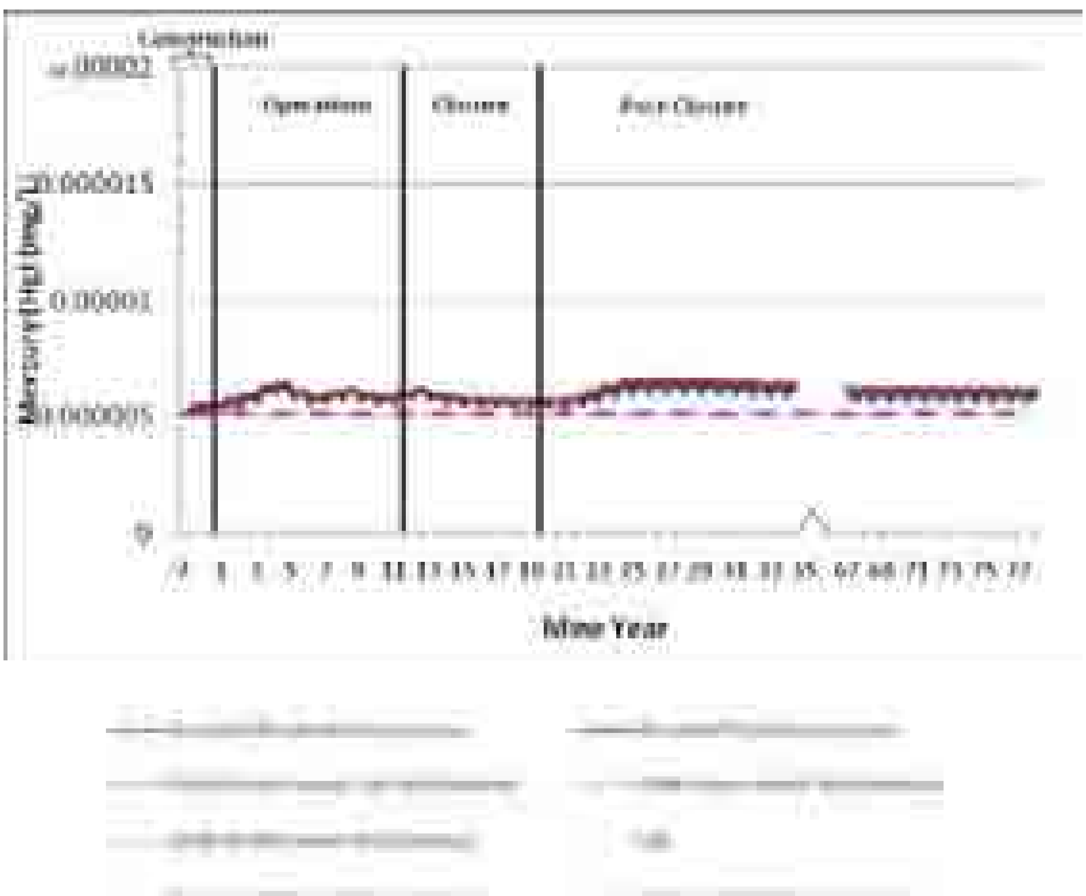
Dissolved and Total Metals (Lake 410) (continued)



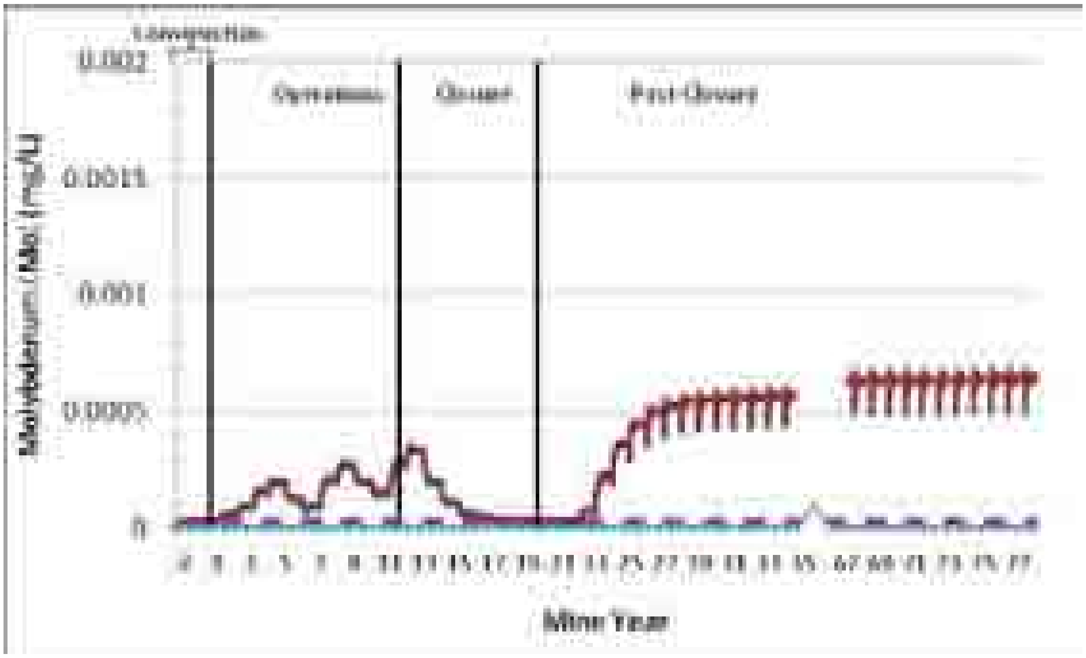


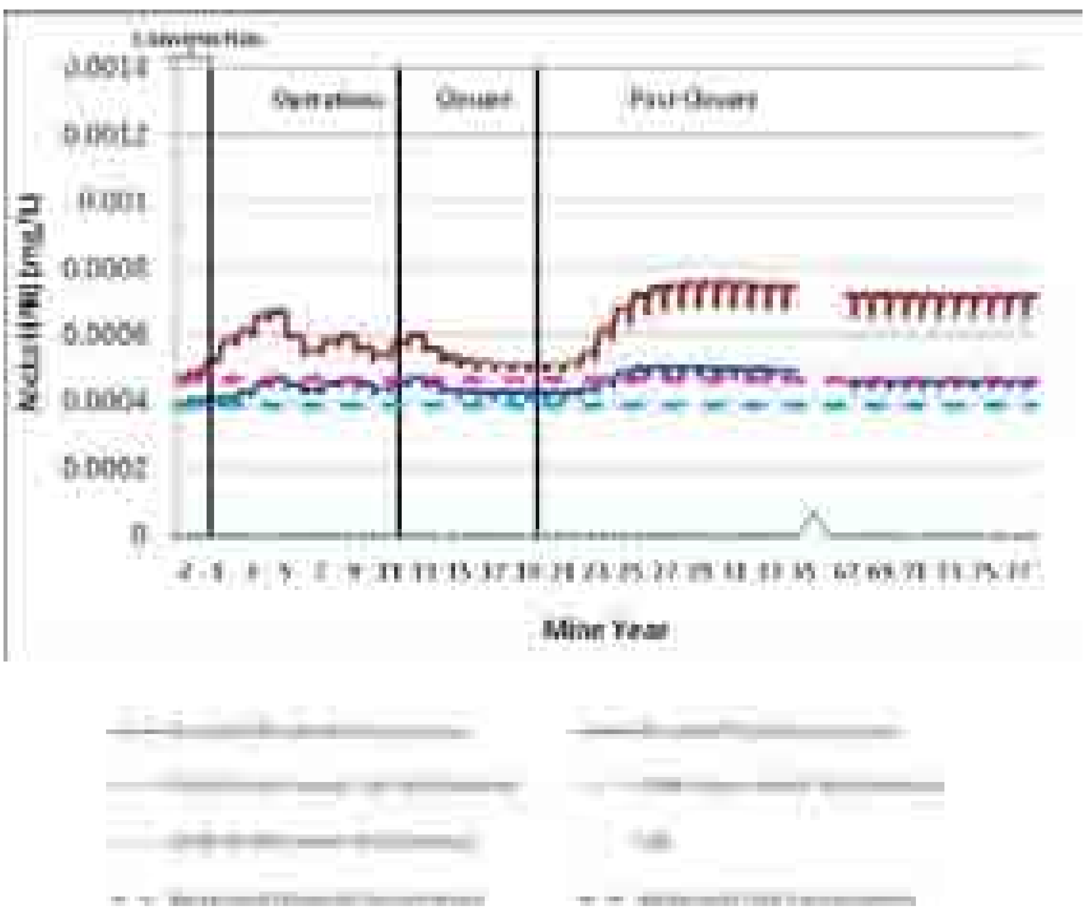
Dissolved and Total Metals (Lake 410) (continued)



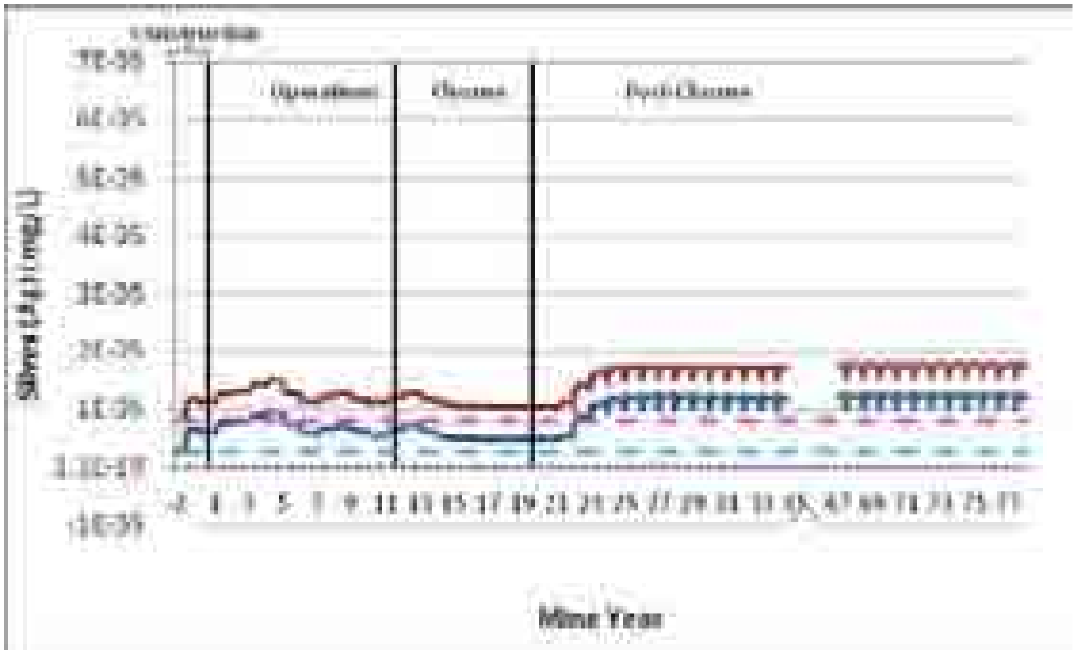


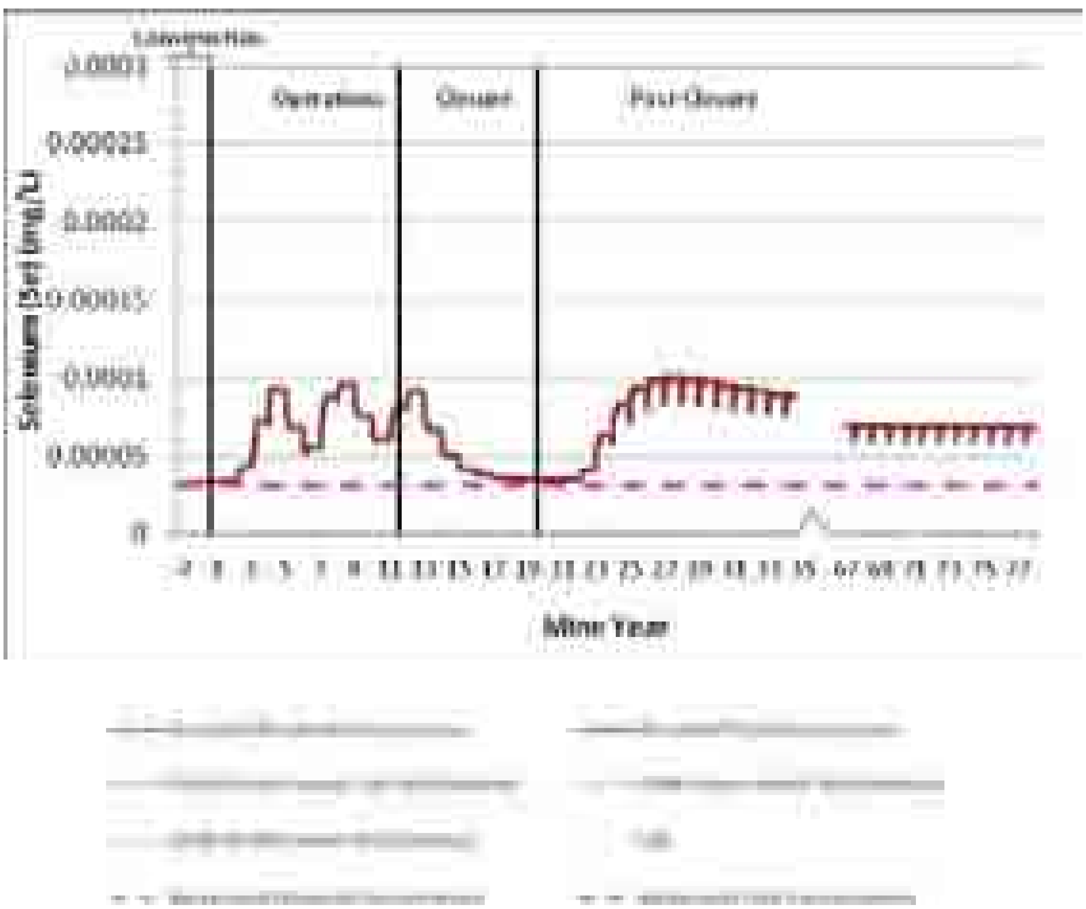
Dissolved and Total Metals (Lake 410) (continued)



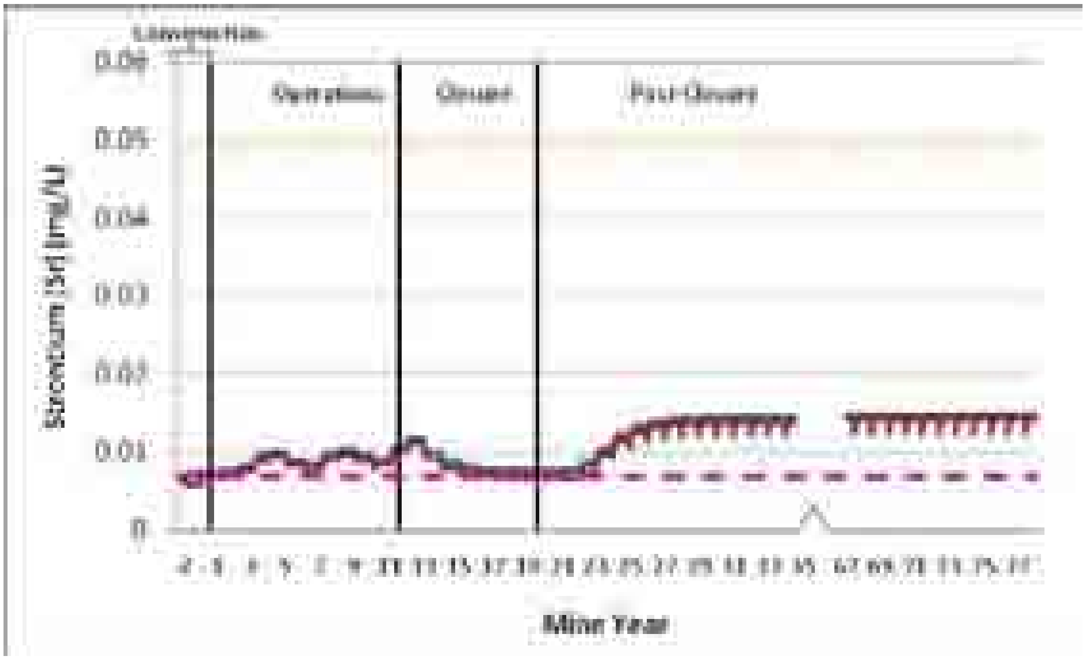


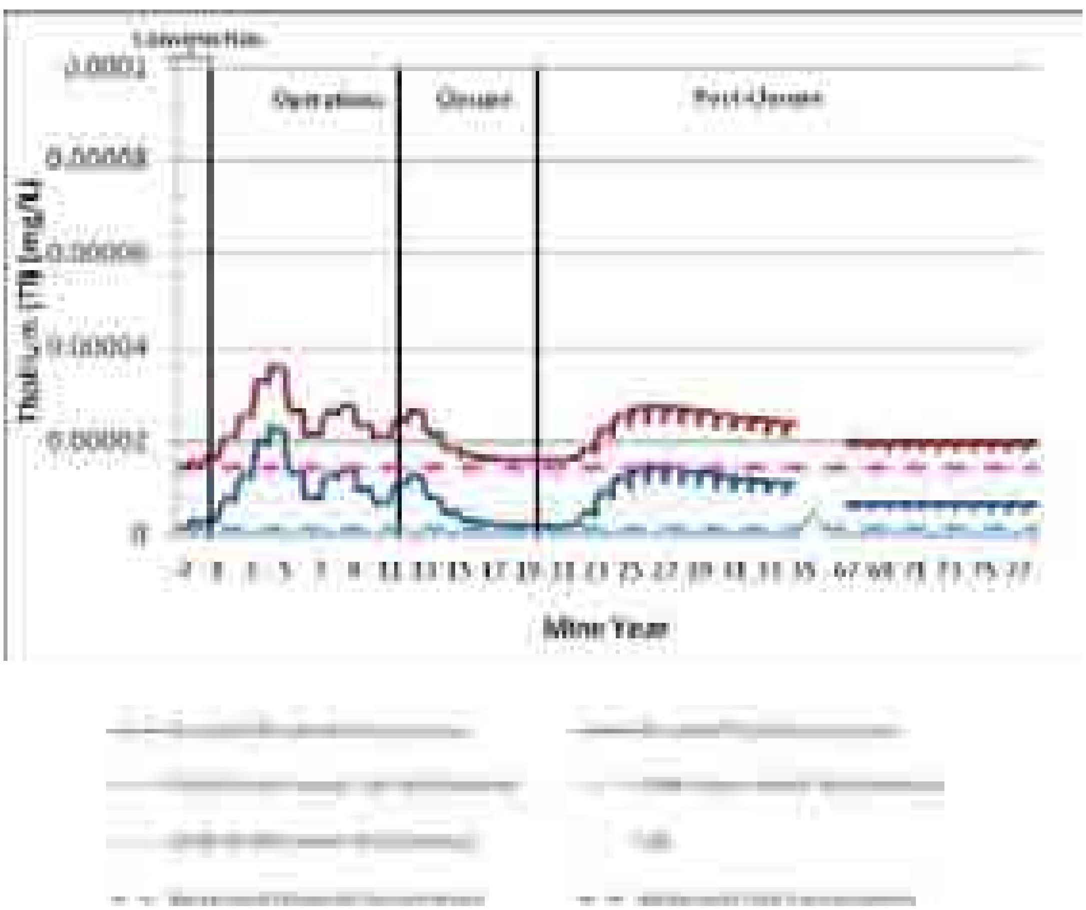
Dissolved and Total Metals (Lake 410) (continued)



