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

Project Activity	Pathway	Effects Statement
Dewatering of Kennady Lake	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
Operational water management	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	
	changes to nutrient levels in the N watershed may result in changes to lower trophic communities and fish and fish habitat in downstream waterbodies	

Table 9.10-2 Valid Pathways and Effect Statements for Effects to Fish and Fish Habitat Downstream of Kennady Lake – Closure and Post-Closure

Project Activity	Pathway	Effects Statement
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, and fish behaviour 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, and fish behaviour in downstream waterbodies	
	changes to 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	

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

9.10.1.3.1 Changes to Lower Trophic Levels

Effects of increases in nutrient concentrations on plankton and benthic invertebrate communities downstream of Kennady Lake were assessed qualitatively. The assessment was based on the understanding of the plankton and benthic invertebrate communities that exist in lakes and streams downstream from baseline investigations, and an understanding of the typical responses of different taxa present to nutrient enrichment, based on the published literature. The literature used included studies of nutrient enrichment and fertilization in oligotrophic sub-Arctic lakes and aquatic effects monitoring reports from operating diamond mines in the Northwest Territories. Because lakes and streams downstream of Kennady Lake are phosphorus-limited, potential effects to plankton and benthic invertebrates were evaluated based on the modelled changes in phosphorus concentrations reported in the water quality assessment (Section 9.8).

9.10.1.3.2 Changes to Fish

Effects of changes on fish and fish habitat due to changes in nutrient levels and trophic status were qualitatively assessed based on projected changes in plankton and benthic invertebrate communities, published literature regarding trophic interactions, food web complexity, and known effects of nutrient additions on fish communities, including studies of nutrient enrichment and fertilization in oligotrophic sub-Arctic lakes and streams and aquatic effects monitoring reports from operating diamond mines in the Northwest Territories.

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

Changes to lower trophic levels and fish habitat due to increases in nutrient concentrations during post-closure were assessed using the same approach as described for the construction and operations assessment (Section 9.10.1).

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

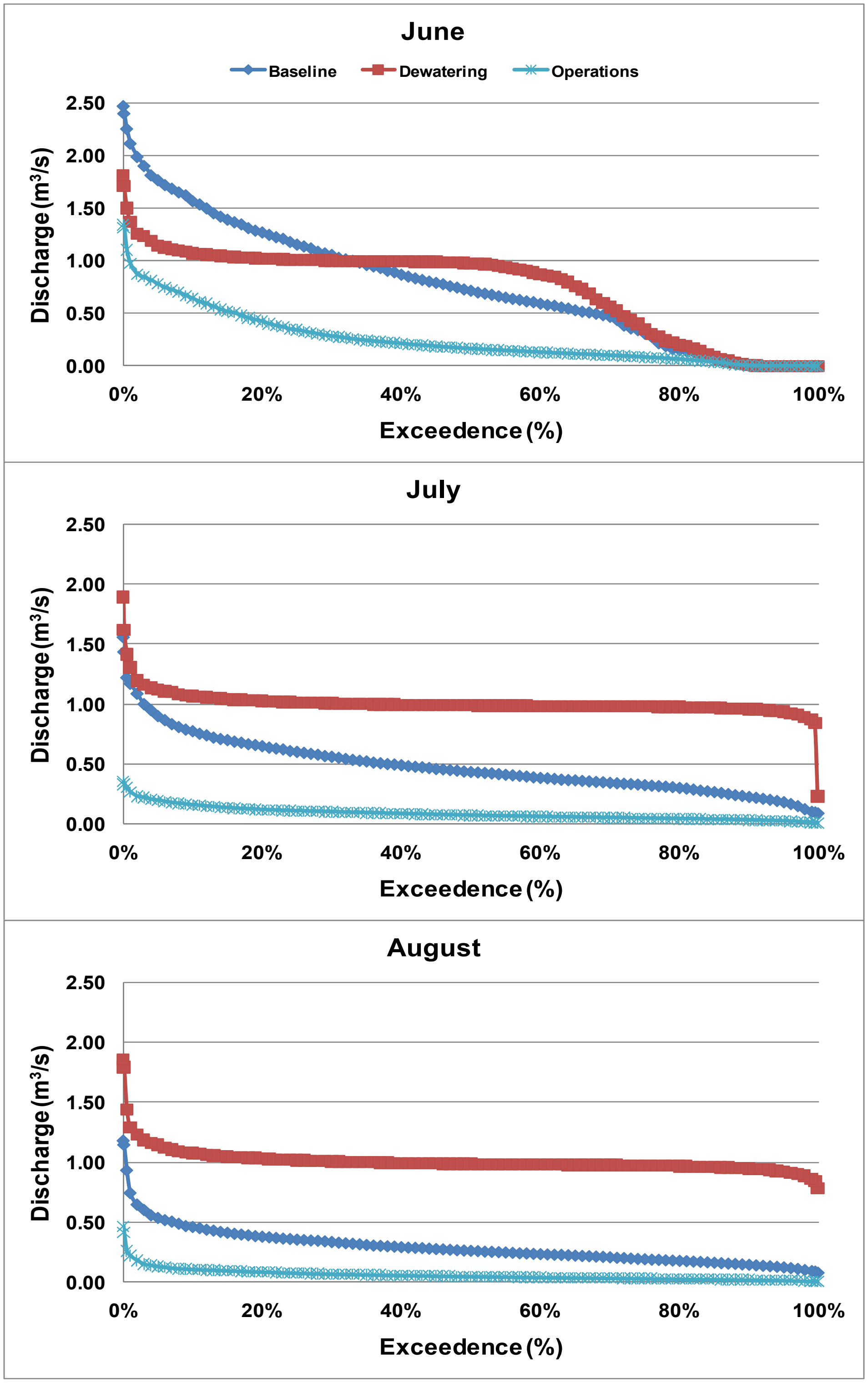
9.10.3.1 Effects of Changes to the Flow Regime in Streams Downstream of Kennady Lake on Fish and Fish Habitat

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

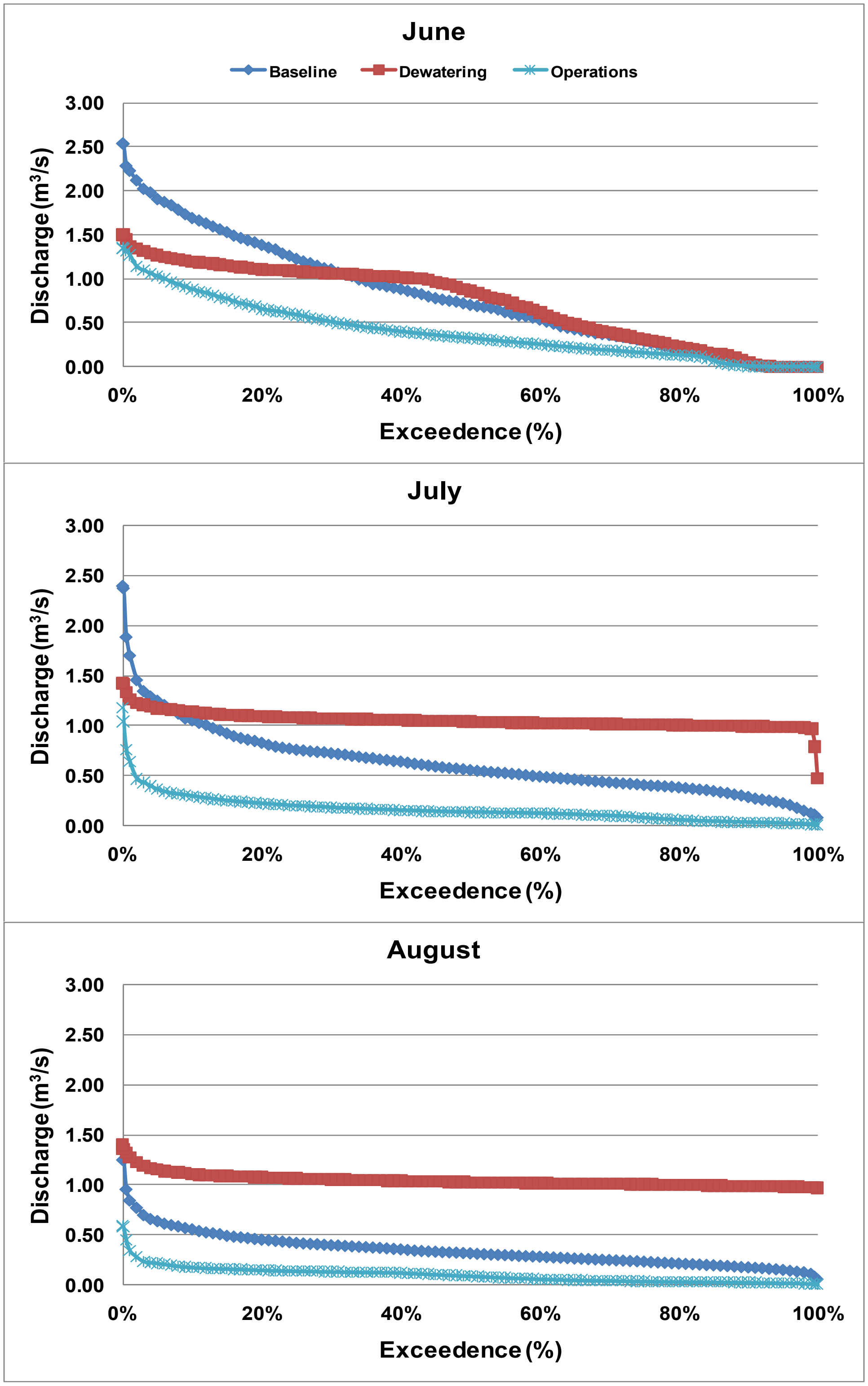
Changes to seasonal flow beyond a 15% change from baseline are predicted in the N, L and M watersheds during both construction and operations. At the Lake 410 outlet, peak flows are similar to baseline conditions during construction; however flow augmentation remains evident between July and September. 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



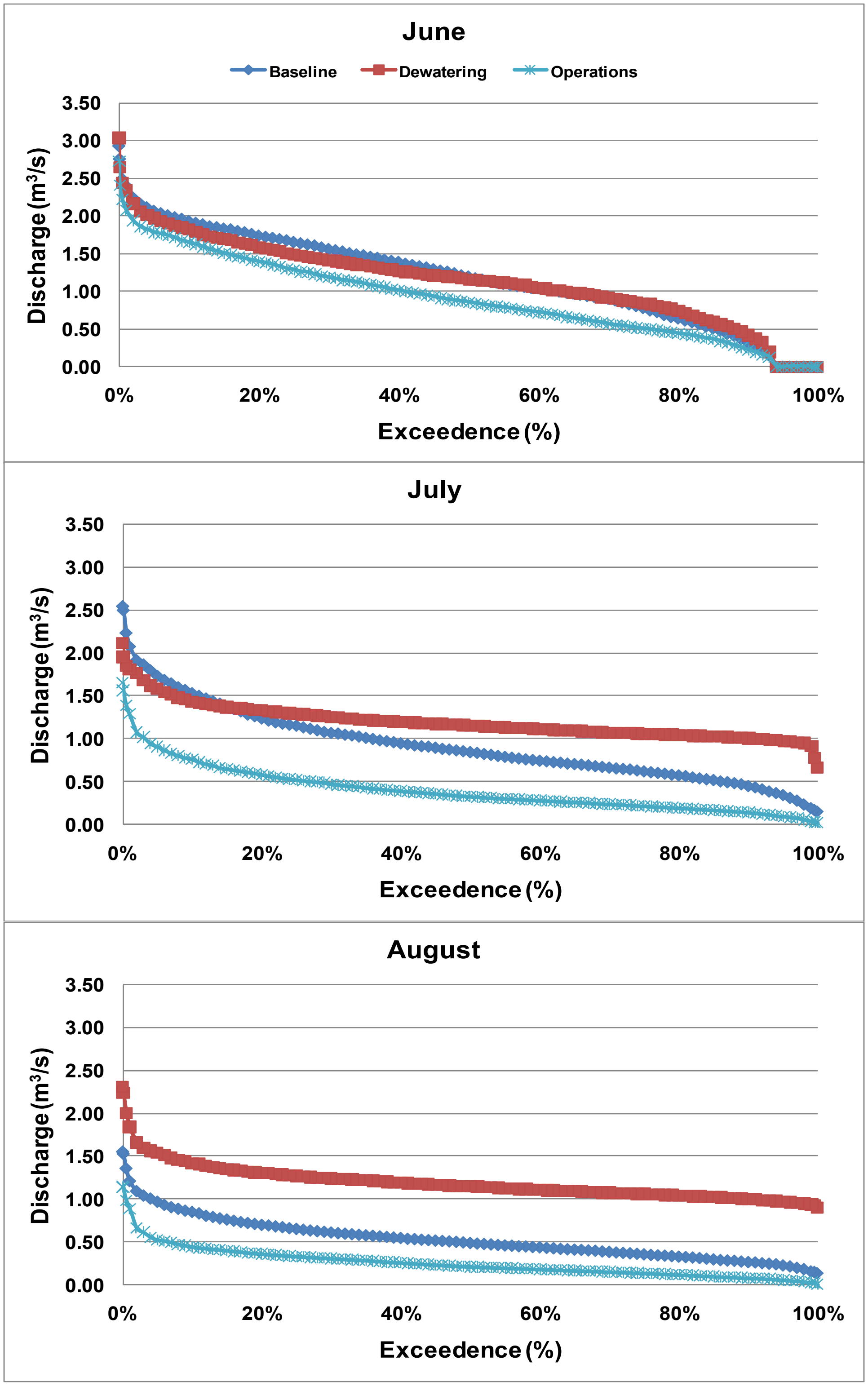
m^3/s = cubic metres per second; % = percent

Figure 9.10-2 Flow Duration Curves for June, July, and August at the Outlet of Lake L1a under Baseline, Construction, and Operations



