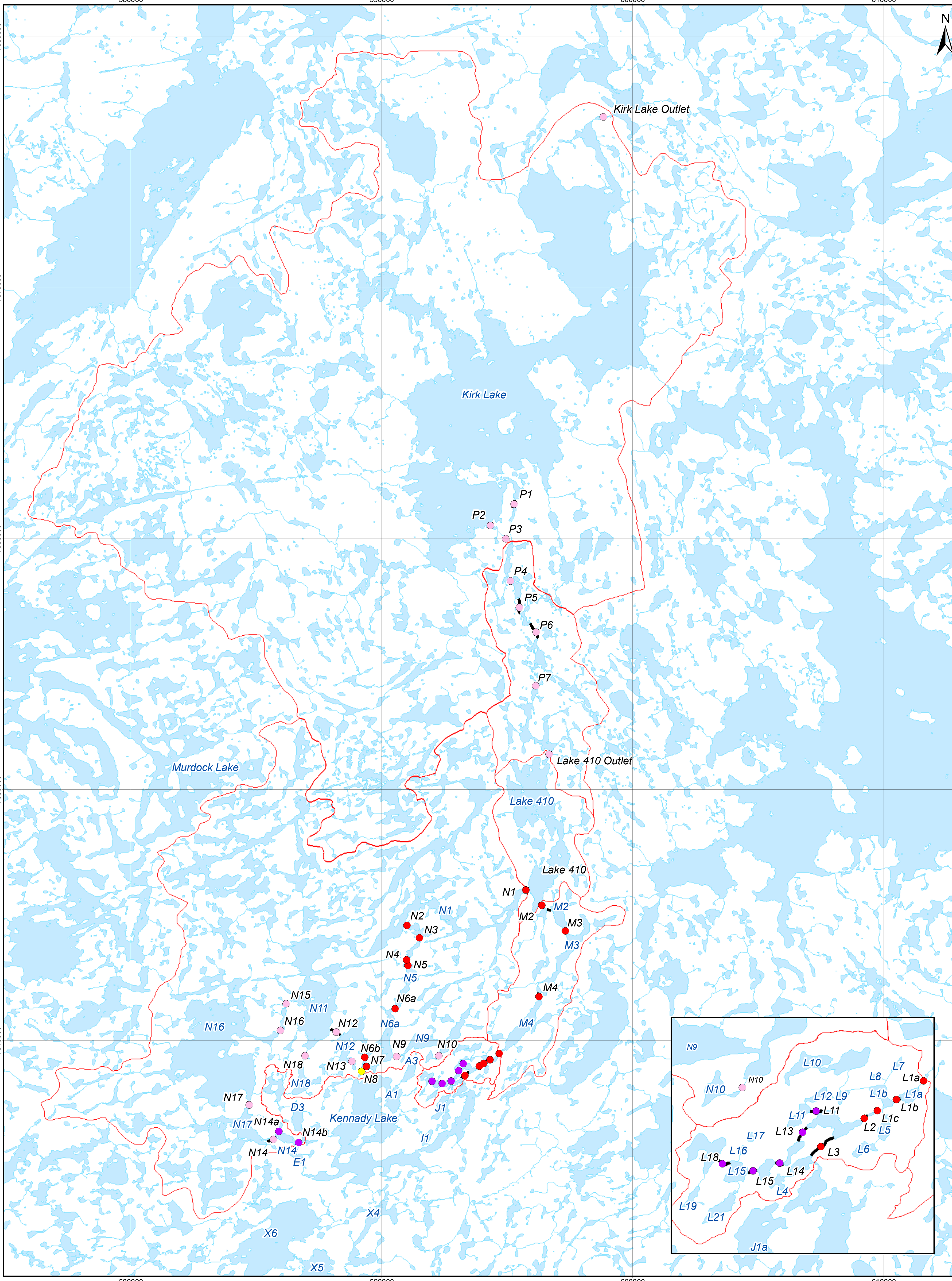



## LEGEND

Watercourse

Waterbody

A1 Lake Identifier

**Sampling Year**

- 2010
- 2005
- 2004
- 2000
- Habitat Survey
- Watershed Boundary

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

I:\CLIENTS\DE_BEERS\09-1365-1004\maps\10_fisheries-aquatics\EIA\E-Fish-132-GIS.mxd

## GAHCHO KUÉ PROJECT

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

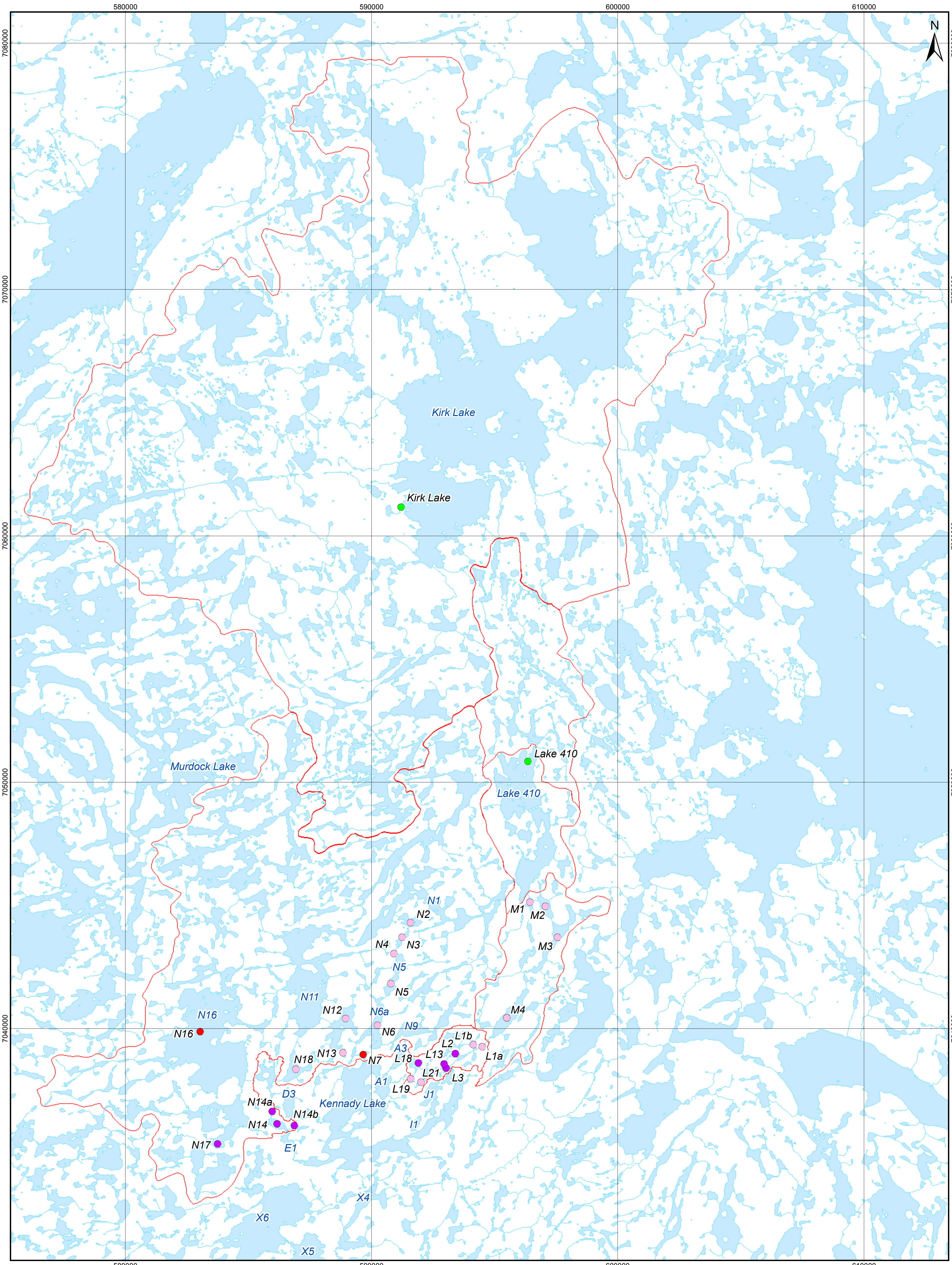
| PROJECTION: | DATUM: |
|---|---|
| UTM Zone 12 | NAD83 |