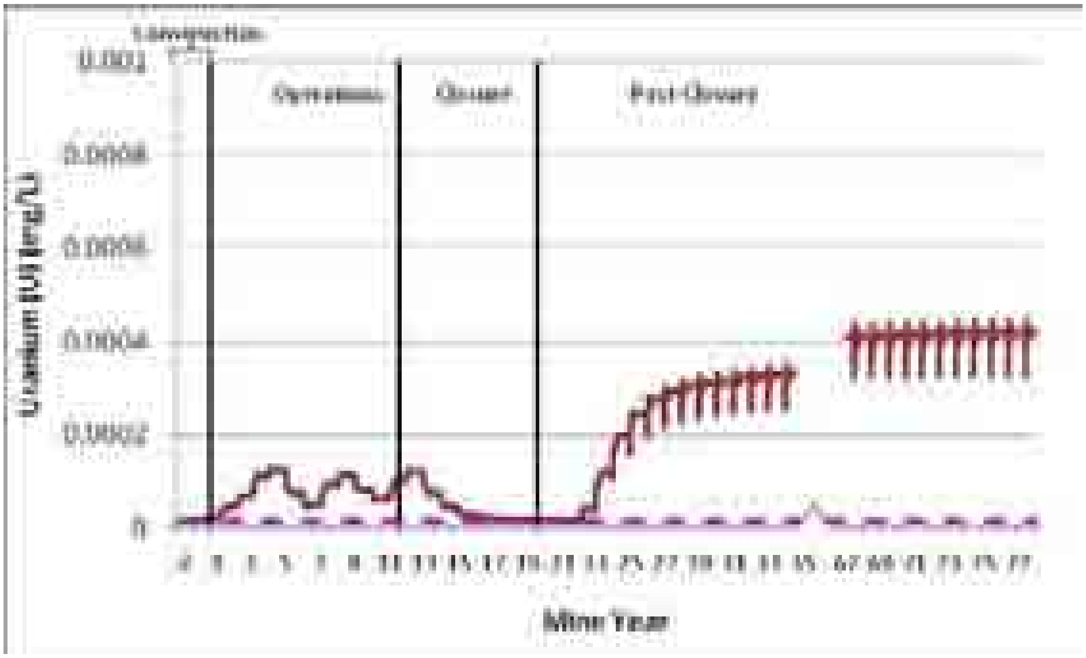


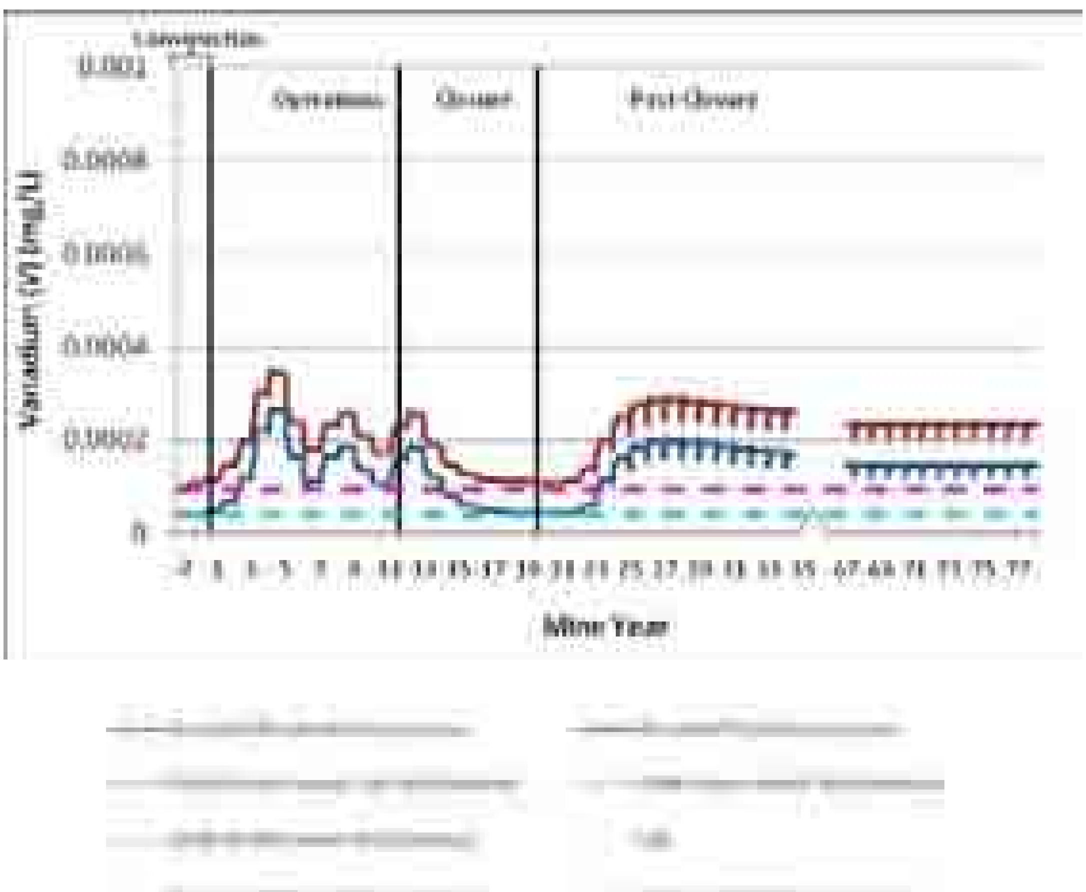
Dissolved and Total Metals (Lake 410) (continued)



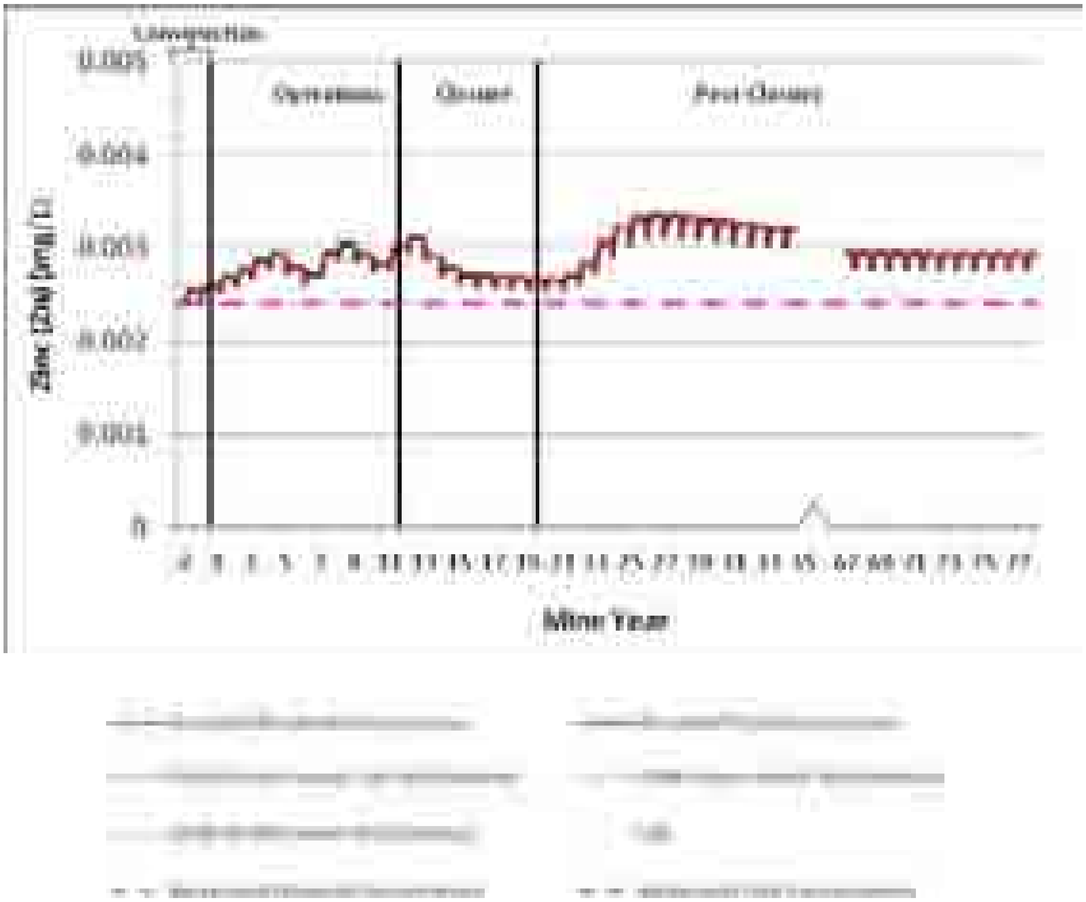


Dissolved and Total Metals (Lake 410) (continued)





Dissolved and Total Metals (Lake 410) (continued)



APPENDIX 9.II

FISHERIES REPORT

TABLE OF CONTENTS

SECTION **PAGE**

LIST OF TABLES

LIST OF FIGURES

9.II.1 INTRODUCTION

The Gahcho Kué Project (Project) has the potential to alter flows in streams downstream of Kennady Lake and in the adjacent 'N' watershed. Flow alterations could impact Arctic grayling (*Thymallus arcticus*), which use these streams for spawning in spring and rearing of young-of-year in summer. Streams near Kennady Lake typically consist of multi-braided channels, with low banks and large boulder substrates. During the spring freshet, flows exceed the banks and flood extensive areas of riparian tundra. These higher flows quickly recede and, by mid-summer, flows in most streams are confined to interstitial spaces between boulders. Arctic grayling in the Kennady Lake and adjoin areas have evolved an adfluvial life history and are adapted to high flow variability in these streams. However, any additional changes to the flow regime can alter suitability of these streams for spawning and rearing and can affect the annual recruitment and sustainability of Arctic grayling populations downstream. Arctic grayling have been identified as a valued component (VC) for the Fisheries and Aquatic Resources impact assessment for the Project.

To assess potential impacts of flow alterations in streams on Arctic grayling, microhabitat data (e.g., depth, water velocity) was collected at representative cross-sections in streams near Kennady Lake during the open-water season. The purpose of these data was to provide an indication of stream conditions spawning adults and rearing young-of-the-year Arctic grayling experience under natural conditions and to provide a means to predict how changes in flow could alter instream habitat conditions for Arctic grayling.

9.II.2 METHODS

Microhabitat data were collected at single cross-sections in 33 streams downstream of Kennady Lake and in the adjacent N watershed in the spring, summer, and fall of 2005, to characterize hydraulic habitat available for Arctic grayling at different water levels (Table 9.II-1). Spring surveys were completed from June 6 to 23, 2005. Summer surveys were completed from July 26 to August 7, 2005, and fall surveys were completed from September 8 to 15, 2005. Cross-sections were located in nine streams between Kennady Lake and Lake 410 plus the Kennady Lake outlet (Stream K5), 15 streams in the adjacent N watershed, and six streams between Lake 410 and Kirk Lake (the P watershed) plus the Lake 410 and Kirk Lake outlets.

Table 9.II-1 Summary of Stream Cross-sections Conducted, by Season, in 2005

Stream	Transect			Stream	Transect		
	Spring	Summer	Fall		Spring	Summer	Fall
Downstream of Kennady Lake							
K5	X	X	X	L3	X	X	X
L1a	X	X	X	M1	X	X	X
L1b	X	X	X	M2	X	X	X
L1c	X	X		M3	X	X	X
L2	X	X	X	M4	X	X	X
N Watershed							
N1	X			N11	X		
N2	X	X	X	N12	X	X	X
N3	X	X	X	N14	X	X	X
N4	X	X	X	N15	X		
N5	X	X	X	N16	X		
N6	X	X	X	N17	X	X	
N9	X			N18	X		
N10	X						
Downstream of Lake 410							
410	X			P4	X	X	X
P1	X			P5	X		
P2	X			P6	X		
P3E	X			Kirk	X		

With the exception of Stream L1c which was almost dry in fall, all nine streams between Kennady Lake and Lake 410, plus the Kennady Lake outlet (Stream K5) were surveyed in all three seasons. Streams in the adjacent N watershed sampled all three seasons included streams N2, N3, N4, N5, N6, N12, and N14. Stream P4 was the only stream that was surveyed between Lake 410 and Kirk Lake in all three seasons. Dangerous flow conditions precluded data collection in the main channel of the Kirk Lake outlet and microhabitat data was collect at a cross-section located only in a side channel.

Methods for data collection at each cross-section were adapted from "*Assessment Methods for Aquatic Habitat and Instream Flow Characteristics in Support of Applications to Dam, Divert, or Extract Water from Streams in British Columbia*" (Lewis et al. 2004). Crew members walked the length of the stream to select a section with appropriate habitat for Arctic grayling spawning. Cross-sections were typically located in a riffle with a variety of substrate types. A 100 m surveyor tape was suspended perpendicular to the water flow and anchored on each bank. A survey level and rod was used to measure elevations at the water's edge, at top and toe of each bank and in the channel at regular intervals along the tape. Cross-sections were typically extended at least 50 metres (m) upslope from the water's edge to provide a cross-sectional profile of the stream "valley". This was done so that water levels predicted to occur during different phases of the mine could be compared to baseline conditions on the cross-section.

A large flat rock away from the stream channel was usually chosen as a benchmark for the elevation measurements. The benchmark and the location of the two end points of the cross-section were marked with spray paint and flagging tape and the Universal Transverse Mercator (UTM) coordinates were recorded in spring to facilitate finding the same cross-section during the summer and fall surveys. The elevation of the water level of the upstream lake was also recorded during each visit.

At regular intervals in the wetted channel, depth, water velocity, relative substrate composition (e.g., gravel, cobble, boulder), maximum substrate size (D90), and cover (e.g., undercut banks, boulders, depth, aquatic vegetation) were recorded. Measurements were made strictly at the required interval along the tape. This frequently meant taking measurements beside or behind boulders. By doing so, an unbiased representation of available microhabitat in the stream was measured. Velocity measurements were made using a Swoffer Velocity Meter. The percentage composition of substrates in a 0.5 m radius circle was assessed visually. Substrates were classified based on size (Table 9.II-2). Photographs upstream and downstream of the cross-section and of the channel banks were taken at each site.

Table 9.II-2 Substrate Size Classes

Class	Size
Fines (F)	< 2 mm
Small Gravel (SG)	2 – 16 mm
Large Gravel (LG)	16 – 64 mm
Small Cobble (SC)	64 – 128 mm
Large Cobble (LC)	12 – 256 mm
Boulders (B)	256 – 4,000 mm
Bedrock (R)	> 4,000 mm

Source: Lewis et al. 2004.

mm = millimetres; < = less than; > = greater than.

9.II.2.1 DATA ANALYSIS

Channel profiles were plotted for each stream in Microsoft Excel. All elevations were relative to the benchmark for each cross-section, which was arbitrarily set to 10 m. Measured water levels in each stream during each site visit in spring, summer, and/or fall were plotted on the channel profiles to show the difference in depth and wetted perimeter during different discharges.

Water levels downstream of Kennady Lake predicted during dewatering, mine operations, and the Kennady Lake re-filling were plotted on the channel profiles in streams between Kennady Lake and Lake 410 to allow comparison to the water levels observed during natural flows in 2005. Manning's equations, a one dimensional uniform flow model, was used to estimate water levels in the lake outlet channel transects at different snapshots of the mine life. Initially, the channel roughness for each transect was calibrated using Manning's equation and depth discharge data collected in the field. When a discharge could not be obtained to pair with a measured water level for calibration, a roughness value was taken from a calibrated transect of similar shape and substrate material. Discharge results from the hydrologic model were then entered into Manning's equation with the calibrated transect to determine the corresponding water level. Assumptions of the different dewatering, operations, and re-filling scenarios are provided in Section 9.7, Effects to Water Quantity.

Average depth, water velocity, and substrate size were calculated at each cross-section in each season. Dominant and sub-dominant substrate types and cover types were determined by most frequent substrate and cover types recorded along the entire length of the cross-section, including flooded vegetated tundra areas in the spring.

Frequency distributions for depth and water velocity in each spring, summer, and fall were plotted separately for data pooled from streams between Kennady Lake and Lake 410, from streams in the adjacent N watershed and from streams between Lake 410 and Kirk Lake. Frequency distributions based on the seven substrate classes were plotted by pooling data from streams in the same three areas. Stream discharges on the days of the spring, summer, and fall surveys were based on hydrometric stations located at Stream K5, L1, N2, N1, N6, N16, and Kirk Lake outlet and reported in Annex H, Climate and Hydrology Baseline.

9.II.3 RESULTS

Habitat characteristics for each stream are summarized in Table 9.II-3. Channels typically exhibited the same general morphology; multi-braided channels with low channel banks, willows and tundra mosses in the riparian area and large (greater than 50 centimetre [cm]), angular boulders. Channel roughness typical of these boulder-dominated streams is depicted in Figure 9.II-1. During the spring, the wetted width was typically larger than the channel width, as the increased water levels led to water overflowing stream banks onto riparian tundra. During the summer and fall, wetted widths decreased with the majority of the flow flowing between or under the large boulders within the defined channel.

Depth and water velocities were highest in spring; depth and water velocities were lower but similar in the summer and fall. Boulders were the dominant substrate in most streams and large cobbles were also common. Vegetation and fines were present but rare. Boulders provided the majority of the cover for fish.

9.II.3.1 STREAMS BETWEEN KENNADY LAKE AND LAKE 410

Channel profiles depicting water levels in spring, summer, and fall of 2005 in streams between Kennady Lake and Lake 410 are provided in Figures 9.II-1 and 9.II-2. Average depths ranged between 0.18 m and 0.32 m in spring while average water velocities in spring ranged between 0.07 metres per second (m/s) and 0.33 m/s (Table 9.II-3). Average depths and water velocities were lower in summer; 0.13 m to 0.25 m and 0.05 m/s and 0.22 m/s, respectively. Average depths and water velocities were lower in fall than in summer. The dominant substrate type in all streams in most seasons was boulders. Vegetation was the dominant substrate type in Streams K5, L2, and L3 in spring because the cross-section included extensive areas of flooded riparian tundra. Wetted widths were highest in the spring, when the streams were flooded over their banks and flow extended into the tundra. During the summer and fall, streams were confined in the boulder channels.

A frequency distribution of depths in streams between Kennady Lake and Lake 410 is provided in Figure 9.II-3. Depths below 0.1 m were most frequent in all three seasons (Figure 9.II-3). The frequency of depths lower than 0.1 m was highest in the fall and lowest in the spring. As expected, the frequency of depths greater than 0.2 m decreased from spring to fall. Water velocities less than 0.1 m/s were most frequent in all seasons (Figure 9.II-4). The frequency of water velocities greater than 0.2 m/s decreased from spring to fall.