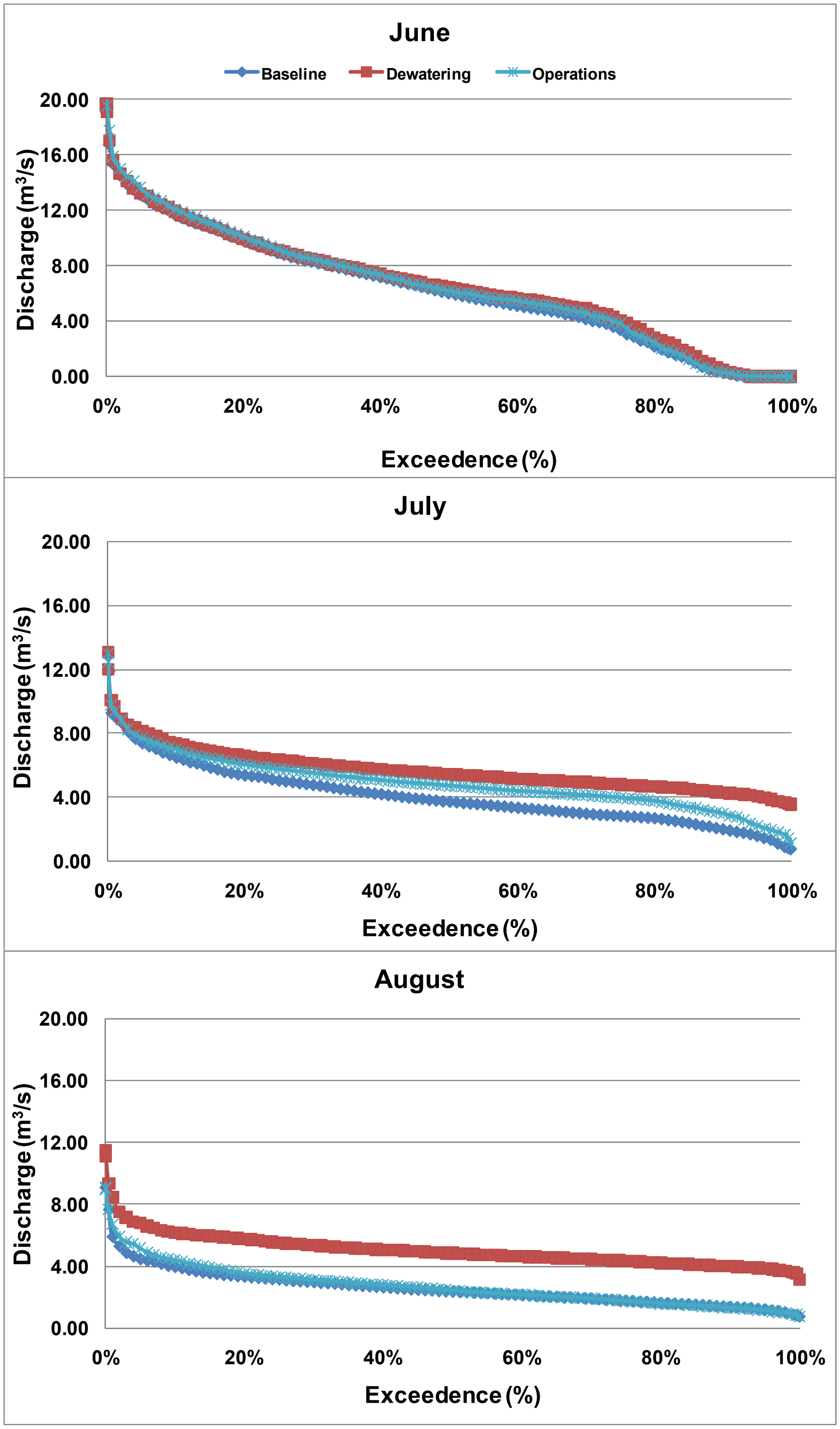
m^3/s = cubic metres per second; % = percent

Figure 9.10-3 Flow Duration Curves for June, July, and August at the Outlet of Lake M1 under Baseline, Construction, and Operations



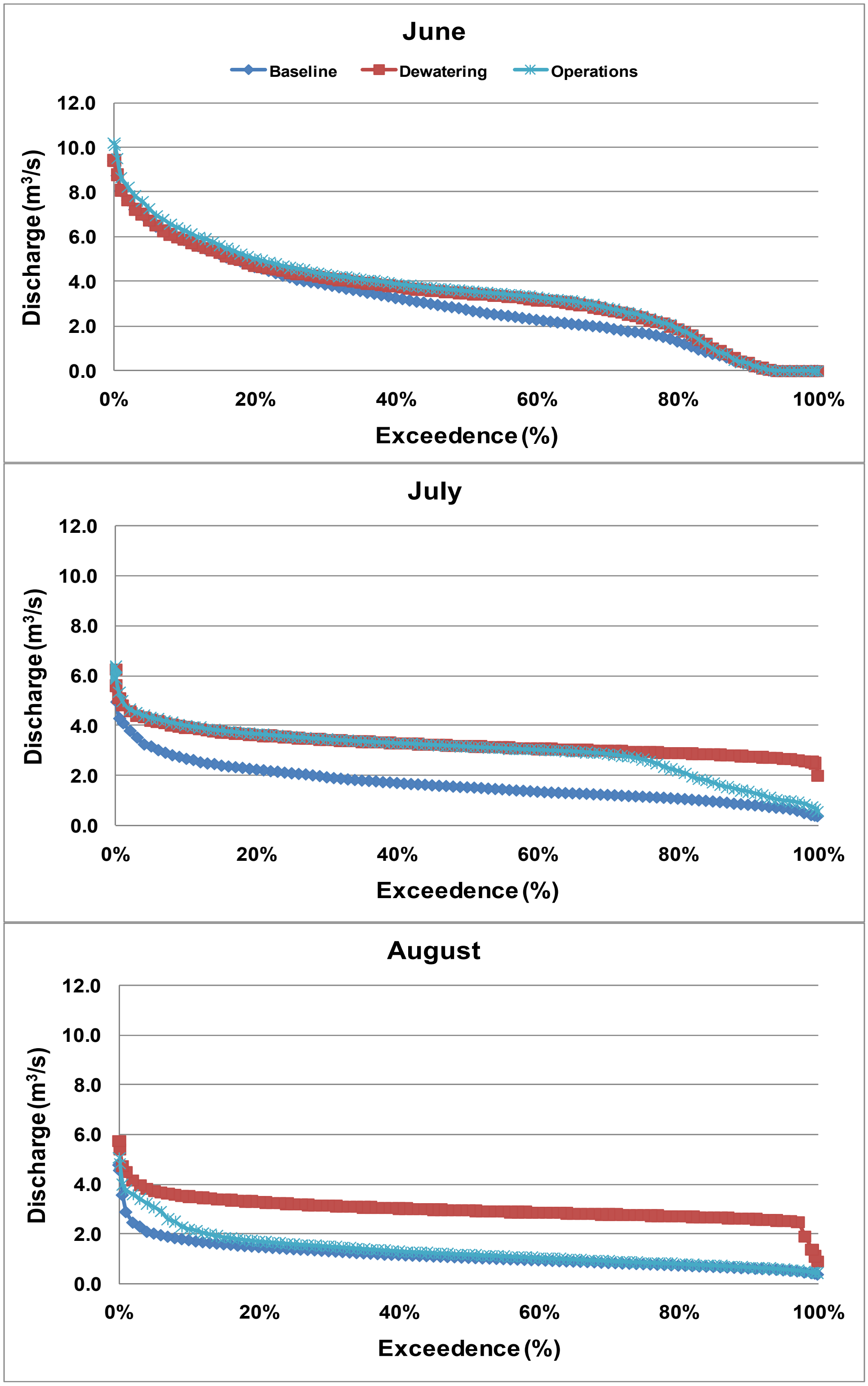
m^3/s = cubic metres per second; % = percent

Figure 9.10-4 Flow Duration Curves for June, July, and August at the Outlet of Lake 410 under Baseline, Construction, and Operations



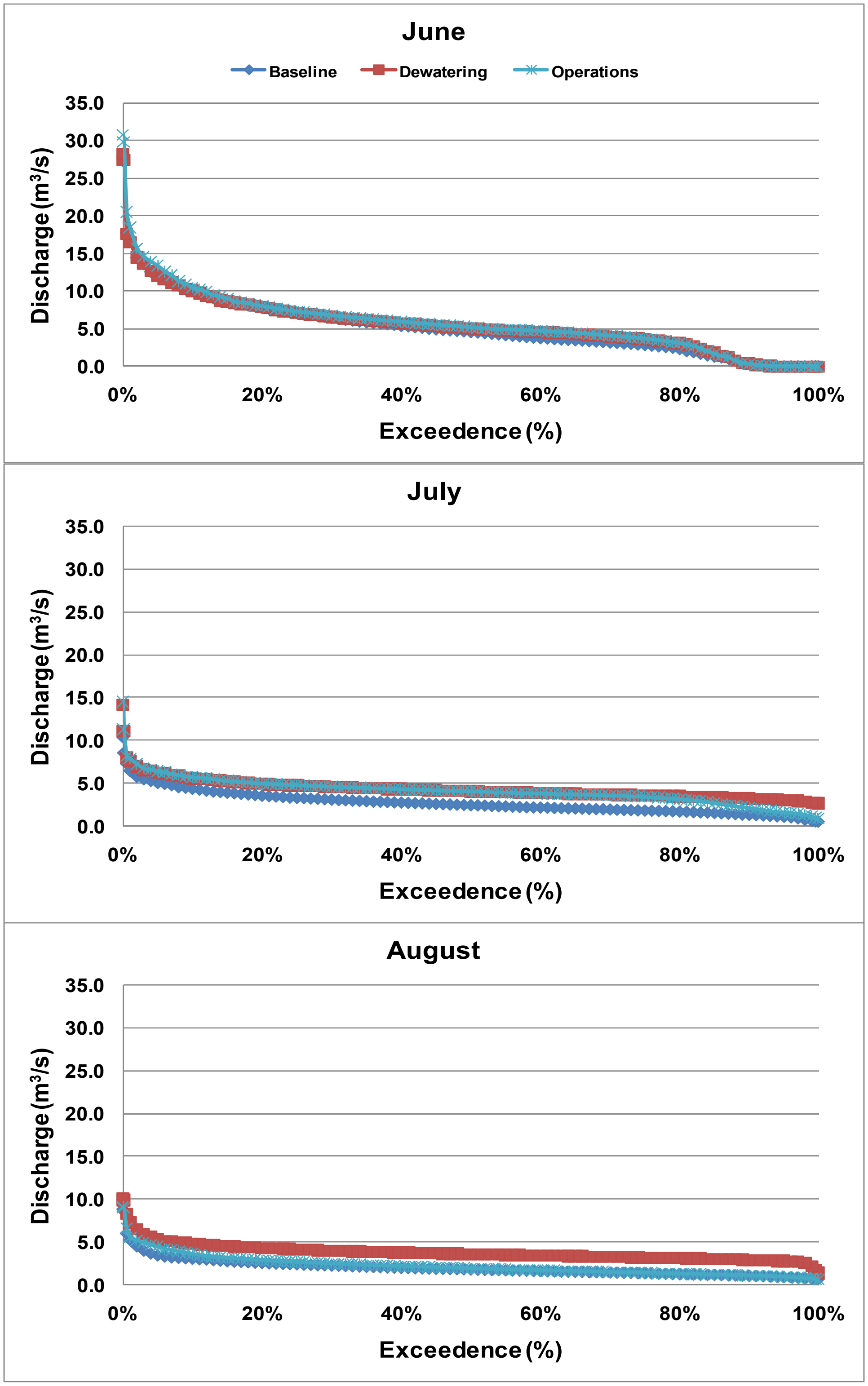
m^3/s = cubic metres per second; % = percent

Figure 9.10-5 Flow Duration Curves for June, July, and August at the Outlet of Lake N11 under Baseline, Construction, and Operations



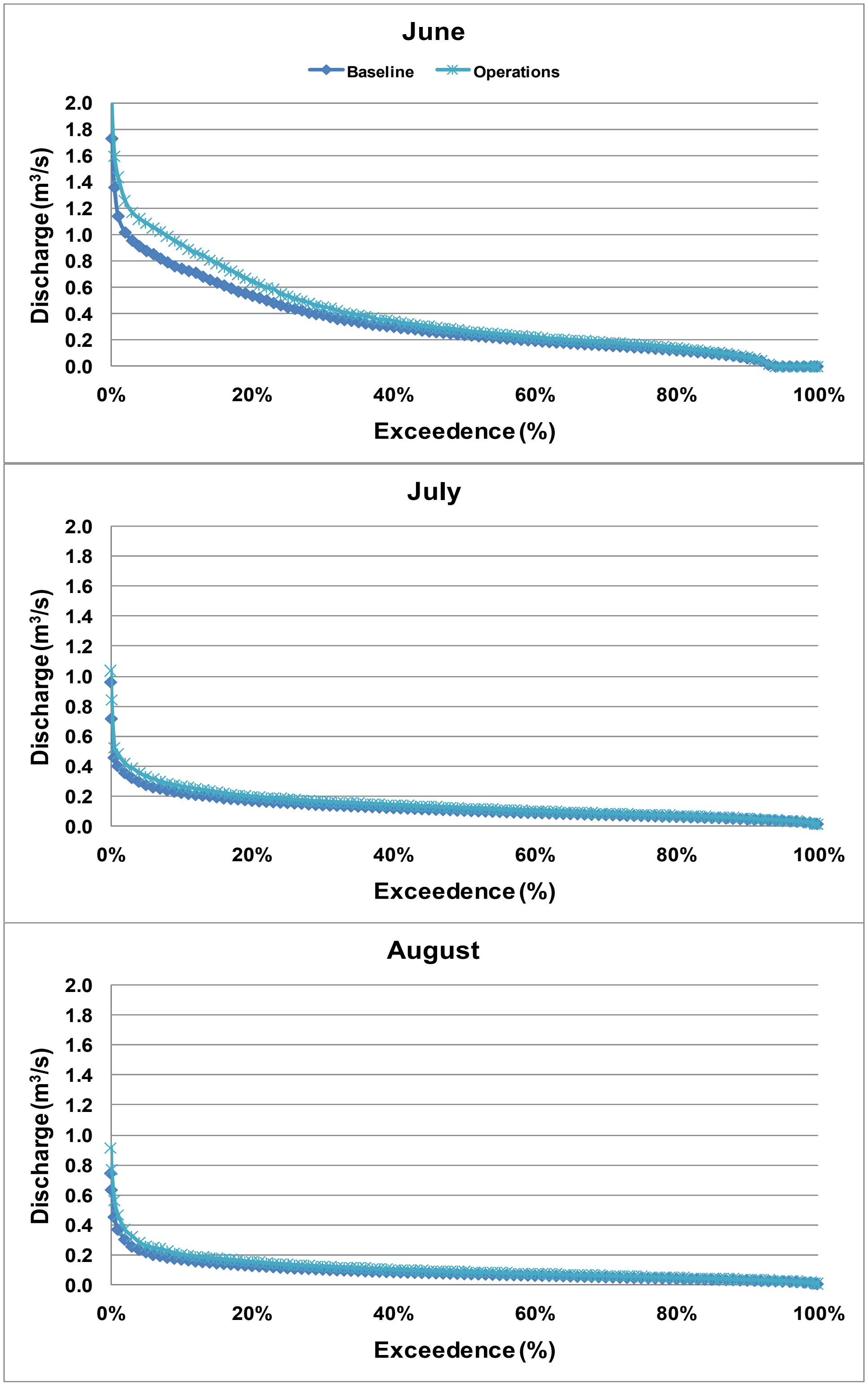
m^3/s = cubic metres per second; % = percent.