Scale: 1:150,000
2 1 0 2
Kilometres

DE BEERS CANADA

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

**Figure 9.3-23**




## LEGEND

Watercourse

Waterbody

A1 Lake Identifier

**Sampling Year**

2010

2007

2005

2004

Watershed Boundary

NOTES

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

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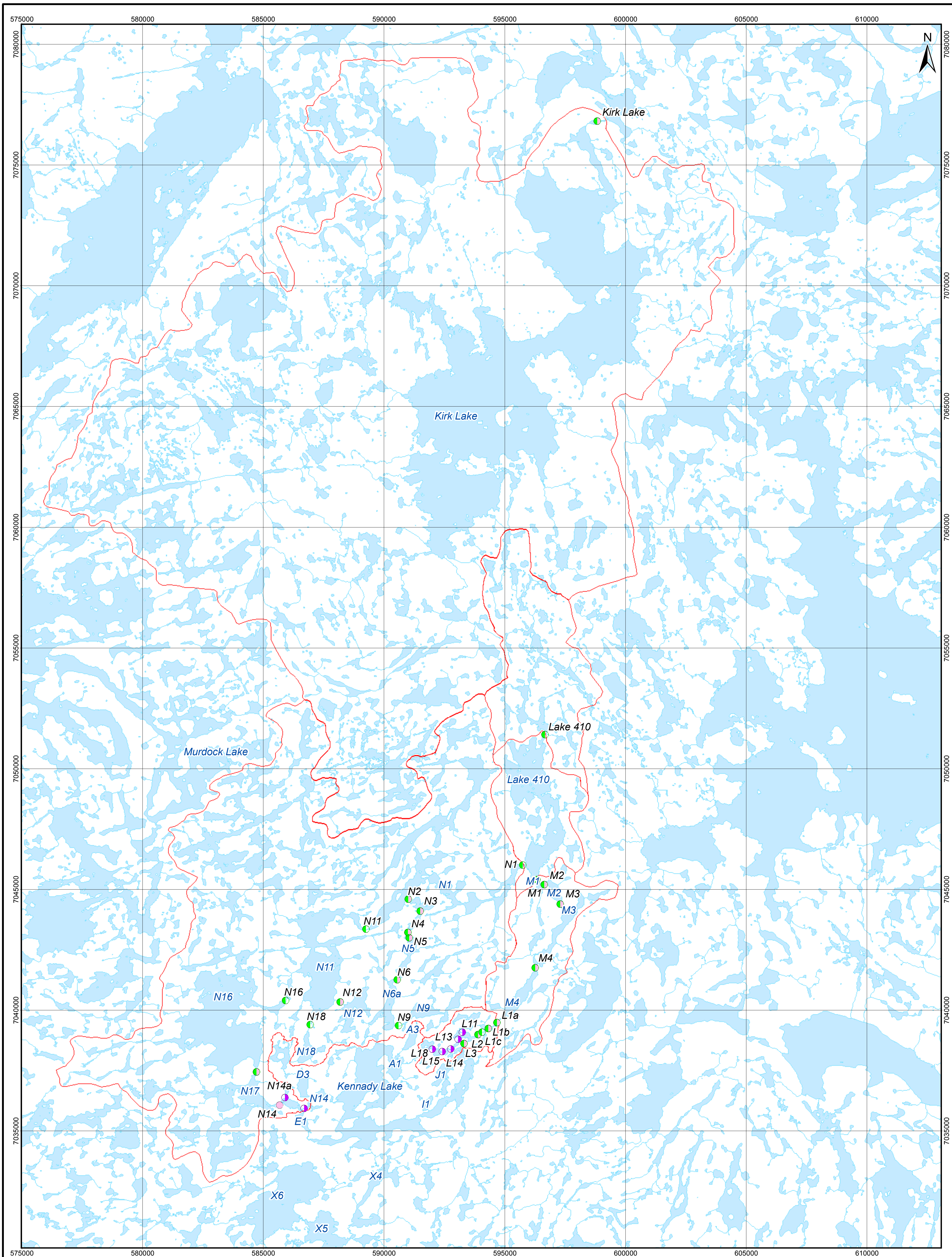
**GAHCHO KUÉ PROJECT**

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

| | | | |
|---|---|---|---|
| PROJECTION: UTM Zone 12 | DATUM: NAD83 | | DE BEERS CANADA |
| Scale: 1:150,000 (2 1 0 2 Kilometres) | | | |
| FILE No: E-Fish-134-GIS | | | DATE: December 17, 2010 |
| JOB NO: 09-1365-1004 | REVISION NO: 1 | | **Figure 9.3-24** |
| OFFICE: GOLD-CAL | DRAWN: SK | CHECK: JF | |

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## LEGEND

Watercourse

Waterbody

A1 Lake Identifier

**Sampling Year**

2010

2007

2005

Watershed Boundary

NOTES

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

**GAHCHO KUÉ PROJECT**

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

| PROJECTION: UTM Zone 12 | DATUM: NAD83 |
|---|---|
| Scale: 1:150,000 (2 1 0 2 Kilometres) | DE BEERS CANADA |
| FILE No: E-Fish-135-GIS | DATE: December 17, 2010 |
| JOB NO: 09-1365-1004 | REVISION NO: 1 |
| OFFICE: GOLD-CAL | DRAWN: SK | CHECK: JF |

**Figure 9.3-25**

## 9.3.5.2 Results

### *9.3.5.2.1 Aquatic Habitat*

**Lakes**

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

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

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

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

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

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

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

(a) Habitat Quality as described:

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

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

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

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

L = Low gradient (<10°).

I = 0 to 2 m depth.