Table 9.II-3 Summary of Habitat Characteristics from Stream Transects

Stream	Season	Average Depth (m)	Depth Range (m)	Average Velocity (m/s)	Velocity Range (m/s)	Dominant Substrate	Subdominant Substrate	Average Substrate Size (cm)	Dominant Cover
K5	Spring Summer Fall	0.24 0.14 0.11	0 – 0.62 0 – 0.32 0 – 0.24	0.12 0.1 0.09	0 – 0.60 0 – 0.37 0 – 0.26	V B B	B LC LC	 18	V/B B
L1a	Spring Summer Fall	0.26 0.15 0.13	0 – 0.56 0 – 0.39 0 – 0.32	0.24 0.18 0.07	0 – 0.73 0 – 0.55 0 – 0.33	B B B	V LC LC	 35	B/V B
L1b	Spring Summer Fall	0.25 0.16 0.11	0 – 0.44 0 – 0.36 0 – 0.25	0.21 0.09 0.06	0 – 0.62 0 – 0.35 0 – 0.29	B B B	LC LC LC	23 29	B/V B
L1c	Spring Summer	0.29 0.12	0 – 0.56 0 – 0.38	0.26 0.09	0 – 0.65 0 – 0.32	B B	LC LC	32	
L2	Spring Summer Fall	0.28 0.16 0.11	0 – 0.64 0 – 0.25 0 – 0.21	0.28 0.22 0.21	0 – 1.05 0 – 0.44 0 – 0.56	V B LC	B LC B	22 18	B B
L3	Spring Summer Fall	0.22 0.25 0.19	0 – 0.66 0 – 0.43 0 – 0.37	0.07 0.15 0.06	0 – 0.65 0 – 0.40 0 – 0.31	V B B	B LC LC	46 46	V B
M1	Spring Summer Fall	0.31 0.2 0.18	0 – 0.68 0 – 0.50 0 – 0.39	0.17 0.08 0.03	0 – 0.48 0 – 0.19 0 – 0.13	B B B	V LC LC	37 22	B/V B
M2	Spring Summer Fall	0.24 0.19 0.2	0 – 0.62 0 – 0.31 0 – 0.45	0.33 0.16 0.13	0 – 1.24 0 – 0.64 0 – 0.41	B B LC	LC SC B	19.8 31 31	B B
M3	Spring Summer Fall	0.32 0.18 0.15	0 – 0.66 0 – 0.54 0 – 0.38	0.22 0.05 0.04	0 – 0.54 0 – 0.26 0 – 0.24	B B B	LC LC LC	27 31	B B
M4	Spring Summer Fall	0.18 0.13 0.15	0 – 0.56 0 – 0.33 0 – 0.28	0.12 0.05 0.06	0 – 0.57 0 – 0.25 0 – 0.15	B B B	LC LC LC	35	B/V
N1	Spring	0.25	0 – 0.48	0.51	0 – 1.36	B	LC	42	B

Table 9.II-3 Summary of Habitat Characteristics from Stream Transects (continued)

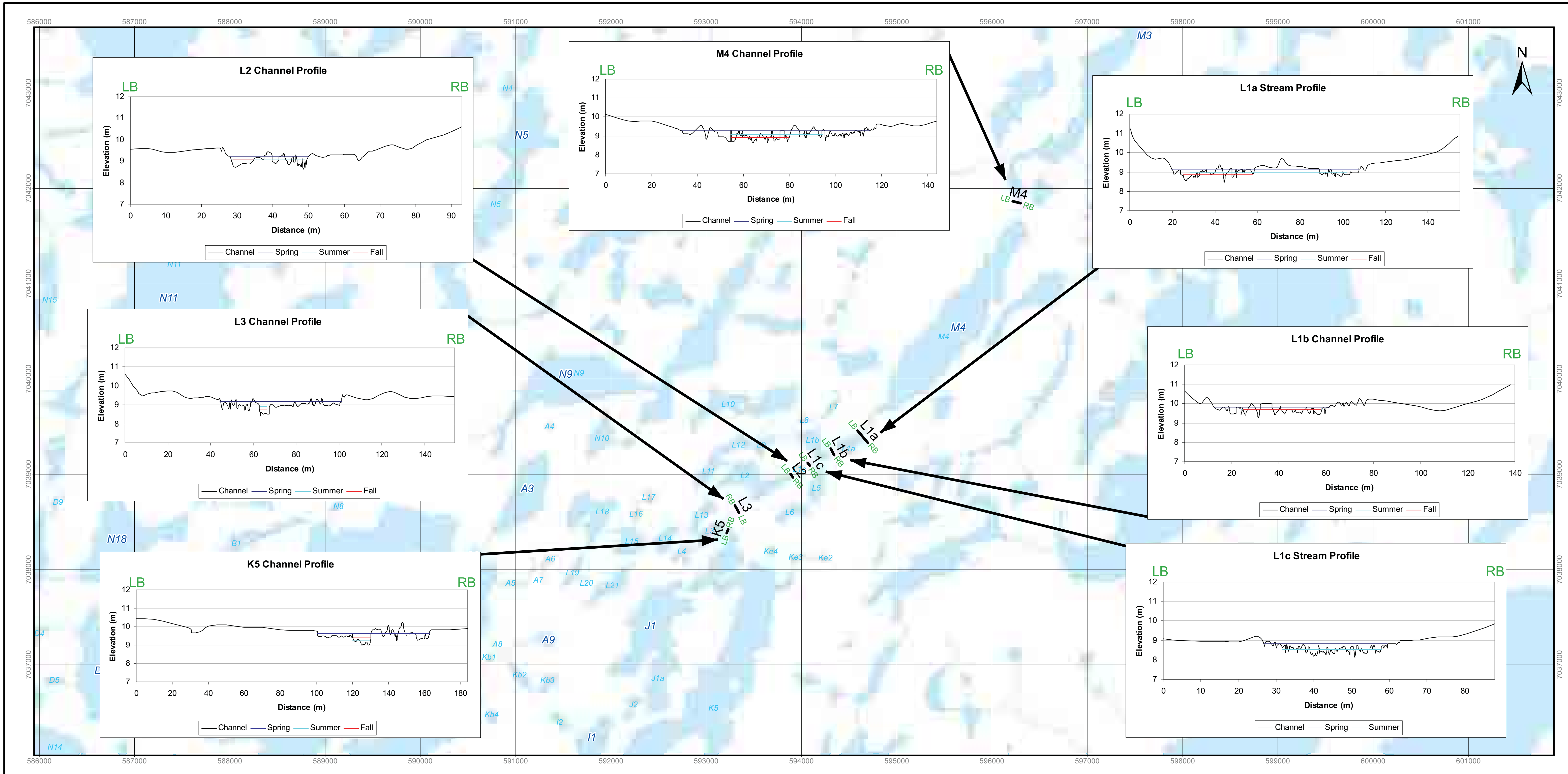
Stream	Season	Average Depth (m)	Depth Range (m)	Average Velocity (m/s)	Velocity Range (m/s)	Dominant Substrate	Subdominant Substrate	Average Substrate Size (cm)	Dominant Cover
N2	Spring	0.28	0 – 0.97	0.16	0 – 0.54	B	V	40	B/V
	Summer	0.16	0 – 0.56	0.05	0 – 0.15	B	F	65	B/V
	Fall	0.16	0 – 0.51	0.02	0 – 0.14	B	LC		
N3	Spring	0.17	0 – 0.43	0.38	0 – 0.92	B	LC	47	B/V
	Summer	0.1	0 – 0.34	0.19	0 – 1.13	B	LC	29	B
	Fall	0.08	0 – 0.19	0.14	0 – 0.68	LC	B		
N4	Spring	0.28	0 – 0.95	0.64	0 – 1.28	B	R	41	B
	Summer	0.15	0 – 0.60	0.04	0 – 0.11	B		46	B
	Fall	0.13	0 – 0.66	0.025	0 – 0.28	B	LC		
N5	Spring	0.25	0 – 0.56	0.04	0 – 0.37	B	F	35	
	Summer	0.11	0 – 0.42	0.01	0 – 0.05	V	B	29	V
	Fall	0.14	0 – 0.32	0.002	0 – 0.03	V	B		
N6	Spring	0.19	0 – 0.52	0.16	0 – 0.54	B	V	44	B
	Summer	0.15	0 – 0.52	0.05	0 – 0.20	V	B	31	
	Fall	0.12	0 – 0.43	0.05	0 – 0.18	B			
N9	Spring	0.24	0 – 0.58	0.11	0 – 0.25	B	F	58	B
N10	Spring	0.24	0 – 0.31	0.11	0 – 0.24	F			V
N11	Spring	0.32	0 – 0.50	0.7	0 – 1.37	B	LC	37	B
N12	Spring	0.15	0 – 0.32	0.09	0 – 0.40	B		80	V
	Summer	0.16	0 – 0.42	0.01	0 – 0.07	F			
	Fall	0.15	0 – 0.42	0.003	0 – 0.04				
N14	Spring	0.19	0 – 0.27	0.09	0 – 0.26	F	V		B
	Summer	0.06	0 – 0.08	0.02	0 – 0.05	F			
	Fall	0.06	0 – 0.12	0.05	0 – 0.26				
N15	Spring	0.29	0 – 0.95	0.18	0 – 0.48	B	LC	56	B
N16	Spring	0.19	0 – 0.36	0.52	0 – 1.1	B	LC	38	B
N17	Spring	0.25	0 – 0.58	0.21	0 – 0.48	B	LC	41	B
	Summer	0.17	0 – 0.44	0.03	0 – 0.13	B	LC		B
N18	Spring	0.21	0 – 0.45	0.07	0 – 0.44	F	B	20	

Table 9.II-3 Summary of Habitat Characteristics from Stream Transects (continued)

Stream	Season	Average Depth (m)	Depth Range (m)	Average Velocity (m/s)	Velocity Range (m/s)	Dominant Substrate	Subdominant Substrate	Average Substrate Size (cm)	Dominant Cover
P1	Spring	0.31	0 – 1.00	0.21	0 – 0.76	F	B	31	B
P2	Spring	0.31	0 – 0.61	0.24	0 – 0.63	B	LC	37	B
P3E	Spring	0.26	0 – 0.70	0.47	0 – 1.49	B	LC	15	B
P4	Spring Summer Fall	0.39 0.22 0.12	0 – 0.73 0 – 0.39 0 – 0.25	0.61 0.36 0.19	0 – 1.31 0 – 1.00 0 – 0.72	B B	LC LC	32 25	B B
P5	Spring	0.47	0 – 0.84	0.17	0 – 0.50	B	LC	26	B
P6	Spring	0.43	0- 0.86	0.35	0 – 0.74	B	LC	51	B
410	Spring	0.34	0 – 0.85	0.22	0 – 0.83	B	V	59	B
Kirk	Spring	0.43	0 – 1.15	0.51	0 – 1.27	B		41	B

Notes: Substrate codes: B – boulder; LC – large cobble; V – vegetation; F – Fines; R – bedrock. Cover codes: B – boulder; V – vegetation.

cm = centimetres; m = metres; m/s = metres per second.

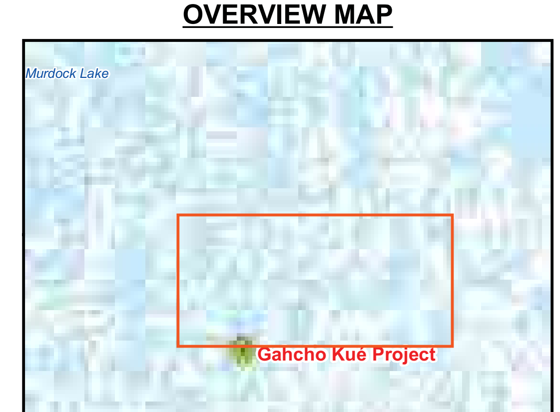


LEGEND

- Gahcho Kué Project
- Watercourse
- Waterbody
- Stream Transect (Channel Profile)
- LB Left Bank of Watercourse
- RB Right Bank of Watercourse

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

OVERVIEW MAP



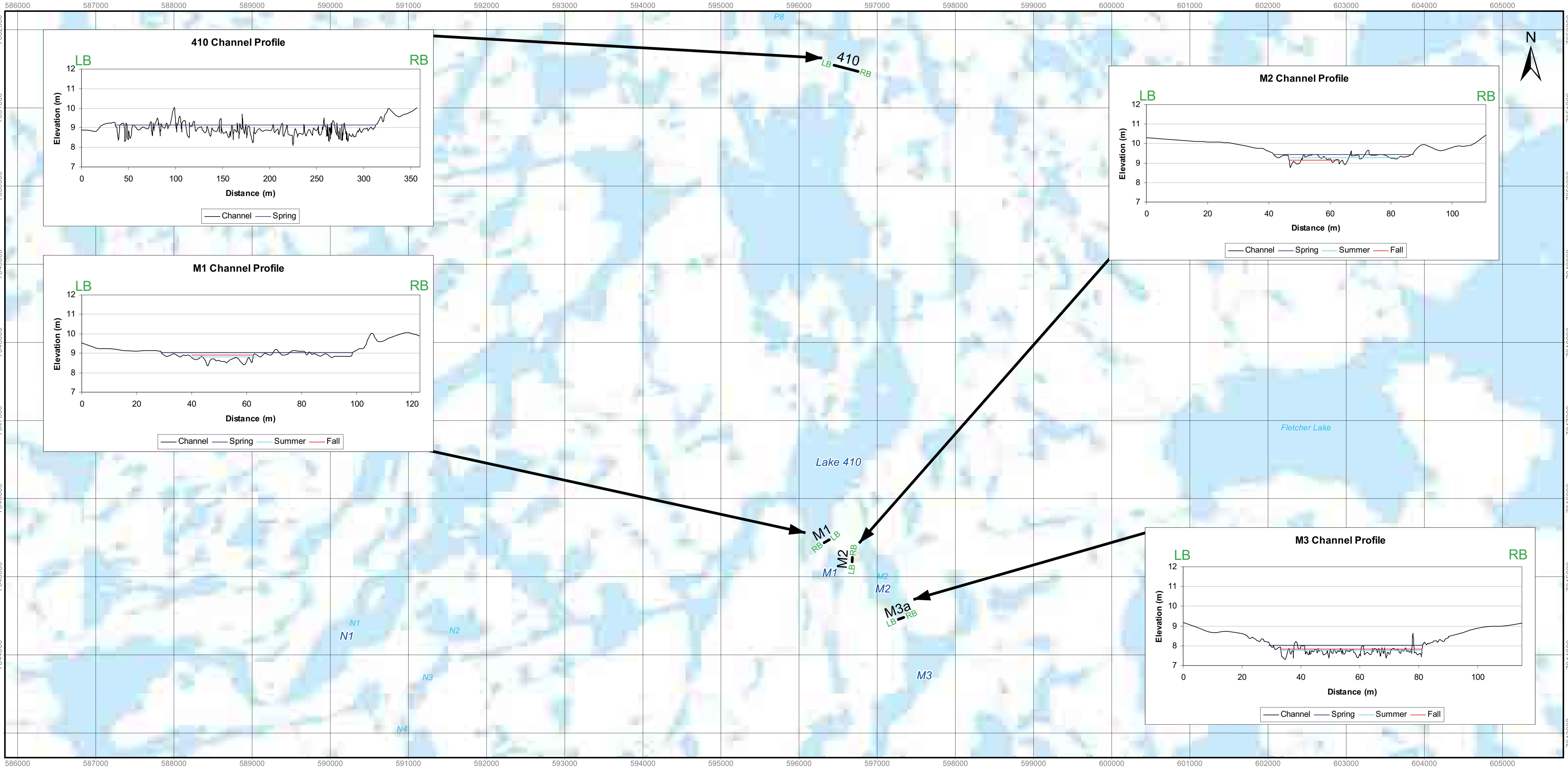
GAHCHO KUÉ PROJECT

Transect Locations and Channel Profiles in Streams of the 'K' and 'L' Watersheds between Kennady Lake and Lake 410

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:40,000 (300 0 300 600 900 Metres)	
FILE No: E-Fish-022-GIS	DATE: December 13, 2010
JOB NO: 09-1365-1004	REVISION NO: 1
OFFICE: GOLD-CAL	DRAWN: SK
CHECK: KC	

Figure 9.II-1

I:\CLIENTS\DE_BEERS\09-1365-1004\maps\10_fisheries-aquatics\EIA\E-Fish-022-GIS.mxd

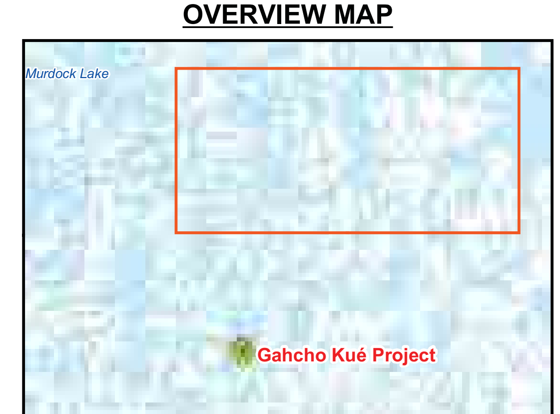


LEGEND

- Gahcho Kué Project
- Watercourse
- Waterbody
- Stream Transect (Channel Profile)
- LB Left Bank of Watercourse
- RB Right Bank of Watercourse

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

OVERVIEW MAP



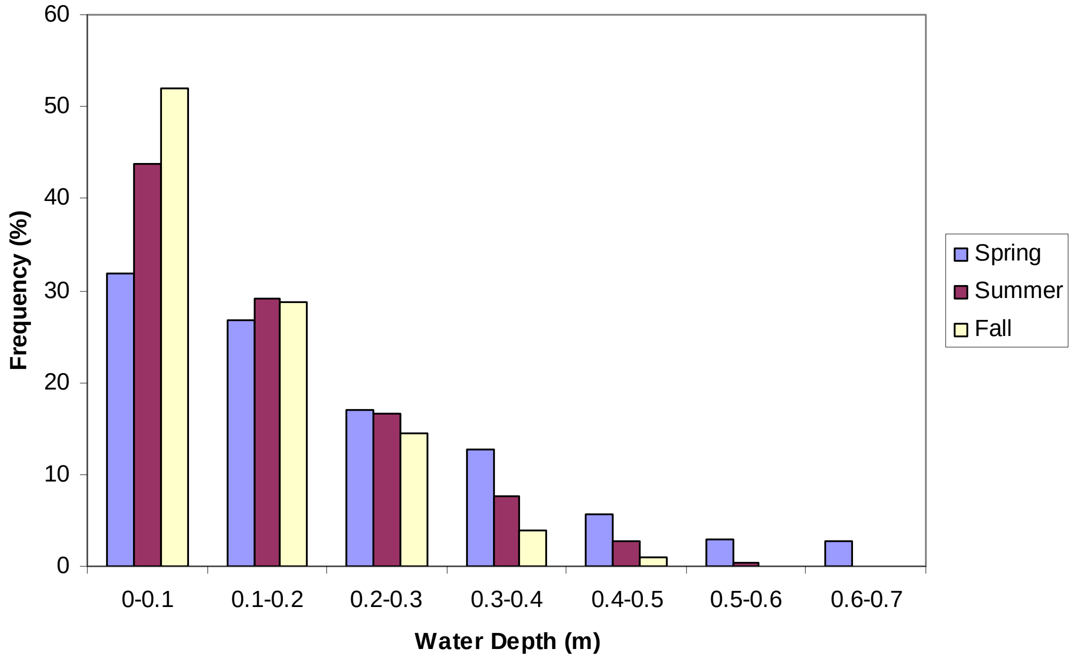
GAHCHO KUÉ PROJECT

Transect Locations and Channel Profiles in Stream of the 'M' Watershed between Kennady Lake and Lake 410

PROJECTION: UTM Zone 12	DATUM: NAD83		
Scale: 1:50,000 (400 0 400 800 1,200 Metres)			
FILE No: E-Fish-021-GIS		DATE: December 13, 2010	
JOB NO: 09-1365-1004	REVISION NO: 1	Figure 9.II-2	
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: KC	

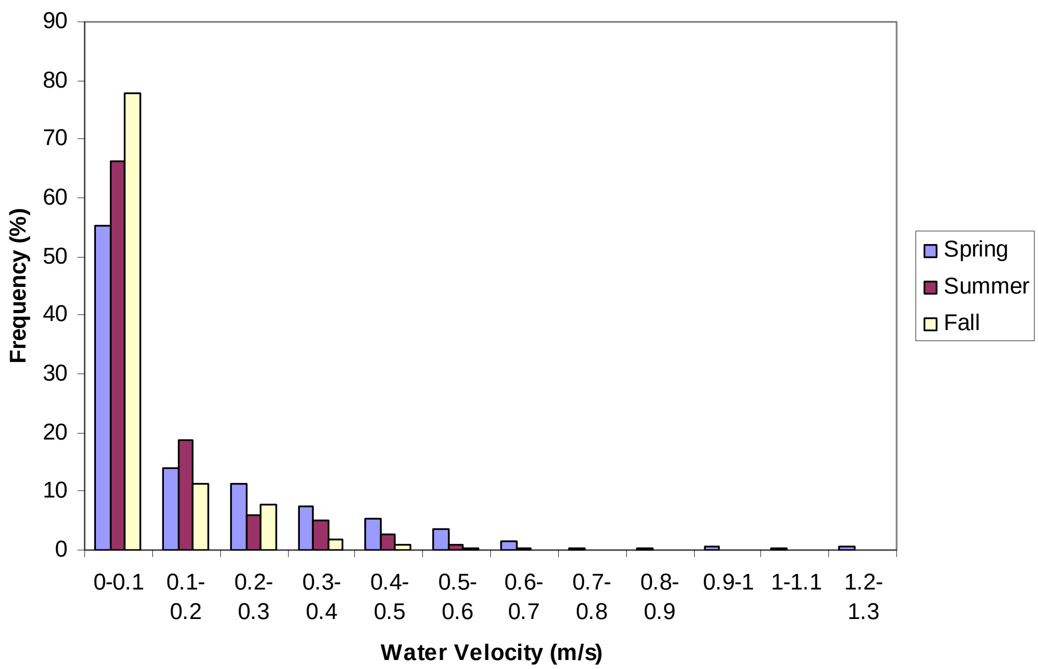
I:\CLIENTS\DE_BEERS\09-1365-1004\maps\10_fisheries-aquatics\EIA\E-Fish-021-GIS.mxd

Figure 9.II-3 Frequency of Seasonal Water Depths in the Downstream Outlet Streams



% = percent; m = metres.