Figure 9.10-6 Flow Duration Curves for June, July, and August at the Outlet of Lake N1 under Baseline, Construction, and Operations



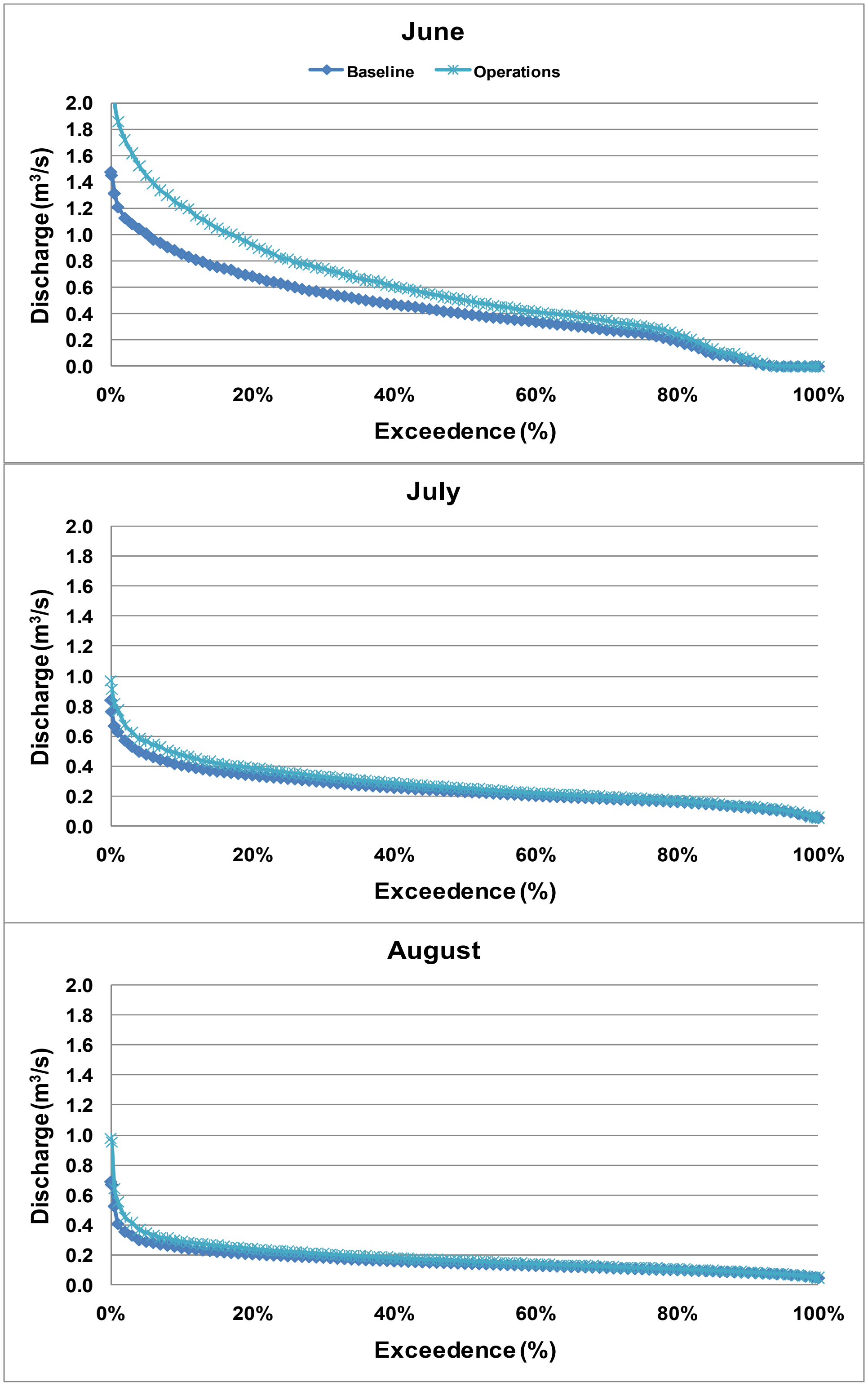
m^3/s = cubic metres per second; % = percent.

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).

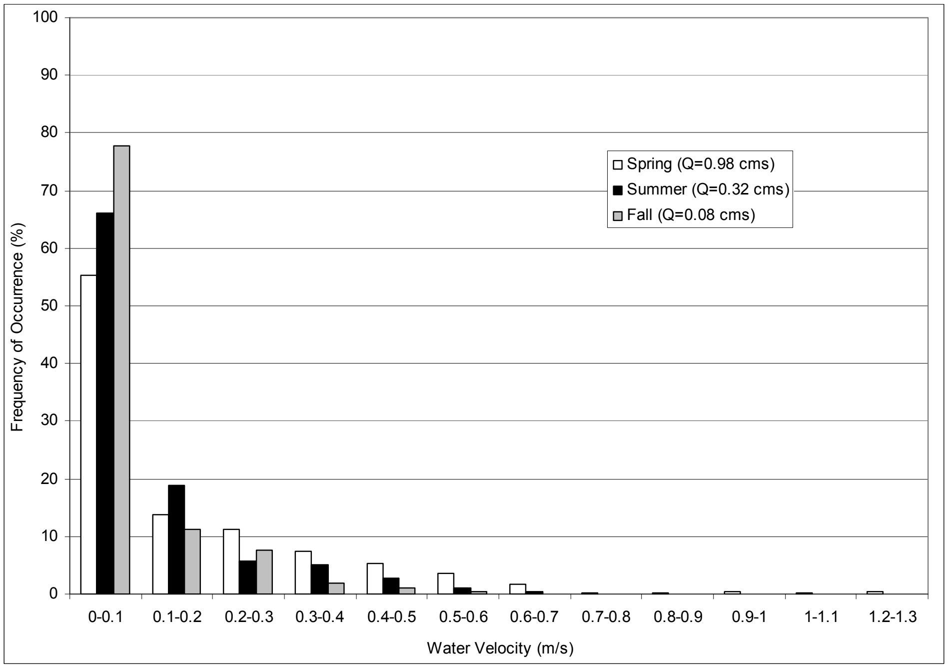
Large boulder substrates dominate the channel and bank substrates in these streams, representing almost 50% of the area (Figure 9.10-10). The large boulders provide an abundance of velocity refugia for small YOY Arctic grayling, similar to what currently exists under baseline flow conditions. Young-of-the-year 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

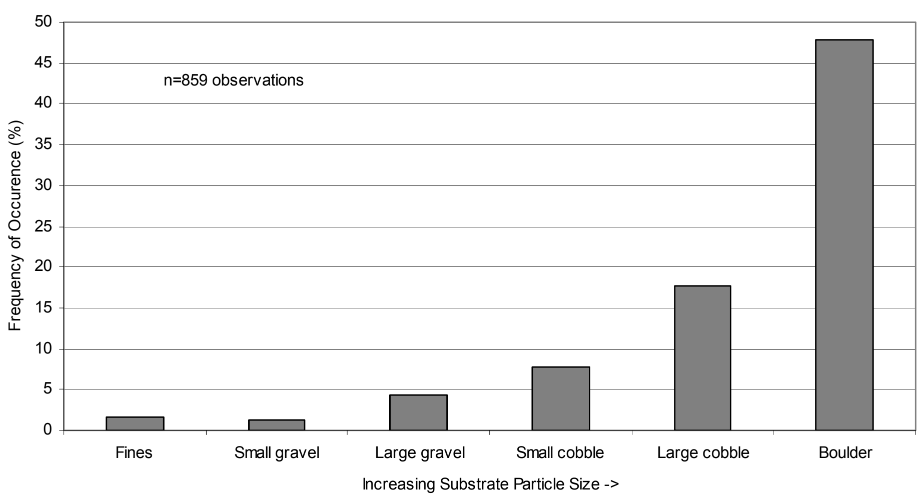
m/s = metres per second.

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.

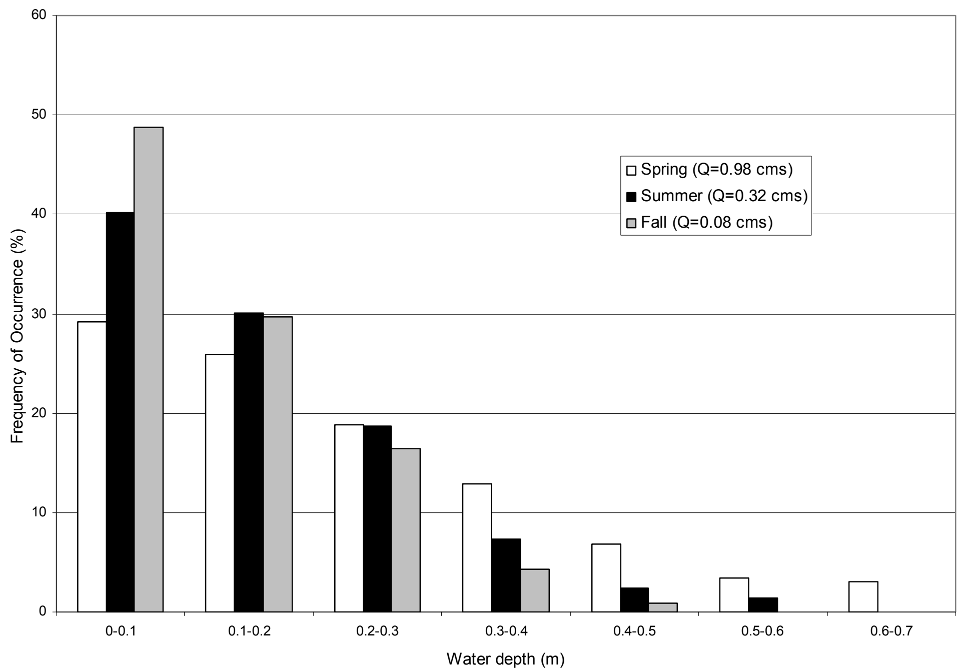
Figure 9.10-10 Substrate Size Frequency Distribution in Streams between Kennady Lake and Lake 410



% = 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

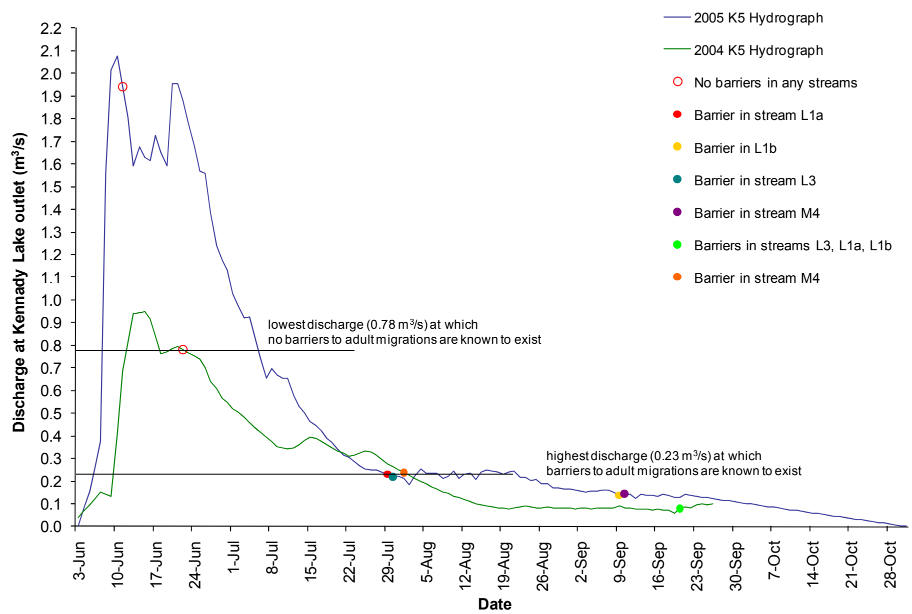
Barriers in streams between Kennady Lake and Lake 410 appear to form as a result of low flows creating unsuitable depths for fish movements, rather than due to high flows creating velocity barriers. Results of barrier surveys conducted in 2004 and 2005 indicated that a barrier to adult Arctic grayling 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.

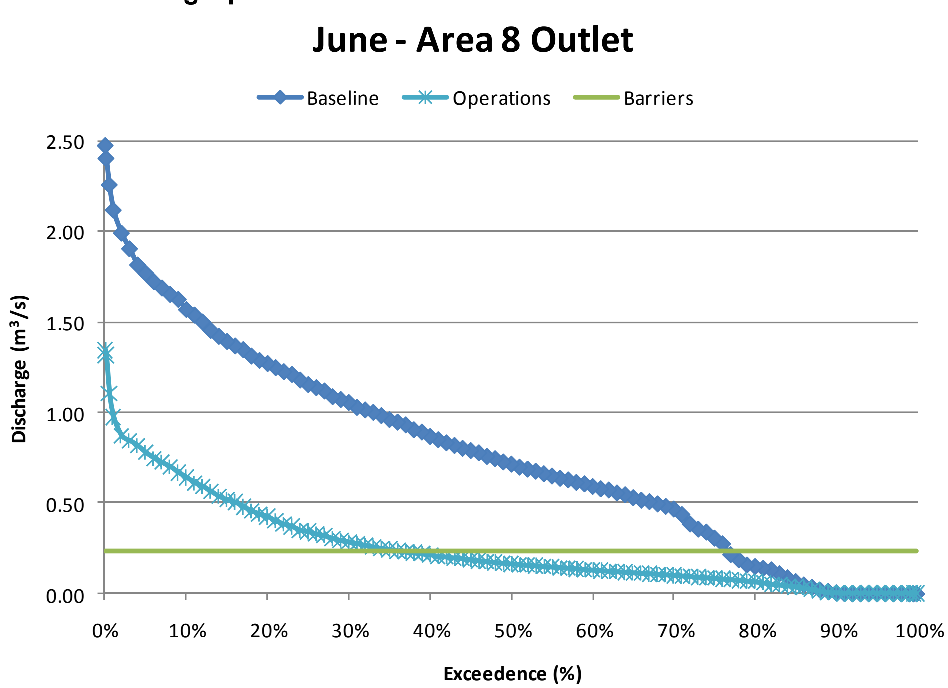
During operations, flows in June are substantially reduced. Under baseline conditions, the barrier to fish migration that is present at a discharge of 0.23 m^3/s would be present about 20% of the time in June, or in other words, would result in a barrier to migration approximately one out of five years. 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



m³/s = cubic metres per second.