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

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

**Streams**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**Winter Road**

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

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

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

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

### *9.3.5.2.2 Large-bodied Fish Community*

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

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

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

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

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

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

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

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

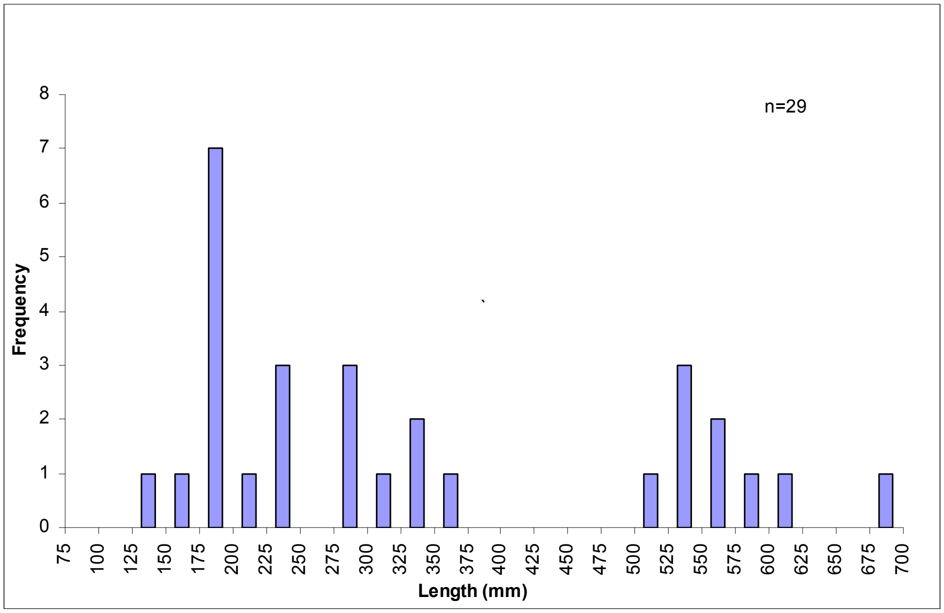
Northern pike were not captured in Lake N16, or anywhere else in the N watershed, but populations exist in Kennady Lake and in Lake 410. Similarly, Arctic grayling were not captured in Lake N16 or Lake 410, but populations exist in Kennady Lake. Arctic grayling are known to use the Lake N16 inlet and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

**Lake Trout in Lake N16**

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

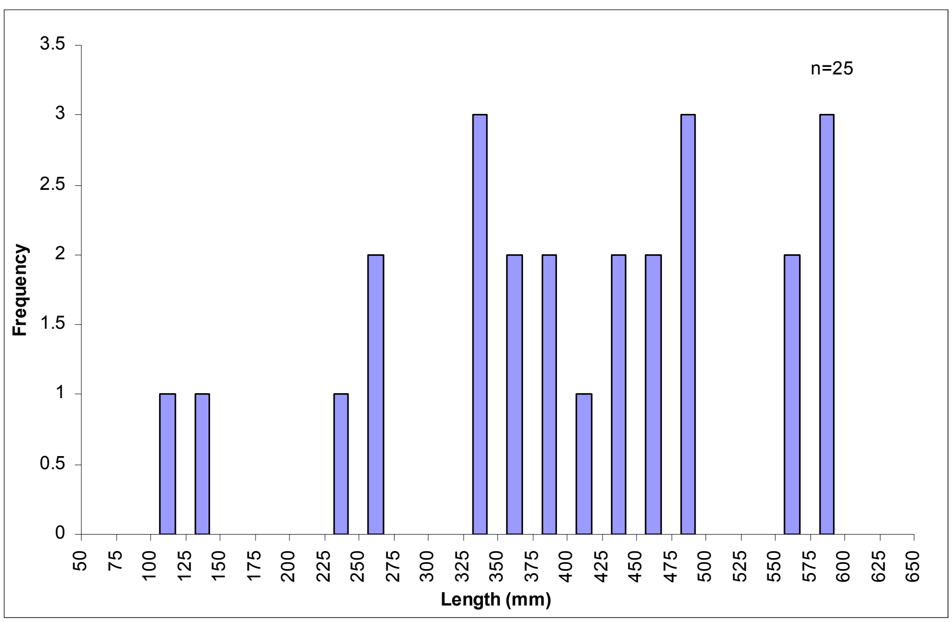
Mean length-at-age and weight-at-age for lake trout captured in Lake N16 in 1996, 1999, and 2004 are presented in Table 9.3-33. Lake trout ranged in age between 3 and 28 years old. Growth rates of lake trout in Lake N16 appear similar to Kennady Lake.

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




n = number of fish; mm = millimetres.

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




n = number of fish; mm = millimetres.

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

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

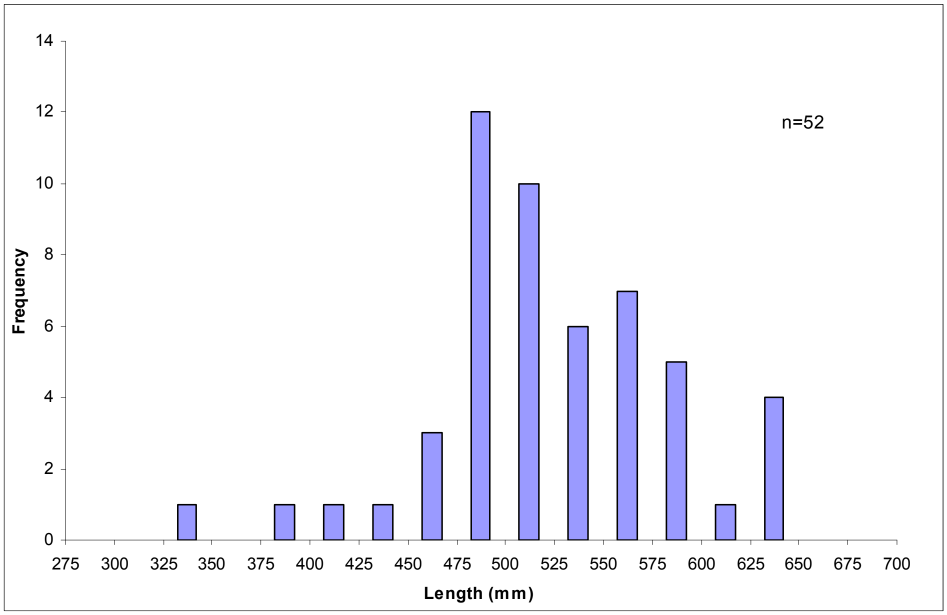
Note: 1996 (n=10); 1999 (n=5); 2004 (n=26). Differences in length and weight sample sizes (n) due to unrecorded lengths.

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

### Lake Trout in Lake 410

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

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




n = number of fish; mm = millimetre.

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

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

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

**Kirk Lake**

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

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

### *9.3.5.2.3 Littoral Fish Community*

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

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

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

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

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

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

### *9.3.5.2.4 Spring Spawning Runs*

A summary of the fish captured (by number, species and direction) in spring fish fences set in streams downstream of Kennady Lake and in the adjacent

N watershed in 2000, 2004, and 2005 is presented in Tables 9.3-36, 9.3-37, and 9.3-38, respectively.

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

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

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

(a) Set to capture fish moving upstream.
(b) Set to capture fish moving downstream.

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

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

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

(a) Downstream count includes one Arctic grayling located in the wing of the fish fence.