Figure 9.II-4 Frequency of Seasonal Water Velocities in the Downstream Outlet Streams



% = percent; m = metres.

9.II.3.2 N WATERSHED STREAMS

The Project has the potential to change flows in streams throughout the N watershed due to the dewatering of Kennady Lake and diversion of Kennady Lake sub-watersheds during mine construction and operations. Unlike streams between Kennady Lake and Lake 410, these streams are not connected in series downstream. As a result, information for these streams is presented separately below. Location of transects and stream cross-sectional profiles for the N watershed streams are provided in Figures 9.II-5, 9.II-6, and 9.II-7.

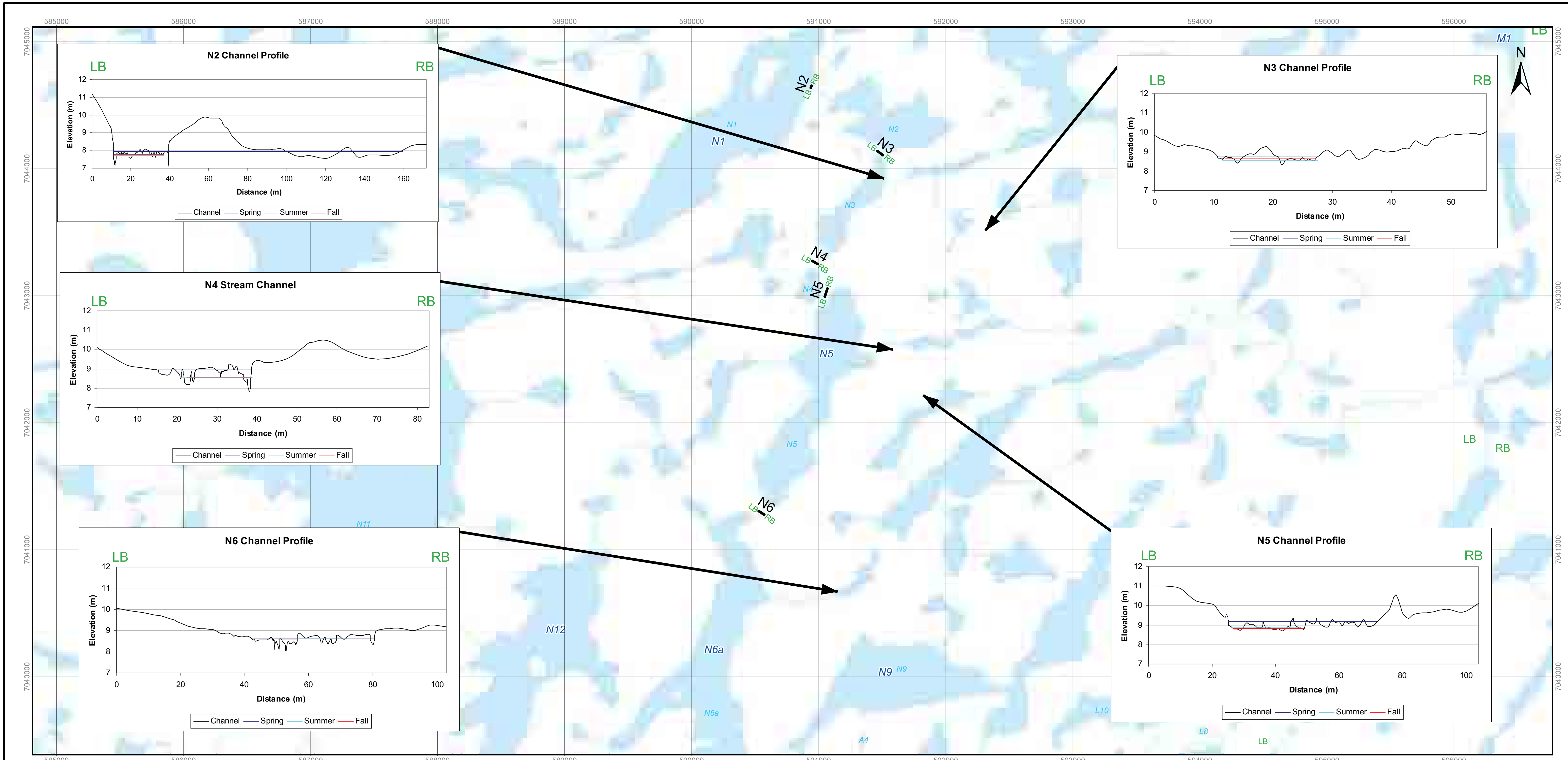
9.II.3.2.1 Stream N1

Stream N1 drains the N watershed to Lake 410. The stream is dominated by large, angular boulder substrates. The average depth in the spring was 0.25 m and the average velocity was 0.51 m/s.

The most frequent depths range was between 0.2 m and 0.3 m (Figure 9.II-8). Shallower (less than 0.1 m) and deeper depths (over 0.4 m) were the least common. Water velocities between 0.3 m/s and 0.4 m/s were the most frequent in spring (Figure 9.II-9).

9.II.3.2.2 Streams N2, N3, N4, N5, N6

Streams N2 to N6 drain a series of lakes in the N watershed immediately north of Kennady Lake and flow into Lake N1. These streams are dominated by boulder substrates, with portions of streams N2 and N4 influenced by bedrock outcrops. Depths less than 0.2 m were most frequent in all three seasons, with the proportion of depths less than 0.2 m increasing in summer and fall (Figure 9.II-10). Depths greater than 0.2 m were the most common spring. Water velocities less than 0.1 m/s were the most frequent in all three seasons (Figure 9.II-11).

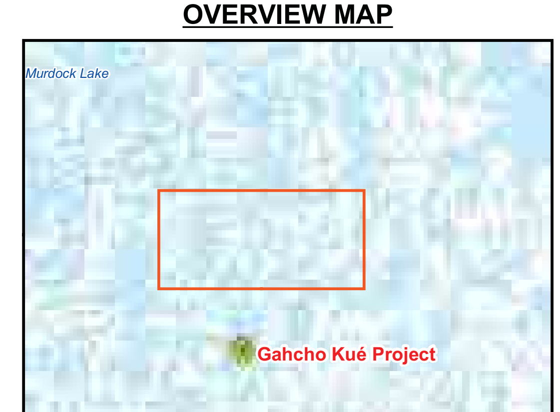


LEGEND

Gahcho Kué Project
Watercourse
Waterbody
Stream Transect (Channel Profile)
LB Left Bank of Watercourse
RB Right Bank of Watercourse

NOTES
Base data source: National Topographic
Base Data (NTDB) 1:50,000

OVERVIEW MAP

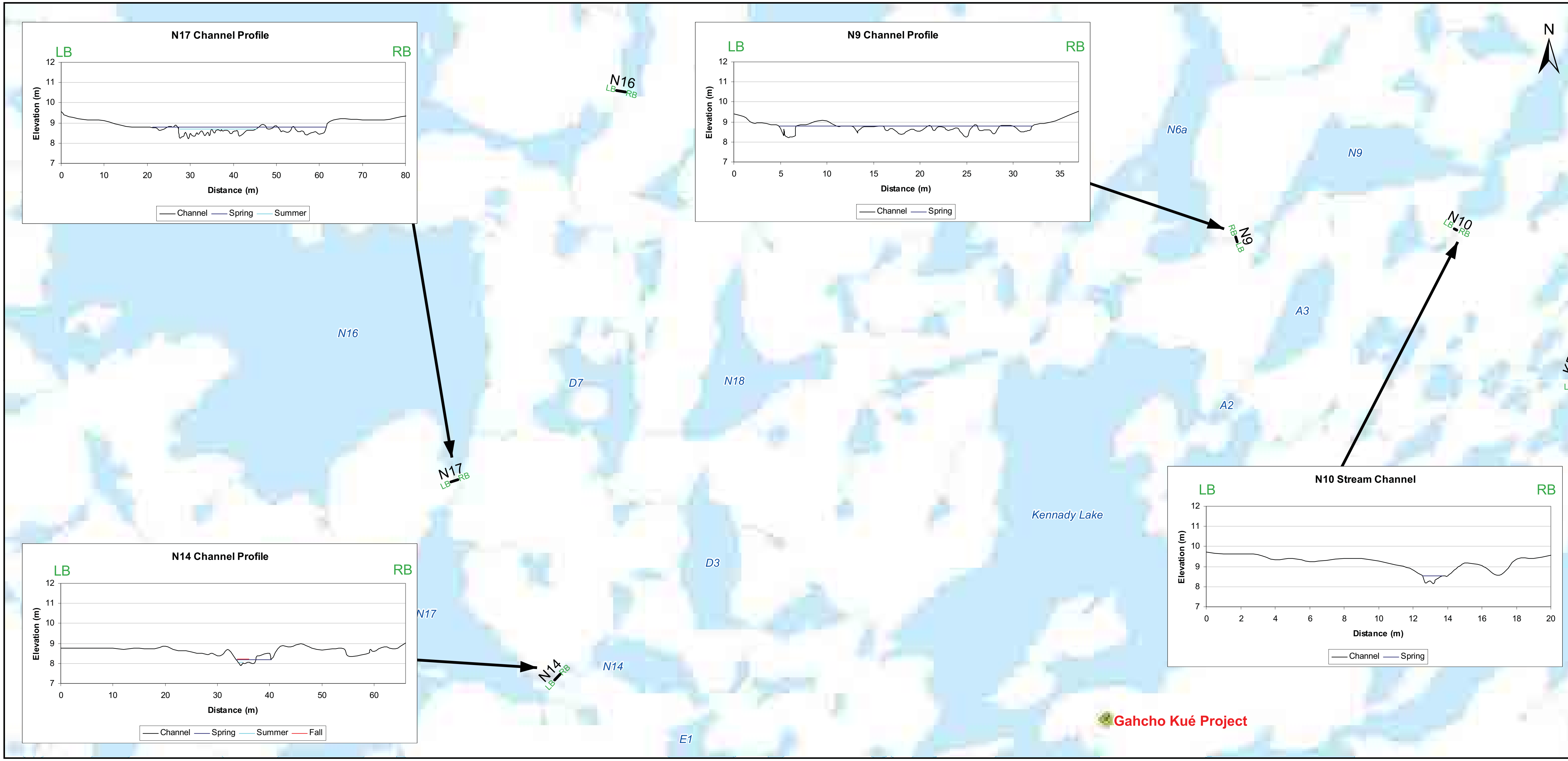


GAHCHO KUÉ PROJECT

Transect Locations and Channel Profiles in Streams along the Proposed Northern Diversion Route in the Adjacent 'N' Watershed

PROJECTION: UTM Zone 12	DATUM: NAD83		
Scale: 1:30,000 (300 0 300 600 Metres)			
FILE No: E-Fish-023-GIS			DATE: December 13, 2010
JOB NO: 09-1365-1004	REVISION NO: 1		Figure 9.II-5
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: KC	

I:\CLIENTS\DE_BEERS\09-1365-1004\maps\10_fisheries-aquatics\EIA\E-Fish-023-GIS.mxd

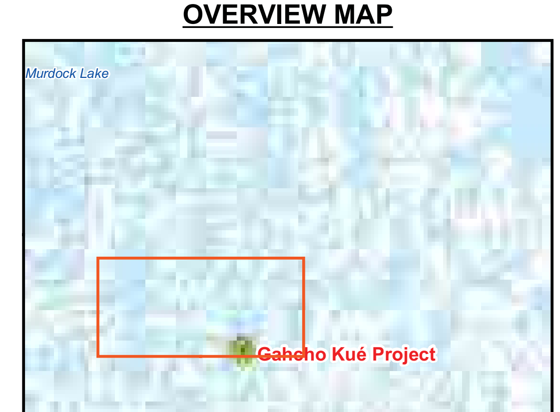


LEGEND

- Gahcho Kué Project
- Watercourse
- Waterbody
- Stream Transect (Channel Profile)
- LB Left Bank of Watercourse
- RB Right Bank of Watercourse

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

OVERVIEW MAP



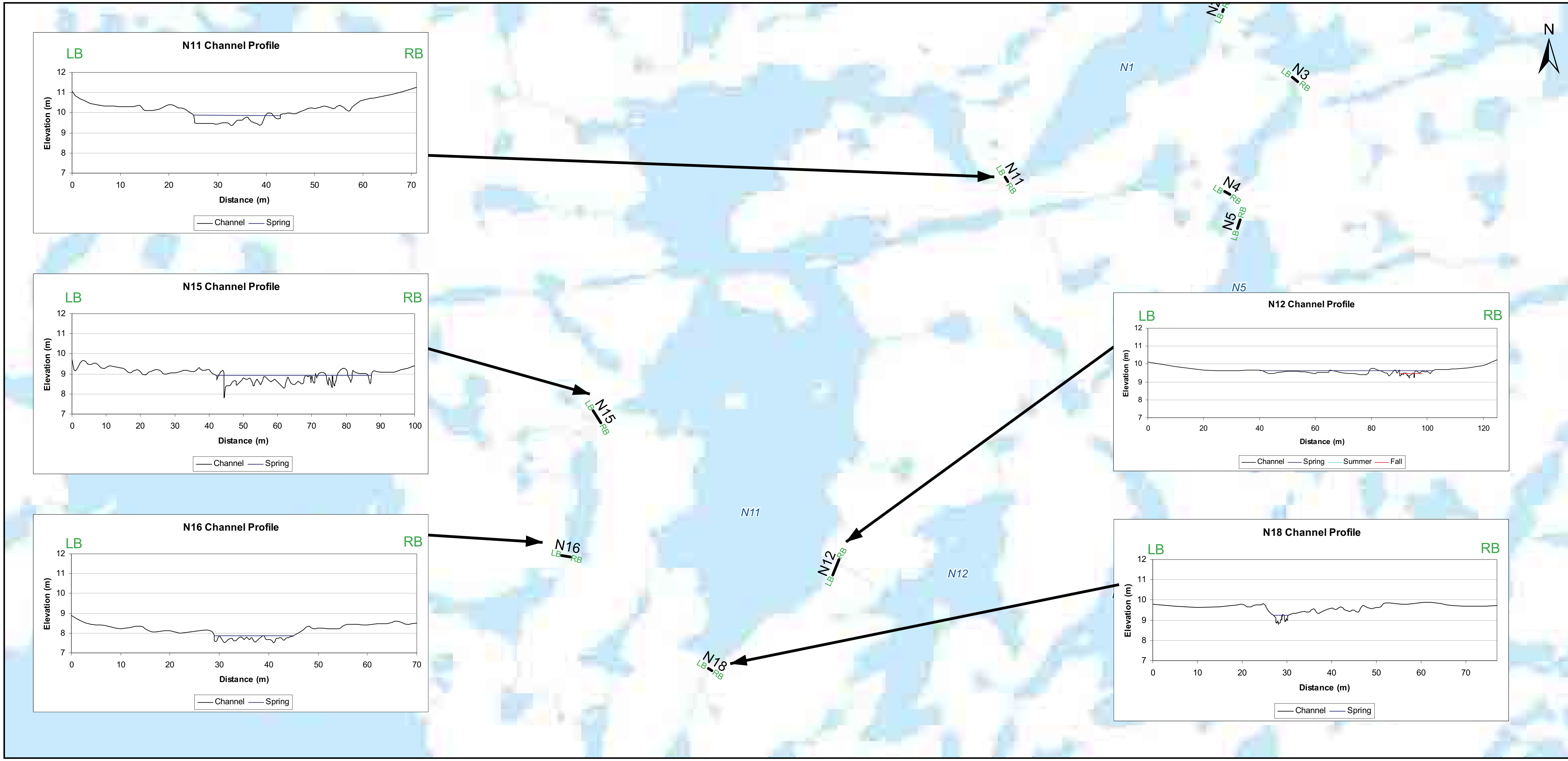
GAHCHO KUÉ PROJECT

Transect Locations and Channel Profiles in Streams in the Adjacent 'N' Watershed

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:30,000 (300 0 300 600 Metres)	
FILE No: E-Fish-025-GIS	DATE: December 13, 2010
JOB NO: 09-1365-1004	REVISION NO: 1
OFFICE: GOLD-CAL	DRAWN: SK
CHECK: KC	

Figure 9.II-6

I:\CLIENTS\DE_BEERS\09-1365-1004\maps\10_fisheries-aquatics\EIA\E-Fish-025-GIS.mxd