Figure 9.10-13 Frequency of Barrier Formation in Streams between Kennady Lake and Lake 410 during Operations



m³/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

9.10.3.3.1 Changes to Lower Trophic Levels

N Watershed

During operations, the N watershed will receive diverted flows from the A, B, D, and E watersheds, and there will be discharges from the Water Management Pond (WMP) to Lake N11. Because the WMP will contain elevated concentrations of nutrients, discharges to Lake N11 are projected to result in increased nutrient concentrations. Concentrations of total phosphorus are predicted to increase from a background concentration of 0.005 milligrams per litre (mg/L) in Lake N11, to a peak of 0.009 mg/L during operations as a result of loading from active WMP discharge. During operations, phosphorus concentration is expected to fluctuate between 0.006 and 0.009 mg/L. The trophic status of Lake N11 would remain oligotrophic, as it is under baseline conditions. Lake N11 is expected to remain phosphorus-limited.

The effect of the increased nutrient concentrations in Lake N11 is expected to be a general increase in productivity at lower trophic levels. Because the increase in phosphorus concentration is small enough to allow the lake to remain oligotrophic and the limiting nutrient will not change, large shifts in composition of plankton and benthic invertebrate communities are not expected. However, biomass of phytoplankton, zooplankton, and benthic invertebrates will increase over time, as these communities take advantage of the increased nutrient supply.

9.10.3.3.2 Changes to Fish and Fish Habitat

Lake N11 and Downstream

Studies have shown that nutrients, and in particular phosphorus, control the rate of fish production in lakes (Colby et al. 1972; Hanson and Leggett 1982; Plante and Downing 1993; Dillon et al. 2004). Studies of experimental fertilization of oligotrophic lakes to increase salmonid production found the following responses in fish: increased egg survival and mean stock of sockeye salmon (*Oncorhynchus nerka*) (LeBrasseur et al. 1978); increased in-lake growth of juvenile sockeye salmon (Hyatt and Stockner 1985); increased length and weight of brown trout (*Salmo trutta*) (Johannessen et al. 1984, cited in Dillon et al. 2004); increased biomass of kokanee salmon (*Oncorhynchus nerka*) (Ashley et al. 1997, cited in Dillon et al. 2004). Fertilization experiments in streams also found increased size of steelhead trout (*Oncorhynchus mykiss*) and coho salmon (*Oncorhynchus kisutch*) fry (Johnston et al. 1990). Stockner and Shortreed (1978) suggested that nutrient enhancement may benefit salmonids in streams through increased autotrophic production.

As a result of the predicted increased nutrients in Lake N11 during operations, it is expected that there will be increases in the food base for fish (e.g., zooplankton and benthic invertebrates), as well as potentially increased production in the small-bodied fish community (e.g., lake chub, slimy sculpin, and ninespine stickleback). Because of the increased food base, there may also be increased growth and production in the large-bodied fish species of Lake N11. Although Lake N11 has not been sampled, large-bodied fish species captured in the upstream lakes and streams include Arctic grayling, burbot, lake trout, and longnose sucker.

Studies have shown that increased phosphorus in lakes may also affect fish habitat through increased algal growth on spawning shoals and declines in dissolved oxygen levels. However, as the increase in nutrients in Lake N11 is not expected to result in a change in the trophic status of the lake, changes to spawning shoals and dissolved oxygen levels are not expected to occur. Wind and wave action within the lake would continue to keep spawning areas clean and minimize the accumulation of silt and attached algae; suitable spawning habitat would continue to be available. Summer dissolved oxygen levels would not be affected as arctic lakes tend to be well-mixed vertically and thermal stratification is weak, if at all; summer dissolved oxygen depletion in a hypolimnion would, therefore, not be an issue. In winter, there may be a slight reduction in under-ice dissolved oxygen levels due to increased total organic carbon remaining in the lake after senescence in the fall; however, as the change is expected to be small, this would not be expected to affect the overwintering habitat availability or suitability for fish species in the lake. Lake N11 is a large lake (538 ha) with a maximum depth of 10 m (Addendum HH). In winter, Lake N11 also maintains flow through the outlet and aerial observations found open water and cracked ice. It is expected that suitable overwintering habitat would continue to be available for species present in the lake. No changes in the fish community structure of Lake N11 are expected.

The Lake N11 outlet stream (Stream N11) flows 174 m to Lake N1. Stream N11 is steep with a series of cascades confined between bedrock outcrops; the channel banks are armoured with boulders, bedrock and till. Stream N11 is a permanent stream that provides year-round passage for fish and high habitat quality, including Arctic grayling spawning habitat. Burbot, lake chub, ninespine stickleback, and slimy sculpin have been captured in Stream N11.

Similar to Lake N11, the predicted increase in phosphorus levels in Stream N11 may increase fish production and growth through an increased food base. For example, Johnston et al. (1990) found increased periphyton standing crop and size of steelhead trout and coho salmon fry after fertilization of a nutrient-deficient stream; the authors suggested that the manipulation of autochthonous primary production can be used to increase salmonid growth in nutrient-poor streams. Deegan and Peterson (1992) found that increases in the density and size of chironomids in the drift increased the growth and condition of YOY Arctic grayling in the Kuparuk River after four years of fertilization. Although there was high year-to-year variation, the growth of YOY Arctic grayling was higher in fertilized reaches of the Kuparuk River than in reference reaches over the 16 year experiment (Slavik et al. 2004).

There is a potential that the nutrient enrichment may cause some increased algal growth on the streambed substrate. However, Stream N11 is expected to remain oligotrophic, and as a result, Arctic grayling spawning habitat likely would not be affected.

Phosphorus levels may be slightly above background in lakes and streams downstream (e.g., Lake N1 and Stream N1); however, the levels will be reduced with distance from Lake N11 due to additional tributary inflows and uptake of phosphorus by biota and subsequent sequestration in the sediments. As such, effects would be less than those described above for Lake N11 and Stream N11. The increases in phosphorus would also be temporary, occurring only during operations. At closure, the discharges to Lake N11 will cease and the phosphorus levels will return to background over time; the aquatic community within the lake will return to pre-Project conditions.

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.

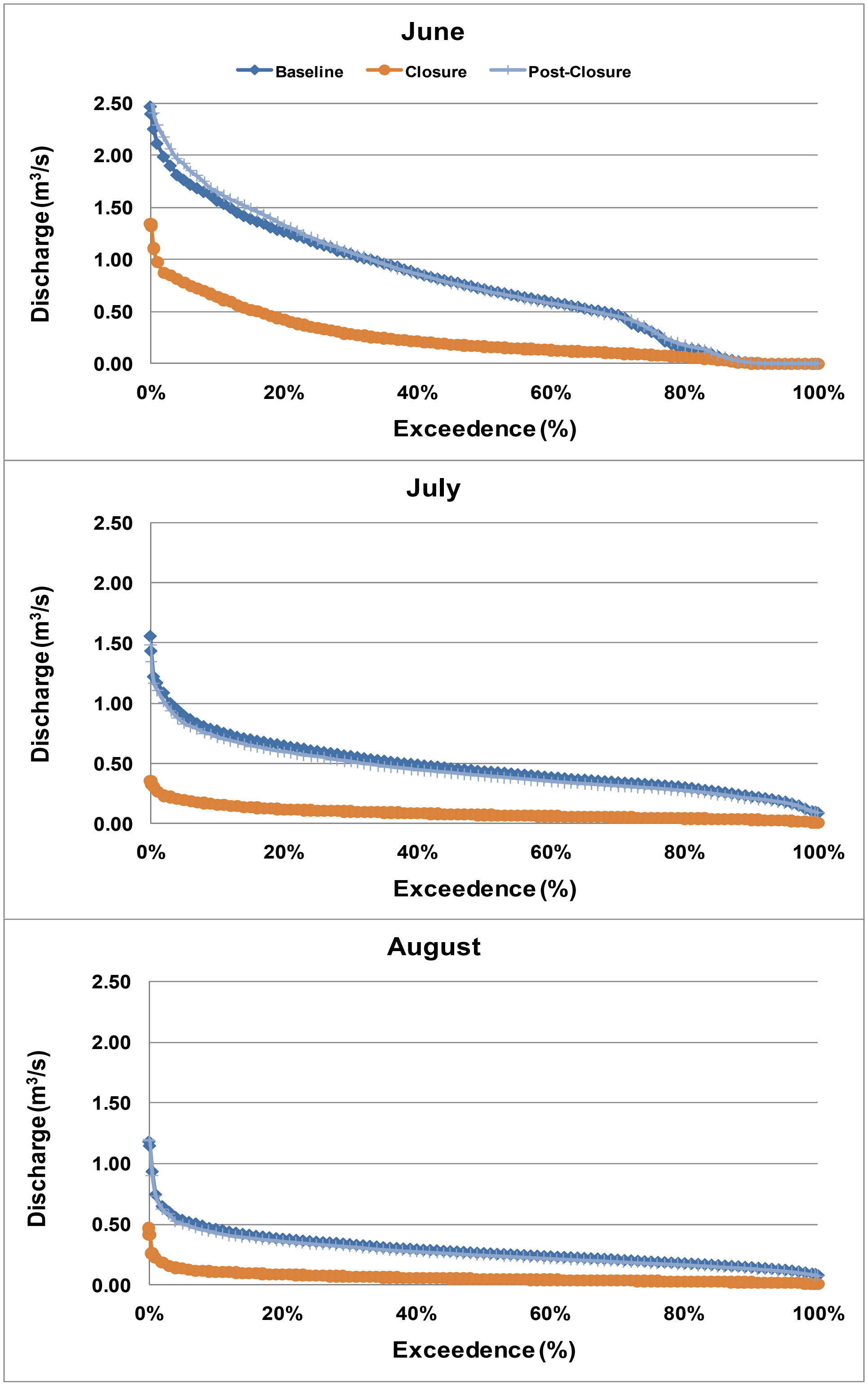
Post-Closure

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

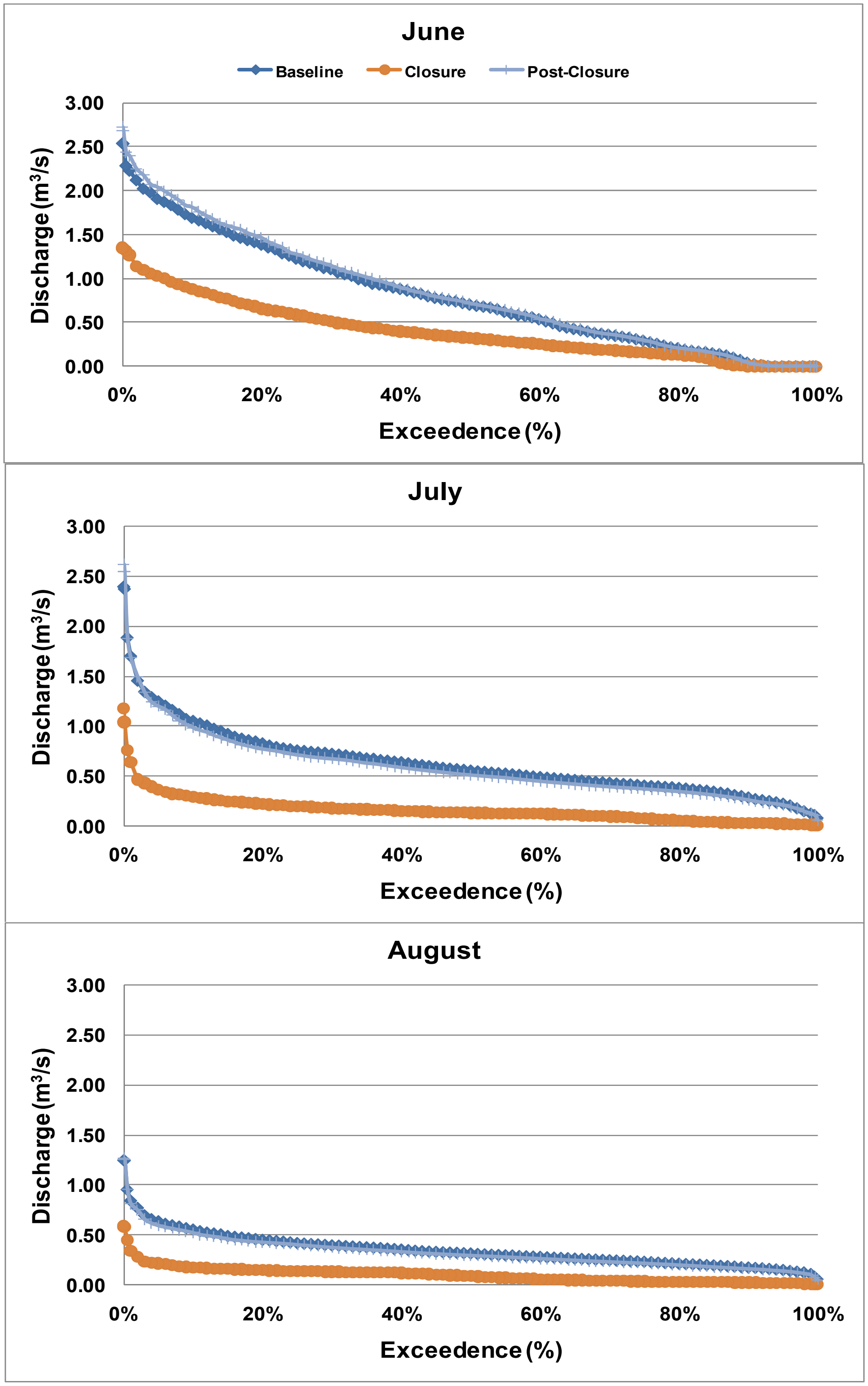
Within the N watershed, changes to the flow regime are not predicted to extend downstream of Lake N11 during closure. Flow reductions persist at closure in the L and M watersheds, but return to near baseline conditions at the outlet of Lake 410. Flows downstream of Lake 410 are near baseline conditions 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.