(b) Upstream from Lake M4

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

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

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

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

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

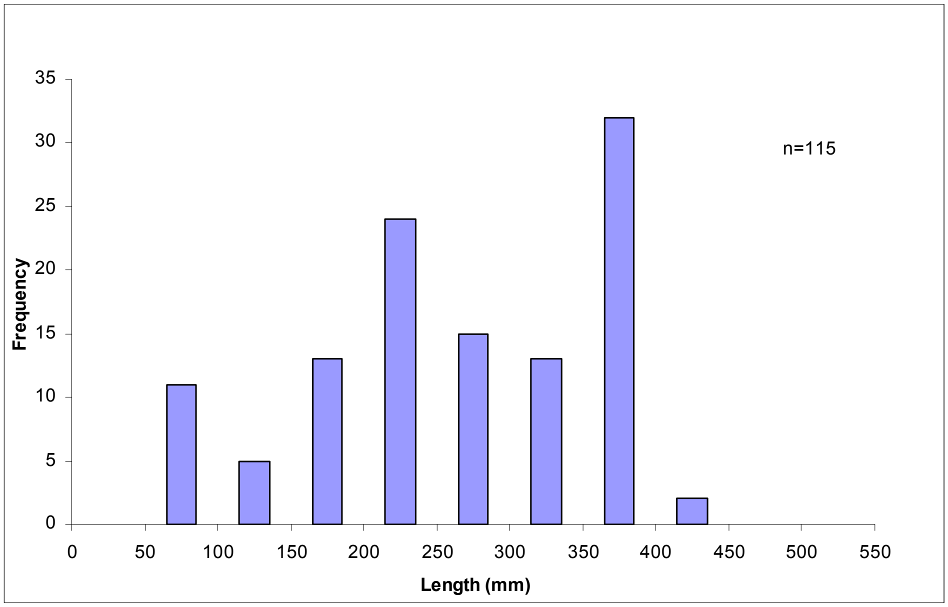
Arctic grayling in Kennady Lake and adjoining areas exhibit an adfluvial life history. Adults and juveniles reside in the lake for most of the year. In spring, adult Arctic grayling migrate into streams soon after ice break-up to spawn. Adults move back into the lake soon after spawning. Eggs hatch in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

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

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

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

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




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

n = number; mm = millimetre.

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

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

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

### *9.3.5.2.5 Small Lakes Surveys*

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

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

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

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

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

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

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

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

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

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

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

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

### *9.3.5.2.6 Stream Sampling*

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

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

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

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

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

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

**Young-of-the-Year Arctic Grayling Stream Utilization**

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

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

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

### 9.3.5.2.7 Fish Movements

**Arctic Grayling**

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

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

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

**Lake Trout**

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

### 9.3.5.2.8 Fish Tissue Burdens

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

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

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

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

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

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

Note: Shaded values equal or exceed the US EPA risk-based criteria.
Metal concentrations are presented as mg/kg wet weight.

(a) Detection limits were used to calculate mean metal concentrations for individuals with metal concentrations below detection limit.

(b) When indicated by a less than sign (<), the maximum concentration was reported at below the sample-specific detection limit.

(c) Risk-based criteria for fish consumption were based on a 70 kg individual consuming 54 g of fish per day over a 70-year period (US EPA 2010). The US EPA screening values were adjusted to a carcinogenic risk of 1E-5 and a hazard quotient of 0.2 for non-carcinogens (carcinogens were multiplied by 10 and non-carcinogens were multiplied by 0.2). When criteria were available for both carcinogenic and non-carcinogenic exposure scenarios, the lowest value was used.

(d) Criterion is for hexavalent chromium.

(e) Criterion is for methyl mercury.

US EPA = United States Environmental Protection Agency; nc = no criterion; mg/kg = milligram per kilogram.

### *9.3.5.2.9 Comparison to Other Large Lakes*

**Lake N16**

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

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

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

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

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

**Lake 410**

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

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

**Kirk Lake**

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

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

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

**Lockhart River Watershed**

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

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

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

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

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

# 9.4 WATER MANAGEMENT PLAN SUMMARY

## 9.4.1 Introduction

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

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

## 9.4.2 Overview

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

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

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

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

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

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

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

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

- Construction phase (initial dewatering) – Years -2 to -1. Kennady Lake is drawn down to increase available capacity and facilitate dyke construction; water is discharged from Area 3 to Lake N11, and from Area 7 to Area 8.
- Operational phase – Years 1 to 11. Water is diverted from mine pits and lake areas to the WMP (Areas 3 and 5); water is discharged from the WMP to Lake N11.
- Closure phase – Years 12 to 20. Water is transferred from the WMP to Tuzo Pit and Kennady Lake is refilled from natural drainage and water pumped from Lake N11.
- Post-closure (i.e., beyond closure) – Year 21 onwards. Kennady Lake receives only natural drainage and releases water to Area 8.

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

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

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

## 9.4.3 Construction

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

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

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

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

The establishment of the Fine PKC Facility in the A watershed will result in the isolation of Lake A3 from Lakes A1 and A2 through the construction of a permanent saddle dam (Dyke C) between Area 1 and Lake A3 to the north

(Figure 9.4-1). Dyke C will raise the level of Lake A3 to a point where the Lake A3 outlet will be permanently diverted into Lake N9.