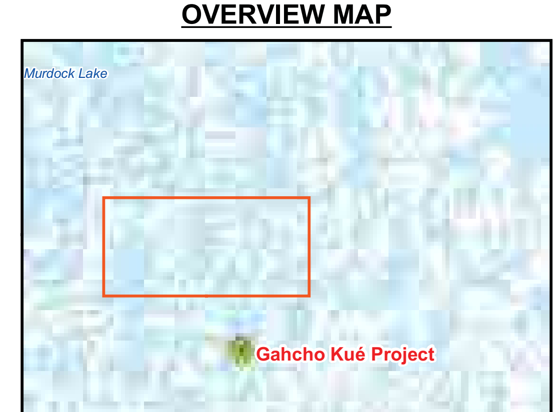


LEGEND

- Gahcho Kué Project
- Watercourse
- Waterbody
- Stream Transect (Channel Profile)
- LB Left Bank of Watercourse
- RB Right Bank of Watercourse

NOTES
Base data source: National Topographic
Base Data (NTDB) 1:50,000

OVERVIEW MAP



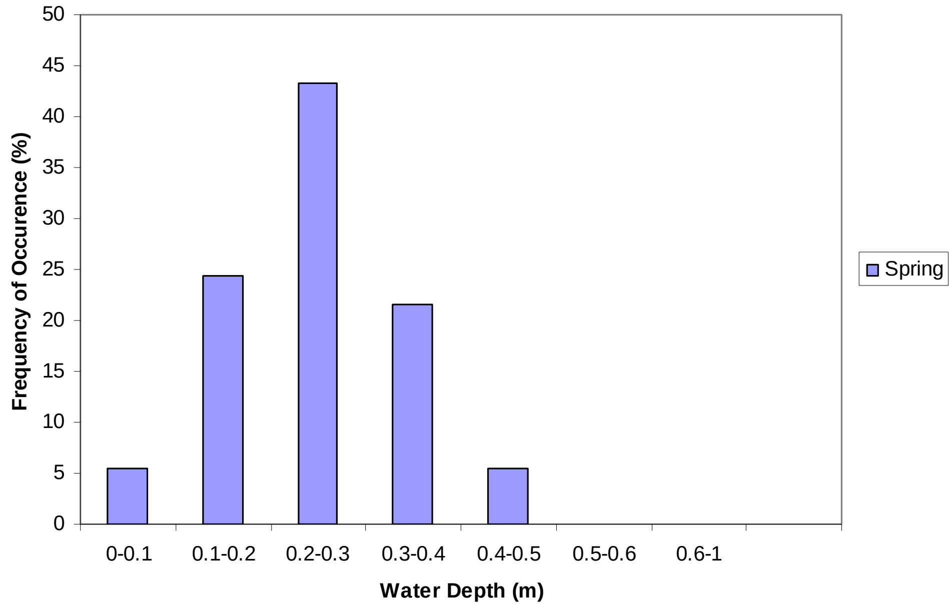
GAHCHO KUÉ PROJECT

Transect Locations and Channel Profiles in Streams in the Adjacent 'N' Watershed

PROJECTION: UTM Zone 12	DATUM: NAD83		
Scale: 1:30,000 (300 0 300 600 Metres)			
FILE No: E-Fish-024-GIS		DATE: December 13, 2010	
JOB NO: 09-1365-1004	REVISION NO: 1	Figure 9.II-7	
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: KC	

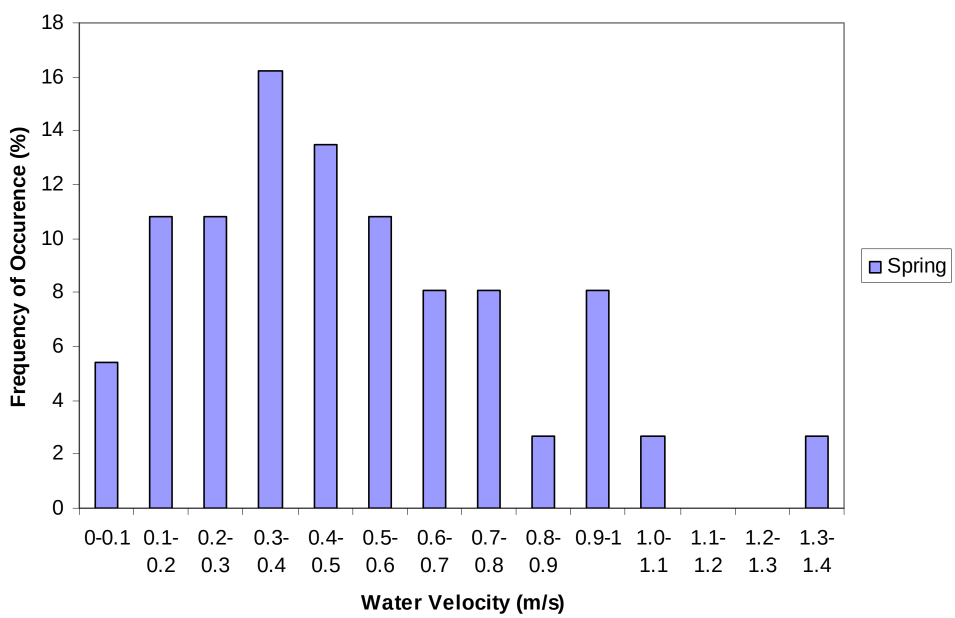
I:\CLIENTS\DE_BEERS\09-1365-1004\maps\10_fisheries-aquatics\EIA\E-Fish-024-GIS.mxd

Figure 9.II-8 Frequency of Spring Water Depths in Stream N1



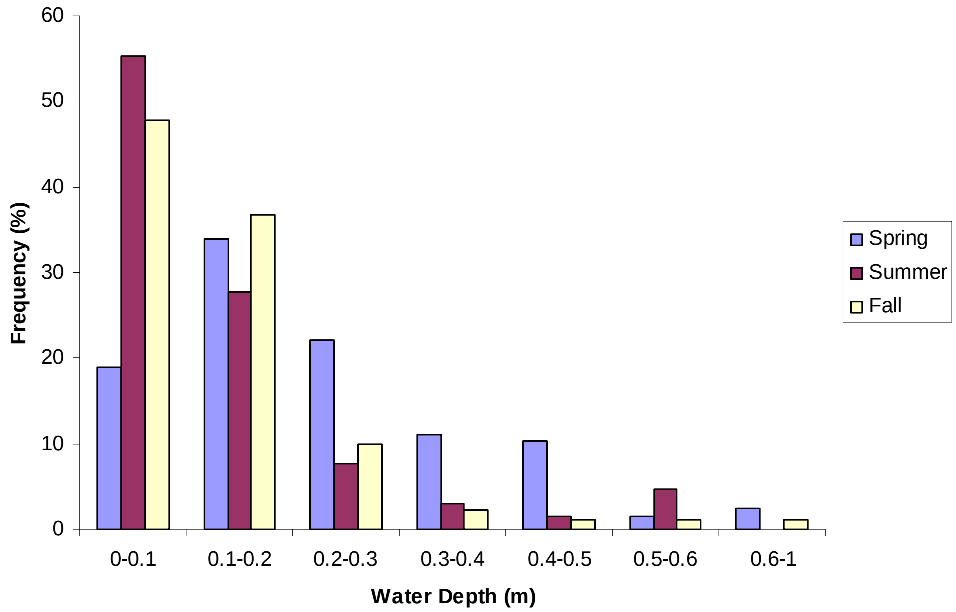
% = percent; m = metres.

Figure 9.II-9 Frequency of Spring Water Velocities in Stream N1



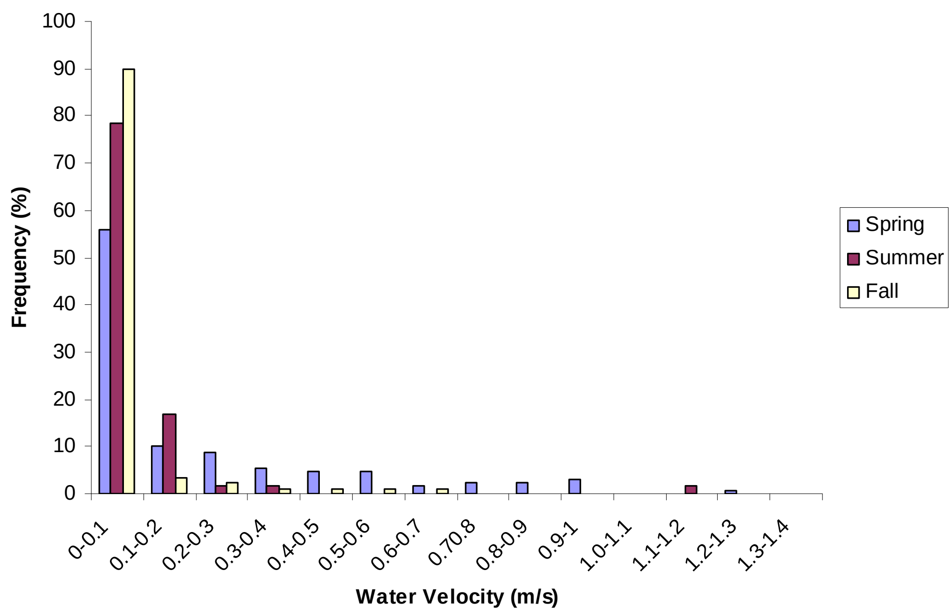
% = percent; m/s = metres per second.

Figure 9.II-10 Frequency of Seasonal Water Depths in Streams N2 to N6



% = percent; m = metres.

Figure 9.II-11 Frequency of Seasonal Water Velocities in Streams N2 to N6



% = percent; m/s = metres per second.

9.II.3.2.3 Stream N11

Stream N11 drains Lake N11 into Lake N1. The stream is dominated by large boulder substrates and includes a series of bedrock cascades in the middle of its length. The cross-section in Stream N11 was located downstream of these cascades. The average depth in the spring was 0.32 m and the average velocity was 0.7 m/s (Table 9.II-3). In spring, the most frequent depth category was between 0.3 m and 0.4 m (Figure 9.II-12). The most frequent water velocities in spring were between 0.5 m/s and 0.6 m/s but water velocities greater than 1.0 m/s were also present (Figure 9.II-13).

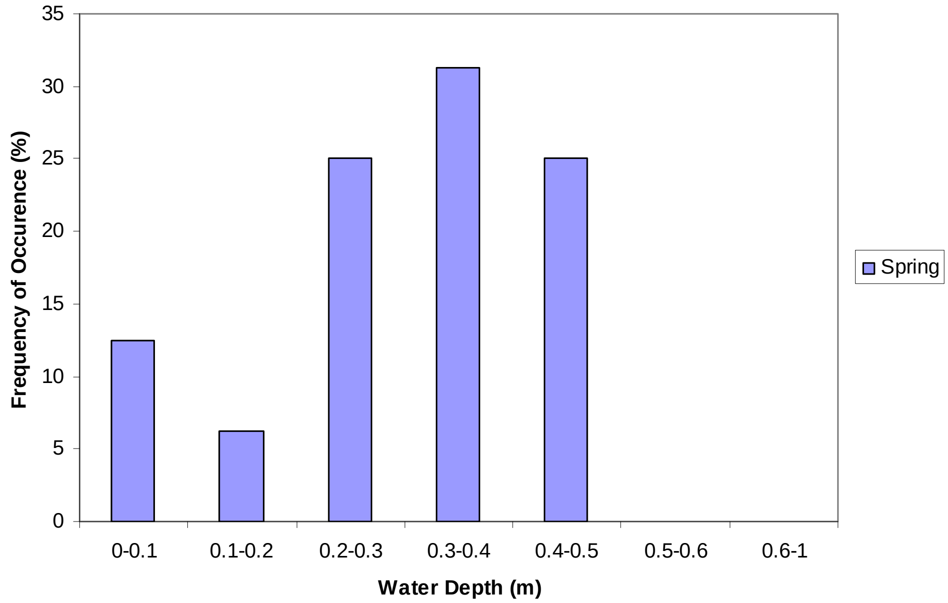
9.II.3.2.4 Stream N12

Stream N12 drains Lake N12 to Lake N11. The average depth in all three seasons was 0.15 m while the average velocity in spring was 0.09 m/s and less then 0.01 m/s in summer and fall (Table 9.II-3). The stream is dominated by boulder substrates. Depths less than 0.1 m were most frequent in all seasons (Figure 9.II-14). The proportion of depths less than 0.1 m was greatest in fall. Only in spring were water velocities greater than 0.1 m/s present in Stream N12 (Figure 9.II-15).

9.II.3.2.5 Stream N18

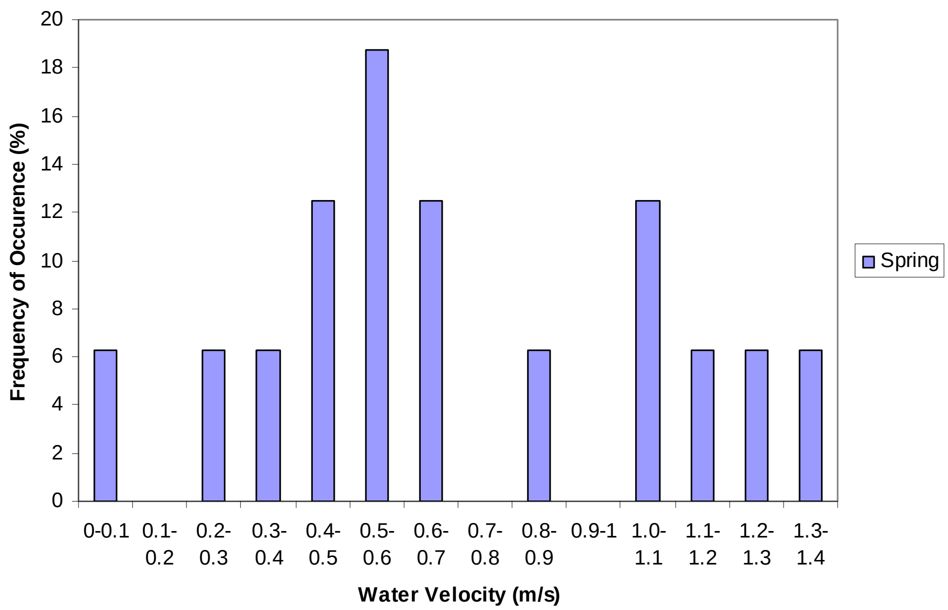
Stream N18 drains Lake N18 into Lake N11. N18 is dominated by boulder substrates. The average depth in the spring was 0.21 m and the average velocity was 0.07 m/s (Table 9.II-3). The majority of depths in spring were less than 0.1 m (Figure 9.II-16). Depths greater than 0.3 m were also available. Most water velocities in spring were less than 0.1 m/s (Figure 9.II-17).

Figure 9.II-12 Frequency of Spring Water Depths in Stream N11



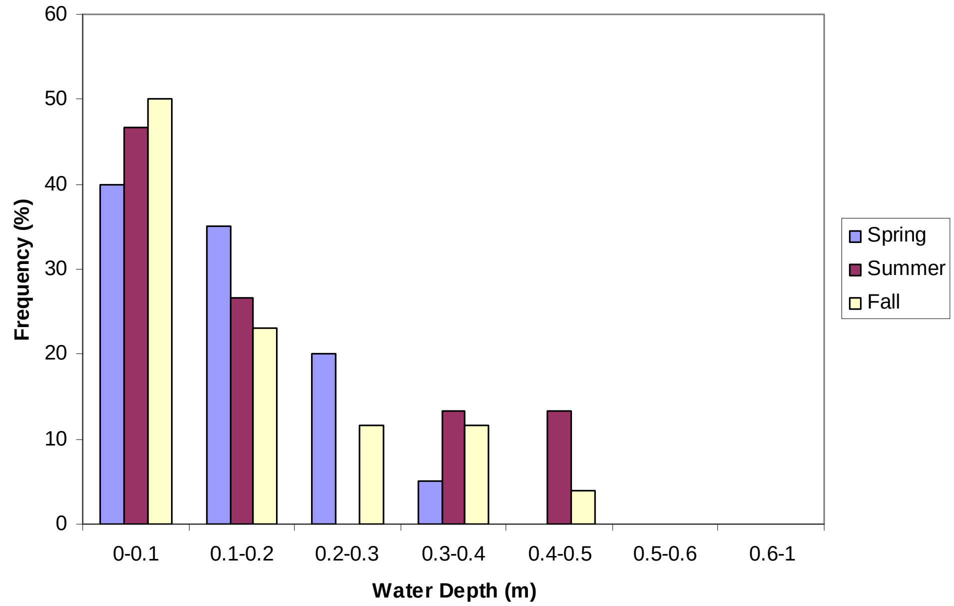
% = percent; m = meters.

Figure 9.II-13 Frequency of Spring Water Velocities in Stream N11



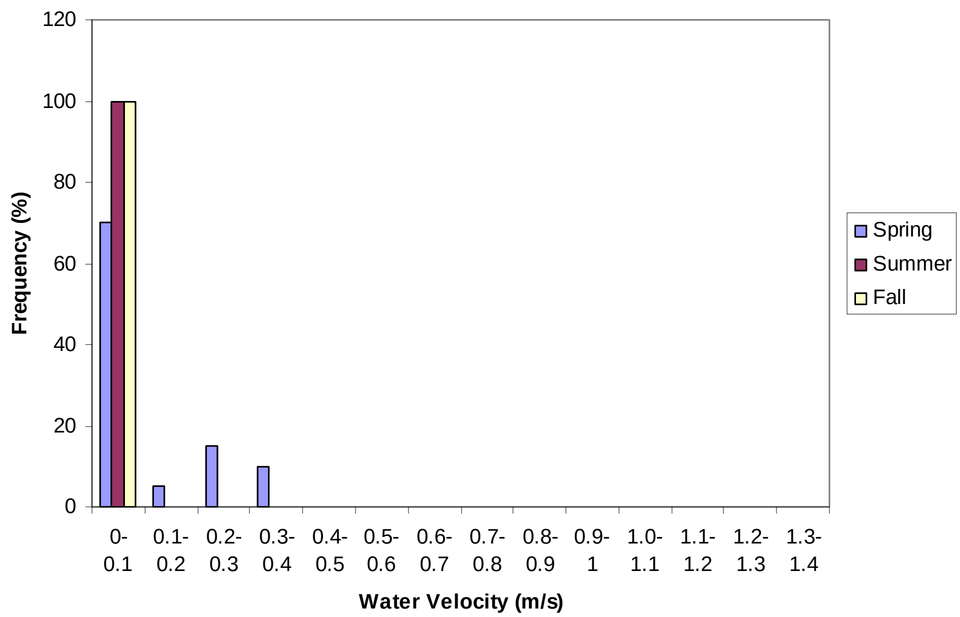
% = percent; m/s = meters per second.