Figure 9.10-14 Flow Duration Curves for June, July, and August at the Outlet of Kennady Lake under Baseline, Closure, and Post-Closure



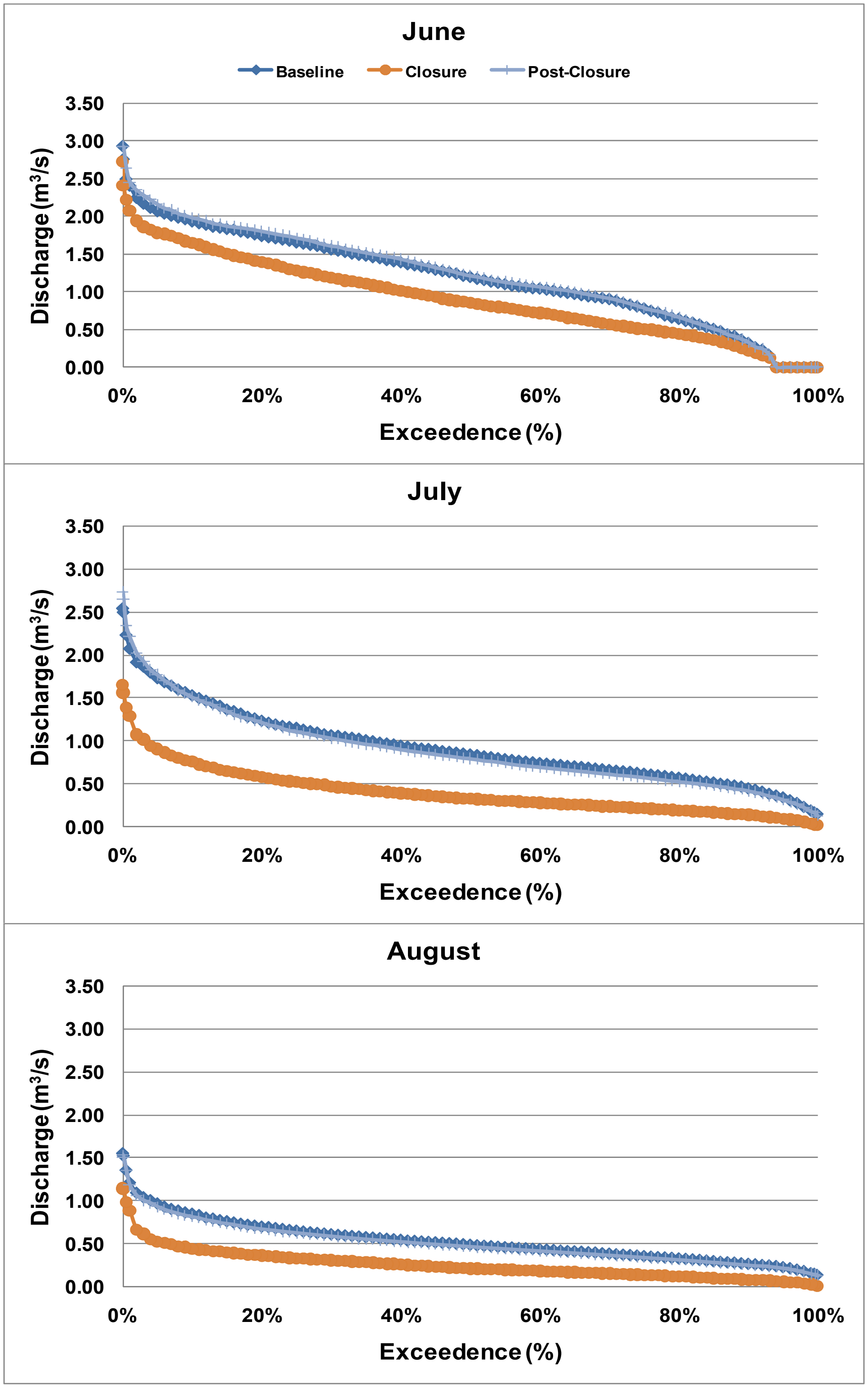
m^3/s = cubic metres per second; % = percent.

Figure 9.10-15 Flow Duration Curves for June, July, and August at the Outlet of Lake L1a under Baseline, Closure, and Post-Closure



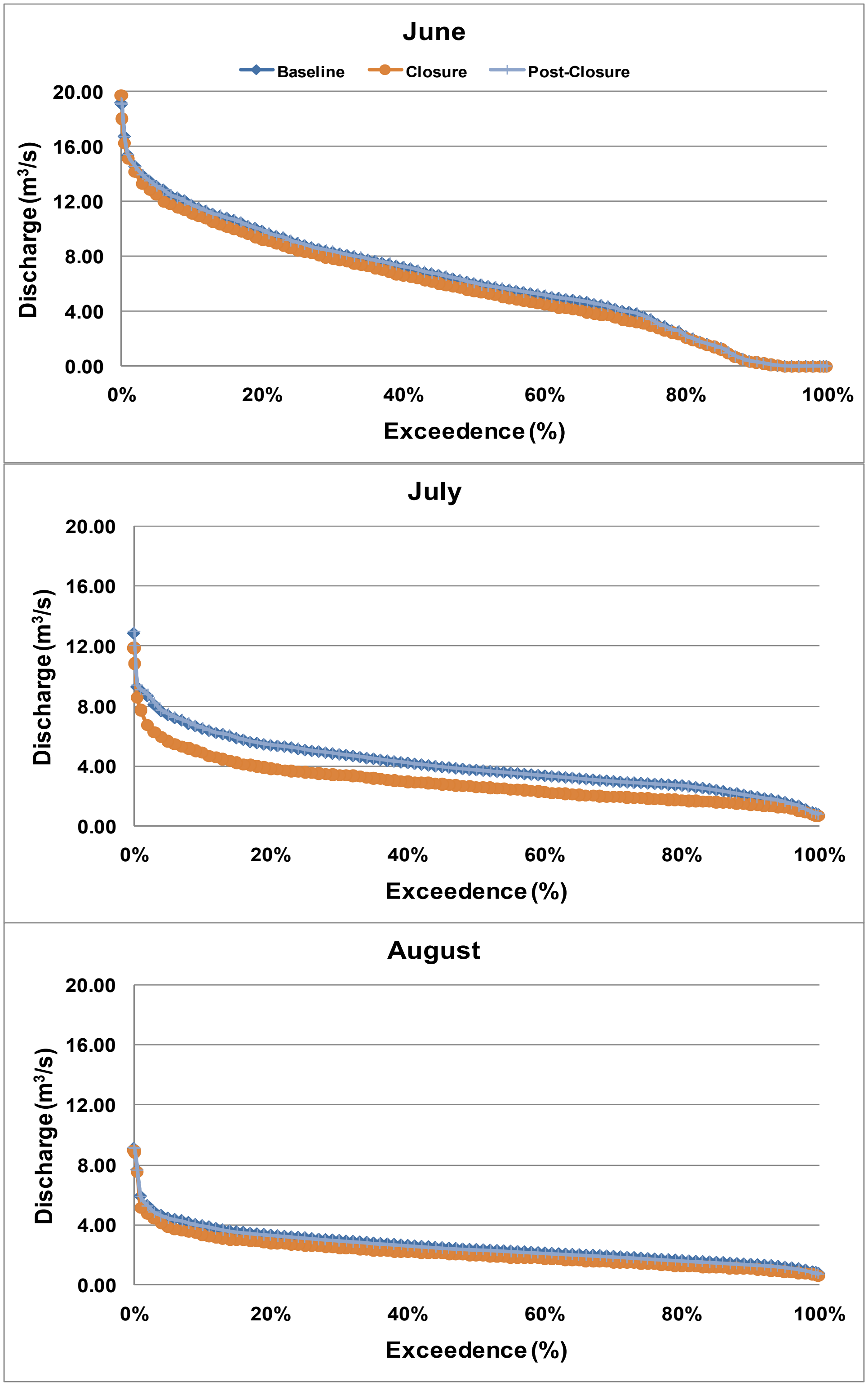
m^3/s = cubic metres per second; % = percent

Figure 9.10-16 Flow Duration Curves for June, July, and August at the Outlet of Lake M1 under Baseline, Closure, and Post-Closure



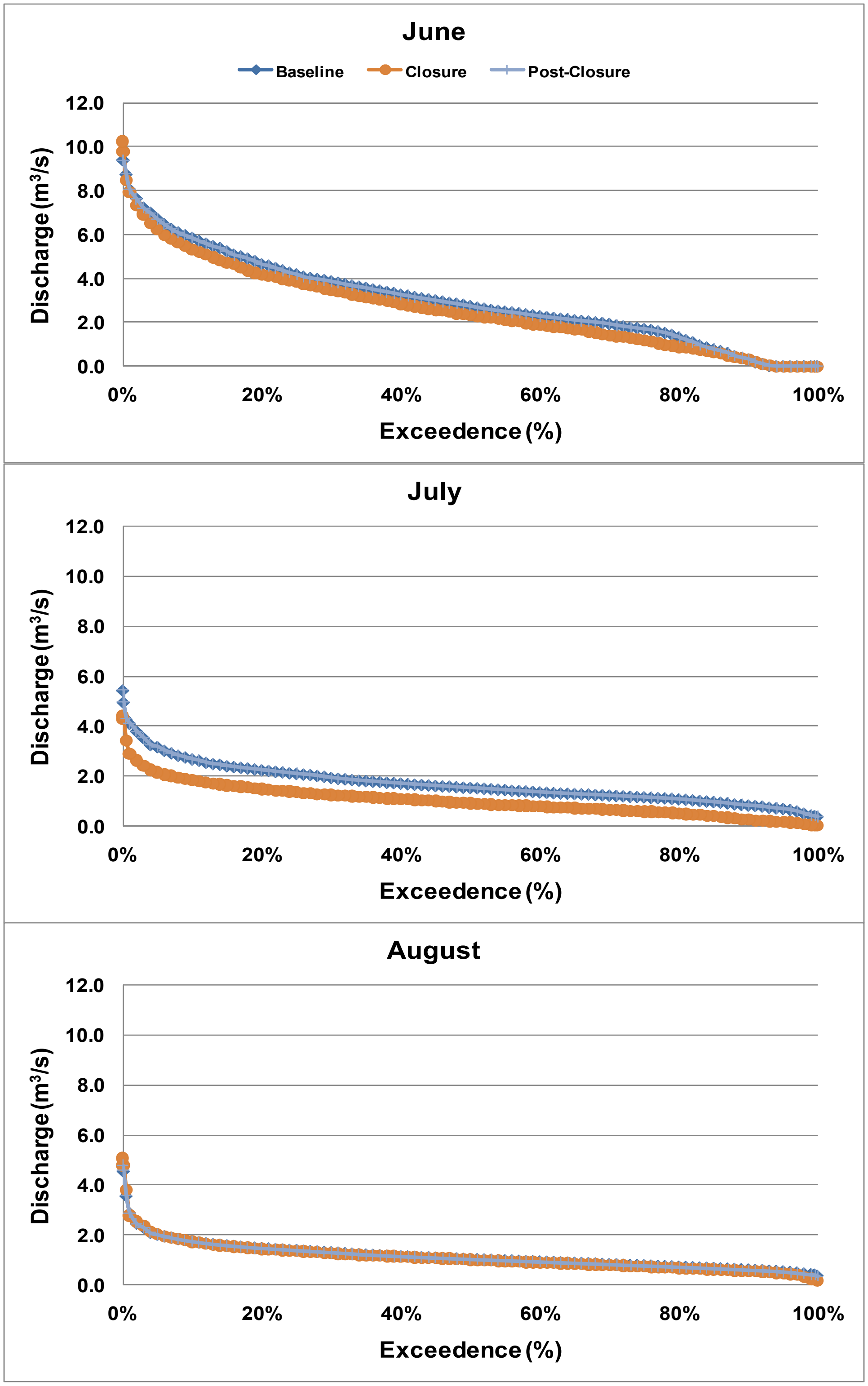
m^3/s = cubic metres per second; % = percent

Figure 9.10-17 Flow Duration Curves for June, July, and August at the Outlet of Lake 410 under Baseline, Closure, and Post-Closure



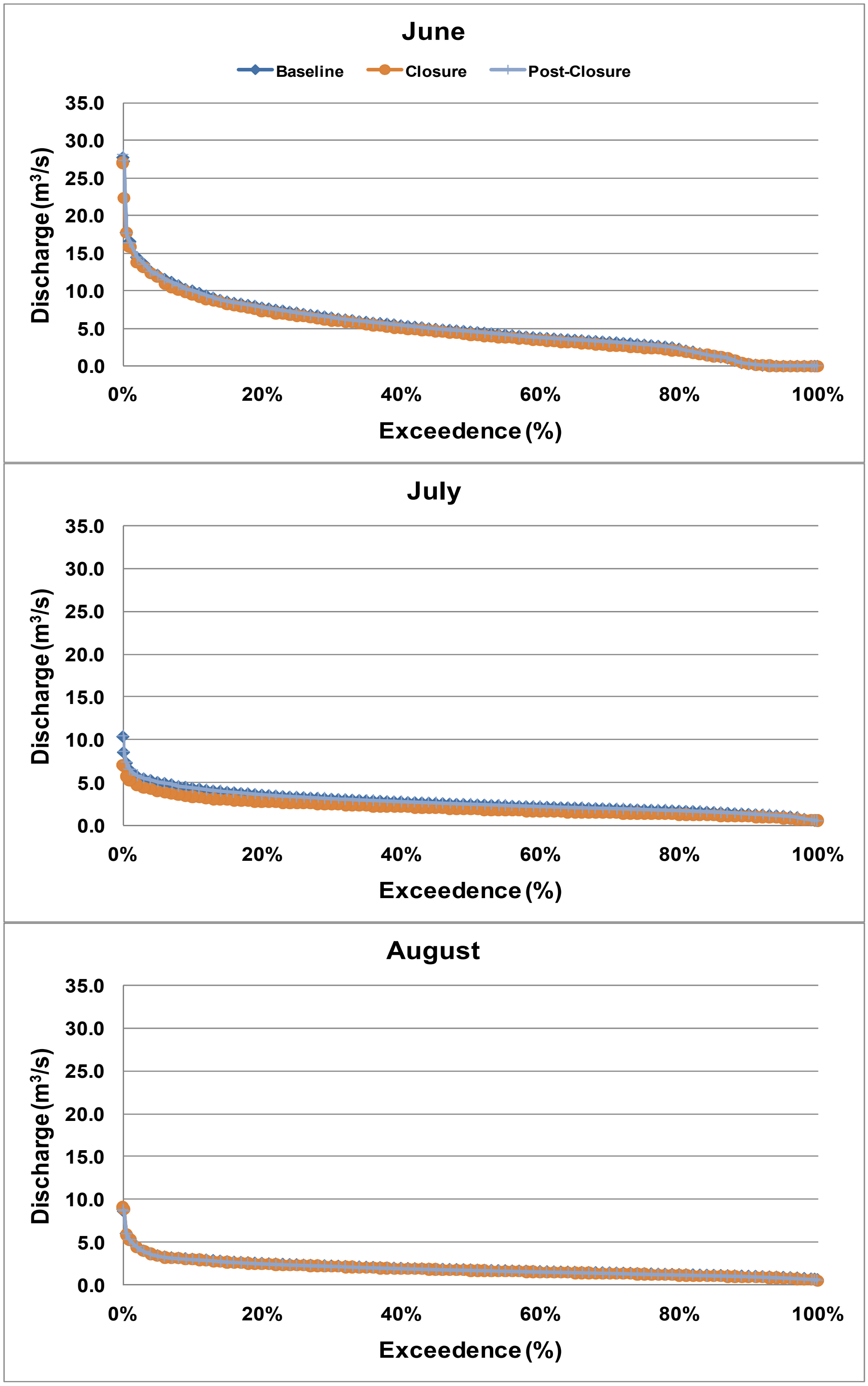
m^3/s = cubic metres per second; % = percent

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

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.