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

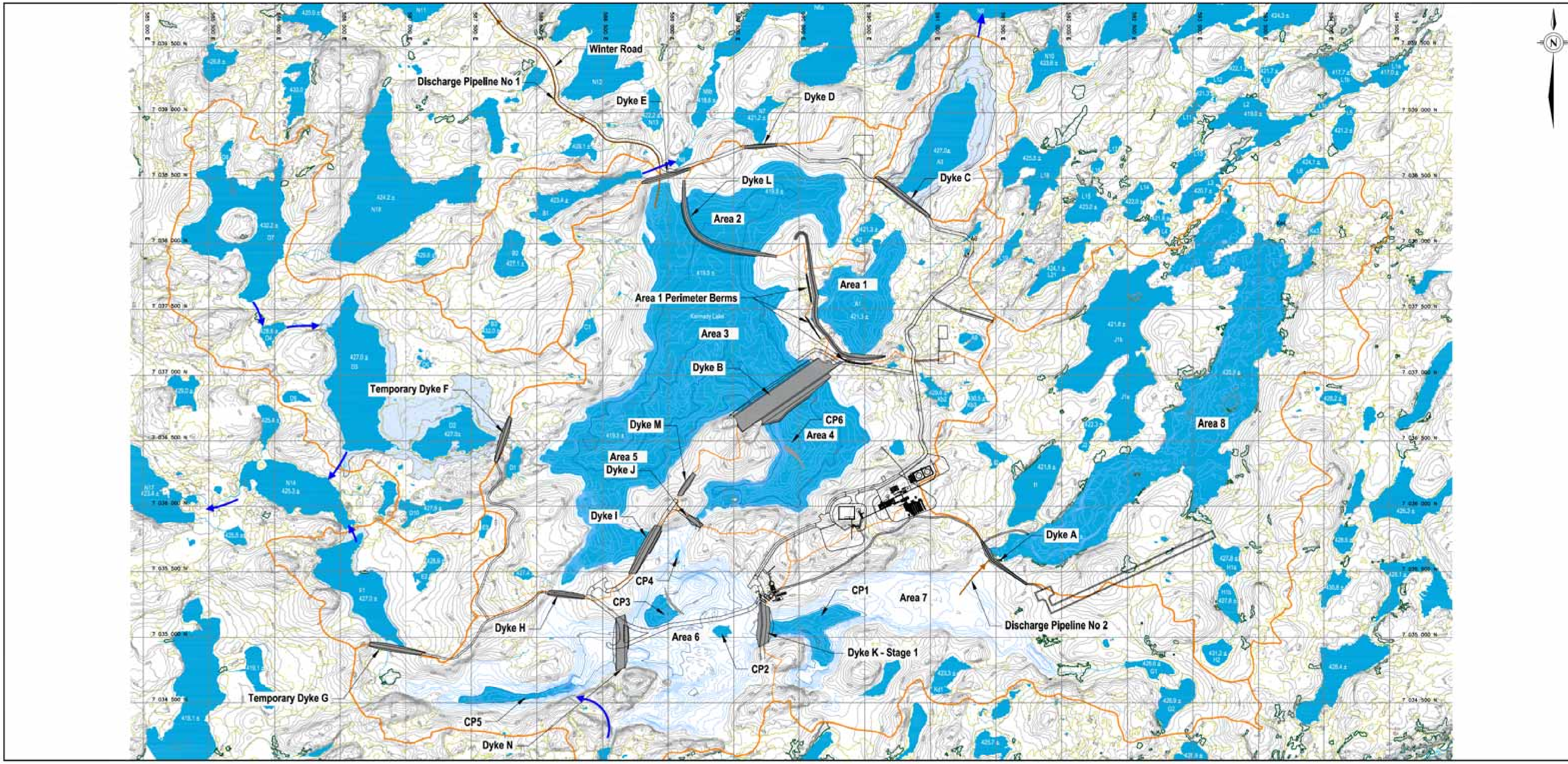
#### 9.4.3.2 Construction of Dyke A

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

#### 9.4.3.3 Dewatering of Kennady Lake

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

The object of the dewatering program is to initially drain Areas 6 and 7 of Kennady Lake, to later drain Areas 2 and 4, and to decrease the amount of water in Areas 3 and 5 to approximately 800,000 cubic metres ($m^3$). The water level of Kennady Lake must be lowered during the open water season, because lake waters can only be pumped out when the surface of the lake receiving the water is not frozen. The dewatering of Areas 3 and 5 will begin at the start of construction to allow the complete draining of Areas 6 and 7. Pumped discharge will initially be into Area 8 (while turbidity remains within discharge criteria) and then subsequently to Areas 3 and 5, allowing early access to the lake bed and underlying kimberlite pipes.




LEGEND

Existing Ground Contours
5m Index - 1m Intermediate

Bathymetry Contours
5m Index - 1m Intermediate

CP Collection Pond

Winter Road

Marsh Area

Scrub

Sub-watershed Boundary

Drainage Flow Direction

Discharge Pipeline

Lake / Pond

Flooded Area

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

**GAHCHO KUÉ PROJECT**

**Water Management Areas Showing Dykes, Diversions, and Pipelines**

| | | |
|---|---|---|
| PROJECTION: UTM Zone 12 | DATUM: NAD83 | DE BEERS CANADA |
| SCALE 500 0 500 METRES | | |
| FILE No: SON-09-001-CAD | | DATE: December 3, 2010 |
| JOB No: 09-1365-1004 | REVISION No: 0 | Figure 9.4-1 |
| OFFICE: GOLD - SAS | DRAWN: TAH | CHECK: JF |

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

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

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

## 9.4.4 Operations

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

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

## 9.4.5 Closure

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

### 9.4.5.1 Refilling of Kennady Lake

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

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

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

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

### 9.4.6 Water Balance pertaining to Downstream Waterbodies

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

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

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

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

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

$m^3/y$ = cubic metres per year.

# 9.5 ASSESSMENT APPROACH

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

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

## 9.5.1 Pathway Analysis

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

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

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

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

### 9.5.1.1 Valued Components

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

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

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

### 9.5.1.2 Water Quality

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

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

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

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

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

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

**Permafrost and Groundwater**

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

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

**Hydrology**

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

**Sediment Quality**

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

**Water Chemistry**

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

#### *9.5.1.2.1 Value of Water Quality*

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

### 9.5.1.3 Fish

#### *9.5.1.3.1 Importance of Fish*

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

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

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

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

#### *9.5.1.3.2 Fish Habitat*

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

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

### 9.5.1.4 Fish Species Selected as Valued Components

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

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

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

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

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

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

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

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

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

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

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

NWT = Northwest Territories; RSA = Regional Study Area.

#### 9.5.1.3.3 Lake Trout

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

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

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

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

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

#### 9.5.1.3.4 Arctic Grayling

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

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

#### *9.5.1.3.5 Northern Pike*

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

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

#### *9.5.1.3.6 Other Fish Species*

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

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

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

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

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

### 9.5.1.4 Assessment Endpoints and Measurement Endpoints

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

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

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

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

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

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

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

### 9.5.2 Spatial and Temporal Boundaries

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

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

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

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

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

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

## 9.5.3 Effects Analysis

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

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

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

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

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

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

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

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

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

## 9.5.4 Cumulative Effects

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

## 9.5.5 Residual Impact Classification

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

### 9.5.5.1 Criteria

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

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

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

## 9.5.6 Significance

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

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

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

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

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

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

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

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

## 9.5.7 Uncertainty

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

- adequacy of baseline data for understanding existing conditions and future changes unrelated to the Project (e.g., climate change);
- model inputs (e.g., change in chemical concentrations in water over time and space);

- degree to which the models used in the assessment accurately describe the key processes that dominate the functioning of the systems being modelled;
- understanding of Project-related impacts on complex ecosystems that contain interactions across different scales of time and space (e.g., how and why the Project will influence surface hydrology); and
- knowledge of the effectiveness of the environmental design features and mitigation for reducing or removing impacts (e.g., environmental performance of the mine rock management area).