Figure 9.II-14 Frequency of Seasonal Water Depths in Stream N12



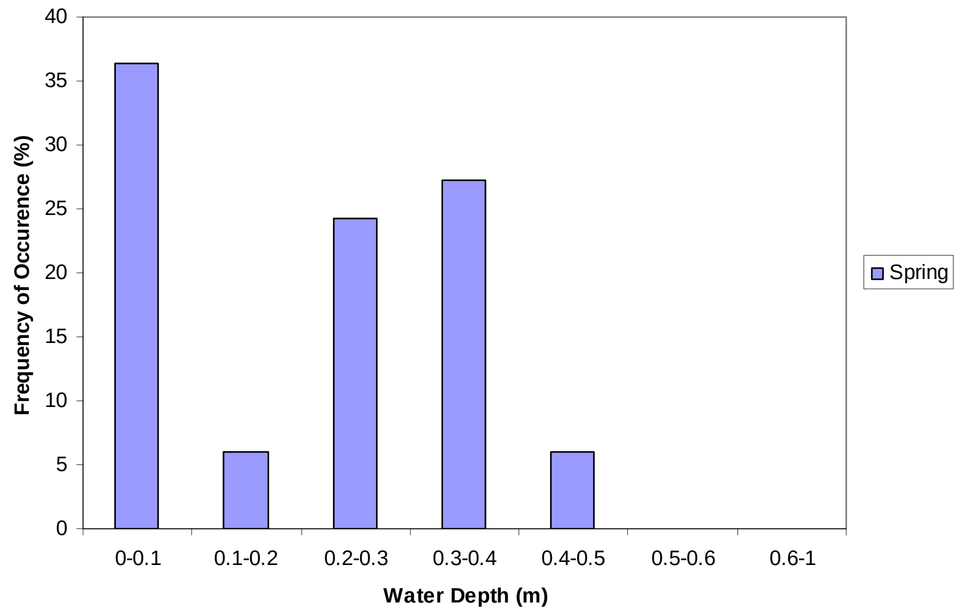
% = percent; m = meters.

Figure 9.II-15 Frequency of Seasonal Water Velocities in Stream N12



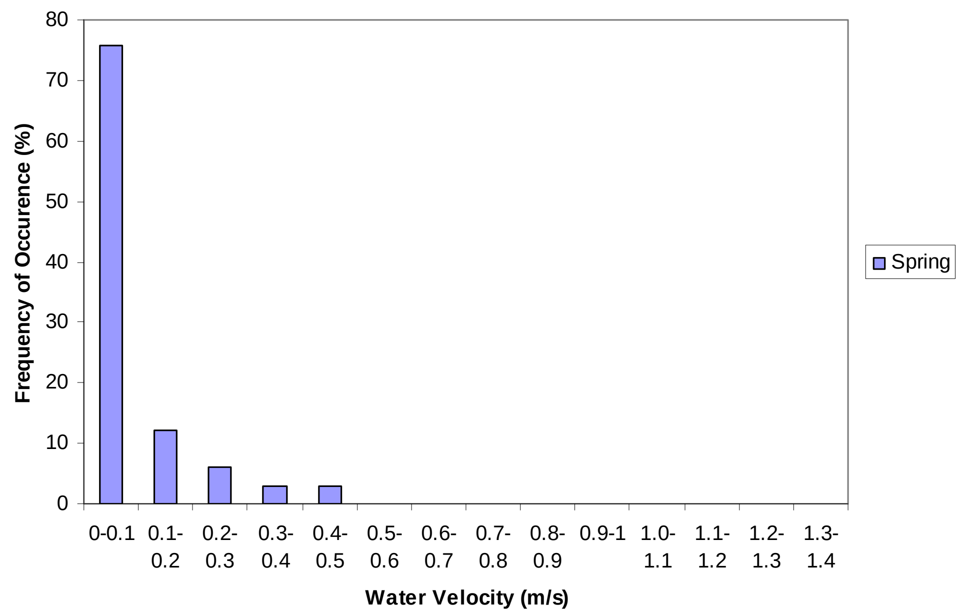
% = percent; m/s = meters per second.

Figure 9.II-16 Frequency of Spring Water Depths in Stream N18



% = percent; m = meters.

Figure 9.II-17 Frequency of Spring Water Velocities in Stream N18



% = percent; m/s = meters per second.

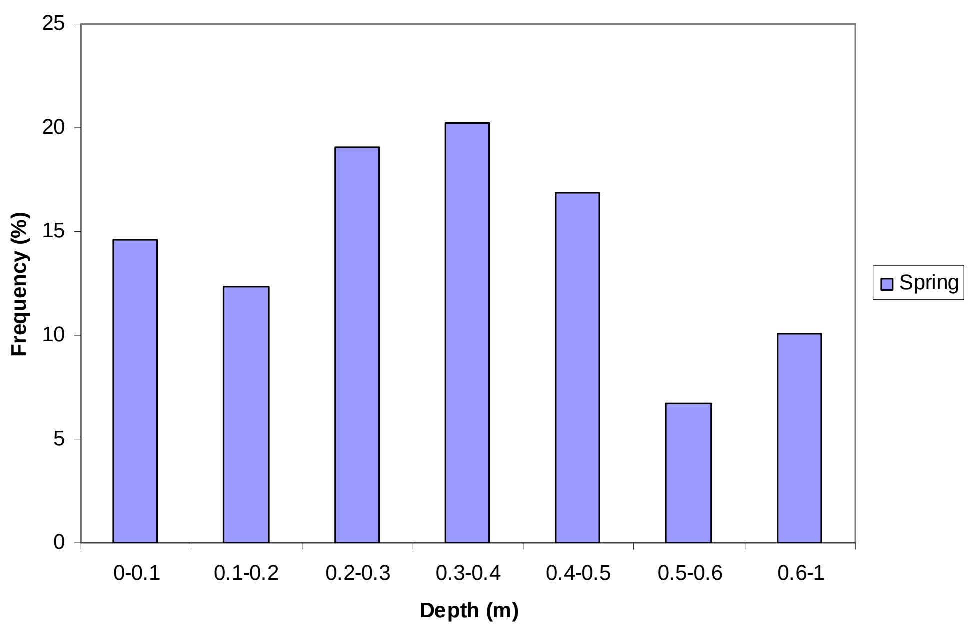
9.II.3.3 LAKE 410 OUTLET, P-DRAINAGE STREAMS, AND THE KIRK LAKE OUTLET

9.II.3.3.1 Lake 410 Outlet

Lake 410 drains to the north through a wide, multi-channelled, boulder-dominated outlet to lakes of the P watershed, and ultimately to Kirk Lake. In spring, the Lake 410 outlet had a wetted width in excess of 200 m. Along the right side of the main channel, there were numerous side channels conveying flow. The average depth of the Lake 410 outlet was 0.34 m with a maximum recorded depth of 0.85 m (Table 9.II-3). The average velocity was 0.22 m/s with a maximum water velocity of 0.83 m/s (Table 9.II-3). The cross-section for the Lake 410 outlet is provided in Figure 9.II-2.

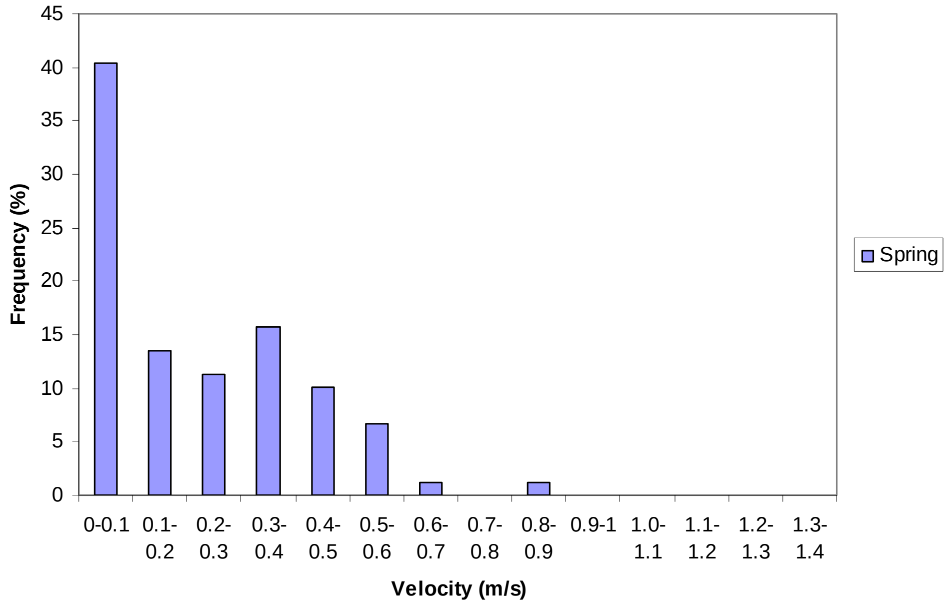
Figure 9.II-18 shows the frequency of depths for the Lake 410 outlet in spring. The most frequent depth category was 0.3 m to 0.4 m but depths ranged evenly from less than 0.1 m to 1.0 m. Water velocities ranged from less than 0.1 m/s to greater than 0.8 m/s but the majority of water velocities measured were between 0 m/s and 0.1 m/s (Figure 9.II-19).

Figure 9.II-18 Frequency of Spring Water Depths in the Lake 410 Outlet



% = percent; m = meters.

Figure 9.II-19 Frequency of Spring Water Velocities in the Lake 410 Outlet

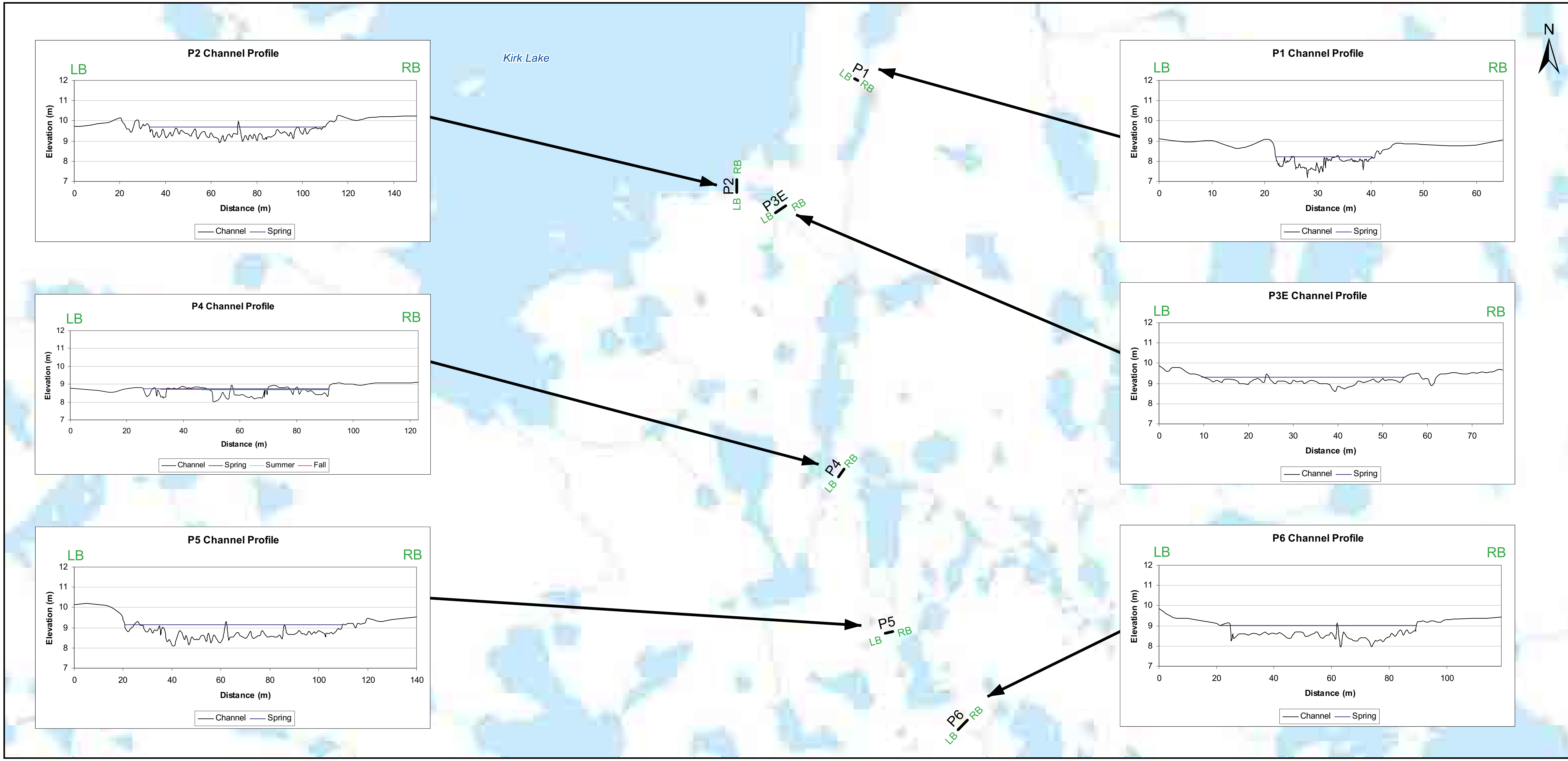


% = percent; m/s = meters per second.

9.II.3.3.2 P Watershed

Streams in the P drainage are wide (typically greater than 200 m), and dominated by boulder substrates. Location of transects and stream cross-sectional profiles for the P watershed are provided in Figure 9.II-20.

Depth and velocity measurements for streams P1, P2, P3, P5, and P6 in spring were pooled and are presented in Figures 9.II-21 and 9.II-22. The most frequent depth category was 0.2 m to 0.3 m but the frequencies for all of the depth categories were less than 20% and depths ranged from less than 0.1 m to 1.0 m (Figure 9.II-21). The most frequent velocity range was 0 m/s to 0.1 m/s but water velocities up to 0.5 m/s were not uncommon (Figure 9.II-22).

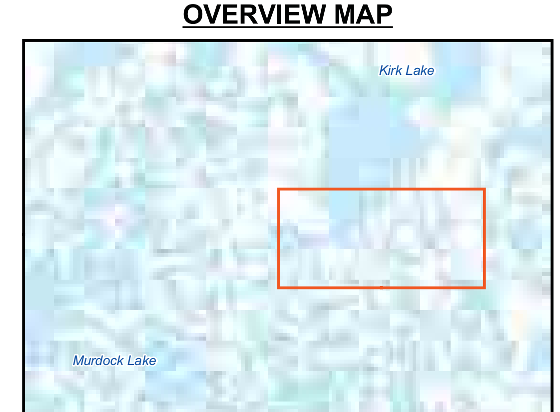


LEGEND

- Gahcho Kué Project
- Watercourse
- Waterbody
- Stream Transect (Channel Profile)
- LB Left Bank of Watercourse
- RB Right Bank of Watercourse

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

OVERVIEW MAP



GAHCHO KUÉ PROJECT

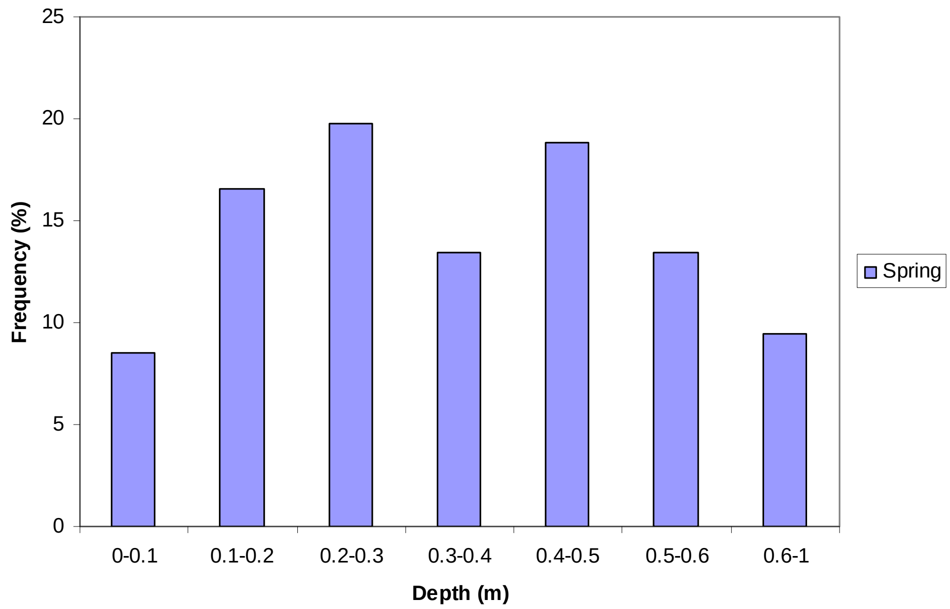
Transect Locations and Channel Profiles in Streams in the P Drainage

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:30,000 (300 0 300 600 Metres)	
FILE No: E-Fish-026-GIS	DATE: December 13, 2010
JOB NO: 09-1365-1004	REVISION NO: 1
OFFICE: GOLD-CAL	DRAWN: SK
CHECK: KC	

Figure 9.II-20

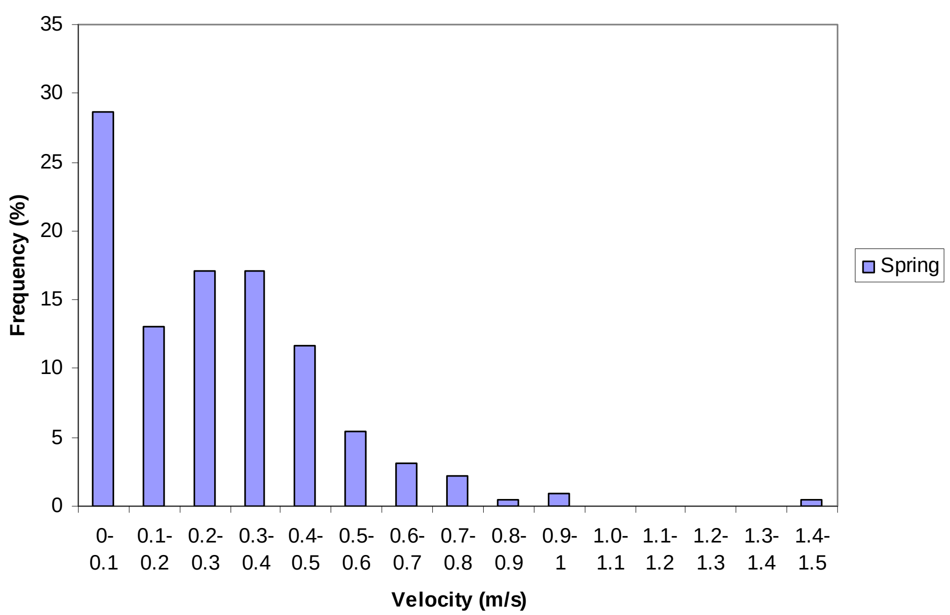
I:\CLIENTS\DE_BEERS\09-1365-1004\maps\10_fisheries-aquatics\EIA\E-Fish-026-GIS.mxd

Figure 9.II-21 Frequency of Spring Water Depths in the P drainage



% = percent; m = meters.

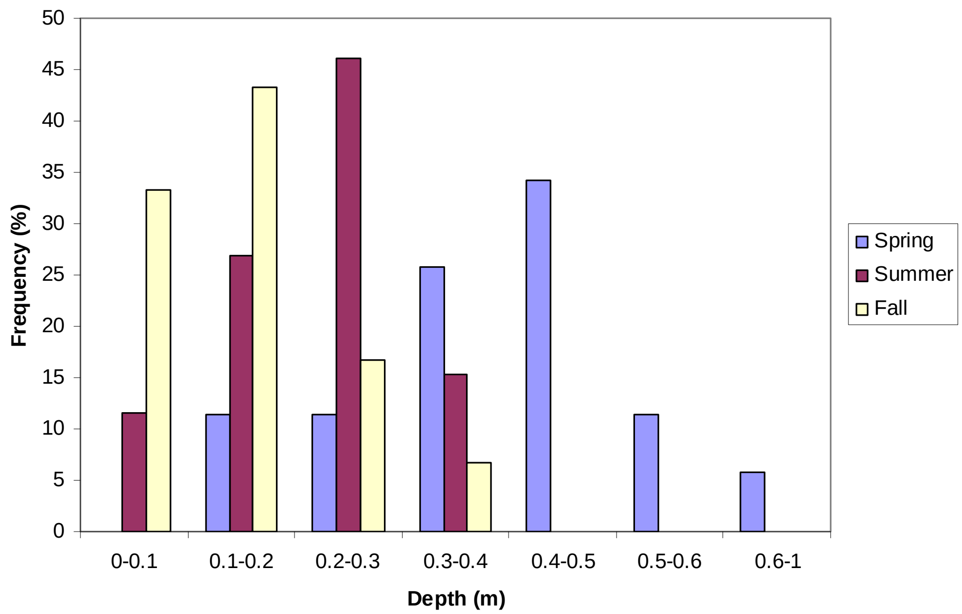
Figure 9.II-22 Frequency of Spring Water Velocities in the P drainage



% = percent; m/s = meters per second.