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

The long-term steady state phosphorus increases in the L and M watersheds during post-closure are a result of seepage from materials located in the mine rock piles, Coarse PK Pile and the Fine PKC Facility to Kennady Lake, which eventually flows downstream. The Fine PKC Facility is the largest contributing source of phosphorus. Using a combination of mitigation strategies, and potentially other options, De Beers is committed to incorporating additional mitigation that limits the loading of phosphorus to Kennady Lake, and subsequently in downstream watersheds. Pre-screening of the options listed above has been completed for the engineering and Project design feasibility and environmental screening of the options is underway.

9.10.4.3.1 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, and discharges from the WMP to Lake N11 will cease. As a result, the phosphorus levels in Lake N11 will be reduced from the peak of 0.009 mg/L to pre-Project levels of 0.005 mg/L. The lake will remain oligotrophic, but at a slightly lower level of productivity than during operations. Lower trophic communities are expected to return to those characteristic of baseline conditions. The expected time-frame for recovery of lower trophic communities in Lake N11 is approximately five years after phosphorus levels decline to the baseline level.

L and M Watersheds, and Lake 410 – Closure and Post-Closure

During closure, increased nutrient concentrations in Area 8 after reconnection to the remainder of Kennady Lake will result in an increase in nutrient concentrations in the L and M watershed, along the flow-path to Lake 410. Both total phosphorus and total nitrogen concentrations will increase over a period of about five years. Thereafter, phosphorus will continue to gradually increase to the long-term steady-state concentration, while nitrogen will decline over a period of about 60 years. These concentrations are anticipated to extend downstream, but decline with distance as inflows from the L and M watersheds dilute the concentrations originating from the Kennady lake watershed.

The predicted mean long-term concentrations of phosphorus and nitrogen in L watershed lakes are 0.015 mg/L and 0.70 mg/L, respectively. Farther downstream, in the M watershed, predicted mean long-term concentrations of phosphorus and nitrogen are 0.013 mg/L and 0.61 mg/L, respectively. In Lake 410, long-term phosphorus and nitrogen concentrations are predicted to be 0.007 mg/L and 0.24 mg/L, respectively. Surface waters in all of these watersheds are expected to remain phosphorus-limited.

These projections are indicative of a gradient in lake trophic status from mesotrophic in the L and M watersheds to oligotrophic in Lake 410, with a corresponding gradient of effects on lower trophic communities.

Effects in the L watershed close to Kennady Lake likely will be similar to those described for Kennady Lake in Section 8.10.4.4.1, including a substantial increase in summer phytoplankton biomass, and altered species composition and dominance, without a shift to strong cyanobacteria dominance. The predicted increase in primary productivity is expected to result in increased secondary productivity and biomass of the zooplankton community, reflecting the increased food supply. Changes in zooplankton community composition are also possible, although difficult to predict, because zooplankton species composition is frequently more strongly controlled by predation than food availability. The predicted increase in nutrient concentrations and primary productivity in these lakes are likely to result in an increase in benthic invertebrate abundance and biomass, reflecting the increased food supply. A shift in benthic invertebrate community composition is also likely, because some groups (e.g., snails) are better able to take advantage of the increased food supply and abundances of certain groups (e.g., chironomids) may be controlled by predation to a greater extent compared to other groups.

Effects in Lake 410 are expected to be lower in magnitude, and more similar to those predicted for Lake N11 during operations. Nutrient concentrations in Lake 410 will increase within the oligotrophic range, with corresponding smaller changes in productivity and lower trophic communities. Increased productivity is expected at all lower trophic levels, likely reflected in increases in biomass of phytoplankton, zooplankton, and benthic invertebrates. Large shifts in the composition of plankton and benthic invertebrate communities are not expected, but some shifts in relative abundances of different plankton and invertebrate groups may occur, as communities adjust to the greater nutrient and food supply.

Nutrient concentrations in the M watershed lakes will be intermediate between those in L watershed lakes and Lake 410, with corresponding changes in lower trophic communities that are expected to be intermediate between those described for the L lakes and Lake 410 above.

Streams in the L and M Watersheds – Closure and Post-Closure

Streams in the L and M watersheds will also experience nutrient enrichment, with corresponding changes in lower trophic communities. Similar to lakes, a gradient of effects reflecting the gradient in nutrient concentrations is expected, with more prominent changes immediately downstream of Area 8 of Kennady Lake. The projected increase in nutrient concentrations in downstream watercourses between Area 8 and Lake 410 is expected to result in an increase in benthic algal growth on stream substrates, representing an increase in food availability for invertebrates. Dramatically increased benthic algal growth was frequently observed after fertilization in Arctic streams (Peterson et al. 1985, 1993; Harvey et al. 1998; Deegan et al. 1997; Slavik et al. 2004). The following short-term effects of fertilization on benthic invertebrates have been reported:

- increases in production and density of certain mayflies, caddisflies, and chironomids (grazers and filterers), coupled with no changes or declines in abundances of other groups (e.g., blackflies) (Hiltner and Hershey 1992; Peterson et al. 1993; Harvey et al. 1998);
- increases in sizes and developmental stages of dominant benthic invertebrates (Peterson et al. 1985; Hiltner and Hershey 1992);
- increases in densities of certain caddisflies but no changes in other groups (Deegan et al. 1997); and
- positive responses at all trophic levels (Slavik et al. 2004).

Upon long-term fertilization (e.g., 16 years), replacement of benthic algae by mosses was observed in the Kuparuk River, Alaska, with subsequent changes in the benthic community (Slavik et al. 2004).

The projected increase in phosphorus concentration in streams downstream of Area 8 is expected to result in changes in the resident benthic invertebrate communities, especially in streams located close to Kennady Lake. In general, an initial positive response is expected, exhibited in increased production and densities of grazing and filter-feeding invertebrate taxa (i.e., chironomids, mayflies, caddisflies). Effects on blackflies may be different (i.e., no change or decrease in abundance). In terms of benthic community composition, these changes may result in a shift in relative proportions of major benthic invertebrate groups as the community adjusts to the new conditions. Based on the information available from a long-term fertilization study (Slavik et al. 2004), unforeseen changes in benthic algae/vegetation, occurring well after the initial effects of fertilization, may further influence the benthic community. However, a negative effect on the benthic community is unlikely, because the overall effect of fertilization is an increase in food supply to invertebrates.

Changes in the water quality in Area 8 may also have an indirect effect on drift in downstream watercourses, such as increased drift density by lake-derived zooplankton due to higher productivity resulting from nutrient enrichment. As well, increased benthic invertebrate density due to nutrient enrichment in streams receiving Area 8 outflow is expected to result in a greater supply of invertebrates that may enter the drift given the right conditions. Drift by chironomids may be enhanced because the density of this group is expected to increase due to nutrient enrichment, and chironomids are often found to drift in closer relation to water velocity than other invertebrate groups (Brittain and Eikeland 1988).

Overall, the combined effect of increased flows and stream productivity due to nutrient inputs from Area 8 may result in an increase in drift of zooplankton and certain benthic invertebrates downstream of Kennady Lake, particularly midges which are one of the primary food items of YOY Arctic grayling.

The downstream extent of the nutrient enrichment effect is estimated as the lakes/streams between Area 8 and Lake 410 (a straight-line distance of about 7 kilometres [km]). Due to dilution within this reach from tributary inflows and within Lake 410, as well as phosphorus uptake by biota and subsequent sequestration in the sediments, nutrient-related effects on primary or secondary producers are not expected in Kirk Lake or downstream of Kirk Lake.

9.10.4.3.2 Changes to Fish and Fish Habitat

N watershed – Closure and Post-Closure

At closure, the trophic status of Lake N11 will return to its previous oligotrophic status; as a result, any increases in fish productivity would be expected to cease, and return to conditions consistent with baseline conditions.

L and M Watersheds, and Lake 410 – Closure and Post-Closure

The L lakes downstream of Kennady Lake are predicted to have increased nutrient levels during post-closure compared to baseline. Based on the projected concentrations, these lakes will be mesotrophic. It is expected that there will be increases in the food base for fish (i.e., zooplankton and benthic invertebrates), as well as in the small-bodied fish community (e.g., lake chub and slimy sculpin). Because of the increased food base, there may also be increased growth and production in the large-bodied fish species in these lakes (e.g., Arctic grayling and northern pike). However, this is difficult to predict, as other factors associated with the change in trophic status will also play a role in the response of the fish population. Furthermore, effects on fish and fish habitat in the L and M watersheds would be expected to correspond to the gradient in lake trophic status from described above for the lower trophic communities. For example, Gascon and Leggett (1977) found that that the abundance and distribution of littoral zone fishes in Lake Memphremagog (Quebec-Vermont) were directly influenced by a nutrient-driven production gradient existing along the long axis of the lake, which was related to primary and secondary production.

The four downstream lakes in the L watershed are small (less than 13 ha), shallow (less than 4 m), with silt covered boulders in the nearshore areas. Fish species captured include Arctic grayling, northern pike, and slimy sculpin (Table 9.10-22). These small lakes likely provide primarily seasonal rearing and feeding habitat for fish, especially juveniles, from Kennady Lake or from larger lakes in the watershed. Northern pike use weedy, shoreline areas of these lakes for spawning and rearing; due to the potential for increased macrophyte growth in shoreline areas, this habitat would likely be improved by nutrient enrichment. Furthermore, the expected increase in zooplankton and benthic production may increase northern pike larval and juvenile survival. Lakes less than 3 m deep are unlikely to provide overwintering habitat for fish because the annual ice depth in the area is typically 2 m thick. Lakes L3, L1b, and L1a likely freeze to the bottom during winter. Lake L2 may have small pockets of water in deeper areas, which likely become de-oxygenated by mid-winter; this lake may provide limited overwintering habitat for small-bodied fish species (e.g., slimy sculpin or ninespine stickleback), but likely would not provide suitable overwintering habitat for large-bodied fish species (e.g., Arctic grayling and northern pike). As these four lakes in the L watershed currently provide nil or limited overwintering habitat, the increased nutrient levels and change in trophic status would not be expected to change the overwintering capability or suitability of these small lakes.

Lakes in the M watershed are larger (11 to 91 ha) and generally deeper (up to 13 m) than the lakes in the L watershed (Table 9.10-22). The M lakes are also predicted to have increased phosphorus levels during post-closure compared to baseline; however, the nutrient levels will be less than the L lakes due to additional tributary inflows, as well as phosphorus uptake by biota and subsequent sequestration in the sediments. These lakes are predicted to be mesotrophic. As a result of increased productivity, there may be increased growth and production in the forage fish community, as well as in the large-bodied fish species from the increased food base. Fish from Lake 410 are likely to increase seasonal movements into these lakes and associated streams to take advantage of the increased food base. Northern pike also use weedy, shoreline areas of these lakes for spawning and rearing; this habitat would likely be enhanced by nutrient enrichment.

Table 9.10-22 Lake Areas and Depths in the L and M Lakes Downstream of Kennady Lake and Fish Species Known to Inhabit the Lakes

Lake	Lake Area (ha)	Maximum Depth (m)	Fish Species Captured
L3	4.4	1.0	NRPK
L2	12.6	3.4	ARGR, NRPK
L1b	5.4	1.8	NRPK
L1a	3.6	1.2	ARGR, SLSC
M4	80.6	13.0	ARGR, CISC, LKCH, LKTR, NNST, RNWH, SLSC
M3	91.0	7.5	BURB, LKTR, NRPK, RNWH
M2	32.1	5.7	CISC, LKTR, NRPK, SLSC
M1	11.0	1.9	BURB, NRPK, RNWH

ARGR= Arctic grayling; BURB = burbot; CISC = cisco; LKCH = lake chub; LKTR = lake trout; NNST = ninespine stickleback; NRPK = northern pike; RNWH = round whitefish; SLSC = slimy sculpin; ha = hectares; m = metres

Based on depth, Lakes M2, M3, and M4 likely provide suitable overwintering habitat for fish, although Lakes M2 and M3 may only have overwintering habitat suitable for species that are tolerant of low dissolved oxygen levels, such as small-bodied forage fish species (e.g., lake chub, slimy sculpin, ninespine stickleback), and potentially large-bodied species, such as Arctic grayling, northern pike and burbot. Cold-water fish species, such as lake trout, cisco (*Coregonus artedi*) and round whitefish, are less tolerant of low dissolved oxygen levels; as such, these lakes may not provide suitable overwintering habitat for these more sensitive fish species. These species likely overwinter in Lake 410 or Lake M4.