## 9.5.8 Monitoring and Follow-up

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

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

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

# 9.6 PATHWAY ANALYSIS

## 9.6.1 Methods

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

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

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

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

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

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

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

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

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

## 9.6.2 Results

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

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

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

### 9.6.2.1 Potential Pathways during Construction and Operations

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

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

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

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

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

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

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

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

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

#### *9.6.2.1.1 Pathways with No Linkage*

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

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

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

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

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

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

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

#### *9.6.2.1.2 Secondary Pathways*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

#### 9.6.2.2 Primary Pathways for Effects from Construction and Operations

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

#### 9.6.2.3 Potential Pathways during Closure

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

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

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

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

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

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

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

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

PK = processed kimberlite

### 9.6.2.3.1 No Linkage Pathways

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

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

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

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

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

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

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

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

#### 9.6.2.3.2 Secondary Pathways

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

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

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

### 9.6.2.4 Primary Pathways for Effects from Closure

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

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

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

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

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

# 9.7 EFFECTS TO WATER QUANTITY

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

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

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

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

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

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

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

## 9.7.1 Effects Analysis Methods – Construction and Operation

### 9.7.1.1 Water Balance Model

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

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

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

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

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

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

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

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

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

### 9.7.1.2 Analysis

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

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

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

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

## 9.7.2 Effects Analysis Methods – Closure and Post-closure

### 9.7.2.1 Water Balance Model

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

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

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

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

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

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

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

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

### 9.7.2.2 Monte Carlo Simulation

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

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

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

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

#### 9.7.2.3 Analysis

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

### 9.7.3 Effects Analysis Results – Construction and Operation

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

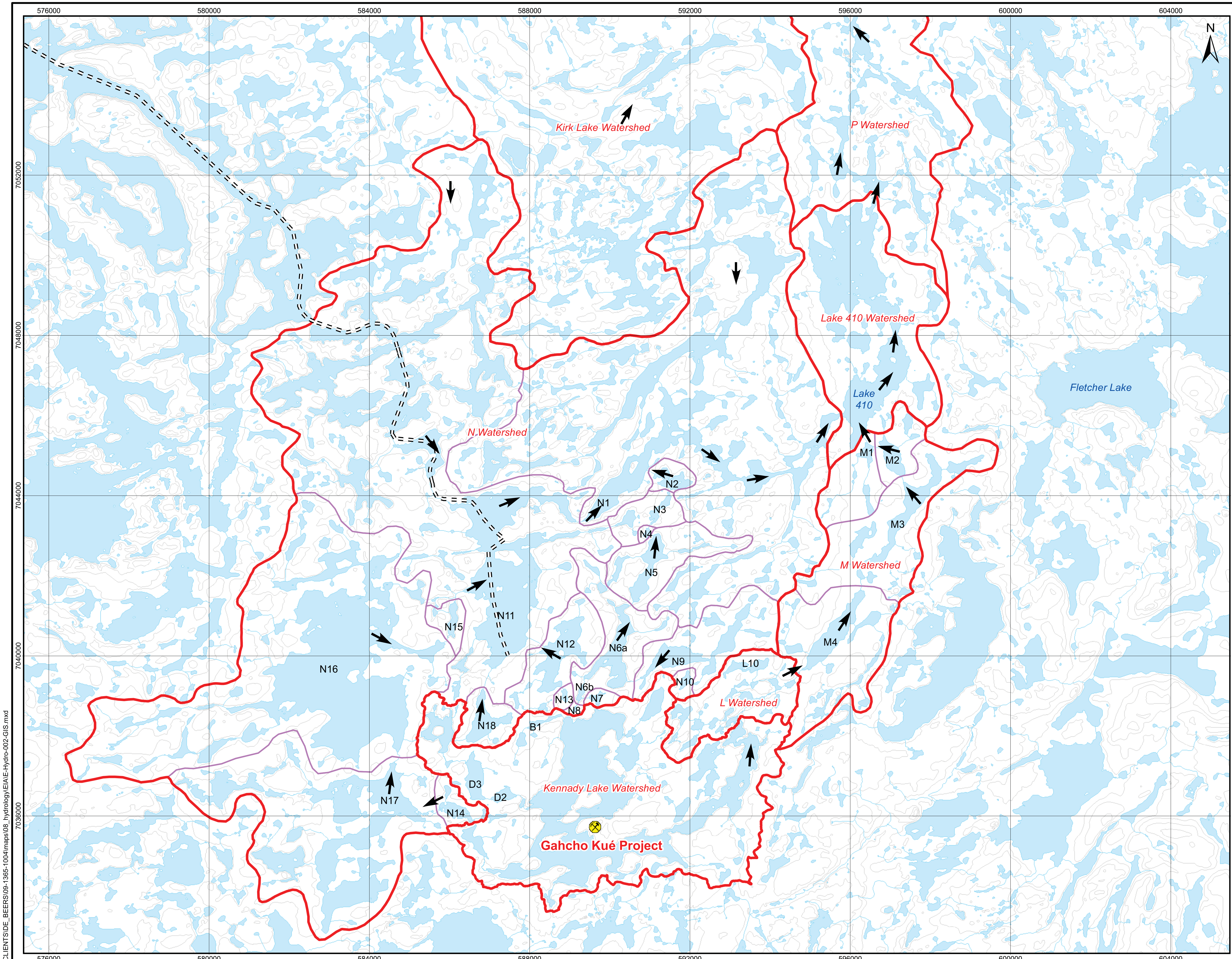
##### *9.7.3.1.1 Project Activities*

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

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

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

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




**LEGEND**

- Gahcho Kué Project
- Proposed Winter Access Road
- Watercourse
- Waterbody
- Contour (10m interval)
- Watershed Boundary
- Sub-Watershed Boundary
- Drainage Direction
- M4 Lake Identifier

NOTES

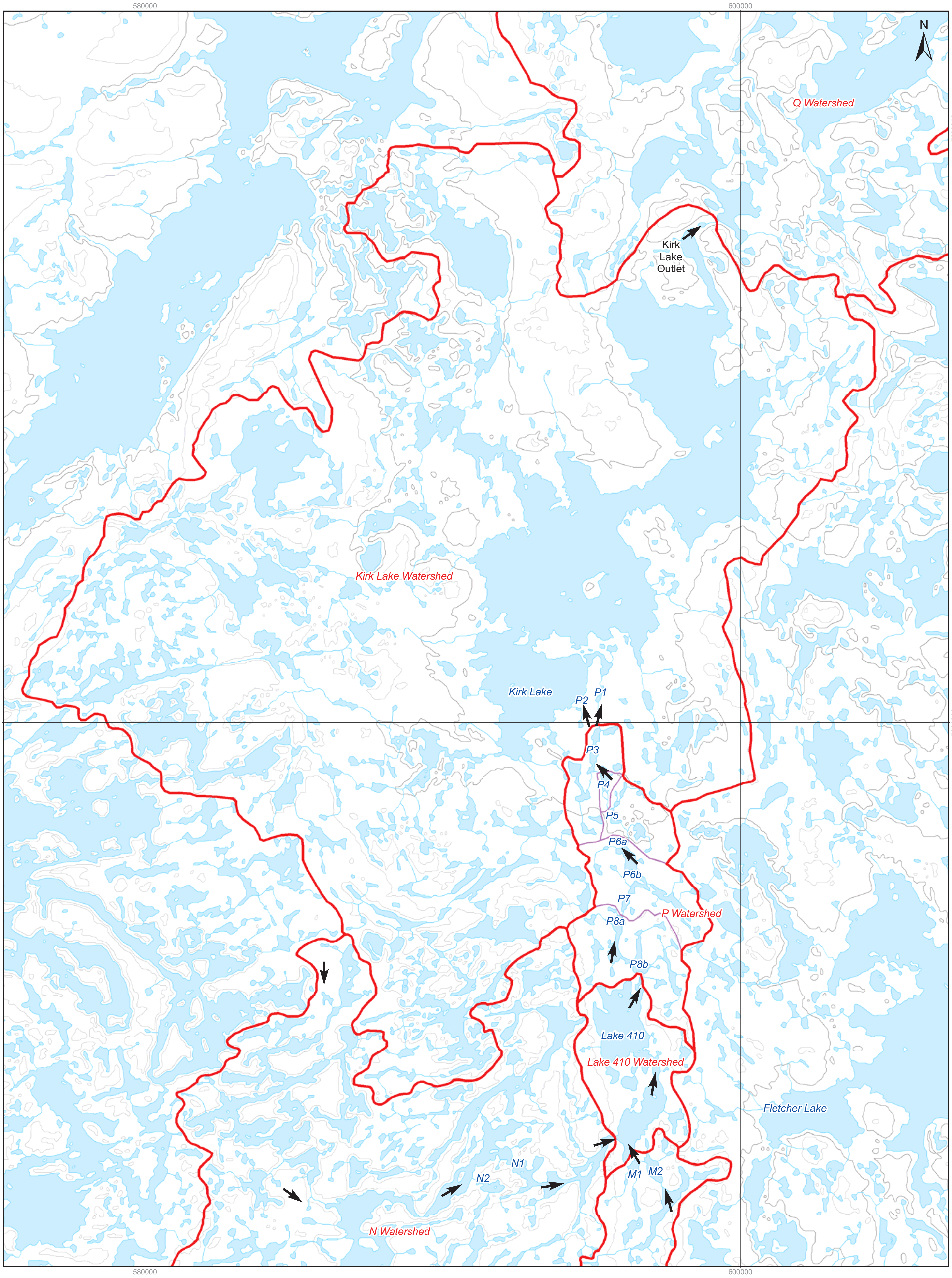
Base data source: National Topographic Base Data (NTDB) 1:50,000