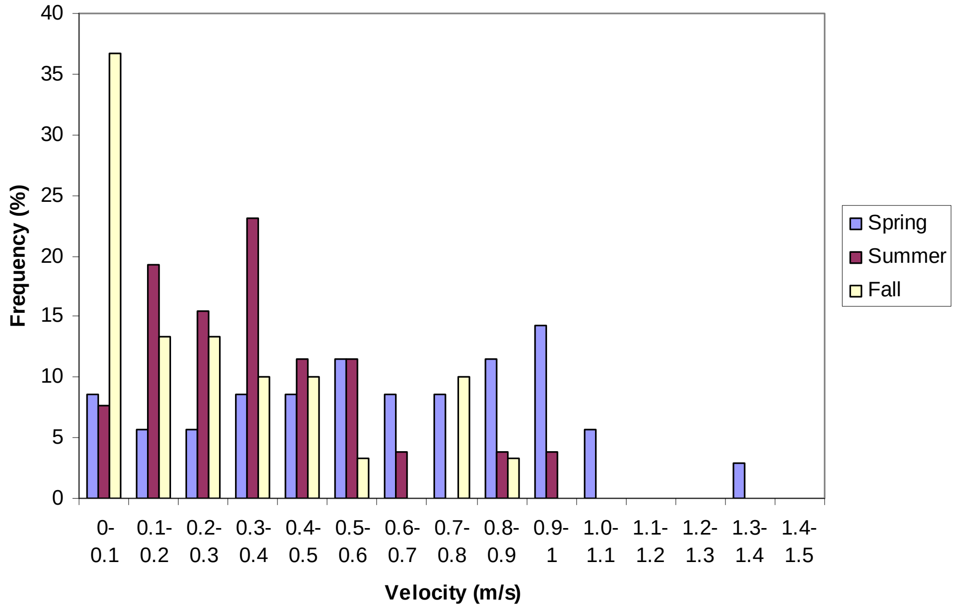
Stream P4 is unique in that it is located adjacent to an esker and includes substrates ranging from small gravel to boulders. Depths and water velocities in spring ranged from 0.1 m to greater than 0.6 m and from less than 0.1 m/s to greater than 1.3 m/s, respectively (Figures 9.II-23 and 9.II-24). The most frequent depth and water velocity categories in spring were 0.4 m to 0.5 m and 0.9 m/s to 1.0 m/s, respectively. The greatest average depth was 0.47 m in spring (Table 9.II-3). The highest average velocity was 0.61 m/s in spring. Average depths and water velocities decreased in summer and fall (Table 9.II-3).

Figure 9.II-23 Frequency of Seasonal Water Depths in Stream P4



% = percent; m = meters.

Figure 9.II-24 Frequency of Seasonal Water Velocities in Stream P4

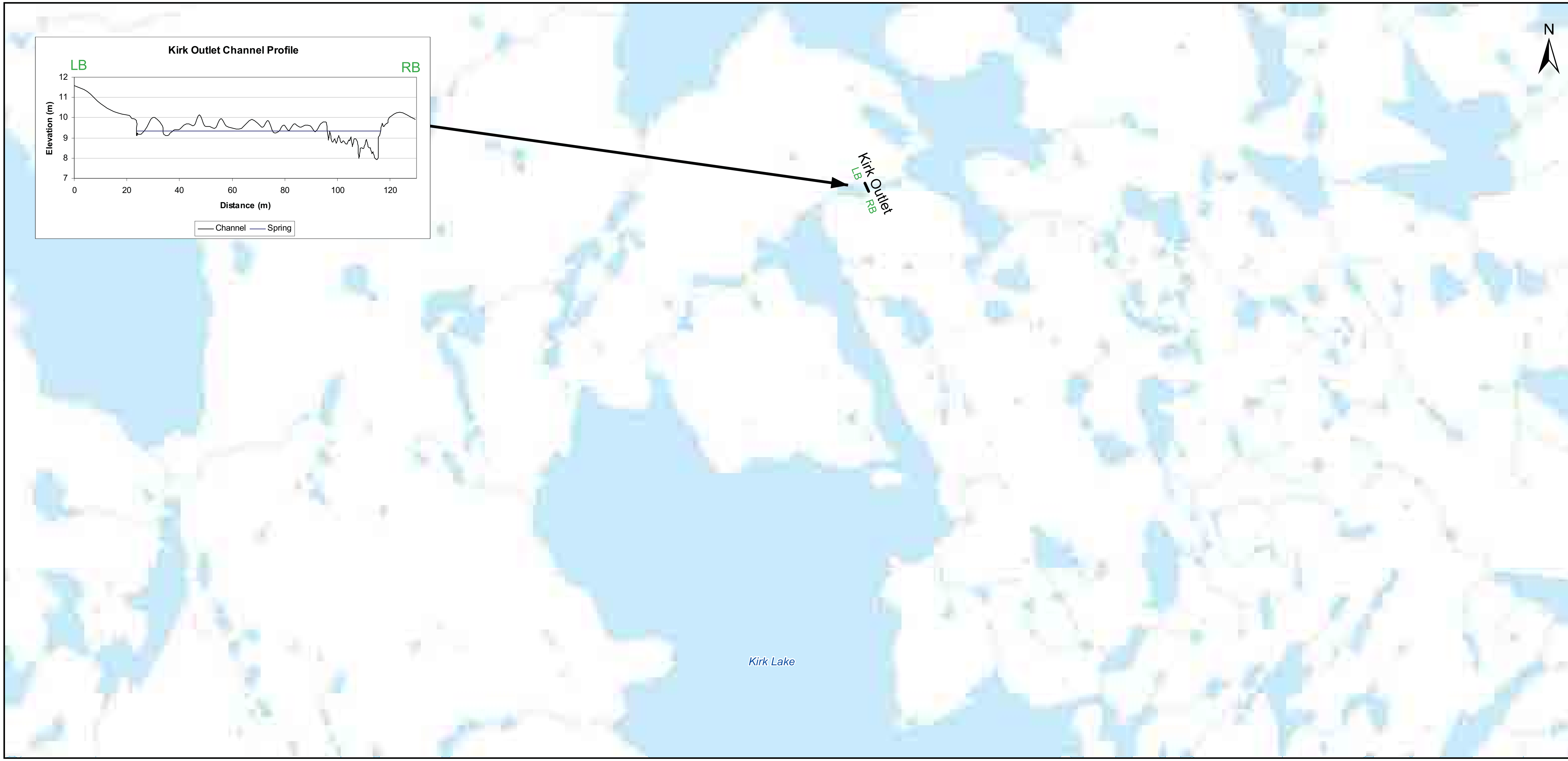


% = percent; m/s = meters per second.

9.II.3.3.3 Kirk Lake Outlet

The Kirk lake outlet is approximately 900 m long and comprised of three sections separated by two small lakes. The cross-section was located in the second of the three sections downstream from Kirk Lake and the channel profile is shown in Figure 9.II-25. The average depth at the cross-section was 0.43 m in spring with a maximum depth of 1.15 m (Table 9.II-3). The average spring water velocity was 0.51 m/s with a maximum water velocity of 1.27 m/s.

Depths in spring ranged from less than 0.1 m to greater than 0.6 m but depths between 0.2 m and 0.3 m were most common (Figure 9.II-26). Water velocities ranged between less than 0.1 m/s and greater than 1.3 m/s but water velocities less than 0.1 m/s were most common (Figure 9.II-27).

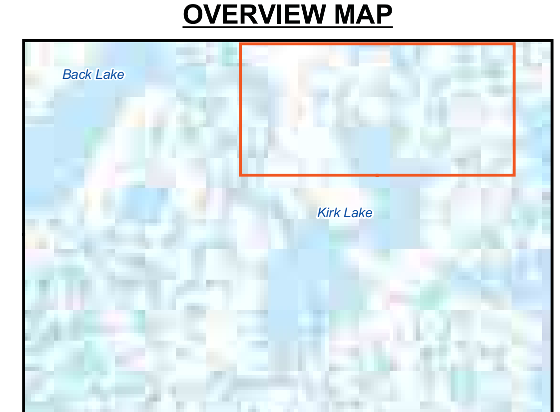


LEGEND

- Gahcho Kué Project
- Watercourse
- Waterbody
- Stream Transect (Channel Profile)
- LB Left Bank of Watercourse
- RB Right Bank of Watercourse

NOTES
Base data source: National Topographic
Base Data (NTDB) 1:50,000

OVERVIEW MAP



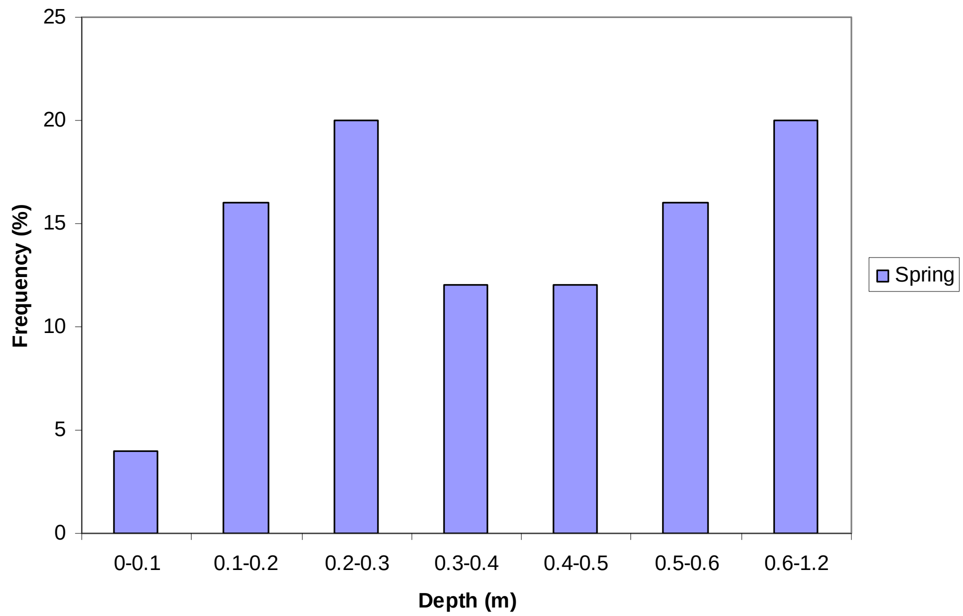
GAHCHO KUÉ PROJECT

Transect Locations and Channel Profile for Kirk Lake Outlet

PROJECTION: UTM Zone 12	DATUM: NAD83		
Scale: 1:40,000 500 0 500 1,000 Metres			
FILE No: E-Fish-027-GIS		DATE: December 13, 2010	
JOB NO: 09-1365-1004	REVISION NO: 1	Figure 9.II-25	
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: KC	

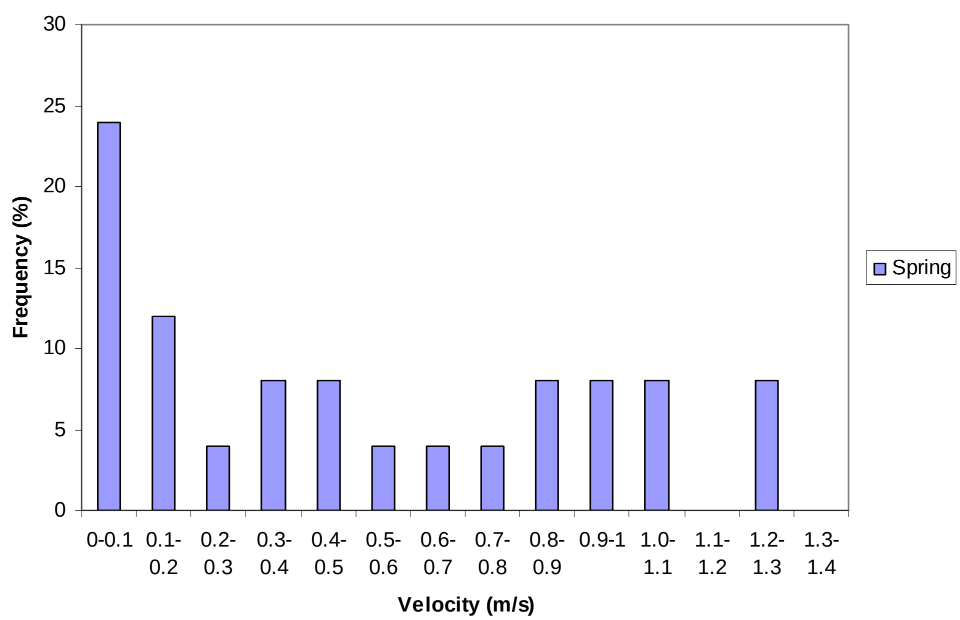
I:\CLIENTS\DE_BEERS\09-1365-1004\maps\10_fisheries-aquatics\EIA\E-Fish-027-GIS.mxd

Figure 9.II-26 Frequency of Spring Water Depths for the Kirk Lake Outlet



% = percent; m = meters.

Figure 9.II-27 Frequency of Spring Water Velocities in the Kirk Lake Outlet

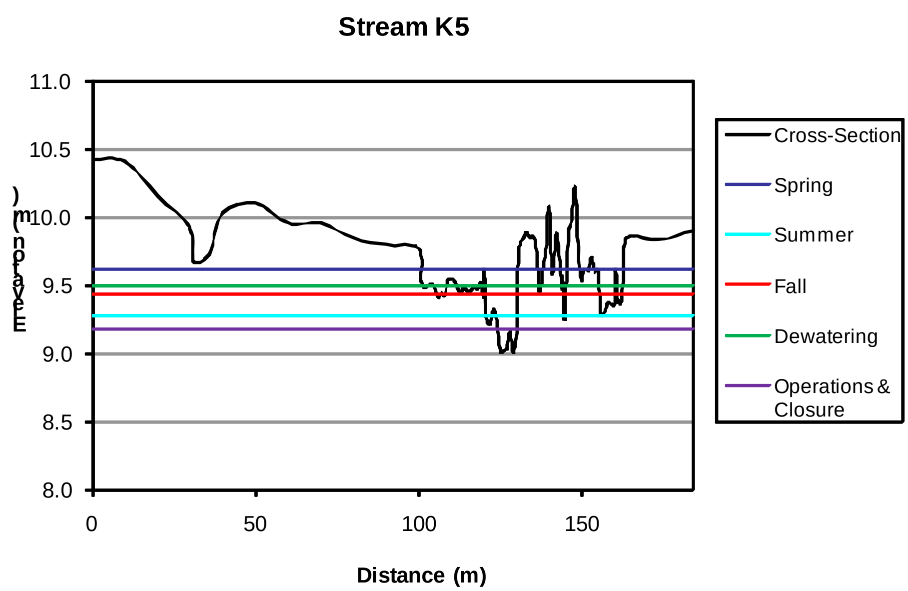


% = percent; m/s = meters per second.

9.II.3.4 COMPARISON OF NATURAL FLOWS TO DEWATERING, OPERATIONS AND REFILL FLOWS

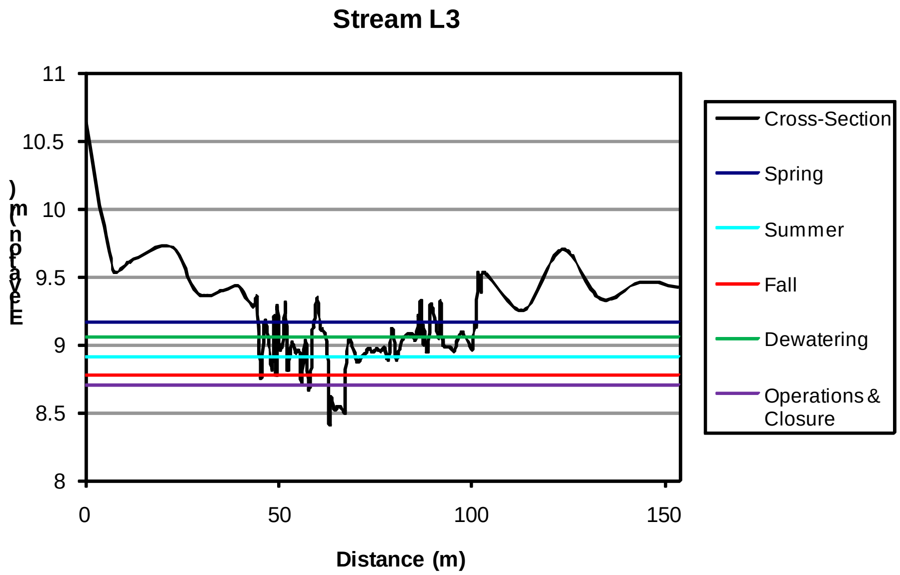
Figures 9.II-28 to 9.II-40 show the channel cross-sections with 2005 baseline water levels and predicted water levels for dewatering, operations and refilling phases for seven of the nine streams between Kennady Lake and Lake 410. The predicted dewatering, operations and closure flows are based on the mean annual flows for each phase of the project.

Figure 9.II-28 Observed 2005 Water Surface Elevations and Predicated Elevations in Stream K5



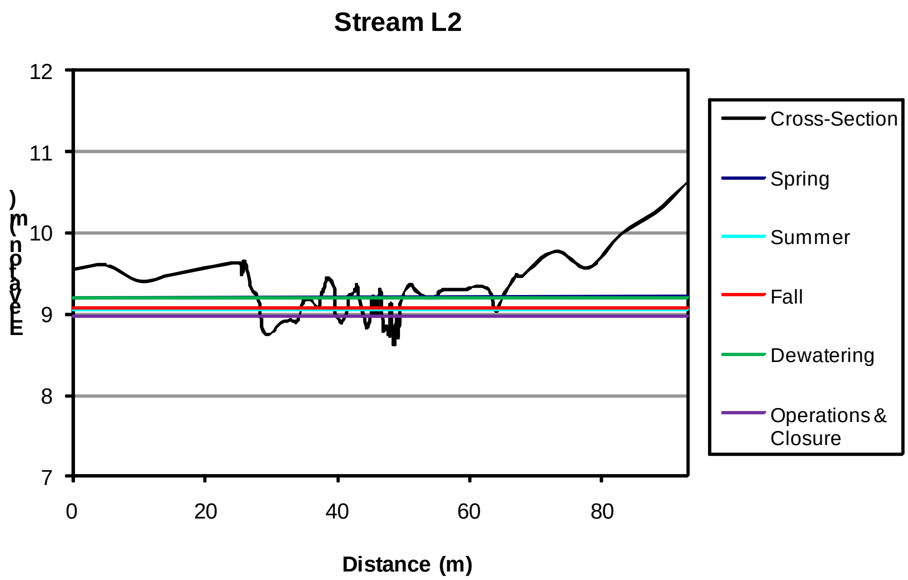
m = metres.