As a result of the predicted increased phosphorus levels, there may be a small reduction in under-ice dissolved oxygen levels compared to baseline conditions from higher winter oxygen depletion rates resulting from the increased total organic carbon remaining in the lake after senescence in the fall. For example, Lienesch et al. (2005) found that winter hypoxia became more pronounced during experimental fertilization of a small, oligotrophic Arctic lake in Alaska. Danylchuk and Tonn (2003) suggested that phosphorus enrichment, among other factors, may increase the frequency or the severity of winterkill in fathead minnows brought about by increased primary production and winter oxygen depletion. Each of the small lakes between Kennady Lake and Lake 410 become isolated once ice freezes solid to the bottom of streams. As a result of the nutrient enrichment, there may be some small reductions in overwintering habitat availability or suitability at post-closure for fish species remaining in these lakes throughout the winter; however, it is expected that the lakes will continue to support the same fish populations over the winter period as under pre-development conditions.

In Lake 410, the phosphorus concentration during post-closure is predicted to be increased compared to baseline. As Lake 410 also receives inflow from the much larger N watershed, the phosphorus levels are predicted to be less than those in the L and M lakes. As a result, the trophic status of Lake 410 is not expected to change and the lake will remain oligotrophic. As a result of the increased productivity in Lake 410, it is likely that there will be increases in the food base for fish (zooplankton and benthic invertebrates), as well as in the small-bodied fish community (e.g., lake chub, slimy sculpin, and ninespine stickleback). Because of the increased food base, there may also be increased growth and production in the large-bodied fish species (e.g., Arctic grayling, burbot, northern pike, lake trout, round whitefish, cisco). However, as Lake 410 will remain oligotrophic, it is not expected that there will be changes in fish habitat in the lake (i.e., changes to spawning shoals or winter dissolved oxygen levels). Changes to the fish community structure of Lake 410 are also not expected.

Streams in the L and M Watersheds – Closure and Post-Closure

After reconnecting the refilled portion of Kennady Lake to Area 8, concentrations of nutrients in Stream K5 are predicted to be higher than during pre-development conditions. The increased levels of nutrients will also be carried into the downstream watershed.

The Kennady Lake outlet, Stream K5, is a low gradient (0.1%) stream, which flows 111 m to Lake L3. As Stream K5 is currently a phosphorus-limited system, an increase in phosphorus concentration during post-closure will likely increase fish production due to increases in primary and secondary productivity. Positive correlations between nutrient concentration and fish production have been noted in streams. For example, fertilization of the nutrient-deficient Keogh River, British Columbia, resulted in significant increases in the mean weights of juvenile salmonids (Johnston et al. 1990); these authors attributed the larger fish sizes at fertilized sites to food availability. In Stream K5, it is expected that there will be increases in the food base for fish (zooplankton and benthic invertebrates), as well as in the small-bodied fish community (e.g., lake chub and slimy sculpin). Because of the increased food base, there may also be increased growth and production in the large-bodied fish species in Stream K5 (e.g., Arctic grayling and northern pike). However, this is difficult to predict, as other factors associated with the change in trophic status will also play a role in the response of the fish population.

Arctic grayling are the most abundant fish species captured in Stream K5. YOY Arctic grayling rear in streams between Kennady Lake and Lake 410 in summer before migrating upstream or downstream to lakes to overwinter. During this first summer, the growth and survival of YOY Arctic grayling is dependent on their ability to find and capture drifting invertebrates. Jones et al. (2003a) found that

YOY Arctic grayling selectively feed on stream-derived chironomid and blackfly larvae instead of the more abundant lake-derived zooplankton. Although less abundant in Stream K5 than Arctic grayling, northern pike may move through the Kennady Lake outlet area to access downstream spawning habitat or to feed on concentrations of Arctic grayling. Larger juvenile and adult northern pike feed primarily on fish (Scott and Crossman 1973); as a result, increased size and abundance of forage fish, as well as juvenile Arctic grayling, would benefit northern pike in Stream K5. Other fish species captured in low abundance in Stream K5 include burbot, lake trout, round whitefish (*Prosopium cylindraceum*), and longnose sucker. Lake trout and round whitefish captured in Stream K5 are likely fish from Kennady Lake that move into the stream to feed. Kennady Lake and the lakes in the L and M watersheds do not appear to support populations of longnose sucker; however, one longnose sucker was captured moving downstream in the fish fence located in Stream K5 in 2000.

Increased phosphorus levels in Stream K5 may also affect stream habitat for spawning and rearing. For example, Stockner and Shortreed (1976) considered nutrients to be the major factor regulating algal growth in their study streams on Vancouver Island, British Columbia. Experimental nutrient enrichment increased algal growth in the phosphorus-limited, oligotrophic streams (Stockner and Shortreed 1976, 1978). As Stream K5 is predicted to become mesotrophic, there may be increased algal growth on the substrate compared to baseline conditions.

The stream habitat downstream of Kennady Lake is the primary spawning habitat for Arctic grayling in Kennady Lake. Arctic grayling prefer to spawn in small gravel- or rocky-bottomed streams (Scott and Crossman 1973) with current velocities less than 1.4 m/s (Evans et al. 2002). Substrate within K5 primarily consists of angular boulders, with abundant gravels and smaller cobbles present. In spring, riffle and pool habitat is present in Stream K5 providing high quality spawning habitat for Arctic grayling. There is the potential that the growth of attached algae on the streambed could reduce suitability and availability of spawning habitat for Arctic grayling in this stream. However, it is expected that Stream K5 will continue to provide Arctic grayling spawning habitat for fish from Kennady Lake and downstream watersheds, because Arctic grayling typically spawn shortly after ice-out in streams. Since the streams typically freeze to the bottom in the winter and spawning occurs during a period of high flow, both of which would act to scour the previous accumulations of algae from the substrate, the effect of increased algal growth may be minimal. In addition, the short incubation time (13 to 18 days at mean temperature of 8.8ºC; Stewart et al. 2007) of eggs in the substrate also would limit the potential effects of increased algal growth on the substrate.

Northern pike spawn on the heavily vegetated floodplains of rivers, marshes, and bays of larger lakes (Scott and Crossman 1973). Northern pike are found in low numbers in Kennady Lake, but are known to use wetland areas near the Kennady Lake outlet (Stream K5) and weedy areas in lakes downstream. Spawning habitat for northern pike in Stream K5 is limited and will not be affected by nutrient enrichment. Younger juvenile northern pike feed primarily on invertebrates and larger juveniles and adults feed almost exclusively on fish; rearing northern pike in Stream K5 should benefit from the increased invertebrate production and increased density of forage fish.

The streams in the L and M watersheds downstream of Kennady Lake are also predicted to have increased nutrient levels during post-closure compared to baseline. Based on the predicted concentrations, these streams will be mesotrophic. Similar to Stream K5, there may be increased growth and production in the forage fish community, as well as in the large-bodied fish species from the increased food base.

Fish species captured in the streams in the L watershed (Streams L3, L2, L1c, L1b and L1a) include Arctic grayling, burbot, northern pike, lake trout, ninespine stickleback, and slimy sculpin. Streams L3, L2, and L1a have high quality spawning habitat for Arctic grayling due to the presence of gravel riffles in spring. These streams also appear to be important spawning habitat for Arctic grayling from downstream in Lake M4. Substrates within these streams are primarily angular boulders, but gravel and smaller cobble substrates do exist in small patches. These are the streams where the largest numbers of YOY Arctic grayling have been found in summer. In summer, water depth and flow is insufficient in most of the streams in the L watershed to provide fish passage for large-bodied adult fish, such as Arctic grayling and northern pike (Section 9.3); as a result, these streams are likely primarily used in summer for juvenile or small-bodied fish rearing and feeding habitat, which would not be negatively affected by the change in nutrient levels, and may in fact be enhanced due to the increased food base.

Fish species captured in Streams M4, M3, M2, and M1 include Arctic grayling, burbot, northern pike, lake trout, round whitefish, lake chub, ninespine stickleback, and slimy sculpin. Streams M4, M2, and M1 were considered to have high quality spawning habitat for Arctic grayling due to the presence of gravel riffles in spring. Substrates are primarily angular boulders, with patches of gravel and cobble. The streams of the M watershed are larger and deeper than the streams in the L watershed (Section 9.3). Baseline studies suggest that the utilization of Streams M4, M3, M2, and M1 by Arctic grayling for spawning is lower than in streams upstream of Lake M4 (i.e., the L streams) and that the habitat is used primarily by local Arctic grayling populations. These streams have areas of confined flow and depth suitable to provide summer rearing habitat for Arctic grayling and northern pike, as well as other stream resident fish. In summer, water depth and flow is sufficient to provide fish passage for large-bodied adult fish, indicating that adults as well as juvenile fish may use these streams for rearing and feeding. It is expected that rearing and feeding habitat would not be negatively affected by the change in nutrient levels, and may in fact be enhanced due to the increased food base. Fish from Lake 410 are likely to increase seasonal movements into these streams to take advantage of the increased food base.

Due to the increased nutrient levels predicted, there is a potential for increased algal growth on the streambed substrates in the L and M watersheds. However, the nutrient levels will decrease with distance downstream from Area 8, and it is expected that any changes to the suitability and availability of Arctic grayling spawning habitat and rearing in the L and M watersheds would be small.

9.10.4.3.3 Downstream Extent of Effects

The downstream extent of this effect is estimated as the lakes/streams between Area 8 and Lake 410 (a straight-line distance of about 7 km; Section 9.8). Due to dilution within this reach from tributary inflows and within Lake 410, as well as phosphorus uptake by biota and subsequent sequestration in the sediments, nutrient related effects on fish and fish habitat are not expected in Kirk Lake or downstream of Kirk Lake.

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

During mine construction, operations, and closure (i.e., lake re-filling), fish populations downstream of Kennady Lake will be affected by changes in the hydrological regime and by changes in surface water quality. During post-closure, increased nutrient concentrations predicted in the refilled Kennady Lake will affect fish and fish habitat in downstream streams and lakes between Kennady Lake and Lake 410 after reconnection. Predicted nutrient levels are indicative of a gradient in trophic status from mesotrophic in the L watershed to oligotrophic in Lake 410, with effects on lower trophic communities, and fish and fish habitat, reflective of this gradient. The aquatic ecosystem, including fish populations, downstream of Kennady Lake are expected to reach a new equilibrium post-closure. The recovery of the aquatic ecosystem downstream of Kennady Lake during post-closure is based on the following:

- flows and water levels will return to near baseline conditions between Kennady Lake and Lake 410, resulting in negligible effects to fish habitat;
- flows and water levels will return to near baseline conditions throughout the N watershed, resulting in negligible effects to fish habitat;
- Lake N11 will remain at an oligotrophic status but at a lower level of productivity, with lower trophic communities and fish productivity expected to return to those characteristic of baseline conditions;
- the increase in nutrient concentrations and primary productivity reflective of the gradient from Stream K5 to Lake 410 is expected to result in increased secondary productivity and biomass of the zooplankton community, as well as an increase in benthic invertebrate abundance and biomass;
- due to increases in the food base for fish (zooplankton and benthic invertebrates) and potentially in the small-bodied forage fish community (e.g., lake chub and slimy sculpin), there may also be increased growth

and production in large-bodied fish species (e.g., Arctic grayling and northern pike), reflective of the gradient in predicted nutrient concentrations from Stream K5 to Lake 410;

- lakes downstream of Kennady Lake are expected to provide habitat similar to baseline conditions, although there may be some slight reductions in overwintering habitat suitability in some lakes, as well as some increased feeding and rearing opportunities during the open-water season;
- streams downstream of Kennady Lake are expected to continue to provide Arctic grayling spawning and rearing habitat, although there may be some increases in growth of attached algae in streams immediately downstream of Kennady Lake;
- although there may be some changes in the utilization of some habitats along the gradient of nutrient enrichment, it is expected that the fish species currently present in the downstream watershed will continue to persist during post-closure;
- the downstream extent of the effect of increased nutrient levels on fish and fish habitat is estimated as the lakes/streams between Area 8 and Lake 410; and
- the assessment of effects to aquatic health concluded that modelled changes in water chemistry will have a negligible effect on the health of aquatic life downstream waterbodies.

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 post-closure, 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 operations, 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^{TM}. 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., post-closure).

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 closure, 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 closure. 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 from a background concentration of 0.005 mg/L in Lake N11, to a peak of 0.009 mg/L during operations as a result of loading from active WMP discharge. Phosphorus levels in the WMP will be influenced by seepage through the mine rock piles, Coarse PK Pile, and the Fine PKC Facility. Phosphorus is mobilized into seepage flows that come into contact with mine rock, coarse PK, and fine PK material as flows travel through the external structures, with fine PK in saturated conditions being the largest contributing source of phosphorus. Following mine operations, any discharge from the WMP to Lake N11 will cease, and as a result, phosphorus concentrations are projected to return to concentrations similar to background within closure. The modelled increases in phosphorus in Lake N11 during operations were developed assuming mitigation strategies for the Fine PKC Facility within the Kennady Lake watershed.

Based on the total phosphorus concentrations projected for operations, including a peak concentration of 0.009 mg/L, an increase in primary productivity would be expected in Lake N11 during operations. However, the trophic status of Lake N11 would remain oligotrophic, as it is under baseline conditions.

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 exception of phosphorus.

Phosphorus

Projected increases in phosphorus over the long-term in Kennady Lake are anticipated to extend downstream, but will decline with distance as inflows from the L and M watersheds dilute the concentrations originating from the Kennady lake watershed. Average long-term steady state phosphorus concentrations for lakes along the main flow path in the L and M watersheds are projected to be 0.015 and 0.013 mg/L, respectively. Based on the trophic classification listed in

Environment Canada (2004) and CCME (2004), these lakes are likely to be mesotrophic in the long-term.

The modelled phosphorus projections for Kennady Lake and downstream waters are due to loading to Kennady Lake from contact of seepage flows with materials located in the mine rock piles, the Coarse PK Pile, and the Fine PKC Facility within the Kennady Lake watershed in post closure, after Kennady Lake is reconnected with the downstream watersheds. Projected phosphorus concentrations in the interlakes has been modelled with supplemental mitigation associated with the Fine PKC Facility, as fine PK under saturated conditions is the largest source of phosphorus to Kennady Lake. These strategies include:

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

De Beers is committed to incorporating additional mitigation that limits the loading of phosphorus to Kennady Lake, and subsequently to downstream watersheds.