## GAHCHO KUÉ PROJECT

## Downstream Watersheds and Flow Paths from Kennady Lake to Lake 410

| PROJECTION: UTM Zone 12 | DATUM: NAD83 |
|---|---|
| Scale: 1:90,000 (1 0.5 0 1 Kilometres) | DE BEERS CANADA |
| FILE No: E-Hydro-002-GIS | DATE: July 9, 2008 |
| JOB NO: 07-1336-0001 | REVISION NO: 1 |
| OFFICE: GOLD-CAL | DRAWN: CW / CHECK: NS |

**Figure 9.7-1**

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## LEGEND

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

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

**GAHCHO KUÉ PROJECT**

**Downstream Watersheds and Flow Paths from Lake 410 to Kirk Lake**

| | | | |
|---|---|---|---|
| PROJECTION: UTM Zone 12 | | DATUM: NAD83 | DE BEERS CANADA |
| Scale: 1:125,000 (2 1 0 2 Kilometres) | | | |
| FILE No: E-Hydro-006-GIS | | | DATE: July 10, 2008 |
| JOB NO: 07-1336-0001 | REVISION NO: 0 | | **Figure 9.7-2** |
| OFFICE: GOLD-CAL | DRAWN: CW | CHECK: NS | |

### 9.7.3.1.2 Environmental Design Features and Mitigation

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

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

### 9.7.3.1.3 Effects Analysis

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

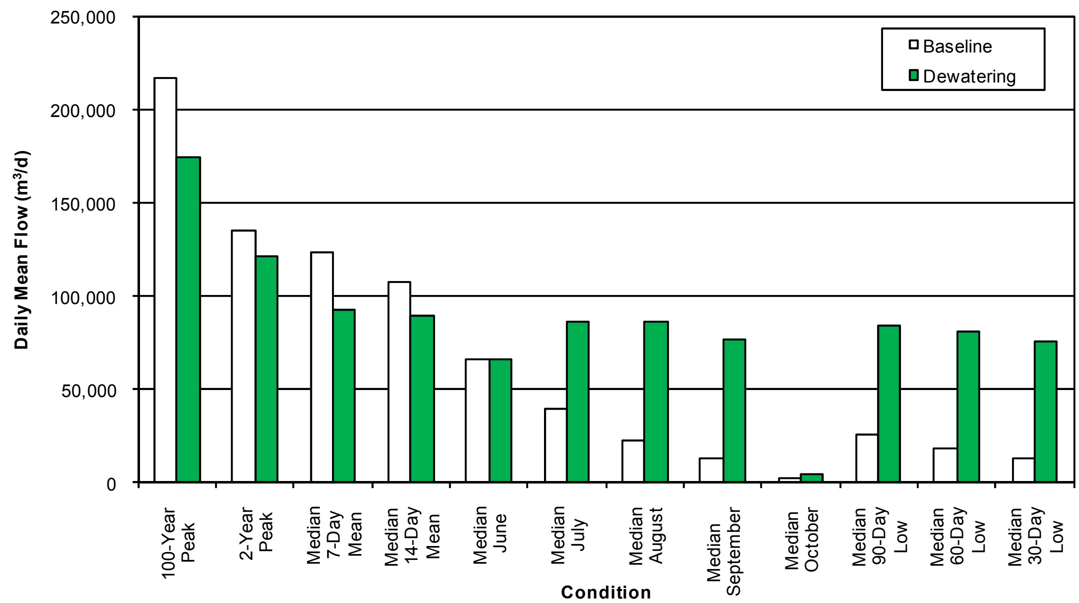
Dyke A will prevent water from flowing between Kennady Lake Areas 2 to 7 and Area 8 during dewatering and operation. Area 8 will be preserved as a free-draining waterbody throughout this period, though its hydrological regime will be changed.

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

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

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

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




$m^3$/d = cubic metres per day.

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

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

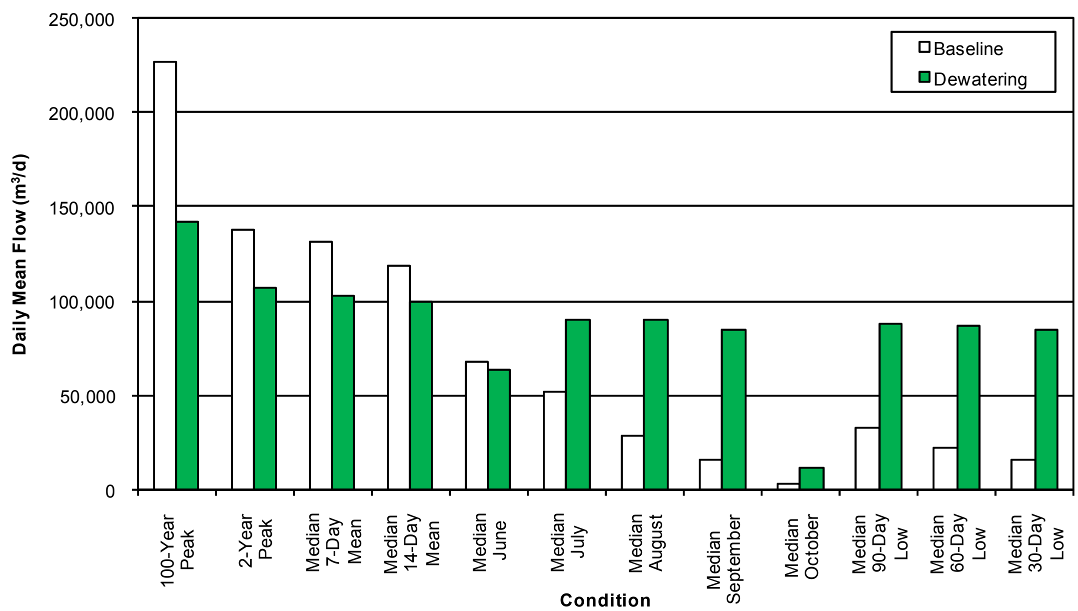
$m^3$/d = cubic metres per day.