Figure 9.II-29 Observed 2005 Water Surface Elevations and Predicated Elevations in Stream L3



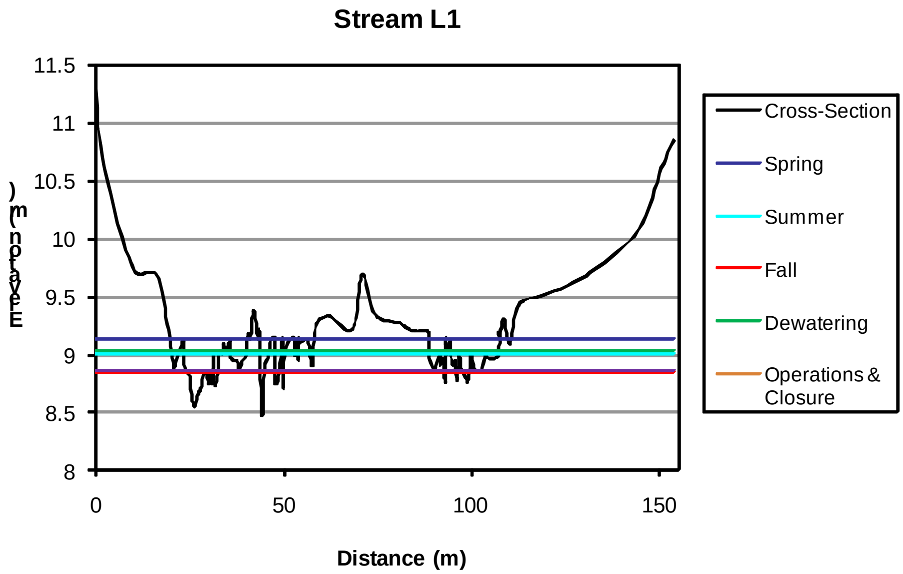
m = metres.

Figure 9.II-30 Observed 2005 Water Surface Elevations and Predicated Elevations in Stream L2



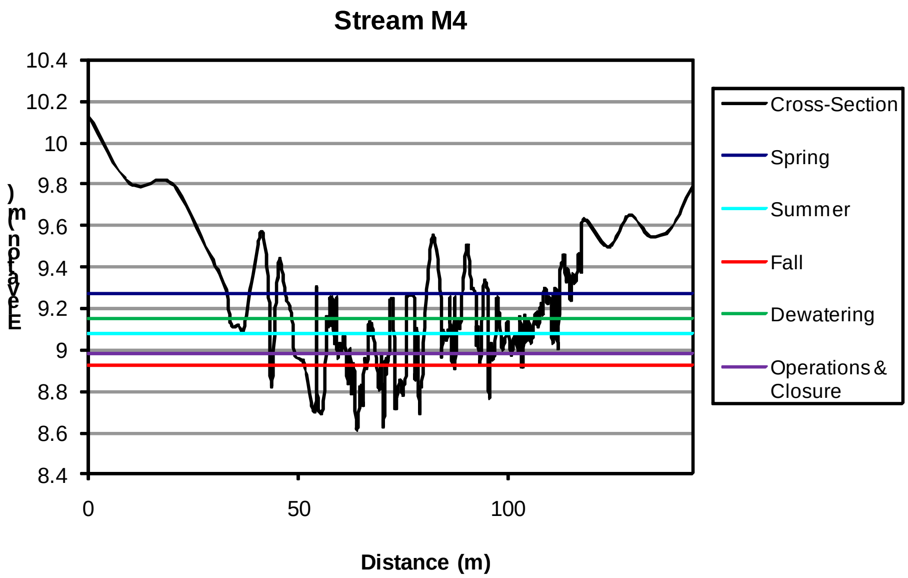
m = metres.

Figure 9.II-31 Observed 2005 Water Surface Elevations and Predicated Elevations in Stream L1



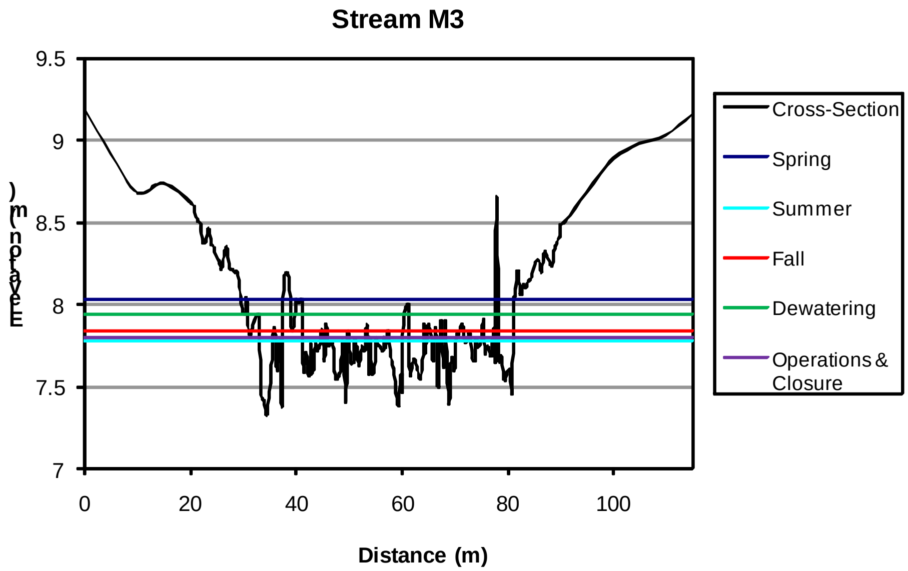
m = metres.

Figure 9.II-32 Observed 2005 Water Surface Elevations and Predicated Elevations in Stream M4



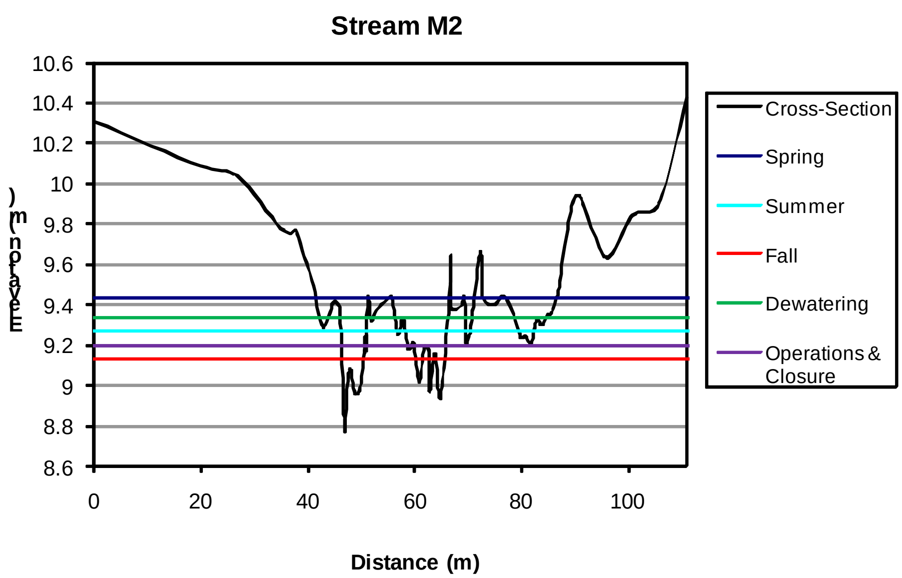
m = metres.

Figure 9.II-33 Observed 2005 Water Surface Elevations and Predicated Elevations in Stream M3



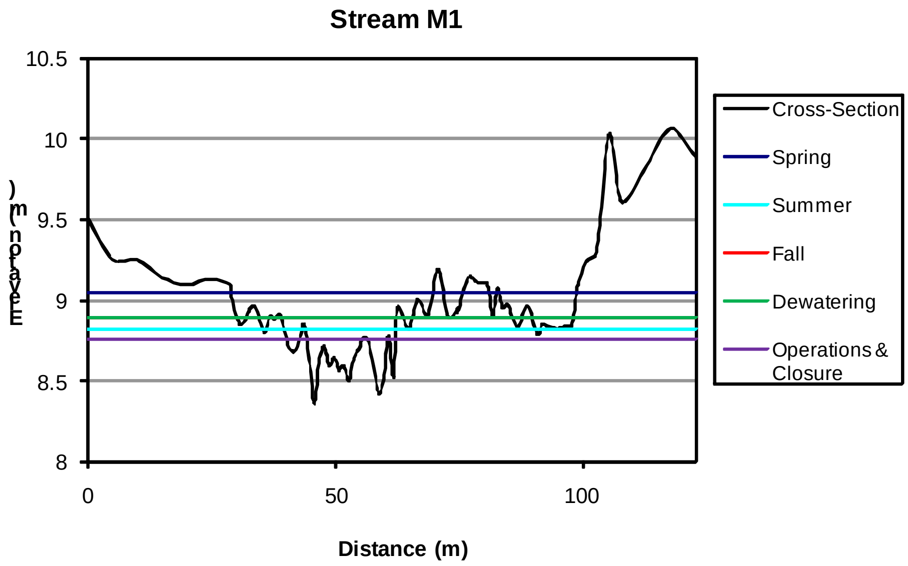
m = metres.

Figure 9.II-34 Observed 2005 Water Surface Elevations and Predicated Elevations in Stream M2



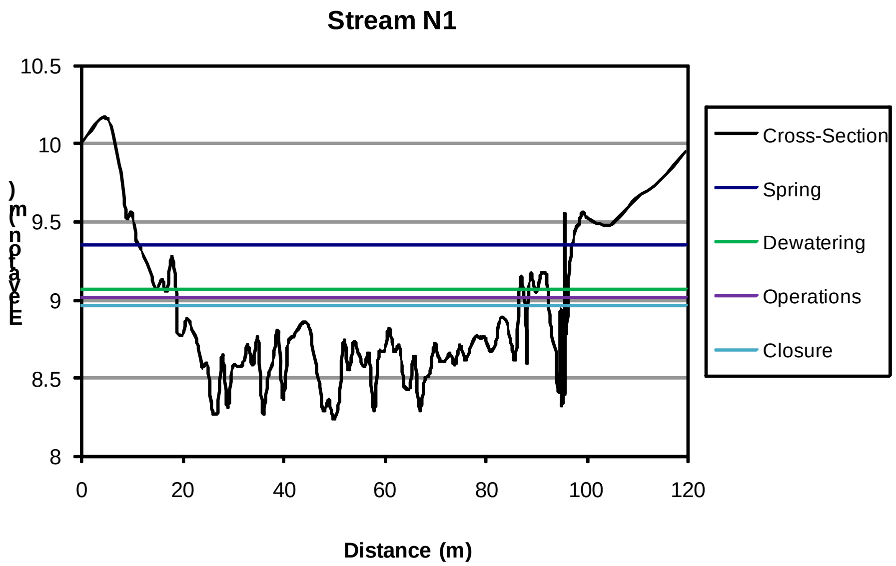
m = metres.

Figure 9.II-35 Observed 2005 Water Surface Elevations and Predicated Elevations in Stream M1



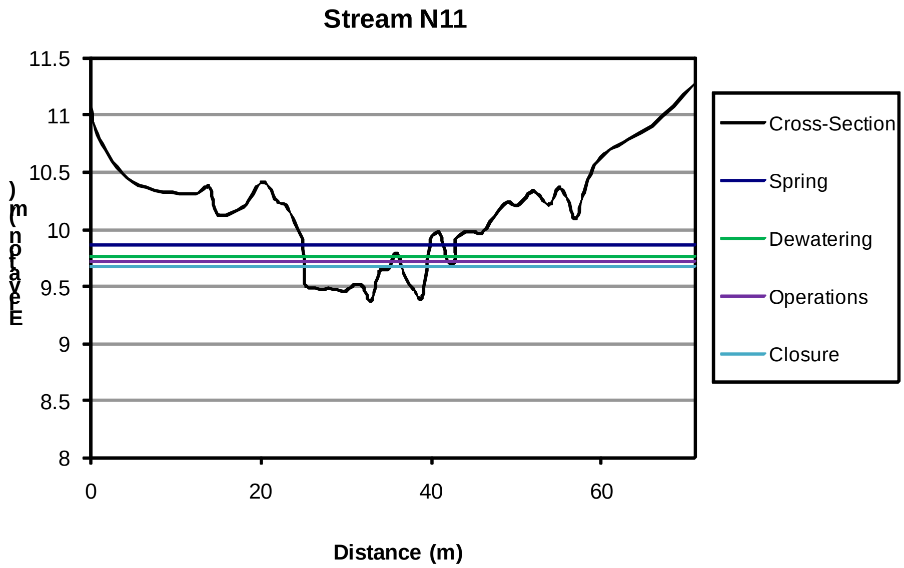
m = metres.

Figure 9.II-36 Observed 2005 Water Surface Elevations and Predicated Elevations in Stream N1



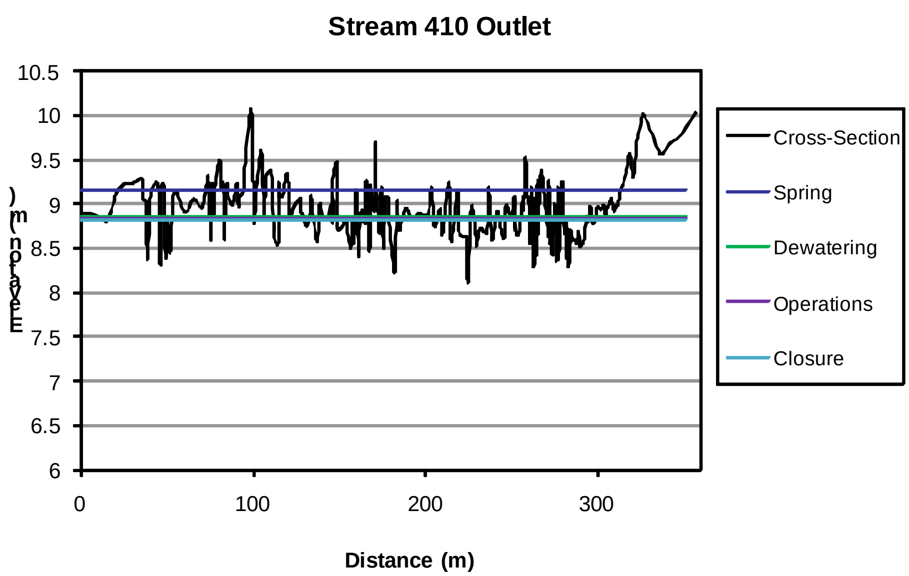
m = metres.

Figure 9.II-37 Observed 2005 Water Surface Elevations and Predicated Elevations in Stream N11



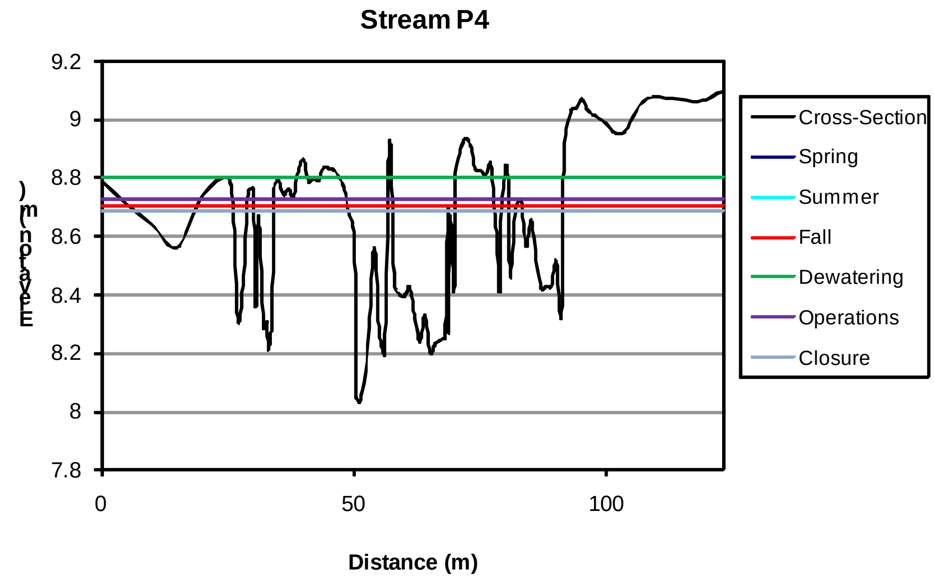
m = metres.

Figure 9.II-38 Observed 2005 Water Surface Elevations and Predicated Elevations in Lake 410 Outlet Stream



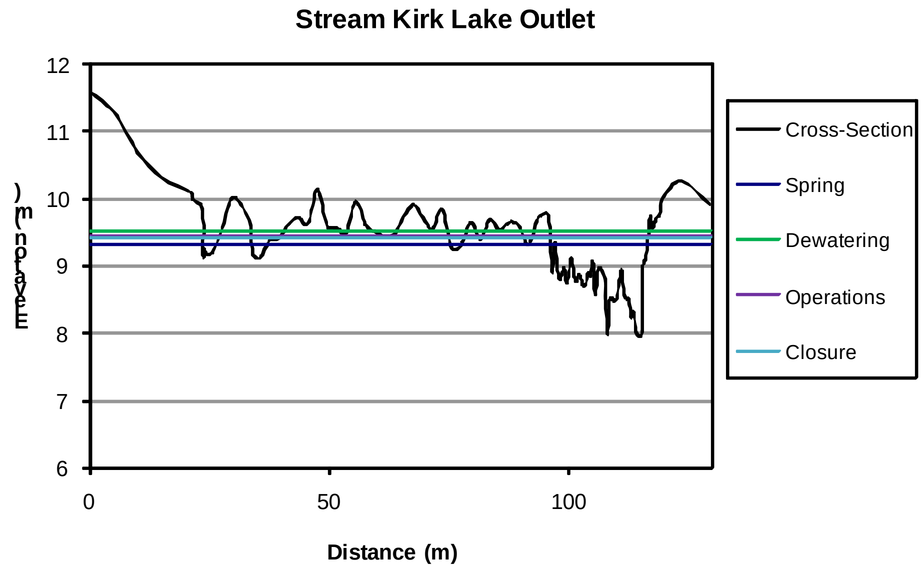
m = metres.

Figure 9.II-39 Observed 2005 Water Surface Elevations and Predicated Elevations in Stream P4



m = metres.

Figure 9.II-40 Observed 2005 Water Surface Elevations and Predicated Elevations in Kirk Lake Outlet Stream



m = metres.

9.II.4 LITERATURE CITED

Bovee, K.D. 1982. A Guide to Stream Habitat Analysis using the Instream Flow Incremental Methodology. Instream Flow Information Paper 12. U.S. Fish and Wildl. Serv. FWS/OBS-82/26. 248 p.

Lewis, A., T. Hatfield, B. Chilibeck and C. Roberts. 2004. Assessment Methods for Aquatic Habitat and Instream Flow Characteristics in Support of Applications to Dam, Divert, or Extract Water from Streams in British Columbia. Prepared for British Columbia Ministry of Water, Land and Air Protection and BC Ministry of Sustainable Resource Management.