The projected increase in phosphorus concentrations in the interlakes will result in a change in trophic status, which will lead to increased primary productivity. Increases in primary productivity may have some implications regarding water column oxygen dynamics. For the lakes with depths greater than 6 m with overwintering habitat for fish (i.e., Lakes M3 and M4), dissolved oxygen concentrations will remain sufficient to support aquatic life. As the small lakes in the L watershed and M watershed, upstream of Lake M3, are currently subject to low under-ice dissolved oxygen levels with nil or limited overwintering habitat for fish, potential increases in winter oxygen depletion due to nutrient enrichment would not be expected to change the overwintering capability or suitability of these small lakes.

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 post-closure, when water is released to Area 8, TDS concentrations will increase slightly in Lake 410 from 16 mg/L to 27 mg/L. In post-closure, 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 post-closure 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 projected to increase in Lake 410 from a background concentration of 0.005 mg/L to a peak of 0.007 mg/L (Figure 9.8-13). The phosphorus increase in Lake 410 during operations and several years into closure will be associated with pumped discharge from the WMP to Lake N11. Increases several years into post-closure will follow the removal of Dyke A and the reconnection of Kennady Lake to the downstream lakes. The increase represents a relatively small change in phosphorus concentrations, considering that some of the predicted change is due to conservative assumptions in the water quality modelling.

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

Trace Metals

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 post-closure, 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

Increased nutrient concentrations in Lake N11 during operations are expected to increase productivity at all trophic levels. Because the lake will remain oligotrophic and the limiting nutrient will not change, large shifts in composition of plankton and benthic invertebrate communities are not expected. However, biomass of phytoplankton, zooplankton, and benthic invertebrates will increase over time. As a result of the increased food base for fish, and potentially increased production in the small-bodied forage fish community, there may also be increased growth and production in the large-bodied fish species of Lake N11. No changes to fish habitat or the fish community structure of Lake 410 are expected.

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 closure 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

Changes to Lower Trophic Levels

At closure, nutrient levels and associated productivity in Lake N11 will return to pre-Project levels; lower trophic communities are expected to return to those characteristic of baseline conditions.

The reconnection of Area 8 to the remainder of Kennady Lake is predicted to result in a rapid increase in nutrient concentrations in the L and M watershed, along the flow-path to Lake 410. These predictions are indicative of a gradient in lake trophic status from mesotrophic in the L watershed to oligotrophic in Lake 410, with a corresponding gradient of effects on lower trophic communities. Effects in the L watershed likely will include a substantial increase in summer phytoplankton biomass, and altered species composition and dominance, without a shift to strong cyanobacteria dominance. The predicted increase in primary productivity is expected to result in increased secondary productivity and biomass of the zooplankton community. An increase in benthic invertebrate abundance and biomass, as well as a shift in benthic invertebrate community composition, is also likely to occur. As Lake 410 is expected to remain oligotrophic, effects are expected to be lower in magnitude, with smaller changes in productivity and lower trophic communities. Nutrient concentrations in the M watershed lakes will be intermediate between those in L watershed lakes and Lake 410.

Streams in the L and M watersheds will also experience nutrient enrichment, with corresponding changes in lower trophic communities, reflecting the gradient in nutrient concentrations. An increase in periphyton and benthic algal growth on stream substrates is expected, representing an increase in food availability for invertebrates. Changes in the resident benthic invertebrate communities are expected in streams downstream of Area 8; however, a negative effect on the benthic community is unlikely, as the overall effect of fertilization is an increase in food supply to invertebrates.

Changes in water quality in Area 8 may also have an indirect effect on drift in downstream watercourses. Overall, the combined effect of increased flows and stream productivity due to nutrient inputs from Area 8 may result in an increase in drift of zooplankton and certain benthic invertebrates downstream of Kennady

Lake, particularly midges, which are one of the primary food items of YOY Arctic grayling.

Changes to Fish and Fish Habitat

In the L and M watersheds downstream of Kennady Lake, an increase in phosphorus concentration during post-closure may increase fish production due to increases in primary and secondary productivity. Because of the increased food base, there may also be increased growth and production in large-bodied fish species.

For some downstream lakes, there may be minor reductions in overwintering habitat availability or suitability at post-closure for fish species remaining throughout the winter. However, open-water rearing and feeding habitat may be enhanced due to the increased food base. Although there is the potential for a reduction in the suitability and availability of Arctic grayling spawning habitat from algal growth on streambed substrates in streams close to Kennady Lake, it is expected that these streams will continue to provide Arctic grayling spawning and rearing habitat.

In Lake 410, there may be increases in fish production during post-closure due to increases in primary and secondary productivity. No changes in fish habitat or in the fish community structure of Lake 410 are expected.

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. Nutrient levels in Lake N11 will return to pre-Project levels, with lower trophic communities and fish productivity expected to return to those characteristic of baseline conditions.

The aquatic ecosystem, including fish populations, downstream of Kennady Lake is expected to reach a new equilibrium post-closure. Between Kennady Lake and Lake 410, flows and water levels will return to near baseline conditions. However, the increase in nutrient concentrations reflective of the gradient from Stream K5 to Lake 410 is expected to result in increased primary and secondary productivity, and potentially in fish production. However, it is expected that lakes and streams downstream of Kennady Lake will continue to provide suitable habitat for fish currently present in the downstream watershed. The downstream extent of the effect of increased nutrient levels on fish and fish habitat is estimated as the lakes/streams between Area 8 and Lake 410.

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, were 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.

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 10 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.

During operations, increased nutrient concentrations in Lake N11 are expected to increase productivity at all trophic levels; however, the lake will remain oligotrophic. After closure, the nutrient levels and associated productivity will return to pre-Project levels; lower trophic communities are expected to return to those characteristic of baseline conditions.

After reconnection of Area 8 to the main body of Kennady Lake (Areas 3 through 7), long-term steady state concentrations of nutrients are predicted to be higher than during pre-development conditions in the L and M watershed, along the flow-path to Lake 410. These predictions are indicative of a gradient in lake trophic status from mesotrophic in the L watershed to oligotrophic in Lake 410, with a corresponding gradient of effects on lower trophic communities.

Effects in the L watershed lakes due to the shift in trophic status likely will include an increase in summer phytoplankton biomass, and altered species composition and dominance, without a shift to strong cyanobacteria dominance. The predicted increase in primary productivity is expected to result in increased secondary productivity and biomass of the zooplankton community. An increase in benthic invertebrate abundance and biomass, as well as a shift in benthic invertebrate community composition, is also likely to occur. This may increase fish production due to the increases in primary and secondary productivity. Nutrient concentrations in the M watershed lakes will be intermediate between those in L watershed lakes and Lake 410. For some lakes, there may be small reductions in overwintering habitat availability or suitability for fish species remaining throughout the winter. However, it is expected that there will be enhanced feeding and rearing opportunities during the open-water period.

Streams in the L and M watersheds will also show changes in lower trophic communities, reflecting the gradient in nutrient concentrations. Changes in the resident benthic invertebrate communities are expected; however, a negative effect on the benthic community is unlikely, as the overall effect of fertilization is an increase in food supply to invertebrates. Increased algal growth may affect the suitability and availability of Arctic grayling spawning habitat in streams close to Kennady Lake; however, ice scour and high flows during the time that Arctic grayling typically spawn (shortly after ice-out in streams) would likely limit the effects of algal accumulations on spawning habitat suitability. In addition, the short incubation time of eggs in the substrate also would limit the potential effects of increased algal growth on the substrate.

Effects in Lake 410 are expected to be lower in magnitude, with corresponding smaller changes in productivity.

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. The rating is based on the projected shift in the trophic status downstream of Kennady Lake after reconnection, with predictions of a gradient in lake trophic status from mesotrophic in the L watershed to oligotrophic in Lake 410, with a corresponding gradient of both positive and negative effects. The increases in nutrients are expected to increase productivity in lower trophic levels, potentially leading to increased growth and productivity for fish, as well as rearing and feeding opportunities. However, there may be some small negative changes to fish habitat (i.e., potential for algal growth on streambed substrates and small reductions in the availability or suitability of overwintering habitat in downstream lakes). These projected impacts are local in geographic extent, long-term in duration, and not reversible.

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.

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. Reconnection of Area 8 to the remainder of Kennady Lake is predicted to increase nutrient concentrations downstream of Area 8 to Lake 410, along a gradient in trophic status from mesotrophic in the L watershed to oligotrophic in Lake 410, with a corresponding gradient of effects on lower trophic communities and fish and fish habitat.

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	neutral	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	neutral	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 - positive	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.

Effects to Arctic grayling from changes in flows in the N watershed are expected to be negligible. The increase in productivity expected in Lake N11 due to increased nutrient concentrations during operations may result in greater food availability to Arctic grayling, which may in turn increase growth and production.

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).

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 negligible.

During the second time period, the projected impacts on the abundance and persistence of Arctic grayling were rated as neutral in direction and negligible in magnitude. The flow regime is expected to return to near baseline conditions. The increased productivity in streams and lakes downstream of Kennady Lake is likely to result in both positive and negative effects to Arctic grayling. Increased nutrients may cause increased growth and production in Arctic grayling from the increased food base. Arctic grayling feed mainly on zooplankton when young, and aquatic and terrestrial insects as adults, and will likely benefit from increased productivity at the lower trophic levels. As a result of the nutrient enrichment at post-closure, there may be increased algal growth on the streambed substrates in streams immediately downstream of Kennady Lake. However, ice scour and high flows during the time that Arctic grayling typically spawn (shortly after ice-out in streams) would likely limit the effects of algal accumulations on spawning habitat suitability, and it is expected that streams downstream of Kennady Lake will continue to provide spawning and rearing habitat for this fish species. Nutrient enrichment may also cause small reductions in overwintering habitat availability or suitability for Arctic grayling remaining in lakes in the M watershed throughout the winter. Arctic grayling show considerable low oxygen tolerance for salmonids, and they will likely be able to continue to overwinter successfully in most of the lakes currently used for overwintering, and the effect of reduced dissolved oxygen conditions is considered to be negligible.

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. The increase in productivity expected in Lake N11 due to increased nutrient concentrations during operations may result in greater food availability to lake trout, which may in turn increase growth and production.

During the second time period, the projected impacts on the abundance and persistence of lake trout were rated as neutral in direction and negligible in magnitude. The flow regime is expected to return to near baseline conditions. The increased productivity in streams and lakes downstream of Kennady Lake may result in both positive and negative effects to lake trout. The increased productivity in streams and lakes downstream of Kennady Lake may cause increased growth and production in lake trout from the increased food base. Lake trout feed on a variety of food items, including smaller fish and macro-invertebrates, with YOY lake trout feeding almost exclusively on zooplankton. As a result, lake trout will likely benefit from the increased primary and secondary productivity due to nutrient enrichment, as well as increased density of forage fish. Lake trout from Lake 410 are likely to increase seasonal movements into the M lakes and streams to take advantage of the increased food base. Based on depth, Lake M4 is likely the only lake between Kennady Lake and Lake 410 that provides suitable overwintering habitat for lake trout. Cold-water fish species, such as lake trout, are less tolerant of low dissolved oxygen levels, and the other more shallow L and M lakes may not provide suitable overwintering habitat for this sensitive fish species. As a result of the nutrient enrichment at post-closure, there may be small reductions in overwintering habitat availability or suitability for lake trout remaining in Lake M4 throughout the winter.

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 to positive in direction and negligible in magnitude (Table 9.14-3). The flow regime is expected to return to near baseline conditions and the increased productivity in streams and lakes downstream of Kennady Lake is likely to result in positive effects to northern pike. The increased productivity in streams and lakes downstream of Kennady Lake likely will result in increased growth and production in northern pike from the increased food base. With the exception of the younger juveniles, northern pike feed almost exclusively on fish and will likely benefit from the increased density of forage fish due to nutrient enrichment. As a result of the nutrient enrichment at post-closure, there will likely be an increase in aquatic macrophyte growth, which would improve the availability of suitable spawning and rearing habitats in lakes and streams between Kennady Lake and Lake 410. As northern pike are fairly tolerant of low dissolved oxygen concentrations, they will continue to be able to overwinter successfully in downstream lakes.

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.

Increased nutrient concentrations in Lake N11 are expected during the period of operations, with predicted increases in productivity; however, the lake will remain oligotrophic. At closure, the nutrient levels and associated productivity will return to pre-Project levels.

After reconnection of Area 8 to the main body of Kennady Lake (Areas 3 through 7), long-term concentrations of nutrients are predicted to be higher than during pre-development conditions in the L and M watershed, along the flow-path to Lake 410. These increases are projected to be indicative of a gradient in trophic status in the downstream watershed from mesotrophic in the L watershed to oligotrophic in Lake 410. The projected increases in phosphorus will not pose a health risk to a viable and self-sustaining aquatic ecosystem downstream of Kennady Lake, though it will likely be different to the pre-development ecosystem (i.e., will become a more productive aquatic ecosystem).

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. Nutrient enrichment after closure may provide for improved productivity in the Arctic grayling population from the increased food base.

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. Nutrient enrichment after closure may provide for improved productivity in the lake trout population from the increased food base. There may, however, be some small changes to overwintering availability and suitability for lake trout in lakes in the M watershed downstream of Kennady Lake.

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. Nutrient enrichment after closure may provide for improved productivity in the northern pike population from the increased food base.

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.

Projections of water quality in the downstream water bodies did not include the development and persistence of permafrost conditions within the mine rock piles, the Coarse PK Pile and the Fine PKC Facility. It was assumed that seepage quantities from these facilities would be representative of no permafrost conditions, and provide seasonal geochemical loading to Kennady Lake after closure. It is recognized that frozen layers may establish during the development of these facilities and that permafrost will likely continue to develop following closure, which will result in lower rates of seepage through the facilities and geochemical loading to Kennady Lake during operations and closure than simulated in this assessment. However, as the assessment of impacts to the suitability of the water quality to support aquatic life includes time periods that extend into the long-term (200 years), the assessment was designed to represent potential future climatic conditions where there would be no permafrost.

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 phase 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.

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9.18 ACRONYMS AND GLOSSARY

9.18.1 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

9.18.2 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

9.18.3 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.