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

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

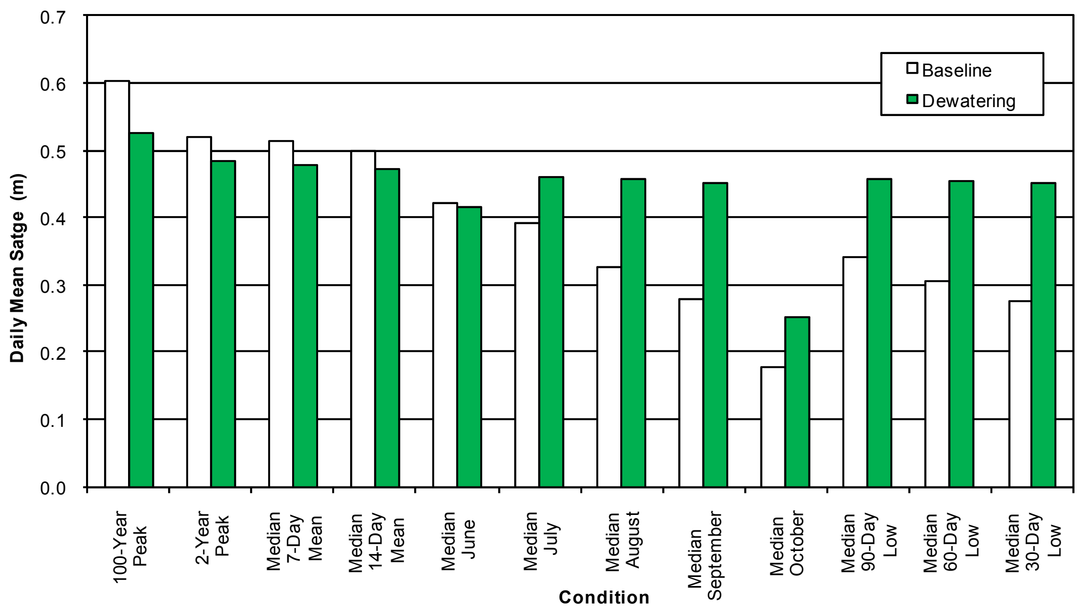
Q = discharge; $m^3/s$ = cubic metres per second; $m^3/d$ = cubic metres per day.

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




$m^3/d$ = cubic metres per day.

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




m = metres.

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

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

$m^3/d$ = cubic metres per day.

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

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

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

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

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

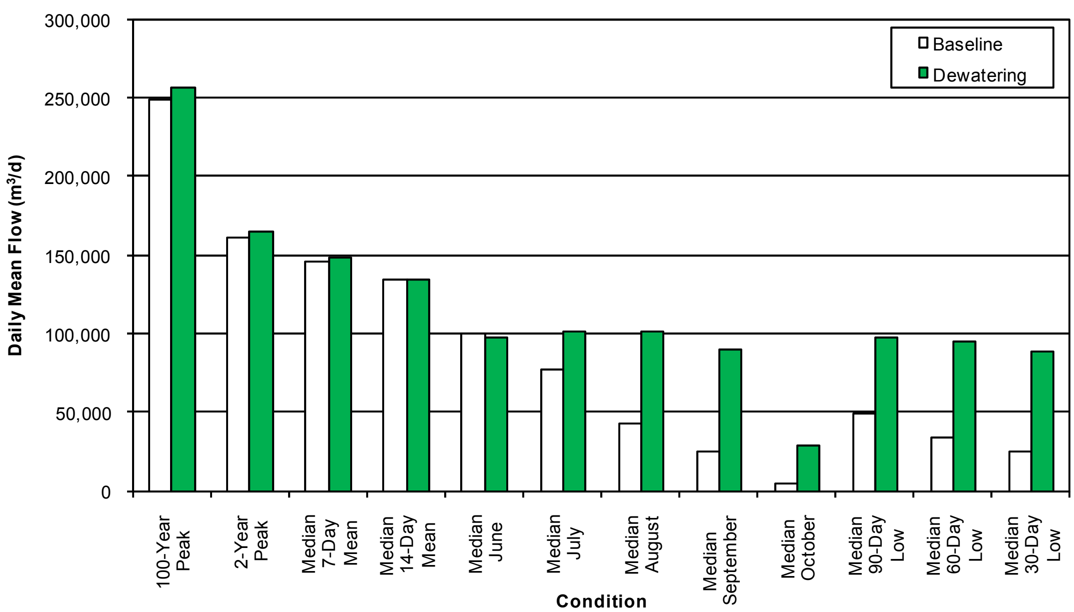
m =metre.

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

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

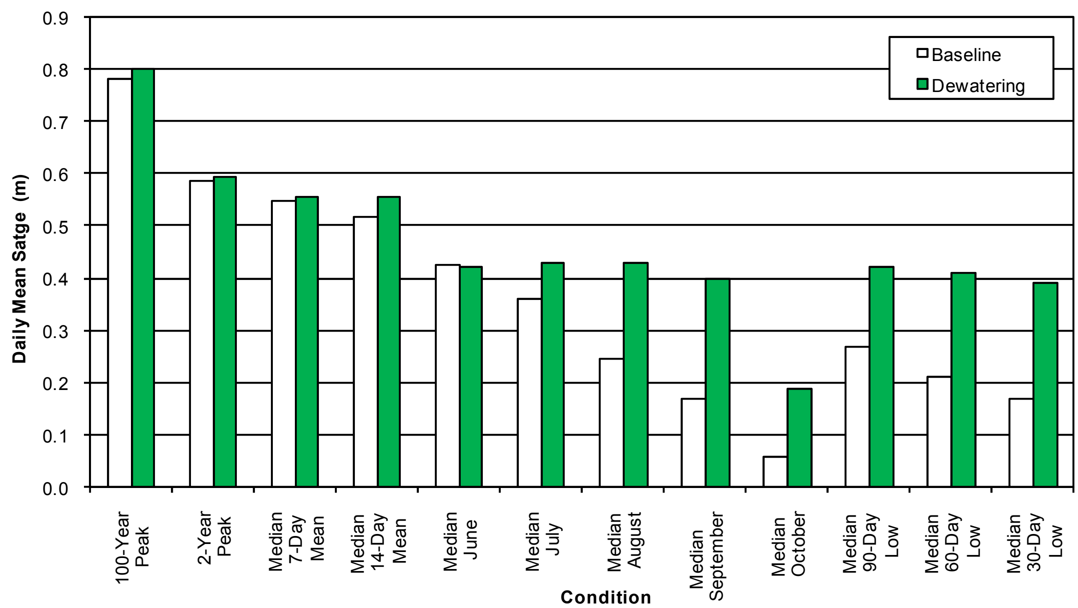
m = metre.

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




$m^3/d$ = cubic metres per day.

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




m = metres.

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

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

$m^3$/d = cubic metres per day.

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

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

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

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

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

m = metre.

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

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

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

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

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

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

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

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

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

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

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

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

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

**Lake N11 to Lake N1 Outlet**

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

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